Applied and Industrial Mathematics (AIM)

The AIM Research Group focuses on using Applied Mathematics and Statistics to investigate a diverse range of real world problems. The emphasis is on actual real-life situations and an interaction with industry with the aim of producing real solutions.

The key steps to our research endeavours are the analysis of real world problems; the formulation of the problem in mathematical terms; the use of that formulation to provide an understanding of the nature of the problems and how they may be solved; and the communication of the outcomes to both the originators of the problems and the wider applied mathematics research community.

Group members call on the vast range of mathematical and statistical techniques supplemented with the application of extensive modern computing methods. The range of techniques and the mathematical thinking skills that experience develops results in an extraordinarily flexible and powerful approach that can be adapted to a huge set of different practical problems as illustrated by the list of projects.

The interdisciplinary nature of the work and the constraints imposed by dealing with genuine practical problems make this a challenging and rewarding area for research. The importance and value of the work is recognised by the success of the group members in obtaining grants and willingness of industry to offer financial support.

PhD student Jennifer Hollis in a field of lupin at the site of the Tripod Fire in Washington, USA. While in USA Jennifer explored woody fuel consumption equations from Consume 3.0, and how the Fuel Characteristic Classification System could be adapted for Australia.

Members

Academic Staff:

Assoc. Prof. Harvinder Sidhu, Director AIM (h.sidhu@adfa.edu.au) BSc *Qld*, DipEd *S'pore*, PhD *Qld*

Assoc. Prof. Rodney Weber (r.weber@adfa.edu.au) BSc *Melb*., PhD *Tas*.

Dr Joanne Chapman (j.chapman@adfa.edu.au) BSc PhD *Lancaster*

Dr Zlatko Jovanoski (z.jovanoski@adfa.edu.au) BSc *Mon*, PhD *UNSW*

Dr Peter McIntyre (p.mcintyre@adfa.edu.au) BSc, PhD *ANU*

Dr Ben O'Neill (b.oneill@adfa.edu.au) BActS(Hons) LLB LLM PhD *ANU*

Dr Leesa Sidhu (l.sidhu@adfa.edu.au) BSc(Hons), DipEd, MEdSt *Qld*, PhD *UNSW*

Dr Isaac Towers (i.towers@adfa.edu.au) BSc Otago, PhD *UNSW@ADFA*

Emeritus Professor:

Emeritus Prof. Colin Pask (c.pask@adfa.edu.au) BSc *Lond*. PhD *UNSW*

Research Associate:

Dr Jason Sharples (j.sharples@adfa.edu.au) PhD *Uni of Canberra*

Visiting Fellows:

Dr Wendy Anderson (w.anderson@adfa.edu.au) BSc *Lond*., MSc *Dund*., PhD *UNSW*

Dr Steven Barry (s.barry@adfa.edu.au) BSc *Adel*., PhD *UNSW*

Assoc. Prof. Ted Catchpole (e.catchpole@adfa.edu.au) BSc *Lond*., MSc *Kent*, PhD *Dund*.

Assoc. Prof. Geoffry Mercer (g.mercer@adfa.edu.au) BSc PhD *Adel*.

Research Students:

Ms Roslyn Hickson - Research Topic - Critical times of multilayer diffusion.

Ms Jennifer Hollis - Research Topic - Coarse woody fuel availability and consumption in Australian forest fires.

Mr Thiansiri Luangwilai - Research Topic - Mathematical modelling of self-heating in compost piles.

Mr Richard Pennifold - Research Topic - Dynamical systems behaviour of the forced Bonhoeffer Van der pol equations.

Mr Philip Zylstra - Research Topic - Forest flammability - modeling and managing a complex system.

Recent Graduate Student:

Dr Brendan Pippen - Research Topic -Fuel moisture and fuel dynamics in woodland and heathland vegetation of the Sydney Basin, PhD 2008.

Current Honours Student:

Adam Burgess

Research Collaborators:

Prof. A. Adesina (University of NSW)

Dr B. Barnes (Dept of Agriculture, Fisheries and Forestry)

Applied and Industrial Mathematics (AIM)

Dr L. Chambers (Bureau of Meteorology Research Centre, Melbourne)
Prof. X.D. Chen (Monash University)
Dr D. Cole (University of Kent, England)
Prof. T. Coulson (Imperial College, London)
Dr M. Cruz (Ensis, Yarralumla, ACT)
Dr P. Dann (Phillip Island Nature Park)
Dr R. Day (University of Melbourne)
Prof. J. Dold (Manchester University, UK)
Dr P. Ellis (Ensis, Yarralumla, ACT)
Dr A. Forster (Plant Protection Chemistry, NZ)
Mr J. Gould (Ensis, Yarralumla, ACT)
Dr V. Gubernov (P.N. Lebedev Physical Institute of the Russian Academy of Sciences)
Prof. R. Henderson (University of Newcastle, Newcastle -upon Tyne, UK)
Mr D. Houston (Department of Conservation, New Zealand)
Dr E. Johannesen (Institute of Marine Research, Norway)
Dr K. King, Postdoctoral Fellow (The Australian National University and Bushfire CRC)
Prof. S. Konar (Birla Institute of Technology, India)
Ms R. Luscome (University of Melbourne)
Prof. T. Marchant (University of Wollongong)
Dr D. Marlow (DSTO)
Dr S. Matthews (Ensis, Yarralumla, ACT)
Dr C. Meathrel (La Trobe University Wodonga)
Dr L. McCaw (Department of Environment and Conservation, WA)
Prof. B. J. T. Morgan (University of Kent England)
Dr M. Nelson (University of Wollongong)
Mr B. Robertson (La Trobe University, Wodonga)
Dr J. Sexton (Geoscience Australia)
Dr K. Stokes (CSIRO, Entomology, Canberra)
Prof. G. Wake (Massey University, NZ)
Dr J. Zabkiewicz (Plant Protection Chemistry, NZ)

