Workshop on CMIP5 Model Analysis and Scientific Plans for CMIP6

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SESSION 1: Wednesday 21st October (morning)

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Detecting dry periods in boreal forest zone with JSBACH biosphere model

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Abstract

Boreal forests are usually not soil moisture limited, but droughts that have substantial effects on forest growth and functioning do occur in boreal zone. Here we investigate dry spells during a 30-yr period (1981-2010) at the forested region of Finland, covering southern, middle and northern boreal zones. A set of drought indicators is adopted, including Standardised Precipitation Index (SPI), Standardised Precipitation-Evapotranspiration Index (SPEI), Soil Moisture Index (SMI) and Soil Moisture Anomaly (SMA). The sensitivity of these indicators to drought is compared both at site level and regionally, by using regional and site-specific soil moisture from JSBACH simulations together with gridded and in situ meteorological and soil moisture observations. The extent of drought by both area and intensity is estimated at regional level. Furthermore, the model capability to predict observed ecosystem drought is explored, focusing on the exceptionally dry summer in 2006 when the regional forest health observations are available for validation. Results show that the SMI calculated from JSBACH simulated soil moisture are capable to reflect severe droughts that have visible effects on forests, whereas SMA is too sensitive to meteorological drought.

Keywords: boreal forest, soil moisture, drougth indicators, extreme events

*Speaker

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A new empirically derived source parametrization for subgrid scale gravity waves based on precipitation in the Met Office GCM

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Abstract

Although many CMIP5 Earth system models (ESMs) adopted enhanced horizontal and vertical resolutions, none were able to represent the middle atmosphere momentum budget to an acceptable accuracy without including parametrizations for small-scale gravity waves. With the inclusion of non-orographic gravity wave schemes that can capture realistic budgets only in the zonal mean, the current generation of ESMs are able to represent key features such as the mean strength of polar night jets or period of the equatorial stratosphere quasi-biennial oscillation. Such models have a characteristic tendency, however, to underestimate tropical variability in the middle atmosphere with quasi-biennial and semi-annual oscillations that observational evidence suggests are too regular. Improved variability is relevant for detection and attribution of climate change signals against the 'natural' control background of the ESM and for prediction of mitigation and adaptation diagnostics that measure onset dates at which given thresholds of change are reached.
The non-orographic gravity wave scheme used in the Met Office general circulation model (GCM) currently has a source which is spatially and temporally invariant. However, various non-orographic sources for gravity waves in the atmosphere have been recognised, of which arguably the most important relates to convection. The inhomogeneity of convective activity both spatially and over time raises an obvious prospect that the representation of gravity wave sources generated by convection is a missing process that can help to address the lack of variability in the ESM. Hence, the ESM's physical realism may be improved by including a process neglected by many current state-of-the-art gravity wave parametrizations, and a better match to observations obtained in cases where this process occurs. Furthermore, in the climate change context, alterations in pattern and occurrence of convection arising from global warming in the future will have the potential to affect the generation of gravity waves and hence feedback on large-scale phenomena such as the Brewer-Dobson Circulation.

Results will be presented from simulations with a new simple parametrization of gravity wave sources within the Met Office model (MetUM) that is based on an empirical relationship with total precipitation. This was derived from analysis of results obtained from a convection-resolving configuration of the same model. The decision to base gravity wave sources on total precipitation derives from an awareness that the distinction between large-scale and convective production of precipitation is not unique and allows for wide variation

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between different GCMs when given cases are intercompared. As a result, although the new sources are greatly in evidence in convective regions of the tropics, they also feature in the extratropical storm-tracks and more broadly across the globe. This enables use of the new parametrization as a replacement which improves upon the previous invariant source without precluding the introduction of further source types (e.g. fronts and jets). Comparison of the model performance with and without the new source has potential to offer insight into the systematic model biases that arise from the use of invariant sources in the model and explore the consequences for model behaviour when the new sources are introduced.

Keywords: EMBRACE, gravity waves, GCM

Improvement foreseen for CMIP6 on the role of clouds and land-atmosphere coupling in mid-latitude continental summer warm biases and climate change amplification

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Abstract

Owing to a multi-model analyses taking advantage of the large suite of CMIP5 experiments, we show that over land, most state-of-the art climate models share a strong summertime warm bias in mid-latitude areas, especially in regions where the coupling between soil moisture and atmosphere is effective. The bias is more intense in AMIP simulations. Coupling with ocean results in a systematic cooling, probably linked to error compensations or model tuning but the bias structure is not distorted.

The most biased models overestimate solar incoming radiation, because of cloud deficit and have difficulty to sustain evaporation. These deficiencies are also involved in the spread of the summer temperature projections among models in the mid-latitudes; the models which simulate a higher-than-average warming over-estimate the present climate net shortwave radiation, which increases more-than-average in the future, in link with a decrease of cloudiness. In areas with soil moisture limited evaporation regimes, the most biased models also respond to climate change with a higher-than-average reduction of evaporative fraction and a larger warming, which is likely to be over-estimated.

