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Abstract book for poster presentations

1-P01

Tropical Precipitation Variability In the CAS FGOALS-f3-H

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CAS FGOALS-f3-H is a next-generation Climate System Model from the Institute of Atmospheric Physics (IAP) State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG), which is participating in CMIP6 HighResMIP. FGOALS-f3-H is featured on the high resolution up to 0.25¡ globally and a scale-aware parameterization of resolving cumulus processes. The present AMIP and relevant climate control run has been carried out on China's Tianhe-2 machine for 65-year simulation. The tropical precipitation characteristics of 0.25¡ FGOALS-f3-H have been investigated using the high-resolution TRMM-based precipitation products, SST products and tropical cyclone best track data (IBTrACS). The evolution of the major tropical systems includes ITCZ, MJO/TISO, the frequency and intensity of tropical daily precipitation, and tropical cyclone/typhoon. The results indicate that 0.25¡ FGOALS-f3-H mitigates the double ITCZ problem, and well reproduces the eastward propagating MJO in the boreal winter and northward propagating TISO over equatorial Indian ocean in the boreal summer, which are taken as the long-standing challenges in the field of climate modeling. The frequency and intensity of tropical daily precipitation are also comparable to TRMM products. In addition, the behavior of the tropical cyclone/typhoon is reported. Finally, some models bias related with tropical precipitation are discussed and the current and future applications are introduced.

Keywords: FGOALS f3 H, HighResMIP, Tropical Precipitation Variability

1-P02

CMIP6 Evaluation with the ESMValTool

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In recent years the scope of model evaluation has expanded dramatically, with new insightful approaches in addition to traditional methods that remain important and therefore are frequently applied to any new simulation. This represents an opportunity to make well-established aspects of model evaluation more routine so that they can be made available more quickly, with less effort, and be a resource to model analysts and developers. To accomplish this in time for CMIP6, the Earth System Model Evaluation Tool (ESMValTool, https://www.esmvaltool.org/) has been developed as open-source software by more than 41 institutions. It has undergone rapid development since the first release in 2016 and is now a well-tested tool that provides end-to-end provenance tracking to ensure reproducibility. It consists of a backend that performs common pre-processing operations and a diagnostic part that includes tailored diagnostics and performance metrics for specific scientific applications. The diagnostic part includes a large collection of standard recipes for reproducing the analysis of many variables across atmosphere, ocean, and land domains, with diagnostics and performance metrics focusing on the mean-state, trends, variability and important processes, phenomena, as well as emergent constraints and detailed diagnostics for monsoon, El Nino Southern Oscillation (ENSO), the Madden-Julian Oscillation (MJO). A growing list of more targeted analysis packages such as the NCAR Climate Variability Diagnostics Package CVDP are also integrated the ESMValTool. It can also reproduce the majority of analyses of the IPCC AR5 climate model evaluation chapter which allows comparison of the new CMIP6 simulations as they are published to the ESGF. In this presentation we will introduce the new ESMValTool version 2.0 and will show results from the CMIP6 evaluation as it stands at the time of the workshop.

Keywords: model evaluation, routine evaluation, ESMValTool, CMIP6

1-P03

Analysis of the IPSL-CM6-LR ensemble of historical experiments

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IPSL CMC has performed an ensemble of 31 members of historical simulations which differ by their initial conditions sampled from a long piControl experiment. Initial analysis indicate that i) while all members warm, the degree of warming between 1850-1900 and present-day varies between 1.0 and 1.4¡C depending on the members and ii) AMOC keeps some memory of the initial conditions throughout the historical simulations. A key question we will try to answer is whether the historical members that perform best in terms of simulated warming are also those that have a climate variability in phase with the observations. A second question to answer is whether modes of natural variability are forced to some extent by some of the forcing agents.

Keywords: historical simulations, IPSL, CM6, LR, aerosols

1-P04

Community Earth System Model version 2 (CESM2)

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An evaluation of the CMIP6 DECK and several MIPs simulations with the Community Earth System Model version 2 (CESM2) will be presented. The simulations use both the low-top and high-top full chemistry versions of the atmospheric component. In comparison to its previous version, CESM2 contains many substantial science and infrastructure improvements and capabilities in all its components. These new advancements include: an atmospheric model component that incorporates significant improvements to its turbulence and convection representations, opening the way for an analysis of how these small-scale processes can impact the climate; improved ability to simulate modes of tropical variability that can span seasons and affect global weather patterns; a land ice sheet model component for Greenland that can simulate the complex way the ice sheet moves and does a better job of simulating calving of the ice into the ocean; a global crop model component that can simulate both how cropland affects regional climate, including the impacts of increased irrigation, and how the changing climate will affect crop productivity; a wave model component that simulates how wind creates waves on the ocean, an important mechanism for mixing of the upper ocean; an updated river model component that simulates surface flows across hill sides and into tributaries before entering the main river channel; and a new set of infrastructure utilities that provide many new capabilities for easier portability, case generation and user customization, testing functionality, and greatly increased robustness and flexibility. Inclusion of new physics and components as well as of improved representations of numerous other processes result in better simulation characteristics in many fields in comparison with available observations.

Keywords: coupled models, CESM2

1-P05

The physical performance and variability of first EC-Earth transient simulation ensemble under CMIP6.

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The EC-Earth 3 model for CMIP6 has been developed and tuned in several Earth System Model configurations, with the Global Climate Model (GCM) and an interactive vegetation module as core physical configurations, supplemented by configurations with/without atmospheric composition, ocean biogeochemistry and Greenland glacier. This poster documents and explores the first ensemble of CMIP6 transient simulations with EC-Earth 3 in GCM mode including dynamic vegetation. Analysis encompasses large scale biases, ocean overturning variability and the main modes of hemispheric scale variability and how well they are represented in the ensemble of transient simulations and how they change over proceeding time intervals. The variability analyses includes the performance of particularly ENSO, AMO, NAO and PNA. Regarding anomalies (precipitation and air surface temperature) associated to ENSO during DJF, teleconnections to North America and the North and tropical Atlantic are evaluated in the transient runs as far as observations and reanalysis data exist. We also examine the spatial pattern, intensity and power spectra of the SST and SLP anomalies related to AMO, as well as related to PNA. Results will allow to judge the robustness and variability within the ensemble, which is important knowledge before starting future scenario simulations for different SSPs under the umbrella of the CMIP6 ScenarioMIP.

Keywords: CMIP6 transient simulation, ensemble, biases, AMOC, ENSO, AMO, NAO and PNA, teleconnections

1-P06

Indian Ocean Dipole and its linkage to South Asian Monsoon in IITM-ESM

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The fidelity in reproducing tropical Indian Ocean (IO) variability, particularly the Indian Ocean Dipole (IOD), and its linkages to South Asian Monsoon Rainfall (SAMR) is investigated in the phase 6 Coupled Model Intercomparison Project (CMIP6) historical simulations of the IITM Earth System Model (IITM-ESM) 1,2. The model simulated sea surface temperature (SST) shows a basin wide negative bias of the order of 1¡C. Conversely, thermocline depth shows positive bias reaching up to 100m in many regions such as the Arabian Sea and the southeast IO. Nonetheless, model successfully simulates many fundamental characteristics of IOD owing to better SST-thermocline coupling and much smaller biases in the IOD region. Although the simulated IOD amplitudes are larger than the observed, model skillfully represents the IOD spatial pattern, periodicity and phase-lock to the monsoon seasonal cycle. IITM-ESM simulates a realistic IOD-SAMR relationship, contrary to most of the CMIP5 models which fail to represent the observed IOD-SAMR correlation due to the overly strong control of ENSO3. In agreement with this, we find a weak correlation (r=0.35) between IOD and ENSO in the model. Further, the study tries to find potential factors responsible for this better representation of IOD-SAMR relationship in the model.

Keywords: ENSO, thermocline, Indian Ocean, teleconnection, Monsoon, IOD, IOD

1-P07

WCRP CORDEX: A Diagnostic MIP for CMIP6

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The COordinated Regional Downscaling EXperiment (CORDEX) is a project under the World Climate Research Programme and a diagnostic model intercomparison project (MIP) in CMIP6. CORDEX coordinates with ScenarioMIP and is structured to allow cross comparisons with HighResMIP and interaction with the CMIP6 VIACS Advisory Board. The Regional Challenges established by CORDEX contribute to this effort by providing a basis for using CMIP6 GCM output to produce downscaled projected changes in regional climates and assess sources of uncertainties in the projections. The Regional Challenges include focus on specific regional phenomena, such as convective systems and climates of urban areas, small islands and inland waters. They provide a basis for distilling output from multiple models into climate change information for vulnerability, impacts and adaptation studies and for improving simulations. To promote this effort, the CORDEX Science Advisory Team has developed a CORDEX Output for Regional Evaluations (CORE) framework that will produce a baseline set of homogeneous high-resolution, downscaled projections for regions worldwide using CMIP6 output as it beomes available. An immendiate intent is to provide output that can support IPCC AR6 assessments. For this reason, the core framework is intended to be ambitious but sufficiently cost-effective to produce timely output for the AR6. CORE is not intended by itself to be the next phase of CORDEX, but CORE simulations can serve a further purpose of providing a foundation in each CORDEX region for further downscaling activities. The current status of the CORE project and support by CORDEX overall for CMIP6 objectives will be reported at the meeting.

Keywords: regional climate processes, vulnerability, impacts and adaptation, high, resolution downscaling, IPCC AR6

1-P08

The MRI Earth System Model ver. 2.0 (MRI-ESM2.0): Basic evaluation of the physical component

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The Meteorological Research Institute Earth System Model version 2.0 (MRI-ESM2.0) has been developed based on previous models, MRI-CGCM3 and MRI-ESM1, which participated in CMIP5. These models underwent numerous improvements meant for highly accurate climate reproducibility. Accumulation of various improvements concerning clouds, such as a new stratocumulus cloud scheme, led to remarkable reduction in errors in shortwave, longwave, and net radiation at the top of the atmosphere, becoming sufficiently small compared with those in the CMIP5 models. The improved radiation distribution brings the accurate meridional heat transport required for the ocean and contributes a reduced surface air temperature (SAT) bias.MRI-ESM2.0 displays realistic reproduction of both mean climate and interannual variability. For instance, the stratospheric quasi-biennial oscillationcan now be realistically expressed through the enhanced vertical resolution and introduction of non-orographic gravity wave drag parameterization. For the historical experiment, MRI-ESM2.0 reasonably reproduces global SAT change for recent decades; however, interdecadal variation is overestimated compared with observations.MRI-ESM2.0 has been improved in many aspects over the previous models, MRI-CGCM3/MRI-ESM1, and is expected to demonstrate superior performance in many experiments planned for CMIP6.

Keywords: climate modeling

1-P09

GFDL's contributions to CMIP6 - highlights from GFDL CM4 and ESM4

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NOAA/Geophysical Fluid Dynamics Laboratory (GFDL) has participated in and contributed to every Coupled Model Intercomparison Project (CMIP) to date. For Phase 6 of CMIP (CMIP6), GFDL has developed two new fully-coupled models: a high resolution physical climate model (CM4), and an earth system model focusing on increased comprehensiveness (ESM4). CM4 and ESM4 will be used to participate in the DECK, as well as 13 specialized Model Intercomparison Projects (MIPs). We present an overview of model advances in CM4 and ESM4 highlighting improvements attained by the models (e.g. ENSO, MJO), as well as ongoing challenges (e.g. dry Amazon). Results will also be compared to AR5 models across a suite of climate variables, and climate benchmarks such as TCR, ECS, and TCRE. Depending on data availability, results will also be compared to other CMIP6 models.

Keywords: ESM4, GFDL, CM4, GFDL, CMIP6

1-P10

The UK Earth system model contribution to CMIP6: First results

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The 1st UK Earth system model (UKESM1) is built on the physical climate model HadGEM3-GC3.1 with the addition of an interactive treatment of the global carbon cycle and stratosphere-troposphere chemistry coupled to an advanced, two-moment aerosol scheme. UKESM1 constitutes the primary UK contribution to CMIP6. We present results from the UKESM1 CMIP6 DECK simulations, particularly an analysis of over 1000 years of piControl simulation, assessing the long-term stability of the simulated physical and biogeochemical climate, the global carbon cycle and vegetation. We further discuss processes contributing to both multi-decadal and centennial timescale variability in this unforced simulation. We then present results from the UKESM1 abrupt-4xCO2 simulation, defining the Effective Climate Sensitivity (ECS) of the model and the 1pctCO2 simulation, from which the Transient Climate Response (TCR) is calculated. Finally, we present an overview of the UKESM1 ensemble of historical simulations, emphasizing evaluation of large-scale, forced climate signals. Implications of the model's sensitivity to CO2, non-CO2 trace gases and aerosol emissions for policy-relevant metrics, such as allowable carbon emissions commensurate with different global warming limits will be discussed.

Keywords: Forced climate signals, climate sensitivity, transient climate response

1-P11

Overview of US Department of Energy's efforts on Model Diagnostics and Metrics for Understanding and Quantifying Model Biases

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The U.S. Department of Energy's Model Analysis program area of the Earth and Environmental Sciences Program has been supporting research to develop diagnostics and metrics for understanding and quantifying model biases in processes spanning across the coupled earth system. These processes are broadly related to the water cycle, extreme events, large-scale circulation features, modes of variability, cloud processes and feedbacks, land surface processes and land-atmosphere interactions, terrestrial and ocean biogeochemistry, high latitude processes, and process interactions and feedbacks. Feature tracking and computation and visualization of diagnostics and metrics are implemented in several packages such as the PCMDI Metrics Package (PMP), International Land Model Benchmarking (ILAMB), Toolkit for Extreme Climate Analysis (TECA), FLEXible object TRacKeR (FLEXTRKR), and Community Data Analysis Tools (CDAT). These tools have been used by a large community of researchers, facilitating model evaluation and intercomparison and providing insights for model development and improvement. The Model Analysis program area is also supporting research to develop use-inspired metrics to evaluate model aspects relevant to stakeholders of regional climate information. This presentation will provide a high-level overview and summarize key activities supported by the Model Analysis effort and provide examples of insights gained through application of the analysis tools in single- and multi-model output.

Keywords: Model biases, diagnostics tools, metrics, understanding

1-P12

The role of the IPCC Data Distribution Centre in supporting assessments of climate change

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The Data Distribution Center (DDC) of the Intergovernmental Panel on Climate Change (IPCC) was established in 1997 to facilitate the timely distribution of a consistent set of up-to-date scenarios of changes in climate and related environmental and socio-economic factors for use in climate impacts assessments, particularly to support the periodic IPCC Assessment Reports. This work could be seen as helping to bridge the gap between intercomparison of models which is conducted within CMIP (Coupled Model Intercomparison Project) and the broader problem of assessing climate change. This presentation will explore two key aspects of this work: firstly, supporting the exchange of data between the physical climate, climate impacts and socio-economic science domains and, secondly, ensuring that data used in assessments, which may be from dynamic research projects, is reliably curated to ensure long term access and proper tracking of data usage. These activities play a critical role in enabling robust assessments by an extended community effort while maintaining transparent data provenance. Our work is underpinned by engagement with the World Data System. In both cases, these goals are supported by applying well established methodologies of data archival and curation. Data exchange is supported by engaging with the science communities to ensure that key datasets are well documented and maintained. The work of the DDC has been made possible by the work of the IPCC Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) which has published a range of guidance documents on data use. The data curation work has a significant role in ensuring that the interests of the data provider are supported. In particular, the data provider should get credit for data which has long term value. The DDC is working with DataCite to provide DOI data references for large climate data projections.

Keywords: data provenance

1-P13

PMIP4-CMIP6 simulations of the Last Glacial Maximum climate: first results

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The Last Glacial Maximum (LGM, ~21,000 years ago) is one of the five periods selected for the PMIP4-CMIP6 exercise. It is a cold climate, forced by low greenhouse gas concentrations and high ice sheets in the northern mid-latitudes, in addition to the Greenland and Antarctic ice sheets. In this work, we will present the first PMIP4-CMIP6 simulations for the LGM. We will examine the large-scale features: land-sea contrasts, polar amplification, position of the jet-streams, intensity of the Atlantic Meridional Overturning Circulation and compare their changes to available reconstructions and to those simulated under 4xCO2 forcing. We will also analyse the impacts of the uncertainty in ice sheet reconstructions on these large-scale features. Indeed, the PMIP4-CMIP6 simulations have been designed to address this question by allowing for two different reconstructions (Kageyama et al., GMD, 2018).

Keywords: LGM, land, sea contrast, polar amplification, atmospheric large, scale circulation, AMOC, 4xCO2

1-P14

Diagnosis of model bias improvement of KIOST Earth System Model

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The Korea Institute of Ocean Science & Technology has developed the KIOST Earth System Model (KIOST_ESM) to participate in the CMIP6 and to develop a climate prediction system. Though the KIOST_ESM is based on the GFDL CM2.5 (Delworth et al., 2012), we applied a new atmospheric convection scheme (Park, 2014), planetary boundary layer scheme (Bretherton and Park, 2009), ocean mixed layer scheme (Noh et al., 2016) and soil respiration scheme (Kim et al., 2018) to the KIOST_ESM. The Southern Ocean warm bias, which is the typical climate model bias, in the KIOST_ESM, has been mostly disappeared as well as the model performance for the MJO (Madden-Julian Oscillation), ENSO (El-Nino Southern Oscillation) has been greatly improved. The KIOST_ESM, however, still show the double ITCZ (Intertropical Convergence Zone) bias and the cold-tongue bias in the equatorial eastern Pacific though mitigated somewhat. To diagnose the model bias improvement of the KIOST ESM, sensitivity experiments were conducted. As a result, the Southern Ocean warm bias is greatly affected by both the atmospheric convection and ocean mixed layer schemes while the model performance for the MJO is mostly dominated by the atmospheric convection scheme. To develop a climate prediction system applying the KIOST_ESM, ocean data assimilation was applied. We have produced a new long-term climate reanalysis data. By comparing with the previous KIOST climate reanalysis, the new climate reanalysis shows that the salinity bias and wind bias around the equatorial Pacific and Southern Ocean are significantly improved, which appears to be related to the improved Double ITCZ and Southern Ocean warm bias in KIOST_ESM. Currently, KIOST is running the KIOST_ESM to participate in CMIP6. We will finish the DECK simulation in February, 2019 and other CMIP experiments in 2019.

Keywords: Earth System Model, atmospheric convection, ocean mixed layer, southern ocean warm bias, Madden Julian Oscillation

1-P15

Development of Process-oriented Diagnostics through NOAA's Climate Model Development Task Force

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Coupled climate models and their components are subject to systematic biases. Continued model development may improve these biases, but it is important to determine whether or not the underlying physical processes are correct and consistent with the model simulations. In other cases, model improvements introduce additional degrees of freedom that need to be evaluated and constrained by observations. Several coordinated analysis efforts exist within the community that are targeted toward model evaluation and performance benchmarks. The MDTF Diagnostics Package differs from existing packages as its primary focus is the development and standardization of process-oriented diagnostics (PODs). Through a proposal-driven approach, the Modelling, Analysis, Predictions, and Projections (MAPP) Division of NOAA's Climate Program Office (CPO) currently supports the development of PODs aimed at improving model simulations of diverse set of quantities. We anticipate development over the next three years PODs related to: ENSO, tropical and extratropical cyclones, Arctic sea ice, lake-effect snowfall, forced shifts in rainfall patterns, warm-cloud microphysical processes, weather typing, the North American monsoon, and ocean-related diagnostics including sea level and the Atlantic Meridional Overturning Circulation. The proposed diagnostics will span timescales from the fast timescales of parameterized convection and cloud processes through seasonal prediction and decadal/centennial climate projections. A prototype analysis framework exists for running the process-oriented diagnostics on GFDL and NCAR model output, but we seek to broaden this framework and incorporate results from a broader collection of CMIP models and experiments. We also seek engagement with other community diagnostic efforts to improve interoperability, sharing of diagnostics, and to identify synergistic opportunities towards a more complete model analysis enterprise that spans the “development-to-production” continuum.

Keywords: modeling, diagnostics, analysis, process, oriented, bias

1-P16

Advancing our understanding of the impacts of historic and projected land use in the Earth System: The Land Use Model Intercomparison Project (LUMIP)

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Human land-use activities have resulted in large changes to the Earth surface, with resulting implications for climate. In the future, land-use activities are likely to intensify to meet growing demands for food, fiber, and energy. The Land Use Model Intercomparison Project (LUMIP) aims to further advance understanding of the broad question of impacts of land-use and land-cover change (LULCC) as well as more detailed science questions to get at process-level attribution, uncertainty, and data requirements in more depth and sophistication than possible in a multi-model context to date. There is a focus on separation and quantification of the effects on climate from LULCC relative to all forcings, separation of biogeochemical from biogeophysical effects of land use, the unique impacts of land-cover change versus land-management change, modulation of land-use impact on climate by land-atmosphere coupling strength, and the extent that impacts of enhanced CO_2 concentrations on plant photosynthesis are modulated by land use. LUMIP involves three major sets of science activities: (1) development of an updated and expanded historical and future land-use dataset, (2) model experiments designed to address LUMIP questions, and (3) development of metrics and diagnostic protocols that quantify model performance with respect to LULCC. Experiments include idealized coupled and land-only model simulations designed to advance process-level understanding of LULCC climate impacts, with a focus on the impact of land management. Additional experiments quantify the historic impact of land use and the potential for future land management decisions to aid in mitigation of climate change. Here, we will present initial results from the LUMIP simulations.

Keywords: land, use change, land management, mitigation

1-P17

The Energy Exascale Earth System Model (E3SM) version 1: Evaluation and Analysis of Climate Sensitivity

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This presentation describes the first version of the U.S. Department of Energy (DOE) new Energy Exascale Earth System Model (E3SMv1). We focus on the standard resolution of the fully-coupled physical model designed to address DOE mission relevant water cycle questions. Its components include atmosphere and land (1-degree resolution), ocean and sea-ice (60 km in the mid-latitudes and 30 km at the equator and poles), and river transport (0.5-degree) models. This base configuration will also serve as a foundation for additional configurations exploring higher horizontal resolution as well as augmented capabilities in the form of biogeochemistry and cryosphere configurations. The performance of E3SMv1 is evaluated by means of a standard set of Coupled Model Intercomparison Project Phase 6 Diagnosis, Evaluation, and Characterization of Klima (CMIP6 DECK) simulations consisting of a long pre-industrial control, historical simulations (ensembles of fully coupled and prescribed SSTs) as well as idealized CO2forcing simulations. The model performs well overall with biases typical of other CMIP-class models. While the E3SMv1 historical ensemble captures the bulk of the observed warming between pre-industrial (1850) and present-day, the trajectory of the warming diverges from observations in the second half of the 20th century with a period of delayed warming followed by an excessive warming trend. Using a two-layer energy balance model, we attribute this divergence to the model's strong aerosol-related effective radiative forcing (ERFari+aci = -1.65 W m-2) and high equilibrium climate sensitivity (ECS = 5.3 K).

Keywords: E3SM model features, DECK experiments, 20th century warming, climate sensitivity

1-P18

BESM developments towards CMIP6

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The improvements of the Brazilian Earth System Model (BESM) towards participating into the CMIP6 project are presented. The presentation is aimed at responding the question: How does the Earth system respond to forcing scenarios? Lessons learned from the coupled ocean-ice-atmosphere responses of BESM to global radiative forcings are presented. Resilient characteristics of the global coupled (e.g. atmospheric radiation and AMOC) and uncoupled (air temperature and ocean ice) oscillations of BESM representation of the global coupled climate system are presented from thousand years long experiments under CMIP5 design; to be replicated under CMIP6. Among the improvements presented are new cloud microphysics, as well as the inclusion of lagrangian capability for passive tracers in the atmospheric component model. The ocean model is MOM5 under free surface assumption and the concurrent integration of ocean biogeochemical TOPAZ model. Based on the integrations with MOM5/TOPAZ, a discussion about the effects of the increase of atmospheric CO2 on the ocean biogeochemical dynamics are also presented. As well, high performance computing aspects are presented in the equation: computation time x binary reproducibility on coupled model long runs

1-P19

Comparison of Earth system models through effective documentation of models and insight about the implementation of forcings

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For effective comparison of Earth system models in large multi-model ensembles one must first have an understanding of the model design, accurate knowledge of the requirements of experiments and insight into how forcing constraints are implemented. Earth system modelling involves many roles, from those involving model construction, to those involving devising, executing, and exploiting numerical experiments. In most cases these roles involve multiple people, and in many cases these people are in different institutions and may only interact via published information (whether journal papers, technical notes, or websites). These multiple people, sources and methodologies lead to scope for misinterpretation of intent and misunderstanding of what was actually done. We present the ES-DOC documentation methodology and information sharing ecosystem which allows the Earth system modelling community to accurately document and share information about both the design of their models and also about how their models are configured to conform to common forcing protocols. We describe how ES-DOC concepts have been applied to the design phase of CMIP6, improving not only the documentation of CMIP6, but also improving the experiments themselves. As a consequence we believe it will be easier for both the MIP designers and participants to be confident that they have requested, understood and/or executed what was required.

Keywords: CMIP6, ES, DOC, forcings, experiments, models, documentation

1-P20

Gauging systematic biases across CMIP generations

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The PCMDI Metrics Package (PMP) is an open-source Python-based capability used to produce and document objective summaries of Earth System Model (ESM) agreement with observations. This is accomplished via a diverse suite of relatively robust high-level summary statistics across space and time scales. These results can be used to quantify model improvements across generations (e.g., CMIP1-CMIP6) and to identify the relative strengths and weaknesses of different models. In this presentation we highlight new metrics that have been incorporated into the PMP, with a particular interest in the possible reduction of systematic biases in the newer generation of (CMIP6) models. Some of these results are based on recent PCMDI research, but a particular emphasis is on collaborations with an assortment of international expert teams. Examples include metrics for extra-tropical modes of variability, ENSO, MJO, monsoons and high frequency characteristics of simulated precipitation. PCMDI curates data from all generations of AMIP and CMIP going back to the early 1990s. The earlier (pre CF conventions) data is gradually and meticulously being brought up to meet community standards. This work positions us to document model improvements over nearly 30 years of model development with attention now turning to CMIP6 as new simulations are being published to the Earth System Grid Federation (ESGF). These multi-model and multi-generation summaries can be helpful for the IPPC process and many other applications. Acknowledgements: This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. We also acknowledge support from the U.S. Department of Energy, Office of Science, Climate and Environmental Sciences Division, Regional and Global Modeling and Analysis Program.

Keywords: systematic errors

1-P21

The importance of data references in CMIP6 data usage and IPCC climate assessments

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Climate research like CMIP (Coupled Model Intercomparison Project) and IPCC (Intergovernmental Panel on Climate Change) Assessment Reports, currently in their 6th cycle, depend heavily on data, which is well-curated and remains available on the long-term (see abstract by Juckes et al., 2018). To improve the traceability of climate research and assessments, the CMIP6 data sources need to be referenced. Data references and thus giving credit to data providers, their funders and contributors have been part of principles for Good Scientific Practice (e.g. DFG, 2013) for several years, but have not yet become a natural and effective part of research workflows. For CMIP6 for the first time in the history of CMIP, it is possible to cite the evolving CMIP6 data on model/MIP and experiment granularities (Stockhause and Lautenschlager, 2017). A good example how to cite data in an article's reference list is provided in the paper by Durack et al. (2018). The CMIP6 data citation service enables data users to find data references: in the ESGF (Earth System Grid Federation) portals for datasets, using Google's Dataset Search, or on the FurtherInfoUrl (global attribute of CMIP6 NetCDF files) landing page. Accompanying initiatives and projects such as the “Enabling FAIR Data” project (Stall et al., 2018) are developing best practices for the integration of data and other digital resources into author guidelines and the general research workflow in collaboration with academic publishers and repositories. Thereby data FAIRness (Findable, Accessible, Interoperable, Reusable data) in the Earth sciences is advanced.

References:

DFG (2013): https://doi.org/10.1002/9783527679188.oth1.
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Stall, S., et al. (2018): https://doi.org/10.1029/2018EO109301.
Stockhause, M., and M. Lautenschlager (2017): https://doi.org/10.5334/dsj-2017-030.

Keywords: data publication, FAIR data, CMIP6, IPCC AR6, Good Scientific Practice, CMIP6 Citation Service

1-P22

Diagnosing climate response and feedback in response to idealized CO2 forgin in K-ACE

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NIMS/KMA (National Institute of Meteorological Sciences/ the Korea Meteo-rological Administration) has participated in the CMIP3 and 5 using ECHO-G and HadGEM2-AO models. To participate in the IPCC 6th report the K-ACE (KMA's Advanced Climate Earth system model), an Earth System Model, has been developed by NIMS/KMA and we simulated the DECK (the Diagnostic, Evaluation and Characterization of Klima) experiments, which is an essential experiment for CMIP6 (Eyring et al., 2016). K-ACE consists of a physical basis model for UKESM, ocean model for MOM4.1, and sea ice for CICE. In this study, we analyzed the response of the mean fields of the atmosphere and ocean to CO2 forcing and climate sensitivity using pre-industrial control simulation and CO2-forced experiments. The CO2 experiments consist of 1%CO2/yr experiment, which increase carbon dioxide by 1% each year, and Abrupt 4xCO2 experiment, which quadrupled the concentration of carbon dioxide as of 1850. Each CO2 experiment was prescribed with an only different carbon dioxide concentration of pi-control simulation and integration period was 151 years from 1850. We used the ECS (Equilibrium Climate Sensitivity) and TCR (Transient Climate Response) as a way to quantify and compare responses to forcing in the model through CO2 experiments, which were compared with the models participating in CMIP5 to assess the performance of K-ACE. The ECS and TCR estimated by the CO2 experiments of the K-ACE was 5.1K, and 3.6K, respectively, and the ECS of the CMIP5 models ranged from 2.1K to 4.7K, and the TCR ranged from 1.1K to 2.6K. The response to the CO2 forcing in K-ACE was somewhat higher than the CMIP5 range.

Keywords: KACE, ECS, TCR

1-P23

input4MIPs: Getting CMIP forcing data in better shape

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input4MIPs (input datasets for Model Intercomparison Projects) is an activity to make available via the Earth System Grid Federation (ESGF) the boundary condition and forcing datasets needed for CMIP6. The project was initiated in 2016 and has subsequently become the primary source of input data for CMIP6 modeling centers. Various datasets are needed for the pre-industrial control (piControl), AMIP, 1 percent compounding CO2 (1pctCO2), abrupt four times CO2 (abrupt-4xCO2) and historical simulations, and additional datasets are needed for many of the 23 CMIP6-endorsed model intercomparison projects (MIPs) experiments that comprise the CMIP6 project. This presentation will provide an overview of the program evolution and the status of forcing datasets being used in CMIP6 simulations. A key advantage of the project, is that the forcing datasets used in simulations will be traceable, with comprehensive documentation provided by ES-DOCs. As these forcing datasets being used in various simulations are also hosted in ESGF alongside the CMIP6 data, they are readily available to analysts during simulation assessment. Such end-to-end data provenance and documentation will allow for an improved assessment of the model suite responses to forcings. In addition, by formalizing and centralizing the forcing datasets being used by simulations, data errors and inconsistencies have been better and more quickly identified, providing an improvement to forcing dataset consistency in CMIP6 when contrasted to earlier CMIP phases.

Keywords: CMIP6, forcing, volcano, change, variability, ocean, atmosphere, land use

1-P24

An overview of the first results from ScenarioMIP experiments

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We will characterize the main features of the new scenario experiments organized under the ScenarioMIP design. In particular, we will focus on analyzing globally/hemispherically/regionally averaged quantities (temperature, precipitation, indices of extremes) and spatial patterns of change by the end of the 21st century. We will use CESM2 output and -- as much as possible -- additional available models in order to perform a first exploration of structural model uncertainties. A comparison to CMIP5 RCPs reaching similar radiative forcing levels by the end of the century (RCP2.6 and 8.5 in particular) will be performed, in order to detect significant differences, if any, particularly in patterns of warming and precipitation changes by the end of the century, used by the well-established emulation techniques. The question of the influence of regional forcings (like land-use and aerosol emissions) which have changed within the new SSP-driven emission trajectories is a central one within the new scenario framework, and even if we do not expect to be able to address it fully and exhaustively by this first analysis, the consideration of the new spatial patterns and their comparison with older, or across scenarios, may provide a first-order assessment of the role of such forcings.

Keywords: SSPs, RCPs, Scenarios, ScenarioMIP, climate change patterns

Session 1 - MIP overviews, Model group overviews and infrastructure

1-P25

The Vulnerability Impacts Adaptation and Climate Services Advisory Board; Towards using CMIP6 outcome in VIACS applications

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The poster will present achievements of Phase I of the Vulnerability, Impacts, Adaptation, and Climate Services (VIACS) Advisory Board for CMIP6, as well as the envisaged transition and initial ideas and perspectives for Phase II. The VIACS Advisory Board was launched in 2015 as an endorsed CMIP6 diagnostic MIP. The main goal is to facilitate communication between VIACS communities (who use climate model outputs) and climate modelers (who create outputs) across CMIP6 leadership and endorsed MIPs. Phase 1 of the VIACS Advisory Board coincided with the design phase of CMIP6, and thus was primarily focused on providing VIACS perspective into the construction and prioritization of model experiments and model outputs for downstream applications. The main focus included an evaluation of VIACS interest in all CMIP5 output variables and MIP experiments. This was done in requests for additional tailored output variables; the creation of specific applications-oriented packages of output data to be available via the CMIP6 data archive; and an indication of specific VIACS communities likely to use each MIP simulation experiment. The VIACS AB also called for enhanced evaluation of key impacts-relevant model diagnostics, perhaps including impacts-oriented observational products (Obs4Impacts). Phase II of the VIACS AB will focus on enhanced evaluation of CMIP6 outputs that are now available and key online diagnostics relevant to VIACS applications. We will also ease the transition of CMIP6 modellers' findings to the VIACS communities in order to raise awareness of known caveats, and will engage different VIACS communities to track the use of CMIP6 outputs incorporating climate variability, predictability, scenarios, and uncertainties in their research and applications. Of particular interest are the interactions between long-term climate trends and the shifting profile of hazards and risk.

Keywords: vulnerability, impact, adatation, climate services

1-P26

AIRS Obs4MIPs V2 Dataset and CMIP6 Model Temperature and Humidity Biases

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The "Observations for Model Intercomparison Projects" (Obs4MIPs) collects, organizes and publishes various well-established satellite datasets for Coupled Model Intercomparison Project (CMIP) model evaluation. We have generated and published the Atmospheric Infrared Sounder (AIRS) Obs4MIPs V2 dataset including the monthly mean tropospheric air temperature, specific humidity, and relative humidity profiles from September 2002 to September 2016. In this paper, we will discuss the AIRS Obs4MIPs V2 dataset and some preliminary results on CMIP6 model temperature and humidity biases based on this dataset.

