Institution: University of Exeter

Unit of Assessment: 10 Mathematical Sciences

a. Overview

The UoA is part of the University of Exeter's multi-disciplinary College of Engineering, Mathematics and Physical Sciences (CEMPS): see www.emps.exeter.ac.uk/mathematics/. The UoA is structured into five research groups that comprise the *Mathematics Research Institute*: the **Centre for Geophysical and Astrophysical Fluid Dynamics (CGAFD)**, **Centre for Systems, Dynamics and Control (CSDC)**, **Pure Mathematics (PM)**, **Exeter Climate Systems (XCS)** located at the Streatham campus in Exeter, and the group **Mathematics and the Environment (MaE)** located at the University's Penryn campus in Cornwall. The group MaE is embedded within the *Environment and Sustainability Institute* (ESI) on the Penryn campus. This structure provides critical mass for the pursuit of internationally excellent transformative research across the UoA as well as an environment that nurtures high standards of research scholarship and training.

b. Research strategy

Research vision:

We aspire to be a unique research unit unconstrained by traditional disciplinary boundaries, where new methodology in mathematics is explored, developed, and successfully applied to address cutting-edge problems in science, engineering and medicine. We aim for world-renowned excellence in research and teaching as a vibrant and attractive cross-disciplinary institute for Mathematical Sciences research.

Review of strategy since RAE2008: Our strategy for the Applied Mathematics UoA at RAE2008 was (a) "Maintain and develop high quality fluid dynamics research, especially for geophysical and astrophysical flows", (b) "Maintain and develop high quality research in dynamical systems and control", (c) "Build on recent appointments to establish a world-leading team in climate systems" and (d) "Exploit synergies between the groups". The priority for the Pure Mathematics UoA at RAE2008 was to "maintain our focus on number theory and arithmetic geometry, performing research at the highest international level". We believe this submission demonstrates we have successfully implemented all aspects of this planned strategy over the last few years. More than 50% growth in staff numbers (from 23FTE across both units in 2008) has been driven by increasing research income (from £590K in 2008 to over £1.71M in 2012) and strong student numbers (30 PhD completions in the period).

Research within the *Mathematics Research Institute* has been pivotal in unlocking the potential of the University of Exeter's "Science Strategy". This strategy (launched in 2005 and described in the RAE2008 submissions) was a sustained commitment by the university, including direct investment of £27M in staffing and infrastructure development on five cross-disciplinary themes: *Climate Change and Sustainable Futures*, *Exoplanets*, *Functional Materials*, *Translational Medicine* and *Systems Biology*. The investment in mathematics includes cross-disciplinary appointments and pump-priming studentships to promote collaboration with other disciplines. The research strategy for Mathematics was developed with reference to these themes, as well as through our research partnerships with industry and government research organisations (in particular, the *Met Office Academic Partnership*). We have implemented this strategy by a strong but balanced expansion in specific application areas whilst continuing to strengthen core expertise in the underpinning mathematical methodologies. We actively encourage members of the UoA to use their mathematical expertise in cross-disciplinary collaborations – academics from mathematics and computer science have played an important role in University-wide science activities. For example, CGAFD and XCS are key research groups in the cross-disciplinary *Climate Change and Sustainable Futures* theme, while many members of CSDC are strongly engaged with the *Systems Biology* and *Translational Medicine* themes. CGAFD collaborates with the Astrophysics group under the *Exoplanets* theme. Members of the UoA were co-Investigators of and engaged strongly with the EPSRC-funded *Exeter Science Exchange: Bridging the Gaps* activities and lead the *ExIStA* regional initiative for Statistics.

Current research groups (group leaders are underlined):

Centre for Geophysical and Astrophysical Fluid Dynamics (CGAFD) *Beare, Berger, Gilbert, Foullon, Kwasniok. Mason, Soward (20%), Thuburn, Vallis, Wingate, Zhang*.

This group, along with XCS, forms the hub of our interactions with the Met Office; for example the NERC/STFC/Met-office funded Gung-Ho project. The group has made important contributions to understanding the large-scale circulation of the atmosphere and ocean, climate dynamics and climate modelling, fluid dynamics, turbulence and numerical methods. Research ranges from the fundamental theory of rotating fluid and boundary layer instability, convection and magnetohydrodynamics through to design and numerical analysis of advanced schemes for simulation of large-scale flows in atmospheres/oceans and astrophysical flows. CGAFD group has strong links to the Astrophysics and Engineering Fluids groups within CEMPS, and the group has recently attracted the world-leading established researchers Vallis and Wingate.