To better understand the involved processes, we then focused on the Earth System Model (ESM) of Institut Pierre Simon Laplace (IPSL), where new developments in boundary layer/convection/clouds parametrizations as well as in the soil hydrology module have been done in preparation for CMIP6. Over the most warm biased areas in the previous ESM version, the bias is reduced as a result of both the atmospheric physics and soil hydrology improvements which is consistent with the previous findings. However, cold biases appeared in previously not biased areas. An analysis of the performance of the model is undergoing at

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the process-level in order to identify the remaining drawbacks. It makes use of instrumented site observations. An idealized climate change experiment based on AMIP and "AMIP+4K" protocols will be eventually conducted to test the impact of the bias reduction on the climate warming amplification. This work received support from the EMBRACE project.

Keywords: multi, modele analysis, temperature bias, soil, moisture atmosphere coupling, cloud radiative effect

Isolating the impacts of mixed layer subduction on the MOC in a CMIP5 model

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Abstract

Large differences in the Atlantic Meridional Overturning Circulation (AMOC) exhibited between the available ocean models pose problems as to how they can be interpreted for climate policy. We have developed a novel Lagrangian methodology for use with ocean models that enables a decomposition of the AMOC according to its source waters of subduction from the mixed layer of different geographical regions. The method is described and used to decompose the AMOC of the CNRM ocean model (a contributor to CMIP5) which is approximately 4.5 Sv too-weak at 26N compared to observations. Contributions from mixed layer subduction to the peak AMOC at 26N in the model are dominated by the Labrador Sea, which contributes approximately 7 Sv, but contributions from the Nordic seas, the Irminger Sea and the Rockall Basin are also important. These waters mostly originate where deep mixed layers border the topographic slopes of the subpolar gyre and Nordic seas. The too-weak model AMOC can be explained by weak model representations of the overflow and of Irminger Sea subduction. These are offset by the large Labrador Sea component, which is likely to be too strong as a result of unrealistically distributed and too-deep mixed layers near the shelf.

Keywords: AMOC, subduction, convection, mixed layer, Labrador Sea, overflow

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†Speaker

Evaluating soil moisture constraints on surface fluxes globally: CMIP5 vs. satellite observations of land surface temperature

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Abstract

Soil water plays a central role in both physical and biogeochemical processes in the Earth System. As soils dry out, evapotranspiration becomes water-limited ("stressed"), and both land surface temperature (LST) and sensible heat flux rise as a result. This change in surface behaviour during dry spells directly affects critical processes in both the land and the atmosphere. Soil water deficits are often a precursor in heat waves, and control where feedbacks on precipitation become significant. Global Climate Models (GCMs) disagree on where and how strongly the surface energy budget is limited by soil moisture. Model evaluation at the large-scale is a major challenge through lack of surface flux observations at an appropriate scale. Whilst a robust global observational dataset for evaluating surface fluxes within GCMs is still some way off, other remotely-sensed data do offer the potential to test how well land models simulate the critical hydrological control on surface fluxes. Satellite observations of LST provide indirect information about the surface energy partition at 1km resolution globally. We use a spatially and temporally aggregated diagnostic to describe the composite response of LST in rain-free periods in distinct climatic regions. The diagnostic is derived from MODIS LST observations and bias-corrected meteorological re-analyses, and compared against the outputs of historical climate simulations of seven models running the CMIP5 AMIP experiment. Dry spell events are stratified by antecedent precipitation and geographic regions to assess the sensitivity of surface warming rates to soil moisture levels at the onset of a dry spell in different climate regions. This methodology allows us to identify for which regions and seasons the simulated dry spell behaviour is inconsistent with observations. These model biases are likely to compromise seasonal forecasts and future climate projections.

Keywords: Global Climate Models, AMIP experiment, dry spells, surface warming

*Speaker

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Assessment of moisture transport and convergence fields in CMIP3 and CMIP5 Global Climate Models in South America

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Abstract

In a previous study we have seen that during austral summer though WCRP/CMIP5 Global Climate Models (GCMs) still underestimate precipitation mainly over southeastern South America, they did so to a lesser extent than those of CMIP3, and the dispersion among the new generation of models was smaller than in the previous one. Two sets of 5 GCMs from each intercomparison project have been previously selected based on their reasonable representation of precipitation over South America. The aim of this study is to assess if the improvements found in CMIP5 models to simulate summer precipitation are due to a better representation of moisture transport and convergence over South America. On the other hand, as CMIP5 models still present some difficulties in simulating summer precipitation, another objective is to evaluate if the deficiencies in simulating precipitation can be at least partially explain by an inadequate representation of the atmospheric circulation patterns. Consequently, principal component analysis is applied to austral summer monthly fields for the 1960–1999 period in order to identify the principal patterns of observed vertically integrated moisture transport and evaluate the ability of both sets of GCMs, individually and/or the ensembles, to represent them. Observed spatial patterns are calculated based on NCEP/NCAR reanalysis data. Moreover, we analyzed if the GCMs are able to represent the accumulated precipitation anomalies fields and the convergence and moisture transport associated only with the second and third principal modes.
The comparison of both ensembles' performance showed no significant changes in the skill of the art of CMIP5 regarding CMIP3 models in representing the main moisture transport patterns. Therefore, the better representation of summer precipitation in South America should be due to an improvement in simulating other processes/mechanisms not related to moisture transport and convergence. Besides, as moisture transport from tropics to extratropics is a key climate feature in South America and strongly determines both the spatial pattern and the sign of rainfall anomalies, its relatively erroneous representation explains at least partially the deficiencies of GCMs to estimate regional precipitation accurately. Thus, this analysis suggests a possible pathway to improve model rainfall representation in South

