OCCAM

OXFORD CENTRE FOR COLLABORATIVE APPLIED MATHEMATICS

SUMMER INTERNSHIPS IN OXFORD

The Oxford Centre for Collaborative Applied Mathematics (OCCAM) is offering internships to carry out short research projects in Oxford for a period of up to 10 weeks during the summer vacation. The bursaries are for mathematicians who are undergraduates in their middle years and those between their undergraduate degree and a Masters course, and provide an excellent opportunity to gain first hand research experience and find out whether you might be suited to a research career.

Application process

There is a two-stage application process. Firstly, applicants should contact potential supervisors at OCCAM to discuss research projects (see attached list of possible topics, but note that this list is not exhaustive) as early as possible, and at the latest by the deadline of noon on 23 April 2009. Those contacting OCCAM supervisors after this date will not be considered. Applicants are responsible for ensuring that a faculty member at their current institution sends a reference to occam-admin@maths.ox.ac.uk by 23 April.

Secondly, selected applicants and their supervisors should then complete the online application form that can be found at https://www.maths.ox.ac.uk/groups/occam/vacancies/summer-internship. The deadline for applications is noon on 1 May 2009. Successful applicants will be notified by the middle of May. Projects will normally be undertaken during the months of July, August and September.

Eligibility

To apply you must be

- Registered at a recognised higher education institution;
- A mathematician in the middle years of an undergraduate degree, or between an undergraduate degree and a Masters degree;
- Able to commit to undertaking a research project over the summer vacation and be based in Oxford throughout its duration.

Scheme details

Each internship provides a bursary of £180 per week for the duration of the project, up to £200 for research expenses associated with the project and up to £500 for travel to Oxford. Interns will be given desk and computing access in OCCAM and will receive assistance in finding accommodation. **For non-EU students, offers will be conditional on you obtaining an appropriate visa for entry in to the UK. This is likely to be via the UK's Tier 5 route under the points-based "government-authorised exchange" scheme, see http://www.ukba.homeoffice.gov.uk/workingintheuk/tier5.**

Students registered at the Mathematical Institute, University of Oxford, who would like to write up the project during a formally assessed component of their degree course in the subsequent years will need to submit the project in the usual way to the Institute's projects committee. The project being submitted for formal assessment will usually need to be an extension of any summer work. Students registered outside Oxford will need to check with their home institution about the regulations surrounding the use of this work undertaken as part of these summer projects for formally assessed components of their degree course. Oxford is not able to provide credit award for an internship project.

More information about OCCAM can be found at http://www.maths.ox.ac.uk/occam

Possible projects and supervisors

Mathematical Modelling of arterial blood flow (Dr Sarah Waters and Dr Robert Whittaker)

Large arteries have significant curvature. To understand the flow in such vessels, and the associated shear stress distribution which is correlated with the likelihood of arterial disease, we have modelled the artery as a tube of uniform circular cross-section, having a centreline which lies on the arc of a circle (Siggers & Waters, 2005, 2008). The blood, modelled as a Newtonian fluid, is driven by a prescribed pulsatile pressure gradient to mimic pumping of blood by the heart. The flow is governed by four key dimensionless parameters: the curvature, steady and unsteady effective Reynolds numbers, and the amplitude of the pressure gradient.

We have a successful ongoing collaboration with Professor van de Vosse and his group (Biomedical Engineering, Technical University of Eindhoven), who undertake experimental and computational dynamics simulations of flows in curved vessels. We are currently seeking to address the following research questions: (1) how do the flow properties change when a non-Newtonian fluid (used experimentally) is considered; (2) how do experimental ultrasound measurements of the flow depend on the location of the ultrasound probe.

The aim of this project will be to address both these question using an analytical approach, in which the dimensionless parameters are taken to be asymptotically large or small as appropriate. The analytical work undertaken by the student will be validated through detailed comparisons with experimental and computational results from the Eindhoven group. A particularly exciting aspect of this project will the opportunity for the student to visit the Eindhoven group to gain first hand experience of working in an interdisciplinary team of experimentalists, computational scientists and mathematicians (this will be directly funded by Eindhoven). It is anticipated that a research publication will arise from this project.

[Contact: waters@maths.ox.ac.uk; whittaker@maths.ox.ac.uk]

Shallow water modelling of radiative transfer in the Jovian atmosphere (Dr Paul Dellar)

Shallow water models of the atmospheres of Jovian planets yield plausible bands, but have difficulty producing a super-rotating equatorial jet. An existing shallow water model [Scott & Polvani 2008 GRL] with a crude modelling of radiative transfer as a damping of the height field does yield equatorial super-rotation. This project will apply the extended shallow water models with separate temperature fields developed for the equatorial ocean [eg Ripa 1993 GAFD, Dellar 2003 Phys. Fluids] to the atmospheres of Jovian planets. These extended models will permit a much more convincing shallow-water treatment of the interaction of radiative transfer and hydrodynamics.