Centre for Systems, Dynamics and Control (CSDC) *Ashwin, Biktashev, Goodfellow, Holland, Jones (20%), Menon, Rodrigues, Sieber, Terry, Tsaneva-Atanasova, Wieczorek (Additional members Walker and Akman are returned to UoA1 and UoA11 respectively)***.**

Members of this group are the forefront of international efforts to develop mathematical methods and apply them to a range of areas, in particular to biomedical and climate modelling. Theoretical research in this group focuses on problems in control theory and dynamical systems, with particular strengths in low dimensional dynamics, bifurcation theory, multiple timescale dynamics and computational modelling of complex systems. Two plenary talks at the *SIAM Applied Dynamical Systems* conference in Snowbird (2011) independently highlighted work from this group: on rate-dependent tipping points and applications to the "compost bomb" instability (Wieczorek) and mathematically-inspired in vivo experiments within the endocrine axis (Terry). Applied cross-disciplinary research in this group ranges from biomedical modelling, systems biology, data assimilation and climate systems to space mission control, solid-state physics and materials modelling. There are strong collaborations with life scientists and medical researchers as well with other researchers across the UoA.

Pure Mathematics (PURE) *Byott, Chapman, Johnston, Langer, Saidi, Tange, Trihan.*

Pure mathematics research has a long tradition at Exeter, and currently focusses on arithmetic geometry, algebraic geometry and combinatorics. Research in this area has recently been invigorated by the appointments of Johnston, Tange and Trihan. Members of the group have a high international profile, especially in the area of arithmetic geometry (Langer, Trihan, Saidi), number theory (Byott, Chapman, Johnston) and Lie theory (Tange). Cross-disciplinary links include secondment to the Heilbronn Institute (Chapman) and collaboration with CSDC in number theoretic problems from dynamical systems (Byott).

Exeter Climate Systems research centre (XCS) *Bailey, Brooks (20%), Ferro, Stephenson, Williamson (Additional members Baldwin, Challenor, Collins, Cox, Friedlingstein, Lambert, Haywood, Jupp and Screen are returned to UoA7).*

This cross-disciplinary centre was formed in 2007 and, working closely with CGAFD, has rapidly grown to become a world-leading centre for innovative and high impact research at the interface of mathematics and weather/climate sciences, having strong research collaboration with the Met Office and other national weather services. Staff are world-recognised for their expertise in climate science with one coordinating lead author (Collins) and three lead authors (Stephenson, Cox, Friedlingstein) contributing to the most recent 5th Intergovernmental Panel on Climate Change assessment report. In addition to understanding and quantifying uncertainty in climate change projections, the other main climate interests are in carbon cycle modelling, forecast verification, and the quantification of extreme weather and climate risk. Work from this group that we wish to return to this UoA is predominantly statistical. This includes spatial statistics (Bailey and Brooks, particularly: spatial epidemiology, statistical ecology, spatial modelling and multivariate spatial methods) and applied statistical modelling/pattern analysis, especially of environmental effects on disease and health. The centre's core mathematical expertise in environmental statistics and numerical modelling of climate have given rise to strong working collaborations with other groups e.g. numerical modelling of atmospheric processes (CGAFD), dynamical system modelling of

climate tipping points (CSDC), and epidemiology (MaE).

Mathematics and the Environment (MaE) *Mueller, Recker, Tidlesley, Torney, Townley.*

Established in 2011, this group is embedded within the University's new Environment & Sustainability Institute (ESI) at the Penryn Campus in Cornwall. Prof Townley relocated from the Exeter Campus in 2011 to set up this research group in Mathematical Sciences, and an accompanying, innovative mathematics degree programme. His appointment was followed by four further appointments. The mathematical research undertaken by this group is primarily in the areas of dynamical systems, control theory, computational modelling and statistics with the group acting also as an interface between established and emerging disciplines within the ESI on the Penryn Campus, including ecology, evolution, animal and human disease epidemiology, environmental factors in human health and renewable energy.

In addition to these research groups, the **Exeter Initiative for Statistics and Applications (ExIStA)**, was founded in 2011. Since then, it has rapidly grown to become a regional focus for statistical expertise. It is led by Prof Steve Brooks who is part-time in the UoA and otherwise CEO of Select Statistics. The Initiative aims to bring together statisticians working within the University and local public and private sector organisations. The Initiative runs a range of events in order to raise awareness of the use and value of advanced statistical methods, to support statisticians and users of statistics in continuing to develop and apply their skills, and to foster and promote inter-disciplinary statistical activity. It currently has 101 members from across the University and 280 members from a wide range of local organisations: see www.exista.org for more details.