*Speaker

America.
Finally, we aim to advance in the understanding of the role of summer moisture convergence as a possible mechanism to explain precipitation projections. For this purpose, the same two subsets of 5 GCMs each were selected. The A1B scenario (for CMIP3) and the medium-low RCP4.5 (for CMIP5) were used to prepare climate change scenarios for the time slices 2020-2029, 2040-2049 and 2070-2079 with respect 1990-1999. Summer precipitation changes and future convergence projections were analyzed for three particular sub-regions within the continent. Results indicate that projected changes in moisture convergence could be attributed as one of the main mechanisms to explain precipitation future scenarios, especially in the last generation of models. In this sense, although this study did not assess the uncertainties associated with climate projections, it suggests a first attempt to understand the role of one of the mechanisms that explain part of the precipitation, such as moisture convergence.

Keywords: CMIP3, CMIP5, South America, moisture transport, precipitation

Improvements of Carbon Cycle Parameterizations in BNU-ESM

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Abstract

The BNU-ESM (Beijing Normal University Earth System Model) is developed to study mechanisms of ocean-atmosphere interactions, natural climate variability and carbon-climate feedbacks at interannual to interdecadal time scales. In the model version participated in CMIP5 (Coupled Model Intercomparison Program Phase 5), BNU-ESM adopted a dynamical global vegetation model based terrestrial carbon scheme which simulates vegetation distribution, species succession and related carbon pools change under climate change, and an idealized ocean biogeochemistry (iBGC) scheme which simulates two main representative biogeochemical processes: net biological uptake in the euphotic zone and regeneration of phosphate. Although some important carbon cycle features and carbon-climate feedback are well simulated in terms of global mean, many biases exist, such as large interannual variability of GPP (Gross Primary Production), underestimated northern high-latitude soil carbon stocks, incorrect representation in seasonal ocean carbon fluxes distribution. In the newly developed BNU-ESM, to reduce systematic biases in carbon cycle, several improvements are implemented or under evaluation. One important improvement in terrestrial carbon cycle scheme is adding nitrogen cycle and carbon-nitrogen interactions, which effectively reduces biases in terrestrial primary productions. The soil carbon scheme is also improved with considering vertical distribution, and simulates better carbon accumulations and dynamics of organic matter in permafrost. On marine carbon cycle, replacing the current iBGC scheme with a new dynamic marine ecosystem scheme is undergoing. The new marine ecosystem scheme has improved parameterizations of dissolved organic materials and detritus, a phytoplankton dynamic module that produces a variable of carbon to chlorophyll ratio, and refined nitrogen regeneration pathways.

Keywords: Earth system model, carbon cycle, carbon, climate feedback

*Speaker

ESMValTool: A community diagnostic and performance metrics tool for routine evaluation of Earth System Models in CMIP

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Abstract

A community diagnostics and performance metrics tool for routine benchmarking and process evaluation of Earth System Models (ESMs) has been developed that allows the comparison of single or multiple models to predecessor versions or to observations. A wide variety of observational datasets is used to assess the simulated climatological mean states and trends of selected Essential Climate Variables (ECVs) in CMIP5 models and to detect systematic biases. A limitation of this approach is that it rarely reveals the extent to which compensating model errors might be responsible for any realistic-looking behavior, and it often fails to even hint at the origins of unrealistic behavior. We therefore also include process- and phenomena-based diagnostics and metrics and evaluate climate variability, atmospheric, ocean and sea-ice processes as well as biogeochemical processes. The Earth System Model Evaluation Tool (ESMValTool) is developed as a community system that is easy to extent with additional diagnostics, open to both users and developers, hence encouraging open exchange of evaluation methods and results. We envisage running the tool routinely on model output submitted to CMIP6 alongside the Earth System Grid Federation (ESGF) and providing a wide range of diagnostics that comprehensively characterize model behavior as soon as the CMIP model output is placed in the archive. This will facilitate and improve ESM evaluation within CMIP beyond the state-of-the-art and can additionally support the modelling groups in their model development cycles. The CMIP6-Endorsed Model Intercomparison Projects and the wider climate community are encouraged to join this effort by contributing innovative analysis codes for a more routine and broad evaluation of CMIP models and a better process understanding.

