ABSTRACTS

Session 1: How important are biotic feedbacks for 21st century climate change?

Will the living planet save us from climate change?

Peter Cox
University of Exeter

Lead author email: p.m.cox@exeter.ac.uk

There is now a growing realisation that accurate prediction of future climate change relies just as much on taking account of links to the Earth's biosphere through its impacts on the chemical composition of the atmosphere, as it does on the modelling of physical climate processes. This evolution of climate models into "Earth System Models" is a key part of the motivation for the QUEST programme.

The paradigm shift is in large part due to James Lovelock, who boldly suggested that the Earth System is akin to a self-regulating organism, in which the living world (i.e. the biosphere) maintains the climate close to conditions optimal for the maintenance of life itself. Lovelock's "Gaia hypothesis" has led some to ask whether the living planet will save us from climate change. This question will be addressed by reference to the fascinating results that are now emerging from first generation Earth System Models.

Session 1: Oral 1-K

Observing the carbon cycle - climate feedback

Wolfgang Knorr
University of Bristol

Lead author email: wolfgang.knorr@bris.ac.uk

Energy production and land use change are the cause for anthropogenic carbon dioxide emissions that have been rising rapidly and are now over 7 GtC per year. Surprisingly, at the interdecadal time scales, the fraction of those emissions remaining in the atmosphere seems to have stayed remarkably constant at around 40% during the last 150 years. This contrasts with the predictions delivered by coupled and off-line terrestrial ecosystem models that the "airborne fraction" should eventually increase as a result of reduced CO_2 uptake by the terrestrial biosphere in response to warming. The question, therefore, is how to detect the possible beginning of this type of positive carbon cycle - climate feedback. This paper will discuss a simple explanation for the current constant airborne fraction, and will then present evidence from CO_2 measurements, remote sensing, and modelling that recently, the terrestrial biosphere did indeed show a reduced CO_2 uptake. Even though the period is short, it may give a hint towards which mechanism may eventually lead to sustained carbon cycle - climate feedback and an accelerated rise of atmospheric CO_2 concentrations.

Session 1: Oral 1-1

Quantifying carbon-cycle and climate feedbacks

Jonathan Gregory[1,2] Jones, C. D.[2]
[1] Walker Institute, University of Reading, [2]Met Office Hadley Centre, Exeter, UK

Lead author email: j.m.gregory@reading.ac.uk

When a radiative forcing is imposed on the climate system, for instance due to changes in atmospheric CO_2 concentration, the system responds in various ways which affect its radiative balance, such as changes in black-body cooling to space, surface albedo and cloudiness. These radiative terms jointly determine the steady-state temperature change for a given radiative forcing. When carbon dioxide is emitted into the atmosphere from combustion of fossil fuels, the carbon system is affected in various ways which lead to release or uptake of carbon in terrestrial reservoirs and the ocean, such as through changes in respiration, primary productivity and solubility. These processes jointly determine the change in CO_2 concentration. Some of them depend on climate change, some on CO_2 concentration. Climate and carbon constitute a coupled system, and their feedbacks can be expressed in formally similar ways. The coupled system determines the co-variation of temperature and CO_2 due to non-CO_2 forcings, such as insolation. The climate-carbon interaction can be viewed as a feedback either on the carbon system or on the climate system. The carbon system may be approximated as a steady state on multi-century timescales, but on decadal timescales it cannot; this suggests a need to find different metrics and experiments for quantifying its behaviour in the coming century.

Session 1: Oral 1-2

Evaluation of the terrestrial carbon cycle, future plant geography and climate-carbon cycle feedbacks using 5 Dynamic Global Vegetation Models (DGVM)

Stephen Sitch[1], C. Huntingford[2,] N. Gedney[1], P. E. Levy[3], M. Lomas[4], S. Piao[5], R. Betts[6], P. Ciais[5], P. Cox[7], P. Friedlingstein[5], C. D. Jones[6], I. C. Prentice[8], F. I. Woodward[4]

[1]Met Office, [2]CEH Wallingford, [3]CEH, Midlothian, [4]University of Sheffield, [5] IPSL/LSCE, [6]Met Office/University of Exeter, [7]University of Exeter, [8]QUEST/University of Bristol

Lead author email: stephen.sitch@metoffice.gov.uk

Five DGVMs are coupled to a fast “climate analogue model”, based on the Hadley Centre General Circulation Model (GCM), and run into the future for 4 Special Report Emission Scenarios (SRES); A1FI, A2, B1, B2. Under the more extreme projections of future environmental change the responses of the DGVMs diverge markedly. In particular, large uncertainties are associated with the response of tropical vegetation to drought and boreal ecosystems to elevated temperatures and changing soil moisture status.

The DGVMs show more divergence in their response to regional changes in climate than to increases in atmospheric CO_2 content. All models simulate a release of land carbon in response to climate, when physiological effects of elevated atmospheric CO_2 on plant production are not considered, implying a positive terrestrial climate-carbon cycle feedback. However the magnitude of this positive feedback varies markedly among DGVMs.

Session 1: Oral 1-3

Complex Mechanisms Dampen Terrestrial Carbon-Cycle Feedback to Climate Warming: Results from an Experimental Warming Study in Great Plains

Yiqi Luo, Xuhui Zhou, and Rebecca Sherry
University of Oklahoma

Lead author email: yluo@ou.edu

We have conducted two warming experiments in a Southern Great Plains prairie of USA to examine feedback processes of ecosystems to climate warming. We used infrared heaters to elevate ecosystem temperature by approximately 2.0 and 4.0°C, respectively, during the experimental period. Our results indicate that plant biomass growth increased by approximately 20% in the warmed plots in comparison to that in the control plots. The increased plant productivity resulted from extended length of growing seasons, increased nitrogen availability and use efficiency, and altered species composition. In particular, warming considerably increased C4 plant biomass and caused slight decreases in growth of C3 plants. Increased C4 biomass and litter production resulted in decreases in quality and decomposition of bulk litter at the ecosystem scale, leading to an increase in litter mass at the soil surface. Soil respiration did not significantly change in the first two years but increased by 8-10% in the last several years, largely due to increased root respiration and litter pool sizes. We did not observe much change in soil C content under warming, indicating that increased plant biomass counterbalanced the increased carbon loss via respiration. Overall, our data do not support the notion that warming stimulation of soil respiration is the major feedback process to climate change.

