2013/14

The 2013 AMSI Winter School

The Mathematics of Planet Earth

The University of Queensland 24 June–5 July 2013

AMSI
AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

Australian Government
Department of Education

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

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COMMERCIAL MATHEMATICS

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Mathematics of Planet Earth 2013 AUSTRALIA

AMSIIntern

INTRODUCTION

BUILDING FUTURE COLLABORATIVE NETWORKS

2013 was the International Year of the Mathematics of Planet Earth, the 8th annual AMSI Winter School took this as its theme. Aimed at post-graduate students and postdoctoral fellows in the mathematical sciences and cognate disciplines, the Winter School set out to broaden and deepen participants mathematical knowledge, and to build collaborative networks with other PhD students and early career researchers.

A series of mini-courses were offered over the two-week long School. The courses in the first week were more introductory in nature, allowing the courses in the second week to lead into current research problems. The courses covered a range of topics in the broad area of the mathematics of planet earth, and were offered by eminent national and international researchers.

The Winter School is one of AMSI's flagship higher-education programs, which comprise vacation schools (Summer School, Winter School and BioInfoSummer), Vacation Research Scholarships and the AMSI internship program. The annual AMSI vacation schools and scholarships are funded jointly by the Department of Education and the Australian Mathematical Sciences Institute.

COMMITTEES

The 2013 AMSI Winter School wishes to acknowledge the generous donation of time and scientific advice of the following committees, without their contribution this event would not be a success.

Scientific Committee

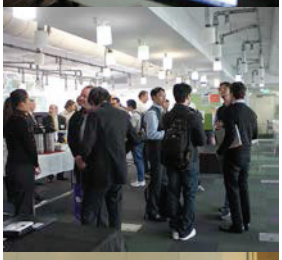
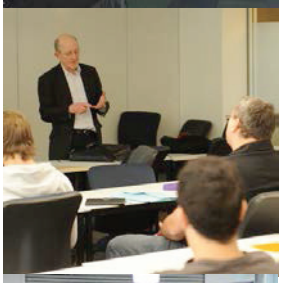
- Dr Gary Froyland, UNSW Australia
- Professor Joseph Grotowski, The University of Queensland
- Dr Markus Hegland, Australian National University
- Assocociate Professor Jon Links, The University of Queensland
- Professor Geoff Prince, The Australian Mathematical Sciences Institute

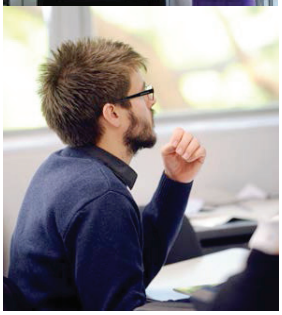
Organising Committee

- Professor Joseph Grotowski, The University of Queensland
- Ms Simi Henderson, The Australian Mathematical Sciences Institute
- Assocociate Professor Jon Links, The University of Queensland (Director)
- Ms Andree Phillips, The University of Queensland
- Professor Geoff Prince, The Australian Mathematical Sciences Institute

PROGRAM



WEEK 1: INTRODUCTRY COURSES

NUMERICAL METHODS ON GRAPHICS PROCESSING UNITS (GPUs)

Dr Vivien Challis, The University of Queensland, Australia

LARGE SCALE INVERSION FOR GEOPHYSICAL EXPLORATION

Assocociate Professor Lutz Gross, The University of Queensland, Australia

DYNAMICAL SYSTEMS & SINGULAR PERTURBATIONS

Dr Peter van Heijster, Queensland University of Technology, Australia

WEEK 2: ADVANCED COURSES

MATHEMATICAL MODELLING OF INFECTIOUS DISEASES

Dr Geoff Mercer, Australian National University, Australia

REGULARIZATION OF INVERSE PROBLEMS IN GEOMATHEMATICS

Professor Volker Michel, Universitat Siegen, Germany

DYNAMICS OF EARTHQUAKE RUPTURE

Dr Louise Olsen-Kettle, The University of Queensland, Australia

OPTIMISATION FOR NATURE CONSERVATION

Professor Hugh Possingham, The University of Queensland, Australia

NUMERICAL METHODS ON GRAPHICS PROCESSING UNITS (GPUs)

The course focused on NVIDIA's language CUDA C, which provides low-level control of the GPU. The course showed some of the subtleties of developing software for the GPU by discussing a number of examples. After looking at some simple examples the course looked specifically at the solution of partial differential equations on the GPU.

