Institution: University of St Andrews

Unit of Assessment: 10 – Mathematical Sciences

a. Overview

Research in the School of Mathematics and Statistics at St Andrews focuses on a number of 'trademark' areas across the mathematical sciences. Activity is structured around *Research Groups*, all of which are well-established internationally: *Solar and Magnetospheric MHD Theory*, *Vortex Dynamics, Algebra and Combinatorics, Analysis* and *Statistics*. There is also a *History of Mathematics* Group with members drawn from across the School. With one of the largest supercomputers in the UK located in the School, computer-intensive research features prominently across the research portfolio.

The School is a founding partner in three interdisciplinary centres with other departments in St Andrews: the *Centre for Research into Ecological and Environmental Modelling* (*CREEM*), the *Centre for Interdisciplinary Research in Computational Algebra* (*CIRCA*), and the *Scottish Oceans Institute* (*SOI*).

The School participates in many collaborative projects, including as lead partner in the National Centre for Statistical Ecology, as a key co-ordinating centre for GAP Computer Algebra, as lead partner in the UKMHD Consortium, and as a major partner in four EU Solar networks.

The School has 33 permanent academic staff, about 30 research staff and 12 active emeritus staff. For a School of its size there is a high number of research students, averaging 1.4 per staff member at any time, and a high research grant income of about £12m since 2008.

The past five years have seen notable successes in all areas of the School's research activity, for instance solving long-standing conjectures in group theory, modelling how turbulent inhomogeneous mixing leads to strong jet streams in planetary atmospheres such as on Jupiter, and introducing highly innovative methods that incorporate spatial information into capture-recapture population estimation.

b. Research strategy

Overall strategy

The University's Research Strategy is '*To build upon its excellent reputation for leadership and competitiveness in all areas of research as measured by international standards so as to create an exciting, innovative and flexible, as well as intellectually and financially sustainable research culture to pursue programmes of world-class research'*.

Within this framework, the School strives for leading international research excellence and to provide a highly invigorating local research environment, two facets that enhance and feed on each other. Our strategic aims are therefore: 1. To undertake cutting-edge research and disseminate it in leading journals and international meetings, 2. To enhance continually our unique environment which underpins our research, as exemplified by top quality staff, students, visitors, and international collaborations, supported by a diverse portfolio of research grants.

To achieve these aims, the School's strategy is to concentrate research on particular areas championed by its research groups, and to support these areas to ensure that they remain at the cutting-edge of research and evolve as subjects advance. There are currently five main groups and the School is proactive in exploring opportunities for new areas. Synergies between groups are encouraged and the centres CIRCA, CREEM and SOI support key interdisciplinary collaborations. As envisaged in RAE 2008, the School has expanded its computational capability enormously and with its very large supercomputer clusters is now in a particularly strong position to undertake computer-intensive research in virtually all areas.

Key to the strategy is enabling research groups to provide a vibrant and supportive environment academically and, indeed, socially, in which staff, postdocs, postgraduates, and visitors all play a full part. Each group runs its own weekly seminar programme as well as a variety of workshops.

The groups facilitate diverse collaborations internally and externally drawing on their extensive international networks. The School allocates each group a budget for travel, conferences, visitors, specialist equipment, etc., to supplement external funding. There are deeply embedded research-teaching linkages, with advanced undergraduate and Masters modules covering all our research areas, and an innovative vacation research programme for the best undergraduates.

The ***Solar and Magnetospheric Theory Group*** develops mathematical models of observed solar and magnetospheric phenomena, with the main emphasis on magnetohydrodynamics (MHD). This includes solar prominences and flares, coronal loops and oscillations, flux emergence, coronal heating and auroral particle acceleration. As anticipated in RAE 2008, the Group has become closely involved in interpreting observations from space missions, notably SoHO, TRACE, Hinode and SDO. Its Guest-Investigator status on these missions is unprecedented for a theory group.

Since 1996 the main funding has come via a multi-million pound STFC consolidated grant (nearly £2m since 2008) along with other significant grants. The consolidated grant has been extended for 2013-16 ensuring future sustainability. As proposed in our RAE 2008 strategy, High Performance Computing (HPC) facilities have been significantly enhanced for the Group and UK MHD researchers by a total grant of £2.2m with £1m coming directly to St Andrews.

