Workshop on CMIP5 Model Analysis and Scientific Plans for CMIP6

20th-23rd October 2015, Dubrovnik, Croatia

SESSION 2: Wednesday 21st October (afternoon)

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Supported by

The EMBRACE project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement no 282672

Progress in representing moist convection and tropical variability at ECMWF in the session on systematic biases

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Abstract

Long-standing model biases in the ECMWF Integrated Forecasting System (IFS), their relation to model physics and progress are discussed in the following areas:

-diurnal cycle of convection, African summer monsoon and continental
dry bias with respect to synoptic observations
-tropical wave activity and mean circulation
-aerosol climatology and Indian summer monsoon
-stratospheric biases and their relation to ozone climatology
and gravity wave representation

Keywords: model bias, IFS, summer monsoon, continental dry bias

*Speaker

Representation of daytime moist convection over the semi-arid Tropics by parametrizations in CMIP6 models

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Abstract

A case of daytime development of deep convection over tropical semi-arid land is used to evaluate the representation of convection in climate models. The case is based on observations collected during the African Monsoon Multidisciplinary Analysis (AMMA) field campaign and includes two distinct transition phases, from clear sky to shallow cumulus and from cumulus to deep convection. a reference large-eddy simulation (LES) and single-column model (SCM) version of different Earth system models, run with identical initial and boundary conditions, are intercompared: in particular CMIP5 and CMIP6 physics packages are evaluated within this framework. As the LES correctly reproduces the observed growth of the boundary layer, the gradual development of shallow clouds, the initiation of deep convection and the development of cold pools, it provides a basis to evaluate in detail the representation of the diurnal cycle of convection by the other models and to test the hypotheses underlying convective parametrizations. Most SCMs have difficulty in representing the timing of convective initiation and rain intensity, although substantial modifications to boundary-layer and deep-convection parametrizations lead to improvements. The SCMs also fail to represent the mid-level troposphere moistening during the shallow convection phase, which we analyze further. Nevertheless, beyond differences in timing of deep convection, the SCM models reproduce the sensitivity to initial and boundary conditions simulated in the LES regarding boundary-layer characteristics, and often the timing of convection triggering. In addition, the ability of full 3D climate models to correctly simulate the diurnal cycle of deep convection over semi-arid land is addressed. This allows to see if the differences induced by modifications to boundary-layer and deep convection parametrizations also lead to improvements in 3D runs.

*Speaker

Keywords: Single, column models, CMIP5 and CMIP6 models, Continental cumulus convection, Diurnal cycle

Towards a better understanding and narrowing of summer mid-latitude uncertainties in CMIP5 climate projections

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Abstract

Beyond the choice of a given concentration scenario, global climate models still represent a major source of uncertainty for simulating climate change at regional and seasonal scales. Here the focus is on boreal summer mid-latitude land where surface warming remains uncertain by about a factor two at the end of the 21st century depending on the selected CMIP5 model. We use both numerical sensitivity experiments (in which the cloud or soil moisture feedback is switched off) and emergent observational constraints to emphasize the contribution of both cloud and land surface feedbacks to the inter-model spread. Beyond model biases, we propose and test more process-oriented metrics to constrain the projected warming in two generations (CMIP3 and CMIP5) of global climate models. Our results emphasize the need of ensemble simulations for separating internal climate variability from model uncertainty and of longer and/or more accurate observations for a significant narrowing of model uncertainties in the late 21st century climate projections.

Keywords: biases, feedbacks, metrics, uncertainties

*Speaker

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The cloud radiative effect on simulating the asymmetry in the strength of the two types of El Niño in CMIP5 models

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Abstract

The asymmetry in the strength of the Bjerknes feedback was pointed to take responsibility on the pronounced amplitude asymmetry between the eastern Pacific (EP) and central Pacific (CP) El Niño. Detailed analyses indicated that this strength asymmetry mainly comes from a weaker sensitivity of the zonal sea level pressure (SLP) anomaly to that of diabatic heating anomaly in the developing phase of the CP El Niño, which is further mostly due to a large cancelation induced by the negative sea surface temperature (SST)–cloud thermodynamic feedback to the positive dynamical feedback. This study validates these observational asymmetries in historical runs of 20 models involved in phase five of the Coupled Model Intercomparison Project (CMIP5). It indicates that the CMIP5 models can generally separate the two types of El Niño based on the currently broadly used definitions. Detailed analyses suggest that the CMIP5 models generally depict well the amplitude asymmetry between the two types of El Niño events, consistent with the successfully simulated asymmetry in the strength of the Bjerknes feedback. Similar to observations of both types of El Niño events, variations in the total cloud amount and short wave radiation also confirm that the cloud radiative effect is key in causing the amplitude asymmetry between CP and EP El Niño events. Analyses based on the AMIP5 outputs also confirms the conclusions mentioned above. However, there also exist severe biases in the CMIP5 models in capturing the realistic CP El Niño structures, i.e., nearly no model can simulate the significantly weaker warming anomalies in the eastern Pacific than those in the central Pacific.