Dr Vivian Challis

School of Mathematics and Physics
The University of Queensland

Dr Challis is a postdoctoral researcher in the School of Mathematics and Physics at The University of Queensland. She received her PhD in 2009, for a thesis in the new area of the topic of Topology Optimisation. She has continued to work in this area, including developing applications in microstructural design problems and problems involving fluid flow, as well as more recently working on GPU implementations.

Vivien currently holds an Australian Research Council Postdoctoral Fellowship associated with the Discovery Project Porous beta-titanium bone implants optimised for strength and bio-compatibility: design and fabrication (2011-2013).

LARGE SCALE INVERSION FOR GEOPHYSICAL EXPLORATION

The course gave an introduction into the inversion of gravity anomaly data and aspects of data collection, the problem formulation and the mathematical analysis of the problem were discussed. Also, an introduction into the finite element method (FEM) as a solver for inversion problems was given and computational aspects using parallel computers were briefly discussed.

Assoc. Prof. Lutz Gross

Deputy Dircetor, School of Earth Sciences
The University of Queensland

Assoicate Professor Lutz joined the Earth Systems Science Computational Centre at The University of Queensland in 2003. He previously worked at the Computing Centre of the University of Karlsruhe, with the scientific software project in the School of Mathematical Sciences at the Australian National University, and at Massey University in Auckland where he established the Centre for Parallel Computing.

From 2001 to 2003 he was senior research scientist at CSIRO Mathematical and Information Sciences in Melbourne. His scientific interests are in the area of the numerical solutions for partial differential equations and parallel computing.

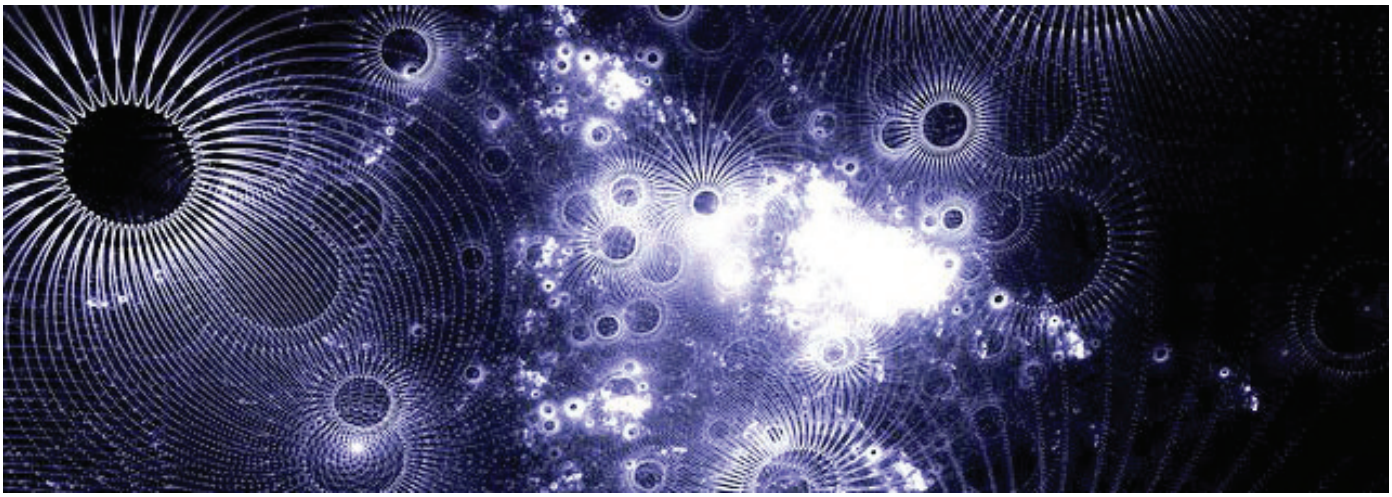
DYNAMICAL SYSTEMS & SINGULAR PERTURBATIONS

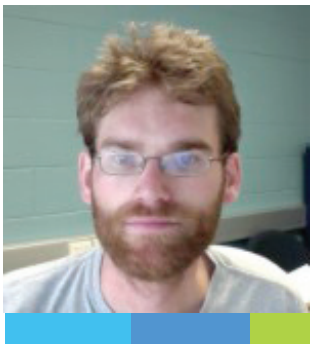
The course discussed the effects a small parameter can have on singularly perturbed (differential) equations and how to still obtain good approximations for the solutions from the reduced problems.

