



AUSTRALIAN RESEARCH COUNCIL CENTRE OF EXCELLENCE FOR  
MATHEMATICAL AND STATISTICAL FRONTIERS



# 2017 ANNUAL REPORT

## ACKNOWLEDGEMENTS

ACEMS would like to acknowledge the support of the Australian Research Council. We would also like to acknowledge the financial and in-kind support provided by our collaborators: The University of Melbourne, Queensland University of Technology, The University of Queensland, The University of Adelaide, The University of New South Wales, University of Technology Sydney and Monash University. We are grateful for the in-kind support received from our partners: AT&T Labs, Australian Bureau of Statistics (ABS), the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Institute of Marine Science (AIMS), Mathematics of Information Technology and Complex Systems (Mitacs), Sax Institute and the Roads Corporation of Victoria (VicRoads).

ACEMS would like to thank the Professional Staff in the Centre for their support: Emily Duane, Kate Lowry, Kate Hall, Ben Hess and Anita Ponsaing at The University of Melbourne; Claudia Deasy, Tim Macuga, Jessie Roberts and Kate Taylor at Queensland University of Technology; Claire Nitsch at The University of Queensland; Snezana Ilic, Hilary Brookes and Sarah Keany at The University of Adelaide; Priscilea Furerri at The University of New South Wales; Lucia Kralova at University of Technology Sydney; and Angelika Nikolov-Arvela at Monash University.

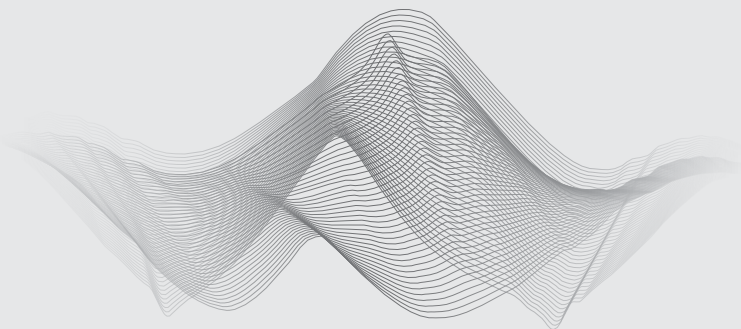


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## COLLABORATORS




## PARTNERS



The cover art was computer generated using multiple graphics and data from the various case studies and research theme reports featured in this annual report. The design was inspired by the process of statistical analysis. In particular, that sometimes seemingly unrelated and disparate data metamorphoses into a complete and understandable object (sometimes graphically as a real object like a sheet of fabric or piece of paper) once compiled, studied and analysed. Credit: Idaho Design & Communication.

## INTENT

To create world-class research  
at the frontiers of the mathematical  
sciences dealing with probability  
and randomness and to translate  
this research into new insights  
that benefit society

The background of the page features a series of thin, light-colored wavy lines that create a sense of depth and movement, resembling a stylized landscape or a mathematical wave pattern. The lines are more densely packed in some areas and more spread out in others, creating a dynamic visual effect.

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# ABOUT ACEMS

THE AUSTRALIAN RESEARCH COUNCIL (ARC) CENTRE OF EXCELLENCE FOR MATHEMATICAL AND STATISTICAL FRONTIERS (ACEMS) BRINGS TOGETHER LEADING AUSTRALIAN APPLIED AND THEORETICAL RESEARCHERS IN THE FIELDS OF MATHEMATICS, STATISTICS, MATHEMATICAL PHYSICS AND MACHINE LEARNING.

Today's world collects a massive amount of data via a multitude of sources daily. Much of this data may be in 'non-traditional' forms such as images, fragments of mathematical functions or more complex mathematical objects, histograms, text or social network interconnections. Many of the resulting data sets have the potential to make vital contributions to society, business and government, as well as impact on international developments, but are so large or complex that they are difficult to process and analyse using traditional tools.

ACEMS brings together for the first time a critical mass of Australia's best researchers in applied mathematics, statistics, mathematical physics and machine learning, with partner researchers to engage in research programs that combine innovative methods for the analysis of data with theoretical, methodological and computational foundations provided by advanced mathematical and statistical modelling. ACEMS will focus on the impact of new insights for end-users working in the Collaborative Domains of Healthy People, Sustainable Environments and Prosperous Societies.

Originally ACEMS organised its research into three research programs:

- Big Data—which uses mathematical, statistical and machine learning tools to analyse data characterised by volume, variety, velocity and complexity
- Big Models—which develops new theories, methodologies and implementations that underpin predictive models required to interpret and utilise big data
- New Insights—which bridge the gap between theory and practice by providing solutions to problems driven by cross-organisational and cross-disciplinary collaboration, using big data and big models

An initial objective of ACEMS was to unify the programs by emphasising:

- Globally innovative research and research leadership across the discipline spectrum;
- Integration and translation, bridging theory and practice so that the research programs are motivated by and inform the Collaborative Domains for real world impact; and
- Training the next generation of quantitative researchers integrating technical expertise, industry exposure and high-level cross-disciplinary and scientific communication skills.

During 2016, ACEMS decided that the optimal way to achieve this was by reorganising its 'Big Data' and 'Big Models' research programs into four themes:

- Challenging Data
- Multiscale Models
- Enabling Algorithms
- Informed Decisions

The 'New Insights' program has remained to focus applications comprising the three Collaborative Domains.

The synergy of the Centre's compelling research programs, together with its strong collaborations, both domestically and internationally; its composition, management and governance arrangements; and research, training and translation strategy; mean that ACEMS will deliver real value for money as well as make a transformative contribution to Australian research in mathematics, statistics, mathematical physics and machine learning.

# CHAIRMAN'S REPORT



IT HAS BEEN AN OUTSTANDING YEAR FOR ACEMS CENTRED ON THE AUSTRALIAN RESEARCH COUNCIL'S MID-TERM REVIEW OF THE CENTRE'S ACTIVITIES. VERY SENSIBLY, THE ARC SETS UP THESE REVIEWS TO PROVIDE VALUABLE MID-COURSE ADVICE TO THE CENTRES IT HAS FUNDED UNDER THEIR CENTRE OF EXCELLENCE PROGRAM.

As such they provide a pause for reflection on what has been achieved, what could have been done better and how the second half of the Centre's activities might look. ACEMS took the opportunity to involve all its members in this process as well as the Governance Advisory Board and the Scientific Advisory Committee. It finished up as a great team effort with all groups in the Centre responding very well to the challenge, with its deadlines and rigorous mock interviews. It would be remiss of me not to single out the outstanding organisational work of Emily Duane our Chief Operating Officer and the leadership of Professor Peter Taylor in guiding what became a real bonding exercise for the ACEMS family.

The Review's findings were largely very positive, noting ACEMS had developed highly collaborative research programs which transcend disciplinary, institutional and geographic boundaries. It also commended ACEMS' role in expanding education, training and mentoring and in the transfer of its research to partners and end-users.

Most pleasingly the Report noted that ACEMS is providing "a supportive and stimulating environment for the next generation of researchers".

Professor Peter Taylor has provided distinguished service to ACEMS so it is particularly gratifying to note that he has been recognised by The University of Melbourne in naming him a Redmond Barry Distinguished Professor. This honour "rewards outstanding leaders within the University and wider community, and either pre-eminence in research or creative activity, or pre-eminence in research and teaching."

Just a few weeks later, Peter was awarded the Ren Potts Medal for service to Operations Research. This medal of the Australian Society for Operations Research is a national award intended to recognise individuals who have made outstanding contributions to theory or practice of Operations Research in Australia.

A Centre of Excellence cannot rest on its laurels and in ACEMS case the decision has been taken to launch a new proposal in the next round of Centre of Excellence applications. As is usual in such cases, the proposal will embody a change of focus with a major push to develop deep mathematical methods to tackle decision-making under uncertainty. The proposal will be led by Australian Laureate Fellow Professor Kate Smith-Miles with Distinguished Professor Kerrie Mengersen as Deputy.

As Chair of the ACEMS Governance Advisory Board it gives me great pleasure to commend this Annual Report to you.

**Dr Ron Sandland**

Chair, ACEMS Governance Advisory Board  
March 2018

# DIRECTOR'S REPORT



FOR THE ACEMS LEADERSHIP, THE YEAR 2017 WAS DOMINATED BY THE AUSTRALIAN RESEARCH COUNCIL'S MID-TERM REVIEW. THE ACTUAL VISIT OF THE REVIEW PANEL TOOK PLACE ON AUGUST 31, BUT THE PREPARATION STARTED BACK IN 2016, AND CONTINUED IN EARNEST THROUGHOUT THE FIRST PART OF 2017.

The University of Melbourne's Pro-Vice-Chancellor (Research Partnerships) Liz Sonenberg and I received verbal feedback from the Panel at the time of the visit. The written feedback arrived later in the year. The Panel made twelve recommendations, that ACEMS should:

- develop more innovative strategies to increase the proportion of cross-node or Partner Organisation co-authorship in Centre outputs
- develop a new Key Performance Indicator (KPI) to measure co-authorship and strive for a more ambitious target than 20 per cent in the remaining years
- foster additional formal international partnerships with highly respected mathematics/statistics centres
- set up cross-node selection panels, emphasising that applicants are joining a Centre, not just an institution
- retain and enhance training and development activities, particularly in the areas of IP management, and communication and outreach with end-users and other stakeholders
- offer the opportunity to participate in the Centre's Annual Retreat to a wider range of stakeholders, including all Partner Organisations and stakeholders—for example, the Red Cross Blood Service, the ATO and Prince Alfred College
- continue, encourage and expand cross-node supervision arrangements
- develop and implement an induction package and process for new Centre members, especially students and postdoctoral researchers, to familiarise them with the Centre, its personnel and processes, and the opportunities on offer
- undertake a review of the Governance Advisory Board (GAB) membership to ensure a more focused GAB that has the appropriate skill sets to advise the Centre in its remaining years
- arrange for the Scientific Advisory Committee (SAC) to meet face-to-face on occasion, potentially timed to coincide with the Centre's Annual Retreat. Further to this, the Centre should invite all members of the GAB

and SAC to the annual Centre retreat and encourage their attendance

- complete a formal gender balance plan in a timely manner
- discuss the future development and enhancement of the central funds pool with Centre Node leaders, the EC, the COO and the GAB. The discussions should focus on drawing from various sources of funding (including re-allocation of existing ARC funds, interest on the ARC Centre grant or other possible sources), and explore possible future strategic initiatives to be supported by the central pool, and revisit how to enhance the flexibility of the central pool.

The ACEMS Executive Committee is currently considering how it will implement each of these recommendations. Almost all of them are aimed at the general objective of ensuring that ACEMS functions as a Centre that is more than the sum of its parts, an objective that the Executive Committee strongly supports. During 2017, ACEMS can claim to have made major progress in this direction.

The preparation for the impending Mid-Term Review was the catalyst for much of that progress. In a series of meetings starting with the 2016 Annual Retreat in November of that year and finishing when more than fifty ACEMS members assembled at The University of Melbourne in the two days immediately before the Panel's visit, a large part of the ACEMS community came together to examine all aspects of the Centre's activities and put in place initiatives that will serve ACEMS for the rest of its life. Among these were a revision of the Strategic Plan, the development of Frontier Questions in each of ACEMS' four Research Themes, a formal Equity and Diversity Policy, a revised Scholarship



scheme, a formal Mentoring Program, and the Research Support Scheme. Each of these initiatives will be discussed in more detail elsewhere in this Report.

Just as important as the decisions that were made and the policies that were agreed upon, the process of relationship building within ACEMS was significantly enhanced throughout the preparatory meetings for the Review. The debates were not always easy, but a way forward always emerged, and I think we all went home with an enhanced appreciation and respect for our ACEMS colleagues.

ACEMS lost one Chief Investigator during 2017; Peter Bartlett left Queensland University of Technology to return to the University of California Berkeley, and consequently resigned as a Chief Investigator. In addition, Kate Smith-Miles moved from Monash University to The University of Melbourne. In response to these circumstances, the ACEMS Chief Investigators decided to invite Professor Rob Hyndman of Monash University to be a Chief Investigator. Rob was a Chief Investigator on one of the original expressions of interest that led to ACEMS and has remained an active collaborator with ACEMS researchers since then. Rob's introductory plenary talk, which demonstrated how easily he will fit into ACEMS research programs was a highlight of the 2017 Annual Retreat.

The organisation of ACEMS research into the four new Research Themes: Challenging Data, Multiscale Models, Enabling Algorithms and Informed Decisions was bedded down through 2017. A detailed description of the work under these Themes appears elsewhere in this report. Here I'll mention just a few highlights.

In the Challenging Data Theme, PhD student Ben Rorhlach, Chief Investigator (CI) Nigel Bean and Associate Investigator (AI) Simon 'Jono' Tuke provided statistical analysis as part of a multidisciplinary team working with the ancient DNA of indigenous people. They developed new methods to understand the migration of pre-historic Aboriginal Australians. The ensuing paper was published in *Nature*, and the team ultimately received the 2017 Eureka Prize for Excellence in Interdisciplinary Scientific Research (page 60).

In the Multiscale Models Theme, CI Tim Garoni, together with postdoctoral fellow Eric Zhou, PhD student Jens Grimm, and overseas collaborators Eren Elci and Youjin Deng, presented a concrete geometric explanation for the apparent breakdown of standard finite-size scaling in some systems and demonstrated universal finite-size scaling in several well-known models, including the Ising model and the self-avoiding random walk.

CI Rob Hyndman and his group, AI Sewandi Kandanaarachchi and PhD students Puwasala Gamakumara, Dilini Talagala, Thiyanga Talagala and Shanika Wickramasuriya, as well as various other co-authors, produced highly-innovative Enabling Algorithms for hierarchical forecasting in time series, as well as detection of anomalies. This work has had significant impact on the forecasting community as Rob and his team have made a practice of providing open-source R packages that implement the algorithms.

In the Informed Decision Theme, CI Kerrie Mengersen and her team have collaborated extensively with ACEMS Partner Organisations, Australian Institute of Marine Science (AIMS) and Australian Bureau of Statistics (ABS) to create decision-making tools for the preservation of valuable ecosystems. One such project represented complex marine systems as Bayesian Networks, parameterised using diverse data sources and expert information from a large interdisciplinary team. The aim was to search for ecological windows when stressors such as dredging would have minimal impact on risk, recovery and resistance of the seagrass.

Research is, of course, the core activity of ACEMS, however, ACEMS also takes its Stakeholder Engagement, Outreach, Communications and Media activities very seriously. In 2017, Jessie Roberts occupied the position of Stakeholder Engagement Officer, Anita Ponsaing the position of Outreach Officer and Tim Macuga the position of Communications and Media Officer. All three have been very energetic.

Jessie has a multi-faceted job coordinating liaison with ACEMS Partner Organisations: the Australian Bureau of Statistics, CSIRO, the Australian Institute of Marine Science, the SAX Institute, Mitacs, VicRoads and AT&T. Jessie has also been building the Industry Affiliate Program, with existing ACEMS Affiliates: the Australian Institute of Sport, the Australian Red Cross Blood Service, the Australian Tax Office and the Cancer Council of Queensland; and new Affiliates: the Bureau of Meteorology, Defence Science and Technology Group, Queensland Academy of Sport and Hwasen Electronics.

ACEMS interacts with its Partner Organisations and Industry Affiliates in a variety of ways, ranging from hosting secondments, to holding joint workshops, through to collaborating on short and long-term joint research projects involving students and postdoctoral fellows. To celebrate and further nurture its relationships with Partners and Industry Affiliates, ACEMS dedicated the first afternoon of the 2017 Annual Retreat to



a series of talks in which speakers from these organisations presented interesting mathematical and statistical problems that were of vital interest to their endeavour. I was very pleased by the fact that some of these representatives decided to attend the rest of the Retreat, where they and ACEMS members had the opportunity to get to know each other better.

ACEMS thinks of its outreach activities as targeted,

- to the mathematics and statistics community,
- to schools, and
- to the general community.

ACEMS' main outreach to the mathematics and statistics community occurs via its support for the MATRIX Research Institute situated in Creswick, which it helps to fund along with The University of Melbourne and Monash University. ACEMS also supports workshops and conferences across a broad spectrum of applied mathematical and statistical disciplines, as well as providing stimuli for research with such initiatives as the 'Advanced Sampling and Exploration Competition' and subject-specific courses such as the FutureLearn MOOC on 'Big Data Analytics' (page 97).

In 2017 ACEMS implemented a deliberate strategy to expand its flagship schools outreach program 'Mathscraft: Doing Maths like a Research Mathematician'. Mathscraft sessions were previously delivered by the program's creator ACEMS Affiliate Member Anthony Harradine working closely with Anita Ponsaing. Following a Mathscraft teacher training workshop held at MATRIX in late 2016, the year 2017 saw many of the seventeen teachers who attended run their own Mathscraft sessions, for teachers from a wide spectrum of schools. ACEMS members, including PhD students supported these sessions in the capacity of mathematical experts. In a further expansion of Mathscraft activities, Anthony and Anita also ran a series of single-day professional development workshops for maths teachers, one in each of the ACEMS node cities.

In other outreach activities, ACEMS

members continued to engage with CSIRO's 'Mathematicians in Schools' program, now renamed 'STEM Professionals in Schools', hosted students in their university departments and interacted with school students in a variety of other ways. Through the leadership of CI Nigel Bean, they also played a seminal role in the Australian Mathematical Sciences Institute's Work Integrated Learning Initiative. These outreach activities are discussed on pages 112-119 of this report.

In June 2017, ACEMS led a consortium of centres, including six other ARC Centres of Excellence, in a repeat of 2016's successful National Science Quiz. There were two events held in Melbourne and Adelaide, in which host Charlie Pickering posed a series of challenging science questions to a panel of scientists, science communicators and comedians. As we saw in 2016, panellists backed up their answers with logical arguments, demonstrations, and occasionally, just bluster. At the Melbourne event, which I attended, there was only one explosion – don't worry, it occurred under controlled conditions, supervised by Mick Moylan from the School of Chemistry at The University of Melbourne, and Dianne Ruka and Errol Hunt from the FLEET ARC Centre of Excellence.

Again, Tim Macuga led ACEMS in encouraging its members to engage with all forms of media. Furthermore, he also took on the task of educating them in how to do so. I have learned a lot from him about writing for 'The Conversation' and engaging with social media via ACEMS' Facebook, Twitter and YouTube channels.

The 2017 ACEMS Annual Retreat, or more correctly Retreats, were held at the Mantra Hotel on the Gold Coast in the first week of November. The Student Retreat and the Early Career Researcher Retreat started on Monday 30 Oct and continued to midday Wednesday 1 Nov, with some activities shared between them, while the Main Retreat started at lunchtime on 1 Nov and extended to the afternoon of Friday 3 Nov. The Retreats were attended by more than 120 ACEMS members and friends, including 13 CIs, 24 postdoctoral research fellows, 44 students, 23 AIs, seven professional

staff, seven industry members, and one member each of the Governance Advisory Board and the Scientific Advisory Committee.

Highlights of the first afternoon were Rob Hyndman's plenary talk and the Partner Organisation and Industry Affiliate Session, while the remaining two days were taken up with more technical discussions of ACEMS' four Research Themes. We were very lucky that Scientific Advisory Board member, Professor Michel Mandjes from the NETWORKS Centre in the Netherlands, could attend the whole Retreat. Michel interacted extensively with ACEMS members and presented the final plenary talk on the Friday morning.

ACEMS members were honoured with prestigious national and international awards were during 2017. These included:

- The above-mentioned Eureka Prize awarded to Ben Rorhach, Nigel Bean and Simon 'Jono' Tuke.
- The prestigious Royal Statistical Society (RSS) Biennial Research Prize, awarded to Postdoctoral Research Fellow Chris Oates
- The EO Tuck Medal of the Australian and New Zealand Division of Industrial and Applied Mathematics, awarded to CI Kate Smith-Miles
- The George W. Snedecor Award for an individual who has been instrumental in the development of statistical theory in biometry, awarded to CI Aurore Delaigle
- The Ren Potts Medal of the Australian Society for Operations Research, which I was lucky enough to receive

A full list of all prizes and awards earned by ACEMS members appears on pages 34-35.

I'd like to finish off by acknowledging the tremendous contribution that ACEMS received during 2017 from its professional staff, led by Chief Operating Officer Emily Duane. Without their efforts, ACEMS would be nowhere near the success that it is today.



**Professor Peter Taylor**  
Director

# ACEMS CHIEF INVESTIGATOR'S CONTRIBUTION TO STATISTICAL THEORY RECOGNISED AT THE JOINT STATISTICAL MEETINGS

The Committee of Presidents of Statistical Societies (COPSS) has honoured ACEMS Chief Investigator Professor Aurore Delaigle with the George W Snedecor Award – one of its top awards.

Aurore was presented the award in August at the Joint Statistical Meetings (JSM) in Baltimore, Maryland, USA. The award recognises biennially a researcher who is instrumental in the development of statistical theory and analysis involving biological data.

In this case, it was for a publication she co-wrote with ACEMS' inaugural director, Professor Peter Hall, who passed away in early 2016. It was entitled, 'Nonparametric methods for group testing data, taking dilution into account', and appeared in *Biometrika* in 2015.

*“This was one of our last collaborations, which makes this award even more special. The paper was accepted when Peter was in hospital and it made his day,”* says Aurore.

“I loved working with Peter, not only because of his amazing theoretical skills, but also because of his passion and enthusiasm. He was always encouraging and often we were excited about the same problems.”

Aurore's research centred around pooled laboratory samples, where the fluids (i.e. blood or urine) from a group of people are combined, and a single test is performed on the pooled fluid. This may be done because there isn't enough money to perform tests on each individual or there isn't enough time. By combining the samples, a positive sample, of say a disease, could be diluted by the rest of the samples which might be negative. Aurore's research is about taking this dilution effect into account. She says the goal is to construct, using the grouped data, a nonparametric estimator of the probability of someone having the disease.

“I got interested in this problem by reading about a paper on the same topic, and I realised I could do better using the tools I

know about deconvolution and measurement errors, which was the topic of my PhD. At some point, I got stuck proving a result I knew to be true. I knew Peter had worked on something similar before, so I asked if he'd help. Luckily, he did,” says Aurore.

In presenting the award, COPSS highlighted Aurore's “fundamental and groundbreaking contributions to the statistical theory of group testing of pooled laboratory samples, and for contributions to measurement error methods and density estimation”.

Aurore is a Professor and ARC Future Fellow at The University of Melbourne. She has been an ACEMS Chief Investigator since the Centre was formed in 2014. Aurore was also an Associate Program Chair for the 2017 Joint Statistical Meetings.



*Aurore Delaigle receiving the George W Snedecor Award at the JSM 2017 from left to right: Nicholas Horton (Chair, COPSS), Aurore Delaigle and Paul Ralhouz (Chair, Snedecor Award Committee). Photo courtesy: American Statistical Association*

# 2017 HIGHLIGHTS

## RESEARCH

- Established the four new research themes of the Centre and developed 'Frontier Questions' for the future direction of the Centre to tackle the problems in these themes of: Challenging Data, Multiscale Models, Enabling Algorithms and Informed Decisions (page 74)
- Made advances in various areas: see the detailed list of research highlights within each research theme report
- Significantly increased cross-node collaborations (page 80)
- Made advances in various areas of the Centre's collaborative domains of Healthy People, Sustainable Environments, and Prosperous Societies.

## ENGAGEMENT

- Expanded the Industry Affiliates Program adding three new organisations: Defence Science and Technology Group, the Bureau of Meteorology and Queensland Academy of Sport (page 104)
- Developed stakeholder relations and partner organisation workshop program
- Significantly contributed to the Work Integrated Learning Initiative (page 108)

## COMMUNICATION

- Major redevelopment of the ACEMS website based on a novel web-based administrative system 'The Reportal'
- Enhanced ACEMS' social media presence (page 130)
- Highlighted work of ACEMS researchers and visitors on the ACEMS YouTube channel
- Highlighted ACEMS Outreach Program 'Mathscraft' on the ACEMS YouTube channel.
- Produced media releases on ACEMS-related research (page 133)
- Contributed articles to major news outlets
- Contributed articles to 'The Conversation'
- Led communications workshops for ACEMS members

## OUTREACH TO SCHOOLS

- Scaled up 'Mathscraft: Doing Maths Like a Research Mathematician' so that it is a national program (page 113)
- Expanded the offering of Mathscraft professional development for teachers (page 113)
- Delivered mathematical outreach programs to school students, across regional and remote Australia, as well as in major capital cities (page 114)
- Participated in the Mathematicians in Schools program (page 114)
- Held a Mathematics Showcase at Brisbane State High School for 200 Senior High School Students (page 114)
- Held a Teacher Professional Development Workshop for Carey High School teachers at The University of Melbourne with AMSI (page 113)
- Developed and established the work experience program at UNSW run by ACEMS CIs Robert Kohn and Scott Sisson

## OUTREACH TO THE GENERAL PUBLIC

- Took the lead, with other Centres of Excellence, in developing and presenting 'The National Science Quiz' to an audience of over 750 people over both Melbourne and Adelaide (page 115)
- Presented talks open to the public (page 120)
- Delivered a 'Big Data Analytics' MOOC (page 97)
- Participated in National Science Week events (page 116)

## OUTREACH WITHIN THE MATHEMATICAL SCIENCES RESEARCH COMMUNITY

- Held the ACEMS 2017 'Sampling & Exploration Competition' (page 118)
- Supported the mathematical research institute MATRIX (page 98)
- Supported relevant workshops/conferences proposed in Australia (page 87)

## MENTORING

- Developed a new and expansive Mentoring and Alumni Program across ACEMS to encourage, support and facilitate ACEMS members across all nodes
- Highlighted and supported student and early career researchers achievements including new publications, grants, awards, international and national travel, collaborations and professional development
- Included mentoring and professional development sessions on communication skills and career development at the Annual Retreats (page 122)
- Provided vacation scholarships and interacted with existing vacation scholarship schemes
- Identified opportunities for ACEMS postgraduate students and early career researchers to engage with the international research community
- Nominated people for prestigious awards

## SUCCESSION PLANNING

- Strategically refreshed the cohort of Chief Investigators (page 26)
- Strategically refreshed the membership nodes

## GOVERNANCE AND OPERATIONS

- Implemented the ACEMS Research Support Scheme for ACEMS Research Fellows and Associate Investigators
- Reviewed the ACEMS Student Scholarship Scheme
- Implemented the Centre's Strategic Plan with sub-plans for Outreach, Communication and Stakeholder Engagement
- Co-Hosted the Centres and Hubs workshop in December with the FLEET CoE at Monash University
- Conducted the ARC Mid-term review and passed with commendation from the ARC
- Reviewed the effectiveness of the Governance Advisory Board with plans to refresh in 2018
- Completed a major redevelopment of the ACEMS website ([www.acems.org.au](http://www.acems.org.au))
- Professional staff changes in 2017:
  - » Officially appointed Ben Hess to the Central and University of Melbourne Node Administrator role in January
  - » Appointed Dr Anita Poinaung to the role of ACEMS Outreach Officer in January

- » Provided Claudia Deasy QUT Node Administrator with a 10-month higher duties role to redevelop the Centre's Website
- » Welcomed Kate Taylor (QUT) to establish the Centre's Mentoring and Alumni program
- » Farewelled Claire Nitsch (UQ), Snezana Ilic (UoA) and Hillary Brooks (UoA) from the Node Administrator roles
- » Appointed Kate Lowry as COO maternity leave replacement for Emily Duane

## EQUITY AND DIVERSITY

- Developed an Equity and Diversity policy with a commitment to establish an Equity and Diversity Committee
- Supported the Australian Mathematical Society's Women in Mathematics Special Interest Group
- Held an International Women's Day Event at The University of Melbourne (page 127)
- Held the Ruth Williams Lunch (page 119)

## OTHER HIGHLIGHTS

- Over 80 national and international Centre visitors from 20 countries (page 93)
- Staff and students recognised for excellence via prizes, awards and other honours (page 34)
- Over 100 Centre members attended the Centre's Annual Retreat (page 122)
- Exceeded almost all official ARC Key Performance Indicator targets (page 138)

# ACEMS STRUCTURE, GOVERNANCE AND MANAGEMENT

ACEMS is a collaborative research centre that links The University of Melbourne (UoM), Queensland University of Technology (QUT), The University of Queensland (UQ), The University of Adelaide (UoA), UNSW Sydney (UNSW), the University of Technology Sydney (UTS) and Monash University, funded by the Australian Research Council (ARC) Centre of Excellence program. ACEMS' Partner Organisations are: AT&T Labs, Australian Bureau of Statistics (ABS), CSIRO, Mathematics of Information Technology and Complex Systems (Mitacs), VicRoads, Sax Institute, and the Australian Institute of Marine Science (AIMS).

As the lead administering node, The University of Melbourne manages the grant and node contributions, and distributes funds in accordance with the signed agreements. These agreements cover ACEMS management, collaboration and policy arrangements.

ACEMS day to day management is overseen by the Executive Committee (EC), which meets fortnightly; every fourth EC meeting is a meeting of all Centre Chief Investigators. The ACEMS Governance Advisory Board and Scientific Advisory Committee meet twice annually.

Led by the Centre's Chief Operating Officer, a strong professional staff team supports all Centre endeavours, and includes officers in administration, finance, outreach, stakeholder engagement, communications and media, and mentoring, as well as a node administration officer at each of the seven collaborating universities.

## CENTRE MANAGEMENT

The ACEMS Executive Committee is responsible for administration as it pertains to Centre policy, performance, financial matters, research output, research training and professional education of members, partnerships,

national and international liaison, commercialisation and outreach.

The members of the Executive Committee are:

**Professor Peter Taylor**, Director

**Professor Nigel Bean**, Deputy Director, Outreach

**Professor Kerrie Mengersen**, Deputy Director, Stakeholder Engagement

**Professor Scott Sisson**, Deputy Director, Communications and Media

## GOVERNANCE ADVISORY BOARD

The ACEMS Governance Advisory Board met in April and October 2017. The meetings focussed on the Centre's mid-term review, finances and reporting, as well as updates about key initiatives such as the Equity and Diversity Program, Mentoring Program and Research Support Scheme.

The GAB members are:

**Dr Ron Sandland (Chair)**, Former Deputy Chief Executive of the CSIRO

**Professor David Abramson**, Director, Research Computing Centre, UQ

**Professor Mike Brooks**, Deputy Vice-Chancellor (Research), UoA

**Professor Robert Calderbank**, Director, Information Futures Initiative, Duke University

**Professor Peter Donnelly**, Director, Wellcome Trust Centre for Human Genetics, Oxford University

**Professor Tony Dooley**, Head of the School of Mathematical and Physical Sciences, UTS

**Dr Emily Duane** (ex officio), Chief Operating Officer, ACEMS, UoM

**Professor Martin Grötschel**, President, Berlin-Brandenburgische Akademie der Wissenschaften (BBAW)

**Professor Tony Guttman**, Former Director of MASCOS, UoM

**Ms Sybille McKeown**, Reconciliation Champion and Program Manager, ABS

(Partner Organisation representative)

**Mr Daniel Owens**, Executive Director (Research), UNSW

**Professor Arun Sharma**, Deputy Vice-Chancellor (Research and Commercialisation), QUT

**Professor Liz Sonenberg**, Pro Vice-Chancellor (Research Collaboration & Infrastructure), UoM

**Professor Peter Taylor** (ex officio), Director, ACEMS, UoM

## SCIENTIFIC ADVISORY COMMITTEE

The ACEMS Scientific Advisory Committee met in March and November 2017. Recommendations included suggestions for improving the website, research themes and retreats, as well as suggestions for additional support for postdoctoral researchers and the upcoming 2020 proposal.

The Scientific Advisory Committee members are:

**Professor Peter Taylor (Chair)**, Director, ACEMS, UoM

**Dr Ken Anthony**, Principal Research Scientist, AIMS (Partner Organisation representative)

**Professor Louis Chen**, Emeritus Professor, National University of Singapore

**Professor Iain Johnstone**, Professor of Statistics and Health Research and Policy (Biostatistics), Stanford University

**Professor Xihong Lin**, Professor of Biostatistics, Harvard University

**Professor Michel Mandjes**, Faculty of Science Professor, University of Amsterdam

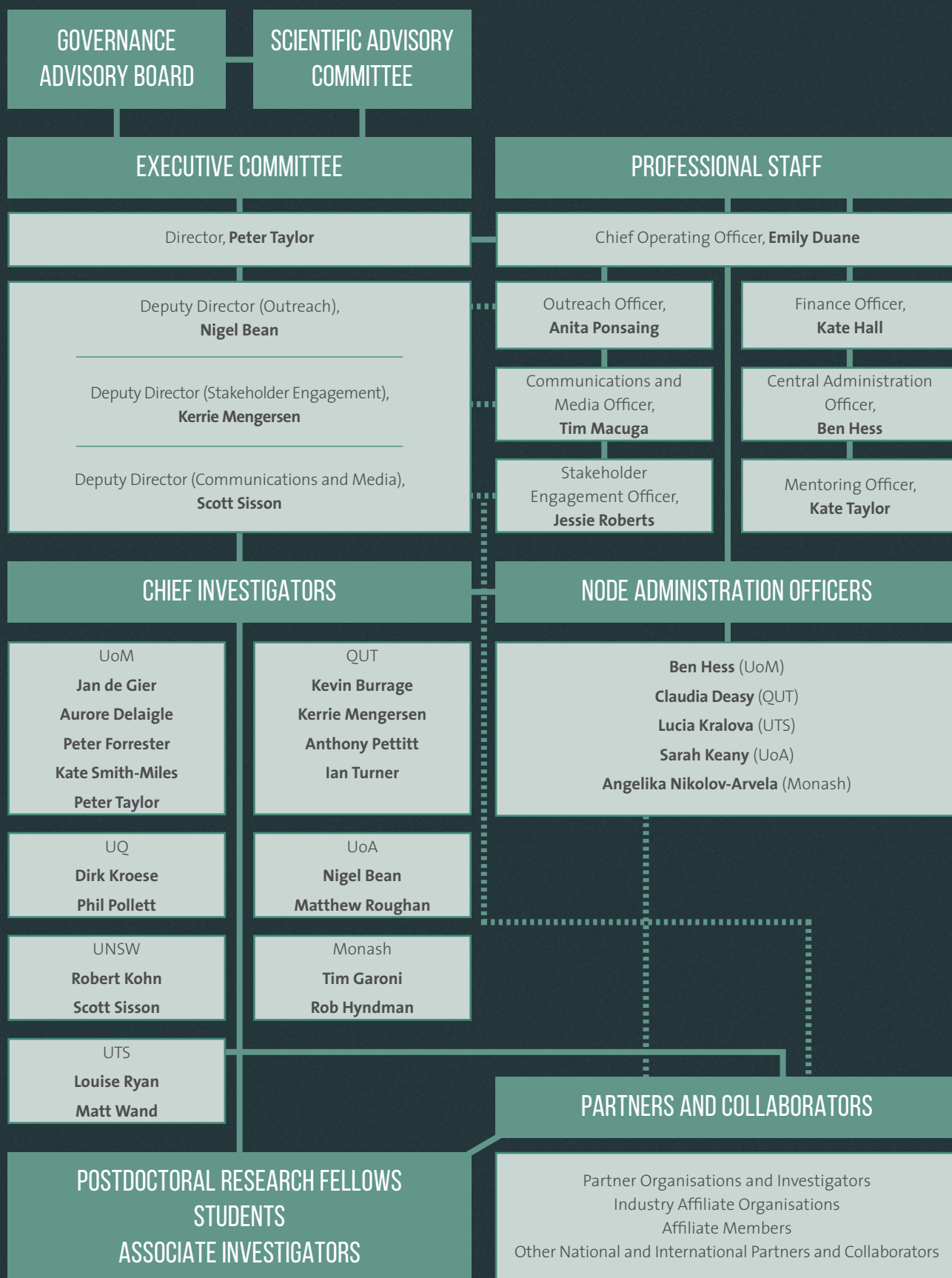
**Professor Herbert Spohn**, Emeritus Professor, TU München

**Professor Terence Tao**, Professor of Mathematics, University of California, Los Angeles

**Professor Ruth Williams**, Distinguished Professor, University of California, San Diego



## ORGANISATION CHART AS AT 31 DECEMBER 2017





# HOW STATISTICIANS ARE USING MATHS TO PREDICT WHAT YOU SHARE ON SOCIAL MEDIA



Lewis Mitchell  
The University of Adelaide

“It’s possible to predict the things you are going to write about based on what your friends have written before you.”

A graphical representation of a social network constructed from discussion on Twitter.

## HOW POPULAR ARE YOU ON SOCIAL MEDIA?

According to a theory known as the ‘friendship paradox’, the answer to that question is: *not as popular as your friends*. This paradox basically states that friends of individuals tend to have more friends than the individual him/herself.

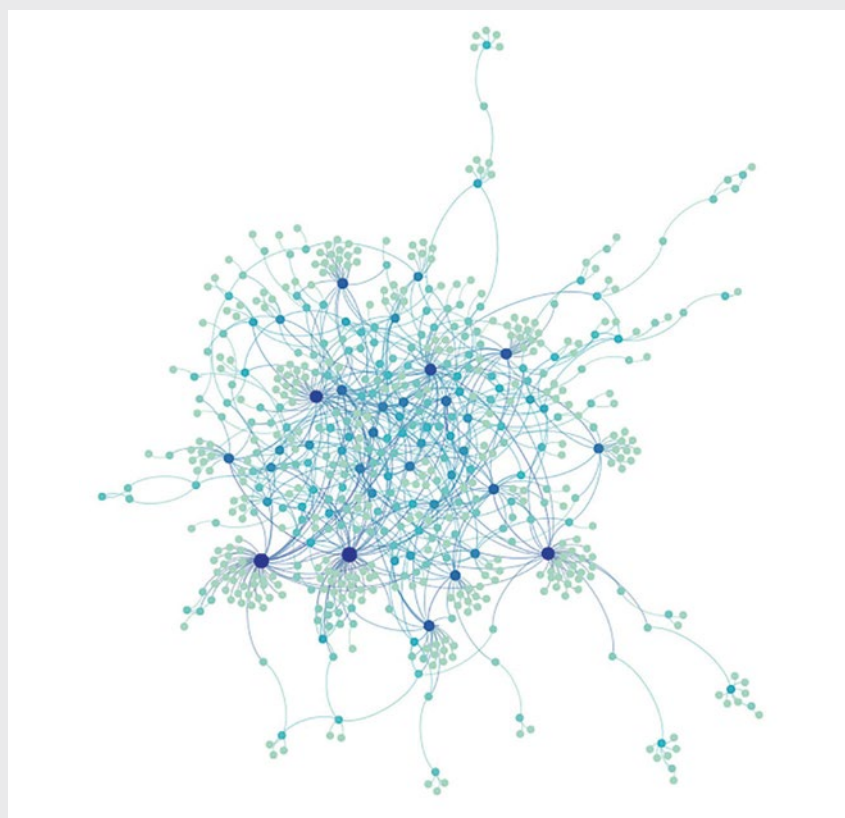
But fascinating research by the statistician Dr Lewis Mitchell has called this theory into question. Lewis is an Associate Investigator at ACEMS and a lecturer at The University of Adelaide. His work uses statistical tools to give meaning to friendships and networks on social media. He is interested in the extent to which we can make predictions about what individuals choose to write and share on social media, based on their social ties.

In an age of political uncertainty and polarisation, we’ve all heard of online ‘echo chambers’ – namely, that social media users are more likely to engage with those that share their political views. Lewis is primarily interested in finding out how these echo chambers develop. But first, he needs to understand how information flows on social networks – and that is where statistics comes in.

“A great thing about the current age of ‘big data’ is that we have mountains of information about the thoughts and feelings of people over time,” Lewis says. “We’ve been collecting data from Twitter and constructing timelines of the things people have written. From this, we can quantify the information that’s shared between different people, using classic mathematical tools borrowed from information theory.”

Because social media gives us information about the timings of the various things people write, Lewis and his team have been able to analyse how much an individual’s friends influence what they write.

“We found that an individual’s social circle contains predictive information



about them,” says Lewis. “That is, in principle, it’s possible to predict the things you are going to write about based on what your friends have written before you.”

But Lewis also found that not all of your friends are equal. Perhaps unsurprisingly, your closest friends (defined as the individuals you contact most frequently) seem to have more influence over you than your distant friends. The extent to which they can be used to predict what you’ll write next is extraordinary – in theory, Lewis’ research suggests that your 12 closest friends contain just as much information about your future writings as your own past history.

The team also found out something new about the so-called friendship paradox. While it is a widely held belief that *your friends are more popular than you are*, Lewis’ research results strongly suggest that the closer your friend is, the weaker the friendship paradox is.

“So we could refine the paradox: ‘your more distant friends are much more popular than you are, but your best friends are no more popular than you’,” says Lewis.

Intriguingly, this finding may also have implications for the offline world – specifically, in the field of health research. As Lewis explains, there is a vaccination strategy called ‘acquaintance immunisation’, which exploits the friendship paradox by distributing vaccines and asking people to give them to their friends.

“Our findings suggest that if your closest friends are ‘famous’, this method is effective at making the vaccine use spread faster and thus the disease spread slower,” Lewis says. “But the flaw is that your closest friends are less likely to be ‘famous’, meaning that people with the most influence are less likely to be immunised – so it may not be as effective as hoped.”

For now, Lewis is enjoying the fact that his latest piece of research has been successfully submitted for publication. He carried it out in collaboration with James Bagrow, an Assistant Professor at the University of Vermont.

Going forward, Lewis is excited about the directions his research will take. He is keen to continue using the power of statistics to explore how information is transferred on social media and to gain a deeper understanding of how online filter bubbles and echo chambers develop.



# ACEMS RESEARCH SAVING SEAGRASSES FROM DREDGING

New statistical modelling developed by ACEMS researchers could provide the key to preserving one of the world's most productive and important ecosystems – seagrass meadows.

Dr Paul Wu, an ACEMS Associate Investigator at QUT, led a research team that included ACEMS Deputy Director Kerrie Mengersen and seagrass experts at Edith Cowan and James Cook universities. With their help, Paul developed a way of predicting the ideal time to dredge in order to give the seagrass the best and quickest chance of recovery.

Dredging is a source for seagrass loss and timing is critical for its removal. "This is called an ecological window," says Paul.

The team of researchers studied 28 seagrass meadows around the world. Their study was published in *Nature Communications* in November 2017.

Seagrasses provide shelter and food to an incredibly diverse community of life, from the tiniest marine creatures to fish, turtles, dugongs, other marine mammals and birds. It is

estimated that one hectare of seagrass can absorb 35-times as much carbon dioxide as a hectare of Amazon rainforest, as well as produce 100-thousand litres of oxygen per day.

Despite this immense value, large areas of seagrass are disappearing every year because of accumulated stressors, including human activities, most notably dredging. Paul developed an advanced statistical model to predict when dredging is least likely to damage seagrass. The model could be used globally, not just in Australia.

"We found that globally, our model can provide up to a four-fold reduction in recovery time, and up to a 35 per cent reduction in local extinction risk for seagrass species," says Paul.

"So if the seagrass can come back more quickly, or you can minimise the impact on it, that will also help everything that depends on it."

The model takes into account resilience. Some areas of seagrass are stronger and healthier and can handle more stress. The model looks at how resistant a system is to change, how quickly it can recover, and considers the probability of extinction in local populations.

*"Being able to tell the difference between a site where you can do some dredging and it will come back, a site that is at its limit and you shouldn't do any more to it, or a site that's already dying and it doesn't make a difference about what you do to it, is very important," says Paul.*

ACEMS Associate Investigator Dr Paul Wu has developed an advanced statistical model to predict when dredging is least likely to damage seagrass.



*Dr Kathryn McMahon, Deputy Director of Edith Cowan University's Centre for Marine Ecosystems Research diving during field trials.*



*A dredged seagrass bed which can now be given the best opportunity at recovery.*



There are dozens of seagrass species around the world. They typically grow along gently sloping, protected coastlines. Seagrasses depend on light for photosynthesis, most commonly found in shallow depths where light levels are high. Dredging can significantly reduce the amount of light reaching the seagrass.

Dr Kathryn McMahon, Deputy Director of Edith Cowan University's Centre for Marine Ecosystems Research, explains that seagrass is much like terrestrial plants. "There are natural phases of seagrass growth and reproduction, therefore, at particular times seagrasses could be more or less vulnerable to dredging pressures," she says.

"By combining our knowledge of the biology of seagrasses with natural environmental fluctuations and human pressures we identify the best time to minimise long-term impacts for human activities."

Paul believes proponents of dredging and coastal development would be among those who could benefit from the use of this model. "The model allows dredging and coastal development to move forward, but helps mitigate the environmental impacts on seagrass and the many ecosystems that depend on it," he says.

Paul's Bayesian network model combines both the use of data with expert knowledge. "As with many ecosystems, there isn't enough data to fully understand the system," says Paul.

"The processes are too complex and there is too much variability in nature. We bolster the data we have with expert knowledge from seagrass scientists who dive on the seagrass beds, studying them and taking samples, decades of valuable experience."

Those experts come from the School of Sciences and Centre for Marine Ecosystems Research at Edith Cowan University, the Western Australian Marine Science Institution in Perth, the UWA Oceans Institute and School of Biological Sciences at the University of Western Australia, and the Centre for Tropical Water & Aquatic Ecosystem Research at James Cook University (JCU).

"What makes the model even more important is that it isn't limited to just seagrass. It could be used to model other natural ecosystems under stress, like mangroves and coral reefs," says Paul.

JCU's Dr Michael Rasheed believes the model is more practical than existing systems. "Global trends indicate favourable windows in autumn and winter where dredging causes the least damage," says Michael.

"Ideally, impact assessments of dredging campaigns do still need to be customised for specific meadows at specific periods in time and incorporate uncertainty associated with forecasted future conditions in the area."

ACEMS Associate Investigator Dr Julian Caley was also involved with the project.



# STRATEGIC PLAN 2017-2020

IN 2017 THE ACEMS EXECUTIVE COMMITTEE IMPLEMENTED THE CENTRE'S STRATEGIC PLAN, DEVELOPED IN COLLABORATION WITH THE GOVERNANCE ADVISORY BOARD. THIS PLAN IS A LIVING DOCUMENT WHICH ADAPTS TO CHANGES IN ACEMS, AND THE MATHEMATICAL AND STATISTICAL SCIENCES, AND ENSURES THAT AS THE CENTRE MOVES THROUGH EACH OF STAGE OF ITS LIFE, IT ALWAYS PUSHES THE FRONTIERS OF RESEARCH. THIS PLAN CAPTURES THE INTENT, OBJECTIVES, HIGH-LEVEL GOALS, STRATEGIES AND MEASURES THAT ARE USED TO GUIDE THE CENTRE.

## INTENT

To create world-class research at the frontiers of the mathematical sciences dealing with probability and randomness and to translate this research into new insights that benefit society.

## STRATEGIC CONTEXT

The mathematical sciences are ever present in day-to-day life. Most of the perplexing challenges facing society have a mathematical or statistical problem at the core. This represents a challenge to the mathematical sciences to develop excellence and push the frontiers of the science and to stay engaged across all other disciplines of physical and social sciences.

The mathematical and statistical disciplines must attract the best minds regardless of race, gender, religion and age and encourage the development of a passion for mathematics and statistics in our community.

This plan addresses our intent through four strategic pillars: capability, capacity, impact, and governance and operations. It is underpinned by three supporting and detailed strategic plans for: stakeholder engagement, media and communications, and outreach. Together these strategies ensure that ACEMS not only delivers world-class research but that it creates a translation pathway and a legacy for the disciplines to attract and retain the best and brightest.

The Strategic Plan 2017-2020 outlines progress against the ACEMS goals to date and articulates the forward strategies to take ACEMS to the next level in each of the four strategic pillars.

## OBJECTIVES

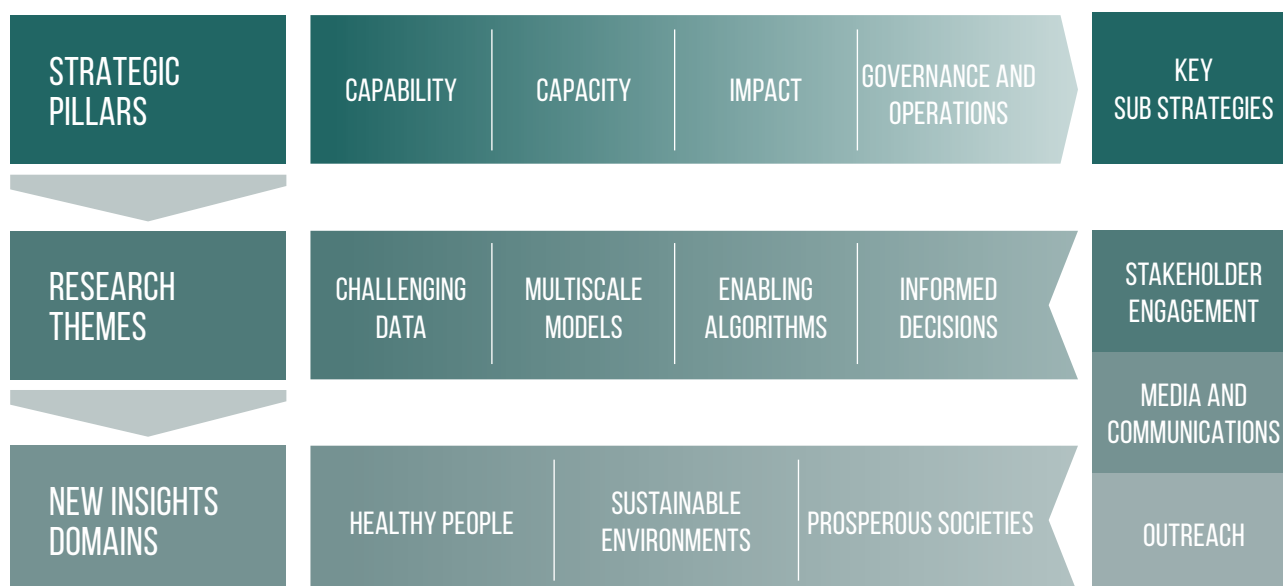
- To pursue this intent through leading-edge research and research training across the research themes: Challenging Data, Multiscale Models, Enabling Algorithms and Informed Decisions.
- To link the streams of research in mathematics, statistics, mathematical physics and machine learning, across the spectrum from theoretical to applied research.
- To align and capitalise on this value chain to deliver impact in the collaborative domains: Healthy People, Sustainable Environments and Prosperous Societies.

## WE ARE SUCCESSFUL WHEN:

- The ACEMS brand is recognised as world-class both within Australia and internationally
- Our research is recognised and respected nationally and internationally
- Our postgraduates and researchers are successful in their chosen career paths
- We attract first-class mathematical and statistical minds regardless of race, gender, religion or age
- Our research is celebrated for the value it adds to solving real-world problems
- The Australian community has a better understanding of the importance of the mathematical sciences to everyday life
- ACEMS governance and operations are transparent, efficient and effective.

# ACEMS STRATEGIC FRAMEWORK 2017 - 2020

**Intent:** To create world-class research at the frontiers of the mathematical sciences dealing with probability and randomness and to translate this research into new insights that benefit society.



## CAPABILITY

HIGH-LEVEL GOALS	FORWARD STRATEGIES	MEASURES
To become an internationally respected and renowned focus for world-class research and research translation	<p>Continue to grow the quality and relevance of ACEMS membership and leverage the international networks of Chief Investigators and senior Associate Investigators for the development of postgraduate students and postdoctoral fellows.</p> <p>Promote ACEMS as a thought leader for public discourse on mathematics and statistics.</p> <p>Continue to grow ACEMS brand through prizes and awards.</p> <p>Develop an Equity and Diversity strategy for ACEMS with a clear focus on gender as an identified area of need for ACEMS.</p> <p>Continue to draw on the eminent group of scientists who comprise the SAC to ensure current and future research directions are on track.</p>	<p>Active ACEMS membership</p> <p>Papers in high ranking journals</p> <p>Presentations at international conferences</p> <p>Public discourse on matters related to ACEMS expertise</p> <p>Awards and recognition</p> <p>Strategy developed and implemented</p> <p>SAC advice implemented</p>
To encourage a collaborative research culture	<p>Grow the ACEMS portfolio of world-class research projects that would not have been attempted without the Centre.</p> <p>Continue to build the collaborative paradigm shift between disciplines. Recognise and celebrate these collaborations.</p> <p>Continue to build the ACEMS national and international research networks by leveraging Chief Investigators' and senior Associate Investigators' personal networks with complementary research groups.</p> <p>Escalate cross-node collaboration through increased focus on postdoctoral researchers.</p> <p>Conduct workshops on each of the four research themes.</p>	<p>International visits</p> <p>International visitors</p> <p>Demonstrated activities with other national and international research groups</p> <p>Collaborative workshops</p> <p>Inter-node interaction</p> <p>Big picture research topics that clearly reflect a merger of the separate disciplines within the Centre</p> <p>Projects that cross theory, methods, computation and application</p> <p>Projects that cross the four research themes</p>

## CAPACITY

HIGH-LEVEL GOALS	FORWARD STRATEGIES	MEASURES
To train world-class postgraduates, researchers and practitioners within the ACEMS research culture	<p>Maintain momentum by building on ACEMS culture of high-quality collaborative learning and training.</p> <p>Create opportunities for students to work in the New Insights Domains with Partner and Industry Affiliate Organisations.</p> <p>Develop graduates and early career researchers who can operate in the collaborative culture and communicate to external stakeholders.</p> <p>Build on the opportunities already established to create long-lasting professional networks.</p> <p>Continue to build national and international collaborative research networks for the benefit of members.</p>	<p>Engagement with early career researcher resources in professional societies</p> <p>Involvement of postgraduates and early career researchers in research translation meetings and projects with external groups</p> <p>Cross-nodal collaboration</p> <p>Visitors to the Centre</p> <p>Overseas research visits</p> <p>ACEMS mentoring program</p> <p>Sponsorship of mentoring and training activities</p>
To engage with Partner Organisations and external collaborators	<p>Leverage relationships with Partner Organisation networks to grow ACEMS' sphere of influence in all New Insights Domains.</p> <p>Target new Partner Organisations that bring mutually beneficial opportunities and access to expertise, data and networks for ACEMS researchers and partners.</p> <p>Continue to develop relationships with cognate national and international research centres.</p> <p>Implement the Stakeholder Engagement Plan.</p>	<p>High quality activities with Partner Organisations</p> <p>Short courses</p> <p>Joint postgraduate supervision with Partner Organisations and collaborators</p> <p>Strategy for inclusion of relevant research and researchers who are not in ACEMS</p> <p>Signed agreements and substantive activity with relevant national and international research centres</p>

## GOVERNANCE AND OPERATIONS

HIGH-LEVEL GOALS	FORWARD STRATEGIES	MEASURES
To operate as a well-managed and financially stable organisation	<p>Provide stable leadership through sound succession planning in the Governance Advisory Board, the Executive Committee, Chief Investigators and the Operations team.</p> <p>Provide timely and accurate information to the Governance Advisory Board that supports its terms of reference.</p> <p>Financial planning for 2017 and beyond will emphasise an ambitious approach to hiring postdoctoral researchers. It accelerates initiatives to support all ACEMS members including by increasing sponsorship, introducing additional mentoring programs, increasing numbers of workshops at each node, and introducing a Research Support Scheme.</p> <p>Maintain the right skills mix in the ACEMS operations team to deliver efficient administration across the Centre.</p> <p>Maintain policies, systems and processes to operate a financially responsible and viable Centre.</p> <p>Deliver transparency and accountability in all processes and systems.</p> <p>Provide timely and accurate information to all stakeholders, including CIs and collaborating institutions.</p> <p>Encourage development of Professional staff.</p> <p>Maintain productive relationships between all ACEMS members, as well as relevant staff at member institutions.</p>	<p>Effective Director, EC and COO, evidenced by feedback from ACEMS members and the ARC</p> <p>Effective, efficient administrative and professional team, evidenced by positive feedback from ACEMS members and the ARC</p> <p>Operational and strategic focus on finance</p> <p>Clear visibility of Centre operations and finances for EC, Chief Investigators and GAB</p> <p>Efficient data collection procedures</p> <p>Uptake of career development opportunities by the Professional Staff</p> <p>Positive feedback based on performance reviews of ACEMS members</p>

## IMPACT

HIGH-LEVEL GOALS	FORWARD STRATEGIES	MEASURES
To add value to society by using ACEMS research to help solve real world problems	<p>Strategically target and engage with significant high value challenges and organisations of significance to the Australian and international community to partner with ACEMS.</p> <p>Be a 'first thought of call' for mathematical and statistical problems in Australia by continually promoting ACEMS' achievements and improving pathways for collaborating partners and clients to easily access ACEMS researchers.</p> <p>Continue to build and support pathways to impact for ACEMS including experimenting and innovating with novel approaches.</p>	<p>Evidence of impact of ACEMS research in practice</p> <p>Effective Media and Communications Plan</p> <p>Effective Stakeholder Engagement Plan</p> <p>Contribution to discussion on impact in the mathematical sciences</p> <p>Database of ACEMS impact measures</p>
To leave a legacy for the mathematical and statistical sciences	<p>Continue to support MATRIX.</p> <p>Implement Stakeholder Engagement, Outreach and Media and Communications plans.</p> <p>Continue to support current successful initiatives such as Mathscraft, the National Science Quiz and CSIRO's Mathematicians in Schools program.</p> <p>Continue to raise awareness of the influence and impact of the mathematical and statistical sciences in the wider community.</p> <p>Continue to attract, retain and train high-quality postgraduate students and postdoctoral researchers from Australia and abroad to work on ACEMS-related research.</p>	<p>Success of MATRIX</p> <p>Plans implemented</p> <p>Developed examples of ACEMS impact</p> <p>Successful ACEMS graduates and early career researchers</p> <p>Effective Outreach Plan</p> <p>Student and early career researcher numbers</p>

# 2018 PLANS THE YEAR AHEAD

## RESEARCH

- Encourage a higher level of cross-node and Partner Organisation collaboration on ACEMS projects in 2018, including through mentorships, encouraging Centre-wide participation in research theme and partner organisation workshops
- Host research workshops aligned with the four research themes: Challenging Data, Multiscale Models, Enabling Algorithms and Informed Decisions. Ensuring that each theme holds at least one workshop per year, and streaming and recording these so that everyone is able to access them
- Create world-class research at the frontiers of the mathematical sciences (see '2018 Research Plan – At a Glance' page 37)
- Hire additional postdoctoral researchers
- Support our postdoctoral researchers and Associate Investigators through Research Support Schemes and new collaborative opportunities.

## MENTORING

- Promote and increase mentoring for postdoctoral researchers and professional staff in particular for new members of ACEMS
- Organise a series of postdoctoral workshops
- Roll out the mentoring seminar series, by broadcasting and recording sessions, making it available for all ACEMS members to participate in
- Facilitate greater cross-node interaction through the promotion of visitor and travel schemes, and cross-node supervision and mentoring
- Provide vacation scholarships and interact with existing vacation scholarship schemes
- Identify opportunities for ACEMS HDR students and ECRs to engage with the international research community
- Evaluate success of the cross-node mentoring program and plan to extend the program across the nodes

## STAKEHOLDER ENGAGEMENT

- Continue to expand and strengthen relationships with our existing Partner Organisations through research collaborations
- Host annual research planning meetings with Partner Organisations and Industry Affiliate Members
- Leverage off the success of the 2017 Australian Taxation Office secondment program to broaden the program to other Partner Organisations and Industry Affiliate Members
- Expand the Woodside 'Work Integrated Learning' Project to Paypal and Commonwealth Bank of Australia and beyond

- Further expand the Industry Affiliate Program
- Further engage with the Australian Mathematical Sciences Institute (AMSI) Industry/Mathematical Sciences Engagement Task Force
- Engage with and make it easier for new Partner Investigators and Industry Affiliate Organisations to work with ACEMS
- Host engagement-focused workshops and expand to recording them for online consumption

## NATIONAL AND INTERNATIONAL LINKS

- Develop fruitful working relationships with major international centres and institutes
- Roll out the student/postdoctoral exchange program with Partner Organisations and international collaborators Mitacs (Canada), Oxford (UK), NETWORKS (Netherlands) and Insight (Ireland)
- Host distinguished national and international visitors
- Engage with existing national and international collaborators
- Strengthen links with other ARC Centres of Excellence

## COMMUNICATION

- Provide opportunities to assist in enhancing the communication and presentation skills of all ACEMS members and provide invaluable experience in communicating research objectives and outcomes to end-users at all levels
- Produce personal stories about Centre members and their research



- Continue to promote the success of ACEMS researchers to the ACEMS community through monthly announcements and stakeholders newsletters
- Continue to expand the ACEMS brand through a presence in media stories
- Continue to grow the Centre's following on social media
- Promote the work of ACEMS to all media including traditional media outlets

## OUTREACH TO SCHOOLS

- Facilitate Mathscraft's continued expansion into teacher training and maintain its cutting edge reputation
- Maintain the Centre's involvement in the CSIRO's Mathematicians in Schools program and actively participate to develop a curated database of resources to share with other participating mathematicians to ensure longevity in the program
- Lead and co-support the re-boot of the Adelaide 'Saturday Morning Maths' program that assists interested and motivated secondary school students
- Support the debate to include 'Introductory Data Science' in secondary schools
- Support and participate in The University of Melbourne's Maths Fair
- Consider opportunities to partner with other existing outreach programs

## OUTREACH TO THE GENERAL PUBLIC

- Expand the National Science Quiz to be held in multiple states
- Investigate the possibility to broadcast the National Science Quiz either through television or as a web event
- Present talks open to the public
- Organise and participate in National Science Week events and World Science Festival in Brisbane

## OUTREACH WITHIN THE MATHEMATICAL SCIENCES RESEARCH COMMUNITY

- Continue financial support of the mathematical research institute MATRIX

- Support and co-organise MATRIX workshops
- Co-Host the AMSI Optimise Conference
- Support the Australian Mathematical Society's Women in Mathematics Special Interest Group
- Support relevant workshops, conferences and events

## SUCCESSION PLANNING

- Review the medium-term career aspirations of all ACEMS Chief Investigators, with a view to maintaining energy and expertise in ACEMS senior leadership
- Identify candidates amongst ACEMS Associate Investigators who might move into Chief Investigator positions in the medium term
- Consider the career prospects of all ACEMS postdoctoral staff and provide appropriate mentoring
- Plan and submit a new proposal for the 2020 Centre of Excellence

## GOVERNANCE AND OPERATIONS

- Continually refine and develop the Centre's Strategic Plan to ensure that the activities as mentioned above achieve the strategic goals set out in the 2020 Plan
- Form, promote and implement the recommendations of the Equity and Diversity Committee
- Closely engage with the Scientific Advisory Committee to monitor the four research themes
- Review and restructure the Governance Advisory Board, by appointing new members to strengthen networks and promote the work of ACEMS nationally and internationally
- Continue to improve the Centre's reporting systems

## OTHER ACTIVITIES

- Nominate ACEMS members for prestigious awards
- Organise the Centre's Student Retreat
- Organise the Centre's Early Career Researcher Retreat
- Organise the Centre's Annual Retreat for all members
- Expand the Advanced Sampling and Exploration competition

# THE POWER OF MATHEMATICS: USING STATISTICS TO FIGHT BUSHFIRES



Sevvandi Kandanaarachchi  
Monash University



Kate Smith-Miles  
The University of Melbourne

“This is the legacy that ACEMS is trying to create – a new generation of mathematicians who have the knowledge, skills and confidence to tackle some of society’s greatest challenges with the power of mathematics.”