Keywords: Bjerknes feedback, CP El Niño, EP El Niño, Cloud radiative effect

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On the anatomy of biases in the northern hemisphere sea ice extent and impacts of different bias correction methods in a set of CMIP5 coupled climate models

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Abstract

We analyze historic behavior and initialized forecasts of the northern hemisphere (NH) sea ice extent (SIE) from the pan-Arctic domain to selected regional averages. Our ensemble of CMIP5 coupled climate models encompasses EC-Earth2, CNRM-CM5, MPI-ESM, CanCM3, CanCM4 and GFDL CM2.1. We explore the connection of the NH and regional SIE biases to biases in sea surface temperature, surface air temperature, mean sea level pressure and surface winds. Furthermore, seasonal forecasts of these CMIP5 models initialized from observationally-based states (OBS) on 1st of May and 1st of November from 1981 to 2012 are examined. A set of deterministic skill measures is evaluated after performing three different post-processing adjustments of model forecasts: the mean or per-pair, the trend and the initial conditions (IC) bias correction method. The trend bias (IC) correction method replaces a linear regression of the model forecasts on the start years (OBS in the first forecast month over the start years) with the linear regression of the corresponding OBS on the start years (OBS in the first forecast month over the start years) at each forecast month and separately for each start dates. The nature of SIE biases is also reflected in the way that different bias correction methods impact prediction skill.

Keywords: Arctic climate, sea ice, historic simulations, seasonal forecasts, bias correction methods

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Processes controlling tropical tropopause temperature and stratospheric water vapour in climate models

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Abstract

A warm bias in tropical tropopause temperature is common amongst CMIP5 models, with the average bias around +2K. The tropical tropopause temperature, or "cold point", is the main factor determining the dehydration of air parcels as they ascend into the tropical lower stratosphere, and therefore largely determines the water vapour concentration in the tropical lower stratosphere. In Earth System models running with interactive stratospheric ozone, as will likely be the case for models participating in the AerChemMIP experiments for CMIP6, the warm bias in tropical tropopause temperature may further increase, leading to too much water vapour entering the stratosphere. A bias in stratospheric water vapour concentrations may have a direct radiative impact on surface climate, and also directly impact the stratospheric circulation, tropospheric jet streams, and stratospheric composition.

Despite the warm tropical tropopause temperatures, on average stratospheric water vapour concentrations in the CMIP5 models agree well with reanalyses and, if anything, are biased slightly low. This is indicative of physical processes in the tropical tropopause region which act to influence lower stratospheric water vapour directly, in the climate models, rather than simply through changes in the tropical tropopause temperature. It also suggests that CMIP5 models may not be getting stratospheric water vapour concentrations correct for the right physical reasons.

A series of sensitivity experiments are run using a version of the Met Office climate model, to investigate the effects of the key processes influencing the tropical tropopause temperature

*Speaker

and lower stratospheric water vapour concentrations. Cirrus clouds, convection, ice microphysical properties, and the vertical advection of water vapour are all found to influence upper tropospheric water vapour concentrations directly, and therefore directly influence lower stratospheric water vapour concentrations in the climate model. The vertical advection of potential temperature, the optical properties of ice crystals, and radiative feedback from ozone concentrations are found to influence the tropical tropopause temperature, and therefore indirectly influence stratospheric water vapour concentrations. Explanations are given as to why each of these processes has the effect it does on tropical tropopause temperature and stratospheric water vapour concentrations.

These sensitivity experiments suggest means of significantly reducing biases in tropical tropopause temperature and stratospheric water vapour concentrations whilst simultaneously improving the physical representation of processes in the tropical tropopause region in climate models, thereby potentially improving climate simulations.

Keywords: tropical tropopause, stratospheric water vapour, climate model biases

On the control of sea surface temperature and air-sea coupling variables by atmospheric boundary layer parameterizations

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Abstract

All but one of the CMIP5 coupled models show warm biases of sea surface temperature (SST) on the east side of the tropical oceans, over oceanic upwelling regions, that also correspond to the occurrence of strato-cumulus.

Based on a cross analysis of coupled and atmosphere-alone simulations, we show that a large part of the SST biases have their origin in biases of the atmospheric model that are already present in prescribed SST experiments.

We propose new metrics that allow to anticipate those SST biases from atmosphere-alone simulations. We then show how the recent improvements of the physical parameterizations of boundary layer turbulence, convection and clouds in the LMDZ model, the atmospheric component of the IPSL coupled model, helped improve the representation of coupling variables (in particular, the near-surface temperature and humidity and the radiative, sensible and latent heat fluxes), and how these improvements reduce the surface biases in the coupled simulations. We show that a large part of the improvements can be attributed to the representation of the non-local vertical transport by organized structures of the boundary layer through a mass flux parameterization, i.e., the thermal plume model.

Keywords: convective boundary layer. Atmosphere ocean coupling. Systematic biases.

