Workshop on CMIP5 Model Analysis and Scientific Plans for CMIP6

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SESSION 4: Thursday 22nd October (afternoon)

No	Abstract title	Presenter
1	Detection and attribution of observed changes in upper ocean stratification	**ANDREWS (OLIVER)**
2	The inconstancy of climate feedbacks and their dependence on SST patterns	**ANDREWS (TIMOTHY)**
3	Tropical controls on the CO_2 atmospheric growth rate in response to the historic El Modoki ENSO event (2010-2011): implications from carbon-climate feedbacks	**BOWMAN**
4	Analysis of the Future Emission Changes in Dust Aerosol in CMIP5 Models related to Bare Soil and Soil Moisture Conditions	**BYUN**
5	Climate sensitivity of the Brazilian Earth System Model, version 2.5	**CAPISTRANO**
6	Sensitivity and reversibility of monsoon systems to climate scenario forcing	**DOESCHER**
7	Moderate global warming triggers abrupt shifts in Earth System Models	**DRIJFHOUT**
8	Where does all the heat go?	**GLECKLER**
9	Decelerating ocean currents main cause of future West European summer circulation changes	**HAARSMA**
10	PMIP Last Millennium simulations and integrated analyses of reconstructions and multi-model simulations	**JUNGCLAUS**
11	Zooplankton control on future changes in marine biological carbon fluxes	**LE QUÉRÉ**
12	CMIP5 Climate Projections for North America and Development of a Process-Oriented Model Diagnostics Framework	**MALONEY**
13	Evaluation of the vegetation biomass in the CMIP5 models over the northern high-latitudes	**MAO**
14	A mechanism for ENSO amplitude changes under enhanced radiative forcing in CMIP5 models	**MARSLAND**
15	Ozone-mediated forcing of the Southern Annular Mode by greenhouse gases	**MORGENSTERN**
16	Regional Climate Variability and Change since 850 C.E.: Considering Internal Variability When Assessing Differences in CMIP5 past1000 Simulations	**OTTO-BLIESNER**
17	The Earth's Energy Budget across CMIP5 Models	**PORTMANN**
18	An assessment of methods for computing radiative forcing in climate models	**SODEN**
19	How should we represent terrestrial carbon-nitrogen cycle interactions in Earth system models?	**STOCKER**
20	Bidecadal North Atlantic ocean circulation variability controlled by timing of volcanic eruptions	**SWINGEDOUW**
21	Sensitivity of regional climate to global temperature and forcing	**TEBALDI**
22	Terrestrial Carbon-Nitrogen Interactions in the UK Earth System Model	**WILTSHIRE**

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Detection and attribution of observed changes in upper ocean stratification

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Abstract

A number of formal, regression-based detection and attribution studies have been conducted to quantify the contribution of external climate forcing to observed changes in ocean properties relative to internal variability. Published studies have focused mainly on identifying a detectable climate change signal within the historical records of ocean temperature, salinity and dissolved oxygen concentration. In addition to these trends, enhanced ocean density stratification has also been associated with intensified climate-driven warming and freshening of near surface waters. Ocean stratification has significant implications for ventilation processes, marine ecosystem productivity and biogeochemical cycles. However, whilst qualitative links have been made between the impact of historical and projected climate forcing on ocean stratification, the role of natural and anthropogenic processes remains uncertain. Here, we build upon recent work highlighting the utility of multivariate signals in the detection and attribution of climate change in the ocean. We synthesise co-located potential temperature and salinity measurements and assess the extent to which observed large-scale changes in ocean stratification between the 1950s and 2000s can be attributed to anthropogenic climate change as simulated by CMIP5 models. Specifically, a single fingerprint optimal detection analysis is applied to test the null hypothesis that observed changes in potential density gradient (between 50 and 250 m depth) at global and ocean basin scales are indistinguishable from internal climate noise as characterised by long (_˜ 1000 year) unforced piControl CMIP5 integrations. Model fingerprints are obtained from a suite of historical CMIP5 experiments, including both all external climate forcing factors (natural and anthropogenic, "historical") and natural forcings only ("historicalNat"), in order to separate the influence of natural external processes, such as changes in solar output and explosive volcanism, on observed trends. Regression of observed changes in potential density gradient against CMIP5 model response patterns using a Total Least Squares method provides scaling factors which quantify the detectability of climate signals within the historical record relative to internal noise. Additionally, calculated regression coefficients and residuals provide a rigorous test of model performance which accounts for the role of natural variability, towards improved projection of future changes in ocean dynamics. We show that the CMIP5 models examined have a systematic bias leading to underestimated stratification trends, particularly in the Southern Ocean. This bias could account for the underestimation by a factor of _˜ 2 - 4 of the historical changes in ocean deoxygenation in two CMIP5 models reported in our earlier studies, suggesting that future trends in deoxygenation could also be underestimated in current generation ESMs.