Areas of Research

Bayesian statistics

Ben O'Neill

Topics covers a range of areas such as the philosophy and foundations of Bayesian statistics, exchangeability and Bayesian modeling, computation problems in Bayesian analysis, informative sampling problems and robustness testing for Bayesian analysis.

Bushfire modelling

Rod Weber, Jason Sharples, Joanne Chapman, Karen King, Wendy Anderson, Phil Zylstra, Geoff Mercer

- Fireline growth
- Spread rates
- Meteorology in the high country and its effects on fire spread
- Impacts of fire on vegetation
- Spread and patterns in discontinuous fuels
- Effects of prescribed burning

Modelling of many aspects of bushfires from the growth of the fireline, fuel dependent spread rates, impacts on live vegetation, determining damage criteria and effects of prescribed burning. Members of the group are actively involved with the Bushfire CRC.

Combustion theory

Harvi Sidhu, Geoff Mercer, Rod Weber, Vladimir Gubernov, Isaac Towers, Jason Sharples

- Combustion waves
- Stability
- Initiation
- Multistep reactions
- Evans function analysis
- Chemical reactors
- Models of composting
- Polymers

Investigation of combustion waves in both solid and gaseous fuels using a broad variety of both numerical and analytic approaches. This work ranges over new combustion wave solutions for chain branching models, stability analysis using Evans function methods, critical initial conditions for combustion to take place and the effects of ambient temperature and heat losses on combustion waves. Others aspects related to combustion studied include chemical reactors (batch and continual flow), models of industrial composting, landfill and waste water treatment.

Defence applications

Geoff Mercer, Harvi Sidhu, Steve Barry

- Minimising detection by enemy radar
- Safest routes through minefields
- Dynamic route changes in real time to minimise risk
- Optimal route for aerial surveillance of ships
- Effects of classification range and turning radius on optimal routes
- Travelling salesman problem applied to aerial surveillance

Different aspect of travel through a risk environment are studied. Determining the minimal detection route through an area under radar surveillance using differential equation based models. This has application to Unmanned Air Vehicle (UAV) deployment and design issues. Calculation of the safest route through a minefield when information on the location of the mines is only discovered once travel is underway. Solutions must be able to be calculated in real time. Many aspects of the aerial surveillance of maritime regions including use of a modified dynamic travelling salesman problem to determine the visiting order of detected but as yet unclassified ships and aspects of the airplanes capabilities such as turning radius. This is joint work with DSTO Air Operations Division.

Applied and Industrial Mathematics (AIM)

Design of large area mode fibres

Isaac Towers & Zlatko Jovanoski

Single-moded optical fibres are preferred for optical communication and for high power applications. The small core of a conventional single-mode fibre leads to high power densities and gives rise to significant unwanted nonlinear optical effects. Nonlinear effects in a fibre can distort the pulses at high bit rate and can produce crosstalk among the closely spaced wavelengths. However, the use of large-core conventional fibres to overcome nonlinear effects is not advisable as the large number of modes in such a fibre reduces the data transfer rate in an optical communication system and affects the beam quality in fibre lasers. It is therefore preferred to use a fibre with a large core yet supporting a single guided mode. The goal of this project is to investigate designs for optical fibres which maximise mode area but allow only a single mode to propagate a meaningful distance.

Dynamical systems

Harvi Sidhu, Geoff Mercer, Richard Pennifold, Zlatko Jovanoski

- Analysing chaotic behaviour
- Dynamics in ecology
- Spread of diseases
- Estuary behaviour
- Forced systems

We utilize methods and techniques from nonlinear dynamics theory such as bifurcation and singularity theories to investigate complex real-world phenomena such as population interactions in ecology, spread of diseases, dynamics of shallow estuaries under drought conditions and forced systems. We also investigate new methods to quantify chaotic behaviour in dynamical systems.

Frailty modelling

Joanne Chapman with Prof. Robin Henderson

Random errors and unmeasurable association within clusters cannot be assumed Normally distributed and ignored in survival analysis as in other areas. The frailty term is introduced to represent these unknowns. A typical assumption is that the frailty variable follows a gamma distribution. Models which extend existing models and allow for the possibility of negative correlation within clusters (as often seen in animal litters) are being developed.

