APPLIED MATHEMATICS

ANNUAL RESEARCH REPORT

2004

Editor: Colin Rogers

Address: School of Mathematics
UNSW SYDNEY 2052
Australia

Telephone: 61 2 9385 7039
Fax: 61 2 9385 7123
email: c.rogers@unsw.edu.au

Typeset: Janette Kos

Contents

1 APPLIED MATHEMATICS AT UNSW, 2004

In 2004, the Department was pleased to welcome Dr Gary Froyland, who joined as a Senior Lecturer with expertise in nonlinear dynamics and broad aspects of optimisation and its applications.

Matthew England and Wolfgang Schief are both to be congratulated on their promotion to Associate Professor.

During 2004, Ian Sloan as Scientia Professor continued his extensive research work, notably in numerical integration and approximation on the sphere. His work as President of ICIAM took him to Zurich where he chaired the annual meeting of the ICIAM Board. He also travelled to Vancouver in connection with its application to host ICIAM 2011, as well as in the Fields Institute in Toronto for a meeting of the ICIAM officers. Michael Banner was Deputy Head of the School of Mathematics and made important contributions to the study of wave breaking. Lance Leslie was on leave at the University of Nebraska. Jason Middleton continued as Head of the Department of Aviation and pursued his marine research. Colin Rogers developed his research in collaboration with Wolfgang Schief on geometric and solitonic structure in nonlinear continium mechanics. He remained on the Editorial Boards of the Journal of Mathematical Analysis and Applications, Studies in Applied Mathematics and the International Journal of Nonlinear Mechanics. He was appointed to the Editorial Board of the new journal Boundary Value Problems. Vaithiligam Jeyakumar had an extremely active year and, in particular, completed a research monograph on Nonsmooth Vector Functions and Continuous Optimisation with Dinh The Luc of the University of Avignon. He was also involved in a co-edited proceedings of an Australian Mathematical Sciences Workshop on continuous optimisation and optimal control to be published by Springer Verlag. Bruce Henry continued his long standing collaboration with Dr Susan Wearne of Mount Sinai, School of Medicine, New York in the area of dendritic branching morphology. His work with Dr Trevor Langlands on Turing pattern formulation and with Professor Batchelor and Dr Burne at ANU on a biotic model for the growth of stromatolites indicated his broad research interests. Rob Womersley's graphics descriptive of approximation on the sphere was recognised by a cover of the Notices of the American Mathematical Society. His international collaborations continued with Lucien Polak at UC Berkeley, USA on optimal discretization and with Xiaojun Chen at Hirosaki University, Japan on underdetermined nonlinear systems. Matthew England continued his well-regarded research in Physical oceanography and climate processes, with particular emphasis to the Southern Hemisphere. Wolfgang Schief concluded his work under his QEII Fellowship concerning Geroch-type transformations in general relativity and, in particular, their connection with infinitesimal Bäcklund transformations as developed in soliton theory. He has also entered into a collaboration with Adjunct Professor McMonnies in a study of the biomechanics of corneal collagen. His international collaborations in the area of

discrete geometry continue with Professor Bobenko at the Tecnische Universität Berlin, Germany and with Professor Burstall and Dr King at the University of Bath, UK. Peter Blennerhassett pursued his long standing collaborative work on hydrodynamic stability with Dr Bassom of Exeter University UK (now promoted to a Chair at UWA). Gary Froyland initiated research under an ARC Linkage Grant on strategic planning of open pit mining projects via discrete optimisation models. Mahadevan Ganesh was on leave at the Colorado School of Mines and continued his work on the analysis and development of computational algorithms. Bill McLean maintained his collaboration with Ivan Graham at the University of Bath, UK and also, during the year, was involved in the release of a Fortran 95 library for boundary element quadratures. John Middleton, with his research on ocean circulation models continued international collaborations with Ole Leth, University of Concepcion, Chile and Gennady Platov (Novosibersk, Russia). He remained as an Associate Editor for the journal Progress in Oceanography. John Murray pursued his research on the mathematical modelling of infectious diseases and was involved in organising both a Mathematical Biology Symposium and a Mathematical Biology Workshop at UNSW during the year. John Roberts continued his very active research in nonlinear dynamics and was involved in international collaborations with Professor Baake, University of Bielefeld, Germany, Professor Capel, University of Amsterdam, Holland and Professor Vivaldi, University of London. He held an AMSI-MASCOS Fellowship during the year. Within Australia, he carried on with his work with Professor Quispel on the construction of higher order integrable maps. Thanh Tran maintained his research in boundary integral equations as well as 'a posteriori' error estimates in the finite element method. He was involved in international collaborations with Professor Guo, University of Manitoba, Canada, Professor Ernst Stephan and Dr Maischak, University of Hannover, Germany (working on an eddy current problem in electromagnetics) and also with Associate Professor Lin at the National University of Singapore (on a problem modelling liquid crystal flows). Adelle Coster carried on with her wide-ranging research on the dynamical modelling of biological systems. This work included an ARC supported study of the electrical conduction system of the heart and a kinetic analysis of a glucose-transporting protein movements in fibroblasts and adipocytes. Chris Tisdell pursued his research involving dynamical systems on time scales and was involved in international collaborations at the Université Catholique de Louvain, Belgium and the Czech Academy of Science, Prague.

The proceeding attests to the wide range and high level of activity of the research within the Department of Applied Mathematics. During the year, a number of members of the Department travelled overseas to be involved in research collaborations or to attend international conferences. Ian Sloan travelled to Berlin to participate in the 60th birthday conference for Professor Peter Deuflhard and to negotiate with Professor Martin Groetschel (the leader of the Matheon research centre) an agreement between Matheon and MASCOS. While in Germany, he also visited the University of Dortmund and took part in a "Geomathematics" meeting at Oberwolfach of which he was one of

the co-organisers. Subsequently, he participated in MCQMC in Juan Les Pins, France, then in a conference at Bedlewo in Poland followed by a visit to the University of Warsaw. In August, Ian participated in the annual conference of China SIAM in Xiangtan and then travelled on to a conference devoted to "Thirty Years of the Double Exponential Transform" in Kyoto, Japan. Later in the year he returned to Germany to a meeting in Dagstuhl on "Algorithms for Continuous Approximation" and then went on to a conference in Linz, Austraia on a similar theme before visiting the University of Graz. Finally, in December he took part in an International Conference on Industrial and Applied Mathematics in New Delhi. Colin Rogers presented invited lectures at the Department of Mathematics, National University of Singapore, the Department of Mechanical Engineering, Hong Kong University (as William Mung Visiting Research Fellow), at the Institute of Applied Mechanics, National Taiwan University and at the Institute of Mechanics, Academia Sinica, Taiwan. He also gave invited lectures at a Symposium on Fluid Mechanics and Scientific Computation at the Hong Kong University of Science and Technology and at the Nonlinear Physics, Theory and Experiment Meeting in Gallipoli, Italy. Bruce Henry was a Session Chair at the 1st IFAC Workshop on Fractional Differentation and its Applications held at the University of Bordeaux, France. Rob Womersley presented an invited lecture in Oberwolfach, Germany at a meeting on Geomatics as well as at a Constructive Functions conference in Atlanta, USA. Bill McLean visited the University of Bath, UK and attended both the 13th Scottish Computational Mathematics Symposium at Strathclyde University and the IMA Conference on Boundary Integral Methods at the University of Reading where he presented a series of lectures on boundary element equations. John Murray travelled to the XV International AIDS conference where he presented aspects of his work on anti-retroviral therapy for HIV/AIDS. John Roberts made three visits to Queen Mary College, University of London, to work with Professor Vivaldi. He also visited the Institute for Theoretical Physics, University of Amsterdam and the University of Bristol. Thanh Tran presented lectures at the Centre for Industrial Mathematics at the University of Singapore. He also lectured at a Joint Colloquim in Analysis at the University of Natural Science and Pedagogical Institute, Ho Chi Minh City. Chris Tisdell visited the Institute of Pure and Applied Mathematics, Université Catholique de Louvain, Belgium as well as the Czech Academy of Sciences, Prague, the University of West Bohemia in the Czech Republic and the University of Augsburg in Germany. He also made research visits to the Univrsity of Nebraska–Lincoln, the University of Dayton and Baylor University in the USA.

There were numerous international visitors to the Department and a vigorous seminar programme and doctoral programe was maintained.

There was extensive research activity by postdoctoral fellows within the Department. This was supported by ARC Discovery Grants, a Vice Chancellor's Postdoctoral Fellowship and the ARC Centre of Excellence in Mathematics and Statistics of Complex Systems (MASCOS). These postdoctoral activities are listed separately in the Research Report.

The research areas of the Department are currently grouped as follows:

- Optimisation and Applied Analysis
- Biomathematics
- Computational Mathematics
- Geophysical Fluid Mechanics
- Nonlinear Phenomena

The research of the Department was recognised by substantial support from the Australian Research Council through Discovery and Linkage Grants as well as the Centre of Excellence in Mathematics and Statistics of Complex Systems.

In summary, the year 2004 witnessed a sustained high level of research activity within the Department of Applied Mathematics.