Session 1: Oral 1-4

The sensitivity of the HadCM3 Amazon "dieback" result to climatic forcings from a HadCM3 "perturbed physics" ensemble and of improved descriptions of both vegetation dynamics and light interception.

Chris Huntingford[1] and Rosie Fisher[2],
[1]Centre for Ecology and Hydrology, [2]University of Sheffield

Lead author email: chg@ceh.ac.uk

Simulations with the HadCM3 GCM, extended to include a coupled climate-carbon cycle model, have predicted a rapid decline in vegetation cover over Amazonia from around 2050 onwards (and for a "business as usual" emissions scenario). Here we investigate the robustness of these predictions to uncertainty in both the land surface model, and the climatic predictions themselves. Three sources of model uncertainty are investigated using IMOGEN, an impacts tool that captures features of HADCM3 and incorporates a coupled carbon cycle. We analyse how the modelled vegetation cover in Amazonia responds to: (1) remaining uncertainty in GCM parameterisation and associated influence on predicted surface climate. This will use the perturbed-physics Hadley Centre QUMP (Quantifying Uncertainty in Model Predictions) ensembles, which are generated by altering key parameters within the GCM. We then (2) investigate the effect of changing the method of simulating vegetation dynamics from an area-based model (TRIFFID) to a quasi individual-based model (ED). Finally (3) we implement a multiple layer canopy light model and compare to the simple 'big leaf' approach used in earlier simulations. Within this framework, we can begin to place confidence limits on the likely rate and extent of

Amazon die-back, and identify the distribution of uncertainty between the atmospheric and land surface components of the GCM.

Session 1: Oral 1-5

Biogenic isoprene and 21st century atmospheric composition

Paul Young, P. J. Pyle, J. A. Zeng, G
University of Cambridge

paul.young@atm.ch.cam.ac.uk

Biogenic isoprene emissions are known to have a significant impact on atmospheric composition and oxidizing capacity. Future changes in the climate and atmospheric composition may lead to changes in the amount and location of isoprene emissions. This is coupled with expected changes in the emissions of reactive trace gases throughout this century, which will mean that the impact of isoprene will be different than it is at present. We have investigated some of the potential sensitivities of this biosphere-atmosphere feedback using a chemistry-climate model and a selection of isoprene emission "scenarios".

Session1: Oral 1-6

The coastal-ocean's role in the global carbon cycle: strategies for including shelf-seas in earth system models.

Jason Holt[1], Icarus Allen[2], Roger Proctor[1], Sarah Wakelin[1], Sylvain Michel[1], Graham Tattersall[1], Jerry Blackford[2], Mike Ashworth[3], Katy Lewis[2]
[1]POL, [2]PML, [3]CCLRC

Lead author email: jholt@pol.ac.uk

Shelf seas can be regions of exceptionally high biological production and also mediate the transport of material from the land to the open oceans. These factors lend them a crucial role in the earth system. Work in the CASIX project has explored the air-sea exchange of CO_2 on the NW European shelf on inter-annual time scales using the POLCOMS-ERSEM model. One of the challenges faced by MARQUEST is how to upscale these model experiments to shelf seas around the globe, to quantify the role of the coastal-ocean in the global carbon cycle, including possible feedback mechanisms. The computational resource required for the coastal-ocean is ~70 times that of an open ocean model of comparable resolution. In this work we explore the strategies available for including shallow seas in earth systems models: ranging from direct high-resolution simulation, to systematic nesting (as underway in the GCOMS project) and highly parameterised representations.

Session 1: Oral 1-7

Contribution of the ocean to the increase in atmospheric CO_2 growth rate

Corinne Le Quéré
University of East Anglia and British Antarctic Survey

Lead author email: c.lequere@uea.ac.uk

Observations of atmospheric CO_2 growth rate are difficult to interpret because of the presence of large interannual variability which mask potential trends. I will present a recent analysis by the Global Carbon Project which highlights a positive trend in the airborne fraction (the fraction of the CO_2 emissions which remains in the atmosphere), accompanied by a decrease in the fossil fuel intensity and a weakening of both the ocean and land CO_2 sinks. Observations and models attribute the weakening of the ocean CO_2 sink to the intensification of the Southern ocean winds, which enhanced the ventilation of natural carbon-rich waters. The ocean outgas of its natural carbon suggests that atmospheric CO_2 would stabilize at a higher level than foreseen on a multi-century time-scale. I will discuss this observed feedback and our ongoing efforts within MarQUEST to explore further feedbacks between marine ecosystem and climate.

Session 1: Oral 1-8

Dynamics of coupled systems with phytoplankton and grazers: building up complexity in ocean biogeochemistry modelling

Bablu Sinha and Tom Anderson
National Oceanography Centre

Lead author email: bs@noc.soton.ac.uk

Choosing an appropriate level of complexity in marine ecosystem models is a major issue confronting the modelling community given the diversity of life in the oceans. We are confronting this issue by comparing the results of a complex model that incorporates five plankton functional types (PFTs) and multiple elements (P, C, Fe, and Si) to stripped-down (simpler) versions of the same model (the simplest with a single compartment for each of nutrient, phytoplankton, zooplankton and detritus). In each case, the models are embedded in a global general circulation model (GCM) of the ocean, OCCAM. A comparison of mean bulk properties (primary production, biomass, export) between the different versions will be shown. Model predictions for geographical distributions of different PFTs will also be presented and compared with results obtained elsewhere (UEA) when running the PFT model in a different physical GCM.