Industrial process modelling

Geoff Mercer, Harvi Sidhu, Steve Barry

- Wool scouring
- Porous filtering
- Wastewater treatment
- Compost
- Bioreactors
- Bloom in chocolate
- Submarine battery charging
- Wine fermentation

Many different industrial processes are studied with in the research group. These research areas have often been initiated by members attendance at the annual Mathematics in Industry Study Group.

Mathematics in Industry Study Group

Geoff Mercer, Harvi Sidhu, Steve Barry, Rod Weber, Roslyn Hickson, Richard Pennifold

Members of the AIMRG are actively involved in the annual Mathematics in Industry Study Group (MISG). They have, and continue to, moderate many problems at the MISG. This provides a rich source of new and exciting research areas of direct relevance to industry.

Modelling extreme temperature effects on living tissue

Geoff Mercer, Harvi Sidhu, Steve Barry

- Skin burns
- Models of skin burns subject to fire exposure
- Automotive airbags
- Design of firefighter clothing to minimise skin burn
- The effect of cold water on a swimmers core temperature
- Modelling hypothermia
- Wart freezing

Human skin and subcutaneous tissue is a complex organ designed to efficiently cope with a wide range of temperatures and conditions. However, at extremely high temperatures, such as exposures during fires or explosions, the skin is unable to transport the heat away fast enough and burns occur. Similarly, at cold temperatures, the skin is unable to insulate properly causing long term heat loss and hypothermia. We look at various models of heat transfer through the skin and subcutanious tissue to better understand this behaviour.

Numerical schemes for parabolic partial differential equations

Isaac Towers

This research project is to develop and implement numerical schemes which solve multi-dimensional partial differential equations (PDE). By using an appropriate set of orthogonal basis functions the goal is to create a spectral method which allows for boundary conditions at infinity while maintaining the speed of an explicit time-marching approach. Operator splitting, integrating factors and the so-called explicit exponential methods are being investigated.

Numerical schemes for simulating optical beam propagation

Isaac Towers

To compliment theoretical investigations of nonlinear optical beams we develop numerical schemes to efficiently study beam propagation. A variety of techniques are being investigated to provide fast and accurate simulations.

Applied and Industrial Mathematics (AIM)

Plant and disease spread

Steve Barry, Geoff Mercer, Harvi Sidhu, Roslyn Hickson

- Models of weed spread
- Intervention strategies
- Seed banks
- Flood events

There are several current models to simulate the spreading of weeds (or any population) in the environment, involving reaction-diffusion equations, integro-difference equations, cellular automata systems, SIR ordinary differential equation, stochastic differential equations, among others. We are currently developing PLANTSIM, a Matlab based package, which allows users to simulate and compare numerous population spread simulation models in either real or artificial situations. A key feature is the Graphical User Interface which allows users to manipulate the complex parameter data sets involved in real simulations. PLANTSIM allows the user to overlay, visualise and manipulate parameter data on satellite imagery, and then run a collection of different simulation routines, with output automatically visualised in a variety of formats with key results summarised and graphed in generated LaTeX and pdf files.

Additional work is being done on formulating new models for weed spread, particularly along river systems. This is being applied to the spread of Lippia in the Murray-Darling system.

Statistical Ecology

In order to ensure the survival of animal populations it is essential to be able to estimate mortality rates in the wild. Two ways of doing this are from the recovery of bands from animals found dead, and from mark-recapture experiments. Models involving survival, recapture and recovery probabilities as unknown parameters, are developed and fitted.

The following projects are currently being undertaken in this area:

Effect of banding on juvenile Little Penguins *Eudyptula minor*

Leesa Sidhu and Ted Catchpole

This work is being conducted in collaboration with researchers from the Phillip Island Nature Park. For more than 50 years, researchers have been marking penguins with flipper bands. Studies of Adélie Penguins and King Penguins have shown that banded penguins have lower survival rates than unbanded birds, and that they use more energy than unbanded birds when swimming. Our earlier work in this area was the first to study the effect of banding on Little Penguins. We showed that banding had a detrimental effect on the survival of adult penguins, with banded birds having an annual survival probability 6% lower than unbanded birds. While the effect of banding on juvenile Little Penguins is currently unknown, it is likely that banding significantly reduces the survival of young birds, particularly in their first year of life, and that our existing estimates of first-year survival underestimate the true survival probability for unbanded birds. A study examining the effects of banding on juvenile Little Penguins is currently underway on Phillip Island. The main aim of this project is to analyse the data from the Phillip Island study, in order to obtain estimates for survival for banded and unbanded juvenile Little Penguins, and for band loss in penguin chicks. The Department of the Environment and Heritage will use the results of this project, together with those from our earlier work, to determine whether banding of Little Penguins will be allowed to continue in Australia.

Analysis of recovery/recapture data for Pacific Gulls *Larus pacificus*

Leesa Sidhu and Ted Catchpole

This work is being conducted in collaboration with researchers from La Trobe University. The Pacific Gull is the only large gull occurring naturally in Australia. There is evidence that its population size is falling, its range contracting, and that it could become extinct. While earlier studies of Pacific Gulls have focused on their biology, there are no existing survival estimates for these birds. This study will be the first to produce age- and time-varying survival estimates for these birds, by analysing a long-term mark-recapture-recovery dataset. Such a study is crucial to improve our understanding of these birds, and to ensure the survival of this species.