Two theories were introduced to do this:

- Geometrical Singular Perturberation Theory
- Fenichal Theory

These theories were applied to study a model used to describe gas-discharge on phenomological levels.





Dr Peter van Heijster

Applied and Computationla Mathematics
Queensland University of Technology

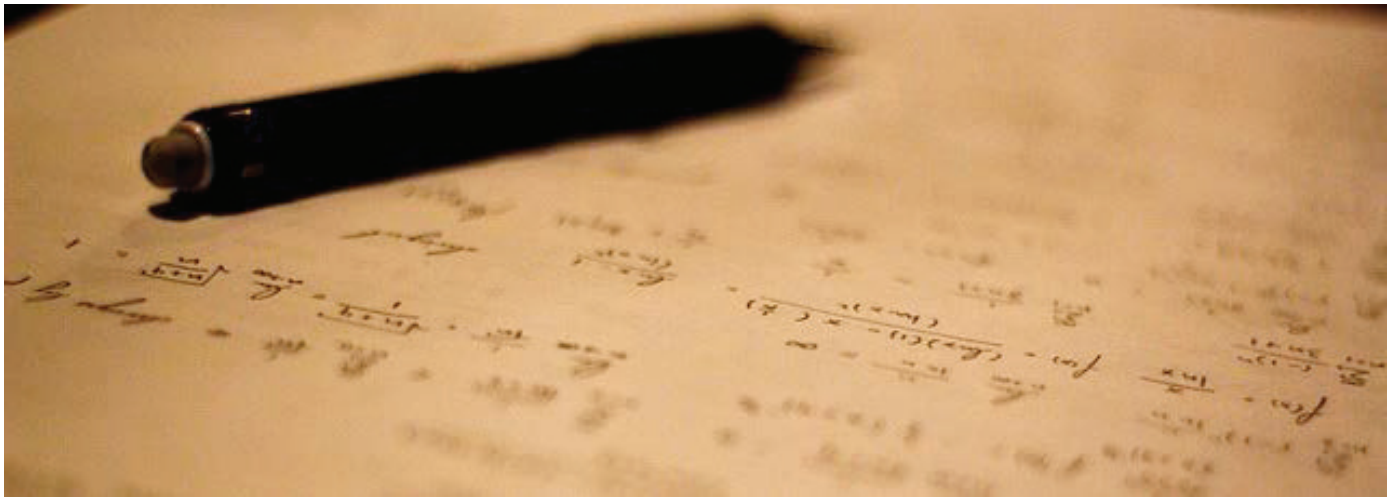
Dr van Heijster is a lecturer in mathematics at Queensland University of Technology, a position he commenced in 2012. Prior to this appointment he held postdoctoral positions at Brown University and Boston University in the USA.

He was awarded his PhD on Front Interactions in a Three-Component System from The University of Amsterdam in 2009. This work studied the ubiquitous feature of pattern formation, which occurs in many branches of science, modelled by reaction-diffusion equations. He is currently the Portal-Editor-in Chief for The Dynamical Systems Web, a networking project of the Society for Industrial and Applied Mathematics.

REGULARIZATION OF INVERSE PROBLEMS IN GEOMATHEMATICS FOR NATURE CONSERVATION

The course assumed a basic knowledge in tertiary mathematics so the following mathematical processes and methods of regularization of inverse problems could be discussed.

- Orthonormal Basis Systems on the Real Line, the Sphere, and the Ball
- Examples of Inverse Problems in Geomathematics
- Splines and Wavelets for Inverse Problems in Geomathematics
- Sparse Regularization With the Regularized Functional Matching Pursuit



Prof. Volker Michel

Head, Geomathematics Group
Universitat Siegen

Professor Michael has been Professor for Mathematics in Engineering at the University of Siegen, Germany, since 2008. Prior to his current position he spent several years at Kaiserslautern, including completion of his Habilitation thesis in 2002 on A multiscale approximation for operator equations in separable Hilbert spaces - case study: reconstruction and description of the earth's interior.