Session 1: Oral 1-9

Ozone deposition processes at the surface its role in the Earth system

Mhairi Coyle and Nemitz, E
CEH Edinburgh

Lead author email: mcoy@ceh.ac.uk

Although tropospheric ozone is a natural constituent of the troposphere, man-made emissions of NO_x and VOCs have led to an increase in concentrations globally. Ozone plays an important role in the Earth System, e.g. by (i) damaging vegetation and changing biodiversity, (ii) changing stomatal functioning, (iii) modifying the oxidation potential of the atmosphere and (iv) by acting as a greenhouse gas. Dry deposition of ozone to terrestrial surfaces governs its potential to cause damage and provides an important atmospheric sink. An increasing number of ozone flux measurements indicate that dry deposition rates depend on canopy temperature and wetness as well as radiation, and thus respond to global change. The current understanding of ozone surface deposition processes is described, together with its feedback on atmospheric concentrations and vegetation.

Session 1: Oral 1-10

Session 2: How are climate and atmospheric composition regulated on timescales of up to a million years?

Understanding global biogeochemical cycles on a glacial/interglacial timescale: what have we overlooked?

F. Alayne Street-Perrott[1], Barker, P.A.[2]
[1]*University of Wales Swansea,* [2]*Lancaster University*

Lead author email: f.a.street-perrott@swan.ac.uk

Over the last 650,000 years, atmospheric CO_2 has varied naturally between ~300 ppmv in interglacials and 180 ppmv in glacials (Siegenthaler et al. 2005). Because total land biomass decreased during glacials, most hypotheses to explain multi-millennial variations in the carbon cycle have focussed on the physics, chemistry or biology of the oceans. Two exceptions are Broecker's (1982) hypothesis that P was remobilised from the continental shelves during sea-level lowstands, and recent investigations of Fe fertilization of marine ecosystems by aeolian dust. Several isotopic and geochemical-modelling studies have concluded that glacial/interglacial variations in chemical weathering were negligible, thereby discouraging scrutiny of the links between orbital forcing, terrestrial biogeochemical cycling and nutrient fluxes to the oceans. We argue that continental biota and nutrient storages played a significant role in the global biogeochemical cycles of Si and P, through processes such as biological weathering, soil formation, erosion, sedimentation and biomass burning.

Session 2: 2-K

Variability in Tropical Circulation, Climate and the Hydrological Cycle: Recent Results

Peter G. Baines
University of Bristol (QUEST Visiting Scientist) and University of Melbourne

Lead author email: p.baines@unimelb.edu.au

Water is essential for most forms of life on the planet, and is also an important component of the atmospheric circulation. In particular, the Hadley circulation has a complex zonal structure which is largely dependent on the distribution of tropical rainfall. Recent observed changes in climate in tropical and mid-latitudes on the decadal time scale may be linked to changes in this tropical rainfall distribution. Observations and mechanisms of these changes will be described, including results based on TRMM satellite data and the example of the late 1960s global climate shift.

Session 2: Oral 2-1

The Southern Ocean and the enigmatic glacial-interglacial carbon cycle.

Agatha De Boer[1], Watson, A. J[1], Edwards, N. R[2]
University of East Anglia[1], Open University[2]

Lead author email: a.deboer@uea.ac.uk

Earlier hypotheses for glacial CO2 update, including the ideas of an increased iron dust supply and extended sea-ice coverage, has come short of explaining the full 100ppmv difference between glacial and modern pre-industrial atmospheric CO2 concentrations. Current thought is that an altered ocean circulation during the glacial acted to reduce outgassing of CO2 in the Southern Ocean. Suggested physical mechanisms responsible for the changed circulation are 1) reduced and equatorward-shifted westerly winds, 2) increased winter stratification due to colder ocean temperatures, and 3) reduced buoyancy input into the Southern Ocean, inhibiting upwelling of deep water there. We discuss these options and show recent work done to test them.

Session 2: Oral 2-2

Global change during the earliest Eocene: a geologic tutorial on the long-term consequences of catastrophic CO_2 release

Andy Ridgwell
University of Bristol

Lead author email: andy@seao2.org

Terrestrial and marine deposits from the early Cenozoic record a 55 million year old transient warming of the Earth's surface, dubbed the 'Paleocene/Eocene Thermal Maximum' (PETM). The occurrence of a prominent carbon isotopic excursion indicates massive release to the ocean and atmosphere of CO_2 and/or CH_4, thought to be similar in magnitude to current fossil fuel reserves. The PETM thus represents a compelling analogue candidate for future greenhouse gas driven global change. In particular, understanding this event could provide us with invaluable insights into key mechanisms of feedback between climate and global carbon cycling as well as what the long-term impacts of surface ocean 'acidification' on calcifying plankton and animals might be. Here I discuss the application of an Earth system model (GENIE-1) to the interpretation of the marine geologic record of the PETM.

Session 2: Oral 2-3

Using the past to constrain climate sensitivity: a review

Tamsin L. Edwards
University of Bristol

Lead author email: tamsin.edwards@bristol.ac.uk

Climate sensitivity is a simple measure of global warming, defined as the change in global mean equilibrium temperature after a doubling of atmospheric CO2 concentration. In 1979, the range of climate sensitivity was estimated to be 1.5-4.5K (Charney, 1979). Since then there have been many attempts to constrain the range with climate data, alone or in conjunction with models: the majority of studies use data from the instrumental period (post-1850) but some use palaeoclimate data instead. Although progress has been made in quantifying the uncertainty in climate sensitivity, the range has not been narrowed. Here we review attempts to constrain climate sensitivity using palaeoclimate data and describe a new approach being developed within PalaeoQUMP, a project in QUEST Theme 2.