Keywords: AIRS, Obs4MIPs, CMIP6

1-P27

The nature of 60-year oscillations of the Arctic climate according to the data of the INM RAS climate model

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Using the data of pre-industrial experiment with the INM-CM5 climate model for the period of 1200 years, we study the mechanism of natural oscillations of Arctic climate with the period of about 60 years. It is shown that for a quarter of the period prior to the Arctic warming there is a flow of Atlantic water into the Arctic ocean being more intense than usual, the salinity and density are less than usual near the coastand shelf border. As the result of advection of Atlantic water after Arctic warming, the water near the coast and shelf border becomes more salty and heavy, which leads to a weakening of the flow of Atlantic water and the change of oscillation phase. The conclusions are confirmed by calculations of the generation of anomalies of temperature, salinity, and velocity of currents by different terms, as well as estimation of the contribution of various components to the change of oscillation phase.

Keywords: mechanism, natural climate variability, Arctic, North Atlantic

1-P28

Project compliant climate model output analysis with CDO's

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CMIP6 defines a data standard in order to facilitate data analysis across results from different models. The German Federal Ministry of Education and Research (BMBF) is funding activities which provide support to German modeling groups in many aspects of standard compliant CMIP6 data production. One aspect is to assist the modeling groups at the customization of the CMIP6 data request. Another focus is on the extension of the Climate Data Operator (CDO) toolkit in order to enable modeling groups to use the CDOs for project-standard compliant formatting of model output, in addition to data analysis and diagnostics. The CDOs is a worldwide popular infrastructure software developed and maintained at the Max Planck Institute for Meteorology (MPI-M). It comprises a large number of command line operators for gridded data, e.g. for statistic, interpolation, or arithmetics. In order for the operators to be usable for CMIP6 data processing, its meta data as well as data model is adapted to that of CMIP6. In addition, a new operator ‘cmor’ has been developed which calls the subroutines of the CMOR (Climate Model Output Rewriter) library developed at PCMDI (Program for Climate Model Diagnosis & Intercomparison). It allows the user to create different project standards by reading a table that describes the target project standard and which is provided as an input argument. The ‘cmor’ operator may be piped with other CDO operators, i.e. no temporary files are created. It is fully integrated in the CDO software infrastructure, therefore the user benefits from the extensive support facilities provided by the MPI-M and the DKRZ.

Keywords: Postprozessing, Tool, Standard

1-P29

The Cloud Feedback Model Intercomparison Project (CFMIP): Current status for CMIP6

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The primary goal of CFMIP is to investigate the main climate responses related to clouds, such as changes in thermodynamics, circulation, and the water cycle, in order to improve our understanding of cloud-radiative feedback mechanisms in a changing climate and use this knowledge to assess climate sensitivity. To achieve these goals, CFMIP brings together climate modelling, observational, and process modelling communities and provides community support (https://www.earthsystemcog.org/projects/cfmip/). CFMIP started in 2003 as a CMIP-endorsed model intercomparison project and now, in relation to CMIP6, proposed the third phase of CFMIP (CFMIP3) experiments (Webb et al. 2017 GMD). The CFMIP3 Tier 1 experiments consist of a compact and inexpensive set: amip+4K, amip4xCO2, amipFuture (building on the DECK amip experiment), and corresponding idealized model experiments in aquaplanet configurations. These experiments are a continuum from CMIP5/CFMIP2 and address the question "What are the physical mechanisms underlying the range of cloud feedbacks and cloud adjustments predicted by GCMs?" We provide outputs from the CFMIP Observational Simulator Package (COSP) and other process diagnostics for quantitative evaluation of modelled clouds with observations. Currently, 15 modeling groups are carrying out the CFMIP3 experiments and are expected to upload their outputs to ESGF by the middle of 2019. In addition, there are a number of Tier 2 experiments to address further science questions. Some experiments require 150-year AOGCM simulations while others follow the AMIP configuration expanding the Tier 1 set. Finally, CFMIP supports informally proposed experiments in order to expand our understanding of cloud processes and their coupling with circulation. Our plans for CMIP6 will be summarized and positioned in the wider context of the WCRP Grand Challenge on Clouds, Circulation and Climate Sensitivity. Also, results from the CMIP6/CFMIP3 experiments will make a significant contribution to the IPCC AR6.

Keywords: clouds, precipitation, circulation, climate feedback, radiative forcing

1-P30

Main Progress of the Beijing Climate Center Climate System Model (BCC-CSM) from CMIP5 to CMIP6

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Main progresses of Beijing Climate Center (BCC) climate system model from the phase five of the Coupled Model Intercomparison Project (CMIP5) to its phase six (CMIP6) are presented, in terms of physical parameterizations and models performance. BCC-CSM1.1 and BCC-CSM1.1m are the two models involved in CMIP5, and BCC-CSM2-MR, BCC-CSM2-HR, and BCC-ESM1.0 are the three models configured for CMIP6. Historical simulations from 1851 to 2014 from BCC-CSM2-MR (CMIP6) and from 1851 to 2005 from BCC-CSM1.1m (CMIP5) are used for models assessment. The evaluation matrices include (a) energy budget at top of the atmosphere, (b) surface air temperature, precipitation, and atmospheric circulation for global and East Asia regions, (c) sea ice extent and thickness and Atlantic Meridional Overturning Circulation (AMOC), and (d) climate variations at different time scales such as global warming trend in the 20th century, stratospheric quasi-biennial oscillation (QBO), Madden-Julian Oscillation (MJO) and diurnal cycle of precipitation. Compared to BCC CMIP5 models, BCC CMIP6 models show significant improvements in many aspects including: tropospheric air temperature and circulation at global and regional scale in East Asia, climate variability at different time scales such as QBO, MJO, diurnal cycle of precipitation, and long-term trend of surface air temperature.

Keywords: BCC model, from CMIP5 to CMIP6, Historical run

1-P31

Overview of the Global Monsoons Model Intercomparison Project (GMMIP) for CMIP6

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The Global Monsoons Model Inter-comparison Project (GMMIP) has been endorsed by CMIP6. The focus of GMMIP is on monsoon climatology, variability, prediction and projection. More than twenty international modelling groups are committed to joining GMMIP. GMMIP aims to answer four primary scientific questions: 1) What are the relative contributions of internal processes and external forcing that are driving the historical evolution of monsoon of the late-19th through early-20th centuries? 2) To what extent and how does atmosphere-ocean interaction contribute to the interannual variability and reproducibility of monsoons? 3) How can high-resolution and associated improved model dynamics and physics help to reliably simulate monsoon precipitation and its variability and change? 4)What is the effect of the orography of the Himalaya-Tibetan Plateau on the development and maintenance of the Asian monsoon? Similarly, what is the impact of orography elsewhere on other regional monsoons? In order of decreasing priority, GMMIP experiments are designed to examine: Tier-1) Model skill at simulating the climatology and interannual-to-multidecadal variability of global monsoons forced by SSTs during the historical climate period ; Tier-2) The role of the Interdecadal Pacific Oscillation and Atlantic Multidecadal Oscillation in driving variations of the global and regional monsoons; Tier-3) The effects of large orographic terrain on the establishment of the monsoons (such as examining the relative influence of the Himalayas and Tibetan Plateau on the regional components of the Asian monsoon). The outputs of the CMIP6 DECK, historical simulation and other endorsed MIPs will be used in the diagnostic analysis of GMMIP to give a comprehensive understanding of the roles played by different external forcings, and potential improvements in the simulation of monsoon rainfall at high resolution. Some emerging results based on the submitted CMIP6 data will be shown and the potential contribution to IPCC WG1 AR6 will be highlighted.

Keywords: Global Monsoons Model Intercomparison Project, GMMIP, internal variability, external forcing

2-P01

Climate sensitivity and feedbacks in the IPSL-CM6 climate model

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A new version of the IPSL-CM climate model has been developed for CMIP6. This version differs from the CMIP5 version by its enhanced horizontal and vertical resolutions, and by significant changes in its physical parameterizations, including in the representations of clouds, convection, turbulence, and radiation. This model version will participate in CMIP6, CFMIP3, and RCE-MIP coordinated experiments. Here we present an analysis of the climate sensitivity, feedbacks, and adjustments produced by this new model in a range of idealized experiments and configurations: coupled ocean-atmosphere, atmosphere-only, aqua-planet, and RCE. We investigate the reasons for the high climate sensitivity (4.7 K) produced by this model, diagnose feedbacks and adjustments using the kernel method, and assess their robustness across a suite of experiments. Particular attention will be paid to the response of tropical clouds to increased CO2 and global warming. After analyzing the IPSL-CM 6model, we perform a multi-model analysis based on available CMIP6 simulations.

Keywords: climate sensitivity, feedbacks, clouds, tropical clouds, adjustments, IPSL, CM6

2-P02

A new multi-variable benchmark for Last Glacial Maximum simulations

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We present a new global reconstruction of seasonal climates at the Last Glacial Maximum (LGM, 21,000 yr BP) made using 3-D variational techniques, with pollen-based site reconstructions of six climate variables and the ensemble average of the PMIP3/CMIP5 simulations as a prior. We assume a set of Gaussian correlations in the error of the prior, in order to produce a climate reconstruction that is smoothed both from month to month and from grid cell to grid cell. The pollen-based reconstructions include mean annual temperature (MAT), mean temperature of the coldest month (MTCO), mean temperature of the warmest month (MTWA), growing season warmth as measured by growing degree days above a baseline of 5¡C (GDD5), mean annual precipitation (MAP) and a moisture index (MI), which is the ratio of MAP to equilibrium evapotranspiration. Different variables are available at different sites, but our approach both preserves seasonal relationships and allows the full suite of seasonal climate variables to be derived at each location. We account for the ecophysiological effects of low [CO2] on vegetation in making reconstructions of precipitation and moisture index, which results in the reconstruction of wetter climates than would otherwise seem from the vegetation composition. Finally, by comparing the error contribution to the final reconstruction, we provide confidence intervals on these reconstructions and delimit geographical regions for which the palaeodata provide no information to constrain the climate reconstructions. The new reconstructions will be used as a robust benchmark for evaluation of the PMIP4/CMIP6 entry-card LGM simulations.

Keywords: Benchmark, Reconstruction, LGM, Data Assimilation, Pollen

2-P03

Biogeochemical feedbacks in CMIP6 Earth System Models

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In this poster we show the first results analysing biogeochemical feedbacks from the first few Earth System model to have submitted results to CMIP6. We explain how an analysis framework has been devised to directly compare these biogeochemical feedbacks with the physical climate feedbacks and also to frame them in terms of carbon budgets. The CMIP6 Earth System models incorporate a variety of feedbacks that may affect the overall sensitivity of their equilibrium surface temperature response to a climate forcing. As well as the carbon cycle feedback, a multitude of other biogeochemical feedbacks have also been identified coupling the fates of short-lived and long-lived species. Climate change can affect the chemistry, transport and removal of reactive gases (such as methane and ozone) and aerosols, and impact the source strength of natural emissions of methane, ozone precursors and aerosols. The evaluation of their importance for future climate change has been very patchy, with quantification for a few of the feedbacks assessed in AR5 (Ciais et al. 2013) from a very few models, and a few single model studies of specific feedbacks since then (e.g. Nowack et al. 2015). This science will take a large step forward with the CMIP6 project. All Earth System models are required to participate in the DECK 4xCO2 and 1% CO2 so for the first time we will analyse the multi-model responses of chemistry, natural emissions and removal of reactive gases and aerosols to a specified changing climate. To complete the feedback loop, the climate effects (effective radiative forcing - ERF) of these species are quantified in AerChemMIP. Specific AerChemMIP experiments are designed to quantify the climate effects of natural emissions of: dust, sea salt, DMS, biomass burning, lightning NOx, and biogenic VOCs.

Keywords: Feedbacks, Aerosols, Chemistry

2-P04

Energy conserving and physically consistent method for isolating the impacts of sea-ice changes in a multi-model framework

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Modeling approaches aimed at isolating the impacts of sea-ice loss more often than not tend to impose non-physical energy flux perturbations in order to achieve the changes in sea-ice cover. This makes it difficult to discern if the observed climatic response really originates from the sea-ice cover changes or if it is altered by the imposed energy flux perturbations. While other, easy to implement approaches, such as 'painting the ice black' or 'turning the ocean white' have the advantage of not imposing spurious heat flux perturbations, they are unphysical and fail to capture the range of processes resulting from the actual disappearance or recovery of sea-ice cover. Here we illustrate a new approach that is both energy conserving and physically realistic, and discuss its applicability in a multi-model framework. Our method employs small perturbations to selected sea-ice physics parameter values that result in sea-ice cover changes. The sea-ice physics parameter perturbations are imposed only within their respective expert defined ranges, allowing for a physically realistic experimental design (within the limits of the model they are applied in). Importantly, this approach does not require any kind of artificial alteration of high latitude energy fluxes to achieve the sea-ice cover changes thus also ensuring energy budget conservation. The impacts of the sea-ice physics perturbations are discussed based on simulations performed with CCSM4 and EC-Earth models, with the aim of setting a benchmark for other multi-model applications. Preliminary analysis suggests that not only do the sea-ice physics parameter perturbations present a useful tool for isolating the impacts of sea-ice loss and sea-ice forcing on climate but that they also provide a new path for improvements in modeling of sea-ice changes.

Keywords: energy budget conservation, sea ice physics parameter perturbations, sea ice loss

2-P05

Assessing the linearity and additivity of water cycle changes simulated by CNRM-CM6-1

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The confidence in global and regional projections of freshwater resources is rooted in the understanding of how the different components of the global water cycle respond to different radiative forcings. The CFMIP and DAMIP approaches are increasingly useful for this purpose. Within CFMIP, both tier 1 and tear 2 simulations have been designed to assess the additivity and/or linearity of the water cycle response to increasing CO2 concentrations. This will be illustrated with preliminary results of the CNRM-CM6-1 global climate model. Beyond global mean precipitation and the so-called hydrological sensitivity, other more policy-relevant features of the global water cycle will be explored. The fast adjustment to CO2 increase will be distinguished from the slower response to the global ocean warming. Moreover, it will be shown that the tier 2 AGCM experiments enable the breakdown of simulated water cycle changes into multiple contributions, including the radiative and physiological CO2 effects, the role of a uniform warming of sea surface temperature (SST), and the role of the anomalous SST pattern or of the sea ice retreat. Within DAMIP, the hydrological responses to anthropogenic and natural radiative forcings can be assessed, as well as their additivity and their potential contributions to recently observed water cycle variations. The small ensembles achieved with CNRM-CM6-1 are not necessarily sufficient for the attribution of regional changes but already suggest promising attribution studies at the global scale.

Keywords: water cycle, hydrological sensitivity, linearity, drivers, attribution

2-P06

North Atlantic response to external forcing and role of the anthropogenic-aerosols

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Results from the IPSL-CM6 large-ensemble of historical simulations and associated detection-attribution model intercomparison project (DAMIP) simulations indicate that the anthropogenic-aerosols have caused an intensification of the Atlantic Meridional Overturning circulation (AMOC) at the end of the twentieth century. The anthropogenic-aerosols have also important impacts onto the global atmospheric circulation. These effects have overcome the influence of greenhouse gases that have contributed to reduce the AMOC. Both, the radiative effect of anthropogenic-aerosol and the associated dynamical changes will be explored within the available CMIP6 database. The impact for the European climate will be also explored. We will finally quantify if the aerosols forcing explain the observed historical Atlantic Multidecadal variability, and investigate the associated uncertainty.

Keywords: detection, external forcings, Climate variability, attribution, AMOC

2-P07

Changes in Growth Rate and Seasonal Cycle Amplitude of Column CO2 in CMIP5 models and Satellite Data

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Earth System Models (ESMs) display a large spread in modeled atmospheric CO2, resulting in uncertain projections for the future. Utilizing the Earth System Model Evaluation Tool (ESMValTool, Eyring et al., 2016), we evaluate emission driven historical simulations from CMIP5 and, as they become available, CMIP6, with satellite data. The comparison focuses on the growth rate and seasonal cycle amplitude of XCO2, which are good candidates to be used in the development of emergent constraints. Emergent constraints are relationships across an ensemble of models between an unobservable Earth system sensitivity and an observable trend or variation in the contemporary climate. Both models and observations show characteristic seasonal cycles in CO2, with lower values in the summer when strong photosynthesis causes plants to absorb carbon dioxide, and higher values in the winter when photosynthesis stops. The seasonal cycle amplitude, defined as the peak-to-trough amplitude of the seasonal cycle, therefore depends on the strength of the summer photosynthesis and the duration of the growing season and is larger in the Northern than in the Southern Hemisphere. The observations and models will be analyzed further to develop robust emergent constraints for multi-model climate model projections, similar to Wenzel et al. 2014 and 2016. In those studies sensitivities of atmospheric CO2 were used to constrain the long-term sensitivity of tropical land carbon storage to climate warming and the magnitude of the CO2 fertilization effect.

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Keywords: Seasonal Cycle, Growth Rate, CMIP5, XCO2, CO2, satellite observations

2-P08

Improving dust forcing in GFDL ESM4 by coupling dust emission from the dynamic land model (LM4.1) and deposition to the ocean biogeochemistry model (COBALT).

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Mineral dust particles interact with the Earth's Climate System by absorbing and scattering solar and terrestrial radiations. Deposition of dust on open oceans provides nutrients for phytoplankton blooming. These interactions may feedback on dust emissions mostly through modulation of the hydrological cycle. Several studies have documented the failure of CMIP5 models to reproduce long-term variability of dust concentration, which may be related to vegetation changes in response to perturbations in the hydrological cycle. Because vegetation and its characteristics are affected by both direct human influences (e.g. deforestation) and climate change (e.g. dieback due to drought), it is important to include vegetation dynamics as one of the predictors of dust emission to accurately simulate past, present, and future dust forcing. The new GFDL Earth's System Model (ESM) version 4 contains fully interactive and consistent dust lifecycle: from its emissions calculated by the dynamic land model (LM4.1) to its long-range transport in the atmospheric model (AM4) followed by its deposition to the ocean where it feeds the tracers of the biogeochemistry model (COBALT). In this poster, we present an analysis of the amplification of dust forcing by vegetation and land-use changes, and its consequences on radiative forcing and ocean productivity, based on GFDL ESM4 simulations in support of CMIP6.

Keywords: Aerosol forcing, Mineral Dust, Earth System Model, Dynamic Vegetation and landuse, Ocean biogeochemistry

2-P09

The impact of fixed ozone in 4xCO2 simulations

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CMIP6 protocol suggests prescribing 1850 ozone concentrations in 4xCO2 simulations. This leads to a mismatch between the dynamical tropopause, which rises due to climate change, and the ozone tropopause, which remains fixed. The result is unphysically high (stratospheric) ozone concentrations in the upper troposphere, leading to biases in high level cloud, cold point temperature, and stratospheric water vapour. In the Met Office climate model this impacts the climate sensitivity and surface climate. In the future, this use of pre-industrial ozone concentrations in 4xCO2 simulations is likely to cause similar problems in other climate models without interactive ozone schemes.

We describe a method to interactively redistribute ozone in 4xCO2 simulations, which removes the inconsistency between the dynamical and ozone tropopause heights whilst retaining the prescribed CMIP6 ozone distributions as closely as possible. This removes any unphysical consequences of the tropopause mismatch from such simulations, whilst still allowing a fair comparison against other CMIP6 model simulations.

After each model year, the monthly mean, zonal mean, dynamical tropopause is formed based on the previous two model years. At each latitude, the ozone tropopause is defined at 1km below the dynamical tropopause by setting ozone concentrations there to 80ppbv, and smoothing appropriately. The mass of ozone removed from the troposphere is added to the stratosphere, by multiplying stratospheric ozone concentrations by the same percentage everywhere. Thus total mass of ozone is conserved. This redistribution is then applied to the 3D monthly mean ozone concentrations, and thus azonal structures in the CMIP6 prescribed ozone are also preserved. The climate model is then run for the following year, using this redistributed ozone, and then the whole process is repeated within the automated system.

We present results from pre-industrial and 4xCO2 simulations. This method can also be used for 1%/year CO2 and transient climate simulations.

Keywords: ozone, climate sensitivity

2-P10

Global monsoon changes in CMIP6 GMMIP pacemaker experiments

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Changes in monsoon precipitation are vital for annual rainfall and thus water supply for agriculture, food and energy of the world's most highly populated and developing regions. The Global Monsoons Model Inter-comparison Project (GMMIP) has been endorsed by the Coupled Model Inter-comparison Project (CMIP) as one of the participating model inter-comparison projects (MIPs) in the sixth phase of CMIP (CMIP6). The tier-2 experiments are designed to examine the roles of the Interdecadal Pacific Oscillation (IPO) and Atlantic Multidecadal Oscillation (AMO) in driving variations of the global and regional monsoons. Using two sets of GMMIP experiments based on NCAR Community Earth System Model (CESM) version1.2, namely historical experiment (hist) and tropical Pacific SST restoring experiment (hist-resIPO), we firstly investigate the relative contributions of internal mode and external forcing to the observational decreasing trend of Indian summer monsoon precipitation in the second half of the 20th century. We show evidence that the observed decreasing trend does not arise from the response to external forcing alone. Rather, the drying itself appears to result from suppressed moisture convergence, associated with an IPO-induced weaker Walker circulation, resulting in depressed convection and advection of relatively drier air from the Eurasian landmass. We then extend to global monsoon to examine the coherent historical variability. Differences between hist and hist-resIPO experiments indicate that global monsoon index in hist-resIPO is better correlated with observation than hist experiment in the past century. Based on the coming CMIP6, we expect the large suite of GMMIP pacemaker experiments carried out by different modeling centers for better understanding the mechanisms of precipitation changes in the global monsoon system and disentangling the influence of SST variability on interannual-to-interdecadal monsoons variability from external forcing.

Keywords: Global monsoon, GMMIP, Pacemaker experiment, External forcing and internal variability

2-P11

Response of permafrost under different solar geoengineering methods

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We conduct a model-based assessment of changes in permafrost extent and carbon storage under solar dimming and stratospheric aerosol injection methods forming part of the Geoengineering Model Intercomparison Project Phase 6(GeoMIP6). The solar dimming experiment G1 is designed to completely offset the global mean radiative forcing due to a CO2-quadrupling experiment (abrupt4_CO2), while in G4 experiment, the radiative forcing due to the representative concentration pathway 4.5 (RCP4.5) scenario is partly offset by a layer of sulphate aerosols in the stratosphere. Both G1 and G4 geoengineering simulations lead to lower temperatures at higher latitudes, but with residual polar amplification effect. It is not clear how the permafrost extent and its carbon stock change under solar dimming and stratospheric aerosol scenarios. In this study, we use BNU-ESM with improved permafrost parameterization scheme to simulate the response of permafrost to different solar geoengineering methods.

Keywords: earth system model, geoengineering, permafrost

2-P12

Projection uncertainties in the next generation of climate models and ensembles

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As our understanding improves, climate models continue to increase in complexity to synthesize all that knowledge. When more observations become available and computational capacity increases, more processes are considered and models are run at higher resolutions. The hope is that models will converge to reality. But are they really, and how do we know? While individual models improve in how they represent quantities we can observe, their spread in future projections has been remarkably stable over decades, both globally and locally. Model agreement on future projections has not increased from CMIP3 to CMIP5. However, model spread in an ensemble of opportunity may be too big if poor models are included, or too small if all models are missing important feedbacks. Here we first systematically quantify model agreement with observations on key quantities like temperature and precipitation to assess model performance of the new CMIP6 ensemble, compared to CMIP3 and CMIP5. Second, we estimate model spread in future projections, using consistent methodologies and taking into account differences in emission scenarios, for the three most recent intercomparisons, and compare these to an uncertainty assessment using model weighting and emergent constraints that takes into account model performance and model dependence. The separation of differences in individual model responses to forcing from differences in how an ensemble in generated, differences in emission scenarios, and contributions from natural variability is an important step in understanding how and why the new CMIP6 projections differ from earlier CMIP intercomparisons. It provides a necessary step towards a quantification of projection uncertainty in future IPCC reports, and an opportunity to reflect on the potential and challenges in reducing these uncertainties in future generations of models and ensembles.

Keywords: projection, uncertainty

2-P13

CMIP5 subtropical marine low cloud feedback interpreted through a unified predictive index

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It has been recognized for many years that low cloud feedback is one of the major sources of the uncertainty in future climate change. The strength of local temperature inversion is a key climate parameter that controls the low cloud amount. The estimated inversion strength (EIS), a predictive index based on the difference in potential temperatures between the 700-hPa level and the surface, is strongly positively correlated with low cloud amount. Very recently, we developed a new predictive index for low cloud amount, the estimated cloud-top entrainment index (ECTEI). This is a refinement of EIS that takes into account a cloud-top entrainment criterion using a specific humidity gap between the 700-hPa level and the surface. In this study, the changes in low cloud amount and these predictive indices in a warmer SST climate are investigated over the subtropical oceans for eight CMIP5 models using amip and amip4K simulations. Most models show that the low cloud amount decreases when SST increases, despite EIS increases. On the other hand, ECTEI decreases. The surface specific humidity is mainly controlled by the saturation specific humidity at the surface and much greater than the specific humidity in free troposphere in most cases. Therefore, the humidity gap increases with SST and leads to reduction of low clouds. The result suggests that this effect exceeds the increase in low clouds due to enhancement of temperature inversion strength in a warmer SST climate. Furthermore, using amipFuture and amip4xCO2 simulations, the influence of SST pattern and low cloud feedback in increased CO2 climate will be discussed. This work clearly indicates the usefulness of ECTEI for interpretation of factors controlling low cloud amount and low cloud feedback.

Keywords: low cloud feedback, low cloud amount, inversion strength, cloud top entrainment

2-P14

Inter-model spread in instantaneous radiative forcing across multiple climate drivers

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The effective radiative forcing is a widely used concept for diagnosing the response of the climate to different forcing agents and has proven to be important for understanding why climate models respond differently to identical emission scenarios. It consists of two parts - the instantaneous radiative forcing, which measures the perturbation in radiative fluxes due solely to a change in the forcing agent, and rapid adjustments, which measure the radiative perturbations induced by the atmosphere's response to the instantaneous radiative forcing. Recent efforts to diagnose uncertainty in effective radiative forcing have largely focused on rapid adjustments, in part because instantaneous radiative forcing is not routinely calculated in climate model simulations. Here we use radiative kernels to systematically diagnose instantaneous radiative forcing in multi-model ensembles of climate model simulations from CMIP5 and the Precipitation Driver and Response Intercomparison Project (PDRMIP) under various idealized forcing scenarios. We show that differences in instantaneous radiative forcing, not rapid adjustments, are the dominant contributor to inter-model spread in effective radiative forcing. Because instantaneous radiative forcing is relatively well constrained by radiative transfer theory, it provides a tractable solution to reducing the intermodel spread in effective radiative forcing and, consequently, future climate change projections.

Keywords: instantaneous radiative forcing, radiative kernels, effective radiative forcing, rapid adjustments

2-P15

Consistency and robustness of emergent constraints for equilibrium climate sensitivity

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An emergent constraint refers to the use of observations to constrain a simulated future Earth system feedback. If physically plausible relationships can be found between, for example, changes occurring on seasonal or interannual time scales and changes found in model simulations of anthropogenically-forced climate change, an observational constraint of multi-model projections might be possible. This offers the possibility to reduce uncertainties in climate projections. Emergent constraints can help guiding model development onto processes crucial to the magnitude and spread of future climate change and to point out future observational priorities.
In this study, selected emergent constraints for equilibrium climate sensitivity published in recent literature are tested in terms of their consistency and robustness. For this purpose, the emergent constraints have been implemented into the Earth System Model Evaluation Tool (ESMValTool, https://www.esmvaltool.org/) to allow for consistent calculations and processing of model data and observational datasets. A focus will be on testing consistency of emergent constraints across different phases of CMIP. Results from emergent constraints derived from CMIP5 simulations will be compared against each other and cross-checked against results obtained from the CMIP3 model ensemble and from CMIP6 as the simulations become available. Uncertainties introduced by using specific observational datasets will be assessed by comparing the results obtained with alternative observations of the same variables and, where available, using uncertainty estimates for the observations. The aim of this study is to assess the consistency and robustness of selected emergent constraints for equilibrium climate sensitivity and to identify opportunities and challenges of this approach with the help of CMIP6 simulations.

Keywords: emergent constraint, ESMValTool, equilibrium climate sensitivity

2-P16

Comparisons of Simulated Cloud-Radiation-Circulation-Precipitation Coupling over Tropical Pacific Oceans in Global Climate Models between CMIP5 and CMIP6: Preliminary Results

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Most CMIP3 and CMIP5 models exclude falling ice from their radiation code. Through controlled simulations with CESM1-CAM5, which is one of the few models that allows falling ice radiative interactions, we found that falling ice reduces both outgoing longwave and surface incident shortwave in convective regions such as the ITCZ and SPCZ. This stabilizes the local atmosphere and forces nonlocal responses in surface winds, temperatures and precipitation, counteracting several common CMIP3 and CMIP5 biases. To our knowledge most CMIP6 models also exclude precipitation radiative effects. Here we examine available CMIP6 fully coupled historical simulations using CloudSat-CALIPSO, CERES and the new ERA5 reanalysis. We focus on the tropical Pacific as it is a heat engine for global climate system. Our preliminary results indicate continued biases associated with the exclusion of precipitating hydrometeors, particularly in the ITCZ, SPCZ and warm pool. In addition, a weak low level mean flow from the warm pool associated with moisture convergence is found. This westerly bias with warm and moist air transport might contribute to the model's northeastward overextension of the SPCZ and the concomitant warm bias in sea surface temperatures and excessive precipitation.

Keywords: Cloud, radiation, precipitation coupling

2-P17

Climate sensitivity and cloud feedbacks in CESM2 and E3SM

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The CESM2 and E3SM are closely related climate models. Their atmospheric components are nearly the same, but E3SM has more vertical levels, and the models have been tuned separately. Other components differ substantially, notably the oceans are entirely different. This study explores climate sensitivity and cloud feedbacks in these two models. We start from the DECK experiments with both models to establish that using conventional measures, these models produce similar climate sensitivity (which is around 5K, on the high side of the CMIP5 ensemble). Changes in cloud radiative effect suggest that the response of subtropical stratocumulus and transitional cloud types are an important contribution to the high sensitivity. A dynamical regimes analysis is used to explore the connection to cloud regimes in more detail. Does the similarity between CESM2 and E3SM signal reduced parametric uncertainty in this family of models? It appears not, and the similarity may be a coincidence. This is demonstrated using CESM2 with a different set of parameters but a substantially lower climate sensitivity. Additional experiments further suggest the variable climate sensitivity is associated with the response of low-level tropical clouds, just as has been described in multi-model ensembles.

Keywords: climate sensitivity, cloud feedback

2-P18

UKESM1: A first assessment of the pre-industrial to present-day anthropogenic forcing and its attribution to different forcing agents

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A quantitative understanding of the role of different forcing agents in both historical and future climate change remains a key motivation and scientific question for the forthcoming 6th Coupled Model Intercomparison Project (CMIP6). Fundamental to this question is the impact on the Earth's radiative balance of physical and chemical perturbations from anthropogenic activities. In this work, effective radiative forcings (ERFs) are quantified for different anthropogenic forcing agents with the UK's Earth System Model, UKESM1. By using a single modelling framework and adopting the protocol from the Radiative Forcing Model Intercomparison Project (RFMIP), pre-industrial to present-day anthropogenic ERFs are calculated consistently for all climate forcers. The forcing agents considered here are the long-lived well-mixed greenhouse gases, stratospheric and tropospheric ozone, aerosols, and land use change. In particular, additional UKESM1 simulations are used to attribute the methane ERF, as an example, to forcing by methane, tropospheric and stratospheric ozone, aerosols, and stratospheric water vapour. Results show that the ozone forcing attributable to methane is close to zero, due to changes in stratospheric and tropospheric ozone offsetting each other. However, the pre-industrial to present-day change in methane gives rise to a positive aerosol forcing through aerosol-cloud interactions by changing the relative contributions of the different sulphur dioxide oxidation pathways and the aerosol size distribution.

Keywords: effective radiative forcing, Earth system, anthropogenic, forcing agents, UKESM1

2-P19

Using simple indices of global climate change: the PMIP4 and CMIP6 simulations and paleoclimate data to evaluate how the Earth system responds to strong forcings

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Simulations of past climates provide 'out-of-sample' tests of Earth system models being used to predict future climate trajectories. Data is available to confirm the sensitivity of these models to forcings, albeit with the data becoming sparser the farther back in time. The 4th phase of the Paleoclimate Modeling Intercomparison Project (PMIP4) will provide this perspective to CMIP6 and IPCC, as PMIP has done since the 1990s. This poster will present a new set of paleo-simulations that are being completed with CESM2: same model, same resolution as the DECK and future scenario simulations. These include: the early Eocene Climatic Optimum (~53-51 million yrs ago, 4xCO2, deepmip-stand-4xCO2), mid-Pliocene (3.2 million yrs ago, 400ppm CO2, midPlioceneEoi400), Last Interglacial (127,000 yrs ago, lig127k), Last Glacial Maximum (21,000 yrs ago, 190ppm CO2, lgm), and mid-Holocene (6000 yrs ago, midHolocene). Simple indices of the surface temperature response to high CO2/low CO2/seasonality of incoming solar radiation: Northern versus Southern Hemisphere temperature change, Northern Hemisphere meridional temperature gradient, land-ocean contrasts, tropical Pacific east-west zonal gradient, polar amplification, will be computed for these past climate simulations and compared to paleoclimate data. In addition, these indices will be computed and compared to the CESM2 4xCO2 (abrupt-4xCO2) simulation. A multi-model comparison with previous PMIP simulations for the mid-Holocene, Last Glacial Maximum, and mid-Pliocene will highlight the evolution of model performances in simulating climate states different from the modern one. As they become available, these simple indices will be computed for the suite of PMIP4/CMIP6 simulations expected to be submitted by international modeling groups in time for the IPCC.

Keywords: PMIP4, model, data comparison, past climate

2-P20

Influence of CMIP6 Forcing on Historical and Decadal Hindcast Simulations with MPI-ESM

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In this study we compare an ensemble of historical simulations using CMIP5 external forcing, performed within the German Medium-term Climate Predictions (MiKlip ? fona-miklip.de) project, with another ensemble using CMIP6 forcing performed for the contribution to the CMIP6. Both ensembles are produced using the same high-resolution version of our Max Planck Institute Earth-System Model (MPI-ESM-HR). The analysis of the model performance and uncertainties of different metrics and trends is applied to the complete historical period (1850-2005) as well as sub-periods (e.g., 1960-2005) to account for the increase of observations. Furthermore, we compare two ensembles of decadal hindcast simulations with each other, also produced with the same MPI-ESM-HR model, using either CMIP5 or CMIP6 forcing. The analysis includes different state-of-the-art prediction skill metrics for decadal climate hindcast evaluation. To account for the small ensemble size the significance of the results is an issue. We estimate the impact of the initialization by comparing the prediction skill rising from the external forcing in the historical simulations with the prediction skill in the decadal hindcast simulations. The comparison of the results caused by the different external forcing bears us the unique possibility to systematically evaluate the impact of the change from CMIP5 to CMIP6 forcing on MPI-ESM simulations.