Colin Rogers
Head, Department of Applied Mathematics

2 STAFF

2.1 Academic and Professional Staff

Scientia Professor

Ian H Sloan, BA, BSc *Melbourne*, MSc *Adelaide*, PhD *London*, FAIP, FAust MS, FAA

Professors

Michael L Banner, BE MEngSc *Sydney*, PhD *Johns Hopkins*
Lance M Leslie, BA/MA Prelim. *Melbourne*, BSc (Hons) MSc *Sydney*, PhD *Monash*
Jason H Middleton, BSc PhD *Monash*
Colin Rogers, BA *Oxford*, MEd *Toronto*, MSc PhD DSc *Nottingham*, FinstP, FAA

Associate Professor and Head of Department

Vaithilingam Jeyakumar, BSc *Jaffna*, PhD *Melbourne*

Associate Professors

Bruce Henry, BSc PhD *UNSW*, FAIP
Robert S Womersley, BSc *Adelaide*, MSc PhD *Dundee*

Senior Lecturers

Peter J Blennerhassett, BE *Western Australia*, PhD *London*
Matthew England, BSc PhD *Sydney*
Gary Froyland, BSc *Queensland*, PhD *Western Australia*
Mahadevan Ganesh, MSc *Trichy*, PhD *Bombay*
William McLean, BSc *Queensland*, PhD *ANU*
John F Middleton, BSc PhD *Monash*
John M Murray, MSc *NSW*, PhD *Washington*
John AG Roberts, BSc *ANU*, PhD *Melbourne*
Wolfgang K Schief, Dipl Phys. *Ludwig Maximilians U*, PhD *Loughborough*
Thanh Tran, BSc Hons *HCM City*, PhD *UNSW*

Lecturers

Adelle Coster, BSc Hons PhD *UNSW*
Chris C. Tisdell, BSc PhD *Queensland*

Honorary Associate Professor

Russell Standish, BSc PhD *ANU*

Adjunct Professor

John Francis Le Marshall, BSc (Hons), PhD, *Monash*, Dip. Met. *Bureau of Meteorology*

Research Fellow

Hou-Duo Qi, BSc *Peking*, PhD *Chinese Academy of Sciences*

Visiting Professors

Gongbing Peng, MSc *Moscow National*
Vidar Thomée, Fil Kand *Lund*, Fil Dr *Stockholm*, KVA *(Sweden)*

Visiting Fellows

Clio Cresswell, BSc PhD *UNSW*
WD McKee, BSc *Adelaide* MSc *Flinders* PhD Cambridge
Alex H Opie, BSc DipEd *Melbourne*, PhD *Monash*, FAIP

Honorary Visiting Fellow

James Neptune Lyness, DPhil *Oxford*
Yufei Yang, PhD *Hunan*

Honorary Associates

William E Smith, MSc *Sydney*, MSc *Oxford*, PhD UNSW, MinstP

Research Associates

Christopher Michael Aiken, BSc *Tasmania*, PhD *UNSW*,
Mark Baird, BE *Sydney*, MSc *Hawaii*, PhD *Warwick*
David Chick, BSc, PhD *Hong Kong*
Joseph Dick, MSc *Salzburg*, PhD *UNSW*,
Stuart C Hawkins, BSc, PhD *Bath, UK*
Kerstin Hesse, Diploma Bonn, PhD *Kaiserslautern*
Frances Kuo, BCMS, PhD *Waikato*
Trevor Langlands, BSc (Hons), PhD *Queensland University of Technology*
Quck Thong Le Gia, BSc *UNSW*, MSc, PhD *Texas A&M*
Ben McNeil, B. Env.Eng. *Queensland*, PhD *Tasmania*
Kassem Mustapha, BSc *Lebanese*, MSc, PhD *UNSW*
Lixin Qi, MSc Chinese Acad meteo Sci, BSc *Zhongshan*, PhD UNSW
Alvise Sommariva, BSc, PhD *Padua*
Patrick Timko, BSc, MSc *Alberta* PhD *Memorial*,

Senior Research Officer

Russel P Morison, MSc *Monash*

Professional Officer

Gregory J Nippard, BSc *Sydney*

Computer Systems Officer

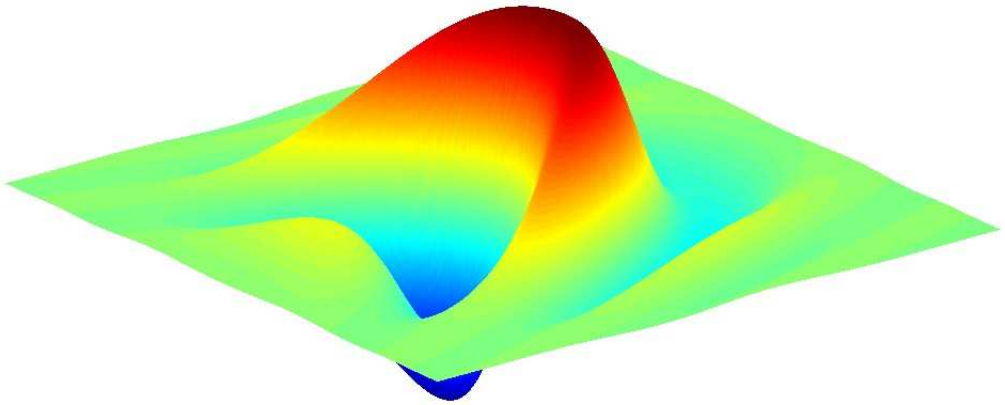
Dave Dowsett, BSc *Sydney*, BA *Macquarie*

2.2 Appointments and Promotions

Gary Froyland joined the school as a Senior Lecturer. David Chick and Stuart Hawkins took up positions as Research Associates. Joseph Dick was appointed as a Postdoctoral Research Fellow. Matthew England and Wolfgang Schief were promoted to Associate Professors effective January 2005.

3 AREAS OF RESEARCH

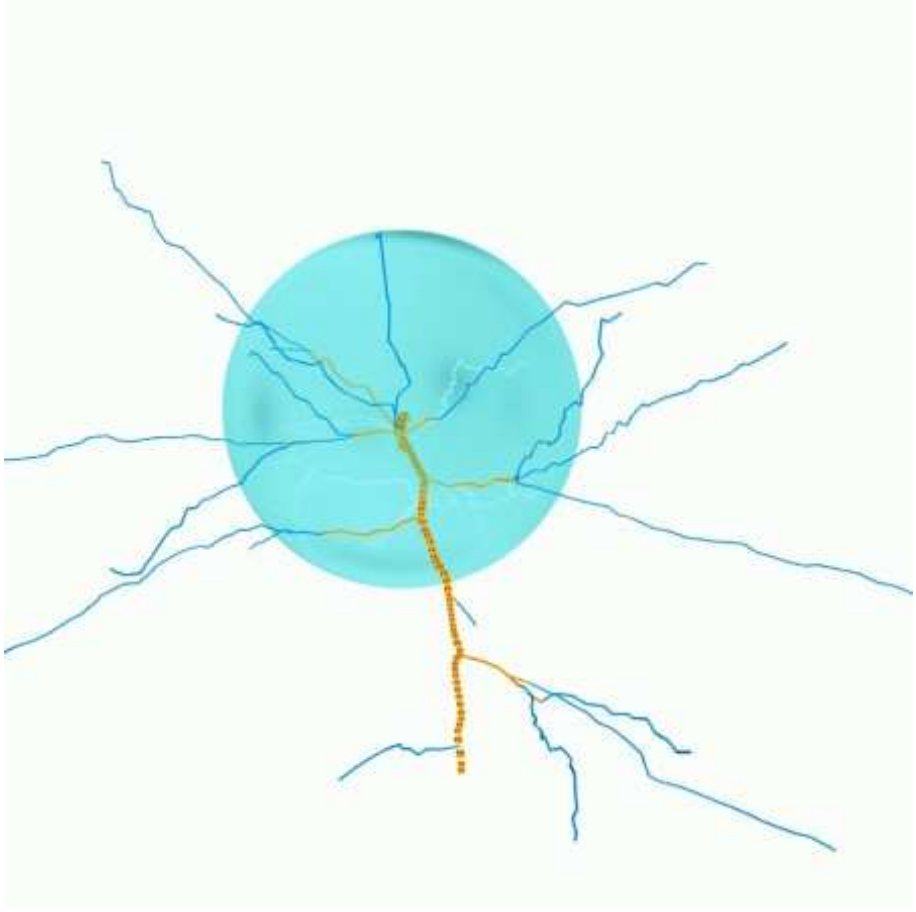
The Department of Applied Mathematics is highly regarded internationally as a centre for research, both fundamental and applied. The main areas of research are listed below,



Optimization and Applied Analysis

V Jeyakumar, J Murray, G Froyland, R Womersley

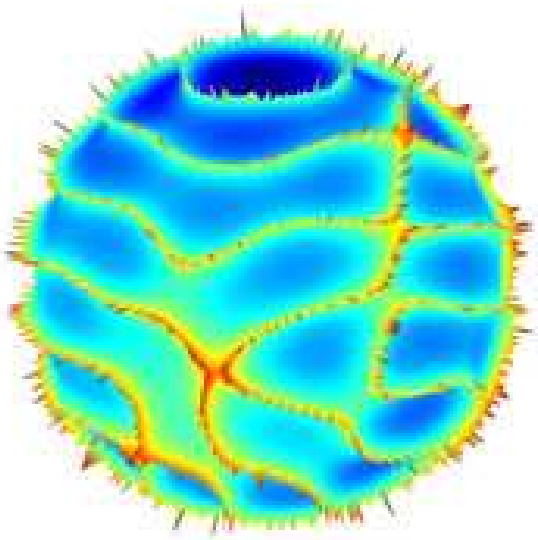
Optimization is the science that integrates information into mathematical models whose solution yields optimal decisions. It is the most widely used branch of Applied Mathematics in commerce and industry. Research areas of special focus include the variational analysis of nonsmooth optimization problems, global optimization and the development of computational methods for structured constrained optimization problems. These areas are both of intrinsic mathematical interest and have wide applications including mathematical finance, medicine and constructive approximation. Extensive use is made of modern variational analysis and high performance computing. Applied Mathematics at UNSW aims to expand its activities to develop discrete optimization.



Biomathematics

A Coster, B Henry, J Murray

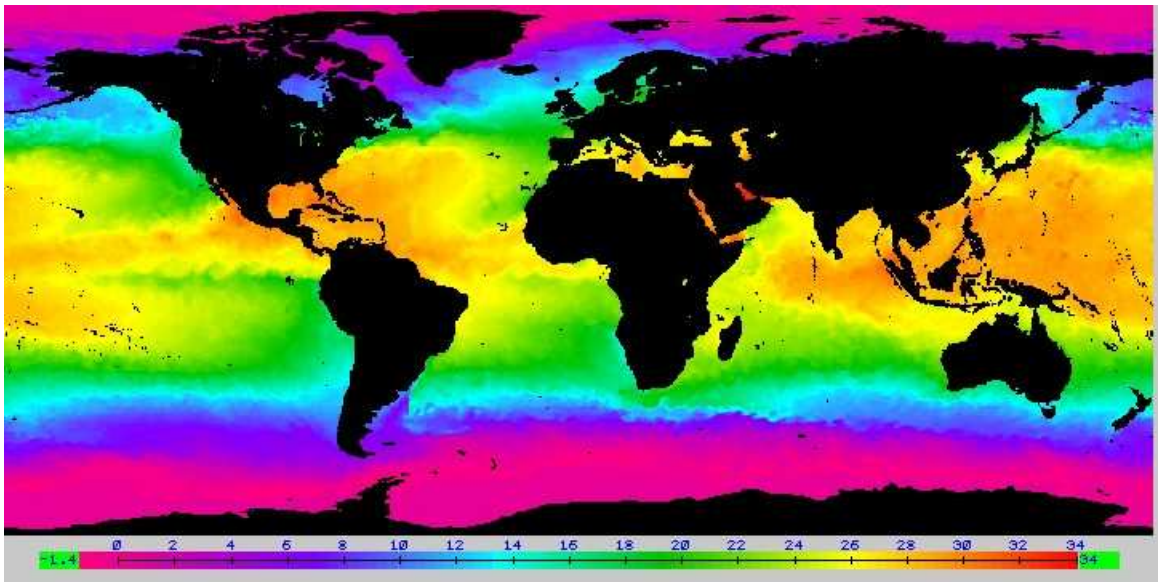
The discipline of biology is changing from a mostly descriptive science to a quantitative science. Biomathematics is facilitating this transition by developing new techniques to convert the logical but qualitative models of biology into formulae that can be used for quantitative prediction and improvement as well as for extracting patterns from complex data. The recently formed Biomathematics group at UNSW already has internationally competitive research projects in HIV, epidemiology, bioelectric phenomena and tumor growth. It has significant links with biomedical research centers both overseas and within Australia, and is well positioned to expand and make major contributions to the field.