*Speaker

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Keywords: Detection and attribution, CMIP5, ocean stratification

The inconstancy of climate feedbacks and their dependence on SST patterns

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Abstract

Atmosphere-ocean and atmosphere-only CMIP5 experiments are used to show that the relationship between the global-mean net heat input to the climate system and the global-mean surface-air-temperature change is robustly nonlinear across models. The nonlinearity is shown to arise from a change in strength of climate feedbacks driven by an evolving pattern of surface warming – particularly the response of clouds to east-west shifts in the tropical Pacific warming pattern. The implication of inconstant feedbacks to the 20th century record and observed estimates of climate sensitivity are investigated using CMIP5 amip type experiments. It is found that the feedback response of AGCMs forced with observed SST patterns are consistent with observed estimates of climate sensitivity (_˜1-2K for doubling CO2), the implication being that observed estimates of climate sensitivity are biased low due to variability in SST warming patterns that produce large negative feedbacks during the satellite era. Targeted AGCM experiments – put forward for CFMIP3/CMIP6 – with idealised and observed SST warming patterns are piloted with the Hadley Centre GCMs to better understand the physical processes and mechanisms behind the dependence of radiative feedbacks on the SST patterns. It is found that in the Californian stratocumulus region there exists a strong positive thermodynamic cloud feedback response which is then modified by lower tropospheric stability change that depends on the SST pattern. The lower tropospheric stability change in response to 20th century patterns of SST change are large enough to offset the positive thermodynamic cloud feedback in this model.

Keywords: Climate feedbacks, Climate sensitivity, Cloud feedbacks, SST patterns, CMIP6, CFMIP3

*Speaker

Tropical controls on the CO2 atmospheric growth rate in response to the historic El Modoki ENSO event (2010-2011): implications from carbon-climate feedbacks

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Abstract

Interannual variations in the atmospheric growth rate of CO2 have been attributed to the tropical regions and have been applied as "emergent constraints" on carbon-climate projections. New satellite observations of solar induced fluorescence, xCO2, and CO offer a unique opportunity to evaluate processes in carbon-climate models at global scales. However, directly relating these quantities to surface exchange processes is challenging. One approach is to use carbon cycle data assimilation systems (CCDAS) to provide a carbon "reanalysis" for evaluating carbon-climate model simulations. The NASA Carbon Monitoring System Flux (CMS-Flux) project is a CCDAS that assimilates these satellite observations to provide a observationally constraint estimate of surface processes including NEE, NEP, GPP, biomass burning, respiration, fossil fuel, and ocean fluxes. We use this system to investigate the spatial drivers of the atmospheric CO2 growth rate and the processes controlling them over the exceptional ENSO event of 2010-2011. This period was marked by a marked shift from an El Nino to La Nina period resulting in historically high sea surface temperature anomalies in the tropical Atlantic leading to serious droughts in the Amazon. However, in 2011, unusual precipitation in Australia was linked to gross primary productivity anomalies in semi-arid regions. We use satellite observations of CO2, CO, and solar induced fluorescence assimilated into the NASA Carbon Monitoring System Project (CMS-Flux) to attribute the atmospheric growth rate to global, spatially resolved fluxes. This system is based upon observationally-constrained "bottom-up" estimates from the Fossil Fuel Data Assimilation System (FFDAS), the ECCO2-Darwin physical and biogeochemical adjoint ocean state estimation system, and CASA-GFED3 land-surface biogeochemical model. The system is used to compute regional tropical and extra-tropical fluxes and quantify the role of biomass burning and gross primary productivity in controlling those fluxes. The potential of CCDAS to evaluate carbon-climate feedbacks in CMIP5 and CMIP6 simulations will be explored.

*Speaker

Keywords: carbon, climate feedbacks, CMS, Flux, CO2 atmospheric growth rate

Analysis of the Future Emission Changes in Dust Aerosol in CMIP5 Models related to Bare Soil and Soil Moisture Conditions

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Abstract

Future changes in dust emission are studied using CMIP5 models. These models simulate climatological spatial distribution of dust emission over the observed major sources; Sahara desert to Aribia and Southwest Asia. Model estimates for the range of global dust emission simulation appear large in the quantity of dust produced and the amplitude of interannual varibility. Accoding to the ensemble mean in global annual emissions, projections of four RCPs do not have significant long-term trends in dust aerosol emissions at the end of 21st century. Meanwhile, over Northeast Asia, annual emissions are projected to decrease significanly in four RCPs. Reductions appear over the major sources of mineral dust. Seasonally, emission reduction in spring is distinct. In april and May, future changes with decreasing emission appear only in RCP4.5 with significance. Aerosol emission amount changes are related to changes in land surface property. We analyze future projection of soil moisture and bare soil area fraction. Regarding the projected decreasing trend in the annual emssion source region in four RCPs. Relatively, the effect of bare soil are change over the smission source apprears in some models and RCPs.

