Met Office

Links between the NWP and Climate communities

Mike Bush

40th EWGLAM and 25th SRNWP Meeting

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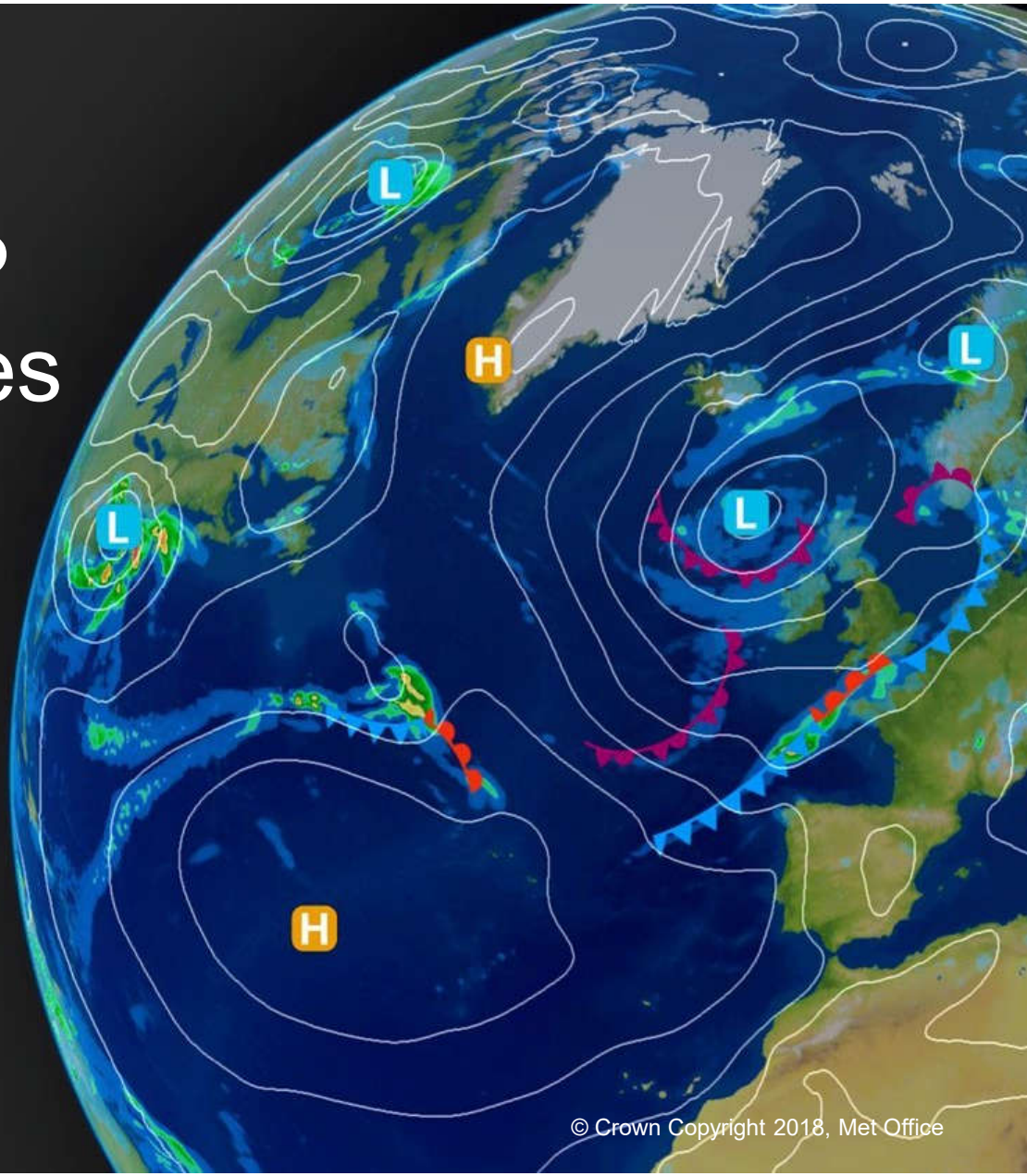
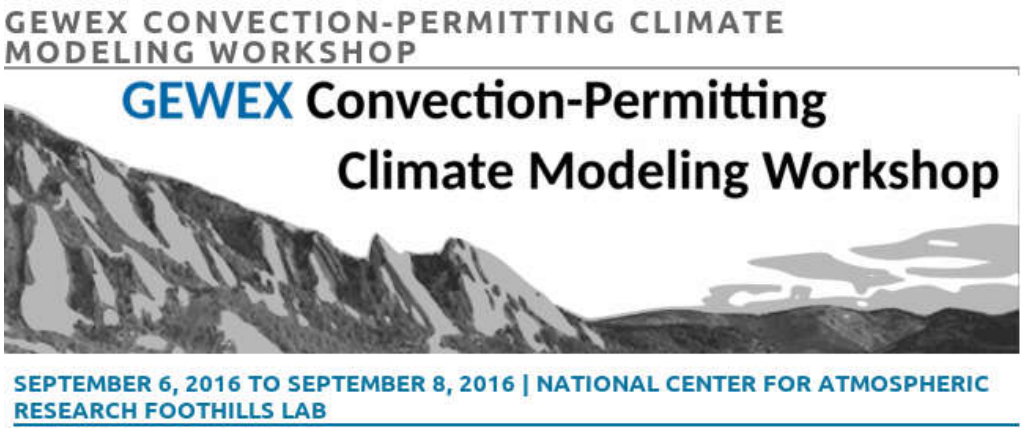
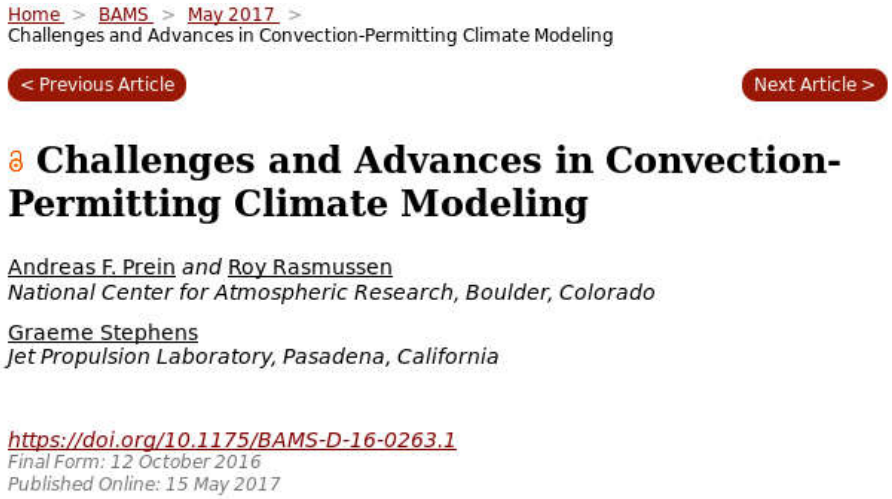


