CELEBRATING 10 YEARS OF INNOVATIVE RESEARCH 2000-2010

CATS
CENTRE FOR THE ANALYSIS OF TIME SERIES

LSE
THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

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1. FOREWORD

We are proud of the achievements of CATS and hope that this 'anniversary issue' conveys something of the excitement of working in and with CATS over the last few years. Perhaps the most remarkable of these achievements has been the establishment of a strong international profile in the area of climate change which many comparable institutions would be proud of. This has been an era of policy making in addition to the science, at a national and international governmental level and in the private sector, such as insurance. It has been a period where the 'truth' has been at a premium. CATS is, we hope, known for its frank and honest approach and with Professor Leonard Smith at the helm has steered a careful course. CATS has come of age and this has been both acknowledged and reinforced in particular with its involvement in the Munich Re programme, the ESRC Centre for Climate Change Economics and Policy, and its seat in the Grantham Research Institute for Climate Change and the Environment. Behind and leading up to these has been strong research output with a firm mathematical basis in non-linear time series, simulation and statistical modeling, all fed by good science and a rich portfolio of research grants. Conducting high level scientific research in areas with, at times, a global decision support imperative requires the right mix of vision, pragmatism and even nerve. We are very proud of and grateful to our like-minded internal and external partners who have been with us on the journey and for the continuing support of the LSE leadership. At a personal level it is a privilege to be associated with CATS.

Professor Henry Wynn
Chair, CATS

II. THE CENTRE FOR THE ANALYSIS OF TIME SERIES: EVOLVING OVER TIME…

The LSE has a long and distinguished history in time series analysis. The Centre for the Analysis of Time Series was founded in 2000, with the appointment of Professor Howell Tong to the Department of Statistics, to which the Centre is affiliated. The Centre's mission was to advance the understanding and application of analysis of time series interpreted in the broadest sense, with a special emphasis on non-linear techniques reflecting the research expertise of the founding members (in particular Professor Howell Tong, Dr Leonard Smith and Dr Qiwei Yao), and reflecting the breadth of Professor Tong's then recently published book 'Nonlinear Time Series Analysis'. This remains the focus today, although with the addition of Professor Henry Wynn in 2003 (co-director and subsequently Chair) and Dr Pauline Barrieu in 2008 (co-director) the application areas have broadened further, and now include significant expansion in the area of climate science in close partnership with the ESRC Centre for Climate Change Economics and Policy (CCCEP) and the Grantham Research Institute on Climate Change and the Environment. While this has significantly raised our international profile in the climate research area, CATS maintains a wider mission in mathematics, nonlinear dynamics, and modern time series analysis, with projects ranging from analysing train time arrivals at Paddington through advanced methods of research assessment via the development of 'no cheating' methods to be used in the analysis of journal citation data, to philosophical issues in the meaning of model simulations and their use in economic planning. A principal intellectual question addressed by the centre involves simulation modelling, and probability forecasts, their formation, interpretation, use, and philosophical foundation. We are active in the socio-economic aspects of weather forecasting and climate modelling, but also investigate a variety of other systems as well as basic mathematical and philosophical questions. While CATS projects continue to evolve over the years, we maintain a core research agenda focused on developing, testing and applying methods for the extraction of robust information from time series analysis of both observations and model simulations, and communicating that information in a form useful to decision makers, be they in policy, industry, or science. Foundational research at the model-reality interface.

Today CATS plays a role at the forefront of international research in applied statistics and mathematics, where it is uniquely able to apply cutting edge developments in mathematics and statistics, developed either in-house or elsewhere, to the interpretation of environmental forecast simulations and communicate these results to industry. Work by CATS Visiting Fellow Kevin Judd and Leonard Smith, has developed new fundamental methods for examining the abilities and limits of simulation forecasts using imperfect models. Joint work of Smith, Broecker, Clarke, Kilminster and Roulston has demonstrated CATS' ability to translate weather forecast information into user-relevant variables and to develop innovative methods for improving this translation and its communication to end users. Experience in education and knowledge transfer is evidenced by CATS' Operational Weather Risk Workshops, held in London and Atlanta in 2004. Smith, Broecker and Clarke presented material in each of these workshops.

There is a standing interest in UK industry for a better understanding of probability forecasts both in the context of weather and in the context of climate. CATS has experience contributing to the science base in both areas. In the weather context, CATS has been active in developing new methods to quantify both the quality of current forecasts and their societal value (**www.wmo.int/thorpex**). In the climate context, CATS has contributed to the design and execution of ensemble climate modeling. The **NAPSTER** project, Nonlinear Analysis & Prediction Statistics from Time series & Ensemble-forecast Realizations, sets the basis for an innovative knowledge transfer mechanism between science base and users of the environmental predictions. CATS thus has the internal experience and external connections to excel in transferring the existing science knowledge base into both private industry and the public sector. Professor Smith has previously participated in the Marie Curie Research Fellowship: 'The dynamics of uncertainty and prediction in nonlinear models of the atmosphere'.

Bottom image: Leonard Smith presenting a talk at EGU, May 2010

II. THE CENTRE FOR THE ANALYSIS OF TIME SERIES: EVOLVING OVER TIME…

Round-table with members of the insurance industry, May 2010

CATS is just beginning work on the NERC project 'End-to-End Quantification of Uncertainty for Impacts Prediction (**EQUIP**). EQUIP is a collaborative project involving eleven UK Universities and research institutions, led at LSE by Leonard Smith and David Stainforth. It brings together the UK climate modelling, statistical modelling, and impacts communities to work closely together for the first time on developing risk-based prediction for decision making in the face of climate variability and change.

To help underwriters better understand the risks associated with climate change, **Lloyd's** is funding a PhD post (Roman Binter) at CATS to investigate how informative climate models are to decision making in the insurance industry. The post is also funded through the Engineering and Physical Sciences Research Council (**EPSRC**) **CASE** programme. Lloyd's are also funding a climate research project, **Blue Gene**, which will utilise the computational resources of the Hartree Centre and examine the ability of state of the art general circulation models to shadow the observations. It will consider both seasonal time scales and beyond, investigating the durations over which models can shadow temperature in Nino3.4 and the Atlantic Main Development region, and establish a methodology of lasting value in evaluating the relevance of large models to the insurance sector, as well as evaluating the current state of the art. This will also set the baseline for designing climate shadowing experiments over decadal periods.

> "CATS is uniquely able to apply cutting edge developments in mathematics and statistics to the interpretation of environmental forecast simulations and communicate these results to industry"

Working with Milena Cuellar (Columbia University) CATS has been working on a citation study, initiated by STICERD funding, entitled '**Can a Citation Database give a Fair View of Research Quality?** Developing multi-faceted statistics for the insightful comparison of researchers, departments, and universities', which looks at how to interpret information in the time series of citations of academic papers.

CATS continues to make contributions to fundamental understanding of nonlinear dynamics and nonlinear time series analysis. Working with Prof Kevin Judd of UWA, applications of the theory of **Indistinguishable States** in forecasting and data assimilation continue to be developed. CATS is working with Dr Chris Farmer of Oxford, who is developing a 'Bayesian' version of our shadowing filter; while Leonard Smith has just published a paper with Dr Shree Kare of Risk Management Solutions on using Indistinguishable States in state estimation.

Foundational work on the quantification and communication of deep uncertainty due to model inadequacy (also called ambiguity, second order uncertainty, ...) is underway, jointly with Dr Roman Frigg of the Philosophy Department. The aim here is to develop additional degrees of freedom available using non-probabilistic odds, which do not exist when probabilities are provided for decision support. Examples are being developed by Dr Reason Machete, who has just left LSE for a 5-year post at Reading, but who continues to work with CATS as a visiting fellow.

Under the **Munich Re programme**, which began in 2008, CATS is working with the Grantham Research Institute and the Centre for Climate Change Economics and Policy (CCCEP) in a

programme entitled 'Evaluating the economics of climate risks and opportunities in the insurance sector'. The focus of the programme is on informing the insurance sector on the impacts of alternative approaches to carbon finance and emission trading; aiding the design of trading schemes and suggesting new financial service products to be developed; informing decision-makers, at the company level and the country level, on how better to balance investment between mitigation and adaptation, survivability and sustainability. Current research streams within this include: development of long-term risk scenarios for US hurricane; Measuring skill in US hurricane risk metrics; Application of normalisation approaches to a global disaster database; and Insurance linked securities markets. CATS works closely with both CCCEP, the Institute (CATS Co-Director Pauline Barrieu is a program leader and Director Leonard Smith is the Institute's (Physical) Science research director). Many CATS postdocs and students contribute directly to Grantham Research Institute projects.