*Representation of fire risk with selected features: Autocorrelation of first order with the Entropy of the signal.*

**THERE ARE ABOUT 50,000 BUSHFIRES EVERY YEAR IN AUSTRALIA, ACCORDING TO A 2009 REPORT BY THE AUSTRALIAN INSTITUTE OF CRIMINOLOGY.**

For many Australians, this number is probably not that surprising. What is more surprising, though, is that mathematicians may have a key role to play in fighting these fires.

One of these fire-fighting mathematicians is Dr Sevvandi Kandanaarachchi – a postdoctoral fellow and Associate Investigator at ACEMS. She works closely with Professor Kate Smith-Miles, one of ACEMS' Chief Investigators.

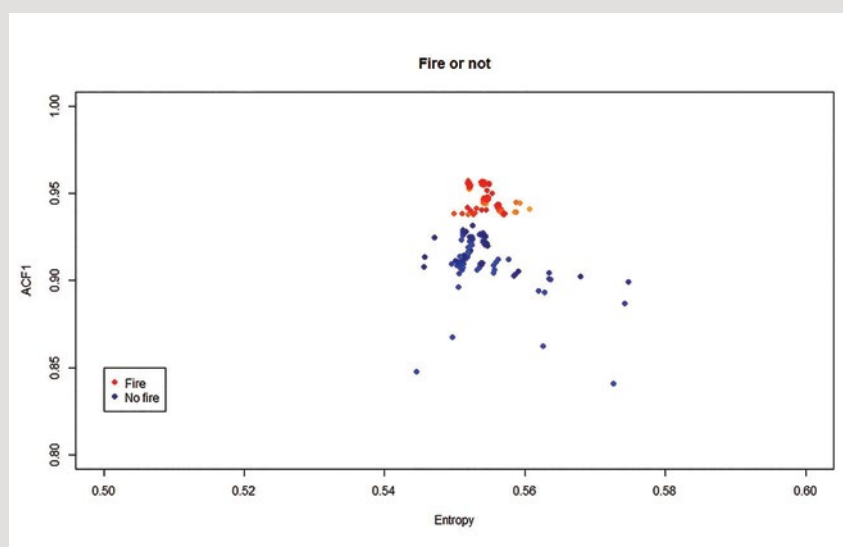
But what's the connection between maths and bushfires? And what inspired Sevvandi to apply her mathematical expertise in this area?

To answer this, we need to rewind to May 2017, when the Victorian Government's Powerline Bush Safety Program (PBSP) launched a Vegetation Detection Challenge. The goal was to develop an algorithm that could be used to assess the risk of a bushfire igniting as a result of vegetation coming into contact with a powerline (for example, a branch falling onto an electric cable).

Sevvandi's imagination was captured by this interesting challenge, and she worked with Dr Mario Munoz Acosta (an ACEMS Associate Investigator at The University of Melbourne) and Priyanga Talagala (a PhD student at Monash University) to respond to it.

As Kate explains, the challenge was a great opportunity for Sevvandi, Mario and Priyanga to develop their mathematical skills and apply them to real-world problems.

"One of the main objectives of ACEMS is to grow capacity for the future," Kate



says. "We have a fantastic cohort of postdoctoral research fellows and PhD students, and I was very enthusiastic to see Sevvandi and the team use their mathematical skills to engage with such a critically important challenge as bushfire prevention."

Previously, Sevvandi's research had focused on finding anomalies in high volume streaming data, with applications for detecting intruders in a security context. So it was exciting to think that the methods she and the team had developed could be extended to something as far removed from this as bushfire prevention.

Using a data set that had been collected by the PBSP – which contained a vast number of photos, videos, test logs and reports on bushfires caused by powerline faults involving vegetation – Sevvandi, Mario and Priyanga created three different mathematical models to assess the risk of a bushfire igniting.

Mathematical modelling is basically a process that uses maths to analyse, predict and provide insights into real-world phenomena, such as bushfires. Almost anything in our lives can be modelled, enabling researchers like Sevvandi, Mario and Priyanga to uncover important patterns and help solve big problems.

"Our first model detects a branch on a powerline and creates an alert," Sevvandi says. "If the branch continues to be on the powerline for longer than a certain amount of time, then the alert is escalated to an alarm. The second model is a visual method to help ascertain the risk of fire, while the third model predicts the fire risk as high or low using a different algorithm."

Using the three models, the team successfully identified certain characteristics that can be used to predict the risk of a bushfire – and they correctly predicted the bushfire outcomes in their sample data set. In recognition of their success, they were awarded second prize in the PBSP competition.

This is an achievement to be proud of and the team's research could have far broader implications going forward. Their algorithm is not only applicable in Australia, but also in other countries where bushfires happen. It's exciting to think that their mathematical prowess could be used to save lives and protect biodiversity by preventing the spread of devastating bushfires.

As for Kate, she is delighted with the team's accomplishment: "As a supervisor, it is always special to realise that you have helped train independent researchers who generate their own successes," she says. "This is the legacy that ACEMS is trying to create – a new generation of mathematicians who have the knowledge, skills and confidence to tackle some of society's greatest challenges with the power of mathematics."

# ACEMS ADDS MONASH UNIVERSITY AS 7TH COLLABORATING ORGANISATION; PROMOTES FOUR TO CHIEF INVESTIGATOR

ACEMS officially added Monash University as its seventh member university in 2017.

*Monash joins The University of Melbourne, where the Centre is headquartered, the Queensland University of Technology, The University of Adelaide, The University of Queensland, UNSW Sydney, and the University of Technology Sydney, as the seventh Collaborating Organisation.*

Monash has two ACEMS Chief Investigators (CI) under the revised structure of the Centre; Professor Rob Hyndman and Associate Professor Tim Garoni. Both Rob and Tim were Associate Investigators when the Centre started in 2014, with Tim becoming a temporary CI shortly afterwards. Tim was confirmed as a continuing CI during 2016, and officially recognised by the ARC in 2017 alongside Professors Kate Smith-Miles and Scott Sisson. Rob joined the cohort of ACEMS CIs in late 2017.

“Kate, Scott, Rob and Tim are four of the most exciting mid-career mathematicians/statisticians in the country who, furthermore, are already demonstrating the leadership qualities that will take ACEMS, and the rest of the mathematical sciences community, forward in the years to come,” says Professor Peter Taylor, Director of ACEMS.

Kate is an ARC Laureate Fellow and President of the Australian Mathematical Society (AustMS). The appeal of ACEMS for her is that it brings together researchers from around Australia who might otherwise never meet.

“I work in a diverse range of sub-fields within the mathematical sciences including optimisation, statistics, machine learning and applied mathematics. These are areas that are normally quite separate in the sense that they have their own conferences and societies, without much overlap,” says Kate.

“Usually I move between these different communities, but within ACEMS, they’re all brought together under some common unifying theme areas. I’m

really looking forward to exploring the synergies between these areas more explicitly through the ACEMS umbrella.”

In addition to his role as a CI, Scott was appointed as an ACEMS Deputy Director. He is also President of the Statistical Society of Australia and was named an ARC Future Fellow in 2017.

“For me ACEMS is an amazing enabler – a catalyst that provides us with the means to boldly step beyond the research that we do within the safety of our own research institutions and disciplines,” says Scott.

“It gives us the opportunity to work on problems and ideas that we would never otherwise do on our own, with people and involving disciplines that we would never otherwise work with. This is how research should be — exciting, challenging and inclusive.”

At Scott’s home university of UNSW, the two ACEMS CIs (the other is Professor Robert Kohn) are in different faculties. The same is true at Monash for Rob and Tim.

“Tim is in the School of Mathematical Sciences in the Faculty of Science, and I’m in the Department of Econometrics and Business Statistics in the Monash Business School. One advantage of



us both being part of ACEMS is that it encourages greater collaboration between our groups,” says Rob.

In addition to ACEMS, Rob is an Editor-in-Chief of the International Journal of Forecasting and a Director of the International Institute of Forecasters.

“My recent research has centred around developing new tools for handling large collections of time series. This work will be accelerated now that I’m an ACEMS CI. I also hope to foster new collaborations with researchers working on similar research topics at other nodes,” says Rob.

One of the strengths Tim says he brings to ACEMS is his work in the mathematical and statistical modelling of traffic.

“This is a good example of where stochastic modellers are working with statisticians on merging the big data and big models paradigms. These collaborations that have formed because of ACEMS are an important step in making our stochastic traffic model a practical tool for transport planners,” says Tim.

ACEMS Director Peter Taylor says the decision to bring Kate, Scott, Rob and Tim on board as CIs and to make Monash a Collaborating Organisation, were the right moves to keep ACEMS moving forward.

“This demonstrates how seriously we take succession planning, as well as research quality,” says Peter.

In all, ACEMS now has 19 CIs spread across its seven member institutions.



*Professor Kate Smith-Miles  
The University of Melbourne*



*Associate Professor Tim Garoni  
Monash University*



*Professor Scott Sisson  
UNSW Sydney*



*Professor Rob Hyndman  
Monash University*



# PERSONNEL

## DIRECTOR

**Peter Taylor**, UoM

## DEPUTY DIRECTORS

**Nigel Bean**, Outreach, UoA

**Kerrie Mengersen**, Stakeholder Engagement, QUT

**Scott Sisson**, Communications and Media, UNSW

## CHIEF OPERATING OFFICER

**Emily Duane**, UoM

**Kate Lowry**, UoM (incoming maternity leave replacement)

## PROFESSIONAL STAFF

**Hilary Brookes**, Administration Officer, UoA •

**Bryce Christensen**, Administration Officer, QUT •

**Claudia Deasy**, Administration Officer, QUT

**Priscilea Furerri**, Administration Officer, UNSW •

**Kate Hall**, Finance Officer, UoM

**Benjamin Hess**, Administration Officer and Central Administrator, UoM

**Jocelyn Hubbard**, Administration Officer, QUT •

**Snezana Ilic**, Administration Officer, UoA •

**Sarah Keany**, Administration Officer, UoA

**Lucia Kralova**, Administration Officer, UTS

**Tim Macuga**, Communications and Media Officer, QUT

**Angelika Nikolov-Arvela**, Administration Officer, MU

**Claire Nitsch**, Administration Officer, UQ •

**Anita Ponsaing**, Outreach Officer, UoM

**Jessie Roberts**, Stakeholder Engagement Officer, QUT

**Kate Taylor**, Mentoring Officer, QUT

• Left ACEMS during 2017

## CHIEF INVESTIGATORS

A Chief Investigator is a member named in Schedule A of the ARC Centre of Excellence Funding Agreement as a Chief Investigator. This person has direct responsibility to the ARC for delivering on ACEMS objectives. Usually, he or she will have overall intellectual responsibility for an ACEMS research project, leading research, providing effective supervision to students and mentoring as required.

**Peter Bartlett**, QUT (outgoing)

**Nigel Bean**, UoA

**Kevin Burrage**, QUT

**Jan de Gier**, UoM

**Aurore Delaigle**, UoM

**Peter Forrester**, UoM

**Timothy Garoni**, MU

**Rob Hyndman**, MU

**Robert Kohn**, UNSW

**Dirk Kroese**, UQ

**Kerrie Mengersen**, QUT

**Anthony Pettitt**, QUT

**Phil Pollett**, UQ

**Matthew Roughan**, UoA

**Louise Ryan**, UTS

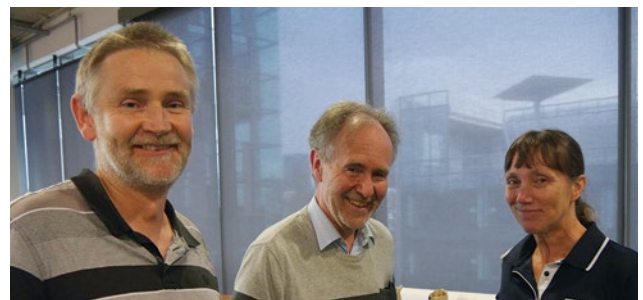
**Scott Sisson**, UNSW

**Kate Smith-Miles**, UoM

**Peter Taylor**, UoM

**Ian Turner**, QUT

**Matt Wand**, UTS



From left to right: CI Nigel Bean, AI Markus Hegland, and CI Kerrie Mengersen

## ASSOCIATE INVESTIGATORS

An Associate Investigator is a member nominated by a Chief Investigator and approved by the Executive Committee, who is employed at an Australian or overseas research institution. An Associate Investigator is not a Chief Investigator but does have significant engagement with ACEMS in some way. For example, this could be by engaging in a significant and ongoing research project in conjunction with an ACEMS Chief Investigator or by being a joint supervisor of an ACEMS student. Associate Investigators are appointed for renewable two-year terms.

**George Athanasopoulos**, MU  
**Davaatseren Baatar**, MU  
**David Balding**, UoM  
**Andrew Barbour**, UoM  
**Adrian Barnett**, QUT  
**Tomasz Bednarz**, UNSW  
**Boris Beranger**, UNSW  
**Andrew Black**, UoA  
**Konstantin Borovkov**, UoM  
**Rhys Bowden**, UoM  
**Richard Boys**, QUT  
**James Brown**, UTS  
**Ross Brown**, QUT  
**Pamela Burrage**, QUT  
**Julian Caley**, QUT  
**Jessica Cameron**, QUT  
**Felix Camirand Lemyre**, UoM  
**Chris Carter**, UNSW  
**Jinyuan Chang**, UoM  
**Sam Clifford**, QUT  
**Nathan Clisby**, Swinburne University  
**Dianne Cook**, MU  
**Paul Corry**, QUT  
**Alysson Costa**, UoM  
**Susanna Cramb**, QUT  
**Sally Cripps**, USyd  
**Tiangang Cui**, MU  
**Daryl Daley**, UoM  
**Aaron Darling**, UTS  
**Hans De Sterck**, MU  
**Pierre Del Moral**, UNSW  
**Christopher Drovandi**, QUT  
**Mark Fackrell**, UoM  
**Yanan Fan**, UNSW  
**Troy Farrell**, QUT

**Davide Ferrari**, UoM  
**Denzil G. Fiebig**, UNSW  
**Mehdi Foumani**, MU  
**David Frazier**, MU  
**Jing Fu**, UoM  
**Victor Gabillon**, QUT  
**John Geweke**, UTS  
**Peter Grace**, QUT  
**Nicholas Graves**, QUT  
**Peter Green**, UTS  
**Anthony Guttmann**, UoM  
**Sophie Hautphenne**, UoM  
**Markus Hegland**, ANU  
**Kate Helmstedt**, QUT  
**Iwan Jensen**, UoM  
**Sevvandi Kandanaarachchi**, MU  
**Paul Keeler**, Weierstrass Institute  
**Mohamed Khaled**, UQ  
**Shev MacNamara**, UTS  
**Tarunendu Mapder**, QUT  
**Gael Martin**, MU  
**Anthony Mays**, UoM  
**James McGree**, QUT  
**Matt McLean**, UTS  
**Lewis Mitchell**, UoA  
**Asghar Moeini**, UoM  
**Paula Moraga Serrano**, QUT  
**Timothy Moroney**, QUT  
**Mario Andres Munoz Acosta**, UoM  
**Mehwish Nasim**, UoA  
**Yoni Nazarathy**, UQ  
**Giang Nguyen**, UoA  
**Malgorzata O'Reilly**, UTas  
**John Ormerod**, USyd  
**Tristan Perez**, QUT  
**Juan Perez Bernal**, Universidad del Rosario  
**Graeme Pettet**, QUT  
**Tung Pham**, UoM  
**Michael Pitt**, Kings College London  
**Thomas Porter**, UoM  
**Thomas Quella**, UoM  
**Matias Quiroz**, UNSW  
**Charl Ras**, UoM  
**David Ridout**, UoM  
**Leonardo Rojas-Nandayapa**, UQ  
**Fred Roosta**, UQ  
**Joshua Ross**, UoA  
**Nathan Ross**, UoM

**Benjamin Rubinstein**, UoM  
**Steven Stern**, QUT  
**Laleh Tafakori**, UoM  
**Thomas Taimre**, UQ  
**Peter Timms**, QUT  
**Ali Tirdad**, UoM  
**Minh Ngoc Tran**, USyd  
**Simon Tuke**, UoA  
**Insha Ullah**, QUT  
**Radislav Vaisman**, UQ  
**Julie Vercelloni**, QUT  
**Mattias Villani**, Linköping University  
**You-Gan Wang**, QUT  
**Ole Warnaar**, UQ  
**Alan Welsh**, ANU  
**Michael Wheeler**, UoM  
**Gentry White**, QUT  
**Nicole White**, QUT  
**Jason Whyte**, UoM  
**Walter Willinger**, NIKSUN  
**Paul Wu**, QUT  
**Hongbo Xie**, QUT  
**Qianqian Yang**, QUT  
**Nan Ye**, QUT  
**Joseph Young**, QUT  
**Lele (Joyce) Zhang**, UoM  
**Zhuo-Song Zhang**, UoM  
**Wenxin Zhou**, University of California, Davis

## PARTNER INVESTIGATORS

A Partner Investigator is a member employed at a Partner Organisation, who is the main contact for that organisation. The person may collaborate with an ACEMS Chief Investigator, act as the main contact for access to in-kind contributions, and contributes to strategic decisions as required.

**John Taylor**, CSIRO  
**Walter Willinger**, AT&T<sup>°</sup>  
**Siu-Ming Tam**, ABS  
**Daniel Elazar**, ABS  
**Arvind Gupta**, Mitacs  
**Keith Weegberg**, Vicroads  
**Michael Caley**, AIMS  
**Mark Bartlett**, SAX Institute

<sup>°</sup> Left AT&T and became an ACEMS AI in 2017

## RESEARCH FELLOWS

A Research Fellow is employed by ACEMS to work directly on an ACEMS research project. The person is responsible for contributing to research, helping with mentoring students and other activities as directed by their supervisor.

**Azam Asanjarani**, UoM\*  
**Dinesha Ranathunga**, UoA\*  
**Craig Anderson**, UTS  
**Wilson Chen**, UTS  
**Praveen Choppala**, UNSW  
**Xuhui Fan**, UNSW  
**Caley Finn**, UoM  
**Alexandr Garbali**, UoM  
**David Gunawan**, UNSW  
**Jia Guo**, UoM  
**Arthur Hung**, UTS  
**Jesper Ipsen**, UoM  
**Je Guk Kim**, UQ  
**Brodie Lawson**, QUT  
**Jarod Lee**, UTS\*  
**Benoit Liquet**, QUT  
**Inna Lukyanenko**, UoM  
**Ross McVinish**, UQ  
**Sarat Babu Moka**, UQ  
**Ellen Muir**, UoM\*  
**Chris Oates**, UTS  
**Bin Peng**, UTS  
**Erin Peterson**, QUT  
**Steven Psaltis**, QUT  
**Rachael Quill**, UoA  
**Matthieu Simon**, UoM  
**Silvio Tarca**, UoA  
**Brendan van Rooyen**, QUT  
**Joanna Wang**, UTS  
**Stephen Wright**, UTS  
**Huaxin Xu**, UTS  
**Zongzheng Zhou**, MU

\*Was an ACEMS Student in 2017

## STUDENTS

A Student is a member who belongs in at least one of the following categories:

1. Is supervised by an ACEMS Chief Investigator;
2. Is a recipient of an ACEMS top-up scholarship;
3. Is supervised by an ACEMS Associate Investigator or Research Fellow in a project that forms part of ACEMS activities.

**Ibrahim Al Khairy**, QUT  
**Fadhah Alanazi**, QUT  
**Ziwen An**, QUT  
**Hugh Andersen**, QUT  
**Azam Asanjarani**, UQ †  
**Aswi Aswi**, QUT  
**Jannah Baker**, QUT  
**Peter Ballard**, UoA  
**Igor Balnozan**, UNSW  
**Luke Barnes**, QUT  
**Abhishek Bhardwaj**, ANU  
**Imke Botha**, QUT  
**Simon Bowly**, UoM  
**Peter Braunsteins**, UoM  
**Lachlan Bridges**, UoA  
**Lachlan Bubb**, UoA  
**Jonathan Budd**, UoM  
**Ariana Cabrera**, UNSW  
**Marcela Cespedes**, QUT  
**Jun Chen**, UNSW  
**Zeying Chen**, UoM  
**Vincent Chin**, UNSW  
**Aaron Chong**, UoM  
**Victor Choy**, UoM  
**Timothy Churches**, UTS  
**Stephanie Clark**, UNSW  
**Brigitte Colin**, QUT  
**Amy Cook**, QUT  
**Alex Cooper**, MU  
**Rose Crocker**, UoA  
**Stephen Crotty**, UoA  
**Doan Khue Dung Dang**, UNSW  
**Matthew DeMaere**, UTS

**Nicholas Xavier Dendle**, QUT  
**Ashley Dennis-Henderson**, UoA  
**Qibin Duan**, UQ  
**Earl William Duncan**, QUT  
**Debajit Dutta**, UoM  
**Anthony Ebert**, QUT  
**Michelle Edwards**, UoA  
**Steven Edwards**, MU  
**Andrew Elvey-Price**, UoM  
**Megan Farquhar**, QUT  
**John Feenstra**, UoA  
**Jack Fenwick**, QUT  
**Benjamin Fitzpatrick**, QUT  
**John Foxcroft**, UoM  
**Puwasala Gamakumara**, MU  
**Lawrence Garufi**, QUT  
**Patricia Gilholm**, QUT  
**Luke Ginn**, QUT  
**Vanessa Glenney**, UoA  
**Max Glonek**, UoA  
**Morgan Grant**, UQ  
**Caitlin Gray**, UoA  
**Taylor Gregory**, QUT  
**Jens C Grimm**, MU  
**Leah Gustafson**, QUT  
**Adam Hamilton**, UoA  
**Shovanaur Haque**, QUT  
**Catriona Hargrave**, QUT  
**Isabelle Harris**, QUT  
**Patrick Hassard**, QUT  
**Grace Heron**, QUT  
**Robert Hickingbotham**, MU  
**Liam Hodgkinson**, UQ  
**Jacinta Holloway**, QUT  
**Wei Huang**, UoM  
**Hon Hwang**, UTS  
**Tim Hyndman**, UoM  
**Farzana Jahan**, QUT  
**Sarah James**, UoA  
**Zhou (Joyce) Jiang**, UQ  
**Yiran Jing**, UoM  
**Madeleine Johnson**, UoM  
**Scott Jones**, QUT  
**Lachlan Kang**, UoA

*ACEMS members prepare for  
the mid-term review*



Ryan Kelly, QUT  
Daniel Kennedy, QUT  
Lachlan Khur, QUT  
Sang Il Kim, UTS  
Christoph Kirch, QUT  
Neco Kriel, QUT  
Julia Kuhn, UQ  
Ashwani Kumar, UoM  
Xuehua (Helen) Lan, UoM  
Brendan Langfield, QUT  
Patrick Laub, UQ  
Mark Lawrence, QUT  
Jarod Lee, UTS †  
Xing Lee, QUT  
Angus Lewis, UoA  
Benjamin Lewis, QUT  
Jaslene Lin, UNSW  
Bing Liu, UoM  
Dennis Liu, UoA  
Qingyang Liu, UoM  
Meirian Lovelace-Tozer, UoM  
Alan Malecki, UTS  
Matthew Males, UNSW  
Jiadong Mao, UoM  
Scott Mason, UoM  
Peter Mathews, UoA  
Lachlann McArthur, UoA  
James McBroom, QUT  
Petra McCullagh, QUT  
Michelle McGrath, QUT  
Rachel McLean, UoA  
Ellen Muir, UoM†  
Kanchana Nadarajah, MU  
Abraham Nasrawi, MU  
Phat Nguyen, UoM  
Tan Nguyen, QUT  
Tui Nolan, UTS  
Michael O'Shea, QUT  
Eric Parsonage, UoA  
Brendan Patch, UQ  
Alan Pearse, QUT  
Jessica Penfold, UoA  
Harris Phan, UNSW  
Ramethaa Pirathiban, QUT

Jacob Priddle, QUT  
Clare Puttick, Garvan Institute  
Shanlin Qin, QUT  
Timothy Quelch, QUT  
Anas Rahman, UoM  
Prosha Rahman, UNSW  
Samithree Rajapaksha, MU  
Dinesha Ranathunga, UoA†  
Nicholas Read, UoM  
Nicolas Rebuli, UoA  
Tristan Reddan, QUT  
Adam Redman, QUT  
Caitlin Reulein, UNSW  
Jessie Roberts, QUT  
Guilherme Rodrigues, UNSW  
Thais Rodrigues, UNSW  
Ben Rohrlach, UoA  
Jacob Ryan, QUT  
Suzanne Ryan, QUT  
Robert Salomone, UQ  
Aviva Samuelson, UTas  
Sarini Sarini, QUT  
Kate Saunders, UoM  
Rohan Shah, UQ  
Shrupa Shah, UoM  
Somayeh Shiri, MU  
Alex Simmons, QUT  
Rachael Smith, QUT  
Simon Smith, UoA  
Karl Somoray, QUT  
Yueyue Song, UNSW  
Leah South, QUT  
Dimitry Stephen, QUT  
Nicholas Sterkenburg, QUT  
Amy Stringfellow, QUT  
Thyraphol Sutanujinda, QUT  
Matthew Sutton, QUT  
Ria Szeredi, UoM  
Priyanga Dilini Talagala, MU  
Thiyanga Talagala, MU  
Ruoxu Tan, UoM  
Jiajun Tang, UoM  
Mingmei Teo, UoA  
Pubudu Thilan, QUT

Aleysha Thomas, QUT  
Nicholas Tierney, MU  
James Totterdell, UNSW  
Erin Trainer, UTas  
Dang Quang Michael Tran, MU  
Jason Tran, UoM  
Michael Ucci, UoA  
Tea Espeland Uggren, UTS  
Abhishek Varghese, QUT  
James Walker, UoA  
Earo Wang, MU  
Erli Wang, UQ  
Riley Whebell, QUT  
Jake Whitaker, QUT  
Tom Whitaker, UNSW  
Jason Whyte, UoM  
Shanika Wickramasuriya, MU  
Brady Willhelme, UNSW  
Ella Wilson, QUT  
Jianyun Wu, QUT  
Wangyue Xie, UQ  
Ming Xu, UNSW  
Yanfan Xu, UNSW  
Hui (Alice) Yao, UQ  
Estefania Yap, UoM  
James Yu, UTS  
Yu Yi Yu, QUT  
Jiyuan Zhang, UoM  
Xin Zhang, UNSW

† Students who have moved to Research Fellow positions within ACEMS in 2017

## AFFILIATE MEMBERS

An Affiliate Member is a person engaged in ACEMS outreach or stakeholder activities, or who contributes to ACEMS via other non-research activities.

Mary Coupland, UTS  
Nicholas Fisher, USyd  
Robyn Grote, QUT  
Anthony Harradine, Prince Alfred College  
Mark Lawrence, UoA  
Miles McBain, QUT  
Alan Pearse, QUT



# PERSONNEL CHANGES 2017

## 2017 WAS A STABLE YEAR FOR ACEMS ALLOWING THE CENTRE TO SETTLE IN TO ITS NEW FOUND STRENGTH.

In 2017 the ARC officially added Professors Kate Smith-Miles, Scott Sisson and Rob Hyndman, and Associate Professor Tim Garoni as Chief Investigators (CIs). Although Kate, Scott and Tim had been brought into the ACEMS fold in 2016 and earlier, it was exciting to have them officially recognised. With very few changes to personnel in 2017 ACEMS saw stability increase across the Centre.

### EXECUTIVE COMMITTEE CHANGES

In December 2016 Jan de Gier was appointed to the position of Head of the School of Mathematics and Statistics at The University of Melbourne. Jan subsequently stepped down from his role on the Executive Committee (EC).

Replacing Jan was new Chief Investigator Scott Sisson as Deputy Director (Communications and Media). Scott has overseen the implementation of the new ACEMS website and the development and expansion of ACEMS communications into new and traditional media outlets. Under Scott the ACEMS social media profile has grown substantially with the support and drive of Communications and Media Officer Tim Macuga. Together Scott and Tim are ensuring that the great work of ACEMS researchers is reaching the world.

### VARIATIONS TO CIS AND NODES

In 2016 after the departures of former Director Peter Hall and John Geweke, it was decided to strategically refresh the CI pool of the Centre. It was announced that Tim Garoni would be confirmed as a continuing CI and Kate Smith-Miles would also join the Centre with Monash University becoming the seventh node. Former AI, Scott Sisson, was appointed as second CI at the UNSW node. This all became official after approval by the ARC in August 2017.

Kate was then offered and accepted a position at The University of Melbourne, and AI Rob Hyndman was appointed as CI to ensure a two CI node at Monash. This change in personnel was approved by the ARC in November 2017.

In August 2017 CI Peter Bartlett (QUT) announced he would be returning to the United States and subsequently resigned as CI. Negotiations are now underway to restore the five CI node at QUT with an up and coming AI.

### PROFESSIONAL STAFF CHANGES

In January 2017 it was announced that two new professional staff members would join ACEMS. Central and UoM Node Administrator Ben Hess and Outreach Officer Dr Anita Ponsaing. Ben had been on secondment from the School of Mathematics and Statistics since September 2016. With a background in mathematics and physics, in addition to several years of experience working in university administration, Ben has been

*ACEMS Executive Committee from left to right: Scott Sisson, Peter Taylor, Kerrie Mengersen and Nigel Bean*



*ACEMS Chief Investigator Team from left to right starting at the top: Robert Kohn, Kevin Burrage, Aurore Delaigle, Tim Garoni, Kerrie Mengersen, Ian Turner, Peter Taylor, Nigel Bean, Kate Smith-Miles, Rob Hyndman, Scott Sisson, Matthew Roughan and Matt Wand (Not pictured: Peter Forrester, Jan de Gier, Dirk Kroese, Anthony Pettitt, Philip Pollett and Louise Ryan)*



*ACEMS Professional staff team at the Annual Retreat from left to right: Kate Taylor, Jessie Roberts, Emily Duane, Kate Hall, Anita Ponsaing, Lucia Kralova, Tim Macuga (Not pictured: Ben Hess, Sarah Keany, Angelika Nikolov-Arvela and Claudia Deasy)*



a fantastic addition to the ACEMS professional staff team.

Anita joined ACEMS in 2015 as an Associate Investigator and began working with the professional team in 2016 on the National Science Quiz. Anita's appointment sees her organising and developing the highly successful Mathscraft program which she has helped take from strength to strength.

During 2017 Kate Taylor moved from her appointment replacing QUT Node Administrator Claudia Deasy (while she concentrated on the implementation of the new ACEMS website) to formalise and implement the Mentoring and Alumni Program.

Node Administrators Angelika Nikolov-Arvela joined the team at Monash and Sarah Keany at UoA, and ACEMS said goodbye to UQ Node Administrator Claire Nitsch, and UoA Node Administrators Snezana Ilic and Hillary Brookes.

In the final weeks of 2017, Kate Lowry was appointed to replace Chief Operating Officer Emily Duane, during her maternity leave in 2018.

# ACEMS DIRECTOR RECEIVES TOP ACCOLADE AND DISTINGUISHED PROFESSORSHIP



*Distinguished Professor Peter Taylor with his Ren Potts Medal*



*The Ren Potts Medal for service to Operations Research awarded by the Australian Society for Operations Research*

You can add the title 'Distinguished Professor' to the list of accomplishments for ACEMS Director Peter Taylor.

On 17 November, The University of Melbourne announced that Peter is one of five professors this year to be awarded the title of Redmond Barry Distinguished Professor.

*“It’s a real honour. There are not many Redmond Barry Professors in the University,” said Peter.*

The honour is named after Sir Redmond Barry, who was instrumental in the founding of The University of Melbourne, and was its first Chancellor from 1853 until his death in 1880. It rewards outstanding leaders within the University for pre-eminence in research and teaching.

For Peter, though, the real honour was the support from a well-respected group of international people who wrote on his behalf as referees.

“Obviously, they said nice things about me, which is a great thing to know. I regard them as among the best stochastic modelers in the world. They are people whom I really respect,” said Peter.

Just a few weeks later, Peter was awarded the Ren Potts Medal for service to Operations Research at the MODSIM/ASOR/DORS conference in Hobart. The Ren Potts Medal of the Australian Society for Operations Research is a national award intended to recognise individuals who have made outstanding contributions to theory or practice of Operations Research in Australia.

Peter came to The University of Melbourne in 2002, and took up the inaugural position of Professor of Operations Research in 2003. He was the Head of the Department of Mathematics and Statistics from 2005 until 2010.

In 2013, the Australian Research Council awarded him a Laureate Fellowship, and in 2016 he became Director of ACEMS.

# STAFF AND STUDENT RECOGNITION: PRIZES, AWARDS AND OTHER PRESTIGE MEASURES

THROUGHOUT 2017 ACEMS MEMBERS WERE RECOGNISED FOR EXCELLENCE OF RESEARCH QUALITY, OUTREACH AND SCIENTIFIC CONTRIBUTION VIA PRIZES, AWARDS AND OTHER PRESTIGE MEASURES. A TOTAL OF 25 PRIZES, AWARDS AND OTHER PRESTIGE MEASURES, INCLUDING FOUR FROM ACEMS, WERE AWARDED TO, OR SHARED BY 26 CENTRE MEMBERS AND COLLABORATORS, EXCEEDING ACEMS' 2017 TARGET OF 15.

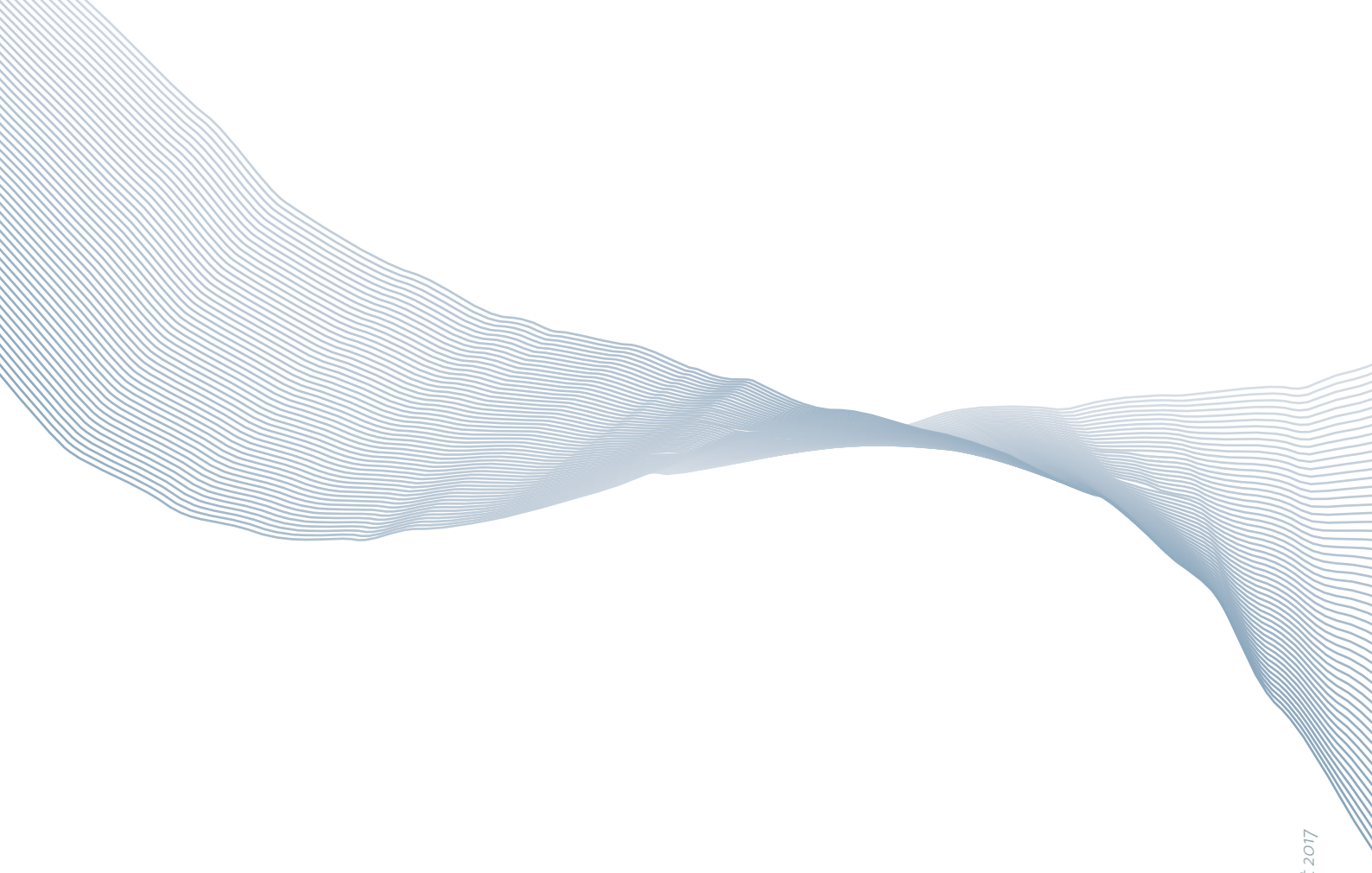


QUT AI Paul Wu receives the Vice-Chancellor's Performance Award

A summary of prizes, awards and other prestige measures are given below:

- Nigel Bean, Adam (Ben) Rohrlach and Simon 'Jono' Tuke were awarded the Eureka Prize for Excellence in Interdisciplinary Research by the Australian Museum.
- Tomasz Bednarz was awarded the Software and Computational Systems Program Award: Global Outlook by CSIRO Data61.
- Tomasz Bednarz was awarded the AIM Above and Beyond Award by CSIRO.
- Konstantin Borovkov was awarded the 'Dean's Award for Excellence in Research Higher Degree (RHD) Supervision' by the Faculty of Science, The University of Melbourne.
- Kevin Burrage was awarded appointed as the Crawford Miller Fellow by St Cross College, University of Oxford.
- Kevin Burrage appeared on the 2017 list of the 3400 most highly-cited researchers across the globe by Clarivate Analytics.
- Marcella Cespedes was awarded the Best Poster Presentation at the International Biometric Society Australasian Region Conference.
- Susanna Cramb was awarded the Early-Career International Research Travel Award by the Australian Epidemiological Association. With additional funding from ACEMS, Susanna was able to attend the Geomed 2017 conference and meet with her collaborators in Spain.
- Aurore Delaigle was awarded the George W. Snedecor Award by the Committee of Presidents of Statistical Societies.
- Liam Hodgkinson won the competition for the best talk at the Applied Probability @ The Rock Conference.



- 
- Sevvandi Kandanaarachchi, Priyanga Dilini Talagala and Mario Andres Munoz Acosta were awarded Second Prize by the Victorian Government, Department of Environment, Land, Water and Planning, for their entry in the Vegetation Detection Challenge.
  - Lewis Mitchell was awarded the ECMS Faculty Learning and Teaching Award by The University of Adelaide.
  - Sarat Babu Moka and Wilson Chen were awarded first and second prize, respectively, in the Research Fellow division for their submissions to the ACEMS Sampling and Exploration Competition; Tim Hyndman and Jun Chen were awarded first and second prize, respectively, in the Student division.
  - Chris Oates was awarded the Research Prize by the Royal Statistical Society “for his outstanding and diverse methodological contributions to computational statistics and his innovative contributions to bioinformatics and machine learning”.
  - Alan Pearse was awarded the Australian Esri Young Scholar Award by Esri Australia.
  - Alan Pearse was awarded the AusIMM Award for Academic Achievement by The Australasian Institute of Mining and Metallurgy.
  - Nathan Ross was awarded the ‘Dean’s Award for Excellence in Research -Teaching and Research’ by the Faculty of Science, The University of Melbourne.
  - Kate Saunders was awarded first prize in the YSC 2017 video competition for her submission Preparing for the worst: Modelling extreme rainfall at the Young Statisticians Conference 2017
  - Kate Saunders, Laleh Tafakori and Alec Stephenson (CSIRO) were the winning team at the Extreme Value Analysis Conference for the ‘Prediction of Spatio-Temporal Extremes’ Challenge. They have been invited to contribute their winning entry to the Extremes journal for publication.
  - Kate Smith-Miles was awarded the E.O. Tuck Medal by Australian and New Zealand Industrial and Applied Mathematics.
  - Peter Taylor was awarded the title of Redmond Barry Distinguished Professor for outstanding teaching and leadership, the first Professor at the School of Mathematics and Statistics at The University of Melbourne to receive such an accolade.
  - Peter Taylor was awarded the Ren Potts Medal by the Australian Society for Operations Research.
  - Jason Whyte was awarded a Lift-Off Fellowship by the Australian Mathematical Society.
  - Jason Whyte was awarded the Faculty of Science Postgraduate Writing-Up Award, supported by the David Lachlan Hay Memorial Fund, The University of Melbourne.
  - Paul Wu was awarded the Vice-Chancellor’s Performance Award by QUT for his mentoring of students and establishing links with industry partners AIS and QAS.



# STUDENT AND EARLY CAREER RESEARCHER RECRUITMENT AND COMPLETION

ACEMS WELCOMED 11 NEW POSTDOCTORAL RESEARCHERS TO THE CENTRE DURING 2017: AZAM ASANJARANI (UOM), XUHUI FAN (UNSW), CALEY FINN (UOM), JIA GUO (UOM), JE GUK KIM (UQ), JAROD LEE (UTS), SARAT BABU MOKA (UQ), ELLEN MUIR (UOM), RACHEL QUILL (UOA), DINESHA RANATHUNGA (UOA) AND MATTHIEU SIMON (UOM).

In total, the Centre had 43 early career researchers – members who are within five years of PhD completion – across both the Research Fellow and Associate Investigator membership categories.

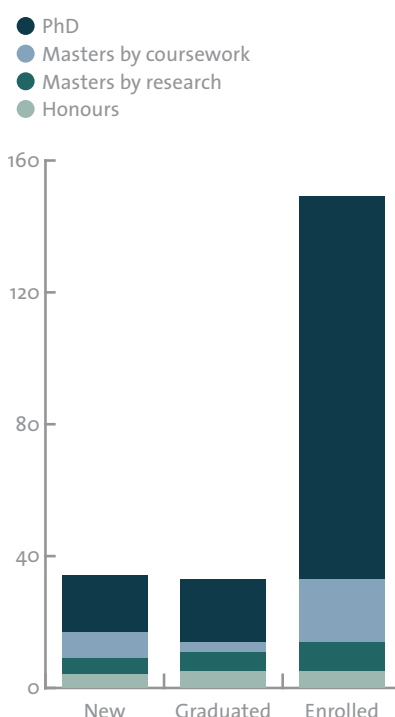
ACEMS members recruited a total of 34 students to the Centre, including 17 PhD students, eight Masters by research students, five Masters by coursework students and four Honours students.

This brought total student enrolments to 149 for 2017: 116 PhD students, 19 Masters by research students, nine Masters by coursework students and five Honours students. Centre researchers also supervised 48 vacation research students, three of whom undertook a second vacation project with a Centre researcher and three of whom commenced a Masters by Research degree with a Centre researcher at the conclusion of the vacation research project in 2017. This brought the total number of students involved in the Centre to 194.

ACEMS celebrated the successful completion of 25 student members, including 19 PhD students, three Masters by research students, six Masters by coursework students and five Honours students. The Centre wishes these students all the very best with their future endeavours.

## ACEMS STUDENT SCHOLARSHIP RECIPIENTS IN 2017 WERE:

- Ziwen An (QUT)
- Abhishek Bhardwaj (ANU)
- Peter Braunsteins (UoM)
- Zeying Chen (UoM)
- Vincent Chin (UNSW)
- Aaron Chong (UoM)
- Qibin Duan (UQ)
- Andrew Elvey-Price (UoM)
- Puwasala Gamakumara (MU)
- Liam Hodgkinson (UQ)
- Wei Huang (UoM)
- Timothy Hyndman (UoM)
- Daniel Kennedy (QUT)
- Patrick Laub (UQ)
- Huan Lin (UNSW)
- Alan Malecki (UTS)
- Jiadong Mao (UoM)
- Brendan Patch (UQ)
- Leah Price (QUT)
- Robert Salomone (UQ)
- Matthew Sutton (QUT)
- Jiajun Tang (UoM)
- Tea Espeland Uggen (UTS)
- Erli Wang (UQ)
- Hui Yao (UQ)



# ACEMS AT A GLANCE - RESEARCH PLANS 2018

## CHALLENGING DATA

Further develop conceptual models of information flow to explore the dynamics of information flow in different network structures

Work on new methods for very high-dimensional time series, designed to be applied in several contexts

Develop new methods for analysing streaming data non-parametrically

Extend the spatial boosted regression tree model to include a temporal smoothing term in order to model global and local trends over time

Establish a number of new collaborative projects: on analysis of Red Cross data, data-record linkage techniques, and analysis of computer security

Extend the case/control sampling ideas to incorporate data coarsening

Find the most computationally efficient of the class of near-optimal symbolic constructions, and verify their performance in a suite of challenging applications

Identify important fragments arising in challenging data settings and derive their message passing updates

## MULTI-SCALE MODELS

Study the construction of an integrable 2+1 dimensional stochastic process using advanced algebras, as well as the calculation of probability distribution functions in multi-species processes

Adapt advanced simulation methods (in particular, the Tau-leaping algorithm) to metapopulation models, and measure aggregation in parasite-host systems

Extend the list of random product matrices for which the exact Lyapunov exponent can be computed using ideas from integral geometry

Extend our dimensional results on universal coupling time limit laws to an arbitrary number of dimensions

Look at realistic modelling of spatially-limiting gene drive strategies, and then realistic spatial models

Obtain bounds on the achievable transaction processing rate, which will be a major contribution to our understanding of how blockchain technology works

Extend a game theoretic model of Huberman, Leshno and Mollemi to study optimal strategies for paying incentives to miners

## INFORMED DECISIONS

Research the properties and capabilities of Bayesian networks to facilitate informed decisions in ecology

Develop powerful new methods to rapidly detect interesting events in noisy signals and time series, especially when the data is streaming at high volumes, for far-reaching, critical impact

Study control techniques to improve the dependability of supply of wind power with utility-scale battery energy storage

Use stochastic optimisation techniques, such as Multi-Armed Bandit Models to provide optimal policies for multidimensional resource allocation models.

## ENABLING ALGORITHMS

Focus on classifications methods for use in projects with the timber industry

Develop data assimilation and homogenisation techniques for multiscale models of complex dynamical systems

Prove conjectures on limit theorems for the coupling time of the one-dimensional stochastic Ising model, developed in 2017 projects

Explore exact and approximate methods for estimating high dimensional and non-Gaussian state space models

Develop copula based universal approximations to multivariate distributions

Research new approaches to constructing efficient sampling and optimisation algorithms, with application to Bayesian learning and robotics control

# BITCOIN'S FUTURE LOOKS BRIGHT, BUT IS THE TECHNOLOGY UP TO THE TASK?



Peter Taylor  
The University of Melbourne



Rhys Bowden  
The University of Melbourne

*“A lot of people from around the world are paying attention to Bitcoin itself and even more so to the idea of blockchain technology.”*

*Identifying and cleaning probable errors from Bitcoin blockchain timestamp data prior to analysis.*

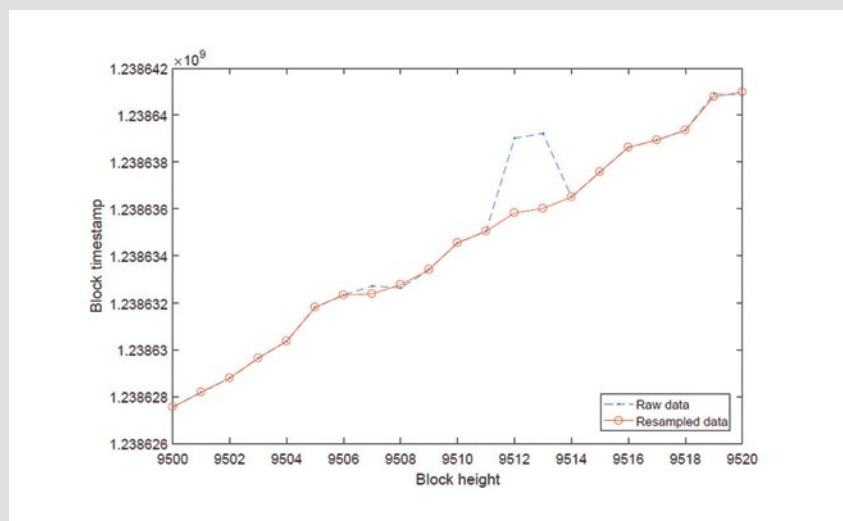
**INTEREST AND INVESTMENT IN THE CRYPTOCURRENCY BITCOIN HAS SKYROCKETED IN THE LAST FEW YEARS, PUSHING UP ITS MARKET VALUE FROM JUST \$0.39 IN 2010 TO AROUND \$12,000 AT THE END OF 2017. BUT ITS INCREASING VALUE AND POPULARITY HAS ALSO BEEN MET WITH A SURGE IN PROBLEMS, PARTICULARLY IN PROCESSING TRANSACTIONS AND VERIFYING ACCOUNTS.**

Bitcoin's banking activities rely on blockchain technology to function effectively, but could this innovative platform be starting to buckle under increasing pressure, and if so, what can be done? Peter Taylor, Director and Chief Investigator at ACEMS, along with ACEMS Associate Investigator Rhys Bowden and colleagues, are searching for answers to these and other questions, and their findings are breaking new ground.

Peter has been conducting research into Bitcoin blockchain technology since 2013. His interest in Bitcoin was piqued after his then PhD student Jonathan Budd approached him with the idea for a new project. Peter involved other colleagues in the project and the international team based in Australia, Germany and South Africa, have been studying Bitcoin blockchain technologies in the context of applied probability.

"I saw it as a real opportunity to do some novel work in an area which was new, interesting, and probably important," says Peter. "A lot of people from around the world are paying attention to Bitcoin itself and even more so to the idea of blockchain technology."

Bitcoin is a decentralised digital currency that was launched in 2009 by an individual or group, under the



pseudonym Satoshi Nakamoto. It can be used to buy and sell goods and services from individuals and companies that accept Bitcoin. Unlike other currencies, Bitcoin has no central authority, but instead uses peer-to-peer blockchain technology to manage transactions. Under this system, users within the network, known as 'miners', process transactions by solving a difficult cryptographic problem using high powered computers and in return are rewarded with Bitcoins.

Peter and his colleagues have been examining the effectiveness of Bitcoin blockchain technology. They have been studying the extent to which communication delays between miners can affect the functioning of the blockchain by causing them to have different versions of the blockchain. Their research shows that the blockchain currently splits a couple of times a day, but fortunately the splits are never serious and repair quickly.

In their first journal publication on Bitcoin in 2016, Peter and his colleagues revealed how miners can use communication delays to manipulate the system – essentially to mine more than their share, but this results in all parties mining less overall. However, they also showed that with adequate monitoring the mining community can detect and rectify the misuse.

What the researchers are now investigating is how the Bitcoin system can be redesigned to cope with increasing demand, so that the transaction processing rate can potentially rival that of Paypal or Visa. Currently, Bitcoin processes about three or four transactions per second worldwide, but this is very low compared to Paypal, which can process about 200 payments per second and Visa, which has the capacity to process up to 50,000 transactions per second, if it needs to.

"What the whole Bitcoin community wants to do right now is increase the transaction processing rate, so that it can process more payments per unit time," says Peter. "And what we are doing is using our mathematical models to see how this can be done, taking into account the fact that information transfer is not instantaneous, and making some realistic assumptions about the amount of time it takes to actually do the computational work."

"We have got some ideas which we are working on and we think are going to be very fruitful. This is really important because, as I say, it is widely recognised that Bitcoin currently cannot be scaled up to be a transactional processing system on the same level as a credit card or Paypal, for example."

Peter is excited about the possibilities that innovations in blockchain technology have for Bitcoin, but also beyond – he sees the potential the technology may have for any type of system that requires a distributed way of maintaining trust. "There is a lot of interest around the idea that you might have a way of keeping records that are maintained by a community in a trustworthy way, not kept by a central authority. Because even if there is a central authority, it might want to implement a blockchain so that people trust it," adds Peter.



# ACEMS MATHS HELPS PROVE GUINNESS WORLD RECORD

An Adelaide man now holds the Guinness World Record for creating the world's largest indoor, free floating soap bubble.

Graeme Denton, aka Marty McBubble, was confident he could break the old record of 8.5 cubic metres with his soap bubble on a cool winter morning at an Adelaide primary school.

He needed to prove it, though.

That's why he reached out to Professor Matthew (Matt) Roughan, a Chief Investigator with ACEMS at The University of Adelaide.

Matt did all the mathematical modelling and calculations that showed that Graeme Denton's soap bubble was 19.8 cubic metres, shattering the previous record.

"I thought it would be a fun project," says Matt. "It turned out to be harder than I thought."

"That's why I did it at 6am, when the humidity was at its highest point. The air was also very cool and slowed down the evaporation of the bubble, which ultimately leads to the popping," says Graeme.

With the conditions just right, and everyone in place, Graeme took out his supersize wand made of two 4-metre fishing rods and a long piece of string. He then dipped the giant wand in his secret bubble recipe, and created the world's largest indoor, free floating soap bubble.

At least that's what he thought. It was now up to Matt to prove him right.

Matt faced two mathematical modelling problems. The first dealt with the shape of the bubble. Small, free-floating soap bubbles will always be spherical.

"They're mathematically interesting because they're what we call a minimal surface. The spherical shape that encloses the bubble has a minimum surface area because of the surface tension," says Matt.

The bigger the bubble gets, though, the more irregular the shape becomes. That was the case with Graeme's giant bubble which evolved into something that almost looked like a huge sausage from the side.

The second mathematical problem Matt was facing dealt with correcting the perspective distortions from the cameras. For example, a picture of something that's far away will appear smaller.

"We had to make sure we had a lot of measurements in the gym to compare the bubble against. We also had to make sure we knew exactly where the bubble was inside the gym in order to be able to correct that perspective distortion. So I had to build a model to actually correct the camera perspective," says Matt.

Matt did his own coding to make sure he understood all of his calculations. He also created a 3D version of his model bubble.

In the end, it took Matt about a week to finish his mathematical proof estimating the size of the bubble. Thanks to that, Guinness World Records have since verified Graeme's bubble as the largest ever indoor, free-floating soap bubble.

Graeme started playing around with giant bubbles a couple

***“Graeme and Matt went to a lot of trouble to make sure that they could accurately estimate the size of the giant soap bubble. The pair made huge scales that looked like giant rulers and laid them out on the floor and walls in the sports hall at Lockleys Primary School in Adelaide. Both Matt and several other photographers then took pictures from several angles showing the bubble in relation to those markers.”***

Graeme knew he needed high humidity and cool temperatures to give the soap bubble its best chance. So he set out to break the record early on the morning of 19 June 2017.

of years ago while developing his educational show for kids as his character, Marty McBubble. 'The Scientific Bubble Show' is available to visit schools and centres across South Australia through Graeme's business Bright Spark Entertainment.

"There's a lot of science you can explain to children through the use of bubbles," says Graeme.

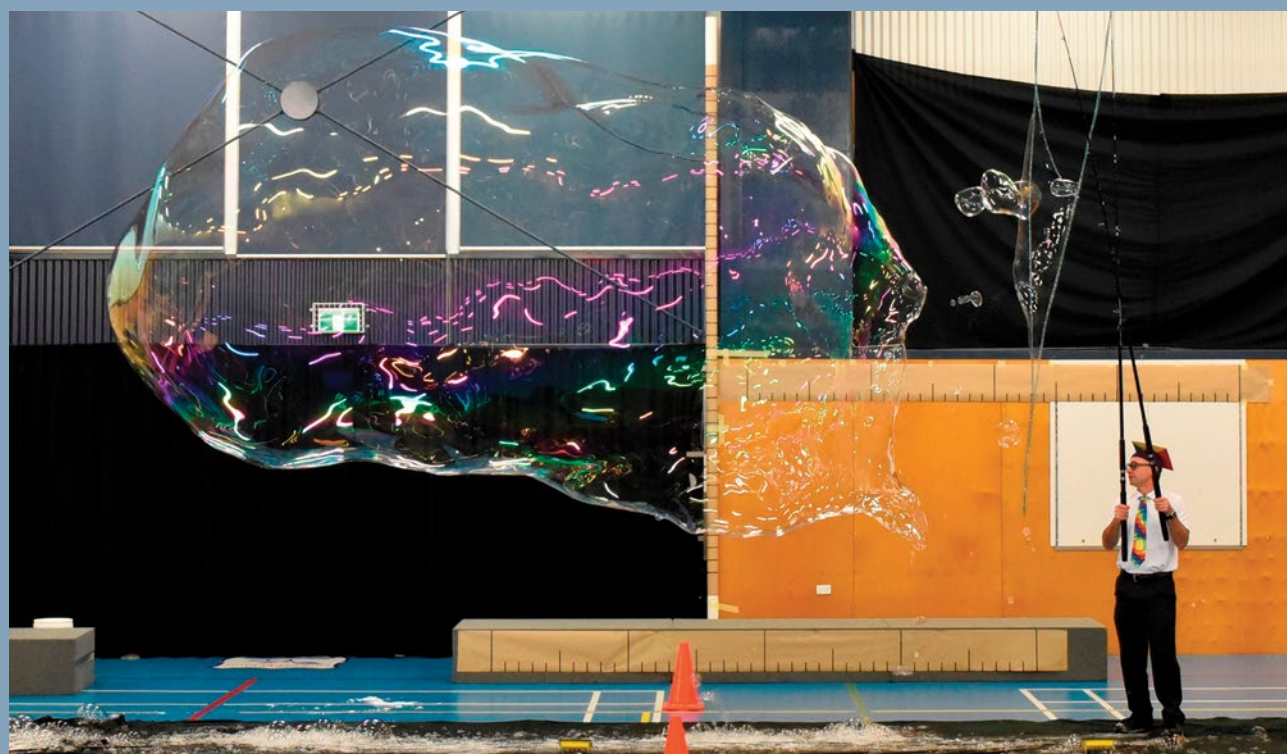
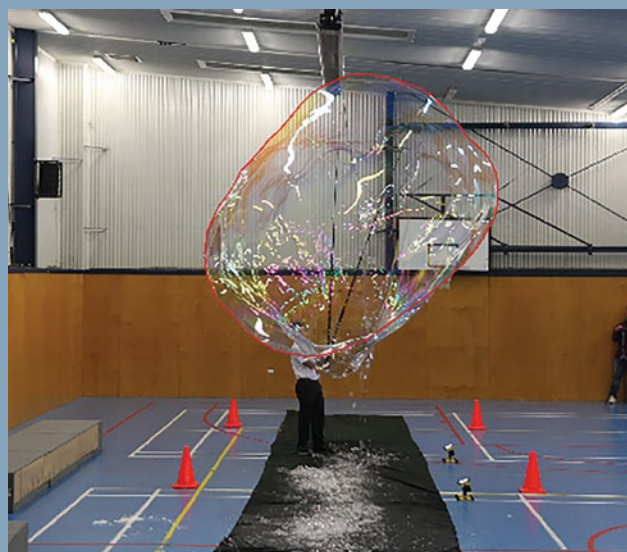
He now knows there's plenty of maths too.

Graeme had never met Matt before this project. He's truly grateful for all the work Matt put into this.

"I had no idea how much work was involved for him. He did it in a much more thorough method than anyone would've ever done before with this record. I was very pleased to have him along," says Graeme.

Graeme also gave Matt something to thank him for all his hard work – his secret recipe for making giant bubbles. Don't try getting it from Matt, though. He says he won't share it!

*Marty McBubble breaks the Guinness World Record for the world's largest indoor, free floating soap bubble.*



# RESEARCH THEMES OVERVIEW

to create world-class research at the  
frontiers of the mathematical sciences  
dealing with probability and  
randomness, and translate this research  
into new insights that benefit society



ACEMS Director  
Peter Taylor  
speaking at the  
ACEMS mock  
mid-term review

## THE ACEMS RESEARCH PROGRAM HAS MATURED AND CONSOLIDATED OVER THE PAST YEAR

One of the obstacles to performing the world-class mathematical and statistical research that addresses our current and future societal needs is the lack of adequate communication and collaboration between the various disciplines working in these fields. This was recognised in the original ACEMS proposal and was a leading motivation for the creation of the Centre. It is commonly acknowledged that although researchers in each discipline may face similar problems, the way in which they think about, understand and ultimately tackle these problems is heavily discipline-specific: mathematicians, statisticians and machine learners have evolved their own bodies of theory, methodology and computational algorithms, and there is often little communication between them. ACEMS aimed to fundamentally change this paradigm: to create a cohesive forum for collaboration and knowledge transfer across the disciplines, and to foster a new generation of researchers for whom the traditional discipline barriers are much more permeable and transparent.

