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CPCM

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VII Convection Permitting Climate Modeling Workshop

BOOK OF ABSTRACTS

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KEYNOTE

Convection Permitting to Snow Drift Resolving and Back Again

Ethan Gutmann
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Abstract

Snow is a crucial water resource, and a major control on the surface energy balance. As such, it is important to model it correctly both for water resource management in a future climate, and to improve high-resolution convection permitting climate models. Here we illustrate some of the key processes that are important for arctic and alpine snow. In particular, blowing snow sublimation and snow redistribution both have important feedbacks to the atmosphere and to water resource management, but are missing, or not well modelled in current convection permitting models. We use new observations from the Sublimation of Snow (SOS) and Surface Atmosphere Integrated field Laboratory (SAIL) field campaigns, combined with airborne lidar snow depth maps from the Airborne Snow Observatory (ASO) to highlight the importance of these processes. We then show how convection permitting models are important to realistically simulate mountain winds so that snow redistribution can be simulated in the first place and illustrate how redistribution changes the kilometer-scale albedo. This has important implications for the snow albedo feedback effect as shown in kilometer scale atmospheric model sensitivity experiments and is likely to have implications for modelling spring and summer orographic convection and valley winds. Finally, we show the first continental scale snow drift resolving simulations using SnowModel on a 100 m grid over the Contiguous United States (CONUS) run using a convection permitting model as input. These simulations and new observations should be used to improve the representation of snow in convection permitting models to improve our understanding of future climate change impacts.

Land-Atmosphere Interactions at High Northern Latitudes

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Abstract

Climate change is influencing the high latitudes more rapidly and significantly than any other region of the Earth. A warmer climate has already led to thawing of permafrost, reduced snow cover, a longer growing season and vegetation shifts; changes, which in turn influence the atmospheric circulation and the hydrological cycle. Still, many studies rely on one-way coupling between the atmosphere and the land surface, thereby neglecting important interactions and feedbacks. LATICE (Land-ATmosphere Interactions in Cold Environments)[1], recognised as a Strategic Research Initiative by the Faculty of Mathematics and Natural Sciences at the University of Oslo, aims to advance the knowledge base concerning land-atmosphere interactions and their role in controlling climate variability and climate change in northern environments. Along with the EMERALD (Terrestrial ecosystem-climate interactions of our EMERALD planet) project[2] funded by the Research Council of Norway, the team focuses on improved understanding of high latitude environmental processes and their representation in Earth System model (ESMs), notable the Norwegian ESM (NorESM). The emphasis is on boreal and Arctic vegetation and the influence of a variable seasonal snow cover. The consortium consists of an interdisciplinary team of experts from atmospheric and terrestrial (hydrosphere, cryosphere and biosphere) research groups, together with key expertise on earth observations (remote and in-situ data) and novel sensor technologies. The talk highlights key activities and scientific achievements, presents some example studies and discusses the way forward.

[1] http://www.mn.uio.no/latice

[2] https://www.mn.uio.no/geo/english/research/projects/emerald/

KEYNOTE

Using European CPMs and observations to understand changes to weather extremes and their impacts.

Hayley J. Fowler[1], Steven Chan[1], Abdullah Kahraman[1,2], Colin Manning[1,2], Elizabeth Lewis[1], David Pritchard[1], Stephen Blenkinsop[1], Sean Wilkinson[1], Sarah Dunn[1], Elizabeth Kendon[2,3]
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Abstract

European-scale CPMs and the CPM ensemble projections over the UK (UKCP Local) have been exploited to examine changes to extreme weather (rainfall, wind, hail, lightning) and their compounding impacts with global warming. These analyses suggest that dynamical changes are important in the manifestation of change to some types of extreme weather which must be addressed in the design of new CPM ensembles. We provide the first analysis of impacts on infrastructure systems using a new consequence forecasting framework and produce guidance for adaptation. The presentation will also introduce new sub-daily precipitation indices now available to the community for climate model evaluation and the benefits of using these rather than reanalysis data for the assessment of extreme precipitation.

KEYNOTE

On the need of a coordinated Convection Permitting regional climate modelling development strategy over the CORDEX domains

Erika Coppola
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Abstract

In the last decade the possibility to reach convection permitting scales for regional climate model projections has been explored and starting from single model experiment studies we have now available coordinated ensemble experiments at convection permitting scale in several continents. The strategy of coordinated ensembles has been adopted to test the reliability of the models as such high resolutions and for the need to compute a signal to noise analysis on the possible detected climate change signals. Due to the limits of the available computational HPC resources the above experiment have been organized for reduced size domains compared to the now standard continental scale regions used for dynamical downscaling as for example in CORDEX community and also in time slice mode.

Although limited in the strategy these experiments have proof the model ability to simulate the present-day climate and have shown the improvement in several statistic at the sub-daily scale due to the explicit convection when compared to the parametrized models. Moreover, through the ensemble approach has been possible to assess the signal of reduced uncertainty for both present day climate and for future projection for frequency intensity and extreme precipitation especially at the hourly time scale. All these advocates for the need to move to the next step of coordination and have multiple coordinated platforms in different continents where discuss the model developments needed to improve the already existing models, to be able to include a more accurate representation of the Earth system components and to establish a set of domains that could maximize the number of models able to produce CP climate projections.

KEYNOTE

CPM for Society and Managing Risk

Jason P Evans
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Abstract

How can CPM be used to help society manage risk? Managing risk is central to many aspects of society from the insurance industry, to the engineering design for structures, to the provision of emergency services. Many (if not most) of the risks we manage for are climate related hazards such as heatwaves, drought, wildfires, extreme rain, hail, floods, extreme wind gusts, tropical cyclones,…. All of these hazards are expected to change due to global warming. Most of these hazards, particularly rare and extreme forms of them, are poorly modelled at low resolution but have large potential to be modelled well at CP resolutions. This talk explores some examples of industry and government needs for knowledge around future changes in climate hazards, examples CPM that addresses these needs, and the remaining large gaps in knowledge that (good) CPM could help society address.

KEYNOTE

Weather-Climate Interations

Kristen Rasmussen
Colorado State University, USA

Topic 1: Mountainous and high-latitude regions

First Ensemble of Kilometer-Scale Simulations of a Hydrological Year over the Third Pole

Emily Collier[1], Bodo Ahrens[2], Nikolina Ban[1], Deliang Chen[3], Xingchao Chen[4], Shabeh ul Hasson[5], Hui-Wen Lai[3], Lu Li[6], Tinghai Ou[3], Emily Potter[1], Andreas F Prein[7], Niklas Richter[1], Koichi Sakaguchi[8], Marie Schroeder[1], Prashant Singh[2], Stefan Sobolowski[6], Shiori Sugimoto[9], Jianping Tang[10], Hongyong Yu[11]
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Abstract

A robust understanding of the current and future water cycle over the Tibetan Plateau is of paramount societal importance, due to the role this region plays as a water tower for densely populated areas downstream. An emerging and promising approach for skillful climate assessments over regions of complex terrain is kilometer-scale climate simulations. As a foundational step towards such simulations over the Tibetan Plateau, we present a groundbreaking multi-model and multi-physics ensemble of kilometer-scale simulations for the hydrological year of October 2019 to September 2020 (WY2020). The ensemble consists of eleven simulations driven by ERA5 reanalysis and configured with a horizontal grid spacing ranging from 2.2 to 4 km over High Mountain Asia. These were performed by a group of international collaborators as part of the CORDEX FPS on Convection-Permitting Third Pole (CPTP) project. The simulations are compared against available gridded, in-situ observations and remotely sensed data, with the aim of assessing the reliability, spread and added value of the model ensemble compared to the driving reanalysis for both the cold and warm seasons and at sub-diurnal timescales. One notable result is that the ensemble improves on many metrics of warm season precipitation compared with ERA5, including correcting the overestimation of wet-event frequency and underestimation of heavy-event intensity. Additionally, the ensemble provides a better representation of sub-diurnal scale precipitation statistics, including the timing and amplitude of convective precipitation and the intensity of wet and heavy hourly precipitation. We note, however, that there is a large spread between the gridded precipitation datasets used as reference over this region. The CPTP ensemble for WY2020 will soon be made available to the wider scientific community and provide an invaluable resource to improve process understanding of the water cycle over this remote but important region.

Topic 1: Mountainous and high-latitude regions

Historical and future changes in extreme snowfall in coastal and mountainous areas in Japan

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Abstract

Japan has much snowfall at the coastal areas along the Sea of Japan, especially in the mountainous areas. The northwesterly related to East Asian Winter Monsoon and warm Sea of Japan bring heavy snowfall over the mountainous areas. The annual maximum snow depth exceeds 5 m. Heavy snowfall, however, sometimes occurs at the plain areas along the Sea of Japan when the Japan sea Polar airmass Convergence Zone (JPCZ) hit the coastal area. The JPCZ is formed by the convergence of northwesterly circumventing the Changbai Mountains in Korea Peninsula. In general, global warming accelerates a conversion from snowfall to rainfall and snow melting. In contrast, the snowfall extreme could be enhanced by global warming because of an increase in water vapor due to ocean and atmospheric warming. This study evaluates the historical and future changes in extreme snowfall at coastal and mountainous areas due to global warming using several high-resolution regional climate datasets including convection-permitting climate simulation.

Historical long-term 5-km simulations indicates that the extreme snowfall has apparently decreased over the plain areas along Sea of Japan, while the decreasing trends is small in the mountainous area and northern parts of Japan. On the other hand, the negative pseudo global warming experiments show that an enhancement of JPCZ and extreme snowfall over the mountainous areas due to global warming. Our future climate projections indicate that global warming largely reduces the snowfall in the coastal areas, while it has a possibility to enhance the mid-winter mountainous snowfall extremes. An enhancement of precipitation induced by JPCZ also results in an increase in extreme snowfall at high elevations.

ORALS

Topic 1: Mountainous and high-latitude regions

Mechanisms of precipitation in the Peruvian Andes: ENSO and extremes

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Abstract

Mountain water resources in the Peruvian Andes are vital for sustaining both rural and urban water supplies, agriculture, hydropower and high-elevation ecosystems. Precipitation in the Peruvian Andes has been linked to the El Niño Southern Oscillation (ENSO), but the exact effects of this large-scale climate phenomena on local precipitation are poorly understood. Here we utilize data from a convection-permitting climate simulation from 1980 to 2018 to better understand these effects over two regions of the Peruvian Andes, the Rio Santa and the Vilcanota-Urubamba.

Our analysis shows that El Niño events cause warming throughout the year in both regions, but has varying seasonal impacts on precipitation, with increased precipitation in November and decreased precipitation in February. The high resolution and long temporal length of the regional climate simulations also facilitates an understanding of the effect of ENSO on extremes. We find that a greater proportion of total precipitation comes from heavier rainfall during El Niño years compared with neutral and La Niña years. Lastly, we explore the mechanisms driving this extreme precipitation and find that convection detected from increased wind convergence at 500 hPa is a greater contributor to extreme precipitation than advection of moisture into the Andes.

Our analysis highlights the need to use data from models explicitly simulating deep convection to fully understand drivers of precipitation variability in this region of complex terrain.

Topic 1: Mountainous and high-latitude regions

Physically based separation of annual maximum precipitation in convection-permitting climate projections

Andreas Dobler, Oskar Andreas Landgren, Anita Verpe Dyrrdal
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Abstract

The Swedish, Finnish, Danish and Norwegian meteorological institutes collaboratively produced the Nordic Convection Permitting Climate Projections (NorCP) using the regional climate model HARMONIE-Climate. The global EC-EARTH and GFDL-CM3 models have been downscaled to a 3 km domain covering the whole of Fennoscandia for the time periods 1986-2005, 2041-2060 and 2081-2100 (following RCP8.5). We present changes in annual maximum precipitation in the NorCP projections and provide an analysis of the convective, stratiform and orographic-stratiform contributions to the changes.

Overall, the projections show more frequent daily and sub-daily heavy precipitation events and fewer low-intensity events with the most pronounced changes in summer. Relative changes in estimated 100-year return levels are generally larger than for 2-year return levels. The same holds true for the 20-year maximum of annual maximum hourly precipitation compared to the 20-year median, implying the largest increase in the most extreme precipitation events. However, exceptions are seen in the northern part of the domain when downscaling GFDL-CM3; a model which was selected due to its strong climate change signal in the north while successfully reproducing the current climate. Here, the 20-year median is increasing more than the 20-year maximum, and the 2-year return level more than the 100-year return level.

A separation of the annual maxima into their convective, stratiform and orographic-stratiform parts shows that changes in the stratiform contribution are generally higher than changes in the convective contribution. Further, contrary to the convective parts, are the changes in the stratiform parts of the 20-year maxima larger than (or similar to) changes in the 20-year median. However, stratiform precipitation contributes only about 10-20% to the median and 5-10% to the highest annual maxima and the annual maxima changes are dominated by changes in convective precipitation.

ORALS

Topic 1: Mountainous and high-latitude regions

The influence of land cover on rain-on-snow climatology over Norway

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Abstract

Rain-on-snow (ROS) events are most commonly found in sub-polar and alpine climates where they pose a considerable threat to society and nature. While the relationship between ROS frequency and large-scale climate features have been identified, little is known about the role of localised factors, such as land cover, in ROS frequency. Importantly, the impact of future land cover changes, such as afforestation, on ROS frequency is also unknown. In this study, we use gridded observational products and kilometer-scale regional climate simulations to investigate the comparative roles of forests and open spaces in ROS frequency, and to identify the impact of afforestation on ROS frequency. The seNorge gridded observational products generally show that evergreen forests have a higher ROS frequency than open spaces despite the large discrepancies in land cover between different datasets. The observed behaviour was well simulated by a regional climate model, albeit with a more pronounced difference between ROS frequency in forests and open spaces. Model-based results show that future changes in ROS frequency are larger in evergreen forests than in open spaces, and afforestation will increase the frequency of ROS events. Our results demonstrate the relationship between land cover and ROS frequency and highlight the need to include unique features of the local climate system, such as ROS events, in studies on climate and land use land cover change. Importantly, our study shows that afforestation policies in sub-polar and alpine regions should carefully consider the impacts of such policies on ROS frequency and the downstream consequences for society and nature.

ORALS

Topic 1: Mountainous and high-latitude regions

Do kilometer-scale climate models really perform better over complex topography?

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Abstract

Climate and weather simulations are challenging in mountainous regions, due to the complex topography and associated mesoscale meteorological processes. With the advent of kilometer-scale regional climate simulations, topography is much better represented - as valleys and peaks are explicitly present on the model grid. These kilometer-scale simulations have been shown to bring significant improvements in the representation of precipitation and temperature. However, knowledge on the added value of kilometer-scale models specifically over complex topography has been obscured by analyses not explicitly taking into account the complexity of the terrain.