Keywords: Decadal Hindcast Simulations, Historical Simulations, CMIP6 forcing

2-P21

Deriving Earth System Feedbacks on multiple timescales

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For over a decade, the global equilibrium response of a climate model to increasing greenhouse gases has been often been categorized by a single temperature - a "climate sensitivity" calculated by assuming a linear forcing-feedback relationship in a simulation where atmospheric Carbon Dioxide concentrations are quadrupled and the system is allowed to equilibrate. However, recent work has shown that feedbacks vary as a function of time and spatial pattern, calling into question the utility and accuracy of this approach. Here, we propose a simple method to decompose the equilibrium response of the climate system into feedbacks which occur on a range of timescales using currently available simulations. When applied to the CMIP5 ensemble, the approach suggests that Earth System response can be categorized by a discrete range of adjustment timescales. Existing 150 year simulations constrain response on shorter timescales, but leave uncertainty in feedbacks on the century timescale. However, our analysis suggests that the equilibrium response of some models in the CMIP5 archive is underestimated by up to 2K by assuming a single feedback strength. The decomposition also allows for a very accurate prediction of Transient Climate Response using only information from a quadrupled CO_2 simulation. Existing emergent constraints on TCR are shown to broadly constrain the faster timescales of climate response, with the slower mode only becoming detectable after emissions cease rising.

Keywords: climate sensitivity, feedbacks, transient climate response, carbon budgets

2-P22

Historical aerosol forcing diagnosis in CMIP6, AerChemMIP and AeroCom models

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A new generation of aerosol models has been implemented in state of the art CMIP6 models. At the same time CMIP6 and AerChemMIP experiments are for the first time coordinated with detailed aerosol modeling in AeroCom models. Special attention has been made to propose refined diagnostics in CMIP6 an AeroCom, which allow for an understanding of bias in aerosol forcing and associated aerosol parameters. The aerosol forcing history in available CMIP6 output is documented and analysed as a function of emissions, aerosol mixing ratios, optical properties, cloud properties. AeroCom historical fixed SST simulations are investigated to see if coupled AOGCM's are significantly different in describing aerosol forcing history. Observational data available in the AeroCom database are used to evaluate these parameters and any bias against observations. The consequences of bias for the uncertainty in aerosol forcing history are discussed.

Keywords: aerosol evaluation, AeroCom, AerChemMIP, historical forcing

2-P23

Polar amplification and atmospheric meridional energy transport in CMIP6 DECK simulations

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How does Arctic and Antarctic sea ice develop in the new set of CMIP6 simulations, how does the atmospheric meridional energy transport change and how does the vertical structure of the atmosphere change? To answer this question, as many available CMIP6 historical, 1%CO2 per year, and 4*CO2 simulations as possible will be evaluated regarding these parameters. It has been acknowledged that the energy transport from the mid-latitudes into the polar regions is one important contributor to polar amplification. While the atmospheric temperature signature of sea ice decline is a bottom-heavy warming, i.e. most pronounced in the boundary layer, the meridional energy transport can increase the temperature further aloft. Therefore it is of interest to assess the meridional energy transport and its role in polar amplification from the CMIP6 simulations. The analysis in changes in polar amplification and meridional energy transport and changing temperature gradients in different atmospheric layers will also help to stimulate discussion about possible impacts on mid-latitude weather characteristics such as synoptic activity and extreme events.

Keywords: Polar amplification, energy transport

2-P24

Global soil moisture-carbon feedbacks: Planned joint analyses from LS3MIP and C4MIP

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The terrestrial biosphere is a major carbon sink as it absorbs about 25 per cent of the human-induced CO2 emissions. However, the rate of land carbon uptake remains highly uncertain, and shows substantial spread in Earth System Model (ESM) projections.
Recent studies have revealed that terrestrial water storage substantially affects changes in atmospheric CO2 concentrations both on interannual time scale in observations (Humphrey et al. 2018), and in long-term projections in ESMs (Green et al. 2019). However, Dynamic Global Vegetation Models (DGVMs) have been found to underestimate this relationship (Humphrey et al. 2018).
This presentation will provide an overview of these results and of planned analyses with the LS3MIP and C4MIP experiments that will assess soil moisture-carbon relationships in the CMIP6 ensemble.

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Keywords:

2-P25

Tools for computing radiative forcing and radiative feedbacks from CMIP6 output

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Radiative forcing is a fundamental quantity for understanding both anthropogenic and natural changes in climate. However, its explicit calculation can be both time consuming and computationally expensive. As a result, most modeling centers neglect to compute the instantaneous radiative forcing (IRF), leaving users of the model output unaware of differences in IRF between model simulations even when integrated under identical emission scenarios. Recent studies have highlighted the importance of such differences in contributing to inconsistencies in model projections of both historical and future climate change. Radiative feedbacks are also pivotal in regulating the response of the climate to external forcings, however differences in the methodology used to compute feedbacks between various modeling groups can bias the reported feedbacks. As part of the NOAA Model Diagnostics Task Force, a set of Python-based tools have been developed to allow users to compute both IRF and radiative feedbacks using standard model output from CMIP6 DECK and related MIPs. These tools use radiative kernels to decompose changes in both top-of-atmosphere and surface radiative fluxes into contributions from individual feedback terms and the IRF. By providing a consistent methodology for computing both feedbacks and forcing, these tools can help to facilitate a better understanding of the cause of intermodel differences in the response to forcings. The poster will describe how to access the software, review the calculation of these diagnostics and highlight their application for a variety of topics related to climate sensitivity, hydrologic sensitivity, and interactions between clouds, aerosols, radiation and the atmospheric circulation.

Keywords: Radiative forcing, Radiative Feedbacks

2-P26

Representation and trends of Organic Aerosols in CMIP6 AerChemMIP Simulations using the Whole Atmosphere Community Climate Model (WACCM6)

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The Community Earth System Model Version 2 (CESM2) Whole Atmosphere Community Climate Version 6 (WACCM6), is participating in CMIP6 DECK and other MIP experiments. WACCM6 includes comprehensive chemistry for the troposphere, stratosphere, mesosphere, and lower thermosphere and simulates interactive aerosols in both troposphere and stratosphere. A new secondary organic aerosol (SOA) scheme has been implemented in WACCM6 to allow the coupling between aerosol precursor emissions and SOA formation, using the volatility bin set (VBS) model framework. The new approach allows interactive coupling between biogenic emissions and organic aerosols (OA), which also interact with chemistry, radiation and therefore climate. Here, we focus on Tier 1 model simulations of the Aerosol Chemistry Model Intercomparison Project (AerChemMIP). We contrast historical simulations with and without pre-industrial near term climate forcers for both AMIP-type and fully coupled simulations between 1850 and 2014, in order to explore the importance of anthropogenic emissions on trends of OA globally and for different regions and their radiative impact. Besides standard AerChemMIP simulations, we performed additional simulations without anthropogenic OA precursor emissions with WACCM6, between 1960 and 2014, and discuss the contributions of different OA precursor sources to the evolution of OA over different regions. We further present an evaluation of simulated OA for present day using ATom aircraft observations and MODIS AOD satellite observations and plan to include other available model results in the analysis.

Keywords: AerChemMIP, Organic Aerosols, WACCM

2-P27

Historical and Future Changes in Tropospheric Ozone using a parameterised Approach with the CMIP6 emissions dataset

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A simple parameterisation of source-receptor relationships for tropospheric ozone (O3) has been developed based on simulations from a range of models participating in the Task Force on Hemispheric Transport of Air Pollutants (TF-HTAP) experiments. Perturbations to precursor emissions (NOX, CO and VOCs) and methane (CH4) abundance are used to quantify changes to tropospheric O3 globally and across 16 regions. The contribution from local, remote and CH4 sources to surface O3 can be provided for each receptor region along with an estimate of uncertainty based on the spread of the results from the models used as input. Here we use changes in O3 precursor emissions and CH4 abundances from the CMIP6 emissions dataset to predict both the historical and future impact on surface and tropospheric O3. Nine different Shared Socio-economic Pathways (SSPs) from the scenario dataset are used to predict the future impact on tropospheric O3 from 2014 to 2050. Scenarios that include weak air pollutant and climate mitigation measures are inadequate in limiting the future degradation of surface O3 air quality and enhancement of near-term climate warming over all regions. Middle-of-the-road and strong mitigation scenarios are able to reduce both surface O3 concentrations and O3 radiative forcing, providing benefits to future air quality and near-term climate forcing. The parameterisation is a simple tool and is used here to study the impacts and associated uncertainties of the local and hemispheric emission control strategies within the CMIP6 scenarios on both surface O3 air quality and the near-term climate forcing by tropospheric O3.

Keywords: ozone, air quality, climate, radiative forcing

2-P28

Analysis of CMIP6 atmospheric moisture fluxes and the implications for projections of future change in regional rainfall

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The projections for future change in regional rainfall presented by the IPCC Fifth Assessment Report are largely based on climate model simulations contributed to CMIP5. For many regions, in particular Australia, the wide range of possible changes in rainfall from the models, both increases and decreases, poses a major research challenge. Part of the variation in simulated rainfall change is associated with the horizontal transport of tropical moisture. The water cycle was discussed in AR5, but a multi-model analysis of moisture fluxes was not presented. Australian studies, at least, were hampered by the lack of suitable data from CMIP5. The new CMIP6 archive includes vertically-integrated moisture flux data, so it should be feasible to do a multi-model assessment of this flux, for the first time. The variable names are intuaw and intvaw, and they are included in the Emon table. Given that the flux has been requested only by PMIP, the assessment may need to focus on the DECK experiments. We study data from 1pctCO2, from available models including the U. K. Met Office's GC2 and Australia's ACCESS-CM2. Feasibly, the present climate can be represented by early decades of this 150-year experiment. The standardized change or 'trend per degree', under rising CO2 concentrations, can be determined from the regression of yearly values with the global mean temperature. We assess the flux, the atmospheric moisture budget, and rainfall. It is found that the future change in the convergence of the flux is highly spatially correlated with the precipitation change. From such multi-model results, prototype probabilistic projections of the change in these variables will be developed. There is the potential for some constraint on projections of future rainfall based on an improved understanding of the moisture budget. This would have a considerable benefit to users of such projections.

Keywords: Moisture transport, Regional rainfall, Projections, Multi model analysis

2-P29

Aerosol forcing of extreme summer drought over North China

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The frequency of extreme summer drought has been increasing in North China during the past sixty years, which has caused serious water shortages. It remains unclear whether anthropogenic forcing has contributed to the increasing extreme droughts. Using the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP/NCAR) re-analysis data and Coupled Model Intercomparison Project Phase 5 (CMIP5) model simulations with various combinations of historical forcings, the authors investigated the driving mechanism behind the observed changes. Metrological drought is usually measured by precipitation anomalies, which show lower fidelity in current climate models compared to largescale circulation patterns. Based on NCEP/NCAR re-analysis, a linear relationship is firstly established between the weakest regional average 850 hPa southerly winds and extreme summer drought. This meridional winds index (MWI) is then used as a proxy for attribution of extreme North China drought using CMIP5 outputs. Examination of the CMIP5 simulations reveals that the probability of the extreme summer droughts with the first percentile of MWI for 1850-2004 under anthropogenic forcing has increased by 100%, on average, relative to a pre-industrial control run. The more frequent occurrence of extremely weak MWIs or drought over North China is ascribed from weakened climate and East Asian summer monsoon (EASM) circulation due to the direct cooling effect from increased aerosol.

Keywords: drought, aerosol forcing, extremes, Asian monsoon

3-P01

Consistent boreal winter forecast skill in current (non-CMIP6) climate prediction systems on seasonal scales

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Climate prediction systems (i.e. initialized climate models) show high to moderate predictive capacity on seasonal scales on important large scale climatic phenomena (e.g. El Nino Southern Oscillation (ENSO), or the North Atlantic Oscillation). Skillful spatial prediction of climatic variables in the northern hemisphere is typically lower and highly variable dependent. For example surface temperature, sea level pressure and precipitation show a decrease in skill in that descending variable order. An analysis of CNRM-CM6, GloSea5 and EC-Earth3.2 on seasonal forecast mode results in consistent large scale and spatial deterministic and statistical forecast skill across models and variables, despite of having very different systematic biases. We explored the sources of predictability in the systems and the possible mechanisms leading to consistent results across models, despite of the systematic bias disagreement.

Keywords: temperature, Circulation, Precipitation, DCPP, Predictability, Predictions, Seasonal

3-P02

A framework for understanding the quality of Southern ocean circulation in coupled climate and Earth System Model simulations.

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The large-scale circulation in the Southern Ocean (SO) is a critical component of Earth's climate system due to its dominant role in exchanging carbon and heat between the ocean and atmosphere and transforming global ocean water masses. Evaluating the ability of fully coupled climate models to accurately simulate SO circulation and properties relative to observations is crucial for building confidence in climate model projections and advancing model fidelity. However, identifying and analyzing model biases relative to observationally-based metrics is just the first step. By analyzing multiple biases collectively across large ensembles of fully coupled climate and Earth System Models, mechanisms governing the diverse mean-state SO circulation found across coupled models can be identified. The analysis presented here (1) assesses the ability of a large ensemble of fully coupled climate models contributed to both CMIP5 and CMIP6 to simulate observationally-based metrics associated with an accurate representation of present day SO circulation, and (2) presents a framework by which the quality of the simulation can be categorized and mechanisms governing the resulting circulation can be deduced. The analysis highlights how different combinations of biases in critical metrics including zonal mean westerly surface wind stress strength and position, properties and transport of North Atlantic Deep Water (NADW) entering the SO in both density and depth space, properties of intermediate and mode waters, and surface buoyancy fluxes, results in distinct mean-state Antarctic Circumpolar Current transports. Furthermore, how these distinct mean-state SO circulations across models impact the carbon and heat budget of the SO is quantified.

Keywords: CMIP5, Earth System Models, Southern Ocean Circulation, CMIP6, Antarctic Circumpolar Current

3-P03

Evaluation of CMIP6 climate models in predicting monsoon rainfall based on bias corrected clustering approach

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In the present study bias corrected cluster (BCC) analysis has been performed on the state-of-the-art global climate models (GCMs) simulations, participating in the Coupled Model Inter-comparison Project Phase 6 (CMIP6). GCMs are developed independently at different institutes, each of which vary in their resolution, treatment of physics and dynamics, representation of orography, physical processes etc. Due to these inter-model differences, it is essential to consider the range of model simulations rather than depending on single climate simulation. In order to get confidence from the multiple models, bias corrected clustering approach has been experimented in the present work. In doing so, bias of each model was corrected in the first step followed by clustering, which is a flexible and unsupervised numerical technique that involves the segregation of data into statistically similar groups or clusters. After the segregation of model output into clusters, each cluster was associated with the confidence index, a procedure that assesses significance of the clusters. The historical simulations were divided in the training as well as testing periods, wherein during the training period the robust cluster at each location were identified and the skill of the identified clusters was checked during the testing phase in predicting the summer monsoon rainfall. The multi-model mean calculated using members of the most-populous cluster viz. the cluster with highest confidence index was identified at each location and was then compared with the simple all-model mean.

Keywords: Climate Models, CMIP6, Multi models, Confidence Index, Clustering, Bias correction, Monsoon rainfall

3-P04

Reducing uncertainty in near-term European climate projections using a model weighting approach

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Climate change adaptation and mitigation requires reliable projections about the future state of the climate system. The upcoming Coupled Model Intercomparison Project phase six (CMIP6) aims to provide an update on such projections based on over 100 models from more than 40 institutions. Combining these projections into actionable information about near-term changes on a regional scale is, however, challenging given high internal variability and model spread. In the European Climate Prediction system (EUCP) project we focus on changes in the European SREX regions from 2041 to 2060 for temperature and precipitation. We apply a model weighting scheme (Lorenz et al., 2018) that accounts for past model performance as well as model inter-dependence. In that, it is based on the assumption that some models perform better than others for certain settings and that many models are not fully independent from each other. Using the CMIP5 ensemble, we show that regionally weighting models by performance and independence reduces future spread and can shift the best estimate significantly compared to a simple unweighted mean. We also discuss the advantages and limitations of applying our approach to model ensembles with multiple initial-condition member in anticipation of the upcoming CMIP6 using a large ensemble of CESM.

Keywords: model weighting, cmip5, cmip6, Europe, EUCP, near, term

3-P05

An anatomy of the forecast errors in the seasonal prediction system with EC-Earth

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Initialization is an essential step when performing climate predictions, and the use of the latest high-quality observations and their assimilation in the model realm is of paramount importance. Less attention has been paid to other essential aspects of initialization that are equally important. For example, incompatibilities between the initial conditions (ICs) products used for the different model components can cause important initialization shocks, hindering the prediction capacity during the first weeks of the forecast. In this study we investigate the different contributions to forecast errors in a seasonal prediction system with EC-Earth where sea ice is initialized via Ensemble Kalman filter assimilation of ESA-derived sea ice concentrations, that was produced within the context of the Climate Model User Group (CMUG) Climate Change Initiative (CCI) from ESA. The largest source of forecast error in Arctic sea ice appears in regions of high observational uncertainty, which hinders the efficiency of the assimilation protocol. We also investigated the development of the systematic error and its competing effect with the shock that emerges from the incompatibility between ocean and sea ice ICs. After 26 (21) days the systematic model error becomes the largest contributor to the forecast error for the May (November) initialized forecasts, with the initial-incompatibility dominating in the previous days. Moreover, the development of both errors is sensitive to the month of initialization: the shock is more pronounced in November than in May. The major differences between both months relate to the systematic error, which is much higher in November, and also to the direction of the shock with respect to the seasonal trend. In both cases the shock leads to sea ice melting, but, unlike in May, in November it happens in a context of sea ice expansion. This opposing effect during November might be accentuating the generation of the drift.

Keywords: seasonal prediction, initialization shock, systematic error, Arctic sea ice

3-P06

A framework to determine the limits of achievable skill for interannual to decadal climate predictions

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Current decadal prediction systems show regionally significant skill in predicting near-surface climate conditions, but much of the skill on decadal time scales originates from warming trends due to external forcing and the benefit from initialisation remains uncertain. Furthermore, initialisation of the predictions is imperfect due to incomplete observational coverage and inconsistencies between observed and model-simulated climate characteristics, and it is unknown what skill would be achievable given improved initialisation. Here we propose a new framework to investigate achievable skill of decadal predictions by comparing perfect-model prediction experiments with predictions of the real world, to identify margins for possible improvements to prediction systems. In addition, we assess the added value from initialisation over changes due to climate forcing in decadal predictions focusing on annual average near-surface temperature. We find that ideal initialization may substantially improve the predictions during the first two forecast years particularly in parts of the Southern Ocean, Indian Ocean, the tropical Pacific and North Atlantic, and some surrounding land areas. On longer time scales, the predictions rely more on model performance in simulating low-frequency variability and long-term changes due to external forcing. This framework identifies the limits of predictability using the NCAR Community Earth System Model (CESM) version 1.0.5, and clarifies the margins of achievable improvements from enhancing different components of the prediction system such as initialization, response to external forcing and internal variability. We encourage similar experiments to be performed using other climate models, to better understand the dependence of predictability on the model used. In particular, it would be useful to complement initialised decadal predictions contributing to the Decadal Climate Prediction Project (DCPP) component A as part of CMIP6 by a similar set of perfect-model experiments, to manage the expectations regarding the achievable skill of interannual to decadal predictions based on current climate models.

Keywords: predictability, decadal prediction, initialization, perfect model, climate variability

3-P07

Understanding CMIP Simulation Biases with NCAR's Climate Model Assessment Tool

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Evaluating climate models with physically relevant global-scale observations of the energy and water cycles is important to both identify biases and establish confidence in their projections. However, several issues must be dealt with in order to do so accurately and meaningfully. Here, the NCAR Climate Model Assessment Tool (CMAT) is described and its application to CMIP simulations across generations (3,5,6) is presented with the goal of identifying ongoing model improvements and persisting biases. A key motivation for CMAT is the need to examine model fidelity in both the climatological mean and across timescales of variability, which in CMAT include both seasonal and interannual variations (i.e. ENSO). State of the art observations are used, including ERA5 and CERES-EBAF4, and context for model-observation differences is provided for by fully accounting for various uncertainties, including the influence of internal variability (estimated from the CESM Large Ensemble). Summary graphics for addressing whether a given model's biases are statistically meaningful, or whether significant differences exist between models, are provided to assess both absolute and relative model performance. An assessment of transient historical simulation characteristics is also produced, including comparisons to key observations (e.g. global surface temperature, ocean heat content) and a detailed assessment of simulation drift. Lastly an objective method for scoring CMIP models is used to provide perspective on the large numbers of simulations included in its archives and the associated progression of skill and reduction in bias across generations related to atmospheric dynamics and the energy and water cycles. Comparison of AMIP and fully coupled runs provides additional insight into the origin of persistent biases. Figure 1: Biases in CESM2 shortwave cloud forcing (SWCF) based on CERES EBAF4 retrievals. Significant biases are indicated (> internal variability=stippled; +observational uncertainty=hatched). The meridional structure of SWCF in CESM2 improves upon a long-standing bias in CMIP models.

Keywords: climate model evaluation, observed climate change

3-P08

Application of a Big Data approach to constrain projection-based estimates of the future North Atlantic Carbon Uptake

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With increasing model complexity and resolution, the size of CMIP6-output is estimated to grow by a factor of 10 to 20 when compared to CMIP5-output. This large amount of data makes the target of understanding and constraining the model-spread highly challenging and calls for the usage of mathematical optimization algorithms. We propose to combine process-based model evaluations with a Big Data approach and show a first application. As a proof of concept, we studied an ensemble of 11 CMIP5-models for a high atmospheric CO2 scenario. The simulated future carbon uptake of the considered ensemble has high uncertainties in the North Atlantic. Our process-based model evaluation shows that the large future model spread is caused by different efficiencies in carbon drawdown, tightly linked to winter mixing and biology. We find that both the contemporary (i) summer oceanic pCO2-anomaly and (ii) fraction of the anthropogenic carbon-inventory below 1000-m depth are good indicators for the future carbon-uptake of a model (with multi-model correlation coefficients above 0.7). Subsequently, we use a genetic algorithm for big data analysis and spatially optimize the results for both indicators. After several technical pitfalls related to the posing of the problem and associated modifications, the algorithm took only a few minutes to successfully identify the subpolar gyre (indicator i) and the North Atlantic Deep Water (indicator ii) as optimal. With the use of observation-based estimates of both indicators in their optimal regions, a constrained model-ensemble with a significantly reduced uncertainty was created. We note that Big Data will be highly suited for CMIP6 model data as it allows for an automatic and fast exploration of variables across the ensemble of models. However, we experienced that the close interaction between climate modelers and computational scientists was and will be critical to achieve a meaningful and successful outcome.

Keywords: Oceanic carbon uptake, reducing uncertainty, observational constraints, process based evaluation, model spread, Big Data

3-P09

Benchmarking CMIP Terrestrial Carbon Cycle and Biogeochemistry Models with the ILAMB Package

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The International Land Model Benchmarking (ILAMB) project is a model-data intercomparison and integration activity designed to inform improvement of land models and, in parallel, to suggest designs of new measurement campaigns to reduce uncertainties associated with key land surface processes. As Earth system models (ESMs) become increasingly complex, there is a growing need for comprehensive and multi-faceted evaluation of model predictions. To advance our understanding of biogeochemical processes and their interactions with climate under conditions of increasing atmospheric carbon dioxide (CO2), the Reducing Uncertainties in Biogeochemical Interactions through Synthesis and Computation (RUBICO) Scientific Focus Area is developing model evaluation metrics to constrain model results and inform model development. Better representation of biogeochemistry-climate feedbacks and ecosystem processes in ESMs is essential for reducing uncertainties associated with projections of climate change during the remainder of the 21st century and beyond. In this presentation, we demonstrate the use of the ILAMB software system by evaluating the fidelity of terrestrial carbon cycle models coupled within Earth system models used to conduct historical simulations for the Coupled Model Intercomparison Project (CMIP). We highlight systematic model biases common to many land models and describe how ILAMB may be used to validate models from model?data intercomparison experiments like C4MIP, LUMIP, and LS3MIP and to serve as a guide during model development. ILAMB is being extended to compute standard feedback parameters and multivariate functional metrics that yield insights into model process representations and emergent ecosystem properties that may constrain future predictability. These new capabilities will be illustrated with CMIP model output in preparation for publication of results in support of the IPCC Sixth Assessment Report.

Keywords: ILAMB, benchmarking, land model, feedbacks, carbon cycle, C4MIP, LUMIP, LS3MIP

3-P10

An emergent constraint on ocean acidification in the subsurface layers based on multi-model analysis

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In the Fifth Assessment Report of Intergovernmental Panel on Climate Change, ocean acidification in the surface ocean projected by CMIP5 models has been analyzed intensively, but not much was mentioned for the subsurface layers, where there are concerns over loss of deep-water coral reef habitat. Here we evaluate, and propose an emergent constrain on, the projected ocean acidification rates of subsurface layers of?the western North Pacific where the strongest sink of atmospheric CO2 is found in the mid-latitudes. We use the outputs of projections under the highest emission scenario of the representative concentration pathways performed by Earth system models (ESMs). The low potential vorticity water mass called the North Pacific Subtropical Mode Water (STMW) shows large dissolved inorganic carbon (DIC) concentration increase, and is advected southwestward, so that, in the sea to the south of Japan, DIC concentration increases and ocean acidification occurs faster than in adjacent regions. In the STMW of the Izu-Ogasawara region, the ocean acidification occurs with a pH decrease of ~0.004 /year , a much higher rate than the previously estimated global average (0.0023 /year), so that the pH decreases by 0.3-0.4 during the twenty-first century and the saturation state of calcite (?Ca) decreases from ~4.8 down to ~2.4. We find that the ESMs with a deeper mixed layer in the Kuroshio Extension region show a larger increase in DIC concentration within the Izu-Ogasawara region and within the Ryukyu Islands region. It is suggested that mixed layer depth in the Kuroshio Extension may serve as an emergent constraint for future projection of subsurface ocean acidification. A similar analysis scheme may apply to the North Atlantic where mode waters are formed along the Gulf Stream.

Keywords: ocean acidification, emergent constraint, mixed layer depth, carbon uptake, subsurface ocean

3-P11

Long-term Balances and Variabilities of Surface Energy and Water Cycles: Preliminary Results from LS3MIP and GSWP3

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Land Surface, Snow, Soil-moisture Model Intercomparison Project (LS3MIP) consists of various sub-components of experiments. Among them, 'land-hist' is the first 'land only' contribution to the Coupled Model Intercomparison Project (CMIP) with roles such as 1) to evaluate how state-of-the-art land surface schemes coupled with climate models represent land processes appropriately and 2) to estimate long-term balances of variabilities of the interactions among the processes. In this study, we report the preliminary results of 'land-hist' experiment of LS3MIP based on the Global Soil Wetness Project 3 (GSWP3) climate driver set for a historical period (1901-2014). It also provides the means to quantify systematic biases and uncertainties, which is of particular interest for climate change impact assessments.

Keywords: LS3MIP, GSWP3, landhist

3-P12

A new diagnostic tool for the energy budgets and transports in climate models

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We present here a novel diagnostic tool for studying some fundamental aspects related to the thermodynamics of the climate system. The tool has been developed as part of the large community effort "ESMValTool", aimed at providing a standardized set of diagnostics for the evaluation of CMIP6 model simulations. The tool includes a number of independent modules. One allows to assess the local and global atmospheric hydrological cycle, in terms of water mass and latent energy. Another one provides estimates of radiative and heat budget at Top-of-Atmosphere, within the atmosphere and at the Earth's surface. It also computes the meridional enthalpy transports and their yearly mean peak locations and magnitudes. Another module computes the atmospheric Lorenz Energy Cycle, isolating stationary and transient eddy components. The last module accounts for the material entropy production, i.e. the entropy production associated with irreversible processes. This is accomplished in two ways, either through convergence of radiative fluxes, or through direct computation of the energy exchanges in each process. In the latter case, the kinetic energy dissipation term is addressed by means of the strength of the Lorenz Energy Cycle. Input fields are the radiation, precipitation and pressure fields at the monthly time resolution, velocity and temperature fields at the surface and in pressure levels at the daily resolution. If a land-sea mask is provided, the tool is also able to perform computations and print outputs separately on land and oceans. Meeting the requirement of providing synthetic global metrics for model intercomparison, results are given as a set of parameters and are automatically compared when a multi-model ensemble is given as input. The diagnostics will be soon made publicly available in the ESMValTool Python package, once the porting to ESMValTool version 2 will be finalized.

Keywords: model diagnostics, ESMValTool, energy budget, energy transports, water mass budget, entropy

Session 3 - Uncertainty, biases and constraints

3-P13

Can we beat climate model democracy in multi-model ensemble projections?

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To effectively plan adaptation to climate change we need climate projections which cover all potential outcomes but are as narrow as possible. Uncertainties in climate projections are a result of natural variability, scenario uncertainty and model uncertainty. Model uncertainty could be decreased by giving more weight to those models that are more skillful for a specific process or application. In addition, models in an ensemble of opportunity are not necessarily independent. This fact needs increased attention in the upcoming CMIP6 ensemble, which will include more than 100 models, many of them similar to each other. We compare multiple approaches on how multi-model ensemble averages can be calculated; e.g., a weighted multi-model mean taking into account performance and independence and the mean of the ten 'best models' (based on RMSE over the historical period) compared to the arithmetic multi-model mean as in IPCC AR5. We investigate how these different approaches influence the long-term projection of temperature over Central Europe and test the skill of the projections in a perfect model test. The weighted multi-model ensemble improves the skill of the projection on average. However, spread is large depending on which diagnostics we use to inform the method, how many of these diagnostics we use, or which model is used as truth. The latter implies that the results are sensitive to which observational dataset is used as reference. Hence, depending on observational uncertainty, it might not be straight forward to determine what a good model is. In addition, there is no clear relationship between how many diagnostics we use and skill of the projection. Therefore, we conclude that close attention has to be paid on choosing diagnostics to inform the weighting which are relevant for the target projection.

Keywords: weighting, uncertainty, long, term projections

3-P14

Bias patterns of 6 daily land surface variables in CMIP5 models and consequences of bias adjustment in terms of changes and associated uncertainty at the end of the century under RCP 8.5

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We present an analysis of biases of CMIP5 models projections under emission scenario RCP8.5 for 6 surface variables (surface minimum, maximum and mean temperature, precipitation, surface wind and solar radiation) after bias adjustment. To our knowledge, this is the first bias adjustment exercice covering so many variables at daily scale for the CMIP5 RCP 8.5 projections. We first show how bias adjustment improves comparison with reanalyses over the historical period and analyse differences by model and variable both at the global and regional scales. We then show how the climatological changes at the end of the century (difference between the 30-year averages of 2071-2100 compared to 1971-2000) and the ensemble uncertainty are affected. To produce the bias corrected CMIP5 data set we used the Cumulative Distribution Function transform (CDF-t) method (Michelangeli et al., 2009, Vrac et al., 2016, Famien et al., 2017). CDF-t is a variant of the quantile mapping (QM) method which consists in comparing the cumulative distribution function (CDF) of a climate variable (e.g., temperature) at large scale (e.g., from GCM) to the CDF of the same variable from observations. The CDF-t method has been extensively used in the literature and for many variables (e.g., Kallache et al., 2011; Vrac et al., 2012; Lavaysse et al., 2012; Vautard et al., 2013; Vrac and Friederichs, 2015). CDF-t estimates the 'future observed' CDF through a mathematical transformation before performing a QM and thus does not depend on the assumption of a same correction for past and future climate, as traditional QM methods have to. As observation-based reference dataset we used the WATCH-Forcing-Data-ERA-Interim data set (WFDEI; Weedon et al., 2014). It includes eight meteorological variables. We used daily averages from 1979 to 2012, for the global land surface at 0.5¡ x 0.5¡ resolution.

Keywords: CMIP5, bias, adjustment, uncertainty, quantile mapping, WFDEI

3-P15

Simulations and evaluations of the version 1.0 of the E3SM Land Model (ELM) for the LS3MIP

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The Land Surface, Snow and Soil Moisture Model Intercomparison Project (LS3MIP) diagnoses interactions between land and atmosphere and assesses the land components of the Earth system models for the CMIP6. One of the key components of the LS3MIP is to conduct offline land model experiments driven by common observational drivers, attributing the causes behind model differences to the driver or structural deficiencies. With the International Land Model Benchmarking (iLAMB) package, we will investigate and present comprehensive benchmarking results of the ELM against best available observations, in terms of the means states and multiyear variations of land surface energy, water, and biogeochemical budgets. Since three meteorological forcings (e.g., the GSWP3, Princeton, and CRU-NCEP) will be utilized to drive the ELM, we will examine the sensitivity of simulated fluxes and stocks to these forcings and partition uncertainty from both internal and external model sources. Also, we will demonstrate possible driving mechanisms underlying long-term changes of major land surface variables using the factorial ELM simulations (e.g., climate change, land use and land cover change, nitrogen deposition, and aerosol deposition).

Keywords: Land Surface Model, ELM, E3SM, LS3MIP, Benchmarking

3-P16

Climate response to the Pinatubo and Tambora eruptions in EC-Earth3.2

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Explosive volcanic eruptions cause episodes of strong negative radiative forcing in the climate system by injecting large amounts of sulphur dioxide into the stratosphere, producing an aerosol which reflects part of the incoming solar radiation. This negative radiative forcing causes a global surface cooling, although there is substantial uncertainty in the magnitude and in the regional climate response in climate models and observations are limited. The aim of this work is to analyse and compare the climate response to the Pinatubo (1991) and Tambora (1815) eruptions, the latter being a significantly greater eruption than the former, in an ensemble of experiments done with the EC-Earth3.2 atmosphere-ocean general circulation model (AOGCM). Both the Pinatubo and Tambora volcanic forcings have been estimated with the Easy Volcanic Aerosol (EVA, Toohey et al., 2016) tool, and the Pinatubo forcing has been validated against the CMIP6 estimate. Previous studies have shown that the background climate conditions may mask the climate response to volcanic eruptions of similar magnitude to Pinatubo, making it difficult to detect dynamical signals (e.g. Ménégoz et al., 2017). Preliminary results show that atmospheric temperature anomalies (tropospheric and stratospheric) in response to the Tambora eruption are significantly greater in magnitude and persist for longer, thus making the volcanic imprints detectable. We analyse the volcanically forced atmospheric and oceanic circulation changes, and how they project onto the main modes of climate variability such as El Ni–o Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO). This analysis is carried out in preparation for the CMIP6 VOLMIP (Zanchettin et al., 2016) experiments.