Analysis of recovery/recapture data for Short-tailed Shearwaters *Puffinus tenuirostris*

Leesa Sidhu and Ted Catchpole

This work is being conducted in collaboration with researchers from La Trobe University. Short-tailed Shearwaters have been studied continuously on Fisher Island, Tasmania since 1946, making it one of the longest continuous studies of any wildlife population in the world. Although life-history data have been collected sporadically over this time period, a detailed mark-recapture-recovery analysis has not yet been conducted. This study will produce age- and time-varying survival estimates for Short-tailed Shearwaters, and examine the effect of individual covariates such as egg size on first year survival.

Comparing first year survival for Little Penguins *Eudyptula minor* **in Phillip Island, Australia and Oamaru, New Zealand**

Leesa Sidhu and Ted Catchpole

This work is being conducted in collaboration with researchers from the Phillip Island Nature Park , the Department of Conservation, New Zealand and the Institute of Marine Research, Norway. While the Phillip Island study has been underway for almost 40 years, the New Zealand study consists of six years of data. Here we estimate and compare the survival of penguins in these two locations and determine to what extent the conclusions of covariate dependence of survival can be extended from Phillip Island to another penguin colony.

Stefan problems with two moving boundaries - modelling swelling processes

Steve Barry, Geoff Mercer, Harvi Sidhu

- Cooking of whole grains
- Swelling of polymer implants in drug delivery
- Exact and asymptotic solutions of Stefan problems
- Swelling of grease layers on wool fibres

During the cooking of whole grains, or the swelling of grease, water diffuses into the outside of the grain causing the outer boundary to swell. This creates a partially swollen region which expands inwards and outwards over time. This then leads to a diffusion problem where the two boundaries defining the diffusive region move (a Stefan problem). We consider modelling this process and finding exact, numerical and asymptotic solutions to the system.

Applied and Industrial Mathematics (AIM)

Vision processes in humans and insects

Peter McIntyre and Colin Pask

Student Research

Critical times of multilayer diffusion

Roslyn Hickson (r.hickson@student.adfa.edu.au) PhD

Field of Study: Applied Mathematics

Diffusion through multiple layers has applications to a wide range of areas in heat and mass transport. An important aspect of multilayer diffusion is the `critical time', which is a measure of how long the diffusive process takes.

This project involves using an exact solution for multilayer diffusion to demonstrate the limitations of traditional averaging methods, which only work for a large number of layers or in the steady state. This solution is used to find a better approximation for a particular definition of critical time. The work is then extended to reaction diffusion models, with application to invasive plant spread.

Coarse woody fuel availability and consumption in Australian forest fires

Jennifer Hollis (j.hollis@student.adfa.edu.au) PhD

Field of Study: Statistics

After the passage of a fire front it is the larger, coarse woody fuels (>6mm diameter) that once ignited by fire, that will greatly influence: total energy output; convection column development; fire behaviour; greenhouse gas emissions; air quality; damage to biotic elements; soil heating; habitat quality; suppression/mop-up difficulty; and potential for re-ignition.

The focus of this research is the determination of proportion of woody fuel consumed and rate of consumption as functions of fire intensity; season; fuel type; and fuel condition in Australian forests. The research also includes testing current empirical and physics-based models of woody fuel consumption and the development of a fuel consumption model suitable for Australian eucalypt forests.

The outcomes of this research will assist the better management woody fuels. The Australian Woody Fuel Consumption Model developed can be incorporated into fire management decision support systems assisting fire and land management agencies to better predict the total fuel consumed in prescribed fires and wildfires and enhance planning for expected fire behaviour, smoke and greenhouse gas emissions and associated fire impact.

Dynamical systems behaviour of the Forced Bonhoeffer Van der pol equations

Richard Pennifold (richard.pennifold@student.adfa.edu.au) PhD

Field of Study: Applied Mathematics

The forced Bonhoffer van der Pol equations provide a description of how nerve impulses travel down the axon of a squid nerve cell under external stimuli. Previous work used bifurcation diagrams and Lyapunov exponents to explore the dynamics of this system. In our study we use continuation methods to clarify the bifurcations of the periodic orbits which had previously been ambiguous. We have developed numerical tools, such as the shooting and Galerkin methods. We also use the recent 0-1 test for chaos and conclude that this test offers a number of advantages over the Lyapunov exponent test. We have also used analytical and semi-analytical methods to determine approximate solutions to the system. We will also analyse the coupled Bonhoffer van der Pol system. The key point of our study is to develop an array of methods (both numerical and analytical) to enable accurate investigations into forced systems.

Forest flammability - modeling and managing a complex system

Philip Zylstra (Philip.zylstra@environment.nsw.gov.au) PhD

Field of Study: Forest fire behaviour

The intent of the project is to develop a complex systems model of fire behaviour which can demonstrate quantitatively the role of different fuel strata, species, dimensions and individual weather parameters in fire behaviour, allowing for more effective management of forest flammability.