In this study, we evaluate a regional climate simulation with a grid spacing of 2 km and its driving simulation at 12 km grid spacing against high-resolution in situ and satellite observations of temperature, precipitation and cloud cover over Europe. We define and distinguish high mountains, low mountains, hills and flatland within various subregions centred on different mountain ranges.

The increase in the resolution is found to clearly improve model performance in simulating mean temperature and precipitation distributions over flatland. However, the added value of using higher resolution is much smaller over complex mountainous terrain than over flatland. Complementary investigation of the diurnal cycle of low and high clouds let us hypothesize that the reduced added value over complex topography could be due to inappropriate parameterizations. Indeed, boundary layer parameterizations typically assume a flat surface and neglect horizontal turbulent fluxes that can matter in valley-scale circulations.

These results suggest that the full potential of kilometer-scale models may not be reached in regions of complex topography, calling for future research to improve the remaining parametrizations and adapt them to the higher resolution.

Topic 2: Extremes and Impacts

Title: TBA

Julia Curio, University of Gothenburg

Topic 2: Extremes and Impacts

Analyses of strong wind events in km-scale climate simulations over Germany

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Abstract

The overall progressing climate change affects processes on all horizontal scales, from the global to the local scale. For the local climate, the impact of climate change is more heterogeneous due to small-scale features like orography, coastlines and effects of urban areas and land use. Apart from mean climate change conditions, even more important with noticeable impacts are the changing frequencies and intensities of extreme events such as midlatitude winter storms and wind gust fronts during strong convective events.

In the project “BMDV - Network of experts: Adapting transport infrastructure to climate change and extreme weather events”, we address the needs of our project partners for high spatial and temporal resolved climate model data by performing km-scale climate simulations with the regional climate model COSMO-CLM. Thus, we analyse the small-scale effects of strong winds, which play an important role, among others, for the traffic infrastructure in Germany.

We performed climate projections on a domain centred over Germany with COSMO-CLM 5.0 on a 3x3 km2 grid width using the RCP 8.5 scenario, dynamically downscaling from MIROC-MIROC5 global model data with an intermediate nest. The convection parameterization was partly turned off, so deep convection was solved explicitly. The simulations were performed for 30-year time slices, covering a historical time period (1971-2000) and two future time periods. An additional evaluation run was performed for the time range of 1971 to 2019, driven by ERA-40 with a two-way nesting for 1971 to 1978 and with direct downscaling of ERA5 from 1979 onwards.

For our analyses of the COSMO-CLM simulations, we use observation data from weather stations and reanalyses data. Focus of our analyses of modelled winds are the extremes as well as the quantification of added value from the high resolution in comparison to the forcing model data. Results of these analyses will be presented.

Topic 2: Extremes and Impacts

Extreme precipitation events during dry years as depicted by the set of FPS-SESA convection-permitting simulations

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Abstract

Extreme daily precipitation events in Southeastern South America (SESA) dominate the contribution to the hydrological cycle, having large impacts on the different productive systems over this highly populated area. Since 2018, SESA has been experiencing unprecedented dry conditions that, combined with high temperatures, have led to widespread crop failures, wildfires and reduced water availability. Although the recent years were characterized by these particularly dry conditions, many extreme and localized precipitation events occurred over SESA.

In the second phase of the Coordinated Regional Downscaling Experiment (CORDEX) Flagship Pilot Study (FPS) over SESA (FPS-SESA) a targeted kilometer-scale climate modeling experiment was designed covering 3 consecutive years from June 2018 to May 2021 to study extreme precipitation events during this exceptional dry period. Different RCMs and institutions contributed to this experiment with 5 simulations, 2 of them based on WRF (University of Cantabria and NCAR South America Affinity Group) and 3 based on RegCM5 (University of Sao Paulo and ICTP).

This study analyses extreme precipitation events during dry conditions over SESA as depicted by this set of convection-permitting simulations (CPRCMs). To this end, different temporal and spatial aspects of daily extreme precipitation (location, intensity, sequence and spatial coverage) are evaluated together with the dominant dry conditions and the occurrence of dry spells, using ERA5 and different observational datasets as reference. The inter-comparison of wet and dry events varied across SESA -depending on the aspect analysed- showing some differences among observational datasets and CPRCMs. Extreme daily precipitation tends to occur in sectorized areas of SESA conditioned by dominant circulation structures. CPRCMs were able to successfully reproduce these features associated with extreme precipitation frequencies but exhibit some spread in their location and intensity.

Topic 2: Extremes and Impacts

More extreme land surface states contribute to the intensification of organised convection in a convection-permitting climate projection

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Abstract

Convection-permitting (CP) climate simulations represent a major advance in capturing land surface effects on convection. From observational analyses in West Africa, we know that land surface conditions are a major driver of storm initiation as well as intensification during later stages of the storm life cycle. Dry soils of 10 km to several 100s of km scale can cause anomalous warming of the planetary boundary layer and affect horizontal circulations, regional moisture convergence as well as instability. However, to date it remains unclear whether, in a warming climate, larger and more intense storms may change the scale and frequency of surface patterns, feeding back on these identified processes. Here, we evaluate the ability of a pioneering convection-permitting (4.4km) pan-African climate simulation to capture the observed land effects on the pre-convective environment in West Africa and subsequent storm characteristics and rainfall intensities. This is compared to a CP climate projection representing a decade under a very high emission scenario around 2100 in order to reveal potential changes in process interactions and consequences for organised convection in the future. Our study shows that the intensification of future storms by mean global warming is further enhanced by higher amplitudes of soil wetting and drying cycles, enhancing hydro-meteorological extreme states on the event timescale.

Topic 3: Model Development

Progress in Tibetan Plateau Climate System Model (TPCSM) Development

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Abstract

The Tibetan Plateau (TP) experiences strong land-atmosphere interactions that significantly influence the regional climate. However, the TP's complex terrain and heterogeneous underlying surfaces pose challenges for regional climate modeling, with apparent biases including too much precipitation and snow cover, too cold near-surface air, and too strong wind speed. To address these issues, we have developed the Tibetan Plateau Climate System Model (TPCSM) based on WRF4.0, which improves the representation of complex terrain and incorporates land surface processes parameterizations specific to the TP. By implementing the turbulent orographic form drag, TPCSM weakens wind speed and water vapor transport, improving the simulation of wintertime precipitation in the western TP and summertime precipitation in the Himalayan range and southeastern TP. The model includes an orographic factor for snow cover simulation and a scheme for shallow snow albedo, reducing overestimations of albedo and snow cover as well as cold bias in temperature. The TPCSM corrects the distorted representation of underlying surface by identifying stony areas using satellite data, which reduces the wet and cold biases in the southern TP. Meanwhile, a new soil hydraulic scheme that considers the soil organic matter has been coupled in TPCSM, enhancing the ability to reproduce soil moisture and precipitation. The introduction of a parameterization of bare ground thermal roughness length effectively improves the simulation of temperature in the TP. In addition, observation-based parameterizations of lake surface and internal thermal processes have been applied in TPCSM, leading to reasonable simulations of lake thermal features and freeze onset timing. Overall, these parameterization schemes have significantly enhanced the ability of TPCSM to simulate the local climate, making it an effective tool for better understanding land-atmosphere interactions in the TP and their impacts on the regional climate.

Topic 3: Model Development

Exploring land surface interactions in convection-permitting simulations for Europe

Kate Halladay, Ségolène Berthou, Elizabeth Kendon
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Abstract

Warm and dry biases were found in 2.2km convection-permitting model (CPM) simulations for Europe that could be larger than in the driving 12 km RCM, so we performed sensitivity tests that aimed to reduce the biases. We found that dry biases could be improved with a more complex runoff scheme taking into account groundwater and topography, reducing the threshold for vegetation water stress and changing to a new double-moment microphysics scheme, which altered the rainfall intensity distribution (i.e. the proportions of heavy and light rainfall). Changes in the rainfall intensity distribution, which also occur as a result of the change from parameterised to explicit convection, affect the proportion of evaporation from vegetation surfaces (canopy evaporation) versus the soil store. This can alter the total evapotranspiration (ET) in some regions. We found that increasing the capacity of the canopy store slightly decreased warm biases, however we recommend additional storage at the surface or below ground combined with a groundwater scheme. We also tested the impact of unlimited soil moisture on precipitation and ET by increasing soil moisture to the critical point across the whole domain using the irrigation scheme. This increased precipitation in southern Europe but not in northern France, northern Germany or the UK suggesting that soil moisture is less connected to precipitation in the northern part of the domain. Instead, precipitation in this area was more impacted by changing the cloud scheme. This work helps to highlight the challenges involved in representing land-atmosphere interactions in CPMs, which are important for future projections.

Topic 3: Model Development

How strong is land-atmosphere coupling in global storm-resolving simulations?

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Abstract

The debate on the sign of land-atmosphere coupling has not been solved so far. On the one hand, studies using global coarse-resolution climate models have claimed that the land-atmosphere coupling is positive. But, such models use convective parameterizations, which is a source of uncertainty. On the other hand, studies using regional climate models with explicit convection have reported negative coupling. Yet, the large-scale circulation is prescribed in such models and interactions with the ocean are neglected. In this study, we revisit the land-atmosphere coupling using a global fully coupled storm-resolving simulation that has been integrated at a grid spacing of 5 km over a full seasonal cycle, and we compare these results to a coarse-resolution climate model simulation using parameterized convection. We find that the coupling between soil moisture and precipitation is weaker in the storm-resolving than in the coarse-resolution simulation. This results both from a weaker coupling between soil moisture and evapotranspiration as well as between evapotranspiration and precipitation. Still, the latter segment of the coupling contributes most to the differences. Reasons for the differences will be mentioned.

Topic 3: Model Development

The ITCZ in convection-resolving climate models

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Abstract

The intertropical convergence zone (ITCZ) is a central element of the general circulation and at the core of the atmospheric heat engine. The representation of the ITCZ in global climate models is plagued by a misrepresentation of the ITCZ's seasonal cycle, often referred to as the double-ITCZ problem. This is considered as one of the most difficult problems in global climate modelling, and it even occurs in atmospheric simulations with prescribed SST.

In this presentation we will address the question whether multiyear limited-area km-resolution atmospheric simulations can alleviate these biases. The simulations use the COSMO model with grid spacings of 3.3 to 12 km over the Atlantic. It is demonstrated that km-resolution simulations driven by reanalysis yield an accurate representation of the ITCZ without double-ITCZ problem. Future climate simulations under the PGW approach show a vertical extension of the troposphere and an associated lifting of the anvil clouds throughout the deep tropics. The ascending branch of the Hadley circulation responds with a narrowing and a localized intensification near the equator. Associated changes in cloud feedbacks deviate substantially from those of the driving GCM.

It is also shown that the beneficial impacts of explicit convection can be replicated in lower-resolution (12 km resolution) simulations when using explicit convection. Experiments with conventional downscaling show that a credible representation of the ITCZ requires the biases of the driving GCM to be accounted for. When debiasing the driving GCM using a variant of the PGW approach, the double-ITCZ bias is removed in the RCM simulation.

Overall, the results show that convection-resolving RCMs are an attractive tool to assess climate feedbacks in the tropics. Both conventional downscaling (with debiasing of the driving GCM) and PGW downscaling are able to remove the double-ITCZ bias of the driving GCM.

Topic 4: CPCM for society, adaptation planning and Mitigating risk

NUKLEUS – Developing Prototype Services from Convection-Permitting Climate Data

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Abstract

With current developments in climate science it becomes increasingly feasible to provide climate information at the kilometer-scale. Within the funding measure RegIKlim by the German Federal Ministry of Education and Research (BMBF), the NUKLEUS project provides the first multi-model ensemble at convection-permitting resolution for Germany. The users of climate information in RegIKlim are organized in six projects across Germany, which cover a wide range of climatic, geographical and socio-economic conditions. The main aim of the first phase of RegIKlim ending in 2023 is to develop prototype interfaces to impact models and decision support tools of the users in the model regions.

NUKLEUS baseline climate information is coming from preliminary EURO-CORDEX CMIP6 simulations, which is further refined to roughly 3 km horizontal resolution and 30-year time-slices for Germany with three convection-permitting climate models (ICON-CLM, COSMO-CLM, REMO-NH). At the interface to the users, NUKLEUS provides easy-access to data and post-processing opportunities using the FREVA system. FREVA offers various access-levels from shell to web-based.

We will present the entire chain from climate simulations to prototype applications at the level of municipalities. Starting with an overview on the created mini-ensemble, how the data is accessed via the FREVA system, and ending with two example applications. The first is related to the meteorological forcing for the urban climate model ENVI-met. In our example ENVI-met is used to investigate hot spells in future climates and their impact on human heat stress in urban areas. The second application is from the model region KLIMAKONFORM. In KLIMAKONFORM climate simulations serve as input to the distributed, physically based hydrologic model WaSiM ETH. Resolutions of 11 km against 3 km in terms of orographic effects focusing discharge will be evaluated.

Topic 4: CPCM for society, adaptation planning and Mitigating risk

Merging convection permitting modeling results with CMIP6 to produce scenarios for local precipitation extremes for the Netherlands

Geert Lenderink, Hylke de Vries
KNMI, De Bilt, Netherlands

Abstract

Convection permitting climate models (CPMs) display much improved present-day rainfall statistics at local scales as compared to common regional and global climate models. Yet, because CPMs are computationally very demanding, runs are short, typically covering 10 to 20 years only, which makes it hard to distinguish the changes due to global warming from the noise due to internal variability. In addition, runs cover a limited set of changes at larger scales as only few global climate models have been downscaled so far. Here, we discus these issues within the context of the production of the next generation Dutch climate scenarios (release fall 2023). We use spatial pooling to improve signal to noise. In addition, pseudo-global warming (PGW) simulation also provide better signal-to-noise, which is in particular useful for large scale winter precipitation extremes where pooling is not effective. To produce scenarios for local rainfall extremes, we combined information from the CPMs with information from CMIP6 and one RCM (RACMO) using a simple scaling framework. From the CPMs we derived sensitivities of changes in rainfall intensity to surface dew point temperature change. By using spatial pooling and by taking out rain frequency change (using wet conditional statistics) a reasonable collapse of the data of 7 CPM simulations could be obtained, with typical dependencies between 1 and 2 times the Clausius Clapeyron relation. The change in rain frequency and the dew point temperature are derived from a set of RACMO simulations using PGW combined with a simple perturbed physics method. With these RACMO simulations we aimed to cover a range in large-scale conditions compatible with CMIP6. Subsequently, rain intensity change and frequency change are combined using a transformation of the observed rainfall distribution. In this way, we could produce a set of climate scenarios for local precipitation extremes covering a wide range in global change conditions.