*Speaker

Understanding and reducing Southern Ocean biases in the HadGEM3 coupled climate model and other IPCC CMIP5 models

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Abstract

The Southern ocean is a critical region for global climate, playing an important role in: climate sensitivity; anthropogenic heat (> 60%) and CO2 uptake (_˜40%); the Meridional Overturning Circulation and water mass formation; sea level through ice shelf/sheet stability; global nutrient cycle; links to remote regions, e.g. Inter-tropical Convergence Zone (ITCZ) position; etc. It is impacted by changes in ozone and sensitive to ocean acidification. It is a highly coupled region with a dynamical connection from stratosphere to deep ocean so biases in any model component often impact on the whole system, resulting is extremely large biases, which differ between models, and could adversely impact on climate projections. Furthermore, due to the impact of ozone changes over recent decades on Southern Ocean winds, recent observed patterns of heat and carbon uptake may not be expected to be good indicators of future uptakes.

We summarise a two year integrated assessment of the representation of Southern Ocean processes, from the stratosphere to the deep ocean, in HadGEM3 GC2 and IPCC CMIP5 models, focussing on the air-sea exchanges. Using a novel net air-sea observational flux product there is a good correspondence at basin scales between atmosphere-only air-sea flux errors and coupled upper ocean heat content errors (for year 5 to 15) in HadGEM3 GC2. This suggests that atmosphere errors are a primary driver of initial coupled heat content biases both in the Southern Ocean (and other regions). Evidence suggests that Southern Ocean net flux errors are both due to radiation errors (_˜50%), mainly short wave due to cloud errors, and turbulent flux errors (_˜50%). Evidence suggests that cloud errors in HadGEM3 are in part due to a lack of super-cooled cloud liquid water content, which is known from observations to be prevalent in polar regions. New mixed-phase cloud and aerosol schemes reduce the HadGEM3 GC2/GA6 atmosphere only net heat flux bias by _˜30%, reducing coupled sea surface temperature (SST) biases by _˜50%.

*Speaker

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Analyses of surface zonal wind stress and SST biases for coupled CMIP5 models indicate a large spread in biases, with the few models with small SST biases tending to have large winds stress errors. Furthermore, surface heat flux error analyses suggest that there are large errors in net flux for many of the CMIP5 atmosphere only simulations, and considerable error cancellation between individual heat flux terms for nearly all the models.

For HadGEM3, we also discuss ocean heat transport and mixing errors, which clearly contribute to coupled heat-content and SST biases. For example, for the HadGEM3 GC2 model, employing a coupled 1/4 degree eddy permitting ocean model roughly doubles the coupled Southern Ocean SST bias, compared to its bias when employing a 1 degree ocean model.
These model error analyses also provide useful insight into causes of key HadGEM3 GC2 and CMIP5 coupled biases in many other regions.

Keywords: CMIP5 model biases, Southern Ocean, surface heat fluxes, HadGEM3, clouds, winds, storms, ocean heat transports

Quantification of Systematic Biases of Clouds, Radiation, Water Vapor and their Impacts on Land/Ocean Surface Processes in CMIP3 and CMIP5 Simulations using NASA Observations

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Abstract

The fidelity of coupled global climate models (CGCMs) in representing cloud mass, water vapor, radiative properties, and their impacts on land/ocean coupled systems are evaluated. It is found that the biases of water vapor, radiation, surface wind stress, evaporation (E), precipitation (P), land surface temperature (LST), sea surface salinity (SSS), and sea surface temperature (SST) are fairly similar in the CMIP models contributed to 20th century simulations of the Coupled Model Intercomparison Project 3 (CMIP3) and Project 5 (CMIP5) relative to observations. One of the potential causes of the CMIP model biases is the missing representation of precipitating hydrometeors in all CMIP3 and most CMIP5 models.
We examine the impacts of falling ice particles on radiation and in turn on the cloud radiative fluxes, atmospheric circulation, evaporation, precipitation, and air-sea heat fluxes, and explore their connections to the common biases of key climate indicators such as LST, SST and SSS in CMIP models using the NCAR Community Earth System Model version one (CESM1) to perform sensitivity experiments with and without snow radiation effects.
It is found that without the falling ice particle radiative effect, the CESM1 produces weaker surface wind stresses with reduced upper-ocean vertical mixing, resulting in increased upper-ocean ocean temperatures and diluted SSS in conjunction with increased precipitation in the sub-tropical and tropical Pacific Ocean. In contrast, in the northwest and central Pacific, colder SSTs are consistent with enhanced vertical mixing induced by stronger wind stresses. The differences in upper-ocean temperatures and salinity with and without snow radiative effects are consistent with the different strengths of vertical mixing and wind stress differences, but cannot be explained by the differences in net air-sea heat fluxes. In addition, the LST changes are mainly due to the effect of changes in downward surface radiative fluxes, but cannot be explained by the differences in surface sensible and evaporative heat fluxes.