CATS work involves academics in many departments, with 'associates' in LSE departments of Statistics (CATS parent department), Economic History (Morgan), Geography (Dietz) and Philosophy (Frigg) as well as the LSE Financial Markets Group (Fankhauser), the India Observatory (Stern) and the Centre for the Study of Human Rights (Gearty). CATS industrial funding allows us to stimulate research in other departments by supplying direct 'buy-out' funds, (we currently have agreements with Philosophy and Geography and hope to include more LSE academics with relevant interdisciplinary interests). CATS' large and distinguished list of Visiting Professors and Fellows form an international mix of wide ranging expertise which informs CATS' interdisciplinary research and allows us connections with relevant departments in other leading institutions around the world, both academic and centres of national research. Longstanding co-Director/Chair Professor Henry Wynn has established extremely close ties with the Statistics and Applied Mathematical Sciences Institute (SAMSI) in the US and negotiated successful EC applications jointly with a group of Norwegian institutions (in Supercomputing, Meteorological, and Insurance).

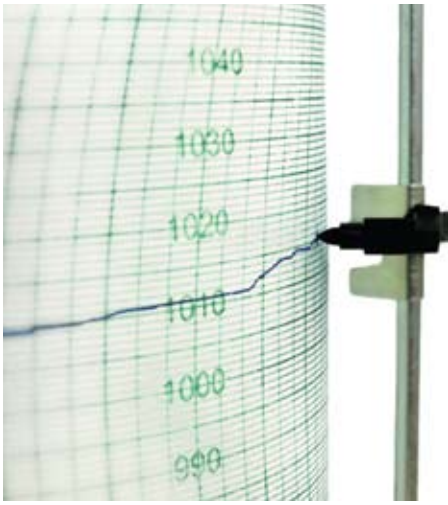
CATS acts as a platform for the translation of quantitative scientific information on forecasting and the limits of modelling between the modellers and users – both specific companies and those dealing with societal impacts. Our aim is to make LSE CATS a world leader in interpreting a range of probability forecasts, some in real time, for society and the social sciences, while also closing the loop with simulation scientists by communicating the user relevant uncertainties and how to make forecasts and projections more useful in decision support.

Dissemination

In addition to the usual publications, we have built more creative/effective methods of dissemination into projects like NAPSTER for example by presenting inhouse educational workshops in selected industrial organisations. It has proved popular with individuals in NERC, the World Meteorological Organization, and industry.

Professor Wynn's work over the last few years has generated much collaboration with other areas and an increased degree of political and public visibility for CATS. He is a member of the Advisory Boards of the Canadian National Institute for Complex Data Structures (NICDS), the Statistics Research Centre PRISM at the University of Warwick and the Imperial College Institute of Mathematical Sciences. He was on the Scientific Advisory Board

Bottom image: CATS 'Weather Roulette' in the LSE Magazine, Summer 2003



WEATHER ROULETTE

FOG

Weather roulette

The Centre for the Analysis of Time Series (CATS) was established within the Department of Statistics at LSE in 2000. The School has a long and distinguished history in time series analysis and continues to develop a world class centre of excellence in this area. **Leonard Smith** explains how weather and epilepsy fit into the picture.

Imagine if you knew exactly what the weather would be like each day this summer. How much easier it would be for people planning days out, or for hotel and theme park owners, transport chiefs and ice cream companies, if they knew that 4 July was going to fall in the middle of a heatwave. Or that on the last Monday in August, the UK's national summer holiday and the main day of London's Notting Hill Carnival, it would rain mid-afternoon.

But even if you never know exactly what will happen, knowing fair odds, or ideally the relative probability of different scenarios, allows much better decision-making: you can hedge your bets.

Can we be more successful at 'weather roulette' than we currently are? At CATS, we believe the answer is yes. This summer our Faraday DME project has launched new technology, developed while working with data from the Met Office, the European Centre for Medium-range Weather Forecasts and the US National Center for Environmental Protection (NCEP). While we are still a long way from predicting what will happen on 25 August, we are now posting two-week probability forecasts for the weather in the UK.

Weather forecasts are made by feeding an estimate of the current state of the atmosphere into a computer programme and then simulating how the atmosphere will behave over the next couple of weeks. Sometimes a small error in the estimate of the current state will make a big difference to how the forecast turns out. Other times, because the atmosphere is in a more stable state, small errors are less important. And then, sometimes, the forecast goes wrong due to shortcomings of the model.

The DME software is based on nonlinear mathematics. What myself and colleagues Drs Mark Roulston, Pat McSharry and Liam Clarke have done is take the ensemble weather simulations and reconfigured these simulations into forecasts which reflect the relative probability of it being hot, normal, or cold. Everyone knows that, sometimes, the forecast is really good, even many days in advance. And sometimes it is not. The DME forecasts provide a way to see if the model thinks its forecast will be precise.

How does this fit in with epilepsy research, you may be thinking? The answer is invention and justification of new nonlinear statistical techniques. In linear systems, the effect is proportional to the strength of the action taken: in a nonlinear system this isn't always the case. Sometimes pushing harder can cause the opposite of pushing softly. So nonlinear analysis can often see things that are literally invisible to linear statistical analysis. The key of course is to be relatively certain that what is 'seen' is really there.

CATS has four main research themes. Two of these reflect two different aspects of predictability. The first attempts to trace out what will happen in the near term – for example, weather forecasts. The second is more concerned with general behaviour and possible events – for example, climate modelling. The third main research theme is nonlinear time series analysis. This is where most of the research you'd expect to find in a statistics department happens, although the approach, while broad, is closely linked to real data and importantly includes comparison with traditional time series techniques. Finally, we consider novel modelling methods, in particular comparing simple observation based models with complicated simulation models. We are interested not only in merging techniques and physical insight, and in evaluating the result in real applications, but also the philosophical underpinning of model building and data analysis – hence we maintain active links with the School's Centre for Philosophy of Natural and Social Science.

And economics? Well, new time series analysis techniques are always applied to financial data, and the provision of tests of goodness, or at least of internal consistency tests, is in great demand. In addition to targeting a better understanding of how to price weather-derivative or weather-related insurance, we promote an end to end approach to weather forecasting, tracing our current uncertainty about the state of the system all the way through the modelling process to enable a user to quantify more clearly the uncertainty in the future economic variables of interest to them, be it airport runway usage, wind energy or the efficiency of electricity generation. The DME website also includes forecasts for heating-degree days.

In practice therefore, our aim is to make the application of statistics much more relevant and immediately useful to a variety of professionals. This has in itself brought us into a debate over methods and scientific ethics. In a letter published in *Nature* magazine in March, myself and my CATS colleague Patrick McSharry, together with Oxford professor Lionel Tarassenko, argued that traditional statistics sometimes contain as much information as new fangled nonlinear creations, the behaviour of which is much less well understood.

Our concern was about research which suggested a new nonlinear way in which epileptic seizures could be more accurately predicted. Epilepsy is one of the most common serious neurological disorders, affecting up to five per cent of the population at some point. Reliable, robust detection of precursors to seizures would improve the quality of life of many epilepsy sufferers. We were concerned that some results which have been oversold, in particular the [illegible] were presented without a stringent [illegible] compare them with more traditional [illegible] a critical social understanding of [illegible] novel methods are widely advertised [illegible] they are novel, without being [illegible] to existing knowledge, how are [illegible] children or to convict a criminal, based [illegible] misspent flashy new scientific results?

It may appear odd that researchers [illegible] the invention and application of [illegible] techniques should argue against [illegible] implications are much broader. The [illegible] 'How are doctors supposed to tell [illegible] a time when decisions about whether [illegible] children or to convict a criminal, based [illegible] evidence, are increasingly linking back [illegible] ever more crucial that professionals and [illegible] given enough information to keep [illegible] joining the list of 'lies, damned lies and [illegible]

This emphasis on the social impact and [illegible] cal basis is, I believe, one of the main [illegible] distinguishes CATS research at LSE. We [illegible] the importance of establishing that new [illegible] a real advance – the kind of benchmark [illegible] in CATS to judge new methods. That [illegible] course, that we often end up shooting [illegible] ideas. But ultimately the use of any compute [illegible] tical method – whether in medical diag [illegible] weather forecasting, or in a range of other [illegible] applications – can be justified only by [illegible] real data that it outperforms well understood [illegible] at statistics or provides complementary [illegible] added information. ■

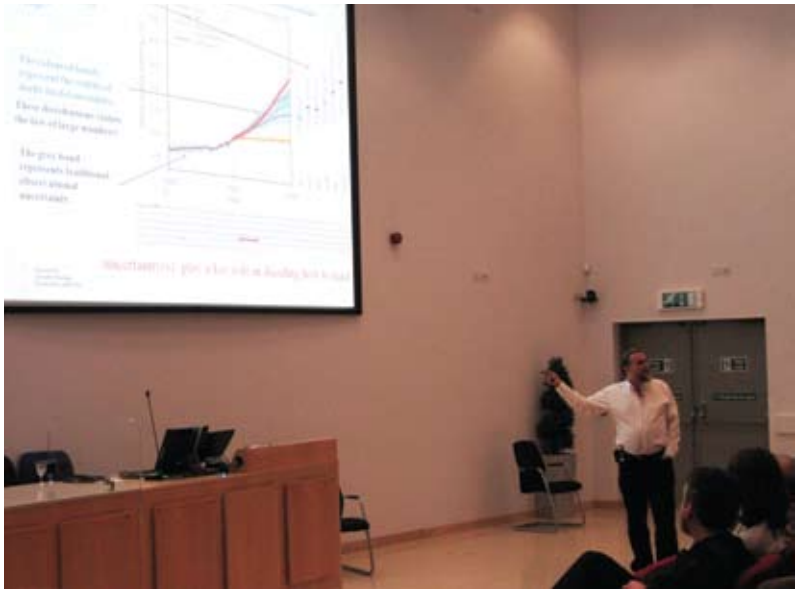
Dr Leonard Smith

is director of CATS, a reader in statistics and senior research fellow at LSE, and a senior research fellow (mathematics) at Pembroke College, Oxford. © Dr Leonard Smith, 2003

CATS is supported by UK research councils, in particular the Engineering and Physical Sciences Research Council, and Department of Trade and Industry Faraday Partners including London Electricity and Risk Management Solutions, and the US Department of Commerce.