Session 2: Oral 2-4

Linking glacial and future climates through an ensemble of GCM simulations

J.C.Hargreaves[1], A.Abe-Ouchi[1,2], J.D.Annan[1]
[1]FRCGC
[2]CCSR
Lead author email: jules@jamstec.go.jp

Palaeoclimate simulations provide an opportunity to validate model performance under substantially different conditions to the modern climate. The last glacial maximum (LGM) has long been recognised as a time which may provide useful information for inferring future climate changes because it is the most recent time when forcings, and the climate state itself, were significantly different from the modern era.

Here we consider a large perturbed-parameter ensemble from the MIROC3.2 GCM. We broaden the scope of previous work, by considering not only annual average temperatures, but look more broadly at the zonal variation, the effects of land and ocean and also the seasonal variations. We also further explore the value of the LGM climate for estimating climate sensitivity.

Our results add support to the suggestion that LGM data from the Antarctic and Tropics may be particularly useful, while further evidence of an asymmetrical response to changing greenhouse gas levels indicates a possible area for concentrating investigations with a wider range of models.

Session 2: Oral 2-5

Ice core records from the Arctic and the Antarctic: Similarities and differences

Jørgen Peder Steffensen
Niels Bohr Institute Copenhagen

Lead author email: jps@gfy.ku.dk

Deep ice cores from Greenland tell a detailed climate story on the past 125,000 years. This story is not completely the same as told by Antarctic deep ice cores. I my presentation I will discuss what can be learned from a detailed comparison. In Greenland ice cores it is possible to date climate events with a very high precision. This dating can be transferred to Antarctic records and the result is an unparalleled picture of the dynamics of the "bipolar see-saw" during the last glaciation. In the North Atlantic region the "bipolar see-saw" caused several abrupt climatic shifts in excess of 10 degrees temperature change in less then 50 years. This International Polar Year a new deep drilling in Greenland aims to obtain a complete record of the last interglacial, the Eemian, to investigate whether a "bipolar see-saw" type climate variation also existed during this interglacial. The Eemian was several degrees warmer than today so studies of this period may serve as an analogue to a possible future with global warming.

Session 2: Oral 2-6

Methane and nitrous oxide in the ice core record

Eric Wolff[1] and Renato Spahni[2]
[1]British Antarctic Survey, [2]University of Bern

Lead author email: ewwo@bas.ac.uk

Polar ice cores contain, in trapped air bubbles, our only directly measured archive of the concentrations of stable atmospheric gases. During the industrial period the concentration of methane in the atmosphere has risen far outside the range experienced in the previous 650,000 years; nitrous oxide is also elevated above its natural levels. There is controversy about whether changes in the pre-industrial Holocene are natural or anthropogenic in origin. Changes in wetland emissions are generally cited as the main cause of the large glacial-interglacial change in methane. However, changing sinks must also be considered, and the impact of possible newly described sources evaluated. Recent isotopic data appear to finally rule out any major impact of clathrate releases on methane at these timescales. Any explanation must take into account that, at the rapid Dansgaard-Oeschger warmings of the last glacial period, methane rose by around half its glacial-interglacial range in only a few decades. The recent EPICA Dome C record shows that methane tracked climate over the last 650,000 years, with lower methane concentrations in cooler interglacials. Nitrous oxide also shows Dansgaard-Oeschger and glacial-interglacial periodicity, but the pattern is less clear.

Session 2: Oral 2-7

Abrupt climate change and the carbon isotope composition of atmospheric methane

Jed O. Kaplan[1], J.R., Melton[2], P. Koehler[3],
[1]Swiss Federal Institute for Forest Snow and Landscape Research, [2]University of Victoria, Canada, [3]Helmholtz Centre for Polar and Marine Research, Germany

Lead author email: jed.kaplan@wsl.ch

Recent measurement of ice core $\partial^{13}C$-CH_4 and deconvolution of the global CH_4 budget during abrupt climate change events has led to a widespread speculation regarding the mechanisms behind observed rapid changes in atmospheric CH_4 concentrations. Using a paleoclimate scenario from an intermediate complexity climate model and a dynamic global vegetation model, we simulate changes in the magnitude and carbon isotope composition of CH_4 emitted from wetlands and fires. In a control scenario, global wetland CH_4 emissions are dominated by the tropics. During full glacial climate conditions of low sea level, tropical continental shelves supported wetland areas larger than those at present. Preliminary results indicate that any shift in the carbon isotope ratio of the CH_4 forming substrate due to changing vegetation composition may have been offset by the effect of warmer temperatures on the fractionation between substrate and CH_4. These results may partially explain why observed $\partial^{13}C$-CH_4 appears stable even at times of rapidly changing atmospheric CH_4 concentrations, and help in ice-core based deconvolution of the atmospheric CH_4 record.