During 2006 he spent time at the Isaac Newton Institute for Mathematical Sciences at The University of Cambridge, and in 2008 at The Department of Applied Mathematics and Theoretical Physics also at Cambridge. He founded the Geomathematics group in Siegen and is an editor of the International Journal on Geomathematics which first appeared in 2010.

DYNAMICS OF EARTHQUAKE RUPTURE

The course investigated:

- The influence of stress heterogeneities on rupture along a bimaterial interface, providing a link between observations at laboratory and field scale.
- An interpretation of laboratory scale earthquake rupture experimental results by identifying a new physical mechanism underlying the transition to supershear speeds present at bimaterial interfaces.
- How nonlinear, mesh-dependent higher order terms can be introduced into a numerical model causing the mesh dependency. This was in an effort to begin resolving the problem of mesh dependency.

Dr Louise Olsen-Kettle

School of Earth Sciences
The University of Queensland

Dr Olsen-Kettle is a researcher in the Earth Systems Science Computational Centre at The University of Queensland. After receiving first class honours in applied mathematics in 2000, she completed her PhD in 2004 on the topic of Large-scale numerical simulations of a nanoscale device with applications in solid-state silicon-based quantum computing.

Her work models earthquake rupture and seismic wave propagation via a solution of non-linear time-dependent wave equations using the finite element method. Her current research investigations include the role of friction in the generation of slip complexity in earthquake cycles, and static Coulomb and dynamic stress triggering in interacting fault systems.

OPTIMISATION FOR NATURE CONSERVATION

The course covered the use of optimisation tools and approaches for formulating and solving problems in nature conservation:

- the "Noah's Ark" problem
- the reserve design problem
- optimal allocation of funds to different biodiversity hotspots.

The course also included discussion of algorithms like simulated annealing and stochastic dynamic programming.

Prof. Hugh Possingham

Director, The Possingham Lab
The University of Queensland

Professor Possingham was appointed joint Professor in Ecology and Mathematics at The University of Queensland in 2000. Since that time he has been awarded the Australian Mathematical Society Medal in 2001, elected to the Australian Academy of Science in 2005, was awarded an Australian Research Council Federation Fellowship in 2007, and won the Eureka Prize for Environmental Research in 2009.

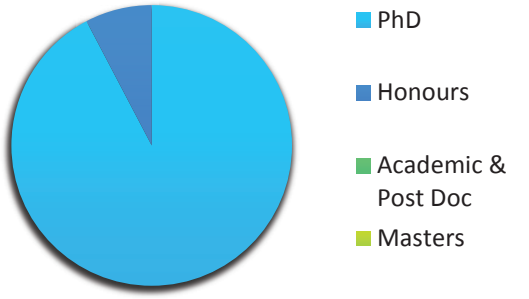
His vast research interests encompass marine reserve design, landscape reconstruction for birds, kangaroo and koala management, and optimal weed control to name a few. He is currently the Director of the Australian Research Council Centre of Excellence for Environmental Decisions and Director of the National Environmental Research Program's Environmental Decisions Hub.

ENROLMENTS

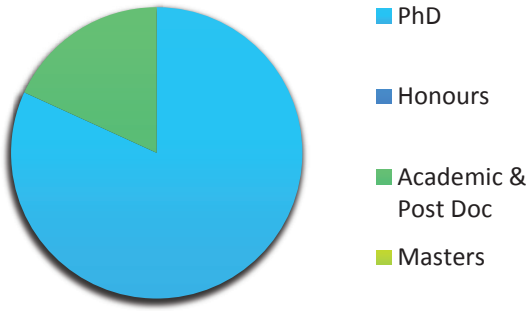
BREAKDOWN BY ENROLMENT STATUS

This data reflects registered participants, and does not include speakers, staff or winter school organisers