CATS works jointly with the Smith Institute, which aims to enhance the academic/industry interface of mathematics and statistics in practice.

II. THE CENTRE FOR THE ANALYSIS OF TIME SERIES: EVOLVING OVER TIME…



Leonard Smith giving a talk at the NCAS/NERC spring school, April 2010

of the World Congress in Statistics in 2008, and leads CATS cooperation in Norway as the Chair of the Advisory Group for the Programme SFI2: Statistics for Industry attached to the Norwegian Computer Centre.

In terms of finance and risk Dr Barrieu leads CATS dissemination in this area, working with the London Development Agency, AXA, and others. She is a member of the Board of Examiners for the Institute of Actuaries (since 2007), while Professor Smith recently gave an evening lecture to the Institute. Dr Barrieu also organised a mini-symposium on Environmental Economics and Stochastics in the ICIAM Conference (Zurich, Switzerland) in 2007, while Dr Frigg (Philosophy) is attempting a new thrust into understanding deep uncertainty in modelling risk. This will be a central unifying thread across CATS members, associates and others. Fundamental questions to be addressed will include translating model diversity into decision relevant uncertainty (Smith), providing a philosophical foundation (Frigg), and working jointly on questions faced by environmental economists (Dietz) and the climate change commission (Fankhauser).

The appointment of Dr Ralph Rayner in 2007, funded indirectly by the US government, has significantly deepened our expertise in oceans modelling and dynamics. Ralph has an international reputation in both economic and physical analysis of marine infrastructure. CATS newest addition is Visiting Professor Keith Beven of Lancaster, who adds both expertise in hydrological systems and decades of reflection on how to cope with model inadequacy. Keith's work has provided inspiration to many CATS researchers for quite some time, and we are happy to have him working directly with us in EQUIP and other projects.

Two recently published books have added to CATS dissemination to industry and the public, Professor Smith's book, *Chaos, A Short Introduction*, OUP, 2007, is a vehicle for disseminating the foundation underlying much of CATS' research agenda (as well as introducing 'chaos' to a lay audience) and has proven one of the most popular of the series' mathematical texts. Dr Barrieu was co-editor of a book published by Wiley in July 2009 *'The handbook of Insurance-Linked Securities,'* with contributors from the industry (key experts in relevant fields).

The future of CATS

In the proposal that led to the formation of the Centre for the Analysis of Time Series, Professor Howell Tong stressed the key role interdisciplinarity played in the history of time series. He cited joint ventures with fields ranging from physics to cement production and stressed the LSE's distinguished history in the field, a history to which he and Qiwei Yao have since extended.

In the last ten years, CATS has revisited some of the historical themes that gave birth to time series analysis. Yule was interested in sun spots and then, with Walker, in understanding the weather; while Fisher's original work focused on weather as well, namely attempts to see through it. Work of lasting value in time series as statistics navigates a path between a rock and a hard place: one must avoid too intense a focus on one particular set of observations or even one particular scientific field, and proceed with mathematical rigour while not slipping into mathematics itself and proving things of no relevance to any observations of nature. To the extent that CATS has succeeded, I believe we owe a debt both to the environment found within the Centre and to the breadth Professor Tong embraced from the beginning. Visitors to CATS soon learn we ask a lot of questions, if not

out of deep insight, then out of ignorance of why things have always been done that way. The wide ranging backgrounds of our members requires a clear presentation of ideas, often several. CATS focused on 'Knowledge Transfer' long before the term came to represent a source of funding. I am happy our seminars are sometimes referred to as 'Roasts'.

By nature, CATS has many lives. Building on the foundational work reuniting statistics and dynamical systems laid by Professor Tong in its early days, CATS has considered an amazing array of 'time series' as diverse as passport applications, the stability of the national electricity grid, and the temperature at London's Heathrow airport. And the future? As Niels Bohr noted, 'Prediction is difficult, especially of the future.' CATS profile has grown not by making forecasts, but by clear, constructive critism of the models and forecasts of others, the framework(s) in which they are made, and the manner in which they are used and evaluated. I expect that this big picture will continue to serve CATS well, although the details will depend on the interests of the next generation. I would hazard a guess that a strand towards finance will grow stronger, bringing together weather and insurance in innovative ways; the analysis of weather and climate dynamics per se will no doubt remain central as it has since the time of Yule, Walker and Fisher; and the melding of information theory with nonlinear statistics in the context of real world questions will continue to yield rigorous results both puzzling to philosophers and of value beyond academia. Perhaps slow dynamical systems like pine beetle populations and forest dynamics will come to the fore?

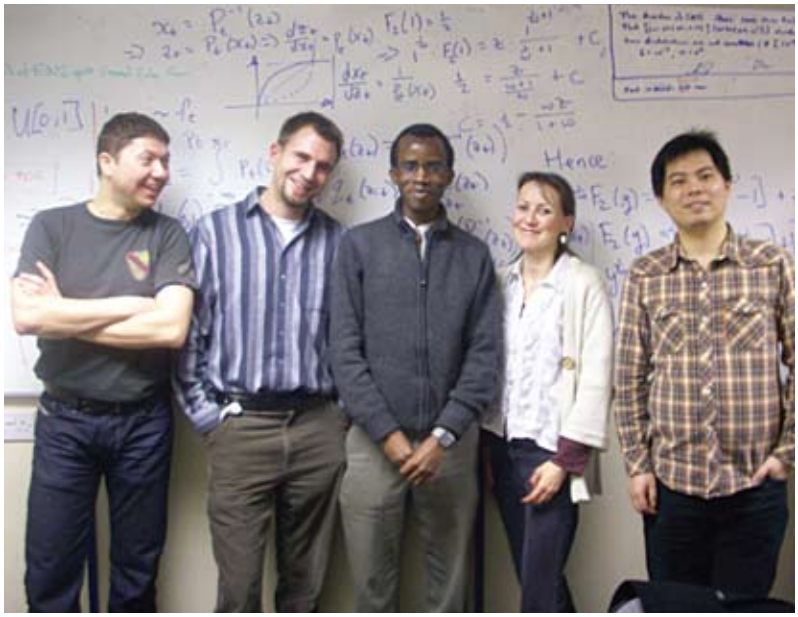
In terms of which time series observations will drive this research, I am happily clueless. The joy in the analysis of time series is in large part extracting insight from observations, sharing that insight, and exploring out-of-the-box connections that often prove unreasonably effective. For ten years CATS has provided a warm environment, supporting a diverse group of people in pursuing that insight, sharing, and exploration. I believe it is that environment of healthy scepticism, intellectual rigour, and unreasonable hope which makes CATS a special place, and which will ensure nontrivial contributions to our understanding whatever detailed pathway the future holds.

Professor Leonard Smith
Director, CATS

"The appointments of Professor Beven and Dr Rayner provide the in-house domain expertise in hydrological systems and marine infrastructure that allows CATS to explore the entire chain from theory, through modelling, to application."

III. CATS PROJECTS PAST AND PRESENT

Below: At the whiteboard in CATS 'mission control' room B717



End-to-End Quantification of Uncertainty for Impacts Prediction (EQUIP). Funded by NERC, EQUIP brings together the UK climate modelling, statistical modelling, and impacts communities to work closely together for the first time on developing risk-based prediction for decision making in the face of climate variability and change. EQUIP is a collaborative project involving eleven UK Universities and research institutions. The project began in January 2010 and is due to finish in December 2012. At LSE the project is led by Leonard Smith and David Stainforth.