Keywords: volcano: volcanic forcing: volmip: climate change

3-P17

Estimating the Uncertainty in Climate Projections

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The IPCC AR5 used a pragmatic approach to quantifying the uncertainty in climate projections. One realisation per model per scenario was picked and defined the ensemble. The 5?95% ensemble spread was used to characterise the uncertainty, which was inflated to account for other sources of uncertainty by interpreting the 5?95% spread as the 16?83% (likely) range. While straightforward and clearly communicated, this approach had several drawbacks, and there has been substantial progress since the AR5 on how to assess the uncertainty of projections. Large ensembles of single climate models have opened up a new perspective on internal variability and model differences and allow a clean separation of these contributors to uncertainty. Initialised prediction experiments and detection and attribution approaches exploit observations to provide information on the future. Model evaluation and diagnosis of model independence have been applied to ensemble weighting schemes. Here we sketch how this recent progress might be synthesised into an estimate of uncertainty in climate projections. We first apply our approach to CMIP5 simulations; later application to CMIP6 simulations should be straightforward.

Keywords: separating uncertainties, internal variability

3-P18

CMIP5/CMIP6 model-analog seasonal forecast skill: a metric for model evaluation of ENSO dynamics

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Recently, Ding et al showed that tropical Indo-Pacific SST forecast skill (both deterministic and probabilistic) from the operational models of the North America Multi-Model Ensemble (NMME) can be matched or even exceeded with a simple "model-analog" method, applied to the corresponding long control runs from each NMME model. In this method, forecast initialization is made directly on a model's own attractor, using an analog approach where model states close to the observed initial state are drawn from a "library'' obtained from prior uninitialized CGCM simulations. The subsequent evolution of those model-analogs yields a forecast ensemble, without additional model integration. This suggests seasonal forecasts can be made using almost all CMIP models. We have made retrospective tropical Indo-Pacific forecasts for the 1961-2015 period from 28 CMIP5 models (and available CMIP6 models), using model-analogs. All show skill for sea surface temperature (SST) forecasts, but there is a considerable range among the models, with even greater skill differences for precipitation. Model-analog forecasts from the ten "best" CMIP5 models have skill for SST and precipitation comparable to that of both the NMME model-analog forecast ensemble and (since 1982) traditional assimilation-initialized bias-corrected NMME hindcasts. ENSO forecast skill has no trend over the 55-yr period. Its decadal variations appear to be random, although skill does improve during epochs of increased ENSO activity. Including the CMIP5-projected effects of external radiative forcings improves the tropical SST skill of the model-analog forecasts, but not within the ENSO region. Finally, we demonstrate that the 55-yr tropical Pacific ocean hindcast skill, plotted on a Taylor diagram for leads of 1-12 months, is also a robust metric of how each CMIP5/6 model's attractor corresponds to nature's attractor, since it directly measures the fidelity of each model's ENSO dynamics (rather than static measures of ENSO) to the observed evolution of all ENSO events.

Keywords: forecasts, ENSO, metrics, predictability

3-P19

Uncertainty in Earth System Models: Benchmarks for Ocean Model Performance and Validation

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The mean ocean CO2 sink is a major component of the global carbon budget, with ocean reservoirs holding about fifty times more carbon than the atmosphere. Marine phytoplankton plays a significant role in the net carbon sink as one quarter of anthropogenic CO2 emissions end up in the ocean. Life in the ocean increases the efficiency of marine environments to take up more CO2 and ultimately reduces the impacts of persistent rise in atmospheric concentrations. However, challenges with appropriate representation of physical and biological processes in Earth System Models (ESM) undermines the effort to quantify seasonal to multidecadal variability in ocean uptake of atmospheric CO2. In a bid to improve analyses of marine contributions to carbon cycle feedbacks, we have developed new analysis methods and metrics as part of the International Ocean Model Benchmarking (IOMB) effort to meet the growing diagnostic and benchmarking needs of ocean biogeochemical models. The package was employed to validate ocean model results with observation datasets. International ocean models that contributed results to the fifth phase of Coupled Model Intercomparison Project (CMIP5) were analyzed. Our analyses suggest that biogeochemical processes that determine CO2 uptake by the global ocean are not well represented in most ESMs. Polar regions continue to show notable biases in biogeochemical tracers. Some of these disparities could have first order impacts on the conversion of atmospheric CO2 to organic carbon. Combined effects of two or more of these forcings on ocean biogeochemical cycles are challenging to predict as additive and antagonistic effects may occur. A benchmarking tool for accurate assessment and validation of marine biogeochemical outputs is indispensable as we continue to improve ESM developments and understand carbon cycle feedbacks from the ocean. Analysis of marine biogeochemical feedbacks in suite of CMIP6 experiments could also be improved.

Keywords: Marine biogeochemical cycle, model evaluation

3-P20

Investigating drivers of midlatitude circulation biases in climate hindcast ensembles

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The projected response of the atmospheric circulation to increasing greenhouse gas concentrations is highly uncertain. One of the primary reasons for this is that the state-of-the-art models we employ to investigate these responses struggle to represent basic features of the midlatitude circulation. Biases also have detrimental effects on predictive skill at climate prediction time scales of seasons to decades. Despite this, physical understanding both of the controls on these features and the drivers of their biases is still limited. The present study investigates ensembles of climate hindcast simulations performed by the Norwegian Earth System Model. This is the model used in the CMIP6 endorsed Decadal Climate Prediction Project. These ensembles are compared to both free runs and AMIP-style simulations with ERA-Interim serving as ground truth. We examine the North Pacific and North Atlantic jets in both winter and summer. We also identify where the observations lie within the predictive distribution of the ensemble. Results show that the wintertime North Atlantic jet is too zonal, extends too far into Europe and is shifted northwards. Virtually the entire North Atlantic sector lies outside the predictive distribution of the ensemble and performance actually degrades in simulations with tighter constraints on the assimilation. By contrast the wintertime North Pacific jet is rather better represented both with respect to pattern as well as magnitude of the biases. This is likely due to the better-represented teleconnections between the tropical and extratropical Pacific. However, there is an asymmetry to the biases with the North Pacific showing the largest biases in summer and the North Atlantic showing the largest biases in winter. Further investigation suggests the biases reside in the atmospheric component of the model and too weak ocean-atmosphere interactions. Physical mechanisms are investigated through decomposition of the momentum budget as well as diabatic processes.

Keywords: climate prediction, climate variability, climate dynamics

3-P21

Potential Predictability Horizon of atmospheric CO2 concentrations in CMIP6 simulations

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Decadal predictions with Earth-System-Model (ESM) simulations can be a powerful tool in predicting the near-term evolution of the global carbon sink. In particular, ESMs can be used to diagnose the internal-variability of carbon sinks and to constrain predictions of atmospheric CO2 concentrations. Previous carbon predictability studies find predictive skill in air-sea CO2 fluxes (North Atlantic: 4-7 years [Li et al., 2016]; global ocean: 4-7 years [Seferian et al., 2018; Lovenduski et al., 2018]). Yet they were based on concentration-driven simulations, in which air-sea and air-land carbon fluxes do not alter atmospheric CO2 concentrations. Hence, as of now, no predictability study exists with a fully coupled carbon cycle based on emission-driven simulations. We perform ensemble simulations in a perfect-model framework based on the CMIP6 version of MPI-ESM-LR under pre-industrial forcing with freely varying atmospheric CO2 (esmControl within C4MIP). Our results place a trend-and-bias-free upper limit on potential predictability of atmospheric CO2 concentrations. We find an eight year predictability horizon of the global atmospheric CO2 signal. The predictability horizon of CO2 flux over land is much shorter than over the oceans, while CO2 flux variability on land is much higher than in the ocean. Comparing the globally-accumulated magnitudes (fractions) of reduced internal variability due to initialization for the first lead year results in a 0.1PgC (75%) reduction of air-sea CO2 fluxes while air-land CO2 fluxes are reduced by 0.6PgC (65%), which indicates a 13%-87% attribution of 1-year atmospheric CO2 predictability to the ocean-land carbon sinks. We find evidence for establishing predictive skill for atmospheric CO2 in emission-driven simulations. Furthermore, the ESM-based predictability horizon surpasses the statistic prediction by Betts et al. [2016] and damped persistence. As simulations under the CMIP6 protocol become available, further multi-model potential predictability comparisons will shed light on the origins of potential predictability in the carbon cycle.

Keywords: predictability horizon, predictability, potential, land carbon sink, ocean carbon sink, carbon sink, carbon, co2 flux, co2, C4MIP, ensemble, emission, driven

3-P22

Development of a new climate model emulator based on CMIP6 multi-model ensemble

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The present study aims to produce an updated list of forcing-response parameters of AOGCMs with additional quantities about differences between the new and previous multi-model ensembles, CMIP6 and CMIP5, and to build a climate model emulator reflecting these model ensembles to be used for probabilistic assessment of the temperature response to climate mitigation scenarios. The method is based on the previous study described in Tsutsui (2017, Climatic Change) with some improvements. The forcing-response parameters are diagnosed through simultaneous curve fitting to global mean timeseries of the surface temperature and the top of atmosphere energy imbalance from two basic CO2-forced experiments, an abrupt quadrupling and 1%-per-year increase in the atmospheric CO2 concentration. This scheme can serves as an improved alternative to the widely-used regression method. The variation of an ensemble of AOGCMs is quantified through a statistical approach including principal component analysis of the impulse response function that is used in the fitting scheme. The principal components also form a basis of the probabilistic assessment. One application of the emulator is an examination of the quantity that relates the temperature to CO2 emissions, termed transient climate response to cumulative CO2 emissions (TCRE). Assuming median quantities for the carbon cycle module in the emulator and using the surface skin temperature as a temperature variable, we have found that the range of TCRE from the 14th to 87th percentile of the CMIP5 variation corresponds to the assessed likely range in the IPCC fifth assessment report, and the median is almost identical between them. The issue of how the new ensemble of AOGCMs as well as the temperature definition would affect this range will be addressed at the workshop using available CMIP6 output.

Keywords: effective radiative forcing, climate feedback parameter, transient climate response, climate model emulator, TCRE

3-P23

Benchmarking the simulated global carbon cycle of CMIP6 ESMs using atmospheric CO2 flask measurements

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Atmospheric CO2 is the ultimate product of global carbon cycle and climate. Its spatio-temporal evolution is not only driven by the large-scale climate dynamics but also by the net fluxes of CO2 seen by the atmosphere, resulting itself from anthropogenic CO2 emissions (such as fossil fuel emissions and aircraft emissions) and land and ocean natural sinks of CO2. Their representation in state-of-the-art emission-driven Earth system models consists thus in a global scale metrics to provide a comprehensive verification of simulated global carbon cycle and Earth climate all at once. Here, we propose to benchmark two generations of Earth system models (CMIP5 and CMIP6) using surface flask CO2 measurements available through the cooperative international air sampling network (https://www.esrl.noaa.gov/gmd/ccgg/). To this end, we use available emission-driven historical simulations as coordinated by the CMIP and C4MIP frameworks. Skill-assessment metrics such as linear trends, seasonal cycle and annual growth rate are used to track how far the ESM skill has changed between CMIP5 and CMIP6. Emergent properties such as the response of the annual growth rate of CO2 to El Ni–o Southern Oscillation or the change in seasonal amplitude to rising annual mean CO2 are used to characterize the reliability of the global carbon cycle as simulated by the two generations of Earth system models.

Keywords: emission, driven simulation, atmospheric CO2, skill, assessment, model, data evaluation

Session 4 - High resolution

4-P01

Mesoscale air-sea interactions in Kuroshio Extension region during winter season simulated by a High-resolution Coupled GCM

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Mesoscale oceanic eddies are very active along the western boundary currents and their extensions, where there are huge energy and water exchanges between the atmosphere and ocean by mesoscale air-sea interactions. In this study, the ability of a high-resolution coupled GCM to simulate the mesoscale air-sea interactions is assessed. The model results used here are from high resolution coupled GCM, in which the oceanic component model is LASG/IAP Climate system Ocean Model (LICOM) ,with horizontal resolution 0.1¡x0.1¡, and the atmospheric model is Community Atmospheric Model(CAM) with 0.23¡x0.31¡ resolution. This study focuses on the mesoscale interactions in Kuroshio Extension region (30¡N-50¡N 140¡E-180¡E) during winter season(ONDJFM). A seven-day temporal running mean and LOESS (locally weighted regression) filter are applied to obtain the mesoscale information in the atmosphere and ocean. By calculating the regression coefficients between high-pass-filtered sea surface temperature (SST) and turbulent heat flux (THF), as well as estimating the secondary circulation of atmospheric response to mesoscale eddies, mesoscale air-sea interaction processes are explored, and some principal results could be concluded that: 1) This high-resolution coupled GCM is able to simulate the basic mesoscale air-sea interaction. 2) The atmospheric secondary circulations above both the warm eddy and cold eddy cases in the Kuroshio Extension region in winter could also be simulated by the high-resolution GCM. 3) The mesoscale air-sea interactions in the two cases selected above belong to the “vertical momentum mixing mechanism”, with significant vertical motions at the edge and vertical secondary circulations aloft.

Keywords: mesoscale eddy, air sea interaction, high resolution coupled model

4-P02

Running the EC-Earth model at ultra-high resolution: challenges and benefits

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Within the framework of the PRIMAVERA H2020 project and the HighResMIP coordinated exercise, BSC has developped a coupled version of the EC-Earth 3.2 climate model at a groundbreaking resolution of about 15 km for all the climate system components (ocean, sea ice, land and atmosphere). We here focus on the technical challenges associated with such a computational costly configuration, both in terms of development and production, in particular in regard to other existing configurations. Also, we stress out the importance of mechanical feedbacks from the ocean to the atmosphere onto the ocean dynamics both in terms of large scale oceanic circulation and mesoscale activity. To do so, we compare a set of two companion simulations with and without the exchange of oceanic surface currents from the oceanic component to the atmospheric component. Finally, we compare this simulation to its low resolution counterparts, to allow identifying the robust benefits of increased model resolution, both in terms of processes resolved and climate predictability.

Keywords: High resolution, HighResMIP, Current feedbadck, PRIMAVERA

Session 4 - High resolution

4-P03

North Atlantic post-tropical cyclones in reanalysis datasets

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Mid-latitude cyclones of a tropical origin are an important natural hazard affecting western Europe and the northeast United States. Herein termed 'post-tropical cyclones', these high-impact weather events expose these regions to hurricane-force wind speeds and extreme precipitation. Their frequency is projected to increase with anthropogenic climate change because warming-induced poleward and eastward expansion of tropical cyclone genesis areas will allow more systems to propagate to the mid-latitude baroclinic region. A quantitative understanding of natural post-tropical cyclone variability ? against which global climate model performance and projections under climate change may be evaluated ? is therefore required. Here, we use an objective feature-tracking algorithm to identify post-tropical cyclones in reanalysis datasets. We then analyse post-tropical cyclone seasonality, interannual variability, structural characterisitics, and lifecycles, as well as the associated precipitation over the North Atlantic basin, focussing on those systems which impact western Europe and the northeast United States. We evaluate the performance of the reanalyses against International Best Track Archive for Climate Stewardship (IBTrACS) data. Finally, we compare the frequency of tropical-to-extratropical lifecycles between reanalyses and, to relate these results to hydrological impacts, quantify the contribution of post-tropical cyclone-associated precipitation to total precipitation. We hope to stimulate further discussion of these systems, not least their tracks, tropical-to-extratropical transition, and representation in global climate models.

Keywords: Atlantic, cyclones, reanalysis, precipitation

4-P04

Air-Sea interactions over the Gulf Stream in an ensemble of HighResMIP present climate simulations

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A dominant paradigm for mid-latitude air-sea interactions identifies the synoptic-scale weather “noise” as the main driver for the observed ocean surface variability. The underlying mechanism, outlined in the seminal paper by Hasselmann (1976; hereafter H76), has been challenged in a number of studies. Based on theoretical arguments and observational evidence Bishop et al. (2017; hereafter B17) point to a more active role for the ocean weather (mesoscale oceanic eddies) in modulating the air-sea interactions, as opposed to the passive ocean H76 view. B17 use the lead-lag covariance patterns of SST (and SST tendency) and surface turbulent heat fluxes to identify areas where air-sea fluxes are either atmosphere- or ocean-driven. Based on this approach, substantial deviations from H76 are found over regions characterized by baroclinically unstable western boundary currents and the Antarctic Circumpolar Current. In this analysis we follow the approach outlined in B17 to assess the role of model resolution in representing the nature of ocean-atmosphere interaction over the Gulf Stream in the HighResMIP (Haarsma et al., 2016) multi-model ensemble of present-climate simulations, performed under the framework of the H2020 PRIMAVERA Project. Special emphasis will be devoted to disentangle the physical processes at play on different spatio-temporal scales.

Keywords: air, sea interactions, Gulf Stream, model resolution, Highresmip

Session 4 - High resolution

4-P05

Influence of changes in large-scale circulation on surface wind projections for wind power over Europe

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European power systems have a significant - and growing - exposure to changes in near-surface wind speeds. Despite this, there is little process-based research on the impact of climate change on European wind, with GCM simulations showing inconsistent responses.This paper quantifies the contribution of changes in large-scale circulation on near-surface wind speeds using reanalysis, the CMIP5 ensemble and new PRIMAVERA high-resolution simulations. In the present-day, reanalysis products reveal a strong connection between near-surface wind variability and the large-scale circulation on daily to monthly timescales, particularly in the cold season. This relationship can be well captured by the first two empirical orthogonal functions (EOFs) of 850 hPa North Atlantic zonal wind. In comparison with reanalysis, historic GCM simulations reproduce the characteristics of the large-scale circulation to surface-wind relationship well but the strength of the connection is typically somewhat weaker. Using regression-based methods, the raw projected climate changes in wind speed over Western Europe are then decomposed into two components: one associated with the large-scale circulation changes, and a 'residual'. The large scale circulation component is shown to explain the windiness projections in the free troposphere over Western Europe, but cannot completely explain the corresponding near-surface wind speed projections (a negative residual is found in the majority of GCMs). This suggests that projected C21 near surface wind speed-changes over Western Europe are the result of two distinct processes: the first associated with changes in the large-scale atmospheric circulation, and a second likely to be associated with more local changes in near-surface boundary-layer structure. Improved understanding of both processes and their representation in GCMs is needed for confident wind projections on multi-decadal timescales.

Keywords: climate variability, wind power, surface wind, wind speed, North Atlantic Jet, climate change

4-P06

Impact of model resolution on Arctic sea ice and North Atlantic Ocean heat transport

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Arctic sea-ice area and volume have substantially decreased since the beginning of the satellite era. Concurrently, the poleward heat transport from the North Atlantic Ocean into the Arctic has increased, partly contributing to the loss of sea ice. General circulation models (GCMs) with finer and finer resolution help understanding the complex interplay of processes at high latitudes. Here, we investigate the impact of model resolution on Arctic sea ice and Atlantic Ocean heat transport (OHT) by using four different state-of-the-art coupled GCMs (with two configurations each) representing the atmosphere, ocean and sea ice. The models participate in the High Resolution Model Intercomparison Project (HighResMIP) of the sixth phase of the Coupled Model Intercomparison Project (CMIP6). Model results over the period 1950-2014 are compared to different observational datasets. We find that a finer ocean resolution drives lower Arctic sea-ice area and volume and generally enhances Atlantic OHT, bringing the models in closer agreement with observations. The representation of ocean surface characteristics, such as sea-surface temperature (SST) and velocity, is greatly improved by using a finer ocean resolution. This study highlights a clear anticorrelation at interannual time scales between Arctic sea ice (area and volume) and Atlantic OHT in all models. However, the strength of this relationship is not systematically impacted by model resolution. The higher the latitude to compute OHT, the stronger the relationship between sea-ice area/volume and OHT. Sea ice in Barents, Kara and Greenland-Iceland-Norwegian Seas is more strongly connected to Atlantic OHT than other Arctic seas.

Keywords: Model resolution, Arctic sea ice, Ocean heat transport

4-P07

Impact of stochastic physics on climate simulations with EC-Earth: looking at the atmosphere

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The inclusion of stochastic physics (SP) schemes in climate models has been found to produce improvements in model performances with respect to the observations, partially filling the gap in the representation of sub-grid scale processes. We analyze two sets of EC-Earth coupled climate simulations performed under the SPHINX project (Davini et al., 2017): one set of simulations includes the Stochastically Perturbed Parametrization Tendencies (SPPT) scheme applied to the atmospheric model; the other set is run with the standard deterministic model, without SP. For both sets the RCP 8.5 scenario forcing is applied. The experiments with SP show a significantly lower climate sensitivity with respect to the standard experiments. We focus here on the differences in the radiative feedbacks between the two ensembles. It is found that the largest differences are present in the tropics and we investigate the implications of this results on the energy balance and meridional transport in the whole atmosphere. Besides, we analyze the performance of both sets of experiments in representing the wintertime (DJF) weather regimes in the North-Atlantic and North-Pacific sectors. The comparison is done in terms of the regime patterns, the associated frequencies and residence times and the transition probabilities between different regimes. We then study the link of each regime with regional temperature/precipitation extremes in both ensembles.

Keywords: stochastic physics, radiative feedbacks, weather regimes

4-P08

Aerosol midlatitude cyclone indirect effects in observations and high-resolution simulations

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The response of midlatitude cyclone cloud properties to a change in cloud droplet number concentration (CDNC) is presented. As part of the PRIMAVERA project, idealized experiments set in convection-permitting global aquaplanet simulations with different CDNC values are compared to thirteen years of remote-sensing observations. Simulations at 7 km horizontal resolution are contrasted with traditional GCM-representative 200 km horizontal resolution simulations. This comparison shows qualitative agreement, but demonstrates more realistic representation of aerosol-cloud interactions at higher resolution. Observations and simulations agree that increased warm conveyor belt (WCB) moisture flux into cyclones is consistent with higher cyclone liquid water path (CLWP). For cyclones that have the same mean cyclone-wide rainrate, higher CLWP is exhibited for higher CDNC. The CLWP adjusts to allow the rain rate to be equal to the moisture flux into the cyclone along the warm conveyor belt. This results in an increased CLWP for higher CDNC at a fixed WCB moisture flux in both observations and simulations. If observed cyclones in the top and bottom tercile of CDNC are contrasted it is found that they not only have higher CLWP, but also larger cloud cover, and albedo.

Keywords: convection permitting global model, lifetime effect, PRIMAVERA

4-P09

Impact of changes in atmospheric and ocean model resolution on modes of variability in historical coupled model simulations

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We use historical simulations from coupled general circulation models (GCMs) participating in the EU H2020 project PRIMAVERA, to assess the impact of changes in ocean and atmospheric model resolution on different coupled modes of variability. In an inter-model comparison across different atmospheric and ocean model resolutions, we analyse differences on the representation of spatial patterns, intensities and frequencies of El Nino Southern Oscillation (ENSO), the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO), the North Atlantic Oscillation (NAO) and the Pacific North America pattern (PNA) compared with observations and reanalysis. Regarding the ENSO spatial pattern, we found that with higher ocean or atmospheric model resolution the GCMs tend to show warmer Sea Surface Anomalies (SST) in the eastern equatorial Pacific. However, we did not find a clear improvement on the ENSO cycle, and on the ENSO power spectra with increased resolution. SST anomalies related to PDO are in general underestimated by all GCMs and there is no clear improvement with increased model resolution. In contrast, with increased resolution most of the GCMs show an improvement of the AMO related SST pattern, with some biases over the north Atlantic. The atmospheric response to ENSO tends to be weaker in all GCMs compared to the reanalysis, showing a systematic weaker Aleutian low response to ENSO with increased model resolution. However most of the GCMs show an improvement in the precipitation anomalies related to ENSO with increased resolution, particularly over North America. Weaker sea level pressure anomalies associated to NAO and PNA are found systematically across models with increased resolution, only NAO (as ENSO) shows an improved representation of its associated precipitation with increased resolution.

Keywords: impact of resolution, high resolution, Climate variability

4-P10

Towards an energetically consistent vertical ocean mixing scheme in MPI-ESM

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Unresolved small-scale turbulent kinetic energy (TKE) needs to be parameterized in ocean models. Below the mixed layer, a constant background diffusivity is commonly assumed. This background diffusivity is supposed to parameterize the breaking of internal gravity waves, but it lacks any specification of its energy source. Although small, this diffusivity is yet important for forcing the large-scale ocean circulation but is inconsistent in that an artificial energy source is created in ocean models. Motivated by this fact, we replaced the artificial background diffusivity in the Max Planck Institute ? Earth System Model (MPI-ESM) by a prognostic equation for the internal wave energy and its dissipation, using the Internal Wave Dissipation, Energy and Mixing (IDEMIX) scheme (Olbers and Eden 2013, doi: 10.1175/JPO-D-12-0207.1). By following the HighResMIP protocol, we performed a twin experiment with 150 yearlong globally coupled control simulations with the MPI-ESM1.2-HR. The reference simulation uses the TKE scheme with a constant background diffusivity, whereas in the sensitivity simulation the background diffusivity is replaced by a prognostic equation for internal wave breaking from IDEMIX. We find a significant effect on the large-scale circulation, when prognostically parameterizing the breaking of internal waves. In particular affected is the circulation in the North Atlantic and in the Arctic Ocean, as well as the water masses in these basins.

Keywords: PRIMAVERA, ocean vertical mixing, internal gravity waves, turbulence, parameterizations, MPI, ESM

4-P11

Extra-tropical transition of Atlantic hurricanes in PRIMAVERA HighResMIP Tier 1 simulations

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We have analyzed the HighResMIP Tier 1 simulations performed by the PRIMAVERA partners with respect to the extra-tropical transition of tropical cyclones. We have focused on the North Atlantic and extra-tropical cyclones that reach Europe. For those storms we have analyzed their characteristics and compared them with observations and reanalyses products. Specifically we addressed the role of warm-seclusion mechanism in the extra-tropical transition using Hart diagrams. Most PRIMAVERA models are able to represent reasonably well the observed characteristics of extra-tropical transition. In agreement with the study of Dekker et al. (2018) about 50% of the storms that reach Europe are warm-seclusion storms.

Keywords: Hurricanes, extra, tropical transition, Europe

4-P12

Critical Southern Ocean climate model biases traced to atmospheric model cloud errors

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The Southern Ocean is a pivotal component of the global climate system yet it is poorly represented in climate models, with significant biases in upper-ocean temperatures, clouds and winds. Combining Atmospheric and Coupled Model Inter-comparison Project (AMIP5/CMIP5) simulations, with observations and equilibrium heat budget theory, we show that across the CMIP5 ensemble variations in sea surface temperature biases in the 40 60¡S Southern Ocean are primarily caused by AMIP5 atmospheric model net surface flux bias variations, linked to cloud-related short-wave errors. Equilibration of the biases involves local coupled sea surface temperature bias feedbacks onto the surface heat flux components. In combination with wind feedbacks, these biases adversely modify upper-ocean thermal structure. Most AMIP5 atmospheric models that exhibit small net heat flux biases appear to achieve this through compensating errors. We demonstrate using the Hadley Centre CMIP6 model that targeted developments to cloud-related parameterisations provide a route to better represent the Southern Ocean in climate models and projections.

Keywords: SST bias, surface fluxes, southern ocean

4-P13

Effects of Orography on the Mean South Asian Monsoon Circulation and Rainfall in CMIP6 Models

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What is the effect of the orography of the Himalaya/Tibetan Plateau on the development and maintenance of the Asian monsoon? Embedded within this question are the hypotheses that the south Asian monsoon is primarily the result of the elevated heat source on the Tibetan Plateau (Ye and Wu 1998 and references therein) and the Himalayas acting as a physical barrier to atmospheric flow, creating a thermal insulator for monsoon development (Boos and Kuang 2010). There is some disagreement about the relative roles of these processes in determining the mean monsoon. The Global Monsoons Model Inter-comparison Project (GMMIP), an endorsed CMIP6 project, focuses on monsoon climatology, variability, prediction and projection. The GMMIP protocol (Zhou et al. 2016) includes two model experiments (amip-TIP and amip-TIP-nosh) designed to examine the effects of the large regional orography on the establishment of the south Asian monsoon. The amip-TIP experiment follows Wu et al. (2007) and Boos and Kuang (2010) by modifying the topography of the Tibetan-Iranian Plateau (TIP) in the model, leveling off the TIP to 500m, with other surface properties unchanged. In the amip-TIP-nosh experiment, the surface sensible heat flux at elevations above 500m over the TIP is not allowed to heat the atmosphere (Wu et al., 2012). The atmospheric component experiences zero surface upward sensible heat flux, whereas the land component is as usual. In this paper, we analyze the results of the amip-TIP and amip-TIP-nosh experiments of GMMIP. The analysis will focus on the mean monsoon circulation and rainfall, and the surface energy budget, including both ensemble mean and intra-model differences.

Keywords: monsoon

4-P14

Deep water formation in the North Atlantic Ocean in high resolution global coupled climate models

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During the past decades, the idea of a weakening and even collapsing Atlantic Meridional Overturning Circulation (AMOC) as a response to global warming, and its possible impact on the climate of Europe, has been a recurrent and heated debate within the climate community. The main argument for a possible decline of the AMOC is the reduction of deep wintertime convective mixing in the North Atlantic. However, many global climate models show large biases and uncertainties in the oceanic deep convection. Here, we analyze the impact of resolution on the representation of the North Atlantic deep convection in coupled climate models.

Coupled historical and control simulations in different resolutions, performed as part of the H2020-EU-PRIMAVERA-project (following the HighResMIP-protocol), are used for the analysis.

Increased resolution leads to increased deep convection in the Labrador Sea and decreased convection in the Greenland Sea. Compared to observations from ARGO-floats, the high resolution models strongly overestimate the convection in the Labrador Sea. The bias is smaller in the Greenland Sea and somewhat reduced compared to the standard resolution model simulations.

The convection in the Labrador Sea is largely governed by the ocean heat release to the atmosphere. Northwesterly atmospheric flows, often connected to a positive state of the North Atlantic Oscillation, increase the ocean heat release and thus the density of the ocean surface in the Labrador Sea. The high-resolution models show stronger surface heat fluxes than the standard resolution models in the convection areas, which agrees with the stronger convection in the Labrador Sea. Also in the Greenland Sea, high resolution leads to an increased ocean heat release to the atmosphere. However, here, the relation between surface heat fluxes and convection is model dependent.

Keywords: high resolution modelling, oceanic convection, Atlantic Meridional Overturning Circulation, North Atlantic

4-P15

Analysis of Mesoscale Convective Systems in MPAS-CAM5 High Resolution and Convection Permitting Simulations

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The Model for Prediction Across Scales (MPAS) is a nonhydrostatic global variable resolution modeling framework. Using MPAS coupled with the Community Atmosphere Model (CAM5) physics package, a suite of simulations is performed including AMIP simulations for CMIP6 HighResMIP at 30 km and 120 km and simulations at grid spacing ranging from 4 km to 50 km using regional refinement over North America. These simulations provide an opportunity to systematically evaluate the impacts of model resolution on simulation of extreme events. We will present analysis of mesoscale convective systems (MCSs), which are responsible for most of the extreme precipitation events during the warm season in the central and eastern U.S. With a distinct nocturnal maximum, failure to simulate MCSs in the U.S. has led to a typical bias in diurnal cycle of precipitation in CMIP3 and CMIP5 models. To evaluate the impacts of model resolution on simulations of MCSs, we compare the observed and simulated MCSs and their large-scale environments across a range of resolutions. Applying an MCS tracking algorithm (FLEXTRKR) to observed and simulated outgoing longwave radiation and precipitation, we compare observed and simulated spatial distribution of MCS precipitation and its contribution to the total precipitation and MCS statistics such as MCS rain rate, size, and propagation speed. Using self organizing maps (SOM), we identify the large-scale environment associated with MCSs in observations and compare the frequency of occurrence of MCS favorable environment in observations and model simulations to understand model biases in simulating MCSs in the U.S. Our analysis demonstrates large differences in spring vs. summer MCS large-scale environment and MCS characteristics, suggesting more challenges for models to simulate summer than spring MCSs, even though MCSs in both seasons contribute almost equally to total precipitation in the central and eastern U.S.

Keywords: mesoscale convective systems, impacts of model resolution, MCS large, scale environment

4-P16

Climate modeling with a multi-grid approach

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The Icosahedral nonhydrostatic (ICON) model is a joint development of Deutscher Wetterdienst (DWD) and of Max-Planck-Institute for Meteorology. The numerical-weather-prediction version of ICON, ICON-NWP, has been running operationally at DWD for more than three years now using a multi-grid approach, i.e. with a horizontally higher resolved domain over Europe connected to a global domain via 2-way nesting.

In the first part of our project, we transferred the multi-grid approach of ICON-NWP to the atmospheric part of ICON-ESM with the aim of producing high-resolution climate projections for Europe. The targeted resolution is 10-20 km. In the second part, we investigate the influence of higher horizontal resolution on (1) extreme events over Europe such as heat waves and heavy precipitation using the atmospheric part of ICON-ESM and on (2) model biases such as the northern-hemisphere continental summer warm bias which has already been present in MPI-ESM and seems to persist in ICON-ESM.

Keywords: high resolution, climate projection, ICON, ESM

4-P17

Cloud feedbacks in extratropical cyclones and anti-cyclones: insight from long-term satellite data and high-resolution global simulations

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Extratropical cloud feedbacks represent one of the leading uncertainties in calculating climate sensitivity. Cloud behavior in the extratropics is a complex mix of large-scale synoptic activity and cloud microphysics encompassing ice and liquid phases. It has been suggested that ice-to-liquid transitions drive the negative cloud feedback across the extratropics. CMIP5 models disagreed by up to 35K as to the temperature where ice and liquid were equally likely in clouds. This modelling uncertainty and its potential impact on climate sensitivity make it important to understand. We use a simple regime-compositing approach to separate cyclones and anti-cyclones and examine the cloud feedback within each regime. We contrast global climate models (GCMs) with horizontal resolutions from 7 km up to hundreds of kilometers with Multi-Sensor Advanced Climatology Liquid Water Path (MAC-LWP) microwave observations of cyclone properties from the period 1992-2015. Inter-cyclone variability in both observations and models is strongly driven by moisture flux along the cyclone's warm conveyor belt (WCB). Stronger WCB moisture flux enhances liquid water path (LWP) within cyclones. We propose two cloud feedbacks acting within extratropical cyclones: a negative feedback driven by Clausius-Clapeyron increasing water vapor path (WVP), which enhances the amount of water vapor available to be fluxed into the cyclone; and a feedback moderated by changes in the life cycle and vorticity of cyclones under warming, which changes the rate at which existing moisture is imported into the cyclone. We show that changes in moisture flux can predict the majority of the observed trend in Southern Ocean cyclone LWP over the last two decades and the response to forcing in CMIP5 GCMs. A set of perturbed physics simulations in the UM is undertaken to separate effects related to ice-to-liquid transitions from meteorological variability.