The first three years of the Centre have seen clear movement towards achieving this goal. The disparate and single researcher focused projects that were introduced at the commencement of the Centre were opened up to the general ACEMS research community. This has led to the discovery of new ideas and avenues for collaboration that would not have occurred without

the Centre. This new research paradigm has permeated into many of the research projects being undertaken by ACEMS postgraduate students and postdoctoral fellows, who are increasingly accessing cross-disciplinary ideas and thinking as part of a novel, blended approach to the discovery of new mathematical and statistical techniques.

This is a seminal achievement in the Australian mathematical sciences community, and one which paves the way for the research program over the next stage of the Centre. It has also resulted in an evolution of the original research programs and projects of the Centre. The new ACEMS Research Themes, discussed below, still adhere to the Centre pillars of 'Big Data, Big Models and New Insights', but now more accurately reflect the cohesive nature of ACEMS research and the sustained and emerging global challenges in this field. Specifically, the 'Big Data' and 'Big Model' pillars have progressively transformed into four over-arching but synergistic Research Themes: 'Challenging Data', 'Multiscale Models', 'Enabling Algorithms' and 'Informed Decisions'. The 'New Insights' pillar remains with its applications focus on 'Healthy People', 'Sustainable Environments' and 'Prosperous Societies'.

The four Research Themes are naturally intertwined with each other and with the three programs in New Insights. Moreover, each of the Themes comprises a spectrum of research from theory to methodology and translation, and an acknowledgement of both long term and short term outputs, outcomes and impact.

The four Research Themes are strongly intertwined with each other and with the three Programs in New Insights. Moreover, each of the Themes hosts a gradient of research from theory to methodology and translation, and an acknowledgement of both long-term and short-term outputs, outcomes and impact.

## CHALLENGING DATA

Modern data are being produced in increasingly varied forms and sizes that are typically not handled well by traditional data analysis methods. Under this theme we explore these new data forms and develop the innovative techniques needed to work with them.

## MULTISCALE MODELS

Multiscale models reflect the fundamental mathematical and statistical structures required to make sense of complex data and systems. Under this theme we develop the fundamentally new models and analysis techniques required to handle highly complex problems and support the Challenging Data theme.

## INFORMED DECISIONS

The purpose of data collection and modelling is to learn more about systems and make the best possible decisions about their operation. Under this theme we construct new decision making methodologies, and exploit the advances in Challenging Data, Multiscale Models, and Enabling Algorithms to make these decisions.

## ENABLING ALGORITHMS

Rapid advancements in computing technology provide the opportunity to create new classes of algorithms that enable improved and viable analyses of data and models. Under this theme we develop the new enabling algorithms required for the analysis of Challenging Data and Multiscale Models.

## NEW INSIGHTS

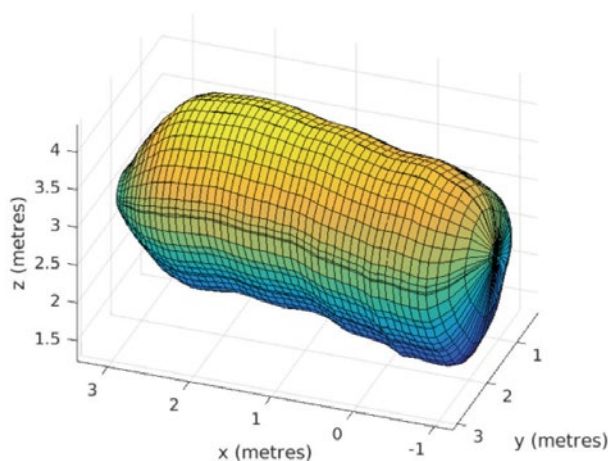
HEALTHY PEOPLE

SUSTAINABLE ENVIRONMENTS

PROSPEROUS SOCIETIES



# THEME 1: CHALLENGING DATA



*The world's largest bubble: the first figure shows the bubble being created, and the second figure shows the model of the bubble.*

## OVERVIEW

Data is the new oil, and like oil, in its raw form it has limited utility. When refined, however, it can be extraordinarily valuable. The goal of the challenging data theme is to distill information from such data.

Refining almost any interesting data is challenging in some respect. Often the challenge is size — 'big data' has become a catch cry — but size isn't everything. Some data sets are arriving so quickly that complex processing is difficult. Other challenges involve data that are unstructured and 'messy', or whose inherent variability is more extreme, or involve data from multiple sources that lack common formats or keys, or where the sampling is irregular and incomplete.

In this theme we explore various ways of sampling, cleaning, exploring, compressing, representing, modelling, and visualising all sorts of challenging data. The theme is wide ranging both in applications (which range from the Red Cross Blood Service, to Internet security, to understanding the Reimann zeta function) and tools and techniques. The significant computational challenges often involve multiple layers of processing, so this theme has strong interactions with the Multiscale Models and Enabling Algorithms themes. As data is a key input for Informed Decisions, there are direct interactions with this fourth theme as well.

## HIGHLIGHTS

- Multidisciplinary work on ancient DNA, involving biologist, linguists, archaeologists, Aboriginal elders, climatologists and mathematicians, developed new methods to understand the migration of pre-historic Aboriginal Australians, published in *Nature*, and ultimately awarded a Eureka prize (see page 60).
- The ACEMS Workshop on Challenges of Data and Control of Networks (December 6-8, 2017) brought several world leading experts on measurement and control of networks to Australia to participate in a focused workshop on challenging data in networks.
- New approximate inference tools for large sophisticated models applied to high volume/velocity data situations, published as a discussion paper in the Journal of the American Statistical Association.
- Contribution to measuring the successful Guinness World Record to create the world's largest bubble (see page 40).
- A Conversation article explaining sentiment analysis was a 'top 50' selection published in the 2017 Conversation Yearbook.

## TEAM

**Theme Leaders:** Aurore Delaigle and Matthew Roughan

**Chief Investigators:** Nigel Bean, Peter Forrester, Tim Garoni, Rob Hyndman, Dirk Kroese, Kerrie Mengersen, Louise Ryan, Scott Sisson, Kate Smith-Miles, Peter Taylor and Matt Wand

**Selected Research Fellows and Associate Investigators:** Tomasz Bednarz, Wilson Chen, Sam Clifford, Jia Guo, Sevvandi Kandanaarachchi, Anthony Mays, Lewis Mitchell, Mehwish Nasim, Giang Nguyen, Chris Oates, Erin Peterson, Dinesha Ranathunga, Nicholas Tierney, Simon 'Jono' Tuke, Julie Vercelloni, Stephen Wright and Nan Ye

**PhD and Masters Students:** Brigitte Colin, Ben Fitzpatrick, Puwasala Gamakumara, Vanessa Glenny, Caitlin Gray, Jacinta Holloway, Wei Huang, Lachlan Kang, Sang Il (Andy) Kim, Peter Mathews, Jiadong Mao, Tui Nolan, Nicholas Read, Cameron Roach, Adam 'Ben' Rohrlach, Kate Saunders, Jiajun Tang, Dilini Talagala, Thiyanga Talagala and Earo Wang.

**Affiliate Member:** Alan Pearse

## DETAILED DESCRIPTION

One of the sub-themes within Challenging Data is the need to process

large, 'messy' data. Quite a few projects touch on this, for instance CI Nigel Bean, AI Jono Tuke and PhD student Ben Rohrlach working with the Australian Centre for Ancient DNA (ACAD) at Adelaide and the South Australian Museum, analysed over 100 Aboriginal Australian whole mitochondrial genomes that predated European arrival in Australia. A method was developed that could take in the mitochondrial (mtDNA) data, and return a matrix of 'genetic distances' between individuals. Methods already exist for allele frequencies in nuclear DNA, but no such methods exist for single-copy DNA, such as mtDNA. A novel method was developed based on techniques for survey analysis in the French literature of the 1960s. Using this novel method, the team were able to show that individuals that were close to one another on the Australian landscape were very likely to be genetically closely related. This work was published in *Nature*, and ultimately the team were awarded a Eureka prize (see page 60 for more details).

Another strand of the ancient DNA work concerns a painting of a bison with a unique mix of physical properties found in prehistoric French cave art. Phylogeneticists thought it may be drawings of the 'Higgs Bison', but no fossils had ever been found. A candidate sample from a single femur, had been identified as a Wisent Bison from mtDNA, and Steppe Bison when the analysis was repeated using nuclear DNA. A method to detect hybridisation in the femur was developed, using a nuclear genome (of approximately 3 billion nucleotides), for each of the three species, and counting the number of mutations in the genome that were unique to each individual. Using these counts, and an associated multinomial distribution based on a mixture of two underlying species trees, the individual was shown to be approximately 10 per cent Steppe Bison.

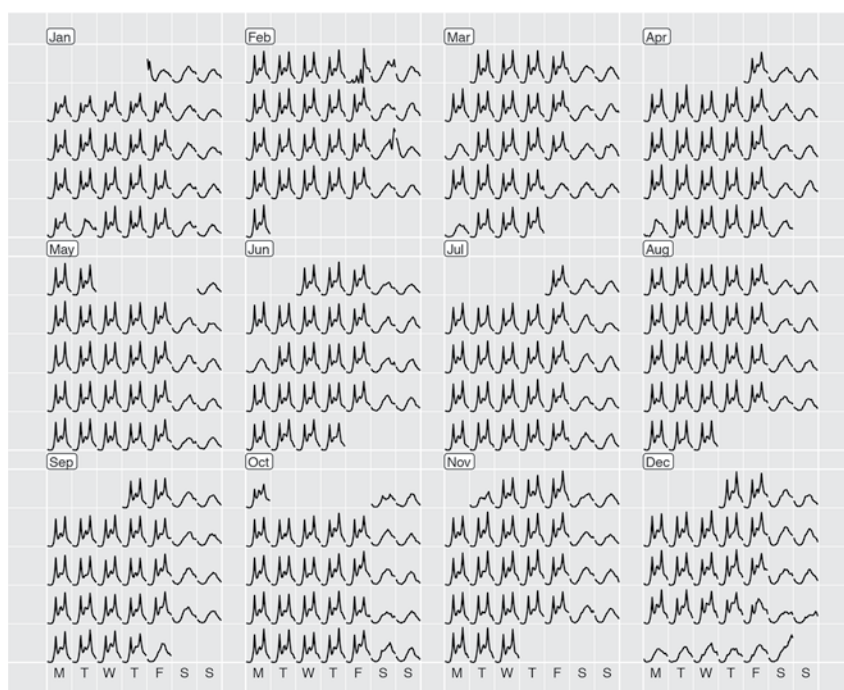
**Flinders St Station:** Hourly pedestrian traffic at Flinders St Station in Melbourne. The strong daily patterns for working days and non-working days are clearly evident.

An Approximate Bayesian Computation (ABC) simulation approach, and an estimate of the posterior distribution using numerical integration, were used to confirm the results. This work was published in *Nature Communications*.

Another topic, related by the nature of the underlying data if not the application, is the analysis of social network data by CIs Nigel Bean and Matt Roughan and AI Lewis Mitchell. Several advances were made on this project through the analysis of large, unstructured text-based datasets collected from online social platforms (mainly Twitter). Work on the 'friendship paradox' (see page 14) published in the proceedings of ASONAM '17 described a previously unexplored connection between contact strength and node degree, and further work on sentiment analysis and health (in collaboration with colleagues at the University of Vermont) appeared in PLoS. An article in The Conversation explaining sentiment analysis was a 'top 50' selection published in the 2017 Conversation Yearbook. Methods for clustering text data using lexical and temporal features were developed, and a paper on retweet cascades accepted

to WWW '17. Methods for statistical prediction from unstructured texts using topic modelling were developed, and methods for determining social network structure using observed information cascades were also developed. In collaboration with Data to Decisions CRC, methods were developed for 'bot' detection and event prediction using real-time streamed Twitter data.

CI Kerrie Mengersen with PhD students Ben Fitzpatrick, Brigitte Colin and Jacinta Holloway investigated the remotely sensed data arising from a variety of sources including satellites, lidar and aerial images. These data are challenging because they are 'big' with respect to the number of pixels; they contain spatial and temporal structure; they can suffer from spatial misalignment, bias and measurement error; and different datasets can be observed at different spatial and temporal scales. A number of projects are being undertaken in ACEMS to develop methods for modelling and analysing these types of data, and applying the new approaches to important applied problems. A new spatial boosted regression tree model is being developed which extends the usual



tree-based machine learning algorithm to include the local spatial information in the remotely sensed data. The problem of transferability has also been tackled, in which models developed at one location or time can be applied to another location or time. New visualisations have included a network flow approach to visualising covariates in decision tree models. The problems to which this research is being applied include estimation of vegetation indices, crop yield and success of reforestation programs.

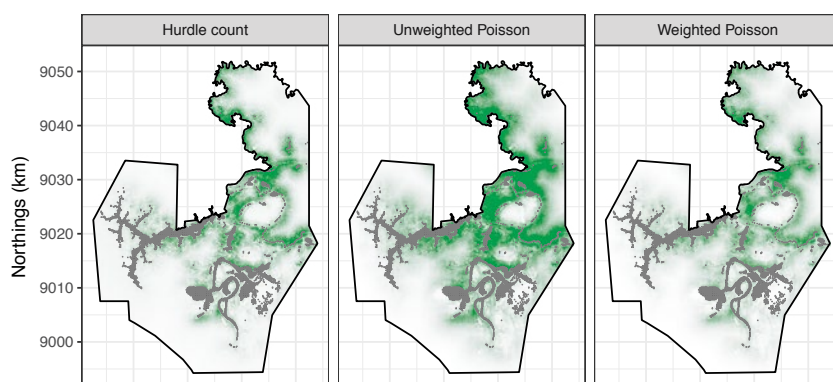
CI Peter Taylor and PhD students Kate Saunders and Nicholas Read have been developing spatio-temporal models for phenomena such as extreme rainfall events and lightning-caused bushfires. In the former case, Kate has fitted max-stable processes to data collected by the Australian Bureau of Meteorology, while in the latter Nick has used a logistic regression model, coupled with a novel way of characterising covariate contributions, to derive bushfire ignition and escalation probabilities from data held by the Victorian Department of Environment, Land, Water and Planning and the Country Fire Authority.

Kerrie Mengersen and her team including AIs Erin Peterson, Sam Clifford, Tomasz Bednarz, Julie Vercelloni and Nan Ye and Affiliate Member Alan Pearse have looked at the data collected or generated by citizens, such as large datasets from video or 3-D images, or sparse data, such as sightings of rare species. But there is a growing awareness about the potential benefits of harnessing such data. This is particularly attractive in fields that are traditionally data-poor. However, the use of this data source requires careful attention to data quality and data integration. A major project this year has been the development of statistical methods that integrate different sources of data, such as ground-truth observations and citizen-provided data, and account for differential quality impacts. Substantive applications of this work include creating a jaguar corridor across the Peruvian Amazon using the knowledge of local people and international experts; monitoring the health of the Great Barrier Reef using observational data, unmanned aerial vehicles and divers' photos; and counting koalas in Queensland using drones and virtual reality (VR). The project has

involved a range of researchers from different disciplines and has attracted undergraduate vacation research students in statistics as well as a team of students who made a VR jaguar game.

CI Louise Ryan with Research Fellows Stephen Wright from UTS and Tung Pham from University of Melbourne have written a paper from their analysis of Australian Red Cross Blood Service data. This area is yet another place where new tools were needed to analyse a very large (and in this case clustered) dataset. The goal of the project was to utilise the Red Cross donor database to identify donors at high risk of vasovagal reaction (fainting) and to explore variation in the rates from donor centre to donor centre. A random effects logistic regression model was not possible because of the size of the dataset. Utilising case/control sampling ideas, a strategy was developed that allowed fitting the model and accurate estimation of donor effects. The method is particularly appealing because it runs using standard software, utilising a simple offset adjustment.

One of the other major sub-themes of Challenging Data is dealing with fast,



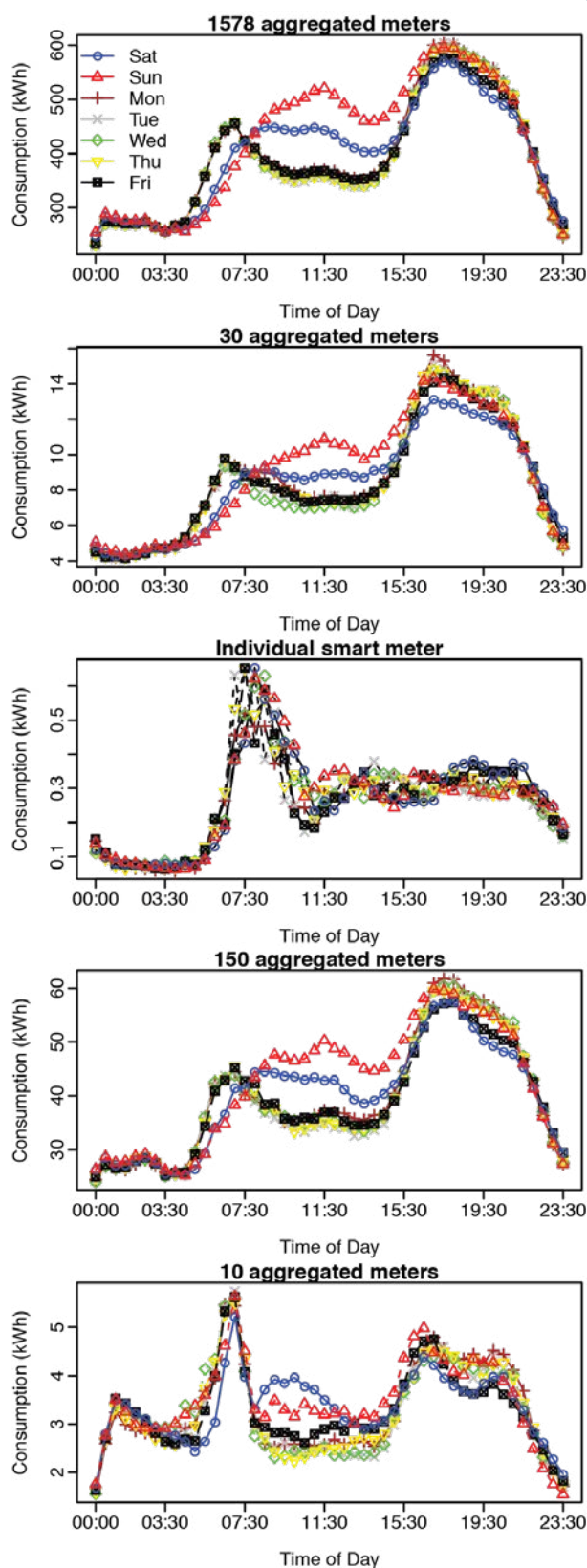
**Citizen data:** Maps of the Imiria region in the Peruvian Amazon, depicting predicted abundance of jaguars based on citizen reported sightings, under three statistical models accounting for reporting uncertainty.



streaming data. CI Rob Hyndman and his team look at very high frequency high-dimensional time series, which can be thought of as a stream, and methods required for handling the data efficiently, which update as new data arrives. Typical examples are security sensors which monitor movement or activity every few seconds in a large number of locations. New methods for detecting anomalous observations that arise in such a stream of data, while allowing for slow changes in stream behaviour over time, are being developed.

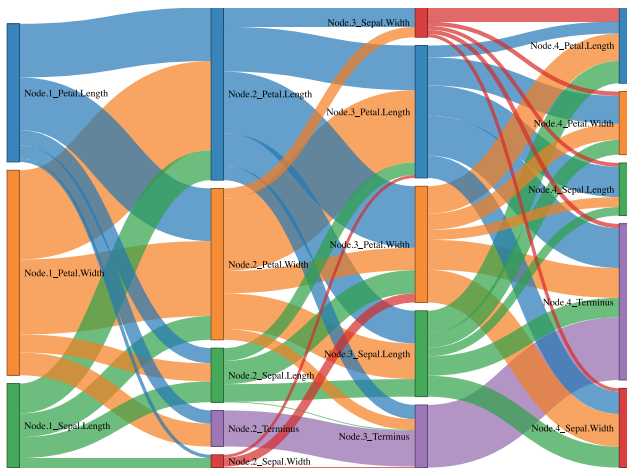
On a related note, symbolic data analysis, from CIs Aurore Delaigle, Kerrie Mengersen, Louise Ryan, and Scott Sisson, is looking promising for analysing large, fast datasets. One way of overcoming the difficulties is to create so-called symbolic data, which are meaningful data summaries that reduce data volume. This cross-node project is working together on various challenges associated with symbolic data such as: how to reduce the data without losing too much in terms of statistical efficiency, how to analyse symbolic data in a way that can answer questions about the original raw data, and taking into account correlation and other important features of the data. Using the symbolic data approach, CIs Ryan and Sisson were able to efficiently analyse large time series that measure air pollution every six seconds over several months, with a view to understanding the extent to which passing coal trains contribute to higher levels of air pollution.

Other datasets incorporate these challenges but have unique challenges of their own. Hierarchical time series present one of those challenges. CI Rob Hyndman, for example, has developed analysis of sales of a multinational company, which can be disaggregated in a geographical hierarchy into countries, regions, cities and stores. The company will then usually require forecasts of total sales, national sales, regional sales, down to sales for an individual store. The company may also produce many products that form a product hierarchy, divided into groups and sub-groups of products. Then forecasts of total sales, and sales within each product grouping are also required. The cross-product of these two hierarchies often results in a very large collection (often comprising millions) of individual time series of sales for each product type in each store. Collaboration with Walmart and Huawei on such time series is ongoing. The main statistical challenge is to produce coherent probabilistic forecasts for both aggregate and disaggregate time series. Similarly, Rob and his team's work on sub-daily data which are becoming increasingly common due to automatic sensors and monitors, provide insights into people's daily schedules relative to events such as work days, weekends, holidays, and special events. Visualisation of such data can be challenging because the time series are usually very long, and simple time plots



**Smart-meters:** These graphs show the intra-day pattern for each day of the week for various groups of smart-meters. For a single meter, there is substantial variability, but as the number of meters is aggregated, the variation is reduced and the patterns are seen more clearly.





**Remotely sensed data:** A new visualisation showing a network flow approach to visualising covariates in decision tree models. It is a Sankey diagram depicting the first five nodes along all of the paths through all of the decision trees in an example random forest based on a famous dataset about characteristics of iris flowers.

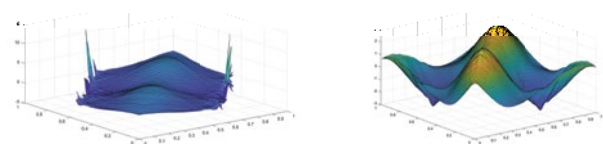
become too crowded to see important structure. The team are developing new methods for organising and visualising temporal data, collected at sub-daily intervals. A new dynamic linear forecasting model for handling such data, called FASSTER: Forecasting Additive Switching Seasonal and Trend with Exogenous Regressors, is being created.

In partially observed functional or surface data, CI Aurore Delaigle with PhD student Wei Huang, use data in the form of functions or curves, for example growth curves of children or rainfall curves at Australian weather stations. When the curves are completely observed, it is easy to estimate, aspects such as the covariance function. However, in real applications, functional data can often be only partially observed: instead of observing the whole sample of curves, only a sample of fragments of curves is observed. Estimating the covariance function in this context is a very challenging problem. To solve it, Aurore's team regarded the covariance function as a surface that has particular properties. The problem then becomes one of fitting a particular bivariate surface from data that are observed on an irregular part of the domain. Using this approach, Aurore and her team developed a tensor product method that produces a consistent estimator of the covariance function.

Surface estimation was also used by CI Matthew Roughan to help estimate the size the world's largest soap bubble. Graeme Denton made the Guinness World Record attempt in June, and needed a technique to estimate the bubble's volume from a limited set of perspective distorted photographs. A technique was developed to build a model of a bubble from a sparse sampling of points on the surface, and these were used to show that his attempt was indeed the largest indoor bubble ever, at 19.8 cubic meters (see page 40 for more details).

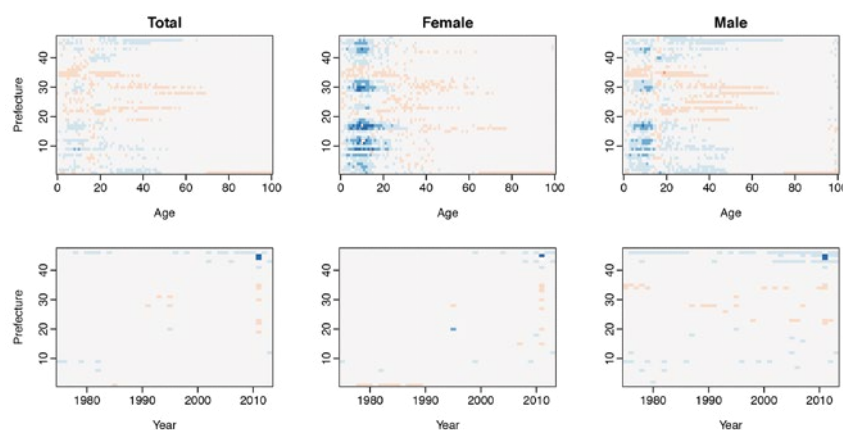
Internet security and privacy also posed some problems of interest for CIs Matthew Roughan and Matt Wand and their PhD student Lachlan Kang, and AI Jono Tuke. In a new collaboration with APNIC (the Asia-Pacific Network Information Centre) on understanding how the current spread of HTTPS (a secure form of the web browsing protocol) might lock some users out of the modern Internet, the challenge in the data was detecting a very weak signal in highly noisy data. Nearly 200 million samples were collected, filtered, and analysed using a variety of statistical tools.

The Riemann zeta function is an analytic tool for studying prime numbers, particularly through the location of the zeros in the complex plane. Therefore, for CI Peter Forrester and his team the huge interest in the mathematical community to compute and discover properties of those zeros has motivated them to take up this problem. One finding the team have explored has been the relationship the zeros have with quantum mechanics. There is evidence that the zeros have the same statistical properties as the high energy states of a chaotic quantum billiard with no time reversal symmetry. A celebrated data set from Andrew Odlyzko gives, to high accuracy, the Riemann zero near 1023 and over one billion consecutive neighbours. Analysing statistical quantities such as the spacing between zeros confirms the hypothesis, but with a small discrepancy; the challenge was to predict this theoretically, and to test the theory by further analysis of the data. It was found that second order functional forms computable from random matrix theory correctly predict the discrepancy. Returning to the data set, variants on the spacing distribution, such as that obtained by thinning the zeros at random, were also analysed, with the random matrix prediction again being verified. The random matrix model is a determinantal point process. To what order this is true of the Riemann zeros remains a very challenging question. Subtracting the theoretical form of the discrepancy from the data leaves only noise. Observing structure at higher order would require the sample size to increase by at least two orders of magnitude. This is only possible with parallel processing and a subtle memory management of the resulting gigantic data sets.



**Partially observed functional data:** When functional data are only partially observed in the form of fragments, standard techniques can only estimate the covariance function on a subset of its domain and with spurious boundary effect (first figure). Using novel techniques, Delaigle's teams is able to estimate the covariance function on its entire domain (second figure).

**Japanese mortality:** These graphs show anomalies between the Japanese mortality rates in each prefecture and each year, compared to the average across all years and all prefectures. The extraordinary longevity of people from Okinawa is clearly seen at the bottom of the graphs, as well as the increased mortality due to the earthquake of 1995 and the tsunami of 2011.



## 2018 RESEARCH PLANS: CI CAMEOS

**CI Nigel Bean:** “We plan to further develop our conceptual models of information flow and use them to explore the dynamics of information flow in different network structures, and also to extend the analysis of pre-European Aboriginal history to explore how Aboriginal and Torres Strait Islander peoples entered Australia. Of particular interest is the route taken, and the timing of the suspected genetically-distinct three groups that arrived. We have over a thousand Aboriginal and South East Asian hunter gatherer mitochondrial genomes and nuclear genomes are also being sequenced. We hope to explore the richer, yet vastly more complicated, story these genomes contain.”

**CI Rob Hyndman:** “We plan to continue working on new methods for very high-dimensional time series, designed to be applied in several contexts. We plan to develop tools and methods for: (1) probabilistic hierarchical forecasting; (2) constrained hierarchical forecasting; (3) visualising large collections of high-frequency hierarchical time series; (4) probabilistic forecasting of smart-meter data; (5) visualisation of large collections of smart-meter data; and (6) anomaly detection in streaming data.”

**CI Aurore Delaigle:** “We plan to develop new methods for analysing streaming data nonparametrically, with a particular emphasis on methods that can be computed automatically and efficiently from the data.”

**CI Kerrie Mengersen:** “Apart from extending the development of the citizen science program, and completing some applied projects in this domain, the spatial boosted regression tree model will be extended to include a temporal smoothing term in order to model global and local trends over time.”

**CI Matthew Roughan:** “In addition to finishing or extending existing projects we plan to establish a number of new collaborative projects: on analysis of Red Cross data, data-record linkage techniques, and analysis of computer security.”

**CI Louise Ryan:** “We aim to extend the case/control sampling ideas to incorporate data coarsening. The idea here is that data volume can be significantly reduced by strategies such as rounding or interval grouping of covariates and outcomes. The statistical challenge and innovation required here is that one needs to do some careful adjustment when using the coarsened data in order to avoid bias.”

**CI Scott Sisson:** “When summarising large and complex datasets by a smaller collection of symbolic, distributional summaries, there are many ways to construct them. Some of these will be obviously bad and can be discarded, others will be good but can be improved upon, and yet others will be optimal but will be computationally intractable to compute with and construct. In 2018 we will be studying in detail how to find the most computationally efficient of the class of near-optimal symbolic constructions, and verifying their performance in a suite of challenging applications.”

**CI Matt Wand:** “We will continue research on scalable statistical methodology based on fast approximate principles such as variational message passing and expectation propagation which, in turn, are expressible as message passing algorithms on factor graphs fragments. Our 2018 research will identify important fragments arising in challenging data settings and derive their message passing updates.”

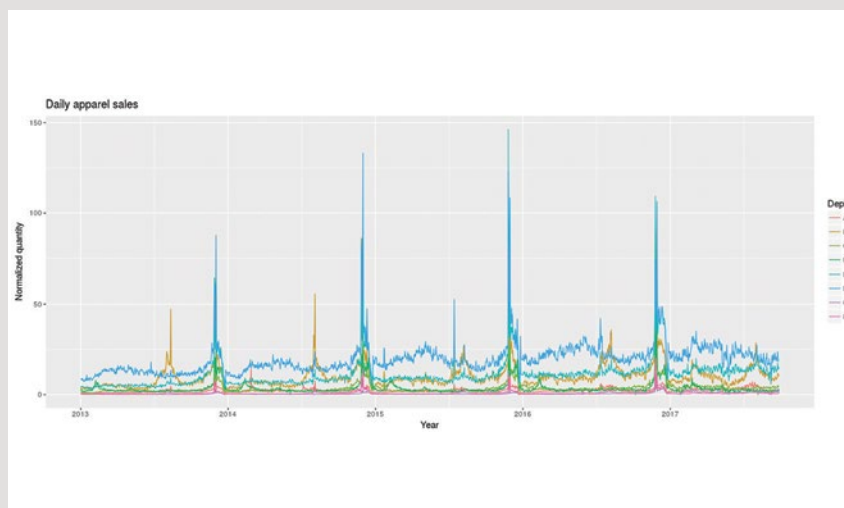
# HOW STATISTICAL ANALYSIS IS KEEPING YOUR FAVOURITE PAIR OF JEANS IN STOCK



Rob Hyndman  
Monash University

“Hierarchical forecasting occurs in almost every industry, including manufacturing, retail, energy, telecommunications, finance and health”

*Daily apparel sales for 8 Walmart departments from 1 January 2013 to 4 October 2017. The large spikes correspond to Christmas sales.*



## WHAT'S THE LINK BETWEEN STATISTICAL ANALYSIS AND A SHOPPING SPREE AT WALMART?

The answer to this question comes in the shape of Professor Rob Hyndman, Chief Investigator at ACEMS. As one of the world's leading statisticians, his research is all about understanding large data sets and using them to make predictions about the future.

A particularly interesting piece of work Rob is doing at the moment involves analysing clothing sales for Walmart's online store. As he explains, the vast array of clothing available at Walmart requires a lot of forward planning.

"The clothes at Walmart can be classified into a 'hierarchical structure'," Rob says. "The clothes are classified as male or female clothing, and then further split up into different clothing types – such as trousers, shirts or dresses – and then into different sizes, and so on. Walmart needs to forecast each clothing type at each size, in order to make sure it has an appropriate amount of inventory stock to meet customer demand."

But forecasting exactly how many items of clothing Walmart needs in each sub-category is pretty complicated. For a start, the forecasts need to match the structure of the data. 'Reconciled' forecasts occur when the forecasts add up appropriately across the hierarchy. For instance, sales of male and female clothing should be equal to the sales of all clothing. However, when each item of clothing is forecasted separately, the separate forecasts tend not to add up to the total number of sales.

"This means that there's a 'reconciliation' process required to adjust the forecasts," explains Rob. "With several collaborators, I have been working on a solution to this problem by developing an 'optimal reconciliation approach'. Our approach works in any context where reconciled forecasts are needed, no matter how big the forecasting problem."

However, reconciled forecasts are not enough for Walmart. The store needs to monitor the probability of running out of a particular item of clothing and ensure that this probability is kept low. At the same time, Walmart does not want to end up with a huge amount of stock it is unable to shift.

That's where Rob's statistical and mathematical expertise comes in. "There's no point in keeping enough stock to meet average demand – the amount of stock on-hand must be sufficient to meet demand almost all of the time," he explains. "We're responding to this challenge by forecasting apparel sales for Walmart's online store based on probability. We call this probabilistic hierarchical forecasting."

To date, Rob's team has been busy delving into huge data sets collected over successive points in time. They are developing exciting new data visualisation tools that uncover patterns in the data on clothing sales and also provide a basis for making smarter and better-informed decisions about inventory stock going forward.

As part of their work on probabilistic hierarchical forecasting, Rob and his team are creating software using the open-source R language that implements their statistical models for everyone to use. The data they have obtained from Walmart will allow them to test out the models and software on a very large and complicated forecasting problem, and to get feedback from Walmart on how the tools can be further improved.

Rob's pioneering work is at the cutting edge of statistics, as no one currently knows how to do optimal probabilistic hierarchical forecasting. And, while it's great that a large global company like Walmart sees the value of Rob's amazing research, the future implications of Rob's project are likely to be much bigger than Walmart.

"Hierarchical forecasting occurs in almost every industry, including manufacturing, retail, energy, telecommunications, finance and health," Rob says. "Our hope is that the results of our research can be applied in millions of organisations all over the world."



# PROBABILITY CONFERENCE AT THE ROCK TO CELEBRATE PHIL POLLETT'S 60TH BIRTHDAY

"I'm already looking forward to my 70th!"

Those were the words of Professor Phil Pollett, shortly after his 60th birthday celebration wrapped up.

About 70 people, many travelling from different parts of the world, gathered in April 2017 to celebrate Phil's 60th with an applied probability conference. It was held in one of Australia's most iconic spots, near Uluru, at Ayers Rock Resort, in Australia's Northern Territory. The conference was called 'Applied Probability at The Rock'.

"I think it was a resounding success, both academically and personally," says Phil, who is a Professor of Mathematics at The University of Queensland (UQ) and a Chief Investigator for ACEMS.

The main theme of the conference was mainstream Applied Probability. The underlying theme of the week, though, was Phil's impact on the lives of many of the people who attended.

Dr Joshua Ross helped organise the event. Josh is an Associate Professor in the School of Mathematical Sciences at The University of Adelaide, an Associate Investigator for ACEMS, and one of Phil's former PhD students at UQ.

"Something that I was well aware of, but that became completely evident during the week, was how tremendous Phil is with mentoring. Not just with his own students, but with the whole applied probability community," says Josh.

In fact, speaker after speaker at the conference talked about the impact Phil has had on their lives.

"I was quite taken aback by the apparent influence I have had on people," says Phil.

"It wasn't just how I helped people with their careers. My idea is to help people find the right path, to encourage them to be balanced in their life."

*"I didn't quite realise it until I heard the words that were said about me and what an impact I have made. Since the conference I've been reflecting quite a lot on that."*

The conference featured several keynote speakers: Distinguished Professor Ruth Williams at the University of California, San Diego, Professor Andrew Barbour at The University of Melbourne, and Professor Erik van Doorn at the University of Twente, the Netherlands.



Attendees for Phil Pollett's 60th Birthday Celebration Probability Conference



*Uluru is one of Australia's best known landmarks and is sacred to Australia's indigenous people*

The other keynote speaker was Phil's PhD supervisor from his days at the University of Cambridge, Professor Frank Kelly, who is still in Cambridge.

"I was privileged to have Phil as my first research student, and was delighted to be able to attend this conference in Phil's honour," says Frank.

Frank was impressed with the talks given by students and early career researchers who attended: "For me, one of the most notable aspects of the conference was the breadth and quality of the contributions from younger participants. This attests to the encouragement and mentoring provided in the Applied Probability field, and to the general environment provided through the discipline's leadership in Australia. Phil can be proud, amongst much else, in this legacy," he says.

Three students finished very closely in the competition for the best talk. In the end, one of Phil's current PhD students at UQ, Liam Hodgkinson, won the prize. Two other ACEMS students, Peter Braunsteins (UoM) and Patrick Laub (UQ) were highly commended.

The conference received support from Australia's top mathematical organisations, with ACEMS, AMSI, AustMS all helping sponsor it, along with The University of Queensland and The University of Adelaide.

Phil was joined by his wife, Patricia, at the conference. The location of the conference was a big attraction for others as well, with more than a dozen people showing up with their partners, and some, even with their kids. Having the conference in Uluru meant a lot to Phil.

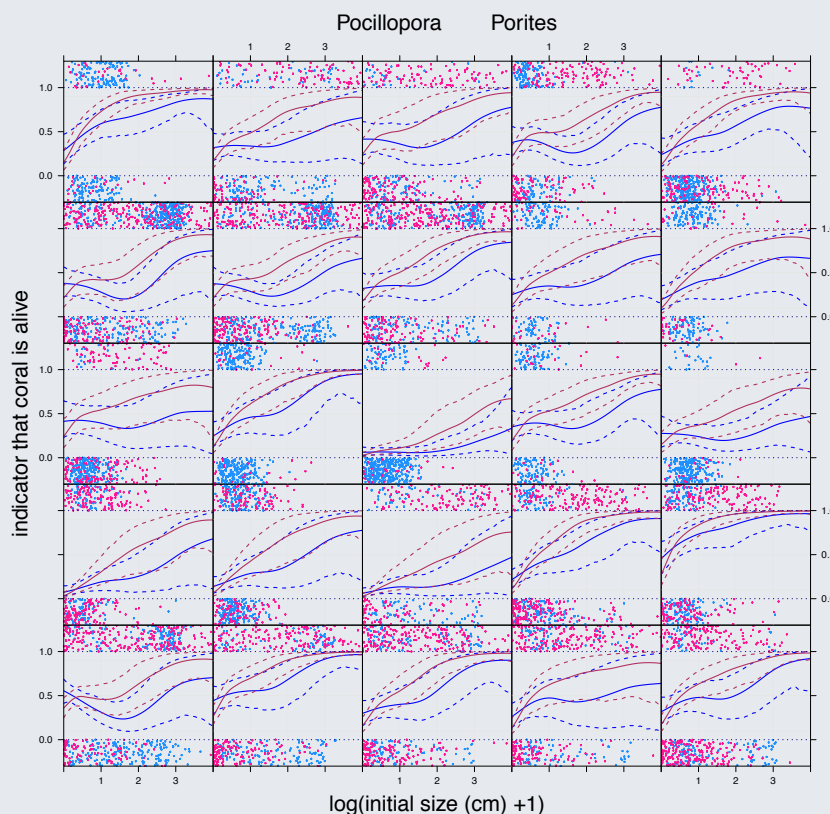
"For us Australians, it's a little bit like going to our spiritual heart. We don't have many places like Uluru to visit and feel like that. But I did feel like that. I felt like there was a spiritual aspect to it," says Phil.

So as he looks back at the week, it's no surprise Phil is already looking forward to the next 10 years, and to the celebration he hopes will take place when that landmark birthday rolls around.



*Phil Pollett and his wife Patricia at the 60th birthday event.*

# THEME 2: MULTISCALE MODELS



*Fitted group-specific probability function estimates for two coral taxa, Pocillopora and Porites, as a function of size. The dashed curves represent pointwise 95 per cent credible sets. Each panel corresponds to a different study site.*

## OVERVIEW

Models are the fundamental structures required to make sense of data and systems. Under this theme we develop the new models, both stochastic and statistical in nature, required by new problems and to support Challenging Data.

## HIGHLIGHTS

- New mathematical models for biological systems, including metapopulations, proliferation processes epidemic models and biosensor experiments
- New mathematical models of the South Australian electricity market
- New theoretical results on the stability of random ensembles of dynamical systems, and their application to modelling epilepsy
- New theoretical results concerning Macdonald polynomials and their relationships to stochastic processes in the KPZ universality class
- A geometric explanation of the anomalous finite-size scaling behaviour exhibited in finite statistical mechanical systems in high dimensions
- New applications of message passing to allow fast approximate inference in large Bayesian semiparametric regression models.
- A point process model for the mining process of blocks in the Bitcoin blockchain
- New models for queueing systems, including ad hoc mobile networks, loss systems, priority queues and queues with scheduled arrivals
- Significant progress was made in our understanding of extinction probabilities in multitype branching processes with infinitely many types



## TEAM

**Theme Leaders:** Tim Garoni, Phil Pollett and Matt Wand

**Chief Investigators:** Nigel Bean, Kevin Burrage, Jan de Gier, Aurore Delaigle, Peter Forrester, Dirk Kroese, Kerrie Mengersen, Tony Pettitt, Matt Roughan, Louise Ryan, Peter Taylor and Ian Turner.

**Selected Research Fellows and Associate Investigators:**

Azam Asanjarani, Andrew Barbour, Rhys Bowden, Pamela Burrage, Julian Caley, Chris Drovandi, Troy Farrell, Alexandr Garbali, Sophie Hautphenne, Jesper Ispen, Ross McVinish, Tim Moroney, Giang Nguyen, Steven Psaltis, Leonardo Rojas-Nandayapa, Joshua Ross, Matthieu Simon, Laleh Tafakori, Radislav Vaisman, Michael Wheeler and Eric Zhou

**PhD and Masters Students:** Peter Ballard, Peter Braunsteins, Lachlan Bridges, Zeying Chen, Jens Grimm, Liam Hodgkinson, Sang Il (Andy) Kim, Patrick Laub, Angus Lewis, Rachel McLean, Nic Rebuli, Shrupa Shah, Jason Whyte and Wangyue (Winnie) Xie

**Other Collaborators:** John Gilbertson, Aminanth Shausan and Nikki Sonenberg.

## DETAILED DESCRIPTION

A cross-node program led by CI Phil Pollett aims to develop mathematical models for population dynamics that account for local population behaviour, individual variation, spatial structure, and differing migration patterns, and to calibrate these models to real data.

This large team is cross-nodal and international, and includes CI Peter Taylor, Research Fellows, Laleh Tafakori and Ross McVinish, Als Leonardo Rojas-Nandayapa and Andrew Barbour with PhD students, Liam Hodgkinson, Patrick Laub, Wangyue (Winnie) Xie and ACEMS collaborator Aminanth Shausan. The team has been developing mathematical models for biological systems, particularly metapopulations (populations that occupy geographically separated patches of habitat), and epidemic models that incorporate spatial structure and individual variation.

Three projects within this program have progressed in 2017. The first concerns approximating the equilibrium of a metapopulation model in which a finite number of patches are randomly distributed over a closed region. The approximation is good when a large number of patches

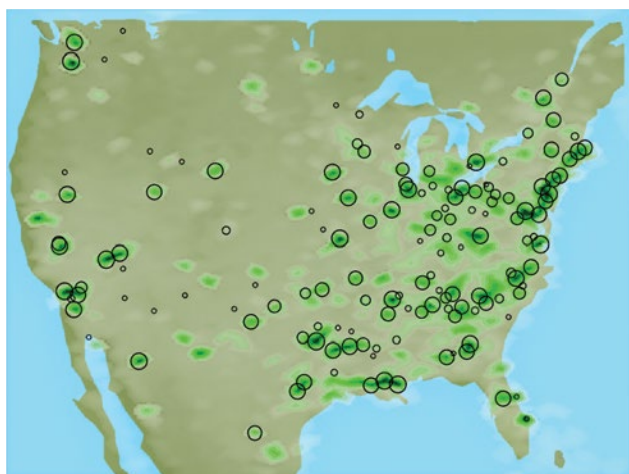
contribute to the colonisation pressure on any given unoccupied patch, and when the quality of the patches varies little over the length scale determined by the colonisation radius. A second project concerns distributional approximations for a very general class of models called ‘occupancy processes’, a class that encompasses metapopulation models, network models in epidemiology, binary probabilistic cellular automata, and a variety of Markov random graph models. They have shown that occupancy processes are approximated well by Gaussian random fields, thus rendering them mathematically tractable. The third topic concerns understanding growth of tissue in a developing organism. Continuum models are derived by scaling discrete agent-based models for cell proliferation.

Significant progress has been made in epidemiological modelling by CI Nigel Bean and AI Joshua Ross. Together with PhD student Peter Ballard, they studied the optimal stage of an epidemic at which to implement an intervention that reduces transmission to maximise the probability of epidemic fadeout. The team determined an explicit approximate decision rule which was demonstrated to be highly accurate. With PhD student Nic Rebuli, the researchers developed a novel method for estimating the basic reproduction number of an emerging epidemic in its early stages, which accounts for the bias that is introduced when one ignores the fact that the disease has been detected. This was shown to provide more accurate estimates, which could see substantial reductions in the initial assessment of the threat of an outbreak in terms of the final epidemic size.

With his PhD supervisors, CI Peter Taylor and Advisory Board member Tony Guttmann, Jason Whyte considered the important problem of identifiability in the use of linear switching system models to estimate the values of parameters for biochemical reactions. With particular application to optical biosensor experiments, he showed that it can be determined *a priori* whether it is even theoretically possible to obtain unique parameter estimates. Jason received his PhD in 2017.

Accurately modelling pricing in the electricity market is inarguably of huge importance to the Australian economy. CI Nigel Bean, AI Giang Nguyen and student Angus Lewis have proposed a regime-switching model to describe the evolution of electricity spot prices in the South Australian market during 2013-2017. The model shows that four regimes are sufficient to capture the essentials of the SA market behaviour: two mean-reverting base regimes with different volatilities, a spike regime, and an extraordinary spike regime for when the prices can increase up to the market price cap. The model also indicates





*Modelling the spread of a population (such as an invasive species) over the USA using an 'Occupancy Process', a stochastic model that incorporates spatial structure and landscape dynamics. Depicted is the predicted long-term likelihood of occupancy for a population emanating from the New York area (heat map in green), and a simulation (the black circles indicate the presence of the species at a given patch; the size of a circle represents patch size).*

that following the official announcement of the closure of the last coal-fired power station in South Australia, almost a year before the closure itself, the market exhibited a marked increase in the volatility of the base price.

Optimal search strategies have been determined by ACEMS researchers in models of animal foraging, where an animal follows either a fixed strategy or an intermittent strategy. In the latter, the animal is allowed to switch from one strategy to another, but only once. Student Lachlan Bridges, together with CI Bean and AI Nguyen, have proposed a model where the animal adopts a Markov-modulated strategy, with the states of the underlying Markov chain representing different search modes, and where the animal can switch from one mode to another multiple times. Analytic expressions for the expected length of such a strategy were derived, and used to determine the optimal parameters for the step lengths and switching rates.

With CI Matthew Roughan and AI Joshua Ross, Masters student Rachel McLean have developed a framework for optimal allocation of resources to combat illegal wildlife trade. This has involved stochastic optimisation algorithms and shortest path problem formulation and solution.

The dynamics of complex systems are often modelled by systems of first-order ordinary differential equations. A fundamental question of interest concerning such systems is to locate and classify (stable or unstable) their equilibria. Research Fellow Jesper Ipsen has recently introduced a random ensemble of such dynamical systems, and proved the existence of a phase transition between a regime containing a single stable equilibrium, and a regime corresponding to exponentially many equilibria. His approach uses an explicit derivation of a stochastic description of the finite-time Lyapunov exponents. Dr Ipsen is currently collaborating with Dr Andre Peterson from St Vincent's Hospital, Melbourne, on an application of this theory to models of epilepsy.

Ipsen has also made a significant contribution to the theory of random matrices. In joint work with CI Peter Forrester, a correspondence was recently established between matrix integrals of the Harish-Chandra/Itzykson-Zuber type, and random

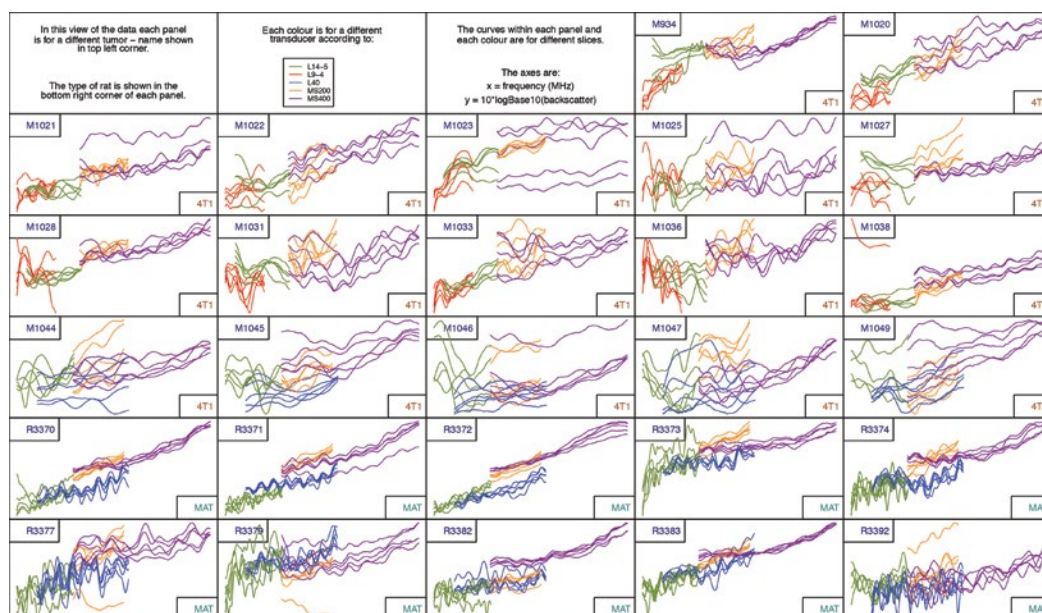
product matrices. The correspondence has been made explicit in relation to a hyperbolic version of this integral, and also for the orthogonal and symplectic Harish-Chandra group integral. These random product matrices can be analysed for a general number of matrices  $M$ , and allow one to study corrections to the large  $M$  regime, when the Lyapunov spectrum dominates.

A multi-node team of researchers, led by CI Jan de Gier from The University of Melbourne and CI Tim Garoni from Monash University, have made a number of contributions towards the Centre's Frontier Question on Universality: "Why do large systems of strongly interacting particles often become insensitive to their microscopic details, and how can we describe mathematically their generic behaviour?"

CI de Gier, together with AI Michael Wheeler and Research Fellow Alexandr Garbali have made a significant extension of previous work performed in 2016, by constructing explicit expressions for Macdonald polynomials using matrix product formulas, a technique which has been used successfully in describing stationary states of certain Markov processes. This new work has been accepted for publication in *Communications in Mathematical Physics*, which is the leading journal in the broad field of mathematical physics.

Macdonald polynomials are important objects in the representation theory of the the Hecke algebra, a deformation of the symmetric group. They have been used extensively recently by groups at Columbia and MIT in their construction of Macdonald stochastic processes, to rigorously describe KPZ universality. These works led to non-Gaussian probability distribution functions for particle processes, such as the Tracy-Widom distribution from random matrix theory. The recent work of Jan de Gier and team establishes a new relationship between Macdonald polynomials and stochastic processes. It is anticipated that the resulting generalisation of Macdonald polynomials will open a new chapter in this field of research.

In related work, Jan de Gier and AI Michael Wheeler, together with PhD student Zeyang Chen have constructed stochastic dualities between multi-species asymmetric exclusion



*Backscatter (log transformed) versus frequency for two different types of induced tumors in mice and rats. Each tumor is scanned at several probe locations using ultrasound technology at University of Illinois, U.S.A. Five different transducers were used.*

processes with different particle content. Such dualities imply, for example, that two-point correlation functions in many particle systems can be described by a two-particle process, and hence can be analysed in great depth and often analytically calculated. The methodology used in this work is highly original and constructive, being based on a functional representation of exclusion processes on polynomial rings.

Finite-size scaling is a fundamental theory within statistical mechanics, describing the asymptotic approach to the thermodynamic limit, of finite systems in the neighborhood of a critical phase transition. It is well known that in sufficiently high dimensions, the limiting behavior of a system near a critical phase transition is typically governed by universal critical exponents taking simple 'mean-field' values. In contrast to the simplicity of this thermodynamic behavior, however, the theory of finite-size scaling in high dimensions is surprisingly subtle, and remains the subject of ongoing debate. In a recent article, published in *Physical Review Letters*, CI Tim Garoni, together with postdoc Eric Zhou, PhD student Jens Grimm, and overseas collaborators Eren Elci and Youjin Deng, presented a concrete geometric explanation for the apparent breakdown of standard finite-size scaling in systems with periodic boundaries in high dimensions. A consequence of this work is to demonstrate the universal finite-size scaling in high dimensions of several models including the Ising model and the self-avoiding walk.

A very strong form of universality has been discovered recently by CI Tim Garoni and Monash researcher Andrea Collecchio, together with collaborators Eren Elci and Martin Weigel, for the scaling limit of the coupling time of the heat-bath process for the Fortuin-Kasteleyn random-cluster model. The random-cluster model is a fundamental class of models in equilibrium statistical mechanics. This work is described in more detail in the Enabling Algorithms theme.

Calculating the partition function of the zero-temperature antiferromagnetic model is an important problem in statistical physics. However, an exact calculation is hard since it is strongly connected to a fundamental combinatorial problem of counting proper vertex colourings in undirected graphs, for which an

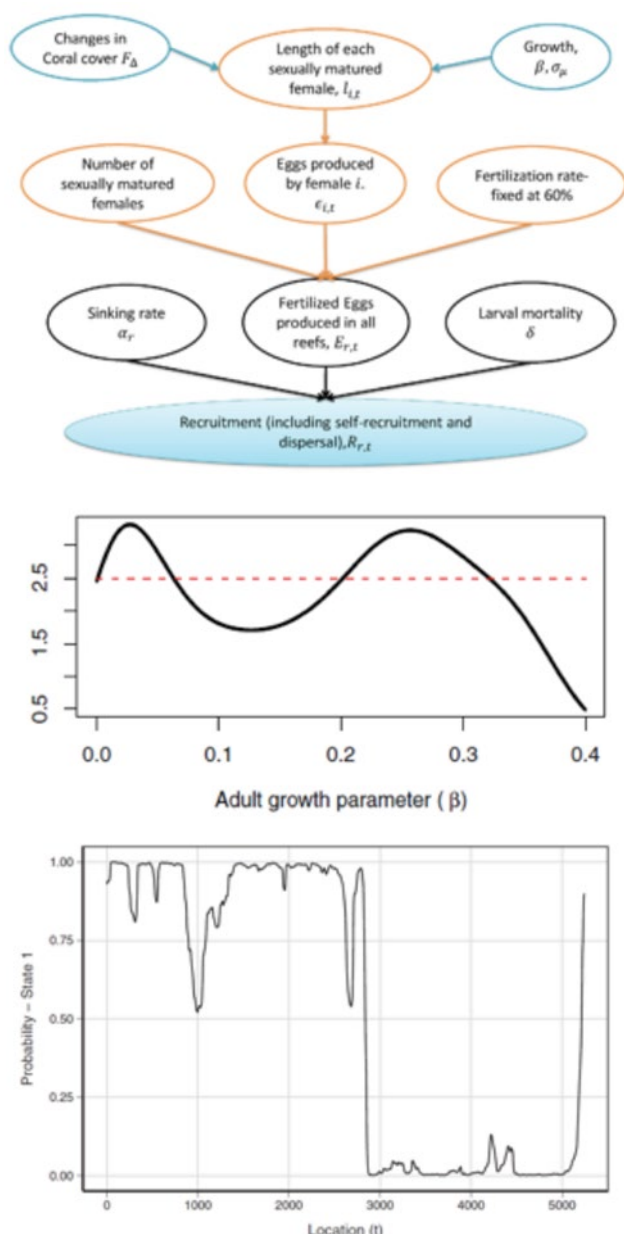
efficient algorithm is not known to exist. Thus, one has to rely on approximation techniques.

CIs Dirk Kroese and Matt Roughan together with AI Radislav Vaisman, have formulated the problem of partition function approximation in terms of rare-event probability estimation, and have investigated the performance of a particle-based algorithm, called Multilevel Splitting, for handling this setting. The proposed method enjoys a provable probabilistic performance guarantee, and a numerical study indicates that this algorithm is capable of delivering accurate results using a relatively modest amount of computational resources.

In recent work, that also has overlap with the Challenging Data and Enabling Algorithms themes, CI Matt Wand has shown how the notion of message passing can be used to streamline the algebra and computer coding for fast approximate inference in large Bayesian semiparametric regression models. In particular, this approach is amenable to handling arbitrarily large models of particular types once a set of primitive operations is established. The approach is founded upon a message passing formulation of mean field variational Bayes that utilises factor graph representations of statistical models. The underlying principles apply to general Bayesian hierarchical models. The notion of factor graph fragments is introduced, and is shown to facilitate compartmentalisation of the required algebra and coding.

Expectation propagation is a general approach to deterministic approximate Bayesian inference for graphical models, although its literature is confined mostly to machine learning applications. ACEMS PhD student Andy Kim, together with CI Matt Wand, have investigated the utility of expectation propagation in generalised, linear, and mixed model settings. Numerical studies indicate expectation propagation is marginally more accurate than a competing method for the models considered.

A project led by CIs Kevin Burrage and Ian Turner is focussed on physical modelling of flows in porous media, including electro-chemical systems, biological media, and coal seam gas. This work involves multiscale modelling with Boundary Element Methods, Lattice-Boltzmann and Smoothed Particle.



Figures 1-3 (top to bottom) from CI Kerrie Mengersen, Als Chris Drovandi and Julian Caley, and PI Ken Anthony. Description in below text.

A number of research projects have been undertaken with ACEMS Partner Organisation the Australian Institute of Marine Science (AIMS). Many of these projects involve complex dynamical systems that can be described through multilevel models over space and time. In one of these projects, undertaken by CI Kerrie Mengersen, together with Als Chris Drovandi and Julian Caley and PI Ken Anthony, the motivating problem was to model the growth and spread of the crown of thorns starfish on the Great Barrier Reef. An appealing way of modelling these systems is through agent based models. Unlike previous models that are typically cohort-based deterministic representations of the system, a new semi-individual agent based method was developed that includes parameter and individual uncertainties and calibrates with observational data. The algorithm includes a replenishment term that enables the use of less informative priors, increases efficiency and reduces computational time, and provides markedly improved parameter estimates.

Figure 1 illustrates the conditional dependencies of biological and ecological processes influencing recruitment which, when combined with a similar figure for mortality, is used to develop the semi-individual agent based model. In Figure 2, an example is given of the model output, namely the posterior distribution for the adult growth parameter (black line) compared with the prior (dotted red line).

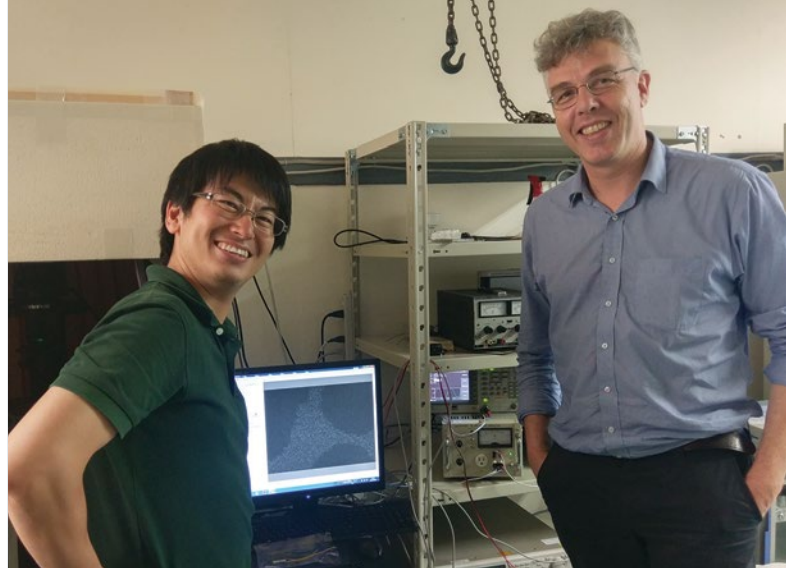
A popular method for describing highly structured data is through a hidden Markov model (HMM). These models depict different 'states' of a process, and the probabilistic transitions between these states, thus partitioning compositionally heterogeneous domains into homogeneous segments. These homogeneous segments may, for example, reflect or reveal biological or ecological function. Despite their appeal, HMMs can be computationally difficult for large, high-dimensional datasets. Kerrie has been developing new HMM representations and computational algorithms to accommodate these larger datasets. A major focus has been on the analysis of DNA sequences. Figure 3 (Totterdell et al., 2017) shows the segmentation results for a two-state HMM used to describe the SV40 genome, which is a virus found in both monkeys and humans. Here, the vertical axis depicts the probability of being in State 1 for different locations on the genome (horizontal axis).

The team, including Research Fellow Steven Psaltis and Als Troy Farrell, Pamela Burrage and Tim Moroney, continued work on the use of Population of Models for estimating parameters in a coal seam gas simulator for the Surat Basin. A journal article was published in Applied Mathematical Modelling.