Challenges and Advances in CP climate Modelling

Andreas Prein et al (2017)





- In September 2016, about 70 representatives from a rapidly growing group of scientists that use convection-permitting models (grid spacings ≤ 4 km) met to discuss the most pressing challenges, future perspectives, and opportunities to collaborate within the CP climate research area
- A central goal of the workshop was to identify key challenges associated with CPMs and strategies to overcome them.
- **“Closely cooperating with the numerical weather prediction community that uses CPMs for weather forecasting would accelerate future model developments”.**

Main Challenges and future research

Andreas Prein et al (2017)

- 1) **The large computational cost of CPM simulations** constrains them to short periods and/or small domains. New computer architectures and running models mainly on GPUs instead of CPUs can lead to significant speedups and enable CPMs to run on larger domains and longer periods (Leutwyler et al. 2016).
- 2) **The big model output data volume** makes it challenging to store, analyze, and share data. Evaluating the CPM simulation online (during the processing), storing data on cloud-based platforms, and analyzing data at central computational systems are promising future pathways to overcome these challenges.
- 3) **Assessing uncertainties in CPM simulations** is difficult because of their high computational costs. Defining common experiments and standards for data output/model evaluation will help systematic investigations of uncertainty.
- 4) **Missing high-resolution, high-quality observational datasets** make CPM evaluation and development challenging and often constrains their application to data-rich regions. International projects are needed that focus on the collection of high-res data, quality assessments, and the distribution of data in common formats.
- 5) **The relevance of CPMs in areas beyond precipitation** including processes such as local wind systems, snowpack dynamics and hydrology, land–atmosphere interactions, evapotranspiration, clouds and radiation…
- 6) **A major challenge in CPMs is the treatment of turbulence.** Studies that investigate the dependence of the model performance on the applied grid spacing, the influence of different PBL schemes, and the role of parameterizing deep convection with scale-aware convection parameterization schemes at convection-permitting scales show strong sensitivities to these changes.