Keywords: Cloud, Precipitation, Radiation, Dynamics, Water Vapor, Wind Stress, SST, sea salinity, CGCM

*Speaker

Kelvin and Rossby gravity wave packets in the lower stratosphere of some high-top CMIP5 models

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Abstract

We analyse the stratospheric Kelvin and Rossby-gravity wave packets with periods of a few days in nine high-top (i.e. with stratosphere) models of the fifth Coupled Model Intercomparison Project (CMIP5). These models simulate realistic aspects of these waves, and represent them better than the tropospheric convectively coupled waves analyzed in previous studies.

There is nevertheless a large spread among the models, and those with a Quasi-Biennial Oscillation (QBO) produce larger amplitude waves than the models without a QBO. For the Rossby-gravity waves this is explained by the fact that models without a QBO never have positive zonal mean zonal winds in the lower stratosphere, a situation that is favorable to the propagation of Rossby-gravity waves. For the Kelvin waves, larger amplitudes in the presence of a QBO is counter intuitive because Kelvin waves are expected to have larger amplitude when the zonal mean zonal wind is negative, and this is always satisfied in models without a QBO. We attribute the larger amplitude to the fact that models tuned to have a QBO require finer vertical resolution in the stratosphere.

We also find that models with large precipitation variability tend to produce larger amplitude waves. However, the effect is not as pronounced as was found in previous studies. In fact, even models with weak precipitation variability still have quite realistic stratospheric waves, indicating either that (i) other sources can be significant or that (ii) the dynamical filtering mitigates the differences in the sources between models.

Keywords: Kelvin waves, Rossby Gravity waves, Equatorial Stratosphere, Quasi Biennial Oscillation, General Circulation Models, CMIP5 models

*Speaker

The next generation of metrics for Arctic sea ice in coupled climate models

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Abstract

A first-order assessment of Arctic sea ice model performance frequently rests on the evaluation of integrated, large-scale quantities such as sea ice extent, area, volume and their respective trends. These metrics are sensible from a climatic point of view as they reflect the mean state or the response of the system that is modelled. They were extensively used in the framework of CMIP3/5 but face two limitations. First, they are helpless to understand regional model biases and their origins. Second, they do not account for the possible compensation of errors in different components of the climate model. In other words, they do not exclude the possibility that models are deemed "realistic", but for the wrong reasons. As a response, the need to move towards even more physical, process-based sea ice metrics has been mentioned in several recent studies and discussed in many previous workshops or conferences. In anticipation to the upcoming CMIP6 where many more sea ice variables will be saved at higher time frequency than CMIP5, we propose and implement three of such process-based metrics for Arctic sea ice, using the already available CMIP5 archive. Our three metrics are intended to characterize sea ice dynamics, thermodynamic growth and melt, i.e., three of the fundamental processes that govern its variability at the seasonal time scale and beyond. We address four specific questions: 1) Can we relate the spread in these process-based metrics to the spread in large-scale diagnostics that have already been noticed in CMIP5? 2) To what extent are these metrics also available from observations? Are they sensible to interannual variability (the same metrics will be applied to different ensemble members from the same model)? 4) Can we relate these metrics to future modelled Arctic sea ice changes? Framing sea ice model evaluation following this approach will contribute to understand the suitability of coupled models for Arctic sea ice studies with improved physical bases.

Keywords: process, based metrics, Arctic sea ice, model evaluation, model biases

*Speaker

The Deep South National Science Challenge: Reducing persistent climate model biases in the Southern Hemisphere

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Abstract

Southern-Hemisphere climate projections are subject to persistent climate model biases affecting the large majority of contemporary climate models, which degrade the reliability of these projections, particularly at the regional scale. Southern-Hemisphere specific problems include Southern-Ocean sea ice, whose mean extent and recent trends presently cannot be satisfactorily reproduced by climate models. Cloud coverage over the Southern Ocean is a further such problem, with satellite-based observations indicating that cloud occurrence in this region is substantially underestimated, with consequences for the radiation balance, sea surface temperatures, and the position of storm tracks. Heat transport in the Southern Ocean, particularly associated with Antarctic bottom water formation, is a key yet poorly understood process with the potential to substantially affect New Zealand's climate. The Southern-Ocean and Antarctic region is generally characterized by an acute paucity of surface-based observations, further complicating the situation.

Motivated by these scientific problems, and recognizing the likely economic and societal impacts of climate change, the New Zealand Government has issued the Deep South National Science Challenge, whose core mission is to develop an Earth System Model not subject to these persistent biases, thereby contributing to improving the fidelity of climate projections available to the country. To achieve this goal, we will pursue a two-pronged approach: We will conduct observational process studies in the Southern-Ocean region, involving research vessels, land-based observations, and participation in international campaigns using aircraft, and using these and other observations we will collaborate with overseas partners to further develop an Earth System Model in the areas outlined above. To aid model validation, we will use paleo-climate information as appropriate, and we will also contribute to the digitization of historical observations recorded in ship logs which will be used in model validation. Complementing the Earth-System Model approach, we will use simpler models to produce larger ensembles of model simulations which will help reduce statistical uncertainty. Progress made under the Deep South National Science Challenge will inform CMIP6 through communication of model improvements to our overseas partners (particularly the UK MetOffice); we may also ourselves contribute simulations to CMIP6.