Mathematics modeling of self-heating in compost piles

Thiansiri Luangwilai (t.luangwilai@student.adfa.edu.au) PhD

Field of Study: Applied Mathematics

The phenomenon of spontaneous ignition due to internal heating in bulk solids such as coal, grain, hay, wool wastes, etc., can be described by thermal explosion theory. In such models heat release is usually represented by a single Arrhenius reaction and combustion is initiated when heat-loss is unable to balance the heat generated by the internal heating of the bulk material. However in industrial processes involving large volumes of bulk organic materials there are in fact two sources of heat-generation: a low-temperature process involving the growth and respiration of micro-organisms, such as aerobic mould-fungi and bacteria, and a high-temperature process due to oxidation of cellulosic materials. Examples of processes where biological heating is important include large-scale composting operations, the storage of industrial waste fuel, such as municipal solid waste, and landfills. In these examples, self-heating due to biological activity is considered desirable, for example in composting. Elevated temperatures of the order 70-90 degree Celsius may be found within a few months or even a few days. Although it has been recognised for over twenty years that biological heating may be an indispensable prelude to self-ignition, very little information is available regarding the mechanism of fires when biological self-heating is involved, despite fires occurring at landfills worldwide. In my PhD program I intend to extend the basic models to include more realistic features such as oxygen consumption, advection through the compost pile, as well as the inclusion of moisture. I will analyse these in both one- and two-dimensional geometries. We believe that the results of my PhD will be one of the first, comprehensive mathematical studies to explain the self-heating process in industrial size compost piles

PhD Opportunities and Scholarships

If you require any further information, are interested in collaborative research with members of the group, or looking at a potential PhD or research Masters topic then please contact:
Assoc. Prof. Harvinder Sidhu (h.sidhu@adfa.edu.au)

Applied and Industrial Mathematics (AIM)

Topics are not limited to those shown in our research areas, and we are open to new areas of research in applied mathematics that are of interest to you and us. Email us and we will discuss any proposals you might have and possible available funding.

Publications

In Press

Journal - Refereed

Hickson, R.I., Barry, S.I. & **Mercer, G.N.**, in press, Critical times in multilayer diffusion. Part 1: Exact solutions, ***International Journal of Heat and Mass Transfer***, accepted.

Hickson, R.I., **Barry, S.I.** & **Mercer, G.N.**, in press, Critical times in multilayer diffusion. Part 2: Approximate solutions, ***International Journal of Heat and Mass Transfer,*** accepted.

Jovanoski, Z. & **Towers, I.**, in press, Domain wall stability, ***ANZIAM Journal (E),*** accepted.

Mahmud, M., Safinski, T.,Nelson, M., **Sidhu, H.S.**, Adesina, A., 2009, Kinetic analysis of oleic acid esterification using lipase as catalyst in a microaqueous environment, ***Industrial & Engineering Chemistry Research,*** accepted July 2009.

Oslington, P. & **Towers, I.**, in press, Pushing economies - and students - outside the factor price equalisation zone, ***Journal of Economic Education.***

Oslington, P. & **Towers, I.**, in press, Trade and migration in a world without factor price equalisation, ***Review of International Economics.***

Sharples, J.J., in press, An overview of mountain meteorological effects relevant to fire behaviour and bushfire risk, ***International Journal of Wildland Fire.***

Conference - Full paper refereed

Luangwilai, T., **Sidhu, H.**, Nelson, M. & Chen, X., 2009, Biological self-heating of compost piles with air flow, *Chemeca 2009*, 27-30 September 2009, Burswood Entertainment Complex, Perth, Australia, accepted. Abstract available at: http://www.chemeca2009.com/abstract/5.asp

Conference - Poster

Hollis, J., 2009, Woody fuel consumption and carbon in the changing climate of Australia, accepted for *Meeting Expectations, AFAC/CRC Conference*, 22-24 September 2009, Gold Coast, Queensland.

Zylstra, P., 2009, The forest flammability model, accepted for ***Meeting Expectations, AFAC/CRC Conference***, 22-24 September 2009, Gold Coast, Queensland.

2009 publications

Journal - Refereed

Gubernov, V., Kolobov, A.V., Polezhaev, A.A., **Sidhu, H.S.** & **Mercer, G.N.**, 2009, Pulsating instabilities of combustion waves in a chain-branching reaction model, ***International Journal on Bifurcation and Chaos,*** 19(3), 873-887, doi: 10.1142/S0218127409023354.

Hickson, R.I., Barry, S.I. & **Mercer, G.N.**, 2009, Exact and numerical solutions for effective diffusivity and time lag through multiple layers, ***ANZIAM J. (E),*** 50, C682-C695.

Nelson, M.I. & **Sidhu, H.S.** 2009, Analysis of the activated sludge model (number 1), ***Applied Mathematics Letters,*** 22(5), 629-635, doi: 10.1016/j.aml.2008.05.003.

Nelson, M.I. & **Sidhu, H.S.**, 2009, Analysis of a chemostat model with variable yield coefficient: Tessier kinetics, ***Journal of Mathematical Chemistry***, 46(2), 303-321, doi: 10.1007/s10910-008-9463-7.