ENROLMENTS BY STATUS: AUSTRALIAN PARTICIPANTS



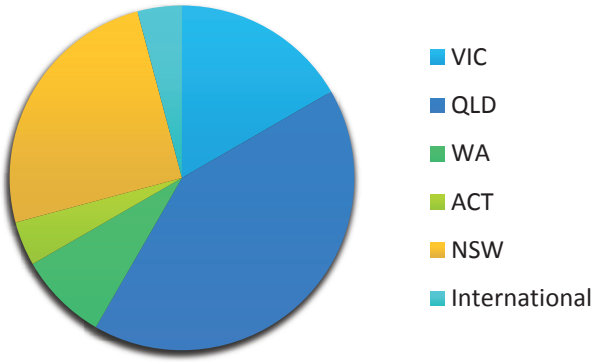
ENROLMENTS BY STATUS: INTERNATIONAL PARTICIPANTS



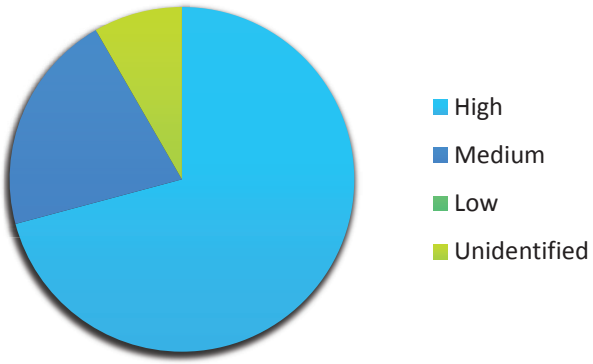
ATTENDANCE BREAKDOWN BY UNIVERSITY

Australian National University	1
Griffith University	2
Macquarie University	1
Queensland University of Technology	3
RMIT	1
Swinburne	2
The University of Melbourne	1
The University of New South Wales	2
The University of Queensland	5
The University of Sydney	2
The University of Western Australia	2
University of Wollongong	1
Victoria University of Wellington, New Zealand	1
Total	**24**

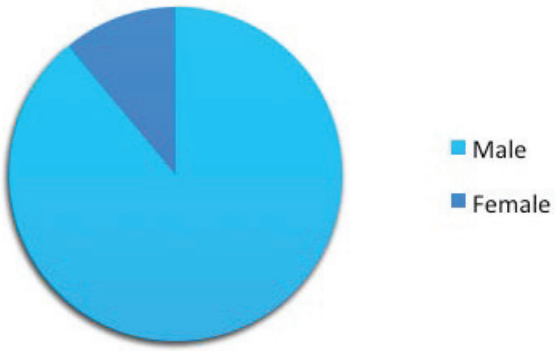
BREAKDOWN BY STATE



BREAKDOWN BY SOCIO ECONOMIC STATUS



BREAKDOWN BY GENDER



ABORIGINAL AND TORRES STRAIT ISLANDER PARTICIPATION

No participants identified themselves as having Aboriginal or Torres Strait Islander heritage.

EVENT HIGHLIGHTS

OPENING

The Opening Ceremony for the Winter School was held in the Science Learning Centre on 24 June. The Hon. Ian Walker, Queensland Minister for Science, Information Technology, Innovation and the Arts, was our key speaker. Minister Walker's speech emphasised the relevance and significance of science in general and in particular mathematics in a range of aspects of contemporary society. The morning lectures started at 9.30am and were one and a half hours in duration. We broke for a coffee break and resumed again for another hour and a half, till the lunch break. The afternoon sessions followed a similar time plan.

On Tuesday and Wednesday of the first week we held student presentations and the finalist was awarded a prize at the conference dinner.

Tutorials were held on the Wednesday and Thursday mornings of the second week.

WELCOME BBQ

A welcome BBQ was held at Emmanuel College on the evening before the conference started. This was an opportunity to register the participants, hand out information bags including program timetables and for everyone to meet each other.

SOCIAL DINNER

On the Friday night, a social dinner was held at the Mongolian BBQ restaurant. Drinks and food were provided for the participants and the event gave them the opportunity to socialise with each other and relax after the first week of the program.

CONFERENCE DINNER

The Conference Dinner was held on Thursday night on 12 July at The Ship Inn at Southbank. Tom Forbes, CEO of Business Development, Operations and Strategy at Biarri was the guest speaker for the evening. He spoke of the significance of Mathematics in the work place and internship opportunities in regards to commercial mathematics.

