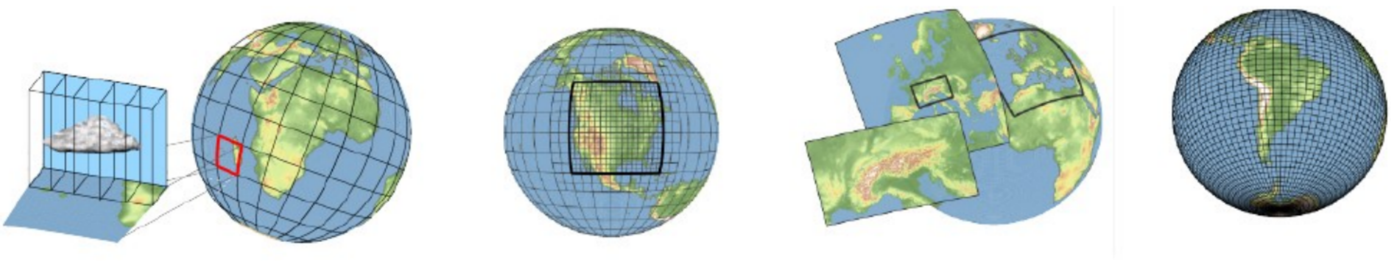
GEWEX Convection-Permitting Climate Modeling Workshop

6th-8th September, 2016, Boulder, CO,USA

Book of Abstracts



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The **GEWEX Convection-Permitting Climate Modeling Workshop** brings together the international research community that works in the field of high-resolution climate information. The aim is to address scientific and technical challenges related to convection-permitting climate modeling (horizontal grid spacing $\leq$4 km). These challenges include the model setup, observational datasets, evaluation techniques, computational resources, model intercomparisons, and the use of convection-permitting simulations in impact research. The 3-day meeting's aim is to foster collaborations and synergies to work on this challenging topic as a community.

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II

Abstracts

1. Model Evaluation

1.1 Oral

1.1.1 Schär (Invited) Challenges in Convection-Resolving Climate Modeling

Christoph Schär1, David Leutwyler1, Nikolina Ban1, Oliver Fuhrer2, Michael Keller1,3, Torsten Hoefler4, Xavier Lapillonne2,3, Daniel Lüthi1, Linda Schlemmer1, Thomas Schulthess5, Heini Wernli1
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Moist convection is a fundamental process in our climate system, but is usually parameterized in climate models. Recent progress with convection-resolving climate simulations at the kilometer-scale resolution provides exciting prospects but also significant challenges. In this presentation a review will be provided with a focus on extratropial climates. The presentation will address key challenges in the areas of model physics (cloud microphysics, soil hydrology, shallow convection), and model validation (using surface and satellite data). It is argued that the improved representation of the diurnal cycle and precipitation process should enable an improved representation of the continental-scale water cycle and the associated climate feedbacks. However, much work lies ahead before such an improvement can be achieved. While studies find added value in convection-resolving climate modeling, validation at high temporal and spatial resolution over climatologically relevant time periods is hampered by the limited availability of adequate observational data. The presentation will be illustrated using results from a decade-long climate simulation covering most of Europe on a large mesh at 2.2 km horizontal resolution (1536x1536x60 grid points). The simulation exploits heterogeneous many-core hardware architectures with GPUs. To efficiently use such computers, the model code underwent significant development, including a rewrite of the dynamical core in C++. With this work, substantial speedup of the code was achieved, enabling climate simulations on large continental-scale domains. Results demonstrate

realistic mesoscale processes embedded into the synoptic scale, such as line convection along cold frontal systems, or the triggering of moist convection by propagating cold-air pools (Leutwyler et al., submitted to GMD, http://dx.doi.org/10.5194/gmd-2016-119; see also project crCLIM, http://www.c2sm.ethz.ch/research/crCLIM.html). Further exploitation of the convection-resolving approach requires major changes in the workflow of extensive climate simulations. It is suggested that the largest supercomputers would in principle be able to support – already now – global convection-resolving climate simulations over decadal periods, provided respectively refactored codes become available, and provided the output challenge can be solved. In particular, while in the past climate modeling was primarily limited by the available compute power, it is about to become limited by data volume and output bandwidth. It is argued that further development and exploitation of high-resolution climate modeling requires an online analysis facility in combination with rerunning model simulations. This will necessitate an interdisciplinary approach with the computer sciences.

1.1.2 Prein: Simulating convective storms: An object based evaluation of a continental-scale convection-permitting climate simulation

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Convective storms are causing extremes such as flooding, landslides, and wind gusts and are related to the development of tornadoes and hail. Convective storms are also the dominant source of summer precipitation in most regions of the Contiguous United States. So far little is known about how convective storms might change due to global warming. This is mainly because of the coarse grid spacing of state-of-the-art climate models that are not able to resolve deep convection explicitly. Instead, coarse resolution models rely on convective parameterization schemes that are a major source of errors and uncertainties in climate change projections. Convection-permitting climate simulations, with grid-spacings smaller than 4km, show significant improvements in the simulation of convective storms by representing deep convection explicitly. Here we use a pair of 13-year long current and future convection-permitting climate simulations that cover large parts of North America. We use the Method for Object-Based Diagnostic Evaluation (MODE) that incorporates the time dimension (MODE-TD) to analyze the model performance in reproducing storm features in the current climate and to investigate their potential future changes. We show that the model is able to accurately reproduce the main characteristics of convective storms in the present climate.

1.1.3 Trier: Influences of PBL Parameterizations on Warm-Season Convection-Allowing Simulations

Stanley Trier
National Center for Atmospheric Research (NCAR), Boulder, CO, USA

Recent convection-allowing climate simulations have indicated significant biases in near-surface temperature and precipitation over continental midlatitude regions during the northern hemisphere warm season (e.g., May-August). Though convection-allowing climate simulations have horizontal grid spacings that are small enough to obviate the need for cumulus parameterizations, unlike LES models the resolution is still coarse enough to require planetary boundary layer (PBL) parameterizations. Such parameterizations may be divided into two main classes that are referred to as local and non-local schemes. In local schemes, the vertical mixing occurs between adjacent model vertical grid points, whereas in non-local schemes it can occur through the depth of the entire PBL. Recent studies using convection-resolving models have indicated significant sensitivity of daytime PBL structure (e.g., depth, mean potential temperature and mixing ratio) to different types of PBL schemes in shorter duration NWP forecasts (e.g., Trier et al. 2011; Coniglio et al. 2013; Clark et al. 2015). In the current study we examine the influence of PBL schemes on 4-month seasonal predictions of precipitation and near-surface temperature during the continental US warm season, and discuss their possible role in the biases of these quantities in recent convection-allowing climate simulations.

References:

Trier et al. (2011; Wea. Forecasting, 26, 3-25)
Coniglio et al. (2013; Wea. Forecasting, 28, 842-862)
Clark et al. (2015; Wea. Forecasting, 30, 613-638)

1.1.4 Chaboureau: Object approaches for exploring high-resolution simulations

Jean-Pierre Chaboureau
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Cloud-resolving and large-eddy simulations have been long used for process-oriented case studies because of their ability in resolving the details of complex atmospheric circulation. This allows one to focus on particular objects, such as thunderstorms. Such gain in resolving fine- scale processes was also found when running convective-permitting models over longer time periods. The added value of such simulations was demonstrated using usual climate metrics such as the diurnal cycle of precipitation or the occurrence of extreme events, for example. Such high-resolution simulations open up new possibilities in exploring meteorological objects over a much larger sampling. Examples will be given from a few current on-going studies. The identification of the tallest updrafts in a Giga-LES of Hector the convector demonstrates the very low dilution experienced by near-surface air parcel reaching the stratosphere. The attribution of dust emission to cold pools shows the added value of convective permitting dust forecasts in the framework of the Fennec dust forecast intercomparison. A tracking method developed for satellite observation was applied to synthetic satellite observations derived from simulations over Brazil and Africa. The convection-permitting simulations show a remarkable realism of the deep convection activity. They however predicted too numerous cloud systems and missed some convective activity during night. Challenges in this object approach and issues on cloud- resolving modeling will be discussed.

This work was partly supported by the DACCIWA project.

1.1.5 Cook: Improved Simulation of the Diurnal Cycle of Precipitation with Convection-Permitting Climate Modeling

Kerry H. Cook, Gang Zhang, Edward K. Vizy, and Weiran Liu
Department of Geological Sciences, University of Texas at Austin

Regional model simulations are used to evaluate the role of model resolution in simulating the diurnal cycle of precipitation over sub-Saharan Africa and improve our physical understanding. Using 3-km resolution and explicitly-permitted convection greatly improves the representation of the diurnal cycle in comparison with simulations using parameterized convection. Afternoon rainfall peaks are either associated with topography or they are located in regions undisturbed by nocturnal systems. Nocturnal rainfall peaks are generally associated with the westward propagation of rainfall systems.

To a great extent, the diurnal cycle of MCSs controls the diurnal cycle of rainfall in this region. Simulations with nested grids at 27-km, 9-km, and 3-km are used to evaluate the added value of convection-permitting simulations. Synoptic-scale analysis provides specific examples of the diurnal processes, with enhanced low-level convergence and increased helicity associated with a southward shift of the dry line in the early afternoon.

Problems remain in the simulation of the diurnal cycle of rainfall. The number of systems in the high-resolution simulations is greater than observed in association with an overestimation of the initiation of afternoon rainfall over topography and a planetary boundary layer that is too deep. The over-production of propagating systems inhibits the development of local instability and afternoon convection. A sensitivity study with an alternate PBL parameterization does not resolve the issue. Thus, while increasing model resolution to convection-permitting space scales significantly improves the diurnal cycle of rainfall, the issue is not fully resolved at least in part because other parameterizations remain.

1.1.6 Iguchi: Precipitation Variability and Diurnal Cycle of Convection-Permitting Deterministic Simulations versus Mesoscale Multi-Physics Ensemble Simulations: A Preliminary Result from the NASA Downscaling Project

Toshi Matsui, Taka Iguchi, and Wei-Kuo Tao
NASA GSFC Code 612

In 2014–2015, a NASA agency-wide team conducted a number of regional climate model (RCM) simulations using the NASA-Unified WRF driven by MERRA2 to explore the capability of dynamical downscaling to provide valid insights into the regional climate impacts over the contiguous US (CONUS). This presentation will specifically address the issues and performance of RCM in comparison between a convection-permitting deterministic simulation and mesoscale multi-physics ensemble simulations in the context of precipitation variability and convection diurnal cycles with emphasize of diurnal amplitude and maxima/minima timing over the climate regimes dominated by local afternoon convections and/or nocturnal propagating convection.

Convection-permitting RCM is configured with Goddard 4ICE microphysics, Goddard radiation, MYJ PBL scheme, and Noah LSM. Mesoscale RCM is configured with four deep cumulus parameterizations with different configuration of shallow convection; Grell 3D ensemble scheme (G3D), Betts-Miller-Janjic scheme (BMJ), the new Kain-Fritsch scheme (NKF), and the new simplified Arakawa-Schubert scheme (NSAS). Each deep scheme includes a companion parameterization for shallow cumulus convection, and only G3D has the option of disabling its native shallow convection component to include the University of Washington shallow cumulus parameterization scheme (UWSC). Results shows that diurnal maxima and minima timings are very realistically captured by both convection-permitting simulation as well as a mean state of the mesoscale multi-physics ensemble simulations, although the mesoscale ensemble member shows the large variability (8hour) of convection timing depending on the choice of convective parameterization. Performance of diurnal amplitudes also varies among the convection- permitting simulation and the mesoscale ensemble simulations over different geographic regions. The convection-permitting simulation tends to overestimate amplitude over Florida peninsula so as most of the mesoscale ensemble simulations. This concludes that convection-permitting RCM enhances dynamics of deep convection, while the performance of rainfall magnitude (e.g., rainfall variability) yet heavily relies on careful customization of the physics scheme, especially microphysics and PBL due to unresolved cloud-precipitation dynamics at this resolution. Finally, we will also address a noble satellite-based microphysics evaluation method and future applications of convection- permitting RCM.

1.1.7 Mahoney: The role of "gray zone" convective model physics in high-resolution simulations of the 2013 Colorado Front Range Flood

Kelly M. Mahoney
NOAA Earth Systems Research Laboratory, Physical Sciences Division

The model convective physics "gray zone" is explored for extreme precipitation using model simulations of the 2013 Colorado Front Range flood at 4-km horizontal grid spacing to evaluate the impact of using explicit convection (EC) versus parameterized convection (CP). Significant differences in simulated heavy precipitation are found across multiple regions in which heavy rain and high-impact flooding occurred in response to changes in model physics at these scales. The relative contribution of CP-generated precipitation to total precipitation suggests that greater CP scheme activity in areas upstream of the Front Range flooding may have led to significant downstream model error.

Comparison among multiple CP schemes demonstrate that there are model convective physics "gray-zone" considerations that significantly impact the simulation of extreme rainfall in this event, and that "scale-aware" updates may yield improvements in simulation skill. Additional CP concerns include upscale feedbacks that impact downstream environments in ways that likely become of increased importance for extended-duration simulations (e.g., regional climate modeling).