Blue Gene project. Sponsored by Lloyd's of London and utilising the computational resources of the Hartree Centre, the Blue Gene project aims to examine the ability of state of the art general circulation models to shadow the observations; starting with EC Earth (the models considered will vary with the permissions granted the Blue Gene team). The aim is to consider both seasonal time scales and beyond, investigating the durations over which models can shadow temperature in Nino3.4 and the Atlantic Main Development region, and establish a methodology of lasting value in evaluating the relevance of large models to the insurance sector, as well as evaluating the current state of the art. This will also set the baseline for designing climate shadowing experiments over decadal periods. In addition, we would hope to assist in climate@home the (US version of climateprediction.net) and to use the climate@home model(s) in parallel shadowing experiments, investigating experimental design incorporating the synergistic use of distributed computing informed by focused Blue Gene runs.

RAPID-RAPIT is a NERC funded collaborative project led by the National Oceanography Centre, Southampton, that will attempt to quantify the likelihood of a shut down in the Meridional Overturning Circulation (MOC) in the North Atlantic. At LSE the project is led by David Stainforth and funds a PhD student who will study the relationship between models and reality in the context of climate change. The research will work towards the design of ensemble experiments which can evaluate the spatial and temporal scales on which complex climate models can potentially provide quantitative information about the future real world climate. In constructing such a design the student will use simple non-linear systems, and simple and intermediate complexity climate models. On weather forecasting timescales techniques have been developed to quantify how long a model can remain close to, shadow, observations. Here the aim is to look at the application of such techniques to climate and climate change, to illustrate and refine the methods with simple models, and to work towards an experimental design which may be applicable to complex climate models, probably within the context of a distributed computing methodology. Such an approach has the potential to clarify where and how model based forecasts can add value to real world decisions and to guide and evaluate the improvement of climate models. The project began in October 2009 and runs until September 2013.

Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector. This is a research programme funded by Munich Re as part of the Centre for Climate Change Economics and Policy. The programme focuses on informing the insurance sector on the impacts of alternative approaches to carbon finance and emission trading; aiding the design of trading schemes and suggesting new financial service products to be developed; informing decision-makers, at the company level and the country level, on how better to balance investment between mitigation and adaptation, survivability and sustainability. The

programme runs until September 2013. For further details see: **http://www.cccep.ac.uk/Research/Programmes/Munich-Re/home.aspx**

Can a Citation Database give a Fair View of Research Quality? Developing multi-faceted statistics for the insightful comparison of researchers, departments, and universities. Funded by STICERD. This project aims to develop, illustrate and evaluate new measures of research quality based on quantitative analysis of the quantity, quality and diversity of citations to an individual's published research papers; to illustrate the need for multi-variate measures; to demonstrate variations between fields of study, and develop methods to account for these variations; and to evaluate the strengths and weakness of proposed statistics, in particular how transparent they are and how easily it might be manipulated.

Managing Uncertainty in Complex Models (MUCM) is a Research Councils UK funded project that started in 2006. It is held by a consortium of 5 universities – Sheffield (the lead partner), Durham, Aston, Southampton and LSE. It is led at LSE by Professor Henry Wynn. MUCM is a multidisciplinary project concerned with quantifying and reducing uncertainty in the predictions of complex models across a wide range of application areas, including basic science, environmental science, engineering, technology, biosciences, and economics. The first phase of MUCM drew to a close in September this year, and it has now entered into a second two-year phase (MUCM2).

Ensemble-based Predictions of Climate Changes and their Impacts (ENSEMBLES). This project was funded by the European Commission under the 6th framework programme to research climate change and its impacts in Europe. The research was conducted between September 2004 and December 2009 by a consortium of 66 research institutes, mostly from Europe, and led by the Met Office Hadley Centre. The project helped develop an ensemble climate forecast system for use across a range of timescales (seasonal, decadal and longer) and spatial scales (global, regional, local). The modelling system is being used to produce probabilistic scenarios of future climate for a quantitative assessment of impacts in a range of applications, to provide policy-relevant information.

“The ENSEMBLES modelling system is being used to produce probabilistic scenarios of future climate for a quantitative assessment of impacts in a range of applications, to provide policy-relevant information.”

Nonlinear Analysis & Prediction Statistics from Timeseries & Ensemble-forecast Realizations (NAPSTER). This project, funded by NERC, ran from 2005 to 2008. The aim of NAPSTER was to improve the use of weather forecasts for decision support in the day to day operations of a range of UK businesses and public services that are subject to weather risk. State-of-the-art forecasts are probabilistic in nature, providing information on what is likely to happen. However these forecasts are largely under-utilised, in part because many organisations are unable to

III. CATS PROJECTS PAST AND PRESENT

Leonard Smith and other particpants at the BIRS Extreme Events workshop, August 2010

process probabilistic information in its present form. Through a series of in-house educational workshops in selected industrial organisations CATS presented a hardware and software platform to enable interested organisations to use new methods of end-to-end forecasting of weather risk to improve their operational decision making. For further information see: **http://cats.lse.ac.uk/NAPSTER/**

Direct & Inverse Modelling in End-to-End Environmental Estimation (DIME). This project was an EPSRC-DTI Smith Institute Faraday Partnership grant, with industrial in-kind support from EDF Energy and Risk Management Solutions. The project aim was to track uncertainty, both from model inadequacy and from the unknown initial state of the atmosphere, all the way through the modelling process, to yield estimates of the uncertainty in quantities of industrial interest. The project was carried out from March 2003 to August 2005.

Real-time Modelling of Nonlinear Datastreams (REMIND) was a second EPSRC-DTI-Smith Institute Faraday Partnership project, this time with the National Grid Company and Intertec. Here the analysis was of time series of frequency of the national grid, extracting information on the state of the grid from very long, high resolution data sets, and on detecting imminent failure in rotating machinery from observations in the way the vibrated.

Climateprediction.net: A practical platform for ensemble Earth System Modelling. CATS participated in this NERC-funded project led by Myles Allen at Oxford University. *Climateprediction.net* is a distributed computing project that aims to produce predictions of the Earth's climate up to 2100 and to test the accuracy of climate models. To do this, it utilises computers of people from around the world – making use of time when they have their computers switched on, but are not using them to their full capacity. It is the world's largest climate modelling experiment.

Climate Variability. This 6-month project (2005-6) was funded by the University of California, San Diego. It focused on ensemble simulations of observed climate variability.

Weather Risk Management. Funded by the University Corporation for Atmospheric Research (UCAR), this one-year project aimed at improving operational weather risk management, demand forecasts and the use of joint distributions. It followed on from work under the NOAA-funded project below.

Towards Identifying and Increasing the Socio-Economic Value of High-Impact Weather Forecasts. Funded by the National Oceanic & Atmospheric Administration (NOAA), this one-year project supported a Pembroke research fellowship in applied probabilistic meteorology, held by Dr Devin Kilminster, from 2003 to 2004.

Improved Risk Management via Probabilistic Weather Forecasts. Funded by Royal Dutch Shell this 18-month project aimed at interpreting ensemble forecasts for risk analysis.

EC Marie Curie Postdoctoral Fellowship, 2002-2003. This Fellowship was held by Dr. Antje Weisheimer, to work with Professor Leonard Smith in CATS on the predictability in large climate models and the uncertainty ranges for evaluation of ensemble climate forecasts.

Nonlinear time series modelling of periodically fluctuating vertebrate population: a spatio-temporal approach. This BBSRC/EPSRC funded project was held by Professor Howell Tong and co-investigators Qiwei Yao and Nils Chr. Stenseth (University of Oslo), from 2000 to 2002.

> "*climateprediction.net* allows us to explore climate models in the same way that we explore other, simpler, nonlinear systems. And the insights from the public is wonderful."

IV. CATS MEMBERS PAST AND PRESENT

Current academic and research staff:

Professor Leonard Smith, Director of CATS, is Professor in Statistics at LSE and Senior Research Fellow of Pembroke College, Oxford. He obtained a PhD in Physics at Columbia University (USA) in 1987. He has held grants funded by many bodies including ONR (US Office of Naval Research) and NOAA (US National Oceanic and Atmospheric Administration) as well as the European Commission and UK Research Councils. Two successful projects – DIME and REMIND – were funded under the UK EPSRC Maths Faraday programme, followed by NERC funded projects NAPSTER (Nonlinear Analysis and Prediction Statistics from Time Series and Ensemble forecast Realizations) and now EQUIP. Professor Smith was active in the formation of climateprediction.net and the science strategy for THORPEX (as co-author of the Socio-Economic Impacts Chapter). In recognition of his mathematically-coherent user-relevant contributions, the Royal Meteorological Society awarded Professor Smith its Fitzroy Prize.

Dr Pauline Barrieu, Co-Director of CATS, is a Reader in the Department of Statistics and director if its Research Students programme. Her research interests are mainly on the study of problems at the interface between finance and insurance, in particular the design of illiquid products and the securitization of non-financial risks. She also works on quantitative methods for risk measurement and robust decision taking, with applications in finance and environmental economics. Pauline qualified as an actuary from l'Institut des Actuaires Français in 2005; she has also been a Visiting Professor (Finance department) at HEC, France, since 2008. She has held a number of grants from sponsors including EPSRC, the London Development Agency, the Columbia-LSE Alliance Collaborative Research Fund and the British Academy.