Computational Mathematics

M Ganesh, W McLean, I Sloan, T Tran, R Womersley

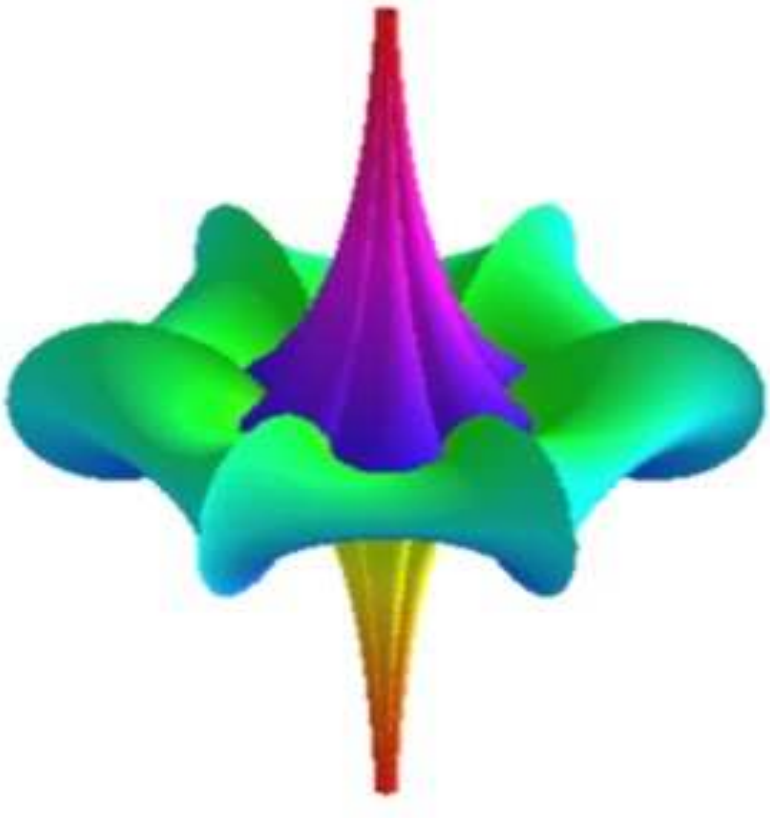
The design and analysis of computational algorithms, an area of strength at an internationally distinguished level at UNSW, underpins computational modelling in every area of technology and science, and nowadays in finance, medicine and the environment. Some areas of special focus include advanced methods for differential and integral equations, and algorithms for high dimensional problems. Developments in quantum computing are expected to become of increasing importance. Academic and research staff in this area make extensive use of high performance computing and advanced visualisation, in combination with modern analysis. They have strong involvement in the Centre of Excellence in Mathematical and Statistical Modelling of Complex Systems.



Geophysical Fluid Dynamics

M Banner, P Blennerhassett, M England, L Leslie,J F Middleton, J H Middleton

This group applies analytical and computational methods, as well as observations and data analysis, to problems of engineering, environmental fluid mechanics, physical oceanography, meteorology and climate. Areas of concentration include convection, stability of shear flows, water waves, internal gravity waves, wave-mean flow interaction and wave-topographic interaction. In the area of physical oceanography and meteorology, the group seeks to observe and model the physical processes occurring in the oceans and atmospheres. Methodologies used range from sea-going experiments and data analysis to numerical and analytical modelling. Interests include wind-wave generation, the circulation of the coastal ocean, extreme weather events, studying the dynamics of the oceans from the tropics to Antarctica. Another key interest is climate change and its effects on regional rainfall and ocean circulation.



Nonlinear Phenomena

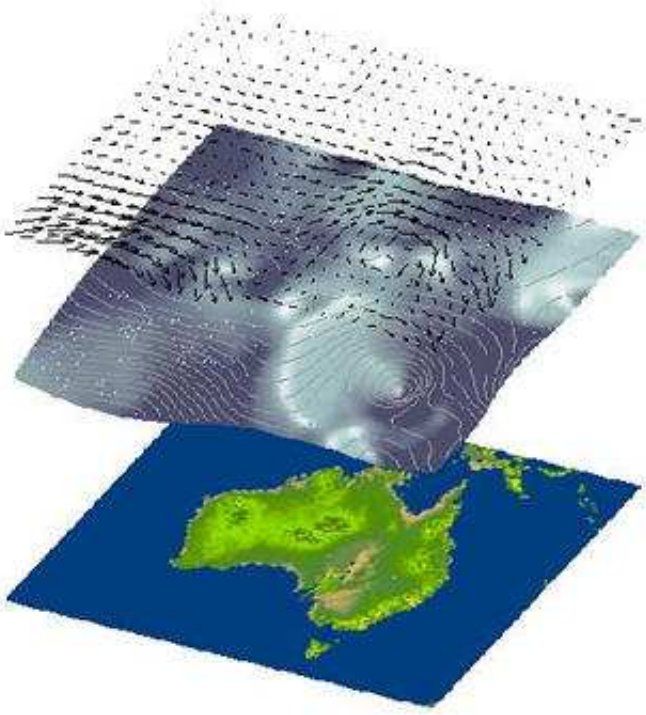
P Blennerhassett, B Henry, J Roberts, C Rogers, W Schief, C Tisdell

"... the progress of physics will to a large extent depend on the progress of nonlinear mathematics of methods to solve nonlinear equations" W.Heisenberg, Nobel Laureate 1932.

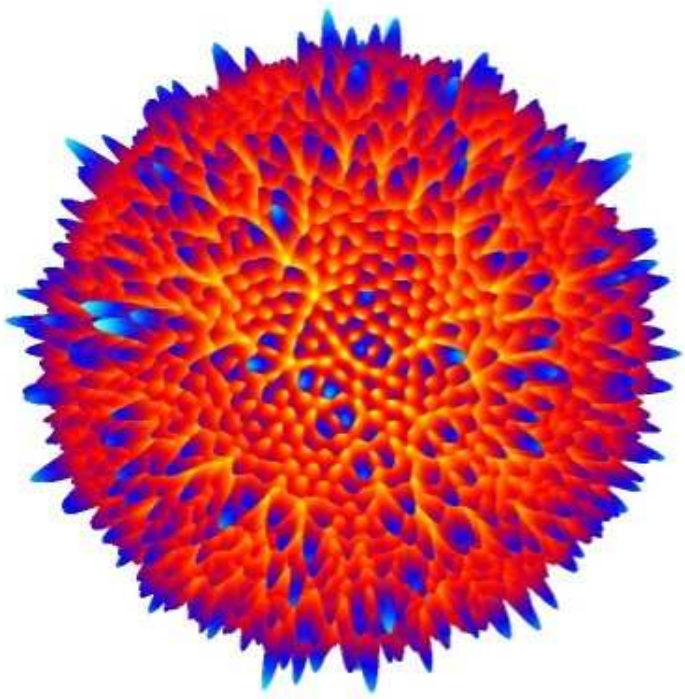
Nonlinear equations describe fundamental physical phenomena in nature ranging from chaotic behaviour in biological systems, plasma containment in tokomaks and stellarators for energy generation, to solitonic fibre optical communication devices. The Nonlinear Phenomena Group at UNSW is world-renowned for its work in soliton theory and dynamical systems and attracts visitors of international repute in these areas on a regular basis. Its activities have been recognised by Chief Investigator representation in the recently awarded Centre for Excellence in Mathematical and Statistical Modelling of Complex Systems. This provides a base for a major research programme involving the analysis of complex physical and biological systems and the systematic investigation of potential new areas of application of modern soliton theory in magneto hydrodynamics, the fabrication of fibre-reinforced composites and elastic shell structure design.

4 RESEARCH CENTRES

Centre for Environmental Modelling and Prediction (CEMAP)



This is a Research Centre in the School of Mathematics, consisting of members from the Department of Applied Mathematics. It is one of Australia's largest and most successful teaching and research groups in meteorology and oceanography, providing high quality postgraduate teaching programmes in environmental modelling and prediction. The Centre produces state-of-the-art environmental prediction models, including coupled ocean-atmosphere-land surface models and predictive systems for the weather, ocean and land surface climate, with a focus on extreme conditions. The Center also produces publications in quality journals and monographs, documentation, software, as well as associated analysis tools for end-users.



Centre of Excellence in Mathematics and Statistics of Complex Systems

In December 2002 the Federal Government announced funding of $11M over five years for the centre. Its mission is to stimulate research in mathematical and statistical modelling of complex systems, and to encourage cross-fertilization of ideas and techniques. Special areas of focus for the centre include dynamical systems, Monte Carlo methods, and scientific computation. The University of New South Wales is one of the four major partners of the Centre (the others being the University of Melbourne, the Australian National University, and the Australian Mathematical Sciences Institute. Of the three Chief Investigators at UNSW, two (Professors Colin Rogers and Ian Sloan) are in the Department of Applied Mathematics.

The Centre of Excellence began operating in 2003. Robert Womersley, Wolfgang Schief, Gary Froyland, Frances Kuo and John Roberts have been appointed as Associate Investigators.

5 RESEARCH ACTIVITIES

During 2004, departmental members have worked on a wide range of research projects in applied mathematics, and have participated in collaborative research activities with several distinguished researchers. The main research activities for the year are given below.