PUBLIC LECTURE: ENVIRONMENTAL INTELLIGENCE FOR AUSTRALIA

Monitoring, assessing and forecasting environmental states and processes will be more and more important in a world facing global change and sustainability limits. Societies will be challenged to maintain - let alone improve - food security, water security and biodiversity, so situational awareness about the environment must be greatly enhanced.

In his talk, Dr Vertessy outlined the Bureau of Meteorology's role as a broad-based environmental intelligence service for Australia. He outlined the new functions that the Bureau has taken on over the last decade to set it on this path, including various new ocean, water resources and space weather services.

These developments come at a time when the planet is changing faster than ever before, society is demanding more of science and technological advances in environmental sensing and earth system simulation are occurring faster than our ability to appropriate them. Dr Vertessy argued that these are exciting and important times for scientific communities and operational agencies specialising in environmental intelligence, emphasising the importance of the mathematical sciences in underpinning these endeavours.

DR ROB VERTESSY
BUREAU OF METEOROLOGY

"The Public Lecture was a real highlight with strong attendance and a very interesting and relevant talk."

- Assoc. Prof. Jon Links

Speaker biography

In 2012, Dr Rob Vertessy was appointed as the Director and CEO of the Bureau of Meteorology. Prior to that, he was head of the Bureau's Climate and Water Division, which is responsible for the National Climate Centre, the national flood forecasting and warning service, and new initiative laying the foundations for a National Plan for Environmental Information. Rob commenced that role in 2007 after a 20-year career as a research scientist at CSIRO.

At CSIRO, he specialised in forest hydrology and catchment modelling and is widely published in these fields. Rob served as Chief Executive of the CRC for Catchment Hydrology (2002–2004) and Chief of CSIRO Land and Water (2004–2007). Between his CSIRO and Bureau appointments, Rob was seconded to the Department of Prime Minister and Cabinet to advise on the establishment of a national water information strategy (2006). This strategy was taken up by the Australian Government in 2007 and is now being implemented by the Bureau.

DIRECTOR'S REPORT

The 2013 AMSI Winter School attracted a wide range of students from across Australian Universities, with one additional participant from New Zealand. The broad range of courses offered under this year's theme of the Mathematics of Planet Earth made it an attractive program not just for post-graduate students in the Mathematical Sciences, but also participants from cognate disciplines. We have continued to attract additional financial support from local external sponsors Biarri and QCIF.

Attendance was driven by the high calibre of professors from various departments including Earth Sciences, who gave lectures on this year's theme, Mathematics of Planet Earth. In all there were 7 lecturers who participated in the program, six from Australia (1 from Queensland University of Technology, 1 from Australian National University and 4 from the University of Queensland) as well as Professor Volker Michel from the University of Siegen, Germany. The first week was scheduled to give preliminary lectures as an

Introduction for the second week of more advanced lectures.

The school received very positive feedback from both participants and lecturers.

A highlight was the public lecture which, due to its relevance to current global issues, recieved much interest from the attendees.

Dr Jon Links, Director

"It's been great meeting other PhD students from around the world and sharing ideas."

- Kerry-Lyn Roberts, University of Sydney

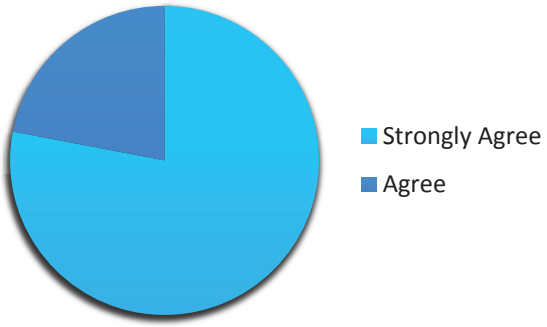
FEEDBACK

What was the best thing about the winter school?