Increasing demands for convection-allowing climate simulations in the face of limited computing resources obliges ongoing consideration of model convective physics treatment at intermediate, "gray zone" scales. As extreme events are generally non-linear in nature, they will often be a fail point for model parameterizations, and thus careful consideration of model physics in the convective "gray zone" will remain important even as climate modeling systems continue to move toward higher resolutions.

1.2 Poster

1.2.1 Goergen: Pan-European convection permitting WRF simulations: Implementation and initial results

Klaus Goergen [1,2], Sebastian Knist [2,3,4], Stefan Kollet [1,2], Harry Vereecken [1,2]
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The ever-increasing performance of today's highly scalable HPC systems, such as the IBM BlueGene/Q or heterogeneous systems with MIC- or GPU-based accelerators, offer the potential to expand convection-permitting simulations to continental model domains. Benefits of such simulations are for example reduced uncertainties related to convection parameterisation, a better representation of convective precipitation, and a more realistic representation of surface heterogeneities (topography, land-use, soils) and boundary layer exchange processes, which impact dynamical processes such as land-sea wind systems. Continent-wide model domains allow in addition to investigate scale-dependent processes like atmospheric moisture budgets, convective system evolution, or widespread frontal system dynamics. Irrespective of necessary code modernisation efforts and co-design developments, we investigate how efficient a current WRF RCM version using single core optimisations, hybrid (OpenMP/MPI) parallelism and different kinds of accelerators (Intel Xeon Phi, NVIDIA GPU) and architectures (Intel Xeon vs. IBM BG/Q) can be used over large model domains. The 3km-resolution model domain encompassing 1600x1552 horizontal grid elements and 50 vertical levels is run over the European CORDEX domain, nested into the 12km EUR-11 grid and laterally driven by ERA-Interim reanalysis for selected (seasonal) time slices. Profiling tools such as Score-P/Scalasca or the I/O characterisation tool Darshan are used to understand the system's runtime behaviour beyond standard scaling experiments. As part of a big data framework, in-situ processing using VisIt helps to decrease data volume and file operations.

1.2.2 Komkoua Mbienda: Sensitivity experiments of RegCM4 simulations to the convective schemes over Central Africa

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In this study, the version 4 of the regional climate model (RegCM4) simulations have been performed for 6 years (from January 2001 to December 2006) over Central Africa using four convective parameterizations: The Emmanuel scheme (MIT), the Grell scheme with Ararakawa-Schulbert closure assumption (GAS), the Grell scheme with Fritsch-Chappell closure assumption (GFC) and the Anthes- Kuo scheme (Kuo). We have investigated the performance of the model to simulate precipitation, surface temperature, local wind and aerosols optical depth. Emphasis in the model result has been made in December-January-February (DJF) and July-August-September (JAS) periods. Also, two subregions have been indentified for more specific analysis: zone 1 which represents the sahel region mainly classified as desert and steppe and zone 2 spanned around the tropical rain forest climates with large area having a bimodal rain regime. We found that regardless of periods or simulated parameters, MIT scheme generally has tendency of overestimation. Model with GAS configuration is preferable in simulating the aforementioned parameters, as well as diurnal cycle of precipitations everywhere over the study domain independently of the season, In JAS, model results are similar in the representation ofregional wind circulation. Apart from the MIT scheme, all convective schemes give the same trends in aerosols optical depth simulations. Additional experiment reveals that the use of BATS instead of Zeng scheme to calculate ocean flux appears to improve the quality of the model simulations. Keywords: Regional climate models, Simulations, Aerosols, Central Africa

1.2.3 Ekström: Are convective permitting simulations meaningful for VIA work on watershed scale?

Dr Marie Ekström
CSIRO Land and Water, Canberra, Australia

Recent work indicate that fine resolution may add value to the study of extremes. Similar success is not necessarily expected for Vulnerability Impact Assessment (IVA) work where skill is sought on often different temporal and spatial scales. As part of the Victorian Climate Initiative (VicCI), output on 2 and 10 km resolution of a 5 year simulation were assessed with regard the importance of spatial resolution in downscaled output for regional runoff projections.

Initial assessment was conducted on stratified data according to seasons and percentile ranges to enhance patterns associated with different seasons and rainfall intensities. Skill is assessed on spatial model domain and for 25 catchments spread across the study region. In light of initial assessments there is no clear evidence that outputting on 2km resolution gives a significantly improved rainfall field for use in hydrological modelling on watershed scale in the assessed region. However, results are likely overly pessimistic due to the smooth qualities of the observed gridded data used for verification and the inclusion of high altitude areas with notable error statistics. Whilst results do not provide clear guidance on whether convective permitting simulations are significantly better skill- wise, other values of the finer resolved output may lie in providing improved understanding of the impact on local scale physical processes and hence the 'credibility' of the simulated climate.

1.2.4 Ganai: The impact of revised simplified Arakawa–Schubert scheme on the simulation of mean and diurnal variability associated with active and break phases of Indian Summer Monsoon using CFSv2

Authors: Malay Ganai, Phani Muralikrishna, P. Mukhopadhyay and M. Mahakur Affiliation: Indian Institute of Tropical Meteorology, Pashan, Pune

The impact of revised simplified Arakawa-Schubert (RSAS) convective parameterization scheme in Climate Forecast System (CFS) version 2 (CFSv2) on the simulation of active and break phases of Indian summer monsoon (ISM) has been investigated in the present study. The results revealed that RSAS showed better fidelity in simulating monsoon features from diurnal to daily scale during active and break periods as compared to SAS simulation. Prominent improvement can be noted in simulating diurnal phase of precipitation in RSAS over central India (CI) and equatorial Indian Ocean (EIO) region during active periods. The spatial distribution of precipitation largely improved in RSAS simulation during active and break episodes. CFSv2 with SAS simulation has noticeable dry bias over CI and wet bias over EIO region which appeared to be largely reduced in RSAS simulation during both the phases of intraseasonal oscillation (ISO). During active periods, RSAS simulates more realistic probability distribution function (PDF) in good agreement with the observation. The relative improvement has been identified in outgoing longwave radiation, monsoon circulations and vertical velocities in RSAS over SAS simulation. The improvement of rainfall distribution appears to be contributed by proper simulation of convective rainfall in RSAS. CFSv2 with RSAS simulation is able to simulate observed diurnal cycle of rainfall over CI. It correctly reproduces the time of maximum rainfall over CI. Besides improvement, RSAS could not reproduce proper tropospheric temperature, cloud hydrometeors over ISM domain which shows the scope for future development.

1.2.5 Geerts: Regional climate simulations of orographic precipitation in Interior Western USA: warm-season vs. cold-season precipitation

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A 10-year convection-permitting Weather Research and Forecasting Model (WRF) simulation, part of the 30-year simulation described in Wang et al. (2016, J. Climate, in preparation) is used to study how well orographic precipitation patterns in Interior Western US can be captured at 4 km resolution. The National Centers for Environmental Prediction National Hourly Multisensor Precipitation Analysis Stage IV dataset (NCEP IV), which uses the NEXRAD network and precipitation gauges, is challenged over mountains because of lack of low-level radar coverage and spatial heterogeneity of precipitation. The gauge-driven Precipitation-Elevation Regressions on Independent Slopes Model (PRISM) dataset does better over complex terrain, but has a poor time resolution (daily or monthly), since it is a statistically- based dataset regressing against terrain. In this study orographic precipitation data from NCEP IV and PRISM are compared against the 10-year WRF simulation. The simulated precipitation is compared also with data from Snow Telemetry (SNOTEL) gauges, which are located in tree- covered mountains and drive PRISM data over mountains.

The results depend on the season, and thus the type of precipitation. We find that in winter WRF compares very well against the aggregate of SNOTEL observations (difference 1 mm in three months), as well as against PRISM in the plains and valleys. The comparison is so good that differences between SNOTEL and WRF can be attributed to “errors” in the terrain height and slope in the model (model height/slope vs real height/slope). Given WRF’s performance, model precipitation can then be used to evaluate the gridded datasets in more data- sparse areas. For instance, PRISM is good in the proximity of SNOTEL gauges but questionable in mountain areas without gauges, esp. in areas above the treeline. The summertime precipitation simulation has much higher biases, with a tendency for convective precipitation to be triggered too late in the model, and convective systems to become too intense over the foothills and plains to the east.

1.2.6 Scaff: Warm season precipitation over the plains east of the Rockies

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The 12-year WRF climatology run over the continental US using 4-km WRF will allow us to utilize the convective resolving mesoscale model for a 12-year climatology analysis of the warm season precipitation east of the US and Canadian Rockies. Using WRF model output we will be able to examine how summertime diurnal convection diminishes and convection triggering mechanisms alter with increasing latitude in the Canadian Prairies versus the US Great Plains. We will be able to better investigate the initiation, maintenance and evolution of MCSs, and assess the contributions of different physical processes to convective initiation such as planetary, synoptic and mesoscale convective mechanisms. This work will advance our understanding of the CI mechanism over the US Great Plains and Canadian Prairies, which will make a significant contribution to the improvement of warm season rainfall predictions with proper representation of such mechanisms in forecast models.

1.2.7 Masarik: Weather Forecasting for Water Resource Management in Mountainous Terrain at Convection-Permitting Scales

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The water resources infrastructure of the Western US is designed to deliver reliable water supply to users and provide recreational opportunities for the public, as well as afford flood control for communities by buffering variability in precipitation and snow storage. Thus water resource management is a balancing act of meeting multiple objectives while trying to anticipate and mitigate natural variability of water supply. Currently, the forecast guidance available to personnel managing resources in mountainous terrain is lacking in two ways: the spatial resolution is too coarse, and there is a gap in the intermediate time range (10-30 days). To address this need we examine the effectiveness of using the Weather Research and Forecasting (WRF) model, a state of the art, regional, numerical weather prediction model, as a means to generate high-resolution weather guidance in the intermediate time range. This presentation will focus on one component of a US Bureau of Reclamation supported project, a case study of the extreme precipitation and flooding event in the Payette River Basin of Idaho, over the period of June 2nd- 4th, 2010. As input boundary conditions to WRF we use NCEP's Climate Forecast System Reanalysis (CFSR) and the North American Regional Reanalysis (NARR) data sets. The model configuration used includes a horizontal spatial resolution of 3km in the outer nest, and 1 km in the inner nest, with output temporal resolution of 3 hrs and 1 hr, respectively. Preparations for the second of two components in this project, weekly WRF forecasts during the intense portion of the water year, will be briefly described. These forecasts will use the NCEP Climate Forecast System version 2 (CFSv2) operational forecast data as boundary conditions to provide forecast guidance geared towards water resource managers out to a lead time of 30 days.

1.2.8 Sarkar: A study to understand the mechanism behind organization of convection during Boreal Summer using observations and Model

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Boreal summer Intraseasonal oscillations (BSISOs) show a meridional propagation from the Indian Ocean (IO) region to the Continental India. The BSISOs are the main source of rainfall variability over the Indian Summer Monsoon (ISM) Region. The complete understanding about the initiation and organization mechanisms of BSISOs remains elusive. One of the important issues from forecaster's point of view would be to know, whether or not a scattered low cloud clusters observed on any day would initiate a deep convection and eventually become large scale organized convection in the subsequent days. Recently Moncrieff et al. 2012 in connection to Year of Tropical Convection (YOTC) has given a framework how the small scale cloud and the large scale organized convection interact with each other. He has proposed that the upscale transformation of energy from cumulus and cumulonimbus cloud to the MJO/MISO through Mesoscale convective systems (MCS) are very much important. He has proposed that the Mesoscle convective organization can bridge the gap between the ISO scale and the cumulus scale in the climate model. Presently no climate model incorporates a satisfactory parameterization of Mesoscale organization. Thus there is a need to understand the mechanism through which the small scale scattered cloud clusters organize into a large scale deep convective cloud and its subsequent propagation. This study uses observation and reanalysis data that covers summers (June-Sep) of 1998 2013 to investigate the mechanism behind the organization of BSISOs. Based on rainfall analyses, two types of BSISOs are defined, one with weaker and the other with stronger intensity. Stronger BSISOs show persisting lower level moisture convergence to the north of the convection centre (CC) and a strong vertical velocity collocated with CC. A new perspective based on the energetics study is applied to understand the mechanism. The analyses reveal that the eddy kinetic energy (KE) and conversion of eddy available potential energy (AE) to eddy kinetic energy (KE) increases as the BSISOs approaches towards organized stage. Thus it appears that eddy kinetic energy (KE) and its conversion from eddy available potential energy play an important role for the movement of BSISOs. Further analyses show that organization and intensification of BSISOs from the initial stage of formation is associated with the reduction in generation of eddy available potential energy. But for the weak events the structure is completely opposite. Also CFS v2 model is used to check the model ability in capturing the processes. These suggest the key role played by the energy transformation.

1.2.9 Schwitalla: Evaluation of high-resolution WRF simulations at different spatial and temporal scales

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In contrast to global climate simulations, regional climate models are usually applied as limited area models with 0.1° to 0.5° due to limited computing resources. However, the representation of synoptic-scale features can deteriorate due to applied boundaries. At longer time scales, these errors can propagate into the model domain and impact the results.

In order to study the effect of very high resolution climate modeling we applied the WRF model for a northern hemisphere latitude belt between 20°N and 65°N to omit zonal boundary effects and to study the performance of the applied parameterization at different resolutions. The model was operated both at 12 km and 3 km resolution (comparable to EURO-CORDEX) for July and August 2013 and forced with ECMWF operational analyses data.