[Contact: dellar@maths.ox.ac.uk]

Background reading:

[1] P. J. Dellar (2003) Common Hamiltonian structure of the shallow water equations with horizontal temperature gradients and magnetic fields, Phys.
Fluids 15 292-297

[2] T. E. Dowling and A. P. Ingersoll (1989) Jupiter's Great Red Spot as a shallow water system, J. Atmos. Sci. 46 3256-3278

[3] P. Ripa (1993) Conservation laws for primitive equations models with inhomogeneous layers, Geophys. Astrophys. Fluid Dynam. 70 85-111

[4] R. K. Scott and L. M. Polvani (2008) Equatorial superrotation in shallow atmospheres, Geophys. Res. Lett. 35 L24202

Cryogenic Freezing of Tumours (Dr Rebecca Shipley and Dr Sarah Waters)

The objective of this project is to develop a mathematical model for the freezing of tumours by cryogenesis, which can be used in combination with image processing data to infer tumour regression properties. Cryogenic freezing is a treatment that destroys abnormal cells through the application of extreme cold by means of a cryoprobe. The technique is generally used for external tumours, but increasingly is also being used to treat internal tumours. The cryoprobe freezes the tumour from the inside outwards, thus developing a moving interface between the frozen and remaining normal tissue. This is the setup of a classical Stefan problem; a group of problems characterized by a moving boundary that must be determined as part of the problem.

The student will address three key research questions: (1) for a given tumour, what is the optimal position of the cryoprobe? (2) what is the optimal length of treatment? (3) how do these answers depend on the underlying physiology?

The student will develop a mathematical model that captures the key components of tumour physiology, and the application of a cryoprobe. In particular, the mathematical model will incorporate the flow of fluid (blood), mechanical stresses (as a consequence of the freezing process) and the transport of heat, for the anisotropic geometries that are typical of tumours. The final coupled model will be complex, so will be reduced through dimensional analysis by taking the dimensionless parameters to be asymptotically large or small as appropriate. The final reduced model will be solved numerically using tumour geometries from MRI images provided by clinicians at the University of Manchester. In this way, the student will develop a patient-specific model and treatment plan for cryogenesis that can be integrated with medical imaging techniques.

Finally, collaborators at the University of Waterloo will be visiting over the Summer, and will conduct experiments on the freezing of slabs of meat. Imaging analysis of this process will be used to validate the mathematical models. This interaction will give the student first hand experience of the collaboration process and an insight into interdisciplinary research.
[Contact: shipley@maths.ox.ac.uk; waters@maths.ox.ac.uk]

Planetary atmospheric flows in the presence of moisture (Dr John Norbury)

Current research into climatic features of the atmosphere uses a suite of models of varying complexity, ranging from process models to general circulation models (GCMs). These models are used to develop a theoretical framework with which to understand observed phenomena, and to make climate-change predictions. GCMs are also used in day-to-day (operational) forecasting centres around the world. However, these models have well identified difficulties with, and inadequately simulate, tropical circulations. In this project, we will study the response of a moist atmosphere to solar heating; moisture will be an integral component, and will play an important role in the tropics.

We currently have a numerical model of some complexity that successfully embeds moisture processes in a Lagrangian-based, inner numerical iteration. Current literature indicates a demand for a framework with which to understand the role played by moisture in many of the planetary-scale features of the atmosphere. Using our model, together with asymptotic theoretical models, we will explore how solar heating in a moist atmosphere determines climatic features such as the Hadley circulation (a circulation, closely related to the trade winds, that dominates the weather of the tropics and subtropics).

We will also analyse mild longitude-dependence. In studying the Hadley circulation, we will have only considered axisymmetric (longitude-independent) solutions. Implicit is the assumption that the Earth can be treated as an `aquaplanet' with no topography. Longitude-dependence will allow us to investigate the heating effect of Earth's continents on planetary flow, thus helping understand features such as the Walker (equatorial, east-west) circulation and monsoons. In addition to examining the effects of solar heating, moisture, and longitude-dependence on the circulation of the atmosphere, it will be useful for the student to develop his or her own `toy' model. This model will focus on a more narrowly defined area of dynamic meteorology, for comparison with our current model and with other existing models; it will be implemented in Matlab.

It is envisaged that this project will be in collaboration with Mr Anthony Lock, a D.Phil. student at OCIAM. [Contact: norbury@maths.ox.ac.uk]

Background reading:
[1] Vallis, G.K. 2006 Atmospheric and Oceanic Fluid Dynamics. Cambridge University Press.

In addition to considering the projects described above, students should feel free to think about their own projects that fit in with OCCAM's research areas (see http://www.maths.ox.ac.uk/groups/occam/research), and are encouraged to contact potential supervisors (well in advance of the deadline) to discuss their ideas.

Other potential supervisors:

Dr Radek Erban [erban@maths.ox.ac.uk]: Multiscale Modelling, Stochastic Simulation Algorithms, Gene Regulatory Networks, Chemotaxis and Applications of Mathematics in Medicine

Dr Chris Breward [breward@maths.ox.ac.uk]: fluid mechanics; surfactants; modelling of industrial and medical processes

Prof David Gavaghan [david.gavaghan@comlab.ox.ac.uk]: computational biology; modelling of the heart and tumours; electrochemical measurement techniques