Keywords: Model evaluation, evaluation tools, performance metrics, systematic biases, process understanding

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Investigating the biases in the Antarctic sea ice - ocean system of climate models using process-oriented diagnostics

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Abstract

Most analyses of Antarctic sea ice in simulations of the CMIP5 archive have so far been oriented towards the quantification of the disagreement between model results and sea ice observations only. Since the decomposition of those biases into distinct physical components is necessary to understand their origins, we propose here an ocean-sea ice-atmosphere integrated and process-oriented approach. Not only the biases in variables essential to the sea ice seasonal evolution are estimated regionally with regard to observations, but their contributions to the sea ice concentration budget and the heat budget of the oceanic mixed layer are estimated.

Following a previously developed method, the sea ice concentration balance over the autumn-winter seasons is decomposed into four terms, including the sea ice concentration change during the period of interest, advection, divergence and a residual accounting for the net contribution of thermodynamics and ice deformation. Concurrently, the full balance in heat content of the oceanic mixed layer is calculated directly from CMIP5 model output fields to disentangle the role of ice-ocean interactions. All components are related together in order to attribute biases in the Antarctic sea ice - ocean system to specific budget terms and their associated processes. In order to assess those biases, the sea ice concentration and velocity as well as the salinity, temperature and depth of the oceanic mixed layer are compared to observations, while winds are compared to reanalyses. Results show that the geographical patterns of all mean sea ice concentration budget terms over 1992-2005 are in qualitative agreement with the observed ones. Sea ice thermodynamic growth is maintained by horizontal divergence near the continent and in the central ice pack, whereas melting close to the ice edge is led by sea ice advection. However, significant errors in all budget terms are observed

*Speaker

due to ice velocities that tend to be overestimated all around Antarctica in several models, leading to a relatively weak divergence in the inner ice pack and to an excessive advection in the marginal ice zone.

This method paves the way for a systematic assessment of forthcoming CMIP6 sea ice model outputs in the Southern Hemisphere.

Keywords: Sea ice, Antarctic, CMIP5, biases, dignostics

Impacts of Snow-Radiation Interaction on Systematic Biases of Large-Scale Circulations in CMIP3/CMIP5 Simulations

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Abstract

In Most of current general circulation models (GCMs), precipitating particles, including snow and rain, are assumed to be removed from the atmosphere as they are formed. The lack of falling hydrometeors results in underestimation of the optical thickness of clouds in GCMs. We performed sensitivity experiments using the Community Earth System Model (CESM) with Community Atmospheric Model version 5 (CAM5) to investigate the impact of missing snow-radiation interaction in GCMs by ignoring snow in radiative transfer calculation. The results show that optically thinner clouds lead to excessive downward surface solar radiation at the surface and outgoing longwave radiation at the top of the atmosphere. Consequently, the more unstable atmosphere produces more convection and precipitation in the tropics. The additional ascending motion strengthens local Hadley circulation and influences the upper- and lower-levels westerlies and easterlies in the subtropics and tropics, respectively. As a result, the upper-level jet streams in the central and eastern Pacific at 35N and 30S are too strong. The deviation from the sensitivity test is notably similar to the systematic bias of the upper-level and low-level zonal winds as well as surface wind stress simulated in the CMIP3 and CMIP5 models.

Keywords: floating hydrometeor, snow radiation interaction, CMIP5 bias

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Constraining hydrological and carbon cycle parameters in JSBACH with micrometeorological flux measurements

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Abstract

The inaccurate representation of model parameters or structures may create systematic biases in land surface model (LSM) simulations. Considering JSBACH, the LSM of the Max Planck Institute for Meteorology's Earth System Model (MPI-ESM), such bias occured in the boreal zone, where JSBACH was unable to transfer the reduced rainfall during summer 2006 into lower levels of gross primary production (GPP).

We reproduced and examined this behaviour on a site scale. As a first step, we attempted to reduce the bias by applying multi-year GPP and latent heat flux data and Bayesian methods in estimation of the model parameter values. We identified key model parameters in soil hydrology, ET and GPP related formulations and tested their effectiveness with elementary methods.

Several parameter optimization runs, with increasing temporal resolution, were performed using Monte Carlo (MC) procedures. The resulting parameter sets were used to generate average daily cycles of GPP and ET for months from May to September for a comparative analysis. The probability densities of the parameters were also examined in parallel. As a result, we will obtain the parameter effectiveness and interrelations using different optimization set-ups. The potential of reducing the model bias with parameter optimization will be assessed.

