Student Conference in Complexity Science

Book of Abstracts
Earth System Complexity

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Earth System Complexity

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10:00 - 11:00 Earth System Complexity 1

Resilience of the Amazon rainforest under human impact

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In complex environmental systems such as the Amazon rainforest, it is often not feasible run ecosystem-scale experiments. Additionally, there will be always variables that cannot be fully controlled. Therefore, environmental scientists usually rely on simulation models, data analysis or a combination. Earth system simulation models can be seen as our best attempt to synthesize environmen- tal processes in a computer model under computational constraints but their complexity can make their output often difficult to interpret. Likewise, the idea that complex behaviour can emerge from a limited set of simple rules suggests that at least for some cases we do not need such advanced models to understand system behaviour. In this study, we make an attempt to analyse and model the core complexity of Amazon forest's vegetation dyanmics from a complex systems perspective. We start from recent insights in savanna ecosystem theory, that sees the local environment as in three possible stable tree cover states (forest, savanna or treeless). We estimate the bifurcation diagram from high-resolution remote-sensed tree cover data and merged remote sensed - gauge rainfall and find that human impact considerably affects the derived hysteresis. Finally, we set up a simple model with a fire component derived from the data. Unexpectedly, anthropogenic changes to fire regime tend to stabilise rather than destabilise the dynamics. Hence, it is rather deforestation and impact on vegetation growth that destabilises the rainforest.

Investigating Cenozoic climate change and carbon cycle conundrums using simple numerical models and analysis

David Armstrong-McKay, University of Southampton, UK (D.Armstrong-McKay@noc.soton.ac.uk)

Early warning signals are hypothesised to commonly precede critical transitions in various different complex systems, leading to the suggestion that climate data could in future be monitored to detect such signals before climatic 'tipping points' are reached. However, there are several potential problems with this approach. For example, the discovery of these signals may be strongly dependent on the parameters chosen when performing the statistical analysis, and not all transitions may produce early warning signals. Here we use palaeoclimate data to attempt to detect critical slowing down and other early warning signals prior to significant climate perturbations hypothesised to be the result of critical transitions such as the Eocene-Oligocene Transition, Eocene Hyperthermals and the mid-Miocene Climate Transition. We also use the same approach on 'quiet' data across periods without any known critical transitions occurring and also significantly vary the parameter choices in our analyses in order to investigate the possible prevalence of 'false positives' when using these methods.

Homeostasis in random ecosystems

Iain Weaver, University of Southampton, UK (isw1g10@soton.ac.uk)

The properties of random matrices are of broad interest to a range of fields. Indeed, their study owes its very existence to applications. In this work, we study the behaviour of an abstract ecosystem model, classifying the behaviour of model fixed points by analysing the properties of matrices of independent random variates.

14:00 - 15:40 Earth System Complexity 2

Predicting global ocean circulation from north-south pressure gradients

Edward Butler, University of Southampton, UK (e.d.butler@soton.ac.uk)

The Meridional Overturning Circulation (MOC) is a large-scale global circulation of water (and heat) throughout the World's ocean. It is an integral part of the climate system and is responsible for significant anomalous warming of the North Atlantic region. Despite the complexity of the global ocean system, numerous attempts have been made to scale the strength of the MOC, principally in the North Atlantic, with large-scale, basin-wide physical properties. In particular, it is a long-held idea in physical oceanography that the strength of the MOC scales with the north-south density gradient, notwithstanding the fact that steady-state meridional flow in geostrophic balance is, in fact, linked to east-west pressure gradients. We return to the theoretical principles underlying such a proposal and adopt an alternative relationship, linking overturning to twice depth-integrated density gradients between northern and southern latitudes. We then test the veracity of this proposed scaling on multiannual, decadal, centennial, and millennial timescales within the complex Nucleus for European Modelling of the Ocean (NEMO) model framework. We find that this simple scaling relationship captures the transient response of global ocean overturning remarkably well across multiple timescales, even modeling the highly nonlinear response observed in the deep ocean, and we discuss the implications of these results for our understanding of global ocean circulation and climate change.