Each group within the Mathematics Research Institute hosts at least one series of internal and external research seminars, and there is a regular colloquium where high-profile speakers (e.g. Prof R MacKay FRS, Prof Roger Heath-Brown FRS) are invited to address the whole of the UoA. A stream of regular and occasional research visitors greatly enriches the research environment within the UoA. Visitors have access to hot-desking space, library and computer facilities.

Future Plans: Specific developments planned over the next few years include a new Living Systems Institute. This £50M building on the Streatham campus, scheduled for completion in Spring 2015, will be located between Biosciences, Engineering, Mathematics and Physics to provide a focal point for research into common problems in biomedical research. We plan to keep Mathematics activities at the Streatham Campus closely co-located while building up a specialist research group on the Penryn campus that resonates with research at the ESI. Our plans are:

a) To maintain internationally leading mathematical research activities over the present range of areas of theoretical and applied relevance.

b) To continue to make further appointments in accordance with our research vision, placing emphasis on problem-driven research and partnership with end-users.

c) To build and exploit synergies between research within the UoA, the University and with external partnerships.

We foresee potential for future growth in the following areas:

- The recent appointments of Vallis and Wingate give an opportunity to invest further in the fluid dynamics of Atmospheres and Oceans. We will grow the group on environmental statistics focussed on modelling weather and climate processes, and any further appointments in Statistics and Data Mining can be linked via ExIStA to a wide range of end users.
- Systems Medicine and data-driven modelling has great potential for expansion, and investment into the areas of Stochastic Analysis/Probability Theory will be very useful as in-house expertise on stochastic modelling applicable to this and other areas.
- Growth within the multi-disciplinary ESI will focus on complex systems, control theory and optimisation, with applications such as statistical ecology and evolutionary dynamics.
- HPC/Scientific Computing is essential for much of the applied and computational research related to the University's strategic themes. We intend to establish a group working on fundamental research in this area; this may be returnable either under UoA 10 or 11.

c. People, including:

(i) Staffing strategy and staff development

All academic staff within the Mathematics Research Institute are located within a research group and are mentored by an *Academic Lead* who is a senior academic working in a related research area. The system of Academic Leads ensures that each research group has representatives on the College Management Group. Staff are supported by centralised administration at the College level. The University has achieved the HR Excellence in Research Award from the European Commission which recognises the University's commitment to improving the working conditions and career development for research staff. The *Concordat to Support the Career Development of Researchers* and the University's *Concordat Implementation Plan* (2009) sets out a development lifecycle for research staff, with milestones from 'good researcher' to 'research leader'. Mentoring by Academic Leads ensures fixed-term researchers employed on projects have separate meetings for project development and career development, and are fully integrated into an annual Professional Development Review (PDR) system. Skills training for research students and staff is provided by the University using the Research Councils and the QAA interpretation of Generic skills to provide training in research management, personal effectiveness, communication skills, networking, team-working and career management. In addition to formalised Generic Skills training, Exeter also implements employability skills training to equip researchers with the necessary skills, knowledge and training to enter academic, commercial or industrial careers.

The University operates a 5-year induction and probationary process for all new academic appointments at Lecturer level, during which appropriate research goals for each appointee are specified. At the end of a successful probationary period (which may be accelerated by early achievement of goals) the expectation is that staff are promoted to Senior Lecturer grade. An Academic Lead offers guidance and support from the outset. As part of their induction, new academics are encouraged to gain experience of supervising a PhD student within the first two years of appointment as first or second supervisor. Through accessing a wide range of PGR funding in addition to EPSRC DTG funds, this aspiration has been achieved. New and established academics are encouraged to apply for BBSRC, EPSRC, MRC, STFC and NERC funding as well as LMS, Leverhulme, Royal Society, EU and CASE funding as appropriate, and they are supported in this by the Director of Research, the Research Administrators and by their Academic Lead.

The College operates a workload allocation system, featuring a reduced lecturing and administrative load for new academics. The workload allocation system is used to balance the demands of teaching, research and administration for all staff. Academic Leads have flexible funds to support academics via a travel fund for research conferences, visitors and related expenses. The University aims to provide staff of all levels with appropriate training, including an academic leadership programme for senior academics. The UoA has been successful in encouraging academics to take up opportunities for study leave to allow them to pursue research projects. This includes project-funded research leave (e.g. Townley 2010-11, Zhang 2011-12, Thuburn 2011-13) and flexibility over scheduling of teaching via use of the workload allocation system.

We are fortunate in having a number of honorary research fellows and distinguished visiting professors who contribute to the research life of the UoA. These range from fellows with long-term collaborations (e.g. Dr E. Blockley, Dr O. Podvigina), senior Met Office researchers (Dr T. Melvin, Prof N. Wood, Prof J. Slingo, Prof. A. Scaife) and senior academics or emeritus staff with lasting research links to Exeter (e.g. Prof M. Field, Prof I. Jolliffe, Prof W. Krzanowski, Prof P. Vamos).