Keywords: JSBACH, Monte Carlo, parameter optimization, model bias, hydrology

*Speaker

Development of Process-Oriented Metrics to Drive Model Development from CMIP5 through CMIP6

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Abstract

Process-oriented metrics are a new paradigm for model evaluation and diagnosis endorsed by the community including the WCRP WGNE Metrics Panel and the WGNE MJO Task Force, amongst other bodies. These metrics are distinguished by going beyond core model performance diagnostics and focusing on the underlying elements of model formulation or design that may be contributing to biases. This focus is intended to provide modeling centers with useful information for focusing development activities in a targeted fashion. This poster will detail a new, significant NOAA Task Force effort supported by the Modeling, Analysis, Predictions, and Projections program, a component of NOAA's Climate Program Office. The Task Force, composed of researchers from the broad Federal and academic communities, is working to develop a diverse set of process oriented metrics covering a wide range of phenomena and areas of model performance and is also developing a framework to support the implementation of these metrics in the diagnostics packages used at NOAA GFDL, NCAR, and other centers. The metrics are being developed based on CMIP5 output and the intention is for them to be utilized by modeling centers as part of CMIP6-era simulations. This poster will detail the Task Force, the metrics it is developing, and early plans for the framework and process for integration at multiple modeling centers.

Keywords: metrics, process, oriented metrics, model development, CMIP5, CMIP6, GFDL, NCAR

*Speaker

Influence of diabatic heating profiles on monsoon circulations

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Abstract

In the tropics, diabatic heating is the main source of energy that drives the atmospheric circulation. The large-scale tropical circulation is significantly influenced by the vertical distribution of latent heat, while surface sensible heating and radiation also play an important role in the seasonal advance and northward penetration of the monsoons. We describe work done in the EMBRACE project to compare the West African monsoon (WAM) and South Asian summer monsoon (SASM) simulations between four model families, and identify characteristic differences in the vertical and horizontal distributions of diabatic heating between the models which may contribute to differences in their monsoon simulations. The four model families are: LMD models from IPSL Paris, ARPEGE models from CNRM Meteo-France, MetUM from Met Office UK, and EC-Earth models from SMHI Sweden. For each model family, atmosphere-only runs of their CMIP5 configurations are compared with more recent configurations which include both parametrisation changes resulting from work done within the EMBRACE project and those ensuing from ongoing model development.

The CMIP5 configurations of these models exhibit significant differences in their simulations of WAM and SASM rainfall patterns and circulations. Excessive radiative heating in the Saharan region in ARPEGE-CM5 appears to be influential in promoting a northward bias of the African Easterly Jet (AEJ) and the WAM rainband in this model, while the opposite tendency is found in HadGEM2-A. In LMDZ5A there is larger contribution from convection to cooling and drying at lower levels in the WAM and Sahel regions than in the other models. There are also significant differences in the heating/moistening profiles over the Gulf of Guinea between the models, related to the different representation of cloud and boundary layer mixing in this region.

*Speaker

Several of these aspects have changed in the newer model configurations, notably the radiative effects of aerosols and clouds over the Sahara and boundary layer mixing over the Gulf of Guinea. There are also significant changes in the balance of diabatic processes resulting from the move to more integrated cloud convection schemes in the MetUM and CNRM model families (increasing the role of large-scale condensation/evaporation) and the inclusion of a thermal plume model, cold pools/wakes and stochastic triggering for convection in the LMD family.

The influence of the vertical and meridional distribution of diabatic heating on the WAM has been investigated using both 3-d and 2-d dynamical models. Both investigations highlight the importance of radiative heating, particularly over the Saharan and Sahel regions, in influencing the dynamical monsoon flow and the strength and position of the AEJ. Experiments applying heating increments in different regions suggest that changes in the Sahara, Sahel and monsoon regions all appear to affect the monsoon flow, while changes in the Gulf of Guinea region appear to have a compensating effect.

Overall, this work illustrates the difficulty experienced by current climate models in representing the characteristics of monsoon systems. On-going model development and EMBRACE-related improvements have resulted in some significant changes to these characteristics in some model families but only modest effects in others.

Keywords: diabatic heating, monsoon, CMIP5 model, parametrisation

Atmospheric OCS measurements and satellite-derived vegetation fluorescence data to evaluate the terrestrial gross primary productivity of CMIP5 models

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Abstract

Predicting the fate of the ecosystem carbon stocks and their sensitivity to climate change strongly relies on our ability to accurately model the gross carbon fluxes, i.e. photosynthesis and respiration. The Gross Primary Productivity (GPP) simulated by the different terrestrial models used in CMIP5 show large differences however, not only in terms of mean value but also in terms of phase and amplitude, thus hampering accurate investigations into carbon-climate feedbacks.

While the net C flux of an ecosystem (NEE) can be measured in situ with the eddy covariance technique, the GPP is not directly accessible at larger scales and usually estimates are based on indirect measurements combining different tracers. Recent measurements of a new atmospheric tracer, the Carbonyl sulphide (OCS), as well as the global measurement of Solar Induced Fluorescence (SIF) from satellite instruments (GOSAT, GOME2) open a new window for evaluating the GPP of earth system models. The use of OCS relies on the fact that it is absorbed by the leaves in a similar manner to CO2, while there seems to be nothing equivalent to respiration for OCS. Following recent work by Launois et al. (ACPD, in review), there is a potential to evaluate model GPP from atmospheric OCS and CO2 measurements, using a transport model and recent parameterizations for the non-photosynthetic sinks (oxic soils, atmospheric oxidation) and biogenic sources (oceans and anoxic soils) of OCS. Vegetation uptake of OCS is modeled as a linear function of GPP and the ratio of OCS to CO2 rate of uptake by plants. For the fluorescence, recent measurements of SIF from space appear to be highly correlated with monthly variations of data-driven GPP estimates (Guanter et al., 2012), following a strong dependence of vegetation SIF on photosynthetic activity. These global measurements thus provide new indications on the timing of canopy carbon uptake.