Michael Banner continued his observational, theoretical and modelling research on wind waves, wave breaking and air-sea interaction. He also continued as Deputy Head of the School of Mathematics.

Research continued on the central theme of improving present understanding of wave breaking, both in the physical domain, as well as in the wave spectrum. We continued to refine our calculations, and now produce spectral distribution of breaking crest length density in addition to the wave spectrum. Comparison with available data has highlighted fundamental new issues that need to be addressed in both the calculations and the measurements.

This year also saw the publication of a third paper with Jinbao Song in our series on two-dimensional wave breaking behaviour inferred from exact computations. This paper examined the influence of proximity of a flat horizontal bottom, as well as a circular arc bottom mound, on the breaking onset that was framed in terms of the mean growth rate of the energy density at the evolving wave group maximum. This study produced very interesting new results on the influence of wave groups interacting with such shallow bathymetric features.

Ongoing research projects during 2004 included:

- observational and computational model studies of the evolution of the wave number spectrum of ocean wind waves, featuring a new source term for the spectral dissipation due to wave breaking;

- an observational study of the source term balance in shallow water wave spectral evolution;

- a laboratory study on the role of microscale breaking waves in the air-sea interfacial gas flux of low solubility gases ...

Professor Banner's Australian collaborators during 2004 included:

WL Peirson, Breaking wave onset and breaking, influence of micrioscale breaking on air-water gas transfer rates;

IR Young and A Babanin (Swinburne) Shallow Water Wind Wave Evolution – Source Terms; (ADFA): Deep and shallow water wave breaking dependences.

His overseas collaborations during 2004 included:

MA Donelan, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Shallow water wind wave evolution – source terms;

J Gemmrich, University of Victoria and Institute of Ocean Sciences, Sydney, British Columbia: Breaking probability analysis in the wave spectrum;

E Walsh, NASA, Boulder, Colorado: Breaking probability estimates in hurricanes;

C Zappa and W McGillis: Lamont Doherty Earth Laboratory, Palisades, New York, Quantifying microscale breaking waves under field conditions.

Peter Blennerhassett continued research in the field of linear and nonlinear hydrodynamic stability, with the main emphasis being on the linear stability of time dependent flows. This work on the instability of unsteady flows was continued with Dr Bassom (Exeter University, U.K.) and a research student, Frank Reid.

Adelle Coster continued her research activities in dynamical modelling of biological systems. Particular interests include the nonlinear dynamics of pulse coupled oscillators, representing the electrical conduction system of the heart, which is the subject of an ARC Discovery Grant. Initial investigations have developed a realistic representation of an ECG using these oscillators, as well as investigation of the effects of conduction block on the dynamics. In another project, a kinetic analysis of GLUT4 (a glucose-transporting protein) movements in fibroblasts and adipocytes (fat cells) in response to insulin is being developed. In this collaboration with Professor David James, Garvan Institute, two refereed publications were produced in 2004 (Traffic, vol. 5(10), 763–771; and Molecular and Cellular Biology, vol. 24(14), 6456–6466). Initial investigations were also made into a model of melanoma growth, in collaboration with Associate Professor Bruce Henry and a vacation scholar, Dave Cameron. Whilst being mathematically a relatively simple model, it already embodies the major features of each stage of melanoma growth.

Matthew England continued his research activities in large-scale physical oceanography, ocean modelling, and climate processes. Particular interests include the circulation and variability of the Southern Ocean and its role in climate, estimating climate change, ocean CO_2 uptake, and future sea level rise. Research continues in the ocean's thermohaline circulation, stability, and feedback to the atmosphere. In 2004, Matthew England made the following findings:-

1. By analysing observations and a coupled climate model, a distinctive pattern of Indian Ocean sea surface temperature (SST) anomalies was found that characterises southwest Australian rainfall variations [England et al., J. Climate].

2. A simple coupled model of the Southern Ocean and overlying atmosphere was developed to show that forced advection can explain interannual Southern Ocean SST variability to leading order [Aiken and England, J. Climate, in press].

3. The role of the Drake Passage throughflow on global thermohaline circulation was assessed [J. Climate, in press].

4. Investigations of the role of Southern Hemisphere winds in controlling mid–latitude ocean properties were completed [ms appeared in J. Climate].

5. The connection between ENSO and the transport rate in the Indonesian Throughflow (ITF) was examined in a global data assimilation model, revealing a significant connection with the ITF exhibiting a 7-9 month lag response [England and Huang, 2005].

Gary Froyland joined the Applied Mathematics department in August 2004. His research interests lie in the areas of nonlinear dynamical systems, ergodic theory, nonlinear time series analysis, Markov chain modelling, integer programming, and stochastic programming.

Since his appointment, Gary has begun work on the ARC Linkage Project "Using Mathematics to Maximise the Value of Open Pit Mines" (industry partner BHP Billiton) in collaboration with Associate Professor Natashia Boland and Professor Peter Taylor of the University of Melbourne. This project is concerned with the strategic planning of open pit mining projects over several decades, which in mathematical terms is a very large discrete optimisation problem (more precisely, a combination of several precedence-constrained knapsack problems). The mathematics has focused on theoretical approaches to allow models with larger numbers of binary variables to be solved in a matter of hours. Gary co-supervises Mr Chris Fricke, a PhD student at the University of Melbourne in this area. Extensions of this work to mining projects where blended products are manufactured are also being pursued. A paper appeared that developed rigorous mathematical methods based on stochastic geological estimates to determine the maximum possible monetary value of undertaking additional drilling. Mine planners may use this method as a decision aid to judge whether the cost of additional drilling can be covered by increased profits via increased knowledge of the geological resource.

In December 2004, Gary hosted Vacation Scholar Mr Mark Fisher, who worked on Perron-Frobenius operator methods of detecting macroscopic stable structures in low-dimensional nonlinear dynamical systems. Gary is interested in extending these theoretical approaches to non-autonomous systems and to apply the resulting numerical methods to real data, in particular to ocean models for which current modeling methods cannot detect or display the persistent or coherent structures observed in nature.

Mahadevan Ganesh continued his research work on the development and analysis of computational algorithms for partial differential and boundary integral equations.

Dr Ganesh published four research papers on numerical solutions of partial differential equations in 2004: The first paper was on high-order algorithms for obstacle scattering

in three dimensions (with Graham); the second one on boundary integral methods for slender body problems; the third paper was on a finite element method (FEM) with quadrature for elliptic problems (with Bialecki and Mustapha); and his fourth publication was on a diffusion-modified FEM with quadrature for nonlinear reaction–diffusion equations.

Dr Ganesh, in collaboration with various researchers, made substantial progress on five distinct topics described in the five-year ARC Discovery Grant he received with Professor Ian Sloan in 2003.

Bruce Henry In collaboration with Dr Trevor Langlands and Dr Susan Wearne, Bruce further explored their fractional calculus model for Turing pattern formation activator-inhibitor systems with anomalous diffusion. In the standard activator-inhibitor systems Turing pattern formation can only occur if the diffusivity of the inhibitor is much larger than that of the activator. This required difference in diffusivities has been an impediment to the adoption of Turing pattern paradigm in many applications. By modelling the effects of anomalous diffusion using fractional order temporal derivatives operating on the spatial Laplacian Bruce's group has established the important result that if the diffusion of the activator is anomalous, then Turing pattern formation can occur even if the diffusivity of the inhibitor is smaller than that of the activator. This work was reported by Bruce as part of an invited workshop (for which Bruce and Susan were session chairs) at the 1st IFAC Workshop on Fractional Differentiation and its Applications, Universitie Bordeaux, Bordeaux, France, July 2004. Bruce also presented an invited talk on this material to the Complex Systems Workshop at the Australian Mathematical Society Meeting in Melbourne in September 2004.

Bruce Henry in collaborative work with Professor Murray Batchelor and Dr Bob Burne, from the Australian National University, continued their development of a simple biotic model for the growth of stromatolites. Modern stromatolites are laminated structures that are produced by colonies of microbiolites living on their surface. There is currently a great deal of interest in whether ancient stromatolites (some of the stromatlities found in Western Australia date back 3.5 billion years) were also produced by colonies of microbiolites or if they were the result of purely physical processes such as sedimentation and chemical precipitation. If they did have a biotic origin then they are the earliest evidence of life on Earth and perhaps even life on Mars.

The groups biotic model, which consists of upward growth of a phototropic map and mineral accretion normal to the surface of the map, can reproduce the essential morphologies of individual ancient stromatolites and colonies of ancient stromatolites. Dr Murray presented an invited talk on this work at the StatPhys Meeting hosted by the Institute of Physics, Academia Sinica, Taipei, in Taiwan June 2004.

In collaborative work with Dr Susan Wearne and Dr Patrick Hof, Mount Sinai, School of Medicine, New York, Bruce continued to develop measurements of the spatial complex-

ity of dendritic branching in neurons that correlate with functional properties. Current efforts of the group are directed towards the development of measures that correlate with age related alterations in dendritic branching morphology. Susan and Patrick presented results from this work at the Society of Neuroscience Annual Meeting, Washington, October 2004.

Vaithilingam Jeyakumar continued to work on a variety of projects across a number of areas of Optimization, Mathematical Programming and Applied Analysis. His research during the year focused on global optimization, and convex optimization with applications. With Regina Burachik (Engenharia de Sistemas e Computacao, Rio de Janeiro, Brazil), a dual technique, called sum-epi-conjugate technique, was developed for studying problems of convex analysis and optimization. It is based on the closure of the sums of the epigraphs of conjugate and provides the basis for enhancing analysis and applications of convex optimization. This technique led to the development of new non-interior point constraint qualifications (CQ) for a stable conjugate duality. With John Ormerod and Rob Womersley, work on the application of semidefinite programming was completed. This work led to the development of a new computational method for solving Machine Learning problems of large-scale data classification, and resulted in a journal publication.

A month long visit in August by Dinh The Luc (University of Avignon, France) saw the completion of a research monograph on Nonsmooth Vector Functions and Continuous Optimization, co-authored by Jeyakumar and Luc. This monograph is a result of over 6 years of successful research collaboration with Dinh The Luc. With the arrival of Zhi-You Wu in October as Research Associate, substantial progress was made on characterizing global solutions of challenging multi-extremal non-convex optimization problems.