Topic 4: CPCM for society, adaptation planning and Mitigating risk

First Rains: Putting CPMs to the test for S2S onset forecasts.

Neil CG Hart
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Abstract

Climate projections are warning of large-scale delays in the start of the rainy seasons in the southern monsoons of Africa and South America, however, actionable forewarnings of delayed onsets remain elusive at subseasonal-to-seasonal (S2S) prediction horizons. This presentation will introduce *First Rains*, a 4-year project focused on determining whether S2S convective-scale forecast systems may advance prediction skill for onset. Two key results have motivated this effort. First, that the rainfall distributions of CPMs better represent the spatial distribution and temporal intensity of the convective rainfall so critical to increasing soil moisture for planting. Second is that there have been a handful of published results suggesting improved subtropical mean climatologies in continental-domain CPM climate simulations. Climate-length CPM simulations completed at the UK Met Office are already available over South America and Africa and initial onset characteristics from these simulations will be presented. A key part of this work is that these characteristics diagnose agricultural specific statistics, moving beyond traditional rainfall accumulation metrics. We will conclude with the outlook for the S2S ensemble experiment designs to be run as part of *First Rains*.

Topic 4: CPCM for society, adaptation planning and Mitigating risk

Exploiting new 100y km-scale projections to gain understanding of future changes in local weather extremes

Elizabeth Kendon [1,2], Chris Short[1], Erich Fischer[3]
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Abstract

At the UK Met Office, we recently released the first continuous 100-year ensemble projections at 2.2km resolution over the UK – the UKCP Local Transient Projections (launched 30 March 2023). These augment the original UKCP Local projections, spanning the past, present and future continuously out to 2080. This is a unique dataset allowing us to explore how changes in local weather extremes will manifest through time, and to put observed events into the context of climate change. Rainfall exceeding 20mm/h – that could lead to flash flooding – is projected to increase 4-times by 2080 compared to 1980s under a high emissions scenario. The intensity of heavy downpours is also projected to increase by 5-15% (depending on location) per °C of regional warming. How these changes are realised on a year-to-year basis, however, is far from a smooth trend. The results show periods of rapid change -- with local hourly rainfall records being broken, some by a considerable margin -- and periods when there is a pause, with no new records set. This is simply a reflection of the complex interplay between natural variability and the underlying climate change signal. In this presentation, I will discuss the implications of these results for the communication of climate change and adaptation planning.

T1-01: High Resolution Downscaling with ICAR over High Mountain Asia

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Abstract

To produce hydrological projections due to anthropogenic climate change, downscaling of general climate models (GCM) is necessary to provide information on relevant spatial and temporal scales. Here we present progress toward a 6 km downscaled projected precipitation data set that covers the High Mountain Asia (HMA). As inputs we use more than 10 different CMIP6 models (Coupled Model Intercomparison Project Phase 6), and up to four different scenarios from the years 2015-2100. In addition, we also downscale historical runs (1950-2015) using the same CMIP6 models. We employ a quasi-dynamical downscaling approach with the Intermediate Complexity Atmospheric Research (ICAR) model. This model uses a complex linear model to describe the wind perturbations, with the inclusion of detailed physical schemes for advection, microphysics, convection, radiation and land surface modeling. The benefit of using ICAR is that this model is computational cheaper compared to regional scale models. Furthermore, ICAR allows for taking into account the dynamics over orographic terrain, compared to statistical downscaling. For input to the ICAR downscaling, the CMIP6 results are first bias corrected against ERA-I reanalysis (1990-2020). Furthermore, ICAR is run with ERA-I reanalysis to evaluate the internal biases in ICAR, which will also be accounted for in the final downscaling product.

T1-02: Evaluation of precipitation environments in the Tropical Andes through the use of the Lapse rate tendency equation.

Alan Garcia Rosales, John Allen
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Abstract

The precipitation simulation in the Tropical Andes is still challenging for the complex topography and the few observation networks. It is vital to have a good representation of Convection Permitting Models (CPMs) for the precipitation dynamics to understand the principal mechanics associated with precipitation development.

In the present research, we use the WRF model in a high spatial resolution (3km) to simulate the precipitation patterns over the Cordillera Blanca (central Andes of Peru) represents the largest concentration of tropical glaciers in the world. However, the atmospheric processes are still little studied in this region. The WRF's outputs are compared with PISCO products and weather stations to determine the adequate representation of the spatial distribution of the precipitation. In addition, we apply the lapse rate tendency equation to evaluate the crucial role of Lapse Rate (LR) in developing convective storm environments, which subsequently cause intense precipitation. The preliminary results show that the lapse rate tendency provides a practical diagnostic framework to assess instability generation and model processed-based performance. Moreover, it shows how

different processes and locations contribute to LR generation, which favors the convective and gives the origin to the precipitation in the Tropical Andes.

T1-03: Projected Changes in Precipitation and Mesoscale-Convective Systems over the Peruvian Central Andes from Convection-Permitting Regional Climate Simulations

Yongjie Huang[1], Ming Xue[1,2], Xiao-Ming Hu[1,2], Elinor Martin[2,3], Hector Mayol Novoa[4], Renee A. McPherson[3,5], Changhai Liu[6], Andres Vitaliano Perez Pachari[4], Isaac Yanqui Morales[4]
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Abstract

Resolutions of global climate models are too coarse to properly represent local forcings and weather, especially for precipitation in regions with complex terrain. Previous studies have shown added values of regional climate model (RCM) dynamical downscaling, especially at convection-permitting resolutions (~ 4 km or less). An RCM based on the Weather Research and Forecasting (WRF) model is run at a grid spacing of 15 km covering the entire South America, along with a nested convection-permitting at 3-km grid spacing covering the Peruvian central Andes region. One historical simulation driven by ERA5 reanalysis data and two future simulations (for SSP2-4.5 and SSP5-8.5 future scenarios over the period of 2070-2080) forced by a bias-corrected global dataset derived from CMIP6 multi-model ensemble are conducted to investigate changes in precipitation characteristics over the Peruvian central Andes regioncovered by the 3-km grid, where precipitation systems are strongly influenced by complex terrain and weather systems such as the South American low-level jets. Results show a slight decrease in mean annual precipitation in the SSP2-4.5 scenario in all examined regions including the west and east slopes of the Peruvian Central Andes and the western Amazon Basin, while no significant changes are seen in the SSP5-8.5 scenario. However, intense hourly precipitation becomes more frequent across all regions in both future scenarios, increasing risks of flash flooding. Changes in diurnal precipitation and mesoscale-convective systems are also examined using an object-tracking method and hourly precipitation data. These results highlight the value of convection-permitting climate simulations in projecting future severe weather hazards, which is needed for climate adaptation, especially in the Peruvian Central Andes region with complex terrain.

T1-04: An overview: extreme precipitation over the Dinaric Alps in the latest EURO-CORDEX simulations

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Abstract

Dinaric Alps and eastern Adriatic present a topographically complex coastal-mountainous region which is one of the rainiest areas in the Mediterranean, frequently affected by heavy precipitation events causing flash floods. We evaluate the regional climate model performance when simulating extreme precipitation and estimate the future extreme precipitation changes over Dinaric Alps as the research on these topics over this region is still limited. We use an unprecedented ensemble of ~80 historical simulations for evaluation and ~140 projection simulations of future climate from the EURO-CORDEX ensemble at 0.11° resolution, to cover as many future conditions and sources of uncertainty as possible. Three different greenhouse gases concentration scenarios (RCP2.6, RCP4.5 and RCP8.5) are used to estimate the climate change signal for several future periods (2041-2070, 2071-2100) with respect to the historical period (1971-2000). The ensemble is comprised of 15 RCMs driven by 11 CMIP5 global climate models. We estimated the following extreme precipitation indices: the 99th percentile of all-day precipitation, precipitation frequency and precipitation amount above the 99th percentile of all-day precipitation, number of heavy and very heavy precipitation days, and maximum one-day and five-day aggregated precipitation sum. The results are highly dependent on period, scenario, season and location. Overall, results show an intensification of both heavy and extreme precipitation events, especially during cold seasons over the northeastern areas for the far future period, with a high agreement between models. In summer, most of the examined indices show intensification in the northern areas and a reduction in southern parts of the domain with a "zero-change" line in between, with lower inter-model agreement than in winter.

T1-05: Kilometer-scale ensemble simulations of mesoscale convective systems in the lee of the Tibetan Plateau

Julia Kukulies[1], Andreas Franz Prein[2], Julia Curio[1], Hongyong Yu[3], Deliang Chen[1]
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Abstract

Kilometer-scale climate model simulations are a useful tool to investigate past and future changes in extreme precipitation, particularly in mountain regions, where convection is influenced by complex topography and land-atmosphere interactions. Here, we evaluate simulations of a flood-producing mesoscale convective system (MCS) downstream of the Tibetan Plateau (TP) in the Sichuan Basin from a kilometer-scale multi-model and multi-physics ensemble. The aim is to better understand the physical processes that need to be correctly simulated for capturing downstream MCS formation. We assess how the ensemble members simulate these processes and how sensitive the simulations are to different model configurations. The preceding vortex evolution over the TP, its interaction with the jet stream, and water vapor advection into the Sichuan Basin are identified as key processes for the MCS formation. Most modeling systems struggle to capture the interaction between the vortex and jet stream, and perturbing the model physics has little impact while constraining the large-scale flow by spectral nudging improves the simulation. This suggests that an accurate representation of the large-scale forcing is crucial to correctly simulate the MCS and associated precipitation. To verify whether the identified shortcomings systematically affect the MCS climatology in longer-term simulations, we evaluate a 1-year WRF simulation based on automatically tracked MCSs in satellite observations. While the model simulations capture the general spatial pattern and magnitude of MCS-associated precipitation, they show systematic biases in MCS

frequencies in some regions south and east of the TP. These biases are not reduced by spectral nudging, suggesting that the MCS processes in these regions are weakly forced by the large-scale circulation.

T1-06: High-resolution atmospheric simulation of precipitation over mainland Southeast Asia

Hui-Wen Lai, Tinghai Ou, Deliang Chen
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Abstract

The precipitation changes over mainland Southeast Asia are important to water supplies in surrounding countries, which is one of the important parts of the regional climate-resilient development. There are several mountainous topography in this region and the complex topography would modulate the precipitation patterns in the locations of heavy rainfall under certain prevailing winds and diurnal cycles of convective activities. The diurnal variations of precipitation over mainland Southeast Asia, especially over mountainous regions, and their mechanism have not been fully investigated. Due to the complex topography and scarcity of observation in some of these regions, convection-permitting atmospheric modeling is needed to explore the precipitation patterns and the impacts of topography. This work aims to study the diurnal precipitation and related physical processes within high-resolution atmospheric simulations. The high-resolution simulation based on the Weather and Research Forecasting (WRF) model driven by ERA5 was conducted with fine grid resolutions of 9 and 3 km. The domain covers mainland Southeast Asia for the period 1979–2019. Preliminary results have shown that downscaling modeling reduces the wet bias that is exhibited in ERA5 in this region. The simulation also captures subdaily precipitation amounts and their peak time within diurnal cycles well compared to ERA5. The analyses will focus on large-scale wind flows and air-land surface interactions to investigate the improvement of the diurnal cycle of precipitation simulations in high-resolution modeling.

T1-07: Two 80-year convection-permitting climate projections over Svalbard

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Abstract

Convection-permitting simulations have previously typically been limited to shorter time periods but are now becoming increasingly feasible also for longer timescales. This presents new opportunities for impact modelling.
The project PCCH-Arctic aims to provide guidance for the preservation of cultural heritage sites on Svalbard, where one of the most pressing challenges is the thawing of permafrost.
We present results from two simulations over Svalbard produced with the convection-permitting regional climate model HCLIM-AROME at 2.5 km horizontal resolution. The global models used are MPI-ESM-1-2-LR and NorESM2-MM, both from CMIP6, with the SSP5-8.5 scenario.

T1-08: Impacts of Snow Assimilation and Dynamic Downscaling on Seasonal Meteorological Forecasts over the Third Pole Region

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Abstract

The Third Pole (TP) contains the largest amount of snow outside the Antarctic and Arctic regions, and is the source of many major rivers in Asia. Accurate seasonal forecasting is critical for this region. The SEAS5 provides long-range global meteorological forecasts, including for the TP. However, its accuracy may be affected over mountainous regions such as the TP as it only assimilates snow below 1500 m altitude.

In this study, we compared twin ensemble reforecasts, initialized with and without snow assimilation above 1500 m altitude over the TP for spring and summer 2018. The Weather Research and Forecasting model (WRF) was then used to downscale the reforecast data, and the impacts of dynamical downscaling (at both 15km and 3 km) on meteorological forecasting and its scale effects are further explored.

The results show that reforecasts without snow assimilation overestimate snow cover and snow depth but underestimate daily temperature, while precipitation reforecasts perform better in the west TP than in the east TP compared to satellite-based data. However, snow assimilation improves snow cover, snow depth and temperature in the spring over TP, increasing temperature and precipitation for the east TP. The correlation coefficient between temperature reforecasts and observation increases, and the error decreases with the increase of resolution after WRF downscaling. After downscaling, temperature increases where snow depth and surface albedo decrease. In addition, the intensity of water vapor transport towards the west is enhanced in the eastern region and southwestern corner of the study area, resulting in an increase in precipitation in the eastern region and a decrease in precipitation in the southwestern corner. The forecast error of temperature and wind speed with snow assimilation over the TP is smaller than that without snow assimilation after downscaling, while the results are reversed for precipitation.

T1-09: Precipitation characteristics of mesoscale convective systems over the downstream of the Tibetan Plateau: regional difference and seasonal variations, the added value of convection-permitting simulation, and the sensitivity of simulated MCS to the different treatment of deep convection

Puxi Li[1], Haoming Chen[1], Kalli Furtado[2], Mark Muetzelfeldt[3], Reinhard Schiemann[3]
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Abstract

In this talk, we will first introduce the regional differences and seasonal variations of MCS precipitation characteristics over the downstream of the Tibetan Plateau (TP). Our results show that the middle-to-lower reaches of the Yangtze River basin receives the largest amount and exhibits the most pronounced seasonal cycle of MCS precipitation over the downstream of the TP, where the MCS contributes over 30.0% to warm season total rainfall. Long-lived MCSs occur over the eastern periphery of the TP (ETP), 25% of MCSs over the ETP persist for more than 18 hours in spring. In addition, spring MCSs feature larger rainfall areas, longer durations and faster propagation speeds. Then, by choosing a typical heavy rainfall event hit the downstream of the TP in 2016, we conducted a series of simulations (one global run ~20km; two regional CPM simulations: ~4km and ~2km) and investigated the added value of CPM in simulating the MCS. We found that CPM better simulate the rainfall pattern, the diurnal variations of precipitation, the small disturbances with the rain-bands, and also reduce the spurious topographical rainfall simulated by the global model. Finally, we will also briefly introduce the sensitivity of simulated MCSs over the downstream of the TP to the treatment of convection (with and without parametrized convection, and a hybrid representation of convection) in a high-resolution GCM at O(10km). In general, explicit convection better simulates the diurnal variations of MCSs over the downstream of the TP, and is able to represent the distinctive diurnal variations over complex terrains, such as the eastern TP and the complex terrains of central-north China. It is shown that explicit convection is better at simulating the timing of initiation and subsequent propagating features of the MCS, resulting in better diurnal variations and further a better spatial pattern of summer MCS precipitation.