CIs Burrage and Turner also have a strong research focus on developing computational models that are based on generalised partial differential equations containing derivatives of fractional order in space, or time, or both space and time for simulating anomalous transport phenomena. These phenomena are driven by the constrained interactions within the complex and non-homogeneous microstructures evident at the pore scale in porous media. The team are analysing these models to study their effectiveness for a range of applications where anomalous diffusion is evident. At the core of this work is the convergence and stability analysis of the underlying numerical schemes, and the development of efficient computational algorithms.



*ACEMS CI Professor Jan de Gier visiting the laboratory of Professor Kazumasa Takeuchi (pictured) and Professor Tomohiro Sasamoto at the Tokyo Institute of Technology during August 2017.*



CI Peter Taylor, along with AI Rhys Bowden and Paul Keeler, and international visitors Tony Krzesinski and Mirte van Weert have been progressing a program of work to study the theoretical underpinnings of blockchain technology.

This program has included a project to devise a point process model for the block mining process of the Bitcoin blockchain. This model reflects the long-term behaviour induced by the world's total mining effort, as well as that induced by short-term stochastic effects. A second project devised a simple Markovian model to study the bounds on the transaction processing rate induced by the interaction of the block size with validation and propagation delay.

Various types of queueing models constitute the objects of interest in a program of work led by CI Peter Taylor. With international visitor and ACEMS Scientific Advisory Board member Michel Mandjes, he devised an analogue of the well-known Erlang Loss Formula that applies to Markov modulated queues. With AI Sophie Hautphenne and PhD student Peter Braunsteins, he has continued to look at various transient performance measures of finite-capacity queues and with international colleagues Na Li, David Stanford and Ilze Ziedins, he established when linear proxies exist for accumulating priority queues with non-linear accumulation functions. With John Gilbertson, he assessed what is to be gained by allowing dynamic scheduling in queues in which customers arrival times can be set. Finally, with Nikki Sonenberg, she investigated an extension of a previous stochastic fluid model for ad hoc mobile networks in which battery energy is finite.

PhD student Peter Braunsteins and his supervisors AI Sophie Hautphenne and CI Peter Taylor pushed the boundaries of our understanding of multitype branching processes with infinitely-many types. It is significant that in these branching processes, two different kinds of extinction event can occur, (i) when the population reduces to zero or (ii) when every type becomes extinct. The probabilities of each of these events can be different but they satisfy the same equations. In this project, the investigators have been working on conditions for characterising the particular solutions that correspond to each kind of extinction event, as well as numerical procedures for evaluating them.

## 2018 RESEARCH PLANS: CI CAMEOS

**CI Jan de Gier:** "In 2018, we will continue our study into the construction of an integrable 2+1 dimensional stochastic process using advanced algebras, as well as the calculation of probability distribution functions in multi-species processes in collaboration with Sasamoto in Tokyo."

**CI Phil Pollett:** "Projects planned for the coming year include adapting advanced simulation methods (in particular, the Tau-leaping algorithm) to metapopulation models, and measuring aggregation in parasite-host systems."

**CI Peter Forrester:** "As far as future plans on this theme go, some ideas are to extend the list of random product matrices for which the exact Lyapunov exponent can be computed using ideas from integral geometry; to compute the exact rate function for large deviations of the Lyapunov exponent; and to study the invariant measure in this setting with applications to disordered systems and population models."

**CI Tim Garoni:** "In 2018, we plan to undertake a cross-node collaboration between Monash University and The University of Melbourne, aimed at extending our one-dimensional results on universal coupling time limit laws to arbitrary dimension."

**CI Nigel Bean:** "With Robert Cope, we will be focusing on improving forecasting, and in particular looking to integrate different data sources. With Thomas Prowse, we will be focusing on gene drives, in particular initially looking at realistic modelling of spatially-limiting gene drive strategies, and then realistic spatial models too. Peter Ballard will be focusing on particle marginal Metropolis Hastings (PMMH) algorithms for characterising novel diseases for detailed household-based models, and looking at other population structures too, as part of his new postdoctoral position."

**CI Peter Taylor:** "The program on blockchain technology will continue. In particular, obtaining bounds on the achievable transaction processing rate will be a major contribution to our understanding of how blockchain technology works. We also plan to extend a game theoretic model of Huberman, Leshno and Mollemi to study optimal strategies for paying incentives to miners."



# ACEMS MEMBERS WIN EUREKA PRIZE FOR THEIR STATISTICAL RESEARCH ON ABORIGINAL HERITAGE PROJECT

*“The resulting map of Indigenous Australia will be a critical resource for people of Aboriginal descent who are culturally disconnected, members of the Stolen Generations, and for the broader Australian public who need to learn about Australian history.”*

Three ACEMS Researchers were part of a team that won a 2017 Eureka Prize, Australia's premier science awards, also known as the 'Oscars of Australian Science'.

PhD Student Adam 'Ben' Rohrlach, CI Nigel Bean, and AI Simon 'Jono' Tuke were part of the team that won the prize for 'Excellence in Interdisciplinary Scientific Research'.

The ACEMS team developed statistical methods in the landmark study, which used DNA from historical hair samples to help link Australian Aboriginals to the land that they have always claimed to inhabit through their stories.

Ben was one of two first authors of the article published in the journal *Nature*. The Aboriginal Heritage Project was led by the Australian Centre for Ancient DNA (ACAD) in partnership with the South Australian Museum and in collaboration with Aboriginal families and communities across Australia.

The DNA used in the project came from hair samples that were collected from Aboriginal people by two anthropologists during a series of anthropological expeditions across Australia from the late 1920s through to the 1960s. The hair samples are now held by the South Australian Museum along with detailed information about the family history of the individuals, including their ancestral birth places.

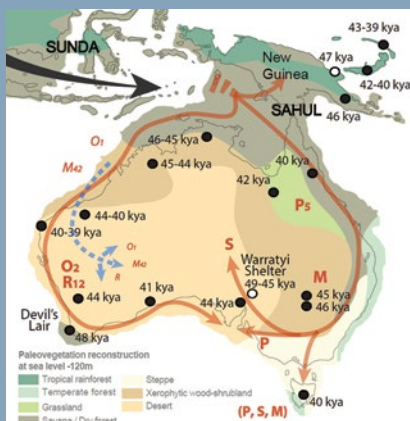
The DNA from these hair samples show that indigenous populations initially settled in these regions approximately 50,000 years ago and that they continued to inhabit these same areas despite climatic and cultural changes. The study found that even when climates became uninhabitable during dry spells brought on by ice ages, the same groups seemed to return to their ancestral lands.

To strengthen the results of their research, the project leaders turned to the ACEMS researchers. Ben, with the help of Nigel and Jono, developed the necessary statistical methods for exploring the genetic data used in the study.

“What they were missing was a rigorous way of assessing what the data seemed to be trying to say. We took their genome data and basically turned it into numbers,” says Ben, who is now an associate lecturer with the School of Mathematical Sciences at The University of Adelaide. “Through this project, and others like it, I hope that other fields can also see the importance of quantitative methods in research. It is exciting research like this that really pushes the frontiers of what we do as statisticians.”

The ACEMS team were thrilled to be part of a project that brought together such a diverse group of researchers.

“This project represents a remarkable example of multi-disciplinary science, bringing together experts from fields as wide-ranging as genetics, mathematics, linguistics, museum archivists, Aboriginal community organisers and researchers, and archaeologists. It is only through the integration of all of these areas that it has been possible to reach our conclusions,” says Nigel.



Map of Australia showing the migration patterns of Australia's first people

"Australia constitutes one of the oldest and most important chapters in human history and yet it remains one of the least well understood," says project leader Professor Alan Cooper, Director of ACAD. "The Aboriginal Heritage Project is reconstructing this missing history and the details of some 50,000 years of Aboriginal heritage."

Under the Aboriginal Heritage Project, Aboriginal families and communities were closely involved with the research from the start and analyses were only conducted with their consent. The teams first discussed results with the families to obtain Aboriginal perspectives before scientific publication.

"I really hope further work continues to strengthen the body of evidence we're starting to put together here, as we've only just started. We really need to make people aware of the importance and richness of Aboriginal and Torres Strait Island culture so that it can be appreciated and respected for its uniqueness. They have such an interesting history, and one which we're only beginning to uncover," says Ben.

*“Amazingly, it seems that from around this time the basic population patterns have persisted for the next 50,000 years – showing that communities have remained in discrete geographical regions,”*

**PROJECT LEADER PROFESSOR ALAN COOPER,  
DIRECTOR OF ACAD, UNIVERSITY OF ADELAIDE.**



*Nigel Bean (left) and Ben Rohrlach (right) received the Eureka Prize for Excellence in Interdisciplinary Scientific Research*

## STATISTICAL BREAKTHROUGH TO HANDLE THE DNA EVIDENCE

The challenge with the DNA collected from the hair samples in this study was that it was single-copy Mitochondrial DNA (mtDNA).

Unlike the rest of DNA in the human genome, mtDNA can only be passed on by mothers so it only follows the history of the female part of the population (hence its popular name, the 'Eve gene'). Nuclear DNA on the other hand is passed down to children from both parents, and so is not single-copy.

Ben says statistical methods existed for this type of analyses for DNA where there are two copies. However, Ben and the ACEMS group at The University of Adelaide developed new methods to enable them to cope with the loss of information introduced by single-copy DNA.

They used a statistical data methodology that was originally developed for survey analysis, called Multiple Correspondence Analysis (MCA). MCA allows the dependency of DNA markers to be quantified. "We know that mutations in DNA are passed down from generation to generation, according to a big family tree. Our method basically assumes that mutations are randomly assigned to individuals, and then it looks for which mutations most fail this assumption by only showing up together, or never at all," says Ben.

"What we managed to do was find the genetic distance between two individual genomes, based on the unique genetic markers, on a continuous scale. We also had a distance between two individuals on a geographic scale. We showed statistically that individuals that were close genetically were far more likely to be close geographically."

That statistical breakthrough provided the rigorous evidence needed for the study, and allowed researchers to create the first detailed genetic map of Aboriginal Australia prior to the arrival of Europeans.

# THEME 3: ENABLING ALGORITHMS

## OVERVIEW

Developing Enabling Algorithms is one of the four key research themes of ACEMS. By an Enabling Algorithm we mean a set of mathematical procedures or methods which can be applied to solve a number of methodological and applied problems. Several good examples of Enabling Algorithms are the EM algorithm, the Metropolis-Hastings method (used extensively in Markov chain Monte Carlo), pseudo marginal particle methods (that allow us to deal with intractable likelihood problems) and Approximate Bayesian Computation (which allows us to deal with intractable likelihood, where densities cannot be evaluated even with the help of latent variables). To some extent, many of the methods and even the applied work at ACEMS involves the development of enabling algorithms. What distinguishes the quality of such enabling algorithms is their generality. This leads to the following observations. We aim to facilitate the use of the enabling algorithms developed at ACEMS by (a) Developing new classes of innovative algorithms that exploit rapid advances in computing technology (b) Providing theoretical and empirical proofs and evidence that the algorithms work as claimed (c) Providing clear descriptions of the algorithms (d) Providing easy to use code, often through an R package.

Our research focuses on developing a range of enabling algorithms at the cutting edge of international best practice that are informed and can assist our partners, and more generally our more applied collaborators, to analyse their data for informed decision-making to increase productivity and financial benefit.

## HIGHLIGHTS OF ACEMS RESEARCH IN 2017

- Used Advanced Monte Carlo methods to model complex network and simulating rare events such as the state-wide power blackout in South Australia in September 2016, natural disasters such as floods and bush fires, or the ensuing chaos when parts of a complex interconnected systems such as the internet fail.
- Developed efficient learning and sampling algorithms for big data and complex models using algorithms and analysis techniques developed for large scale optimisation and sampling problems that arise in machine learning.
- Utilised Bayesian inference for big data simulation tools based on data subsampling with the ability to scale to large data sets for many observations and many parameters.
- Applied Factor Graph Fragments for Measurement Error and Missing Data Models to explore message passing approaches to semi parametric regression analysis.
- Explored variability in physiological systems where significant variability is a common feature, in order to understand and explain differences in susceptibility to pathological conditions, and how medical treatments can potentially succeed or fail even when applied to treat the same condition.
- Investigated lattice reduction and invariant measures that span linearly independent vectors over integers to find a basis of shortest vectors in the lattice. This has applications in cryptography, coding theory, the global positioning system, and statistical signal processing.
- Explored Splitting Methods for Optimisation and Estimation utilising new and fast splitting algorithms for systems of particles that move around in space and time and have the possibility to die out or split into multiple particles at certain times. Such systems can be used to solve complicated estimation and optimisation problems.

## TEAM

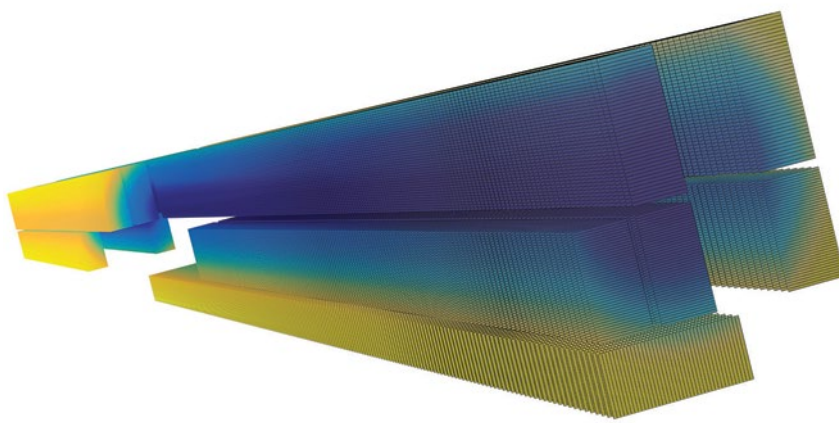
**Theme Leaders:** Robert Kohn, Dirk Kroese and Ian Turner

**Chief Investigators:** Nigel Bean, Peter Bartlett, Kevin Burrage, Peter Forrester, Tim Garoni, Rob Hyndman, Kerrie Mengersen, Tony Pettitt, Louise Ryan, Scott Sisson, Kate Smith-Miles, Peter Taylor and Matt Wand

### **Selected Research Fellows and Associate Investigators:**

Tomasz Bednarz, Pamela Burrage, Chris Carter, Wilson Chen, Christopher Drovandi, Xuhui Fan, Yanan Fan, Troy Farrell, Denzil Fiebig, David Gunawan, Peter Green, Markus Hegland, Sevvandi Kandanaarachchi, Mohamed Khaled, Je Guk Kim, Brody Lawson, Benoit Lique, Sarat Babu Moka, Tim Moroney, Chris Oates, Tung Pham, Erin Peterson, Steven Psaltis, Matias Quiroz, Minh Ngoc Tran, Simon 'Jono' Tuke, Radislav Vaisman, Mattias Villani, Stephen Wright, Hongbo Xie, Qianqian Yang and Nan Ye

**PhD and Masters Students:** Abhishek Bhardwaj, Vincent Chin, Puwasala Gamakumara, Morgan Grant, Megan Farquhar, Sang Il (Andy) Kim, Dang Doan Khue Dung, Jarod Lee, Michelle McGrath, Tui Nolan, Tan Nguyen, Robert Salomone, Matthew Sutton, Dilini Talagala, James Todderel, Thiyanga Talagala, Shanika Wickramasuriya, James Yu and Jiyuan Zhang



To be able to compare the measured MOE values with those predicted from the virtual boards, we use the MOE obtained from static bending. The static bending is performed on a shorter test sample, with the length of this test sample being determined by the cross-section dimensions of the board. For 96 x 40 mm studs, the test sample is 2 m long, while for the 72 x 40 mm studs it is 1.5 m. Each of these test samples is taken from the butt or top end, with the end being determined randomly. The virtual boards that we simulate static bending on (for Tree 1) are shown in the figure, indicating their geometry and predicted MOE gradient from low (blue) to high (yellow).

## DETAILED DESCRIPTION

One of the key successes behind ACEMS research as well as one of its key strengths is that the ACEMS CIs and AIs have diverse mathematical and statistical backgrounds in areas of both theoretical and applied research. This diversity and the interaction between ACEMS members informs the development of algorithms that will have greater generality and impact. In 2017 ACEMS CIs and AIs engaged in research in a range of areas on enabling algorithms.

CI Nigel Bean has worked on the probabilistic interpretation of doubling algorithms, together with Nguyen Federico Poloni (Pisa), currently the most efficient method for solving algebraic Riccati equations. Together with Nguyen, and Vikram Sunkara (FU Berlin) Nigel has also worked on stochastic fluid-fluid models by constructing a discontinuous Galerkin method to approximate the stationary distribution of a stochastic fluid-fluid model.

CI Peter Forrester in collaboration with Persi Diaconis (Stanford) considered the invariant measure when sampling uniformly from classical matrix groups. This helps formulate diagnostic tests for mixing of Markov chains proposed in the machine learning community to sample from the rotation group for very large dimension [See P. Diaconis and P.J. Forrester, 'Hurwitz and the origins of random matrix theory in mathematics', *Random Matrices: Theory and Applications* Vol. 6 (2017)]. Forrester's work with Masters student Jiyuan Zhang is on the topic of invariant measures associated with lattice reduction. In high dimensions, algorithms for this purpose have been chosen as in the top 10 most important for the 20th century. Outputs on this topic are 'Volumes for  $SL_n(\mathbb{R})$ , the Selberg integral and random lattices', *Found. Comput. Math.* (2018), and 'Volumes and distributions for random unimodular complex and quaternion lattices', arXiv: 1709.08960

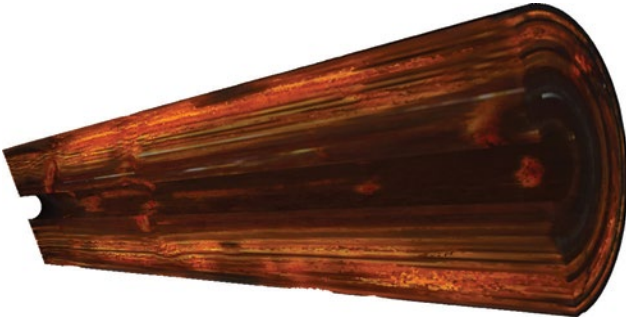
CI Tim Garoni together with Andrea Collevocchio (Monash) and overseas collaborators are investigating the Coupling From The Past (CFTP) refinement of the Markov chain Monte Carlo (MCMC) method, which automatically determines the required running time of a Markov chain, and then outputs exact samples, rather than approximate ones. The price for these two significant benefits is that, unlike naive MCMC, the running time of CFTP

is random. The key question being investigated by Tim Garoni is determining the efficiency of the CFTP method for the heat-bath process for the Fortuin-Kasteleyn random-cluster model by understanding the distribution of its random running time, or coupling time. The random-cluster model is a fundamental class of models in equilibrium statistical mechanics.

CI Rob Hyndman and his group, AI Sevvandi Kandanaarachchi and PhD students Puwasala Gamakumara, Dilini Talagala, Thiyanga Talagala and Shanika Wickramasuriya, as well as various other coauthors, are working on hierarchical forecasting in time series. This work is innovative, highly creative and different to most current work in time series because it cleverly takes into account the relationships within the hierarchy to improve estimation and prediction. The work has had significant impact on the forecasting community because of its practicality as well as the availability of R packages. Rob Hyndman also works on the detection of anomalies in time series, with some of this work in collaboration with CI Kate Smith-Miles.

CI Robert Kohn and his team postdoctoral fellows David Gunawan and Matias Quiroz and PhD students James Todderel, Vincent Chin and Dang Doan Khue Dung, have worked on a number of projects. The first is dealing with Big Data by combining MCMC methods with subsampling methods in the survey sampling literature. The first fundamental paper 'Speeding up MCMC by efficient data subsampling' has been accepted by the Journal of the American Statistical Association. The second paper on extending the ideas in the first paper to a delayed acceptance framework will appear in the Journal of Computational and Graphical Statistics (JCGS). Both papers are co-authored with Matias, as well as AIs Minh Ngoc Tran and Mattias Villani. Extensions to Hamiltonian Monte Carlo and exact subsampling methods are available on arXiv and are joint with these authors and PhD student Dang Doan. Robert is working on a second project with AI Mohamed Khaled on developing flexible methods that scale up with dimension and provide provably universal approximations to copula models. Although copula models and methods are of interest in their own right, they also provide flexible universal approximations to multivariate distributions that allow for separately modeling





*To visualise the reconstructed billet we utilise the volume rendering package, Drishti (Limaye, 2012). This allows us to obtain a volumetric rendering of the billet as shown in the figure. We are able to slice through the data to reveal the internal structure of the billet or to cut a board from within it. One of the major advantages of this approach is that we are able to represent the three-dimensional billet in full colour.*

the marginal and joint dependence of any multivariate distribution. Robert has also developed a general method for handling copulas with mixed marginal densities with Mohamed and David. A third project is on the development of Variational Bayes methods. A paper on a novel VB method for intractable likelihoods will appear in JCGS, co-authored with AI Minh Ngoc Tran and David Nott (NUS). A new method for handling high dimensional state space models has been developed jointly with Matias and David. This allows the handling of high dimensional spatial temporal models. A fourth project deals with flexible estimation methods for panel data models with applications in health economics. This project is with AIs Deniz Fiebig, David Gunawan, Chris Carter, Vincent Chin and CI Scott Sisson. The fifth project with UNSW AIs Chris and David is on developing particle MCMC strategies for time series models with intractable likelihoods that will allow the estimation of complex high dimensional time series.

CI Dirk Kroese and AI Radislav Vaisman and their group continued their work on the main themes of Advanced Monte Carlo Methods for Complex Network and Splitting Methods for Estimation and Optimisation. The first theme saw significant advances in the way in which important properties of large graphs, such as their number of independent set and colourings, can be estimated via Monte Carlo. The work has been applied to the reliability analysis and design of complex networks. In addition, fundamental research was conducted on efficient sampling algorithms for particle methods, leading to sometimes orders of magnitude improvement in their efficiency. As part of the second theme, new splitting-based optimisation algorithms were developed for highly multi-extremal and multi-objective optimisation problems that can outperform state-of-the-art methods. A powerful generalisation of a famous tree-counting algorithm by Knuth was developed that is likely to have an important impact on the way

people assess the computational effort of recursive algorithms. PhD student Liam Hodgkinson and Research Fellow Ross McVinish are developing fast approximate simulation methods for large spatial Markov population models arising from the study of epidemics and metapopulations. Additional projects involved novel quantile-based action selection procedures for decision making under uncertainty (with robotics applications), and the efficient simulation and intensity estimation of spatial point processes. During this period two new Research Fellows Sarat Babu Moka and Je Guk Kim were appointed, the third edition of Simulation and the Monte Carlo Method appeared.

CI Kerrie Mengersen and her group have worked on projects involving enabling algorithms and we discuss three as exemplars of this work. The first involves extensions, improvements and applications of the Approximate Bayesian Computation (ABC) algorithm and involves many ACEMS members, but in particular AI Christopher Drovandi. An example of one problem that was tackled in 2017 is Bayesian model criticism using approximate Bayesian predictive p-values, obtained with a regression-adjusted ABC algorithm. This new method allows for weakly informative prior distributions and enables the computation of hitherto unavailable expensive model checking statistics, and calibration of posterior predictive p-values so that they are uniformly distributed under some reference distribution for the data. The plan is to continue to develop and improve this methodology and apply it to substantive problems in health, ecology and industry. The second project aims to characterise vectors and assess the similarity between a pair of vectors using fuzzy entropy which provides a robust statistic that quantifies the complexity or regularity of non-linear time series. New results obtained by AI Hongbo Xie and coauthors include the derivation of asymptotic normality of this statistic and its variance for finite samples. The approach has been successfully applied to fundamental issues in subspace de-noising and is shown to be superior to existing techniques including wavelet decomposition approaches. Applications to date have included the analysis of chaotic time series and biological signals. The third project involves developing Experimental Design methods to analyse big data by sampling from it in a statistically principled manner. This work has been developed in collaboration with Professors Chris Holmes (Oxford) and Sylvia Richardson (Cambridge). Adaptive design approaches developed in 2016 have also been extended and applied to substantive environmental problems, in collaboration with ACEMS Partner Organisation the Australian Institute of Marine Sciences (AIMS).

Two other projects carried out by Kerrie's group are on fast simulation and estimation of complex queues and Bayesian group lasso for high dimensional variable selection.

CI Louise Ryan together with PhD student Jarod Lee and AI Peter Green developed at UTS strategies for fitting random effects multinomial models more efficiently. The method has important implications for how algorithms work with big data. With Research Fellow (formerly PhD student) Stephen Wright

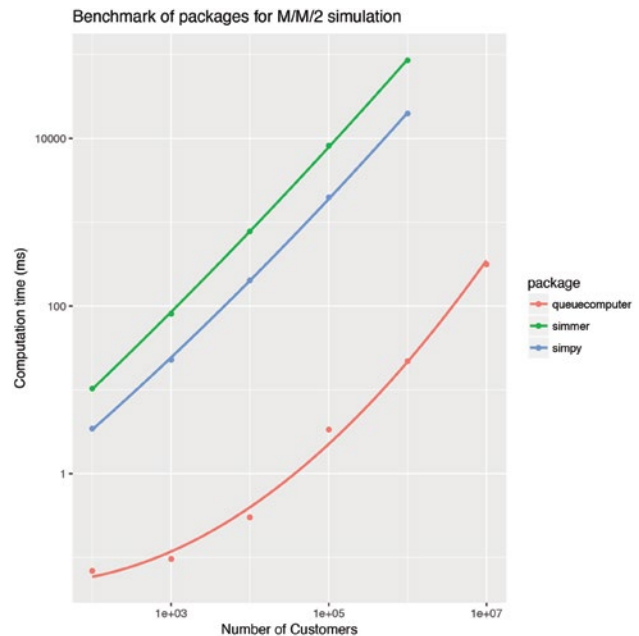
and AI Tung Pham from The University of Melbourne, Ryan has developed a method that utilises case/control sampling ideas to manage the analysis of very large data sets using a random effects logistic regression model, with an application to a Red Cross donor data base random effects logistic regression model.

CI's Peter Taylor and Nigel Bean have found that the solution of polynomial matrix equations lies at the heart of the application of matrix-analytic methods to stochastic models. Many algorithms have been proposed (and are still being proposed) to solve these equations. In order to improve upon one algorithm, or to understand the qualities which make one better than another, it often helps to develop a physical understanding of the behaviour of the process. Peter and Nigel have been working with their Belgian colleague Guy Latouche to contribute to this agenda. Specifically, they have given a physical explanation for the iterations of Newton's method as applied to the solution of a matrix quadratic equation that arises in the study of quasi-birth-and-death processes, and compared it with the state-of-the-art logarithmic and cyclic reduction algorithms.

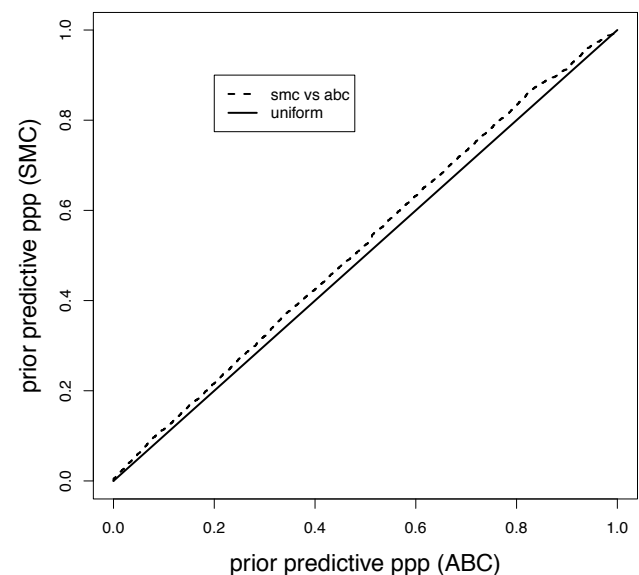
CI Ian Turner and his group have carried out research on a number of areas. The first is on Fractional Dynamical Systems, which continues work with Professor Fawang Liu (QUT) and other international collaborators on developing novel numerical methods and supporting analysis for solving fractional dynamical systems. The work involves using a range of fractional operators, with applications related to biological systems, anomalous transport in porous media, medical imaging, finance, and fluid dynamics. 15 journal articles were written on this topic during 2017.

Ian's PhD student Megan Farquhar, working with CI Kevin Burrage and AIs Tim Moroney and Qianqian Yang, has almost completed her project on heart modeling. Megan's work is based on developing computational models for simulating electrical signal propagation in cardiac tissue. Together with Masters student Michelle McGrath, Ian is using three-dimensional motion analysis to determine whether quantitative criteria can be found for the Prechtl's Qualitative Assessment Method of General Movement classifications of writhing and fidgeting in the normative infant population.

In a cross-node collaboration with CI's Peter Taylor and Kevin Burrage, Ian is working on proving the non-singularity of a Markov-modulated version of Erlangs Loss Formula which arises in Markov-Modulated Erlang loss queues. The assumption of non-singularity is fundamental for the rest of the analysis of the process. A range of techniques from linear algebra are being explored, particularly those related to positive stable matrices, M-matrices and inverse M-matrices. In collaboration with AI Markus Hegland, Ian is approximating functions of the precision matrix of Gaussian processes and jointly with PhD student Abhishek Bhardwaj, Ian is developing a Bayesian approach to solve inverse problems.

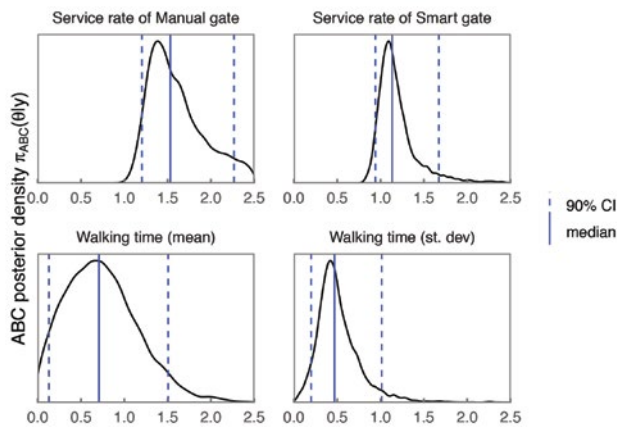


*Developing algorithms for the fast simulation and analysis of complex queuing networks*

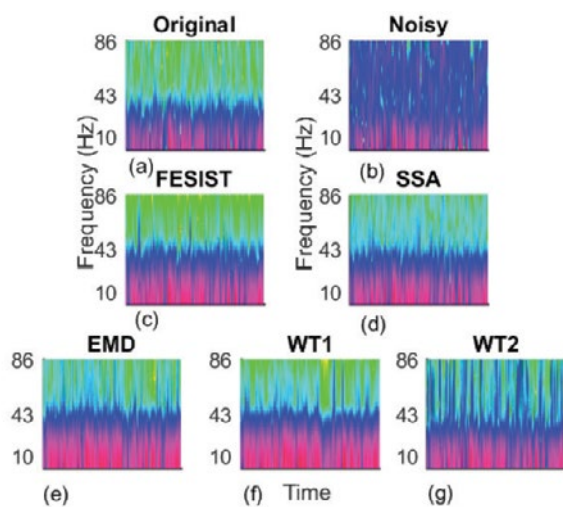


*Bayesian model criticism using approximate Bayesian predictive p-values obtained with a regression-adjusted ABC algorithm*

ABC posteriors for Airport–DQN parameters (Real data)



Initial results in estimating different components of a queuing system found in an airport



The spectrogram of the clean and the noisy EEG signals as well as the de-noised EEG signals using the proposed fuzzy entropy method (FESIST), subspace filtering (SSF), empirical mode decomposition (EMD), Bayesian wavelet (WT1), and wavelet soft threshold (WT2) approaches.

CI Scott Sisson has been working with Research Fellow Xuhui Fan on new stochastic algorithms for partitioning models, developing an efficient stochastic patching process and a binary space partitioning tree, which can be applied to relational datasets such as social networks. With recent PhD student Xin Zhang, he has developed new Dirichlet allocation model algorithms, with Als Minh-Ngoc Tran and Chris Drovandi he has developed novel algorithms for fitting variational Bayes approximations within the synthetic likelihood framework. Finally, in addition to constructing several new methods within the ABC setting, jointly with Ai Yanan Fan he has completed contributing to and editing the world's first book on ABC methods, *The Handbook of Approximate Bayesian Computation*, to be published in 2018.

CI Matt Wand and his group, PhD students Sang Il (Andy) Kim, Tui Nolan and James Yu and Research Fellows Chris Oates and Ye (Wilson) Chen, are doing fundamental work on message passing approaches to semiparametric regression analysis which advocates a new-wave general approach to

statistical analyses in the face of big data sets and models. Matt introduced the notion of factor graph fragments as a means of compartmentalising requisite algebra and computer code which builds on this work and develops factor graph fragment updates, based on both variational message passing and expectation propagation principles, for semiparametric regression model components corresponding to data that are subject to measurement error or are partially missing.

The work till the end of 2017 has developed a strong basis for both the foundations and methodology of enabling algorithms. In 2018, we intend to identify, formulate and solve some of the grand challenges in our particular areas of enabling algorithms. A few examples of such challenges are (i) the extension of ABC methods to applications having many parameters where it is difficult to find appropriate summary statistics; (ii) effectively combining Hamiltonian Monte Carlo with particle MCMC methods to tackle high dimensional spatial temporal models; (iii) Using more flexible distributions in variational Bayes problems; (iv) combining multiscale models with experimental data to improve the accuracy and predictability of these models in field locations where there is no data available.

## CI CAMEO'S

**CI Ian Turner:** "My group will focus on classifications methods for use in our project with the timber industry and also on data assimilation and homogenisation techniques for our multiscale models of complex dynamical systems."

**CI Tim Garoni:** "In 2018, our group will begin trying to prove some of the conjectures outlined in our recent *Journal of Statistical Physics* article, beginning with limit theorems for the coupling time of the one-dimensional stochastic Ising model."

**CI Robert Kohn:** "We will explore a number of exact and approximate methods for estimating high dimensional and Non-Gaussian state space models. This includes a combination of particle methods and Hamiltonian Monte Carlo, as well methods based on Variational Bayes. We will also develop copula based universal approximations to multivariate distributions."

**CI Dirk Kroese:** "At The University of Queensland we will continue to research new approaches to constructing efficient sampling and optimisation algorithms, with application to Bayesian learning and robotics control."

**CI Kevin Burrage:** "In 2018 my group will continue doing research in emulation and multi scale modelling of the electrophysiology of the heart."

# ACEMS DEPUTY DIRECTOR AWARDED ARC FUTURE FELLOWSHIP

The Australian Research Council (ARC) welcomed Professor Scott Sisson as an ARC Future Fellow in 2017.

Scott is a Professor of Statistics at UNSW Sydney, President of the Statistical Society of Australia, and is a Deputy Director and Chief Investigator for ACEMS. The statistician is one of 91 researchers around the country named by the ARC as Future Fellows. He will receive just over \$1 million for his project titled, 'Frontiers in Data Science: Analysing Distributions as Data'.

"The Future Fellowships scheme encourages research in areas of national priority, with preference given to researchers who can demonstrate a capacity to build collaboration across industry, with other research institutions and with other disciplines," says Ms Leanne Harvey, who was Acting Chief Executive Officer of the Australian Research Council when the Future Fellows were announced.

Scott credited his work with ACEMS in helping him obtain a Future Fellowship.

"There are huge ACEMS links here. In fact, all of the interesting applications that I'm going to be working on, touch on my work within ACEMS, which is fantastic for me," says Scott.

Scott's research is in a field known as symbolic data analysis. The aim of the project is to develop the statistical foundations of a new approach to analyse large and complex data. It would be based on building distributional approximations of the data, which can then be analysed by standard statistical methods.

"The trick then becomes, how do I fit models and analyse the data that underlies those distributions, but only by looking at the distributions?" says Scott.

"You're basically summarising the billions of regular data points into a smaller number of distributions. The key is then not to lose all of the critical information that will still allow you to fit your models."

Scott says the project can help with analysis of important issues like public health, environmental pollution, computer network security and climate extremes.

Scott has looked at these kinds of problems through his ACEMS collaborations in the past, but through a different lens. One such project was with ACEMS Chief Investigator Louise

Ryan, from the University of Technology Sydney, and her work analysing the impact of pollution from rail traffic in the Hunter Valley on the health of residents.

Another project was in collaboration with ACEMS Chief Investigator Matthew Roughan, from The University of Adelaide. This project provided Scott with the challenge of analysing data on computer network traffic to determine points of congestion and external attack.

*"The project expects to change our way of thinking in how to be smarter about what data we use for analysis, rather than relying on brute force analysis of large datasets," says Scott.*

ACEMS Associate Investigator Dr Boris Beranger (UNSW) is helping him with the project, along with three PhD students.

Scott says the Fellowship will allow him to do, what he believes will be substantially important work in this field, and that he's very much looking forward to getting started.



ACEMS Chief Investigator Scott Sisson speaking at the Australian Academy of Science



# THEME 4: INFORMED DECISIONS

## OVERVIEW

The purpose of data collection and modelling is to learn more about systems and make the best possible decisions about their operation. Under this theme we develop new decision-making methodologies, and exploit Challenging Data, Multiscale Models, and Enabling Algorithms to characterise optimal decision-making strategies over a range of timescales.

## HIGHLIGHTS

- Created decision-making tools for the preservation of valuable ecosystems to develop and increase understanding of how they change with time and region through working with international organisations such as the United Nations
- Developed the Australian Cancer Atlas to provide estimates of incidence and relative survival at the micro level for a large range of cancers, and to allow community members and researchers to see for the first time, the picture of how cancer affects Australians, at both a national and local level
- Established novel and general methodology for calibrating Populations of Models to the distributions of a set of measured values in a dataset to for the study of cardiac atrial electrophysiology
- Developed a Markov model to aid in the crucial decision-making process of patient suitability for proton therapy by simulating of the outcomes of the treatment, in comparison to the traditional radiation therapy, using statistical insilco analysis
- Tackled key mathematical challenges in the scheduling of a complex pathology testing in cancer diagnostic instrumentation
- Worked on the question of how much improvement batteries can make on the stability/performance of a modern electricity network for the optimisation and control of distributed energy resources in a microgrid
- Modelled the impact of carbon reduction policies to provide tools to assist managerial insights into the feasibility of replacing traditional strategies with more environmentally-friendly alternatives.
- Investigated the design, development and manufacture of intrusion detection systems, with systems deployed across the world to allow for key technology in using fibre optic cables as sensors

- Used dynamic programming models to comment on issues of efficient trading. Observing that welfare gains of allowing dynamic trading can be substantial, even allowing a profit-targeting dynamic exchange to generate greater social welfare gains
- Used Multi-Armed Bandit models to describe multidimensional Markov decision processes in which only one, or a limited number of dimensions can be acted on at a time

## TEAM

**Theme Leaders:** Kevin Burrage and Louise Ryan

**Chief Investigators:** Nigel Bean, Rob Hyndman, Kerrie Mengersen, Matthew Roughan, Kate Smith-Miles, and Peter Taylor

**Selected Research Fellows and Associate Investigators:**

Pamela Burrage, Julian Caley, Susanna Cramb, Alysso Costa, Christopher Drovandi, Mark Fackrell, Mehdi Foumani, Jing Fu, Brodie Lawson, Sevvandi Kandanaarachchi, Paula Moraga Serrano, Mario Andres Munoz Acosta, Giang Nguyen, Rachael Quill, Silvio Tarca, Ali Tirdad and Paul Wu

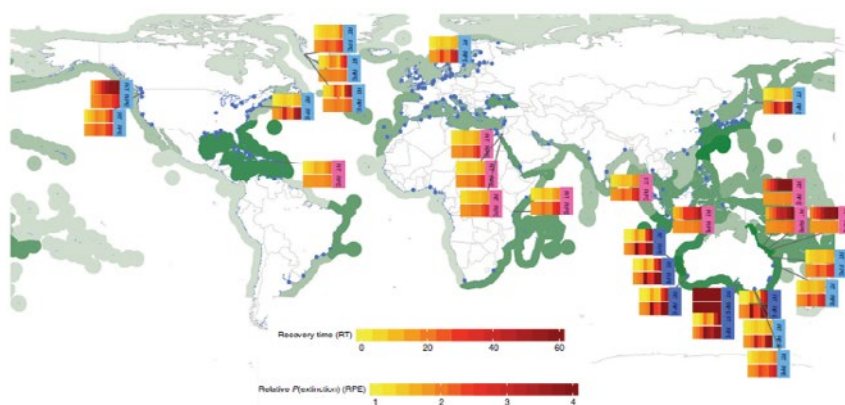
**PhD and Masters Students:** Jonathan Budd, Earl Duncan, Steven Edwards, Jacinta Holloway, Ashwani Kumar, Ellen Muir, Jessie Roberts and Dilini Talagala

## DETAILED DESCRIPTION

Throughout 2017, CI Kerrie Mengersen and her team including Als Paul Wu and Julian Caley have collaborated extensively with ACEMS partner organisations Australian Institute of Marine Sciences (AIMS) and Australian Bureau of Statistics (ABS) to create decision-making tools for the preservation of valuable ecosystems and to develop and increase understanding of how they change with time and region. This work will ensure that international organisations such as the United Nations have at their disposal the right tools to protect and encourage sustainable environments around the world.

One such project explored the representation of complex systems with Bayesian networks. In collaboration with AIMS, the team investigated the ability to capitalise on these probabilistic graphical models, which can capture spatial and temporal dynamics, and applied them to data describing the impact of dredging on seagrass communities around the world. These

Figure 1. The global distribution of seagrasses and ports showing resilience to dredging, based on the ACEMS model.



Bayesian networks were parameterised using diverse data sources and expert information from a large interdisciplinary team. The aim was to search for ecological windows when stressors such as dredging would have minimal impact on risk, recovery and resistance of the seagrass. The results of the modelling showed that for 28 globally distributed seagrass meadows, scheduling dredging in an optimal manner can achieve an up to fourfold reduction in recovery time and 35 per cent reduction in extinction risk. As shown in Figure 1 above.

Kerrie, with PhD Student Jacinta Holloway teamed up with ACEMS PI Siu-Ming Tam from ABS to participate in the United Nations Global Working Group tasked to create The Handbook which provides a guide for the National Statistical Offices using satellite imagery data for official statistics. Official statistics agencies around the world are embracing the challenge of using other sources of data to complement or replace their usual surveys and samples. Figure 2 illustrates the type of data available, in this case a Landsat image of a region with patchy vegetation. There are many ways in which official statistics agencies might use this type of data to address Strategic Development Goals, including vegetation assessments, crop identification and crop yield estimation, calculation of economic growth and poverty indices via nightlights, and so on. The Handbook summarises the results of four pilot projects produced by task team members: ABS, Instituto Nacional de Estadística Geográfica e Informática, Mexico, Departamento Administrativo Nacional de Estadística, Colombia, and Google. This project has also led to the development and delivery of a short course on this topic by ACEMS and ABS presenters in Australia and Colombia, with the latter being held at the UN Conference on Big Data. The course is also scheduled to run in Asia in 2018.

Across ACEMS there are research teams working to use statistical modelling to create healthier Australians through informed decision making.

As in many areas, the past few decades have seen an explosion in the volume, availability and variety of data on, and for, sport and sportspeople. Also, as in many areas, sports scientists are keen but currently ill-equipped to capitalise on this new information. ACEMS is taking up the mantle to meet a global demand for new statistical, mathematical and machine learning methods and training. Working through our Industry Affiliate Program an ACEMS team led by CI Kerrie Mengersen with Als Christopher Drovandi and Paul Wu have been brought together with the Australian Institute of Sports and the Queensland Academy of Sports to develop new insights. In addition to joint workshops and research projects, the team have hosted two undergraduate



Figure 2. Landsat image of a region with patchy vegetation using satellite imagery

vacation research camps that involved maths and stats students from first to fourth year. The students have tackled a range of problems in cycling, swimming and other sports, dealing with performance improvement and athlete resilience.

Figure 3 shows results obtained by Lawrence Garufi (QUT) for describing the variability in the power output of an athlete in a cycling race. A hidden Markov model was fitted to classify the variability into five states. This information can be used to improve athlete performance and manage fatigue.

Another side of health research is understanding who, what, where and how illness affects Australians. In the pursuit of preventing illness mathematical modelling is extremely informative.

Each year, more than 120,000 Australians are diagnosed with cancer. From state and territory-based reports we know that there are differences in cancer incidence, survival and screening practices across Australia. However, we don't know how these patterns compare nationally. Kerrie, with Als Earl Duncan, Susanna Cramb and Paula Moraga Serrano and Masters student Jessie Roberts are co-leading the development of an online Australian Cancer Atlas. The atlas will provide estimates of incidence and relative survival at the micro level for a large range of cancers, and will allow community members and researchers to see for the first time, the picture of how cancer affects

Power State Distribution on the Course Race 1

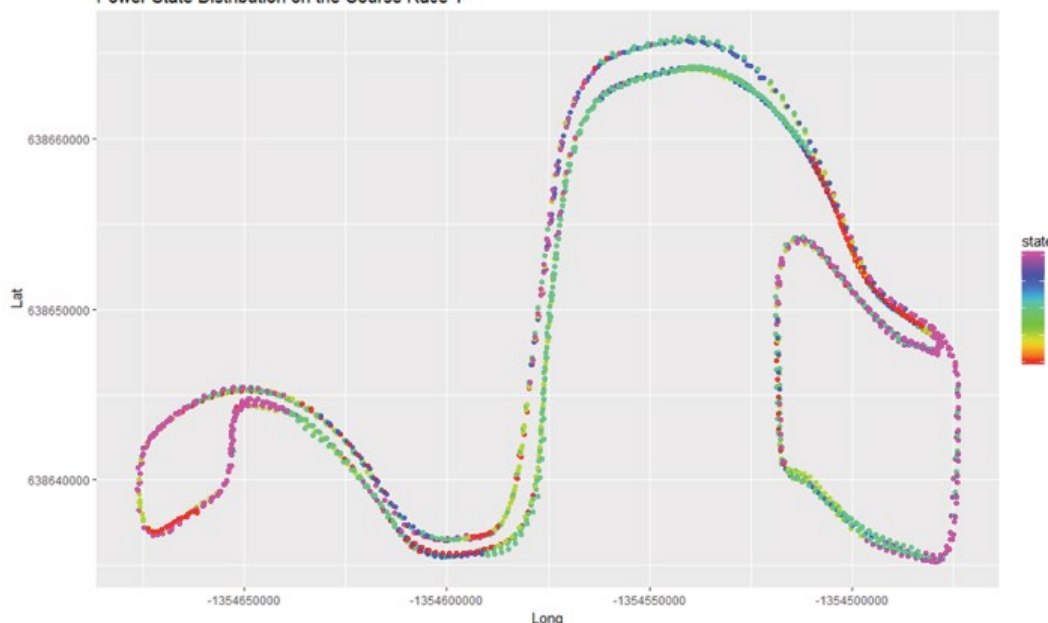


Figure 3.  
Power output  
of an athlete in  
a cycling race.

Australians, at both a national and local level. The project involves the CRC for Spatial Information (CRCSI), the Australian Institute for Health and Welfare and the Cancer Council of Queensland, with input from Cancer Councils around the country. This is the first time that data from the disparate Cancer Councils has been collated for such a purpose. The project has attracted television and newspaper media attention, and has led to a range of other collaborations. In addition to the important translation aspect of the project, there are new research directions in the development of appropriate statistical models that provide robust estimates for a large number of small areas, while preserving privacy.

Visualisation of these estimates and their uncertainty is also an important part of the project. The aim is to extend the usual choropleth maps, of the type illustrated in Figure 4 on the opposite page. This figure shows the results of a related study on modelling the relative risk of dengue fever over time in a region of Indonesia, produced by PhD student Aswi Aswi. The problem that arises here, is the development of appropriate spatio-temporal models for the complementary problem of the incidence of cancer in a small number of areas.

Based on this and other related work on spatial modelling, Kerrie was asked to write a White Paper for the CRCSI on the value of people-centred spatial information for use in decision and policy making. This was presented at a roundtable attended by national and state government organisations, as well as representatives from Partner Organisation CSIRO. The paper has been accepted as a contribution to the development of a long-term strategy for spatial information in Australia.

Research teams led by CI Kevin Burrage with Als Christopher Drovandi, Pamela Burrage and Research Fellow Brodie Lawson, in collaboration with Blanca Rodriguez (Oxford), have been looking at unlocking datasets by calibrating populations of models to data density through a study in atrial electrophysiology. The understanding of complex physical or biological systems nearly always requires a characterisation of the variability that underpins them. Additionally, the data used to calibrate such models may also often exhibit considerable variability.

A recent approach to deal with these issues has been to calibrate Populations of Models (POMs), that is multiple copies of a single mathematical model but with different parameter values. To date, this calibration has been limited to selecting models that produce outputs that fall within the ranges of the dataset, ignoring any trends that might be present in the data. We present here a novel and general methodology for calibrating POMs to the distributions of a set of measured values in a dataset. We demonstrate the benefits of our technique using a dataset from a cardiac atrial electrophysiology study, based on the differences in atrial action potential readings, between patients exhibiting sinus rhythm or chronic atrial fibrillation and the Courtemanche-Ramirez-Nattel model for human atrial action potentials. Our approach accurately captures the variability inherent in the experimental population, and allows us to identify the differences underlying stratified data as well as the effects of drug block. This work will appear in Science Advances in January 2018.

CI Nigel Bean and AI Giang Nguyen have been working with the first Australian Centre for Proton Therapy which will open in South Australia in 2018. Proton therapy is an emerging and precise form of cancer treatment allowing radiation oncologists to treat tumours close to organs, or in children, with minimal damage to the surrounding healthy tissue. However, due to its limited availability, proton therapy is a much more expensive option not available to every cancer sufferer, meaning that patients need to be selected for treatment. The ACEMS team have developed a Markov model to aid in this crucial decision-making process. Through the simulation of the outcomes of proton therapy, in comparison to the traditional radiation therapy, and the performance of statistical insilco analysis, our statistical model can demonstrate how the use of proton therapy can, on a hypothetical six-year-old patient with a skull base chordoma, give the child a significantly higher chance of experiencing less side-effects and improving quality of life.

Nigel and Giang, working with medical professionals, have produced a suite of papers addressing the nature of

homeostasis in the hypothalamus-pituitary-thyroid system. The pair have developed a new and simpler model that is consistent with all known data, unlike the currently-accepted model. This has potential impacts on the treatment of thyroid conditions, and one that is not obviously thyroid related.

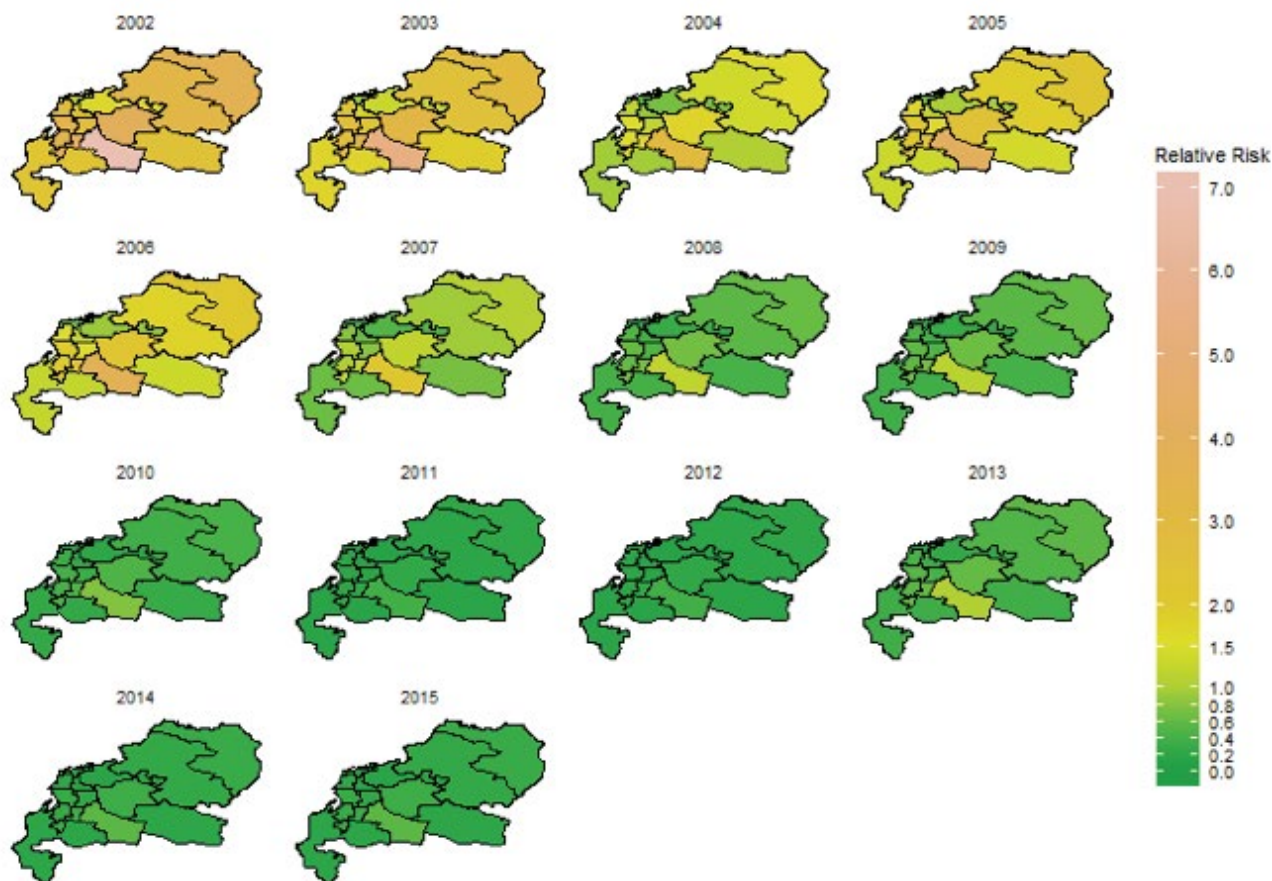
In collaboration with ARC Linkage partner Leica Biosystems, CI Kate Smith-Miles and her team including Davaatseren Baatar (Monash) and PhD student Steven Edwards investigated robotic decision making in cancer diagnostic instrumentation. Specifically, the team have tackled key mathematical challenges in the scheduling of a complex pathology testing instrument. The robots inside the pathology testing instrument must dispense liquid chemical reagents to pathology slides containing tissue samples, in a manner, which strictly follows a set of protocols with maximum and minimum separation times between steps. The scheduling must be done in order to maximise the throughput of slides in a day, while not ruining any slides in the process due to failure to observe the timing requirements for each protocol. Additionally, there are complicated constraints such as power consumption limits, and the need for rapid rescheduling due to user interruption. During 2017 a new algorithm was developed by Steven, and tested on some benchmark instances simulating various real-world lab scenarios. In addition, the connections between this problem and related work in project scheduling, hoist scheduling and other industrial scheduling problems was explored. A method for identifying symmetries in such problems is currently being investigated, which has potential for reducing the computational burden not just for our industry partner's problem, but other problems such

as the travelling salesman problem.

A key political issue in 2017 was the health of Australia's energy market. It is important that Australia has access to not only reliable energy but also a sustainable system. Using the South Australian network as the prime example, CIs Matthew Roughan and Nigel Bean and their team including Research Fellows Silvio Tarca and Rachael Quill have worked on the very topical question of how much improvement batteries can make on the stability/performance of a modern electricity network. Preliminary research has begun on the optimisation and control of distributed energy resources in a microgrid using confidential data, solar photovoltaic generation and load, from a field trial in Salisbury, South Australia. The team will develop this study in 2018 to look at control techniques for an improved and dependent supply of wind power with utility-scale battery energy storage. The team hopes to show that if wind farms were able to supply wind power scheduled during pre-dispatch, using unconstrained intermittent generation forecasts, then wholesale electricity prices would be less volatile and, on average, lower.

As governments around the world develop policies to encourage industry to adopt green energy practices, it is important to have mathematical models to enable the effectiveness of such policies to be determined. Given the assumption that industry will aim to maximise profits, can we model the optimisation problem that enables them to make the most informed decisions in the presence of carbon reduction policies including taxes, caps and carbon trading schemes? In 2017 the team driven by CI Kate Smith-Miles with AI Mehdi Foumani

Figure 4. These choropleth maps show modelling for the relative risk of dengue fever over time in a region of Indonesia.





has commenced work to model the impact of these policies on green flowshop scheduling to provide a tool to assist managerial insights into the feasibility of replacing traditional strategies with more environmentally-friendly alternatives. The team hopes that the models can also assist government to decide which policies are likely to provide sufficient reward to encourage a shift in industry practice.

Protecting critical infrastructure, such as transportation networks and military facilities from accidents or malicious attacks, is vital for the safeguard of lives and assets. CIs Kate-Smith Miles and Rob Hyndman, Als Sevvandi Kandanaarachchi and Mario Andres Munoz Acosta and PhD student Dilini Talagala have been working on the first line of defence - intrusion detection systems which monitor the state of a facility and raise an alarm when unauthorised access is suspected. Investigating the design, development and manufacture of intrusion detection systems, with systems deployed across the world allows for key technology in using fibre optic cables as sensors, which can be attached to a fence or buried under the ground. As a light pulse signal travels down the cable, disturbances can be detected since vibrations (perhaps due to climbing or cutting the fence or walking near the sensor) cause measurable changes in the phase, intensity and timing of the signal. Intrusion events are localised, rare and short lived; hence, they must be detected as soon as they start, but before they end so suitable action is taken.

Of course, vibrations can be caused by other things besides intruders such as an animal walking by, a child dragging a stick, rain falling or wind blowing. Such nuisance events must be distinguished from genuine intrusions to avoid committing resources and unnecessarily overloading the system. Eventually, a significant number of false alarms would diminish the system's trustworthiness.

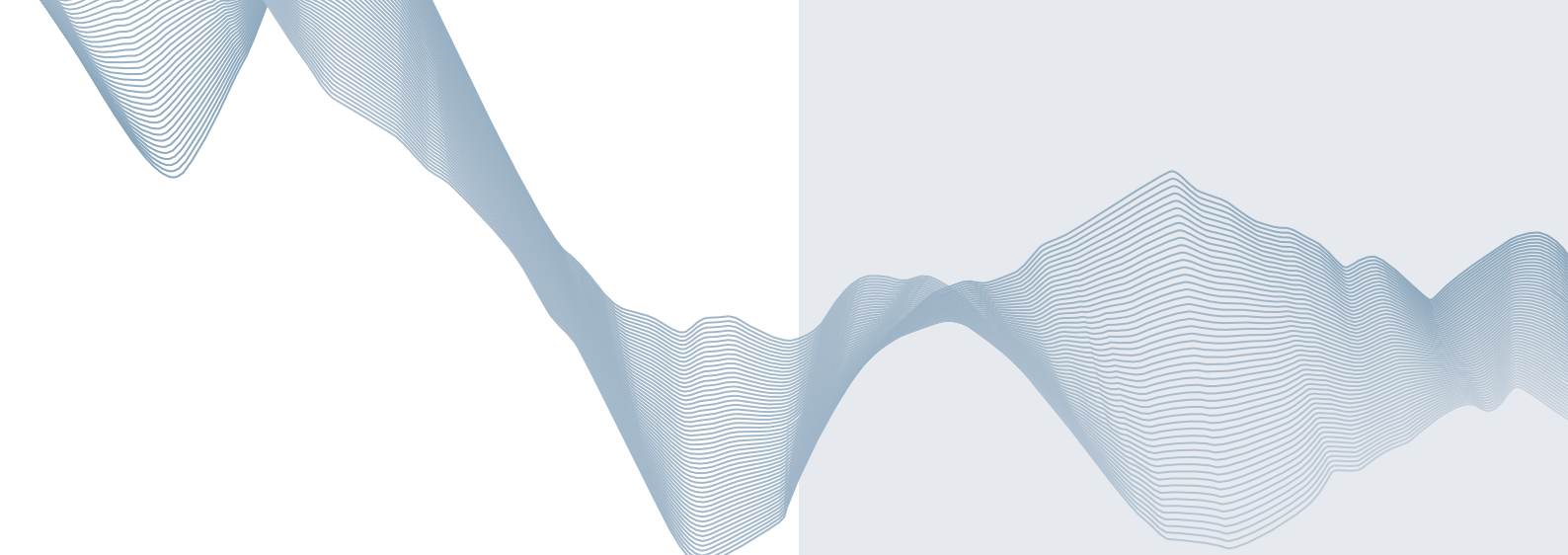
The system produces large quantities of highly noisy time series data, that is, nearly one gigabyte per minute for each kilometre of cable. Moreover, the characteristics of the signal depend not only on the type of event, but also on the physical properties of the fence or soil (which determine how well vibration is propagated), the fibre optic technology (including the pulse width and frequency limits), the environmental conditions (such as the season, time of the day or current wind speed), and even the climbing or walking style of the intruder.

For these reasons, event detection and classification methods

must be robust to noise, technical and environmental conditions, quick to identify the event before it ends, and efficient to deal with large amounts of data. The aim of the project is to tackle the key mathematical challenges in the early detection and classification of events in noisy time series, under changing and complex technical and environmental conditions. The developed methods need to be robust to such conditions, hence, the need for tuning parameters must be minimised while ensuring a suitable balance between probability of detection, and false alarm rates. In 2017, several methods to tackle this problem have been developed by the cross-nodal team at Monash and The University of Melbourne based on extreme value theory, with and without knowledge of the normal operating conditions, and in the presence of concept drift. The team has also been successful in tackling related problems such as detecting vegetation on power lines that presents a risk for bushfire ignition.