*Speaker

In this work, we propose a dual approach that combines the strength of both OCS and SIF observations to evaluate the seasonal variations and the amplitude of the GPP simulated by the CMIP5 models. We will follow the approach of Launois et al. (ACPD) using the LMDz transport model to investigate the phase and amplitude of CMIP5-GPP. Forward transport simulations and inverse approaches where the monthly GPP and respiration fluxes are optimized to match the spatial and temporal gradient of OCS and CO2 concentrations will be used. A more simple correlation analysis between GPP and SIF from the GOME-2 product (K´ohler et al., 2014) will provide an independent diagnostic of the phase of the simulated GPP. The combination of both tracers will be key to avoid the potential flaws of each method and to derive a more robust diagnostic of any model-GPP biases.
We will review the strength and weaknesses of both approaches and then present a synthesis of GPP biases at regional scale for each CMIP5 terrestrial model (phase and amplitude). We will further compare these results against more conventional diagnostics based on the comparison with NEE measurements at FluxNet sites.

Keywords: CMIP5, GPP, carbon, atmospheric OCS, fluorescence

Coupling between convection and large-scale circulation in cloud-resolving and single-column models

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Abstract

A set of single column models (SCMs) and cloud-resolving models (CRMs) are run under consistent methods of parameterization of the large-scale dynamics; the weak temperature gradient (WTG) method and the damped gravity wave (DGW) method in order to assess these methods and to understand the characteristics of the interaction between circulation and convection in each model.
SCMs display a wider range of behaviors than CRMs, with deficit or excess of precipitation compared to the equivalent radiative-convective equilibrium. In particular, SCMs exhibit more complex profiles of vertical motions than CRMs, with larger extrema.

The WTG method yields a wider range of behaviors than the DGW method, and more complex vertical structure of the ascending and/or subsiding motions. Multiple equilibria are also more commonly obtained with the WTG method than the DGW method. The latter does not yield any in CRMs.
These experiments confirm the parameterizations of large-scale dynamics are a promising approach to validate and assess the interaction of existing or new physical parameterizations with the large-scale circulation in a simple framework.

Keywords: circulation, convection, precipitation, tropics

*Speaker

Analysis of the West African monsoon annual cycle using a two-dimensional model: Some key factors contributing to the rainband displacement

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Abstract

The processes that drive the annual cycle of the West African Monsoon (WAM) is the result of a complex interplay between the ocean, the land and the atmosphere in which several scales interact.This study presents an idealized axisymmetric numerical model that retains all the moist physics with the ultimate objective of studying the different regional couplings and processes involved in the WAM. Starting from previous work by Peyrillé and Lafore (2007) in which the same tool has been used to study a steady monsoon regime, the axisymmetric framework is adapted to the study of the annual cycle. The model represents most of the main features of rainfall annual cycle (meridional displacement of the rainfall maximum) and its dynamical structures (Saharan heat Low, ITCZ).
As a first step the annual cycle of rainfall and the moisture convergence maximum found in Thorncroft et al. (2011) are analyzed. The processes that lead the ITCZ from an equatorial regime to its northernmost location are examined using temperature and humidity budget. A relay of dry process in winter- early spring and moist processes in summer helps the monsoon to migrate to the north. In winter/spring the Saharan heat low strengthens through radiation and turbulence and drives moisture to converge ahead of the rainfall maximum. The low layers of the atmosphere are moistened by the turbulent vertical fluxes and by the shallow meridional circulation associated to the SHL and described by previous authors.
Sensitivity experiments are realized to isolate the role of some of the key processes: meridional advection of temperature and humidity, convective downdraft and ground evaporation. The meridional advection by the monsoon flow is a 1st order process to moisten the continent. Ground evaporation drmatically modulates the extent and intensity of rainfall during the whole seasonal cycle. The convective downdraft helps to moisten the lower atmosphere and decrease the rainfall amount in spring and summer. The signature of each process is derived in terms of rainfall location and intensity and can be used as guide to analyse climate models rainfall patterns.