Keywords: future change, dust emission

*Speaker

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Climate sensitivity of the Brazilian Earth System Model, version 2.5

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Abstract

The Brazilian Earth System Model, coupled ocean-atmosphere (BESM-OA2.5) is the coupling of the CPTEC/INPE Atmospheric General Circulation Model (AGCM) and the GFDL/NOAA ocean model (MOM4p1). The piControl and Abrupt4xCO2 simulations were used in the study of BESM-OA2.5 climate sensitivity. The model has Equilibrium Climate Sensitivity (ECS) of 2.95 K and Cloud Radiative Effect (CRE) of -0.11 Wm-2K-1, which are comparable to other CMIP5 models. Furthermore, comparisons were made between the results of BESM-OA2.5 and other CMIP5 models, chosen arbitrarily as representative of the state of the art models in global climate modeling: NCAR's CCMS4, GFDL's ESM2M and the Hadley Centre's HadGEM-ES. The BESM-OA2.5 simulates the warming in the Arctic, a feature observed in CMIP5 models, but absent in the previous version of the model (BESM2.4). This result was the consequence of several improvements in BESM, namely the physical representation of the AGCM, especially in the parameterization of cloud microphysics and the formulation of wind, humidity and temperature near the surface. The temperature increase in the Arctic region exceeds 12C for all models evaluated in this study in a scenario of quadrupling the concentration of carbon dioxide (CO2) in the atmosphere. The BESM-OA2.5 and ESM2M models present a cooling region around 60N in the Atlantic Ocean, this is probably due to a same oceanic feature, possibly associated with the fact that both use the same ocean model. In addition, the BESM-OA2.5 shows agreement with other models on the location of maximum heating in different parts of the globe, such as: northern and southern Africa; center part of Australia; northeastern North America; northern and central South America; in the south of the Middle East; northern and central Asia; over the ocean near Antarctica. In the case of global precipitation, there is greater variability in the spatial patterns of increase/decrease of the total annual average precipitation in comparison to the temperature. The largest deviations are presented by HadGEM2 model, while BESM-OA2.5, CCSM4 and ESM2M present variations of the same order of magnitude among them. Moreover, the analyzed models feature a westward shifted South Pacific convergence zone (SPCZ) in a climate with 4xCO2, which means an increase (a decrease) of precipitation over the western (central and eastern) part of the South Pacific.

Keywords: Earth System, Climate Sensitivity, abrupt4xCO2

*Speaker

Sensitivity and reversibility of monsoon systems to climate scenario forcing

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Abstract

The poster targets the response and sensitivity of the South Asian monsoon and West African monsoon variability to the 190 year ramp-up/ramp-down RCP8.5 forcing as simulated by five ESMs models (EC-Earth, HadGEM2-ES, MPI-ESM, GFDL- ESM and IPSL). We are determining whether there are systematic changes in intensity, variability and/or preferred timing or geographical location of monsoons, as forcing is increased during the ramp-up period of the simulation. Systematic changes are then tested for reversibility in the ramp-down simulations. We also analyse whether there are any abrupt changes as the forcing progresses upwards and back down.
A primary finding is that inter-model spread between the models, both in terms of present-climate simulation of these phenomena and the response of the phenomena to GHG forcing, is still very large. This is particularly the case with respect to precipitation responses over Africa and South Asia. The South Asian monsoon rainfall appears to show a general tendency to increase as GHG forcing increases which largely reverses during the ramp-down period. This increase in rainfall with increasing GHG forcing (or SST) is opposite to what is suggested from large-scale dynamical measures of monsoon circulation, suggesting dynamical (circulation) and thermodynamic (increased surface evaporation following Clausius-Claperyon) effects may act against each other, with the thermodynamic effects inducing a slight increase in monsoon rainfall even though the large-scale circulation suggests a decrease.

Over West Africa, a large surface temperature response is seen through the ramp-up phase which is reversed during the ramp-down. Models have widely different simulated precipitation climatologies over West Africa and no clear signal is seen in terms of precipitation change across the models. Likewise, there is no consistent change in monsoon onset or duration across the 2 models analysed.
There is little evidence of abrupt or irreversible changes in any of the monsoon systems. Due to greatly differening simulations, improved models seem to be a pre-requisite before reliable estimates of future change in any of these three phenomena can be delivered.