Work on the co-edited proceedings of the Australian Mathematical Sciences Institute Special Workshop (with Alexander Rubinov) on continuous optimization and optimal control was largely completed, and is to be published as a research monograph by Springer, New York in 2005.

In December, he organized a one-day satellite conference on Continuous Optimization at UNSW.

Lance Leslie has continued his work in a variety of atmospheric modelling areas from global scales down to microscales. These include mesoscale and urban meteorology, high performance computing, predictability, and numerical weather prediction. Other research areas include severe weather events, prediction of air quality, and soil erosion modeling.

Bill McKee retired in July 2003, but is still associated with the department as a Visiting Fellow. He is continuing his investigations into the propagation of water waves across a shearing current.

Bill McLean In September, Bill McLean visited the U.K. to collaborate with Ivan Graham at the University of Bath and to attend two meetings: the 13th Scottish Computational Mathematics Symposium, at Strathclyde University in Glasgow, and the IMA Conference on Boundary Integral Methods at the University of Reading. In Reading, he gave an invited lecture on the conditioning of boundary element equations, which included recent joint work with Ivan Graham treating the case of anisotropically-refined meshes. He also continued work with Ian Sloan and Vidar Thomée on an exponentially-convergent numerical scheme for a class of parabolic integro-differential equations, and released a Fortran 95 library for boundary element quadrature. This library implements some complicated transformation formulae, due to Stephan Sauter and Christoph Schwab, that regularize singular integrals of the type arising in some 3D boundary element methods. Bill also continued his work as an associate editor of the ANZIAM Journal.

Jason Middleton continued his oceanographic research on the East Australia Current (EAC), being joined by Research Associate Patrick Timko. The EAC model was further developed by Patrick Timko and Mark Baird's mechanistic nutrient-phytoplankton-zooplankton model added. A manuscript on the 2-dimentional simulation was published in the Journal of Marine Systems with Peter Oke. The final paper from Moninya Roughan's thesis was published, as was earlier work on nutrient uptakes on Warraber Island by co-authors Mark Baird, Moninya Roughan, Rob Brander (BEES), and Greg Nippard. Later in the year Professor Middleton led a 12 day cruise aboard RV Southern Surveyor (SS08), with objectives being the detailed examination of the EAC frontal regions, as well as the wake of North Solitary Island, located Off the north coast of NSW. Greg Nippard undertook a substantial part of the cruise preparation and was a key part of the experimental team, which included Iain Suthers (BEES) and personnel from his group. Debbie Cox began her PhD, making solid progress on applying the ROMS model to island wake simulations, and participating in cruise SS08 to acquire data to compare against her model simulations. All members of the team attended the AMSA meeting in Hobart, in honour of Peter Holloway. Ann-Marie Wong continued her work on Antarctic ocean circulation and bottom water formation driven by sea-ice formation, and her thesis was approved and she graduated in 2004. Kenn Batt's thesis on the meteorology of storms and their impacts on sailing was also approved.

John Middleton John Middleton (http://web.maths.unsw.edu.au/ jffm/) continued his research into ocean circulation, with focus on that of the Chilean and South Australian shelf and slope. In collaboration with Ole Leth (University of Concepcion), two papers appeared detailing a new mechanism for the upwelling on the Chilean shelf. Using a numerical model, it was shown the extraordinary upwelling of nutrients for the Gulf of Arauco region is likely driven by local winds and the advection by a meso-scale eddy and a headland eddy: the 50 km Gulf can account for up to 4% of the world?s

fish landings. In addition, it was shown how 2-D and 3-D upwelling are related and why the equatorward boundary condition must be tested to ensure the correct degree of wind-forced upwelling: many numerical models of upwelling have ignored this important aspect of numerical modelling. Work on the shelf and slope circulation of the S.A. region continued through further collaboration with Dr Tim Ward and Sam McClatchie (S.A. Research and Development Institute) and other researchers. Work with Gennady Platov (Novosibersk, Russia) also continued on the development of a S.A. Regional Ocean Model (SAROM). A preliminary report has been submitted to the Fisheries Research and Development Corporation on this funded research. Collaborative agreements with the Bureau of Meteorology and several global modelling groups have also been obtained so as to obtain the best surface and boundary forcing for this regional model. An important new result is the demonstration that El Nino events a) enhance summertime upwelling and b) have raised the level of cold 11.5 C water by some 100 m over the last 20-30 years. Work on the role of the effect of the canyons of the region is progressing with MSc student Craig Arthur. Einar Oalson (Iceland Exchange student), is also doing a research project with John on the large-scale ocean circulation around Iceland. As Treasurer, John Middleton also continued with the organization of the Cairns 2005, Joint Assembly of the International Associations of Geodesy, the Physical Sciences of the Oceans and Biological Oceanography – a major task. John was also asked to act as the Australian University representative a working group to develop a framework for an Australian Integrated Ocean Observing System. The work-group has reported to on the Dept Environment and Heritage through its Ocean Policy and Advisory Group. His role as associate editor for "Progress in Oceanography" continues.

John Murray continued is research in mathematical modelling of infectious diseases. He presented a poster on the likely effects of widespread availability of anti-retroviral therapy on the HIV/AIDS epidemic in sub-Saharan Africa at the XV International AIDS conference in Bangkok in July. John also helped coordinate mathematical biology initiatives at UNSW. These included organising a Mathematical Biology Symposium in June, and a Mathematical Biology Project Workshop in November. These encouraged interdisciplinary collaboration through the university. Details can be found on the Mathematics and Statistics in the Biosciences website

http://www.maths.unsw.edu.au/interdisciplinary/mathstatsbiohome.html

John Roberts successfully completed his research projects and papers were submitted for publication on the following topics:

i) evidence of universal distributions for orbit lengths of rational planar maps over finite fields with and without time-reversal symmetry (with Professor F Vivaldi, University of London);

ii) symmetries and reversing symmetries of polynomial automorphisms of the plane

(with Professor M Baake, University of Bielefeld);

iii) duality in discrete integrable systems (with Professor R Quispel, La Trobe University, and Professor H Capel, University of Amsterdam).

Ongoing research pursued in 2004 includes the construction of higher-dimensional integrable maps (with Quispel) and an algebraic geometric approach to planar integrable maps (with Vivaldi and PhD student D Jogia).

Jim Pettigrew began a PhD on algebraic dynamics with John in March 2004. In October, John and Jim supervised a Year 11 student for a week as part of the CSIRO Student Research Scheme.

Colin Rogers has continued his research in collaboration with Dr Schief into hidden integrability in nonlinear continuum mechanics. His work in this area is conducted as Chief Investigator within the ARC Centre of Excellence and Statistics of Complex Systems. Current international collaborations involving Professor M Kléman, Université in Pierre et Marie Curie, Laboratoiré de Minéralogie–Christallographie de Paris, the area of liquid crystal theory, Professor K Chow, University of Hong Kong on complex vortex structures in gasdynamics and magnetogasdynamics and Professor P Amster, University of Buenos Aires on boundary value problems for Painlevé equations. During 2004, Professor Rogers gave invited lectures at the National University of Singapore, Hong Kong University (as William Mong Visiting Research Fellow), Academia Sinica, Taiwan and the Institute of Applied Mechanics, National University of Taiwan. He also presented lectures at a Symposium on Fluid Mechanics and Scientific Computation, Hong Kong University of Science of Technology and at the Nonlinear Physics Theory and Experiment Meeting in Gallipoli, Italy.

Wolfgang Schief concluded his research on the project "The generation and application of Geroch-type transformations in soliton theory" as part of his Queen Elizabeth II (QEII) Fellowship which ended in May 2005. The project brought together for the first time the analysis of symmetry transformations of Geroch type as known for the Ernst and Einstein-Maxwell equations of general relativity and infinitesimal Bäcklund transformations in the context of a very general integrable (soliton) system, the so-called Loewner-Konopelchenko-Rogers (LKR) system.

In addition, Dr Schief has continued his research in collaboration with Professor Rogers on the amalgamation of soliton theory, classical differential geometry, difference geometry and continuum mechanics. In particular, he has worked on the isolation of hidden integrable structures in hydrodynamics, magnetohydrodynmamics, the theory of shell membrane equilibria, liquid crystal theory and on the algebra-geometric origins of discrete master soliton systems. Within the ARC Centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS), the study of periodic vortex structures in gasdynamics and magnetogasdynamics has also been an area of extensive research.

He has also made an excursion into the biomechanics of corneal collagen with a view to modelling the effects of both corneal thinning disorders and contact lens use.

Dr Schief's collaborators included Professor AI Bobenko, Tecnische Universität Berlin, Germany, Professor F Burstall and Dr AD King, University of Bath, UK and Adjunct Professor CW McMonnies and Professor C Rogers, The University of New South Wales, Australia.

Ian Sloan continued his research in a number of different areas. In quasi-Monte Carlo methods he collaborated with Frances Kuo, Xiaoqun Wang, PhD student Ben Waterhouse and Henryk Woźniakowski (Columbia and New York), on problems of high dimensional numerical integration and approximation. With Robert Womersley, Kerstin Hesse and PhD student Paul Leopard, he continued to work on problems of integration and approximation on the sphere. With William McLean and Visiting Professor Vidar Thomée he continued research on approximation schemes for parabolic problems with memory terms. With Rolf Grigorief he studied problems of approximation with sphlines with multiple knots, and with Mahaduran Ganesh and Stuart Hawkins he studied scattering problems for Maxwell's equations.

Chris Tisdell carried on with his investigations into dynamic equations on time scales (aka measure chains). These type of very general equations have the potential to model stop-start processes where time may flow continuously and discretely at different stages in the one model.

Dr Tisdell also endeavoured to build and solidify links with expert researchers from overseas. He was delighted to host three international visitors during 2004 and was fortunate enough to visit some world-class universities, such as: Institute of Pure and Applied Mathematics, Université Catholique de Louvain (Jean Mawhin); and The Czech Academy of Sciences, Prague (Pavel Drabek).

Thanh Tran continued his research in two main areas: efficient solvers for boundary integral equations and a posteriori error estimates in the finite element method. A project on a new analysis for the p-version boundary element method in 3D using Jacobi-weighted Besov spaces was started with Professor B Guo (University of Manitoba). He also continued his collaboration with colleagues at the University of Hannover (Professor E Stephan and Dr M Maischak) to work on efficient preconditioners for the FEM-BEM coupling of the eddy current problem in electromagnetics. On the topic of a posteriori error estimates, he has been generalising the techniques he developed for 1D problems to 2D and 3D problems. An investigation of a posteriori error estimates for the Navier-Stokes equations and for a problem modelling liquid crystal flows has been carried out with Associate Professor P Lin (NUS).