T1-10: Modeling water resource change in Andean water towers

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Abstract

The food and water security of 90 million people depends on the Andean mountain water towers. Climate change is depleting the stores of water held in snow and causing glacier retreat. Our project aims to assess the sensitivity of water resources across the Andes to the changing supplies of snow and ice in response to climate change. Taking a pan-Andean approach, we identified 10 glacierized catchments of interest, spanning across the tropical Andes, the desert Andes, the Southern Andes of Chile, and Pandagonia. To capture the regional climatology and resolve orographic processes over the steep topography of the Andes, numerical downscaling using high-resolution simulations with the Weather Research Forecasting Model (WRF) will be conducted. We apply a nested grid, using a 25 km outer grid and five inner grids covering the catchments at convective permitting scale. Some initial simulation results over the two southern domains over Patagonia will be presented, with a focus on the representation of seasonality and variability of snowfall to total precipitation ratio in the convective permitting simulations.

T1-11: Future response of precipitation extremes over the Nordic region in a convection-permitting regional climate model - what is the role of large-scale circulation changes?

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Abstract

In the Nordic Convection-permitting Climate Projection (NorCP) project the HARMONIE-Climate regional climate model (HCLIM-AROME) has been run at 3 km grid spacing over the Nordic region with boundary conditions from both ERA-Interim reanalysis and two global climate models for present and future climate under two scenarios. The Nordic region is in many respects a complex region with steep topography, long coast-lines and a large number of lakes. The spatial and temporal variability of precipitation and its extremes in this region is largely driven by the large-scale atmospheric flow over the Euro-Atlantic sector. At the same time, changes in the large-scale atmospheric circulation and variability on longer time scales from years to decades contribute significantly to uncertainty in projections of future climate change for the 21st century.

HCLIM-AROME has shown high skill in representing weather and climate conditions over the Nordic region in recent climate, especially the warm season precipitation is much better simulated than coarser-resolution models. Furthermore, in a warmer future climate, HCLIM-AROME exhibits stronger future increases in precipitation extremes, compared to the coarser forcing models, particularly at sub-daily time scales. Through an analysis of circulation types (CTs) using a clustering methodology we present further insight on the influence of changes in the large-scale circulation regimes on the different model precipitation responses, with emphasis given to extremes. In which circulation type situations do the km-scale models behave differently than coarser models behave differently and how does it relate to the projected precipitation changes?

T1-12: Lake-effect snowfall over Great Lakes using convective-permitting climate model .

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Abstract

Lake-effect snowfall is caused by the flow of cold air over relatively warm water and the subsequent triggering of convection. The high occurrence of lake-effect snowfall events and the great quality of precipitation observations (high density of gauges and multiple radars) over the Great Lakes region make it an interesting place to evaluate the performance of high-resolution, convection-permitting models (CPMs). Here, we evaluate the added value of a convection-permitting configuration of the Canadian Regional Climate Model (CRCM6) over a convection parametrised one in representing lake-effect snowstorms. The CRCM6/GEM5 model is runed for two grid-spacing, 12km and 2.5 km. Two simulations at 2.5 km are performed: a convection parametrised and a convection-permitting. All

simulation driven at the boundaries by ERA5 reanalysis. Simulations are compared with STAGE IV precipitation estimate and gauge observations (from about one hundred stations) for several case-studies between 2015 and 2021. The evaluation focusses on the representation of precipitation geospatial patterns. Results show that the model reproduces key features of the lake-effect storm, including the location of the heaviest snowfall and the formation of mesoscale convective bands. However, the model also exhibits some biases in the timing and intensity of precipitation and the intensity of convection, which may be improved through further refinement of the model's physical parameterizations. The study highlights the potential of convection-permitting models to improve our understanding and prediction of extreme weather events and provides insights for future model development and refinement.

T1-13: Climate Initiative for Iberian Mountain Areas (CIMAs): Improving our understanding of climate variability in mountain areas using high resolution modelling.

Cristina Vegas-Cañas[1], Emilio Greciano-Zamorano[1], Jesús Fidel González-Rouco[1], Jorge Navarro-Montesinos[2], Elena García-Bustamante[2], Félix García-Pereira[1], Ernesto Rodrígue-Camino[3], Esteban Rodríguez-Guisado[3]
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Abstract

Mountain areas are especially vulnerable to climate change: they usually present a complex distribution of climates and ecosystems, and experience an amplification effect of climate change, to a point they have been referred as “the third pole” in IPCC reports. Additionally heterogeneity in the occurrence, amount, and distribution of precipitation in mountainous areas is relevant for water resources in Spain, and stresses the need for high[1]altitude observations and high-resolution modelling over complex terrain.

However, the harsh weather conditions and the complex orography associated with these environments hinder a continuous monitorization and pose challenges for regional climate models.

CIMAs is a joint effort aiming at improve our understanding of climate variability in mountain regions. A pilot area with higher than usual observations density have been selected over Spanish Sistema Central, aiming at study climate variability trough very high (1km) resolution simulations, exploring models ability to capture relevant processes at that scale.

Preliminary results, comparing ERA5 to three different WRF simulations (9,3 and 1Km) over a reduced domain show a clear improvement with increasing resolution for temperature. However, for precipitation, some altitude-related biases appear. Results from an in depth analysis and some sensitivity tests being conducted are shown.

T1-14: Two Perspectives on Seasonal Snowpack Trends in the Western United States: SNOTEL Observations and a retrospective CPCM Simulation, the CONUS404

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Abstract

Analysis of SNOTEL data over the western Contiguous United States (CONUS) shows interesting patterns in the trends of the maximum snow water equivalent (SWE), as well as the onset, end, and length of the snow seasons over multiple decades. While record lengths greater than or equal to 25 years are considered, many SNOTEL records go back 43 years. Looking at 460 sites that meet our selected criteria, dependencies on latitude, longitude and elevation are considered, and a complex and important story emerges. The analysis is then applied to the CONUS404 CPCM data set. Designed to support hydroclimate studies, the CONUS404 data were produced by NCAR as a part of a collaborative project between NCAR and the USGS. As suggested by its name, the CONUS404 is a 43-year long (water years 1980 through 2022), 4-km resolution retrospective WRF simulation over the CONUS. The CONUS404 simulation generally does a good job reproducing the geospatial patterns of snowpack trends. This presentation will introduce our approach and present analyses focussed on maximum SWE and snow season length.

T1-15: Influences of topography resolution on precipitation over the Himalayan slopes

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Abstract

Nocturnal precipitation occurs over the Himalayas and its foothills as well as the afternoon precipitation at the mountain ridges and steep slopes. A cloud resolving model (CRM) is required to simulate and understand precipitation process with active diurnal cycle over such kind of complex topographic region. In this study, to investigate an influence of topography resolution on precipitation over the Himalayas, we conducted two numerical experiments using the WRF model. One is the simulation with 2-km horizontal resolution for both atmosphere and topography (HighRes exp). Another has 2-km horizontal resolution for atmosphere but uses topography with approximately 10-km horizontal resolution (LowRes exp). We analyzed July and August from 2003 to 2010.

In the HighRes exp, spatial precipitation maximum is simulated in response to the fine topographic irregularities during both afternoon and midnight, which seems to be consistent with the result using the TRMM PR data shown in Fujinami et al. (2021). Meanwhile, in the LowRes exp, active precipitation occurs limitedly during afternoon at the higher altitude inland region where exists the mountain slope with large elevation difference. As a result, precipitation overestimates at the higher altitude inland regions during afternoon and evening in the LowRes exp while it underestimates at the lower altitude regions during midnight and early morning.

Smooth topography in the LowRes exp intensifies the afternoon upslope wind speed. Then, water vapor is excessively transported to the higher altitude inland region, which induces an overestimation of precipitation. Large-scale moisture flow effectively converges with mountains at the lower altitude Himalayas during night and causes nocturnal precipitation in the HighRes exp. Nocturnal downslope wind also promotes precipitation occurrence as suggested by Sugimoto et al. (2021). Such nocturnal precipitation is not found well in the LowRes exp due to smooth topography.

T1-16: NMBU's climate station: a Norwegian high latitude field site for monitoring land-atmosphere interaction in an rural environment

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Abstract

The Norwegian University of Life Sciences (NMBU) in Ås, about 30 km south of Oslo, was established as an agricultural education institution in the mid-1800. Almost from the very beginning, a meteorological field site was established to support the agricultural research.

Today, we can look back onto a 150-year-old climate data record which documents interannual meteorological variations as well as the ongoing climate-change typically for this part of Norway.

The meteorological field site was several times modernized and constantly extended to support the growing research areas at NMBU. Additional to the measurements of a standard weather station, measurements at Ås also encompass diverse radiation parameters, energy and gas fluxes in the ground and lower atmosphere, thus allowing for a complete description of the energy balance on the ground. Radiosonde facilities couple these observations to the processes in the entire boundary layer and troposphere.

In recent years, a research project with the Norwegian Meteorological institute focussed on the interaction between land and atmosphere for a better representation of the local water cycle and convective events in numerical weather forecast model. The site is also used for testing new equipment in an accessible environment before deploying them in more extreme conditions. Currently, a set of low quality sensors and IoT-technology are tested. Both can be used in short-term high density networks, helping to extend the spatial representativeness of the measurements.

The location of Ås features interesting convective situations during the extending summer season and is characterized by a changing snow-climate during winter typically for non-extreme high-

latitude regions. In this poster, we present NMBU's field site in more detail and highlight some of the datasets.

T1-17: Convection-permitting simulations of current and future climate over the Third Pole region

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Abstract

The Tibetan Plateau (TP), known as Asian Water Tower, provides a vital water resource for the downstream regions. Previous studies of water cycle changes over the TP have been conducted with climate models of relatively coarse resolution, leading to potential misrepresentation of key physical processes. In this study, we presents results from a high resolution climate change simulation that permits convection at about 4-km grid spacing with focus on the TP region using the Icosahedral Nonhydrostatic Weather and Climate Model (ICON). Two 12-year simulations were performed, consisting of a retrospective simulation (2008-2020) with initial and boundary conditions from ERA5 reanalysis and a pseudo-global warming projections driven by the modified reanalysis-derived initial and boundary conditions through adding the monthly CMIP6 ensemble-mean climate change under SSP5-8.5 scenario. The retrospective simulation shows overall good performance capturing the annual/seasonal/sub-seasonal precipitation and surface temperature. The future climate simulation suggests that the TP will be wetter and warmer under SSP5-8.5 scenario. The ICON-downscaled climate change simulations provide a high-resolution dataset to the community for studying regional climate changes and impacts over TP.

T2-01: Enhancing the understanding of Italy's current climate at convection-permitting scale

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Abstract

The capability to represent current climate condition and projected scenarios at km-scale is a challenging task for the climate community. In recent years, different studies, research initiatives (as CORDEX Flagship Pilot Studies on Convective phenomena) and projects (as H2020 EUCP, Impetus4Change) tested the performances of the so called "convection permitting" models. The ability of km-scale models is proved in the representation of the hourly extreme precipitation features over complex orographic area as the Alps. The overestimations of maximum temperatures derived from the km-scale simulations are noted. The Italian peninsula, like other countries of the Mediterranean area, has been observing an increase in extreme weather events (as heavy rainfall and increase in temperature), causing huge impacts (as floods, droughts, heat waves) with consequences to assets and people. Therefore, enhancing the understanding of the local climate represents a pillar in the framework of the climate change adaptation process. In this perspective, the CMCC tried to go beyond the current limitation in the convection permitting strategies (as 10-year time-slice approach), simulating more than 30-years at around 2 km grid spacing over the whole Italian peninsula. CMCC applies dynamical downscaling (relying on the COSMO-CLM numerical model) of the ERA5 in order to understand the current climate. Results are analysed against several independent observational datasets and reanalysis products. Hourly precipitation patterns, orography effects, and urban climate dynamics are also investigated, highlighting the weaknesses (i.e. losses in performances occur in coastal and flat areas) and strengths (i.e. gains in performances are achieved in mountainous areas) of the convection-permitting model. The adopted urban parameterisation is demonstrated to simulate heat detection for two Italian cities. Finally, a subset of extreme climate indicators is evaluated, finding a region-dependent response.

T2-02: Future projections of low-level atmospheric circulation patterns over South Tropical South America: Impacts on precipitation and Amazon dry season length

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Abstract

A lengthening of the dry season in southern Amazonia has been evidenced during the last decades in relation to a delay in the onset of the South American Monsoon System (SAMS). Using the pattern recognition framework of atmospheric circulation patterns (CPs), previous studies have identified specific atmospheric situations related to the onset of the SAMS. Here, we analyze the future changes in the CPs that largely define the main hydro-climatological states of Tropical South America. We evaluated the CP changes that occurred between two periods: historical (1970 - 2000) and future (2040 - 2070), using 6 General Circulation Models (GCMs) from the Coupled Model Intercomparison Project Phase 6. Future changes from these models show spatio-temporal variations in the CPs associated with the dry season in southern Amazonia during the mid-21st century. These changes are related to both a late onset of the SAMS and an early demise of the SAMS. Particularly, the CP methodology allowed for a better understanding of the behavior of the southern Amazon dry season under future conditions, showing an increase in the frequency of the CPs typically observed during the dry season. The occurrence of dry days in the Amazon basin during the austral winter of the mid-21st century increases by 19,4% on average, with respect to the historical period. This methodology also identified a future increase in the frequency of dry CPs, both at the beginning of the dry-to-wet transition period and at the end of the wet-to-dry transition season.

T2-03: Cold and warm extreme temperatures in the subtropical Andes: evaluating convection-permitting simulations with in-situ observations

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Abstract

Temperature-related climate hazards directly affect human health and comfort, as well as energy management and multiple socio-economic activities. The magnitude of their consequences often depends on the location and susceptibility of the affected population, demanding regional-to-local climate information. Regional climate models can be used to address such problems, although model resolution can be a limitation for their representation, especially in regions with complex topography. In this line, the Andes mountain range poses a particular challenge over the South American continent. Thereby, the brand-new high-resolution models at convection-permitting scales (CPM) arise as valuable tools that can provide tailored climatic information to carry out impact studies over the Andes.