Keywords: monsoon, tropics, forcing, multi, model, reversibility, abrupt

*Speaker

Moderate global warming triggers abrupt shifts in Earth System Models

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Abstract

Abrupt transitions of regional climate in response to the gradual rise in atmospheric greenhouse gas concentrations are notoriously difficult to foresee. Yet such events could be particularly challenging in view of the capacity required for society and ecosystems to adapt to them. We present the first systematic screening of the massive CMIP5 climate-model ensemble informing the recent IPCC report, and reveal evidence of 41 regional abrupt changes in the ocean, sea ice, snow cover, permafrost and terrestrial biosphere. Many of these events occur for global warming levels of less than 2 degrees, a threshold sometimes presented as a safe limit. While most models predict one or more such events, any specific occurrence typically appears in only a few models. We find no compelling evidence for a general relation between the overall number of abrupt shifts and the level of global warming. However, we do note that abrupt changes in ocean circulation occur more often for moderate warming (less than 2 degrees), whilst over land they occur more often for warming larger than 2 degrees.

Keywords: abrupt climate change, Earth System, RCPs, CMIP5 ensemble

*Speaker

Where does all the heat go?

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Abstract

The ocean stores over ninety per cent of the Earth's uptake of heat associated with greenhouse-gas-attributed warming. In this presentation, we use available in-situ based estimates of upper (0 – 700m), intermediate (700 – 2000m) and abyssal (2000m – bottom) global ocean heat content (OHC) changes to evaluate the CMIP5 Historical simulations. These results are presented in the context of the substantial observational, modeling, and experimental framework uncertainties. First steps toward a formal detection and attribution analysis of heat uptake in the deeper ocean are taken with a signal to noise analysis on multi-decadal time scales. Preliminary results will be shown to quantify sub-basin scale contributions (e.g., upper Tropical Pacific, intermediate North Atlantic, abyssal Southern Ocean) to the total heat uptake of the CMIP5 Historical simulations.

Keywords: Ocean warming, thermosteric sea level rise

*Speaker

Decelerating ocean currents main cause of future West European summer circulation changes

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Abstract

We use the CMIP5 climate model data base, sensitivity experiments with state-of-the-art climate models and observations to show that the projected higher summer pressures over the British Isles due to global warming are part of an atmospheric response to decelerating ocean currents, that cause a reduction in the associated northward heat transport, keeping the North Atlantic relatively cool. However, considerable inter-model differences in the projected weakening of the Atlantic meridional overturning circulation lead to a large spread in the projected wind changes. Hence, the uncertainty in the projected reduction of oceanic heat transport is the main source of uncertainty in projections of Western European climate change. Better-constrained projections of European summer climate thus rely heavily on a more realistic representation of ocean processes in climate models.

Keywords: Regional climate change, Atlantic Meridional Overturning Circulation, European summer climate

*Speaker

PMIP Last Millennium simulations and integrated analyses of reconstructions and multi-model simulations

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Abstract

The last millennium is the best-documented period of climate change in a multi-century time frame. Climate has varied considerably during the late Holocene and these changes left their traces in history (Medieval Climate Optimum, Little Ice Age). However, the relative magnitude of natural fluctuations due to internal variability of the Earth's climate system and to variations in the external forcings (sun, orbital, volcanic) and the present global warming, attributed to anthropogenic greenhouse gases, is still under debate. Simulations of the last millennium (LM) therefore directly address the first CMIP6 key scientific question "How does the Earth System respond to forcing". Investigating the response to (mainly) natural forcing under climatic background conditions not too different from today is crucial for an improved understanding of climate variability, circulation, and regional connectivity. LM simulations also allow assessing climate variability on decadal and longer scales and provide information on predictability under forced and unforced conditions. These are are crucial for near-term predictions and thus address the third CMIP5 scientific question "How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios". In providing in-depth model evaluation with respect to observations and paleoclimatic reconstructions, LM simulations serve to "understand origins and consequences of systematic model biases?", thus addressing also the second CMIP6 scientific question.
We summarize progress and main results from PMIP3/CMIP5 "past1000" simulations, focusing on the response to external forcing, and on the mutual assessment of reconstructed and simulated climate. The latter is based on a major effort by the PAGES community to reconstruct regional climate variations over the last 2000 years.

Main results are:

Significant correlations between the PAGES2K regional temperature reconstructions and climate model simulations suggest that, at multidecadal scales and above, regional temperatures respond to external forcing. The inter-regional correlations were shown to be lower in the reconstructions than within the models' world, the latter evidencing a more homogeneous spatial temperature response.