Keywords: cloud feedbacks, mixedphase cloud feedback, cloud physics, climate sensitivity, PRIMAVERA, NICAM, ICON, CASIM, high, resolution, midlatitudes, extratropics, cyclones, observations

4-P18

Impact of stochastic physics on climate simulations with EC-Earth: looking at the ocean.

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Stochastic physics schemes provide a more realistic representation of the unresolved scales in global circulation models by improving both mean climate and climate variability. We study the impact of including a stochastic physics scheme in the atmospheric component of EC-Earth on the simulated ocean state. The experiments consist of coupled climate simulations in which three ensemble members constitute the control runs and three ensemble members include stochastic physics. For the latter, the Stochastically Perturbed Parametrisation Tendencies (SPPT) scheme is incorporated in the atmospheric component of EC-Earth. The period of simulation spans from 1850 to 2100 and the future scenario corresponds to RCP8.5. The two ensembles present a different climate sensitivity. We compare both ocean states to investigate the ocean model response to a perturbed atmosphere. The surface net downward heat flux in the ocean results higher for the control runs. The difference is approximately 4x10^23 J in the entire period of 250 years. The meridional heat transport (MHT) in the oceans results also higher in the case of the control runs. The Pacific and Atlantic oceans contribute roughly with 57% and 43% of the total difference, respectively. The larger amount of MHT in the Atlantic in the control runs respect to the stochastic runs, causes differences in the Atlantic Meridional Overturning Circulation as well. An abrupt loss of winter sea ice in the Arctic occurs at the end of the simulated period for the control runs only. In this case, the global annual surface air temperature reaches the threshold value for an abrupt collapse of winter sea ice in the Arctic. This feature is not observed when the stochastic physics is included, at least during the analyzed period. Including stochastic physics in EC-Earth might yield differences in the simulated climate comparable to differences between models.

Keywords: Stochastic physics, EC_Earth, Ocean.

4-P19

Bomb Cyclones in PRIMAVERA Simulations

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Bomb cyclones or explosively developing extratropical cyclones can cause serious hazards for society. Thus, it is important to understand how the global warming influence bomb cyclones. In this study, we try to address two questions: 1) How will bomb cyclones will change due to the global warming? 2) How are bomb cyclones influenced by model resolutions? To address these questions, we analyze outputs of PRIMAVERA project under collaboration between PRIMAVERA and CLIVAR. A novel experiment design of PRIMAVERA is that the same experiment is repeated for lower and higher resolutions of each model, and this allows us to address the second question. At the time of abstract submission, we have investigated the second question only by analyzing historical simulation outputs of five AGCMs, but we will extend our analysis for future simulations and will answer the first question too. Bomb cyclones are identified by a detection algorithm over the Northern Hemisphere. The locations of bomb developments are clustered over the western North Atlantic and western North Pacific, roughly collocated with the Kuroshio and the Gulf Stream and their extensions, consistent with observed features. It is found that the number of bomb cyclones increase in the higher resolution version of models than in the lower resolution version for most of models and across different models. If we estimate the bomb cyclone number as a function of model resolution, the expected number of 25 km resolution is more than 30% larger that of 100 km. Although this is a crude estimation, it is strongly suggested that typical standard CMIP5/CMIP6 model resolution can substantially underestimate bomb cyclones.

Keywords: model resolutions, extratropical cyclones, bomb cyclones, air sea interaction, CLIVAR

4-P20

Temporal and spatial intermittency of sub-daily precipitation in Australian monsoon and maritime continent linked to GCM precipitation biases

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Despite some improvement in coupled GCM development seen over recent years, large precipitation biases across tropical regions remain, especially across the Maritime Continent and Australian Monsoon domain. Often climate model biases on multi-year and global scales both develop within a few days of the start of the simulation and are closely related to deficiencies in the simulation of processes on much shorter and smaller scales. Different model parameterizations can produce either very intermittent or very persistent rainfall at the level of the model's time-step and grid scale, and also produce a poor representation of the processes and timing associated with the diurnal cycle of convection over land. Such deficiencies can have a significant impact on the regional-scale circulation and water cycle and thereby undermine confidence in projections of the spatial and temporal characteristics of heavy rainfall in a future climate. In our study, we examined the distribution of rainfall intensity, and its coherence across temporal and spatial scales, over the Maritime Continent domain and the tropical Australia monsoon region in a subset of recent-generation coupled atmosphere-ocean global climate models. We use a recently-published set of diagnostic tools (ASoP) which allows sub-daily rainfall data from the models to be compared with those from satellite observations (here: CMORPH and TRMM) and provides insight into how the rainfall variability changes as the temporal and spatial scales increase. Results will be presented.

Keywords: precipitation bias, monsoon, diurnal cycle

4-P21

Moisture transport associated to Tropical Cyclones.

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Tropical cyclones (TCs) transport energy and moisture along their pathways interacting with the climate system. The impact on June-to-September precipitation due to zonal moisture transport associated with TCs in the Maritime Continent and the meridional moisture transport carried by TCs in the North Atlantic are investigated in a set of AMIP (atmosphere-only simulations forced with observed sea surface temperatures) and coupled simulations performed at different spatial resolutions. The role of TCs in removing humid air from the Maritime Continent during the boreal summer season is highlighted comparing precipitation and vertically integrated zonal water transport between years with intense TC activity and low TC activity years along the period 1980-2015. This is made evident based on JRA-55 atmospheric reanalysis and confirmed by modelling experiments where results from a TCs resolving model are compared to a lower resolution model. The radial average distribution of specific humidity along the TC tracks is also inspected and used in evaluating the TCs meridional moisture transport in the North Atlantic. When compared to observation (IBTRACS and JRA-55 reanalysis), the simulated water content associated to TCs displays reasonably good performance in high-resolution model configuration in Tropical areas. In extra-tropical region, instead, models overestimate the TCs water content compared to observation. This effort is part of HighresMIP and it is developed in the framework of the EU-funded PRIMAVERA project.

Keywords: Tropical cyclones, moisture transport, Maritime Continent, North Atlantic

4-P22

Quantifying tropical cyclone rainfall and size in high resolution climate simulations

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Recently, general circulation models run at high horizontal resolutions have been used to study the large-scale controls of global and regional tropical cyclone (TC) activity in past, present and future climate. The main focus of this work is to better understand the extreme precipitation associated with TCs, with an emphasis on landfalling TCs in the Eastern U.S. In particular, this study uses various configurations of the Community Atmosphere Model version 5 (CAM5), a comprehensive atmospheric general circulation model, forced with prescribed sea-surface temperatures (SSTs) and greenhouse gases for present climate. Three different variable-resolution grids with horizontal grid spacing of approximately 25 km over all, or parts, of the North Atlantic are investigated. The impact of the variable-resolution grid choice on simulated TCs and their associated precipitation is investigated using the updated TempestExtremes software to calculate storm size and extract storm relative rainfall. This is also an important first step in investigating how TC variability, size and extreme rainfall will be altered in a future climate. This work is synergistic with High Resolution Model Intercomparison Project (HighResMIP) activities as the TempestExtremes framework is designed to allow for efficient model intercomparison of extreme events.

Keywords: Extremes, High Resolution, Tropical Cyclones

4-P23

Coordinated Global High Resolution Climate Modelling ? PRIMAVERA and CMIP6 HighResMIP

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One of the uncertainties in the role that model horizontal resolution plays in global climate simulation has been the lack of a coordinated experimental design and a large ensemble of multi-model, multi-resolution simulations to enable detailed analysis of the relevant processes. The CMIP6 HighResMIP protocol for 1950-2050 has provided the former, while the European H2020 project PRIMAVERA is contributing 7 different models to the multi-model ensemble (in addition to other international groups), at resolutions ranging from 250km-1 to 25km-1/12.

With a focus on the Atlantic and European climate variability and change, our analysis has examined mean state biases such as SST, precipitation, Gulf Stream position and variability, as well as fluxes between the Atlantic and Arctic systems. Aspects of variability such as the Atlantic Meridional Overturning Circulation (AMOC) and Atlantic Multidecadal Oscillation (AMO) have been examined, as well as Atlantic tropical cyclones.

One of the main challenges in analysing datasets such as these are the data volumes ? we expect to store at least 3 PB of data. Our coordinated analysis has used a common platform (CEDA-JASMIN), on which our data, algorithms and processing resource are available. We also have ongoing analysis with a variety of other partners (e.g. CLIVAR, tropical cyclone community, IPCC chapters), for which the application of standardised methods and algorithms will enable us to share results more easily - this approach emphasises moving the algorithm to the data rather than vice versa. The datasets, both raw model output and some derived products such as storm tracks, will be uploaded to the CMIP6 ESGF and CEDA archives.

In addition, we have been investigating the number of ensemble members necessary to produce robust results in both the impact of horizontal resolution, as well as separating climate change signals and trends from internal variability and weather noise.

Keywords: HighResMIP, resolution, multi, model

4-P24

Sensitivity of Atlantic Ocean biases to horizontal resolution in prototype CMIP6 simulations with AWI-CM

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Most of the climate models show substantial biases in the deep ocean that are larger than the level of natural variability and the response to enhanced greenhouse gas concentrations. Here we analyze the influence of horizontal resolution in a hierarchy of five multi-resolution simulations with the AWI Climate Model (AWI-CM), which employs a sea ice-ocean model component formulated on unstructured meshes. The ocean grid sizes considered range from a nominal resolution of 1¡ (CMIP5-type) up to locally eddy-resolving. We show that increasing ocean resolution locally to resolve ocean eddies leads to a major reduction in deep ocean biases. A detailed diagnosis of the simulations allows to identify the origins of the biases. We find that two major sources at the surface are responsible for the deep bias in the Atlantic Ocean. Furthermore, the Southern Ocean density structure is equally improved with locally explicitly resolved eddies compared to parameterized eddies. Part of the bias reduction can be traced back towards improved surface biases over outcropping regions, which are in contact with deeper ocean layers along isopycnal surfaces. Our prototype simulations provide guidance for the optimal choice of ocean grids for AWI-CM to be used in the final runs for phase 6 of the 'Coupled Model Intercomparison Project' (CMIP6) and for the related flagship simulations in the 'High Resolution Model Intercomparison Project' (HighResMIP). Quite remarkably, retaining resolution only in areas of high eddy activity along with excellent scalability characteristics of the unstructured-mesh sea ice-ocean model enables us to perform the multi-centennial climate simulations needed in a CMIP context at (locally) eddy-resolving resolution.

Keywords: CMIP, Atlantic Ocean, AWICM

4-P25

Attribution of recent changes in extreme weather over Europe

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The issue of recent changes in midlatitude extreme weather and their causes has been an important topic in recent years. In particular, a lot of attention has been given to the possible links between Arctic amplification (AA), changes in atmospheric flow waviness (amplified Rossby planetary and synoptic waves) and extreme weather. We revisit this topic based on three scientific questions: What is the observational evidence supporting the claim for more extreme weather in recent decades? Can we detect and attribute changes in extreme weather (and flow waviness) to changes in external forcings and/or internal variability? How robust is the observational/model evidence linking extreme weather to amplified Rossby waves ? Here we focus on the 1950-2017 (and future) periods and temperature extreme events at large spatial scale by considering regions such as Europe. Often contrasted (anomalously warm/cold) extreme weather events at these large spatial scales occur simultaneously owing to an amplified ridge/trough pattern across a continent. We then define a simple extreme weather index (EWI) based on area-average absolute anomalies using several observed daily temperature datasets. We then show that EWI monthly winter trends are not statistically different from zero while EWI positive summer (July-August) trends are depicted over Europe. We then investigate the attribution question using different single and multi-model ensembles, both SST-forced (HiResMIP/PRIMAVERA) and coupled (HiResMIP/PRIMAVERA, CESM-LENS, all and single-forcing simulations) and examine the sensitivity of the results to atmospheric horizontal resolution based on the PRIMAVERA multi-model ensemble. Finally, we use a waviness index (RWI) based on Rossby wave packet envelope to show that extreme EWI summer days are commonly linked to (and caused by) anomalously high RWI values. We then show that there currently is no strong observational evidence supporting the claimed link between AA and changes in waviness and extreme weather in summer.

Keywords: extreme weather, atmospheric circulation, attribution, horizontal resolution, Europe

4-P26

Projection of Tropical Cyclone Activity in the Western North Pacific Using a Single Column Ocean Coupled Model

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GFDL high-resolution (25-km) AGCM HiRAM and HiRAM coupled with SIT (Snow/Ice/Thermocline) single column ocean model were used for climate experiments following HighResMIP protocal. In the Tier 1 experiment HiRAM well simulates mean climatology, Asian Monsoon seasonal evolution, frontal activity, and tropical cyclone-intraseasonal oscillation relationship. Strength of simulated extreme precipitation is compatible with TRMM precipitation. In the Tier 2 historical experiment HiRAM-SIT produces similar climatology as HiRAM, but better diurnal cycle of precipitation, near surface temperature and MJO eastward propagation. Due to the lack of ocean circulation in the HiRAM-SIT coupled model, simulated 0.25-deg SST were nudged to CMIP5 1-deg ensemble SST in the Tier 2 future experiment to avoid climate drift. It is noticed that tropical cyclone activity in the western North Pacific is projected to be significantly weakened in the projected future climate. This is due to the equatorward contraction of convection and the corresponding anomalous subsidence poleward of the equatorial convection belt. Strongest response occurs in the western North Pacific and results in significantly weakened convection and westward extension of the subtropical anticyclone. Vorticity budget analysis finds that the background state decides the amplitude of response. The anticyclonic response is the largest in this monsoon trough (cyclonic) region. This is true even if the low level divergence anomaly is zonally symmetric. Dynamical Interaction between vorticity and divergence anomalies, the associated thermodynamic components, and the dynamical thermodynamic interaction likely further enhance the response in the monsoon trough and cyclonic regions.

Keywords: HiRAM, TC activity

4-P27

The role of Stochastic Physics and model resolution for the simulation of Tropical Cyclones in AGCMs

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Over the past decades, climate models have started to make use of resolutions that enable geophysical vortices with characteristics that increasingly resemble realistic tropical cyclones. For instance, a number of studies from the US CLIVAR Hurricane Working Group have demonstrated how tropical storm tracks, including their geographical distribution, variability, trends, are credibly represented by AGCMs employing 20km mesh size. The number of Tropical Cyclones in each hemisphere (and even for key basins) starts to be credibly simulated at 20km and beyond. However, the majority of the models analysed can still only simulate storms up to Category 3, while Category 4 and above are significantly or entirely underestimated. The push for increasing resolution continues, with AGCMs starting to operate under 10km, with the aim of improving realism, but at the same time it has been suggested that the use of Stochastic Physics may act as a surrogate for high resolution, by providing a more dynamic environment for instabilities to grow. Results from the analysis of a large ensemble of AMIP-type simulations with the ECMWF IFS (project SPHYNX) and the MO Hadley Centre HadGEM3 family of models (PRIMAVERA project) indicate that the use of Stochastic Physics at moderate to high resolution provides a 30-50% increase in the number of simulated Tropical Cyclones, which is roughly equivalent to a doubling of resolution. An investigation of the mechanisms behind this model behaviour, using a hierarchy of sensitivity studies, points to the prominent importance of the Stochastic Kinetic Energy Backscatter scheme for TC formation, but this seems to be largely model dependent, as many of the settings were previously tuned for maximising NWP performance at each centre. These results justify a push for a more systematic investigation, coordinated via the EU-Horizon 2020 PRIMAVERA project.

Keywords: Tropical Cyclones, High Resolution, Stochastic Physics

4-P28

Role of ocean mesoscale eddies for the response of climate system to strong greenhouse gas forcing

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The efficiency of the ocean in uptaking heat and carbon can notably alter the transient and equilibrium climate response. Recent studies show that these uptakes can be strongly affected by oceanic meso-scale eddies. Current generation climate models generally do not resolve oceanic meso-scale eddies and have to rely on eddy parametrizations. It is found that the effect of parameterized eddies differs from that of resolved eddies. Thus, it is possible that the climate response projected by a climate model with an eddy-resolving ocean differs from that projected by a climate model with a non-eddy-resolving ocean. Thus far, this possibility has not been systematically studied. Here, we quantify whether and to what extent climate response is affected by oceanic meso-scale eddies using a set of abrupt 4xCO2-runs carried out with the Max Planck Institute - Earth Systems Model (MPI-ESM) with T127 atmospheric resolution (~1 degree) and varying ocean resolutions (1, 0.4 and 0.1 degrees). The analysis of these runs aims at identifying the effect of meso-scale eddies, not only on the fast and slow climate responses measured by air temperature, but also on the responses of oceanic circulations, heat penetration into the deep ocean, air-sea interactions, and regional responses for regions directly influenced by strongly eddying boundary currents such as the Gulf Stream.

Keywords: climate response, ocean mesoscale eddies, ocean heat uptake

Session 4 - High resolution

4-P29

Evaluation of extreme precipitation and temperatures as simulated by the available CMIP6 HighResMIP models

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Using recently developed tools of the Coordinated Model Evaluation Capabilities (CMEC) program, we evaluate the ability of available HighResMIP models to simulate extremes of pentadal precipitation and 3 day temperature maxima and minima. Using a non-stationary extreme value approach, we compare long period return values of these quantities as simulated by the models to gridded observational products over North America, Europe and parts of Asia. Evaluation of these results against previous generation lower resolution models will be presented as well as a discussion of the possible sources of errors as well as improvements, if any.

Keywords: extreme precipitation, extreme temperature, climate model performance

4-P30

Improved meltponds in climate models

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The reduction of Arctic sea ice is an alarming sign of the on-going climate change with consequences not just for the Arctic but for the entire climate system through the albedo feedback. A realistic representation of the sea ice albedo is therefore key to better understand present and future changes in the Arctic. An important feature of sea ice during the summer season is the occurrence of meltponds that make the ice appear darker and increase the absorption of solar radiation. Many climate models account for this effect either implicitly by reducing the ice albedo during summer or with an explicit meltpond scheme. Within the framework of the PRIMAVERA project, UCL has developed a new topographic meltpond scheme for the LIM3 sea ice model in which the meltpond evolution is computed from the ice topography. The scheme assumes that the surface melt waters are collected in the depression of the ice topography, and that the ice thickness distribution can be used to determine the reservoir capacity of the depressions. The amount of water in the ponds is calculated from the detailed budget of input melt water and losses due to ice processes. This new meltpond scheme has been integrated in the EC-Earth model with standard and with high resolution. The first preliminary analysis show a reduction of the Arctic sea ice volume with the new meltpond scheme indicating a larger sensitivity to an increased climate forcing. We also find a better representation of the seasonal cycle of the Arctic sea ice when interactive meltponds are used. We further investigate the response of the Arctic climate to the changes in the sea ice induced by meltponds, and assess the impact thereof on the European climate.

Keywords: Arctic climate, sea ice model, PRIMAVERA

4-P31

Using ESMValTool to Assess the Impact of Resolution and Forcings on Ocean and Sea Ice Properties in the Southern Ocean

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ESMValTool has been established as a useful standard tool for model evaluation. Here, we use the new version 2 of ESMValTool, in particular our extension of its capabilities with regridding for irregular grids as commonly used in ocean models in the preprocessor stage of the tool.

This new ability is employed to perform analysis of ocean and sea ice properties in Antarctica and the Southern Ocean, tracking the progress and changes of the newest model generation used in CMIP6 as compared to CMIP5. Furthermore, the influence of changes in model resolution on these crucial parts of the earth system is explored using the high resolution studies from PRIMAVERA project, thus improving the understanding of the role they play in climate models.

The flexible architecture of ESMValTool together with its extensive support for observational datasets and the easy integration of model data that complies with the CF conventions, means that the analysis can easily be streamlined and applied to new observational datasets as they become available, and readily be performed across other model datasets, e.g. from the wide gamut of CMIP6 experiments.

In this way, we gain insight into the model response to different forcings, here by comparing the pre-industrial control simulations with the historical runs from CMIP6.

Keywords: southern ocean, resolution, forcings, esmvaltool, antarctic, sea ice

5-P01

Combing decadal predictions and near-term projections to obtain reliable information for the upcoming 30-40 years

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This work is embedded in the EU Horizon 2020 project called EUCP, aiming to develop a European prediction system of the next 40 years. The main goal of this work is to inform the community about the skill and limitations of current decadal predictions and to present first results showing to what extent these predictions are beneficial for constraining near-term projections. We explore the skill and reliability of current decadal predictions from the CMIP5 archive with a strong emphasis on Europe. Several methods are tested to merge the predictions with the respective model's near-term projections. This includes merging decadal predictions and near-term projections by weighting models according to their ability to simulate past climates. All results are verified in terms of probabilistic skill scores, e.g. ranked probability score and reliability scores. First results applying simple calibration methods to the CESM Large Ensemble demonstrate potential improvements of reliability and skill of northern European temperature projections. However, even though reliability is improved using these methods, the resulting projection remains overconfident. From the medium-range up to seasonal time-scales, the use of stochastic physics to represent model uncertainties has been shown to substantially improve reliability of the prediction. However, stochastic physics parameterisation is currently not included in decadal prediction systems. Here we analyse potential benefits of including stochastic physics beyond seasonal time-scales by comparing decadal predictions with current long-term seasonal forecasts for the upcoming 13 months.

Keywords: decadal prediction, near term projections, skill, reliability

5-P02

Extreme Summer Temperatures in the Northern Hemisphere and their Link to the Atlantic Multidecadal Variability in Decadal Hindcasts

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It remains an unsolved challenge to predict summer temperature extremes on the seasonal-to-decadal time scale. One possible way to understand the emergence of summer temperature extremes, and therefore their prediction, is to identify connections between large-scale features of climate variability and such temperature extremes. Here, we show evidence that the phase of the Atlantic Multidecadal Variability (AMV) influences the occurrence and decadal prediction skill of summer temperature extremes on the Northern Hemisphere. We use a 10-member ensemble of yearly initialized decadal hindcasts with the CMIP6 version of the MPI-ESM-HR model covering the period 1960-2017. We show for different regions in the Northern Hemisphere mid- to high- latitudes (Central Europe, Scandinavia, North-East Asia, and the Central Midwest USA) that the likelyhood of summer (JJA) temperature extremes predicted by the hindcasts increases from 15% in negative AMV phases to 22% in positive AMV phases. The amount of summer temperature extremes predicted by the model is highly correlated between the four regions, because the AMV and the occurrence of such extremes between these regions are strongly connected via a circumglobal atmospheric Rossby Wave, the circumglobal wave train. Predictions of summer temperature variability are skillful for up to 8 years ahead in the regions in Scandinavia, North-East Asia and the USA. Moreover, prediction skill for summer temperatures in these regions strongly depends on the phase of the AMV: summer temperatures in Scandinavia and the USA show high predictive skill in positive AMV phases, while North-East Asia shows high predictive skill in negative AMV phases. Conversely, due to a large number of other mechanisms influencing summer temperature extremes over Central Europe, we find no decadal prediction skill for European summer temperature extremes in this model simulation.

Keywords: Decadal Prediction, Surface Temperature Extremes, AMV, Wavetrain

5-P03

Disentangling the CO2 seasonal cycle form its terrestrial, oceanic and anthropogenic sources.

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The terrestrial biosphere and the ocean play a key role in the Earth's climate. Together, they absorb approximately half of the anthropogenic carbon dioxide emissions released into the atmosphere. Understanding and simulating the carbon cycle is a crucial issue, which inherently leads to benchmarking model carbon fluxes through the use of atmospheric CO2 data, which provides a strong constraint on the fluxes at continental scales. However, there are potential limitations. Indeed, models may reproduce the atmospheric CO2 seasonal cycle at many stations, but perform poorly when compared to carbon flux estimates at continental scale (atmospheric inversions). We have developed a methodology, which combines these two approaches and builds on the concept of Months and Regions of Influence. Carbon fluxes of each month of the 1980-2009 period and of each of the 22 so-called TRANSCOM regions were transported separately. This resulted in a fine grain decomposition of the simulated CO2 at 31 worldwide monitoring stations. This study uses the outputs of 23 CMIP5 ESMs and the results of 3 atmospheric CO2 inversions, and will be extended to CMIP6 models. We focus on land carbon fluxes and analyse the contribution of the most influential regions and months to the amplitude (and trend thereof) of the CO2 seasonal cycle. This provides further insights on the reasons for which a model correctly reproduces, or not, the atmospheric signal and allows to compare with similar contributions obtained from atmospheric inversion fluxes. Ultimately, this enables to pinpoint toward the likely physical and biogeochemical processes to be improved. At Barrow, we show that models share roughly the same region-months of influence than the MPI_JENA inversion (80% similarity) and overestimate the seasonal amplitude by 3.4 ppm (-6.2 to 27.5) with most important biases in boreal regions during mid and late growing season period.

Keywords: Benchmarking, Earth System Models, carbon fluxes, terrestrial ecosystems, climate change

5-P04

The Brewer-Dobson circulation in CMIP6 models

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The Brewer Dobson circulation (BDC) is the mean meridional circulation in the stratosphere. It is responsible for mass transport in the stratosphere and thus it is important for the distribution of trace gases in the stratosphere and its thermal structure and has implications for troposphere-stratosphere interactions. In the last decades, the BDC has received large attention as most climate models simulate a strengthening of the BDC in response to increasing greenhouse gas emissions in future scenarios. These studies have focused mainly on the shallow branch of the residual mean circulation while the deep branch has been less explored. In addition, the specific mechanisms responsible for the enhanced wave driving that accelerate the stratospheric circulation are still not well understood and previous model intercomparison works show a wide spread. The Coupled Model Intercomparison Project phase 6 provides a new opportunity to assess the robust features and quantify uncertainties in the climatology and trends of the BDC in the latest generation of coupled atmosphere-ocean models with a well resolved stratosphere. Our study will focus on both the shallow and deep branches of the residual circulation , and investigate the wave forcing of the residual circulation and its future changes and the dynamical mechanisms. In addition to the residual circulation diagnostics, the mean age of air will be examined to inform on the net mass transport, including two-way mixing.

Keywords: mean meridional circulation, Dobson circulation, Brewer, wave driving

5-P05

Processes linking the intensity of the Atlantic Multidecadal Variability to the climate impacts over Europe as assessed from CMIP6/DCPP-C pacemaker experiments

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Targeted sensitivity experiments have been proposed within CMIP6/DCPP to isolate the climate response to the Atlantic Multidecadal Variability (AMV) through a modeling framework based on pacemaker-type simulations. Those consist in restoring the modeled North Atlantic Sea Surface Temperature (SST) to an anomalous pattern (provided through input4MIPs for coordination) that is representative of the observed AMV, while the rest of the system remains fully coupled. Following DCPP-C guidelines, so-called ensemble AMV-experiments (hereafter 1xAMV) have been conducted with the CNRM-CM5 model. Additional ensembles have been produced by multiplying the anomalous AMV-related anomalies by 2 and 3 (hereafter 2xAMV and 3xAMV) to evaluate the sensitivity of the model response to the intensity of the AMV and to help isolate the mechanisms at work. We concentrate on the winter season and show that responses in 1xAMV are overall weak in temperature and precipitation, whereas more robust and significant signals emerge in 2xAMV and 3xAMV. Positive AMV then leads to large-scale continental warming (maximum loading along the Atlantic flank of Europe) and enhanced rainfall (except over Scandinavia). To deepen our understanding of the full AMV-forced response, we have adapted a so-called flow analogs method to isolate the respective contribution of the dynamical versus thermodynamical processes. We show that the AMV-forced atmospheric anomalous circulation tends to cool down the European continent, whereas the thermodynamical response leads to warming through the advection of warmer and more humid oceanic air penetrating inland and through the modification of the surface radiative fluxes linked to altered cloudiness and snow-cover reduction. In 1xAMV, dynamical and thermodynamical contributions cancel each over, whereas the latter clearly overcomes the dynamical cooling in 2xAMV and 3xAMV and explains the overall warming. Our study clearly emphasizes the non-linearity of the AMV-forced response with respect to the intensity of the AMV-forcing, and in particular its dynamical component.

Keywords: decadal variability, AMV, DCPP

5-P06

Top Precipitation Extremes from Event Prospectives: Observation, Simulation, and Attribution

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Events of extreme precipitation have a huge influence on society. Extreme rainfall leads to flooding and landslide including risk to human life, damage to buildings and infrastructure, and loss of crops and livestock. From past IPCC reports, it is commonly expected that frequency and intensity precipitation extremes will both increase as the climate warms. Although there are plenty of studies working on the topic, the uniqueness of our work is on both using high-resolution global and regional climate models and the search of events by spatial and temporal connection of extreme heavy rainfall occurrences. High resolution models in general better capture the the intensity and occurrence of heavy rainfall. The advantage of event identification is the possibility to link the volume to the ranking and potential damages of the extreme events in additional to usual assessment of mean changes in frequency and intensity. With the growing historical records and observational analysis, one can make comparison and objectively rank the historical events according to their severeness. The same approach can be applied to CMIP climate model simulation to obtain spatial and temporal evolution of extreme precipitation events. The event associated environmental thermal and dynamical conditions in different climate regions can be constructed to further delineate the underlying physical processes and how they change through time in the past and into the future. Additional effort to quantify the attributable risks of extreme events due to human impact or other individual forcing can be studied using designed numerical experiments with large ensemble members in CMIP.

Keywords: extreme rainfall

5-P07

Decadal variability in weather regimes and teleconnections in reanalysis datasets and climate simulations.

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Atmospheric intraseasonal variability, especially in the extratropics during the cold season, is characterized by preferred large-scale quasi-stationary flow patterns that have non-Gaussian characteristics. They are known as weather regimes and can be associated with significant temperature and precipitation anomalies. Several observation- based and model studies have shown that El Nino-Southern Oscillation (ENSO) and Madden and Julian Oscillation (MJO) forcing affects the relative frequency of occurrence of circulation regimes. The ENSO forcing is particularly important for the Pacific North-American (PNA) region, whose intraseasonal variability is directly linked to tropical Pacific SST anomalies. The MJO forcing affects the occurrence (and sub-seasonal predictability) of the North Atlantic Oscillation (NAO) and, to a lesser extent, the Euro-Atlantic Blocking. On the other hand, several recent studies have shown that wintertime large scale extratropical circulation over both the Pacific North American and the Euro-Atlantic sectors exhibits a non-negligible interdecadal variability, which seems to be related to a decadal modulation of the tropical-extratropical teleconnections. In this study we use century reanalysis datasets and a range of climate simulations to investigate the interdecadal variability of extratropical weather regimes and their associated tropical and extratropical teleconnections. The implications of the results of this study for assessing future climate change are discussed

Keywords: Natural Climate variability, Decadal variability, Tropical, extratropical teleconnections, Weather regimes

5-P08

Forced response, warming pauses and surge events in temperature and heavy precipitation extremes

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Regional trends in extremes can be substantially amplified or masked by internal variability. Thus, it is particularly challenging to isolate the forced response in extremes both from observations and individual model simulations. Reliable estimates of the forced response of extremes are however particularly important for detection and attribution as well as for uncertainty quantification. Ultimately, it is forced response that determines long-term changes in return levels of extremes. Based on the few CMIP5 models that provided daily output for several initial condition members, we had demonstrated that the disagreement between individual simulations primarily arises from internal variability. CMIP6 provides multiple initial condition members for substantially more models and allows to better separate unforced internal variability from the forced response in extremes. I will be using this for a more comprehensive quantification of uncertainty and robustness of projections of extremes. Due to internal variability, regional trends in extremes may deviate strongly from the forced response in individual simulations and in the real world. This may lead to multi-decadal warming pauses or stagnation periods in extremes, similar to the hiatus or warming holes of hot extremes. Such stagnation periods, during which the forced response is potentially hidden by large variability, may lead to a serious underestimation of the changes in the probability of extremes. Likewise, such a stagnation periods are often followed by a surge event during which extremes break previous records by a large margin. CMIP6 in combination with existing large initial condition large ensembles will be used to quantify the time scales and probability of such pauses and surge periods in extremes to occur. The findings of this study directly address caveats identified in the framework of the WCRP Grand Challenges of Extremes and in the early drafting of IPCC AR6 chapters.

Keywords: Extremes, heatwaves, uncertainties, internal variability, forced response

5-P09

Natural decadal sea-level variability in the Indian Ocean: Lessons from CMIP models

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Understanding natural sea-level variability is crucial to identify any secular change in sea level, since the observed sea-level trends are a combined response to both anthropogenic as well as natural climate changes. However, one of the main caveats, particularly for the IO, is the lack of long sea-level observation and inconsistencies in the representation of decadal sea-level variability among observation-based sea-level products. Those observational issues are a strong incentive to investigate the leading modes of IO decadal sea-level variability in climate models from the Coupled Model Intercomparison Project (CMIP). Two consistent modes of IO decadal sea-level variability, which collectively explain about 50% of the total decadal variance, are identified in 26 CMIP control simulations. With opposite sea-level signals in the southwestern and eastern tropical IO, mode1 is largely related to the decadal modulation of the Indian Ocean Dipole (IOD). Co-variability of decadal IOD with the El Ni–o-Southern Oscillation (ENSO), yields sea-level signals along the west coast of Australia (WAC), transmitted from the western Pacific via Indonesian Throughflow. Mode2 consists of a broad sea-level pattern east of Madagascar, mainly driven by the wind-stress curl associated with the Mascarene High decadal modulations. In about one-third of the models, mode2 is lag-correlated to mode1 and in such models, sea-level variations along the WAC propagate westward as Rossby waves and contribute to sea-level mode2. These sea-level modes identified in CMIP are broadly consistent with those derived from the relatively short altimeter dataset. In a poor observational sampling context, this suggests that the CMIP database can provide guidance for identifying robust modes of IO decadal sea-level variability.

Keywords: El Ni–o Southern Oscillation (ENSO), IOD, Indian Ocean, sea level,

5-P10

AMOC hysteresis in a pre-CMIP6 GCM and a proposal for comparing AMOC feedbacks.

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There has long been evidence from paleo observations, theory and simplified models that the Atlantic Meridional Overturning Circulation (AMOC) has the potential to collapse and for hysteresis (where it does not recover after forcing is removed). Although hysteresis has been seen in a few low resolution and flux adjusted GCMs, it has proved difficult to demonstrate in complex, coupled GCMs leading to suggestions that the presence of other feedbacks in complex GCMs may hinder hysteresis.