The University ensures Equal Opportunities in the recruitment and support of research staff, and in 2010 was recognized as a 2 Ticks employer for its support of disabled people. Following the Equality Act of 2010, the university conducted Equality Impact Assessments on recruitment processes to ensure compliance with best practice. Strategies to support diversity follow the university's *Equality Objectives and Action Plan* (2010-12). The *International Review of Mathematics* 2010 identified that nationally the balance of male to female staff within the UoA is generally poor. Exeter is working actively to improve this and as a result of this, the University gained a *Bronze Athena Swan* award in 2011. Since then the appointment of *Foullon*, *Rodrigues*, *Tsaneva-Atanasova* and *Wingate* means that we now have female staff represented at all levels of seniority within the UoA. We are working to improve procedures and management processes with

the intention of applying for a discipline Athena Swan award in the near future. During the period 2008 to 2013, we have gone from 28% to 34% in terms of female PhD students and from 6% to 15% in terms of female Research and Academic Staff.

(ii) Research students

A vital part of the UoA's work is the training and nurturing of the "people pipeline" for research. Recruitment, training and the research activities of PGR students are regarded as being of great importance for the health and sustainability of the UoA. Students on the four-year MMath and MSci Mathematics undergraduate programmes regularly engage with research via summer research placements and final year projects. Many progress on to PhDs at Exeter or other institutions, and we have variants of the MSci programme that link directly to research activities in CGAFD, XCS and CSDC. PhD intake has steadily increased over the assessment period and the UoA continues to recruit excellent applicants from home and overseas, funded in a variety of ways including EPSRC, NERC, BBSRC and government sponsored studentships. The MSc Advanced Mathematics provides a route for PhD students to join the UoA, as well as providing additional training modules in topics such as numerical methods and scientific computing for PhD students.

First year PhD students must undertake a programme of training and assessment consisting of at least 100 hours of advanced PhD training modules, in compliance with EPSRC expectations for Mathematics PhDs. Opportunities for this training include MSc modules offered on the *Advanced Mathematics* or related MSc, lecture courses from the EPSRC-supported *MAGIC* programme (http://maths-magic.ac.uk) and attendance at *Advanced PhD Training in Statistics* (APTS) courses. Exeter has played a leading role in the development of the *MAGIC* TCC, through setting up a programme committee, review participation, subsequently as Deputy Director and member of the management committee (Ashwin). Students are encouraged to attend relevant external courses and workshops such as the NCAS summer school in atmospheric measurement, the STFC course on solar physics and the European Research Course in Atmospheres (ERCA).

Skills training http://as.exeter.ac.uk/support/development/researchstudents/ provided by the University of Exeter (as outlined in the previous section) includes formalised Generic Skills training and employability skills. Students undergo a formal monitoring process after three months (a short review) and at the end of the first and second years. The first year monitoring includes a report, presentation to a small group of academic staff, a viva and a formal review of training undertaken, ensuring that students have clear objectives on entering their second year. PhD students must give at least one research seminar during the first two years of their degree. They are actively encouraged to organize or co-organize events (such as group meetings or workshops) as well as being funded to participate in relevant international or national research conferences and workshops.

The UoA has trained many PhD students who have gone on to successful academic and highly skilled careers. Of 30 PhD graduates since 2008, two are working as scientists in the Met Office, four as university lecturers (assistant professors) and eleven as postdoctoral researchers in the UK and abroad while others are working in business or industry as, for example, statistical modellers and market risk officers. Researchers, including PhD students, work in shared offices to promote interaction and informal exchange of technical and computing skills. The College has separate Directors of Postgraduate and of Postdoctoral Researchers who champion all aspects of infrastructure and career development for postgraduates and research fellows, respectively.

d. Income, infrastructure and facilities

Research council income within the UoA comes from a wide range of research sources, with funding from NERC, EPSRC, BBSRC, MRC and STFC, as well as EU, NSF, LMS, Leverhulme Trust and Royal Society. For example, members of CSDC and MaE (Ashwin, Tsaneva-Atanasova, Terry, Townley, Valeyev) have received significant funding from EPSRC, BBSRC, EU and MRC to pursue research with biomedical and climate-related applications while members of CGAFD and XCS have significant funding from NERC, STFC, EU and the Met Office. CASE studentships include, for example, EPSRC collaborations with the Met Office (Beare, Kwasniok, Thuburn) and BBSRC collaborations with Pfitzer (Valeyev). Funding in PURE has included an EPSRC grant for studying the arithmetic of function fields (Trihan), a fellowship (Zerbes) and a secondment to the Heilbronn Institute of 2009-2010 (Chapman). There are significant cross-group funded projects

such as PREDEX, CliMathNet (EPSRC-funded between CSDC and XCS) and Met Office academic partnership (XCS and CGAFD) as well as significant roles in external projects (for example, Brooks & Townley for the EPSRC/NERC National Centre for Statistical Ecology). The UoA includes researchers who will supervise students on the NERC GW4+ DTP. Currently funded fellowships include Foullon (STFC), Williamson (EPSRC) and Recker (Royal Society URF).