With a unique combination of expertise in large scale computational modelling, sophisticated analytical techniques and involvement with next generation solar space missions, the Group will continue to lead the field. Key projects include: HPC investigation of solar magnetic fields and heating of the solar corona (Hood); kinetic theory and particle acceleration in solar theory (Neukirch); magnetosphere-ionosphere coupling and auroral particle acceleration (Wright); cutting-edge work on magnetic reconnection and prominence theory (Parnell, Mackay); development of MHD wave theory for a new range of observations (De Moortel, Wright).

The ***Vortex Dynamics Group*** focuses on fundamental aspects of geophysical flows in planetary atmospheres, including the Earth's, a timely area given climate change concerns. Diverse approaches are used, from rigorous analytical theory to modelling based on laboratory experiments. State of the art numerical methods are employed throughout, including Dritschel's innovative extremely efficient computational software tailored to study highly complex geophysical fluid behaviour.

As anticipated in RAE 2008, the Group leads the way in the development and exploitation of new parallel-computing paradigms. Their research has led to new understandings of complex, non-linear fluid flows, from the breaking of internal ocean waves and of planetary waves in the atmosphere, to the interaction of intense coherent vortices (e.g. Jupiter's red spot), to turbulence across many spatial scales, and to the general structure of planetary circulations (e.g. bands, jets, currents and eddies). In particular, we understand far better how mixing through wave breaking leads to 'inhomogeneous mixing'.

Ongoing research includes: interaction between the ocean surface (lens vortices) and the deep interior (Dritschel, Perrot); the formation of banded circulation patterns (e.g. the jet stream, bands on Jupiter) (Scott, Dritschel); dynamics of the polar stratosphere (Scott, Liu); new rigorous estimates for turbulent flows, including MHD flows (Tran, Scott, Dritschel); stability and nonlinear interactions of oceanic vortices (Reinaud); extension of known analytical solutions for vortices in idealised (asymptotic) models to realistic models of ocean dynamics (Reinaud, Tsang, Dritschel); the structure and evolution of large-amplitude oceanic internal waves, impacting on coastal oceanography and engineering (Carr, King, Dritschel).

The Group will continue fundamental research, but with a new focus to understand a major unresolved area in geophysical and astrophysical fluid dynamics: how waves and turbulence *together* lead to inhomogeneous mixing and the formation of coherent structures like fronts and vortices. They will strengthen their interdisciplinary research profile by unifying aspects of fluid dynamics normally studied in near isolation, including MHD, thus linking to the Solar Group.

Central to strategy of the ***Algebra and Combinatorics Group*** is collaborative research leading to cross-fertilisation across the whole spectrum of discrete mathematics and exciting progress in emerging areas. In particular this involves interdisciplinary research with computer science through CIRCA. As well as underpinning such interaction, the individual expertise of each researcher has impact and influence on traditional areas including finite and infinite groups, representation theory, semigroups, finite fields, computational algebra and combinatorics of permutations.

Such interactions have recently led to solutions of several long standing problems. For example, Ruskuc (with former postdoc Gray) answered a question of Nambooripad (1979) by showing that every group occurs as a maximal subgroup of a free idempotent generated semigroup, and Quick, Roney-Dougal and Menezes obtained detailed bounds on the probabilistic generation of finite almost simple groups, answering questions of Wiegold (1974) and Mel'nikov (1978).

The Group's strategy is to 'export' its algorithmic and computational expertise into novel settings. This is reflected in new directions such as extension of work on generating sets of groups, semigroups and other structures (Quick, Roney-Dougal, Ruskuc); deep insights into generating properties of infinite groups and semigroups of transformations (Mitchell, Peresse, Quick, Ruskuc); work on Thompson's simple groups (Bleak); expansion and systematisation of the application of automata (Bleak, Quick, Ruskuc); the 'synchronization project' on the interaction between automata, groups, semigroups and graph homomorphisms (Cameron).