Dr Tran's collaboration with Associate Professor S Rahman (School of Petroleum Engineering, UNSW) continues with him giving advice to Rahman's PhD and Master

students on the use of FEM and BEM in simulations of fractures in reservoirs.

In January he visited the Centre for Industrial Mathematics, NUS, and delivered two one-hour talks. He also visited the University of Natural Science and Pedagogical Institute, Ho Chi Minh City, where he talked in their Joint-Colloquium in Analysis, before holding a discussion with their members of staff about mathematics departments in Australia and at UNSW.

Rob Womersley works on the development, analysis and application of computational techniques for a wide range of problems, including n problems, constructive approximation and mathematical finance. Particular projects included point distributions, approximation and cubature on the sphere, distribution of minimum energy points on manifolds (which produced a cover for the Notices of the American Mathematical Society), optimization under uncertainty, maximum likelihood methods involving high dimensional integrals and implied volatility models in finance.

Catherine Morgan completed her research MSc on "Robust Optimization with Application to Naval Force Structure". Paul Leopardi, jointly supervised with Ian Sloan, continued his PhD on approximation, cubature and point distribution on the sphere, and gave a talk on partitioning the sphere into regions of equal area and small diameter at the Constructive Functions Tech-04 conference in Atlanta. He also-co-supervised Zhi Guo who is doing a PhD with Ben Goldys on implied volatility.

Dr Womersley gave an invited talk at the Oberwolfach, Germany, meeting on Geomethematics in May and at the Constructive Functions Tech-04 conference in Atlanta, USA, in August.

Dr Womersley gave a series of lectures on portfolio optimization problems and constrained density/covariance estimation for the AMSI 2004 Summer School. He also continued work on optimal discretization of continuous optimization on problems with Lucien Polak (UC Berkeley, USA) and on existence of solutions to underdetermined nonlinear systems of equations and their application to establishing existence of spherical designs with the optimal order for the number of points with Xiaojun Chen (Hirosaki University, Japan). He also worked with Vaithilingam Jeyakumar and John Ormerod on the used of ellipsoidal knowledge constraints for support vector machines.

5.1 Post-Doctoral Fellows

Mark Baird. During 2004, Mark completed a 3 year ARC project developing a coupled physical-biological model of the East Australian Current, off the NSW coast. The principal simulations can be viewed at: www.maths.unsw.edu.au/ mbaird/eacsims.html. This work is the first example of a coupled physical-biological model applied to the NSW continental shelf, and the first 3D application of a novel biological model. This work has

been a collaboration with Jason Middleton and Patrick Timko of SoM, and Iain Suthers in BEES.

Mark also continued his collaboration with scientists at the University of Hawaii. Supported by an Australian Academy of Science travel grant, he undertook a series of laboratory experiments with Dr Jim Falter investigating the effects of free stream turbulence on nutrient uptake rates on coral-shaped objects.

Finally, Mark laid the theoretical foundations for his next 5 years of research by deriving a size-resolving plankton population model. The theoretical work was presented at a Mathematical Biology Workshop in November 2004, and underpinned a successful ARC Research Fellowship application for 2005-2009, which will include collaborations with Jason and John Middleton, Peter Blennerhassett and Bruce Henry.

Stuart C Hawkins. Since joining UNSW in September 2004 Stuart has been developing an efficient algorithm for electromagnetic scattering problems with Dr M Ganesh. This continues previous work of Dr Ganesh on acoustic scattering problems and his previous work on wavelet methods for acoustic scattering and other problems. He completed a paper with Dr K Chen (University of Liverpool, UK) and Dr P Harris (University of Brighton, UK) on a wavelet scheme for acoustic scattering using a boundary integral technieque.

Kerstin Hesse. In 2004 Kerstin continued to work on numerical integration and also approximation on the sphere with Professor Ian Sloan. Three papers with Professor Sloan presenting the joint results (from ongoing work in 2003 and 2004) on error analysis for numerical integration on the sphere in Sobolev spaces have been submitted to international journals. In addition, Kerstin started a new project on hyperinterpolation on the sphere in Sobolev spaces with Professor Sloan. Joint work with Paul Leopardi on energy of spherical designs on the sphere has been submitted. She also works with Willi Freeden on vectorial spline interpolation on the sphere, which arose from her PhD. Kerstin gave talks at two international conferences: 'Meeting Geomathematics' in May 2004 at Oberwolfach, Germany (invited talk), and 'Constructive Functions Tech 04' in November 2004 in Atlanta (contributed talk). In addition she gave talks in November 2004 at Texas A & M, College Station, United States; Potsdam-Institut Für Klimafolgenforschung, Berlin, Germany; and Universität Stuttgart, Stuttgart, Germany.

Frances Kuo is a Vice-Chancellor's Postdoctoral Fellow and a MASCOS associate investigator. Her research aim is to analyse multivariate problems, such as integration and approximation, in various settings, and develop constructive algorithms tailored for these problems. Her main interest is with quasi-Monte Carlo methods and lattice rules. These are numerical integration rules for high-dimensional integrals. She worked with Ben Waterhouse and Ian Sloan on using randomly-shifted lattice rules for unbounded integrands that arise from variable transformation. In a joint project with Ian Sloan

and Henryk Wozniakowski (Columbia and Warsaw), she studied lattice rules for function approximation and obtained constructive algorithms with error bounds better than any non-constructive results known previously. She collaborated with Josef Dick, Friedrich Pillichshammer (Linz) and Ian Sloan on constructing digitally-shifted polynomial lattice rules. In an ongoing joint project with William Dunsmuir, Matt Wand, Ian Sloan and Rob Womersley, she worked on applying quasi-Monte Carlo methods to several maximum likelihood integrals in statistics, an area rich of high-dimensional integrals. These integrals are then embedded in some optimization procedure for finding the parameters which lead to the maximum likelihood. Frances presented her works in international conferences in France, Poland, and Germany, and she was invited to visit Ronald Cools at the University of Leuven. She started a new joint project with Ronald Cools (Leuven), Dirk Nuyens (Leuven) and Ian Sloan on constructing an embedded lattice rule which is extensible in terms of the dimension, and can be used with any number of points ranging from roughly a thousand to a million. The embedding property of this rule is very attractive in practical applications.

Trevor Langlands has furthered his research in 2004 on the numerical simulation and linear stability analysis of systems of fractional reaction-diffusion equations. This work is in collaboration with Associate Professor Bruce Henry and Dr Susan Wearne and extends their work on Turing pattern formation in fractional systems (Henry and Wearne (2002)).

Two forms of the fractional reaction-diffusion equations were investigated where Riemann-Liouville temporal fractional derivatives acted on the diffusion terms alone and where the fractional derivative acted on both reaction and diffusive terms. Activator-inhibitor systems were investigated with the reaction kinetics given by the Brusselator and Gierer-Meinhardt model kinetics.

An implicit numerical solution scheme was developed with the use of the standard finite difference approximations for the integer order derivatives combined with the L1 scheme developed by Oldham and Spanier (1974) to numerically evaluate the fractional derivative. Analysis of the numerically stability of this scheme showed the method was unconditionally stable. This work was presented at the Raglan meeting of the NZIMA thematic programme on Dynamical Systems and Numerical Analysis held on 30 August 2004 to 3 September 2004.

The behaviour of the fractional reaction-diffusion equations was investigated both through linear stability analysis and direct numerical simulation. The introduction of the fractional derivatives of order $1-\gamma$ acting solely on the diffusive terms (equal for both species) for which Turing instability induced patterns start to occur. As γ was decreased from 1 (standard diffusion) to 0 (extreme subdiffusion) this parameter was reduced. The Fourier modes predicted from linear stability analysis were consistent with those observed from the numerical simulations and also varied with exponent. The temporal

behaviour of the solution in these cases was oscillatory. In contrast, in the case where the fractional derivative operated on both reaction and diffusive terms, modifying the fractional exponent had no impact on the onset of Turing instability or on the Fourier modes excited. In each case the modes and patterns observed were identical to the standard diffusion case ($\gamma - 1$) though with slowed temporal evolution to a steady state.

Dr Trevor Langlands is now in the process of deriving a fractional variant of the Nernst-Planck/Cable equation for nerve cell signalling. Continuous Time Random Walks from which the systems of fractional reaction-diffusion equations where derived by Henry and Wearne (2000) are being considered here. Analytic solutions of the linearised fractional cable equation in the infinite and finite one-dimensional domains have been found in terms of the Fox function and Mittag-Leffler functions respectively.

Quoc Thong Le Gia has conducted the following research programs in scientific computation.

- Approximation of the Navier-Stokes equations on the unit sphere

  Researchers in the project: M. Ganesh, (Colorado School of Mines, USA); QT Le Gia, IH Sloan, (School of Mathematics, UNSW).
  Progress report: The functional setting of the Navier-Stokes equation on the unit sphere has been developed. We have obtained a new error estimates (unreported in known literature on Navier-Stokes equations on the unit sphere). The results were announced in the conference in Constructive Function Theory in Georgia Tech University in Atlanta, November 7 to November 12, 2004. The implementation of the spectral method using vector spherical harmonics on Matlab 6.0 is in progress.

- Preconditioners for solving elliptic PDEs on the unit sphere

  Researchers in the project: Q. T. Le Gia, I.H. Sloan, T. Tran, UNSW, Australia.
  Progress report: We take the real scattered data from the NASA's satellite MAGSAT and apply our new preconditioning algorithm on selected global subsets of initially very large data sets. The algorithm gives good results in all cases up to 7663 points, in which the CPU times and number of iterations has been reduced compared to conjugate gradient method without preconditioners. The theory is under development.

Lixin Qi's research interest is involved in climatology and severe weather systems over Australia and New Zealand. He continues to work on the development and application of the UNSW HIRES numerical weather prediction model.

He is involved in the study on the developing south eastern Tasman Sea extra-tropical cyclones, or meteorological "bombs". These highly transient systems, which have a damaging impact upon New Zealand, are frequently accompanied by destructive winds, flood rains, and coastal storm surges.

An invited paper is currently in preparation concerning the cut-off lows over southwest Pacific ocean and will be published at the end of this year.