Professor Henry Wynn, Chair of CATS, is Professor of Statistics at LSE. He was Convenor (Head) of the department from 2003-2006. He leads a research group: the Decision Support and Risk Group, well supported by research grants, particularly from the EU. He was (2000-2005) part-time Scientific co-Director of EURANDOM, the international stochastics institute attached to Eindhoven Technical University (TUE), in the Netherlands. He was recently appointed Chair of the Scientific Board of the new Norwegian statistical research centre, Statistics for Innovation (sfi)2.

Dr Hailiang Du is a Research Assistant in the Grantham Research Institute on Climate Change and the Environment and a member of CATS. He obtained his PhD in Statistics in June 2009. His main research was on data assimilation and parameter estimation for deterministic nonlinear systems. He was also involved in the ENSEMBLES project and focused on evaluating and combining multi seasonal model outputs. He is currently working on real time series forecasting and interpreting model output for decision makers. His research interests are nonlinear time series analysis, parameter estimation, forecast interpretation.

Dr Max Fehr is a Research Assistant on the Munich Re programme `Enabling Carbon Markets: efficient carbon trading systems and finance'. His current research focuses on applications of mathematical finance and stochastic optimal control to problems arising in commodity and particularly in energy and carbon markets. His papers deal with topics such as modeling and design of emission trading schemes, option pricing in commodity markets, portfolio optimization in energy industry and numerical methods to solve stochastic control problems. He graduated in theoretical Physics and wrote his Phd in Mathematics at the Institute for Operations Research at ETH Zurich. He holds an ETH Medal, the EURO Excellence in Practice Award and was recognized with the Walter Saxer Prize for his Phd Thesis on `Market Design for Emission Trading Schemes'.

IV. CATS MEMBERS PAST AND PRESENT

Dr Ana Lopez is a research officer within the Centre for Climate Change Economics and Policy, with expertise in probabilistic climate change projections and their use in the quantification of future impacts and adaptation to climate change. Her previous experience includes research in theoretical physics in different universities in USA, Argentina and UK, and more recently as a Tyndall Research Fellow at Oxford University, where she explored different approaches to identify the difficulties and potentialities of using large ensembles of climate models to project impacts of climate change, quantify their uncertainty, and extract robust and relevant information to develop adaptation pathways in different systems, with a focus on water resource management and biodiversity. Ana's research interests include climate model validation and evaluation, predictability measures and limits to predictability, temporal and spatial limits for impact relevant climate model information, vulnerability approaches to mitigation and adaptation to climate change, and the intersection between climate science and decision making under deep uncertainty.

Dr Falk Niehörster is a Research Assistant on the project 'Quantifying the uncertainty in economic impacts and increasing the economic relevance of climate modelling' financed by the Munich Re programme. He graduated in mathematics and focussed on computational physics to simulate high dimensional complex systems. In his PhD time he was working on the development of climate models and quantification of uncertainties in climate feedback mechanisms. His research interests are statistical predictability in non-linear systems and the theory of decision making under deep uncertainty.

Dr Nicola Ranger is a Research Fellow within the Centre for Climate Change Economics and Policy. Her research interests include decision-making using uncertain climate model information, quantifying risks from extreme events and the role of insurance in adaptation. She has come to LSE from the catastrophe modelling firm, Risk Management Solutions, where she worked on climate change implications for the insurance industry, and previous to this held positions as a scientific advisor and policy analyst for the 'Climate, Energy and Ozone: Science and Analysis' division of Defra (now part of DECC) and on the 'Stern Review on the Economics of Climate Change' at HM Treasury. She holds a PhD in Atmospheric Physics from Imperial College London and a first class honours degree in Physics from the University of Warwick

Dr Ralph Rayner is a professorial research fellow with CATS. He is an oceanographer with more than 25 years experience of the provision of consultancy services to the maritime industries and to government agencies concerned with the marine environment. He currently coordinates industry involvement in ocean observations on behalf of the US Federal Interagency Ocean Observation Committee and chairs the Intergovernmental Oceanographic Commission Global Ocean Observing System Scientific Steering Committee. Ralph works at Board level with a number of specialist ocean science and technology businesses in the UK and the United States; is a Vice President of the Institute of Marine Engineering, Science and Technology (IMarEST); a member of the Council of the Society for Underwater Technology and an Executive Council member of the Association of Marine Scientific Industries. He contributes to a number of international research programmes concerned with understanding and predicting the ocean environment and has authored numerous marine scientific papers and reports as well as contributing to a number of books on ocean science and technology.

David Stainforth is a Senior Research Fellow in the Grantham Research Institute. He is a physicist by training and has many years experience of climate modelling. While a researcher at Oxford University he co-founded and was chief scientist of the climateprediction.net project, the world's largest climate modelling experiment. He has been both a NERC Research Fellow and a Tyndall Research Fellow at Oxford University. His current research interests focus on how we can extract robust and useful information about future climate, and climate related phenomena, from modelling experiments. This includes issues of how to design climate modelling experiments and how to link climate science to real-world decision making in such a way as to be of value to industry, policy makers and wider society.

Emma Suckling is a Research Assistant within CATS. Her research interests include developing informative forecast systems for the EQUIP project, which brings together climate modelling, statistical modelling and impacts communities to deliver risk-based prediction for decision making in the face of climate variability and change. She is a physicist by training, having pursued both her undergraduate degree and a PhD in theoretical nuclear physics at the University of Surrey, before joining CATS in May 2010.

Dr Swenja Surminski has recently joined CCCEP/CATS as a Senior Research Fellow with focus on the Munich Re programme. She was previously Adviser, Climate Change, at the Association of British Insurers, advising the ABI on climate change mitigation and adaptation. Key areas of work are climate impacts, mitigation policies, and the role of insurance in the climate change context. She has co-ordinated the ABI's response to the 2007 summer floods in the UK and sits on various research steering groups, guiding the knowledge exchange between climate scientist and the insurance industry. She is involved in several governmental working groups, representing the views of the industry. Swenja is a member of the Management Committee of the industry's ClimateWise initiative, of the European Insurance Industry Climate Change Taskforce (CEA) and of the London Climate Change Partnership Steering Group. She has been advising on climate change risks at UN, EU and UK level and is the author of several papers on these topics. Prior to taking up this role in April 2007, Swenja was working in the Risk Management division of insurance broker Marsh McLennon and in the Geoscience Team at Munich Reinsurance Company. Swenja was a Fulbright Scholar in the US, studying Environmental Economics and International Relations at the University of New Hampshire. Swenja received a PhD in Economics/Political Science from Hamburg University for her work on 'Climate Change and the Insurance Industry' in 2000.

Noha Youssef is a Research Officer in CATS working on the Research Councils UK funded project MUCM (Managing Uncertainty in Complex Models) with Professor Henry Wynn. Her PhD at LSE is on optimal design for computer experiments. She obtained her MSc. from Cairo university on handling incomplete data for longitudinal studies

IV. CATS MEMBERS PAST AND PRESENT

Visiting Professors & Fellows

Dr D James Baker is a Visiting Senior Fellow at CATS and the Director of the Global Carbon Measurement Program of the William J. Clinton Foundation, working with forestry programs to reduce carbon dioxide emissions and alleviate poverty through use of remote sensing and geospatial systems in developing countries. He is also involved with developing global observing programs for forestry and climate. He is a member of the World Bank's Roster of Experts for the Forest Carbon Partnership Facility and was the lead author on the recent paper 'Achieving forest carbon information with higher certainty: a five part plan,' published in the journal Environmental Science and Policy. Previously, Dr Baker served as Under Secretary for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration (NOAA) at the U.S. Department of Commerce. He was elected the twenty-seventh President and CEO of The Academy of Natural Sciences in Philadelphia, the oldest natural history institution in the western hemisphere, in April 2002. He has a PhD in Physics from Cornell University.

Professor Keith Beven, Professor of Hydrology and Fluid Dynamics at Lancaster Environment Centre, has recently been appointed a Visiting Professor to CATS. In his academic research he has developed ways of trying to imitate landscape dynamics by means of computer simulations but one of the fascinating aspects of this as a research area is the sheer impossibility of capturing the wonderful natural dynamics of the landscape without ambiguity by approximate mathematical means. Recent projects have been concerned with risk and uncertainty in flood inundation and flood forecasting as part of the UK Flood Risk Research Consortium; a Defra project on identifying hydrological change; looking at uncertainties in Water Quality modelling; the use of pervasive sensors in constraining model uncertainties; and concepts of environmental models of everywhere. While in Uppsala recently he has been finishing a book on Uncertainty in Environmental Modelling.