In this work, we evaluate the state-of-the-art convection-permitting WRF simulation developed by NCAR at 4 km grid spacing over South America. The assessment is focused on the representation of the a) air temperature diurnal cycle in the CPM simulations; b) threshold-based indices of cold and warm days (days with TMIN<0 C and TMAX>30 C, respectively) over selected meteorological stations located in the subtropical section of the Andes. The simulations were compared against in-situ observations and the MSWX dataset during 2000-2007 (the available simulated period at the time of submitting this abstract). Also, the added value of the CPM resolution was explored by including ERA5.

A first insight into the model runs shows that the diurnal cycle is well captured by WRF. In general, the reproduction of cold days is a more complex task than the warm days, for which larger discrepancies among the datasets are detected. The results that arise from these analyses indicate an overall good performance of the CPM simulations, with some added value representing the indices in the meteorological stations.

T2-04: Impact of convective rainfall on the dryland water balance

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Abstract

Convective rainfall is common during rainy seasons in dryland regions and is critical for the water balance. Critically, high intensity, short-lived, and spatially restricted convective rainfall events can lead to high infiltration rates, runoff, and focused groundwater recharge. Whereas, if rainfall is prolonged and low intensity evaporative losses will be higher. Therefore, the representation of convection in models is critical for capturing essential dryland rainfall characteristics and their impact on hydrological processes. The Horn of Africa drylands (HAD) are one of the most food and water insecure regions on Earth, rainfall is highly spatially and temporally variable, with critical rainy seasons frequently failing to materialize. Being able to predict how rainfall is partitioned into different water stores is crucial for food and water security, especially during drought periods. The Convection Permitting Model for Africa (CP4 Africa) offers an opportunity to evaluate whether convection-permitting (CP) models represent a step-change improvement in dryland rainfall representation relative to parameterised climate models. Here, we compare the CP and parameterised climate models against gridded data in terms of hydrologically relevant rainfall metrics and PET dynamics over the HAD, and assess how these differences impact the water balance. We show that parameterised climate models systematically overestimate wet hour frequency and underpredict prolonged dry periods. The CP model produces better representation of hourly extremes and does not appear to dramatically overestimate extremes even at its native resolution. While differences exist in PET simulations, they are muted relative to rainfall. Using model rainfall and PET a series of 1-D hydrological experiments were conducted along an aridity gradient across the HAD and the impacts of explicit (vs parameterized) convection on the water balance were assessed using both present-day and future simulations.

T2-05: Hourly Temperature and Precipitation Time Series Characteristics in São Paulo with Urban Land Use Type of Convection-Permitting Model (CPM) outputs

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Abstract

The influences of regional atmospheric drivers on the joint distribution of temperature and precipitation from a Convection-Permitting Model (CPM) over São Paulo are explored. Time series of temperature and precipitation are extracted from urban land data points from a 22-year Weather Research and Forecasting (WRF) model simulation between 2000 and 2021 from the South American Affinity Group (SAAG). These hourly time series are aggregated into daily, monthly, and annual time series for both maximum and mean values, and their anomalies are computed. Comparisons with ERA5 reanalysis show that the CPM simulations for São Paulo have higher local temperatures and more intermittent precipitation, with higher variance and rougher surfaces. This means that the spreads of CPM simulated distributions are larger and their tails longer resulting in more intense extreme events.

Regarding regional variability drivers, the Atlantic Meridional Mode (AMM) is useful in explaining monthly variations in precipitation, while the multivariate El Nino-Southern Oscillation index (MEI) is related to temperature and nonstationary extreme distributions for daily precipitation maxima. When analysing the joint distribution of temperatures and precipitation amounts, joint distributions differ dependent on the AMM phase. Therefore, if the AMM signal is captured accurately, it will allow the prediction of extreme temperature and precipitation events from the joint distribution.

This study provides a framework to explore multiscaling relationships by considering the distribution of convection-permitting model simulations. This framework will be useful in investigating how multiple urban land use types affect precipitation and temperature extremes. Such effects will be analysed in future sub-kilometre simulations focused on São Paulo. The findings of this study will be valuable for regional planning for sustainable development goals 11 and 13 related to climate action in cities and communities.

T2-06: Development of a Case-Selective Dynamical Downscaling Strategy for Extreme Precipitation Over Belgium

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Abstract

Short-duration extreme precipitation events (1-3h) frequently induce flash floods, which cause fatalities and damage critical infrastructure. As these events are often driven by convective processes, convection-permitting models (CPMs) are needed to resolve the convective dynamics and improve the statistics of convective rain. Climate attribution studies currently experience a lack of high-resolution climate simulations that span a sufficiently long time period, as emphasized by the WWA study of the 2021 Western European floods. Due to their high resolution, CPMs are very demanding in terms of computational resources, often constraining the duration of simulations and the size of a CPM ensemble. The question addressed here is whether the CPM simulations can be limited to downscaling only a selected range of extreme cases. To this end, we select periods with extreme precipitation from a low-resolution convection-parameterized simulation. Only these periods are then downscaled to a convection-permitting scale using the same model version running at a higher resolution. This new case-selective technique will save significant computing time while still retaining the robust statistics of the extreme precipitation cases obtained from long transient runs at the convection-permitting scale. A preliminary feasibility study was conducted on ERA5 reanalysis data. The study found that by selecting a set of extreme precipitation events that account for 10% of the total simulation time, the full statistics of those events might be reconstructed. The cost-saving case-selective approach may enable more efficient downscaling of climate scenarios, leading to an increase in the CPM ensemble size and a large increase in robust knowledge of extreme precipitation over Belgium.

T2-07: Coupled Atmospheric-Hydrologic Simulations of Convection During the RELAMPAGO Field Campaign in Argentina

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Abstract

The foothills of the Sierras de Córdoba in Argentina is home to some of the deepest and most intense thunderstorms on earth that cause tornadoes, hail, and flooding. The Remote Sensing of Electrification, Lightning, and Mesoscale/Microscale Processes with Adaptive Ground Observations (RELAMPAGO) field campaign was conducted during an intensive observation period from November–December 2018 to investigate the characteristics of such storms, the environments in which they form, and the hydrometeorological interactions. While much has been documented on the properties of these storms, less consideration has been given to how interactions between the land surface, hydrology, and atmosphere contribute to the formation of convection in this region. We aim to fill this gap by investigating how two-way coupled simulations between an atmospheric model (WRF) and a hydrologic model (WRF-Hydro) influence convective initiation over the terrain of the Sierras de Córdoba. The WRF simulations are run at 1-km grid-spacing to properly resolve the convective details of the storms, the land surface model (Noah-MP) is also run at 1-km, and the WRF-Hydro channel routing is run at 100 m to capture the local hydrological network. Feedbacks between the land surface, hydrology, and atmosphere are analyzed to understand how these various components contribute to the upscale growth of convective systems to improve prediction of intense convective systems in this region.

T2-08: Representation of precipitation extremes in convection permitting scale climate simulations - event characteristics and hydrological implications

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Abstract

In the last years, extreme precipitation events in Germany have caused significant casualty losses and damages. One example is the Ahr/Erft/Meuse flooding event in July 2021, which caused close to 200 casualties and several 10-billion Euro damages. Large uncertainties exist regarding the return periods and associated risks of such events. For instance, for the July 2021 event, the precipitation intensities and flood levels superseded the estimates from the observational record. In addition,

climate warming will likely increase the peak intensities of such events, which could be demonstrated by pseudo-global-warming simulations of this event (e.g., Ludwig et al., 2022).

Convection-permitting resolutions are necessary to realistically describe the intensities and the spatial and temporal distribution of such extremes over complex terrain. On the other hand, long-time series or large ensembles are necessary to robustly estimate return periods of hundred years or more. Ehmele et al. (2022) used the large regional ensemble LAERTES-EU to estimate flood level curves for the Rhine catchment up to ca. 1000 years for the present-day climate. In the last years, large ensembles of global climate simulations based on CMIP5 and CMIP6 scenarios have become available, which offer multiple realizations of the future climate and a sufficient number of very high return period events. However, it has yet to be shown how realistically such events are represented in GCMs, especially if complex topography and/or convection play an important role. We analyse the scale-dependent representation of such events along existing model chains from GCMs over RCM-scale to convection-permitting scale simulations for Central Europe from CORDEX FPS Convection, the KIT-KLIWA ensemble, and the new NUKLEUS 3 km CMIP6 downscaling simulations for Germany.

T2-09: Tracking storms and extreme rainfall over South America in convection-permitting simulations of present and future climate

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Abstract

South America is highly vulnerable to storms and extreme precipitation. These extremes are produced from a range of systems, including large, organised mesoscale convective systems above the Amazon to fronts associated with extratropical cyclones across Argentina. Future warming will likely bring changes to storm characteristics and precipitation extremes across the region. However, the coarse horizontal resolution of current global climate models fails to explicitly resolve convective processes, making any future changes uncertain. Here, cutting-edge convection-permitting simulations over South America, run by the UK Met Office, are used to assess the representation of mesoscale convective systems in both present and future climate simulations. These ten-year simulations will be compared with satellite observations and coarser global climate models using a cloud tracking algorithm (*tobac*), with brightness temperature and precipitation as input variables, to generate storm tracks and assess differences in storm representation. Comparisons will be based on storm characteristics such as track density, propagation velocity, maximum precipitation rate, size and speed. Based on existing literature for African and European domains, we expect the convective-permitting simulations to better represent present day storms and their associated precipitation compared with the current generation of global climate models. This would improve the representation of many elements of South American climate, which may be key to providing improved projections of storms and extreme rainfall with future climate change. In turn, this may help policymakers across South America to reduce the vulnerability of the population to storm-related natural disasters. Here, overarching aims of the project will be presented, as well as preliminary results from tracking mesoscale convective systems within the present-day convection-permitting simulations.

T2-10: The sensitivity of extreme rainfall simulations to model parameters in the Weather Research and Forecasting model during two enhanced southwest monsoon events in the Philippines

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Abstract

Forecasts of extreme rainfall events in the Philippines have inherent inaccuracies partly due to the theoretical or experimental design of physics schemes in Numerical Weather Prediction models. The Weather Research and Forecasting (WRF) model specifies numerous model parameters that significantly affect rainfall forecasts. However, the multitude of parameters makes it difficult to optimize parameter values and identify which of these are key factors for rainfall predictions.

This study utilizes the Morrison-One-At-a-Time (MOAT) Global Sensitivity Analysis (GSA) to ascertain the sensitivity of 11 output variables to 23 tunable model parameters across seven physics schemes in WRF. The MOAT mean and standard deviation are used as sensitivity measures and calculated for two enhanced southwest monsoon events in August 2012 and 2013 over the central Luzon region in the Philippines. Initial results show that model parameters associated with convection or cumulus physics exhibit the strongest influence on the most number of output variables in the WRF model including forecasted rainfall. To investigate the optimum parameter set for each of the two events, the root mean square error (RMSE) is computed between the simulated rainfall from the WRF model and the observed rainfall from the Global Satellite Mapping of Precipitation (GSMaP) product. The model run with the lowest RMSE is treated as the optimized run and is compared with the simulation using default parameter values. Considering both 2012 and 2013 events, parameter optimization can reduce error by as much as 42 % relative to the default run. While more sophisticated optimization methods can be explored in the future, this study provides insight into which model parameters can be further optimized

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T2-11: Sub-hourly precipitation extremes in a convection-permitting climate projection over Germany

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Abstract

The intensification of extreme precipitation in a warming climate in Europe is expected to be largest for events of short duration. This prospect is a major concern because these events have the potential to trigger flash floods or landslides. Besides the rainfall depth, such impacts of extreme events are influenced by their temporal profile, including the timing of the peak and peak intensities, which often occur on sub-hourly time scales. It is therefore crucial to accurately represent this scale in climate models to increase the confidence in predicted climate change signals.

The new generation of climate projections at the convection-permitting (CP) scale has been shown to improve the representation of extreme events. However, previous studies analyzing extreme precipitation have often been limited to daily or, less frequently, hourly model output, and little is known about sub-hourly extremes.

Therefore, we investigate sub-hourly precipitation in the KIT-KLIWA ensemble – a CP climate ensemble driven by 4 CMIP5 GCMs, coupled to the regional climate model COSMO-CLM. The domain is centered over Germany with a grid resolution of 2.8km. In 3 ensemble members, we compare extreme precipitation of a resolution down to 5 minutes in the historical period (1971-2005) with the dense observation network in Germany.

Using an event-based approach, we found that the majority of events has a (very) front-loaded profile, which was reproduced by the CP simulations. The slight underestimation of the frequency of the highest intensities at sub-hourly resolution can be attributed to an underestimation of the peakedness of short events. The overestimation of extreme values for longer aggregation times is associated with an overestimation of the duration of extreme precipitation events in CP compared to observations. Our results document the benefit of an event-based analysis of extreme precipitation for the understanding of sub-hourly extremes in observations and CP simulations.

T2-12: Urban enhancement of rainfall in convection-permitting climate simulations over Africa

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Abstract

Urban areas modify their local climate by altering the surface energy balance, resulting in the well-known urban heat island (UHI) phenomenon whereby urban areas are warmer than surrounding rural areas. In recent years, there has been growing interest into the role of urban areas on modifying rainfall, with numerous studies finding enhanced rainfall particularly over and downwind of cities. Modification of rainfall over cities is important as they are particularly vulnerable to surface water flooding. A key mechanism for this enhancement is thought to be destabilisation of the atmosphere by the UHI effect which could lead to increased trigging/enhancement of rainfall. In this work, we analyse 4.5 km convection permitting climate simulations (CP4A) ran as part of the Future Climate for Africa (FCFA) project to examine influences of the city of Johannesburg, South Africa on local rainfall. We identify a novel approach to disentangle the UHI impact on rainfall from the reverse (i.e. localised rainfall tending to reduce temperatures over the city). We find that large summertime UHI effects in the pre-convective environment are associated with increased rainfall frequency over the city. There is also some evidence of increased rainfall intensity. Enhanced low-level convergence associated with the UHI suggests that increased triggering and amplification of rainfall is caused by a local, UHI-induced thermal circulation. Observations from the Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (GPM-IMERG) also show increased daily mean frequency of rainfall over Johannesburg, however this is accompanied by a decrease in intensity, suggesting rainfall enhancement in CP4A may be overestimated but that more work is needed to understand the processes. This has important implications for the reliability of rainfall projections over cities, and hence climate change risk assessment and adaptation planning (e.g.,upgrading urban drainage systems).