We demonstrate the benefit of a very high resolution by validating both simulations with respect to precipitation, temperature, moisture and wind.

We will also present first results of comparing different WRF boundary layer schemes down to the LES scale with Lidar measurements from the HOPE campaign in 2013.

1.2.10 Sukumarapillai: Towards Achieving Potential Predictability of Indian Summer Monsoon in Climate Forecast System model by Addressing the Physics Errors

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The goal of this study is to extend the realized predictability limit of a dynamical coupled model over Indian monsoon region. In this study we present an optimal way to design a multi-model ensemble prediction system from a suite of different variants of Climate Forecast System (CFSv2) model to increase the spread without compromising the limit of potential predictability of each individual models. The ensembles are generated not only by perturbing the initial condition, but also using different resolutions, parameters, physics formulation and coupling configurations of the same model. Each of these configurations was created to address the role of different physical mechanisms known to have control on the error growth in the 10-20 day time-scale. We also present the bias errors arising from incorrect humidity-convection relationship. The prominent biases of the model simulations are a wet bias of rainfall over Western equatorial Indian Ocean and a dry bias over Indian landmass and Bay of Bengal. We hypothesize that most of these biases arise from relative humidity based entrainment formulation in the model and are addressed by performing a few targeted experiments using a possible range of humidity-entrainment relationships. We carry out a model tendency budget analysis to diagnose and evaluate the modifications to the entrainment formulation.

1.2.11 Tan: Influence of topography on precipitation and its diurnal cycle in the Maritime Continent

Haochen Tan, Florida Institute of Technology; Pallav Ray, Florida Institute of Technology;

Understanding the multi-scale interactions between the diurnal cycle in the Maritime Continent (MC) and large-scale circulations remain a challenge to the atmospheric community. The problem is further exacerbated by the fact that most models have difficulty in simulating the precipitation over the MC, presumably due to error from model physics and resolution that has to deal with the complex topography of the MC.

A series of simulations with the Weather Research and Forecasting (WRF) model is conducted to understand the role of topography on the precipitation and its diurnal cycle. The 'Control' simulation captures the spatial distribution of precipitation well including the heavy rainfall areas, although it appears to overestimate over land and underestimate over ocean. The peak amplitude of diurnal precipitation in 'Control' simulation is 3 hours earlier than observation over land, but captures the diurnal cycle of precipitation over ocean. The results from 'no-topo' (i.e., topography replaced to a unified flat island), 'no-topo-1000m' (i.e., no topography above 1000m), and 'no-topo-2000m' (i.e., no topography above 2000m) will be discussed. Another set of sensitivity tests was conducted to explore the role of individual islands by removing those islands in the model. The results from these simulations and its possible implications will be discussed in the meeting.

1.2.12 Xue: Sensitivity of precipitation to clouds over upwind ocean in the Hawaii Island

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A fine resolution, convection-permitting, 10-year regional climate simulation over the entire Hawaii archipelago is being conducted at the National Center for Atmospheric Research (NCAR). Numerical sensitivity simulations of the Hawaiin Rainband Project (HaRP, a filed experiment from July to August in 1990) showed that the simulated precipitation properties are sensitive to initial and lateral boundary conditions, sea surface temperature (SST), land surface models, vertical resolution and cloud droplet concentration. The convection-permitting regional climate simulations not only provide physically based detailed atmospheric and hydrologic information for impact assessments but also serve as high quality data for further downscaling simulations. Traditionally, no cloud hydrometeor field is available in reanalysis data sets to reflect its impacts on dynamics, thermodynamics and precipitation in the simulations driven by such data. This study tries to quantitatively address the specific question of how existing cumulus over the upwind ocean impact the precipitation over the Hawaii island by running weeklong, 500 m grid spacing simulations, driven by the 1.5 km regional climate outputs, with and without hydrometeor fields in the initial and lateral boundary conditions. The results will provide guidance for future downscaling studies making use of the convection-permitting regional climate data sets.

1.2.13 Zhao: Assessment of precipitation simulation by NARCCAP regional climate models and the relationship with large-scale circulation bias

Yating Zhao, Ming Xue, Xiaoming Hu
(CAPS, University of Oklahoma, United States)

It is known that climate change is likely to have many effects on nature and society. To investigate the uncertainties in regional-scale climate projections of future climate the North American Regional Climate Change Assessment Program (NARCCAP) produced high resolution climate change simulations. Given the desire to use this dataset for impact assessments and the lack of the comparison between its different model outputs, the goal of this research is to assess the precipitation simulation by NARCCAP regional climate models and to figure out some questions. Are certain RCM model outputs more appropriate for assessing the precipitation in some certain regional areas? Why the models do well in some regions and less well in others? The research using Stage IV data and NCEP-DOE Reanalysis2 data suggests that nudging RCMs in NARCCAP tend to have better ability in capturing the large-scale circulation than the non-nudging ones, which is very important for the simulation of precipitation. It is shown that the non-nudging RCMs produce much intense dry bias in the great plain areas, which very likely due to its simulation of weaker Low level jet and negative bias in low level humidity. This analysis could help us to better understand the sources of errors in the regional climate models.

1.2.14 Monaghan: High resolution regional climate simulations over Alaska

Andrew Monaghan, Martyn Clark, Jeffrey Arnold, Andrew Newman, Keith Musselman, Michael Barlage, Lulin Xue, Changhai Liu, Ethan Gutmann and Roy Rasmussen

In order to appropriately plan future projects to build and maintain infrastructure (e.g., dams, dikes, highways, airports), a number of U.S. federal agencies seek to better understand how hydrologic regimes may shift across the country due to climate change. Building on the successful completion of a series of high-resolution WRF simulations over the Colorado River Headwaters and contiguous USA, our team is now extending these simulations over the challenging U.S. States of Alaska and Hawaii. In this presentation we summarize results from a newly completed 4-km resolution WRF simulation over Alaska spanning 2002-2016 at 4-km spatial resolution. Our aim is to gain insight into the thermodynamics that drive key precipitation processes, particularly the extremes that are most damaging to infrastructure.

1.2.15 Chang: Evaluating Changes in Extreme Weather During the North American Monsoon in the Southwest U.S. Using High Resolution, Convective-Permitting Regional Atmospheric Modeling

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The North American monsoon (NAM) is the principal driver of summer severe weather in the Southwest U.S. Monsoon convection typically initiates during daytime over the mountains and may organize into mesoscale convective systems (MCSs).Most monsoon-related severe weather occurs in association with organized convection, including microbursts, dust storms, flash flooding and lightning. A convective resolving grid spacing (on the kilometer scale) model is required to explicitly represent the physical characteristics of organized convection, for example the presence of leading convective lines and trailing stratiform precipitation regions.Our objective is to analyze how monsoon severe weather is changing in relation to anthropogenic climate change. We first consider a dynamically downscaled reanalysis during a historical period 1948-2010. Individual severe weather event days, identified by favorable thermodynamic conditions, are then simulated for short-term, numerical weather prediction-type simulations of 30h at a convective-permitting scale. Changes in modeled severe weather events indicate increases in precipitation intensity in association with long-term increases in atmospheric instability and moisture, particularly with organized convection downwind of mountain ranges. However, because the frequency of synoptic transients is decreasing during the monsoon, organized convection is less frequent and convective precipitation tends to be more phased locked to terrain. These types of modeled changes also similarly appear in observed CPC precipitation, when the severe weather event days are selected using historical radiosonde data. Next, we apply the identical model simulation and analysis procedures to several dynamically downscaled CMIP3 and CMIP5 models for the period 1950-2100, to assess how monsoon severe weather may change in the future with respect to occurrence and intensity and if these changes correspond with what is already occurring in the historical record. The CMIP5 models we are downscaling (HadGEM2-ES and MPI-ESM-LR) will be included as part of North American COordinated Regional climate Downscaling EXperiment (CORDEX). Results from this project will be used for climate change impacts assessment for U.S. military installations in the region.

2. Climate change assessments

2.1 Oral

2.1.1 Dai: Changes in Precipitation Characteristics over North America by the Late 21st Century Simulated by a Convection-Permitting Model

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Global climate models project increasing precipitation intensity but decreasing frequency in the 21st century as greenhouse gases (GHGs) increase. However, the exact physical mechanism for the decreases in precipitation frequency remains unclear. A possible explanation could be that each storm in a warmer climate would remove more moisture from the air and it would take longer for local and remote surface evaporation to replenish the depleted moisture before the next storm forms, leading to longer dry spells and fewer storms. However, the coarse spatial resolution of current global models prevents detailed simulation and analyses of changes in these and other precipitation characteristics. Here, we analyze hourly data from a newly completed set of regional climate change simulations with 4km grid spacing covering most of North America using the Weather Research and Forecasting (WRF) model. The WRF model was forced with current and future boundary conditions, with the latter being derived by adding the CMIP5 multi- model ensemble mean changes to the current condition. The hourly precipitation rates for each 4km grid cell resolve most individual storms and allow us to examine the changes in the length of dry spells and storm duration, precipitation frequencies at different intensities, and the entire histograms of hourly precipitation. Preliminary results show that the WRF control simulation reproduces reasonably well the seasonal and spatial variations in precipitation frequency and precipitation histograms over the contiguous U.S. (CONUS) seen in NCEP Stage IV observational hourly precipitation data. The future-minus-present differences show increased percentage contribution to total precipitation amount by heavy precipitation (P>10mm/hr) but decreased contribution by

light precipitation (P<2mm/hr). Dry spells generally become longer and more frequent while light precipitation becomes less frequent, which enhances drought. Moderate to heavy precipitation events (P>2mm/hr) become more frequent over most of the CONUS and most of the season, although they become less frequent and the intervals between them increase over the central U.S. during JJA. Precipitation amount from each precipitation event increases by 5-10% per 1K local warming, slightly above the 7%/K increase for saturation water vapor; however, the decrease in the number of precipitation events reduces this rate to generally below 5%/K for seasonal mean precipitation. The results suggest that the decreases in overall precipitation frequency come mainly from a reduction in light precipitation events (possibly to due to reduction in RH), while the number of heavy precipitation events could increase, which could lead to more flooding. They also show substantial differences seasonally and regionally.

2.1.2 Di Luca: Using convection permitting simulations to study the intensity of extreme East Coast Lows

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Australian East Coast Lows (ECLs) are cyclones that either form or cross over the Tasman Sea adjacent to the Australian eastern seaboard. ECLs are responsible for much of the high impact weather affecting the east coast of Australia including a large number of major floods, damaging winds and large ocean waves.

Our current understanding of how the most extreme ECLs will respond to a changing climate is severely limited by current climate simulations in three main regards. Firstly, the interannual variability of extreme ECLs is very large, which prevents robust analyses of their changes when using standard 30 year periods. Secondly, moist processes and the effects of latent heat release play a major role in the most extreme ECLs but their accurate representation requires very high model resolutions. Lastly, the representation of fine scale oceanic conditions and atmosphere ocean interactions might be crucial to accurately simulate the intensity of ECLs, calling for the use of high resolution atmosphere ocean regional coupled models.

In this presentation, we will show an experimental setup that combines convection-permitting dynamical downscaling simulations with the pseudo global warming approach to study extreme ECLs and their plausible future changes. We will discuss some issues related with the experimental setup such as the use of large-scale nudging and of multi- physics simulations. We will also present some preliminary results derived from the application of the methodology to a specific event and possible future changes in precipitation and wind fields.

2.1.3 Hoogewind: The Impact of Climate Change on Severe Convective Storms in the United States: Insight from High-Resolution Dynamical Downscaling

Kimberly Hoogewind
Coauthors: Jeff Trapp (UIUC) and Mike Baldwin (Purdue)

Growing evidence from climate model projections suggest that large-scale environmental conditions favorable for severe thunderstorms may increase in frequency in the future due to anthropogenic climate change. The resolution of global climate models (GCMs), though, remain much too coarse to adequately represent the scales at which severe convective weather phenomena occur, including processes that may lead to the initiation of deep convection. This work uses the Weather Research and Forecasting-Advanced Research WRF (WRF-ARW) is to dynamically downscale GFDL-CM3 simulations of historical (1971-2000) and future (2071- 2100; RCP8.5) climate for the purpose of examining potential impacts upon hazardous convective weather (HCW). Our procedure for downscaling involves a succession of 30-hour model integrations initialized daily at 0600 UTC, with an hourly data output frequency. While high-resolution (4-km) WRF simulations can resolve broad convective circulations, such grid spacing cannot directly resolve tornadoes or other small-scale convective features. Thus, model proxies will be used to estimate the occurrence of a simulated HCW event such as large hail, damaging wind, and/or tornadoes. This approach is similar to that currently being used in short- range numerical weather prediction for the forecasting of HCW. Herein, we show that HCW increases in the future owing largely to enhanced convective available potential energy. Our results highlight the advantages of regional climate modeling at convective-permitting resolution as opposed to assessment of favorable convective environments from the GCM alone, as there are indications that the environment-event relationship may be altered in the future.