Substantial parts of the Group's research have resulted in major software contributions to the GAP ('Groups, Algorithms, Programs') algebra software system which contains a vast number of packages across all areas of algebra, see http://www.gap-system.org. As one of four centres which oversee GAP and with three staff on the GAP Council, St Andrews plays a leading role in developing and coordinating this invaluable research and teaching tool.

The ***Analysis Group*** is one of the leading groups in fractal and multifractal geometry and dynamics with their work driving current research worldwide. Olsen's rigorous multifractal formalism and Falconer's affinity dimension are particularly influential and highly cited.

As anticipated in RAE 2008 the Group's interests have evolved and broadened to include: non-commutative fractal geometry (Falconer, Olsen, Samuel); properties of typical and prevalent sets, measures and functions (Olsen, Fraser); fractal stochastic processes (Falconer); multifractal zeta functions (Olsen). Further broadening of the Group's base has resulted from the strategic appointment of Todd with his background in ergodic theory and equilibrium states and of Jin with expertise in probabilistic methods. This has led to significant progress on Mandelbrot martingales and cascade processes (Falconer, Jin) and non-uniformly hyperbolic dynamical systems (Todd).

Building on its strengths, the Group is engaging with exciting emergent topics, including fractal and multifractal tube formulae, dimension theory of non-linear non-conformal systems, and the use of CP-processes to study geometrical properties of fractals. Promising synergies are also developing with recently appointed lecturers in the Algebra Group (Bleak, Mitchell) in the areas of fractal groups and symmetries of fractals.

The ***Statistics Group*** is a world leader in statistical ecology. It has long been a pioneer of distance sampling methods for wildlife population assessment, authoring industry standard software and funding its development by training workshops and sponsorship. Lately the Group has led the development of Bayesian capture-recapture methods (King), spatially-explicit capture-recapture methods (Borchers), and integration of these with distance sampling and other forms of data (Borchers, Buckland, King, Thomas). The Group has also recently pioneered methods for analysing passive hydroacoustic survey data for estimating marine mammal abundance/trends (Thomas).

St Andrews is the largest and lead partner in the National Centre for Statistical Ecology (NCSE) http://www.ncse.org.uk founded in 2005, described in EPSRC documentation as '*a bold initiative aimed at improving our understanding of how populations of wild animals develop and predicting*

how changes in the environment will affect species'. The Group led the bid which secured EPSRC and NERC £1m funding for 2010-15 for an expanded NCSE, which now includes 8 UK universities and 7 partner institutes, with over a third of its active researchers in St Andrews.

The Group continues to expand its research horizons, aided by new staff and collaborations and currently has 13 research staff to support academic staff. This expansion includes the areas of biodiversity (Buckland, Illian), spatial modelling (Illian, King), and Bayesian inference methods, particularly applied to bioinformatics and epidemiology (King, Overstall, Papathomas). The Group's strengthened research grant portfolio (income of around £4.6 million since 2008) maintains a broad base of funders.

The Group is in a stronger position than ever to seek funding and develop research, both theoretical and applied, in its areas of current and emerging strength. It will build further on its reputation in interdisciplinary research in statistical ecology and spatially-explicit capture-recapture, where, for example, it is ideally placed to capitalise on the international growth areas such as biodiversity monitoring methods and the environmental impact of renewable energy.

c. People, including:

i. Staffing strategy and staff development

The School strategy has been to combine appointing promising *early career researchers*, often linking such appointments to initial fellowships, with *strategic appointments* at a senior level. Paramount is the selection of researchers with the highest potential, keeping in mind the strategies both of enhancing and evolving the existing activities of research groups and of developing new directions and synergies. Specifically, the School is currently seeking to appoint an outstanding Regius Professor with the expectation of developing a new research area.

Since 2008 the number of *permanent academic staff* has increased from 31 to 33 (including 11 Professors, 6 Readers and 3 Senior Lecturers) of whom 9 are women (3 Professors, 1 Reader and 1 Senior Lecturer). With 12 new staff and 7 retirements since 2008, there is now a healthy age balance of 40% ≤ 40; 25% 41-50; 35% > 50, with each research group including both senior members and future leaders. Appointments attract many international applicants; of the recent recruits, 6 are from UK, 3 from continental Europe and 3 from the rest of the world.