Session 2: Oral 2-8

Antarctic link to deep flow speed variation during MIS 3 in the NW Atlantic

Babette Hoogakker[1], McCave, I.N.[1], Vautravers, M.J.[2],
[1]University of Cambridge [2]British Antarctic Survey

Lead author email: bhoo03@esc.cam.ac.uk

A reconstruction of bottom flow vigour, using the mean grain size of the sortable silt, at Blake Outer Ridge (ODP 1060, 3481 m), suggests a complex pattern of variability of flow vigour of the North Atlantic's deep western boundary undercurrent during Marine Isotope Stage 3. 'Slow events' of reduced flow vigour are observed that appear uncorrelated to Greenland climate variability but can instead be linked to the warming phases of Antarctic Warm Events. The connection between 'slow events' and Antarctic warmings suggests either a reduction in the volume flux of Southern Source Waters and/or its density was reduced giving a smaller density contrast and weaker geostrophic flow. These results do not show the expected pattern if northern convective activity controlled deep flow. Instead it seems that Dansgaard/Oeschger cycles were associated with a mode of MOC variation involving perturbations of only the shallow Glacial Gulf Stream-Glacial Northern Source Intermediate Water cell.

Session 2: Oral 2-9

The Glacial-Interglacial North Atlantic Deep Water paradigm tested

Jimin Yu, Harry Elderfield
University of Cambridge

Lead author email: he101@esc.cam.ac.uk

It is generally thought that the production of North Atlantic Deep Water (NADW) decreased, possibly dramatically, during glacial periods and that NADW, which currently occupies the deep Atlantic, occurred as a nutrient-depleted water mass (Glacial North Atlantic Intermediate Water) limited to depths shallower than about 2000 m with no contribution from the Norwegian-Greenland Sea. Below 2000m, nutrient-depleted NADW was replaced by nutrient-rich water of southern origin. This view is based principally on proxy evidence from $\partial^{13}C$ and to a lesser extent Cd/Ca in benthic foraminifera. We have developed a new proxy using B/Ca in benthic foraminifera to estimate carbonate ion saturation state and generated a record of the changing hydrography of the North Atlantic since the Last Glacial Maximum. Combination of the new data with $\partial^{13}C$ shows that there are two sources contributing to the northern end member in the glacial Atlantic and that one source derives from the Norwegian-Greenland Sea.

Session 2: Oral 2-10

Palaeofires: observations and simulations of the impact of climate change on biomass burning

Mitch Power[1], Marlon, J.[2] Thonicke, K.[3] Ortiz, N.[3] Bartlein, P.[2] Harrison, S.[3] Mayle, F.[1]
University of Edinburgh, University of Oregon, University of Bristol
IGBP Paleofire FTI Participants

Lead author email: Mitch.Power@ed.ac.uk

Global fire regimes have responded to long-term changes in global climate since the last Glacial Maximum. Fire has a key role in ecosystem disturbance and global carbon emissions, and increasingly poses serious threats to human activities. To understand the climate and environmental controls on fire regimes in order to provide a more robust assessment of likely future changes, we have examined the linkages among climate, vegetation, fire, and human activities on millennial timescales by comparing evidence of changes in fire activity since the Last Glacial Maximum, and comparing these reconstructions with model simulations for three key time slices, 21,000, 6000, and 0 cal years BP. A newly created global sedimentary charcoal database was used to establish the long-term incidence of fire and the coupled vegetation-fire LPJ-SPITFIRE model was used to simulate spatial patterns in global fire regimes for these key time slices. Data-model comparisons provide a unique opportunity to identify the controls of changing fire regimes and evaluate the performance of models when simulating past and future fire activity.

Session 2: Oral 2-11

Session 3a: How much climate (change) is dangerous?

Abstracts Appendix

How much climate change is dangerous?

Nigel Arnell
University of Southampton

Lead author email: n.w.arnell@soton.ac.uk

Article 2 of the UN Framework Convention on Climate Change commits signatories to take actions to prevent dangerous anthropogenic interference with climate, but it is extremely difficult to define "dangerous". What is challenging for one sector or community may be unproblematic for another, and the "significance" of impact will depend on the metric used and the ability to adapt. However, in order to evaluate climate policy, and to inform global-scale adaptation actions, it is necessary to estimate the impacts of different magnitudes and rates of climate change across the globe. This presentation reviews the methods used to characterise impacts across the global domain, and examines the scientific and methodological issues that remain to be addressed. The presentation will not answer the question in the title….

Session 3: Oral 3-K

Climate prediction for robust policy making

Jo House[1], Sarah Cornell[1], Chris Huntingford[2], Wolfgang Knorr[1], Jason Lowe[3], Colin Prentice[1]
[1]QUEST, [2]CEH Wallingford, [3]Met Office,

Lead author email: jo.house@bris.ac.uk

Climate policy makers have, through the UNFCC, stated an aim to avoid "dangerous climate change". Towards this aim the EU has set a target of limiting global temperature rise to 2˚C above pre industrial levels. The Stern Review recently talked of the desire to stabilise greenhouse gas forcing at between 450 and 550 ppm CO_2 equivalent (we are currently at around 430 ppm CO_2e). Following this report the UK government this month set a target of reducing emissions to 60% of 1990 levels by 2050. The science in fact tells us that the eventual cuts would have to be far deeper than this to significantly reduce the probability of experiencing dangerous impacts. What does the science say is necessary to achieve stabilisation? Does it align with the policy decisions? What happens if we overshoot our emissions targets - can we still achieve the desired stabilisation levels? What happens if we overshoot our concentration or temperature targets? Can we come back down again over a reasonably short time period? What new science is necessary to inform policy-making? What can QUEST and the wider scientific community do to provide this evidence?

Session 3: Oral 3-1

Is a weakening of the Atlantic thermohaline circulation dangerous climate change?

Dr. Till Kuhlbrodt
Potsdam Institute for Climate Impact Research

Lead author email: kuhlbrodt@pik-potsdam.de

We present results from a recently completed project that carried out an Integrated Assessment of changes in the thermohaline circulation (THC). It consisted of a comprehensive impact analysis, an elicitation of experts' judgments, and an Integrated Assessment model. The impact analysis started with long-term model scenarios of global warming that display THC weakening. Then, impacts on climate, marine ecosystems, and vegetation were studied, using various models on different spatial scales. This included economic impacts in fishery and agriculture. Given the still large uncertainties about the THC, we conducted an extensive elicitation of experts' views on the THC and it's weakening. Finally, an Integrated Assessment model was developed to identify mitigation strategies - namely carbon emission paths - that avoid a THC weakening. We believe that the integrated approach followed here is helpful in determining whether a THC weakening is dangerous in the sense of Art. 2 UNFCCC.