Western boundary current dynamics - are they really that simple?

Ed Doddridge, University of Oxford, UK (Edward.Doddridge@magd.ox.ac.uk)

Western boundary currents form an important and extremely energetic part of ocean circulation. Despite their importance for local, regional and global climate very little is known about the fundamental dynamics of western boundary currents. The differences in vertical structure for velocity and temperature remain poorly explained. I will present the results of high-resolution modelling studies of western boundary currents in domains with idealised bathymetry. By analysing the vorticity dynamics we hope to elucidate the physical mechanisms that determine the vertical structure of western boundary currents.

Ekman's Demon: Ocean-atmosphere communication in climate models

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Coupled climate models of the ocean and atmosphere rely crucially on the depth of the oceanic mixed layer. This layer facilitates the complex conversation between the two, through exchanges of heat, gas and momentum and varies in depth between tens and hundreds of meters. Its extent sets the exchange of properties between the deep and surface ocean through "Ekman's demon", an emergent system property through which only winter watermasses penetrate to depth, removing factors such as carbon and heat from the surface. However, most ocean models fail to give a fair representation of the mixed layer. In the crucially important oceans around Antarctica the depth of this layer can be off by hundreds of meters. The best model representation of mixed layer depth is found in the NEMO model. Here we examine the mixed layer in observations and use the numerical NEMO model in resolutions from 1 degree to 1/12 degree to determine why. We conclude that the deep structure of the ocean is fundamentally important, a property which even low resolution models can readily simulate.

Shallow-water gaseohydrothermal plume study after massive eruption at Panarea, Aeolian Islands, Italy

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Marine water dynamics in the near field of a massive gas eruption near Panarea (Aeolian Islands volcanic arc, SE Tyrrhenian Sea) is described. ADCP current-meters were deployed during the paroxysmal phase in 2002 and 2003 a few meters from the degassing vent, recording day-long timeseries. Datasets were sorted to remove errors and select good quality ensembles over the entire water column. Standard deviation of error velocity was considered a proxy for inhomogeneous velocity fields over beams. Timeseries intervals had been selected when the basic ADCP assumptions were fulfilled and random errors minimized. Backscatter data were also processed to identify bubbles in the water column with the aim of locating bubble-free ensembles. Reliable timeseries are selected combining these data. Two possible scenarios have been described: firstly, a high dynamic situation with visible surface diverging rings of waves, entrainment on the lower part of the gas column, detrainment in the upper part and a stagnation line (SL) at mid depth where currents were close to zero and most of the gas bubbles spread laterally; secondly, a lower dynamic situation with water entraining into the gas plume at all depths and no surface rings of diverging waves. Reasons for these different dynamics may be ascribed to changes in gas fluxes (one order of magnitude higher in 2002). Description of SL is important to quantify its position in the water column and timing for entrainment-detrainment, and it can be measured by ADCP and calculated from models.

The wavey spin-up of an antarctic subpolar gyre

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The Antarctic shelf seas are of great climatic importance due to their vigorous interactions with the atmosphere and cryosphere, which influence continental deglaciation, global sea level, and the production of dense bottom waters. However, understanding of these interactions and their impacts is confounded by sea ice, which covers the region for much of the year. In particular, little is known about the local oceanic response to the recent changes in Antarctic freshwater discharge. Here, we use satellite measurements of sea surface height (SSH) during ice-free months and an ocean circulation model to show that over the last two decades (1992-2011) Antarctic coastal sea level has risen at least 2 ± 0.8 mm yr-1 above the regional mean south of 50°S, and that this signal is a steric adjustment to increased glacial melt from Antarctica. Our findings demonstrate the strength of the sea level response to accelerating Antarctic discharge, and expose a significant climatic perturbation to the cryospheric forcing of the Southern Ocean.