Reconstructions of modes of atmosphere and ocean variability such as PDO, ENSO, IPO,

*Speaker

PNA, NAO, SAM or the gyre system in the North Atlantic were presented. In most cases, they show very limited resemblance to their simulated counterparts, suggesting an overall lack of evidence for a direct external forcing imprint on many modes. Concerning reconstructed modes a remaining issue is the low agreement in the available reconstructions of some of the modes. Such inconsistencies may reflect large spatial changes in the positions of the centers of action that are not captured with index definitions based on fixed locations or eigenvector approaches.
The specific fingerprints of volcanic solar and anthropogenic contributions were analyzed from the perspective of various methodologies. Approaches to apply advanced statistical methods were discussed. The participants identified opportunities in integrated model-data analyses beyond direct comparison, such as process-based studies and model-guided mode definition or proxy-site selection.

Keywords: climate variability, volcanic forcing, teleconnections and circulation regimes

Zooplankton control on future changes in marine biological carbon fluxes

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Abstract

Global ocean biogeochemistry models currently used in climate change projections represent marine ecosystems in a highly simplified way. In order to explore the role of ecosystem dynamics in a changing environment, we developed a model (PlankTOM10) based on the representation of ten plankton functional types (PFTs), including three types of zooplankton and bacteria (Le Quéré et al., 2015). PlankTOM10 is coupled to the NEMO physical model and forced by observed meteorological fields from ECMWF over recent decades. In our model, the largest zooplankton – the macrozooplankton (represented as crustaceans) – has a predominant role in controlling the phytoplankton biomass, and hence the biological productivity and associated carbon fluxes. Improving the representation of zooplankton dynamics corrected the high Southern Ocean summer Chlorophyll bias that is present in most published models.
We forced this PlankTOM10-NEMO model combination with surface conditions from HadGEM2-ES RCP8.5 climate change projections during 1860-2100. We show that changes in macrozooplankton abundance are the primary driver for changes in primary production and associated biological carbon fluxes in our model. This is different from most published studies where changes in biological carbon fluxes are primarily explained through the direct influence of changes in light (through mixed-layer depth), temperature and nutrient supply on primary production. Our results suggest that changes in ecosystem dynamics in the ocean, particularly changes in trophic cascades due to the presence of slow-growing organisms, could play an important role in regulating carbon exchanges between the ocean and the atmosphere in a changing environment.

We conducted and present a range of sensitivity studies around this main result, including tests for the presence of pteropods (a pH-sensitive zooplankton) and for the effect of ocean acidification on ecosystem processes. We also compare the results with those of the CMIP5 models.

Reference:

Le Quéré, C., E. T. Buitenhuis, R. Moriarty, S. Alvain, O. Aumont, L. Bopp, S. Chollet, C. Enright, D. J. Franklin, R. J. Geider, S. P. Harrison, A. Hirst, S. Larsen, L. Legendre, T. Platt, I. C. Prentice, R. B. Rivkin, S. Sathyendranath, N. Stephens, M. Vogt, S. Sailley, and S. M. Vallina. Role of zooplankton dynamics for Southern Ocean biomass and global biogeochemical cycles. To be submitted to Biogeosciences in April 2015.

*Speaker

Keywords: Marine ecosystems, carbon fluxes, zooplankton dynamics

CMIP5 Climate Projections for North America and Development of a Process-Oriented Model Diagnostics Framework

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[5]NOAA – United States

Abstract

This presentation will first discuss multimodel ensemble CMIP5 projections of North American climate under the RCP8.5 emissions experiment. The NOAA MAPP CMIP5 Task Force conducted this assessment, which was an activity done in parallel with a broader effort to assess CMIP5 North American model performance in current climate. We will discuss projected changes in North American continental-scale temperature and the hydrologic cycle, extremes events, and storm tracks, as well as regional manifestations of these climate variables. Changes in eastern North Pacific and North Atlantic tropical cyclone activity and North American intraseasonal to decadal variability, including changes in teleconnections to other regions of the globe, will also be discussed. We will also present differences in projections from those of CMIP3, and highlight areas where substantial intermodel disagreement exists. These areas of disagreement include regional projections of changes in snow water equivalent, Arctic sea ice extent, regional precipitation magnitude and sign changes, extreme heat events, and Atlantic and east Pacific tropical cyclone activity. This assessment effort by the NOAA MAPP CMIP5 Task Force has inspired an ongoing activity to develop a common framework for process-oriented diagnostics of global models that provides process-level understanding of model deficiencies, assesses whether models are producing the correct simulation of climate for the right reasons, and aids parameterization improvements. A proposed effort among GFDL, NCAR, and the United States university community to develop a common software framework to aid process-oriented model development of CMIP and other global models will be presented. Potential collaborations between this effort and complementary diagnostic efforts under WGCM and EMBRACE will be discussed.