Session 3: Oral 3-3

How Mitigation Stymies Adaptation

Roger Pielke Jr.
CIRES, Colorado

Lead author email: pielke@cires.colorado.edu

During the early policy discussions on climate change in the 1980s, adaptation was understood to be an important option for society. Yet for much of the past two decades the mere idea of adapting to climate change became problematic for those advocating emissions reductions, and was treated “with the same distaste that the religious right reserves for sex education in schools. That is, both constitute ethical compromises that in any case will only encourage dangerous experimentation with the undesired behaviour” (Thompson, M..et al 1998). Indeed, former US vice-president Al Gore forcefully declared his opposition to adaptation in 1992, explaining that it represented a “kind of laziness, an arrogant faith in our ability to react in time to save our skins”. But perspectives have changed. Adaptation is again seen as an essential part of climate policy alongside greenhouse-gas mitigation. Both the recent Stern Review on the Economics of Climate Change2 and the efforts of the Intergovernmental Panel on Climate Change3 demonstrate that adaptation is firmly back on the agenda.

Session 3: Oral 3-4

Dangerous climate change: Science as the evidence base for policy

Nicola Patmore
Defra

nicola.patmore@defra.gsi.gov.uk

The ultimate objective of the UNFCCC is to stabilise levels of greenhouse gases in the atmosphere at a level that will avoid dangerous anthropogenic interference with the climate system. This objective has raised several important questions for policy makers, most significantly: what is dangerous climate change? And what must we do to avoid it? This talk will look into what answering these crucial policy questions mean in terms of developing the scientific evidence basis, drawing insights from the Avoiding Dangerous Climate Change conference in Exeter in 2005 and the risk-based approaches employed by the Stern Review on the Economics of Climate Change.

Session 3: Oral 3-5

Session 3b: How much climate change can be avoided by managing the biosphere?

Trouble in Paradise: Linking Mitigation and Adaptation in the Caribbean Tourism Case

Fritz Reusswig
Potsdam Institute for Climate Impact Research (PIK)

Lead author email: fritz.reusswig@pik-potsdam.de

The climate change discourse has recently shifted from a scientific understanding paradigm (with climate scepticism and climate alarmism as two major positions) towards a social decision and action paradigm. As it has become widely accepted that humans change the global climate, the major questions are now: what is an acceptable (dangerous) window of change (kind, degree, timing), and what portfolio of economic, political and cultural measures have to be taken by whom, where, when and at what costs in order to find the optimal mix between adaptation and mitigation options. As it has become equally clear that the old distinction between mitigation as a task for the political North and adaptation as a challenge for the political South does no longer hold given the facts of climate change, interesting questions with regard to regional and policy mixes arise.

Session 3: Oral 3-6

Reducing emissions from deforestation, policy context, science needs

Johannes Ebeling
EcoSecurities

Lead author email: johannes.ebeling@ecosecurities.com

Tropical deforestation is the second largest source of global greenhouse gas emissions, contributing 25 percent to the total, and has recently become a focus of international climate policy initiatives. Among the variety of policy framework options, integrating avoiding deforestation into international carbon markets presents the largest mitigation potential. However, there is an urgent need for scientific input to facilitate an international agreement and realise the potential benefits. For example, the definition of national deforestation baselines against which to measure mitigation efforts will determine incentives for individual countries but it is questionable whether historical trends can be simply extrapolated. Reliable scenarios of the realistic potential to lower deforestation and related opportunity costs also do not exist, raising fears of an uncontrolled "flooding" of the carbon markets with cheap forestry credits. Furthermore, potential climate feedback exacerbating droughts and forest fires may make forestry-based climate mitigation non-permanent. Finally, degradation rather than outright forest conversion may release significant amounts of carbon but is difficult to quantify and may go unrecognised in schemes of avoided "deforestation".

Session 3: Oral 3-7

How much climate change can be avoided by managing the biosphere? The global contribution to mitigation from agriculture

Pete Smith
University of Aberdeen

Lead author email: pete.smith@abdn.ac.uk

Agricultural lands occupy about 40–50% of the Earth's land surface. Considering all gases, the global technical mitigation potential from agriculture (excluding fossil fuel offsets from biomass) by 2030 is estimated to be ~5500–6000 Mt CO_2-eq. yr-1. Economic potentials are estimated to be 1500–1600, 2500–2700, and 4000–4300 Mt CO2-eq. yr-1 at carbon prices of up to 20, 50 and 100 US$ t CO2-eq.-1, respectively. About 70% of the potential lies in non-OECD/EIT countries, 20% in OECD countries and 10% for EIT countries. In addition, agriculture can supply feed-stocks for bio-energy. The economic mitigation potential for agricultural bio-energy in 2030 is estimated to be 70–1260, 560–2320 and 2720 Mt CO2-eq. yr-1 at prices up to 20, 50 and above 100 USD t CO2-eq.-1, respectively. These potentials represent mitigation of 5–90% of all other agricultural mitigation measures combined. An additional mitigation of 770Mt CO2-eq. yr-1 could be achieved by 2030 by improved energy efficiency in agriculture.

Session 3: Oral 3-8

Science needs for the UNFCC convention negotiations

Jim Penman
Defra

Jim.penman@defra.gsi.gov.uk

The availability and interpretation of scientific information continues to be a major factor in the UNFCCC negotiations. The presentation will discuss what the effect has been and what the current needs are.