Appointments since 2008 are consistent with the above strategies. Professorial appointments, Cameron and Bailey, have, with their wealth of experience, greatly strengthened Combinatorics and Statistics respectively. Several early career researchers have moved from RCUK or other fellowships to lectureships: Tran has brought his analytic skills in turbulence to the Fluids Group. Bleak, Huczynska and Mitchell have broadened Algebra and Combinatorics in infinite group theory and computational and dynamical methods, and Illian and Thomas, along with new lecturers Donovan, Overstall and Papathomas, have broadened the statistics base and reinforced statistical ecology. New lecturer Todd has brought expertise in ergodic theory to the Analysis Group and Archontis, a Royal Society Postdoctoral Fellow, has strengthened computational MHD.

Internal promotions on merit encourage high quality work, provide future leaders and help to retain outstanding staff. A distinctive, but discerning, feature of the St Andrews promotions procedures is a personal interview with candidates. Since 2008 3 staff in the School have been promoted to Personal Chairs, 3 to Readerships and 3 to Senior Lectureships.

Retired staff who remain research active are provided with office space and research facilities so the School can continue to benefit from their expertise and experience. Without exception, the 7 staff who have retired since 2008 have continued to make active and lively contributions.

Three academic staff have left since 2008: Stratmann is now Professor at the University of Bremen, Bhattacharjee is Associate Professor at the University of Hyderabad, and Neunhöffer is a software researcher in Cologne.

Research staff

Since 2008, several researchers have held *personal fellowships* within the School:

Royal Society University Research Fellows: De Moortel (2004-13), Archontis (2011-)
Royal Society Dorothy Hodgkin Fellow: Huczynska (2004-08)
Royal Society Isaac Newton International Fellow: Jin (2011-12)
Leverhulme Trust Research Fellow: Dritschel (2011-12)

Leverhulme Emeritus Fellow: Priest (2011-)
PPARC Advance Fellow: Mackay (2005-09); *EPSRC Postdoctoral Fellow:* Gray (2008-10)
EPSRC PhD Plus Fellows: Peresse, Samuel (2010-11), Blackburn, Pfeiffer (2013-14)

Research Assistants have been funded from many sources, including EPSRC, STFC, NERC, EU, contract funding, etc., with a total of about 40 research assistants since 2008. This includes 10 supported by the Solar Group rolling grant and 20 in Statistics funded by a combination of research grants and contracts for ecological and environmental projects.

Many of our research staff go on to permanent academic appointments, including recently to the Universities of Aberystwyth, Dundee, East Anglia, Manchester, Warwick and Florida.

The School has a healthy turnaround of academic *visitors* for whom full research facilities are provided. Long term collaborators who have visited recently include Michael Albert (Otago), Julien Barral (Paris 13), Chris Brien (Adeleide), Matthew Brin (Wisconsin-Madison), Marcel Goossens (Leuven), Robert Gray (East Anglia), Kathryn Hare (Waterloo), Byron Morgan (Kent), Vince Vatter (Miami), Norman Zabusky (Weizmann Inst.).

Non-academic support staff are crucial to enable research to be carried out efficiently and smoothly. Specialist computing requirements are supported by 6 full-time computer officers, 4 of whom (Solar, CREEM, CIRCA and HPC) are funded by research council or contract income. The Solar Group, CREEM and CIRCA have dedicated secretaries funded from research and contract income and 3 other School secretaries support the remaining research areas.

Staff development support
The University's Centre *CAPOD* (*Centre for Academic, Professional and Organisational Development*, www.st-andrews.ac.uk/capod) provides generic support and training at all career stages for both research and permanent staff, with regular workshops covering all aspects of research activity. In particular, it sets up an induction plan for each new staff member. New staff are allocated a mentor and are reviewed regularly during their probationary period. There is a comprehensive appraisal and development scheme for all staff operating on a yearly cycle. The research groups provide subject specific support, with established members helping new researchers form international links and prepare grant applications.

Allocation of *lecturing and administrative duties* takes into account career development and research activity, aiming to make the best use of each individual's particular talents. New staff are given reduced teaching loads for up to five years.