*Speaker

Reference:
The Deep South National Science Challenge, http://www.deepsouthchallenge.co.nz

Keywords: Southern Hemisphere, Earth System Modelling, persistent bias, sea ice, Southern Ocean, Antarctica

Role of clouds, aerosols, and aerosol-cloud interaction in 20th century simulations with GISS ModelE2

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Abstract

Simulations of aerosols, clouds and their interaction contribute to the major source of uncertainty in predicting the changing Earth's energy and in estimating future climate. Anthropogenic contribution of aerosols affects the properties of clouds through aerosol indirect effects. Three different versions of NASA GISS global climate model are presented for simulation of the twentieth century climate change. All versions have fully interactive tracers of aerosols and chemistry in both the troposphere and stratosphere. All chemical species are simulated prognostically consistent with atmospheric physics in the model and the emissions of short-lived precursors [Shindell et al., 2006]. One version does not include the aerosol indirect effect on clouds. The other two versions include a parameterization of the first indirect aerosol effect on clouds following Menon et al. [2010]. One of these two models has the Multiconfiguration Aerosol Tracker of Mixing state (MATRIX) that permits detailed treatment of aerosol mixing state, size, and aerosol-cloud activation. The main purpose of this study is evaluation of aerosol-clouds interactions and feedbacks, as well as cloud and aerosol radiative forcings, for the twentieth century climate under different assumptions and parameterizations for aerosol, clouds and their interactions in the climate models.
The change of global surface air temperature based on linear trend ranges from +0.8C to +1.2C between 1850 and 2012. The model with no indirect effect of aerosol on clouds shows the smallest decrease of the low level clouds over the historical period that leads to the smallest shortwave and total (shortwave and longwave) cloud radiative cooling trend at the top of the atmosphere. Water cloud optical thickness increases with increasing temperature in all versions with the largest increase in models with interactive indirect effect of aerosols on clouds.

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Keywords: aerosol, clouds interactions and feedbacks, cloud and aerosol radiative forcings, indirect effect of aerosol on clouds

*Speaker

On the ability of NEMO-LIM3 to simulate sea ice dynamics using a simplified Maxwell-elasto-brittle rheology

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Abstract

Satellite observations of the Arctic sea ice reveal the existence of linear kinematic features which are quasi linear patterns present in the strain field that stretch all across the Arctic basin and that are associated to the the formation of leads. Current sea ice components of global climate models fail to reproduce those linear kinematic features and the observed statistical distribution of deformation rate. In order to refine the physical representation of sea ice dynamics in large-scale sea ice models, a new approach has been proposed for the ice rheology. This approach, based on a Maxwell-elasto-brittle rheology, is integrated in the NEMO-LIM3 global ocean-sea ice model (www.nemo-ocean.eu ; www.elic.ucl.ac.be/lim) which is part of several CMIP5 climate models. In the present study, we compare the ability of NEMO-LIM3 to reproduce the observed sea ice dynamics of the current reference rheology of LIM3, i.e. the elastic-viscous-plastic rheology, and a simplified Maxwell-elasto-brittle rheology in both hemispheres. We will analyse the impact of the more accurate representation of leads permitted by the Maxwell-elasto-brittle rheology on the simulation of sea ice and the air-ice-ocean fluxes.

Keywords: cryosphere, sea ice, dynamics, leads, fluxes, Arctic, Antarctic

*Speaker

Missing pieces of the puzzle: understanding decadal variability of Sahel rainfall using CMIP5 and higher resolution models

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Abstract

The instrumental record shows that substantial decadal fluctuations affected Sahel rainfall from the West African monsoon throughout the 20th century. Climate models generally underestimate the magnitude of decadal Sahel rainfall changes compared to observations. This shows that the processes that control low-frequency Sahel rainfall change are misrepresented in most CMIP5-era climate models. Reliable climate information of future low-frequency rainfall changes thus remains elusive.

Here we identify key processes that control the magnitude of the decadal rainfall recovery in the Sahel since the mid-1980s. We show its sensitivity to model resolution and physics in a suite of experiments with global HadGEM3 model configurations at resolutions between 130-25 km. The decadal rainfall trend increases with resolution and at 60-25 km falls within the observed range. Higher resolution models have stronger increases of moisture supply and of African Easterly wave activity. Easterly waves control the occurrence of strong organised rainfall events which carry most of the decadal trend. Weak rainfall events occur too frequently at all resolutions and at low resolution contribute substantially to the decadal trend. All of this behaviour is seen across CMIP5, including future scenarios. Additional simulations with a global 12km version of HadGEM3 show that treating convection explicitly dramatically improves the properties of Sahel rainfall systems. We conclude that improved interaction between convective scale and global scale processes is crucial for decadal rainfall changes in the Sahel.