Industrial funding comes from partners such as AXA, Met Office, Willis, ESA and Thales. Especially important for the UoA has been its pivotal role in founding the Met Office's Academic Partnership with the Universities of Exeter, Leeds, Oxford and Reading. This partnership has part-funded Profs Thuburn and Stephenson since 2005. In 2012 we were awarded a contract to provide advanced training to Met Office staff. Industrially funded aerospace projects include ESA funded research (Menon) with GMV (Spain) and NGC (France), as well as projects with Astrium Space Transportation (France), THALES Alenia Space (Italy) and SCISYS (UK).

The University of Exeter has made significant investment into infrastructure and staffing at the University, with over £250M invested in recent years and a major expansion in STEM/M associated with the University becoming a member of the Russell group in 2012. This includes a programme of new buildings (including the ESI at Penryn) and updating and refurbishment of all of the academic buildings (such as Harrison building at Streatham, where most of the staff and researchers within this UoA are situated).

The University has invested £9.5M in the Libraries as well as the updating of IT systems, and provision of new office accommodation of a high quality. The University received significant funding to support Open Access from both RCUK (£500K) and the Wellcome Trust (£90K), and completed a successful £250K project funded by JISC to embed a culture of Open Access across the institution. The University's institutional repository (ORE: Open Research at Exeter) and central support for staff enables them to publish their work in Open Access Gold and Green formats.

Some of the research undertaken within the UoA requires the use of high performance computing, especially the work undertaken CGAFD and XCS on geophysical and astrophysical flows, climate and weather modelling, and by CSDC on systems biology. CGAFD and XCS research has been supported by a number of clusters purchased by the University and STFC funding over the last few years, including the Zen and Neptune clusters. Systems biology research within CSDC has been supported by the provision of another cluster Zeus for high throughput computing as well as by use of HECToR. We have well-developed IT support infrastructure both at College and University levels and a *University HPC governance group* is tasked with Strategic oversight of the University's HPC facilities.

The University's *Research and Knowledge Transfer* (RKT) department provides support and guidance to academics and researchers involved in all forms of research and consultation. This ranges from providing contacts, negotiating contracts and intellectual property agreements to an annual "impact award" that aims to promote excellence in impact and innovation arising from research.

e. Collaboration or contribution to the discipline or research base

Members of the UoA are very active in research collaborations at international and national levels. Examples of research groups with whom members of the UoA have international collaborations include those at the *National Center for Atmospheric Research* (Colorado, USA), *Spin Lab and IGPP* (Los Angeles, UCLA), *Météo-France* (Paris), *Los Alamos National Laboratories* (USA), *Helio Research* (Los Angeles, UCLA), *HKU* (Hong Kong), *CAS* (China), *ETH* (Switzerland), Observatoire de Nice (France), *RIMS* (Kyoto, Japan), *Max-Planck Institute for Dynamics and Self-Organization* (Göttingen, Germany), *Nagoya University* (Japan), *Princeton University* (New Jersey, USA), *Max-Planck Institute for Mathematics* (Bonn, Germany) and a wide variety of Universities abroad. We are a Partner Institute for the *Mathematical Biosciences Institute* based at the Ohio State University (USA). Members of this UoA are taking a leading role in CliMathNet, an EPSRC funded Mathematics for Climate Network that aims to promote close interaction between Climate Sciences and Mathematical Sciences, to the mutual benefit of both. We have strong links to the NSF-funded networks *Maths for Climate Research Network* (the Director, Jones, holds a 20% appointment with us) and *Statistical Analysis of Atmospheres and Oceans* and the *Industrial Maths KTN*. Other UK links include *Systems Biology* centres at Aberdeen, Warwick, Leicester,

Edinburgh and Manchester, the *National Oceanograpy Centre* (Liverpool/Southampton) and the *National Centre for Statistical Ecology* (Brooks, Townley).