CI Peter Taylor, together with PhD student Ellen Muir and her second supervisor Simon Loertscher, who is a Professor of Economics, have been studying markets in which participants, either buyers or sellers, arrive over time. The market manager has a decision to make between waiting for more participants to arrive, with its consequent increase in opportunities for advantageous trades, and matching participants early so that profits can be realised before discounting takes effect. For a simple, but rich, model, the investigators used dynamic programming to solve the mechanism design problem. They proved that the optimal solution is of threshold type: when the number of participants crosses a threshold then the manager should clear the market. The investigators used this analysis to comment on issues that are currently of great interest to the microeconomics community, such as the possibility of efficient trading. They observed that the welfare gains of allowing dynamic trading can be substantial, even allowing a profit-targeting dynamic exchange to generate greater social welfare gains than a welfare-targeting market maker that uses a less sophisticated mechanism. Ellen received her PhD early in 2017 and is now working in the School of Economics at Stanford University.

PhD student Jonathan Budd and his supervisor CI Peter Taylor investigated the optimal setting of limits for credit cards. There is a trade-off between setting a limit high, which costs the financial institution in terms of its prudential responsibility to reserve a proportion of the limit and setting it low which might mean that opportunities to collect commission on



purchases are lost. For a `transacting credit card customer' who pays off his or her balance every month, Jonathan and Peter formulated the problem of determining the optimal limit and were able to show that this limit is bounded above by the solution of the well-known `newsvendor problem' and below by a solution obtained by assuming that all activity is stopped once the user attempts to make a purchase that takes him or her over the limit. Jonathan received his PhD in 2017 and is now working at Salesforce.

CI Peter Taylor and AIs Mark Fackrell and Alysso Costa have been supervising PhD student Ashwani Kumar on his project to schedule elective patients at Monash Medical Centre. Having fitted length of stay (LOS) distributions to various categories of patient, the investigators have approached the patient scheduling problem by repeatedly sampling a sequence of LOSs and then solving the consequent deterministic scheduling problem as if they know the future. With some reasonable restrictions, such as requiring that a schedule should be periodic, and by allowing cancellations of surgery when the wards become full, they were able to show the one or two schedules are robust to the randomness inherent in the LOS process. This project is separately funded by ARC Linkage Grant LP140100152. However, Ashwani, Mark and Alysso have been active members of the ACEMS community through their participation in the networking, professional development and mentoring opportunities that ACEMS affords.

Multi-Armed Bandit models are used to describe multidimensional Markov decision processes in which only one, or a limited number of, dimensions can be acted on at a time. In a standard Multi-Armed Bandit model the components which are not acted on remain in their current state, while they can change state in a Restless Multi-Armed Bandit model. Approaching problems of optimal resource management via the Multi-Armed Bandit paradigm is a major interest of ACEMS AI Jing Fu. With CI Peter Taylor and colleague Bill Moran, she has been looking at assignment of virtual network resources, such as CPUs and data links by thinking of them as Restless Multi-Armed Bandits. With AI Ali Tirdad, she has also applied this technology to the problem of designing optimal call lists for the MonashWatch program, which aims to provide in-home monitoring for chronically-ill patients, a project that is also separately funded by ARC Linkage Grant LP140100152.

## 2018 RESEARCH PLANS: CI CAMEOS

**CI Kerrie Mengersen** "In 2018, we will continue our research into the properties and capabilities of Bayesian Networks for modelling environmental problems that are brought to us by our Partner Organisations and Industry Affiliates. Of special interest will be the translation of these results to facilitate informed decisions in ecology."

**CI Kate Smith-Miles** "In 2018 we will continue developing more powerful methods that minimise false alarms, and adapt to changing environmental conditions. We have also identified broader challenges and potential applications beyond the security industry. The CIs' past collaborations with epidemiologists, atmospheric scientists, ecologists, electricity suppliers, and the Australian credit bureau demonstrate that noisy signals and time series are generated in many applications, and powerful new methods to rapidly detect interesting events in these signals, especially when the data is streaming at high volumes, is critical with far-reaching impact. There are several promising applications arising through collaboration with other ACEMS nodes as well that will be explored."

**CI Nigel Bean** "Based on the research findings, [we will] propose the deployment of tariff structures and implementation of control techniques in an SA Power Networks field trial scheduled to commence in the second half of 2018. [Using] study control techniques to improve the dependability of supply of wind power with utility-scale battery energy storage. We conjecture that if wind farms were to dependably supply wind power scheduled during pre-dispatch using unconstrained intermittent generation forecasts, then wholesale electricity prices would be less volatile and, on average, lower."

**CIs Peter Taylor and Kate Smith-Miles** "We plan to collaborate on a project reconciling the different approaches to optimisation under uncertainty that are employed by different communities within the mathematical sciences. By facilitating a discussion between researchers with a background in deterministic optimisation, machine learning, statistics and stochastic modelling, we will build a shared understanding of the strengths and weaknesses of different approaches, develop new hybrid methodologies and apply the results to systems of interest to ACEMS Industry Affiliates."

# ACEMS FRONTIER RESEARCH QUESTIONS

WHAT ARE THE QUESTIONS AT THE FRONTIER OF MATHEMATICS, STATISTICS AND MACHINE LEARNING THAT ACEMS IS TACKLING?

## QUESTIONS IN OUR RESEARCH THEMES

### Challenging Data

*“There is an explosion in the collection of symbolic data, but what do we do with it?”*

#### Dealing with Symbolic Data

A challenge that is being faced by almost every area of science, business and society is how to analyse large datasets. One approach is to summarise the data in such a way that the resulting summary dataset is of a manageable size and yet retains as much of the knowledge in the original dataset as possible. This summarised dataset no longer comprises single values, but can be represented by lists, interval histograms and other distributions. This type of summarised data is known as *symbolic data*.

The amount of symbolic data is exploding due to the increase in the use of sensors, images, natural language and so on. The challenge now is to develop appropriate ways to model and analyse these types of data.

This is a global frontier challenge that is being tackled by ACEMS. Led by CI Scott Sisson at the UNSW node, the problem brings together mathematicians, statisticians and machine learners from across ACEMS.

Solutions to the problem are being employed immediately to analyse the globally relevant question of how to monitor changes in air quality over time, predict crop types from large spatial datasets (with ACEMS' Partner Organisation, the Australian Bureau of Statistics) estimate global species abundance and understand the properties of computer network systems.

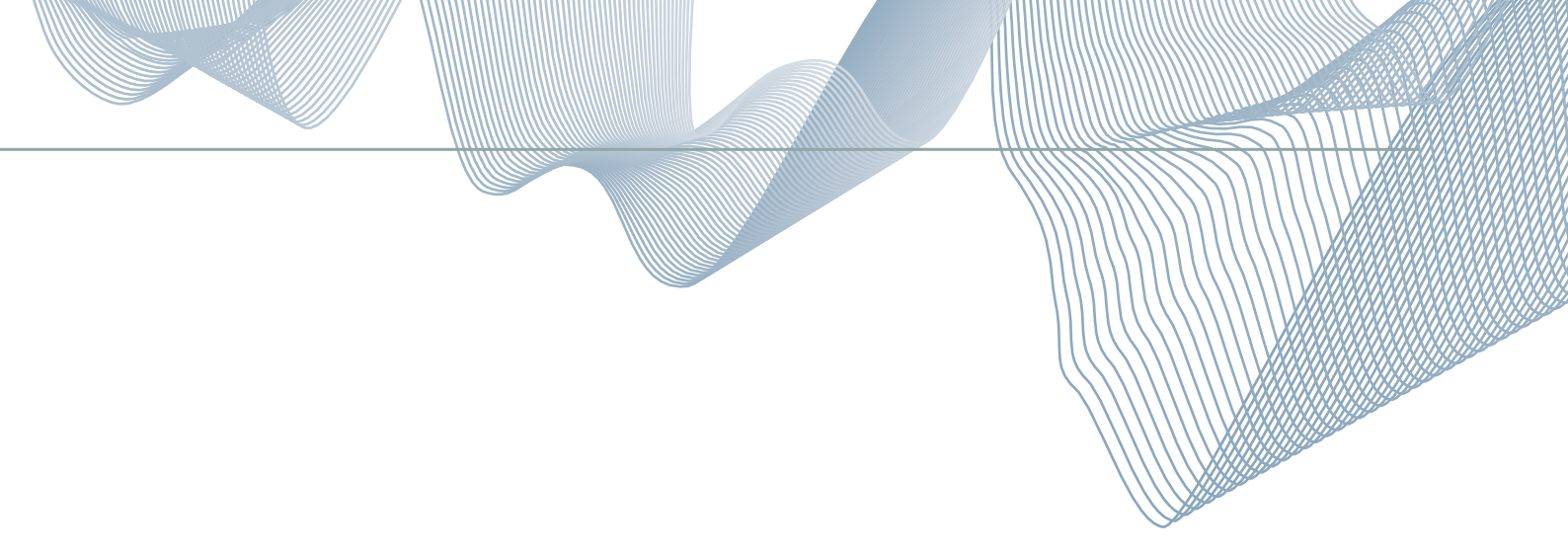
This Frontier Research Question links closely with the Enabling Algorithms Research Theme and the Collaborative Domains, Healthy People and Sustainable Environments.

### Multiscale Models

*“Why do large systems of strongly interacting particles often become insensitive to their microscopic details, and how can we describe mathematically their generic behaviour?”*

#### Universality

The *central limit* theorem is a cornerstone of classical probability theory; it explains why the sum of a large collection of independent random variables is governed by the normal distribution, regardless of the specific details of the individual random variables. In many applications, however, ranging from the hard sciences and engineering to the social sciences, there typically exist strong dependencies between the individual



particles in a system. Such strongly-interacting systems are much less well understood than the independent case, and few generic mathematical tools exist to describe such systems.

Nonetheless, predictions from theoretical physics suggest that strongly interacting systems can again exhibit the sort of insensitivity to microscopic details that arises in the independent case. However, the resulting generic behaviour is then no longer described by the normal distribution, but instead by more exotic ‘universality classes’, such as the now famous Kardar-Parisi-Zhang (KPZ) universality class. Understanding how such universality arises, and explaining the appearance of particular universality classes is a highly active research area in contemporary mathematics; three Fields Medals have been awarded in the past decade directly related to such questions.

ACEMS researchers are actively engaged in explaining universality in a number of settings, including random matrix theory and statistical mechanics (both equilibrium and non-equilibrium).

Since the presence of strong interactions typically renders traditional simulation techniques inefficient, this Frontier Research question links closely with the Enabling Algorithms Research Theme, where ACEMS researchers are engaged in the design of algorithmic procedures for the analysis of interacting systems with high degrees of dependencies.

### Enabling Algorithms

*“What do we do when parts of the model are unavailable?”*

Intractable Likelihoods

Many systems of interest in today’s world are so complex that they cannot be modelled using traditional methods. In a traditional framework, a problem would be described with a mathematical or statistical model in which the behaviour of the data is described via a probability function known as a *likelihood*. In these more challenging contexts, either the likelihood is unable to be written down, or it is very complex, or it is unable to be used in computational procedures that run in a realistic time.

Systems with these features occur in many applied areas such as genomics, artificial intelligence, ecology, psychology and finance. Dealing with such systems is also an intrinsically interesting problem from a statistical perspective, which is attracting researchers from around the world to the development of new theory, methods and applications.

The collective skills of mathematicians, statisticians and machine learners in ACEMS are being used to push the frontiers of this challenging question, which links closely with the Challenging Data and Informed Decisions Research Themes.

### Informed Decisions

*“How do we ensure that individuals acting in their own interest contribute to an efficient system-wide outcome?”*

Management of Distributed Systems

Many systems in the modern world are designed as distributed systems, for example, the internet, electricity grids, our health systems, computer networks, transportation networks, economic markets, and distributed ledgers built on blockchain technologies. They also occur in the natural world, for example, a typical ecosystem consists of plants and animals ‘pursuing their own survival’ as individuals and as species.

Distributed systems cannot be managed using continuous intervention. The best that can be hoped for is that the manager can put in place ‘rules’ that govern the behaviour of entities within the system. Sometimes rules that we might think are straightforward can lead to counter-intuitive outcomes, adverse system-wide outcomes or oscillatory behaviour. Understanding how to manage distributed systems is a global frontier challenge that ACEMS is confronting head-on.

This Frontier Research Question links closely with the Multiscale Models and Enabling Algorithms Research Themes and all three Collaborative Domains, Prosperous Societies, Healthy People and Sustainable Environments.



## CHALLENGES IN OUR COLLABORATIVE DOMAINS

Through its Collaborative Domains ACEMS endeavours to build deep relationships with Partner Organisations so that the skills of the Centre can be brought to bear on solving some of the grand challenges in health, society and the environment. These endeavours require the diverse skills that the Centre cultivates, the Frontier Research Questions arising from the Research Themes, and the critical mass of ACEMS researchers across the pipeline from theory to methods and computational algorithms, all the way through to applications.

### Healthy People

#### *In partnership with the Sax Institute and the Queensland Cancer Council*

##### Improving Cancer Diagnosis and Treatment

Cancer is one of the world's most pervasive and challenging diseases. Although great strides have been made in diagnosis, treatment, influencing factors, prediction and prevention, there is still much more to be done. Cancer is the business of two of ACEMS partners, the Sax Institute (a Partner Organisation) and the Queensland Cancer Council (an Industry Affiliate Organisation). The collaboration with ACEMS allows them to combine their deep domain knowledge with frontier methods in mathematics, statistics and machine learning in order to solve a number of important problems:

- improving the way we image patients during cancer treatment through the use of new symbolic and high dimensional data analysis methods developed in ACEMS
- safer drug screening using new populations of models methods
- identifying aberrant behaviour in space-time cancer profiles using new space-time anomaly detection methods
- assisting decisions about cancer diagnostics
- creating Australia's first online, interactive national cancer atlas

Solving these problems involves a synthesis of all four research domains with researchers in mathematics, statistics and machine learning coming together.

### Sustainable Environments

#### *In partnership with the Australian Institute of Marine Science (AIMS)*

##### Reducing the Vulnerability of our Ocean Environments

Our oceans, coral reefs, seagrasses and species biodiversity are becoming increasingly vulnerable and susceptible to long term or even permanent damage. Protecting the health of these environments is inarguably crucial. In collaboration with its Partner Organisation AIMS, ACEMS has developed solutions to a wide range of problems around reducing ocean vulnerability.

The collaborative projects include:

- using dynamic Bayesian Networks to aggregate diverse data sources to save seagrass sanctuaries
- using citizen science data to improve models of coral reef health
- modelling randomness to examine the impact of bleaching on coral growth
- using population models to describe the movement of fish and why populations go extinct
- using new statistical message passing methods to confront bigger and bigger data sets and models that have more and more parameters
- helping AIMS to make more informed decisions about the oceans and the Great Barrier Reef

### Prosperous Societies

#### *In partnership with the Australian Bureau of Statistics*

##### Dealing with Big Data in Government Statistics

Governments face serious challenges from the increasing presence of 'big data', where 'big' does indeed relate to volume, variety, velocity, veracity and value. In addition to the problems of storing, managing and analysing these data, organisations are also challenged by the stark reality of insufficient capability and capacity. ACEMS is working with government agencies to help them overcome these hurdles and unlock the insights that may reside in these large, diverse and often unstructured datasets.

These challenges cannot be tackled by a single research group. Only a Centre of Excellence can provide the required critical mass and breadth of expertise.

Together with the Australian Bureau of Statistics, ACEMS is translating state of the art research and operational techniques to allow the Bureau to advance the frontiers of official statistics. This work is also extending to other agencies, including the Australian Institute of Health and Welfare (AIHW) and the Australian Taxation Office (ATO).

The collaborative projects include:

- increasing capability and capacity by the creation of an ACEMS-QUT-FutureLearn Massive Online Open Course (MOOC) on the statistical and mathematical underpinnings of Big Data Analysis and Visualisation
- creating new methods for analysing satellite data for official statistics, resulting in the co-publication a major United Nations report and the delivery of short courses in China and South America
- developing new data linkage and new data privacy methods based on state-of-the art statistical and machine learning methods and algorithms

# THE UNIVERSITY OF MELBOURNE HONOURS TWO ACEMS RESEARCHERS

*Congratulations to ACEMS Associate Investigators Dr Nathan Ross and Professor Konstantin (Kostya) Borovkov who were both awarded prestigious 'Dean's Awards for Excellence' by The University of Melbourne.*

Nathan received the 'Dean's Award for Excellence in Research - Teaching and Research', and Kostya was given the 'Dean's Award for Excellence in Research Higher Degree (RHD) Supervision'.

ACEMS Director, Professor Peter Taylor commended the pair for their success, "it's great to see the ongoing efforts of ACEMS members recognised by their universities. The fact that this keeps happening is testament to the achievements of ACEMS staff," says Peter.

In recognising Nathan, The University of Melbourne said, "He has demonstrated research excellence through ARC grant success, publishing in the very best probability journals, being invited to speak at the most important conferences in his

discipline area, and through collaborations and research visits with some of the best probabilists and statisticians in the world."

"I'm grateful for the support of the School of Mathematics and Statistics at The University of Melbourne, and am happy that I can be a part of their successes," says Nathan.

Nathan's research is at the interface of probability and statistics. He studies the fundamental properties of sophisticated probability models. These models are now routinely generated by 'big data' applications such as random networks used to model associations of various kinds.

"Part of my research is to connect these kinds of models to mathematical objects, such as random metric spaces, so that tools for these objects can be applied to the models," says Nathan.

In recognising Kostya, the University said, "Kostya has provided an environment for his PhD students to flourish and excel by fostering a culture of curiosity and scholarship within his group. This has led to a cohort of graduating students who have gone on to excel in both academia and finance."

Kostya is supervising two students, including ACEMS PhD Student Aaron Chong. The students are working on questions of ruin probability for insurance companies. Ruin probability uses mathematical models to describe an insurer's vulnerability to insolvency, or ruin.



Dr Nathan Ross (left) and Professor Kostya Borokov (right) receive their Dean's Awards for Excellence from Dean of Science, Professor Karen Day.

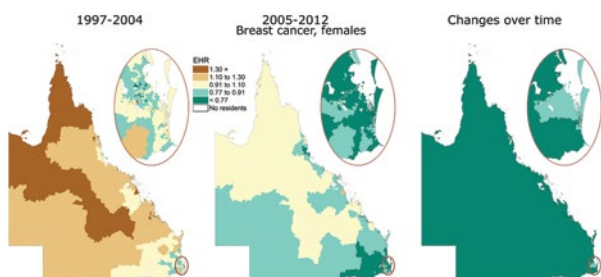


# COMPLEX MODELLING RESEARCH INFORMS NATIONAL CANCER STRATEGIES



Susanna Cramb  
Queensland University of Technology

“In Australia alone, more than 134,000 Australians are diagnosed with cancer each year”



The underlying areas used are Statistical Areas Level 2 (SA2s). These maps of excess hazard ratios (EHRs) represent the risk of dying from breast cancer within 5 years in comparison to: 1) the Queensland average in 1997-2004 (for both 1997-2004 and 2005-2012) and 2) in comparison to each individual SA2 (“Changes over time”), so 1 = the same EHR in that SA2 during 1997-2004. SA2s aim to represent a community that interacts together socially and economically; there are 526 SA2s covering all of Queensland without gaps or overlaps.

## WHERE YOU LIVE COULD HAVE IMPORTANT IMPLICATIONS ON YOUR CHANCES OF DEVELOPING CANCER AND SURVIVING THE DISEASE, ACCORDING TO PIONEERING RESEARCH AT ACEMS.

Dr Susanna Cramb, a former ACEMS PhD student and now an ACEMS Associate Investigator who is currently with Cancer Council Queensland, is investigating small-area differences in cancer incidence, survival and screening in Queensland and across the country.

These unique insights are informing preventive health programmes and cancer treatment services in Australia and Susanna's modelling approach has been adopted internationally. Such breakthroughs are sorely needed as an alarming one in two Australian men and women will be diagnosed with cancer by the age of 85. In 2013, cancer was ranked the leading cause of death in the country.

"In Australia alone, more than 134,000 Australians are diagnosed with cancer each year," says Susanna. "This disease has a huge impact on people and the economy, but because cancer is one of the few diseases with almost complete incidence data available, there is a unique opportunity to use routinely collected data to gain understanding of the disease.

"There is some evidence that cancer incidence and outcomes may differ based on where you live. Often people living in either more remote or socioeconomically disadvantaged areas tend to have worse outcomes from cancer.

"Yet small-area differences in cancer incidence, survival and screening have never been examined comprehensively across the country. We need to know where cancer patients are experiencing less than optimal outcomes."

Susanna's Queensland study was an eye opener – it confirmed that where you live can affect your risk of being diagnosed with or surviving cancer. For example, it showed that if you are diagnosed with localised breast cancer, regardless of where you live in Queensland, you have a very high survival rate. However, for advanced breast cancers, there is much poorer survival among more remote areas. In contrast, bowel cancer often has lower survival in more remote areas regardless of the cancer stage at diagnosis.

The study, 'Spatial variation in cancer incidence and survival over time across Queensland, Australia', published in 2017, examined the space-time differences in cancer incidence and survival for the five most common cancers (bowel, melanoma, lung, breast, prostate), diagnosed during 1997-2004 and 2005-2012, across 516 small areas in Queensland.

The researchers concluded that there were enduring variations in cancer incidence and survival across small-areas in Queensland, requiring further research to understand the reasons behind the disparities. The work builds on several studies, including the 'Queensland Atlas of Cancer' published in 2011, that examined small-area cancer disparities using spatial modelling.

These findings are being used by government agencies, health policy makers, and non-government organisations to inform state and local planning policies and underpin preventive health programmes and cancer treatment services. In addition, the work feeds into strategic objectives designed to reduce variations in cancer indicators in Queensland between metropolitan, regional and rural areas, as well as among socio-economic groups.

The Queensland Atlas has been instrumental in achieving a doubling of Queensland Health's Patient Travel Subsidy Scheme, and a State Government commitment of \$100 million in additional funding over four years, improving access to health services for regional patients. The research has also led to placement of additional Cancer Council Queensland staff positions in regional areas to assist in supporting and providing information to rural/remote cancer patients.

From a knowledge perspective, these studies have improved understanding of at-risk populations and strengthened the evidence-base available to public health advocates. They have also laid a path for future research into geographic disparities and survival trends. Methods utilised in the study have been adopted internationally by those such as the Institute of Cancer Epidemiology, Lubeck, which has produced the small-area Cancer Atlas Schleswig-Holstein, Germany.

Susanna's next project, in collaboration with ACEMS Deputy Director and Chief Investigator Distinguished Professor Kerrie Mengersen, and ACEMS researchers Jessie Roberts and Dr Earl Duncan, is to create a National Cancer Atlas for Australia. The study is supported by Cancer Council Queensland, Queensland University of Technology, the Australian Institute of Health and Welfare, and Australia and New Zealand Cooperative Research Centre for Spatial Information.

The project will investigate small-area differences in cancer incidence, survival and screening across the country to pinpoint where cancer patients are experiencing less than optimal outcomes. The Atlas, available online from July 2018, will enable users to understand the patterns in cancer incidence and survival for more than 20 types of cancer, as well as screening for bowel, breast, cervical and prostate cancers. Underpinning the estimates will be complex statistical models. Such statistics are vital in identifying those at greatest risk, monitoring the success of existing cancer strategies and developing adequate services.

"No-one can fight an invisible foe," explains Susanna. "Statistics are used to illuminate and monitor cancer: to see whether mortality is decreasing, survival is improving, to plan for where services are needed, and understand what ages are affected. Our focus is on monitoring cancer at the small-area level."



# CROSS-NODE COLLABORATION

THERE TRULY IS A SENSE OF COHESION AND COLLABORATION WITHIN ACEMS. ACEMS IS MORE THAN ANY ONE PROJECT OR ANY ONE RESEARCHER. AS A COLLECTIVE RESEARCH CENTRE THAT PROMOTES CROSS-NODE COLLABORATION 2017 PROVED MORE THAN EVER THAT THIS APPROACH TO RESEARCH IS BRINGING ABOUT SOME OF THE MOST INFLUENTIAL AND IMPORTANT RESEARCH OUTCOMES IN THE MATHEMATICAL SCIENCES.

In 2017 ACEMS established and cemented the research direction for the second half of the Centre's life. This manifested itself through the foundational Research Themes developed in 2016 and further in the form of the ACEMS Frontier Questions. (see page 74) These strategic devices have been effectively designed to demonstrate to the ACEMS members that they are a part of collaborative centre with a united and directed purpose.

The specific attention to fostering cross-node collaborations in 2017 has been apparent in the number of workshops, co-supervision of students, and publications which have seen ACEMS researchers work together in ways that would never have been possible without the existence of ACEMS. It is not just cross-nodal research collaborations that ACEMS seeks to achieve. With the establishment of the Mentoring@ACEMS Program in 2017, we have set up 14 cross-node mentoring relationships which we plan on increasing in 2018.

The dedicated focus of ACEMS to nurture these collaborations have led to the following cross-node research highlights in 2017:

## PROJECTS:

ACEMS members are constantly collaborating together, the following are the details of cross-nodal projects in 2017

- CI Kerrie Mengersen and her team including AIs Erin Peterson, Sam Clifford, Julie Vercelloni and Nan Ye (QUT) teamed up with AI Tomasz Bednarz (UNSW) to work on citizen data in particular the project 'Helping Save Jaguars with a Virtual Peruvian Jungle'
- CI Louise Ryan (UTS) with Research Fellow Stephen Wright (UTS) and AI Tung Pham (UoM) have written a paper from their analysis of Australian Red Cross Blood Service data
- CIs Aurore Delaigle (UoM), Kerrie Mengersen (QUT), Louise Ryan (UTS), and Scott Sisson (UNSW) have been working on symbolic data analysis
- CIs Matthew Roughan (UoA) and Matt Wand (UTS) with their PhD student Lachlan Kang (UoA), and AI Jono Tuke (UoA) have been working on a new collaboration with APNIC (the Asia-Pacific Network Information Centre) on understanding how the current spread of HTTPS (a secure form of the web browsing protocol)
- CIs Peter Taylor (UoM) and Nigel Bean (UoA) have explained the physical interpretations of algorithms for the solution of polynomial matrix equations that lies at the heart of the application of matrix-analytic methods to stochastic models
- CIs Peter Taylor (UoM), Kevin Burrage (QUT) and Ian Turner (QUT) are working on proving the non-singularity of a Markov-modulated version of Erlangs Loss Formula which arises in Markov-Modulated Erlang loss queues
- CI Scott Sisson (UNSW) and AI Minh Ngoc Tran (USyd) have developed new Dirichlet allocation model algorithms
- CI Scott Sisson (UNSW) and AI Chris Drovandi (QUT) have

developed novel algorithms for fitting variational Bayes approximations within the synthetic likelihood framework

- A cross-node program led by CI Phil Pollett (UQ) aims to develop mathematical models for population dynamics that account for local population behaviour, individual variation, spatial structure, and differing migration patterns, and to calibrate these models to real data. The team includes CI Peter Taylor (UoM), Research Fellows, Ross McVinish, Als Leonardo Rojas-Nandayapa, Laleh Tafakor and Andrew Barbour and PhD students, Liam Hodgkinson, Patrick Laub, Wangyue (Winnie) Xie
- A multi-node team of ACEMS researchers, led by CIs Jan de Gier (UoM) and Tim Garoni (MU), have made a number of contributions towards the Centre's Frontier Question on Universality: "Why do large systems of strongly interacting particles often become insensitive to their microscopic details, and how can we describe mathematically their generic behaviour?"
- CIs Dirk Kroese (UQ) and Matthew Roughan (UoA) together with AI Radislav Vaisman (UQ), have formulated the problem of partition function approximation in terms of rare-event probability estimation

## WORKSHOPS:

ACEMS held several cross-nodal workshops in 2017

- In March CI Kerrie Mengersen and Als Paul Wu and Christopher Drovandi (QUT) teamed up with AI Dianne Cook (Monash) to hold the Maths and Stats for Sports Research Workshop at QUT
- In April at CI Philip Pollett's 60th Birthday Conference at

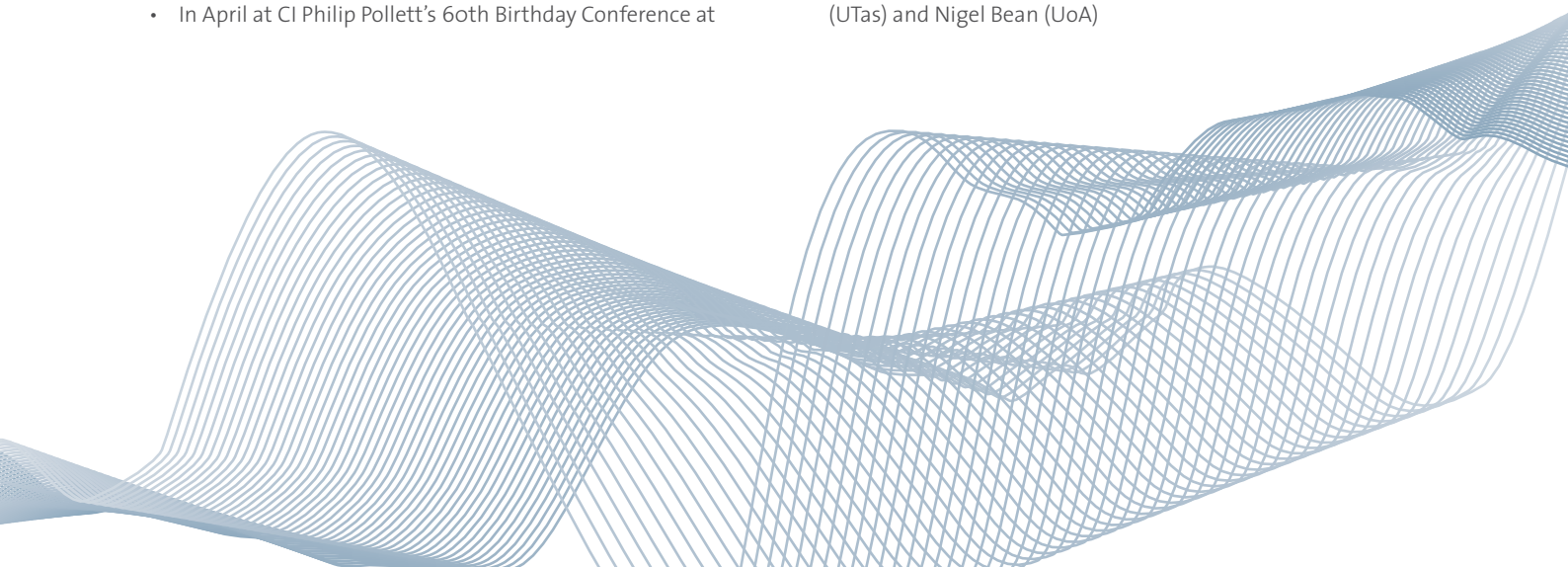
Uluru (see page 52) CI Nigel Bean with help from Als Giang Nguyen and Joshua Ross, organised the 'Applied Probability @ The Rock' Workshop, which saw ACEMS researchers from all over Australia come together

- In June CIs Philip Pollett (UQ) and Jan de Gier (UoM) 'ACEMS Workshop on Mutli-Variable Polynomials and Stochastic Systems' in Brisbane
- CIs Kerrie Mengersen, Nigel Bean and Scott Sisson with Research Fellow Erin Peterson and AI Kate Helmstedt put on the 'Novel approaches to informing decision-making in ill-defined ecological communities' workshop at QUT in August

## STUDENTS:

In 2017 there were six ACEMS students receiving cross-nodal supervision

- Abhishek Bhardwaj co-supervised by AI Markus Hegland (ANU) and CI Ian Turner (QUT)
- Doan Khue Dung Dang co-supervised by CI Robert Kohn (UNSW) and AI Minh Ngoc Tran (USyd)
- Alan Malecki co-supervised by CI Louise Ryan (UTS) and CI Scott Sisson (UNSW)
- Samithree Rajapaksha co-supervised by CI Tim Garoni MU and AI Lele 'Joyce' Zhang (UoM)
- Aviva Samuelson is co-supervised by AI Małgorzata O'Rielly (UTas) and Nigel Bean (UoA)
- Erin Trainer was co-supervised by AI Małgorzata O'Rielly (UTas) and Nigel Bean (UoA)



# MENTORING AT ACEMS

## IN MID-2017 ACEMS COMMITTED TO REENERGISING AND REFOCUSING THE ACEMS MENTORING INITIATIVES.

Led by CIs Kerrie Mengersen and Kevin Burrage with the assistance of Project Officer Kate Taylor, the team set about revising and implementing the ACEMS Mentoring Plan.

At the ACEMS Retreat in November 2017 Mentoring@ACEMS was officially launched. The newly revitalised program consists of seven activities, including: Individual-Level Mentoring; an Alumni Program; informal online mentoring networks; an online seminar series as well as dedicated in-person workshops and events; and a focus on developing international partnerships for student and postdoctoral exchange programs.

The standout success for Mentoring@ACEMS in 2017 has been the establishment of the ACEMS Individual-level Mentoring Program which now consists of two main sub-programs: Next-Level-Up Mentoring and Cross-Node Mentoring. The response to the program has been encouraging with over 20 per cent of ACEMS members volunteering to participate.

For this first program, members were matched on the eve of the ACEMS Retreat and encouraged to take advantage of the opportunity to make contact during the Retreat. Ten next-level-up and 14 cross-node mentoring relationships were established (details in table). The first program has been established for an initial six months, and participants will be given the option of continuing after the period has ended, or be matched with someone new to develop wider networks and relationships.

The program is mentee driven and those mentees have been asked to keep track of each time they meet with their mentor and report on this through the ACEMS online reporting tool. So far, the program is proving to be successful and participants have reported on 24 individual meetings.

## ACEMS INDIVIDUAL-LEVEL MENTORING PROGRAM MATCHES

### CROSS-NODE MENTORING

MENTEE	NODE	MENTOR	NODE
Tea Espeland-Uggen	UTS	Adrian Barnett	QUT
Angus Lewis	UoA	Thomas Taimre	UQ
Sam Clifford	QUT	Peter Taylor	UoM
Christopher Drovandi	QUT	Scott Sisson	UNSW
Puwasala Gamakumara	Monash	Robert Kohn	UNSW
Robert Salmone	UQ	Timothy Garoni	Monash
Thiyanga Talagala	Monash	Scott Sisson	UNSW
Patricia Gilholm	QUT	Kate Smith-Miles	UoM
Shrupa Shah	UoM	Louise Ryan	UTS
Priyanga Dilini Talagala	Monash	Matt Wand	UTS
Farzana Jahan	QUT	Ali Tirdad	UoM
Aaron Chong	UoM	Nigel Bean	UoA
Abhishek Bhardwaj	ANU	Steven Psaltis	QUT

### NEXT-LEVEL UP MENTORING

MENTEE	NODE	MENTOR	NODE
Jacinta Holloway	QUT	Sam Clifford	QUT
Anthony Ebert	QUT	Kate Helmstedt	QUT
Shovanaur Haque	QUT	Jan de Gier	QUT
Matthew Sutton	QUT	Sam Clifford	QUT
Brigitte Colin	QUT	Brodie Lawson	QUT
Kate Saunders	UoM	Laleh Tafakori	UoM
Hongbo Xie	QUT	Anthony Pettitt	QUT
Insha Ullah	QUT	Anthony Pettitt	QUT
Paul Wu	QUT	Ian Turner	QUT
Aswi Aswi	QUT	Earl Duncan	QUT
Leah Price	QUT	Kerrie Mengersen	QUT

## THE PROGRAM

Mentoring@ACEMS aims to change the way our members see their role in the Centre and seeks to:

1. engender a community of academic and non-academic support amongst its members
2. facilitate discussion and advice about broad professional issues
3. develop skills in areas such as leadership, public speaking and communication
4. encourage a life-long awareness of, and participation in, mentoring

The revitalised ACEMS Mentoring Program 'Mentoring@ACEMS' consists of seven activities:

### 1. CREATE AN ACEMS ALUMNI PROGRAM

Comprised of former ACEMS members, this aspect of the program aims to keep those who have moved through ACEMS and on to bigger and better things engaged with the Centre. Through volunteering to mentor our younger and early career researcher; participating in ACEMS outreach activities, like Maths Craft, or our Mathematicians in Schools involvement; attending the Annual Retreat; or just keeping up to date on ACEMS research, news and events.

### 2. FORMALISE ACEMS INDIVIDUAL-LEVEL MENTORING PROGRAMS

ACEMS has always had an individual-level mentoring program between pairs or small groups of ACEMS members. Under the newly revitalised program, Mentoring @ACEMS has been split in two with specific focus. The program now consists of a Next-Level-Up Mentoring Program and a Cross-Node Mentoring Program.

### 3. ORGANISE MENTORING EVENTS AT ACEMS WORKSHOPS AND RETREAT

Postgraduate and Early Career Researcher workshops are held regularly and provide excellent forums for targeted mentoring activities. These events are designed to engage and enhance the experiences all of our members have within the Centre, over and above the research they do every day.

*Mentoring in action at the ACEMS Student Retreat, November 2017*

### 4. ESTABLISH THE ACEMS MENTORING SEMINAR SERIES

In 2017, ACEMS began work on establishing a seminar series which will be delivered across all of the ACEMS nodes via video conferencing and online as a legacy resource. The series will include a mix of professional development topics delivered by experts and practical research tutorials delivered by ACEMS researchers.

### 5. ENCOURAGE AN INFORMAL ONLINE MENTORING FORUM

Another key component is developing tools to facilitate and encourage informal mentoring. The Mentoring@ACEMS Slack channel was created in 2017 and uptake has been promising. It encourages an online collaboration space where members from all across ACEMS nodes can discuss issues at the forefront of their research, share stories and resources, and where members can make connections.

### 6. IDENTIFY NATIONAL AND INTERNATIONAL ENGAGEMENT OPPORTUNITIES

ACEMS has made the commitment to encourage and facilitate international exchanges and relationships. In 2017, ACEMS invited expressions of interest from all members to take on the role of International program Director. In the end two co-Directors were appointed Als Christopher Drovandi and Thomas Taimre. The pair in collaboration with ACEMS Stakeholder Engagement Officer Jessie Roberts are working on developing strong relationships with our international partners in pursuit of this activity.

### 7. ESTABLISH A MENTORING PROGRAM FOR ACEMS PROFESSIONAL STAFF

This program is set to kick off in 2018, but at the end of 2017, strong interest has been shown from ACEMS Professional Staff to engage.





# EDUCATION AND TRAINING

THROUGHOUT 2017, ACEMS WAS COMMITTED TO PROVIDING EDUCATION, TRAINING AND PROFESSIONAL DEVELOPMENT TO ALL OF ITS MEMBERS: INDUSTRY PARTNERS AND STAKEHOLDERS, THE EDUCATION SECTOR AND THE COMMUNITY MORE BROADLY.

ACEMS has developed and expanded its Work Integrated Learning Initiative with Woodside (see page 108), its flagship Mathscraft program, which included a national tour in November 2017 (see page 113), and has kicked off its Industry Affiliate Secondree Program which saw two Australian Taxation Office (ATO) staff spend six months at the ACEMS QUT node (see page 88).

In 2017 ACEMS also launched its new Mentoring@ACEMS Program, which includes level up and cross-node mentoring. The first iteration of the program is showing strong success, with 24 mentoring relationships established. Further details of the ACEMS Mentoring Program and future plans can be found in the Mentoring Report on page 82.

The Centre has outperformed on its key performance indicators in this space with all training and professional development courses offered by the Centre attended by at least 20 members. Staff and postgraduate students have attended 23 separate professional training courses, three of which were offered by ACEMS. Further information on the nature of these courses is provided in the table on page 86.

The Education and Training highlights for 2017 are explained below:

## ACEMS BIG DATA ANALYTICS MOOC

Following its enormous success in 2016, the ACEMS Big Data Analytics Massive Open Online Course (MOOC) was held for a third time in 2017 by ACEMS CI Ian Turner and Research Fellow Steven Psaltis. The MOOC was a four-course series that was offered over May-August 2017, the courses were:

- From data to decisions (May 2017)
- Statistical inference and machine learning (June 2017)
- Mathematical modelling (July 2017)
- Data visualisation (August 2017)



*The Conversation's Michael Lund speaking at the Building your 'Brand' as a Researcher Workshop at QUT in August.*

## ACEMS PROFESSIONAL DEVELOPMENT WORKSHOPS

Several professional training and development courses were offered by the Centre throughout 2017 and at the ACEMS retreat.

In August 2017, ACEMS held the Building your 'Brand' as a Researcher workshop at QUT. The workshop was organised by ACEMS Communications and Media Officer, Tim Macuga, and covered what researchers can do to establish their brand as a researcher and why it is so important. Also attending and presenting was Science Editor from The Conversation, Michael Lund. The workshop was attended by approximately 30 people, including at least 20 Centre members. Additional information on the workshop is given in the Communications and Media report, page 130.

ACEMS organised multiple professional training and development workshops for its annual retreats. These included: 'IP workshop', presented at the main retreat by QUT's Director of Research, Michael McArdle; 'Introduction to Julia', presented as a joint session at the ECR and Student retreats by ACEMS CI Matthew Roughan; and, a GitHub and R packages session, presented at the Student and ECR retreat by ACEMS PhD Student, Nicholas Tierney.

## ACEMS PROFESSIONAL STAFF DEVELOPMENT

In addition to supporting its researchers, early career researchers and students, ACEMS has been committed to developing its Professional Staff to work more effectively in their current roles and their future careers.

ACEMS Professional Staff attended the Queensland ARC Centres and Hubs Professional staff workshop that was organised by the EQUUS Centre of Excellence. The Victorian ARC Centres and Hubs Professional Staff Workshop at Monash University in December. Organised by ACEMS and the Centre of Excellence for Future Low-Energy Electronics Technologies (FLEET), the workshop was well attended with over 50 attendees from 18 CoEs and Industrial Transformation Research Hubs and Training Centres from around Australia. A full report on the Victorian ARC Centres and Hubs Professional staff workshop can be found on [page 95](#).

In 2017, ACEMS funded QUT Node Administrator Claudia Deasy to undertake a Certificate IV in Project Management Practice at TAFE Queensland. ACEMS supported Claudia in completing the 18-week fully accredited course and later offered her a higher duties position to lead a redevelopment of the ACEMS website where she was able to apply these skills.

## PRESENTATIONS AND ATTENDANCE AT PROFESSIONAL DEVELOPMENT AND RESEARCH TRAINING WORKSHOPS

ACEMS Members have presented at numerous research training and professional development workshops around Australia and overseas. A summary of research training, short courses, and other professional development workshops Centre members have presented at are given below:

MEMBERS	RESEARCH TRAINING	LOCATION
Ian Turner, Steven Psaltis	ACEMS Big Data Analytics MOOC	Online
Tim Macuga	Building Your 'Brand' as a Researcher	Brisbane
Miles McBain, Susanna Cramb, Patricia Gilholm	Introduction to the Tidyverse	Brisbane
Matthew Roughan	Introduction to Julia	Gold Coast
Nicholas Tierney	GitHub and R packages	Gold Coast
Jessie Roberts	ACEMS and Data to Decisions: Science Communication Workshop	Sydney
Kerrie Mengersen	Bayes for Beginners	Morocco
Erin Peterson	Spatial Statistical Modelling on Stream Networks using GIS and R Statistical Software	United States (multiple)
Kerrie Mengersen	Australian Bureau of Statistics: Data Mining Workshop	Brisbane
Anita Ponsaing, Nigel Bean and Anthony Harradine	Mathscraft: Professional Development Workshop	Adelaide
Peter Taylor	SECAN Workshop: Developing an academic career	Melbourne
Chris Drovandi, Brendan van Rooyen and Davide Ferrari	AMSI Winter School 2017	Brisbane
Scott Sisson, Kerrie Mengersen and Markus Hegland	AMSI Summer School 2017	Sydney

A summary of professional training courses attended by Centre Staff and Students are given below:

PROFESSIONAL TRAINING ATTENDED
Certificate IV in Project Management Practice
Building Your 'Brand' as a Researcher*
PhD student media training workshops
Design your ePoster: Make it visual
Keep it short, sharp and to the point: Working with text
Google Summer of Code
How to Engage Industry for Research: Three-part master class
Victorian ARC Centres and Hubs Professional Staff Workshop
Queensland ARC Centres and Hubs Professional Staff Workshop
SSAI: Prevention and Treatment of Missing Data
AMSI Winter School 2017
AMSI Summer School 2017
Applied Bayesian Statistics Summer School
Research Bazaar Conference
Open.Res Conference
QRSNet Forum 2017: Striving and Thriving with your Research Degree
Industry Doctoral Training Centre mid-year conference
Spatio-temporal Modelling Course
Thesis Bootcamp
Allinea High Performance Computing Training
Introduction to Julia*
GitHub and R packages*
ACEMS and Data to Decisions: Science Communication Workshop

\* Professional training courses offered by ACEMS.

# SPONSORSHIPS

MATRIX is Australia's first international research institute for the mathematical sciences. ACEMS was a key contributor in the establishment of the Institute and ACEMS members hold positions on its Advisory Board and Scientific Committee. MATRIX is the biggest recipient of ACEMS sponsorship and for good cause, the institute saw almost 500 international visitors from over 23 countries in 2017, and hosted 16 research programs specific to the mathematical sciences. In 2017 ACEMS sponsored MATRIX to the amount of \$100,000. For more information on MATRIX see, page 98.

ACEMS considers carefully the events that it sponsors, to ensure that the Centre is sponsoring events that have the most impact on the mathematical and statistical sciences, whether that be in research excellence, facilitating a more inclusive culture or supporting emerging researchers. The full list of ACEMS sponsored events in 2017 is below.

ACEMS SPONSORED EVENTS 2017	DATE	AMOUNT
2017 WIMSIG Conference, South Australia, September	Apr-17	\$ 6,000
6èmes Rencontres R, France, June	Jun-17	\$ 1,000
International Conference on Robust Statistics, NSW, July	Jul-17	\$ 1,000
University of Melbourne Mathematical Physics Seminar program, Melbourne, July	Jul-17	\$ 600
Melbourne Maths & Science Meet Up, Melbourne, July	Jul-17	\$ 200
AMSI winter school, Brisbane, July	Jul-17	\$ 5,000
Data to decisions CRC PhD Workshop, Brisbane, August	Aug-17	\$ 1,100
QUT Maths School Career and networking evening, Brisbane, August	Aug-17	\$ 1,000
Novel mathematical approaches workshop, Brisbane	Aug-17	\$ 5,000
SSA Young Statistician Conference, Gold Coast, September	Sep-17	\$ 5,000
Melbourne Maths and Science Meet Up, Melbourne, September	Sep-17	\$ 200
ROpenSci Unconference, Melbourne, October	Oct-17	\$ 2,000
Biometrics by the Border, NSW, November	Nov-17	\$ 5,000
Bayes on the Beach, Gold Coast, November	Nov-17	\$ 7,500
MATLAB Competition 2017, Brisbane, November	Nov-17	\$ 2,000
Visualisation Matters 2017, Sydney, November	Nov-17	\$ 2,000
Centres of Excellence Professional Staff Workshop, Melbourne, December	Dec-17	\$ 1,000
Mathematical Education Software Interest Group (MESIG), Melbourne, December	Dec-17	\$ 363
Statistical Challenges in astronomy, Sydney, December	Dec-17	\$ 5,000
		\$ 150,963

For the second year running ACEMS organised the National Science Quiz. The Quiz was held in Melbourne and Adelaide and co-sponsored by Centre of Excellence for Biosecurity Risk Analysis, ARC Centre of Excellence for All-sky Astrophysics, ARC Centre of Excellence in Exciton Science, ARC Centre of Excellence for Climate System Science, ARC Centre of Excellence in Future Low-Energy Electronics Technologies and ARC Centre of Excellence for Biodiversity and Heritage.

SPONSORSHIP RECEIVED BY ACEMS
National Science Quiz, Melbourne, May - \$19,928



# ATO WORKERS BRING REAL-WORLD PERSPECTIVE TO ACEMS IN EXCHANGE FOR AN IMMERSION IN MATHS AND STATS

*“It’s one thing to dip your toes in the shallow end of a pool, but it’s quite another to jump head first into the deep end – and that’s exactly what two Australian Taxation Office (ATO) employees did when they spent six months at ACEMS’ QUT node in 2017.”*

Sarah Hepworth and Jessica Michie completed secondments with ACEMS, expanding their theoretical and applied statistical knowledge through on the job exposure, in addition to retreats, workshops, social networking and even Massive Open Online Courses (MOOCs).

“I expected to be immersed in statistics, and I was,” says Sarah, who is a data analyst with the ATO in Brisbane.

Both Jessica and Sarah said they came to ACEMS with the hope of improving their statistical knowledge to help with projects they were implementing in their work at the ATO.

“We’ve had a big reinvention program in the ATO and one of the key strategic focuses is using data in a better way,” says Jessica, who is a lead business intelligence analyst for the ATO.

Jessica used her time at ACEMS to add to her statistical toolbox for her work at the ATO.

“It’s very easy getting stuck in what you know, and to go with one technique where you try to make every problem fit that one technique. Instead, we need to say, ‘this is our business problem,’ and then try to find the best technique for that problem. That’s where tapping into networks like ACEMS can be fantastic,” says Jessica.

One problem that Sarah examined during her time at ACEMS, dealt with record linking, or using mathematical and statistical methods for linking data sets. To do that, she collaborated with ACEMS Chief Investigator, Professor Matthew Roughan at The University of Adelaide.

“He’s applying network theory techniques to treat each link between data sets as semirings, which is quite cool,” says Sarah.

Although physically positioned at QUT, the ACEMS network provided Sarah with the opportunity to not only work with many of the researchers at QUT, but also with ACEMS researchers at The University of Melbourne.

ACEMS Stakeholder Engagement Officer Jessie Roberts helped arrange the secondments with the ATO through the QUT Business School. Jessie says this initial trial with the ATO was a big success.

“We proved that the secondment format is an effective framework for building bridges with industry, particularly large organisations where data privacy can significantly inhibit research projects,” says Jessie.

“Jessica and Sarah have a much greater understanding of the data, problems and organisational culture within the ATO than any external researcher will, so they can bring all that knowledge with them to ACEMS and trial out new approaches and strategies without compromising data privacy and security, which is paramount to many organisations.”

Having Sarah and Jessica around wasn’t a one-sided exchange. Their daily presence gave ACEMS researchers, particularly postgraduate students and early career researchers, on-the-spot exposure to people who work in government. Both agree the biggest value they provided to ACEMS was forcing the researchers they met to explain their research in a non-academic context.

“In government, you may need to explain a concept and not be able to use an equation. So, to be able to translate your knowledge into something the business can understand and see the benefit of, is really important,” says Jessica.

Both took part in a retreat in March 2017 at The University of Queensland, for ACEMS postdoctoral researchers from around the country.

“We workshopped with them on how to pitch what they’re doing. Just having them explain to us what they’re working on was really meaningful,” says Sarah.

There was one more thing about the secondment that was really special to Jessica. It was part-time, which says helped her a lot because she has a small child at home.

“When you have roles that work better part time, they should be championed,” says Jessica.

# ATO SECONDMENT PROGRAM GROWS

For Jessica, it was also important to see women doing maths, and roles like this help make that happen.

Jessica and Sarah's secondments with ACEMS were just one of several the ATO had with QUT.

"The secondees program helps build our staff's mathematical and statistical knowledge and to establish a network of contacts with experts. We see the knowledge and contacts as helping us provide better solutions to our business problems," says Rohan Baxter, a Senior Director with the ATO.

Jessie Roberts says she hopes this is just the beginning of ACEMS' relationship with the ATO.

"We aim to host additional secondees from the ATO and explore a secondment into the ATO," says Jessie.

"It's great to welcome them into the ACEMS network as ACEMS Industry Affiliate Members, and we look forward to both seeing ATO staff at our workshops but also pushing forward on applied research problems."

Looking ahead, both Sarah and Jessica are moving into the data science area with the ATO. They want to continue to work closely with ACEMS as they do that.

"Both Jessica and I are really making an effort to promote ACEMS work and the value of the relationship back to the ATO so we can keep working with ACEMS," says Sarah.

They both hope it leads to actual projects between the two groups that they can work on. In other words, they're already in the deep end of the pool... and they're just warming up!



Jessica Michie and Sarah Hepworth on secondment from the ATO

The end of 2017 saw the ACEMS secondment program expand even further as three new secondees joined ACEMS at QUT.

Stephen Jeffrey is from the Queensland Government, Department of Science, IT and Innovation (DSITI) where he works in the Ecosciences Precinct.

"Most of my experience has been in climate modelling and climate data analysis. During my time at ACEMS I will be investigating whether neural networks can predict pasture growth given the past and present climatic conditions. Accurate forecasts of growth would enable graziers to better manage the impact of climate variability," says Stephen.

Peta Townend is from the Infrastructure Group within the Department of Infrastructure, Local Government and Planning in Queensland Government. The project she is working on is seeking to identify how the state government can use big data and data analytics in developing improved infrastructure policy, planning and investment decisions.

Mark Gordon is from the Queensland Government Chief Information Office.

"My focus here at ACEMS will be on the subject of big data and analytics 'business readiness,' says Mark.

Mark says that during his time with ACEMS he will be looking at questions of how the Queensland Government can leverage opportunities in this domain. He also wants to explore what options are available to organisations to support more data-driven decision making.

All three will provide invaluable insight for ACEMS researchers on working with and within government.

ACEMS believes it not only has a responsibility to push the frontiers of mathematics and statistics, but also to find innovative methods for breaking down the barriers between industry and academic institutions. This is one mechanism for doing that, which ACEMS has trialled and found to be very successful, and one that it will pursue into more organisations in the future.

# NATIONAL AND INTERNATIONAL ENGAGEMENT

## ACEMS IN THE MEDIA

ACEMS has seen significant growth of its online and social media presence. Over 2017, ACEMS has seen a 40 per cent increase in the number of its Facebook followers, over 6,000 views on its YouTube channel and is one of three Centres of Excellence to have over 1,000 Twitter followers. 2017 also saw the launch of the new ACEMS website, parts of which are linked to the ACEMS Members Portal and online reporting tool so updates are posted to the website in real-time, keeping the website up-to-date. For further details, see the Communications and Media Report, page 130

ACEMS research and ACEMS members attracted significant media attention throughout 2017. ACEMS and its members were featured in multiple national and international news stories and press releases, including 23 press releases, 54 print and electronic articles and 14 radio and television stories. A full list of articles is given on page 133

Graeme Denton and ACEMS Chief Investigator, Matthew Roughan, entered the Guinness Book of Records for the *Largest free floating soap bubble (indoors)*. Matthew calculated the size of the bubble and demonstrated to the satisfaction of the Guinness Book of Records the soap bubble was 19.8 cubic metres, smashing the previous record. The world record attempt and Matthew's unique proof gathered a significant amount of attention on social media, print media, television and radio. For the full story, see page 40.

## RESEARCH EXCELLENCE AT ACEMS

In collaboration with ACEMS Industry Affiliate organisation, Cancer Council Queensland, ACEMS Associate Investigator, Susanna Cramb, published a study building on the Queensland Cancer Atlas and demonstrating significant differences in cancer survival rates between different geographical locations in Queensland. The scope of the study is now being expanded to complete a National Cancer Atlas for Australia which will include additional ACEMS researchers Kerrie Mengersen, Jessie Roberts and Earl Duncan. For the full story, see page 78.

ACEMS Associate Investigator, Paul Wu, received significant media attention for his research on better understanding the impact of dredging at different times to preserve seagrass. Paul featured in multiple radio and television stories as well as multiple press releases and news articles. Paul's work was published in *Nature* and attracted significant interest from the dredging industry and conservation groups. For the full story, see page 16.

ACEMS PhD student, Adam 'Ben' Rohrlach, working alongside CI Nigel Bean and AI Jono Tuke, were a part of an international collaboration which demonstrated Indigenous Australians had occupied some parts of Australia for up to 50,000 years.

The research findings were published in *Nature* and were disseminated to the public via multiple press releases and other news stories. Ben was later awarded 2017 Eureka Prize for Excellence in Interdisciplinary Research by the Australian Museum for his contributions to the Aboriginal Heritage Project. For the full story, see page 60.

## COLLABORATIONS WITH INTERNATIONAL RESEARCH ORGANISATIONS

ACEMS formalised its connections to the Insight Centre for Data Analytics in Ireland by signing a Memorandum of Understanding. Under this new partnership, ACEMS and Insight will implement a student exchange program for extended research visits between the two centres.

A long-time collaborator of Robert Kohn, Matias Villani, Linköping University, was welcomed as a new Associate Investigator of ACEMS in 2017, bringing the total number of ACEMS Associate Investigators based at an overseas institution to six. Matias will contribute to the ACEMS project Enabling Bayesian inference for big data under the Enabling Algorithms research theme.

## COLLABORATIONS WITH INDUSTRY

The ACEMS Industry Affiliates program continues to expand with the addition of the Bureau of Meteorology and Defence Science Technology Group in 2017. In August, together with the Bureau of Meteorology, ACEMS organised the Statistical Challenges in Climatology workshop in Melbourne. Later in 2017, the Bureau of Meteorology and Defence Science Technology Group reached out to the ACEMS community with their industry presentation at the ACEMS Annual Retreat. Further information is available in the Stakeholder Engagement report, page 100.

As part of a newly established Work Integrated Learning Initiative, ACEMS sent nine maths students from undergraduate to Masters' level from four ACEMS nodes to work at Woodside Petroleum analysing and unravelling the huge amounts of data the company generates. The program led by ACEMS Chief Investigator Nigel Bean is specifically designed to address a shortage of employable mathematicians in Australia and internationally by developing the skills that industry needs. For the full story, see page 108.

Sarah Hepworth and Jessica Mechie of the Australian Taxation Office undertook secondments with ACEMS at the QUT node. During her time at ACEMS, Sarah leveraged the cross-node opportunities available through ACEMS to collaborate with ACEMS Chief Investigator Matthew Roughan at The University of Adelaide and several others at The University of Melbourne. For the full story, see page 88.

## OUTREACH TO THE PUBLIC

ACEMS expanded the National Science Quiz in 2017, holding two events in June in both Melbourne and Adelaide. Both events were hosted by TV personality Charlie Pickering and featured a variety of well-known scientists, science communicators and comedians including Alan Duffy, Alice Williamson, Tanya Monro, Sarah Keenihan, Adam Briggs and Tom Gleeson. For the full story, see [page 115](#).

## OUTREACH TO SCHOOLS

ACEMS' flagship outreach program, Mathscraft, has undergone significant growth over 2017. At least 15 Mathscraft workshops have been held, attended by approximately 300 students from years 5-10 and 90 teachers from 70 different schools from around Australia. For the full story, see [page 113](#).

## OUTREACH TO THE MATHEMATICAL SCIENCES

Multiple ACEMS Chief Investigators and Associate Investigators continue to serve on editorial boards of prestigious journals and advisory boards of professional societies. Some examples in 2017 include: Kate Smith-Miles joined the ARC College of Experts panel, Scott Sisson and James Brown joined the Methodological Advisory Committee for the Australian Bureau of Statistics and Dirk Kroese joined the FWF Austrian Science Fund.

Led by ACEMS Chief Investigator Dirk Kroese and Associate Investigator Radislav Vaisman, ACEMS held the Sampling and Exploration Competition in 2017. The challenge to the participants was to find the optimal configuration for Frida the Frog to lay her eggs in various scenarios using the MATLAB coding environment. Students and postdocs from ACEMS and abroad participated in the competition. ACEMS PhD Students Tim Hyndman and Jun Chen took first and second prize, while Krzysztof Bisewski and Nick Verheul from Centrum Voor Wiskunde en Informatica, the Netherlands, won third place. ACEMS Research Fellows Sarat Moka and Wilson Chen won first and second prize in the Postdoc division. For further details, see [page 118](#).

## NATIONAL AND INTERNATIONAL VISITORS

Over 2017, ACEMS nodes hosted 84 visitors from across Australia and overseas. Of the 64 visitors that originated from overseas, 6 of them visited ACEMS multiple times or visited multiple ACEMS nodes. A full visitor list and map showing the origins of ACEMS' visitors is shown on [pages 93](#).

Michel Mandjes of the ACEMS Scientific Advisory Board visited The University of Melbourne node of ACEMS. During Michel's extended research visit, Michel participated in a Mathscraft event at Westbourne Grammar School (Vic), attended the November SAC meeting in person and gave a keynote presentation at the ACEMS Annual Retreat.

ACEMS organised an informal luncheon for the female academics and students at The University of Melbourne node. The event was hosted by ACEMS Scientific Advisory Board member, Ruth Williams, during her visit to the Monash and The University of Melbourne nodes. The event was very well attended, primarily by female students and early career researchers. Further information is given on [page 119](#).

During an extended research visit to Australia, Mark Girolami of Imperial College London and University of Warwick toured all the ACEMS nodes. Mark's tour of ACEMS facilitated valuable interactions between Centre researchers and students and included several seminars at multiple nodes. ACEMS very much looks forward to hosting distinguished visitors for similar tours in 2018 and in the future.

## VISITS TO OTHER COUNTRIES

In 2017, 52 ACEMS members visited 27 countries a total of 101 times. These visits include research collaborations as well as conferences, seminars and courses. See [page 94](#) for a map of countries visited by ACEMS members in 2017.

ACEMS Masters student, Jacinta Holloway, travelled to Bogota, Columbia, to present a satellite imagery for official statistics workshop which was created in collaboration with Statistics Canada, Australian Bureau of Statistics, QLD Department of Science, Information Technology and Innovation, Geoscience Australia and CSIRO. She also attended the United Nations Annual Big Data conference, which provided her an opportunity to meet in person with international collaborators she had been working with on the UN Satellite Imagery Task Team for 2 years. See [page 126](#).

## ORGANISED WORKSHOPS AND CONFERENCES

ACEMS members organised or co-organised 11 research workshops and conferences during 2017. Many of these workshops and conferences attracted national and international audiences and two workshops were held overseas. A full list of research workshops and conferences is shown on [page 96](#).

ACEMS proudly sponsored the first ever WIMSIG conference which was held in September 2017. ACEMS was also strongly represented at the conference with Chief Investigators Aurore Delaigle, Kerrie Mengersen, Nigel Bean, Matt Wand, Kate Smith-Miles and Peter Taylor giving presentations or attending. For the full report on the event, see [page 127](#).

ACEMS and its members organised the Applied Probability @ the Rock Conference, the 3rd Melbourne-Singapore Probability and Statistics Forum and Visualisation Matters 2017. A full list of workshops and conferences organised or co-organised by ACEMS is given on [page 96](#).