Research active staff are granted *research leave* of one semester in eight and there is a very flexible approach to teaching arrangements to enable staff to make research and conference trips at other times. Staff are strongly encouraged to participate in international conferences and research visits, with School funds available to supplement grants.

The University has a robust *Equality and Diversity* policy, see www.st-andrews.ac.uk/staff/policy/hr/equalitydiversityinclusion. All staff undertake diversity awareness training. Equality and diversity issues are central in appointment, promotion and REF related procedures.

The University and School implement the *Concordat to Support the Career Development of Researchers*, and in 2012 the University was awarded the European Commission HR Excellence in Research Award in recognition of this. The University has received the Athena Swan Bronze Award and the School Equality and Diversity Committee is finalising a submission for a department award.

ii. Research students

Recruitment
Given its size, the School has been outstandingly successful in recruiting and training research students with 60 PhDs graduating since 2008. There are around 70 applications for about 12 funded PhD places each year, coming from all over the world, not least through our own MSc or MMath programmes. Well-qualified applicants are invited to St Andrews to discuss their proposed studies (with the School covering travel costs) or to have a Skype discussion if outside the UK. For 12 years the School has run a 6 week Summer Programme to give a taster of research for some 15 undergraduates about to enter their final year, with funding from the Nuffield, Carnegie

and Cormack foundations and other sources. Though primarily intended for St Andrews students, other universities (recently Edinburgh, Lancaster, Oxford, Belgrade, Konstanz and Vienna) have sent students to the Programme. Published papers have often resulted, and the School gave an invited presentation on the scheme at the 2013 BMC.

As well as PhD funding from EPSRC, NERC, STFC and overseas government scholarships, a substantial amount comes from research overheads, consultancy and the School's own budget, with additional 'Anniversary Studentships' in 2013 to mark the University's 600th Anniversary. Funds from different sources are combined imaginatively to maximise the overall benefit.

Training

General and transferable skills: Research students choose at least two University 'Gradskills' workshops each semester from an extensive list www.st-and.ac.uk/capod/gradskillsprogramme on generic topics such as 'Conference Presentation' or 'Online Collaboration Tools'.

Broad mathematics training: The School is a key partner in the EPSRC-funded Scottish Mathematical Sciences Training Centre (SMSTC) which provides 8 broad subject streams, each taught by a two-semester video-conferenced course. New PhD students normally take 3 streams, spending up to 75% of their first six months studying this material. St Andrews staff lecture in 5 of the streams, with several involved as stream leaders and on the Academic Steering Committee.

Specialist training: Research groups arrange specialist training, e.g. courses in GAP, parallel computing, STFC Summer Schools, a 3 month induction programme in Solar MHD, and APTS (statistics training) weeks. Students may also take courses from our Masters level portfolio, e.g. in Advanced Fluid Dynamics, Solar Theory, Group Theory, Ergodic Theory or Ecological Dynamics.

Supervision and Monitoring

Each research student is assigned two supervisors (main and secondary, or joint) with scheduled weekly meetings and informal contact often daily. There is a formal progress review at the end of each year, including a substantial report by the student, assessments by supervisors, and a confidential meeting between student and the Postgraduate Committee to identify problems students might feel unable to discuss with their supervisors. Every student records their training, seminar and course attendance, etc. in a logbook. All research students tutor undergraduate groups for which both general and course-specific training is provided.

Integrated research culture

Above all, it is the research groups that provide a supportive and lively research environment in which students play a full part and develop both a broad perspective and specific expertise.

Each student presents at least one, and usually more, research group seminars each year on their own or other recent work. Groups of students have set up seminar programmes on their own initiative, e.g. an 'Algebra and Analysis' seminar on topics of common interest to the two pure groups, and a weekly 'Research Students Seminar' from which staff are specifically excluded.

Students are strongly encouraged to publish work when it reaches an appropriate stage. They frequently collaborate with other group members, not only their supervisors, and during the assessment period over 100 papers (single- or joint-authored) have been published by research students. Funds are provided for all research students to attend and speak at international conferences and go on research visits, as well as to attend the meetings specifically aimed at research students arranged by LMS, EMS and SMSTC. Contacts established at such meetings have often led to networking and collaborative work.