Dr Jochen Bröcker is a scientist at the Max Planck Institute for Physics of Complex Systems in Dresden. He was previously a Research Officer in CATS, working on DIME and other projects. His research interest is at the interface of practical application, theoretical development and industrial exploitation of the analysis of dynamic systems. Currently he is particularly focussed on environmental risk and the socioeconomic value of weather forecast and climate model products. Furthermore, he is working on real time time series analysis (e.g. data assimilation, parameter estimation, and nonlinear filtering), as well as foundational issues in the theory of predictability and the communication of probability forecasts.

Milena Cuellar obtained a Physics degree from Universidad de Los Andes at Bogota, Colombia. She presented there two dissertation projects on Fundamentals of Quantum Physics and Nonlinear Time Series Analysis. She obtained her PhD in Statistics at LSE, working in CATS under the supervision of Professor Leonard Smith. Her project, thesis title: 'Time series analysis, model parameters estimation', was framed in the REMIND project, funded by the National Grid Transco (NGT), and managed by the Smith Institute for Industrial Mathematics and System Engineering. She was a Tyndall Research Fellow at Oxford University Centre for the Environment (OUCE) in 2006/2007, working on the extraction of information from large ensembles of climate models. She now lives in New York City where she is an Adjunct Assistant Professor of City University of New York (CUNY) at Bronx Community College. She is also co-supervising Andreas Svedin's PhD dissertation on Predictability of Solar Activity at the Department of Astronomy of Columbia University in collaboration with Edward A. Spiegel, the Rutherfurd Professor of Astronomy at Columbia University. Her research interests are Non-linear time series analysis, parameter estimation of deterministic models, state estimation, and forecast of real dynamical systems. Perfect and imperfect models. Probabilistic forecasts and uncertainty measures. Model error, evaluation, predictability and variability.

Jerome Ellepola has moved from the Position of Upstream Petroleum Economist with Shell UK E&P to the new role of Network Masterplanning and Optimisation in the Shell Projects & Technology Organisation in the Netherlands. As an Economist he supported operational and commercial decisions on the portfolio and major assets in the UKCS (e.g. Brent-Penguins, Nelson etc) on late life field redevelopment strategies and decommissioning. In his new role he will be part of an integrated team developing network masterplans (Crude Oil/Gas/Power/CO2 etc). He will also be part of a team designing and optimising the next generation of manufacturing plants through the application of MINLP and NLP techniques based on yields and lifecycle Economic KPIs.

Dr Neil Gordon, General Manager, Science Research and Development, at Meteorological Service of New Zealand Limited, is a Senior Visiting Fellow to CATS. He joined MetService in 1968, and has been a senior manager since 1988. He played a key role in its transition from a government department to a government-owned commercial company in 1992. From then until 2005, as General Manager National Weather Services, he was responsible for the delivery of public good services under a commercial contract with the New Zealand government. He currently runs the MetService Advanced Technology division which incorporates training, the Automated Meteorological Prediction Systems group, and development and support of the Weatherscape television weather graphics system. Neil has been involved in CAeM since 1983; he was vice President from 1990 to 1999, and President from 1999 to 2006. He has also been actively involved in PWS activities including expert teams and in-country training events, and co-authored a publication on performance assessment of public weather services.

James A Hansen is a Visiting Senior Fellow to CATS. He is Lead Scientist in the Probabilistic-prediction Research Office at the US Naval Research Laboratory, Monterey. He brings operational experience to CATS via his work in hurricane prediction for the US Navy and his long running association with ensemble climate modelling via climateprediction.net. He also carried out joint research on CATS' NOAA and UCAR grants, from 2003 to 2006.

Professor Nigel Harvey, Professor of Judgment and Decision Research, UCL, is a Visiting Professor to CATS. His Interests are Judgmental forecasting and control of dynamical system behaviour: self-assessment of skilled performance. He has worked with CATS on joint research into the use and interpretation of probabilistic forecasts.

Dr Kevin Judd is an Associate Professor at the School of Mathematics and Statistics, University of Western Australia. He works in the area of dynamical systems theory, optimization and computer aided teaching. His research is generally in the area of dynamical systems theory and optimization. For example: the reconstruction of nonlinear dynamical systems from time series, in particular the application of Minimum Description Length, and variable embedding; The theory of indistinguishable states and shadowing trajectories and its application to state estimation and ensemble forecasting, especially in very high dimensional systems like the atmosphere. He is particularly interested in understanding and quantifying uncertainty in forecasts when using imperfect models. He has past and current collaborations with a wide range of researchers including engineers, medical doctors, insurers, physicists, meteorologists and climatologists.

IV. CATS MEMBERS PAST AND PRESENT

Dr Reason L Machete is a Visiting Fellow in CATS from the University of Reading where he has recently taken up a research position. He is an expert in the mathematical theory of non-linear dynamics and its broad application to real systems. The overarching theme of his research is the quantification of model error and its role in probabilistic forecasting. Theoretical and practical issues of predictability of real systems are primarily his concern. His key aim is to minimise uncertainty subject to some degree of calibration. From 2008-10 he was a research officer in CATS and prior to that he was a mathematics lecturer at the University of Botswana.

Dr Simon Mason, Research Scientist Climate, Disasters, International Outreach at The International Research Institute for Climate and Society, The Earth Institute at Columbia University. Simon has been involved in seasonal climate forecasting research and operations since the early 1990s. He has published numerous papers on seasonal climate forecasting and verification, climate change, and southern African climate variability. He has extensive experience in the production of seasonal climate forecasts in contexts such as the Regional Climate Outlook Forums, and works closely with the World Meteorological Organization (WMO) to promote the definition and adoption of forecasting and verification standards through engagement in the relevant WMO Expert Teams and through the WMO CLIPS Capacity Building Workshops. Mason joined the IRI in 1997, working initially at the Scripps Insitution of Oceanography, and moving to Columbia University in 2003. Prior to joining the IRI, Mason was Deputy Director of the Climatology Research Group at the University of the Witwatersrand, in South Africa, where he developed empirical models for predicting southern African rainfall variability. Mason is a Visiting Senior Fellow in CATS.

Trevor Maynard is currently studying at the LSE for a PhD in CATS with Professor Smith. He is deputy head of exposure management at Lloyd's of London. He has authored or edited the majority of Lloyd's published reports on Climate Change. He represents Lloyd's on various climate change related initiatives including: ClimateWise, UNEPFI, Geneva Association and London Climate Change Partnership. Trevor is on the management board of the Lighthill Risk Network, a collaboration between Lloyd's and others in the insurance market which seeks to join up the business world with that of academia. He also sits on the Industry Advisory Board of the Industrial Maths Knowledge Transfer Network. Until 2010 he sat on the Maths Strategic Advisory Team for the Engineering and Physical Sciences Research Council. Trevor has previously worked for: Royal and Sun Alliance, Friends Provident and Mercer. He is a Fellow of the Institute and Faculty of Actuaries and has bachelor and master of science degrees in pure mathematics from the University of Warwick.

Dr Patrick E McSharry is a Royal Academy of Engineering/EPSRC Research Fellow at the University of Oxford, a Research Associate at St Catherine's College, Oxford and a Senior Member of the IEEE. His research interests include biomedical engineering, complex dynamical systems, signal processing, systems biology, risk management, operations research, and forecasting.

Professor Arthur Petersen is Munich Re Programme Visiting Professor at LSE. He is Director of the Methodology and Modelling Programme at the Netherlands Environmental Assessment Agency (PBL). He received graduate training as theoretical physicist (MSc), atmospheric scientist (PhD) and philosopher of science (MA and PhD). Since 2001, he has gained considerable experience in shaping the science-policy interface at Dutch, European and global levels on issues of climate change and sustainable development. He has become a world-leading expert on assessing and communicating uncertainties. In particular, he has studied major uncertainties in climate simulation.

Dr Mark Roulston was recently a Probability Forecast Applications Specialist at the UK Met Office, and prior to that was a tenure track (Assistant Professor) at Pennsylvannia State University. He was a co-investigator on CATS' SHELL project, and active participant on the ENSEMBLES project. He is a co-author on a number of joint papers and was also a co-presenter of our US Operational Weather Risk meetings. His research interests are: Promoting new applications for weather and climate forecasts and the integration of probabilistic forecasts into decision support.

Dr Antje Weisheimer was an EU-funded Marie Curie Fellow at CATS from 2002-2004 working on the project 'Uncertainty ranges for evaluation of ensemble climate forecasts'. She currently works at the European Centre for Medium Range Weather Forecasts (ECMWF). As a Visiting Research Fellow she continues to work closely with CATS.

Roland Young, who was a Research Officer at CATS in 2009, has now returned to Oxford where he did his D.Phil., working as a postdoc in Peter Read's Atmospheric, Oceanic and Planetary Physics Group. He has moved from studying the rotating annulus to studying the dynamics of giant planet atmospheres (specifically Jupiter and Saturn) using general circulation models.