O'Neill, B., 2009, Exchangeability, correlation and Bayes' effect, ***International Statistical Review,*** 77(2), 241-250, doi:10.1111/j.1751-5823.2008.00059.x.

Rowe, M.P., **Sidhu, H.S.** & Mercer, G.N. 2009, Military aviation application for a springs and masses safest path determining model, ***Journal of Battlefield Technology,***12(1), 27-32.

Sharples, J.J., McRae, R., **Weber, R.O.** & Gill, A.M., 2009, A simple index for assessing fire danger rating, ***Environmental Modelling & Software,*** 24(6), 764-774, doi:10.1016/j.envsoft.2008.11.004.

Sharples, J.J., McRae, R., **Weber, R.O.** & Gill, A.M., 2009, A simple index for assessing fuel moisture content, ***Environmental Modelling & Software,*** 24(5), 637-646, doi:10.1016/j.envsoft.2008.10.012.

Sidhu, H.S., Gubernov, V.V., Kolobov, A.V., Polezhaev, A.A., **Mercer, G.N.** & **Sharples, J.J.**, 2009, Oscillatory combustion waves in a chain branching model, ***ANZIAM J. (E),*** 50, C1017-C1032.

Sidhu, H.S., Watt, S.D. & Nelson, M.I., 2009, Performance comparison between a two-reactor cascade and a single reactor in an activated slude wastewater treatment process, ***International Journal of Environment and Waste Management,*** 3 (3/4), 214-225.

Conference - Full paper refereed

Sharples, J.J., Gubernov, V.V., **Sidhu, H.S.**, **Towers, I.N.**, Kolobov, A.V. & Polezhaev, A.A., 2009, Behaviour of combustion waves in one-step and two-step models, ***Proceedings of the 18th IMACS World Congress and MODSIM09,*** 13-17 July, Cairns, pp. 4453-4459.

Sharples, J.J., Mills, G.A., McRae, R.H.D. & **Weber, R.O.**, 2009, Fire danger anomalies associated with foehn-like winds in southeastern Australia, ***Proceedings of the 18th IMACS World Congress and MODSIM09***, 13-17 July, Cairns, pp. 268-274.

Sharples, J.J., McRae, R.H.D. & **Weber, R.O.** 2009, An empirical probabilistic study of wind directions in complex terrain, ***Proceedings of the 18th IMACS World Congress and MODSIM09,*** 13-17 July, Cairns, pp. 4446-4452.

Sharples, J.J., **Weber, R.O.**, McRae, R.H.D. & Gill, A.M., 2009, A simple method for assessing fuel moisture content and fire danger rating, ***Proceedings of the 18th IMACS World Congress and MODSIM09,*** 13-17 July, Cairns, pp. 275-281.

Weber, R.O., Dold, J.W. & Zinoviev, A., 2009, Including suppression effectiveness in fireline growth models, ***Proceedings of the Royal Society of Queensland Bushfire 2006 Conference Special Edition,*** 115, pp. 45-49.

Whiten, B., Fulford, G., **Hickson, R.I.** & Pritchard, G., 2009, The response of power systems to autonomous ``Grid Friendly Devices", ***Proceedings of the 2008 Mathematics in Industry Study Group,*** T.R. Marchant, M. Edwards, **G.N. Mercer** (eds), pp. 81-101.

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Conference - Abstract

Hollis, J. & McCaw, W.L., 2009, Woody fuel consumption and carbon in the changing climate of Australia, presented at, ***Institute of Foresters Australia Conference,*** 6-10 September 2009, Caloundra, Queensland, Australia.

2008 publications

Book - Chapter

Dovers, S., Hutchison, M., Lindenmayer, D., Manning, A., Mills, F., Perkins, P., **Sharples, J.J.** & White, I., 2008, Uncertainty, complexity and the environment, in ***Uncertainty and Risk; Multidisciplinary Perspectives,*** G. Bammer, M. Smithson (eds), Earthscan, UK, pp. 245-260.

Nelson, M.I., Chen, X.D. & **Sidhu, H.S.**, 2008, Reducing the emission of pollutants in industrial wastewater through the use of membrane bioreactors, in ***Aspects of Mathematical Modelling,*** R.J. Hosking, E. Venturino (eds), Birkhauser, Basel, pp. 95-107.

Journal - Refereed

Ahmed, M.S., Kayali, O.A. & **Anderson, W.R**., 2008, Chloride penetration in binary and ternary blended cement concretes as measured by two different rapid methods, ***Cement and Concrete Composites,*** 30(7), 576-582, doi:10.1016/j.cemconcomp.2008.02.005.

Amos, K.J., Croke, J.C., Hughes, A.O., **Chapman, J**., Takken, I. & Lymburner, L., 2008, A catchment-scale assessment of anabranching in the143,000 km^2 Fitzroy River catchment, north-eastern Australia, ***Earth Surface Processes and Landforms***, 33(8), 1222-1241, doi: 10.1002/esp.1609.

Barry, S.I. & **Caunce, J.F.**, 2008, Exact and numerical solutions to a Stefan problem with two moving boundaries, ***Applied Mathematical Modelling,*** 32(1), 83-98, doi:10.1016/j.apm.2006.11.004.