Our research students go onto highly successful careers. At least 30 of our PhD graduates from the past 15 years now hold permanent university positions; others take their skills outside academia, including recently at US National Solar Observatory at Tucson, Met Office, GCHQ, Wildlife Conservation Society, UN FAO, US Geological Survey and Siemens.

d. Income, infrastructure and facilities

Research governance

The School is managed by a Head of School in consultation with the School Management Group and other officers and committees. Several School committees are particularly pertinent to research: the Postgraduate, Research and Equipment Committees consider matters spanning the

research groups, allocate School resources, and link to University and external bodies. An Ethics Committee monitors projects (mainly in statistics) where there may be ethical concerns.

Infrastructure
The School is housed in two pleasant buildings well-suited to encouraging interaction amongst staff and students: the *Mathematical Institute,* and the nearby *Observatory Building* which houses most of Statistics and CREEM. Offices are provided for all staff, including all postdocs, research students, visitors and active retired staff. Both buildings have ample on-site seminar and lecture rooms, most refurbished in 2008 with full multimedia facilities, dedicated video conference suites, and the all-important common rooms. Office occupation is near full capacity, but both sites have possibilities for expansion which are being explored.

Facilities
All staff, postdocs and research students are provided with research facilities (computers, software, etc.) tailored to individual needs and there is University-wide wireless networking. The video conference facilities and conferencing software on individual machines have dramatically improved remote collaboration. An earlier High Performance Computer was replaced in April 2011 by a new STFC funded £1.1m 2400 processing core Bull machine, one of the largest supercomputers in the UK. The Vortex Group has its new own cluster of 48 superfast processors.

Library resources have improved enormously since 2008 with £14m spent on refurbishment of the Main University Library and local Maths/Physics Library. There are much improved electronic resources with 38,000 e-journals and many databases now available, providing direct access from offices to almost all relevant research journals. The words 'library cuts' are no longer heard.

Research Funding
Several University-wide bodies support funding initiatives: FAS (Financial Advice and Support) assists with grant costing and applications; RBDC (Research Business Development and Contracts) provide skilled negotiation for research contracts and consultancy; KTC (Knowledge Transfer Centre) supports knowledge transfer whilst protecting intellectual property.

The School has received research funding totalling about £12m since 2008 from a wide range of sources: Research Councils, UK, EU and foreign Government bodies and NGOs, private companies, charities and international commissions.

Major long-term funding continues to benefit research groups, including:
- The *Solar Group* have been supported by an STFC rolling grant since 1986, renewed for £1.34m for 2010-13 and for £750k for 2013-16, with a further £2m since 2006 for the high-performance computing network.
- *CIRCA* received a £1.1m EPSRC Critical Mass grant for 2005-10 for computational algebra and applications, and are currently seeking grants to develop next generation computational algebra.
- The *National Centre for Statistical Ecology*, for which St Andrews is lead partner, was initially funded by an EPSRC Multidisciplinary Critical Mass Award for 2005-10 and was renewed by EPSRC/NERC for £1m for 2010-15. This supports postdocs, PhD students and conferences.
- *Thomas (Statistics)* received £1.3m from the USA Office of Naval Research for development of hydroacoustic survey methods for estimating marine mammal abundance.

We intend to obtain extensions or replacements of the major funding in these and other key areas to ensure their long-term vitality.

Project specific grants totalling about £5m have been obtained from research councils, including:
- *Reinaud, Scott & Dritschel*, EPSRC £383k for The structure of geophysical vortices.
- *Scott,* NERC £207k for Potential vorticity control of the Brewer-Dobson circulation.
- *Neunhöffer & Roney-Dougal,* EPSRC £442k for Solving word problems via small cancellation.
- *Ruskuc,* 3 EPSRC project grants totalling £510k in algebra and combinatorics.
- *Falconer,* EPSRC £280k for Fractal and multifractal analysis of nonlinear nonconformal systems.
- *King,* EPSRC £531k for Statistical methods for modelling and understanding animal movement.

S*mall grants* from societies such as LMS and EMS are particularly cost effective for visits, visitors and conferences, and we have received about £60k (not included in REF4b) from such sources.