T2-13: Daily cycle of the urban-rural contrast in South America derived from the FPS-SESA multi-model, convection-permitting RCM ensemble

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Abstract

We demonstrate the potential of convention-permitting regional climate models (CPRCMs) to capture urban-rural contrasts in different variables over large cities in South America. We used the multi-model ensemble developed as part of the CORDEX Flagship Pilot Study on Extreme Precipitation Events in Southeastern South America (FPS-SESA). It comprises three-year-long coordinated CPRCM simulations centered over subtropical South America at a resolution of 4 km. We also included the 4-km-resolution simulation from the NCAR South America Affinity Group, which covers the entire South American continent. Together, these simulations form a five-member ensemble consisting of two models in different configurations (two WRF and three RegCM5 members).

We assess the ability of this ensemble to capture city footprints in three major South American cities: Buenos Aires, Córdoba, and Porto Alegre. Differences between urban and rural environments were computed to identify the urban signal on temperature, referred to as the urban heat island (UHI), relative humidity and wind intensity. The analysis also includes the response of the urban environment to extreme conditions such as heat waves. Simulated data have been compared against observed hourly station data.

CPRCMs successfully captured the UHI signal for the three South American cities. The UHI effect was most pronounced during nighttime hours with a magnitude of approximately 2ºC. The magnitude of this effect was found to be greater in the summer than in the winter. The models also captured the drier nighttime conditions over the cities, which may be associated with the UHI effect, although they tended to overestimate (by up to 10%) the cities' drying effect. Additionally, the models reproduced the observed weaker intensity of the wind over the cities, although the magnitude of the difference was overestimated. During heat waves, the CPRCMs were also able to capture the exacerbated warming and

T2-14: Convection-Permitting Present and Future Climate Simulations Based on CMIP6 for the Black Sea Basin

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Abstract

The Black Sea Basin, including the coastal areas of the Black Sea and a broad part of the Anatolian Peninsula, is one of the climate change hot spots with its complex topographical features and where strong air-sea interactions occur. In this study, we performed decade-long convection-permitting climate simulations at 3 km horizontal resolution for the reference and future periods (2005-2014 and 2061-2070) based on the SSP3-7.0 greenhouse gas emission scenario over the Black Sea Basin. To this end, we downscaled the last generation CMIP6 MPI-ESM1.2-HR outputs by using the WRF model. The results indicate that the daily 2-meter mean, minimum and maximum air temperatures increase in the spring, summer, and autumn by about 3°C compared to the 2005-2014 reference period over the study area. The transition period from winter to spring indicates a sudden temperature increase which is caused by circulation change in March. This sudden temperature change intensifies the snow melt process in the upper Euphrates basin and causes an earlier onset of the melting season. In terms of precipitation, the total precipitation amount decreases in spring and summer over the Black Sea Basin. On the other hand, the total precipitation amount increases significantly by about 3 mm/day in winter over the Eastern Black Sea region due to the evaporation increase of around 15%. The maximum daily precipitation amount reaches 350 mm over the northeast of Türkiye and the Caucasus. The intensification of the daily precipitation is most pronounced in the subregions of the Black Sea coasts. Furthermore, the results highlight the intensification of sub-daily precipitation in these regions. In particular, the afternoon precipitation increases in autumn over the coastal regions of Türkiye.

T2-15: The Multi-Scale Interactions of Atmospheric Phenomenon in Extreme and Mean Precipitation

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Abstract

The intensification of extreme precipitation events is among the most hazardous climate change impacts on society and the economy. Extreme precipitation has intensified in most regions of the world and will continue this trend with progressing climate change. However, the magnitude of these changes might depend on the region and particularly on the type of storms that produce extreme precipitation. Here we present an objective multi-feature tracking algorithm that allows us to identify and follow low and high-pressure systems, frontal zones, tropical cyclones, atmospheric rivers, and mesoscale convective systems (MCSs) at the same time. We apply this algorithm to a combination of observations and ERA5 reanalysis data to quantify which processes are involved in the production of hourly and daily precipitation extremes on a global scale. Our results show that MCSs are responsible for most hourly extreme precipitation events in the tropics and some mid-latitude land regions. Atmospheric rivers contribute heavily to mid- and high-latitude ocean basins and west coast region extremes while tropical cyclones only show up as contributors in the subtropical ocean and east-coast regions. Importantly, extreme precipitation events are typically caused by the combination of several atmospheric processes that interact such as a couplet of high- and low-pressure systems that intensifies the onshore flow of an atmospheric river or frontal zones that help organize MCSs.

T2-16: 20 years of MCSs simulations over South America using WRF

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Abstract

It is well known that the mesoscale convective systems (MCSs) supply a great part of the precipitation and cause severe weather across the globe. However, simulating their occurrence and behavior is still a challenge, especially in the Global South. In South America, where some of the most intense MCSs happen, very few efforts have been made in order to fill this knowledge gap. Therefore, the focus of the present study is to evaluate simulated with observed MCSs over South America in terms of their occurrence and behavior in different subregions and seasons. For that, we used 20 years (2001-2021) of hourly 4 km resolution simulations of the Weather Research and Forecasting model (WRF) v4.1.5 performed by the South America Affinity Group (SAAG) at the National Center for Atmospheric Research (NCAR). The simulation downscales ERA5 reanalysis data. For regionalizations, we are using the Intergovernmental Panel on Climate Change (IPCC) regions. We find that despite the overestimation of MCSs frequency in WRF (~24% more than observed over South America), mainly during the summer months, it represents the seasonal and diurnal cycle of the MCSs very close to the observations. WRF also reproduces the spatial distribution of MCSs well. WRF overestimates the density of MCSs over the higher topography regions in northern South America: over the Andes in the west of the Amazon basin; over the Guiana Shield in the northern Amazon basin; and over the Bourborema Plateau, in Northeastern Brazil. Ongoing investigations focus on the atmospheric environment that is favorable for Amazonian MCSs and their interannual variability.

T2-17: Heatwave future changes from an ensemble of km-scale regional climate models within CORDEX-FPS convection

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Abstract

Evidence suggests that CPRCMs significantly modify the soil moisture-precipitation feedback and precipitation recycling. During the warm half of the year, this translates into drier conditions in km-scale simulations. Consequently, a different partitioning between heat fluxes modulates temperature extremes and heatwaves (HWs) representation.

In this study, we explore whether these findings extend to future projections, modifying HW future changes. We leverage a multi-model ensemble of twelve CPRCMs downscaled from CMIP5 GCM projections for historical and end-of-century periods (RCP8.5) over the Greater Alpine Region. GCMs are downscaled to an intermediate 12–15 km resolution (convection-parameterized RCMs) and then further downscaled to the kilometer scale (~3km).

Analyses are two-fold: (i) Determine whether the km-scale warmer/drier tendency is more realistic and more accurate than the RCMs. Here, distribution-based grid- and station-scale evaluation metrics are considered. (ii) Assess whether the km-scale signal is stationary or if an amplification/damping of future summer temperatures and HWs can be discerned. Key HW statistics (e.g., amplitude, persistence magnitude) and land-atmosphere coupling magnitude metrics are analyzed.

Preliminary results show an added value in the km-scale simulations compared to their parameterized counterparts. RCM cold biases are reduced and summer maximum temperature distribution is improved over a majority of reference sites. Concerning future changes, the km-scale ensemble exhibits an intensification of HW and land-atmosphere coupling metrics. Additionally, we observe increased inter-model agreement for all HW metrics.

To conclude, CPRCMs are warmer than RCMs during the historical period, resulting from improved physics. This also translates into a modulation of the future change signal. The next steps will elucidate which part of the modulation can be ascribed to land–atmosphere coupling and/or "atmospheric only"

T2-18: Summertime wind gusts in convection-permitting climate simulations

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Abstract

Changes in summertime convective activity may have implications for the wind gust climate due to their close association with intense precipitation and the formation of cold pools. Here, we analyse the present-day and future summertime wind gust climate in the convection-permitting regional climate model (CPM) HCLIM38-AROME. Statistics are derived from differences between two time-slice experiments for 1995-2005 and 2089-2099 (using the RCP8.5 scenario).

The hourly CPM data is analysed using a diagnostic tracking tool and a threshold of 20 m/s for a subdomain encompassing the Netherlands and low-lying parts of Western Europe. Gust 'cells' are identified by locating continuous areas of the wind gust field above the threshold. To discriminate convective events from other events several filters are applied (e.g., the ratio between the cell-maximum wind gust and the subdomain-wide spatial average). The wind gust strength distributions are then stratified according to the 'depth' of the associated cold pool, defined via the one-hour time difference of the 2m-temperature field around the tracked gust cell. In this way it is confirmed that wind gust maxima over low-lying western and central Europe in the CPM are generally strongly coupled to the cold pool depth, with a deeper cold pool being associated with stronger wind gust maxima. As extreme precipitation intensities increase in the warmer climate, the associated cold pools which are related to the cooling from the evaporation of rain, are found to also deepen systematically, and thereby give rise to wind gusts with amplitudes stronger than found anywhere in the current climate.

The process of cold-pool formation is not well resolved by convection parameterized regional climate models (RCMs). Therefore, we expect that the future wind gust changes derived from CPMs will also be quite different from those derived on the basis of RCMs, especially over land and during the summer.

T2-19: Identifying Boundary Conditions for Dynamic Downscaling of Extreme Weather Events

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Abstract

Convection-permitting models (CPMs) offer an unprecedented opportunity to capture the actual physics underlying the formation and dynamics of extreme precipitation events. However, due to the infrequent occurrence of extreme events, their direct simulation requires either very long simulations or an ensemble of them and are often computationally prohibitive using CPM resolutions. Recent advances in rare event algorithms based on large deviation theory have shown promise in identifying extreme events in intermediate complexity global climate models. In this study, we lay the groundwork for a novel approach to address computational limitations of robustly simulating extreme events using CPMs and illustrate the approach using an intermediate complexity model.

Our method involves utilizing the strengths of coarse global climate models, which are computationally efficient, to identify extreme event boundary conditions using a rare event algorithm. This algorithm is design such that it tilts the distribution of events, making the rare ones more probable in simulation. By first sampling these extreme events in coarse models using the algorithm and then constructing boundary conditions from them, we can downscale the extreme events using CPMs. This downscaled approach allows us to study extreme events with state-of-the-art models while CPMs without incurring excessive computational costs.

The potential of the method is demonstrated by the construction of seasonal-mean extreme precipitation and temperature events using a general circulation model of intermediate complexity. In this simpler framework, we obtain a computational gain of 100 to 1000 times compared with the tradition approach of running a very long simulation or an ensemble of them.

T2-20: Improved Simulations of Tropical-Extratropical Cloud Bands and Related Extremes over South America Using Convective-Permitting Models

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Abstract

Tropical-extratropical cloud bands are typical of the South American climate, accounting for over 60% of the rainy season precipitation. Thus, their correct representation in climate models is fundamental for the accuracy of simulated precipitation. Here, we investigate the representation of these cloud bands and related extreme precipitation, in two convective-permitting simulations. The first is a 10-year simulation with 4.5 km spatial resolution produced by the UK Met Office, with two different runs: a control run forced by a high-resolution global climate model (HadGEM3-GC3.1-

n512) and a hindcast run forced by a reanalysis product (ERA-Interim) downscaled by an RCM. The second is a 22-year retrospective simulation produced by the NCAR Water System Program, using a WRF model with 4-km grid spacing. The cloud bands are identified using an objective detection algorithm applied to OLR (Zilli and Hart, 2021). All simulations represent the location and seasonal cycle of observed cloud bands well, despite overestimating the precipitation rates. Intense cloud band events are defined as the top 20% of events with (a) the most extensive land area with precipitation above a threshold and (b) the largest average precipitation over the land areas with precipitation above the same threshold. The models correctly simulate the large-extent events during austral summer, which contribute to ~10% of precipitation in tropical areas. However, the models underestimate the frequency of intense precipitation events during spring (SON), failing to reproduce the correct location and contribution of these events over the subtropics. Future scenarios (UK Met Office simulations only) indicate a decrease in the number of days with cloud bands but an increase in the frequency and intensity of the intense cloud events. Future research will focus on understanding the thermodynamic environment related to the development of the intense cloud band events both in observations and simulations.

T2v-20: Hydrological modelling of the Uruguay River with convection permitting dynamical downscaling.

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Abstract

The second objective of the CORDEX Flagship Pilot Study in Southeastern South America (FPS-SESA) proposed to develop actionable climate information from statistical and dynamical downscaling based on co-production with the impact and user community. As a result, new RCM simulations were designed for the planned impact studies of streamflow modelling of the Uruguay river. A 3-year period, June 2018 to May 2021, was selected to study the ability of convection-permitting (CP) RCM simulations outputs to reproduce the Uruguay River streamflow when used to feed the Variable Infiltration Capacity (VIC) hydrological model. During these 3 years extremely, dry conditions developed and persisted over the basin with high impact on water resources in the region including very low streamflow. Nonetheless, extreme precipitation events were also observed during warm months, which makes this period particularly interesting to study extreme discharges through hydrological modelling. The outcomes of the second phase of the FPS-SESA initiative provide four CP simulations conducted with WRF and RegCM5 RCMs, to which we have added simulations with NCAR WRF provided by SAAG. Daily outputs of precipitation, maximum and minimum temperature from all models as well as ground-based observations and ERA5 data were used to force VIC to simulate discharges in the Uruguay River which were compared with observed discharges at 7-gauge stations distributed along the upper, middle, and lower basin. Results evidenced the need to produce multi-model simulations to account for different uncertainty sources.

T2v-21: Understading the impact of physical processes on convection permitting simulations of an extreme hydrometeorological event in South America´s biggest megacity.

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Abstract

Convection-permitting models (CPMs) have been increasingly used to understand not only the urban climate but also to simulate high-resolution extreme weather events such as heavy rainfall, hail, microbursts, and wind gusts over large cities in the world. Recent studies have shown that CPMs

may improve the simulation of extreme events influenced by complex interactions between the atmosphere and the urban environment. Despite advances in recent decades, numerical forecasting of these events still has great uncertainties, especially at urban scales. In this way, we investigate the ability of the WRF-CPM using local climate zones (LCZs) to simulate extreme precipitation that occurred on February 10, 2020, over the Metropolitan Area of São Paulo. The simulations used three one-way nesting domains (9, 3, and 1 km grid spacings), with the convection of the two inner domains explicitly resolved. To validate the numerical experiments, we used the 10-minute real-time precipitation data from the rain gauges of the National Center for Monitoring and Natural Disaster Alerts and the 5-minute precipitation estimated by the meteorological radar of the São Paulo Flood Alert System. Data from the dual-frequency precipitation radar of the GPM mission's core observatory were used to analyze the atmospheric microphysical characteristics of the event as well as atmospheric variables from ECMWF ERA5. Our main findings were: (a) the CPM experiments better reproduced the extreme precipitation than the 9-km simulations; (b) the combination of two-moment Morrison MP with Bougeault and Lacarrere PBL schemes had the best performance among the simulations, in agreement with the main observed features of the extreme event and with smaller errors in 1-km than 3-km horizontal resolutions. This configuration will be used to evaluate the impact of using urban canopy models on future simulations of extreme precipitation events.

