Physical Climate System

Projects 2014-15

(1) **Propagation of past rapid climate change**
Prof. Christopher Ramsey (Archaeology), Dr. Victoria Smith (Archaeology) and others

How does abrupt environmental change propagate through the earth's climate system? This project will look at palaeoclimate records with good absolute or relative age controls to see the extent to which past rapid changes to the climate have been synchronous globally. Depending on the interests/strengths of the student this project could include palaeoclimate modelling, focus on quantification of the effects in a range of different records, or look at human responses to climate change.

(2) **Climate signals from long-term satellite cloud observations**
Dr Roy Grainger (Physics), Dr Gareth Thomas (RAL Space, STFC Rutherford Appleton Lab), Dr Caroline Poulsen (RAL Space, STFC Rutherford Appleton Lab)

This project will make use of recent advances in the observation of clouds from satellites to determine whether climate change has produced detectable changes in the amount and type of cloud cover across the globe in the past twenty years. The first stage of the project will involve application of a state-of-the art cloud retrieval scheme to a long time series of satellite observations and characterisation of the stability – due to both instrumental effects and natural variability of cloud cover – of the resulting cloud products. The second part of the project will centre on the development of methods to detect trends in cloud properties which might be expected from climate change and their application to the data.

(3) **Large-scale hydrological modeling to investigate land-atmosphere feedback in tropical wetlands**
Simon Dadson (Geography) and Richard Washington (Geography)

The aim of this studentship is to quantify the feedbacks between tropical African wetlands and climate. The student will do this by combining a dynamic wetland inundation scheme in an Earth system model, with field and EO data on soil moisture, cloud cover and methane (CH_4) concentration.

(4) **Atmospheric Sounding with the IASI satellite instruments**
Dr Anu Dudhia (Physics)

Developing retrieval algorithms for nadir-viewing infrared fourier transform spectrometers such as the IASI instruments on the MetOp satellites, with particular regard to handling inhomogeneous scenes caused by cloud and surface structure

(5) **Melting-driven instabilities of ice shelves floating in warm oceans Melting-driven instabilities of ice shelves floating in warm oceans**

Dr Andrew Wells (Physics)

The response of the Greenland and Antarctic ice sheets to ocean forcing represents one of the major uncertainties in predictions of future sea-level rise. When ice sheets flow out into the ocean, an "ice shelf" can form: a floating tongue of ice that provides a thermodynamic coupling with the underlying ocean. Recent observations have revealed the presence of deep channels incised in the base of some floating ice shelves, which may have consequences for ice-shelf break up. This project aims to provide insight into why and when these basal channels arise, by considering the potential for instability due to coupling between the buoyancy-driven flow of fresh meltwater under the ice shelf, and the changing shape of the melting ice-shelf base. The project provides opportunities for the student to develop and apply skills in theoretical modelling, stability analysis, and numerical solutions of fluid mechanical problems, whilst providing insight into the relevance of basal-melt channels for ice-shelf dynamics in a warming climate.

(6) **Fluid mechanical controls on gas and chemical transport through sea ice**
Dr Andrew Wells (Physics)

In addition to providing a dramatic indicator of changes in climate, the evolving sea ice cover drives important feedbacks on the climate system. Rather than forming an impermeable barrier between atmosphere and ocean, sea ice is in fact a porous material comprising of solid ice crystals bathed in liquid brine. The liquid pore space provides a habitat for life inside the sea ice, and a pathway for the exchange of climatically-active gases and chemicals between the ice, ocean, and atmosphere. The goal of this project is to develop a novel physical theory to describe a mixture of liquid, gas bubbles, and solid, which can be applied to model the transport of gases through a porous sea ice cover. This project will provide opportunities to develop and apply adaptable skills in theoretical analysis and numerical modelling of fluid mechanical and thermodynamical processes, whilst building understanding of poorly constrained contributions to the climate system.

(7) **The Optimal Representation of Microphysics in Aerosol and Climate Models**
Dr. Philip Stier (Physics)

Aerosol effects “continue to contribute the largest uncertainty to the total radiative forcing” on climate (IPCC, 2013). This project will focus on the uncertainty in the global assessment of the aerosol microphysical state, which determines the aerosol lifetime, radiative properties, and aerosol cloud interactions and therefore the aerosol radiative effects on climate. The project will use detailed aerosol microphysics models in synergy with measurements from a new range of in-situ instruments providing novel insights into aerosol microphysics.