African Easterly Waves (AEWs) are also associated with the most intense hurricanes found in the Atlantic. The performance of CMIP5 models in representing AEWs, and how this relates to the African Easterly Jet simulation, will be shown, in conjunction with a series of HadGEM3 configurations at different resolutions. There is a strong relationship between these properties in HadGEM3, with implications for its Atlantic tropical cyclone performance.

Keywords: rainfall, sahel, decadal trends, CMIP5, tropical cyclones, high resolution

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Overview of the West African monsoon in CMIP5 and updated models

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Abstract

The present comprehensive assessment of the West African monsoon in the models of the fifth phase of the Coupled Model Intercomparison Project (CMIP5) indicates little evolution since CMIP3 in terms of both biases in present-day climate and climate projections.

The outlook for Sahel precipitation in twenty-first-century coupled simulations remains uncertain, as models still disagree on the sign of the trends. This contrasts with the relatively robust spring and summer warming of the Sahel, larger by 10 to 50% compared to the global warming.

CMIP5 coupled models still display major sea surface temperature (SST) biases in the equatorial Atlantic, inducing a systematic southward shift of the monsoon. Because of these strong biases, further evaluation of the African monsoon is performed in SST-imposed CMIP5 simulations along the AMMA meridional transect, across a range of timescales ranging from seasonal cycle, intraseasonal fluctuations and diurnal cycle.

Our emphasis is (i) on the comprehensive set of observational data now available to evaluate

*Speaker

in depth the monsoon representation across those scales, (ii) on the usefulness of high-frequency outputs provided by some CMIP5 models at selected sites along the AMMA transect and (iii) on the added value of recent conceptual models, developed trough a better understanding of the West African monsoon and its variability, and which provide a physical basis to analyse climate model deficiencies.

Most CMIP5 models capture many features of the African monsoon, but with varying degrees of accuracy. In particular, the top-of-atmosphere and surface energy balances, in relation with the cloud cover, surface albedo and aerosols, the day-to-day intermittence of precipitation, the diurnal cycle of precipitation and the couplings between African easterly waves and convection demand further work from modelling centres to achieve more realistic simulations.

The analysis of a few updated model versions, whose physical packages have been improved during the last few years, especially throughout the FP7-EMBRACE project, shows that some of CMIP5 model deficiencies over West Africa have been reduced .

Keywords: West African monsoon, CMIP5, EMBRACE models, TOA and Surface energy balances, clouds, synoptic and intraseasonal variability, diurnal cycle

Two CMIP5 GCMs performance for the Mexican area: Identification of high and low frequency events.

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Abstract

The Mexican southern area is located in the tropics and the northern one in the extra-tropics; the great surface variability observed in the Mexican territory is associated to tropical and extra-tropical processes and a combination of both affected by abrupt orography. The reproduction of these complex dynamics by global models is a big issue.
The regional climate in Mexico (oceanic and continental) is modulated largely by perturbations such as easterly waves (EW), hurricanes (H) and cold fronts (CF), its structure, high incidence and evolution generates rainfall and descending surface temperatures, modulating the regional climate. These perturbations interact with the intertropical convergence zone (EW and H), with the Caribbean low level jet: 925hPa (EW and H) and with the high level jet: 500hPa in the Pacific (CF). Also, these perturbations modulate the intensity and duration of the North American Monsoon which affects the northwestern Mexico and the southwestern United States.

EW, with high spatial and temporal variability, can be tracked from Africa to the American Continent. In Mexico, these disturbances impact seasonally in convective rainfall and are precursors of tropical storms and hurricanes. On the other hand, CF, with a wave guide southward from Canada and United States, penetrating Mexico and Central America every year, these invasions of cold air can generate strong winds, rainfall and surface temperature descending from 2 C to 15 C in 24 hours.

We evaluated the performance of two GCMs of the CMIP5 experiment: CanESM2 and HadGEM2, based on daily data for three variables at several vertical levels: mean air temperature, precipitation and wind. These analyses were performed for the Mexican area in four two sub-regions: tropical and extra-tropical. A mechanism for regional assessment of GCMs is the identification of its capabilities in daily simulations to reproduce these processes (EW, H, CF, and the ITCZ position and intensity) in the historical period: 1979 to 2010 by applying wavelet analysis to identify the frequency in the variables: wind, temperature and precipitation, analyzing periods of wave activity and its intraseasonal, annual and interannual variability.

Additionally, it was identified in these GCM outputs, the location, intensity, structure and variability of the high level jet in the Pacific Ocean (at 500hPa) from November to May, as

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well as the low level jet in the Caribbean Sea (at 925hPa) from May to November for the historical period 1979-2010.
This analysis of the reproduction of the regional dynamics at different scales is suitable for estimating the reasons for the performance of global models identifying the possible reasons for the bias that may have these simulations. The implications of these results are discussed in terms of the observed atmospheric regional processes.