ACEMS co-organised the Victorian ARC Centres of Excellence Hubs and Staff Workshop. The workshop was held at Monash University and was very well attended by professional staff from multiple ARC Centres of Excellence and Industrial Transformation Research Hubs and Training Centres from around Australia. For the full story, see [page 95](#).

ACEMS played a pivotal role in organising the Melbourne leg of the AMSI-ANZIAM Lecture tour which was given by Associate Professor Maria Vlasiou. The event was held at The University of Melbourne and attended by up to 80 members of the public. Further information details are given on [page 119](#).



## INTERNATIONAL LINKS: INSTITUTIONS

In 2017, a total of 53 visits by 31 Centre members were made to 40 different overseas institutions in 16 countries.

INSTITUTION NAME	COUNTRY	VISITS
Auckland University of Technology	New Zealand	1
Bocconi University	Italy	1
Cardiff University	United Kingdom	1
Central University of Finance and Economics	China	1
City University of London	United Kingdom	1
Columbia University	United States	1
Free University Amsterdam	Netherlands	1
Fudan University	China	1
IBM Thomas J Watson Research Center	United States	1
Imperial College London	United Kingdom	2
Inserm	France	1
InterDisciplinary Institute of Data Science, Università della Svizzera italiana	Switzerland	1
Istituto di Matematica Applicata e Tecnologie Informatiche	Italy	1
Korean Statistical Society	Republic of Korea	1
Massachusetts Institute of Technology	United States	1
Max Planck Institute for Polymer Research	Germany	1
Max Planck Institute for the Science of Human History	Germany	1
Medical Research Council Biostatistics Unit, University of Cambridge	United Kingdom	1
National Center for Epidemiology, Health Institute Carlos III	Spain	1
National Institute for Mathematical and Biological Synthesis	United States	1
Oxford University	United Kingdom	6
Peking University	China	1
Sebelas Maret University	Indonesia	1
The University of Manchester	United Kingdom	3
The University of Nottingham	United Kingdom	1
Université catholique de Louvain	Belgium	1
Université Libre de Bruxelles	Belgium	1
Université Pierre and Marie Curie	France	1
University College London	United Kingdom	1
University of California Berkeley	United States	4
University of California San Diego	United States	1
University of Cologne	Germany	1
University of Copenhagen	Denmark	1
University of Leeds	United Kingdom	3
University of Ryukyus	Japan	1
University of Twente	Netherlands	1
US Department of Energy Bonneville Power Administration	United States	1
US Forest Service Rocky Mountain Research Station	United States	1
Victoria University of Wellington	New Zealand	1
York University	Canada	1

# NATIONAL AND INTERNATIONAL VISITORS

DURING 2017, ACEMS NODES HOSTED 84 VISITORS FROM 20 COUNTRIES: 20 FROM AROUND AUSTRALIA AND 64 FROM OVERSEAS, SIX OF WHICH VISITED ACEMS MULTIPLE TIMES OR VISITED MULTIPLE ACEMS NODES.

\* Visited multiple times in 2017

† Visited multiple nodes in 2017

## NATIONAL VISITORS

- Dr. Zdravko Botev, UNSW Sydney
- Prof. Mardi Dungey, University of Tasmania
- Dr. Ronen Galaiduk, Australian Institute of Marine Science
- Dr. Gery Geenens, UNSW Sydney
- Ms. Charles Grey, La Trobe University
- Dr. Juri Hinz, University of Technology, Sydney
- Dr. Sandra Johnson, Flight Centre
- Dr. Petra Kuhnert, CSIRO Data61
- Dr. Kim-Anh Lê Cao, University of Technology, Sydney
- Prof. Vladimir Mangazeev, Australian National University
- Dr. Melanie Massaro, Charles Sturt University
- Mr. George Michaelson, Asia Pacific Network Information Centre
- Dr. Rafael Possas, University of Sydney
- Prof. David Pyne, Australian Institute of Sport
- Dr. Melanie Roberts, IBM Research

- Dr. Yong Song, The University of Melbourne
- Ms. Lou Stanley, Queensland Police Service
- Dr. Katharine Turner, Australian National University
- Dr. Marijke Welvaert, Australian Institute of Sport
- Mr. Xin Zhang, UNSW Sydney

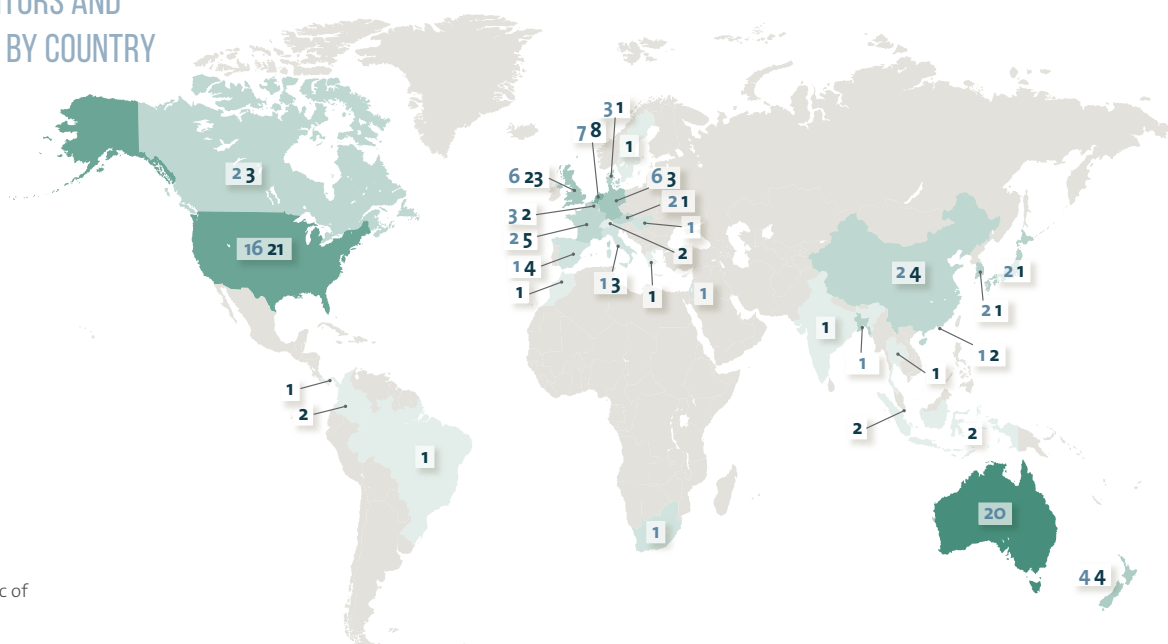
## INTERNATIONAL VISITORS

- Dr. Maryam Alavishoshtari, University of Auckland, New Zealand
- Prof. James Albert, Bowling Green State University, United States †
- Mr. Foysal Mohammad Arifur Rahman, East West University, Bangladesh
- Prof. Søren Asmussen, Aarhus University, Denmark †
- Prof. Paul Barford, University of Wisconsin, United States
- Ms. Diana Benavides Prado, Auckland University of Technology, New Zealand
- Prof. Howard Bondell, North Carolina State University, United States
- Mr. Roy Castillo, Victoria University of Wellington, New Zealand
- A/Prof. Jose Chacon, University of Extremadura, Spain
- Prof. Hendrik de Bie, Ghent University, Belgium
- Prof. Youjin Deng, University of Science and Technology of China, China\*
- Prof. John Doyle, California Institute of Technology, United States
- Dr. Anne Driemel, Eindhoven University of Technology, Netherlands
- Mr. Gyorgy Feher, Budapest University of Technology and Economics, Hungary
- Prof. Mark Girolami, Imperial College London / Warwick University, United Kingdom †
- Prof. Sonja Greven, Ludwig-Maximilians-University Munich, Germany
- Dr. Wesley Griffin, National Institute of Standards and Technology, United States
- Dr. Eric Hare, Omni Analytics Group, United States
- Prof. Moshe Haviv, Hebrew University of Jerusalem, Israel
- Prof. Qi-Ming He, The University of Waterloo, Canada
- Dr. Christian Hirsch, Ludwig-Maximilians-University Munich, Germany
- Prof. Susan Holmes, Stanford University, United States †
- Mr. Alexander Howse, University of Waterloo, Canada
- Prof. Lancelot F James, Hong Kong University of Science and Technology, Hong Kong
- Mr. Stephen Johnson, Newcastle University, United Kingdom
- Dr. Stella Kapodistria, Eindhoven University of Technology, Netherlands
- Dr. Mario Kieburg, Bielefeld University, Germany
- A/Prof. Yoshio Komori, Kyushu Institute of Technology, Japan
- A/Prof. Nikolaos Kourentzes, Lancaster University, United Kingdom
- Prof. Anthony Krzesinski, Stellenbosch University, South Africa
- Prof. Jean-Bernard Lasserre, Laboratory for Analysis and Architecture of Systems, France

- Prof. Guy Latouche, Université libre de Bruxelles, Belgium
- A/Prof. Eun-Kyung Lee, Ewha Womans University, Republic of Korea
- Prof. Alun Lloyd, North Carolina State University, United States
- Prof. Michel Mandjes, University of Amsterdam, Netherlands
- Prof. David Mason, University of Delaware, United States
- Dr. Nikolai Matni, University of California, Berkeley, United States
- Prof. Brendan McCabe, University of Liverpool, United Kingdom
- Dr. Sheik Meeran, University of Bath, United Kingdom
- Prof. Alexander Meister, University of Rostock, Germany
- Dr. Lawrence Mosley, Omni Analytics Group, United States
- Prof. Bernard Nienhuis, University of Amsterdam, Netherlands
- Prof. Yong-Guen Oh, IBS Center for Geometry and Physics, Korea, Republic of
- Prof. Roger Peng, Johns Hopkins Bloomberg School of Public Health, United States
- Mr. Oscar Peralta, Technical University of Denmark, Denmark
- Prof. Pierre Pinson, Technical University of Denmark, Denmark
- Prof. Eric Ragoucy-Aubezon, Laboratoire d'Annecy-le-Vieux de Physique Théorique, France
- Dr. Gareth Ridall, Lancaster University, United Kingdom
- Prof. Fabrizio Ruggeri, CNR Imati Milano, Italy
- Mr. Yves Sagaert, Ghent University, Belgium
- Prof. Tomohiro Sasamoto, Chiba University, Japan
- Prof. Michael G. Schimek, Medical University of Graz, Austria
- Dr. Johannes Schmidt, University of Cologne, Germany
- A/Prof. Ali Shojaie, University of Washington, United States
- Prof. Alfred Stein, University of Twente, Netherlands
- Prof. Antony Unwin, University of Augsburg, Germany
- Miss Mirte van Weert, Eindhoven University of Technology, Netherlands
- A/Prof. Maria Vlasiou, Eindhoven University of Technology, Netherlands
- Prof. Arndt von Haeseler, University of Vienna, Austria
- Prof. Chris Wild, The University of Auckland, New Zealand
- Prof. Ruth Williams, University of California, San Diego, United States
- Prof. Stephen Wright, University of Wisconsin, United States
- Dr. Jingjin Timothy Wu, United International College, China
- Dr. Yihui Xie, RStudio Inc, United States

## NUMBER OF VISITORS AND MEMBER VISITS BY COUNTRY

20	-	Australia	2	1	Switzerland
2	1	Austria	1	1	Thailand
1	-	Bangladesh	6	23	United Kingdom
3	2	Belgium	16	21	United States
-	1	Brazil			
2	3	Canada			
2	4	China			
-	2	Columbia			
3	1	Denmark			
2	5	France			
6	3	Germany			
-	1	Greece			
1	2	Hong Kong			
1	-	Hungary			
-	1	India			
-	2	Indonesia			
1	-	Israel			
1	3	Italy			
2	1	Japan			
2	1	Korea, Republic of			
-	1	Morocco			
7	8	Netherlands			
4	4	New Zealand			
-	1	Panama			
-	2	Singapore			
1	-	South Africa			
1	4	Spain			
-	1	Sweden			



• Origins of ACEMS Visitors

• Countries Visited by ACEMS Members

In 2017, a total of 101 visits to 27 countries were made. These visits include research collaborations as well as conferences, seminars and courses.

# VICTORIAN ARC CENTRES AND HUBS PROFESSIONAL STAFF WORKSHOP

How do ARC Centres of Excellence become 'more than the sum of the parts'? What strategies have professional staff found to enhance and maintain centre cohesiveness? What works with respect to managing reporting requirements and collecting KPI data? What doesn't work?

These questions and many more were discussed at the inaugural Victorian ARC Centres and Hubs Staff (VACHS) Workshop held in Melbourne on 14 December 2017. The event brought together professional staff teams from predominantly Victorian-based ARC Centres of Excellence, ARC Industrial Transformation Research Hubs and ARC Training Centres to share best practice and learnings, find efficiencies, and develop future networks among similar roles.

In total, 51 professional staff from 18 ARC-funded research centres attended the event including chief operating officers, centre managers, business managers and staff in finance, communications, outreach, mentoring, stakeholder engagement, education and training, central administration and node administration.

The event was proudly co-hosted by the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS) and the ARC Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET), with the organisation of the event led by ACEMS and FLEET Chief Operating Officers, Dr Emily Duane and Dr Tich-Lam Nguyen.

The central theme of sharing best practices was addressed via eight self-nominated 'what we do well' presentations covering topics such as maintaining centre cohesiveness, financial management, outreach, social marketing and academia, internal communications, education and training, mentoring, and equity and diversity.

Brainstorming sessions brought together common roles to identify shared challenges and possible solutions. These sessions also facilitated the establishment of many new relationships that will continue after the workshop.

Emily Duane (ACEMS) and Natalie Jones (CBNS) presented their top tips and lessons learnt from recent successful centre mid-term reviews, while Stephen Gray (Climate Extremes) and Lisa Walker (EQuS) shared their experiences of preparing successful centre rebids.

Penny Bambrick from the Australian Research Council also shared perspectives from the ARC about business management of centres and hubs; Penny is Assistant Director of the National Competitive Grants Program Major Investments.

Workshop feedback was overwhelmingly positive with participants already looking forward to the next event in 2018. In the meantime, existing networks as well as the important new relationships established at the workshop will be fostered by both informal and formal networking, mentoring and collaboration opportunities.



*ACEMS Professional Staff at the workshop: Emily Duane, Jessie Roberts, Claudia Deasy, Anita Ponsaing, Kate Hall and Kate Taylor*



*ACEMS Outreach Officer Anita Ponsaing talked about the National Science Quiz and Mathscraft*



*Brainstorming sessions helped to identify shared challenges and possible solutions*

## PARTICIPATING ORGANISATIONS:

ARC Centres of Excellence: Mathematical and Statistical Frontiers (ACEMS), Future Low-Energy Electronics Technologies (FLEET), Climate Extremes, Engineered Quantum Systems (EQuS), Gravitational Wave Discovery (OzGrav), Convergent Bio-Nano Science and Technology (CNBS), Exciton Science (ACEx), Particle Physics at the Terascale (COEPP), Advanced Molecular Imaging, and Environmental Decisions (CEED).

ARC Industry Transformation Research Hubs: World-class Future Fibre Industry (Future Fibres Hub), Bioprocessing Advanced Manufacturing Initiative (BAMI), Computational Particle Technology, Digital Enhanced Living Hub, and Nanoscience based Construction Materials Manufacturing (Nanocomm).

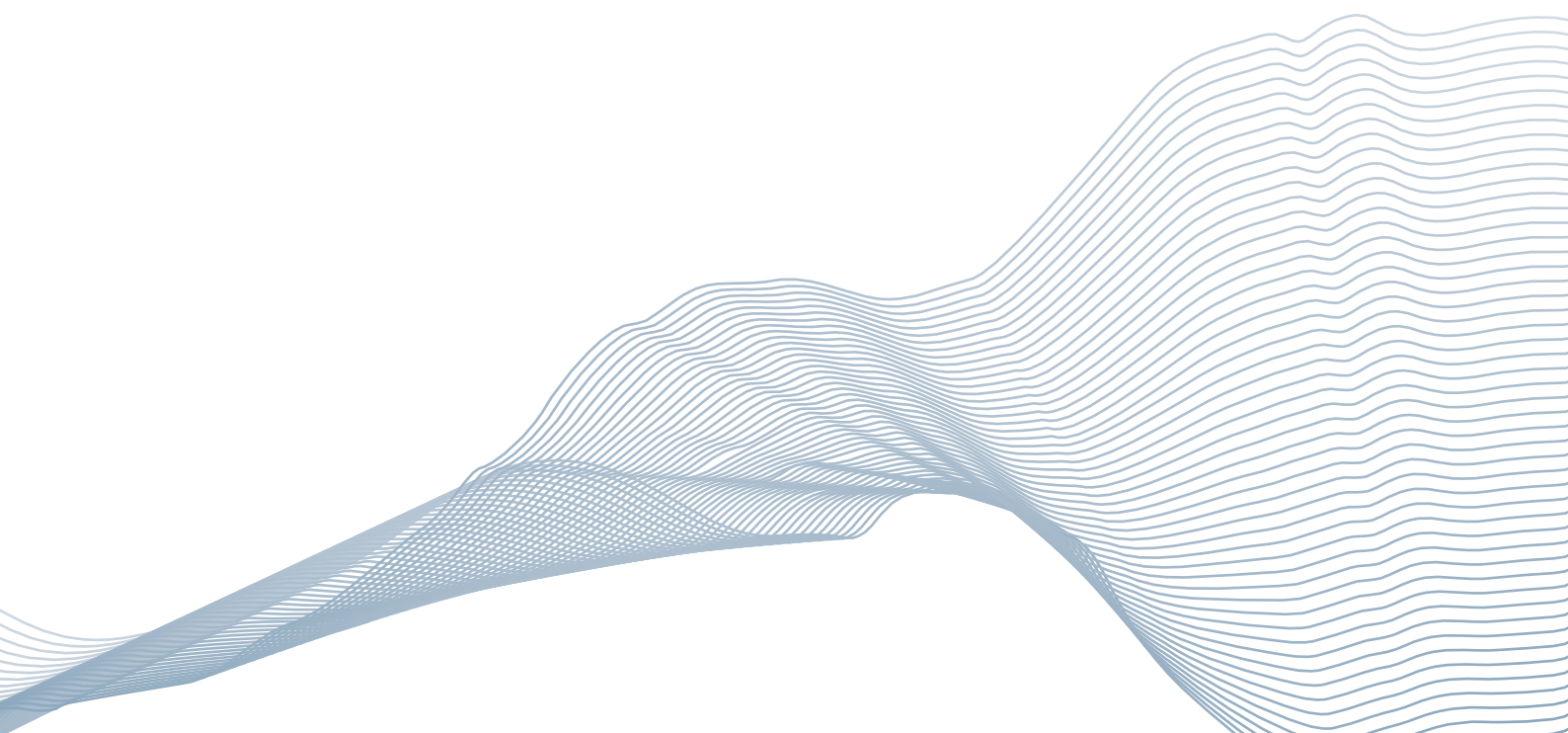
ARC Training Centres: Personalised Therapeutics Technologies (CPTT), Alloy Innovation for Mining Efficiency (mineAlloy), and Lightweight Automotive Structures (ATLAS).



# NATIONAL AND INTERNATIONAL WORKSHOPS AND CONFERENCES

The following 11 national and international research workshops and conferences were organised or co-organised by the Centre and its members during 2017:

WORKSHOP/CONFERENCE NAME	LOCATION	MONTH
ACEMS Workshop on Maths and Stats for Sports Research	Brisbane	March
Applied Probability @ The Rock	Uluru	April
ACEMS Workshop on Approximate Bayesian Computation and its Applications	Melbourne	May
ACEMS Workshop on Multi-Variable Polynomials and Stochastic Systems	Brisbane	June
2016 ABS Census Data Seminar	Sydney	July
Novel approaches to informing decision-making in ill-defined ecological communities	Brisbane	August
WIMSIG 2017: Celebration of Women in Australian Mathematical Sciences	Adelaide	September
3rd Melbourne-Singapore Probability and Statistics Forum	Melbourne	September
Ingenuity and integrability in statistical mechanics	Netherlands	October
Visualisation Matters 2017	Paddington	November
ACEMS Workshop on Challenges of Data and Control of Networks	Adelaide	December



# ACEMS MEMBERS TAKE OUT THE CHALLENGE AT EXTREME VALUE ANALYSIS CONFERENCE 2017

At the 10th Extreme Value Analysis Conference in June 2017, three ACEMS members - The University of Melbourne's, PhD Student Kate Saunders and AI Laleh Tafakori, and Senior CSIRO Data Analyst Alec Stephenson took out first place in the 'Prediction of Spatio-Temporal Extremes' Challenge.

The conference, held at the Technical University of Delft, Netherlands, each year offers the Challenge which asks entrants to use precipitation data to predict spatio-temporal extremes and estimate high quantiles to extrapolate through time and space. Kate, Laleh and Alec were invited to contribute to a discussion session at the conference where they could explain their predictive algorithm, and prepare a short paper for publication in the journal *Extremes*, where the trio ended up in first place.



*Attendees to the 10th Extreme Value Analysis Conference, held at the Technical University of Delft, Netherlands where ACEMS members Kate Saunders, Laleh Tafakori and Alec Stephenson were amongst the winning teams of the EVA 2017 Challenge.*

# ACEMS HOLDS BIG DATA ANALYTICS MOOC THIRD YEAR RUNNING

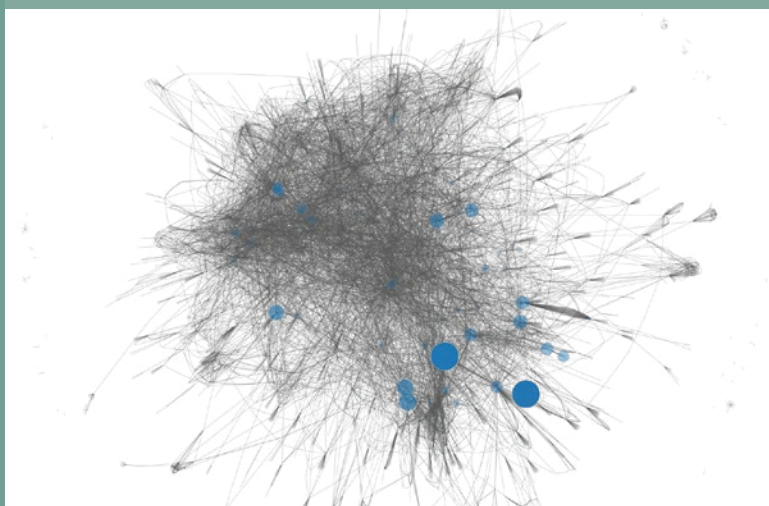
Teaming up with online education platform FutureLearn, ACEMS Research Fellow Steven Psaltis, and CI Ian Turner held a four-course series of MOOCs (Massive Open Online Courses) on big data analytics between May and August 2017. The series covered a range of topics in analytics, including making decisions from data, statistical inference and machine learning, mathematical techniques for data analysis and visualisation. Learners gain hands-on experience in a range of software tools, through a range of practical examples.

In 2017 there were a total of 26,309 enrolments across the four courses, including from the United Kingdom (22 per cent), India (7.1 per cent), the United States (5.9 per cent), Australia (5 per cent), and Spain (2.1 per cent).

"I've very much enjoyed working through this course, and found it to be a very positive experience. It was made all the more interesting and valuable because of the use of MATLAB to try out the examples, and also the provision of articles for supplementary and further reading."

"I loved the course. Everything was perfect, the examples, the application, the help, the teachers. One of my favorites."

*Graph visualisation showing connections between a subset of webpages on the World Wide Web.*



# MATRIX

MATRIX IS AUSTRALIA'S FIRST INTERNATIONAL RESEARCH INSTITUTE FOR THE MATHEMATICAL SCIENCES. FUNDED THROUGH A PARTNERSHIP BETWEEN THE UNIVERSITY OF MELBOURNE AND MONASH UNIVERSITY, WITH SEED FUNDING FROM ACEMS, MATRIX PROVIDES INTENSIVE RESIDENTIAL MATHEMATICAL PROGRAMS AT MATRIX HOUSE IN CRESWICK, VICTORIA.



MATRIX Creswick House

MATRIX has had a highly successful 2017, coordinating and presenting eight research programs:

- Hypergeometric Motives and Calabi-Yau Differential
- Computational Inverse Problems
- Integrability in Low-Dimensional Quantum Systems (ISQS2017)
- Elliptic Partial Differential Equations of Second Order: Celebrating 40 years of Gilbarg and Trudinger's book
- Combinatorics, statistical mechanics, and conformal field theory
- Mathematics of Risk
- Tutte Centenary Retreat
- Geometric R-matrices: From Geometry to Probability

MATRIX received consistent positive feedback across all programs held in 2017, with many participants already scheduled to return to the Institute in 2018.

MATRIX has developed a prolific relationship with ACEMS and the Centre holds its influential and extremely successful Maths Craft workshops at the institute's rural Victorian premises.

MATRIX has now hosted 16 research programs spanning 38 weeks, attracting 490 scientists from 23 countries and continues to attract world-leading mathematicians to their programs. In 2017, MATRIX welcomed Youssef Marzouk and





*The grounds at the Creswick property in Victoria*

Karen Willcox from Massachusetts Institute of Technology (MIT) as well as Fields Medallist Andrei Okounkov from Columbia University, who presented at the Geometric R-matrices: From Geometry to Probability program.

2017 also saw MATRIX produce its first book, the MATRIX 2016 Annals which documented the scientific activities of MATRIX's first five programs.

MATRIX continues to strengthen ties with colleagues in the Asia-Pacific region through its relationships with the Asia Pacific Center for Theoretical Physics and the Center for Geometry and Physics, in Korea.

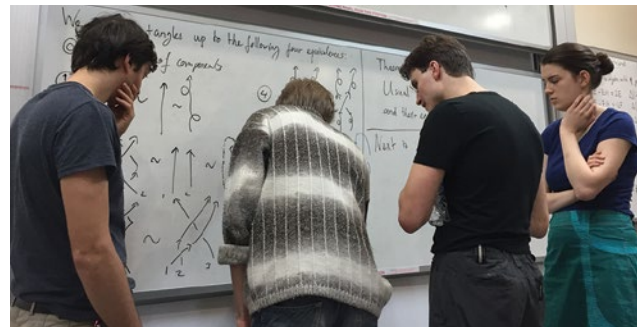
In 2017, MATRIX graciously secured generous donations from The University of Queensland, the University of Technology, Sydney, and a University of Melbourne alumnus, to provide funding for programs that focus on mathematics and statistics.

The Institute continues to attract and secure travel grants for each program with funding received from AMSI, AustMS, APTCP and ANZIAM.

MATRIX looks forward to a busy 2018, with eight programs planned:

- Non-Equilibrium Systems and Special Functions
- Algebraic Geometry, Approximation and Optimisation
- On the Frontiers of High Dimensional Computation
- Month of Mathematical Biology
- Dynamics, Foliations and Geometry in Dimension 3
- Recent Trends on Nonlinear PDEs of Elliptic and Parabolic Type
- Functional Data Analysis and Beyond
- Geometric and Categorical Representation Theory

Further information on Matrix programs can be found at: <https://www.matrix-inst.org.au/>



*Program participants in 2016*



*This unusual 12-sided 'summing die' is in the shape of hexagonal trapezohedron – a polyhedron where every face is in the shape of a kite. A summing die is one that, when rolled, has two sides face-up instead of one; to work what the roll is the values on those two faces are added together. This die was created by Anita Poinsoing for the Geometric R-Matrices Workshop*



# STAKEHOLDER ENGAGEMENT

## IN 2017 THE ACEMS' STAKEHOLDER ENGAGEMENT PROGRAM STRENGTHENED AND BROADENED ITS RELATIONSHIPS WITH ITS PARTNER ORGANISATIONS (PO) AND INDUSTRY AFFILIATE MEMBERS (IAM).

The ACEMS partnership network which has enabled collaboration with a broad array of organisations has been instrumental in projects of international significance. The Industry Affiliate Program, launched in 2016, enabled ACEMS researchers to connect and work with industry partners through short term projects.

Over the last 12 months ACEMS has implemented initiatives aimed at connecting our partners and collaborators to the wider ACEMS cohort, as well as to each other, to expand and develop initiatives and knowledge in the mathematical and statistical sciences. The Centre has provided 14 briefings to government, industry and stakeholder groups; three collaborative research workshops; and welcomed three new organisations as IAMs: the Defence Science and Technology Group, the

Queensland Academy of Sport, and the Bureau of Meteorology. Further reports on activities with our POs and IAMs: can be seen throughout this section.

ACEMS knows that industry and external stakeholder engagement is increasingly important in the current research environment, and is dedicated to ensuring that the experience these organisations have with ACEMS is productive and valuable. In the mathematical sciences, research engagement and translation have huge potential to produce innovative technologies, optimise processes and systems, quantify evidence, and model and predict future events. The mathematical sciences have unparalleled potential to significantly impact the bottom line and effectiveness of industry, government and applied research entities.

### STAKEHOLDER ENGAGEMENT AT ACEMS

ACEMS highly values the perspectives and opportunities our POs and IAMs bring to our research. An important driving force behind ACEMS' growth is the relationships we have fostered with our partners and the relationships established under the new Industry Affiliate Program.

### PARTNER ORGANISATIONS

2017 has seen ACEMS POs continue to be actively engaged, exploring new collaborations and research opportunities.

The Centre's POs include:

- AT&T Labs
- Australian Bureau of Statistics (ABS)
- Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Australian Institute of Marine Science (AIMS)
- Mathematics of Information and Technology and Complex Systems (Mitacs)
- Roads Corporation of Victoria (VicRoads)
- Sax Institute



## AT&T

In 2017, ACEMS continued to work with AT&T to address mathematical challenges in network management and security. Despite the importance of the telecommunications network to our everyday lives, traditional network management is still a complex art form. Network operators use a combination of 'gut feeling', and 'experience' to troubleshoot and fix problems in a somewhat ad hoc way. Therefore, AT&T has an interest in developing more automated and systematic processes to manage their networks, and have enlisted ACEMS academics to work out how best to systematise their networks using advanced mathematics. Using linked data, the collaborative teams will be able to detect, prevent or minimise the impact of poorly

constructed network systems. Collaborating with the expertise of ACEMS academics, AT&T Labs will be able to investigate and identify novel techniques to allow network operators to ensure network safety and security.

*"AT&T Labs has had a long history of support for mathematical and statistical research. In particular, modern telecommunications networks are an artefact that has been built on strong mathematical techniques."*

**Vijay Gopalakrishnan**  
AT&T



## Australian Bureau of Statistics

Throughout 2017 ACEMS was exceptionally active with the ABS, and has continued to build and broaden its collaborations with the organisation. Through its relationship with the ABS, ACEMS has been involved with the UN Global Working Group on Big Data for Official Statistics. PhD student Shovanur Haque has continued her work on Data Linkage with the organisation; and the Centre has explored new collaborative project opportunities and delivered technical training specifically targeted to ABS staff's technical needs.

ACEMS' involvement in the UN Global Working Group on Big Data for Official Statistics has given its researchers the opportunity to further collaborate with the Queensland Government's Department of Science, Information Technology and Innovation (DSITI), Statistics Canada, GeoSciences Australia, and the CSIRO. The working group has developed innovative methodologies for the use of satellite imagery to generate official statistics for the National Statistics Offices. The results of this collaboration were delivered in a Task Team Report, recently published on the UN Website, and through a technical workshop and presentation at the UN Big Data Conference in Bogota, Colombia, in November 2017. The workshop included around 30 representatives from across the globe. An additional workshop is scheduled for Asia in April 2018. This ongoing project has been a collaboration of international standing and has created important tools for government and research organisations globally. See page 126.

The joint PhD project on Data Linkage, undertaken by Shovanur and supervised by CI Kerrie Mengersen, is motivated by a need for efficient and reliable Data Linkage methodologies.

The project utilises pseudo-data from the ABS to enable the development of official statistics in response to opportunities inherent in Big Data.

Beyond these ongoing projects, the Centre has focused on broadening and diversifying collaborations with the ABS through several initiatives. The ACEMS/ABS collaborative research workshop, which was hosted at the ABS office in Canberra in October 2017 was well attended, with 11 ABS staff and 13 ACEMS researchers participating. The workshop participants identified a range of research challenges to focus on in 2018. These discussions continued at the ACEMS Annual Retreat several weeks later, when the ABS team presented their research challenges to the wider ACEMS cohort as part of a special industry collaborators session. The involvement of the ABS staff in the annual ACEMS retreat provided a valuable opportunity for the wider ACEMS community, from research students to senior academics and other industry partners, to come together, network and discuss potential future collaborations and projects.

Complementing these research opportunities, Kerrie and fellow ACEMS Affiliate Member (AM) Miles McBain delivered a 'Machine Learning, Statistics and Big Data' workshop. Designed specifically by ACEMS for ABS staff, the workshop was attended by over 60 ABS employees. Data analytics and big data methods are constantly evolving, and workshops like these are fantastic opportunities to build bridges for knowledge transfer between research institutions and industry organisations. This is a challenge that ACEMS believes is important, as we continually strive to explore new models for industry engagement and knowledge transfer in the mathematical and statistical sciences.

## CSIRO

During 2017 CSIRO and ACEMS have formed collaborations on a number of projects with a standout being the 'Project R Middleware for Immersive Experiments and Visualisations in VR/AR'. This is a proof of concept project, demonstrating how statistical packages can be used as immersive analytics engines. This project, between AM Miles McBain, AI Tomasz Bednarz and CSIRO Project Officer Josh Bowden developed Virtual Reality (VR) and Augmented Reality (AR) middleware, which are computational tools that enable data visualisation and virtual reality to easily interface. They provide a powerful enabling tool for researchers from a wide variety of domains, that due to prior limitations in computer science expertise, would not have previously been able to access the use of VR/AR technologies in their research.

In November, ACEMS and CSIRO along with UNSW, EPICentre, Brisbane SIGGRAPH Chapter, and CSIRO's Data61 co-hosted the Visualisation Matters 2017 conference, in Sydney. The conference attracted more than 160 participants, from various fields of art, science, design, engineering, and maths. The conference hosted two keynote speakers; Pol Jeremias from Pixar and Juan Miguel de Joya from Digital Fish at Facebook. The pair delivered talks about importance of artificial intelligence, maths in computer



graphics, and VR as an empathy machine. The second day featured three workshops: WebGL 2.0, Visual Analytics and Creating Music with RPI. The conference was a huge success with plans for Visualisation Matters 2018 already in train.

Further to this, collaborations continue to be fostered by the CSIRO Visiting Scientist roles held by ACEMS CI Ian Turner, and AI Steve Psaltis, and through the co-supervision of PhD student Kate Saunders by CSIRO scientist Alex Stephenson, ACEMS Director Peter Taylor and the well-known climate scientist David Karoly. Kate has been fitting max-stable processes to climate data collected by the Bureau of Meteorology. She and Alec also collaborated with AI Laleh Tafakori to win the 'Prediction of Spatio-Temporal Extremes' Challenge at the Extreme Value Analysis Conference in Delft.



## Mitacs

Throughout 2017, ACEMS and Mitacs have worked together on the implementation of the Globalink Research Award and Accelerate International student research mobility initiatives. These exciting international exchange programs, managed by Mitacs, will establish connections and relationships between Australian and Canadian research organisations and industry, and provide high quality training opportunities for postgraduate students in both sectors. This is an exciting pathway for not only ACEMS members, but also the wider Australian mathematical and statistical community.

The Globalink Research Award and Globalink Partnerships Award will open up opportunities between Australian and Canada for up to 20 students, yearly. With approximately 50 per cent of students participating in either direction, this bilateral agreement will run for the next three years. Mitacs and ACEMS are committed to working together to expand these mobility programmes in Australia.



## VicRoads

In 2017, ACEMS' collaboration with VicRoads involved three main directions, each of which is forming part of Samithree Rajapaksha's PhD project. The first was a theoretical investigation of calibration methods for simulation models, using approximate Bayesian computation. In principle, these methods are applicable to any simulation model and we have been investigating their use in simple traffic models, as a preliminary step towards studying them in more complex models.

The second direction involved a statistical analysis of the dwell times and boarding/alighting times for trams in the Melbourne network, as well as buses in China. The ultimate goal of this study is to better understand how to model tram dwell times in network simulation models. The results in 2017 suggested that dwell times can be modelled rather well by log normal distributions, with fairly universal parameter values. Based on these promising results, data has been sought to try to understand the correlations between consecutive tram stops.

Finally, the third direction undertaken was a study of VicRoads' DOMINO simulation package. Issues involving licensing and non-disclosure were finally resolved towards the end of the year, and Samithree has begun familiarising herself with the model.

## Australian Institute of Marine Science



In 2017 ACEMS and AIMS continued their work together developing frontier research that advances marine science and, in particular, the conservation and management of the Great Barrier Reef. AIMS' partnership with ACEMS in the past year has taken advantage of new opportunities in the area of coral reef monitoring and decision management to develop policy for maintaining water quality, as well as monitoring and managing the detrimental effects of the Crown of Thorns Starfish. AIMS has the largest long-term dataset for coral reef monitoring in the world, but has limited capacity to integrate alternative data sources into its decision-making tools.

Collaborations between AIMS and ACEMS have built stronger environmental and ecological forecasting models, accounting for climate change, to enable management strategies that will help to sustain a resilient reef system well into the future. New collaborations involving ACEMS Research Fellow Erin Peterson and AI Kate Helmstedt have produced novel ideas to explain how marine ecosystems, and specifically the Great Barrier Reef, should be monitored. This will inform proactive environmental practice and demonstrate when and where a 'trade-off' might be necessary in order to support the resilience of key ecosystem services. By working at the nexus of Big Data, environmental statistics, complex ecosystem modelling and decision science, AIMS and ACEMS are able to advance cross-disciplinary reef science outcomes, and deliver real solutions to enable policy and future management.

One study supervised by Erin analysed the design for coral reef monitoring within the Reef Integrated Monitoring and Reporting Program, a major part of the Reef 2050 Plan. The study describes how a spatial statistical model can be used to form the basis for analyses of coral status and trends, and to guide the design of a coral monitoring program that most effectively captures these dynamics in space and time.

AIMS and ACEMS continue working together to foster high quality postgraduate education. The PhD project of Pubudu Thilan 'Bayesian Adaptive Sampling' has utilised the mathematical and statistical expertise of ACEMS supervisors, including Erin, James McGree and Chris Drovandi. Pubudu presented his outcomes at the biannual Bayes on the Beach Conference in November 2017.

## Sax Institute



In July 2017 the co-funded postdoctoral position between ACEMS and the Sax Institute (40 per cent ACEMS, 60 per cent Sax) held by Joanna Wang and supervised by ACEMS CI Louise Ryan, wrapped up when Joanna was offered an exciting position at the NSW Bureau of Crime Statistics. It is great to see Joanna succeed and move to this position, which is quite senior in the Bureau, however, Joanna's presence in the ACEMS community and at the Sax Institute will be missed.

The co-funded postdoctoral position at the Sax Institute was highly successful and Joanna's work played a major role in providing information, using linked and routinely collected data, and informing key health policy and practice decisions. Impact of her work can be seen in the NSW state-wide integrated health care strategy and state-wide workplace health promotion programs. Similarly, the novel methodological work provided population health researchers with an understanding of the key limitations of using longitudinal data, and helped to develop tools in the assessment and management of these limitations. Joanna has co-authored two key papers with Louise and presented at Macquarie University seminar series in 2017.

The co-funded model was a significant success from the perspective of both ACEMS and the Sax Institute, and both partners are in discussion about continuing the format.

*"The co-funded postdoctoral position has addressed the need for skilled statistical support within the Sax Institute. The structure of a co-funded position, supervised by ACEMS CI Professor Louise Ryan from UTS, enabled the Sax Institute to attract higher calibre applicants than would have otherwise been possible."*

### Mark Bartlett

ACEMS Partner Investigator  
Manager, Analysis for Policy Program  
The Sax Institute



## ENGAGEMENT

The mathematical and statistical sciences have the potential to provide significant value to Australian industry and other end-users. Whether it is innovating technologies such as modelling bitcoin chains; optimising processes like reducing donor wait times for the Red Cross Blood Service; understanding systems and patterns such as differences in cancer incidence and survival rates across Queensland in collaboration with the Cancer Council Queensland; or predicting future events such as extreme weather patterns, mathematics and statistics have the potential to guide better decision making in government, improve business efficiencies and profits, and advance research methods within other disciplines.

However, challenges exist in connecting expertise within mathematical and statistical departments to industry and end-users. This is where ACEMS can play a leading role, working with industry partners to link the expertise within the Centre to problems in the real world. The Centre's activity is clearly seen in the 14 briefings to industry affiliates or other end-users conducted in 2017, and the nine collaborative projects with new partners that emerged from these briefings.

## BRIEFINGS

ACEMS conducted 16 briefings to the following government, industry and stakeholder groups in 2017:

- Woodside\*
- Cloudera
- Data to Decision CRC\*
- Bushfire and Natural Hazards CRC
- GHD Australia
- Department of Agriculture and Fisheries\*
- Bureau of Meteorology\*
- Mitsubishi
- STEM Network
- Cotton Research and Development Corporation\*
- Healthy Land & Water \*
- Queensland Public Service Association\*
- Brisbane Airport Corporation\*
- Defence Science Technology Group– Joint & Operations Analysis Division (DST Group)\*
- Australian Institute of Sport (AIS)
- Queensland Academy of Sport (QAS)\*

\*indicates briefings that progressed to collaboration

## INDUSTRY AFFILIATE PROGRAM

The Industry Affiliate Program affords industry, as well as philanthropic and government organisations, the opportunity to experience the value a relationship with ACEMS can offer without them being formally added as POs to the Centre. It has facilitated the establishment of a number of longer term, mutually beneficial partnerships.

ACEMS' Industry Affiliate Members are:

- Bureau of Meteorology (BOM)
- Defence Science Technology Group, Arms & Combat Unit (DST Group)
- Cancer Council Queensland (CCQ)
- Red Cross Blood Service
- Australian Institute of Sport (AIS)
- Queensland Academy of Sport (QAS)
- Australian Taxation Office (ATO)
- Hwashen Electronics

The program provides a way for new collaborators to engage with the ACEMS community in a flexible manner, the goal being to develop and establish key partnerships and working relationships with the Centre. IAMs engage with the Centre through a range of initiatives, including secondments, vacation research experience projects, collaborative research projects and workshops, training workshops, social and professional networking events and attendance at the ACEMS Annual Retreat and other network events.

In 2017 ACEMS welcomed the Australian Bureau of Meteorology and the DST Group's Arms and Combat Unit as new IAMs. This program is allowing ACEMS to reach and engage a wider section of the community than could have been possible at its inception. ACEMS is dedicated to growing the program well into its future.



**Australian Government**  
**Bureau of Meteorology**

## Bureau of Meteorology

ACEMS welcomed the BOM to the Industry Affiliate Program in August 2017. To begin exploring research projects, 10 ACEMS academics and eight BOM research staff came together in August for a collaborative research workshop to explore methodological challenges and problems within weather science. This vibrant workshop identified a range of potential collaborative research projects, including: the use of satellite remotes sensing data for sampling upper air characteristics; dealing with non-normality; the use of data assimilation for climate quality control; next generation high quality rainfall datasets; and uncertainty visualisation and communication.



**Australian Government**  
**Department of Defence**  
**Science and Technology**

## Defence Science Technology Group

Building on collaborations that began in 2016, and which explored sensor placement optimisation, the DST Group's Arms & Combat Unit officially joined ACEMS as an IAM in 2017. New research projects in uncertainty quantification have begun, and DST Group's Wayne Power attended the ACEMS Annual Retreat to present on future challenges. ACEMS is looking forward to a rewarding collaboration with the Group in the future.



## Cancer Council Queensland

Although only formally joining the ACEMS Industry Affiliate Program in 2016, CCQ has been an ACEMS collaborator since 2015. ACEMS and CCQ projects are focused around the development of the National Cancer Atlas Project, which is a national study designed to visually demonstrate the extent of geographical variation in cancer screening, incidence and survival across Australia. The project is an extension of the Atlas of Cancer in Queensland published in 2011, and is a collaboration between ACEMS, CCQ, Australian Institute of Health and Wellbeing (AIHW), and the CRC for Spatial Information (CRC SI).



**Australian Red Cross**  
**BLOOD SERVICE**

## Australian Red Cross Blood Service

The primary mechanism of engagement between ACEMS and the Red Cross Blood Service has been the co-funded postdoctoral position held by Stephen Wright, supervised by CI Louise Ryan. This three-year position saw Stephen spend 0.5FTE at the Blood Service supporting core Blood Service research activities and providing in-house biostatistical support. Stephen spent the remaining 0.5FTE at UTS, conducting high quality methodological research driven by problems encountered through his applied work.

This hybrid position, which successfully embedded cutting edge methodological research within a business context, came to completion in October 2017. As a testament to its success, Stephen has transitioned to a permanent position within the Blood Service and will continue to lead collaborative projects with ACEMS.

"I would like to take this opportunity to enthusiastically endorse the value of our partnership with ACEMS. As the official representative of the Australian Red Cross Blood Service for our partnership with ACEMS, I have been very satisfied with the outcomes of the partnerships, both for our business and academically. We look forward to continuing and expanding our work with ACEMS for the duration of the current Funding Agreement and beyond.

*"There are no other mechanisms in Australia that can provide access to the high levels of statistical expertise, with an intent of developing solid groundings in understanding the Blood Service business context. To date, the partnership has been highly successful and we look forward to strengthening the collaboration further."*

### David Irving

Director, Research and Development  
Red Cross Blood Service

Adjunct Professor, University of Technology, Sydney of Health and Wellbeing (AIHW), and the CRC for Spatial Information (CRC SI).

## Australian Institute of Sport and Queensland Academy of Sport

ACEMS' three-party collaboration with AIS and QAS has seen the group exploring new research collaborations that address current challenges in sports research. The relationship has fostered knowledge transfer from the Centres' applied statistics academics to this passionate field of Australian sports researchers.



**Queensland Government**

Supported by the Queensland Academy of Sport

In 2017, the Centre hosted the first of an ongoing collaborative research seminar series in sports statistics that brought together sports and mathematical statistics researchers; the aim of which was to identify new methodological challenges specific to supporting our elite Australian athletes.



**Australian Government**  
**Australian Taxation Office**

## Australian Tax Office

In 2017 the ATO seconded two employees into ACEMS. Jessica Michie and Sarah Hepworth spent six months at the ACEMS QUT node directly developing applied expertise and theoretical knowledge, and honed their data analysis skills working on projects relevant to the core business functions of the ATO.

Under the supervision of CI Kerrie Mengersen, the secondees developed a range of modern case studies that outlined different applications for big data analytics platforms in large Australian organisations; identified research techniques on data linkage, enabling statistical models that include uncertainty parameters; developed a white paper of machine learning techniques to address core business challenges of the ATO; and conducted research into constrained Markov decision processes.

*"Access to the expertise within ACEMS has been a highly valuable resource for rapidly investigating and selecting appropriate techniques that can meet the ATO's needs, and have enabled me to gain a deeper understanding of the technical and applied aspects of pertinent statistical methods."*

**Jessica Ross**

Australian Tax Office  
(ACEMS Secondee)

*"One highly valuable aspect of the partnership with ACEMS was the ability to tap into the expertise across its network, and beyond the QUT node where we were placed."*

**Sarah Hepworth**

Australian Tax Office  
(ACEMS Secondee)



**华神**  
**HWASHEN**

## Hwashen Electronics

ACEMS AI Hongbo Xie joined forces with Hwashen Electronics to develop a novel filter for statistical learning and fuzzy logic in biomedical signal, image and speech applications. In 2017 Hwashen received CN¥500,000 funding from Danyan City, Jiangsu Province, China, to industrialise this technique in a microchip application. Hongbo visited Hwashen Electronics in November 2017.

## BROADENING RELATIONSHIPS WITH INDUSTRY COLLABORATORS

In 2017 ACEMS invited all Partner Organisation and Industry Affiliate Program members to the ACEMS Annual Retreat. This proved to be a great success, giving the ACEMS community as a whole an opportunity to understand the challenges industry and government face on a day-to-day basis. It also gave ACEMS students and early career researchers the opportunity to network with professionals from industry, and offered ACEMS members, who had not yet been provided an opportunity to engage and work with industry, the chance to explore potential collaborations and build relationships in an informal context.

In attendance were: DST Group's Arms & Combat Unit and Joint & Operations Analysis Division; QAS; BOM; and ABS. The initiative, which the Centre will continue to adopt in the future, was a huge success.



Mapping problems at the ABS/ACEMS collaborative workshop



Attendees at the ABS/ACEMS collaborative workshop in October 2017

## BUILDING CONNECTIONS BETWEEN INDUSTRY COLLABORATORS

ACEMS is focused on addressing problems and research challenges at the frontiers of mathematics and statistics. In 2017 ACEMS invested in bringing together the Centre's industry collaborators with the aim of identifying frontier challenges common to each of them. Such questions are not easy to determine so ACEMS took advantage of two occasions: a partners' meeting for the mid-term review and a partners' lunch during the Annual Retreat. Sharing experiences and knowledge around mathematical, statistical and data related challenges gave ACEMS CIs a unique opportunity to better understand how the engagement relationship can work for pure and applied research. The methodological challenges that multiple partners are facing were identified and discussed, and the Centre looks forward to exploring these further in 2018. More information on the Frontier Questions can be found on [page 74](#).



Maths and Stats in Sports Workshop with QAS in February 2017

## COLLABORATIVE RESEARCH WORKSHOPS

ACEMS collaborative research workshops are important initiatives for working with our industry and government partners. These one day workshops bring together key ACEMS stakeholders and academics to work together and identify potential research pathways, and provide a forum to discuss future collaborations.

In 2017 ACEMS held three collaborative research workshops with our partners. In March ACEMS hosted the Maths and Stats for Sport Research in Brisbane, bringing together members of the Australian sports research community, including participants from the AIS and the QAS. In August, and in collaboration with the BOM, ACEMS hosted a workshop on Statistical Challenges in Climatology in Melbourne. And in October, the Next Generation of Official Statistics Reservation was held in collaboration with the ABS in Canberra.

These workshops have helped build the ACEMS community beyond the academic environment and encouraged cross-nodal collaboration. They are important opportunities for professional development of the Centre's early career researchers and students, providing attendees with access to the real problems faced by industry and demonstrating the difference between industry needs and the academic culture. The workshops also offer early career researchers and students the knowledge and networks to bridge the industry-academia gap, and develop closer and more effective relationships with industry partners.

ORGANISATION	WORKSHOPS TYPE	ACEMS' PARTICIPANTS	COLLABORATORS' PARTICIPANTS
Bureau of Meteorology (BOM)	Collaborative Research Workshop	7	8
Australian Bureau of Statistics (ABS)	Collaborative Research Workshop	13	11
Data to Decision CRC	Science Communication	15	16
All ACEMS Stakeholders, Members, POs and Industry Collaborators (Two Events)	ACEMS Meet & Greet (June) (Networking Event)	38	28
QAS and AIS	Maths & Stats for Sports Research	10	22
ABS, BOM and DST Group.	Industry Presentation at the ACEMS Annual Retreat	~100	7
AMSI and SOUNDelve (local tech start-up)	Career Trajectories: Invited Speaker Presentations + Panel Discussion	~80	
ABS	Machine Learning, Statistics and Big Data	~60	



# BRINGING STUDENTS TO INDUSTRY

IN EARLY 2017, AS PART OF A NEWLY ESTABLISHED WORK INTEGRATED LEARNING PROGRAM, SOME MATHS STUDENTS SPENT FOUR WEEKS AT WOODSIDE'S PERTH HEADQUARTERS WORKING ON CHALLENGES FACED BY AUSTRALIA'S LARGEST INDEPENDENT OIL AND GAS COMPANY. WOODSIDE HAS EMBRACED DATA SCIENCE AS THE KEY TO UNLOCKING MORE THAN 30 YEARS OF COLLECTIVE ORGANISATIONAL INTELLIGENCE, USING THE METHODS TO DERIVE INSIGHTS TO IMPROVE DECISION MAKING AND DELIVER REAL-TIME OPTIMISATION.



*Images supplied by Woodside*

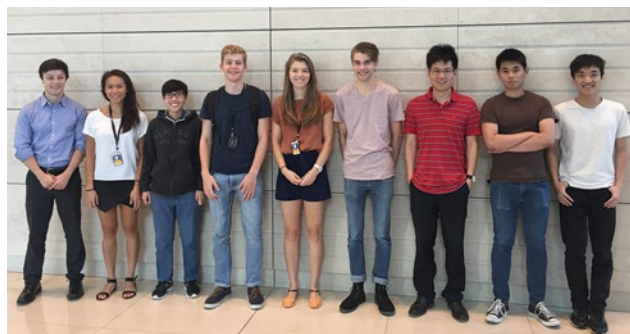
The nine maths students from undergraduate to Masters level from four ACEMS universities were organised into three teams and spent from mid-January to mid-February 2017 analysing and unravelling the huge amounts of data the company generates. When it comes to Woodside's production facilities, it is rich in data – streaming more than 2000 records per second from its operating assets, equating to more than 10 GB per day.

The students worked closely with the Woodside Data Science team, says Caitlin Gray, who started in 2017 as an ACEMS PhD student at The University of Adelaide.

“We were given a massive data set. Although we did not go out to the plant, we had access to data scientists and process engineers who could provide the context. But the company was more interested in an outsider's perspective of ‘What can you



*Students participating in the Work Integrated Learning Initiative at Woodside*



*Images supplied by Woodside*

tell us, just from this data'. And we identified links and connections which confirmed and advanced hypotheses held within the organisation," Caitlyn says.

"At university, it's often hard to see where maths can take you, so it was great to see the power of data science in the oil and gas industry. Also, at university, you just don't get data sets of such size, and problems of such an open nature. With these kinds of industry problems, there's often no 'right' answer, and no-one to tell you if it's right or wrong. There could be no solution, one solution or potentially 10 solutions, and you've got to figure out what's true. It's a big learning curve — challenging, but very exciting."

The company has been able to build on the results of the students work and expect to use it in commercial decisions to improve the efficiency of the plant's operations. At the same time, the students found out what real-world industry application has to offer.

This bespoke mathematical sciences Work Integrated Learning Program, led by Nigel Bean, ACEMS Deputy Director and Chief Investigator from The University of Adelaide, is part of an industry-driven initiative to help address the shortage of employable mathematicians in Australia and internationally. The aim is to improve the development of the skills that industry needs, particularly the ability to structure and tackle the kind of hard, open problems that industry constantly needs to solve, often involving large amounts of 'messy' data.

The initiative has an engine-room of ACEMS personnel — Nigel, ACEMS Director, Peter Taylor from The University of Melbourne, Chief Investigators Ian Turner from the Queensland University of Technology and Kate Smith-Miles from The University of Melbourne, and Affiliate Dr Mark Lawrence, Chair of the initiative.

The other major stream of work is to change the general attitude to maths in schools and the community, in part by establishing a national awareness program about the

rapidly increasing demand in industry for mathematical skills and also by gaining broad commitment and support for maths at the senior levels of government and industry.

Building on the success of the pilot, the program has expanded for the 2017-18 summer. Commonwealth Bank of Australia and PayPal Australia joined with Woodside to host maths students. 65 students from 12 universities applied for internships of between six and eight weeks and 18 students were selected from 10 universities in five states.

Three of those students started work with PayPal Australia on 4 December 2017, investigating their merchant data to see which of the PayPal products were likely to drive growth for those merchants in each industry segment. We await the exciting outcomes of their work, and those of the students at Woodside and Commonwealth Bank of Australia, in mid-February 2018.



*Images supplied by Woodside*



# COMMERCIALISATION AND TECHNOLOGY TRANSFER

COMMERCIALISATION IS THE PROCESS OF DEVELOPING A NEW PRODUCT, IDEA OR SERVICE AND INTRODUCING IT INTO THE MARKET THROUGH THE PROCESS OF TECHNOLOGY TRANSFER.

When done effectively, technology transfer allows universities to ensure that public investment in science is impactful. It enhances economic development and serves public interest. University technology transfer must enhance teaching and learning, and research and discovery, as well as contribute to economic and societal outcomes that help advance the national interest and improve quality of life.

ACEMS plays a leading role in university research commercialisation and technology transfer (CTT) in the following three ways:

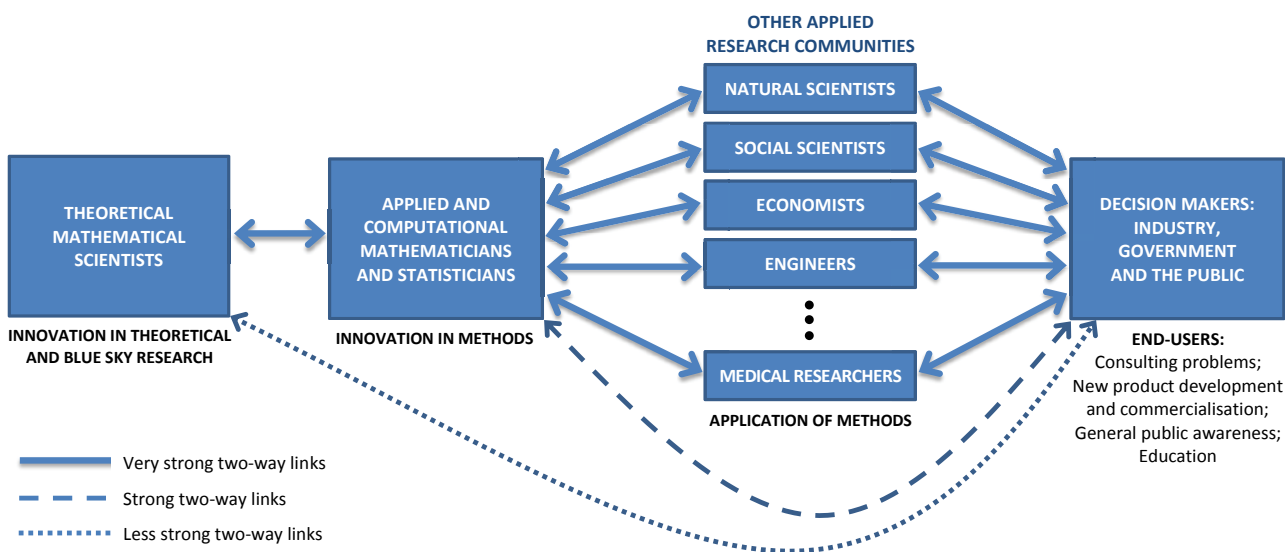
## LEADERSHIP

CTT of research outcomes is an increasingly important topic for all universities. Driven by impending changes around impact and engagement requirements from government funding bodies, there is much discussion about how CTT is to be achieved in the mathematical and statistical sciences. ACEMS continues to play a leading role in these discussions by bringing together key stakeholders that can contribute to the discipline cohesively moving forward in this area.

## ACTION

Within ACEMS, CTT is framed in the context of the Pathways to Impact Pipeline (see figure on [page 111](#)). Within this pipeline, there are two mechanisms by which outputs from ACEMS contribute to moving technology towards the marketplace: direct development of new technologies consumed by a 'market' (for example, the development of new R packages and statistical methods); and the provision of technical solutions to developing technologies in industry (the optimisation of fuel cell design, or better understanding distribution and testing methods, for example). New mathematics can be used to





Linear model of the research process

efficiently achieve complicated optimisation solutions, and new statistical methods can be developed to estimate consumption and efficiency parameters.

While the research at ACEMS falls mainly into the latter category of consulting and helping stakeholders to better understand their systems, it continues to push frontiers for new and innovative processes. Models and systems in the process of being developed could see our researchers laying the groundwork for dramatic changes in the way society and people interact.

## TRAINING

With the increasing emphasis on impact, and acknowledging the changing landscape of university funding as well as industry employment, we believe that it is important to provide our members with exposure to CTT concepts. In 2017 ACEMS provided new opportunities to enhance knowledge in this area. Intellectual property and commercialisation workshops

were held at the Annual Retreats, which included special guest lectures from successful entrepreneurs. Dr John Vial, founder of the Brisbane-based technology start-up SOUNDelve spoke to the ACEMS cohort about his personal journey from a research position at CSIRO to founder of his own venture, detailing the lessons learnt along the way. Highlighting real world examples of mathematicians and statisticians managing to crack the code of research CTT shows our early career researchers, in particular, that such pathways are open to them.



# ACEMS OUTREACH PROJECTS

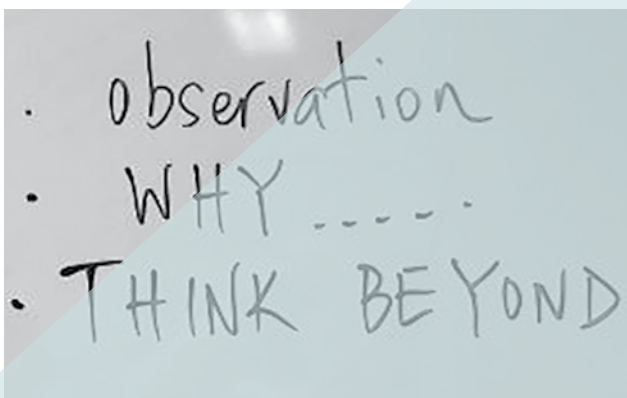
ACEMS MEMBERS ARE CONSTANTLY ENGAGING WITH THE PUBLIC THROUGH A WIDE VARIETY OF AVENUES. ACEMS IS A WELCOMING MATHEMATICAL COMMUNITY AND ITS MEMBERS ARE ALWAYS LOOKING TO ENGAGE THE PUBLIC, SCHOOL STUDENTS AND THE WIDER MATHEMATICAL COMMUNITY IN MATHS INSPIRED EVENTS. JUST CHECK OUT ALL OF THE EVENTS AND ACTIVITIES WE HAVE BEEN INVOLVED IN THROUGHOUT 2017.

## OUTREACH TO SCHOOLS

ACEMS knows how important it is to engage children and get them excited about maths at a young age and is committed to developing the mathematical skills of Australia's future generations. Through programs like Mathscraft and Mathematicians in Schools, ACEMS is opening up these young and bright minds to a world of possibility.