(8) **Aerosol Effects on Convective Clouds and Climate**
Dr. Philip Stier (Physics)

Aerosol effects on convective clouds have been suggested from theory, modelling and observations and are a key uncertainty in anthropogenic climate change. This project, part of the

EU wide BACCHUS collaborative project, will investigate aerosol effects of on convective clouds as a basis for improved estimates of the anthropogenic climate effects, combining numerical modelling with in-situ and remote sensing observations. *Note: This is an externally funded project open to UK/EU applicants.*

(9) **Reducing precision to improve forecast quality in weather and climate models**
Tim Palmer (Physics) & Peter Düben (Physics)

Numerical models are crucial for obtaining reliable forecasts of future weather and climate. The quality of these forecasts is strongly dependent on the resolution used, which is limited by the available computing power. Recent studies made within our group show that the precision used in many parts of today's climate models is much greater than necessary. The redundancy of precision is partly caused by the chaotic, non-linear, multi-scale nature of the climate system. It might be possible to increase the resolution of climate models if methods with lower precision are used that are able to reduce the computational cost. The project will investigate the use of imprecise but efficient methods in weather and climate models. This investigation could have the potential to change fundamental views on precision in weather and climate models and high performance computing in general.

(10) **Testing parameterisations of baroclinic heat transport in the laboratory**
Prof. Peter L. Read (Physics)

Baroclinic eddies play a major role in the transport of heat, momentum and composition in the atmosphere and oceans. A quantitative understanding remains elusive, especially for eddy parameterization in climate models, where baroclinic eddies may be inadequately resolved. This project aims to quantify the dependence of heat transport due to baroclinic eddies over a wide range of parameters, by direct measurements of thermally-driven flows in rotating, stratified fluid dynamical experiments.

(11) **Modelling African Climate Change**
Richard Washington (Geography), Simon Dadson (Geography) and Richard Jones (Geography)

Climate prediction rests on the performance of climate models. Relative to many other parts of the world, the fidelity of climate model simulations of Africa climate is unexplored. Yet Africa is predicted to be one of the regions hardest hit by climate change. The aim of this project is to assess changes in African climate based on the assessment of models which have been proven to be trustworthy based on their ability to reproduce established mechanisms of the climate system in Africa. The project will involve a number of key data sets including Coupled Model Intercomparison Project 5 and CORDEX.

(12) **Saharan Dust Storms and links to the West African Monsoon**
Richard Washington (Geography) and Sebastian Engelstaedter (Geography)

The Saharan climate system has several unique features including the largest atmospheric loadings of mineral aerosols (dust) found anywhere on the planet. This dust in turn interacts with the climate system, influencing features such as the West African Monsoon. The aim of this project is to exploit the observed data sets emergent from the NERC funded 'Fennec: The Saharan Climate System' grant to evaluate and improve climate model performance over North and West Africa. Both global and regional models will be used.

(13) **Atlantic jet stream variability**
Tim Woollings (Physics)

This project will investigate the physic of the jet stream over the North Atlantic, which strongly influences European weather and climate. The aim is to deepen our understanding of the mechanisms that lead the jet to vary, and identify factors that could act to influence the jet (such as the oceans or sea ice). The work will involve analysis of observational datasets and the use of simple and/or complex computer models.

(14) **Seamless Prediction of Weather and Climate**
Tim Palmer (Physics) & Antje Weisheimer (Physics)

The key aim of the project is to explore the extent to which information obtained in verifying initial value predictions (ie weather and seasonal climate forecasts where verification data is relatively plentiful) can be used to constrain predictions of climate change (where verification data is sparse or non-existent).

(15) Ocean-Atmosphere interaction on decadal timescales
Laure Zanna (Physics)

Coherent large-scale sea surface temperature anomalies are present in the observed record in the Atlantic. Those temperature patterns can strongly impact the temperature and precipitation over Europe, Sahel droughts, the storm track extent over Europe or the frequency of Atlantic hurricanes. The aim of the project is to further our understanding of the physical mechanisms (ocean, atmosphere, external anthropogenic forcing) leading to the generation of those coherent large scale temperature patterns and examine their influence on the climate of Europe & North America on decadal timescales. The project will combine theory, a hierarchy of models and observations.