T2v-23: Large-eddy simulation-based representation of urbanization influence on the 2015 Chennai flood event

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Abstract

We investigated a flood event that occurred in the coastal region of Chennai, India, during the winter monsoon season in 2015. The flood resulted in significant losses to society, infrastructure, and agricultural land. The rainfall during this event was exceptionally heavy, three times stronger than the total amount of rainfall typically experienced in the winter season in the region. To investigate the causes of such intense rainfall in a relatively dry coastal area, we conducted a near-to-large eddy simulation (LES) at 200-m in the Chennai region of India. The LES simulation was compared with the convection-permitting simulations of 9-physics ensembles, which utilized three nested domains of 25 km, 5 km, and 1 km. The physics ensemble includes microphysics and boundary layer physics. LES simulation explicitly simulates the boundary layer. The results of the study indicated that the LES simulation successfully captured the heavy rainfall over the urbanized Chennai region, which the physical ensembles were unsuccessful to replicate. We observed that larger surface heat fluxes, indicating increased surface turbulence, played a significant role in intensifying the urban atmosphere dynamics. LES simulation can simulate urban-induced turbulence (UIT) as compared to physics ensembles. In summary, the study highlighted the impact of urban-induced turbulence on the intensification of urban atmosphere dynamics and subsequent precipitation over the urbanized Chennai region during the flood event.

T2v-24: Revisiting the 1988 rainfall extreme in Sudan with Convection-Permitting Modelling

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Abstract

The 1988 extreme rainfall remains a remarkable event in the history of Sudan. During the 4 - 5 August 1988, extreme rainfall occurred over Khartoum and the surrounding areas; and ~1.5 million people lost their homes. Rainfall measured in Khartoum is 200, corresponding to a return period of 500 years. Previous studies have shown that the extreme event was exceptional for a non-mountainous area since the cloud top temperature was maintained below -40°C for 12 hours and reached a minimum of -79°C. The study aims to revisit the 1988 rainfall extreme in Sudan using convection-permitting modelling (CPM), allowing for a more in-depth investigation of the extreme event. Motivation for the study includes: a) a lack of CPM in the study area compared to the global north and West Africa; b) CPM provides substantial improvements of processes not only concerning small-scale characteristics of rainfall but also the large-scale circulation; c) CPM can reduce the limitation introduced by deep convection parameterisation; d) and lastly, it can provide insights into the relationship among soil moisture, convection initiation, and rainfall compared to regional climate modelling (e.g., 50 km resolution) where the feedback's sign among these variables can be the opposite to CPM. Thus, the Advanced Research version of the Weather Research and Forecasting (WRF) model driven by the European Centre for Medium-Range Weather Forecasts reanalysis (ERA5) is used to reconstruct the extreme event. The WRF setup includes one parent domain (27 km) and two nested domains (9 km & 3 km) for two weeks (23 July - 5 August, excluding 24 hours for spin-up) since some rainfall events occurred in that period. The cumulus physics scheme was turned off for the innermost domain to explicitly allow the model to resolve deep convection. Despite the scarcity of station data, we will evaluate the WRF output against satellite observations (e.g., CHIRPS). Quantitative in-depth analysis of the event is still ongoing.

T2v-25: Cell tracking in CPMs: sensitivity of climate-change signal to tracking algorithm and cell definition

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Abstract

Lagrangian analysis of convective precipitation involves identifying convective cells (“objects”) and tracking them through space and time. The Lagrangian approach helps to gain insight into the physical properties and impacts of convective cells and, in particular, how these may respond to climate change. Lagrangian analysis requires both a fixed definition of what constitutes a convective object and a reliable tracking algorithm. Whether the climate-change signals of various object properties are sensitive to the choice of tracking algorithm or to how a convective object is defined has received little attention. Here we perform ensemble pseudo-global-warming

experiments at a convection-permitting resolution to test this question. Using two conceptually different tracking algorithms, Lagrangian analysis is systematically repeated with different thresholds for defining a convective object, namely minimum values for object area, intensity, and lifetime. It is found that the threshold criteria for identifying a convective object can have a strong and statistically significant impact on the magnitude of the climate-change signal, for all analysed object properties. The tracking method, meanwhile, has no impact on the climate-change signal as long as the precipitation data have a sufficiently high temporal resolution: in general, the lower the minimum permitted object size is, the higher the precipitation data's temporal resolution must be. For the case considered in our study, these insights reveal that irrespective of the tracking method, projected changes in the characteristics of convective rainfall vary considerably between cells of differing intensity, area and lifetime.

T2v-26: Decomposing the Precipitation Response to Climate Change at Convection-Permitting Scales over the continental United States

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Abstract

Explicit representation of finer scale processes can affect the sign and magnitude of the precipitation response to climate change between convection-permitting and convection-parameterizing models. We compare precipitation within a set of dynamically downscaled regional climate simulations at 4 km grid spacing (WRF) against bias-corrected Community Earth System Model (BC-CESM) output used to initialize and force the downscaled simulations. In the historical climate, the downscaled simulations demonstrate less overall error when compared to observations for most portions of the continental United States (CONUS). Both sets of simulations overestimate the incidence of environments with moderate to high precipitable water while BC-CESM generally simulates rainfall that is too frequent but less intense. In end of century projections, reductions in rainfall are stronger in the downscaled WRF simulations than in BC-CESM, particularly during the warm season. Regions such as the Northwestern United States experience 50% reductions in June-August seasonal accumulations compared to 23% in BC-CESM. This reduced drying in BC-CESM is attributed to relatively higher rainfall frequency in environments with high concentrations of precipitable water and weak vertical motion. As a result, the warmer and moister climate state within the end of century simulations naturally favours more rainfall in BC-CESM than WRF due to differences in rainfall frequency. Our results challenge the validity of rainfall projections in global climate models and highlight an extra dimension of uncertainty when comparing convection-permitting models against convection-parameterizing models. Further study is needed to diagnose the cause of this response and its robustness across several sets of downscaled simulations.

T3-01: A new method for dynamical downscaling of heatwaves by convection-permitting climate models: event-based downscaling

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Abstract

Heatwaves in urban areas can amplify urban heat island effects, which can further increase the risk of morbidity and mortality. To take into account the meteorological effects in urban planning and climate change adaptation, climate information at high spatial resolution is needed. The km scale simulations by Convection Permitting Regional Climate Models (CPRCM) provide detailed climate information at regional scale, but the computational cost of performing CPRCM simulations is very high. The standard regional climate downscaling with an ensemble of GCMs and RCMs and scenarios over 100 - 150 years is beyond the reach of CPRCMs and improved downscaling procedures are required to fully benefit from their unique characteristics. One such approach is to downscale targeted heatwave events of interest. However, CPRCMs usually need months to years of spin-up to reach physical equilibrium. Clearly, running a long spin-up to simulate e.g. weeks-long heatwave event defies the purpose.

This study optimises the procedure for downscaling of heatwave events from coarse resolution models (e.g., GCM) to kilometre scale resolution using CPRCMs. A novel approach combining offline LSM and coupled simulations is proposed to speed up the initialization procedure for the simulation of a larger ensemble of heatwave events at kilometre or even sub-kilometre scale. The pseudo-global warming (PGW) approach is applied to create the boundary conditions for the CPRCM. We will downscale and analyze a couple of heatwave events over southern Sweden during historical and future periods under different warming levels. The CPRCM used in the study is the Harmonie-Climate (HCLIM) model. The optimized event-based downscaling method significantly reduces high computational costs and improves the productivity of simulations associated with the current downscaling procedure.

T3-02: First steps with convection-permitting regional climate modelling at the Hungarian Meteorological Service

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Abstract

Regional climate modelling activity at the OMSZ has been conducted since the early 2000s in order to provide climate change information for adaptation in Hungary. Currently, the hydrostatic ALADIN-Climate5.2 and REMO2015 models are applied for a domain covering Central and Southeast Europe with 10 km horizontal resolution, using the RCP4.5 and RCP8.5 scenarios for future projections. Based on the model outputs and measurement data, a climate information system is established.

The KLIMADAT application currently contains regional temperature and precipitation climate indicators in form of annual, seasonal or monthly means for 30-year periods covering 1971–2100 with 10-year shifts. Assessment of projection uncertainties is supported by quantile-based and probability maps. The climate indicators can be displayed as grid point values over Hungary with 0.1-degree resolution and as averages for NUT3 and LAU1 regions.

Regional climate model outputs do not provide information about the sub-daily precipitation characteristics, which is important for certain impact assessments, e.g. urban planning. Therefore, we have extended our field of interest towards the convection-permitting approach. In 2022, we joined the HCLIM consortium, and have been adapting the HARMONIE-Climate regional climate model, whose non-hydrostatic, convection-permitting configuration (HCLIM43-AROME) is applied to run climate simulations with a horizontal resolution of a few km over the Carpathian Basin. On this poster, we would like to present the preliminary results of the tests and the evaluation.

Participating in this workshop provides an opportunity to gain further knowledge on this topic which would help the evaluation of the model and support our further work to produce fine resolution climate information in order to assess the impacts of climate change for the region and to provide data for impact assessments and decision makers.

T3-03: Lateral spin-up of precipitation in convection-permitting simulations over North America

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Abstract

A fundamental issue associated with the dynamical downscaling technique using limited-area models is related with the existence of "spatial spin-up" belt close to the lateral boundaries where simulated fields cannot be trusted. Here, we develop a method to identify the spatial spin-up distance of precipitation fields in convection-permitting model (CPM) simulations. We go on to apply the method to an ensemble of simulations that differ on the nesting approach and the variables used to drive the CPM simulation. We show that for simulations using a single nesting the distance can attain about 300 km (i.e., about 120 CPM grid points) and that the spatial spin-up distance varies strongly for different seasons, boundaries and driving variables. We show that the largest spin-up distances are found in winter at the western and southern boundaries, possibly due to the strong inflow in these seasons and boundaries. Our results clearly show the advantages of using a double nesting approach with a full set of microphysical variables to drive the CPM simulation. For such simulations, the computational gain from decreasing the spatial spin-up exceeds the cost of the more demanding intermediate simulation of double nesting. Our results have important practical implications for optimizing the configuration of CPM simulations including the choice of domain and the driving strategy.

T3-04: RegIPSL: South American activities and new developments of the regional earth system modeling platform

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Abstract

RegIPSL is the regional earth system modeling platform developed by the 'Institut Pierre Simon Laplace' (IPSL, France). RegIPSL dynamically couples dedicated models for most of the components of the climate system: ORCHIDEE (land and routing), WRF (atmosphere), NEMO (ocean), OASIS (coupler) and XIOS (input/output). After a first implementation over Europe/Mediterranean area, RegIPSL is being used over the South American continent for different purposes and projects. In this work we will show the current different uses of the platform as well as the ongoing plans of its upgrading.

We have been using the platform in continental regional resolution (20 km) experiments in which we analyzed, for example, the feedback into the atmosphere when the floodplains wetlands are simulated, and the impact of the deforestation in the local water budget and the tropical circulation patterns in the Amazonian Basin. We are starting to perform the first tests at kilometer-scale resolution over the transition between Amazon basin and the Andes mountain range in the area of the 'Altiplano' region. Current upgrading plans include the update of the WRF version from v3.7.1 to v4.3.3, ORCHIDEE from v2.2 to v4, as well as XIOS and OASIS upgrades.

With current activities and planned projects we hope that RegIPSL could provide reliable and complete information useful for climate and impact studies as well as for policy and decision making in the region.

T3-05: A pan-European km-scale setup of the regional climate system model TSMP to study the impact of human interventions on the terrestrial water cycle

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Abstract

The goal of the German Research Foundation Collaborative Research Centre project DETECT is to explore and understand observed patterns of hydrological change, that are related to persistent modifications of the coupled water and energy cycles of land and atmosphere, which are – aside from greenhouse gas forcing and natural variability – impacted by decades of human-induced land-use change, and intensified water use and management, contributing considerably to observed water storage trends at the regional scale. To investigate the associated terrestrial water cycle interactions and feedbacks, we use a fully coupled regional climate system model, TSMP (www.terrsysmp.org) that simulates the coupled groundwater-land surface-atmosphere system in a continuum approach. In its current implementation, TSMP consists of the COSMO atmospheric model, the Community Land Model, and the integrated hydrological model ParFlow, linked with each other through the OASIS3-MCT coupler. It has been shown previously, that TSMP can simulate the closed terrestrial water cycle, including anthropogenic water redistribution through pumping and irrigation. As part of the DETECT experiments, TSMP is used in a convection-permitting (3km) setup and configuration for a pan-European model domain. With a few pre-production-run ERA5-driven sensitivity study-simulations for short seasonal time spans, we try to explore the benefit of combining the added value of the convection-permitting resolution in combination with the 3D subsurface hydrodynamics simulation at the continental scale. Runs with human water use are compared to standard reference runs without human water use and an additional simulation with simplified 1D hydrodynamics. The altered (re-)distribution of surface and subsurface water impacts the subsurface-land-atmosphere coupling and soil water storage and eventually also atmospheric water budgets.

T3-06: Flux exchange over heterogeneous land surfaces

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Abstract

Contrary to the atmosphere, where horizontal diffusion effectively reduces small scale fluctuations, land surfaces exhibit significant variability at very small scales. Surface processes need to be considered with a finer spatial resolution than atmospheric processes. In land surface models, flux aggregation techniques, such as tile or mosaic approaches, subdivide the land surface into patches for one atmospheric grid box to address for subgrid scale variability. The tile approach subdivides the surface based on a specific criterion, such as land use, as opposed to the mosaic approach, which uses an explicit, geographical sub-grid. Since fewer patches are employed in the tile approach, less computing time is needed and it is now commonly used in Earth system models. However, because it considers multivariate heterogeneity, the mosaic technique is more flexible and precise. In this study, we use the scale-consistent, highly modular, physics-based, massively parallel, and fully integrated groundwater-vegetation-atmosphere regional Earth system modeling framework Terrestrial Systems Modeling Platform (TSMP, https://www.terrsysmp.org) to examine the effect of different flux aggregation methods on regional climate. TSMP is composed of the atmospheric models ICON or COSMO, the land surface model Community Land Model (CLM), and the ParFlow subsurface-surface hydrological model, coupled using OASIS3-MCT. We present the impact of flux aggregation techniques on atmospheric and land surface states, and outline further strategies for tackling heterogeneous land surfaces in regional climate modeling.