2.1.4 Rasmussen: High-resolution regional climate simulations of warm season convection in the United States

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Convective storms and mesoscale convective systems are vital to hydrologic and energy cycles on Earth. As the global climate changes, patterns of severe weather are likely to shift. In order to accurately represent all types of storms in numerical forecasts and climate models, it is becoming increasingly important to incorporate the effects of physical mechanisms and specific details involving clouds and mesoscale processes, storm life cycle, mesoscale organization, topographical and diurnal effects, latent heating, and precipitation from such storms. High-resolution regional climate simulations (i.e., the pseudo-global warming technique; Rasmussen et al. 2011) that model current and future climate scenarios in a convection-resolving framework have recently been completed for thirteen years of current and future climate in the United States. We will present results from these simulations focused on the warm season in the U.S. In addition, changes in the thermodynamic environment supporting convection and the resulting intensity and frequency of convective storms will be shown. Understanding how future changes in climate will impact convective storms of all scales and intensities is an important research topic that may define the weather and climate intersection.

2.1.5 Ban: Scaling and Intensification of Extreme Precipitation in Climate Change Simulations at Kilometer-Scale Resolution

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Scientific analysis of convection-permitting climate simulations Consistent with the Clausius-Clapeyron relation, it is generally accepted that extreme day-long events will increase at a rate of about 6-7% per degree warming. However, recent studies suggest that sub-daily (e.g., hourly) precipitation extremes may increase at about twice this rate (referred to as super-adiabatic scaling). Conventional climate models are not suited to assess such events, due to the limited spatial resolution and the need to parameterize convective precipitation.

Here we employ a regional climate model at horizontal resolution of 2.2 km across an extended region covering the European Alps and its larger-scale surrounding from Northern Italy to Northern Germany. Validation using ERA-Interim driven simulations with rain-gauge observations reveals significant improvements with the 2.2 km resolution, in particular regarding the diurnal cycle of mean and extreme precipitation, the representation of hourly extremes, and replication of observed super-adiabatic and adiabatic scaling at precipitation stations.

Consistent with previous studies, climate change simulations using an RCP8.5 greenhouse gas scenario reveal a significant decrease of mean summer precipitation. However, unlike previous studies, we find that both extreme day-long and hour-long precipitation events asymptotically intensify with the Clausius-Clapeyron relation in the summer season. In other seasons, the change in extreme hour-long precipitation events exceeds the Clausius-Clapeyron rate. Here we will address these differences, and also show that it is inconsistent to extrapolate from present-day precipitation scaling into the future.

Ban, N., J. Schmidli and C. Schär (2016): Analysis of precipitation extremes using generalized extreme value theory in convection-resolving climate simulations. In preparation.

Ban, N., J. Schmidli and C. Schär (2015): Heavy precipitation in a changing climate: Does short- term summer precipitation increase faster? Geophys. Res. Lett., 42: 1165-1172, doi: 10.1002/2014GL062588

Ban, N., J. Schmidli, and C. Schär (2014), Evaluation of the convection-resolving regional climate modeling approach in decade-long simulations, J. Geophys. Res. Atmos., 119, 7889–7907, doi:10.1002/2014JD021478

2.1.6 Kawase: Challenges of convection-permitting regional climate simulations in Japan - SOUSEI program -

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To investigate the climate changes around the Japanese archipelago, high-resolution regional climate experiments were conducted using Non-Hydrostatic Regional Climate Model (NHRCM) developed in Meteorological Research Institute (MRI) in Japan. The horizontal grid intervals of NHRCM are 5 km and 2 km. In the model with 2 km grid intervals, convection has been explicitly handled. The lateral boundary conditions are derived from MRI-Atmospheric General Circulation Model (AGCM) with 20 km equivalent grid intervals. We focus on the end of 21st century under the RCP8.5 scenario. The SST in the future climate simulations were constructed as the sum of the reanalyzed SST and three warming patterns in the coupled GCMs in CMIP5, which were classified by the cluster analysis, and the ensemble mean of three SST change patterns.

In the present climate simulations, the NHRCM with 5km and 2km grid intervals well reproduced an intensity of hourly precipitation in Japan. The 2km-NHRCM simulated the seasonal variation of snow depths in the mountainous areas better than the 5km-NHRCM did. The 2km-NHRCM includes the urban model that instruments a snow cover model. The snow depth and temperature in the urban areas were improved in comparison with the NHRCM without the urban model. However, since the high resolution NHRCM still has some biases, we develop some bias correction methods for air temperature, precipitation, maximum snow depths, and so on. In the presentation, we also introduce the latest results of our NHRCM simulations in the future climates in Japan.

2.1.7 Gutmann: Internal Variability and Convection Permitting Regional Climate Simulations

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Nearly as important as the mean change in the climate signal, is the uncertainty within that change. One major source of uncertainty in climate change is due to the chaotic internal variability of the climate system itself. Here we examine the climate change signal from 6 members of the CESM-Large Ensemble downscaled with a convection-permitting regional climate model (WRF). The change signal is calculated between 1990-1999 and 2070-2080 for each of the 6 ensemble members. These simulations were performed with a 4km grid over a nearly 1000 km by 1000 km domain centered on the Colorado Rockies. We examine both the mean change signal as well as the variability in that signal as a function of elevation, precipitation intensity, and land cover type.

2.2 Poster

2.2.1 Dai: A New Approach to Construct Representative Future Forcing for Dynamical Downscaling

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Dynamical downscaling of future climate change has traditionally used 6-hourly output from individual simulations by global models as the lateral boundary forcing. However, individual model runs often contain large realization-dependent internal variability that can overshadow greenhouse gas (GHG)-induced climate change on decadal and regional scales. This complicates the interpretation of the downscaled changes. Furthermore, GHG-forced future climate changes from one global model may differ substantially from another. These issues make such downscaled regional climate changes un-representative of GHG-forced future climate change. Using a large ensemble of downscaling forced with output from different global models can help, but that is often impractical because it requires a large amount of computer and human resources. Another approach is the so-called pseudo-global warming (PGW) experiment in which a mean perturbation is added to current 6-hourly forcing data from a re-analysis product. The PGW forcing captures the mean response to future GHG forcing, but it does not include changes in transient weather patterns including many extreme events. To overcome the major short comings in these approaches, we recently proposed a new approach to construct representative future forcing for regional dynamic downscaling. This approach combines the transient weather signal from one select global model simulation with the monthly mean climate states from the multi-model ensemble mean for the present and future climate periods, together with a bias correction term. It ensures that the mean climate difference in the forcing between the present and future periods represent GHG-forced changes while changes in transient weather patterns are also considered based on one select model run. This approach has been applied at NCAR to construct the forcing data for the second phase of the WRF-based CONUS downscaling over much of North America with 4km grid spacing. We will discuss the key aspects and some of the issues involved in this approach.

2.2.2 Chen: On simulation of the possible impact of climate warming and terrain height on extreme weather using WRF model

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Through using the weather research and forecast (WRF) model, which was developed at the National Center of Atmospheric Research (NCAR) in USA, we simulated an extreme storm event occurred in central China in August 1975, a well-known event in China as the 758-storm. The reanalysis data, ERA40, from the European Centre for Medium-Range Weather Forecasts (ECMWF) is employed as the WRF's boundary. The spatial resolution at the center of the simulated storm is set to be 2 km, which is realized by means of nested domains.There are 60 levels in the sigma coordinate system at the vertical direction and the top level pressure is defined as 50hPa.

We first analysed 3-dimension structure of the 758-storm, showing how the storm was developed and what is the mechanism of its formation. Afterwards, two extra experiments were carried out: one is modifying the temperature-related variables by 2C heigher; and another one is altering the terrain height of the simulation area. With these experiments we would explore how the climate warming and terrain height have possible impact on extreme storm event.

2.2.3 Bao: Future increases in extreme precipitation exceed observed scaling rates

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Models and physical reasoning predict that extreme precipitation will increase in a warmer climate as a result of the increased atmospheric humidity1-3. Observational studies seeking a scaling relationship between extreme precipitation and local temperature have, however, reported a puzzling variety of scaling rates including strong rates in mid-latitude locations but weak or negative rates in the tropics4,5. Analysis of extreme precipitation events in Australian cities, Darwin, Sydney and Melbourne, reveals that temporary local cooling associated with the events themselves reduces these apparent scaling rates, especially in warmer climatic conditions. A regional climate projection ensemble6 for Australia, which implicitly includes these effects, accurately and robustly reproduces the highly variable scaling rates inferred from observations throughout the continent for daily precipitation extremes. Projections from the same model show that the future extremes increase at rates almost everywhere exceeding those inferred from observed scaling, and likely exceeding the 7%/C rate of humidity increase.

2.2.4 Mbaye: Impact of statistical bias correction on the projected climate change signals of the regional climate model REMO over the Senegal River Basin

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We assess the impact of a statistical bias correction method based on histogram equalization functions on the projected climate change signals of regional climate model (RCM) simulations over the Senegal River Basin in West Africa. Focus is given to projected changes in precipitation, temperature, and potential water balance (P - PET) following the RCP4.5 and RCP8.5 emission scenario pathways by the end of the 21st century (2071–2100) compared to the 1971–2000 reference period. We found that applying the bias correction substantially improved the simulations of present day climate for both temporal and spatial variations of the analysed climate parameters when compared to gridded observations data sets and station data. For the future, the non-corrected RCM projections show a general decrease of precipitation by the end of 21st century for both scenarios over the majority of the basin, except the Guinean highlands where a slight increase is found. The reduction in mean precipitation is accompanied by a projected increase in the annual number of dry days, most pronounced in the northern basin. Furthermore, a general temperature increase is projected over the entire basin for both scenarios, but more pronounced under the RCP8.5 scenario. In addition, the deficit in the water balance (P - PET) above 12N is projected to increase in the future. Applying the bias correction to the RCM projections leads to a general dampening of the projected change signals, strongest in the case of heavy precipitation events. However, for all analysed parameters the general directions of change as well as the predominant large-scale change patterns are conserved after applying the bias correction.

2.2.5 Marinier: On the study of a major ice pellet storm in the Toronto area in a climate change context

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Winter storms have a major impact on society whether it's from an environmental, social or economical point of view. Damages caused by those phenomena can lead to catastrophic consequences such as power outages and transportation issues. These consequences are mainly due to the occurrences of precipitation when the temperature is near 0C. Freezing rain, ice pellets and/or a combination of both can lead to ice accumulation on the ground and are particular difficult to forecast. It is critical to improve our understanding of their formation to better anticipate changes in their occurrences with climate change. The goal of this study is to conduct a case study of a major ice pellets storm in the Toronto area and to investigate this storm in a climate change perspective. To address this, we used both 4-km resolution WRF CONUS in historical and PGW simulations. A particular attention is paid on the 21–24 December 2004 event that affected the central United States and eastern Canada. First, the large-scale weather conditions will be compared with observations such as the surface pressure fields and accumulated precipitation. Second, the vertical structure of the atmosphere such as the temperature, humidity and hydrometeor profiles will be studied over southern Ontario. Third, the overall storm will be compared with the same storm produced in the PGW experiment. A comparison of the precipitation types, timing, location and characteristics will be investigated. Overall, this is a first step towards a better understanding of the mechanisms leading to winter precipitation types at near 0C in the context of a warmer climate.

2.2.6 Martynov: Simulations of hailstorms over Switzerland in a warmer climate, using a surrogated climate change approach

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The WRF model was used for simulating the hailstorms over Switzerland in summer periods of 2012, with 2-km horizontal resolution and using the ECMWF analysis for boundary forcing. The climate conditions, expected towards the end of the XXI century (RCP85 scenario) were simulated by introducing biases of air temperature and of soil temperature/water content, based on CMIP5 simulations. The relative air humidity was left constant in one experiment and let to change, following the CMIP5 simulations, in the second configuration. Based on the comparison with the unbiased present day simulation, changes in spatial and temporal distributions of precipitation patterns and of hailstorms, in characteristics of thunderstorm clouds and in parameters of ground-reaching hailstones were studied. Considerable increase of mean and maximal precipitation rate has been remarked. More hail days, more frequent hailstorms and larger hailstones were produced in the climate change simulations. The air humidity conditions, set in the surrogated climate change runs, strongly influence the hailstorm activity in the future climate.

2.2.7 Trapp: Application of the pseudo-global warming methodology to extreme tornadic storm events

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This research seeks to answer the basic question of how current-day extreme convective storm events might be realized under future anthropogenic climate change. The "pseudo-global warming" (PGW) methodology, which is a particular form of dynamical downscaling, is employed for this purpose. In our application of this methodology, global climate model simulations under historical and future (RCP8.5) conditions are used to modify the initial and boundary conditions applied to an ensemble of WRF-model simulations of three high-end tornadic events. We find that the PGW modifications act to suppress convection initiation in many of the experiments, but otherwise tend to result in supercellular convection with enhanced updrafts with enhanced vertical rotation.

2.2.8 Wang: The Remote Effect of the Tibetan Plateau on Downstream Flow in Early Summer

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By using numerical experiments and observational data, this study examined the uplifting and thermal effects of the Tibetan Plateau (TP) on downstream airflow in early summer. Our principal finding is that the uplifting effect of the TP in an Atmospheric General Climate Model (AGCM), including air made warmer than its surroundings climatologically by the huge topography, results mainly in a local response in the atmosphere, i.e., a large ridge north of the TP in the troposphere in June. There was no Rossby wave response to the uplifting effect. However, simulations and statistical analyses strongly suggested that the anomalous TP atmospheric heating associated with global climate warming tends to excite a Rossby wave originating from the TP via Lake Baikal and continuing to move through the Okhotsk Sea to downstream areas. The appearance of the Rossby wave coincides with the positive phase of the eastern part of a normal stationary wave originating in the Caspian Sea traveling via the Okhotsk Sea to the sea area east of Japan that often occurs in June. Thus the TP atmospheric heating acts as an additional wave source in relaying and enhancing the eastern part of the normal wave propagation. Its path usually lies beyond 40°N latitude, which is where the westerly jet stream takes over the role of waveguide.