Session 3: Oral 3-9

Session 4: Observing and Modelling the Earth System (and Earth System Atlas)

Phytoplankton functional types derived from global remotely sensed ocean colour data using a bio-optical approach

Jim Aiken, T. Hirata, N.J Hardman-Mountford, T. Smyth, J. Fishwick
CASIX, Plymouth Marine Laboratory

Lead author email: casix_dir@pml.ac.uk

An understanding of the functional role of plankton in aquatic ecosystems is crucial to quantifying and understanding the Earth system and its role in the regulation of climate. The use of taxonomic groups or functional types to represent ecosystem functioning is a practical strategy, used by models such as ERSEM (Blackford et al., 2004) and DGOM (Le Quéré et al., 2005). Data for the initiation or validation of ecosystem models with phytoplankton functional types (PFTs) are rare but the requirement is great. We present remotely sensed ocean colour data (SeaWiFS, MODIS, MERIS) interpreted in terms of PFTs using algorithms derived from in situ measurements of bio-optical relationships and characteristic properties (bio-optical traits) for phytoplankton populations dominated by key phytoplankton taxonomic groups.

Session 4: Oral 4-1

CARBO-OCEAN: towards a comprehensive mapping of atmosphere-ocean CO_2 exchanges

Andrew Watson and Ute Schuster
University of East Anglia and Carbo-Ocean project members

Lead author email: a.watson@uea.ac.uk

The North Atlantic Ocean is the most intense ocean sink region for atmospheric carbon dioxide, and is thought to take up ~0.4 PgC from the atmosphere each year. Inversion models suggest the sink is highly variable, but ocean carbon models mostly suggest little variation. Direct observations from instrumented commercial ships over the last 12 years suggest that the inverse models are right and the ocean carbon models wrong: a large (>50%) decadal variability, coupled to climatic signals such as the North Atlantic oscillation is seen, including a steep decrease from the mid-90s to the early 2000s. An observing system based on 5-6 commercial vessels has been in place under the EU Carbo-Ocean integrated project since 2005, and is now delivering maps of the uptake by the North Atlantic with seasonal time resolution. A powerful new constraint on the Northern hemisphere carbon budgets is thus obtained efficiently and cost-effectively. We are seeking a way to continue this observation beyond 2009, when the Carbo-Ocean project finishes.

Session 4: Oral 4-2

Diagnosing land-atmosphere feedbacks using remote sensing

Chris Taylor[1], R.J. Ellis[1], P.P. Harris[1], D.J. Parker[2]
[1]CEH Wallingford [2]University of Leeds

Lead author email: cmt@ceh.ac.uk

Soil moisture exerts a strong control on the partition of surface energy into sensible and latent heat fluxes. This affects the temperature and humidity of the lower atmosphere, which can in turn influence rainfall. Climate models show that this feedback process can play an important role in shaping the climate of some regions of the world. However, different models produce very different sensitivities to soil moisture, and observations at the scale of the feedback processes are lacking.
Combining remote sensing of the surface with cloud imagery, we show how soil moisture features influence the development of convective storms in the Sahel. Aircraft observations from the African Monsoon Multidisciplinary Analyses campaign during the 2006 wet season confirm our interpretation of the satellite data and provide understanding of the mechanisms responsible for the feedback.

Session 4: Oral 4-3

Assimilation into a coupled ocean physics-biology model

James While and Keith Haines
ESSC University of Reading

Lead author email: kh@mail.nerc-essc.ac.uk

The behaviour of numerical ocean biological models is constrained to a large degree by the underlying physical models in which they are embedded. Thus, better representations of the ocean physics should lead to improvements in the biological models. We present here results of twin experiments, where the semi-prognostic method has been used to assimilate water density data into coupled ocean physics-biology models. The results of these experiments lead, away from the equator, to improvements in the representations of both the ocean physics and biological processes. So far this method has been tested on two models: the HadCM3 coupled ocean-atmosphere model with HadOCC biology (a Nutrient, Phytoplankton, Zooplankton, and Detritus model) and the NEMO ocean model with PlankTOM5 biology (a Plankton Functional Type model). Results from both of these experiments will be presented.

Session 4: Oral 4-4

Modelling ocean circulation, climate and oxygen isotopes in the ocean over the last 120,000 years

Robert Marsh[1], E.J. Rohling[1], U. Krebs[1], H. Elderfield[2], P.J. Valdes[3], D. J. Lunt[3], T.M. Lenton[4]
[1]*National Oceanography Centre, Southampton,* [2]*University of Cambridge,* [3]*University of Bristol,* [4]*University of East Anglia*

Lead author email: rma@noc.soton.ac.uk

An Earth System Model of Intermediate Complexity (GENIE-1) is used to simulate the most recent glacial-interglacial cycle under prescribed orbital forcing, CO_2 concentration, and time-evolving ice sheets. Also included in the model is a basic scheme for forcing oxygen isotope ratios in the ocean, by changes in both climate (precipitation, evaporation, runoff) and ice sheets (growing, melting). Additionally accounted for are temperature-related changes in the fractionation of stable oxygen isotopes between water and calcite. Simulated oxygen isotope records are directly compared with measurements in the calcite extracted from deep-sea sediment cores. A series of experiments are designed to investigate the influence on simulated climate and oxygen isotope proxies of: (1) episodic meltwater pulses (MWPs) at both northern and southern high-latitudes; (2) thermohaline circulation stability, controlled by a prescribed fraction of Atlantic-Pacific moisture exchange. The method and results should inform simulations of the last deglaciation with a more complex model (GENIE-2).