Keywords: West African monsoon, surface evaporation, advections, rainfall pattern

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Atmospheric long-term changes in the Southern Hemisphere simulated by CMIP5 models

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Abstract

Southern Hemisphere (SH) climate variations in the past 30 years result to be strongly driven by ozone long-term changes in the austral spring-summer season. Since the 1970s the stratospheric ozone reduction and its strong depletion over Antarctica has led to a long-term cooling of the stratosphere that seasonally superimposes to the GHG cooling. The polar lower stratospheric cooling has contributed, together with the GHGs-induced upper tropospheric warming at tropical latitudes, to enhance the meridional temperature gradient delaying the polar vortex breaking and propagating down to the troposphere accelerating and poleward shifting the mid-latitude tropospheric jet, and projecting onto the positive phase of the Southern Annular Mode (SAM). This work attempts to demonstrate, through multi-model analysis, that a limited representation of stratospheric processes in the Coupled Intercomparison Project Phase 5 (CMIP5) models leads to a bias in the representation of simulated SH stratospheric and tropospheric long-term changes as well as in simulated sea level pressure patterns of the SAM. More in detail, we pay particularly attention to the importance of the stratospheric chemistry-dynamics coupling represented in climate models. We show that only models with a proper representation of both dynamical and chemical stratospheric processes succeed in capturing more realistic SH summertime lower stratospheric cooling in the past and the following changes in the tropospheric circulation and in their projections onto the SAM index. Indeed, models not including an interactive stratospheric chemistry and dynamics show biases in underestimating the SH long-term changes found in ERA 40 and ERA Interim reanalysis. Implications for future changes including two different scenarios for GHGs increase and ozone recovery are also analyzed. Specifically, we verify if the relationships between lower stratospheric trends and tropospheric/surface changes, discussed for the historical simulations, are also found in two different RCPs scenarios.

Keywords: Southern Hemisphere long term changes, biases in CMIP5 simulations, stratosphere troposphere coupling, Multi model analysis of CMIP5 simulations

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Improvement of the representation of boundary-layer, convection and clouds in the LMDZ general circulation model and impact on tropical climate simulations.

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Abstract

Substantial parameterization development was undertaken in the last decade in LMDZ, the atmospheric component of the IPSL climate model: The introduction of a mass-flux approach to represent boundary-layer structures and shallow convection in a unified way, as well as a parameterization of the cold pools generated under convective systems by the evaporation of precipitation led to the IPSL-CM5B version of the model, which was used for part of the simulations run for the CMIP5 exercise. The new physical package leads in particular to significant improvement in the representation of low-level clouds and convective precipitation timing. Regarding tropical variability, results are mitigated, as for example the previously too-low intra-seasonal variability over the Indian Ocean is enhanced but the already too restricted latitudinal extension of the West-African Monsoon is further narrowed. This version however exhibits some similar mean biases as the previous IPSL-CM5A version, partly due to a lack of maturity in the comprehension of the new physical package behavior at global scale. It opened however a new framework to investigate the impact of key physical processes on climate simulations, like the vertical mixing by thermals within the boundary-layer, the mixing and triggering specification for the deep convection scheme, the thermodynamical effect of ice, the entrainment at the top of stratocumulus clouds or the sub-grid representation of cloud fraction.

Here we will present the methodology used to build step by step the latest version of the model, which shows promising results for tropical climate variability as well as mean climate features.

Keywords: convection parameterization tropical variability

*Speaker

Accounting for observational uncertainties in the evaluation of low latitude turbulent air-sea fluxes simulated in CMIP5 models

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Abstract

Turbulent momentum and heat (sensible heat and latent heat) fluxes at the air-sea interface are key components of the whole energetic of the Earth's climate and their good representation in climate models is of prime importance. In this work, we use the methodology developed by Braconnot & Frankignoul (1993) to perform a Hotelling T2 test on spatio-temporal fields (annual cycles). This statistic provides a quantitative measure accounting for an estimate of the observational uncertainty for the evaluation of low-latitude turbulent air-sea fluxes in a suite of IPSL model versions. The spread within the observational ensemble of turbulent fluxes data products assembled by Gainusa-Bogdan et al (submitted) is used as an estimate of the observational uncertainty for the different turbulent fluxes. The methodology holds on a selection of a small number of dominating variability patterns (EOFs) that are common to both the model and the observations for the comparison. Consequently, it focuses on the large-scale variability patterns and avoids the possibly noisy smaller scales. There are two main advantages of this methodology. First, it provides a statistic (a metric) of the model-observation agreement that can be tested against an H0 hypothesis (the difference between the model and the observations is zero). Therefore, it is possible to calculate a p_value associated with the statistic, and define a threshold value above which the model is considered as significantly different from the observations, given an estimate of the observational uncertainty. The statistic also comes with a confidence interval that provides an interesting means to compare the results of several models between them. Second, we can actually evidence many features of the model-data agreement, and differences (in terms of large scale pattern, magnitude and seasonal phasing), following the EOFs decomposition needed to calculate the statistic.

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We present the results for all available CMIP5 models. This work is a first attempt to use such statistic on the evaluation of the spatio-temporal variability of the turbulent fluxes, accounting for an observational uncertainty, and is represents a starting point for future improvement.

Keywords: Evaluation, turbulent fluxes, uncertainty, latent heat flux, wind stress, biases

Explicitly resolved vs parameterized mesoscale processes in the Labrador Sea: impact on the AMOC

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Abstract

The aim of this study is to assess how the North Atlantic large-scale circulation is responding to the effects of small scale processes either explicitly resolved either through parameterizations with a focus on the Labrador Sea where strong mesoscale and submesoscale activity occurs.