2.2.9 Wang: The change of extreme precipitation events in a changing climate over Interior Western USA: a study using regional climate simulations

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This work uses two 30-year convection-permitting regional climate simulations with 4-km horizontal grid spacing to study the impact of climate variability and projected global warming on extreme precipitation events in Interior Western US. The WRF retrospective simulations are firstly being run over a 30-year period from 1980 to 2010 with initial and boundary conditions from CFSR. Orographic precipitation is captured very well, especially in winter, as is evident from comparisons with the aggregate of Snow Telemetry (SNOTEL) precipitation gauge data and Parameter-elevation Regressions on Independent Slopes Model (PRISM) data. Details of the model setup and the validation against SNOTEL and PRISM data can be found in Wang et al. (2016, J. Climate, in preparation). The same WRF model is then rerun over 30 years centered on 2050 with the modified initial and boundary condition produced from the CMIP5 ensemble- mean climate change.

A number of extreme precipitation indices are calculated covering intensity, magnitude, frequency, and duration of excessive dryness. Results show that WRF model can capture both the multi-year mean spatial patterns and temporal trends of extreme precipitation indices reasonably well in the studied domain. Comparison between retrospective and future climate simulations indicates that the magnitude of extreme precipitation events will generally increase for both short duration events (1-2 days) and longer duration events (5-10 days) at a given return period. Finally, the effect of elevation on the change of extreme precipitation will be presented by showing the results from four mountainous subregions: the Montana Rockies, the Greater Yellowstone area, the Colorado Rockies, and the Wasatch Range.

3. CPM grid spacing

3.1 Oral

3.1.1 Fosser: Impact of different convection permitting resolutions on the representation of heavy rainfall over the UK

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Previous studies (e.g. Ban et al, 2015; Fosser et al, 2015 and 2016; Kendon et al, 2015) have shown that convection permitting models are able to give a much more realistic representation of convection, and are needed to provide reliable projections of future changes in hourly precipitation extremes.

In this context, the UKCP18 project aims to provide policy makers with new UK climate change projections at hourly and local scales, thanks to the first ensemble of runs at convection permitting resolution. As a first step, we need to identify a suitable UK domain, resolution and experimental design for the convective-scale ensemble. Thus, a set of 10-years long simulations driven by ERA Interim reanalysis data has been carried out over the UK using the Met Office Unified Model (UM) at different convection permitting resolutions, namely 1.5 km, 2.2 km and 4km. Different nesting strategy and physical adjustments are also tested. Two observational gridded datasets, based on rain gauges and radar, are used for validation.

The analysis aims to identify the impacts of the different convection permitting resolutions (as well as domain size and physical settings) on the representation of precipitation, especially when convection is a predominant feature. Moreover, this study tries to determine the physical reasons behind the found differences and hence to determine if there are any benefits of increasing the horizontal resolution within the convection permitting regime in a climatological context.

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3.1.2 Noda: Resolution dependency of clouds and precipitation derived from 14-kilometre- to sub-kilometer-mesh nonhydrostatic global simulations

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The NICAM research team recently succeeded a global 870-m mesh nonhydrostatic simulation using the Japanese supercomputer K. Compiling knowledge derived from the highest-resolution global simulation along with that from our previous dataset (up to 3.5-km mesh simulations), we have evaluated detailed influences of such different grid sizes on modelled cumulus-scale behaviour and associated large-scale circulations over the globe. Using those NICAM dataset, we will discuss resolution dependencies of cloud behaviour from various perspectives, including diurnal variations of cloud and precipitation, morphology of convective clouds, cloud-size statistics, and impacts on cloud-radiation interaction, the results from which are beneficial to apply for advanced greyzone modelling.

3.2 Poster

3.2.1 Eghdami: Orographic moist processes and the transition between isotropic and anisotropic turbulence in WRF

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The vertical structure of zonal wind kinetic energy (KE) spectra produced by Weather and Research Forecasting (WRF) is studied for multiple simulations in the Southern Appalachian Mountains under weak (9-12, July 2012) and strong (12-16, May 2014) synoptic forcing using nested grids from 15km horizontal resolution in the outer domain down to 0.25km in the innermost domain and for different microphysics schemes and Planetary Boundary Layer (PBL) parameterizations. The results show that in the innermost domain, spectra for sub-kilometer grid spacing exhibit Kolmogorov and Corrsin-Obukhov -5/3 scaling in the PBL, while Bolgiano-Obhukov scaling is approached at higher levels. However, at 1.25km and above grid spacing, the scaling behavior at low levels exhibits a slope flatter than -5/3 that is unphysical, indicative of aliasing of small scales. Higher levels show a scaling behavior similar to the convective/nonconvective transition approaching Bolgiano-Obhukov scaling. Further, it is shown that the scaling behavior of variables such as heat and moisture flux, temperature and mixing ratio statistics, and energy spectra are affected differently by grid resolution, which should have important implications for the effective implementation of “scale-aware”. Therefore, a comprehensive analysis and scaling of flow behavior condition on stability regime for both KE and moist processes (total water, cloud water, rainfall) is necessary to elucidate scale-interactions among different processes in the model for different grid spacing, grid geometry, and mesoscale forcing toward identifying the effective model resolution, that is the scale at which generalized scaling behavior is reproduced.

3.2.2 Mazzaro: Limitations of Mesoscale-to-LES Grid Nesting in a Convective Atmospheric Boundary Layer

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Accurate models of atmospheric phenomena are essential for predicting wind energy production, fire propagation, pollution transport and weather conditions. Such predictions require information about both micro-scale flow patterns, and meso-scale weather conditions. Models with both meso and microscale capabilities make it possible to perform grid-nesting between mesoscale parent domains and microscale nests. However, due to nesting resolution- ratio limitations, the mesoscale domain is usually run at resolutions higher than what the models were designed for, in a range known as the Terra Incognita. In cases containing atmospheric convection, this practice can result in the presence of unrealistic flow structures in the parent domain. In the present study we quantify the effect of these unrealistic structures on a nested, Large-Eddy Simulation (LES).

We use the Weather Research and Forecasting Model to perform two sets of nested simulations containing different convective structures: rolls and cells. The parent domains are run at resolutions within the terra-incognita, and contain unrealistic structures. We compare the vertical profiles of turbulent momentum flux, turbulent heat flux, energy spectra and turbulent kinetic energy of the nested LES and reference LES domains with periodic boundary conditions. Through this analysis, we are able to evaluate the influence of mesoscale flow structures on the nested domains. By quantifying this biasing effect we address the limitations of the grid-nesting technique for meso-to-microscale models. This new understanding of the limitations of grid-nesting will improve nesting practices and inform developers as to where model improvements are needed most.

3.2.3 Tawfik: Dynamic Scale Awareness: Switching convection on when the asymptotic assumptions is valid

Ahmed Tawfik; NCAR; Project Scientist 1, Climate and Global Dynamics; Nation Center for Atmospheric Research

As climate simulations approach convective permitting resolutions their needs to be a more dynamic way for convective parameterizations to be activated under the appropriate assumptions. In particular, mass-flux parameterizations (among others) make the asymptotic assumption, which is to say that the area of a convective structure must be much smaller than the model grid area (i.e. sigma « 1). Using the Heated Condensation Framework as a means of parameterizing convective initiation, sigma can be directly calculated allowing for the sigma limits to be tested by turning off the deep convection scheme in CESM when the limit is violated. This presentation explores a few different sigma limits and evaluates precipitation characteristics including extreme events. Some mention will also be made regarding its use in Variable Resolution simulations to allow for a more dynamic scale awareness in locations that approach convective-permitting resolution.

4. Land-Atmosphere interactions

4.1 Oral

4.1.1 Flores: The Accidental Climate Modeler: The Increasingly Important Role of Land-Atmosphere Models for High Resolution Ecohydrologic Process Study

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Coupled land-atmosphere models capable of explicitly resolving convective processes are increasingly an indispensable tool for researchers seeking to use models to investigate ecohydrologic phenomena in sparsely observed regions. Workflow for such investigations typically include: (1) Setting up and running the coupled land atmosphere model over the region of interest, (2) verifying simulated atmospheric variables against the (albeit sparse) surface observations that are available, and (3) archiving and making available those surface variables required as inputs to application models (e.g., precipitation, air temperature, humidity, wind vector, radiant fluxes, etc.). When used at spatial resolutions capable of resolving convection, these coupled land-atmosphere models have key advantages that make them particularly useful in complex, sparsely observed regions. For example, in topographically complex landscapes these models are capable of capturing topographic characteristics that are directly responsible for forced convection. These models also serve as frameworks that fuse a variety of multi-resolution datasets capturing spatial variation in topography, soil texture, and vegetation cover/land use through a physical representation of the land-atmosphere system. Moreover, because the output surface hydrometeorological data is ultimately derived from a model it is spatially continuous and serially complete – a critical requirement when used as input to subsequent models. Use of these coupled land- atmosphere models to generate environmental forcing data as effectively proxies for otherwise nonexistent observational data is not, however, without important limitations. First, regional climate models generate a tremendous amount of data, on the order of hundreds of terabytes for decadal simulations of large regions. Management, documentation, and curation of these data, including making them quickly available to the broader community, is becoming an increasingly important portion of modeling workflows and is increasingly demanded by funding agencies. Analyses of such large datasets increasingly requires novel data science approaches that are only beginning to become available to the broader earth sciences community. Finally, because they are often used to synthesize climate datasets in sparsely observed regions it is necessary to develop innovative ways to verify and confirm model results using remote sensing datasets that often only indirectly capture the variables of interest. This presentation reports on a couple of case studies where regional climate models, run at convective-permitting spatial resolutions, have been used to synthesize datasets whose purpose is primarily for use as input to subsequent ecohydrologic models. The first case involves a 30 year historical run of the Weather Research and Forecasting (WRF) for the Snake and Boise River Basins in the interior Pacific Northwest and details some of the cyberinfrastructure improvements made at Boise State to effectively host these data. The second case reports on the use of the WRF model to investigate how land-use changes in Mozambique, driven in part by a long-term civil war and associated impacts on agriculture and collapse of large populations of herbivores, has potentially impacted regional hydroclimatic patterns. This case reports on the important relationship between the researchers and stakeholders in the region.

4.1.2 Goergen: Added value and land-atmosphere coupling in convection-permitting WRF climate simulations over a Middle European domain

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High-resolution regional climate models with a more detailed representation of heterogeneous land surface properties, as well as an explicit treatment of deep convection can lead to an improved simulation of meteorological processes and the climate system at the meso-gamma scale. In this study, results from 10 years of ERA-Interim driven convection-permitting WRF simulations at 3 km spatial resolution for a central European model domain are analyzed. In our analysis, we focus on precipitation and land-atmosphere coupling strength. Simulations from both resolutions are compared, and evaluated against high-resolution reanalysis data and gridded observations over three regions with a very moderate, low mountain and high mountain topography. Added value in the 3 km simulation is found especially at the sub-daily scale in the reproduction of intensity, diurnal cycle and spatial extent of precipitation. A positive precipitation bias found for both resolutions is more dominant in the 12 km simulation, where too much light precipitation is generated. For different seasons precipitation clearly differs between both simulations with largest differences over mountainous regions and during summer months with high convective activity. Different metrics, which quantify soil moisture-temperature coupling and feedbacks, are applied for the comparison of land-atmosphere coupling strength. For both resolutions, the interannual variability in coupling strength is consistent with the individual climate conditions; however, coupling strength is slightly stronger in summer in the 3 km simulations. The study is complimented by sensitivity experiments on the impact of surface properties and heterogeneities upon the coupling.

4.1.3 Letcher: Dynamic and non-local responses to the snow albedo feedback over the Colorado Rocky Mountains

Theodore Letcher
University at Albany

The snow albedo feedback (SAF) is a significant regional climate feedback in mountain regions with transient snow cover. Here we use high-resolution regional models to investigate how the SAF modulates local and regional scale mountain wind systems over the Colorado Rocky Mountains, and how the SAF may influence the downstream convective environment over the Great Plains. We examine output from 7-year semi-idealized high-resolution control and pseudo global warming experiments run at 4 and 12-km horizontal grid spacing. For the 12-km experiment, we run a second pseudo global warmed simulation in which the surface albedo is held fixed to that of the control simulation, effectively removing the SAF from the experiment. This allows for a cleaner attribution of changes in the climate to the SAF. We evaluate the control simulations against a mesoscale network of surface observations within the region and find that diurnal wind systems are generally well represented in the models.

We find that the SAF modulates diurnal mountain wind systems primarily by enhancing the thermal contrast between high and low elevation ranges. In general, this mechanism increases the strength of daytime upslope flows and weakens overnight downslope flows. Increased boundary layer mixing during the daytime caused by the SAF also modulates mountain wind systems, though this mechanism is of secondary importance These results are appear to be highly sensitive to model configuration. While mountain wind systems show similar changes across model configurations, there are substantial differences in the details, which are primarily related to the differences in modeled SAF strength.