We present a suite of idealised experiments using HadGEM3-GC2 (which is a precursor to the Met Office's CMIP6 eddy-permitting GCM) to test for the presence of thresholds in the AMOC using an ensemble with different rates and lengths of freshwater forcing. We show that the AMOC does not always recover after freshwater forcing is stopped, and can remain in a weak state for at least a couple of hundred years. The recovery or not depends on how much the AMOC is weakened by the forcing and we show that this occurs through the interplay of advective feedbacks.

These results, however, are for one GCM and we wish to understand how these feedbacks vary across GCMs and whether we can learn more about the feedbacks, and hence potential for bistability, in the real world. Hence we set out a proposal for a multi-model study to examine the freshwater feedbacks. Although we physically understand many of the feedbacks on the AMOC, both advective and through surface fluxes, we do not have a good understanding of the relative strengths and which dominate. CMIP6 provides an opportunity to study these feedbacks in state-of-the-art GCMs and to take advantage of improvements in resolution and representations of processes.

Keywords: AMOC, threshold, tipping point

5-P11

Global monsoon response to sea surface temperature during the 20th century: Evidences from AGCM simulations

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Multi-decadal variations of global land monsoon are observed during the 20th century, with an increasing trend in the first half of the 20th century, followed by a decreasing trend up to 1980s and showed an upward trend later. By examining the outputs of two AGCMs (viz. GISS-E2-R and HadAM3) forced by historical sea surface temperature (SST), we reveal the mechanisms of the global monsoon precipitation changes during 1901-2000 and suggest that the significant changes can be attribute to atmosphere's response to SST anomalies. The climatological characteristics and the interdecadal variations of observed global land monsoon precipitation are reasonably reproduced by two AGCMs. The changes of global land precipitation are mainly contributed by the Northern Hemisphere monsoon domain accompanied with the variations of NHSM circulation and Walker circulation. At the interdecadal time scale, the global land monsoon precipitation anomalies and NHSM circulation are highly correlated with SSTA over North Atlantic and tropical Pacific. Both North Atlantic and La Ni–a pattern-like Pacific can lead more water vapor transport to monsoon regions by strengthening Pacific subtropical highs and trade winds, then further lead to the increase of monsoon precipitation. The outputs of GMMIP experiments will be used for our further research. The results of tier-1 experiments will be used to repeat above work to confirm the results are robust and not rely on individual model. The results of tier-2 experiments, which include "hist-resIPO" and "hist-resAMO" runs, will be used to reveal the contribution of SST anomalies over the tropical Pacific and the North Atlantic to monsoon precipitation changes. We aim to answer: How does atmosphere-ocean interaction affect the interdecadal variations of global monsoon? Can we predict monsoon precipitation changes in the coming decades given SST variability?

Keywords: Global monsoon, Sea surface temperature, Climate variability, Monsoon circulation

5-P12

Sea level variability in marginal seas from CMIP simulations. Strengths, weaknesses and ways to solve them.

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Sea level is a key variable for the climate system that needs to be modeled as accurately as possible. It is an important indicator of climate change as it integrates changes in the ocean heat content and land ice melting, among others. In coastal regions, changes in the mean sea level and in the extreme events can have a critical impact on infrastructures and ecosystems. An adequate management of those potential impacts require robust projections from climate models. Up to now, may studies have analysed the projections of regional sea level based on CMIP simulations. This has proven to be adequate for most oceanic regions but in semienclosed marginal seas (e.g. Mediterranean, Caribbean, Red Sea), the performance of global climate models is usually poor due to its coarse resolution and limited skills reproducing local dynamics. Understanding and quantifying the limits of applicability of those models in terms of sea level variability in highly populated marginal seas is thus of paramount importance. This even more true in a time in which more and more stakeholders are looking into CMIP simulations to define adaptation plans for the forthcoming sea level rise. In this presentation we will analyse the strengths and weaknesses of CMIP model outputs in terms of sea level variability in the Mediterranean Sea as a paradigm of vulnerable highly populated marginal seas. We will focus on different spatial scales (from basin to coastal) comparing the outputs among models as well as with observations (from altimetry and coastal tide gauges). Finally, we will present some explanations for the model weaknesses based on their ability to reproduce some key processes in the region.

Keywords: Sea Level, Mediterranean Sea, Marginal Seas, Model skills.

5-P13

Quantifying the Agreement Between Observed and Simulated Extratropical Modes of Interannual Variability

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Using Historical simulations of CMIP5 and CMIP6, models and multiple observationally-based datasets, we employ skill metrics to analyze the fidelity of the simulated Northern Annular Mode (NAM), the North Atlantic Oscillation (NAO), the Pacific North America pattern (PNA), the Southern Annular Mode (SAM), the Pacific Decadal Oscillation (PDO), the North Pacific Oscillation (NPO), and the North Pacific Gyre Oscillation (NPGO). We assess the benefits of a unified approach to evaluate these modes of variability, which we call the common basis function (CBF) approach, based on projecting model anomalies onto the observed empirical orthogonal function (EOF). The CBF approach circumvents issues with conventional EOF analysis, including the need to correct for arbitrary signs of EOF's, and the need to test if higher-order model modes better compare with the observed modes. Compared to conventional EOF analysis of models, the CBF approach indicates that models compare significantly better with observations in terms of pattern correlation and root-mean-squared-error (RMSE) than heretofore suggested. The skill metrics proposed in this study provide a useful summary of the ability of models to reproduce the observed EOF patterns and amplitudes. Additionally, the skill metrics can be used as a tool to objectively highlight where potential model improvements might be made. We advocate more systematic and objective testing of simulated extratropical variability, especially during the non-dominant seasons of each mode, when many models are performing relatively poorly. Time-permitting, analysis of power spectra of the principal component time series and diagnosis of the modes of variability will be discussed.

Keywords: Common basis function, Metrics, Modes of variability, EOF, CMIP5 model evaluation

5-P14

Investigating the ENSO teleconnection response to global warming using a multi-model large-ensemble experiment

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The El Ni–o-Southern Oscillation dominates interannual variability of the climate system, with widespread global teleconnections that influence regional precipitation and temperature. ENSO teleconnection patterns are generally projected to shift eastward over the Pacific-North America sector under global warming (medium confidence in IPCC AR5 report; approximately 25% of models disagree), due to either an eastward shift of tropical convection associated with the warm pool expansion or changes in the midlatitude circulation. Better constraining future changes in ENSO teleconnections remains a challenge because of model uncertainty in how (a) tropical convection and (b) the midlatitude circulation will respond to global warming, as well as (c) large internal variability of the teleconnection pattern, which makes it challenging to isolate the forced signal. Here, we tackle (b) and (c) using large-ensemble simulations (at least 100 members per experiment) from 5 CMIP models. Prescribed-SST experiments are designed to test how teleconnections from the same ENSO events evolve under different background climates (present and future). The present day teleconnection pattern is relatively well simulated, with the models placing the North Pacific centre-of-action within 400 km of its position in ERA-Interim. A slight northeastward shift (approximately 250 km) of the North Pacific centre is found in 3 out of 5 models, despite large internal variability (ensemble spread) in the position of this centre. In these models, tropical convection also shifts eastward, despite no change in the ENSO SST forcing. Some asymmetry exists between the two ENSO phases, with La Ni–a exhibiting smaller spread and less northeastward shift than El Ni–o in 4 out of 5 models. Associated shifts in temperature impacts are weak, while precipitation impacts in regions along the North American west coast are accentuated and expand inland.

Keywords: ENSO teleconnections, internal variability, global warming, model intercomparison, large ensemble simulation

Session 5 - Variability and extremes

5-P15

Towards predicting the variable ocean carbon sink

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The ocean comprises one of the globe's most important sinks for anthropogenic carbon but this sink has been shown to vary substantially on interannual to decadal time-scales. Our investigations, using a grand ensemble of 100-member simulations based on the Max Planck Institute Earth System model(MPI-ESM), suggest that the variations of the ocean carbon sink can be attributed to the large internal climate variability. By assimilating observations of atmosphere and ocean physical fields into MPI-ESM based decadal prediction system, we can further produce variations of the ocean carbon sink consistent with observation-based estimates. Our results show that the variations of the ocean carbon sink are predictable up to 2 year globally, while the predictive skill is higher up to 5 years regionally. We further separate the predictability into thermal (i.e., affected by CO2solubility) and non-thermal (i.e., affected by ocean circulation and biology) components. We find that the shorter-term (< 3 years) predictive skill of the ocean carbon sink is maintained by the thermal drivers, however, the longer-term (> 3 years) predictive skill is determined by the non-thermal drivers. To further assessing the predictability of the ocean carbon sink in the context of global carbon cycle interactively, we move one step further to run emission-driven simulations of decadal predictions. The emission-driven assimilation captures the variations of the global carbon cycle in comparable to the global carbon budget. The decadal predictions based on ESMs are an important tool for monitoring the future evolution of the global carbon cycle and to determine if we are on the right track meeting longer term climate targets. An extension of our predictions in the context of CMIP6 DCPP multi-model framework is planned and this will further facilitate improvement of predictive skill in the global carbon cycle.

Keywords: predictability, ocean carbon cycle, internal variability, global carbon cycle

5-P16

Tropical North Atlantic as a non-stationary modulator of ENSO-European rainfall teleconnection

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El Ni–o-Southern Oscillation (ENSO) impact on the North Atlantic European sector (NAE) still rises many unanswered questions. Nowadays, there is a growing evidence advocating for a non-stationary feature affecting both, the tropospheric and the stratospheric pathways, of the ENSO-NAE teleconnection. In particular, a changing link between ENSO and the spring Euro-Mediterranean rainfall has been documented in response to different phases of the Atlantic Multidecadal Oscillation (AMO). Nevertheless, the underlying physical explanations are far to be completely understood. In this study a purely tropospheric mechanism, in which the Tropical North Atlantic (TNA) plays a major role, is presented. Our results rely on the distinct capacity of ENSO to generate a zonal SST gradient over the TNA under different AMO phases. Consequently, a atmospheric response, also related to ENSO, can be triggered from the TNA to the European sector. The occurrence of this ENSO-NAE teleconnection via TNA could be subject to inter-decadal changes of ENSO properties and Atlantic background conditions. In this study this issue is analyzed in 1) observations, and 2) low-resolution and high-resolution atmospheric and coupled GCM simulations. It is expected that the novel proposed mechanism gives a step forward in the understanding of the role of the Atlantic basin as modulator of the ENSO-NAE teleconnection.

Keywords: ENSO, European rainfall, climate teleconnection, AGCM, CGCM

5-P17

Variability in the northern North Atlantic and Arctic oceans in the past millennium: A review of CMIP5/PMIP3 efforts

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The past millennium climate showed large decadal to multi-centennial variations, like the Little Ice Age (LIA) cold period. Causes behind such variations are still debated, although North Atlantic circulation changes have often been proposed to be key. Combined proxy model analyses complement and strengthen the interpretation of past ocean changes and processes, including the role of external forcings and internal processes in climate variability. We here discuss current knowledge of past millennium North Atlantic variability in climate simulations with the IPSL-CM5A-LR, CESM, and MPI-ESM models performed within the context of the CMIP5/PMIP3 initiatives. No evident model consensus is found in variations in the AMOC, subpolar gyre, and Denmark Strait overflow strengths, three key elements of the North Atlantic large-scale dynamics. These show different responses to external forcings across models, even after accounting for sampling effects due to different model ensemble sizes. Differences in the external forcings among model simulations may partly explain model differences, highlighting the need for increased standardization of model forcings and experimental protocols. Furthermore, the potentially large role of internal variability calls for ensemble approaches to isolate externally forced signals properly. Lag-zero linear regressions between SSTs and large-scale ocean circulation show varying degrees of agreement among models and seem to be period dependent. This questions the robustness and stationarity of SST fingerprints of ocean circulation. Disagreement also arises in Medieval-Climate-Anomaly-vs-LIA and preindustrial-vs-industrial SST changes between models and a state-of-the-art compilation of high-resolution paleoceanographic records. The PMIP4/CMIP6's past1000 experiment proposes for the first time common forcings and relatively larger ensemble sizes. Yet long transient simulations are still limited by model resolution, which hampers the representation of key oceanic processes in the North Atlantic. Further advances in our current understanding of North Atlantic last millennium variability will rely on the success of such new coordinated experiments.

Keywords: Past millennium, North Atlantic and Arctic climate variability, CMIP5/PMIP3 climate models

5-P18

A multi-model comparison of the ocean contributions to multidecadal variability in the North Atlantic

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In this study, we analyse the inter-relationships between the Labrador Sea densities, the boundary currents, the Atlantic Meridional Overturning Circulation (AMOC) and, more generally, the wider climate of the North Atlantic across an ensemble of long CMIP5 preindustrial simulations. The study also relies on the analysis of two 300-year long high-resolution coupled control simulations (with HadGEM3-GC2 and HiGEM, respectively). The ultimate goal is to shed light on the reasons for the model spread, and to explore the potential use of different climatological properties as emerging constraints to identify which models are more compatible with the current (and limited) AMOC observations, and thus are more likely to represent realistically decadal variability in the North Atlantic. Our results suggest that all models consistently show a strong link between the Labrador Sea Densities and the AMOC at subpolar latitudes (45N), but have little coherence regarding their relationship with the subtropical AMOC (26¡N, i.e. the latitude of the RAPID array). This link with the subtropics tends to be higher in models with a stronger and deeper AMOC cell, and also in models with more weakly stratified Labrador Sea Densities. In both cases, models closest to the observational values support a weak link of Labrador Sea Densities with the subtropics. Interestingly, regardless of the previous inter-model differences, all models show a coherent delayed link of Labrador Sea Densities with ocean temperatures in the Eastern Subpolar Gyre, supporting recent works that relate the recent record-breaking cold anomalies in the Eastern North Atlantic to a slowdown in the AMOC.

Keywords: Atlantic Meridional Overturning Circulation, Decadal Variability, Emerging Constraints

5-P19

ENSO and PDO modulation of sudden stratospheric warmings: a multi-model study

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In this work we evaluate how El Ni–o-Southern Oscillation (ENSO) and the Pacific Decadal impact the stratospheric polar vortex variability, and particularly the occurrence of sudden stratospheric warmings (SSWs). The tropospheric variability in the North Atlantic-European sector is associated with the North Atlantic Oscillation (NAO), which dominates European climate on interannual time-scales and is strongly influenced by SSWs, as it was shown during late-winter/spring of 2018. ENSO is thought to have an impact on the NAO strength and duration via a stratospheric pathway, however this relationship may not be linear and depend on other factors. The direct effect of the PDO on the NAO and/or the polar stratosphere has been much less analyzed and remains unclear. ENSO and the PDO can modulate the occurrence of SSWs since both are associated with anomalous wave propagation in the North Pacific that can interfere with the climatological wave pattern over the Aleutian Low region and affect the wave injection into the stratosphere. To achieve our goal, we use a set of idealized experiments that allows to investigate separately the ENSO and PDO teleconnections to the polar vortex; a control experiment with climatological SSTs, a sensitivity experiment prescribing a canonical ENSO event on top of the seasonal cycle, and two sensitivity experiments prescribing respectively the positive and negative phase of the PDO with an annual pattern. These simulations were performed using three different general circulation models with a well-solved stratosphere: EC-EARTH/IFS, CNRM/ARPEGE and CMCC/CAM, which contribute to the ERA4CS-funded MEDSCOPE project.

Keywords: teleconnections, ENSO, PDO, SSW, stratosphere

5-P20

ENSO evaluation in CMIP models

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Since the establishment of the basic physical mechanisms 30 years ago, major progress in El Ni–o-Southern Oscillation (ENSO) research has been made. This resulted in a better understanding of ENSO mechanisms, dynamics and forecasting and much improved simulations of ENSO statistics in coupled ocean atmosphere general circulation models (CGCMs). Beyond the traditional scientist-driven exploratory model evaluation, and with the advent of climate services, there is now a need to document ENSO properties for a growing number of stakeholders outside the modelling community. This requires to co-construct the related science questions between ENSO experts and model information end users is many disciplines. We here report on the progress made by the CLIVAR ENSO Research Focus group to propose consensus metric collections on specific ENSO related science questions: ENSO performance and teleconnections in historical simulations and ENSO processes. First application to CMIP6 vs. CMIP5 simulations is presented. The pilot technical implementation of an ENSO metrics package independent of the software infrastructure used also paves the way for future standards in model evaluation.

Keywords: ENSO metrics, CMIP5 vs CMIP6, ENSO performance, ENSO teleconnections

5-P21

Atlantic Multidecada Variability and North Atlantic Storm Track

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The influence of the Atlantic Multidecadal Variability (AMV) on the North Atlantic storm track and related impacts on the European climate are assessed via a coordinated analysis of idealised simulations with state-of-the-art coupled models. The rationale for the approach is that the modulation of sea surface temperature by the AMV phases modifies temperature gradient and land-sea thermal contrast in the core of the Atlantic extratropical storm track region. Consequent changes of the growth of eddies and their propagation can lead to modifications of the mean position and speed of the low-level jet. Data used are obtained from a multi-model ensemble of AMV± experiments conducted under the framework of the Decadal Climate Prediction Project component C (DCPP-C). These experiments are performed nudging the surface of the Atlantic ocean (temperature and salinity) to states defined by imposing observed (ERSSTv4) AMV± anomalies onto the model climatology. The focus of the analysis is on the AMV-driven modifications to high frequency atmospheric eddies and their feedback on the mean flow. The signature of these dynamical changes on anomalous temperature and precipitation over Europe is also inspected. The analysis will shed light on a potential combination of dynamical (jet displacement) and thermodynamic (advection of thermal anomalies) AMV impacts on Europe. The potential outcome of this analysis is informative of the processes generating uncertainty of impacts in the multi-model DCPP-C framework.

Keywords: Atlantic Multidecadal Variability, Jet stream variability, European Climate

5-P22

A Monte Carlo Assessment of Changes in Summertime Precipitation Characteristics Under RCP8.5-Sensitivity to Annual Cycle Fidelity, Overconfidence, and Gaussianity

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Typically, climate change modelling studies assess changes and uncertainty using multi-decadal averages of seasonal mean quantities (e.g., Tebaldi et al. 2005; Lopez et al. 2006, Collins et al. 2013, Kitoh et al. 2013, Wang et al. 2014, Sperber et al. 2016, Kitoh et al. 2017). Using 5-day averaged precipitation from all initial condition realizations of 33 CMIP5 models (Taylor et al. 2012), the added-value of this work is the assessment of summer precipitation in terms of amount, onset and withdrawal date, and length of season (duration) through the analysis of probability distributions of interannual anomalies, and the specification of confidence intervals for the changes in the mean. Also, we calculate changes in the probability of below-normal, normal, and above-normal precipitation in the RCP8.5 climate change simulations calculated using Historical simulation thresholds for three equally probable categories (Leith 1973). We explore the sensitivity of the anthropogenic climate change to (1) using all models, (2) using 1 model per modelling group to circumvent overconfidence due to the lack of model independence (Knutti et al. 2010), (3) the impact of only using models that are most realistic in the simulation of the annual cycle in terms the timing and variability of onset and duration of summer rainfall, and (4) we compare results based on Gaussian and non-parametric statistics, the latter based on Monte Carlo sampling of the different initial condition realizations.

Keywords: Anthropogenic Climate Change, Precipitation, Annual Cycle Skill, Monte Carlo Sampling

5-P23

Atlantic Multidecadal Variability in CMIP6 Historical Simulations

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Atlantic Multidecadal Variability (AMV) is a major driver of important climate impacts in many parts of the world. As yet, however, there is no consensus on the dominant causes of AMV. There is strong evidence that AMV can arise from processes that are purely internal to the climate system. In particular, decadal variability in the Atlantic Meridional Overturning Circulation is believed to be an important driver of AMV. However, there is also evidence that external forcings - both natural (solar, volcanic) and anthropogenic (e.g. greenhouse gases, aerosols, land use) - can also influence AMV, and may have done so in significant ways during the twentieth century. There has been particular debate, arising from CMIP5 results, about the role of anthropogenic aerosols. CMIP6 presents a new opportunity to address these important issues. This paper will present results from analysis of historical simulations with the UK GC3.1 model. If time permits, comparisons will be made with results from UKESM and other CMIP6 models. This work is being done as part of the UK Atlantic Climate System Integrated Study (ACSIS) programme (www.acsis.ac.uk).

Keywords: Atlantic Multidecadal Variability

5-P24

Tropical air-sea CO2 flux variations in two ESMs with an ocean data assimilation system

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Interannual-to-decadal fluctuations of the global-mean atmospheric CO2 concentration are observed associated with internal climate variations, and these fluctuations sometimes cancel out and at other times support the centennial increasing trend of the global-mean CO2 concentration due to accumulation of anthropogenic CO2 emissions. One direct cause of the fluctuations is the oceanic absorption or release of CO2 through the global air-sea CO2 flux variations which are dominated by the tropical Pacific. Therefore, deeper understanding of the tropical oceanic processes and properly initializing oceanic states including marine ecosystem are of importance in future predictions of the global CO2 concentration together with quantification of human-influences. In the present study, we evaluated and examined the simulated air-sea CO2 flux variations in the tropical Pacific in two ESMs (MIROC-ES2L and MIROC-ESM) with the same ocean data assimilation system. Although the assimilation procedures are the same, observed anti-correlated relationship between interannual variations of the upward air-sea CO2 flux and the sea surface temperature (SST) in the tropical Pacific are well captured in MIROC-ES2L, but the relationship is reversed in MIROC-ESM. Tropical climatic-mean state of MIROC-ESM shows significant biases of weaker trade winds, more diffuse equatorial thermocline than observations, and simulated amplitude of interannual variations of NINO3-SST is about half as large as observations. When observations are assimilated into the model, these biases lead to non-negligible correction terms on the governing equations of ocean temperature and salinity, which induces an anomalous spurious equatorial upwelling during El-Ni–o events. The spurious upwelling brings dissolved inorganic carbon rich water in the subsurface layer to the surface mixed layer. Consequently, an anomalous upward air-sea CO2 flux is occurred during El-Ni–o, as opposed to observations and MIROC-ES2L. Better modeling physical processes in the tropical climate system is suggested to be essential for better marine ecosystem modeling and reanalysis.

Keywords: air, sea CO2 flux, tropics, ESM, initialization

5-P25

Decadal predictability in the CMIP6 models

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In order to investigate the potential for initialization to improve decadal predictions, we will quantify the initial value predictability of upper 300 m temperature in the two northern ocean basins for the CMIP6 models, and we will contrast it with the forced predictability in the DECK experiments. We have developed the methodology to estimate initial value predictability from long control runs. When we applied the method to the CMIP5 models, we found that 1) initialization has the potential to improve skill in the first 5 years in the North Pacific and the first 9 years in the North Atlantic, and 2) the impact from initialization becomes secondary compared to the impact of RCP4.5 forcing after 6 1/2 and 8 years in the two basins, respectively. We plan to update the knowledge with the CMIP6 experiments. If there are not many multi-model outputs available by the time of the workshop, we will focus on the CESM2 simulations and discuss change in the initial value predictability from CCSM3, CCSM4, CESM1 to CESM2.

Keywords: decadal predictability, decadal prediction

5-P26

Simulation of historical and projected climate change in arid and semiarid areas by CMIP5 models

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Based on Climatic Research Unit Time Series 3.1 temperature and Global Precipitation Climatology Center full data reanalysis version 6 precipitation data, the abilities of climate models from the fifth phase of the Coupled Model Intercomparison Project to simulate climate changes over arid and semiarid areas were assessed. Simulations of future climate changes under different representative concentration pathways (RCPs) were also examined. The key findings were that most of the models are able to capture the dominant features of the spatiotemporal changes in temperature, especially the geographic distribution, during the past 60 years, both globally as well as over arid and semiarid areas. In addition, the models can reproduce the observed warming trends, but with magnitudes generally less than the observations of around 0.1 0.3 C/50a. Compared to temperature, the models perform worse in simulating the annual evolution of observed precipitation, underestimating both the variability and tendency, and there is a huge spread among the models in terms of their simulated precipitation results. The multimodel ensemble mean is overall superior to any individual model in reproducing the observed climate changes. In terms of future climate change, an ongoing warming projected by the multi-model ensemble over arid and semiarid areas can clearly be seen under different RCPs, especially under the high emissions scenario (RCP8.5), which is twice that of the moderate scenario (RCP4.5). Unlike the increasing temperature, precipitation changes vary across areas and are more significant under high-emission RCPs, with more precipitation over wet areas but less precipitation over dry areas. In particular, northern China is projected to be one of the typical areas experiencing significantly increased temperature and precipitation in the future.

Keywords: Climate projection, Climate simulation, Climate change, CMIP5, Arid and semiarid areas

5-P27

Evaluating climate model simulated extremes

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Climate extremes heavily affect all socio-economic sectors causing losses, damages and fatalities. Understanding their dynamics, representing them in climate model simulations, and then projecting their evolution under future scenarios is of upmost importance. Therefore, tailored statistical procedures must be developed and applied to evaluate models and estimate changes in the coming decades. Recently proposed approaches, able to identify and quantify complex nonlinear changes in climate extremes, are here reviewed and discussed. Applications to CMIP5 and EURO-CORDEX simulations are shown. Then, concurrent extremes are introduced together with a suite of innovative methods to detect nonlinear spatio-temporal changes. Finally, the importance of concurrent extremes in global risk assessments is discussed by using an application to HELIX projections.

Keywords: climate extremes

5-P28

Impact of initialisation on the reliability of decadal predictions

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Bringing together initialised decadal climate predictions and non-initialised climate projections in order to provide seamless climate information for users over the next decades is a new challenging area of research in the field of climate prediction. This can be achieved by comparing the predictions based on global initialised and non-initialised simulations for common prediction time horizons. A number of studies have focussed on assessing the added-value of initialised decadal predictions vs. non-initialised simulations in terms of forecast quality. However, the impact of initialisation on the reliability of decadal forecasts has not yet been investigated sufficiently. Forecast reliability quantifies the agreement between the predicted probabilities and observed relative frequencies of a given event. Users are particularly sensitive to the lack of reliability of the probabilistic climate information because it implies that the uncertainty formulation is not trustworthy. In this communication, multi-model initialised decadal hindcasts from CMIP5 (and if available, CMIP6) will be compared to the corresponding non-initialised historical simulations in terms of reliability over their common period 1960-2005. Instruments like rank histograms, reliability diagrams and maps of the reliability component of the Brier score will be used to assess the added-value of the initialisation in terms of reliability for different variables (surface temperature, precipitation, sea-level pressure, ...) and different forecast times at both the global and European scales.

Keywords: decadal predictions, forecast quality, reliability, initialisation

5-P29

Decadal Climate Prediction with EC-Earth

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This study provides an overview of the contribution of the Barcelona Supercomputing Center to the Decadal Climate Prediction Project (DCPP) using the EC-Earth coupled global climate model (https://www.ec-earth.org). Particular focus will be given on the production and results of the initialised decadal hindcasts from 1960 to 2017, ie the DCPP Component A. Our ensemble hindcasts comprise 10 members initialised yearly on 1st November, that is 580 different initialised decadal simulations. The decadal predictions are performed with a resolution of T255L91 in the atmosphere and 1¡ and 75 vertical levels in the ocean. Atmospheric initial conditions are generated using ERA-40 and ERA-Interim. Ocean and sea-ice initial conditions have been produced using a NEMO-only simulation forced by DFS atmospheric fields and nudged towards ORAS4. We will show results of the quality of deterministic and probabilistic hindcasts, such as anomaly correlation coefficients or Brier skill scores of near surface temperatures, verified against observations and reanalysis products. We will also assess the impact of initialisation on forecast reliability quantifying the statistical relationship between the predicted probabilities and the observed relative frequency of an event. Special emphasis will be given to the representation of the Atlantic Multidecadal Variability as a major source of decadal predictability and other modes of variability such as the Inderdecadal Pacific Variability or the Arctic Oscillation. Initialised hindcasts will further be compared to an ensemble of non-initialised historical simulations assessing the potential added value of initialising the model towards the observed climate state in near-term climate predictions.

Keywords: Earth, EC, AMV, decadal prediction, A, DCPP, DCPP

5-P30

The recent abrupt cooling over North Atlantic: A forced signal or natural variability?

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The subpolar North Atlantic (SPG) is a region known as no long-term warming in contrast to the global warming in response to the anthropogenic forcing. Observations during the 20th century indicates that SPG experienced periods of both abrupt cooling (e.g., around 1970, and more recently round 2010) as well as rapid warming (e.g., in mid-1990s), implying there exists large decadal variability in the region. Model studies suggested that abrupt SPG cooling may result from either disruption of the Atlantic Meridional Circulation (AMOC) or a collapse of SPG convection, both are possible responses to the global warming trend. In this study, we investigate the relative role of natural variability to the anthropogenic forcing in driving the abrupt changes in SPG. Preliminary analyses of multi-century simulations with constant forcings (ie., piControl experiments) using two versions of EC-Earth (ie., the CMIP5 and a post-CMIP5 version) indicate that significant warming and cooling trends of 15-20 years occur frequently and alternatively. In particularly the strength of the cooling trends are comparable with that observed in mid-2010s. The analysis extended to the EC-Earth CMIP5 historical and RCP 8.5 experiments show similar results, suggesting the recent observed SPG cooling may well be phenomenon of natural climate variability. We currently extend these analyses to the CMIP6 experiments of EC-Earth and also other CMIP6 models. To understand the mechanism leading to different trends, the upper ocean heat content, the stratification in SPG, as well as the AMOC associated with the warming and cooling will be assessed and compared to present-day observations. Their connection with the atmospheric North Atlantic Oscillation will also be investigated.

Keywords: Cooling trend, Subpolr North Atlantic

6-P01

On the Causes of Poleward Shift of the Indian Summer Monsoon Low Level Jetstream

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The Indian summer monsoon rainfall has seen a declining trend over parts of the Indian subcontinent in recent decades. These decreases are offset by increases in other parts. In climate model simulations, greenhouse gas forcings increase the monsoon precipitation while aerosol forcings lead to a decrease. Models forced with best estimates of historical anthropogenic aerosols reproduce the observed decline in South Asian monsoon precipitation (Bollasina et al.; Science, 2011). Polson et al., (GRL, 2014) implicated anthropogenic aerosol forcings in the decline in global monsoon precipitation. Guo et al., (Atmos. Chem. Phys., 2015) further showed that models that include the aerosol indirect effect show a larger decrease in South Asian monsoon season rainfall. The large-scale monsoon changes (both globally and regionally over South Asia) include subtle regional details. One such is a drying trend over the southern part of the west coast of India and an increase further north in recent decades. Sandeep and Ajayamohan (Clim. Dyn., 2015) showed that CMIP5 and CMIP3 model simulations (historical as well as future scenarios) indicate that this pattern of decline in rainfall appears to be a consequence of a poleward shift in the monsoon low level jetstream. The genesis location of monsoon low pressure systems (LPS) that distribute more than half the precipitation over central India are also found to be shifted poleward from the Bay of Bengal to Indian subcontinent towards the end of 21stcentury in RCP8.5 simulations, consistent with the shift in low level flow (Sandeep et al., PNAS, 2018) indicating a link between changes in precipitation and dynamics in addition to aerosol microphysical effects. In this study examine the drivers of these dynamical changes using individual forcing simulations from the CMIP5 (and CMIP6 as available) to understand their relative roles in producing the observed patterns of precipitation change.

Keywords: monsoon low level jet stream dynamical response single forcing

6-P02

Contrasting methods of detecting and attributing the impact of external forcings

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Detection and attribution is based on the assumption that the impact of natural and anthropogenic forcings on the climate system can be well approximated by linearly adding the effects of individual forcings. This assumption has been validated for global averages and spatial patterns of (mostly) temperature related variables. Modelling groups in CMIP5 undertook these detection and attribution experiments in various ways, some adding each historical forcing to a preindustrial control, others eliminating certain forcings from a historical all-forcing simulation. Many studies have assumed these methods produce similar results, however the available experiments have not allowed this assumption to be tested until now. Here for the first time we compare these two methods of detection and attribution in ensemble simulations with the CESM1-CAM5 coupled climate model. For example, are the results of a simulation that includes all external forcings but for ozone depletion similar to the results of adding the output of all individual single-forcing experiments but for those driven by ozone changes? Results suggest that similar evolutions of global temperatures and precipitation are found between the two methods, with some notable differences in the response to aerosols. Our experiments enable us to go beyond the global average temperature response and explore different variables at different spatial and temporal scales so to characterize in a systematic fashion where the linearity holds and where it breaks down.

Keywords: detection, attribution, internal variability, ensembles, aerosols

6-P03

Attribution of Ocean Temperature Change to Anthropogenic and Natural Forcings using the Temporal, Vertical and Geographical Structure

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We examine whether significant changes in ocean temperatures can be detected in recent decades and if so whether they can be attributed to anthropogenic or natural factors. We compare ocean temperature changes for 1960-2005 in four observational datasets and in historical simulations by atmosphere-ocean general circulation models (AOGCMs) from the Coupled Model Intercomparison Project phase 5 (CMIP5). Observations and CMIP5 models show that the upper 2000m has warmed with a signal that has a well-defined geographical pattern that gradually propagates to deeper layers over time. Greenhouse gas forcing has contributed most to increasing the temperature of the ocean, a warming which has been offset by other anthropogenic forcing (mainly aerosols), and volcanic eruptions which cause episodic cooling. By characterizing the ocean temperature change response to these forcings we construct multi-model mean fingerprints of time-depth changes in temperature and carry out two detection and attribution analysis. We consider first a two-signal separation into anthropogenic and natural forcings. Then, for the first time, we consider a three signal separation into greenhouse gas, anthropogenic aerosols and natural forcings. We show that all three signals are simultaneously detectable. Using multiple depth levels decreases the uncertainty of the results. Limiting the observations and model fields to locations where there are observations increases the detectability of the signal.

Keywords: ocean: climate change: detection and attribution

6-P04

Implication of Mid Holocene and Last Interglacial changes in insolation seasonality on high and mid latitude climate

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The mid-Holocene (MH), 6000 years BP, and the Last Interglacial (LIG), 127000 years BP, are key reference periods for the 4th phase of the Paleoclimate Modeling intercomparison Project (PMIP, Kageyama et al., GMD, 2018; Otto-Bliesner et al., GMD, 2017), and will contribute to the overall understanding of the response of the climate system to external forcing as part of CMIP6. These two interglacial periods are characterized by enhanced (reduced) seasonality of the incoming solar radiation at the top of the atmosphere in the northern hemisphere (southern hemisphere). In the annual mean, larger obliquity also increases solar radiation in high latitudes and decreases it in the tropics. Trace gas atmospheric concentrations are similar to pre-industrial values. The poster will present the new sets of available simulations with the aim to characterize the differences in snow and ice feedbacks in high latitudes resulting from differences in the magnitude of the changes in seasonality between the two periods. The impact of this feedback on polar amplification will be investigated. Also both periods are characterized by enhanced monsoons in the tropical regions. These first analyses will investigate how monsoon seasonality is related to the characteristics of the solar forcing and to feedbacks from ocean circulation and land surface properties. For both periods, model results can be analyzed in the light of available paleoclimate reconstructions. In addition, the mid-Holocene is considered as an entry card for the paleoclimate simulations in CMIP6, because it has been a reference period for PMIP since the first PMIP phase (Joussaume and Taylor, 1995). A comparison with previous MH PMIP simulations will highlight the evolution of model performances in simulating a climate state different from the modern one.