UoA members have been active in organizing and contributing to scientific committees of research meetings and workshops, including co-organization of several *Isaac Newton Institute* programmes; *Fundamental Groups and Arithmetic Geometry* (2009, Saidi), *Mathematical and Statistical Approaches to Climate Prediction* (2010, Stephenson and Thuburn), *Topological Dynamics in the Physical and Biological Sciences* (2012, Gilbert), and *Multiscale Numerics for the Atmosphere and Ocean* (2012, Wingate). Examples of international conferences and workshops recently organized at Exeter by members of the UoA include *International Workshops on Rotating Fluids* (2011 and 2013; Gilbert, Zhang), *CliMathNet Conference* (2013, Ashwin), *Royal Meteorological Society Conference* (2011, Thuburn) *British Combinatorial Society conference* (2011, Chapman), *Frontiers of Multidisciplinary Research: Mathematics, Engineering and Biology* (September 2010), *p-adic Hodge theory* (2009, Langer), *LMS Regional Meeting and Workshop on Iwasawa Theory* (2011, Byott and Langer). Members of the UoA run an innovative series of video-conferenced *Access Grid Dynamics Seminars* as well as *CliMathNet e-seminars*.

Members of the UoA are regularly invited to speak and co-organize specialist meetings in the UK and overseas, including short courses or seminar series; for example on various statistical topics at Universities in UK, Norway, Portugal, Brazil, Finland and Australia (Bailey and Stephenson). Other examples include *Chair of Organizing Committee, The 2nd and 3rd International Symposiums on Earth and Planetary Interiors, Beijing* (Zhang 2010; 2013); *Victor P. Starr Memorial Lecturer, MIT* (Vallis 2008)*;* Co-organizer and keynote speaker, Edinburgh, ICMS/Newton Institute workshop on *Tangled Magnetic Fields* (Berger 2012); Organizer of *BrainModes* (Terry 2009); Co-organizer of *BioDynamics* (Terry 2013); Organizers of ICMS workshop on *Tipping points* (Sieber, Wieczorek 2013), Organizers of *Santa Fe Ocean Turbulence Conference* (Vallis, Wingate 2013); Co-organizer of *PDEs on the Sphere workshops* (Wingate 2009, 2010, 2012); Organizer of the AGU Session *Shape, Internal Structure, Gravity, and Winds of Jupiter and Saturn* (Zhang 2013); Plenary speaker, *International Conference on Difference Equations and Applications, Barcelona* (Rodrigues 2012). Co-organiser of a semester on the *Arithmetic of function fields*, *Barcelona* (Trihan 2010).

Members of the UoA have contributed to the life of the discipline via journal editorships including: *J. Mathematical Neuroscience* (Ashwin, Terry), *Dynamical Systems; an International Journal* (Ashwin, joint editor-in-chief), *J. London Mathematical Society* (Byott), *Fluid Dynamics Research* (Gilbert, Vallis), *Book Review Editor, Geophysical and Astrophysical Fluid Dynamics* (Gilbert) *Journal of Combinatorics and Number Theory* (Chapman), *Surveys in Geophysics* (Kwasniok), *Physica D* (Jones), *SIAM Journal on Applied Dynamical Systems* (Sieber), *Geophysical and Astrophysical Fluid Dynamics* (Soward, editor-in-chief, emeritus), *EPJ Nonlinear Biomedical Physics* (Terry, Tsaneva-Atansova), *J. of Climate* (Stephenson), *Quarterly J. of Royal Met. Society* (Thuburn, joint editor-in-chief), *Discrete and Continuous Dynamics Series B* (Wieczorek), *J. of the Physics of the Earth and Planetary Interiors* (Zhang) and *Research in Astronomy and Astrophysics* (Zhang).

Other activities include; *Member of RSS Council* (Brooks), *Chair, Royal Statistical Society Environmental Statistics Section* (Ferro), *Review panel for CMSO (Center for Magnetic Self Organization in Laboratory and Astrophysical Plasmas),* (Berger), *EPSRC review college* (Ashwin, Biktashev, Terry, Townley). Fellowships include: *Fellow of the Royal Statistical Society* (Bailey, Brooks, Ferro, Stephenson) *Fellow of the Royal Meteorological Society* (Beare, Ferro, Stephenson, Thuburn), *Fellow of Institute of Maths and Applications* (Ashwin, Biktashev, Gilbert), *Member of the Academia Europaea* (Stephenson), *Fellow of Royal Astronomical Society* (Berger, Gilbert), *Fellow of SIAM* (Jones), *Fellow of American Geophysical Union* (Zhang).