Keywords: North America climate projections, model bias, process, oriented diagnosis

*Speaker

Evaluation of the vegetation biomass in the CMIP5 models over the northern high-latitudes

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Abstract

Global vegetation biomass stores huge amounts of carbon and is thus important to the global carbon budget. For the past few decades, different observation-based estimates and modeling of biomass in the above- and below-ground vegetation compartments have been comprehensively conducted. However, uncertainties still exist, in particular for the simulation of biomass magnitude, tendency, and the response of biomass to climatic conditions and natural and human disturbances. In this study, we evaluate the simulated biomass of 16 coupled climate models with the latest gridded observations across northern-high latitudes. We find that the models generally underestimate the total biomass, which is mainly attributed to the underestimation of the roots biomass. The models, however, are roughly consistent with the observation-based data in terms of the high sensitivity of the biomass components to the changing precipitation across different biomes. The preliminary results demonstrate large uncertainties of the models in biomass estimation, and suggest potential improvements to the carbon allocation schemes and dynamic response mechanisms to the environmental conditions.

Keywords: Biomass, Evaluation, CMIP5, Carbon Allocation, Benchmarking

*Speaker

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A mechanism for ENSO amplitude changes under enhanced radiative forcing in CMIP5 models

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Abstract

A reliable estimate of the possible future changes in El Niño–Southern Oscillation (ENSO) due to global warming is important, yet the state-of-science climate models project diverse ENSO changes in global warming simulations. Here, we investigate the impact of enhanced radiative forcing, due to a CO2 concentration 4 times its pre-industrial value, on the simulated ENSO amplitudes in 19 CMIP5 climate models. We find that the amplitude of ENSO-related sea surface temperature (SST) variability increases in half of these models, and decreases in the other half, in response to the enhanced radiative forcing. The contrasting changes in ENSO amplitude in the two groups of models are predominantly forced by similar changes in the antecedent central equatorial Pacific zonal wind stress (ZWS) anomalies. We find a robust relationship between changes in this ZWS forcing of SST and the changes in the strength of ZWS–deep convection coupling in the central-western Pacific, indicating an important role for this coupling in ENSO amplitude changes. Indeed, the nature of changes in the coupling strength is shown to be a good indicator of whether the simulated ENSO amplitude increases or decreases under enhanced CO2 forcing. These results indicate that reducing the uncertainty in the simulated response of the deep convection-surface zonal wind coupling to global warming may also reduce the uncertainty in the projected ENSO amplitude changes in climate models.

Keywords: ENSO, CMIP5, climate change, radiative forcing, abrupt4xCO2, feedbacks

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†Speaker

Ozone-mediated forcing of the Southern Annular Mode by greenhouse gases

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Abstract

The Southern Annular Mode (SAM) is the leading mode of meteorological variability in the Southern Hemisphere; it essentially describes the variations of large-scale pressure differences between southern mid- and high latitudes. Its trends are of principal interest in Southern-Hemisphere climate change. Presently, it is thought that the mode is strengthening in all seasons; during summer, Antarctic stratospheric ozone depletion is driving a distinctive strengthening of the mode, whereas during the other seasons such strengthening is mostly due to forcing by long-lived greenhouse gases. However, chemical ozone depletion is not the only reason for ozone to change; stratospheric cooling associated with increasing greenhouse gases, acceleration of stratospheric overturning, and the chemical impacts of changing methane and nitrous oxide also affect ozone, particularly on multi-decadal time scales. Using an atmosphere-ocean climate model with optional stratosphere-troposphere interactive ozone chemistry, we assess on how these indirect, ozone-mediated effects affect the behaviour of the SAM in the Representative Concentration Pathway 6.0 scenario.
Using pairs of ensembles that include or exclude, respectively, ozone responses to the applied greenhouse gas (GHG) changes, we assess how important ozone feedbacks are in the development of the SAM under climate change. We assess several different ensembles of simulations: One has ozone-depleting substances fixed at their 1960 levels, and another has ozone fixed at 1960 levels. Both of these ensembles produce a strengthening of the SAM during summer, but in the ensemble with fixed ozone the trend is significantly larger than in the ensemble with fixed ozone-depleting substances. Further ensembles also include the effects of chemical ozone depletion and recovery; regression analysis of these confirms that the direct impacts of GHGs onto the SAM are offset by their indirect impacts mediated by ozone. The results imply that GHG-induced impacts on ozone should be considered adequately in setting up climate models. This can be done either online (by running a suitable interactive chemistry scheme) or off-line, by using an ozone climatology which was created making suitable assumptions about how ozone responds to GHG changes. By inference, ozone cannot be the same across a range of GHG scenarios.

Reference:

Morgenstern, O., G. Zeng, S. M. Dean, M. Joshi, N. L. Abraham, and A. Osprey (2014), Direct and ozone-mediated forcing of the Southern Annular Mode by greenhouse gases, Geophys. Res. Lett., 41, 9050–9057, doi:10.1002/2014GL062140.