As a co-editor, he has been involved in two special issues of Meteorology and Atmospheric Physics: Special Issue on Air Quality, Special Issue on Regional Climate Variability and Change.

Alvise Sommariva is working with Professor Ian Sloan and Associate Professor Womersley writing a paper on Integration by RBF over the Sphere, where they consider the problem of approximating the integral of a function $f : S^2 \to \mathbb{R}$ when the values of f are known only on scattered data $X = \{x_i\} \subset \mathbb{S}^2$. Following a common notation, $\mathbb{S}^2$ denotes the unit 2-sphere. It can be proved that such cubature rules are *optimal* in the sense of Golomb-Weinberger.

In the meantime, Alvise has revised the paper "Numerical cubature on scattered datas by Radial Basis Functions" (with Professor Marco Vianello, University of Padua, Italy) submitted to Computing and accepted, subject to minor modifications. In this investigation, we consider the aforementioned cubature problem on the square $[0, 1] \times [0, 1]$; such step has been fundamental to start the analysis over the unit 2-sphere $\mathbb{S}^2$.

Alvise has refereed 2 papers, respectively for "Numerische Matematik" and "IMA J. Num. Anal."

6 2004 PUBLICATIONS

6.1 Journal Articles and Conference Papers 2004

In the following list, papers are grouped by staff member. Thus, papers with more than a single author from the department appear more than once.

Publications

[1] P. Amster, M. C. Mariani, C. Rogers, C. C. Tisdell, On two-point boundary value problems in multi-ion electrodiffusion, *J. Math. Anal. Appl.*, **289** (2004), 712–721.

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6.2 Applied Mathematics Reports 2004

1. **J. Dick** and F. Pillichshammer, Dyadic Diaphony of digital nest over Z2, AMR04/1.
2. **J. Dick** and F. Pillichshammer, Diaphony, discrepancy, spectral test and worst-case error, AMR04/2.
3. **T. Tran** and T.-B. Duong, 'A posteriori' error estimates with the finite element method of lines for a Sobolev equation, AMR04/3.
4. **J. Dick, F.Y. Kuo**, F. Pillichshammer and **I.H. Sloan**, Construction algorithms for polynomial lattice rules for multivariate integration, AMR04/4.
5. **M. Ganesh and K. Mustapha**, A fully discrete H1-Galerkin method with quadrature for parabolic nonlinear advection-diffusion-reaction equations, AMR04/5 .
6. **V. Jeyakumar** and N. Dinh, Avoiding duality gaps in convex semidefinite programming without Slater's condition, AMR04/6.
7. **V. Jeyakumar**, G.M. Lee and N. Dinh, Liberating the subgradient optimality conditions from constraint qualifications, AMR04/7.
8. **V. Jeyakumar,** N. Dinh and G.M. Lee, A new closed cone constraint qualification for convex optimization, AMR04/8.
9. **M. Ganesh and K. Mustapha**, A diffusion-modified quadrature FEM for nonlinear reaction-diffusion equations, AMR04/9.
10. **M. Ganesh and K. Mustapha**, A quadrature H1-Galerkin method for nonlinear hyperbolic problems, AMR04/10.
11. M.A. Goberna, **V. Jeyakumar** and D. Dinh, Dual characterizations of set containments with strict convex inequalities, AMR04/11.
12. **J. Dick** and P. Kritzer, Tar discrepancy estimates for digital $(t, m, 2)$-nets and digitan $(t, 2)$-sequences over Z_2, AMR04/12.
13. **J. Dick,** G. Leobacher and F. Pillichshammer, Construction algorithms for digital nets with small weighted star discrepancy, AMR04/13.
14. J. Henderson, B. Karna and **C.C. Tisdell**, Existence of solutions for three-point boundary value problems for second order equations, AMR04/14.
15. A.C. Petersen, Y.N. Raffoul and **C.C. Tisdell**, Three point boundary value problems on the scales, AMR04/15.
16. **I.H. Sloan and X. Wang** and H. Wozniakowski, Finite-order weights imply tractability of multivariate integration, AMR04/16.
17. **P. Leopardi**, A generalized FFT for Clifford algebras, AMR04/17.

18. J. Henderson and **C.C. Tisdell**, Five-point boundary value problems for third order differential equations by solution matching, AMR04/18.
19. J. Henderson, A. Peterson and **C.C. Tisdell**, On the existence and uniqueness of solutions to boundary value problems on time scales, AMR04/19.
20. A.C. Peterson and **C.C. Tisdell**, Boundedness and uniqueness of solutions to dynamic equations on time scales AMR04/20.
21. L. Erbe, A. Peterson and **C.C. Tisdell**, Existence of solutions to second-order BVPs on time scales, AMR04/21.
22. J. Henderson and **C.C. Tisdell**, Boundary data smoothness for solutions of three point boundary value problems for second order ordinary differential equations, AMR04/22.
23. **C.C. Tisdell**, P. Drabek and J. Henderson, Multiple solutions to dynamic equations on time scales, AMR04/23.
24. N. Raffoul and **C.C. Tisdell**, Positive periodic solutions of functional discrete systems and population models, AMR04/24.
25. R.S. Burachik and **V. Jeyakumar**, A simple closure condition for the normal cone intersection formula, AMR04/25.
26. R.S. Burachik and **V. Jeyakumar**, A dual condition for the convex subdifferential sum formula with applications, AMR04/26.
27. **K. Hesse and I.H. Sloan**, Cubature over the sphere S2 in Sobolev spaces of arbitrary order, AMR04/27.
28. bf J. Dick, A Taylor space for multivariate integration, AMR04/28.
29. **J. Dick**, H. Niederreiter and F. Pillichshammer, Weighted star discrepancy of digital nets in prime bases, AMR04/29.
30. **J. Dick** and K. Kritzer, A best possible upper bound on the star discrepancy of $(T, M, 2)$-nets, AMR04/30.
31. **K. Hesse** and **I.H. Sloan**, Optimal order integration on the sphere, AMR04/31.
32. **K. Hesse and I.H. Sloan**, Optimal lower bounds for cubature error on the sphers S2, AMR04/32.
33. W. Freeden and **K. Hesse**, Spline modelling of geostrophic flow: theoretical and algorithmic aspects, AMR04/33.
34. **K. Hesse and P. Leopardi**, The coulomb energy of spherical designs on S2, AMR04/34.

7 EXTERNAL RESEARCH SUPPORT FOR 2004

The Department maintains a strong commitment to high quality research, and consistently attracts significant funding from the Australian Research Council.

7.1 Discovery Project Grants

A.C. Coster $68,000
Nonlinear dynamics of pulse coupled oscillators

V. Jeyakumar, A.M. Rubinov $94,158
Necessary and sufficient conditions for global minimum in multi-extremal global continuous optimization

H.D. Qi $102,646
Nonsmooth optimization in constrained spline interpolation

C.C. Tisdell $43,700
Dynamic equations on measure chains

R.S. Womersley $70,000
Approximation, cubature and point designs on spheres

7.2 ARC- Linkage Grant

L.M. Leslie, D.W. Buckley, J. Le Marschall and L. Qi $39,580
Western Australia severe weather prediction: optimising forecasts using new data sources and improved high-resolution models

J.H. Middleton $30,000
Measuring boundary layer flows with airborne LIDAR

7.3 University Research Support

M.L. Banner $12,000
Refining new breaking wave parameterisation in storm seas

M.H. England $12,000
Extratropical ocean variability and its role in extremes and predictability of Australian climate

L.M. Leslie $12,000
Ensemble forecasting methods for tropical cyclone modelling and prediction

J.F. Middleton $9,000
Upwelling within submarine canyons, the Flinders current and atmospheric forcing

J.H. Middleton and M.E. Baird $10,000
East Australia current frontal processes at 30S

J.M. Murray $7,000
Quantitative analysis of human immunodeficiency virus and the immune system

J.A.G. Roberts $12,000
Integrability and symmetry of rational maps over finite fields

T. Tran and W. McLean $14,000
Efficient solvers for boundary integral equations

7.4 ARC – Centre of Excellence Grant

A.H. Dooley, C. Rogers and I.H. Sloan $523,488
Australian Research Council Centre of Excellence in Mathematics and Statistics of Complex Systems

A.H. Dooley, C. Rogers and I.H. Sloan $53,903
Department of State & Regional Development

8 VISITORS 2004

1. Dr Elvin Akin, University of Missouri-Rolla, 22 May–12 June, (C Tisdell)
2. Professor Michael Baake, Universitat Tubingen, Germany, 22–29 November, (J Roberts)
3. Dr Ian Benn, University of Newcastle, 29–30 July, (J Kress)
4. Dr Martin Bohner, University of Missouri-Rolla, 22 May–12 June, (C Tisdell)
5. Associate Professor Regina Burachik, Rio de Janeiro, Brazil, 27–31 January, (V Jeyakumar)
6. Professor Robert Conte, Saclay, Paris, 17 November–7 December, (C Rogers, W Schief)
7. Dr Rolf Grigorieff, Technical University of Berlin, 5–31 March, (I Sloan)
8. Professor Benqi Guo, University of Manitoba, Canada, 6–19 July, (T Tran)
9. Professor David Gurarie, Case Western Reserve University, 6–11 December, (C Rogers)
10. Professor Maurice Kléman, Université Pierre et Marie Curie Paris, 5–12 September, (C Rogers, W Schief)
11. Professor Epameinondas Kriezis, Aristotle University of Thessaloyiki, 12 January–10 February, (M Banner)
12. Professor Chong Li, Zhejiang University, China, 13–16 December, (V Jeyakumar)
13. Professor Fang Li, Zhejiang University, China, 5–8 February, (J Du)
14. Professor Dinh Luc, University of Arignon, France, 1-31 July, (V Jeyakumar)
15. Dr Matthias Maischak, University of Hannover, 4 August–6 September, (T Tran, W McLean)
16. Professor Willard Millar, University of Minnesota, 29 June–13 July, (J Kress)
17. Professor Hossein Mohebi, University of Kermin, Iran, 19–30 April, (V Jeyakumar)
18. Dr Lin Ping, National University of Singapore, 4–28 June, (T Tran)
19. Professor Allan Pinkus, Technion, 25–27 February, (I Sloan)
20. Dr Gennady Platov, Institute of Computational Mathematics, Russia, 26 June–14 August, (John Middleton)
21. Professor Elijah Polak, UC Berkeley, 4–20 June, (R Womersley)
22. Professor Liqun Qi, The Hong Kong Polytechnic University, 28 June–11 July, (H Qi)