Barry, S.I., **Hickson, R.** & Stokes, K., 2008, Modelling Lippia spread down flooding river systems, ***ANZIAM J. (E.)***, 49, C359-C375.

Barry, S.I. & Sweatman, W.L., 2008, Modelling heat transfer in steel coils, ***ANZIAM J. (E.)***, 50, 668-681.

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Grants

External Grants

H.S. Sidhu, **G.N. Mercer** & **R.O. Weber**, Analysing instabilities in complex combustion models for different geometrical configurations ARC Discovery Project, $301,118 (2008: $90,000, 2009: $90,000, 2010: $90,000, 2011: $31,118).

Bushfire CRC, HighFire 2006 to 2008, $225,000.

UNSW Grants

B. O'Neill, New Staff Start-Up Grant for 2009: $7,480.

G.N. Mercer, Benchmarking optimum route planning methods for airborne maritime surveillance operations, Defence-Related Research Funding Scheme Grants, 2008: $3,445.

L.A. Sidhu, Analysis of recovery/recapture data for Pacific Gulls, Early Career Researcher Grant, 2008: $12,324.

L.A. Sidhu, Effect of banding on juvenile Little Penguins, Start-up Grant, 2008: $9,970.

H.S. Sidhu & A.A. Adesina, Process intensification for autothermal generation of hydrogen from light hydrocarbons by periodic composition forcing, UNSW Silverstar Award for their ARC project 2008: ($10,000 each).

J.R. Taylor, **H.S. Sidhu** & R.J. Hughes, Investigation of uncertainties in bathymetric retrievals using a semi-analytic method, Defence-Related Research Funding Scheme, 2008: $18,627.

Conference Participation

From 28 January-1 February 4 2008 **Geoff Mercer, Steve Barry, Zlatko Jovanoski** and **Roslyn Hickson** attended the annual *Mathematics in Industry Study Group (MISG)*.

Geoff Mercer, Harvi Sidhu, Steve Barry, Rod Weber and **Roslyn Hickson** attended the annual *Australian and New Zealand Industrial and Applied Mathematics (ANZIAM) Conference* in Katoomba from 4-7 February 2008.

PhD student **Roslyn Hickson** was awarded funding to attend both the *Graduate Industrial Mathematics Modelling Camp* and the *Industrial Problem-Solving Workshop (IPSW)* at University of Regina, Canada from 9-20 June 2008. For the IPSW she worked with a small group on a local area positioning problem from Accutrak. Accutrak research, design and develop accurate steering systems for agriculture. This particular problem involves determining the location of a tractor relative to beacons which have been placed around a field. The beacons communicate with the tractor receiver via a particular frequency with a known wavelength. Accutrak's system cannot determine the integer number of wavelengths from the beacons to the receiver, however it can detect the fractional component of the wavelength. To find the position of the tractor the fractional components from at least 3 beacons are used to set up a system of nonlinear equations. This system is not trivial to solve, but the real complexity comes from the variety of sources of errors within the system. GPS is not sufficiently accurate for this task, as its reliable accuracy is only ±10 metres for moving objects.

At the *Australian Statistical Conference* in Melbourne in 30 June-3 July 2008, 41 early career statisticians contested the EJG Pitman Prize for the most outstanding talk by a student or recent statistics graduate. **Leesa Sidhu**, with her talk entitled "Little Penguins: to band or not to band?", was one of four early career statisticians who received an honourable mention for presentations that achieved a very high standard.

A poster by **Geoff Mercer**, Winston Sweatman (Massey University, NZ) and Alison Forster (Plant Protection Chemistry, NZ) won the best poster (out of 73 posters) at the *15th Biennial Conference of the European Consortium for Mathematics in Industry* 30 June-4 July 2008 in London

Accutrak group photo taken at the Industrial Problem-Working Workshop, University of Regina, Canada.
Back row (left to right): Ewout van den Berg, David Clark, Neville Fowkes, Nathan Shaw.
Front row: **Roslyn Hickson**, Melanie Roberts, Edward Doolittle.

At the *14th Biennial Computational Techniques and Applications Conference* held at ANU (13-16 July 2008), 5 academic staff members from PEMS (**Zlatko Jovanoski, Isaac Towers, Steve Barry, Geoff Mercer** and **Harvi Sidhu)**, 2 PhD students (**Roslyn Hickson** and **Richard Pennifold**) and a CDF student (**Martin Rowe**) presented a total of 10 talks. Geoff and Harvi were also on the organizing committee of this important national conference.

The 2008 joint *NSW/ACT Australian and New Zealand Applied and Industrial Mathematics* branch mini-meeting was held at Batemans Bay 21-22 November 2008. The organising committee for the minimeeting comprised Dr M.I. Nelson (Uni Wollongong) and **Harvi Sidhu** (UNSW@ADFA, PEMS). The meeting had a strong PEMS delegation giving a wide variety of talks from ethanol production, compost modelling, bush fire modelling, analysing the effects of diffusion in multilayer media and wastewater modelling. Everyone agreed that our students **Thiansiri** and **Roslyn** gave excellent talks. Roslyn was specially singled out with a highly commended award.