Session 4: Oral 4-5

Palaeoclimatic reconstructions from the Quaternary loess: filling the 'gap' in the DIRTMAP model

Barbara Maher[1], H.M. Roberts[2], S.P. Harrison[3]
[1]*University of Lancaster,* [2]*University of Wales, Aberystwyth,* [3]*University of Bristol*

Lead author email: b.maher@lancs.ac.uk

Dust may play a key role in amplifying or modulating external climate forcing. So far, global dust models hindcast far-field dust deposition (i.e. ice core/marine records) reasonably well but are unable to capture terrestrial dust fluxes. To identify possibly key dust flux/climate linkages, regional (rather than global-scale) climate and dust modelling is required, validated by ground truthing against high-quality, temporally-resolved terrestrial dust flux and climate data. Such data are retrievable from the loess sequences of the Eurasian steppe, an area of loess deposition through the late Quaternary, where high-resolution chronological control and hence dust fluxes can be obtained via newly developed optically stimulated luminescence methods, and a validated magnetic climofunction can be used to quantify palaeo-rainfall variations. These data address directly the present 'gap' in the DIRTMAP model for this major loess belt, and the over-prediction of mid-continental desiccation in Eurasia in the mid-Holocene.

Session 4: Oral 4-6

Insights into the performance of climate and Earth-system models through comparison with palaeo-data.

Mary Edwards[1], H. Elderfield[2], S. Harrison[3], F. Mayle[4], A. Street-Perrott[5], C. Tzedakis[6], K. Willis[7], S. Baghwat[7], H. Binney[1], R. Fraser[5], B. Hoogaker[2], P. Oksanen[3], M. Power[4]
[1]University of Southampton, [2]University of Cambridge, [3]University of Bristol, [4]University of Edinburgh, [5]University of Swansea, [6]University of Leeds, [7]University of Oxford

Lead author email: M.E.Edwards@soton.ac.uk

The potential of components of the Earth system to generate significant feedbacks to global warming on timescales of decades to centuries for example, via changes in the nature of trace-gas sources and sinks requires that such responses be realistically modelled. Earth-system models simulate global climate while incorporating key aspects of the carbon cycle and atmospheric chemistry as well as physical land-atmosphere-ocean interactions. Their performance can be evaluated by challenging them to simulate past conditions using benchmarks constructed from palaeo-data. Polar ice-core trace-gas records form integrated global targets. Continental-scale gradients in past temperature and/or moisture and strong zonal differences also provide robust benchmarks. Data-model comparison studies to date using atmosphere-ocean general circulation models illustrate the utility of the approach and demonstrate, for example, i) complexity in land-surface feedbacks that influence monsoonal circulation, ii) the critical role of sea-surface temperature computations, iii) the importance of vegetation feedback to climate at high latitudes.

Session 4: Oral 4-7

The NERC Data GRID

Helen Snaith[1] Bryan Lawrence[2] and the NERC Data Grid Team[1,2,3,4,5]
[1]NOCS, [2]BADC, [3]BODC, [4]PML, [5]CCLRC

Lead author email: h.snaith@noc.soton.ac.uk

The NERC Data Grid (NDG) provides the infrastructure which allows users to: (i) Find data (ii) Explore what is known about datasets (iii) Access, manipulate and visualise data! Like the web, the NDG has no “owner” or “central control”; data remain with data providers - be they managed data centres in the UK or abroad, or semi-managed data archives in large research groups. The location of the data can be transparent to the user, while still allowing data providers to maintain their intellectual investment by controlling access.

The NDG team provides two community services which all NDG participants may avail themselves of: (i) The “NDG Discovery Service”: A database of discovery information, harvested from data providers around the world, together with a portal web-site and a set of web-services, for exploiting that database. (ii) The “NDG Vocabulary Service”: Databases of environmental thesauri and ontology tools to map between terms.

Session 4: Oral 4-8

Observing the Earth system – a policy perspective

Andy Shaw
Earth Observation Co-ordinator, Defra

andrew.shaw@defra.gsi.gov.uk

The Department for Environment, Food and Rural Affairs (Defra) is currently developing an Earth Observation (EO) strategy driven by:

- Increasing need for the best available evidence to underpin a range of policy issues;
- Departmental leadership in key international EO programme such as GMES and GEOSS.

The vision for the Department is to be an 'intelligent customer' for all forms of EO data and services that meet policy needs. But what does it mean to be an 'intelligent customer' in the area of Earth System Science? How do we identify and express policy requirements in a manner appropriate to the debate? How do these needs translate into action at national and international scale? How can the science community better respond to our needs to ensure we are always 'first with the best evidence'?

The talk will look at what is currently driving Defra policy priorities and how the EO strategy is seeking to ensure that Defra has access to the right capability both now and in the coming decades. This sets the context for deciding how best to view the Earth System Atlas and other aspects of EO science.

Session 4: Oral 4-9

The Earth System Atlas

Dork Sahagian and Stephen Reid
Lehigh University

Lead author email: dork.sahagian@lehigh.edu

There is a wealth of global data on the Earth System, yet access to and knowledge of data sources and their reliability and limitations is frequently a major stumbling block for scientists, policy makers, NGOs, educators and others. The need for an Earth System Atlas has been identified by the IGBP **(International Geosphere Biosphere Programme)**, which has developed a blueprint for the Atlas as both a key resource for scientists and a tool for communication and outreach.

The Earth System Atlas should provide scientists and other users with "one-stop shopping" for high-quality, peer-reviewed global data sets of important Earth System information, including physiography, ecosystems, climate and socio-economic variables, with information on past to future changes and drivers of change. It will use state-of-the-art visualization tools such as Google Earth, and will be accompanied by detailed information and targeted interfaces for scientific and non-scientific users.

Session 4: Oral 4-10