We also find that enhanced boundary layer mixing and lower-tropospheric warming caused by the SAF can increase mid-level lapse rates and cap strength downstream of the Rocky Mountains. We investigate the impact of these changes on convective storms over the Great Plains.

4.1.4 Minder: Diagnosing and evaluating the snow-albedo feedback over complex terrain in high-resolution regional climate change simulations

Justin Minder
University at Albany

The snow-albedo feedback (SAF) may strongly modulate regional climate change over mid-latitude mountains. Since the dominant spatial scales of snow-cover variability and change are often small over mountainous terrain, high-resolution regional climate models (RCMs) are necessary to adequately represent the effects of the SAF. Here we present techniques for diagnosing the strength the SAF in high-resolution RCM simulations and for evaluating aspects of model skill relevant to the SAF. These techniques are applied to RCM experiments conducted with the Weather Research and Forecasting (WRF) model over domains centered on the Rocky Mountains of Colorado. Comparisons between 7 years of paired control and pseudo global warming climate change experiments are used to focus on the regional response to large-scale thermodynamic changes in climate.

First, we demonstrate how linear feedback analysis can quantify variations in the strength of the SAF and the processes that modulate it across seasons, models, and regions. The simulated SAF over the Colorado Rockies strength maximizes in April, when snow loss coincides with strong incoming solar radiation. Simulations with 4-km and 12-km horizontal grids produce a similar SAF whereas a coarser 36-km grid has a SAF with a different character due to differences in snow accumulation and ablation caused by terrain smoothing.

Second, we demonstrate how high-resolution satellite retrievals from the Moderate Resolution Imaging Spectroradiometer (MODIS) can be used to evaluate RCM skill at simulating observed variations in snow cover and albedo. We consider a pair of 4-km RCM simulations of the same 7-year period with differing model configurations. While both simulations generally reproduce the seasonality of snow cover and the influence of topographic features, they also exhibit important biases. One simulation substantially over-predicts sub-pixel fractional snow cover over snowy pixels causing large positive biases in surface albedo, likely due to the lack of explicit representation of canopy effects in the land surface model used. The other simulation exhibits a persistent negative bias in areal snow extent. Under climate change the simulations show substantially different springtime SAF-enhanced warming. Linear feedback analysis shows March-April SAF strength differs by a factor of 1.8. Differences in the SAF are tied to the differences in snow cover in their control climates of the two simulations.

4.2 Poster

4.2.1 Kollet: Terrestrial simulations from groundwater into the atmosphere over Europe and North Rhine Westphalia, Germany

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The Centre for High-Performance Scientific Computing develops and applies coupled terrestrial models from groundwater across the land surface into the atmosphere in order to improve predictions and uncertainty estimates of states and fluxes of the terrestrial water and energy cycle. Currently, HPSC TerrSys maintains two integrated models based on the Terrestrial Systems Modeling Platform (TerrSysMP) over the European CORDEX domain at 12.5km and at convection permitting resolution of 1km over North Rhine-Westphalia, Germany. The models are used to interrogate the influence of atmospheric variability on surface runoff and water resources and, in turn, of subsurface hydrodynamics on weather and climate generating processes at different space and time scales. Ongoing continuous real-time simulations consisting of three and one day forecasts of all states and fluxes for both domains, respectively, demonstrate the potential for, e.g., water resources monitoring and flood modeling in a fully integrated framework closing the water cycle from groundwater into the atmosphere. In case of the model of North Rhine-Westphalia, uncertainty quantification is performed via an ensemble of 80 model runs with different configurations of subsurface hydraulic properties.

4.2.2 Chen: Using 4-km WRF CONUS simulations to diagnose surface coupling strength

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Uncertainties in representing land-atmosphere interactions can substantially influence regional climate simulations. Among these uncertainties, the surface exchange coefficient, Ch, is a critical parameter controlling the total energy transported from the land surface to the atmosphere and directly impacts the land-atmospheric coupling strength. Yet it has not been properly evaluated for regional climate models. This study assesses the representation of surface coupling strength in 4-km WRF simulations through comparing Ch derived from WRF simulations, from offline Noah-MP simulations, and from data collected at eight FLUXNET sites of the Canadian Carbon Program (CPC), which were then categorized into four ecoclimate regions. The seasonal variations of Ch for different land-cover types in Canada calculated by using 10-year half-hourly FLUXNET data are used to evaluate surface coupling strength in WRF. Also, Ch calculated from offline Noah-MP simulations is used to contract to these from WRF to understand the impacts of uncertainties in coupled WRF simulations and in offline Noah-MP simulations on Ch. Such analysis is used to evaluate 4-km WRF simulated surface heat fluxes.

4.2.3 Nie: Modeling Study on the Impact of Anthropogenic Heat on Summertime Rainfall in Beijing using WRF

Wanshu Nie
Johns Hopkins University

Anthropogenic heat is an important component of the urban energy budget that can affect land surface and atmospheric boundary layer processes. Representation of anthropogenic heat in numerical climate modeling systems is, therefore, important when simulating urban meteorology and climate, and has the potential to improve weather forecasts, climate process studies, and energy demand analysis. Here, we incorporate spatiotemporally dynamic anthropogenic heat data estimated by the Building Effects Parameterization and Building Energy Model (BEP-BEM) into the weather research and forecasting system (WRF) to investigate its impact on simulation of summertime rainfall in Beijing, China. Simulations of four local rainfall events with and without anthropogenic heat indicate that anthropogenic heat leads to increased rainfall over the urban area. For all four events, anthropogenic heat emission increases sensible heat flux, enhances mixing and turbulent energy transport, lifts PBL height, increases dry static energy and destabilizes the atmosphere in urban areas through thermal perturbation and strong upwelling motion during pre-storm period, resulting in enhanced convergence during the major rainfall period. Intensified rainfall leads to greater atmospheric dry-down during the storm and a higher post-storm LCL.

4.2.4 Ray: Evaluation of near surface temperature using urban-aware simulations and its sensitivity to the PBL schemes

Pallav Ray, Florida Institute of Technology; James Brownlee, Florida Institute of Technology; and Mukul Tewari, IBM, T.J. Watson Research Center, New York

Numerical simulations without hydrological processes tend to overestimate the near surface temperatures over urban areas. This is presumably due to underestimation of surface latent heat flux. To test this hypothesis, a new single-layer urban canopy model (SLUCM) within the Weather Research and Forecasting (WRF) model is evaluated over Houston. Four simulations were conducted from August 24-26, 2000. The simulations include the use of the default BULK urban scheme, the SLUCM without hydrological processes, and the SLUCM with hydrological processes. The fourth simulation evaluates a mitigation option by employing the multi-layer green roof.
The results show that the BULK scheme was least accurate, and it overestimated the near surface temperatures and winds over the urban regions. The SLUCM, without any hydrological processes, was most accurate. In the presence of urban hydrological processes, the SLUCM underestimates these parameters. An analysis of the surface fluxes suggests that the error in the BULK scheme is due to a lack of moisture at the urban surface, while the error in the SLUCM with hydrological processes is due to increases in moisture at the urban surface. These results confirm earlier studies in which changes in near surface temperature were primarily due to the changes in the latent and sensible heat fluxes in the presence of hydrological processes. In the absence of hydrological processes, however, our results indicate that the changes in radiative flux contribute more to the near surface temperature changes than the latent and sensible heat fluxes. The sensitivity of these results on the planetary boundary layer (PBL) schemes will be discussed in the meeting.

5. Observational Datasets and global CPM efforts

5.1 Oral

5.1.1 Newman: Development of Gridded Ensemble Precipitation and Temperature Datasets over the Entire 50 United States

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Gridded precipitation and temperature products are inherently uncertain due to myriad factors. These include interpolation from a sparse observation network, measurement representativeness, and measurement errors. Generally, uncertainty is not included in gridded products of precipitation or temperature; if it is present, it may be included in an ad-hoc manner. A lack of quantitative uncertainty estimates for such hydrometeorological forcing fields limits their utility to support land surface and hydrologic modeling techniques such as data assimilation, probabilistic forecasting and verification.

To address this gap, we have developed a first of its kind gridded, observation-based ensemble of precipitation and temperature at a daily increment for the period 1980-2012. Statistical verification of the ensemble indicates it provides generally good reliability and discrimination of events of various magnitudes, but has a small dry bias for high probability events. The ensemble mean is similar to other widely used hydrometeorological datasets (e.g. Maurer et al. 2002) but with some important differences. The ensemble product is able to produce an improved probability-of-precipitation field, which impacts the empirical derivation of other fields (e.g. surface shortwave radiation) used in land-surface and hydrologic modeling. The ensemble is being used to verify dynamically downscaled regional climate simulations using the Weather Research and Forecasting (WRF) model. Use of the observation ensemble allows for identification of regions where WRF lies within observational uncertainty, or conversely, identifies regions where WRF is highly likely to be performing poorly.

Additionally, we are developing high resolution products for Alaska and Hawaii (2km and 250 m respectively) to complete the first ensemble observation based product suite for the entire 50 states. Initial results for Alaska and Hawaii will be presented along with plans for updates and improvements to the original CONUS product discussed above.

5.1.2 Fowler: Understanding changes in short-duration rainfall extremes under global warming: The GEWEX cross-cut on sub-daily rainfall extremes (INTENSE)

Fowler, H.J., Kendon, E.J., Chan, S., Roberts, N. Blenkinsop, S., Lewis, E., Barbero, R., Li, X., Guerreiro, S., Lenderink, G.

Rainfall extremes appear to be changing around the world but there is little information on how extreme short-duration events might change. This talk will present the aims and objectives of the GEWEX cross-cut on sub-daily rainfall extremes (INTENSE). Discussion will be made of new results from 1.5km CPM climate change integrations over southern and northern UK domains, in particular in regard to intensity, T-P scaling and duration changes. The construction of a global sub-daily precipitation dataset is underway and this will be presented as well as first results from analysis of trends and P-T scaling from this dataset.

5.1.3 Malardel: Is the ECMWF model ready for convection-permitting modeling?

Sylvie Malardel, Nils Wedi and Peter Bechtold
ECMWF

The presentation will address all the different aspects involved in the preparation of the ECMWF model for the future resolutions higher than 5 km, both in term of computer resources and improvement of physical processes. As one of the partner of the European project PRIMAVERA (PRocess-based climate sIMulation: AdVances in high resolution modelling and European climate Risk Assessment), ECMWF will perform high resolution (about 30 km) but also ultra high resolution (about 5 km) runs. One of the main objective of the Ultra High simulations is to study the sensitivity of different metrics to the repre- sentation of deep convection (parametrized versus permitted) in the models. Diagnostics on preliminary results focussed on scale interactions and energy cascades will be presented.

5.2 Poster

5.2.1 Chen: Reliability of high temporal and spatial resolution precipitation observation under weather extremes

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Hurricane and Typhoon are the major contributors to the annual damage and economic lost due to natural disaster around the world. How the characteristics of these high-impact weather extremes changes in a warming climate have attracted considerable interests from research community. One key uncertainty regarding to the previous studies is the intensity of tropical cyclone and accompanying extreme rainfall are often underestimated. With high-resolution global climate model reached 20-30 km resolution (e.g. MRI, CAM5, HiRAM, etc.), we found that these high-resolution models can start to reasonably capture the typical wind-pressure relationship found in the observed tropical cyclone. Nevertheless, the composite of rainfall associated with tropical cyclone in the model are several times higher than the corresponding typhoon rainfall estimate from satellite observation (e.g. TRMM). To explain such discrepancy, the possible underestimate from satellite rainfall retrieval for extremes associated tropical cyclone was supported from surface observation during typhoon landing period. The motivation of study is to work on a more throughout examination of the satellite rainfall estimate with surface observation along all the tropical cyclone tracks.

For high temporal and spatial resolution near global rainfall analysis, different satellite observations had been used to retrieve and construct the precipitation distribution from the combination of active and passive sensors. to calibrate the rainfall retrieval scheme. Normally surface rainfall observation was used However, they are typically optimized for all rainfall conditions from light shower to heavy downpour. Such strategy in developing retrieval algorithm might loose the dynamical range of observational signal in the heavy rainfall tail end associated with tropical cyclone. Our study co-located the available satellite and surface rainfall observation along the tropical cyclone best tracks data archive and systematically evaluate the characteristics of satellite rainfall estimate during different stages of tropical cyclone life cycle.

5.2.2 Dandu: Understanding the Revival of the Indian Summer Monsoon after Breaks

Govardhan Dandu1, Vadlamudi Brahmananda Rao2 and Karumuri Ashok1

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In this paper, we suggest a dynamical mechanism involved in the revival of summer monsoon after breaks. In this context, we carry out a diagnostic analysis using the datasets from National Centres for Environmental Prediction reanalysis-2 for the period 1979-2007 to identify a robust mechanism that typifies breaks and subsequent revival of monsoon. We find that during the peak of significant breaks, an anomalous southward shift of subtropical westerly jet stream, which is invariably accompanied by anomalous northward shift of a stronger-than-normal easterly jet. These major changes during a break facilitate an instability mechanism, which apparently leads to formation of a synoptic disturbance. Formation of such a disturbance is often critical to the subsequent revival of summer monsoon. Our computations of energetics and correlation analysis suggest an increase in the eddy kinetic energy at the expense of the mean kinetic energy during the breaks, in agreement with the formation of the synoptic disturbance with monsoon trough deepening. This demonstrates that barotropic instability in the presence of a monsoon basic flow is the primary physical mechanism that controls the summer monsoon breaks and subsequent revival of the monsoon.