Keywords: Global Models, Performance, Tropics, Perturbations

Reproducibility of the present-day Leaf Area Index by CMIP5 Earth System Models

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Abstract

Leaf Area Index (LAI) is not only an important factor to determine the amount of photosynthesis, but also a key ground surface condition which gives significant impact to atmosphere through some aspects including albedo and transpiration. We examined the reproducibility of the present-day LAI by Earth System Models (ESMs), by comparing the outputs by 18 CMIP5 ESMs and remote sensing data (GLOBMAP, http://www.globalmapping.org/globalLAI/). Here, to get an overall sketch, we compared the 60 month averages from Jan. 2001 to Dec. 2005, after regridding all data to the 2.8125 x 2.8125 grid system. The result shows that average of ESM outputs overestimate LAI by more than twice (2.1 to 0.9) in global average, and the regions where the rate of overestimation is small (below twice) are north Africa (underestimated), west Eurasia, eastern part of North America, Amazon-basin and Congo Basin. The extent of the overestimation is unlikely related to vegetation types, and the magnitude of LAI. Interestingly, the overestimation by ESMs are acceptably removed (the global average becomes almost same as the ESM output) when the remote sensing data (in about 0.07 x 0.07 spatial resolution) is regridded by taking the maximum value, instead of the average, in each of 2.8125 x 2.8125 grid. This indicates CMIP5 ESMs do not represent the average LAI in each grid, but represent the best possible LAI (as average in a small, here 0.07 x 0.07, area) in each ESM grid. An interpretation of the result is that sub-grid scale conditions constraining LAI, e.g. slope and soil erosion, are not represented in the current ESMs.

Keywords: Leaf Area Index, Earth System Models, remote sensing, overestimation

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Systematic model biases in the Benguela: an update from PREFACE

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Abstract

We give an overview of ongoing activities within the PREFACE consortium towards understanding the causes of systematic model biases in the South-East Atlantic. Results from the analysis of coupled seasonal-to-decadal forecasts are presented, the modelling strategy adopted for hypothesis testing, and initial results from model experiments. We focus on the separate role of the air-sea coupling fields generated by the atmospheric and oceanic model compoents in generating coupled-model biases, and how they further depend on air-sea interactions.

Keywords: atmospheric model, ocean model, SST biases, seasonal forecasts, decadal forecasts, upwelling, coupled feedbacks

*Speaker

Robustness, uncertainties, and emergent constraints in the radiative responses of stratocumulus cloud regimes to future warming

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Abstract

Future responses of cloud regimes are analyzed for five CMIP5 models forced with observed SSTs and subject to a patterned SST perturbation. The stratocumulus regime becomes less frequent in all models under the surface temperature increase. A significant correlation is found in the stratocumulus regime for the inter-model difference between its in-regime cloud radiative effects in the control climate and their response to warming. The inter-model spread in in-regime albedo drives the correlation. All models overestimate the in-regime albedo of stratocumulus. Models with smaller in-regime albedo apparently perform better against observations, suggesting an increase in albedo and a negative contribution to the feedback. However, it is found that this overestimate of the in-regime albedo originates from compensating errors due to an underestimate of cloud cover and an overestimate of in-cloud albedo, and that models which have smaller bias in the in-regime albedo actually have larger biases in cloud cover and in-cloud albedo. More detailed analysis reveals that the origin of the bias is that all models systematically underestimate the relative occurrence of overcast cases but overestimate that of broken clouds within the stratocumulus regime. In the warmer climate, the relative occurrence of overcast cases tends to decrease and that of broken clouds increases. The larger the bias in the control climate, the more the change in relative frequency of occurrence of these clouds. This detailed evaluation of contributions of clouds with different cloud cover to the in-regime albedo rather suggests a positive feedback, i.e. a decrease in in-regime albedo with temperature increase. It is further found that the inter-model difference in sign of the in-cloud albedo feedback is consistent with the difference in sign of the in-cloud liquid water path response. A strong correlation is found in the inter-model difference in the in-regime liquid water path in the control climate and its future response. Since cloud water is a physical property and is independent of a model's radiative assumptions, it could potentially provide a useful emergent constraint on cloud feedback.

*Speaker

Keywords: stratocumulus, cloud regime, liquid water path, cloud feedback, cloud radiative effect, climate model

Sensitivity of AMIP simulations to model resolution and the temporal resolution of the forcing

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Abstract

Several studies in the past have given evidence that higher model resolution can result in a better representation of the variability and extremes in global climate models. We investigate the expected improvements a series of AMIP simulations with different horizontal resolution that were done for the EMBRACE project. Our analysis of near-surface temperature and precipitation focuses on the three target regions for the HELIX project: Europe, sub-Saharan Africa and South-East Asia. The results are compared against a series of CMIP5 models with varying resolution. In addition to the effects of the horizontal resolution we also study the impact of the temporal resolution of SST forcing. AMIP simulations as they were done for CMIP5 are driven with monthly mean SST in general, but we suspect that monthly forcing can lead to an underestimation of the variability of climate variables. First results indicate that the variability is improved when monthly forcing is replaced by daily forcing which could give a hint for the design of AMIP experiments for CMIP6.