We will continue to apply for a wide range of grants, keeping in mind priority areas of funding

bodies. For example, the Vortex Group is seeking funding to address the effects of water vapour on climate (NERC Climate System Theme), Statistics and Computer Science to develop 'future-proof' software for spatially explicit capture-recapture methods (EPSRC Statistics Priority Area), and Algebra and Computer Science for computational discrete algebra (EPSRC Connections Between Mathematical Sciences and Information Communication Technologies Priority Area).

Consultancies and professional services

The Statistics Group has been particularly successful in attracting contract research income, earning £3.5m since 2008. Their many projects include work for Scottish Natural Heritage and the International Whaling Commission. Substantial consultancy has also been undertaken for the UK and USA navies to assess the risk of navy sonar adversely affecting cetaceans, as well as risk mitigation consultancy to the offshore renewables industry via the SAFESIMM programme.

To facilitate knowledge transfer and generate funds, CREEM hosts two annual training workshops on distance sampling (which have attracted 800 people from 67 countries) using industry standard software authored by staff. CREEM also presents regular workshops on statistical modelling, Bayesian methods in ecology, and spatial modelling, and about 3 workshops overseas each year. These workshops in turn lead to further collaborative links and research impact.

e. Collaboration and contribution to the discipline or research base

The exemplars in this section are representative of a far greater range of activity.

National and international collaboration

All research groups are involved in a range of team and/or individual collaborations, supported by grant or School funding. Use of video-conferencing is an important facility. For some examples:

- The *Solar Group* leads the UKMHD Consortium providing high-performance computing for groups across the UK, and is a major partner in the EU SOLAIRE, SHOCK, SOLSPANET and SWIFF networks, facilitating collaboration, travel and training in solar and interplanetary physics.
- St Andrews is the lead partner in the *National Centre for Statistical Ecology*, which includes 8 UK universities and 7 partner institutes, with virtual collaboration playing a key role.
- *CREEM* have a multi-grant collaboration with Oregon State University, USA Space & Naval Warfare Systems Centre, USA Naval Undersea Warfare Centre and Woods Hole Oceanographic Institute to develop hydroacoustic methods for surveying cetaceans
- *Dritschel* is working with the UK Met Office and collaborators in Reading and Exeter on the use of his numerical software in global models of the atmosphere.
- *Ruskuc* is working on novel approaches to combinatorics of permutations with long-standing collaborating teams in Otago, NZ, and Florida, US.
- *Bailey* works with medics and the pharmaceutical industry on design of clinical trials.
- The *Analysis Group* collaborates with emergent fractal groups in China (Tsinghua, Shanghai).

Interdisciplinary research

The School is a partner in three Centres which facilitate interdisciplinary research in St Andrews and with external stakeholders. Research at *CREEM*, http://creem2.st-andrews.ac.uk, with Statistics, Biology and Geography, includes wildlife population assessment and modelling animal movements. The SOI, http://soi.st-andrews.ac.uk , covers oceanic systems science in the broadest sense, and involves the Statistics and Vortex Groups, and Biology and Geography. *CIRCA*, www-circa.mcs.st-and.ac.uk combines the expertise of Algebra and Computer Science in computer assisted research, and develops research software for release in GAP.

Prizes and distinctions

Royal Astronomical Society prizes:
RAS Gold Medal (*Priest*, 2009); Chapman Medal (*Roberts*, 2010); Fowler Award (*De Moortel*, 2010); Group Achievement Award (*Hood, for UKMHD Consortium*, 2013)
Institute of Physics Payne-Gaposchkin Prize (*Priest*, 2009)
Leverhulme Prize in Astronomy and Astrophysics (*De Moortel,* 2009)
Jenks Memorial Prize for contributions to Computer Algebra (*GAP Collaboration*, 2008)
Leverhulme Emeritus Fellowship (*Priest*, 2011)
Royal Society of Edinburgh
Elected FRSE (*Dritschel*, 2008); Elected to RSE Young Academy (*De Moortel*, 2011)
4 current (+7 emeritus) staff are FRSE and *Priest* is FRS.