(16) The Influence of Solar Variations on Seasonal and Decadal Forecasting
Prof Lesley Gray (Physics)

There is increasing evidence for the influence of decadal-scale solar variability on regional weather and climate. Solar variability is evident on many different timescales, including an 11-year cycle and longer-term centennial-scale variations. The next few decades will be a period of particular interest, since recent observations suggest that the Sun's variability is changing, and will possibly descend into a Maunder Minimum-like conditions with much lower output and variability than recently. Overall, the global-averaged, annual-averaged solar signal at the surface is extremely small but there are much larger signals that are localised both regionally and seasonally. A recent Oxford - Met Office study of 150 years of mean sea level pressure and sea surface temperatures has demonstrated a clear 11-year signal in the mean surface pressure over the Azores and corresponding sea surface temperature anomalies. The signal is consistent with a positive phase of the North Atlantic Oscillation (NAO) following a solar maximum which appears to involve complicated interactions between the stratosphere, troposphere and oceans that can amplify a small signal over a timescale of several years. The phase of the NAO is closely related to weather patterns over Europe and it has been suggested that the recent very cold winters in 2009/10 and 2010/11 were influenced by the very deep solar minimum that occured in 2009. It may therefore be possible to improve seasonal forecasts for Europe if we can improve understanding of the mechanisms for solar influence and adequately include them in forecast models. There are also similar regional-scale solar signals in the Pacific and Indian monsoon regions. This study will examine global observational data and compare with model simulations to better characterise the observations, determine how well models are able to simulate the signals and, through carefully designed model simulation experiments, determine the mechanisms that give rise to these signals so that they may be used to improve forecast models of the future. The project requires a good foundation in physical processes and will be best suited to someone with good mathematical and IT skills.

(17) Interaction of the Madden Julian Oscillation and Sudden Stratospheric Warmings

Prof Lesley Gray (Physics) and Dr Sana Mahmoud (Met Office)

The Madden Julian Oscillation (MJO) is the dominant mode of intra-seasonal (30-90 days) variability in the tropics. It consists of an eastward propagating large scale coupled pattern in circulation and tropical deep convection. Recent research has identified a link between certain phases of the MJO and the North Atlantic Oscillation (NAO) through Rossby wave generation and propagation from the tropics into the extra-tropics (Cassou, 2008; Lin et al., 2009). The stratosphere also has great potential as a source of additional predictability for medium and extended range weather forecasts. Several studies have demonstrated that during particularly dynamically active periods known as Stratospheric Sudden Warmings (SSW), tropospheric forecasts can be sensitive to the stratospheric evolution on timescales of ten days (Baldwin and Dunkerton, 2001). Observational and modelling studies have demonstrated that SSWs influence the tropospheric jets and can influence the phase of the NAO following an event (Wittman et al., 2004, Polvani and Kushner, 2004). Observational evidence suggests that there may be a connection between the MJO and SSWs (Garfinkel et al., 2012). This project aims to investigate the robustness of this key connection in both observations and in model simulations. A study of the interactions between the MJO, SSWs and the NAO will be performed with the aim to better determine the physical mechanisms behind the possible stratospheric / tropospheric pathways in the MJO-NAO connection and the frequency on which it occurs. The latest generation of Met Office coupled models will be used to examine the predictability and causality of the MJO-NAO connection. The project will be a CASE student partnership with the Met Office and outcomes of the study will feed through to the Met Office sub-seasonal to seasonal predictability forecast research. The project requires a good foundation in physical processes and will be best suited to someone with good mathematical and IT skills.

(18) What sets the strength of the Atlantic Meridional Overturning Circulation?

David Marshall and David Munday (Physics), Helen Johnson (Earth Sciences) and Sybren Drijfhout (University of Southampton)

The Atlantic Meridional Overturning Circulation (AMOC) is responsible for transporting about one Petawatt of heat northward and has a significant impact on the climate of northwest Europe. Climate model projections suggest that the AMOC is likely to weaken over the next century in response to anthropogenic climate change. Despite its importance, our understanding of what sets the strength of the AMOC remains limited. In this project, the student will use a combination of theoretical conceptual models, idealised numerical models and eddy-resolving circulation models to investigate the factors controlling the strength of the AMOC, and its relation to other major currents such as the Antarctic Circumpolar Current.