Geoff Mercer and **Harvi Sidhu** attended the *7th Australia and New Zealand Mathematics Convention* at University of Canterbury, Christchurch from 8-12 December 2008. Harvi was the invited speaker for the "Applied dynamical systems in engineering and the physical sciences" session. His talk was titled "Classical and pulsating combustion waves in a chain-branching reaction model". Geoff, gave a talk titled "Determining a safe path through a dynamic threat environment in real time". Part of this work was undertaken

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by a CDF student, **Martin Rowe**, that Geoff and Harvi supervised this year. DSTO are currently interested with the algorithms that the group have devised for real-time calculations.

Roslyn Hickson attended the *Maths in Industry Study Group (MISG)* in Wollongong, held from 27-31 January 2009. She was the student moderator for the 'Coil Slumping Problem' sponsored by Bluescope Steel. Bluescope Steel manufactures, stores and transports steel strip coils. The current limiting step of this production, from an economic perspective, is the unpredictable 'coil slumping' which occurs when the coil cannot hold up its own mass and maintain the integrity of its cylindrical shape. Even minor slumping is an issue, and the cost of an individual coil is such that even the loss of one coil in a thousand is unacceptable. There was much lively debate over an appropriate approach to the problem, making for an exciting and interesting week.

Roslyn Hickson gave a presentation at the *ANZIAM Applied Mathematics Conference* held in Caloundra from 1-5 February 2009. From a field of 41 talks competing for the highly sought after T.M. Cherry student prize, Roslyn was awarded an honourable mention. At the conference Roslyn was also elected as a representative on the ANZIAM Executive Committee.

Roslyn Hickson attended the *European Study Group with Industry* on 30 March-3 April 2009 in Southampton, England. She mostly worked on a decontamination problem, with applications such as cleaning railway rolling stock, removal of traffic film from road vehicles, and graffiti removal. She also worked on an electric arc problem, with application to circuit breakers. There were approximately 80 delegates at the conference.

The following week she attended the *British Applied Mathematics Colloquium* on 6-9 April 2009 in Nottingham, where she presented her work titled "Critical times of multilayer diffusion".

Jennifer Hollis spent the month of July 2009 with the Fire and Environmental Research Applications (FERA) team based in Seattle, Washington at the Pacific Wildland Fire Sciences Laboratory (PWFSL). She met with Dr Roger Ottmar, a research forester with FERA and spent time in the office and field discussing woody fuel consumption equations from Consume 3.0, collaborating on a manuscript and discussing how the Fuel Characteristic Classification System could be adapted for Australia. On July 10th 2009 she presented a seminar at the Pacific Wildland Fire Sciences Laboratory on woody fuel consumption in Australian forest fires, and on July 31st 2009 met with Dr Mark Finney at the Missoula Fire Lab in Montana to discuss potential application of the Burnup model for predicting woody fuel consumption. From 6-10 September 2009 she attended the *Institute of Foresters Australia Conference* in Caloundra, Queensland and presented a conference paper and poster on "Woody fuel consumption and carbon in the changing climate of Australia".

Visitors

Mark Nelson, an applied mathematician from the University of Wollongong, spent a significant part of his SSP in PEMS (2008) with **Harvi Sidhu,** and other members of the Applied and Industrial Mathematics group working on various chemical/biochemical engineering problems, including optimising ethanol production through continuous fermentation, modelling of heat generation from composting, ignition of coal piles and modelling the passage of food down the human/animal gut.

In early 2008, **Leesa Sidhu** and **Ted Catchpole** were visited by Mr Bruce Robertson, a biologist studying Pacific Gulls. The aim of the visit was to discuss the details of the data collection and the biology of these birds, to enable Leesa and Ted to analyse the mark-recapture-recovery data.

Leesa Sidhu and **Ted Catchpole** hosted a visitor, **Dr Peter Dann**, from 2-4 February 2009. Peter (also known as the "Penguin Man") is the Research Manager of the Phillip Island Nature Park. The purpose of the visit was to continue their study of the effect of banding on the survival of adult and juvenile Little Penguins. The results of these analyses will be used by the Department of Environment and Heritage to determine whether banding of Little Penguins will be allowed to continue in Australia

Dr Vladimir Gubernov visited PEMS from 3 March-1 April 2009. Vladimir is from the P.N. Lebedev Physical Institute of the Russian Academy of Sciences and his visit was funded by the Rector's Visiting Fellowship scheme. During his visit, he worked closely with **Harvi Sidhu** and **Jason Sharples** to investigate instabilities in multi-step combustions models. Vladimir is well known in the mathematical combustion modelling community for his expertise in using intricate mathematical methods to illuminate complex behaviour. Later this year, Jason will visit Vladimir at his institution in Moscow.

Prof. Swapan Konar from the Birla Institute of Technology, Mesra, Ranchi, India was funded as a Visiting Fellow to PEMS. He visited PEMS during 15 May-15 July 2009 and worked with **Isaac Towers** and **Zlatko Jovanoski** in the area of optical solitons.