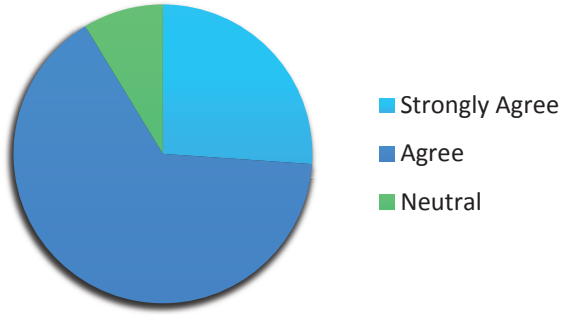
"I picked up some useful ideas to apply in my research"

"Being able to explore and bounce ideas off my peers as extensions to what we learnt in class"

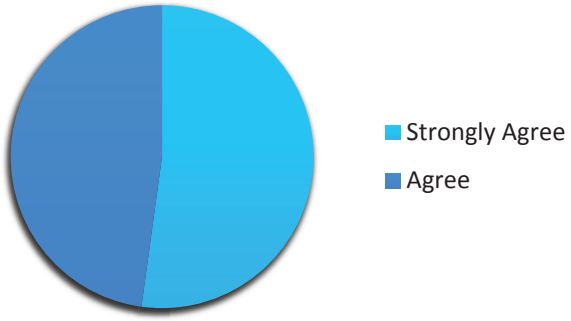
THE COURSES WERE WELL ORGAINSED AND THE LECTURERS KNEW THE CONTENT WELL



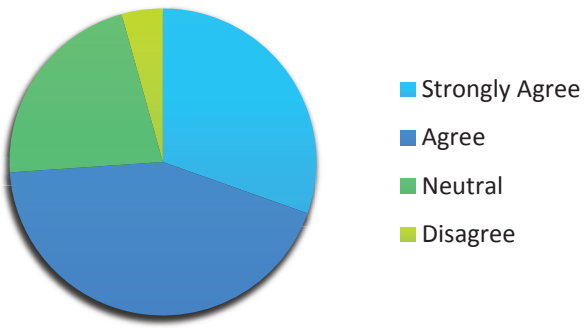
THE SCHOOL ALLOWED ME TO DEVELOP NETWORKS WITH MY PEERS



IT IS IMPORTANT TO BE AWARE OF OTHER RESEARCH BEING UNDERTAKEN IN MY FIELD



THE SCHOOL INCREASED MY KNOWLEDGE OF OTHER RESEARCH BEING UNDERTAKEN IN MY FIELD



STUDENT PROFILE

Ground breaking mathematics: breaking the ground of geothermal resources

Being able to analyse and predict the behaviour of a geothermal source over time is one of the most critical components to generating geothermal power. And with the growing push for sustainable energy sources, simulations and models are downright indispensable.

John Snadden, 2013 AMSI Winter School attendee, married his passion for numbers and the environment when he embarked on a collaborative PhD with the University of Western Australia and CSIRO. John has been able to develop simulations of how water and heat flow in geothermal reservoirs.

JOHN SNADDEN
UNIVERSITY OF WESTERN AUSTRALIA

'In the last few decades, the computational resources available to theoretical science have increased dramatically. Unfortunately there are few people with technical expertise in both parallel software development and geomechanics, so there are very few codes available to this end,' John said.

Attending the 2013 AMSI Winter School gave John the opportunity to present some of his work and its implementation in MOOSE – a complex systems simulation framework developed by Idaho National Laboratory.

'AMSI events are always great — I have been to quite a few — students gain unique access to experts and academics that they wouldn't be able to otherwise,' John said. 'The summer and winter schools are especially good for this, while other events broaden my horizons and introduce me to fields of research otherwise hidden.'

The use of computer models has enabled researchers in existing fields, like John, to perform their calculations with far higher precision and efficiency – opening up many new areas of inquiry.

'Maths can model just about anything. And with 2013 being the International Year of the Mathematics of Planet Earth I feel pretty privileged to be able to discuss the progress I have made in modelling cleaner energy sources,' John said.

John also enjoyed being surrounded by like-minded people: 'Talking about ideas spreads them and helps them to grow. AMSI events bring like-minded people together, which has a knock-on effect for future collaborations.'

When we share insights and knowledge between disciplines there is a greater chance of finding innovative solutions to pressing matters. Collaborations between scientists and mathematicians are vital to this process – as are young students with the drive to create multi-disciplinary collaborative ventures.

Australian Mathematical Sciences Institute

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