Keywords: monsoon, hydrological cycle, climate feedback, Paleoclimate, polar amplification

6-P05

The response of climate variability in PMIP4/CMIP6

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There has been substantial effort devoted to determining how variability will change as global climate changes. This has used a range of information ranging from past observations, future simulations and climate proxy reconstructions. One such example is the recognition that the El Ni–o-Southern Oscillation (ENSO) was weaker than today throughout much of the past ~10,000 years (the Holocene). Analysis of the multi-model simulations performed for the Palaeoclimate Model Intercomparison Project helped understand the mechanisms for this, but has been challenging to replicate for other modes (such as the North Atlantic Oscillation and the Southern Annular Mode). The new features of fourth phase of the Palaeoclimate Model Intercomparison Project (PMIP4) combined with the infrastructure advances associated with CMIP6 provide a great opportunity systematically investigate the forced response of variability. PMIP4 has expanded to encompass more past climates: Tier 1 comprises of four equilibrium simulations and forced transient simulation of the last millennium. This provides the many years required to better characterise changes in low-frequency modes of variability. Additionally, the Climate Variability Diagnostics Package (part of the ESMValTool) has made the computation of many climate modes routine, as well as providing diagnostics. Combined, this makes simultaneous analyses across multiple experiments, multiple climate models and multiple features of climate variability feasible. Here we explore the response of the amplitude of climate variability to various Earth System forcings - such as orbital changes, land configuration and greenhouse gases. We characterise how the main modes change in these climate states, but also how the changes in regional interannual variability respond to the changes in those modes. Additionaly PMIP enables the constraining future climate changes through the combined use of emergent multi-model relationships and palaeoclimate reconstructions. We will highlight instances that show potential to use proxy observations to constrain future projections of climate variability.

Keywords: past climate, variability

6-P06

Increased variability of Eastern Pacific El Ni–o surface temperature under greenhouse warming

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The El Nino Southern Oscillation (ENSO), the dominant year-to-year climate phenomenon on the planet, severely disrupts global weather patterns, with impacts on the lives and livelihoods of millions of people around the world. Observations show that there are two distinct ENSO regimes, one with a sea surface temperature (SST) anomaly centre in the equatorial central Pacific, and the other with an anomaly centre in the equatorial eastern Pacific, referred to as CP and EP ENSO, respectively. Under greenhouse warming, CP SST variance is projected to increase with a modest inter-model consensus contributed by increased frequency of strong La Ni–a events. However, the issue of how EP ENSO SST may change continues to be plagued by a persistent lack of apparent inter-model agreement in the response of eastern Pacific SST to anthropogenic greenhouse gas forcing. Here we show for the first time that if we focus on the unique anomaly pattern for each model, rather than on an index from a fixed geographical region (e.g. Ni–o3), there is in fact a robust increase in EP ENSO SST variance with a strong inter-model consensus.

Keywords: Global Warming, El Nino

6-P07

Climate Scenarios for the Fifth United States National Climate Assessment

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The Third U.S. National Climate Assessment (NCA3) mainly used climate scenarios generated using the CMIP3 suite of climate model simulations with some generated using CMIP5. The Fourth U.S. National Climate Assessment used the CMIP5 suite of simulations, and also used the Localized Constructed Analog (LOCA) statistical downscaling dataset to generate scenarios of extremes such as changes in heavy precipitation events. With the CMIP6 suite of simulations becoming available the intent of the U.S. Global Change Research Program is to utilize these simulations as much as possible for the Fifth U.S. National Climate Assessment. One major question raised during the NCA process is how extremes, such as hydrological extremes, have changed and will change in the future. Here we examine heavy precipitation events by finding the largest multi-day events for various sized areas (e.g. 50,000 km2) in the observed record for the eastern United States, then examine both the simulations directly from CMIP5 and two statistical downscaling methods driven by CMIP5 simulations for their ability to produce similar precipitation events. Secondly, we examine the ability of both models and downscaling methods to reproduce the observed spatial coherence of the point precipitation amounts across the simulated precipitation events. Lastly, we expect to have preliminary results from CMIP6 simulations to complement these analyses.

Keywords: climate assessments, downscaling, Climate Scenarios

6-P08

Transient Climate Response to Cumulative Emissions in CMIP6 models. Preliminary results from the C4MIP experiments

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The Transient Climate Response to Cumulative Emissions (TCRE) is a near linear relationship between anthropogenic emissions of CO2 cumulated over time and the global surface temperature warming. This quantity is strongly relevant for climate policies as it allows quantifying the remaining carbon budget compatible with any climate target such as 1.5¡C or 2¡C.

Using coupled climate-carbon cycle simulations performed by Earth System Models of different level of complexity, IPCC AR5 assessed that TCRE is likely in the range of 0.8¡C to 2.5¡C per 1000 GtC. Here we use preliminary results from the 1% CO2 increase per year simulations from the CMIP6 deck to assess TCRE. We further decompose TCRE in its two main contributions: climate sensitivity (dT/dCO2) and airborne fraction (dCO2/dEmi), this latter being further decomposed in the concentration-carbon (beta) and climate-carbon (gamma) feedbacks components.

Initial results from CMIP6 simulations currently available suggest that TCRE might be at the high end of the CMIP5 range, implying that the remaining allowable carbon emissions for 1.5 and 2¡C could be lower than the most recent estimates from the IPCC Special Report on Global Warming of 1.5¡C.

Keywords: TCRE, C4MIP, Carbon feedbacks

Session 6 - Future Projections

6-P09

Assessing the robustness of marine heatwave projections

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Some of the recently observed marine heatwaves (MHWs) revealed the high vulnerability of marine ecosystems and fisheriesto such extreme climate events. Satellite observations and a suite of CMIP5 Earth system model (ESM) simulations show that MHWs have already become longer-lasting and more frequent, extensive and intense in the past few decades, and that this trend will accelerate under further global warming (Frolicher et al. 2018). Between 1982 and 2016, we detect a doubling in the number of MHW days. If temperature were to rise by 3.5¡C by the end of the twenty-first century, the average increase in the probability of MHWs would be 41 times higher than in preindustrial times. At this level of global warming, the spatial extent of the heatwaves would be 21 times larger, their duration would increase to 112 days and their maximum intensity would rise to 2¡C. The largest changes are projected for the western tropical Pacific and the Arctic Ocean. An important assumption underlying the analysis is that the employed ESMs simulate MHWs in a sufficiently realistic manner. Whereas this is the case for the frequency and the maximum intensity of MHWs, it is not the case for the duration and spatial extent, which might be caused by the relatively coarse resolution of the ESMs. Here using daily sea surface temperature output from CMIP6 ESM simulations (piControl, historical, ScenarioMIP) as well as a new global high-resolution ESM (GFDL-CM2.6, ocean model horizontal resolution of 0.1¡), we test the robustness of these earlier CMIP5 ESM results. A particular emphasis will be given to the relative role of changes in mean ocean temperatures, changes in temperature variability or a combination of the two.

Keywords: Marine heatwave, Ocean warming, Climate modeling, Climate change, Extreme events

6-P10

Responses of terrestrial aridity to climate change and global dry land expansions

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The dryness of terrestrial climate can be measured by the aridity index, AI, i.e., the ratio of annual precipitation (P) to potential evapotranspiration (PET). The PET represents the evaporative demand of the atmosphere, which depends on the surface air temperature, relative humidity, wind speed, and available energy. Drylands are area of lands with low amount of water in soil with AI < 0.65, which comprise of more than 40% of the global terrestrial area, and are home to more than one third of global populations. Knowledge of how anthropogenic climate change will affect aridity and extent of drylands is essential for water resource and land use management in these regions. Feng and Fu (2013) for the first time examined the change of terrestrial aridity in the past and in the future and its impact on the dryland area by analyzing both observations and CMIP5 simulations. They showed that global drylands have expanded in the past and will continue to expand in the 21st century. It was suggested that the relative increase in evaporation over the ocean, which controls the relative change in precipitation over land, is slower than the increase in PET over land, leading to a drier terrestrial climate (Sherwood and Fu 2014; Fu and Feng 2014; Fu et al. 2016). This presentation will examine how the terrestrial aridity responds to global warming in terms of P/PET and how this response would impact the dryland area and the its components including hyper-arid, arid, semi-arid, and sub-humid regions by analyzing the CMIP 6 output. We will also compare the results with those from CMIP5.

Keywords: Terrestrial aridity, drylands, climate change

6-P11

Evaluation of the PMIP4/CMIP6 palaeosimulations

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Past climate states provide an opportunity to evaluate how well models simulate large climate changes. The mid-Holocene (MH, 6000 yr BP) and the Last Glacial Maximum (LGM, 21,000 yr BP) provide strongly contrasting climate states, have been used as targets for model evaluation in previous rounds of PMIP/CMIP, and are "entry cards" in the suite of palaeoclimate simulations that are being run by PMIP members in CMIP6. In this presentation, we will describe the palaeoclimate observations that are available for benchmarking and evaluation of these (and other) palaeoclimate simulations, with emphasis on new global hydroclimate datasets including (a) isotopic records from speleothems, (b) lake status records of hydroclimate, and (c) quantitative climate reconstructions that account for the ecophysiological effects of changing [CO2]. The interpretation of these palaeo-records is not always straightforward, and requires innovative techniques for data-model comparison, including uncertainty propagation, forward modelling and process diagnosis, and we will discuss data-model comparison approaches that are currently under development

Keywords: process diagnosis, forward modelling, observations, palaeo, benchmarking, model evaluation, palaeoclimate

6-P12

Monsoon precipitation responses to global warming and their regional differences simulated by CMIP models

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Global climate models used in a global warming projection have been extensively developed and improved for the past several decades. However, a projection of regional precipitation change still faces challenges because of its large spatial variation and large uncertainty. Using climate model experiments in the Coupled Model Intercomparison Project (CMIP) phase 5, we have investigated precipitation responses to global warming and their uncertainty in various monsoon regions worldwide, and have tried to understand regional differences in the responses. The CMIP phase 5 models project that summer monsoon precipitation will increase in most regions in a warmer climate, but with large regional variations in terms of the magnitudes including a larger increase in Asia and a decrease in North America. The models project that heavy precipitation will increase much more than the mean precipitation over all monsoon regions, with a larger increase in Asia. A moisture budget analysis reveals that an increase in atmospheric moisture (thermodynamic change) contributes positively to the precipitation changes, but a general weakening of the monsoon circulation (dynamic change) acts to oppose the positive thermodynamic change. In most monsoon regions, the thermodynamic component overwhelms the dynamic component. Interestingly, in the Asian monsoon regions the negative dynamic change is much less than in other monsoons, resulting in larger increases in precipitation. Further analysis using idealized multi-model experiments indicates that CO_2-induced enhancement of the land-sea thermal contrast and resultant circulation changes are the most influential in the South Asian monsoon, leading to the largest increase in precipitation, which suggests an important role of the land warming on the Asian monsoon response. We are expecting that an analysis with updated climate models participating in the ongoing CMIP phase 6 will support our findings and provide more confident results.

Keywords: Asian monsoon, monsoon precipitation, CMIP models, global warming

6-P13

How far is the carbon sink predictable in a multi-model framework?

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Several prediction system based on Earth system models include the carbon cycle components and thereby enable predictions of the ocean and land carbon sinks. Such prediction systems are forced with prescribed historical atmospheric CO2 concentrations and assimilate only the physical climate data, albeit using different assimilation and initialization designs. The land and ocean carbon cy- cle models run as passive components adjusting to the state and the phase of the physical climate system. Based on the outcomes of 6 ocean carbon cycle components and 3 land carbon cycle components included in different prediction systems, we perform a first attempt of a multi-model assessment of the ocean and land carbon sinks predictive skills. We use available observational synthesis products and the estimates of the Global Carbon Budget to establish predictive skill. Additionally, the potential predictive skill is evaluated against the models' own reconstruction or assimilation simulations. We find a potential predictive skill of up to 3 years and of about 1 year for the global ocean and the global land carbon sinks, respectively. More modeling centers will integrate their car- bon cycle components as part of CMIP6 DCPP simulations, facilitating a more comprehensive assessment of the carbon sink predictability. This new knowl- edge is pivotal for predicting the fate of anthropogenic CO2 emissions and for facilitating verification of near-term emission trends in support of the UNFCCC global stocktakes.

Keywords: predictability of the ocean and land carbon sinks, DCPP, C4MIP

6-P14

The Global Carbon Cycle emissions driven simulations in the NASA-GISS climate model

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We present simulations of the global (land-ocean-atmosphere) carbon cycle from the NASA-Goddard Institute for Space Studies (NASA-GISS) coupled climate model. This incarnation of CMIP6-level simulations are driven by emissions of CO2 from different sources, including land, ocean, biomass burning, land-use change and fossil fuel emissions. Both land and ocean carbon components have been spun up to equilibrium using prescribed, pre-industrial era forcings and continue with the CMIP6 greenhouse gas forcing scenarios. CO2 is fully interactive with atmospheric radiation and affects longwave absorption and increase of surface air temperature. Results are compared with the prescribed-concentration driven runs in the same model.

Keywords: CO2, emissions, carbon cycle, land, ocean, atmosphere

6-P15

Transient simulations over the Common Era using comprehensive Earth System Models: The PMIP4/CMIP6 past2k experiment

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The Common Era (CE, i.e. the two millennia before the industrialization) is among the periods selected by the Paleo Model Intercomparison Project (PMIP) for transient experiments contributing to CMIP6 and the fourth phase of PMIP (PMIP4). In an ongoing effort, the Past Global Change 2k (PAGES2K) initiative is providing an extensive proxy database on continental and regional scale climate change over the last 2000 years. For PMIP4, novel estimates and updates of external forcing have been compiled (Jungclaus et al., 2017). The new volcanic and solar forcing data sets also allow for an extension of the temporal range. Therefore, in addition to the Tier-1 category simulation past1000 for the period 850 CE to 1849 CE, the Tier-3 past2k experiment covers the entire CE. Here we present first results from two Earth System Models, CESM1.1(Zhong et al., 2018) and MPI-ESM1.2, following the PMIP4 past1000 and past2k protocols. These simulations extend the pool of current ESM simulations into the 1st millennium CE and represent an important basis to assess the models' response to external forcing. We analyze regional trends and variations over the last 2000 years in comparison with PAGES2k reconstructions. Regarding the first millennium, we focus on the representation of the effects of a cluster of strong volcanic eruptions in the first half of the 6th century CE. Jungclaus, J.H. et al., 2017: The PMIP4 contribution to CMIP6 Part 3: The last millennium, scientific objective, and experimental design for the PMIP4 past1000 simulations. Geosci. Model Dev., 10, 4005-4033, doi:10.5194/gmd-10-4005-2017. Zhong, Y., et al., 2018: Asymmetric cooling oft he Atlantic and Pacific Arctic during the last two millennia: a dual observation-modelling study. Geophys. Res. Lett., 45, doi:10.1029/2018GL079447.

Keywords: past climate, response to external forcing, model data intercomparison

6-P16

Regional and vertical structure of ocean heat uptake in the UKESM1 CMIP6 simulations of the historical climate

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Of the additional heat in the Earth system about 93% have been taken up by the world ocean over the past couple of decades. Hence this process is crucial for moderating global surface temperature change. For the current, CMIP6 generation of Earth System models it is equally crucial to estimate ocean heat uptake processes accurately in order to deliver robust and reliable projections of climate change in the coming decades. Previous generations of climate models displayed systematical biases in ocean heat uptake, e.g. a too weak simulated vertical temperature gradient, suggesting that the added heat is distributed too far deep in the models. In addition, the inter-model spread in ocean heat uptake efficiency contributes significantly to the uncertainty in the transient climate response. Here we analyse the UKESM1 historical simulations for CMIP6 in these regards. We show an analysis of the vertical structure of ocean heat uptake compared to observations. Furthermore, we analyse the horizontal structure of ocean heat uptake, putting a focus on the relative roles of the North Atlantic and the Southern Ocean. It is envisaged to entrain more CMIP6 Earth System models in this study, and to put the results in the context of Earth's energy imbalance.

Keywords: ocean heat uptake, historical simulations, UKESM1, Earth's energy imbalance

6-P17

A multi-model analysis of the historical carbon fluxes and compatible fossil fuel emissions in CMIP6 Models

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Many Earth System models have recently performed a series of simulations for Phase 6 of the Coupled Model Intercomparison Project (CMIP6). This poster presents a multi-model analysis of the results of many CMIP6 models' historical simulations, covering the period from 1850 - 2015, with a focus on the carbon fluxes between the atmosphere, land and ocean. We present the ranges of historical land and ocean carbon uptake simulated by the models. Knowing the land and ocean uptake, we can infer the amount of fossil fuel carbon that can be emitted to maintain the CO2 concentration pathway driving the models; we also show, therefore, the range of compatible fossil fuel emissions from the CMIP6 models over the historical period.

Keywords: carbon fluxes, cmip6, earth system modelling, compatible emissions

6-P18

Stratosphere-Troposphere Circulation Changes

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The stratospheric vortex is one of the dynamical factors driving near surface long term weather and climate. Through the analysis of the CMIP5 multi-model ensemble, clear evidence of the impacts of boreal winter stratospheric dynamical changes on surface climate emerged (e.g., Manzini et al 2014; Simpson et al 2018). However, these studies have also illustrated a considerable degree of uncertainty in the boreal winter stratospheric vortex response to the anthropogenic increase in greenhouse gases. Here we build upon these previous results to assess the boreal winter stratospheric vortex response and its relationship to the surface climate response, by means of multi-model analysis of historical and scenario experiments performed within CMIP6 and report consistency or differences with respects to the previous phases of CMIP. In addition, making use of the newly requested diagnostics of resolved and parametrized stratospheric wave driving (DynVarMIP), we attempt a momentum budget of the atmospheric changes and search for across-model relationships between stratospheric changes and model biases in the stratospheric vortex basic state.

Manzini, E., et al. (2014) Northern winter climate change: Assessment of uncertainty in CMIP5 projections related to stratosphere-troposphere coupling, J. Geophys. Res. Atmos., DOI:10.1002/2013JD021403.

Simpson, I.R., et al. (2018) The Downward Influence of Uncertainty in the Northern Hemisphere Stratospheric Polar Vortex Response to Climate Change, J. Climate, DOI: 10.1175/JCLI-D-18-0041.1

Keywords: circulation, stratosphere, dynamics

6-P19

Present and future seasonal land snow cover simulated by CMIP coupled climate models

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Snow is a crucial component of the climate system. It perennially covers the large continental ice sheets and the sea ice almost entirely, as well as approximately 45 million km2 of the northern hemisphere during the cold season. The snow cover plays multiple roles in the climate system: through the snow albedo feedback, it amplifies global warming. It also insulates the soil, influencing the carbon storage in permafrost, and affects the atmospheric circulation. Observations show a general decrease in fall and spring snow cover extent and duration, with regional and seasonal variability driven by the competing influences of temperature and precipitation. Earth system models include snow modules from one-layer to multiple-layer schemes with a large range in complexity in the representation of process involving snow-vegetation interaction, snow metamorphism, and the surface energy budget. Previous studies highlighted that CMIP5 models simulate well the relationship between the boreal temperature and the snow cover extent in the Northern hemisphere, but underestimate the polar amplification, inducing an underestimation of the snow cover decrease over the last decades. Because of a coarse resolution, snow cover is also poorly represented over mountainous areas in CMIP5 models. The CMIP5 ensemble experiments suggest that the magnitude and even the sign of 30-yr regional trends of snow cover can be strongly modulated by internal variability. Initial snow cover analysis based on CMIP6 model outputs will be presented during the workshop, as part of the ESM-SnowMIP and LS3MIP initiatives. New observational datasets provided by the ESA CCI-snow project will be used as soon as they become available.

Keywords: satellite observations, CMIP models, climate variability, snow cover

6-P20

Attribution of the observed intensification of extreme precipitation over dry and wet regions

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Human-induced global warming is expected to accompany changes in hydrological cycle through lower-tropospheric water vapor increases, which would result in changes in the spatial distribution of precipitation, potentially amplifying differences between dry and wet regions. Recently, extreme precipitation increase was identified, providing important implications for risk of flooding with global warming. In this study, we examine causes of the observed intensification of extreme precipitation over the dry and wet land areas for the past 60 years (1951-2010) by applying an optimal fingerprinting technique to CMIP5 and CMIP6 multi-model simulations. The observed and model simulated annual maximum of daily precipitation (Rx1day) is converted into a standardized probability-based index ranging from 0 to 1 before analysis, following previous studies. Results based on CMIP5 multi-models show that anthropogenic signal is detected in the observed increase in extreme precipitation over both dry and wet regions. We further demonstrate that the detected anthropogenic influence is separable from natural forcing and that the counteracting drying influence of anthropogenic aerosols is also detected over the wet region. A few available CMIP6 models confirm the observed intensification of extreme precipitation over dry and wet regions for the extended period up to 2014. By utilizing individual forcing simulations provided by the Detection and Attribution Model Intercomparison Project (DAMIP), we will conduct an updated attribution analysis. Also, results will be compared with CMIP5-based ones, including model skills for extreme precipitation amplitude, variability, and wet-dry region distributions.

Keywords: extreme precipitation, detection and attribution, dry and wet regions, anthropogenic forcing

6-P21

Future evolution of the Greenland ice sheet in a coupled climate and ice sheet model (CESM-CISM)

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There are large uncertainties in the projections of 21st century global mean sea-level rise. Part of the uncertainty stems from the lack of ability to robustly resolve interactions and feedbacks between ice sheets and the climate system. Coupling an ice sheet model to a climate model will help us in this regard. The Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6) is a CMIP6-endorsed MIP that focusses on the Greenland and Antarctic Ice Sheets. One ISMIP6 goal is a set of experiments with climate models coupled to ice sheet models (ISM). This way we can assess the climatic impact of the ice sheet dynamic response onto the climate. The AOGCM-ISM experiments are identical in set-up to the CMIP6 AOGCM experiments. The Community Earth System Model version 2 (CESM2) has the capability to couple bi-directionally to the Community Ice Sheet Model (CISM) over the Greenland Ice Sheet. We can assess ice sheet processes and feedback mechanisms, such as the ice-albedo feedback and multiple elevation feedbacks. Further, routing of ice sheet meltwater to the ocean and adaptive ice sheet topography enables studying the impact of a changing ice sheet on atmospheric and ocean circulation patterns. Here we present preliminary results of the ISMIP6 efforts with CESM2 with a dynamically evolving Greenland Ice Sheet of the DECK-runs: pre-industrial control (piControl) steady state simulation and the 1% yr-1 CO2 concentration increase (1pctCO2) simulation. Focus will be on key features of the global and polar climate simulation: the time evolution of the North Atlantic Meridional Overturning Circulation (NAMOC) strength, the atmospheric and ocean meridional heat transport, Greenland albedo, surface melt and surface mass balance (SMB), and the dynamical ice sheet change and contribution to eustatic sea level rise of the Greenland Ice Sheet.

Keywords: ISMIP6, sea level rise, Greenland ice sheet, AOGCM, ISM

6-P22

Seasonal amplification, phase shift, and uncertainties for ocean acidity during the 21st century

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Comparison of nine CMIP5 Earth System Models indicates that the amplitude of the annual cycle of surface-ocean free acidity [H+] is projected to increase by 81 ± 16% during the 21st century under the RCP8.5 scenario despite minor changes in the seasonality of sea surface temperature and salinity (Kwiatkowski and Orr, 2018). Although the annual cycles of other ocean acidification variables are also altered, they exhibit smaller changes in amplitude. For instance, the annual cycle of surface-ocean pH is attenuated by 16 ± 7%, a counterintuitive result when compared with the change in amplitude in free acidity, which is larger and of opposite sign. The projected enhancement of the seasonal amplitude of ocean acidity is likely to exacerbate future impacts on marine organisms, relative to the case of considering no change in seasonality. At lower latitudes, marine organisms would be exposed to relatively higher acidity in the summer and lower acidity in winter; in the higher latitudes, it would be the opposite. This CMIP5 analysis is now being extended to the CMIP6 models as their output becomes available. It is also being complemented by an assessment of shifts in seasonal phasing, showing in some regions complete phase reversals. The extended analysis also includes a decomposition of uncertainties from internal variability, differences between models, and differences between scenarios, a classic approach but one that focuses on changes in the annual cycle, not the annual mean.

Keywords: CMIP5, CMIP6, ocean, acidity, pH, CO2, uncertainty analysis, annual cycle, amplitude, phase

6-P23

Regional analysis of present and future marine productivity

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The future evolution of marine biogeochemistry is key to understanding how the ocean's role in carbon uptake and its provision of resources may change. For instance, anthropogenic drivers are expected to induce ocean warming, altering vertical stratification and upward nutrient supply, while ocean acidification and deoxygenation are expected to impact marine ecosystems. Underpinning the credibility of these forecasts is the realism of the model-simulated present-day, in particular the spatial and temporal representation of marine productivity. Here we aim to identify patterns in the drivers of regional productivity at the present-day. For instance, how well do models agree with observed regional distributions of productivity? And do models agree on the relative importance and roles of underlying driving factors such as ocean circulation, nutrients and mixed layer depth for setting these patterns? Extending to the future, we aim first to quantify regional trends across models, and then to evaluate whether there are common underlying mechanisms for these changes are. Essentially, are there common patterns in change, and are these driven by the same mechanisms, or are CMIP-class models divergent given the same future forecast? Analysis will initially make use of an ensemble of CMIP6 Historical and ScenarioMIP simulations using the UKESM1 model, with the aim to extend across the CMIP6 ensemble.

Keywords: ocean biogeochemistry, regional

6-P24

Attributing the Indo-Pacific warm pool expansion: seasonal changes and its impacts on precipitation

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The Indo-Pacific warm pool (IPWP) plays a critical role for global atmospheric circulation and hydrological cycle, and attribution of the observed changes in IPWP intensity and area is important for understanding global and regional changes in precipitation patterns and circulation. In this study, we conduct an attribution analysis of the observed changes in seasonal IPWP during 1953-2012 by comparing observations with CMIP5 and CMIP6 multi-model simulations performed under different external forcings including anthropogenic and natural factors. In order to consider model biases, models are first evaluated in terms of the seasonal climatology and about a half of models are selected and used for the attribution analysis. Observations show that the expansion of the Indian Ocean warm pool has largely contributed to the total IPWP expansion, more strongly in boreal winter and autumn seasons. In contrast, the observed changes in the IPWP intensity was similar across seasons and basins. CMIP5 models including anthropogenic forcings are found to capture the observed IPWP changes, with some overestimation in the Pacific and underestimation in the Indian Ocean. Attribution results show that the anthropogenic signals are detected robustly in the IPWP area and intensity increases for all seasons, indicating that human-induced greenhouse gases was the major cause of the seasonal IPWP growth. Further, the regional impacts of IPWP expansion are analyzed on the associated changes in precipitation. It is found that models with larger expansion in the Indian Ocean than in the Pacific Ocean, similar to the observed, tend to have rainfall increases over the western Indian Ocean and Maritime Continents while models with stronger expansion in the Pacific Ocean exhibit precipitation decreases over East Asia. CMIP6 models will be further analyzed for the IPWP bias and trends in comparison with CMIP5 models.

Keywords: detection and attribution, anthropogenic forcing, precipitation, IndoPacific warm pool

6-P25

Detecting changes in North Atlantic variability under global warming

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Under global warming, mean climate state in the North Atlantic and surrounding continents is expected to change considerably. However, much less is known about changes to spatial-temporal characteristics of its internally-generated variability, modifications in their teleconnections, and significance of those changes. Here, we address these gaps in our understanding using the Max Planck Institute Grand Ensemble (MPI-GE) that consists of 100-member ensembles for several scenario experiments. Using MPI-GE, we can quantify exchanges in internal variability over time by performing robust statistical analysis along the ensemble domain, such as ensemble variance, lead-lag ensemble correlation, EOFs in ensemble space, etc. In addition, a large ensemble enables more robust estimates of spectral characteristics and boosts confidence in spectral peaks. We present an evaluation of variability changes in frequency space for different timescales and provide analyses of evolving relationships between the variability of climate indices (e.g. the North Atlantic Oscillation, NAO) and regional climate variability. We use the historical, RCP8.5 and 1% CO_2-increase-per-year scenario, and find that the North Atlantic undergoes substantial changes in the variability of ocean and air-sea exchange quantities, spatial patterns of dominant SST variability and teleconnections between different climate quantities. For example, AMOC variability decreases with time, as with its 4-year lag correlation with air-sea heat flux over the Labrador Sea. Dominant spatial variability patterns such as the Atlantic Multidecadal Variability looses their present-day characteristics. We also find that while variability of the NAO may not change under global warming, its relationship to regional surface temperature variations over Europe, Africa, and North America is significantly affected, especially on decadal to bi-decadal timescales. These findings have important consequences for the understanding of regional climate change. The modification of spatial relationships under changing external forcing ask for caution when using current, well-established climate indices for assessment of past changes and near-term prediction.

Keywords: internal variability, teleconnection, NAO, EOF, spectral characteristics

6-P26

Assessing co-behaviour of climate processes over southern Africa using CMIP5 Models

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Using CMIP5 models, we assess how co-behaviour of climate processes is captured in models. As established in our earlier research, co-behaviour does play a pivotal role in influencing the regional climate of southern Africa. We use Self-Organizing Map (SOM) technique, which is a type of artificial neural network and has already been introduced to climatology to classify circulation patterns. Then we apply varimax rotated Principal Component Analysis (PCA), a multivariate statistical technique used frequently in statistics and climatology to identify strongly associated patterns across the data while bootstrapping their statistical significance. Through this, 8 possible modes of co-behaviour are identified. We study co-behaviour by developing climate indices from the CMIP5 models for three important processes of the southern African climate; El Ni–o Southern Oscillation (ENSO), Antarctic Oscillation (AAO) and Inter-Tropical Convergence Zone (ITCZ). The combinatory impact of the modes of these processes are then mapped to precipitation and surface temperature patterns across the distinct regions over southern Africa to better understand their influence on surface expressions.

Keywords: co, behaviour, cmip5, ENSO, AAO, self, organising map

Session 6 - Future Projections

6-P27

Detection and attribution of anthropogenic dynamical and thermodynamical contributions in extreme events over East Asia based on CMIP6 DAMIP

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Anthropogenic warming has been shown to drive recent summer extremes in different regions of the world. In the midsummer of 2018, an unprecedentedly long and intense heat wave hit northeast Asia, setting a record for regional temperature. This heat wave was accompanied with an anomalous anticyclone over northeast Asia, induced by the unprecedented northward shift of the western Pacific subtropical high. Using the analogue-based attribution method and reanalysis data, we found that the atmospheric circulation was the main triggering factor of this heat event, which could be responsible for three fourths of the temperature anomaly. Nevertheless, thermodynamical changes of the recent decades made an irreplaceable contribution to the risk ratio of heat events, especially for those more extreme events. With the above results, we will mainly focus on the attribution of anthropogenic dynamical and thermodynamical contributions in extreme events over East Asia based on CMIP6 DAMIP. We will firstly apply the analogue-based methods to multi-model historical and histNAT simulations in DAMIP Tier1 Experiment, to disentangle anthropogenic dynamical and thermodynamical contributions of changes in the likelihood of occurrence of this extreme heat events. We then quantify the relative role of greenhouse-gas and aerosol in anthropogenic dynamical and thermodynamical contributions to extreme heat events based on histGHG and histAER simulations. The above attribution processes may also be conducted for extreme precipitation events in East Asia.

Keywords: attribution, anthropogenic, dynamical and thermodynamical contributions, extreme events, East Asia

Session 6 - Future Projections

6-P28

Tracking the impact of climate model complexity in future climate projections

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Constraining future climate projections requires detailed information on the model response to external forcing which arises from the combination of model resolution (low versus high resolution), tuning/calibration (parameters selection) and complexity (Earth system models vs General Circulation models). Here, we use a large variety of CMIP6 experiments (i.e., DECK, historical, AerChemMIP, RFMIP, C4MIP, ScenarioMIP) to investigate how far the model complexity impact the model response to external forcing and hence future climate projections. To address this question, we use the Atmosphere-Ocean General circulation model and Earth system model developed at CNRM (namely, CNRM-CM6-1 and CNRM-ESM2-1) that offer a fully-traceable numerical framework based on the same suite of physical parameterization and model resolution. We show that increasing model complexity with the inclusion of Earth system components (e.g., aerosols, vegetation or ocean chlorophyll distributions) impact more prominently the response to external forcing than the modeled present-day mean state. Differences in present-day climate between CNRM-CM6-1 and CNRM-ESM2-1 are mainly explained by the land-cover-aerosols interactions where differences in land-cover distributions impact dust aerosols' loads leading in turn to biases in surface radiation and climate. Interactive aerosols play a secondary role in explaining the difference between models' response to external forcing; this latter is driven by Earth system feedbacks such as CO_2-stomata-water feedback which induce a negative climate gain of -0.11, damping global warming by about 0.5¡C.

Keywords: Earth system models, traceability, feedbacks, carbon cycle, aerosols

6-P29

The lifetime of fossil-fuel derived carbon

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Carbon released to the atmosphere by the combustion of fossil fuels is exchanged with the land and ocean compartments, and eventually leaves the active part of the carbon cycle in time frames that span between decades to millennia. Determining the amount of time that it takes to remove fossil-fuel derived carbon can give important insights on the overall time-scales of carbon cycling in the Earth system, and can give valuable information to policy makers to better address climate change mitigation and adaptation. However, the quantification of time scales of carbon cycling from Earth system models is not trivial, and generally requires a special type of simulations in which the models are spun up to equilibrium and an impulsive impulse is injected to the system to observe its dynamics over the long-term. This method relies on assumptions of linearity and steady-state, and cannot be used for transient climate change simulations. In a recent publication (Metzler et al. 2018, PNAS 115: 1150-1155), we developed a new theoretical framework for the estimation of time-scales for nonlinear and out of steady-state conditions. We intend to use this framework to compute the time it takes to remove fossil-fuel derived carbon from the Earth system for different models and transient simulations from the CMIP6 project. In this contribution, we will introduce our computational framework and the data requirements needed for these computations.