Media interest http://www.emps.exeter.ac.uk/mathematics/news/ includes research studies especially on Climate-related stories; for example the effect of clustered hurricanes on ecosystems and the compost bomb instability for peat-lands. We are active in outreach to schools at several levels; for example our close involvement in setting up the innovative *Exeter Mathematics School* http://www.exetermathematicsschool.ac.uk/ means we will from 2014 be able to use research-level problems to inspire gifted 16-18 year old school students, while our hosting of the annual *Royal Institution Mathematics Masterclasses* reaches a significant number of local schools. Finally, we briefly list some research highlights by research group:

CGAFD: Recent contributions include understanding of the role of turbulent eddies in driving the global ocean circulation (Vallis), improved understanding and modelling of turbulence and dispersion in the atmospheric boundary layer (Beare), the development of low-order models of the climate and their application to understanding extremes (Kwasniok), pioneering the use of Lagrangian Averaged Navier-Stokes as a subgrid model in ocean modelling (Wingate), and the development of numerical methods that underpin the new Met Office weather and climate prediction model dynamical core, known as ENDGame (Thuburn). Other research deals with vortex dynamics and mixing, hydrodynamic and magnetohydrodynamic stability and turbulence, the fluid dynamics of rapidly rotating stars and planets, the magnetohydrodynamics of planetary and stellar dynamos and the solar corona (Berger, Foullon, Gilbert, Mason, Soward, Zhang), and observation of Kelvin-Helmholtz instabilities in solar plasma (Foullon). Examples of cross-disciplinary work includes work with Physics on providing a theoretical understanding for microscopic and magnetotactic bacteria “swimmers” (Gilbert, Zhang), with Engineering on applying topological ideas to understand the properties of synthetic functional materials (Berger), and with JPL/UCLA on the NASA JUNO spacecraft (launched in 2011 and now on its way to Jupiter) project for understanding the shape, gravity and winds of Jupiter (Zhang).

CSDC: Recent theoretical contributions include control-based continuation (Sieber), predictability of extremes in chaotic dynamical systems (Holland), properties and applications of heteroclinic attractors (Ashwin), classification of non-generic cusp bifurcations (Rodrigues), Lagrangian data assimilation (Jones) and analysis of multiple timescale systems (Wieczorek). Papers evaluated by *Faculty of 1000* Biology include Terry (PLoS Biology). Terry’s *Proc Royal Soc B* 2010 paper (not submitted as an output), was one of the 10 most cited of 2010 in that journal. Holland’s work with members of XCS at Exeter and Mathematics at Groningen has given an improved understanding of the robustness of extreme value statistics. Other applications include development by Menon of “*Worst-Case Analysis Tools*” for space mission design. Further applications include collaborations with laser physicists (Erneux and Panajotov in Brussels, Uchida in Saitama) and palaeo-climatologists (Crucifix in Louvain), cell biologists (Steinberg at Exeter), endocrinologists (Lightman and McArdle in Bristol, Shipston in Edinbrugh) and epileptologists (Richardson, King’s College London and Walker, University College London). Other work includes research into the mechanisms underpinning human disease (steroid resistance in nephrotic syndrome, pain transmission) in collaboration with clinicians and pharmaceutical companies (Valeyev, BBSRC Case Studentship with Pfizer). Former members Bates and Soyer secured funding through a BBSRC sLOLA while at Exeter in 2012, while Bates published a textbook *Feedback Control in Systems Biology*, CRC Press, 2011. Mathematical research into the hypothalamus-pituitary-adrenal (HPA)-axis has been recognised through the award of an MRC fellowship (Walker, UoA1). Goodfellow received an EPSRC doctoral prize fellowship on the strength of his PhD work. Tsaneva-Atansova uses nonlinear dynamical systems and complex networks to understand a wide variety of biological and clinical problems in areas including cardiology, endocrinology and neurophysiology. Jones is director of the NSF-funded *Mathematics and Climate Research Network* since 2010; Exeter is a partner and has hosted a number of visitors funded by the associated *Science across Virtual Institutes* (SAVI) programme.

PURE: Contributions made by this group includes developments in the study of Hopf-Galois structures and the arithmetic applications of Hopf algebras (Byott). Byott’s collaboration with Elder (Blacksburg, Virginia) seeks to generalise classical ramification theory to obtain refined ramification invariants that suffice to determine the absolute Galois module structure of ideals in p-adic fields. With members of CSDC he has applied algebraic number theory to solve problems related to understanding properties of piecewise isometric maps. Contributions of Chapman include advances in the representations of integers by quadratic forms, Stirling numbers, q-analogues of Wilson's theorem, generalized Ehrhart-Macdonald reciprocity, lattice path enumeration, theta functions and Eisenstein series. Langer’s collaboration with T. Zink (Bielefeld) and C. Davis (Irvine) funded by EPSRC, has constructed an overconvergent de Rham-Witt complex by imposing a growth condition on the de Rham-Witt complex of Deligne-Illusie and proved that its rational cohomology computes the rigid cohomology for a smooth variety over a perfect field and Monsky-Washnitzer cohomology, if the variety is affine. This approach solved a fundamental problem in the construction of p-adic cohomology theories. Saidi's research in the last few years has identified him as one of the leading UK researchers in non-abelian fundamental groups and the anabelian