Keywords: AMIP, model resolution, forcing

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Summer Arctic sea ice albedo in CMIP5 models

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Abstract

Spatial and temporal variations of summer sea ice albedo over the Arctic are analyzed using an ensemble of historical CMIP5 model simulations. The results are compared to the CLARA-SAL product that is based on long-term satellite observations. The summer sea ice albedo varies substantially among CMIP5 models and many models show large biases compared to the CLARA-SAL product. Single summer months show an extreme spread of ice albedo among models; July-values vary between 0.3 and 0.7 for individual models. The CMIP5 ensemble mean, however, agrees relatively well in the Central Arctic but shows too high ice albedo near the ice edges and coasts. In most models, the ice albedo is spatially too uniformly distributed. The summer to summer variations seem to be underestimated in many global models and almost no model is able to fully reproduce the temporal evolution of ice albedo throughout the summer. While the satellite observations indicate the lowest ice albedos during August, the models show minimum values in July and substantially higher values in August. Instead, the June values are often lower in the models than in the satellite observations. This is probably due to too high surface temperatures in June, leading to an early start of the melt season and too cold temperatures in August causing an earlier refreezing in the models. The summer sea ice albedo in the CMIP5 models is strongly governed by surface temperature and snow conditions, particularly during the period of melt onset in early summer and refreezing in late summer.

The summer surface net solar radiation of the ice covered Arctic areas is highly related to the ice albedo in the CMIP5 models. However, the impact of the ice albedo on the sea ice conditions in the CMIP5 models is not clearly visible. This indicates the importance of other Arctic and large scale processes for the sea ice conditions.

Keywords: Arctic, sea, ice, sea, ice albedo

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Land carbon-nitrogen interactions in CMIP5 and CMIP6

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Abstract

Nitrogen (N) is an essential component of any living organism, and scarce in the natural environment because of the high energy requirement for converting atmospheric molecular N2 into biologically accessible forms. The first generation of coupled carbon-cycle climate models simulated the effects of changes in anthropogenic fossil-fuel emissions and ensuing climatic changes on the global carbon (C) balance but largely ignored the consequences of widespread terrestrial N limitation.

In the Coupled Model Intercomparison Project, phase 5 (CMIP5), Earth system model ensemble only one land surface scheme (CLM4) accounted for terrestrial N availability. Based on plausible ranges of terrestrial C:N stoichiometry, we show that the terrestrial C sequestration projections of nine other CMIP5 models for four representative concentration pathways (RCPs) are largely not consistent with estimates of N supply from increased biological fixation, atmospheric deposition, and reduced ecosystem N losses. Omitting N constraints lead to an overestimation of land C sequestration in these models between the years 1860 and 2100 by between 97 Pg C (69–252 Pg C; RCP 2.6) and 150 Pg C (57–323 Pg C; RCP 8.5), with a large spread across models.

In CMIP6, a larger number of coupled carbon-cycle climate models will include a representation of the processes that lead to the N limitation of the terrestrial biosphere, which adds substantial complexity to the estimation of carbon-climate interactions because of the tight coupling of the terrestrial N and C cycles. The CMIP6 version of C4-MIP suggested a number of additional tier 2 experiments compared to the traditional definition of the carbon-concentration and carbon-climate interactions, with the aim to estimate the effects of N limitations on the carbon cycle and climate projections in of the CMIP6 models, and thereby identify the strength of the N constraint in these models. Here we detail the design of these experiment and provide a first analysis of the potential outcome using a sequence of uncoupled simulations of the O-CN model, driven by simulated climate of the IPSL-CM5A-LR CMIP5 model.

Keywords: terrestrial biosphere, carbon, concentration interaction, carbon, climate interaction, carbon, nitrogen interaction, C4MIP

*Speaker

On the Double ITCZ Bias in CESM and the CAS ESM

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Abstract

Double Inter-Tropical Convergence Zone (ITCZ) is a common systematic bias in coupled climate models. We used the Community Earth System Model (CESM) and the Chinese Academy of Sciences (CAS) Earth System Model (ESM) to study the causes of the double ITCZ biases in these two models. Biases in these two models are also compared with the biases in the ensemble of CMIP5 models. Multiple atmospheric physical parameterization schemes of deep convection, shallow convection, boundary layer turbulences are used to investigate the sensitivity of double ITCZ bias to scheme parameters as well as their formulations in the CESM and CAS ESM. We show that middle tropospheric moisture field has a dominant impact on the formation of the bias, which in turn greatly depends on the entrainment parameterization of atmospheric convection.

Keywords: Double ITCZ, Convection Schemes, Interaction of dynamics with physics

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