Keywords: Transit time, age distribution, dynamical systems, state transition operator

6-P30

Multi-model analysis of the climatic effects of idealized global deforestation experiments

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Past modelling studies showed diverse results regarding the signs and magnitudes of biogeophysical effects of land use and land cover change (LULCC) on climate. The relatively small amplitude of LULCCs in historical reconstructions and future scenarios and the various modelling strategies of their implementation in Earth System Models (ESMs) lead to incoherent signals across models. We will present first results of idealized deforestation experiments designed within the Land Use Model Intercomparison Project (LUMIP) to address the above-mentioned shortcomings of previous studies: Increasing the signal-to-noise ratio and guaranteeing a harmonized implementation across participating ESMs. Therefore, global forest extent is linearly decreased by 20 million km2 over a period of 50 years starting from pre-industrial climate conditions followed by at least 30 years of constant forest cover. While ocean and atmosphere conditions may adapt to the biogeophysical effects of this large-scale deforestation, other forcings such as atmospheric CO2 concentration are kept constant. First analyses of the MPI-ESM reveal statistically significant increases in tropical and decreases in boreal near-surface temperatures (Tas) along with uniform decreases of precipitation in regions of deforestation. Interestingly, these changes in Tas develop from the centre (first 10-30 years) to the margins of deforestation (after 40 years), e.g. in the Amazon region, hinting to the influence of non-local land cover change impacts on climate that add on to the local deforestation signal. We aim to include further analyses from different ESMs (eg IPSL, CESM) as well as advanced detection methods biogeophysical and biogeochemical effects.

Keywords: land cover change, biogeophysical effects, biogeochemical effects, idealized scenario

6-P31

What's up with what's going down? Trends in primary and export production

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A critical part of the ocean's interior carbon cycle is played by the marine biota in the upper ocean. There, carbon is fixed into organic matter by phytoplankton and, while mostly recycled there through the ecosystem, a fraction is exported into the ocean interior via the so-called biological pump, elevating the ocean's natural carbon storage. However, under future change, it is anticipated that marine productivity will generally decline, potentially altering the size of this carbon reservoir, and with implications for deep ecosystems. Here we analyse the distribution of surface productivity and export production, and the relationships that exist between both. This initially focuses on the identifying present-day relationships and their driving factors, particularly across biogeochemical provinces (e.g. upwelling, oligotrophic, shallow water, sea-ice and seasonally-mixed regimes). This is followed by tracking how these relationships evolve into the future under anthropogenic-driven change. In particular, how the biological pump changes; what the mechanisms driving this are; and what the implications for the ocean interior (including O2 and consumer communities). Such changes have potential implications for ecosystem services such as carbon storage and fish production. Analysis will initially make use of a limited set of CMIP6 Historical and ScenarioMIP simulations, with the aim to extend across the CMIP6 ensemble.

Keywords: Marine, biogeochemistry, production, export

7-P01

Multi-Model Climate Vulnerability, Impacts And Adaptation Assessments Of Extreme Ocean Events In Gulf-Of-Guinea Coasts

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The climate change impacts on coastal erosion, flooding, and sea level rises require simulations with validated models and multiple climate projections. The study was conducted in the Gulf of Guinea region of the North Atlantic which stretches from the Senegal in the West to Gabon to the South-Eastern part of Africa. It is home to a large number people and socio-economic activities with over fifty (50) million African population. The multi-model projection methodology is based on a statistical downscaling approach. The study used CMIP6-based climate projections approach over West Africa. Monthly and annual sea surface temperature data were obtained from the National Oceanic and Atmospheric Administration (NOAA), ECMWF Model, NCEP-CFS2 over the Gulf-of-Guinea region between 1972 to 2017 (45 years) were analysed in relation to three El Nino-Southern Oscillation (ENSO) phases. Tools were developed using the ArcGIS 10.5 and Idrisi Terrset software to enable users conduct risk analyses of coastlines by classifying vulnerable areas, and also to produce outputs for further analysis. The recommendations from this research thus enhance the capacity and knowledge of governments and other policy makers with the expectations of climate change and extreme events. A coastal spatial planning designed and then the Integrated Coastal Zone Management framework for West Africa coastal region was developed. The results from this study would help to improve weather prediction thus developing the economy as well as saving lives and properties during climate-related hazards such as erosions, forest fires and floods. The Coupled Model Intercomparison Project 6 (CMIP6) was found to be the ideal framework within which to conduct such a study, due to the strong inter-relation with models being developed regionally and globally. In addition, the CMIP6 provide a mutual dialog between climate modelers and experts/users with the application for a wider (or global) coverage.

Keywords: Coastal, Model, Projections

7-P02

Inter-comparison of the mass budget of Arctic sea ice and snow in CMIP6 models

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Sea ice is a key component of the global climate system and a very visible indicator of climate change. Arctic summer sea ice cover has declined by over 13% per decade since satellite observation began, and there is much interest in how this decline will continue in the future. Global coupled models are arguably the best tool we have for making predictions of Arctic sea ice, but generate a wide spread of projections of 21st century decline. Comparing integrated quantities like ice extent and volume is not sufficient to understand the reasons for differences in model projections. Hence it is becoming increasingly clear that it is necessary to consider, compare and evaluate the underlying processes causing ice growth and decline, and how they are likely to change in a warming world. This inter-comparison will use sea ice budget diagnostics included in the SIMIP data request to evaluate the mass budget of the Arctic sea ice and snow over a defined region of the Arctic Ocean for the period 1960-2100. Area-weighted monthly-mean budget terms representing the dynamic and thermodynamic processes causing ice formation and loss will be calculated by participating modelling centres. We will compare the seasonal cycle of these budget terms, over a defined reference period, to determine how closely models agree on the relative importance of the processes causing growth and decline of sea ice. Where possible, budget components will be compared with observations. Then we will compare the evolution of these terms as the ice declines during the 21st century, to establish the dominant changes in the budget, and to what extent the changes are robust across models. So far, 10 modelling centres have expressed interest in joining this inter-comparison. Here we present early results from those modelling centres who have completed the appropriate model integrations.

Keywords: Arctic sea ice processes intercomparison

7-P03

Impacts of Climate Change on Agricultural Systems

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Climate change is expected to impact considerably on agricultural production, activity of great importance in the Argentinean economy. In this context, there has been an increasing interest on how climate change could affect areas of agricultural production and yield crops. In this context, perennial crop production, such as viticultural production, is considered highly vulnerable to climate change. Recently, Cabré and Nunez (2018) have assessed the impacts of climate change on viticulture using climatic projections from the IPSL-CM5A-MR model for two temporal horizons (2015-2039, 2075-2099) under two emission scenarios (RCP4.5, RCP8.5) [submitted to Climatic Change]. This model has been chosen for being the best for the study region among 24 climate models from CMIP5 Project (3CN, 2014). The analysis was carried out taking into account which could be possible geographical shifts of Argentinean winegrowing regions Results showed that a significant southwestward displacement of winegrowing regions is projected to occur, mainly for 2075-2099 under RCP8.5 scenario. This southwestward displacement may face both opportunities and/or challenges on Argentinean viticulture, because some winemaking regions could be favored; while other winemaking regions could be disadvantaged, especially by 2075-2099 under RCP8.5. These outcomeswere thought in terms of changes in vineyards location, varieties selection, quality and quantity of grapevines andcould be very useful for the impact community related to the wine sector. In this context, similar studies of impacts of climate change on viticulture or on any agricultural system could be of valuable importance for our country. Accordingly, the results of CMIP6 models could be used for going on with future works, validating the CMIP6 Project models for different regions in Argentina, choosing the best results for present climate and using them for future climate with the new socioeconomic scenarios in order to study the possible impacts of future climate conditions on agricultural systems.

Keywords: Climate Change Impacts, Argentina, IPSL CM5A MR model, emission scenarios RCP4.5 RCP8.5

7-P04

Prediction skill assessment of large-scale variability influence in summer southeastern South America rainfall in multi-model CMIP decadal predictions

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The leading co-variability mode (SVD1) between summer southeastern South America (SESA) rainfall and tropical sea surface temperatures (SST) anomalies over the 1962-2013 period exhibits significant variability ranging from the interannual scale to long-term trends. It shows a clear global warming signal, mainly related to warming in the Pacific and Indian Oceans, in association with a rainfall increase in SESA. After detrending the series, the spatial distribution of both SST and SESA precipitation anomalies associated with the first mode resembles that typically related with El Ni–o-Southern Oscillation (ENSO). The objective of this work is to to assess the prediction skill of SVD1 in decadal hindcast simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5) and CMIP6 (if available) of the World Climate Research Programme, using different methodologies to deal with the multi-member/model ensemble. Three methodologies to perform SVD1 will be presented that made use of multi-member/model ensemble information for prediction skill: i) SVD1 computed for the multi-model mean anomalies; ii) SVD1 calculated after concatenating all ensemble members; iii) SVD1 computed projecting all ensemble members in the spatial modes obtained using the multi-model mean anomalies in methodology i). Methodologies ii) and iii) allow to obtain probabilistic prediction information, so that internal variability uncertainties could be also assessed. The three methodologies were applied to both detrended and undetrended anomalies. It was found that initialized CMIP5 decadal hindcasts are able to represent SVD1 spatial structures with and without considering trends for the different methodologies, improving results from analogous uninitialized simulations. Although detrended SVD1 activity shows skill in the first two prediction years, differences between methodologies will be discussed. These facts represent a promising result for the predictions of rainfall in the SESA region on interannual and longer time scales.

Keywords: South America, Ensemble, Decadal prediction, Covariability

7-P05

Projected trends of heavy rainfall events from CMIP5 models over Central Africa

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In this study, the projections of daily rainfall from an ensemble mean of 20 global climate models (GCMs) are used to examine projected trends in heavy rainfall distribution over Central Africa, under the representative concentration pathway 8.5. For this purpose, two analyses periods of 40-years have been selected (2006-2045 and 2056-2095) to compute trends in the 90th and 99th percentiles of the daily rainfall distributions. We found that large increase trend is mostly found in the 99th percentile of rainfall events, over southern Chad, northern Cameroon, northern Zambia, and in the Great Lakes Area. This can be attributed to the increase of moisture convergence intensified by the presence of the Congo Basin rainforest. It is also shown that the largest number of GCMs with a trend of the same sign as the average trend is observed over the above regions. It is thus clear that the projected increase trends in heavy rainfall events may further worse floods which are real problems in the Central African's countries. Therefore, strong subregional policies are needed to help design effective adaptation and mitigation measures for the region's countries.

Keywords: Central Africa, CMIP5, heavy rainfall, future change, trends

Session 7 - Regional and Impacts

7-P06

(will not be presented)

Extreme events in the Arctic and their association to low-frequency climate variabilities and sea ice cover changes

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Arctic climate has experienced a rapid warming in past decades, associated with an extensive loss in sea ice cover. Those changes have been associated with unusual weather events over the Arctic and mid-latitude climates, which have been found to negatively impact ecosystems and human activities in boreal regions. Yet links between the variability in those extreme weather events (droughts/cold events/heatwaves/extreme rain or snowfall that may account for anomalies in both duration and intensity) and changes in the seasonal-mean climate remain poorly understood. In particular, it is unclear whether a drastic reduction in sea ice cover--as observed in recent years-- can have a substantial influence on the occurrence of extreme weather events at mid- and high-latitudes. Here, I describe extreme weather events and their spatio-temporal variations in mid- and high-latitudes regions, in a large ensemble of fixed present-day condition EC-Earth simulations. First, I document and explain low-frequency variations in extreme weather events at mid and high-latitudes, and then seek to relate them to interannual or decadal modes of Arctic climate variability. Associations between extreme events and sea ice cover anomalies--occurring concurrently or prior to those extreme event--are quantified to assess seasonal predictability in both present-day and future climate conditions. To understand how extreme events respond to decadal changes in sea ice conditions, I then analyze Arctic climate variability in long-run Pre-CMIP6 (H2020 PRIMAVERA) simulations in which sea ice cover evolves freely, and compare them to a large set of PAMIP simulations in which sea ice cover is prescribed and held invariant across years. Finally, model biases in extreme weather events are assessed by comparing Pre-CMIP6 and PAMIP simulations to observations of the past decades.

Keywords: Arctic climate variability, extreme weather events, sea ice cover

7-P07

Fidelity of the CAS FGOALS-f3 in representation of summer rainfall climatology and extreme precipitation over Tibetan Plateau

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The Tibetan Plateau (TP) is known as the third pole of the world. And the complex land-air interactions over it play essential roles in the formation and variability of nearby general circulation patterns, thus affect the regional and even global weather and climate, especially the East Asian Monsoon. However, lots of the climate models show an insufficient performance to reproduce the land-air interactions over the TP. One of the possible reasons is the coarse model resolutions. Using a 9-year simulation, this study evaluates the performance of extreme precipitation over Tibetan Plateau in the CAS climate system model FGOALS-f3 with two different horizontal resolutions (100km and 25km). FGOALS-f3-L (100km resolution) participates in DECK experiments for CMIP6, while FGOALS-f3-H (25km resolution) participates in HighResMIP for CMIP6. The evaluation is about the possible benefits of the increased horizontal resolution on precipitation over the Tibetan Plateau and surrounding areas, particularly focusing on the summer climatology and extreme precipitation. The preliminary results show that a higher resolution is helpful to reproduce the bias of the precipitation gradient over TP. As identified in TRMM satellite products, FGOALS-f3-H shows the more detailed distribution of the precipitation in this region, with a sharp northwestward decreasing gradient of precipitation that starts southeast slope of TP, while FGOALS-f3-L with 100km resolution failed to reproduce the characteristics. Both FGOALS-f3-H and FGOALS-f3-L is able to reproduce the frequency of occurrence for extreme precipitation, although models slightly overestimate the heavy precipitation events. For example, both of the FGOALS-f3-H and FGOALS-f3-L is able to capture extreme precipitation up-to 200 mm/day. Finally, the roles of model physics and air-sea interaction are discussed to reduce the bias of precipitation on the south slope of TP.

Keywords: summer rainfall climatology, Tibetan Plateau, extreme precipitation, f3, CAS FGOALS

7-P08

Contribution of land use and land cover alterations to changes in regional surface energy balance in CMIP6 Earth System models.

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Land use and land cover change (LULCC) has been long recognized as one of the important factors affecting near-surface climate. Biophysical effects of LULCC has been demonstrated to play an important role in water and energy exchanges on regional scales. The effects of LULCC can play even stronger role on local scales. For example, shorter vegetation on croplands or pastures will interact with the atmosphere differently than in a neighboring forest, even if the near-surface atmospheric conditions are the same or similar. Local land surface properties, such as albedo, roughness length, leaf area index, and soil and canopy water availability are known to induce differences in radiative and turbulent fluxes and in near-surface climate. Previously, the analysis of local land-atmosphere interactions was hindered by the unavailability of sub-grid scale information in climate and Earth System Models' output. Land Use Model Intercomparison Project (LUMIP) provides sub-grid land surface climate data by land-use type: cropland, pasture, urban, and secondary plus natural lands. Here we present multi-model analysis of CMIP6 DECK, historical, and LUMIP future experiments to explore local-scale effects of LULCC on the near-surface climate, including local climate contrast [Malyshev et al. 2015]. We compare and contrast energy balances in neighboring land-use tiles and analyze physical mechanisms that induce the differences. We compare the local effects of LULCC from model simulations with the available observational data.

Keywords: energy balance, land surface, land use, climate change, surface fluxes

7-P09

Evaluation of the CNRM-CM6 Global Climate Model simulation over West Africa within CMIP6

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We assess a set of historical simulations of the CNRM-CM6 Global Climate Model (GCM) which has been used in CMIP6. Extreme precipitation and temperature are analysed in order to investigate the ability of this global climate model to faithfully represent the present day climate over Sahel, Gulf of Guinea, and West Africa. Such assessment is carried out through extreme climate indices in comparison with Global Precipitation Climatology Centre for precipitation (1988-2005) and with Climatic Research Unit for temperature (1981-2010). We found that the CNRM-CM6 model reproduces well the main patterns of consecutive wet days, consecutive dry days, very and extremely wet days, and rainfall intensity during the summer season over West Africa. However, the model tends to overestimate the magnitude of theses climate indices, except dry days, over the Sahel. In addition, heavy rainfall and rainfall intensity are slightly underestimate around coastal regions. The annual cycle of over the Sahel, shows that the model captures well the temporal signal of these extremes eventhough it exhibits an overestimation mainly from August to November and an undersestimation from April to July. In the Gulf of Guinea regions, CNRM-CM6 overestimates wet days, rainfall intensity and the total rainfall during July-Agust-Septembre. As for temperature, the model generally underestimates over West Africa; the cold biases are more pronounced in the Sahel. However, the model presents the highest variability with substantial warm bias in the sahelian region. Furthermore, the seasonal cycle of mean temperature and the diurnal temperature range over both regions shows an underestimation. This evaluation shows that the CNRM-CM6 is able to represent the spatial and temporal variability of the present day climate over West Africa eventhough some biases exist. For climate change impact studies, bias correction and statistical downscaling could be applied to brige the gap between the GCM and impact models.

Keywords: CMIP6, CNRM, CM6 Global Climate Model, precipitaion, temperature, West Africa

7-P10

Rainfall in MetUM over Central Africa: Process-based Evaluation

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Climate models are tool used for investigating the response of the climate system to various forcings and for making projections of future climate. Unfortunately, due to little attention that has been devoted to Central Africa, only few mechanisms governing climate in that region are known. This generally lead to misrepresentation of climate parameters in models over the region. The present study shows that, latest versions of the Met Office Unified Model (MetUM), a modeling system developed and used at the Met Office, depict wet (dry) bias over the Congo Basin (along the Atlantic coast south) in September-November season. Both local and remote drivers of vertical motion are used here to explain those biases. Results show that, dry bias over the coastal area is due to an overestimation of moisture divergence over that area. Furthermore, convection motion is less deep, thus favoring an enlargement into the land of ocean subsidence leading to dry conditions. Over Congo Basin, wet bias is due to an underestimation of the AEJ-S intensity, witch is favorable to more convection motion, then more precipitation. Moreover, in the MetUM, the Congo Basin Walker circulation shift a little eastward in SON season and intensify precipitation over the region. Precipitation over Congo Basin is also linked to Indian Ocean dipole mode. It appear that, in MetUM, the Indian Ocean dipole mode is not well represented, leading to a weakening of the downward branche of Indian east-west overturning circulation. Wind over the Indian Ocean is then moving westward, carring with him moisture which contibute to the overestimation of rainfall over the Congo basin.

Keywords: Rainfall Bias, MetUM, Vertical motion, Congo Basin Walker circulation, Indian Ocean dipole

7-P11

How dynamical downscaling can advance our understanding of large- and local-scale drivers of regional climate change

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In recent years more and more regional climate model (RCM) simulations have been generated within the Coordinated Regional climate Downscaling Experiment (CORDEX) framework. The first analysis of the CORDEX ensembles shows that RCM simulations and their respective driving global climate model (GCM) simulations may project contradicting climate change signals on regional scales, for example in precipitation. Moreover, it was found that different RCMs downscaling the same GCM may also produce contradicting future projections in precipitation. From one side, one can argue that dynamical downscaling increases the range of uncertainties in future climate projections. However, an alternative interpretation is that such contradictions in future projections provide a useful insight into uncertainties in regional climate change. It stands clear that local-scale processes defined by RCM parameterisations can be much more important than large-scale drivers dictated by the driving GCMs. We use a number of 'contradicting examples' based on GCM and Euro- and Africa-CORDEX RCM simulations to identify local-scale processes responsible for the contradictions. We also discuss how such 'contradicting examples' can help in improvement of both global and regional climate models.

Keywords: downscaling climate uncertainties regional CORDEX

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7-P12

Challenges for Brazilian Earth System Model (BESM)

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In the context of global climate change as evidenced by the reports IPCCs numerical models are fundamental instruments to detect and predict climate anomalies. Computational tools based on numerical modeling of time series of environmental data are developed to estimate the frequency of extreme climate events. The National Institute for space research of Brazil (INPE) developed the Brazilian model of the Earth system (BESM) to provide information about changes in global climatic processes and particular phenomena in the southern hemisphere. The BESM model is able to predict the frequency and magnitude of seasonal climate events on a time scale that can reach 100 years. The forecasts generated are basis for guidelines for the Territorial Planning and creation of policie for mitigation and adaptation strategies to climate change and extreme events. The BESM program inserted Brazil in the frame of the program CMIP5, based in comparison between measurements the models. Among the current challenges in the development of the model BESM's task of creating simulations to verify which are the extremes that can transform classic processes such as anomalies of sea surface temperatures in the South Atlantic and your possible influence on rainfall, thermohaline circulation, heat transport between the oceans and atmosphere and air-sea CO_2 flux, ocean carbon flux and sea ice dynamics. Current BESM version need incorporate biogeochemical models to find answers about the behaviour of ecosystems to face climate change. The BESM program contribute to develop questions about what are the effects of processes such as the increase of the temperature in the atmosphere and in the ocean and your relationship with other components of the Earth system.

Keywords: computacional tools, global climate change, numerical modelling

7-P13

Process-based model evaluation and projections over southern Africa from regional and global climate models

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Decision-scale relevant climate information on climate change is needed to inform policy and decision making but often involves high uncertainty due to internal variability, emissions scenarios and differing model representations of climate processes at different spatial scales. In order to increase confidence in future climate changes it is valuable to disaggregate the inter-model differences into regional circulation scales and local process scales. This is particularly valuable when interrogating dynamically downscaled ensembles such as Coordinated Regional Climate Downscaling Experiment (CORDEX) where differences between changes projected by the general circulation model (GCM) and the regional climate model (RCM) are frequently observed. This study explores a methodology to investigate projected change as a function of changes in frequency of synoptic circulation with the aid of Self-Organizing Maps (SOM). The approach examines how dynamically downscaled future climate from two RCMs of the CORDEX, driven with four GCMs, can give rise to surface climate changes that differ from those of the driving GCMs. The study focuses on changes in precipitation and the circulation processes driving the projected changes from the regional climate simulations. Results shows that atmospheric circulation is relatively well simulated in both RCMs and GCMs, i.e, the RCM and GCM are in phase regarding to circulation patterns. And all of them project similar changes in atmospheric states for this region. This implies that much of the difference in the projected rainfall could rather be due to the representation of local subgrid-scale parameterized processes, such as convection and/or the representation of coastlines and topography. This suggests that over southern Africa the climate change signal could be a local response dynamic rather than circulation dynamic.

Keywords: CORDEX, CMIP5, precipitation changes, SOM, southern Africa

7-P14

Analysis of future changes in extreme climate indices in Indonesia region using AIMS

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Climate change has brought great environmental impacts that have caused economic losses due to extreme climate phenomena such as floods, droughts and changes in rain and temperature characteristics in Indonesia. Information on projections of changes in rainfall characteristics and temperature trends is challenging and it is very important to make adaptation, mitigation and operational planning for various impacted sectors. In this study we use observational data from 50 observation weather stations in Indonesia for 30 years from 1981 to 2010 which have been quality controlled. Raw model data from 27 historical GCM (Global Circulation Model) are analyzed based on spatial pattern similarity and temporal patterns with patterns of station's observation. Spatial reproducibility is evaluated using variogram analysis, and while the uncertainty ranges is obtained by increasing the number of GCMs. Future changes in rain characteristics and temperature were examined use Bias-Correction of SQM (Simple Quantile Mapping) of the CMIP5 (Coupled Model Intercomparison Project Phase 5) for (Representative Concentration Pathway) RCP 4.5 and RCP 8.5 Scenarios. Future changes investigated in terms of extreme climate indicators based on the ETCCDI (Expert Team on Climate Change Detection and Indices), including annual total precipitation, consecutive dry days, consecutive wet days, maximum monthly maximum value of daily temperature and monthly minimum value of daily minimum temperature, for all regions in Indonesia using the MME (Multi-Model Ensemble). The outputs of 27 GCMs were statistically derived using AIMS (APEC Climate Center Integrated Modeling Solution), and we analyze the probability values of extreme climate indicators for the assessment of climate change impacts in the periods 2011-2040, 2041-2070 and 2071-2100.

Keywords: future changes, uncertainty, extreme climate indices, reproducibility, AIMS

7-P15

Intercomparison of Sea-Ice Observational and CMIP6 multi-model datasets

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In this study we investigate possible uncertainties (and their cause) and differences in various sea-ice observational and CMIP6 historical datasets, including sea-ice concentration, area and extent. We use several observational datasets (namely, National Snow & Ice Data Centre - NSIDC, Ocean and Sea Ice Satellite Application Facility - OSISAF, European Space Agency Climate Change Initiative - ESACCI, Integrated Climate Data Center - ICDC, National Oceanic and atmospheric Administration - NOAA and Met Office Hadley Centre - UKMO) and compare them to CMIP6 multi-model historical datasets (as many as possible subject to availability) from model output. The focus of our analysis is on both the Northern and Southern Hemispheres. The products differ by the retrieval methods that were employed as well as by their horizontal resolution (varying from about 0.1_ to 0.25_). We illustrate differences and uncertainties over the historical period by applying several univariate (climatologies, trends, standard deviations) and multivariate (per-pair root mean square error - RMSE, principal component analysis ? PCA, Singular value decomposition ? SVD and dendrograms amongst others) statistical indices. This approach allows us to i) evaluate the ability of each of the datasets to simulate the observed climatology in regions of focus, ii) analyze similarities and contradictions in historical dataset between multiple observational datasets and model output and iii) estimate the level of observational uncertainty and gauge its impact in climate model evaluation studies.

Keywords: Intercomparison, Ice area, Sea, Ice concentration, Sea, Observations, CMIP6

7-P16

Evaluation and projected changes in daily rainfall characteristics over Central Africa based on a multi-model ensemble mean of CMIP5 simulations

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This study uses daily rainfall data from global climate models simulations, participating in the phase 5 of the Coupled Model Intercomparison Project (CMIP5) and eight rainfall indices defined by the Expert Team on Climate Change Detection and Indices (ETCCDI), to investigate the changes in extreme weather conditions over Central Africa (CA) under the representative concentration pathway 8.5. The performance of the multi-model ensemble (MME) mean which in fact refers to the best performing models selected through the Taylor diagram analysis was evaluated by comparing with two gridded observation datasets during the historical period (1998-2005). Results show that although some uncertainties may exist between the gridded observation datasets, MME consistently outperform individual models and reasonably reproduced the observed pattern of daily rainfall indices over the region. The assessment of the climate change signal in those indices was done for the mid and late twenty-first century (2026-2056 and 2066-2095 respectively), relative to the baseline historical time period (1976-2005). We found a significant increase in PRCPTOT over southern (northern) CA from December to February (from September to November). This is mainly due to the increase of high intense rainfall events rather than their frequency. The results also reveal that the increase in PRCPTOT was coupled with increase in RX5DAY), R95, and in R95PTOT, with more robust patterns of change at the late twenty-first century. The increase in extreme rainfall events is likely to increase flood risks. Also, the decrease in CWD and PRCPTOT coupled with the increase in CDD observed could worsen drought risk and significantly disrupt priority socio-economic sectors for development. For that, decision-makers are invited to seriously consider adaptation and mitigation measures, in order to limit the risks of natural disasters that CA countries may suffer in the future.

Keywords: Central Africa, Global climate model, CMIP5, Extreme rainfall events, Future change

7-P17

How different Arctic do we see from CMIP6 models?

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Arctic has been changing fast with its temperature increase at twice the rate of the northern hemisphere and global mean. Rapid decline of sea-ice cover (and sea-ice thickness) is another symbolic change that has been observed in the past two decades. Both CMIP3 and CMIP5 model generally underestimated the rapid decline of Arctic sea-ice extent, yet a dozen of them do simulate the climatological means and magnitude of seasonal cycle in good agreement with observations. In this study we will investigate all available CMIP6 models on their performance of sea-ice simulations (mainly on sea-ice cover) in their historical runs and pre-industrial control runs to address the following questions: 1) do CMIP6 perform better than CMIP3 and CMIP5 when compared with observations in their historical runs? 2) How much of the model uncertainties are contributed by the internal variability which will be determined from the pre-industrial control simulations. We will then investigate the projections of the future sea-ice cover from these models, and to find out how different of current CMIP6 model projections comparing with previous CMIPs. This study will try to identify the origins and consequences of systematic model biases in the sea ice simulations.

Keywords: projections, sea ice, Arctic, mode uncertainties

7-P18

Substantial increase in the joint occurrence and human exposure of heat and haze hazards over South Asia in the mid-21st century

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Greenhouse gas emissions, if not abated aggressively, will lead to large increases in frequency and intensity of heat extremes. Another major health hazard is degraded air quality, leading to millions of premature deaths yearly (Lelieveld et al., 2015; WHO, 2017). An integrated assessment of human exposure to the joint occurrence of heat and haze extremes and the future changes has been missing (except for few studies at local scales; Doherty et al., 2009; Jackson et al., 2010). Based on a high-resolution decadal-long model simulation using a state-of-the-science regional chemistry-climate model that is bias-corrected against meteorological reanalysis and evaluated thoroughly, here we show that: when daily average wet-bulb temperature of 25°C is taken as the 'deadly' threshold (Mora et al., 2017), heat extreme frequency averaged over South Asia increases from 48±4 days/year during Decade 2000 (1997-2004) to 76±3 days/year in Decade 2050 (2046-2054) under Representative Concentration Pathway 8.5 (RCP8.5) scenario, along with a 83% increase in the mean duration of heat events. The human exposure to hazy weather over South Asia is also projected to increase substantially under RCP8.5, in contrast to projected air quality improvement globally. With daily averaged PM2.5 surface concentration of 60 ?g/m3 defined as the threshold for such "unhealthy" extremes (CPCB, 2009), the area-weighted average of haze extremes would occur 132±8 days/year in Decade 2050 under RCP8.5, which is 64-76% higher than Decade 2000. Even more concerning is the model projection of the joint occurrence of heat and hazy hazard (HHH). These rare events would have large increases in the future with a 160% increase in frequency and a 450% increase in duration. A holistic view of health impact of heat and haze hazard (HHH) is thus urgently needed.

Keywords: impact, model, scenarios

7-P19

Fidelity of the Observational/Reanalysis Datasets and Global Climate Models in Representation of Extreme Precipitation in East China

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Realistic reproduction of historical extreme precipitation has been challenging for both reanalysis and global climate model (GCM) simulations. This work assessed the fidelities of the combined gridded observational datasets, reanalysis datasets, and GCMs [CMIP5 and the Chinese Academy of Sciences Flexible Global Ocean"Atmospheric Land System Model" Finite-Volume Atmospheric Model, version 2 (FGOALS-f2)] in representing extreme precipitation over East China. The assessment used 552 stations' rain gauge data as ground truth and focused on the probability distribution function of daily precipitation and spatial structure of extreme precipitation days. The TRMM observation displays similar rainfall intensity frequency distributions as the stations. However, three combined gridded observa- tional datasets, four reanalysis datasets, and most of the CMIP5 models cannot capture extreme precipitation ex- ceeding 150 mm day21, and all underestimate extreme precipitation frequency. The observed spatial distribution of extreme precipitation exhibits two maximum centers, located over the lower-middle reach of Yangtze River basin and the deep South China region, respectively. Combined gridded observations and JRA-55 capture these two centers, but ERA-Interim, MERRA, and CFSR and almost all CMIP5 models fail to capture them. The percentage of extreme rainfall in the total rainfall amount is generally underestimated by 25% 75% in all CMIP5 models. Higher-resolution models tend to have better performance, and physical parameterization may be crucial for simulating correct extreme precipitation. The performances are significantly improved in the newly released FGOALS-f2 as a result of increased resolution and a more realistic simulation of moisture and heating profiles. This work pinpoints the common biases in the combined gridded observational datasets and reanalysis datasets and helps to improve models' simulation of extreme precipitation, which is critically important for reliable projection of future changes in extreme precipitation.

Keywords: Extreme precipitation, High resolution, CMIP5, CMIP6, FGOALS f3 L

7-P20

Are Climate models reliable in projecting the impacts of half-degree warming increment on heat extremes over China?

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Projecting the climate impacts of half-degree warming increment has been on the highest level on the post-Paris Agreement science agenda, but climate model projection generally has uncertainties and its reliability needs to be assessed. As the real world has already witnessed a 0.5¡C global warming increment, we have compared the impacts of the past half-degree warming on the heat extremes in China derived from observational records to the CESM historical simulation and CESM low warming experiments future projection. We find that under the perspective of spatially aggregate, the heat extremes change over China under 0.5¡C warming increment are detectable in observation records. The changes are generally reasonably captured in the CESM historical simulation but with slightly weaker amplitude. The changes of intensity indices in observational records are better analogues to the simulation than the frequency and duration indices. The daytime extremes change in observational records can serve as conservative estimations for future projection, while the nighttime extreme indices show comparable or slightly weaker changes in the future than the observations. We plan to apply this metric on the GMMIP experiments by comparing the heavy precipitation changes under half-degree GMST increment over the global monsoon regions in the HadEX2 and GHCNDEX observational datasets to the GMMIP model simulations and then evaluate the future projections. We also plan to use this metric on the CORDEX to evaluate the model ability in simulating the half-degree GMST increment impacts on regional climate extremes including heat extremes and heavy precipitation, and then assess the reliability of future projection on a spatial aggregate perspective. We believe that close resemblance between the observational records and the historical simulation can add confidence to future projection for climate change adaption and risk managing.

Keywords: regional climate extremes, half degree warming, CORDEX, GMMIP

7-P21

Evaluation of CMIP6 models in the context of Precipitation over the Tibetan Plateau

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The Tibetan Plateau (TP hereinafter) have showed its importance to the Asian hydrologic cycle, as well as global atmospheric circulation. But as a result of the steep and complex terrain, the observation on TP was insufficient and data from reanalysis and model simulations became preference. We compared multiple satellite and reanalysis data in the context of total precipitable water on TP. And based on it, the spacial uneven trend of precipitation on TP, characterized by the drying southeastern plateau and the wetting northwestern plateau, was further analyzed. Applying moisture budget and vertical velocity diagnostic formula, we found that the drying southeastern TP was caused by abnormal cold advection and the wetting northeastern TP was a result of diabatic feedback. Previous studies have shown that most models have overestimated the precipitation on TP. On the basis of the above results, we will focus on the simulation ability of CMIP6 models in context of TP precipitation using the historical simulation experiments. We will evaluate and group the CMIP6 models according to their simulation ability of TP precipitation. Then the reason for difference will be analyzed utilizing climate dynamics diagnostic methods which was mentioned above. As a result, we will firstly provide some information about whether the ability of CMIP6 models have been improved in context of precipitation simulation on complex terrain areas, then some origins and consequences of systematic model biases will also be found, in order to help model developers to improve the models.

Keywords: model evaluation, precipitation, Tibetan plateau, topographic precipitation, model bias