External roles include:
European Solar Physics Division (*De Moortel,* Secretary 2011-)
ISSI (International Space Science Institute) Committee on Flux Emergence (*Hood*, 2011-)
International Biometrics Society Council (*King*, 2010-13)
UKSP (UK Solar Physics) (*De Moortel,* Deputy Chair 2010-)
Royal Society International Grants Panel (*De Moortel,* 2008-11)
RSE Young Academy of Scotland (*De Moortel,* Co-Chair 2012-)
EPSRC Peer Review College (*Falconer* 2012-*, Ruskuc* 2006-)
STFC: Advisory Panel (*Hood*, 2012-), Ernest Rutherford Fellowship Panel (*De Moortel*, 2011-12)
RAS Council (*Hood*, 2009-)
LMS Council (*Falconer*, Publications Sec. 2006-09; *Roney-Dougal*, 2010-, IMU delegate, 2010)
British Combinatorial Committee (*Cameron*, Chair 1994-)
RSS Panel on Statistics for Ecosystem Change (*Buckland*, 2007-10)
Scottish Natural Heritage, Review Group assessing Research Monitoring (*Buckland*, 2008)

Editorial board membership
Since 2008 staff have been on the boards of over 25 journals, including Adv. Math. (*Falconer*); Biometrics (*Buckland*); Geophys. & Astrophys. Fluid Dynamics (*Dritschel*); J. Geophys. Res.: Space Physics (*Mackay, Parnell*); J. RSS Ser. C (*Borchers*, *Illian*, *King*); LMS J. Comp. & Math (*Roney-Dougal*); Math. Proc. Cambridge Phil. Soc. (*Falconer*); Proc. Edinburgh Math. Soc (*Olsen*, *Quick*); Quarterly J. Roy. Met. Soc (*Scott*); Royal Soc. Edinburgh Proc. A (*Hood*, *Dritschel*).

Major conferences organised include:
Groups St Andrews, the flagship international meeting on group theory organised by St Andrews every four years since 1985, including at Bath (2009) and St Andrews (2013, 200 delegates).
International Statistical Ecology Conference, St Andrews initiated this biennial series and coordinates the Scientific Committee with the inaugural meeting held in St Andrews in 2008.
International Biometric Soc. Channel Network Conf. (St Andrews, 2013, 150 delegates).
UK National Astronomy Meeting (St Andrews, 2013, 600 delegates).
Hinode 6 (St Andrews, 2012, 200 delegates).
British Combinatorial Conference (St Andrews, 2009)
LMS/EPSRC Short Course in *Computational Group Theory* (St Andrews, 2013).
Isaac Newton Institute Programme Organisers: Combinatorics & Statistical Mechanics (Cameron, 2008), *Design of Experiments* (Bailey, 2008), *High Reynolds Turbulence* (Dritschel, 2009), *Design & Analysis of Experiments* (Bailey, 2011).
Matrix Group Recognition, ICMS workshop (Edinburgh, 2008), Roney-Dougal an organiser.

Keynote and plenary lectures include:
De Moortel: Keynote plenary, *Workshop on Magnetism* (Boulder, May 2012)
Illian: Keynote at *Bayesian Inference for Latent Gaussian Models* (Trondheim, May 2012).
King: Keynote at *Conference on Mathematical and Theoretical Ecology* (Essex, Sept 2011)
Thomas: Keynote at *International Statistical Ecology Conf.* (Krokkleiva, Norway, July 2012)
Tran: Keynote at *International Symposium on Bifurcations and Instabilities* (Barcelona, July 2011)
Falconer: Opening plenary lectures, *Fractals & Related Fields* (Pourquerolles, France, July 2011) and *Advances on Fractals & Related Fields* (Hong Kong, Dec 2012).
Borchers: Plenary speaker at the *EURING Analytical Meeting* (Pescara, Italy, Sept 2009)
Hood: Plenary talk at *UK-Germany National Astronomy Meeting* (Manchester, March 2012)
Huczynska: Plenary talk at *Int. Conf. on Finite Fields and Applications* (Magedburg, July 2011)
Cameron: LMS Forder Lecturer (New Zealand, 2008)*, LMS Gresham Lecture* (London, 2013)