T3-07: Comparison of Various Satellite Inputs with HEC-HMS and Mike+ Model in the Headwaters of Afghanistan

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Abstract

Hydrological models serve as valuable tools for a multitude of purposes, yet their application often requires substantial input data, which may be inaccessible in certain developing nations. Afghanistan, a country grappling with climatic extremes, is currently in its developmental phase, seeking to harness its water resources for electricity generation and agricultural production. The primary obstacle encountered in initiating any project is the scarcity of meteorological data required as input for hydrological models. This study employs a diverse range of available satellite meteorological data in conjunction with two hydrological models, the HEC-HMS and Mike+ Model, over Afghanistan's headwaters. The models' outputs are calibrated and verified against observed data from gauging stations across various climatic zones in Afghanistan. Furthermore, the satellite data input for the models is compared with the limited available observed meteorological data. The findings of this study will be beneficial for water resource planners and managers in designing hydraulic structures, planning irrigation schemes, and developing adaptive measures for the rivers of Afghanistan.

T3-08: The effect of reduced floating-point precision on climate simulations: A statistical analysis

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Abstract

Simulating our atmosphere at km-scale resolution substantially improves the representation of many atmospheric processes. However, today's climate models are still predominantly run at coarser resolutions due to prohibitively high computational costs. One way to substantially reduce these

costs is by reducing precision in the representation of floating-point numbers. However, while reduced precision is used in some operational numerical weather prediction models, climate simulations are still typically run in double precision.

Recent studies indicate that reduced precision is also justified for climate simulations. However, these studies focus on idealized cases, decadal averages of a few key variables, or use atmospheric models with simplified physics parameterizations.

We will present a statistical analysis of 100-member 10-year-long regional climate ensembles in double and single precision performed with the COSMO model in a EURO-CORDEX configuration. For the analysis, we use a verification methodology developed originally to detect tiny differences in model behavior caused by hardware or software updates (https://doi.org/10.5194/gmd-15-3183-2022).

By applying the statistical testing at a grid-cell level for 47 output variables every 12 or 24 hours, we only detected a marginally increased rejection rate for the single-precision climate simulations compared to the double-precision reference. This increase is much smaller than that arising from minor variations of the diffusion coefficient in the model. Therefore, we deem it negligible.

To our knowledge, this study represents the most comprehensive analysis so far on the effects of reduced precision on a climate simulation with a fully-fledged climate model in a realistic setting. The verification methodology is model agnostic, meaning it can be applied to any model. For COSMO, our findings encourage exploiting the runtime reduction of ~40% obtained from reduced precision for climate simulations.

T3v-09: First steps towards convection-permitting climate simulations for Germany with ICON-CLM

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Abstract

The weather forecast model ICON, which is in operational use at Deutscher Wetterdienst (DWD) in Germany, can now also be used in climate mode (called "ICON-CLM") for regional climate modeling in a horizontal range down to the km scale. We are currently on the way to migrate our activities in simulating the regional climate for Germany and Central Europe on convection-permitting scale from COSMO-CLM (the former standard regional climate model at DWD) to ICON-CLM.

These activities include the following. First, a downscaling of ERA5 for Germany usable as reference for climate change simulations and as additional information for many variables which cannot be measured in such high temporal or spatial frequency. Second, climate change simulations for the German research project "Network of Experts – Adapting transport and infrastructure to climate change and extreme weather events ", where high-resolution information on precipitation and wind extremes are needed to improve the resilience of the national transport infrastructure towards extreme weather and climate change; and others.

As there is no recommended configuration yet on the convection-permitting scale for climate simulations with ICON-CLM, we are evaluating a few options, which include finding an optimal model domain and resolution as well as investigating possible namelist settings. The results of the found sensitivities from different test simulations will be presented, as well as comparisons to previous COSMO-CLM simulations.

T4-01: Use of the output convection-permitting climate modeling (CPCM) for building energy simulation in Indonesia

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Abstract

The building sector has contributed to climate change due to the large consumption of fossil energy for heating and air conditioning systems. A clear understanding of the spatial and temporal local climate system including diurnal and seasonal variations represented by weather models is needed to design energy-efficient buildings in the future. A CPCM has been simulated by the Indonesian Agency for Meteorology Climatology and Geophysics (BMKG) based on Weather Research and Forecasting (WRF) model which is assimilated with observational data. The model outputs for the simulated period of January to December 2022 were the 160 weather elements with a spatial resolution of 9 km and a 3-hourly temporal resolution. The outputs have 19 vertical altitude levels within the Indonesian region whose domain boundary ranges from 93,7°E to 143,9°E and 15,0°S to 9,9°N. The weather elements resulting from the output of the WRF model were used to evaluate the ratio of energy supply and energy demand applied to the design of the residential building type 70m^2. This design used 2 solar panel cells measuring an area of 3,2 m^2 and a wind turbine with a blade length of 1,8 m in all grid locations. Energy demand in the form of energy consumption for air conditioning systems to achieve thermal comfort has been calculated based on temperature data. The total energy supply in the form of the potential of photovoltaic energy was calculated based on the downward short-wave flux at the ground surface and the potential of wind energy was calculated based on wind speed. Results show that the ratio between energy demand and energy supply varies significantly within Indonesian regions. Additionally, simulation results of building energy analysis based on the output of the WRF model show that the energy supply is greater than the monthly energy demand in highland areas. Meanwhile, in lowland areas, the energy demand typically exceeds the amount of the energy supply provided by renewable energy.

T4v-02: CPM parametrization scheme for community-based resiliency modeling

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Abstract

The ocean has been warming since 2005, continuing the multi-decadal ocean warming trends as documented in the IPCC Fifth Assessment Report (AR5). Yearly rainfall displays a great deal of climatic fluctuation resulting in an error or delays in resiliency planning. Due to poor correlation in parameters and grid resolution, it's important to consider the local surface reflectivity, knowledge base, and resource as part of resiliency planning. We explore scaling parameter permutation with risk priority based on distribution at convection-permitting resolution from 10Km to 2Km range on how a community can benefit from such resiliency planning.

T4v-03: EDUCAS - CPRCM uncertainty set in RCM and GCM context to inform users

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Abstract

With the new CPRCM datasets over the Alps and other regions in Europe, we want the data to be used in climate impact studies and decision making. The data is asked for and much appreciated, though additional information about the data needs to follow along. This is particularly important in the non-Alpine regions, e.g. Scandinavia, with only 2 to 4 simulations available. To avoid the fall back to using only single simulations as the truth, like many years ago, we need to provide uncertainty information along with the data.

In a national project (EDUCAS) as well as in the EU project (EUCP) we set CPRCMs in the context of RCM and GCM ensembles to learn about their spread and uncertainty. A 10 member ensemble over the Alps informed us about the relation of downscaling to change in spread in climate change signals of user relevant climate indicators. Though no clear pattern could be found to transfer to other regions, like Sweden, the representation of the CPRCM ensemble covers most parts of the RCM ensemble (EURO-CORDEX). This information is communicated to three example users within hydrology, urban climatology, and oceanography. By focussing on indicators chosen in discussion with the users and visualisation of the results in close cooperation with the users, we could provide a guided usage of CPRCM data.

T5-01: Exploiting netCDF-4 features for high-resolution model output storage and access

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Abstract

NetCDF has been the format of choice to store climate model output data since its inception in the 1990s. With the release of netCDF version 4.0 (netCDF-4, 2008), the use of different data file formats as storage layers was allowed, along with the definition of an interface library that abstracts the underlying storage with respect to the data model layer. Therefore, netCDF-4 is no longer just a multidimensional data and metadata encoding format (as was the netCDF-3 classic format), but it is now an enhanced data model (netCDF-4 data model) with a reference library that supports classic netCDF formats, but also reading other disk or remote formats or protocols as OPeNDAP or S3/ZARR. We discuss in this work the possibilities of this abstraction layer for the storage and access to convection-permitting (CP), high-resolution model output.

HDF5 provides a powerful and flexible storage layer for netCDF-4, enabling efficient management of multidimensional data. This storage layer transparently provides netCDF-4 with features such as chunking, lossless compression, and parallel I/O, which enhance performance and storage capabilities. These features enable efficient access to large datasets, reduce storage requirements, and improve data I/O performance and transfer. Some HDF5 features, such as chunking and filters, provide powerful collateral advantages such as lossy compression by means of data quantization and truncation. Additionally, the HDF5 storage format provides many other advanced features, including virtual file drivers, virtual object layer and virtual datasets, that offer further benefits for netCDF-4.

As an example, in this work we also test different lossy-compression data encoding settings on CP climate model output from CORDEX-FPSCONV. Depending on the physical field, deflation ratios up to 50% are obtained, which lead to considerable savings in storage space, transfer rates and, ultimately, the carbon footprint of the maintenance of these large datasets.

T6-01: Understanding water vapour concentration trends and biases in the UTLS region using a km-scale model: a study over the Third Pole region

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Abstract

The water vapour in the upper troposphere and lower stratosphere (UTLS) is crucial in the Earth's radiation budget, influencing climate and weather systems. This study utilised a high-resolution model, ICON-CLM with Dx = 3.3 km, to examine the trends and variations in the water vapour concentration in the UTLS region over the Third Pole region and contrasted the results with ERA5 reanalysis data. In the UTLS region, our findings indicate a strong correlation between the ICON-CLM simulation and ERA5 reanalysis data. During the months preceding the monsoon, the simulation showed a higher specific humidity at 100hPa than ERA5. During monsoon months, ERA5 predicted substantially higher specific humidity than ICON-CLM. In general, ERA5 indicated increased specific humidity over the south-central portion of the Tibetan Plateau (TP), whereas the simulation indicated high specific humidity over the southeast portion of the TP. During the post-monsoon period, both simulation and reanalysis indicated that the northern portion of TP had a higher specific humidity than the southern portion. In addition, during dry winter months, the ICON-CLM simulation revealed a substantial quantity of specific humidity in the UTLS region of the North and Central TP region, whereas ERA5 did not exhibit this trend. Nevertheless, from May to July, simulation and reanalysis demonstrated an increase in specific humidity in the UTLS region as the monsoon moved from the southeast to the central portion of TP. In the reanalysis, this trend continued to shift to the north of TP during August and September, whereas the simulation indicated high specific humidity in the southern TP, which shifted northward in September, like ERA5. In addition to synoptic features, the km-scale simulation shows more localised features. These findings could enhance our understanding of the trends and biases of water vapour concentration in the UTLS region and the added valu of km-scale simulations.

T6-02: Convection-permitting modelling improves simulated precipitation over the Tibetan Plateau

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Abstract

The Tibetan Plateau (TP) plays an essential role in influencing the global climate, and precipitation is one of its most important water-cycle components. However, accurately simulating precipitation over the TP is a long-standing challenge. In this study, a convection permitting model (CPM; with 4km grid spacing) that covers the entire TP was conducted and compared to two mesoscale models (MSMs; with model horizontal resolutions of 13km and 35km) over the course of a summer. The

results showed that the two MSMs have notable wet biases over the TP and can overestimate the summer precipitation by more than 4.0 mm day-1 in some parts of the Three River Source region. Moreover, both MSMs have more frequent light rainfall, increasing horizontal resolution of the MSMs alone does not reduce the excessive precipitation. Further investigation reveals that the MSMs have a spurious early-afternoon rainfall peak, which can be linked to a strong dependence on convective available potential energy (CAPE) that dominates the wet biases. Herein, we highlight that the sensitivity of CAPE to surface temperatures may cause the MSMs to have a spurious hydrological response to surface warming. Users of climate projections should be aware of this potential model uncertainty when investigating future hydrological changes over the TP. In comparison, the CPM removes the spurious afternoon rainfall and thus significantly reduces the wet bias simulated by the MSMs. In addition, the CPM also better depicts the precipitation frequency and intensity, and is therefore a promising tool for dynamic downscaling over the TP.

T6-03: Probing the state of the atmosphere in 4-dimensions using observations of the isotopic composition of water vapor and precipitation

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Abstract

Thanks to differences in the molecular properties of water stable isotopes, the water isotopic composition of water vapor and precipitation are an integrated recorder of the phase change history of the atmospheric hydrological cycle. As such, water isotopes provide information on moisture transport, cloud processes, weather systems, and moisture origin from present-day and paleoclimate archives in models and observations.

As field deployable laser spectrometer together with robust calibration protocols are becoming available for deployments on land, sea, and by air, it is now possible to use the water isotopic composition in addition to the humidity of the atmosphere as a tool to benchmark the treatment of hydrological cycle in models. In fact, the recent decade has provided observational records of water isotopic composition in both water vapor and precipitation continuously spanning more than 10 years, spatial observations from networks of measurements carried out on 50 meter tall towers, atmospheric observations on drones, ultra-light aircrafts, tethered and free balloon platforms, and aircraft. These measurements span from centimetres above the surface up to 7 km above sea level and on temporal time scales down to minutes.

This vast dataset offers up the possibility for a joint effort between the modelling and observations community to utilize these observations to improve specific model parameterizations. Of convective permitting climate model only the COSMO and WRF models has water isotopes implemented as tracers of the atmospheric water vapor. However, studies have so far predominantly been focused on benchmarking the performance of the modeled water stable isotopes against observations with only little effort on directly improving parameterizations implemented in the models. Here I will present case-studies highlighting how high-resolution observations of both water vapor and precipitation isotopes can be utilized to improve model parameterizations.

T6v-04: Sub-km simulations over Denmark with HCLIM38: Any benefits?

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Abstract

A double-nested set of simulations have been performed with the convection permitting non-hydrostatic Harmonie-Climate cy38 model with the AROME physical parameterization driven by ERA5, with a 750 m domain covering Denmark inside a 5 km domain covering the North Sea, southern Scandinavia and the Baltic Sea. The simulation covers 7-month periods, April-October for the 5 years 2007, 2011, 2014, 2015, and 2017. These years were chosen due to observed extreme precipitation during the periods and are therefore not intended as being representative.

The new simulations were compared with existing 3 km and 12 km Scandinavian simulations from the NorCP project, as well as with point observations. Both hourly and sub-hourly extreme events were analysed. Geographical patterns of precipitation improve with higher resolution, but there is less improvement in the description of extreme precipitation than expected; this emphasizes the need to adapt parameterisations to the higher resolution in order to gain added benefit from very-high-resolution simulations.

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