5.2.3 Fall: Characterization and predictability of rainfall convective systems in the Sahel: focus on Senegal

Cheikh Modou Noreyni Fall*1, Cheikh Dione2, Mamadou Simina Drame3, Christophe Lavaysse4, Amadou Thierno Gaye1
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In West Africa, rainfall is a determining factor for the global population consists mostly of rural living on agriculture. In this area, the water cycle has a high variability on all spatial and temporal scales and depends on the dynamics of the system of the West African monsoon. Rainfall is generated by Mesoscale convective systems and squall lines (Mesoscale convective systems multicellular), but also with local storm systems of any size, such as isolated thunderstorms. The spatial and temporal distribution of the seasonal cumulative rainfall depends on the number of occurrence of these various convective systems.

This work highlights the rainfall characteristics at a small scale including that of Senegal center area. Using the synoptic observation network of ANACIM (National Agency of Civil Aviation and Meteorology) to and IRD (Institute of Research for Development) to 12 stations in center of Senegal, Thies, Fatick, Kaolack, Diourbel, Mbour, Bambey from 1960 to 2011. We generally observe a high spatial and temporal variability of the annual total and descriptors of the rainy season. including the onset, wet and dry spells and high impact rainfall or extrems events.

This high spatial and temporal variability is observed between separate stations a few kilometers. Indeed, Diourbel recorded a rain deficit in 2007 season, while for the same year was in surplus Kaolack. We showed the high frequency nature for the short dry and wet spells while the long dry and wet spell are low frequencies and strongly modulate the seasonal accumulation of rain.

Consequently, to understand this high rainfall variability in the Sahel, it is necessary to distinguish between local systems and meso-scale convective systems (MCSs). Thus, we first made a climatology of different types of convective systems observed in the Sahel from satellite data (TRMM), observations and radar (NPOL). This classification allowed us to properly quantify the contribution of each type of system on the cumulative rainfall in the area.

The originality of this study lies in the characterization of convective activity via OLR (Outgoing longwave radiation) data just before and after a long dry and wet spell. Indeed, the duration of such extreme breaks will dry the soil which helps to decrease the latent flux to increase the sensitive flux, which will warm the atmosphere. Thus, the mesoscale convective systems (MCS) and the squall lines can not be supplying moisture and therefore they will dissipate.

5.2.4 Havenga: Using classification algorithms provided by COST733CLASS (Phillip et al,. 2014) the study aims to identify homogeneous synoptic scale patterns associated with severe hailstorms over South-Africa, and more specifically Johannesburg - Southern-Africa's economic hub.

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Using classification algorithms provided by COST733CLASS (Phillip et al,. 2014) the study aims to identify homogeneous synoptic scale patterns associated with severe hailstorms over South-Africa, and more specifically Johannesburg - Southern-Africa's economic hub.

Severe storms and hail events can cause food insecurity, sickness and death, and even more so in developing countries. Past research on the synoptic scale circulation associated with hail in South-Africa has been done by Held and Carte (1979) who studied different synoptic situations that gave rise to a variety of hailstorms during 1975 in the Johannesburg area, the synoptic situations for hail days were not much different from days with normal thunderstorm activity; usually characterized by a trough or low pressure system over central South-Africa and a high-pressure system over the northern South-Africa. According to Olivier (1989) line storms along squall lines are linked with severe weather damage, but accounts for less hail fall than scattered and isolated thunderstorms in the Highveld.

Classification tools offer us an method to better understand the synoptic processes in the atmosphere and the link these processes have to severe storms. It also has benefits for short term forecasts, medium term forecasts and as a model validation tool. This understanding paves the way to understand and possibly mitigate the impacts of severe weather events.

5.2.5 Heinzeller: Towards convection-resolving, global atmospheric simulations with the Model for Prediction Across Scales (MPAS): an extreme scaling experiment

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The Model for Prediction Across Scales (MPAS) is a novel set of Earth system simulation components and consists of an atmospheric model, an ocean model and a land-ice model. Its distinct features are the use of unstructured Voronoi meshes and C-grid discretisation to address shortcomings of global models on regular grids and the use of limited area models nested in a forcing data set. This allows to include the feedback of regional land use information on weather and climate at local and global scales in a consistent way. The ability to resolve regions at different resolutions, depending on the region of interest and the particular question of research, in one consistent global model run opens the door to an entire new approach in convection-permitting climate modelling. We present an in-depth evaluation of MPAS with regards to technical aspects of performing model runs and scalability. In particular, we conduct extreme scaling tests on a global 3 km mesh with more than 65 million horizontal grid cells on up to half a million physical cores. We uncover model limitations, identify new aspects for the model optimisation and discuss necessary modifications of the model code to improve its parallel performance in general and specific to the HPC environment. We confirm good scaling (70 % parallel efficiency or better) of the numerical solver of MPAS and provide numbers on the computational requirements for experiments with the 3 km mesh. This demonstrates that global, convection-resolving atmospheric simulations with MPAS are within reach of current and next generations of high-end computing facilities.

5.2.6 Hughes: Dynamical downscaling overcomes deficiencies in gridded precipitation products in the Sierra Nevada, California

Mimi Hughes, Jessica Lundquist, and Brian Henn

Uncertainties in gridded and regional climate estimates of precipitation are large at high elevations where observations are sparse and spatial variability is substantial. We explore these uncertainties for a climatologically-unusual water year across California's Sierra Nevada in 10 datasets: six WRF regional climate downscalings with differing lateral boundary conditions and microphysical parameterizations, and four gauge-based, interpolation-gridded precipitation datasets. Precipitation from these 10 datasets is evaluated against 95 snow pillows and a precipitation dataset inferred from stream gauges using a Bayesian inference method. During this water year, the gridded datasets tend to underestimate frozen precipitation on the windward slope of the Sierra Nevada, particularly in vicinity of Yosemite National Park. The WRF simulations with single-moment microphysics tend to overestimate precipitation throughout much of the region, whereas the WRF simulations with double-moment microphysics tend to better agree with both the snow pillows and inferred precipitation estimates, although they somewhat overestimate windward/leeside precipitation contrast in the northern Sierra Nevada. In addition, the WRF simulations, in particular those with single-moment microphysics, better distinguish wet-versus-dry pillows and watersheds than the gridded estimates.

5.2.7 Margaryan: The Assessment of the Most Extreme Values Changes of Marmarik River Flow (in the Hankavan Hzdrological Point) for Spring Floods on the Context of Global Climate Change

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In the work we discussed and analyzed the maximum runoff of the river Marmarik, analyzed and evaluated the dynamics of change of the maximum runoff, based on the selected scenarios to assess the vulnerability and risk. As a source material used the actual observations of Armstatehydromet of the Ministry of emergency situations of RA for maximum runoff, air temperature and atmospheric precipitation.

5.2.8 Michaelis: Introducing Multi-Scale Kain-Fritsch scheme to the Model for Prediction Across Scales (MPAS) Global Model

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The Model for Prediction Across Scales (MPAS) is a new generation variable grid resolution global model with promising features suitable for weather prediction as well as air quality modeling. In the light of persistent reductions in NAAQS for ozone, models such as MPAS offer a natural solution to account for the global transport of air pollution that contributes to the background concentrations at local scales. Unfortunately, almost all global models suffer from the lack of scale aware physics and chemistry, constraining the accuracy of meteorological and air quality predictions. Of these processes, convective clouds play a prominent role on the atmospheric dynamics, thermodynamics, and chemical state of the atmosphere. To introduce multi-scale physics in such variable resolution models, we introduce the Multi-scale Kain-Fritsch (MSKF) scheme to the MPAS.

The objective of this research project is to test the performance of the MSKF convective parameterization scheme (Alapaty et al. 2012; Zheng et al. 2015) using the MPAS-A numerical model. MPAS-A is a non-hydrostatic, global atmosphere model that makes use of centroid Voronoi tessellations to create variable-resolution horizontal meshes. This technique allows for a gradual expansion from a localized region of mesh refinement to larger grid spacing on the rest of the globe, rather than a harsh discontinuity between domains with different grid lengths. The current Kain-Fritsch convective parameterization scheme available in MPAS-A was designed for optimization at grid lengths of 25-km. Therefore, precipitation biases tend to arise when this scheme is implemented at higher resolutions. To combat these biases, the MSKF scheme introduces several modifications, such as sub-grid scale cloud-radiation interactions, a dynamic adjustment timescale, and scale dependent entrainment effects are few among other modifications that will allow the CP scheme to scale appropriately with varying resolutions.

To study the performance of the MSKF scheme, a season long global simulation is performed starting from May 15, 2006 for 3 months. A global horizontal grid varying from 15- km over the continental United States to 60-km over the remainder of the globe was used. Results from the simulation using the MSKF scheme are compared to a simulation using the default KF scheme as well as to observational datasets, such as the Tropical Rainfall Measuring Mission (TRMM) for precipitation and quality controlled local climate data (QCLCD) for surface parameters. Evaluation results of this research will shed light on the performance of the MSKF in a global setting. Results show simulations with MSKF produce an increase in cloud cover, particularly along the ITCZ, over southern Asia, and across the United States, as well as precipitation patterns more comparable to observations.

5.2.9 Watson: Developing a 30-year hydroclimate dataset for the interior Pacific Northwest via a convection-permitting regional climate simulation

Katelyn Watson1, Matt Masarik1, Megan Maksimowicz1, and Alejandro Flores1
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Observational weather and climate data in the semiarid West, in general, and mountainous regions, in particular, are sparse, temporally discontinuous, and often poorly representative of the domain of interest. Yet these data are critically important for advancing fundamental understanding of hydrologic processes and informing water resources decision-making. Convection-permitting regional climate models can provide a stand-in for and complement the sparseness in observational data, but are computationally intensive and require substantial data management capacity. For this project we use the Weather Research and Forecasting (WRF) model to dynamically downscale the North American Regional Reanalysis (NARR) within two domains in the interior Pacific Northwest, USA for a period extending from 1985-present. The first domain resolves the entire Snake River Basin at 3 km horizontal resolution. The inner, more refined domain captures the Boise River Basin at 1 km horizontal resolution, and contains the Dry Creek and Reynolds Creek Experimental Watersheds. We evaluate modeled precipitation and temperature through comparison with gauge observations and gridded climate products. A significant component of this work involves simultaneous development of cyberinfrastructure (e.g., scripts, web-hosting, and data exploration tools) to distribute and disseminate these data to stakeholders in the area as well as the broader scientific community. This poster will describe the current status of the project from both a scientific and cyberinfrastructure perspective.

5.2.10 Schroeer: The variability of temperature sensitivity of extreme precipitation from a regional-to-local impact scale perspective

Katharina Schroeer (1,2) and Gottfried Kirchengast (1,2,3)

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Relating precipitation intensity to temperature is used to assess potential changes of extreme events that could increase rainfall induced hazards in a warming climate. Throughout existing studies there is substantial variability in scaling rates, but also consistent findings. Increases beyond the expected consistency with the Clausius-Clapeyron (CC) equation are a feature of short-duration, convective, sub-daily to sub-hourly high-percentile rainfall intensities at mid-latitudes. Exponential growth ceases or reverts at threshold temperatures that vary regionally, as moisture supply becomes limited. Here we test the meaningfulness of the scaling approach on a regional to local level, where the risk of climate and weather impact is dealt with. Temperature sensitivities are assessed using quantile regression on hourly and sub-hourly precipitation data from 189 stations in the Austrian south-eastern Alpine region. The observed scaling rates vary substantially, but distinct regional and seasonal patterns emerge. High sensitivity exceeding CC-scaling is seen on the 10-minute scale more than on the hourly scale, in storms shorter than 2 hours duration, and in shoulder seasons, but it is not always significantly different from median intensity sensitivity. To be impact relevant, change rates need to be linked to absolute rainfall amounts. We show that the highest scaling rates occur in lower temperature conditions and thus have smaller effect on absolute precipitation intensities. While pure percentage numbers should be treated with care, scaling studies can add value to process understanding on the local scale, if the factors that influence scaling rates are considered from both a methodological and a physical perspective.

6. Tropical Climate

6.1 Oral

6.1.1 Weber & Mass: Why Convection-Allowing NWP is Needed: An Evaluation of CFSv2/GFS Tropical Convection on Subseasonal Time Scales

Nick Weber and Cliff Mass
Department of Atmospheric Sciences, University of Washington

Simulating tropical convection in global models remains an important challenge for global prediction on all time scales. Tropical convective features like the Madden-Julian Oscillation (MJO), El Niño/Southern Oscillation (ENSO), and others have a large impact on global weather and climate through teleconnections, but are often poorly captured in forecast models. The MJO, for example, has a profound impact on global subseasonal predictability and global circulation statistics on synoptic to climate timescales. In this study, Climate Forecast System version 2 (CFSv2) long range reforecasts and Global Forecast System (GFS) medium range forecasts are used to examine how U.S. operational models represent tropical convection on daily to subseasonal time scales. Results show that, as lead time increases, the models tend to produce more stationary tropical convective anomalies, rather than the observed propagating features. Furthermore, CFSv2 exhibits a seasonally robust convective bias in which the model under-produces convection over tropical land and over-produces convection in the western equatorial Pacific. The latter aspect of this bias may be important regarding the model's ability to simulate the MJO, as a wet West Pacific can inhibit convective propagation past the Maritime Continent. In agreement with previous literature, the MJO produced by CFSv2 exhibits a slower phase speed than the observed MJO and is typically unable to propagate past the "Maritime Continent barrier."