*Students working through problems at Mathscraft sessions*





## MATHSCRAFT – DOING MATHS LIKE A RESEARCH MATHEMATICIAN

ACEMS' flagship outreach program, Mathscraft, was widely successful in 2017. The program consists of a series of workshops for students in Years 5 to 10, which run regularly in each of ACEMS' four node cities, and beyond.

The workshops bring together students and teachers from nearby schools, allowing them to work with mathematicians to solve problems, just as a research mathematician would. The students are encouraged to explore, notice patterns, make conjectures – which can be proven or disproven – figure out why they have arrived at a certain answer, and think of ways to extend the problem.

The Mathscraft program is not just aimed at students, but teachers as well. Mathscraft endeavours to train Australia's maths teachers to think differently, and to not be confined by the 'right answer' in a text book. In November 2016 ACEMS ran its first session leader workshop, which was attended by 17 teachers from Brisbane, Sydney, Adelaide and Melbourne. This year those very same teachers ran Mathscraft workshops for local schools in their areas, and word has been spreading.

At least 15 workshops took place in 2017, attended by approximately 300 students (Years 5-10) and 90 teachers from about 70 different schools in Adelaide, Brisbane, Maroochydore, Cairns, Mackay, Sydney and Melbourne.

Two Mathscraft teachers also ran a session at the state finals of the Queensland Association of Mathematics Teachers' Year 7/8 Quiz.

*“With continued support from two donors, the re-boot of a 30+ year tradition has continued. We went from less than 10 attendees at each session to an average of at least 30. The activity is now firmly entrenched under the auspices of UoA.”*

## TEACHING TEACHERS TO DO MATHS LIKE A RESEARCH MATHEMATICIAN

In November, we ran a series of four single-day professional development workshops for maths teachers, with one workshop in each of ACEMS' node cities (Melbourne, Sydney, Brisbane and Adelaide). Putting the teachers through some problems, and talking about the pedagogical and mathematical theory behind them, has given these teachers the skills to take a different approach to teaching maths in the regular classroom. There were 30 teachers in attendance at each event, which were overwhelming in demand – all four events booked out more than a month in advance.

ACEMS Mathscraft was also asked to run a short session at the Queensland Association of Mathematics Teachers' Senior Maths conference held in Brisbane on 24 November.

ACEMS plans to expand and continue Mathscraft's reach throughout the life of the Centre and beyond. In 2018 the plan is to expand professional development offerings even further and to run a number of new workshops throughout the year.

## TEACHER PROFESSIONAL DEVELOPMENT WORKSHOP

In response to a request from Carey Grammar School, the School of Mathematics & Statistics at The University of Melbourne hosted a pilot professional development workshop for teachers on the morning of Monday 17 July, 2017. The event was co-sponsored by the School, ACEMS and the Australian Mathematical Sciences Institute (AMSI). ACEMS COO Emily Duane was one of the organisers of the workshop.

The event was attended by 33 teachers from seven schools, the majority of whom came from Carey Grammar, which organised for their mathematics and computing teachers to attend.

The programme consisted of short talks from academics on mathematical and statistical topics, presentations from AMSI and ACEMS about outreach and career opportunities, and a demonstration of a classroom statistics activity. ACEMS Director Peter Taylor and Outreach Officer Anita Ponsaing were among the six presenters for the morning. Peter gave a talk on the maths of bitcoin, while Anita spoke about the importance of maths in society, as well as ACEMS' outreach program Mathscraft.

Feedback from the teachers was very positive, with calls to run the workshop on a regular basis.



ACEMS Outreach Officer Anita Ponsaing speaking at the Teacher Professional Day



## BRISBANE STATE HIGH SCHOOL VISIT TO QUT

On 23 June 2017, over 200 Brisbane State High School Senior Maths C students visited QUT for a showcase of applied mathematics, statistics and operations research. It was great to see so many keen, budding mathematicians on campus.

A number of talks were delivered by ACEMS members and collaborators, including:

- Jess Michie - A Career in Government with Mathematics and Statistics
- Brodie Lawson - Maths Keeps Me Alive
- Steven Psaltis - An Accidental Mathematician
- Sam Clifford - Machines can do the work so humans have time to think

Even though the event was held on the students' last day of term, there was no lack of excitement!

## MATHEMATICIANS IN SCHOOLS

A number of ACEMS members volunteer for the 'Mathematicians in Schools' program as part of CSIRO's STEM Professionals in Schools scheme. ACEMS is helping to support and grow this program, with some of the Centre's members taking the lead in the Maths sector. Craig Anderson from UTS has been involved for over two years, leading a group of "talented and gifted" Grade 3-5 girls at Loretto Kirribilli in Sydney. Craig attended the school each week to teach them new maths skills.

"Typically, I introduced them to topics and ideas that went a little bit beyond their normal classroom mathematics curriculum. I tried to focus on real life scenarios where mathematical ideas occurred, and I think this helped to keep them engaged every week," says Craig.

"I really enjoyed working with these kids, and was regularly surprised and impressed by their natural aptitude to mathematics. It was refreshing to see their passion and excitement for the subject."

Women are generally under-represented in STEM subjects, and ACEMS is making a point of encouraging young girls across Australia to get into maths. Programs such as Mathematicians in Schools provides a great opportunity for that.

"...this sort of work seemed particularly important to me in terms of encouraging and inspiring talented female students to pursue science, and particularly mathematics and statistics, from an early age," says Craig.

To foster this program, ACEMS has begun collecting resources and experiences from the volunteers, and sharing them around. The aim is for all academics in the program to have access to these shared resources, by creating a year-levelled curriculum database for all volunteers across the program to use. CSIRO will be making these resources available on their website in the future, and this is all thanks to the committed and enthusiastic ACEMS volunteers.

## ADDITIONAL SCHOOL OUTREACH EVENTS AND ACTIVITIES

- AMSI ChooseMATHS mentoring (Lewis Mitchell)
- ChooseMaths student day - QUT visit (Kate Helmstedt)
- Secondary school student mentoring
- Maths Prepared - A briefing given to a group of Heads of Mathematics on industry's strong desire for mathematically-trained workers (Nigel Bean)
- QUT Careers Practitioners Day (Sam Clifford): Speaking with career counsellors, guidance counsellors, QTAC staff and other education system employees about the potentials for a career as a mathematician and statistician, and how careers in maths and stats are no longer solely about number crunching.
- Real World Examples of Statistics for High School Students (Sam Clifford, Jessie Roberts, Kerrie Mengersen, Nick Tierney, and Susanna Cramb): Organised by Dr Peter Howley (School of Mathematical and Physical Sciences/Statistics, The University of Newcastle), ACEMS contributed to a recording of real world examples of statisticians. The short recordings will be used to create a short video for High School Students to give exposure to statistics and encourage them to consider studying statistics in the future. Five ACEMS members at QUT volunteered to be a part of the recording.
- Stats is Awesome (Kerrie Mengersen)
- Saturday Morning Maths (Nigel Bean)
- TSXPO (Nan Ye): Australia's largest tertiary studies expo
- QUT Future Leaders (Sam Clifford)
- School visit to Melbourne Grammar School (Anita Ponsaing)
- QUT Vice Chancellor's STEM Camp (Steven Psaltis and Erin Peterson)
- QUT School Careers and Networking Evening (Erin Peterson)
- Young Women in Technology 'Cryptomath for Beginners' (Matthew Roughan)
- Science Experience 'How to share a secret' (Matthew Roughan)
- Mathematical Association of Victoria Stimulus Camp for rural Year 9 and 10 students, who are gifted or talented in mathematics (Nathan Ross)

*"I participated in the development and lead-up to VC's STEM Camp, where a group of high school students undertake a mathematics project at QUT."* Erin Peterson

Mick Moylan from the School of Chemistry at The University of Melbourne explodes a balloon, for scientific purposes of course!



Top, the Melbourne Panel from left to right: Tom Gleeson, Alice Williamson, Andi Horvath, Michael Fuhrer and Alan Duffy and host, Charlie Pickering.

Below, the Adelaide panel from left to right: Andy Stapleton, Sarah Keenihan, Adam Briggs, Tanya Munro, Alan Cooper, with Charlie Pickering.



## OUTREACH TO THE GENERAL PUBLIC

ACEMS members are passionate about maths and stats, and love having the opportunity to share that passion with others. 2017 was no different and saw ACEMS members holding a range of events to engage the public across Australia.

### THE NATIONAL SCIENCE QUIZ

In 2017 ACEMS extended the successful National Science Quiz, offering two events at the end of June in Melbourne and Adelaide. Charlie Pickering, the host for the second year running quizzed a panel of scientists, science communicators and comedians with a series of curiosity-provoking science questions. In true National Science Quiz form, panellists were required to back up their answers with demonstrations, and luckily not too many explosions, with the help of Mick Moylan from the School of Chemistry at The University of Melbourne, and Dianne Ruka and Errol Hunt from the FLEET Centre of Excellence.

The events were held at Camberwell Grammar School (Melbourne) and Prince Alfred College (Adelaide), and were attended by approximately 750 people, aged from 8 to 80.

The National Science Quiz 2017 was co-sponsored by the School of Mathematics and Statistics at The University of Melbourne, the Centre of Excellence for Biosecurity Risk Analysis (CEBRA), and the Monash Centre for Atomically Thin Materials (MCATM), along with six other ARC Centres of Excellence: the ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav), the ARC Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET), the ARC Centre of Excellence for All-sky Astrophysics (CAASTRO), the ARC Centre of Excellence for Climate System Science (ARCCSS), the ARC Centre of Excellence in Exciton Science, and the ARC Centre of Excellence for Australian Biodiversity and Heritage (CABAH).

Special thanks goes to all our panellists at the NSQ events:

#### Melbourne

Alan Duffy  
Alice Williamson  
Andi Horvath  
Michael Fuhrer  
Tom Gleeson

#### Adelaide

Adam Briggs  
Alan Cooper  
Andy Stapleton  
Sarah Keenihan  
Tanya Munro





ACEMS AI Anthony Mays at the 'Maths Arcade' National Science Week event 2017

ACEMS COO Emily Duane at 'Maths Arcade'



## NATIONAL SCIENCE WEEK

As to be expected, ACEMS was heavily involved in the 2017 National Science Week (11-20 August). University of Melbourne AI Anthony Mays ran a number of events, including a demonstration of his now-famous Mathematics of Juggling show at Melbourne's 'Market of the Mind' organised by Re-science, as well as showing off his mathematical (juggling) skills at the Lunchtime Carnival of The University of Melbourne's Science Festival. Never to be outdone Anthony also gave a public talk on 'Really Big Numbers' at The University of Melbourne event, drawing an audience of 100 people aged 6 to 60.

In addition, the Maths Arcade made a comeback at the Melbourne Science Festival, with a continuous stream of visitors coming to play maths-themed arcade style computer games. Visitors were able to try out the virtual reality programs developed by the ACEMS research team led by CI Kerrie Mengersen.

*“I organised and ran a maths stall at this large engineering, computer and mathematical sciences event held at Adelaide Convention Centre for high schools and members of the public.”* **Lewis Mitchell**

## ADDITIONAL PUBLIC OUTREACH EVENTS AND ACTIVITIES

- Sponsoring Melbourne Maths and Science Meetup
- Open Access Bazaar (Ben Fitzpatrick and Anthony Ebert)
- 'Mendelssohn Salon 1828' public talk and concert, by Arun Ram and Michael Leslie (Anita Ponsaing)
- Fresh Science – pub night and schools' forum (Lewis Mitchell)
- Involvement in university Open Days: Monash (Kate Smith-Miles, Rob Hyndman, Dianne Cook, George Athanasopoulos and Gael Martin), QUT (Kate Helmstedt), UoA (Lewis Mitchell and Dinesha Ranathunga), UoM (Jan de Gier and Anthony Mays), Swinburne (Nathan Clisby)
- Ingenuity at Faculty of Engineering, Computer and Mathematical Sciences, University of Adelaide
- Big Data MOOC (Steven Psaltis and Ian Turner)

*“This was the third run of the FutureLearn MOOC on Big Data Analytics - mathematical modelling”*



*CI Kerrie Mengersen using the VR headsets to revisit the Peruvian jungle.*



*ACEMS Stakeholder Engagement Officer Jessie Roberts and partner with the drone and high tech equipment used in the Jaguar project.*



*Attendees at the World Science Festival Brisbane*

## WORLD SCIENCE FESTIVAL – BRISABANE

The World Science Festival – founded by renowned Physicist Professor Brian Greene and Emmy award-winning journalist Tracy Day – has been held annually in New York for a decade. In 2016 the Queensland Museum Network secured the exclusive licence to host World Science Festival in the Asia Pacific from 2016-21. ACEMS is proud to have been a part of this dynamic and popular science program in 2017.

World Science Festival explores and celebrates the entanglement of science and art through a curated program of thought-provoking conversations, inspiring theatrical and cinematic experiences, interactive workshops and engaging demonstrations. The ACEMS project ‘Seeing Through Many Eyes’ was part of this exciting program in 2017, and took participants on a virtual reality tour of Jaguar habitats in Peru using VR. This interactive project was however more than just a gimmicky visual adventure. ‘Seeing Through Many Eyes’ brings together virtual reality, statistical modelling, environmental conservation and community engagement to inform better conservation and habitat planning for local jaguar populations. The exhibition had over 200 visitors explore the virtual environments and learn about statistical modelling and how it can change the world.



“The panel session and social event highlighted the contribution of women in mathematical sciences.”

Kerrie Mengersen

## OUTREACH TO THE MATHEMATICAL SCIENCES RESEARCH COMMUNITY

ACEMS is committed to being a leader in the mathematical and statistical sciences community and is particularly focused on developing and encouraging up and coming researchers and promoting equity and diversity.

### 2017 ACEMS 'SAMPLING & EXPLORATION COMPETITION'

Run by CI Dirk Kroese and AI Radislav Vaisman at UQ, this competition invited mathematical sciences students and postdocs from all over the world to tackle 'Frida's Eggs' problem.

Frida has laid too many of her eggs on a surface, and needs to remove some of them (without moving the remaining ones) so that none of the eggs overlap. The goal is to write some code to remove certain eggs so that the remaining eggs cover as much area as possible.

The competition was open to individuals and teams, and received high quality submissions from across ACEMS. First place was awarded to Tim Hyndman (UoM) in the student competition and Sarat Babu Moka (UQ) in the postdoc competition. Awardees were presented their awards and cash prizes at the ACEMS Annual Retreat.

### INTERNATIONAL WOMEN'S DAY EVENT – THE UNIVERSITY OF MELBOURNE

In 2015, the School of Mathematics and Statistics initiated a controversial move and advertised three female-only academic positions. This highly-publicised decision was made in an attempt to address the male-dominated nature of the mathematical sciences. For International Women's Day (8 March), ACEMS PhD student Kate Saunders organised a panel discussion and Q&A, with the aim of bringing to light some of the gender issues that drove this hiring decision, discussing legalities and giving people the opportunity to ask questions.

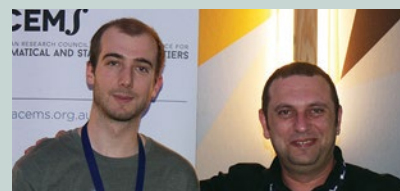
The panel consisted of Professor Aleks Owczarek (Head of School at the time of the decision), Professor Kerry Landman, ACEMS AI Dr Sophie Hautphenne and Dr Jennifer Flegg.

ACEMS is taking gender inequality in the mathematical sciences extremely seriously and is dedicated to opening these lines of discussion to help encourage more women into this field.

### HIGHLIGHTS

The ACEMS 2017 'Sampling & Exploration' Competition winners were announced and presented with their awards and cash prizes at the Annual Retreat.

First place was awarded to Tim Hyndman (UoM) in the student competition and Sarat Moka (UQ) taking out the postdoc competition.



### ADDITIONAL MATHEMATICAL SCIENCES OUTREACH EVENTS

- Organised Simon Tavaré public lecture for the Launch of Melbourne Integrative Genomics (Jan de Gier)
- Women in Mathematical Sciences - AMSI 2017 (Kerrie Mengersen)
- Guest speaker at the Women's College valedictory dinner (Kerrie Mengersen)

ACEMS members participating in an International Women's Day Event at The University of Melbourne, from left to right: Alison Harcourt, ACEMS CI Jan de Gier, ACEMS AI Sophie Hautphenne, Jennifer Flegg, Deputy Dean of Science at The University of Melbourne, Aleks Owczarek, First female Professor of Mathematics at The University of Melbourne, Kerry Landman, ACEMS PhD Student Kate Saunders and ACEMS Director Peter Taylor





*Associate Professor Maria Vlasίου from Eindhoven University of Technology, Netherlands presents at the AMSI-ANZIAM Public Lecture at The University of Melbourne*

## AMSI-ANZIAM PUBLIC LECTURE

Throughout 2017, ACEMS has continued to engage with its partners in the mathematical and statistical sciences community. In February 2017 ACEMS played a pivotal role in organising the Melbourne leg of the AMSI-ANZIAM Lecture tour which was given by Associate Professor Maria Vlasίου from Eindhoven University of Technology, Netherlands.

Maria's lecture 'Queues on Interacting Networks' was held at The University of Melbourne and attended by up to 80 people. Afterwards, a private dinner function was co-hosted by ACEMS and AMSI and was attended by ACEMS Associate Investigators and early career researchers, as well as senior members of AMSI.

The dinner provided for valuable interaction between some of ACEMS' early career researchers, such as Ellen Muir and Laleh Tafakori and senior members of the mathematical sciences community such as Maria, AMSI Director, Geoff Prince (pictured with ACEMS Director, Peter Taylor), and Executive Director for the AMSI Choose Maths program, Inge Koch.



*Professor Ruth Williams speaks with female mentees at The University of Melbourne*



*Left to right, AMSI Director Geoff Prince, Associate Professor Maria Vlasίου and ACEMS Director Peter Taylor*

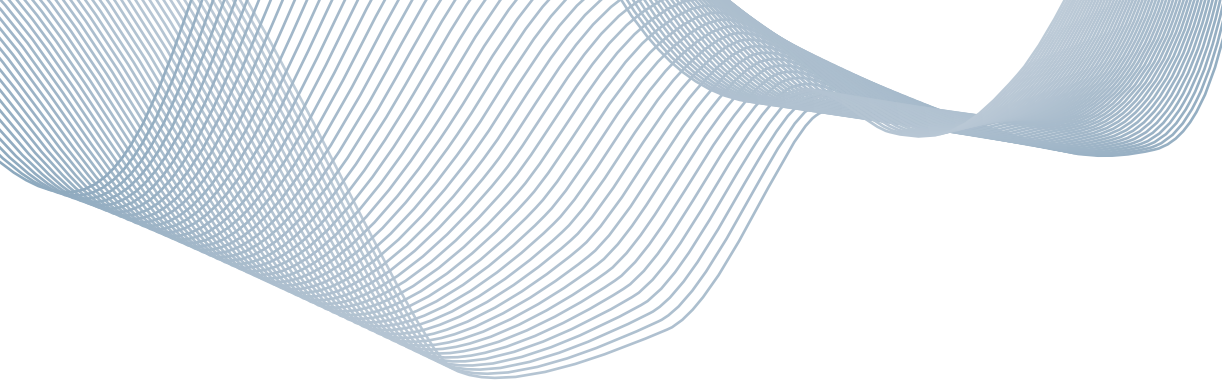
## RUTH WILLIAMS LUNCH

Distinguished Professor Ruth Williams of the University of California, San Diego and member of the ACEMS Scientific Advisory Board, visited The University of Melbourne and Monash nodes in March-April 2017. ACEMS was proud to organise an informal luncheon on Ruth's behalf, during her time here, for all female students and academics of the School of Mathematics and Statistics at The University of Melbourne.

The luncheon was held at University House on Professors Walk on 5 April 2017 and was very well attended, primarily by students and early career researchers, with a total of 30 attendees. The lunch was a great opportunity for our junior (and not so junior) female researchers to meet and be inspired by the path that Ruth has travelled as an academic mathematician.

Encouraging women of all ages into STEM subjects and careers is a core commitment of ACEMS and we were lucky to have Ruth here in Melbourne to visit. ACEMS hopes to hold more events like these in the future with more inspiring female mathematicians and statisticians.

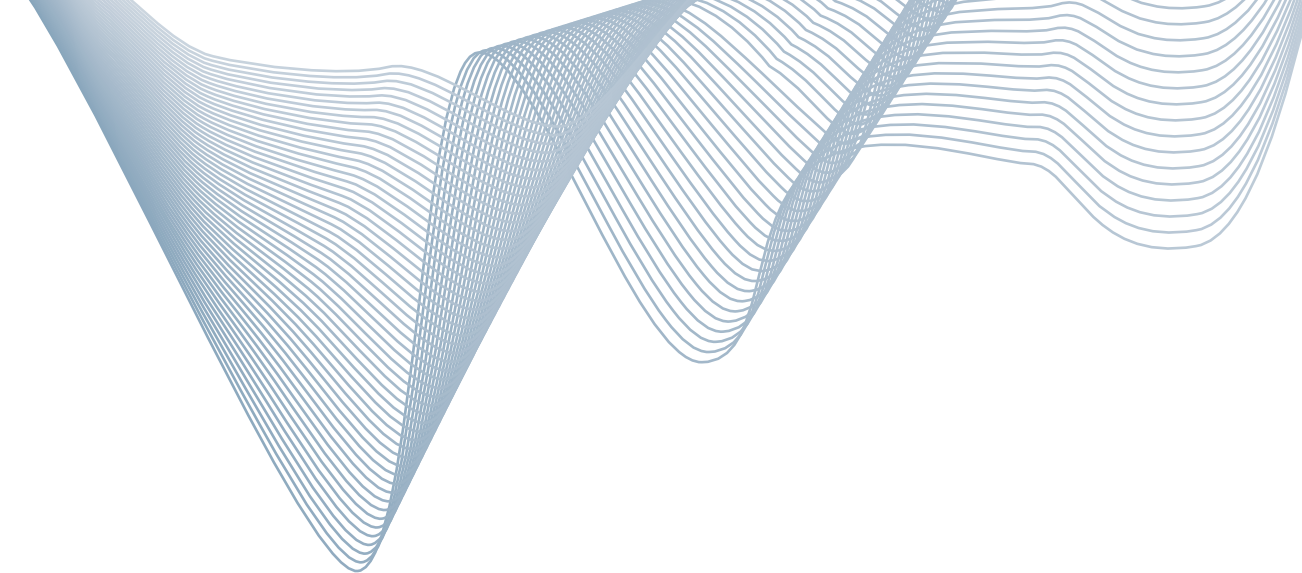




## PUBLIC TALKS

ACEMS has well exceeded its 2017 target of 15 talks given by the Centre staff open to the public. Centre members delivered 50 presentations that were open to the public to attend, including some talks that were repeated in multiple locations. These presentations are summarised below.

MEMBER	TITLE	LOCATION
Tomasz Bednarz	Art of real time and collision of cultures - Expanded perception and interaction	Singapore (Singapore)
Tomasz Bednarz	CG in Australasia: developing links between industry and higher education in CG	Los Angeles (USA)
Tomasz Bednarz, Kerrie Mengersen	AMSI Summer School - Mathematics and statistics of big data	Sydney
Tomasz Bednarz	Data visualization tutorial - Collision of cultures	Sydney
Tomasz Bednarz	Girls in STEM	Bangkok (Thailand)
Tomasz Bednarz	Immersive visualisation for science, research and art	Los Angeles (USA)
Tomasz Bednarz	Live-drawing with Code	Paddington
Boris Beranger	First steps in the analysis of symbolic data	Melbourne
James Brown	Introduction to multilevel modelling for repeated measures data	Canberra
Wilson Chen	On the sampling problem for kernel quadrature	Sydney
Aurore Delaigle	Analysing fragments of functional data	Sydney
Aurore Delaigle	Analyzing partially observed functional data	Paris (France)
Aurore Delaigle	Classification and clustering of functional data using projections	Lausanne (Switzerland)
Aurore Delaigle	Deconvolution when the error distribution is unknown	Brisbane
Kate Helmstedt	Making better decisions for conservation ecology	Brisbane
Kate Helmstedt	Using maths to improve decisions for ecological management	Brisbane
Arthur Hung	Meta analysis for growth velocity and diarrhoea	Brisbane
Sarah James	DNA sequence estimation using alignment and quality data	Adelaide
Daniel Kennedy	A Bayesian model-based approach to finding cell-type level associations in heterogeneous methylation samples	Cambridge (UK) and Oxford (UK)
Je Guk Kim	Data-driven optimal decision making via stochastic programming	Brisbane
Dirk Kroese	Counting by stochastic enumeration	Enschede (Netherlands) and Sydney
Kerrie Mengersen	Bayesian statistics and big data	Marseilles (France)
Kerrie Mengersen	How to be Bayesian in the big data era	Canberra
Kerrie Mengersen	Statistics and virtual reality	Brisbane
Kerrie Mengersen	Telling stories with maths and stats	Spring Hill
Kerrie Mengersen	Women in statistics	Sydney
Lewis Mitchell	Information flow in social media	Sydney
Chris Oates	Bayesian probabilistic numerical computation	Sydney
Brendan Patch	Detecting Markov chain instability: A Monte Carlo approach	Amsterdam (Netherlands) and New York (USA)



MEMBER	TITLE	LOCATION
Alan Pearce	Using R as a GIS - A crash course in open-source cartography and geoprocessing	Brisbane
Anita Ponsaing	Mathscraft - Doing Maths like a Research Mathematician	Newcastle
Thomas Quella	From the indistinguishability of particles to topological quantum computation	Melbourne
Jessie Roberts, Anthony Ebert, Benjamin Fitzpatrick	Open Access Week: Open data and software	Brisbane
Leonardo Rojas-Nandayapa	Applied probability and extremes	Exeter (UK)
Leonardo Rojas-Nandayapa	Fitting phase-type scale mixtures to heavy-tailed risks	Amsterdam (Netherlands), Brisbane and London (UK)
Leonardo Rojas-Nandayapa	Monte Carlo simulation and insurance risk	London (UK)
Nathan Ross	Comparing exponential and Erdos-Renyi random graphs, and a general bound on the distance between Bernoulli random vectors	Newark (USA), Princeton (USA) and Cambridge (USA)
Louise Ryan	But I'm a data scientist too, aren't I?	Seoul (South Korea), Washington (USA) and Sydney
Scott Sisson	AMSI Summer School - Bayesian inference and computation	Sydney
Kate Smith-Miles	Annual Alan Tayer Applied Mathematics Lecture - Optimization in the Darkness of Uncertainty: When you don't know what you don't know, and what you do know isn't much!	Oxford (UK)
Kate Smith-Miles	Maximising impact through mathematics – And having fun too!	Melbourne (multiple venues)
Kate Smith-Miles	Optimization in the Darkness of Uncertainty: when you don't know what you don't know, and what you do know isn't much!	Warwick (UK), Melbourne and Brisbane (multiple venues)
Kate Smith-Miles	The ARC College of Experts - What I can share with you that might help	Melbourne
Matthew Sutton	Variable selection and dimension reduction methods for Omics datasets	Oxford (UK) and Paris (France)
Matthew Sutton	A unified regularized group PLS algorithm scalable to big data	London (UK)
Ian Turner	Modelling approaches for characterising and simulating transport processes in wood	Melbourne
Tea Espeland Uggen	Automatic classification of post-stroke aphasia by severity	Adelaide
Lele (Joyce) Zhang	A multi-line and multi-cycle skip-stop scheduling problem	Nanjing (China)
Lele (Joyce) Zhang	Modeling traffic disruptions	Hefei (China)
Lele (Joyce) Zhang	Studies of traffic disruption	Hefei (China)

# ACEMS ANNUAL RETREAT

## SURF, SUN, SAND, STATS & MATHS!

The ACEMS Annual Retreat moved to the Gold Coast in 2017, with an added gathering.

In addition to the usual main and student gatherings, a retreat for early career researchers (ECRs) was added to

the week-long program held at the end of October/beginning of November.

The week started with the students and ECRs meeting for their retreats at the Mantra Legends Hotel in Surfer's Paradise.

The student and ECR retreats covered a variety of professional and personal development topics, including media and communications, coding, and career trajectories. The groups also spent time

getting to know each other, looking for possible collaborations they could create moving forward.

The main retreat started mid-week and focused on ACEMS' four main research themes: Challenging Data, Multiscale Models, Enabling Algorithms, and Informed Decisions. Researchers at ACEMS' seven collaborating organisations updated the group about a range of exciting projects taking place in all four themes.

The event included a keynote talk from ACEMS' newest Chief Investigator, Rob Hyndman from Monash University.

"My recent research has centred around developing new tools for handling large collections of time series. This work will be accelerated now that I'm an ACEMS Chief Investigator," says Rob.

The main retreat also featured talks from current industry partners and affiliates, highlighting the types of projects that could use ACEMS' expertise. Speakers included Jason Looker and Wayne Power from DST Group, Jeff Greenhill from the Queensland Academy of Sport, Sybille McKeown from the Australian Bureau of Statistics, and Simon Grainger from the Bureau of Meteorology.

There was also a workshop on intellectual property from Michael McArdle, who is a director of research at QUT.

Following the great success of the 'WIMSIG 2017: Celebration of Women in Australian Mathematical Sciences' conference held in Adelaide during September, Chief Investigator Aurore

*The 2017 ACEMS Annual Retreat was held on the sunny Gold Coast at Mantra Legends Hotel at Surfer's Paradise*



ACEMS members at the Main Retreat discussing the Frontier Questions







Delaigle organised a women's dinner for the final evening of the retreat which was very well attended.

A keynote talk by Professor Michel Mandjes, the Director of NETWORKS in the Netherlands and an ACEMS Scientific Advisory Committee member, closed the retreat.

In all, the retreats proved popular, with more than 120 people attending the main retreat:

- 13 Chief Investigators
- 24 Postdoctoral Research Fellows
- 23 Associate Investigators
- 44 Students
- 7 Professional Staff
- 7 Industry Members
- 2 Governance Advisory Board and Scientific Advisory Committee members, and
- 3 others



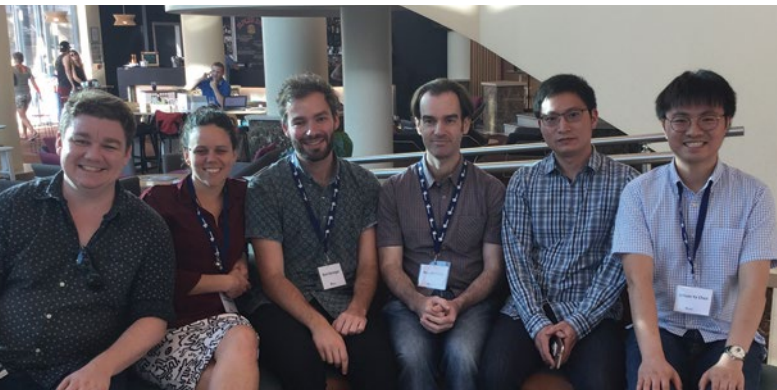
*ACEMS Students practice their coding (top) and playing video games at the Annual Retreat (below)*



*ACEMS members at the 2017 Annual Retreat*



# ACEMS EARLY CAREER RESEARCHER RETREAT



*ACEMS ECR Retreat Organising Committee from left to right: Sam Clifford, Jessie Roberts, Boris Beranger, Ross McVinish, Eric Zhou and Wilson Chen*

- ACEMS CI Aurore Delaigle
- ACEMS Affiliate Member Mark Lawrence, Managing Director of Mark Lawrence Group, a Melbourne-based, global advisory firm specialising in governance, risk management and financial regulation for large financial institutions and corporates.
- John Vial, a former CSIRO researcher and founder of SOUNDelve, a start-up that uses statistical and machine learning techniques to identify problems in industrial machine operations.

Another topic discussed at length was the various challenges faced by ECRs in their current roles, such as teaching and designing teaching materials, supervising HDR students, and preparing for academic job interviews. The group heard from CIs Robert Kohn (UNSW) and Matt Wand (UTS) during one of these sessions, where they shared their experiences, perspectives and advice with the group.

The final theme of the retreat, held jointly with the Student Retreat, was 'building skills around modern computing and collaborative platforms'. The group had a session on collaborative coding and version control with GitHub. It included information on how to bundle code for distribution as a package for R, one of the most popular statistics programming environments. GitHub has an online platform for sharing codes with the rest of the world.

In all, the ECRs tackled a lot of ground in less than three days. The time spent collaborating during the day continued into the evening with social events, comprising a welcome BBQ, a joint BBQ with PhD students (including 'academic speed dating'), dinner outings, socialising at nearby bars and karaoke.

"Despite the variety of research interests and home institutions, the ACEMS ECR retreat made me feel connected to a wider community of people like me. I thoroughly enjoyed the opportunity to explore new ideas and methods with faces I can now put to names," says Sam.

The group believes this ECR retreat was one of the most enjoyable retreats they'd attended, and say it laid the groundwork for future ACEMS gatherings where participation is active by design.

Projects and discussions included:

- Methods for linking and modelling quantitative and qualitative datasets for athlete resilience

## FOR THE FIRST TIME EVER, THE ACEMS RETREAT WEEK INCLUDED AN ACEMS EARLY CAREER RESEARCHER (ECR) RETREAT.

The ECR Retreat, which was held two days immediately prior to the main ACEMS Retreat on the Gold Coast, had a twist. It was run according to the principles of an 'unconference', which minimises formal presentations, and prioritises collaborative projects and sharing expertise and knowledge.

"As one of the organisers, many of the attendees I spoke to said they really enjoyed the new format as a refreshing change from workshops that just feature a series of talks," says Sam Clifford, an ACEMS AI QUT.

The primary focus of the retreat was on collaborations and exploring leading edge research concepts and, in the run-up, the group proposed collaborative projects to work on and discuss.

Early sessions were spent talking about the different types of research the ECRs were involved with so that collaboration opportunities could be identified. A wide variety of projects were included and worked on over the course of the retreat.

"The collaborative nature, enthusiasm and quality of research challenges made me very excited about what the future Australian maths and stats community will achieve in terms of academic work, engaging young people in this field and solving real world problems. I would feel confident putting these emerging academics in front of our industry collaborators," says Jessie Roberts, ACEMS Stakeholder Engagement Officer

Careers were also a significant focus, and the retreat included a session on career trajectories. The speakers for the session were:

# ACEMS STUDENT RETREAT

- Estimation of probability transition parameters based on the behaviour of the agents
- Unsupervised classification / clustering
- Road blocks & solutions for variational bayes
- Time series & spatio temporal road blocks & solutions
- Learn how to make R packages + Using Github
- The egg packing competition
- Continuing an Ozwomen's sports project
- Big data and / or big models
- The landscape of state space models and methods: HMMs, DBNs, etc.
- Challenges faced by early academic researchers
- Managing a coherent policy in large networks
- Making the most of the ACEMS ECR network
- Modelling of spatial extremes
- Ensemble Kalman filter



*ACEMS students participating in one of the new seminars held at the 2017 student retreat*

THE ACEMS STUDENT RETREAT HELD ALONGSIDE THE ECR RETREAT AT THE MANTRA LEGENDS HOTEL IN SURFERS PARADISE HOSTED OVER 45 STUDENTS FROM EACH OF THE ACEMS NODES AND EVEN STUDENTS FROM THE AUSTRALIAN NATIONAL UNIVERSITY AND THE UNIVERSITY OF TASMANIA. FEEDBACK FROM THE STUDENTS WAS VERY POSITIVE, WHO RATED SOME OF THE NEWLY INTRODUCED SESSIONS AS THE MOST USEFUL.

PhD Student Shrupa Shah (UoM) says there were many highlights at this year's retreat.

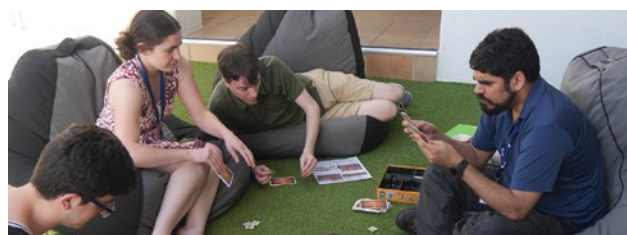
"I got to know loads more people from different nodes because the event was designed as such. I liked the tutorial type workshops run for writing packages in R and submission to Git."

"The variety of things to do at the retreat made it the best retreat I have yet attended and gave us plenty of opportunity to interact with students from other nodes," she says.

The retreat included sessions for meeting and collaborating with other students and ECRs, workshops on giving presentations and communicating research to the general public, a panel session on thesis writing and another on career trajectories (jointly with the ECRs), two sessions for developing coding skills, and a talk by a UQ Student Counsellor on taking care of one's mental health while studying and doing research.

Special thanks goes to the ACEMS Student Retreat organising committee consisting of Masters students Angus Lewis (UoA) and Michelle McGrath (QUT), PhD student Abraham Nasrawi (Monash), CI Tim Garoni (Monash) and Outreach Officer Anita Ponsaing (UoM).

*Playing cards at the ACEMS Retreat*



# ACEMS RESEARCHERS INVOLVED IN UN PROJECT TO BRING SATELLITE DATA TO MANY COUNTRIES

*“ACEMS researchers are working with a team from the United Nations to help countries around the world unlock the valuable information hidden inside satellite imagery data.”*

ACEMS Deputy Director and Chief Investigator Kerrie Mengersen is a member of the UN Task Team on Satellite Imagery and Geospatial Data. “We’re talking about data that can help deal with problems like crop production, the movement of populations, poverty, disease, and threatened species, just to name a few,” says Kerrie.

After a two-year international collaboration, the UN Task Team in December 2017 released a handbook for National Statistical Offices (NSOs) considering using satellite imagery or earth observations data for official statistics. The handbook shows the different types of earth observations data, the sources for it, and how the data produces statistics. Countries can then use this data to gain important insights into issues they’re facing.

“This is a big change for official statistics agencies in many countries. A lot of them don’t have any training, expertise or resources when it comes to this type of data,” says Kerrie. “This report examines questions like, what is observation data, what does satellite data look like and how do we analyse it. Also, how do we store the data and what is its purpose for official statistics?”

In addition to the report, the team held a workshop in November 2017 in Bogota, Colombia, as part of the UN Conference on Big Data. Kerrie was the lead presenter at the workshop.

Jacinta Holloway, who was with the Australian Bureau of Statistics (ABS) and is now with ACEMS, organised and coordinated the UN Task Team meetings and workshop. “The trip to Colombia was hard work but so enjoyable. The participants in the workshop said they found it very helpful and some had plans to implement things they had learned when they went back to their organisations,” she says.

The initial report lays the groundwork for many NSOs. Jacinta

says the UN team will meet again in April 2018, this time in Bangkok. “In the next phase, the group will be developing methods and models for producing these statistics, and sharing them with other organisations.”

“It’s a really rewarding group to work in because you can clearly see how using freely available data sources to gain insights into a country is highly valuable to developing countries that can’t necessarily afford to run surveys to learn more about their people and their environment.”

Dr Siu-Ming Tam, who is Chief Methodologist for ABS, got the team up and running. Siu-Ming got to know some of the ACEMS researchers over the past two years after two joint ABS-ACEMS workshops, and invited them to be a part of the UN Team.

Other members of ACEMS at QUT who were involved in the initial project include James McBroom, Brigitte Colin, Ben Fitzpatrick and Matthew Sutton.



Kerrie Mengersen addressing UN Big Data Conference



From left to right: Kerrie Mengersen, Michael Holt from the Australian Bureau of Statistics and Jacinta Holloway



# EQUITY AND DIVERSITY AT ACEMS



*The Panel at the International Women's Day Debate at The University of Melbourne from left to right: Aleks Owczarek, Kerry Landman, Sophie Hautphenne, Jennifer Flegg and Kate Saunders*



*ACEMS AI Sophie Hautphenne and PhD student Kate Saunders with Jennifer Flegg at the International Women's Day Debate*

## THE ACEMS COMMUNITY IS COGNISANT OF THE STARK GENDER IMBALANCE IN THE MATHEMATICAL SCIENCES, AND WITHIN THE RESEARCH MEMBERSHIP OF THE CENTRE.

Since ACEMS' inception, senior members have worked proactively towards changing the culture within the mathematical sciences community, including initiatives that support and promote equity and diversity across the Centre.

In 2017 one of the objectives of ACEMS' strategic plan was to develop an Equity and Diversity Program which will be overseen and guided by a newly established 'ACEMS Equity and Diversity Committee'. The primary function of this committee will be to develop initiatives to enact the Equity and Diversity Program which includes actions focussed on supporting equity and diversity (including but not limited to gender balance), among ACEMS members; in ACEMS recruitment; in the profession; and in the community at large. The committee will develop policy for implementing flexible and inclusive working environments and arrangements, the establishment of gender and diversity targets for hiring of new staff, the award of new scholarships, and will usher in fundamental changes to the way the Centre operates.

Further, the committee will assess all ACEMS programs and consider the impacts that travel, work hours, conference attendance and ACEMS sponsored events may have on ACEMS members.

ACEMS has developed a comprehensive Code of Conduct that explicitly requires that ACEMS members act in an inclusive, respectful and supportive manner and defines classes of undesirable behaviour that will not be tolerated.

ACEMS plans to be a leader on this issue, not only because it is the right thing to do, but because it makes the mathematical sciences, and research in general, better because of it.

## PROMOTING EQUITY AND DIVERSITY

ACEMS is proactive in its support of women in the mathematical sciences, and STEM in general, and believes that the membership of ACEMS should represent the membership of the wider community. That is why in 2017 ACEMS proudly supported some important initiatives to help promote and encourage a more inclusive culture in the Australian mathematics and statistics community. For more outreach events promoting equity and diversity, see [page 119](#).



# ACEMS PROUD TO PLAY A KEY ROLE IN FIRST-EVER WOMEN IN MATHEMATICS SPECIAL INTEREST GROUP (WIMSIG) CONFERENCE

MATHEMATICS IS, OF COURSE, MORE THAN JUST ABOUT NUMBERS. HOWEVER, ONE NUMBER REALLY STOOD OUT AT A MATHEMATICAL SCIENCES CONFERENCE HELD IN SEPTEMBER 2017 AT THE UNIVERSITY OF ADELAIDE, SOUTH AUSTRALIA: 85 PER CENT OF THE ATTENDEES WERE WOMEN.

Nearly 200 people attended the WIMSIG 2017 Conference: Celebration of Women in Australian Mathematical Sciences. This was the first-ever conference in Australia showcasing the research of women in the mathematical sciences and ACEMS was proud to be a Platinum Sponsor for the event. The conference was organised by WIMSIG, the Women in Mathematics Special Interest Group of the Australian Mathematical Society (AustMS).

ACEMS Chief Investigator Kate Smith-Miles, who is also President of AustMS, was among six other ACEMS CIs attending the inaugural conference, "Women are so used to showing up at a conference and seeing few or no other women there, so it was great to be at a conference surrounded by women," Kate says.

"It was about researchers feeling supported in what they do, finding mentors, having discussions with people about their future plans and how we can all help each other."

ACEMS was strongly represented at the conference with Deputy Director Kerrie Mengersen (QUT) being invited as plenary speaker. In addition to Kate and Kerrie, five other ACEMS CIs attended pictured below from left to right: Aurore Delaigle, Kerrie Mengersen, Nigel Bean, Matt Wand, Kate Smith-Miles and Peter Taylor. (Not pictured: Tim Garoni)

"It was quite unlike any other conference I'd ever been to. The high quality technical and plenary talks were similar to conferences such as the AustMS Annual Meeting. But the feel of the conference was quite distinct. It was more collegial or supportive in some sense," says Tim.

Kate led a panel discussion that looked into the issue of equity and diversity in the mathematical sciences. "People came up to me afterwards and told me the panel discussion was the highlight of the conference for them," says Kate.

The panel included Kerrie, Nalini Joshi and Jacqui Ramagge from The University of Sydney, Aleks Owczarek from The University of Melbourne, and Cheryl Praeger from The University of Western Australia.

The conference covered the broad range of the mathematical sciences. In all, there were 98 research presentations and six posters, all from women.

"I loved it. I thought it was a fantastic conference. As a woman, I just loved being surrounded by other women. The whole atmosphere was really different," Aurore says.

"I thought it was a fantastic event. Not only was it of great quality scientifically, but it was clearly a very effective conference from a networking and connection perspective. It was a really interesting experience being in the minority at a maths-stats conference," Nigel says.

Peter briefly addressed the conference and spoke about the ACEMS' Equity and Diversity Program.

"We have the program not because it's the right thing to do. We have it because we believe having a more diverse and equitable group of people makes us a better organisation," Peter told the crowd.

The conference attracted attendees from 44 different institutions and 10 different countries, including more than 50 students.

"I think everyone enjoyed it greatly, and there is a strong momentum to make this a regular, biennial or triennial, event," says Nigel.

Aurore said she hopes that is true. "I'm hoping they're going to do another soon!"



ACEMS Deputy Director Kerrie Mengersen giving her plenary presentation at the inaugural WIMSIG Conference

# NEW ACEMS CHIEF INVESTIGATOR PICKS UP PRESTIGIOUS AWARD FROM ANZIAM

ANZIAM (Australia and New Zealand Industrial and Applied Mathematics) awarded new ACEMS Chief Investigator Kate Smith-Miles one of its top awards in 2017 – the E.O. Tuck Medal.

The E.O. Tuck medal is a mid-career award that recognises outstanding research and distinguished service to the field of applied mathematics, and is named in honour of the late Ernest Oliver Tuck. Kate received the award at the ANZIAM conference held in February 2017 in South Australia.

“It is a great honour to receive the E.O. Tuck Medal, and it has come at a great time for me, just as I have been debating with colleagues about what is good applied mathematics in the modern era,” says Kate.

*“Is it the development of new mathematical techniques motivated by an application area? Is it the novel adaption of the wealth of existing mathematical techniques to tackle a practical problem, which has been translated into the right mathematical question? Over the last 20 years, my research has contributed to both of these types of applied mathematics approaches,” says Kate.*

Kate was named as an ACEMS Chief Investigator in 2016. During 2017, Kate moved from Monash University to The University of Melbourne, where she is now a professor in the School of Mathematics and Statistics. Kate is also the Chair of the Advisory Board for AMSI’s “Choose Maths” program, which is aimed at

trying to increase female participation in mathematics.

Kate is delighted that all three prizes awarded at the 2017 ANZIAM conference dinner were awarded to women. In addition to Kate’s award, Jody Fisher from Flinders University won the T.M. Cherry student prize and Alys Clark from the University of Auckland won the J.H. Michell medal for an early career researcher.

“It is so important for young female mathematicians to feel that their gender doesn’t define their mathematical capabilities, to find role models, and to believe that they are encouraged and supported to achieve their potential,” says Kate.

“To be honoured in this way by ANZIAM has been very affirming, and I will keep striving to contribute to both the novel application and development of mathematics.

“I believe that such balance is important, and creates a sustaining duality: ensuring impact in the short term from the toolkit of existing mathematics while providing the impetus to create the new mathematics that will lay the foundations for future mathematical toolkits.”

Kate has a Laureate Fellowship from the Australian Research Council (ARC), and is also the President of the Australian Mathematical Society (AustMS).



*Mrs Helen Tuck presenting Professor Kate Smith-Miles with the annual Ernest Oliver Tuck Medal for outstanding research and distinguished service to the field of Applied Mathematics.*



# ACEMS MEDIA AND COMMUNICATIONS IN 2017



ACEMS Deputy Director Kerrie Mengersen films for Network Ten kids science program Scope TV



ACEMS Media and Communications Officer Tim Macuga speaking at 'Building your Brand' ACEMS Comms workshop in August 2017

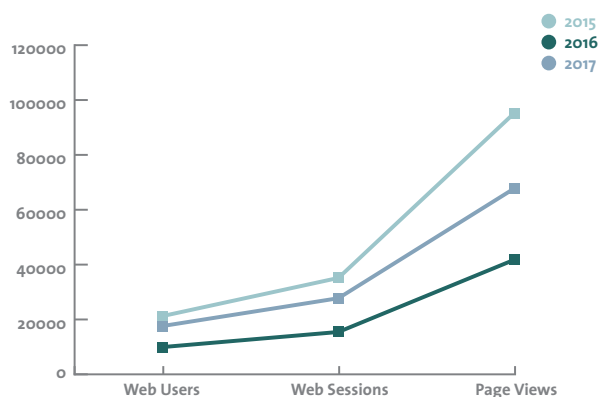
## THE STORY OF ACEMS, ITS PEOPLE AND ITS RESEARCH ON THE FRONTIERS OF MATHEMATICS AND STATISTICS CONTINUES TO ATTRACT A LARGER AND WIDER AUDIENCE.

That audience saw and heard Centre members on TV and online talking about a wide range of topics, from using mathematics and statistics in projects like the investigation into the effects of dredging on seagrass or the Australian Cancer Atlas, to statistical analysis of the marriage equality vote and using mathematics to prove a Guinness World Record.

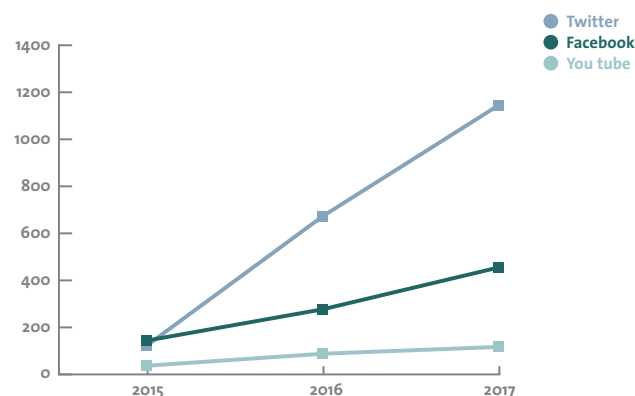
The digital platforms that spread the news about ACEMS all saw strong growth in 2017. For example, one of the biggest communication projects of the year was the makeover of the ACEMS website. The Centre redesigned the website to improve its appearance and usability. The new site places an added emphasis on the ground-breaking research conducted by Centre members. It is also more dynamic, reflecting the latest and most current news, events and research.

The makeover led to a huge jump in website usage. In fact, the new site was launched at the start of June, so was only active for the last seven months of 2017, however, those seven months accounted for 75 per cent of the activity. Overall, for 2017, the website saw a 30 per cent rise in key web metrics compared to the previous year, such as the number of users and page views.

ACEMS also saw strong growth on its social media platforms, Facebook and Twitter. The two platforms saw a 40 per cent increase in audience size over the course of 2017. Facebook and



ACEMS WEBSITE	2016	2017
Users	17,616	21,239
Web Sessions	27,750	35,146
Page Views	67,774	95,253

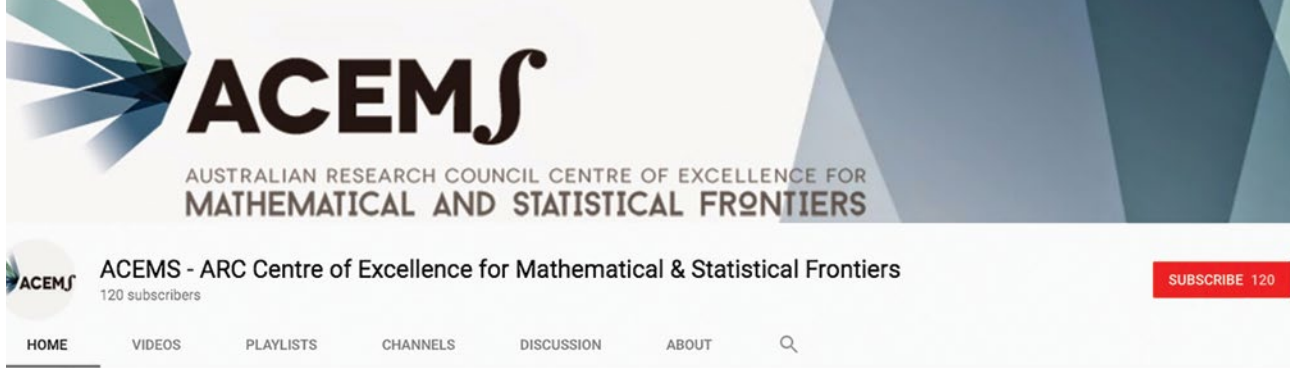


TOTAL FOLLOWERS	2016	2017	HIGHLIGHT
Twitter	673	1,145	ACEMS is one of only three 2014 CoEs with more than 1,000 followers
Facebook	277	455	40% growth in followers
YouTube	88	117	6,159 views of ACEMS videos

Twitter allow ACEMS to spread news about research (both within and outside of ACEMS), job openings, events, as well as activities involving Centre members.

One highlight was having ABC's Charlie Pickering use his hugely influential social media platforms to help spread the news about the National Science Quiz. ACEMS led the organisation of two live events, which Charlie hosted in Melbourne and Adelaide.





ACEMS YouTube page



ACEMS Research Fellow Erin Peterson talks to Scope TV's Lee Constable about Virtual Reality and the Great Barrier Reef

The ACEMS YouTube channel continued to provide video content about the Centre's activities. Featured videos include our MathsCraft outreach program for secondary students, interesting research talks, as well as interviews with people involved with ACEMS in 2017.

Centre members also wrote eight different articles for The Conversation, an online news platform sourced by academics. While some of the articles reported on specific research, ACEMS researchers were able to use ACEMS developed mathematical and statistical analysis to deal with the hotly debated topic of Australia's marriage equality vote, by looking at the statistics involved, both before and after the vote. Other articles considered fun and interesting questions relating to viral maths problems, as well as asking whether the internet knows you're happy and whether Usain Bolt is the greatest athlete ever.

Finally, one of the key communications initiatives involved Communications and Media Officer Tim Macuga working with Centre members on the importance of communicating their research and building their brands as researchers. That included a workshop attended by ACEMS members in Brisbane, featuring Dr Lee Hickey, who was named the 2017 Queensland Young Tall Poppy Scientist of the Year.

As for the Guinness World Record mentioned earlier (see page 40), which involved an Adelaide man trying to get into the record books for the largest indoor soap bubble. To get the proof he needed to show his soap bubble was the biggest, he turned to ACEMS Chief Investigator Matthew Roughan from The University of Adelaide. The bubble record, and Matthew's unique mathematical proof, picked up a lot of attention from both TV and online news sources.

From serious research to the lighter side of maths and stats, ACEMS members continued to engage in the communications process. After all, they have the stories that are worth telling. We can't wait to hear what they have to tell us in 2018!

# MEDIA RELEASES AND MEMBERS IN THE MEDIA

ACEMS AND ITS MEMBERS WERE MENTIONED IN 23 MEDIA RELEASES IN 2017, INCLUDING 12 ISSUED BY THE CENTRE, EXCEEDING ITS TARGET OF FIVE FOR 2017.

1. ACEMS, "New ACEMS Chief Investigator Picks Up Prestigious Award from ANZIAM", 13 February 2017: <https://acems.org.au/kate-smith-miles-anziam>
2. QUT, "Statistician serves up science of tennis at QUT", 23 February 2017: <https://www.qut.edu.au/news?news-id=114657>
3. ACEMS, "Royal Statistical Society Honours ACEMS Research Fellow", 28 February 2017: <https://acems.org.au/chris-oates-rss-award>
4. ACEMS, "Statistics Strengthen Landmark Study Supporting Aboriginal Australian Cultural Attachment to Land", 9 March 2017: <https://acems.org.au/ben-rohrlich-nature-study>
5. The University of Adelaide, "Aboriginal Hair shows 50,000 years connection to country", 9 March 2017: <https://www.adelaide.edu.au/news/news91042.html>
6. Cancer Council Queensland, "Australian researchers map the way to a cancer-free future", 11 April 2017: <https://cancerqld.org.au/news/australian-researchers-map-way-cancer-free-future/>
7. ACEMS, "Australian Researchers Map the Way to a Cancer-Free Future", 11 April 2017: <https://acems.org.au/aus-cancer-atlas>
8. ACEMS, "Using Maths to Give Meaning to Social Media", 10 May 2017: <https://acems.org.au/adelaide-social-media>
9. UNSW Sydney, "UNSW Awarded more than \$20-million in research grants", 5 June 2017: <http://newsroom.unsw.edu.au/news/general/unsw-awarded-more-20-million-research-grants>
10. ACEMS, "ACEMS Deputy Director Awarded ARC Future Fellowship", 5 June 2017: <https://acems.org.au/scott-sisson-arc-future-fellow>
11. Australian Bureau of Statistics, "It's time to register for a Free Census Data Seminar", 9 June 2017: <http://www.abs.gov.au/ausstats/abs%40.nsf/mediareleasesbyCatalogue/A13C5712CB3178C2CA258139001C8225?OpenDocument>
12. ACEMS, "ACEMS Adds Monash University as Collaborating Organisation; Promotes Two Associate Investigators to Chief Investigator", 22 June 2017: <https://acems.org.au/news/acems-adds-monash-university-collaborating-organisation-promotes-two-associate-investigators>
13. Cotton Australia, "Cotton collective industry forum a huge success, unites the industry", 26 July 2017: <http://cottonaustralia.com.au/news/article/cotton-collective-industry-forum-a-huge-success-unites-the-industry>
14. ACEMS, "Adelaide Man Bursts World Record with Giant Bubble", 2 August 2017: <https://acems.org.au/Adelaide-bubble-record>
15. La Trobe University, "Top Maths Mind to Tackle the Unknown", 18 September 2017: <http://www.latrobe.edu.au/news/articles/2017/release/top-maths-mind-to-tackle-unknown>
16. University of South Australia, "Not so hidden: Australia's top female figures in maths meet in Adelaide", 22 September 2017: <https://www.unisa.edu.au/Media-Centre/Releases/2017-Media-Releases/Not-so-hidden---Australias-top-female-figures-in-maths-meet-in-Adelaide/#.WcgzL7ljGpo>
17. AMSTAT, "Statisticians Honored by COPSS", 1 October 2017: [http://magazine.amstat.org/blog/2017/10/01/copss\\_jsm/](http://magazine.amstat.org/blog/2017/10/01/copss_jsm/)
18. ACEMS, "ACEMS Proud to Play a Key Role in First-Ever WIMSIG Conference", 8 October 2017: <https://acems.org.au/WIMSIG-2017>
19. AMSTAT, "2017 COPSS Awards", 1 November 2017: <http://community.amstat.org/copss/home>
20. ACEMS, "Saving Seagrasses from Dredging - New Research Finds Solutions", 3 November 2017: <https://acems.org.au/news/stats-modelling-saving-seagrass>
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## DURING 2017, ACEMS AND ITS MEMBERS WERE MENTIONED IN 54 UNIQUE PRINT AND ELECTRONIC ARTICLES, AND 14 RADIO AND TELEVISION STORIES, WELL EXCEEDING ITS TARGET OF THREE MEDIA ARTICLES FOR 2017.

### RADIO AND TELEVISION STORIES:

- ACEMS Deputy Director, Kerrie Mengersen, featured in Channel 11's Scope TV program (Season 3, Episode 147). A link to watch the program online can be found at: <https://tenplay.com.au/channel-eleven/scope/episode-details/innovative-science>
- ACEMS Director, Peter Taylor, was interviewed on Channel 7 News about the odds of a newborn sharing the same birthday as its mother and grandmother. Peter's comments were used in other TV stories and other media coverage. Further details on the story can be found at: <https://au.news.yahoo.com/vic/a/34982524/melbourne-baby-born-on-same-date-as-both-mum-and-grandma/#page1>
- ACEMS Deputy Director, Kerrie Mengersen, featured in Channel 9's broadcast about the Queensland Cancer Atlas. The full story and broadcast can be found at: <https://www.9news.com.au/national/2017/04/11/17/34/online-tool-to-determine-cancer-risk-based-on-postcode>
- A recorded interview featuring ACEMS Associate Investigator, Adrian Barnett, was repeated on the ABC's World Today radio program about research on adverse health effects due to exposure to traffic exhaust fumes. The full story can be streamed online and downloaded from the ABC website: <http://www.abc.net.au/worldtoday/content/2016/s4660436.htm>
- ACEMS Associate Investigator, Lewis Mitchell, was interviewed on ABC Radio National regarding his work on analysing story arcs in literature. The interview can be found on the ABC's website: <http://www.abc.net.au/radionational/programs/booksandarts/story-arcs-in-fiction-according-to-artificial-intelligence/8546220>.
- ACEMS Associate Investigator, Adrian Barnett, gave short live-interviews on ABC Radio Melbourne Breakfast and Drive programs about adverse health effects due to cold houses. The ABC Radio Melbourne Drive interview can be found at: <http://www.abc.net.au/radio/melbourne/programs/drive/cold-houses/8577120>.
- ACEMS Research Fellow, Silvio Tarca, was interviewed live on ABC Radio Adelaide about the National Science Quiz, which was held in both Adelaide and Melbourne in 2017.
- ACEMS Chief Investigator, Louise Ryan, was part of a discussion on 2SER FM dealing with the huge amount of data in the healthcare industry, and how making the most of that data can help the industry. A podcast of the program can be found at: <https://2ser.com/data-decoding-healthcare/>
- ACEMS Director, Peter Taylor, did the maths on winning the lottery for Channel 9 News. The story can be viewed on Channel 9's website at: <https://www.9news.com.au/videos/cjskikbc600ouohp8k3oyxdor/what-are-the-odds-of-winning-the-lottery>.
- ACEMS Chief Investigator, Matthew Roughan, was interviewed by ABC Radio Australia about his work on measuring the world's largest indoor soap bubble;

a new guiness world record. The story was also featured on multiple TV and viral video channels online. Further information can be found on page 40.