Dave Frame is Deputy Director of the Smith School of Enterprise and Environment, he is a Visiting Lecturer in the Department of Physics at the University of Oxford, and is a Hugh Price Fellow at Jesus College. He is also Lead Scientist on the climate*prediction*.net Transient Experiment. Dave looks at new ways in which advances in climate change research can improve the physical science inputs into climate change policy. His current research has two main strands: Bridging the divide between climate science and climate policy; Understanding the capabilities and limits of environmental models. Dave holds a PhD in physics and a Bachelors degree in philosophy and physics from the University of Canterbury, in New Zealand. He spent two years working in the Policy Coordination and Development section of the New Zealand Treasury as an economic and social policy analyst, followed by a post-doc in the Department of Meteorology at the University of Reading, working on the PREDICATE project. In 2002 Dave moved to the Climate Dynamics group in Atmospheric, Oceanic and Planetary Physics, at the University of Oxford, where he managed climate*prediction*.net. Prior to taking up his current role he was James Martin Fellow in climate change in the Environmental Change Institute. From September 2009 until April 2010 he was on secondment to the Department of Energy and Climate Change as part of a NERC/DECC Fellowship programme.

IV. CATS MEMBERS PAST AND PRESENT

Associate members from across LSE

Dr Simon Dietz, Deputy Director of both the Grantham Research Institute and the Centre for Climate Change Economics and Policy, joined the LSE in 2006, and is a lecturer in the Department of Geography and Environment. Previously he worked at the UK Treasury, as an economic adviser on the 'Stern Review on the Economics of Climate Change'. Simon holds a starred first class honours degree in Environmental Science from the University of East Anglia, and Masters and PhD degrees from the LSE, specialising in environmental policy and economics. Much of his current research focuses on the economics of climate change, and he has recently authored a number of papers on the question of whether economic analysis can support strong action on climate change.

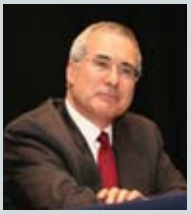
Dr Sam Fankhauser is a Principal Research Fellow at the Grantham Research Institute and member of the Financial Markets Group at LSE. He is also a member of the UK Committee on Climate Change, a government watchdog that monitors UK climate change policy. A former Deputy Chief Economist at the European Bank for Reconstruction and Development (EBRD), Sam served on the 1995, 2001 and 2007 assessments of the Intergovernmental Panel on Climate Change (IPCC). He studied economics at the University of Berne and the London School of Economics, and holds a PhD from University College London.

Dr Roman Frigg is a Senior Lecturer in Philosophy in the Department of Philosophy, Logic and Scientific Method, and Deputy Director of the Centre for Philosophy of Natural and Social Science (CPNSS). His main research interests lie in the field of general philosophy of science (scientific representation, modelling, explanation) and philosophy of physics (quantum theory, statistical physics, chaos theory).

Professor Conor Gearty was born in Ireland and graduated in law from University College Dublin before moving to Wolfson College, Cambridge in 1980 to study for a Master's Degree and then for a PhD. He became a fellow of Emmanuel College Cambridge in 1983 and in 1990 he moved to the school of law at King's College London where he was first a senior lecturer, then a reader and finally (from 1995) a professor. On 1 October 2002, he took up a new appointment as Director of the Centre for the Study of Human Rights and professor of human rights law at LSE. He has published widely on terrorism, civil liberties and human rights. Conor is also a barrister and was a founder member of Matrix chambers from where he continues to practice. He has been a frequent adviser to judges, practitioners and public authorities on the implications of the UK Human Rights Act, and has frequently lectured at home and abroad on the topic of human rights. He has appeared in human rights cases in the House of Lords, the Court of Appeal and the High Court. He has also been a visiting professor at Boston University, the University of Richmond and the University of New South Wales.

Professor Mary Morgan is Professor of the History of Economics in the Department of Economic History. Her research interests include history, philosophy and sociology of economics and statistics; Models, measurements, observations and facts in history and philosophy of science.

Professor Nick Stern. Lord Stern has been Chair of the Grantham Research Institute since it was founded in 2008. He is also Chair of the Centre for Climate Change Economics and Policy; IG Patel Professor of Economics and Government (the first holder of this position) at the Suntory and Toyota International Centres for Economics and Related Disciplines (STICERD); Chair of the Asia Research Centre; and Director of the India Observatory at LSE. Lord Stern was adviser to the UK Government on the Economics of Climate Change and Development from 2005-2007, where he was Head of the Stern Review on the Economics of Climate Change, published in 2006. He was Head of the Government Economic Service from 2003-2007; Second Permanent Secretary to Her Majesty's Treasury from 2003-2005; Director of Policy and Research for the Prime Minister's Commission for Africa from 2004-2005; and Chief Economist and Senior Vice President at the World Bank from 2000-2003.



IV. CATS MEMBERS PAST AND PRESENT

Current Research Students

Roman Binter has been funded by Lloyd's through the EPSRC CASE studentship scheme. With the aim of helping underwriters better understand the risks associated with climate change, Roman's PhD investigates how informative climate models are to decision making in the insurance industry. He is due to submit his thesis soon, and has recently started work in the private sector.

Joseph Daron has a first class honours degree in Meteorology from the University of Reading. He is now a third year PhD student under the supervision of David Stainforth and Leonard Smith. His PhD is sponsored by Lloyd's of London and the working thesis title is 'Extracting decision-relevant information from climate models for the insurance industry'. During his second year Joseph spent six months working as part of an internship at the UK Met Office Hadley Centre in the Climate Impacts Team working on a project entitled 'Probabilistic Networks for Climate Risk'. Joseph has also been an active member of the student PhD meteorology community having been on the organising committee for the past two Royal Meteorological Society student conferences in Manchester and Exeter.

Daniel Hawellek has studied economics, mathematics and statistics in Hamburg, Cambridge and at the London School of Economics. His research interests are local moments, cumulants and dependency structures. At LSE he has worked wit Professors Nick Stern and Leonard Smith and is currently finishing his PhD under the supervision of Professor Henry Wynn. His thesis title (provisional) is 'i-Shadowing in Dynamical Systems'.

Sarah Higgins completed her MSc in Statistics at the LSE and is currently a part-time PhD student in CATS under the supervision of Professor Leonard Smith. Her thesis is on the link between weather and global cereal prices.

Alex Jarman is a PhD research student working on a project entitled 'Quantitative Applied Climate Economics for the Insurance Industry' sponsored by the reinsurance company, Munich Re. He graduated with a Physics degree from the University of Auckland, followed by a Masters in Applied Meteorology at the University of Reading where he was awarded a NERC studentship. His research interests include forecast evaluation and decision-making with forecast information, the physics and predictability of weather and climate, and geosciences applied to adaptation and economics.

Edward Wheatcroft begins his PhD in October 2010 as part of the NERC-funded RAPID-RAPIT project, a collaborative project led by the National Oceanography Centre, Southampton. Edward will study the relationship between models and reality in the context of climate change. The research will work towards the design of ensemble experiments which can evaluate the spatial and temporal scales on which complex climate models can potentially provide quantitative information about the future real world climate.

Previous staff, students and visiting fellows

Dr Mary Altalo was a Visiting Research Fellow to CATS from 2004 to 2006 and also Programme Director of the LSE CATS and IOC/BPOS programme. She was Vice-Chair of the Board of the Intergovernmental Panel of the Global Ocean Observing System.

Anna Andrianova, completed her PhD at CATS, thesis title: 'Incorporating weather forecasts into the energy markets'. Anna now works as a Coal and freight Options trader for RWE, an energy company that owns Npower and is the biggest Utillity company in Germany. RWE trades Gas, Power, Coal, Freight, Oil and CO2. It trades physical assets and also paper markets. They also optimise the run of power stations and invest in pipe lines and infrastructure around the world.

Professor Anthony Atkinson is Emeritus Professor of the Department of Statistics at LSE. A member of the Statistics Department since 1989, he was a Visiting Professor to CATS from 2004 to 2006. Although his main research interests are experimental design, clinical trials and robust data analysis using the Forward Search, he has an interest in the analysis of times series using the Kalman filter.

Dr Ron Bates was a senior Research Fellow in the Department of Statistics and CATS from 2003 to 2008, working with Henry Wynn on a number of European and EPSRC funded projects. He has a BSc in Electronic Engineering and a PhD in Robust design of complex systems. He is currently working at Rolls Royce. His main research interests are: Robust Design; Design of Experiments; Spatial modelling (emulators, response surface methods, neural networks, etc.); Numerical Optimisation; Multiphysics modelling; Multivariate Process Control; Process Economics; Product Development Risk.

Neil Bathia completed his PhD earlier this year, thesis title: 'Factor modelling for high dimensional time'. He is currently doing a postdoc with Professor Peter Hall in the Maths department at the University of Melbourne and he is working on problems in high dimensional data analysis and model selection.