*Speaker

Keywords: ozone, stratosphere, stratosphere, troposphere coupling, Southern Annular Mode, methane, nitrous oxide

Regional Climate Variability and Change since 850 C.E.: Considering Internal Variability When Assessing Differences in CMIP5 past1000 Simulations

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Abstract

The climate of the past millennium provides a baseline for understanding the background of natural climate variability upon which current anthropogenic changes are superimposed. As this period also contains high data density from proxy sources (e.g. ice cores, stalagmites, corals, tree rings, and sediments), it provides a unique opportunity for understanding not only global but regional-scale climate responses to natural forcing. The Northern Hemisphere temperature differences between the Medieval Climate Anomaly and Little Ice Age in the CMIP5 past1000 simulations assessed in the IPCC AR5 lie within the lower half of the reconstructed range of temperature changes and simulated regional temperature changes for the multi-model mean are quite muted as compared to the much richer regional responses in the data archives. Models also have not robustly captured an increased probability of El Nino events 1-2 years after major volcanic eruptions found in some ENSO proxies.
Questions still remain on how much of the past millennium climate variability is a forced signal and how much is associated with internal variability of the climate system. The CMIP5 modeling groups generally only submitted one past1000 simulation to the database making it difficult to separate structural differences between models in response to the forcings as compared to internal variability. Towards that end, an ensemble of simulations with the Community Earth System Model (CESM1) for the period 850-2005 (the CESM Last Millennium Ensemble, or CESM-LME) is now available to the community and will be submitted to the CMIP6 data archive. This 30-member ensemble set includes simulations forced with the transient evolution of solar intensity, volcanic emissions, greenhouse gases, aerosols, land use conditions, and orbital parameters, both together and individually, as well as two long control simulations.
In this presentation, we will assess regional climate changes in the CMIP5 past1000 simulations in light of this new ensemble of past1000 simulations with CESM1, and the implications for the analyses of the CMIP6 past1000 simulations. We will highlight in our comparison: the regional temperature changes, North American drought severity, and ENSO variability – among the CMIP5 past1000 simulations, within the CESM-LME, and as compared to proxy reconstructions. We will also consider the robustness of an El Nino – volcanic eruption signal using the CMIP5 and CESM-LME responses to the Tambora eruption.

*Speaker

Keywords: CMIP5 past1000 simulations, ensembles, forced responses versus internal variability, regional changes

The Earth's Energy Budget across CMIP5 Models

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Abstract

The earth's energy budget is analyzed across models in the CMIP5 archive and compared with observations. The total energy added to the system along with the fate of that energy is analyzed. The energy added to the system is related to the radiative forcing and is separated into individual forcing terms. The fate of the energy is dominated by changes in the ocean heat content, and the energy radiated to space due to a changing surface temperature. All of these terms are very sensitive to adjustments estimated from the pre-industrial control simulations. The adjustments (mean biases and drifts) are analyzed and their effect on the energy budgets is quantified. In some cases the adjustments are too large to allow meaningful computation of the budget terms. It is found that while the multi-model means of the terms in the earth's energy budgets are in reasonable agreement with observations there are substantial range across individual models.

Keywords: earth's energy budget, radiative focing, ocean heat content, model drifts

*Speaker

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An assessment of methods for computing radiative forcing in climate models

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Abstract

Because the radiative forcing is rarely computed separately when performing climate model simulations, several alternative methods have been developed to estimate both the instantaneous (or direct) radiative forcing and the adjusted radiative forcing. The adjusted forcing accounts for the radiative impact arising from the adjustment of climate variables to the instantaneous forcing, independent of any surface warming. Using climate model experiments performed for CMIP5, we find the adjusted forcing for a CO2 quadrupling ranges from roughly 5.5 to 9 W m-2 in current models. This range is shown to be consistent between different methods of estimating the adjusted radiative forcing. Decomposition using radiative kernels and offline double-call radiative transfer calculations suggests that this spread in adjusted forcing receives a substantial contribution (roughly 50%) from intermodel differences in the instantaneous component of the radiative forcing. This implies that intermodel differences in performing radiative transfer are responsible for substantial differences in radiative forcing and therefore in the projected climate response.

Keywords: radiative forcing, radiative adjustments

*Speaker

How should we represent terrestrial carbon-nitrogen cycle interactions in Earth system models?