- ACEMS Research Fellow, Erin Peterson, appeared on Channel 11's Scope TV program about quantifying the beauty of the Great Barrier Reef. A video of the interview can be found on Scope TV's Youtube Channel: <https://www.youtube.com/watch?v=FL0NB7wZ554&feature=youtu.be>
- ACEMS Associate Investigator, Lewis Mitchell, was interviewed on ABC Radio National Drive program regarding his work on sentiment analysis, used by social media companies to measure how people feel based on their social media activity. His work was also featured in multiple print and electronic articles. The interview can be found on the ABC's website: <http://www.abc.net.au/radionational/programs/booksandarts/story-a>
- ACEMS Chief Investigator, Kate Smith-Miles, gave a recorded interview for ABC Radio Adelaide on improving gender equality in the mathematical and statistical sciences. The interview can be found at: <http://www.abc.net.au/radio/adelaide/programs/worldtoday/improving-gender-equality-in-traditionally-male-fields/8988878>
- ACEMS Associate Investigator, Paul Wu, appeared on ABC News regarding his work on better planning dredging works to save seagrasses. The story also appeared in multiple print and electronic articles. The ABC News story can be viewed on TheQUTube's Youtube channel: <https://www.youtube.com/watch?v=38LiWJqjCA&feature=youtu.be>

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*Daily Telegraph*: <https://www.dailytelegraph.com.au/news/national/northside-hot-spots-need-to-take-care/news-story/1c06201edba136bd9df350168e1f1bba?csp=4d8cbc2fbfc8e0ada55ca1653215f3b8>  
*Herald Sun*: <http://www.heraldsun.com.au/news/national/northside-hot-spots-need-to-take-care/news-story/1c06201edba136bd9df350168e1f1bba?csp=fa83768cf5eda7aef5af9ae aad757d49>  
*NT News*: <http://www.ntnews.com.au/news/national/northside-hot-spots-need-to-take-care/news-story/1c06201edba136bd9df350168e1f1bba?csp=287c1f573d0bc3f569c69394fce21ee9>  
*The Advertiser*: <http://www.adelaidenow.com.au/news/national/northside-hot-spots-need-to-take-care/news-story/1c06201edba136bd9df350168e1f1bba?csp=02f841c98e29f85fo877cefe9195de437>  
*The Mercury*: <http://www.themercury.com.au/news/national/northside-hot-spots-need-to-take-care/news-story/1c06201edba136bd9df350168e1f1bba?csp=78b144635b1b92f63aaa3e46216e575a>

# 2017 KEY PERFORMANCE INDICATORS

## RESEARCH FINDINGS

PERFORMANCE MEASURE	TARGET FOR 2017	OUTCOME IN 2017	DETAILS IN ANNUAL REPORT
Number of research outputs	55 journal articles 25 other	<i>Refereed written outputs</i> 128 journal articles 4 Book Chapters 15 refereed conference proceedings  <i>Other written outputs, including non-refereed contributions</i> Another 31 outputs were produced by Centre members, including non-refereed conference papers, unpublished reports and other contributions to journals	See Publications, <a href="#">page 144</a>
Quality of research outputs	80 per cent of publications will be in peer reviewed, international journals  CI recognition through awards and honours, particularly those from abroad	All listed journal articles were in internationally recognised and fully refereed scientific journals  Numerous CIs and other members recognised through awards, high-citation counts, and leadership roles in the national and international mathematical sciences community	See Publications, <a href="#">page 144</a>  See Staff and Student Recognition: Prizes, Awards and Other Prestige Measures, <a href="#">page 34</a>
Number of invited talks/papers/keynote lectures given at major international meetings (including those held in Australia)	30	36	
Number and nature of commentaries about the Centre's achievements	5 media releases 3 articles	23 media releases 54 print and electronic articles 14 radio and television stories 9 YouTube videos	See Media Releases and Members in the Media, <a href="#">page 133</a>  YouTube videos can be accessed via the ACEMS website
Citation data for publications	320	2,259	See <a href="#">page 145</a> for number of citations



## RESEARCH TRAINING AND PROFESSIONAL EDUCATION

PERFORMANCE MEASURE	TARGET FOR 2017	OUTCOME IN 2017	DETAILS IN ANNUAL REPORT
Number of professional training courses for staff and postgraduate students attended	4	23	See Education and Training, page 84
Number of Centre attendees at all professional training/development courses offered by the Centre	20	At least 20 Centre attendees at all professional training/development courses offered by the Centre	See Education and Training, page 84
Number of new postgraduate students working on core Centre research and supervised by Centre staff	12 PhD students 4 Masters by Coursework students	17 PhD students 8 Masters by Research Students 5 Masters by Coursework students	See Student and Early Career Researcher Recruitment and Completion, page 36
Number of new postdoctoral researchers recruited to the Centre working on core Centre research	6	11	See Student and Early Career Researcher Recruitment and Completion, page 36
Number of new Honours students working on core Centre research supervised by Centre staff	10	4	See Student and Early Career Researcher Recruitment and Completion, page 36
Number of postgraduate completions and completion times, by students working on core Centre research and supervised by Centre staff	12 PhD students (4y FTE) 5 MSc (2y FTE)	15 PhD Students (ffi 4y FTE) 4 PhD Students (> 4y FTE) 2 Masters by Research (ffi 2y FTE) 1 Masters by Research (> 2y FTE) 6 Masters by Coursework students (ffi 2y FTE) 5 Honours students	See Student and Early Career Researcher Recruitment and Completion, page 36
Number of Early Career Researchers (within five years of completing PhD) working on core Centre research	18	43	See Student and Early Career Researcher Recruitment and Completion, page 36
Number of students mentored	30	19 one-on-one Mentoring Relationships 48 Vacation Students	See Mentoring at ACEMS, page 82
Number of mentoring programs offered by the Centre	6	6	See Mentoring at ACEMS, page 82



## 2017 KEY PERFORMANCE INDICATORS

### END-USER LINKS

PERFORMANCE MEASURE	TARGET FOR 2017	OUTCOME IN 2017	DETAILS IN ANNUAL REPORT
Number of government, industry and business community briefings	5	14	See Stakeholder Engagement, page 100
Number and nature of public awareness/outreach programs	20 School visits 5 National Science Week events 6 Other public activities/events	16 different schools visited a total of 33 separate occasions by 30 Centre members 5 National Science Week events 1 Big Data Analytics Massive Open Online Course (MOOC) 2 National Science Quiz events 15 Mathscraft events involving 12 different schools with approximately 300 participants 29 other activities and events	See ACEMS Outreach Projects, page 112
Currency of information on Centre's website	Review of website structure with goal of improving in line with emerging web technologies	Major overhaul of ACEMS website commenced and completed in 2017	See ACEMS Media and Communications in 2017, page 130
Number of website hits	2,000 Active social media engagement (measure by tweets, re-tweets and similar measures)	35,146 web sessions 21,239 website users 95,253 website page views 1,145 Twitter followers 732 re-tweets of ACEMS tweets 455 Facebook followers 117 YouTube subscribers 9 new videos 170 new photos	Communications in 2017, page 130
Number of talks given by Centre staff open to the public	15	50	See Public Talks, page 120

## INTERNATIONAL, NATIONAL AND REGIONAL LINKS AND NETWORKS

PERFORMANCE MEASURE	TARGET FOR 2017	OUTCOME IN 2017	DETAILS IN ANNUAL REPORT
Number of international visitors and visiting fellows	18	64	See National and International Visitors, page 93
Number of national and international workshops held/organised by the Centre	2	11	See National and International Workshops and Conferences, page 96
Number of visits to overseas laboratories and facilities	18	53	See International Links: Institutions, page 92
Examples of relevant interdisciplinary research supported by the Centre	Publications, reports and high profile activities in relevant area of application, where Centre staff have played a key role. More than 50% of projects will be interdisciplinary	Case studies and publications 20 conferences and workshops sponsored by the Centre 11 national and international workshops organised by the Centre All projects involving Partner Organisations and Industry Affiliate Organisations	See case studies pages 14, 24, 38, 50 & 78 See ACEMS Sponsorships page 87 See National and International Workshops and Conferences, page 96 See Stakeholder Engagement page 100

## NATIONAL BENEFIT

PERFORMANCE MEASURE	TARGET FOR 2017	OUTCOME IN 2017	DETAILS IN ANNUAL REPORT
Contribution to the National Research Priorities	Case studies detailed in Annual Report of how the Centre is contributing to relevant National Research and Innovation priorities including: <ul style="list-style-type: none"> <li>• Contribution to Frontier Technologies: Breakthrough Sciences</li> <li>• Smart Information Use</li> </ul>	Five new case studies featured in 2017 Annual Report	Case studies: pages 14, 24, 38, 50 & 78

## STAFF RECOGNITION

PERFORMANCE MEASURE	TARGET FOR 2017	OUTCOME IN 2017	DETAILS IN ANNUAL REPORT
Prizes, awards, other prestige measure of Centre researchers and students for excellence of research quality, outreach and scientific contribution	15	25	See Staff and Student Recognition: Prizes, Awards and Other Prestige Measures, page 34

## 2017 KEY PERFORMANCE INDICATORS

### ORGANISATIONAL SUPPORT

PERFORMANCE MEASURE	TARGET FOR 2017	OUTCOME IN 2017	DETAILS IN ANNUAL REPORT
Annual cash contributions from Administering and Collaborating Organisations	\$388,242 UoM \$325,094 QUT \$109,173 UoA \$56,903 UNSW \$109,173 UQ \$155,243 UTS	\$388,242 UoM \$355,555 QUT \$109,173 UoA \$109,013 UNSW \$107,084 UQ \$0 UTS	See 2017 Financial Statement, page 156
Annual in-kind contributions from Administering and Collaborating Organisations	\$352,322 UoM \$507,744 QUT \$87,936 UoA \$43,700 UNSW \$81,244 UQ \$474,851 UTS	\$1,456,236 UoM \$1,702,262 QUT \$507,255 UoA \$467,692 UNSW \$413,508 UQ \$829,567 UTS	See 2017 Financial Statement, page 156
Annual cash contributions from Partner Organisations	Nil	Nil	See 2017 Financial Statement, page 156
Annual in-kind contributions from Partner Organisations	\$30,00 AT&T \$140,718 ABS \$10,992 CSIRO \$25,277 Mitacs \$75,000 Vicroads \$13,740 Sax \$172,728 AIMS	\$33,600 AT&T \$51,280 ABS \$22,400 CSIRO \$2,250 Mitacs \$32,100 Vicroads \$32,465 Sax \$181,956 AIMS	See 2017 Financial Statement, page 156
Other research income secured by Centre staff	\$1,500,000 ARC Grants \$0 Other ACG \$100,000 Public Sector \$50,000 Industry	\$23,841,928 ARC Grants \$4,198,816 Public Sector \$5,249,501 Industry	See 2017 Financial Statement, page 156
Number of new organisations collaborating with or involved in, the Centre	6	9	See Stakeholder Engagement, page 100
Level and quality of infrastructure provided to the Centre	High quality of research spaces, adequate space and other infrastructure at all institutions.	High quality infrastructure is provided at all seven ACEMS nodes	See Infrastructure Report, page 143

### SCIENTIFIC OUTCOMES

PERFORMANCE MEASURE	TARGET FOR 2017	OUTCOME IN 2017	DETAILS IN ANNUAL REPORT
Centre-recognised leadership in discoveries and insights relating to mathematical modelling, statistical analysis and subsequent applications	These are difficult to specify in advance but will be highlighted in Centre Annual Reports	Five new case studies in 2017 Annual Report  Numerous prestigious prizes and awards for Centre researchers and students	See case studies: pages 14, 24, 38, 50 & 78  See Staff and Student Recognition: Prizes, Awards and Other Prestige Measures, page 34



# INFRASTRUCTURE

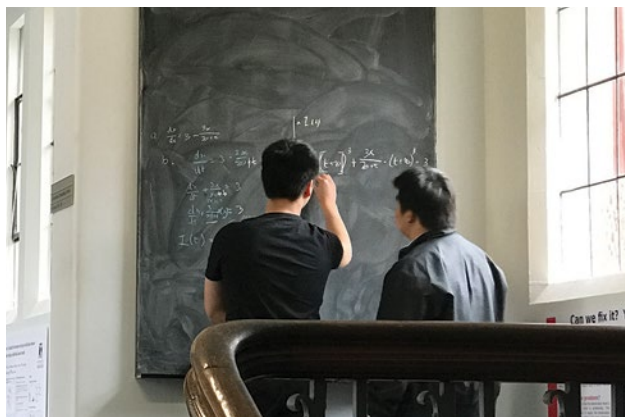
## ACEMS IS WELL REPRESENTED IN INCLUSIVE AND COLLEGIAL SPACES AT EACH OF THE UNIVERSITY NODES.

In the lead up to the mid-term review, ACEMS looked at the infrastructure offered by each of our host universities and is proud to provide high quality, collaborative spaces for our members. It is important that research and professional staff are co-located to ensure an inclusive environment.

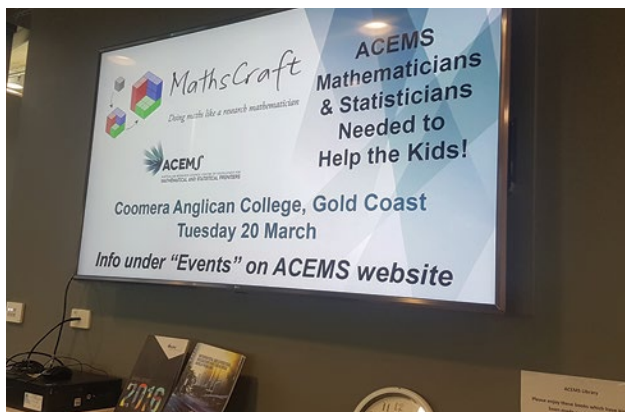
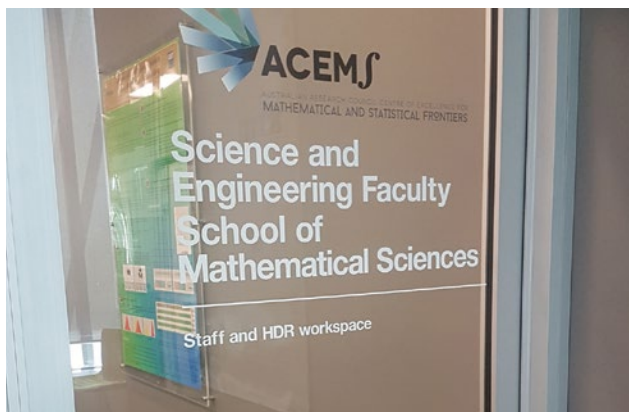
Presentation of ACEMS, its logo and affiliations can be found at each of the nodes to ensure that the ACEMS brand is well known for its excellence in research and the mathematical sciences.



*Peter Taylor and his research group using the Thomas Cherry Room at The University of Melbourne*



*ACEMS Members at The University of Melbourne*



*The ACEMS offices at QUT*



# PUBLICATIONS

## BOOKS AND BOOK CHAPTERS

In 2017, Centre members published four new book chapters.

1. Burrage, K., Burrage, P., Leier, A. and Marquez-Lago, T. (2017) A review of stochastic and delay simulation approaches in both time and space in computational cell biology. In Holcman, D. (Ed.), *Stochastic processes, multiscale modeling, and numerical methods for computational cellular biology* (pp. 241-261). Switzerland: Springer International Publishing. doi: 10.1007/978-3-319-62627-7\_11.
2. Fackrell, M. and Taylor, P. (2017) Allocation in a vertical rotary car park. In Boucherie, R.J. and van Dijk, N. M. (Eds.), *Markov decision processes in practice* (pp. 337-370). Switzerland: Springer International Publishing. doi: 10.1007/978-3-319-47766-4\_12.
3. Wang, E., Kurniawati, H. and Kroese, D.P. (2017) CEMAB: A Cross-Entropy-based Method for Large-Scale Multi-Armed Bandits. In Wagner, M., Li X. and Hendtlass, T. (Eds.), *Artificial life and computational intelligence* (pp. 353-365). Switzerland: Springer International Publishing. doi: 10.1007/978-3-319-51691-2\_30
4. Xie, H. and Guo, T. (2017) Two-directional two-dimensional principal component analysis based on wavelet decomposition for high-dimensional biomedical signals classification. In Singh, B. (Ed.), *Computational tools and techniques for biomedical signal processing*. Hershey, PA: IGI Global. doi: 10.4018/978-1-5225-0660-7.ch005

were published in scholarly refereed journals. This figure only includes ACEMS publication outputs; Centre members' outputs solely from other projects and grants are not included in this list.

By the end of 2017, Centre publications have already achieved 2,259 citations; this includes 72 citations across 120 journal articles that were published during 2017. See the table on [page 145](#) for a breakdown of the citation data by year.

1. Alajajian, S.E., Williams, J.R., Reagan, A.J., Alajajian, S.C., Frank, M.R., Mitchell, L., Lahne, J., Danforth, C.M. and Dodds, P.S. (2017) The lexical calorimeter: Gauging public health through caloric input and output on social media. *PLoS ONE*. **12**(2), e0168893, doi: 10.1371/journal.pone.0168893.
2. Anderson, C., Lee, D. and Dean, N. (2017) Spatial clustering of average risks and risk trends in Bayesian disease mapping. *Biometrical Journal*. **59**(1), 41-56, doi: 10.1002/bimj.201600018.
3. Anderson, C. and Ryan, L.M. (2017) A comparison of spatio-temporal disease mapping approaches including an application to ischaemic heart disease in New South Wales, Australia. *International Journal of Environmental Research and Public Health*. **14**(2), 146, doi: 10.3390/ijerph14020146.
4. Austin, A.M., Douglass, M.J.J., Nguyen, G.T. and Penfold, S.N. (2017) A radiobiological Markov simulation tool for aiding decision making in proton therapy referral. *Physica Medica*. **44**, 72-82, doi: 10.1016/j.ejmp.2017.11.013.
5. Baker, J., White, N., Mengersen, K., Rolfe, M., and Morgan, G.G. (2017) Joint modelling of potentially avoidable hospitalisation for

five diseases accounting for spatiotemporal effects: A case study in New South Wales, Australia. *PLoS ONE*. **12**(8), e0183653, doi: 10.1371/journal.pone.0183653.

6. Ballard, P.G., Bean, N.G. and Ross, J.V. (2017) Intervention to maximise the probability of epidemic fade-out. *Mathematical Biosciences*. **293**, 1-10, doi: 10.1016/j.mbs.2017.08.003.
7. Benham, T., Duan, Q., Kroese, D.P. and Lique, B. (2017) CEoptim: Cross-entropy R package for optimization. *Journal of Statistical Software*. **76**(8), 1-29, doi: 10.18637/jss.v076.i08.
8. Beranger, B., Padoan, S.A. and Sisson, S.A. (2017) Models for extremal dependence derived from skew-symmetric families. *Scandinavian Journal of Statistics*. **44**(1), 21-45, doi: 10.1111/sjos.12240.
9. Black, A.J., Geard, N., McCaw, J.M., McVernon, J. and Ross, J.V. (2017) Characterising pandemic severity and transmissibility from data collected during first few hundred studies. *Epidemics*. **19**, 61-73, doi: 10.1016/j.epidem.2017.01.004.
10. Bornemann, F., Forrester, P.J. and Mays, A. (2017) Finite size effects for spacing distributions in random matrix theory: Circular ensembles and Riemann zeros. *Studies in Applied Mathematics*. **138**(4), 401-437, doi: 10.1111/sapm.12160.
11. Bouchet, P.J., Meeuwig, J.J., Huang, Z., Letessier, T.B., Nichol, S.L., Caley, M.J. and Watson, R.A. (2017) Continental-scale hotspots of pelagic fish abundance inferred from commercial catch records. *Global Ecology and Biogeography*. **26**(10), 1098-1111, doi: 10.1111/geb.12619.
12. Brock, A.R., Carole, C.A., Ross, J.V. and Esterman, A. (2017) The impact of antimalarial use on the emergence and transmission of *plasmodium*

## REFEREED JOURNAL ARTICLES

In 2017, 128 articles by Centre members

*falciparum* resistance: A scoping review of mathematical models. *Tropical Medicine and Infectious Disease*. **2**(4), 54, doi: 10.3390/tropicalmed2040054.

13. Brock, A.R., Ross, J.V., Greenhalgh, S., Durham, D.P., Galvani, A., Parikh, S. and Esterman, A. (2017) Modelling the impact of antimalarial quality on the transmission of sulfadoxine-pyrimethamine resistance in *Plasmodium falciparum*. *Infectious Disease Modelling*. **2**(2), 161-187, doi: 10.1016/j.idm.2017.04.001.
14. Bueno-Orovio, A. and Burrage, K. (2017) Exact solutions to the fractional time-space Bloch–Torrey equation for magnetic resonance imaging. *Communications in Nonlinear Science and Numerical Simulation*. **52**, 91-109, doi: 10.1016/j.cnsns.2017.04.013.
15. Burrage, K., Cardone, A., D'Ambrosio, R. and Paternoster, B. (2017) Numerical solution of time fractional diffusion systems. *Applied Numerical Mathematics*. **116**, 82-94, doi: 10.1016/j.apnum.2017.02.004.
16. Carr, E.J., Turner, I.W. and Perré, P. (2017) Macroscale modelling of multilayer diffusion: Using volume averaging to correct the boundary conditions. *Applied Mathematical Modelling*. **47**, 600-618, doi: 10.1016/j.apm.2017.03.044.
17. Carvajal, G., Branch, A., Sisson, S.A., Roser, D.J., van den Akker, B., Monis, P., Reeve, P., Keegan, A., Regel, R. and Khan, S.J. (2017) Virus removal by ultrafiltration: Understanding long-term performance change by application of Bayesian analysis. *Water Research*. **122**, 269-279, doi: 10.1016/j.watres.2017.05.057.
18. Carvajal, G., Roser, D.J., Sisson, S.A., Keegan, A. and Khan, S.J. (2017) Bayesian belief network modelling of chlorine disinfection for human pathogenic viruses in municipal wastewater. *Water Research*. **109**, 144-154, doi: 10.1016/j.watres.2016.11.008.
19. Cespedes, M.I., Frapp, J., McGree, J.M., Drovandi, C.C., Mengersen, K. and Doecke, J.D. (2017) Comparisons of neurodegeneration over time between healthy ageing and Alzheimer's disease cohorts via Bayesian inference. *BMJ Open*. **7**(2), e012174, doi: 10.1136/bmjopen-2016-012174.

## CITATION DATA FOR REFEREED JOURNAL ARTICLES

		YEAR OF PUBLICATION				
		2014	2015	2016	2017	TOTAL
NUMBER OF PUBLICATIONS INCLUDED IN CITATION COUNT*		18	231	127	120	496
NUMBER OF PUBLICATIONS WITH AT LEAST ONE CITATION		17	206	100	37	360
NUMBER OF CITATIONS BY YEAR OF CITATION	2014	5	2**	0	0	7
	2015	41	184	0	0	225
	2016	45	651	84	1	781
	2017	54	781	340	71	1,246
TOTAL CITATIONS BY YEAR OF PUBLICATION		145	1,618	424	72	2,259

Please note that the figures quoted are sourced from the bibliographic database Scopus. Scopus is held in high regard by librarians for its ease of use and accurate albeit sometimes modest citation numbers in comparison to other bibliographic databases, such as Google Scholar.

\* This citation data relates to refereed journal articles only and does not include citation information for books, book chapters or conference proceedings. As bibliographic databases also rely on regular database updates via APIs, manual data entry and so forth, and as only a selection of our journals' citation information could be retrieved from the Scopus database, the figures quoted are a conservative lower bound. Despite our modest approach to reporting our citation figures, the Centre's total citation numbers of 2259 are well above the 320 citations target for 2017.

\*\* ACEMS defines 'year of publication' as the year that a published work appears in print. As there is often a delay between the article being published electronically and appearing in print, it is possible for articles to be cited before being published in print.

20. Chen, C.C.-M., Drovandi, C.C., Keith, J.M., Anthony, K., Caley, M.J. and Mengersen, K.L. (2017) Bayesian semi-individual based model with approximate Bayesian computation for parameters calibration: Modelling Crown-of-Thorns populations on the Great Barrier Reef. *Ecological Modelling*. **364**, 113-123, doi: 10.1016/j.ecolmodel.2017.09.006.
21. Chen, C.C.-M., Keith, J.M. and Mengersen, K.L. (2017) Accurate phenotyping: Reconciling approaches through Bayesian model averaging. *PLoS ONE*. **12**(4), e0176136, doi: 10.1371/journal.pone.0176136.
22. Chen, C.C.M., Bourne, D.G., Drovandi, C.C., Mengersen, K., Willis, B.L., Caley, M.J. and Sato, Y. (2017) Modelling environmental drivers of black band disease outbreaks in populations of foliose corals in the genus *Montipora*. *PeerJ*. **2017**(6), e3438, doi: 10.7717/peerj.3438.
23. Chipperfield, J., Brown, J. and Bell, P. (2017) Estimating the count error in the Australian census. *Journal of Official Statistics*. **33**(1), 43-59, doi: 10.1515/JOS-2017-0003.

24. Chipperfield, J., Brown, J.J. and Watson, N. (2017) The Australian census longitudinal dataset: Using record linkage to create a longitudinal sample from a series of cross-sections. *Australian and New Zealand Journal of Statistics*. **59**(1), 1-16, doi: 10.1111/anzs.12177.
25. Clark, S., Sisson, S.A. and Sharma, A. (2017) Nonlinear manifold representation in natural systems: The SOMersault. *Environmental Modelling and Software*. **89**, 61-76, doi: 10.1016/j.envsoft.2016.11.028.
26. Colin, B., Clifford, S., Wu, P., Rathmanner, S. and Mengersen, K. (2017) Using boosted regression trees and remotely sensed data to drive decision-making. *Open Journal of Statistics*. **7**, 859-875, doi: 10.4236/ojs.2017.75061.
27. Cramb, S.M., Moraga, P., Mengersen, K.L. and Baade, P.D. (2017) Spatial variation in cancer incidence and survival over time across Queensland, Australia. *Spatial and Spatio-temporal Epidemiology*. **23**, 59-67, doi: 10.1016/j.sste.2017.09.002.
28. Cusimano, N., Burrage, K., Turner, I. and Kay, D. (2017) On reflecting boundary conditions for space-fractional equations on a finite interval: Proof of the matrix transfer technique. *Applied Mathematical Modelling*. **42**, 554-565, doi: 10.1016/j.apm.2016.10.021.
29. Da Silva, R., Mazumdar, A., Mapder, T., Peketi, A., Joshi, R.K., Shaji, A., Mahalakshmi, P., Sawant, B., Naik, B.G., Carvalho, M.A. and Molletti, S.K. (2017) Salinity stratification controlled productivity variation over 300 ky in the Bay of Bengal. *Scientific Reports*. **7**(1), 14439, doi: 10.1038/s41598-017-14781-3.
30. Diaconis, P. and Forrester, P.J. (2017) Hurwitz and the origins of random matrix theory in mathematics. *Random Matrices: Theory and Application*. **6**(1), 1730001, doi: 10.1142/S2010326317300017.
31. Dodds, P.S., Dewhurst, D.R., Hazlehurst, F.F., Van Oort, C.M., Mitchell, L., Reagan, A.J., Williams, J.R. and Danforth, C.M. (2017) Simon's fundamental rich-get-richer model entails a dominant first-mover advantage. *Physical Review E*. **95**(5), 052301, doi: 10.1103/PhysRevE.95.052301.
32. Drovandi, C.C., Holmes, C.C., McGree, J.M., Mengersen, K., Richardson, S. and Ryan, E.G. (2017) Principles of experimental design for big data analysis. *Statistical Science*. **32**(3), 385-404, doi: 10.1214/16-STS604.
33. Fan, W., Liu, F., Jiang, X. and Turner, I. (2017) A novel unstructured mesh finite element method for solving the time-space fractional wave equation on a two-dimensional irregular convex domain. *Fractional Calculus and Applied Analysis*. **20**(2), 352-383, doi: 10.1515/fca-2017-0019.
34. Fan, Y., Olson, R. and Evans, J.P. (2017) A Bayesian posterior predictive framework for weighting ensemble regional climate models. *Geoscientific Model Development*. **10**(6), 2321-2332, doi: 10.5194/gmd-10-2321-2017.
35. Feenstra, J., Punt, A. and McGarvey, R. (2017) Inferring absolute recruitment and legal size population numbers of southern rock lobster (*Jasus edwardsii*) in South Australia's Southern Zone fishery using extended forms of depletion modelling. *Fisheries Research*. **191**, 164-178, doi: 10.1016/j.fishres.2017.02.019.
36. Feng, G., Gao, J., Peng, B. and Zhang, X. (2017) A varying-coefficient panel data model with fixed effects: Theory and an application to US commercial banks. *Journal of Econometrics*. **196**(1), 68-82, doi: 10.1016/j.jeconom.2016.09.011.
37. Feng, L., Liu, F., Turner, I. and Zhuang, P. (2017) Numerical methods and analysis for simulating the flow of a generalized Oldroyd-B fluid between two infinite parallel rigid plates. *International Journal of Heat and Mass Transfer*. **115**, 1309-1320, doi: 10.1016/j.ijheatmasstransfer.2017.08.105.
38. Feng, L.B., Zhuang, P., Liu, F., Turner, I., Anh, V. and Li, J. (2017) A fast second-order accurate method for a two-sided space-fractional diffusion equation with variable coefficients. *Computers and Mathematics with Applications*. **73**(6), 1155-1171, doi: 10.1016/j.camwa.2016.06.007.
39. Fitzgerald, S.P., Bean, N.G. and Ruberu, R.P. (2017) A method of decision analysis quantifying the effects of age and comorbidities on the probability of deriving significant benefit from medical treatments. *Journal of Comorbidity*. **7**(1), 50-63, doi: 10.15256/joc.2017.7.93.
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41. Forrester, P.J., Rahman, A.A. and Witte, N.S. (2017) Large N expansions for the Laguerre and Jacobi  $\beta$ -ensembles from the loop equations. *Journal of Mathematical Physics*. **58**(11), 113303, doi: 10.1063/1.4997778.
42. Foster, S.D., Hosack, G.R., Lawrence, E., Przeslawski, R., Hedge, P., Caley, M.J., Barrett, N.S., Williams, A., Li, J., Lynch, T., Dambacher, J.M., Sweatman, H.P.A. and Hayes, K.R. (2017) Spatially balanced designs that incorporate legacy sites. *Methods in Ecology and Evolution*. **8**(11), 1433-1442, doi: 10.1111/2041-210X.12782.
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## REFEREED CONFERENCE PROCEEDINGS

In 2017, Centre members had 15 conference papers published in scholarly refereed conference proceedings. This figure only includes ACEMS publication outputs; Centre members' outputs solely from other projects and grants are not included in this list.

1. Abbasi-Yadkori, Y., Bartlett, P.L. and Gabillon, V. (2017) Near Minimax Optimal Players for the Finite-Time3-Expert Prediction Problem. *31st Conference on Neural Information Processing Systems (NIPS 2017)*, Long Beach, United States.
2. Abbasi-Yadkori, Y., Bartlett, P.L., Gabillon, V. and Malek, A. (2017) Hit-and-Run for Sampling and Planning in Non-Convex Spaces. *20th International Conference on Artificial Intelligence and Statistics*, Florida, United States.
3. Bagrow, J.P., Danforth, C.M. and Mitchell, L. (2017) Which friends are more popular than you? Contact strength and the friendship paradox in social networks. *2017 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining*, Sydney Australia. doi: 10.1145/3110025.3110027.
4. Ben Taieb, S., Taylor, J.W. and R.J. Hyndman (2017) Coherent probabilistic forecasts for hierarchical time series. *34th International Conference on Machine Learning*, Sydney, Australia.
5. Bilal, A., Rextin, A., Kakakhel, A. and Nasim, M. (2017) Roman-txt: forms and functions of roman urdu texting. *19th International Conference on Human-Computer Interaction with Mobile Devices and Services*, Vienna, Austria. doi: 10.1145/3098279.3098552.
6. Briol, F.X., Oates, C., Cockayne, J., Chen, W. and Girolami, M. (2017) On the Sampling Problem for Kernel Quadrature. *34th International Conference on Machine Learning*, Sydney, Australia.
7. Gong, L., Huang, L., Tune, P., Han, J., Chuah, C.N., Roughan, M. and Xu J. (2017) ForestStream: Accurate Measurement of Cascades in Online Social Networks. *26th International Conference on Computer Communication and Networks (ICCCN)*, Vancouver, Canada. doi: 10.1109/ICCCN.2017.8038387.
8. Ji, Y. and Xie, H. (2017) Stationary wavelet and two-directional 2dpca for pattern recognition of electromyographic signal. *2017 International Conference on Wavelet Analysis and Pattern Recognition (ICWAPR)*, Ningbo, China. doi: 10.1109/ICWAPR.2017.8076668.
9. Kim, J and Bednarz, T. (2017) Virtual reality to save endangered animals: Many eyes on the wild. *2017 IEEE Virtual Reality*, Los Angeles, United States. doi: 10.1109/VR.2017.7892364.
10. Lee J. (2017) Extracting More Value from Confidentialised Tabular Data. *International Statistical Institute Regional Statistics Conference*, Bali, Indonesia.
11. Mathews, P., Mitchell, L., Nguyen, G. and Bean, N.G. (2017) The nature and origin of heavy tails in retweet activity. *26th International Conference on World Wide Web Companion*, Perth, Australia. doi: 10.1145/3041021.3053903.
12. Muñoz, M.A. and Smith-Miles, K. (2017) Generating custom classification datasets by targeting the instance space. *The Genetic and Evolutionary Computation Conference 2017*, Berlin, Germany. doi: 10.1145/3067695.3082532.
13. Tarca, S., Roughan, M., Ertugrul, N. and N.G. Bean (2017) Dispatchability of Wind Power with Battery Energy Storage in South Australia. *1st International Conference on Energy and Power*, Melbourne, Australia. doi: 10.1016/j.egypro.2017.03.131.
14. Wrigley, A., Sun Lee, W. and Ye, N. (2017) Tensor Belief Propagation. *34th International Conference on Machine Learning*, Sydney, Australia.
15. Xie, H. and Liu, H. (2017) Myoelectrical signal classification based on S transform and two-directional 2DPCA. *European Symposium on Artificial Neural Networks (ESANN 2017)*, Bruges, Belgium. doi: 10.1177/0142331217704035.

# ROYAL STATISTICAL SOCIETY HONOURS ACEMS RESEARCH FELLOW

The Royal Statistical Society (RSS) awarded ACEMS Research Fellow Chris Oates its prestigious biennial Research Prize in 2017.

Chris was just one of two people to receive the award in 2016-17 and one of just 13 people since the award's inception in 1992.

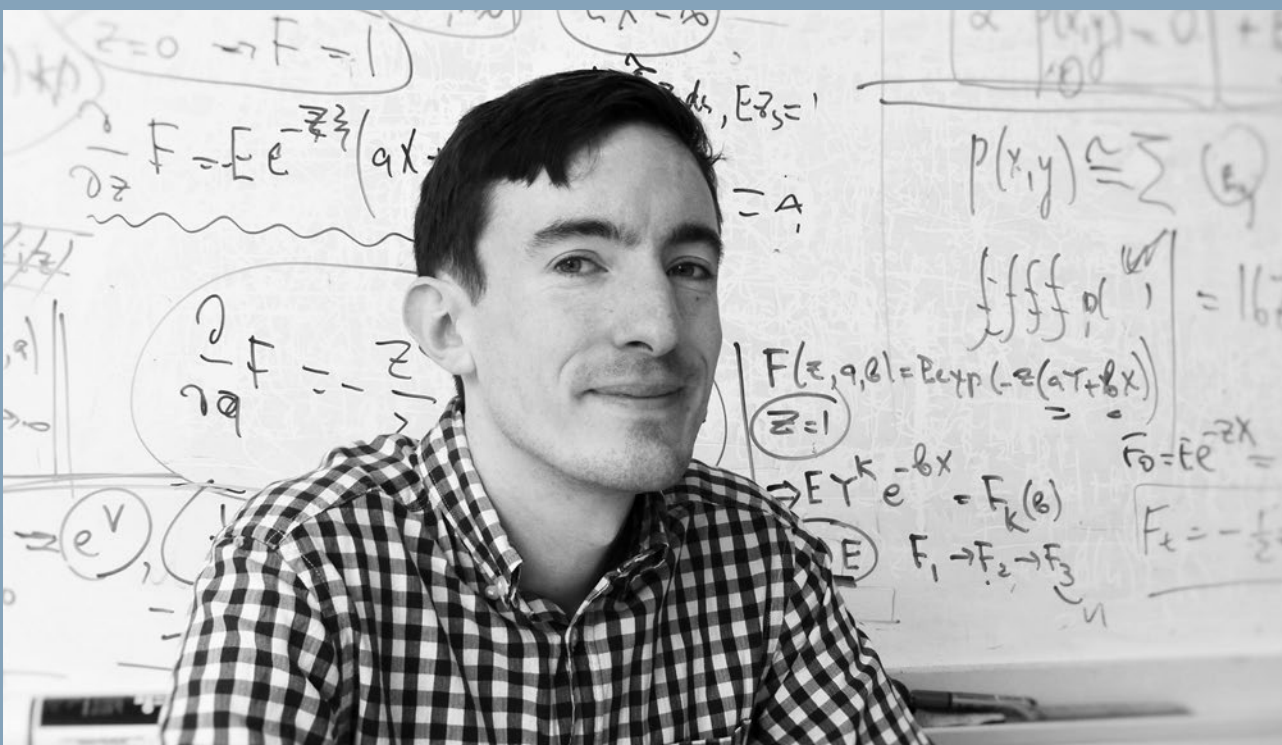
*“In its announcement, the RSS cited Chris’ outstanding and diverse methodological contributions to computational statistics and his innovative contributions to bioinformatics and machine learning.”*

The RSS acknowledged Chris’ “wide-ranging” research, highlighting how his research is playing a key role in the development of probabilistic numerical methods, which Chris says has only recently emerged as a coherent research field.

“It’s great to be recognised specifically for that because it’s still quite a young field,” says Chris. “I’m excited because these methods have the potential to impact on how future decisions are made based on computer output, to better understand and mitigate numerical risk.”

Chris finished up with ACEMS at the University of Technology, Sydney at the end of April 2017. He moved back to the United Kingdom to start as a Senior Lecturer in statistics at Newcastle University. In June, he was seconded to the Alan Turing Institute in London, as a group leader for the Programme on Data-Centric Engineering.

Chris was officially awarded the RSS Research Prize in September, at the RSS 2017 Annual Conference in Glasgow, UK.



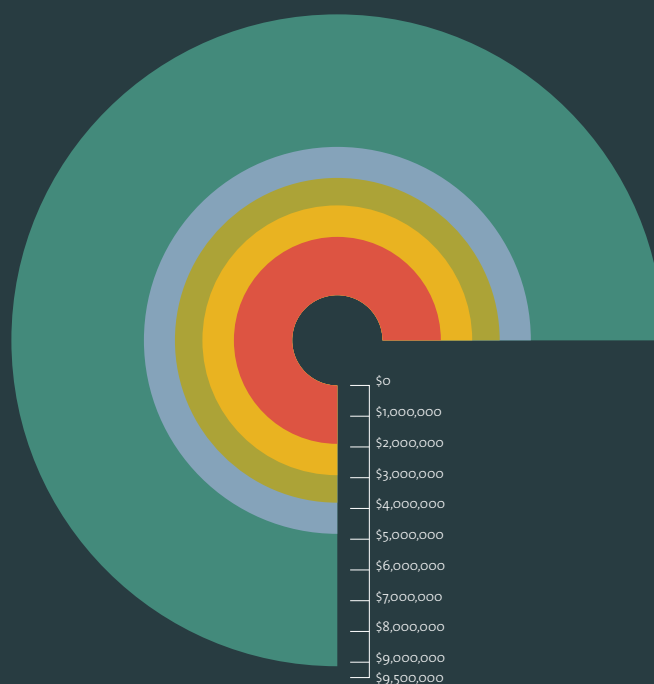


# GRANTS AND OTHER RESEARCH INCOME

ACEMS MEMBERS ATTRACTED \$9,050,310 IN ADDITIONAL SUPPORT DURING 2017, EXCEEDING THE TARGETS SET FOR OTHER RESEARCH INCOME SECURED BY CENTRE MANAGEMENT.

## NEW FUNDS IN 2017

FUNDING CATEGORY	TOTAL AMOUNT (\$)
ARC DISCOVERY	1,931,916
ARC FUTURE FELLOWSHIP	1,001,000
QUEENSLAND DEPARTMENT OF STATE DEVELOPMENT	980,000
AUSTRALIAN ACOUSTIC OBSERVATORY	900,000
OTHER	237,394
<b>TOTAL</b>	<b>9,050,310</b>



## ACEMS CHIEF INVESTIGATORS:



*Back Row (L-R): Phil Pollett (UQ), Dirk Kroese (UQ), Matthew Roughan (UoA), Louise Ryan (UTS), Scott Sisson (UNSW), Nigel Bean (UoA), Peter Taylor (UoM), Ian Turner (QUT), Tim Garoni (MU)*

*Front Row (L-R): Aurore Delaigle (UoM), Jan de Gier (UoM), Kerrie Mengersen (QUT), Matt Wand (UTS), Kevin Burrage (QUT)*

*Not pictured: Peter Forrester (UoM), Robert Kohn (UNSW), Tony Pettitt (QUT), Kate Smith-Miles (MU)*

The following two tables list grants that were active in 2016. The total of these grants is \$23,841,928. All of this income is over and above the income specified in the Centre agreement

## ACTIVE ARC GRANTS

New in 2017

GRANT TYPE	ARC GRANT ID	ACEMS INVESTIGATOR/S	TOTAL VALUE OF GRANT (\$)
ARC DECRA	DE150101044	Hautphenne, S.	315,000
ARC DECRA	DE150101842	Yang, Q.	345,000
ARC DECRA	DE160100584	Rubinstein, B.	370,000
ARC DECRA	DE160100690	Black, A.	373,316
ARC DECRA	DE160100958	Wheeler, M.	307,536
ARC Discovery Project	DP1092805	Sisson, S.	404,000
ARC Discovery Project	DP140100125	Delaigle, A.	415,000
ARC Discovery Project	DP140100441	Wand, M.	375,000
ARC Discovery Project	DP140100559	Garoni, T.	300,000
ARC Discovery Project	DP140101110	Jensen, I.	370,000
ARC Discovery Project	DP140101956	Kroese, D.	280,000
ARC Discovery Project	DP140102201	de Gier, J.	330,000
ARC Discovery Project	DP140102613	Forrester, P.	390,000
ARC Discovery Project	DP140103220	Hyndman, R.	335,000
ARC Discovery Project	DP150100828	Burrage, K.	367,391
ARC Discovery Project	DP150101459	Ross, N.	591,800
ARC Discovery Project	DP150101728	Martin, G.	277,000
ARC Discovery Project	DP150102345	Hegland, M.	225,900
ARC Discovery Project	DP150103588	Barbour, A.	310,700
ARC Discovery Project	DP150103675	Turner, I.	359,198
ARC Discovery Project	DP150103710	Rubinstein, B.	216,000
ARC Discovery Project	DP150104292	Koo, B. and Anderson, H.	262,400
ARC Discovery Project	DP150104595	Williamson, B.	426,700
ARC Discovery Project	DP150104630	Kohn, R.	333,581
ARC Discovery Project	DP160101325	Farrell, T.	290,000
ARC Discovery Project	DP160101520	Ridout, D.	444,216
ARC Discovery Project	DP160104292	Wang, Y.	305,500
ARC Discovery Project	DP170102028	Forrester, P.	318,000
ARC Discovery Project	DP170102434	Delaigle, A.	339,000
ARC Future Fellowship	FT130100098	Delaigle, A.	736,000
ARC Future Fellowship	FT170100079	Sisson, S.	1,001,000
ARC Laureate Fellowship	FL130100039	Taylor, P.	2,750,000
ARC Laureate Fellowship	FL140100012	Smith-Miles, K.	2,830,000
ARC Laureate Fellowship	FL150100150	Mengersen, K.	2,435,586
ARC Linkage Infrastructure	LE170100033	Bednarz, T.	900,000
ARC Linkage Projects	LP140100152	Fackrell, M., Taylor, P. and O'Reilly, M.	410,000
ARC Linkage Projects	LP140100282	Mengersen, K.	877,736
ARC Linkage Projects	LP140100489	Roughan, M.	194,873
ARC Linkage Projects	LP140100923	Mengersen, K.	686,929
ARC Linkage Projects	LP140101063	Smith-Miles, K.	421,276
ARC Linkage Projects	LP160100707	Turner, I. and Moroney, T.	417,290
ARC Linkage Projects	LP160101885	Hyndman, R., Smith-Miles, K. and Munoz Acosta, M.	204,000
			<b>23,841,928</b>

## OTHER ACTIVE GRANTS AND RESEARCH INCOME

New in 2017

INCOME SOURCE	ACEMS INVESTIGATOR/S	TOTAL VALUE OF INCOME (\$)
Asian Office of Aerospace Research and Development	Burrage, K., Mapder, T. and Burrage, P.	134,723
Australian Agricultural Company (AACo)	Mengersen, K. and Colin, B.	30,000
Australian Bureau of Statistics	Brown, J.	23,000
Australian Institute of Marine Biology (AIMS)	Mengersen, K., Peterson, E., Vercelloni, J., Caley, J., Wu, P. and McBain, M.	19,720
Australian Red Cross Blood Services, University of Technology Sydney	Ryan, L.	421,666
Bill and Melinda Gates Foundation	Ryan, L.	949,406
BMT Oceanica	McGree, J.	5,000
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	McGree, J., Mengersen, K., Drovandi, C. and Cespedes, M.	22,753
Community Benefit Funds Unit	Cramb, S.	10,000
Cooperative Research Centre Data to Decisions	Bean, N.	661,262
Cooperative Research Centre Data to Decisions	Bean, N.	668,377
Cooperative Research Centre for Spatial Information (CRCSI)	Mengersen, K. and White, G.	15,000
Cooperative Research Centre for Spatial Information (CRCSI)	Mengersen, K., Cramb, S., Moraga Serrano, P., Burrage, P., McGree, J. and Roberts, J.	291,000
Cooperative Research Centre for Spatial Information (CRCSI)	Bednarz, T.	105,947
Cooperative Research Centre for Spatial Information (CRCSI)	Mengersen, K.	25,000
Cotton Research and Development Corporation	Peterson, E.	14,000
Cotton Research and Development Corporation	Peterson, E.	299,960
Cotton Research and Development Corporation	Peterson, E.	652,088
CSIRO Information and Communication Technology (ITC) Centre	Pettitt, A.	40,000
CSIRO Information and Communication Technology (ITC) Centre	Turner, I.	50,000
Data61	Hyndman, R. and Cook, D.	151,200
Defence Science and Technology Group – Maritime Division	Perez, T.	30,000
Defence Science and Technology Group – Maritime Division	Perez, T.	575,681
Department of Social Security (OCS)	Mengersen, K., Wu, P. and Cameron, J.	685,448
Department of State Development (DSD) (QLD)	Mengersen, K.	50,000
Department of State Development (DSD) (QLD)	Mengersen, K.	930,000
Ergon Energy Corporation Limited	Mengersen, K.	9,660
Ernst & Young	Corry, P., McGree, J., Helmstedt, K., Mengersen, K. and Hsieh, J.	850,000
Expedia Inc.	Mengersen, K. and Fitzpatrick, B.	63,436
Forest & Wood Products Australia	Turner, I. and Farrell, T.	99,896
Huawei	Hyndman, R.	86,586
Hunter Industrial Medicine (HIM)	Mengersen, K.	40,000
Ministry for Primary Industries (New Zealand)	Mengersen, K.	8,589
Office of Naval Research, Dept. of the Navy, USA	Kroese, D.	69,000
Plant Biosecurity Cooperative Research Centre (PBCRC)	Mengersen, K.	230,000
Queensland Government	Bednarz, T.	10,800
Queensland Government	Nazarathy, Y.	8,921
Queensland Government	Mengersen, K., Harch, B. and Peterson, E.	200,000
QUT Institute for Future Environments	Peterson, E.	49,563
Sax Institute, University of Technology Sydney	Ryan, L.	330,000
Southeast Queensland Healthy Waterways & Catchments Partnership	Peterson, E.	150,000
The Yield Technology Solutions Pty Ltd	Perez, T.	221,141
University of Queensland, Flinders University and Sunshine Coast Hospital and Health Service	Nazarathy, Y.	7,000
US Department of Energy Bonneville Power Administration	Peterson, E.	71,630
ViCBiostat	Anderson, C.	2,000
VicRoads/Monash Graduate Research Industry Partnership	Garoni, T.	78,864
		<b>9,448,316</b>

# ACEMS FINANCES

A CONCERTED EMPHASIS THROUGHOUT 2017 ON THE DEVELOPMENT OF NEW RESEARCH COLLABORATIVE SUPPORT INITIATIVES, STRATEGIC PLANNING, A COMMITMENT TO INCREASE NEW APPOINTMENTS AND THE AWARD OF SCHOLARSHIPS TO BRING IN THE BEST MATHEMATICIANS AND STATISTICIANS FROM AROUND THE WORLD WILL SEE ACEMS GO FROM STRENGTH TO STRENGTH. IMPORTANTLY, IT WILL ALSO INCREASE EXPENDITURE ACROSS THE CENTRE, WHICH HAS BEEN AN ASPECT THAT HAS BEEN SLOW TO TAKE OFF.

The 2017 expenditure figures, while being consistent with 2016, did see an increase, from \$3,390,173 in 2016 to \$3,657,943 in 2017, as can be seen in the Financial Statement on page 156.

In order to address the underspend at each of the ACEMS nodes, the Executive Committee on the recommendation of the Governance Advisory Board, implemented a number of initiatives to bolster support for the ACEMS objectives. One such scheme is the Research Support Scheme which is designed to give ACEMS Research Fellows and AIs the opportunity to apply for funding to support side projects that fit within the strategic priorities of ACEMS. This, it is planned, will help facilitate cross-nodal collaboration, as well as collaborative projects with industry and government partners. Another initiative to further support research at ACEMS was to divest the scholarship programs to the nodes, rather than have them be administered centrally. This move was motivated by the idea that CIs and AIs at each node were best suited to identifying promising and talented postgraduate students to bring into the ACEMS community.

ACEMS plans to continue its support of all ACEMS members in all areas of academic research, from academic to professional development courses and workshops, as well as to supporting individual retreats for students and early career researchers.

ACEMS will also continue to support and expand its flagship Mathscraft program to reach into more high school curriculums across Australia as well as provide support for the MATRIX Institute which holds highly skilled research programs for mathematicians across the world.

On the recommendation of the ARC through the mid-term review process in 2017, ACEMS is also looking at strengthening its centrally held strategic funds to create better flexibility in providing support across the Centre. Due to the hard and dedicated work of the ACEMS Executive and Professional Staff in 2017, as ACEMS heads into the second half of its life, it is in a stronger position than ever.



# 2017 FINANCIAL STATEMENT

Statement of income and expenditure for year ended 31 December 2017, preceding calendar years and estimated budget for 2018

REPORTING PERIOD	2014	2015	2016	2017	2018 (ESTIMATED BUDGET)
<b>INCOME</b>					
ARC Income*	2,943,492	2,996,205	3,047,140	3,092,847	2,856,843
Node/University Contributions					1,199,874
The University of Melbourne	526,400	377,013	365,699	388,242	
Queensland University of Technology	159,336	476,006	315,580	355,555	
The University of Queensland	98,280	100,479	100,479	107,084	
The University of Adelaide	47,870	98,110	101,948	109,173	
UNSW Sydney	60,227	59,251	30,802	109,013	
University of Technology Sydney^^	-	147,636	299,949	-	
Monash University				29,839	
Other Income		75,000	17,817	23,678	
<b>TOTAL INCOME</b>	<b>3,835,605</b>	<b>4,329,700</b>	<b>4,279,414</b>	<b>4,215,431</b>	<b>4,056,717</b>
<b>EXPENDITURE</b>					
Salaries	226,747	1,816,017	2,599,067	2,662,505	3,034,557
PhD Stipend Top Ups & Scholarships#	4,790	80,703	106,321	241,250	250,000
Travel, Accommodation and Conferences	53,417	317,124	345,015	491,682	600,000
Consultants, Materials and Provisions~	109,324	37,907	17,727		-
Scholarships		59,100	82,400		
Marketing and Outreach and Sponsorship	6,007	96,965	42,776	132,440	164,500
Sponsorships**			129,593	121,123	150,000
Equipment~	17,974	15,875	18,710		20,000
Strategic Operations				21,448	200,000
Operating Expenses/Other	180,643	53,092	48,563	-12,505	100,000
<b>TOTAL EXPENDITURE</b>	<b>598,903</b>	<b>2,476,783</b>	<b>3,390,173</b>	<b>3,657,943</b>	<b>4,519,057</b>
<b>BALANCE</b>	<b>3,236,702</b>	<b>1,852,917</b>	<b>889,242</b>	<b>557,488</b>	<b>-462,340</b>
Six-month ARC/Uni Contribution Carry Forward***	-1,699,382	-159,336			
<b>CLOSING BALANCE AT END OF THE YEAR</b>	<b>1,537,321</b>	<b>1,693,581</b>	<b>889,242</b>	<b>557,488</b>	<b>-462,340</b>
Previous year carry forward		1,537,321	3,230,902	4,120,144	4,677,632
<b>ADJUSTED SURPLUS AT END OF THE YEAR</b>	<b>1,537,321</b>	<b>3,230,902</b>	<b>4,120,144</b>	<b>4,677,632</b>	<b>4,215,292</b>
<b>SIX-MONTH ARC/UNI CONTRIBUTION CARRY FORWARD TO 2021</b>	<b>1,699,382</b>	<b>1,858,718</b>	<b>1,858,718</b>	<b>1,858,718</b>	<b>1,858,718</b>

\* 2018 ARC Budget as per original ACEMS Funding Agreement — indexation is not included

^^ UTS received 2 x years Uni Contribution payments in 2016

\*\* Sponsorships reported separately from 2016

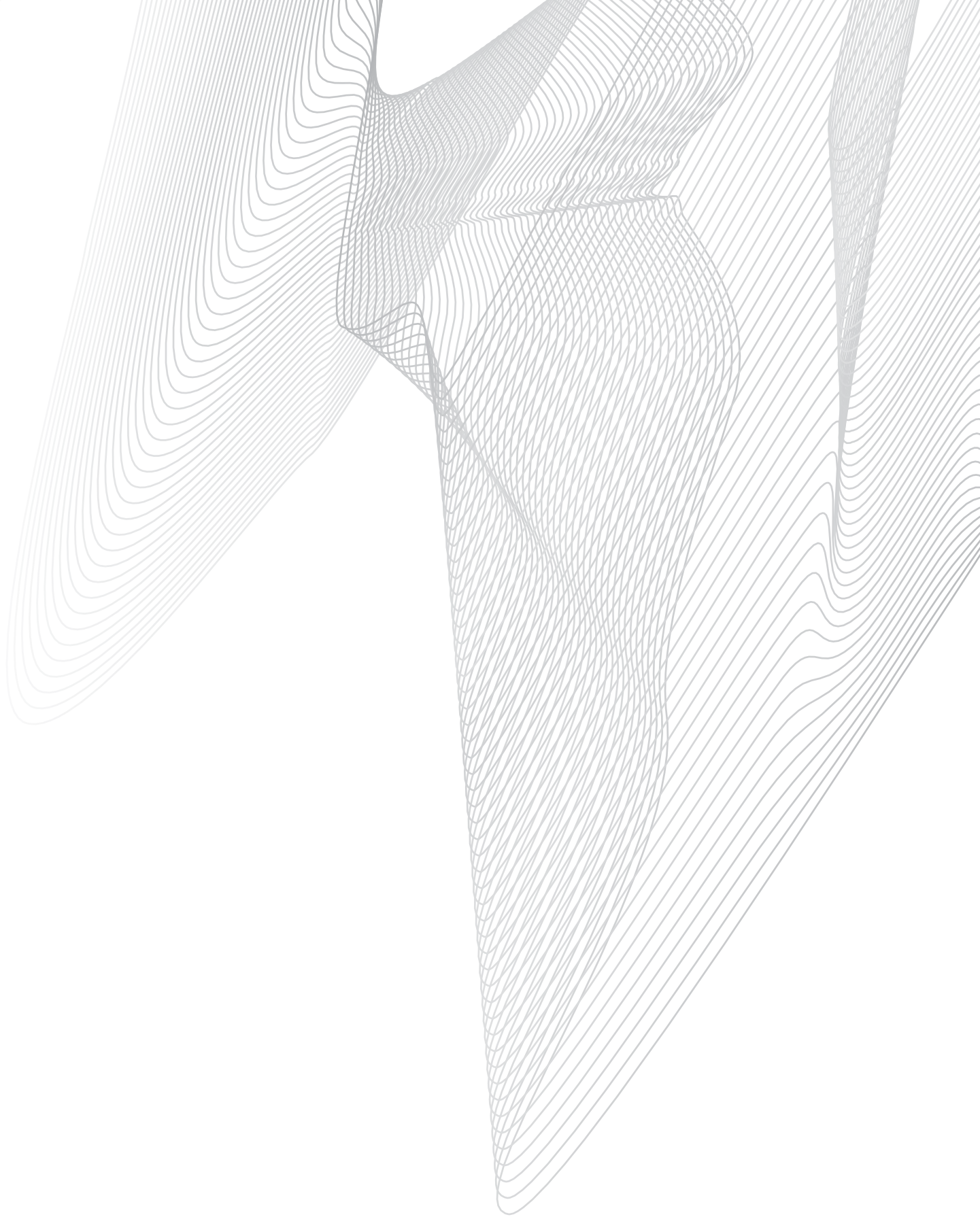
\*\*\* Six-month carry forward to final year due to July 2014 start. Funds from the ARC, UoM, UNSW and UQ were received in 2014, and from QUT in 2015

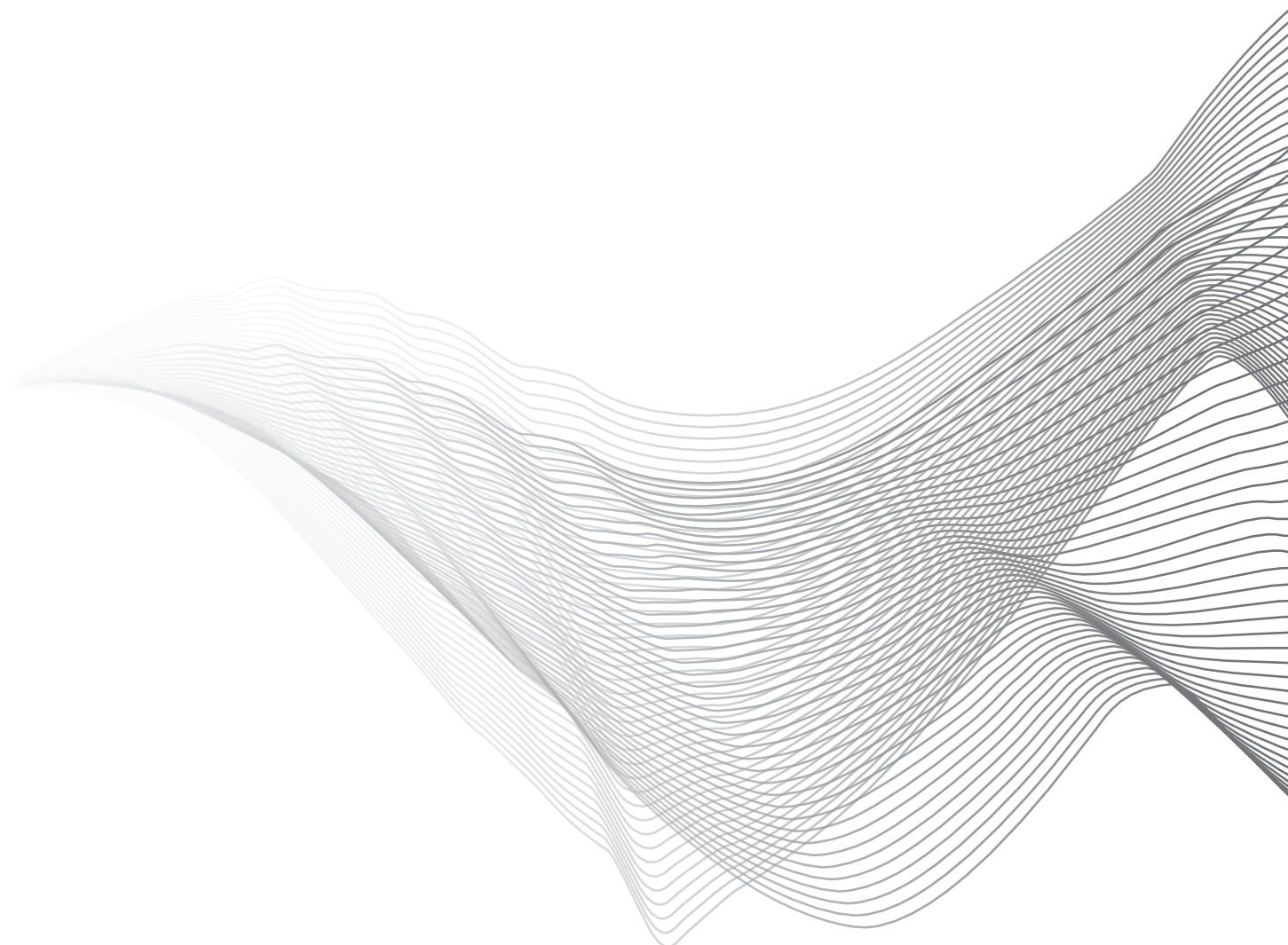
# Scholarships reported with Stipends from 2017

~ Reported under Strategic/Operating Expenses from 2017

## IN-KIND REPORT 2017

The University of Melbourne	1,456,236
Queensland University of Technology	1,702,262
The University of Adelaide	507,255
UNSW Sydney	467,692
The University of Queensland	413,508
University of Technology Sydney	829,567
Monash University	285,076
ACEMS members from other universities/institutions	135,036
Australian Bureau of Statistics (ABS)	51,280
Australian Institute of Marine Science (AIMS)	181,956
Sax Institute	32,465
Commonwealth Scientific and Industrial Research Organistaion (CSIRO)	22,400
Roads Corporation of Victoria (VicRoads)	32,100
AT&T Labs	33,600
Mathematics of Information Technology and Complex Systems (Mitacs)	2,250
<b>TOTAL</b>	<b>6,152,683</b>





## ARC CENTRE OF EXCELLENCE FOR MATHEMATICAL & STATISTICAL FRONTIERS

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