geometry of hyperbolic curves. Saidi's work on the anabelian geometry of hyperbolic curves over finite fields and the Grothendieck anabelian section conjecture has resulted in an ongoing collaboration with A. Tamagawa from Kyoto University. Trihan has made fundamental contributions to the Iwasawa-Theory of abelian varieties over function fields and p-adic Hodge-Theory. Recent research results include collaborations with Wuthrich (Nottingham) on the p-parity conjecture for abelian varieties in characteristic p and with Burns (KCL) on geometric Iwasawa theory and special values of L-functions. He has now developed a highly-regarded analogue of non-commutative Iwasawa theory, for abelian varieties over function fields in joint work with Vauclair. Tange's research on Lie theory in positive characteristic includes work on the centre of the universal enveloping algebra of a reductive Lie algebra and of quantum sl_n at a root of unity, and he obtained a very strong technical contribution to a famous result of Premet who gave a negative answer to the Gelfand- Kirillov conjecture outside types A, C and G2. Moreover Tange has contributed to the representation theory of the Brauer algebra and its relation to the symplectic group, explicit formulas for highest weight vectors for polynomial functions under the adjoint action of GL_n and the centre of the distribution algebra and truncated invariants. Tange has also achieved some remarkable results on the Zassenhaus variety of a reductive Lie algebra and on spherical varieties in finite characteristic. Johnston's research is in algebraic number theory and related topics, including the equivariant Tamagawa number conjecture (ETNC), noncommutative fitting invariants and integral representation theory. The ETNC relates special values of L-functions to certain arithmetic objects. In joint work with Burns (KCL) Johnston proved a nonabelian Stickelberger theorem which uses the framework of the ETNC for Tate motives. In another paper with Nickel (Bielefeld) Johnston further develops the theory of noncommutative Fitting invariants. Recently Johnston and Nickel proved a remarkable result on the ETNC for Tate motives including unconditional annihilation results; they prove new cases of the p-part of the ETNC for a finite Galois extension of number fields.

XCS: Much of Bailey's research has been collaborative and has involved academics and professionals from a variety of different fields particularly in epidemiology and health care, both in the UK and internationally. Brooks' methodological contributions include the development of new Markov chain Monte Carlo methods; his recent contributions are described in the monographs *Bayesian Analysis for Population Ecology* and *Handbook of Markov Chain Monte Carlo* (both published by CRC). Stephenson and Ferro are renowned for their work in statistical climatology, which involves developing and applying novel statistical methodology to problems in weather and climate science. Areas of expertise include forecast evaluation and scoring of probabilistic forecasts, methods for making inference from ensembles of weather and climate predictions, and stochastic modelling of extreme events such as severe storms. Stephenson was a key founding member in 2006 of the *Willis Research Network*, which is now the world's largest partnership between academia and the insurance industry. Williamson (Savage award for PhD thesis from *International Society for Bayesian Analysis*, 2012) has contributed to Bayesian Uncertainty Quantification (UQ) for computer simulators of complex physical systems, with particular interest in developing methodology for performing UQ for and providing policy support using climate models. Stephenson and two other members of XCS are lead authors for the forthcoming 5th IPCC report.

MaE: Townley's renewable energy research is funded by the EU and GWR, whilst his work in ecology is currently funded by two EPSRC grants. He has active and funded collaborations with Cambridge, Nebraska, Surrey, UCL and UQ-Brisbane. Work with Iain Stott (PhD Student) published in *Ecology Letters* and *Methods for Ecology and Evolution* won the British Ecological Society *Robert May Young Investigator Prize* in 2010. Mueller has developed new results for robust stabilization and control of time-varying systems and has co-developed optimal control techniques for wave energy converters that promise a doubling of extracted power. Tildesley uses mathematical and statistical modelling to understand diseases in livestock, especially disease transmission and control. Recker holds a Royal Society URF to develop mathematical models to investigate the interactions between hosts and pathogens that facilitate immune evasion, pathogen evolution and the emergence and re-emergence of infectious diseases. Torney works on mathematical modelling and numerical simulation of collective behaviour, primarily concentrating on decision making and information processing within social aggregates. The group publishes in a wide variety of journals including Science, Ecological Letts, PLoS, and Nature.