23. Professor Reinout Quispel, La Trobe University, 12 November, (J Roberts)
24. Professor Chris Reason, University of Capetown, 11–16 July, (M England)
25. Professor Manfred Reimer, University of Dortmurd, Germany, 13–25 April, (I Sloan)
26. Dr Alexander Rubinov, University of Ballarat, 14 May, (I Sloan)
27. Professor Oleg Saenko, Canada Centre for Climate Modelling and Analysis, 28 January–11 February, (M England)
28. Professor Siegfried Schaible, University of California, 12–16 December, (V Jeyakumar)
29. Dr Bin Shu, East China Normal University, 26 April–16 June, (J Du)
30. Professor Wen Song, Harbin Normal University, China, 14 December–28 January, (V Jeyakumar)
31. Dr Defeng Sun, National University of Singapore, 12–26 June, (H Qi)
32. Professor Michael Thera, Université de Limoges, France, 6–8 December, (V Jeyakumar)
33. Ms Caroline Ummenhoffer, University of Wales, 17 May–30 June, (M England)
34. Professor Franco Vivaldi, Queen Mary University of London, 19 April–1 May, (J Roberts)
35. Associate Professor Xiaoqi Yang, Hong Kong Polytechnic University, 27–29 June, (V Jeyakumar)

9 CONFERENCES AND SEMINARS

9.1 Applied Mathematics Seminars

Organizer: John Roberts
26 February
Professor Allan Pinkus (Department of Mathematics Technion – Israel Institute of Technology)
Negative Theorems in Approximation Theory

18 March
Professor Herbert Huppert (University of Cambridge, U.K.)
Gravity currents: from hot lava flows through cool sea breezes to hazardous rockfalls

15 April
Professor Manfred Reimer (Department of Mathematics, University of Dortmund)
Polynomial approximation on the sphere: recent theoretical and numerical improvements

22 April
Professor John Perram (The Maersk Mc-Kinney Moller Institute, University of Southern Denmark)
Experiences with teaching analytical mechanics as asynchronous distance learning

27 May
Dr Stephane Lafortune (Departments of Mathematics, University of Arizona and University of Sydney)
Stability analysis of local deformations of an elastic rod

3 June
Dr Elvan Akin (Department of Mathematics, University of Missouri-Rolla
Some dynamics equations

9 September
Professor Maurice Kléman (Paris-6 University, LMCP/CNRS)
Liquid crystals defects: geometric aspects

28 October
Dr David Chik (Department of Applied Mathematics, UNSW)
Global coherent activities in inhibitory Neural systems

25 November
Professor Robert Conte (Service de physique de l'état condensé, CEA-Saclay, France)
Completeness of the time-independent Hénon-Heiles Hamiltonians

9 December
Professor David Gurarie (Mathematics Department, Case Western Reserve University)
Inviscid 2D fluids, statistical equilibria, sinh-Poisson equation and 'vortex solitons'

16 December
Dr Jim Denier (School of Applied Mathematics, University of Adelaide)
So what's new in boundary-layer theory?

9.2 Applied Mathematics/MASCOS Seminar

Organizer: John Roberts

19 August
Mr David Shteinman, (Managing Director – Stamen Paper Pty. Ltd; Industry Fellow – MASCOS)
Understanding a complex industrial process – successes and difficulties in model building and implementation

20 October
Professor Ian Wilkinson, School of Marketing, UNSW
Complexity and modeling the dynamics and evolution of business networks

9.3 Australian Meteorological & Oceanographic Society Seminars

Organizer: Matthew England

4 March
Dr Richard Matear, (CSIRO Marine Research)
The oceanic carbon cycle in a changing climate

4 March
Dr Ben McNeil, (The University of New South Wales)
The importance of the oceanic carbon cycle: past and present

10 March
Mr Willem Sijp, (The University of New South Wales)
Role of the Drake Passage in the global thermohaline circulation

18 March
Professor Herbert Huppert (University of Cambridge, UK)
Gravity currents: from hot lava flows through cool seabreezes to hazardous rockfalls

12 May
Mr Agus Santoso, (The University of New South Wales)
Variability of circumpolar deep water in a coupled climate model

13 July
Professor Chris Reason, (University of Cape Town, South Africa)
Interannual climate variability of the South Atlantic and South Indian Oceans

9 August
Ms Jaci Brown, (The University of New South Wales)
How water crosses the equatorial vorticity barrier in the Eastern Pacific

15 September
Dr Gerd Folberth, (Canadian Centre for Climate Modelling and Analysis)
Atmospheric chemistry and the biosphere – a walk-through to tropospheric chemical composition

23 September
Associate Professor Matthew England, (The University of New South Wales)
Southern hemisphere ocean and climate variability

27 September
Ms Caroline Ummenhofer, (The University of New South Wales)
Australian climate variability

29 October
Ms Stephanie Dupre, (The University of New South Wales)
Latitude shifts in Southern Ocean westerly winds and their impact on past and present climate

29 October
Mr Michael Bates, (The University of New South Wales)
The effect of enhanced Antarctic meltwater on global ocean circulation and climate

9.4 Computational Mathematics Seminars

Organizer: Thanh Tran

25 March
Professor Rolf Grigorieff (Technische Universitaet, Berlin)
A minimax equality by Melkman & Micchelli has important applications, has it also a proof?

17 June
Dr Ping Lin, (Department of Mathematics, National University of Singapore)
A sequential regularization formulation for incompressible Navier-Stokes equations

26 August
Dr Matthias Maischak, (University of Hannover)
Least squares methods for transmission problems with FEM and BEM

16 September
Dr Thong Legia, (School of Mathematics, UNSW)
Approximation of linear partial differential equations on spheres

9.5 Postgraduate Seminars

Organiser: Ben Waterhouse

1 April
Dr Andrew Francis, (University of Western Sydney)
Some experiences of life in academia after a UNSW PhD

22 April
Mr Ben Warhurst, (School of Mathematics, UNSW)
Introduction to Teichmuller spaces

6 May
Mr Patrick Costello, (School of Mathematics, UNSW)
Basics of Quantum Mechanics

20 May
Mr Danesh Jogia, (School of Mathematics, UNSW)
An introduction to elliptic curves

3 June
Mr Robert Taggart, (School of Mathematics, UNSW)
Functional calculus for dummies

19 August
Mr Edward Cripps, (School of Mathematics, UNSW)
Bayesian inference and Markov chain Monte Carlo computational technique

2 September
Mr Rupert McCallum, School of Mathematics, UNSW)
Affine transformations

16 September
Mr Paul Leopardi, (School of Mathematics, UNSW)
A partition of the unit sphere S^d with equal measure and small diameter

7 October
Mr Petr Stehlik, Dept. of Mathematics, University of West Bohemia, Pilzen, Czeck Republic)
Periodic boundary value problems on time scales

4 November
Mr Danesh Jogia, (School of Mathematics, UNSW)
Rational time discrete dynamics in the plane

10 GRADUATE PROGRAMME

The Department maintains an active programme of study at the graduate level, by both course work and research. The degrees that can be obtained by course work at the graduate level are the Master of Science and Technology in Mathematics (MScTech) and Graduate Diploma in Oceanography (GradDip). The Doctor of Philosophy (PhD) and Master of Science (MSc) degrees are research degrees, obtained by carrying out a research project under the supervision of a member of staff. A total of 22 students were enrolled during 2004 for studies leading to higher degrees.

10.1 PhD Programme

The PhD degree provides a training in research up to the level necessary for initiating and carrying out unsupervised original work. The normal requirement for admission is an honours degree with a good class of honours but transfer from MSc candidature is also possible for MSc candidates who are making exceptional progress. Part-time PhD candidature is encouraged but only for candidates who can spend at least 20 hours per week on their research and are able to maintain regular contact with the university. A total of 11 students were enrolled in PhD programmes during 2004.

Student	**Research Topic**	**Supervisor**
Jaclyn Brown	Atmosphere-Ocean dynamics	Leslie
Deborah Cox	Stratified flow in the coastal ocean	Jason Middleton
Danesh Jogia	Dynamical systems	Roberts
Paul Leopardi	Approximation on sphere	Sloan
James Pettigrew	Dynamical systems studies using algebraic and number theoretic approaches	Roberts
Agus Santoso	Ocean and climate variability	England
Alexander Sen Gupta	Ocean and climate physics	England
Willem Sijp	Climate and ocean dynamics	England
Barbara Singh	Atmospheric modelling and photochemical smog	Leslie
Caroline Ummenhofer	Interannual to decadal extra-tropical climate variability	
Benjamin Waterhouse	Quasi-Monte Carlo methods	Sloan

10.2 MSc Programme

The MSc degree provides a basic training in research. Each candidate is given an individual research topic, after consultation with members of staff, and carries out research on the topic under the personal supervision of a member of staff. An honours

degree is normally required for admission as an MSc candidate, but applicants with good pass degree may be admitted to a qualifying programme, which usually consists of part or all of the honours year of the department. The MSc degree can be undertaken either full-time or part-time (or in some cases, externally). A total of 4 students enrolled in MSc programmes during 2004.

Student	**Research Topic**	**Supervisor**
William Arthur	Oceanography of shelf-slope currents	John Middleton
Kenneth Batt	Meteorology	Leslie
Pimphen Charoen	Immunological Dynamic System	Murray
Francis Reid	Hydrodynamic Stability	Blennerhassett

10.3 Research Students

In 2004, 7 students were awarded a PhD in applied mathematics.

Student	**Research Topic**
Pen Xu	A computational model for the assessment and prediction of salinisation in irrigated areas
Josef Dick	Digital lattice rules: multivariate integration and discrepancy estimates
Kassim Moustapha	Analysis of fully discrete element methods with quadrature for second order nonlinear parabolic and hyperbolic problems
Eunjoo Jung	Numerical simulation of Asian dust events: The effects of convective transport and wet deposition
Ann-Marie Wong	Deep convection processes off the coast of Adelie Land, East Antarctica
Haixiong Zhuang	Parameterizations of atmosphere-ocean and atmosphere land surface interactions, with an application to the Australian Monsoon

10.4 Honours Programme

In 2004 the following completed an Honours degree in Applied Mathematics:

Student	**Research Topic**	**Supervisor**
K.W. Chui	'A posteriori' error estimation for two-point boundary value problems	Thanh Tran