Dr Liam Clarke was a postdoctoral research officer in CATS from 2003-2008, working on NAPSTER, REMIND and other projects. His research interests are in the application and interpretation of probabilistic forecasts particularly in the context of weather, seasonal and climate applications. Liam currently works for the Financial Services Authority in London.

IV. CATS MEMBERS PAST AND PRESENT

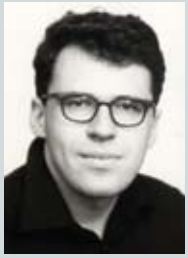
Dr Jost Graf von Hardenberg has worked with CATS on applications of prediction research in the European theatre (precipitation) and print work with ECMWF. He is a researcher at the Institute of Atmospheric Sciences and Climate, CNR, Turin, Italy.

Dr Devin Kilminster carried out joint research on CATS' NOAA and UCAR-funded projects on prediction and forecasting from 2003 to 2006, and was subsequently a Visiting Fellow from 2004 to 2006.

Dr Frank Kwasniok was a Research Officer in CATS and subsequently a Visiting Fellow from 2004 to 2006. Previously he held research positions at the Alfred Wegener Institute for Polar and Marine Research (Bremerhaven, Germany), the University of Oldenburg (Germany), the Leibniz Institute for Atmospheric Physics (Kuehlungsborn, Germany) and the Max Planck Institute for Meteorology (Hamburg, Germany). He joined the University of Exeter in March 2006 as a Lecturer in Applied Mathematics. He is a member of the Exeter Climate Systems centre and the Centre for Geophysical and Astrophysical Fluid Dynamics.

Dr Hugo Maruri Aguilar is now lecturing in the Statistics Department at Queen Mary, University of London. He was a Research Officer on the CATS UK Research Councils funded project, MUCM from 2006 to 2009, working with Henry Wynn.

Dr Christian Merkwirth is currently a postdoctoral researcher at the Department for Information Technology of the Jagiellonian University (UJ), Poland. He obtained the German doctorate degree in 2000 from the University of Goettingen, Germany. He is a physicist with strong experience in numerical methods and computer science. His teaching experience comprises various aspects of computer science, statistical /machine learning, applied data analysis, operating system principles as well as programming in C++. His key research areas are statistical learning/machine learning, time series forecasting and nonlinear dynamics.



Jeremy Penzer started working at the LSE in 1995 as a research assistant to Professor Atkinson. He took up a lectureship in 1997 and in 1998 became the Programme Director for the MSc in Statistics. During his time as an academic, his research interests were state space modelling and applied time series analysis. While at the LSE, Jeremy taught and developed a large number of courses and, in his own words, 'was privileged to teach and supervise a remarkably talented group of people'. Jeremy left the LSE in 2007 to pursue a career in financial services.

Edward Tredger was a PhD research student who completed his thesis in 2009 with the title "On the Evaluation of Uncertainties in Climate Models". His work focused on a statistical analysis of climate model output informed by physical understanding of the system modelled. Analysing the world's largest ensemble of climate simulations (from climateprediction.net), Ed considered internal consistency and policy relevance of climate simulation. He is currently working for DEFRA.

Professor Howell Tong is currently the Saw Swee Hock Professor of Statistics at National University of Singapore, and Emeritus Professor of Statistics at LSE. Professor Tong got his Bachelor of Science (1966), Master of Science (1969) and Doctor of Philosophy (1972) all from the University of Manchester Institute of Science and Technology (UMIST) where he studied with Maurice Priestley. In 1982, he was the founding Chair of Statistics at the Chinese University of Hong Kong. Four years later, he returned to England to be Chair of Statistics at the University of Kent at Canterbury until 1999. From 1999 to September 2009, Professor Tong was a Chair of Statistics at LSE, where he was the founding member of CATS in 2000. Between 1997 and 2004, Professor Tong was also Chair of Statistics and sometime Pro-Vice Chancellor and Founding Dean of the Graduate School, University of Hong Kong. Professor Tong was elected a Fellow of the Institute of Mathematical Statistics in 1993, an Honorary Fellow of the Institute of Actuaries in 1999, and a Foreign Member of the Norwegian Academy of Science and Letters in 2000. He won the State Natural Science Prize, China in 2000. The Royal Statistical Society awarded him their Guy Medal in Silver in 2007 in recognition of his '...many important contributions to time series analysis over a distinguished career and in particular for his fundamental and highly influential paper 'Threshold autoregression, limit cycles and cyclical data', read to the Society in 1980, which paved the way for a major body of work in non-linear time series modelling.'

Professor Qiwei Yao is professor of statistics at LSE with research interests including: time series analysis; non-parametric regression; Dimension reduction and factor modelling; Spatio-temporal modelling; Financial econometrics. He has maintained a constant presence in journal publications and given invited presentations and keynote addresses at various international meetings. His collaboration with ecologist Professor N C Stenseth on modelling biological populations was graded 'A' by the BBSRC in 2003. He is currently PI on an EPSRC funded project, 'High-Dimensional Time Series, Common Factors, and Nonstationarity'. Professor Yao was one of the founding member of CATS in 2000 along with Howell Tong and Leonard Smith.

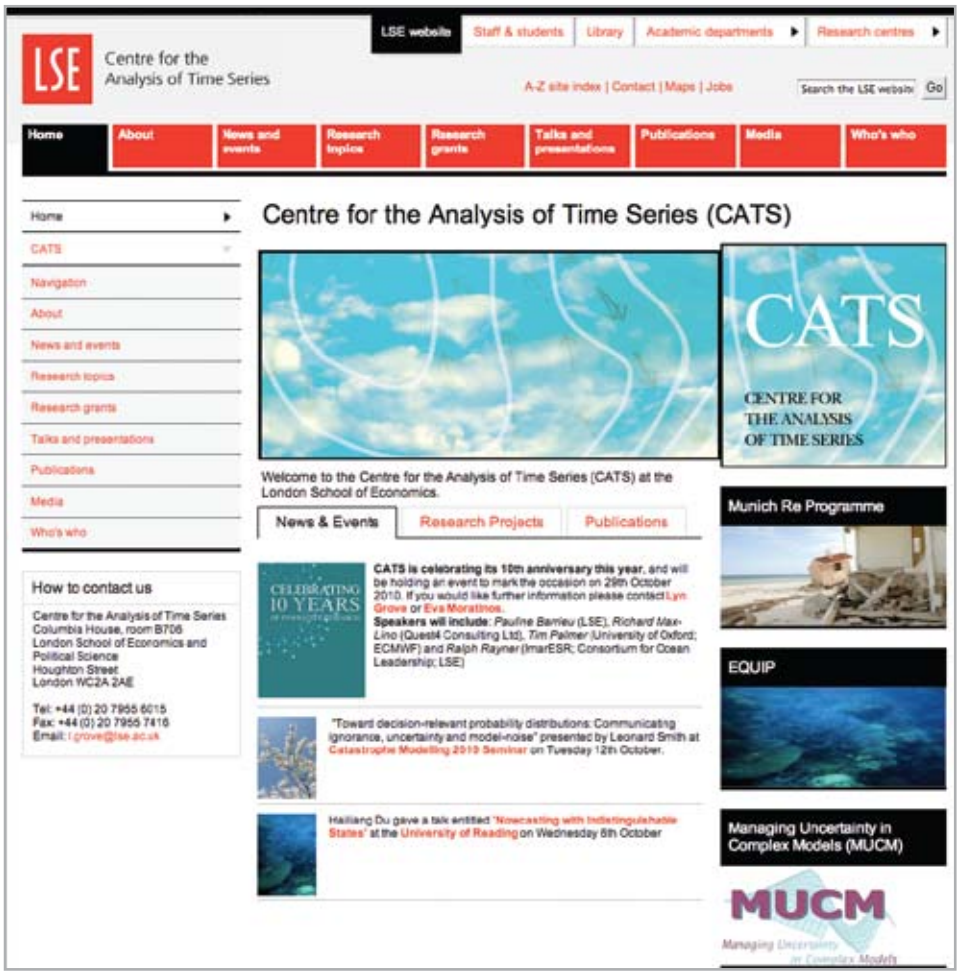
Administrative Staff

Lyn Grove has been at LSE since 2001, initially as Department Manager of Statistics and subsequently as Centre Manager of CATS. She is also responsible for the administration of the Munich Re programme of the Centre for Climate Change Economics and Policy within the Grantham Research Institute on Climate Change and the Environment.

Eva Moratinos is administrative assistant in CATS. She has a degree in Industrial Engineering from the University of Oviedo, which she hopes to make use of in the near future.

V. FURTHER INFORMATION

Further information on all CATS work and activities, papers and other publications, can be found on our new website, lse.ac.uk/CATS



This brochure is available in alternative formats please contact:
Lyn Grove, CATS

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