Verification of the GFS/CFSv2 and other global modeling systems highlights a deficiency in the capability of global models to produce realistic tropical convection, particularly convection associated with propagating systems. Other studies have noted how models that explicitly resolve convection significantly improve upon their parameterized counterparts in terms of simulating such convection. With this in mind, an experiment is proposed in which the Model for Prediction Across

Scales (MPAS) produces global subseasonal forecasts with explicitly-resolved convection in the tropics.

6.1.2 Nolan: Comparisons of Parameterized versus Explicit Convection in Global-Scale Simulations Using the WRF Model in Aquachannel and Aquapatch Configurations

David S. Nolan
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University of Miami

Numerous studies using both global and regional models of the atmosphere have found daunting sensitivities of the structure and dynamics of the intertropical convergence zone (ITCZ) to the representations of unresolved processes, particularly the convective parameterization (CP). Evaluations of these results by comparison to high-resolution simulations with explicit convection have been rather limited, due to the large computational burden of using grid spacings less than 10 km over large domains representative of the Earth's tropics. This study introduces a framework that allows the use of cloud-resolving grid spacings over the tropics and larger spacings over remainder of the domain. The Weather Research and Forecasting (WRF) model is used in an "aquachannel" beta-plane configuration, zonally periodic with length equal to that of the real equator. This model reproduces the general circulation and eddy statistics of similarly configured aquaplanet models. A channel shortened to one third the length of the equator (the "aquapatch") also reproduces the zonal-mean circulations and eddies. Finally, nested grids embedded in the aquapatch are used to simulate tropical convection with 5.15 km resolution. The nested 5.15 km simulations produce broader and lighter rainfall distributions, making single ITCZs wider and smoothing out double ITCZ structures. They also show quite different rainfall production rates for atmospheric parameters such as convective available potential energy (CAPE) and column relative humidity (CRH). The apparent reason for these differences is that the higher resolution allows for the representation of squall lines and associated cold pools that propagate meridionally, re- distributing rainfall away from the ITCZ. Some new results with a slab ocean model will be presented, and directions for future research using this technique of nested grids in zonally periodic channels will be discussed.

6.1.3 Lackman: High-Resolution Numerical Studies of Tropical Cyclones and Climate-Change

Gary M. Lackmann
North Carolina State University

A robust aspect of dynamical climate projections, consistent with thermodynamic theory, is an increase in lower-tropospheric water vapor content with warming, while in some oceanic regions, relative humidity remains approximately constant. What are the dynamical consequences of these thermodynamic changes for cyclonic systems? Investigation of this question benefits from high resolution (6 km grid length or less) numerical experiments. Such simulations are used here to investigate how changes in the thermodynamic environment affect tropical cyclones (TC) frequency and intensity.

Dynamical mechanisms acting in tropical cyclones respond to thermodynamic changes in ways that affect both TC maximum intensity and frequency. Numerical experiments based on projected thermodynamic changes clarify the mechanism leading to (i) increases in the intensity of the strongest tropical cyclones, and (ii) the processes responsible for decreased future TC frequency. For the TC intensity study, 2-km grid length idealized simulations illustrate that a decreasing thermodynamic efficiency accompanying warming aloft helps to mitigate strengthening that would result from warmer SSTs. Strong sensitivity to the warming profile is evident. For the TC frequency problem, we use a PGW approach to demonstrate that dynamically similar disturbances in moisture-limited environments fail to undergo genesis in a warmer environment with constant relative humidity. The increased saturation deficit in mid-levels accounts for this frequency decrease, with TCs forming in marginal humidity environments accounting for most of the decrease in future activity.

6.1.4 Moncrieff: Simulation and Parameterization of Organized Tropical Convection

Mitchell W. Moncrieff, Changhai Liu, and Peter Bogenschutz

Organized tropical convection associated with the April 2009 MJO during the Year of Tropical Convection (YOTC) virtual global field campaign is simulated by the WRF model with a 1-km computational grid. ECMWF global analysis provides the initial and lateral boundary conditions, and TRMM provides verification data. This MJO event features remarkable hierarchical scale-interaction among squall-lines, mesoscale convective systems, superclusters and equatorial waves. Nonlinear dynamical models define a new paradigm for organized tropical convection parameterization: multiscale coherent structures in a turbulent environment. In 'gray-zone' nomenclature, cumulus parameterization represents sub-grid convection and dynamical models approximate the embedded (resolved-scale) organized convection. The effects on the global atmospheric circulation are examined using the Community Atmosphere Model (CAM). In overall agreement with the TRMM data, the spatial distribution of precipitation is strongly impacted in the western Pacific warm pool and the adjoining regions. In this locale the MJO is convectively active, scale-invariant cloud systems are observed (TOGA COARE), and the effects of convective heating are known to be communicated world-wide via Rossby-wave teleconnection.

6.1.5 Wang: Cloud, microphysics, radiation and dynamics – lessons from cloud-permitting simulations of the DYNAMO MJO events

Shuguang Wang, Adam Sobel
Columbia University

During October and early December of 2011, two MJO events were observed in the equatorial Indian Ocean. During the active phases of these events, the most prominent feature viewed from space is its extensive spreading cloud systems. These clouds dominate the transfer of solar and infrared radiation, reducing the radiative cooling of the atmospheric column. It has been argued that such cloud-radiation feedback (CRF) effect has important implications on the dynamics of the MJO. Based on the DYNAMO observations, we have studied in detail cloud-radiative feedback in the DYNAMO MJO events using observational analysis and numerical experiments.

In this presentation, we will show that: (1) Analysis of the column-integrated moist static energy (MSE) indicates that the MJO's MSE anomalies grow and are sustained to a significant extent by the radiative feedbacks associated with MJO moisture and cloud anomalies. (2) Cloud-resolving model (CRM) simulations driven by the large scale forcing dataset derived from the DYNAMO northern sounding array observations indicates that the simulated stratiform cloud coverage are crucial for radiative fluxes in numerical models. (3). Using limited-area CRM simulations with parameterized large-scale dynamics, we will show disabling the effect of cloud on radiation substantially reduces the amplitude the MJO, implying that CRF significantly amplifies the MJO. (4). Simulations of the MJO at gray resolution indicates that modifying the CRF substantially alters the large-scale flow and propagation of the MJO. Our findings indicate that more accurate parametrization of CRF is important step toward improving tropical convection and the MJO in cloud-permitting climate models.

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6.1.6 Ruppert: Tropical Climate Forcing by the Diurnal Cycle of Convective Clouds

James Ruppert
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Although the importance of the diurnal cycle in modulating clouds and precipitation has long been recognized, its impact on the climate system at longer timescales has remained elusive. Mounting evidence indicates that the diurnal cycle may substantially affect leading climate modes through nonlinear rectification, such as the Madden–Julian oscillation and El Niño/Southern Oscillation. In this talk, such evidence is first reviewed. Second, an idealized cloud-resolving model experiment is described wherein a diurnal timescale feedback is isolated in the shallow cumulus regime over the tropical warm pool. This feedback is isolated by lengthening the diurnal cycle, which amplifies the diurnal thermodynamic forcing that clouds respond to. It is found that the diurnal cycle accelerates the large-scale transition from shallow to deep convective clouds by increasing daily-mean cumulus heating, which in turn reduces the moisture sink due to large-scale subsidence (represented here through the "weak temperature gradient" approximation). This timescale feedback fundamentally owes to the covarying diurnal cycles in cloud-layer destabilization and moistening, which amplify with increasing diurnal period, in turn yielding more vigorous moist convection. The local invigoration of clouds by the longwave cloud–radiation effect (increased upper-cloud cooling and low- level warming) bolsters this diurnal timescale feedback, since this effect scales with cloud depth (i.e., optical thickness), and hence diurnal forcing. These findings highlight the pressing need to remedy longstanding problems associated with the diurnal cycle in climate models. Given the evident sensitivity of climate variability to diurnal processes, doing so may yield advances in climate prediction at longer timescales.

6.2 Poster

6.2.1 Zhang: The DYNAMO observations offer observational constraints for convection-permitting climate simulations

Chidong Zhang, University of Miami
Shuguang Wang, Columbia University

The recent accomplished DYNAMO (Dynamics of the MJO) field campaign collected a plethora of observations over a variety of platforms in the Indian Ocean during the boreal fall and winter seasons of 2011-2012. These observations have been extensively used to constrain numerical simulations of tropical convection and the Madden Julian Oscillations in regional and global cloud-permitting models. This talk will present a brief review of the modeling work of the DYNAMO MJO events in the past by the DYNAMO participants. We will also discuss opportunities for future observation-modeling integration offered by DYNAMO observations in several key aspects of modeling, e.g., microphysics, radiation, air-sea interaction, for GEWEX convection-permitting climate modeling activities.

6.2.2 Michaelis: Representation of Extratropical Transition of Tropical Cyclones using Global Models

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Tropical cyclones (TCs) impact society in many direct ways, and play a crucial role in Earth's energy and water cycles. Recurving TCs, and those undergoing extratropical transition (ET) are especially important in the North Atlantic and western North Pacific basins as these systems can impact major population centers outside the tropics or sub-tropics, as Irene (2011) and Sandy (2012) have recently demonstrated in the US. Further, outflow from recurving or transitioning TCs can lead to the formation or amplification of midlatitude Rossby wave trains, which can be associated with impactful weather, such as cold-air outbreaks or heavy precipitation far removed from the location of the TC itself. Finally, numerical weather prediction (NWP) models are demonstrably challenged in representing these outflow-generated wave trains. Previous work has been done investigating potential changes in TCs due to warming; however, there remain some important gaps in understanding how climate change affects tropical cyclones. Additionally, relatively few studies have examined how climate change would affect the process, frequency, and intensity of TC extratropical transition (ET).

The overall objective of this project is to examine how the intensity and frequency of recurving and extratropically transitioning TCs will be affected by climate change. To do this, high- resolution seasonal simulations will be conducted in current and future thermodynamic environments. TCs will then be tracked to construct current and future climatologies of recurving and ET TCs. The Model for Prediction Across Scales (MPAS) and the Global Weather Research and Forecasting Model (GWRF) are candidate models for conducting this research. First, however, initial model comparison concerning the treatment of large-scale mean fields such as jet stream location, annual precipitation patterns, and stationary pressure systems will be done. This comparison between the initial runs of MPAS and GWRF will be done at coarse resolution (60km horizontal grid spacing).

Additionally, simulations of several individual ET TC events exhibiting varying degrees of intensity will be completed to determine the appropriate modeling aspects, such as grid spacing, physics parameterizations, fine-resolution mesh and nest placement, etc. that result in the most accurate representation of the extratropical transition process. Ensembles for these case studies will include varying initial conditions and convective parameterization schemes. Grid spacing for the fine-resolution mesh or innermost nest will most likely be on the order of 4 km in order to best capture the ET process. A pseudo-global warming (PGW) technique will be implemented to simulate the same ET TC cases in a future thermodynamic environment under the IPCC AR5 RCP 8.5 emissions scenario to examine how these events would be altered by climate change.

The results to be presented include the initial model comparison and case study analysis. Time permitting, comparison of TC climatologies in the current climate, including recurving and ET TCs, between the model and observations will be shown.

6.2.3 Coumba: Influence of Madden-Julian Oscillation on the summer West African monsoon in AMIP simulations

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Intraseasonal variability of rainfall over West Africa plays a significant role in the economy of the region and is highly linked to agriculture and water resources. This research study aims to investigate the relationship between Madden Julian Oscillation (MJO) and rainfall over West Africa during the boreal summer in the the state-of-the-art Atmospheric Model Intercomparison Project (AMIP) type simulations performed by Atmosphere General Circulation Models (GCMs) forced with prescribed Sea Surface Temperature (SST). It aims to determine the impact of MJO on rainfall and convection over West Africa and identify the dynamical processes which are involved in the state-of-the-art climate simulations.

The simulations show in general good skills in capturing its main characteristics as well as its influence on rainfall over West Africa. Most of the models simulate an eastward spatiotemporal propagation of enhanced and suppressed convection similar to the observed MJO, although their signal over West Africa is weaker in some models. In addition, the ensemble average of models gives a better performance in reproducing the main features and timing of the MJO and its impact over West Africa. The influence on rainfall is well captured in both Sahel and Guinea regions thereby adequately producing the transition between positive and negative rainfall anomalies through the different phases as in the observation. Furthermore, the results show that a strong active convective phase is clearly associated with a stronger African Easterly Jet (AEJ) but the weak convective phase is associated with a much weaker AEJ.

Our analysis of the equatorial waves suggests that the main impact over West Africa is established by the propagation of low-frequency waves within the MJO and Rossby spectral peaks. Results from the simulations confirm that it may be possible to predict anomalous convection over West Africa with a time lead of 15-20 day.