The Atlantic Meridional Overturning Circulation (AMOC) plays a key role in the regulation of the Earth climate. This large-scale circulation represents a synthetic view of the basin-wide transport with a northward warm and salty flow at the surface and an equatorward cold and fresh flow at depth. The latter is dominated by the Deep Western Boundary Current (DWBC) which exports to the south dense water masses such as the Labrador Sea Water (LSW) formed during winter convective events in the interior Labrador Sea.

Previous studies have shown that low horizontal resolution (of the order of 1) ocean models hence climate models are not able to adequately represent boundary currents such as the DWBC nor mesoscale processes, which affects its dynamics and thermohaline properties. The lack of resolved mesoscale activity alters the post-convective restratification and implies systematic errors in convective regions (such as overestimated mixed layer depth and erroneous localization of convection, among others).

In a simplified, laminar view of the AMOC which characterizes climate models, a direct link exists between dense water formation in the Labrador Sea and the DWBC transport intensity. Nevertheless, recent studies suggest that this link may be more complex. Indeed, it seems that the LSW, once formed, may be exported to the surrounding DWBC by lateral

*Speaker

density turbulent fluxes. It is also put forward that dense water formation signal may be lagged by several years when reaching the DWBC due to eddies. So the small scale processes may be key in both the LSW formation rate and its export to the DWBC. The exploration of these dynamics requires numerical models of very high resolution due to the small Rossby radius deformation in the Labrador Sea (about 7km).

We develop a high resolution primitive equation configuration which relies on a global configuration at 1/2 horizontal resolution including two embedded grids covering respectively the North Atlantic (1/8) and the subpolar gyre (1/32). At the highest resolution, the mesoscale and submesoscale processes are respectively explicitly resolved and permitted by the model and lead for instance to a strong seasonality in the dynamics due to convection. Our objective here is to contrast the explicit mesoscale effects in the highest resolution with those resulting from the use of a parameterization with a focus on the AMOC variability.

Keywords: AMOC, DWBC, small scale processes, convection

Disentangling atmospheric biases in the tropical Atlantic region

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Abstract

Most state-of-the-art coupled general circulation models (GCMs), like CNRM-CM5, have serious biases in the tropical Atlantic, one of them being a westerly bias in the equatorial surface winds. In CNRM-CM5, using a Transpose-CMIP configuration, we have shown in Voldoire et al. (2014) that biases settle in a few months and that coupling feedbacks amplify the biases. However, a wind bias already exists in atmosphere-only simulations forced with observed sea surface temperatures (SSTs), as also pointed out in Richter et al. (2014) for many CMIP5 models in AMIP mode. The atmospheric model is not able to simulate the equatorial winds with enough realism to adequately drive the ocean circulation. Thus we have moved to atmospheric only simulations driven by observed SSTs. Given the speed of the bias development, we keep on analysing the bias development in initialised mode using the so-called Transpose-AMIP protocol. An analysis of the different terms in the zonal momentum budget highlights the important role of biases in the east-west pressure gradient for the development of the zonal wind bias, which in turn might be linked to biases in tropical convection over South America and Africa. Further sensitivity experiments are carried out in order to investigate if modifying convective heating properties can impact the east-west pressure gradient and thus the zonal wind bias. The results may provide some indications on how to improve coupled GCMs in the region.

Keywords: tropical Atlantic, SSTs, Wind, Transpose, AMIP, convection

*Speaker

From global to regional: translating improved resolution for ocean biogeochemistry in CMIP6

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Abstract

As a key component of the wider IPCC Assessment Reports, CMIP establishes a challenging suite of simulations that inform policy and cross-calibrate climate modelling at an international scale. In staffing and computing, and in time and effort, CMIP participation is an expensive endeavour, and preparations start years before simulations begin. An unavoidable consequence of setting this high bar is that the climate models used often lag those used in leading-edge research. For example, in CMIP5, ocean model resolution was typically 1-degree, far below that routinely used in contemporary oceanography, and completely omitting the critical mesoscale of eddies and boundary currents. However, CMIP6 participants such as UKESM1 will be using higher ocean resolution, and their simulations will resolve such key oceanographic features, permitting a more complete assessment of oceanic change than hitherto possible. Here we present the results of extant simulations that illustrate the nature and magnitude of the changes we can expect, and underscore the importance of resolution for realism. Our analysis will focus on four key areas where the interactions between ocean physics and biogeochemistry will significantly improve from CMIP5 to CMIP6: the Arctic, where a complex interplay of extreme change and limiting factors will shape future productivity; boundary currents, whose pathways and magnitudes will be realistically represented; upwelling regimes, pivotal in deoxygenation, acidification and our most productive fisheries; and mixing, which controls carbon exchange between the deep ocean and atmosphere and structures ocean communities throughout the world ocean. Where CMIP6 models support such resolutions, their intercomparison across these topics will provide valuable insight into ocean change unattainable in previous CMIPs.

Keywords: ocean, biogeochemistry, grid, resolution

*Speaker