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Abstract

The terrestrial carbon cycle-climate and carbon cycle-CO2 feedbacks are subject to large uncertainties. Recent addition of model realism by explicit representations of carbon-nitrogen cycle interactions has increased rather than decreased model spread and reflects the lack of understanding of the basic governing mechanisms. Earth system models take different approaches of implementing a set key mechanisms that determine how the degree of nitrogen (N) limitation affects the terrestrial C balance under increasing CO2 and changes in climate (e.g., control of biological N fixation, tissue stoichiometry, N losses). Recent empirical and theoretical advances are providing new insights that should be used to inform model development and constrain existing models. We present first results from a model of ecosystem C-N coupling based on the transactional costs of nutrient uptake and balanced tissue stoichiometry. This model successfully predicts (i) variations in leaf C:N stoichiometry across climate gradients and different CO2 levels, (ii) variations of plant C allocation to above- and below-ground tissues and export to the rhizosphere across soil fertility gradients, and (iii) a substantial and positive CO2 response of NPP also in N limited ecosystems. Constraining simulated responses of terrestrial biogeochemistry to basic environmental drivers with robust experimental findings bear great potential to reduce uncertainties carbon cycle climate feedbacks.

Keywords: terrestrial carbon cycle, nitrogen cycle, vegetation modelling

*Speaker

Bidecadal North Atlantic ocean circulation variability controlled by timing of volcanic eruptions

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Abstract

Understanding the mechanisms driving Atlantic Meridional Overturning Circulation (AMOC) decadal variability is critical for climate predictability in the Northern Hemisphere1. North Atlantic paleoclimate proxy records exhibit variance at the bidecadal scale but the drivers of this variability remain poorly understood. Here we show that the subset of CMIP5 historical simulations that produce such bidecadal variability exhibit a robust maximum in AMOC strength 15 years after the 1963 Agung eruption, followed by a second maximum in the 1990s, caused by the reset of a bidecadal cycle. The mechanisms at play involve salinity advection from lower latitudes and explain the timing of Great Salinity Anomalies observed in the North Atlantic in the 1970s and 1990s. Simulations as well as Greenland and Iceland paleoclimate records indicate that coherent bidecadal cycles were excited following five Agung-like volcanic eruptions during the last millennium. Over the last decades, climate simulations and a conceptual model reveal interference patterns associated with the timing of subsequent volcanic eruptions. Destructive interference caused by the Pinatubo 1991 eruption may have led to a stable AMOC in the 2000s. It is shown that the response to volcanoes account up to around half of the AMOC decadal variability during the 1975-2005 period. Our results imply a long-lasting impact of volcanic eruptions on AMOC, North Atlantic Ocean and climate, and potentially significant multi-decadal predictability following the next large volcanic eruption.

Keywords: climate dynamics, volcanic eruption, meridional overturning circulation, great salinity anomalies, last millennium variability, decadal predictability

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Sensitivity of regional climate to global temperature and forcing

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Abstract

The sensitivity of regional climate to global average radiative forcing and temperature change is important to setting global climate policy targets and designing scenarios. Setting effective policy targets requires an understanding of the consequences of exceeding them, even by small amounts, and effective design of sets of scenarios requires knowing how much different emissions, concentrations, or forcing needs to be to produce substantial differences in climate outcomes. Using CMIP5 climate model simulations, we quantify how differences in global average quantities relate to differences in both the extent and magnitude of climate outcomes at regional (250 –1250 km) scales. We show that differences of about 0.3C in global average temperature or 0.75 Wm-2 in global radiative forcing are required to generate statistically significant changes in regional annual average temperature over more than half of the Earth's land surface. A global difference of 0.8C is necessary to produce regional warming over half the land surface that is not only significant but reaches at last 1C. As much as 2.5 to 3C is required for a statistically significant change in regional annual average precipitation that is equally pervasive. Global average temperature change provides a better metric than radiative forcing for indicating differences in regional climate outcomes due to the path dependency of the effects of radiative forcing. For example, a difference in radiative forcing of 0.5 W/m2 can produce statistically significant differences in regional temperature over an area that ranges between 30% and 85% of the land surface, depending on the forcing pathway.

Keywords: Scenario Differences, Regional Climate Change, Global radiative forcing

*Speaker

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Terrestrial Carbon-Nitrogen Interactions in the UK Earth System Model

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Abstract

The availability of nitrogen has been shown to play an important role in the future terrestrial carbon sink. A lack of reactive Nitrogen will impact upon the ability for ecosystems to sequest carbon through CO2 fertilisation. In addition future warming will likely increase soil respiration and release Nitrogen enhancing plant growth in Nitrogen limited regions.

In this poster we show the development of a terrestrial coupled Carbon-Nitrogen cycle model for UKESM1. We also trial the C4MIP experiments protocol using the CN model coupled to the IMOGEN GCM analogue model. This modelling framework couples the complex land surface model with a simplified climate and ocean model. This approach allows for rapid first assessment of the role of biogeochemical feedbacks in a changing climate.

Keywords: carbon budgets, biogeochemical cycles

*Speaker