- September 2018 workshop. Key Topics:
- 1) Convection-permitting modelling and the water cycle
- 2) Modelling of tropical phenomena
- 3) Analysis of convection-permitting climate & weather simulations
- 4) Model setup in convection-permitting simulations
- 5) Observational datasets and advanced evaluation techniques
- 6) Convection-permitting modelling across scales (S2S)

Dynamical downscaling at CP scales: is it worth it? (Roy Rasmussen)

- Do we need to go to Global CP modelling?
- Do Global models with convection parametrizations provide good enough LBCs for CP LAMs?
- “Dreary state of ppn in Global models” Stephens et al. (JGR, 2010)
- Key issues of getting the correct ppn intensity, frequency, duration, sequence and phase.
- Implications for soil moisture runoff and surface hydrology
- Met Office experience of running CP NWP simulations over Singapore is that there is a huge forecast quality sensitivity to the driving model.
- Important implications for model development - it is tempting to tune the model and inadvertently introduce compensating errors

Dynamical downscaling at CP scales: is it worth it? (Roy Rasmussen)

- Peak in the diurnal cycle of convection occurs at different times over the USA due to the different modes of convection. MCSs over the central U.S lead to a midnight maximum whilst the East Coast has a late afternoon maximum due to locally generated convection.
- Met Office experience of looking at the diurnal cycle of convection shows that we have different systematic errors in the initiation and time of maximum convection in the mid-latitudes and the tropics – a signal which is not well understood.
- It is important to distinguish the different modes of convection when compositing statistics for evaluation.
- Bigger (increased rain rate and rain area) MCSs in future climate?

ABOUT PANELS ACTIVITIES EVENTS

WATER FOR THE FOOD BASKETS OF THE WORLD

GEWEX leads the WCRP Grand Challenge on Water Availability, which focuses on assessing how fresh water availability will shift in some of the major food producing regions of the world due to climate change.

Scope

The overarching science question guiding this Grand Challenge is "*how will a warming world affect available fresh water resources globally, specifically in the food basket regions, and how will it change human interactions with these resources and their value to society?*" While considering water supply and demand, the question also addresses societal and environmental responses: the concentration will be on geophysical processes and the anthropogenic influences on those processes.

Geography

The main regions tackled in this Grand Challenge are the Central Valley and Great Plains of North America, the Pannonian Basin in Europe, and the wheat- and rice-producing regions of Eastern Asia, particularly China. Each of these regions have distinctly different hydrological regimes and associated issues, providing a unique opportunity to study the effects of global climate change on water-related phenomena.

Science

Local and regional changes in the availability of fresh water due to natural climate variability at different timescales, as well as regional and worldwide environmental change, are key human challenges. The processes in the hydrological cycle involve both vertical and horizontal transports important to the (re)distribution of water on both global and regional scales.

GEWEX

WCRP'S GRAND CHALLENGES

WATER FOR THE FOOD BASKETS OF THE WORLD

UPCOMING EVENTS

22-26 OCT 2018
ANDEX – GHP – INARCH MEETINGS AND WORKSHOPS

22 - 23 OCTOBER, 2018
UTCC PROES WORKSHOP, FRANCE

13–16 NOV 2018
THE EARTH'S ENERGY IMBALANCE WORKSHOP

26-29 NOVEMBER

HOME RESOURCES CONTACT

Water for the food baskets of the world (Peter Van Oevelen)

- Our knowledge of the water cycle is essentially of a system perceived as natural. How true is this currently? Farming/agriculture
- Need to better quantify human control on the water cycle before we try and turn climate change forecasts into impact forecasts. Humans react more to socio-economic changes than geophysical ones.
- Human control is more than just irrigation, but also ground water extraction and reservoir management.
- Parametrizations exist e.g. Integrated parameterization of irrigation in the land surface model ORCHIDEE (P. de Rosnay, J. Polcher).
- For NWP we have soil moisture analyses which pick up satellite estimates of soil moisture that can “see” the effects of irrigation. This is not the case for climate runs.

Modelling MCSs and their Large Scale environments (Ruby Leung)

- MCSs are responsible for 60% of Summer rainfall in the Great Plains of the U.S and 50-60% of tropical rainfall globally.
- Deficiencies in modelling MCSs lead to errors in the diurnal variability of precipitation in these areas.
- Understanding the environmental conditions producing long-lived MCSs is a priority for understanding future changes to ppn characteristics.
- Diagnostics of MCS lifetime, event mean precipitation and equivalent diameter.

April MCSs	Summer MCSs
Strong synoptic scale forcing associated with baroclinic waves	High pressure over central U.S.A
Strong low level jet (LLJ)	Weaker LLJ
Moisture supply from the Gulf of Mexico	Lower predictability so error growth much faster. Summer dry bias important and soil moisture important.

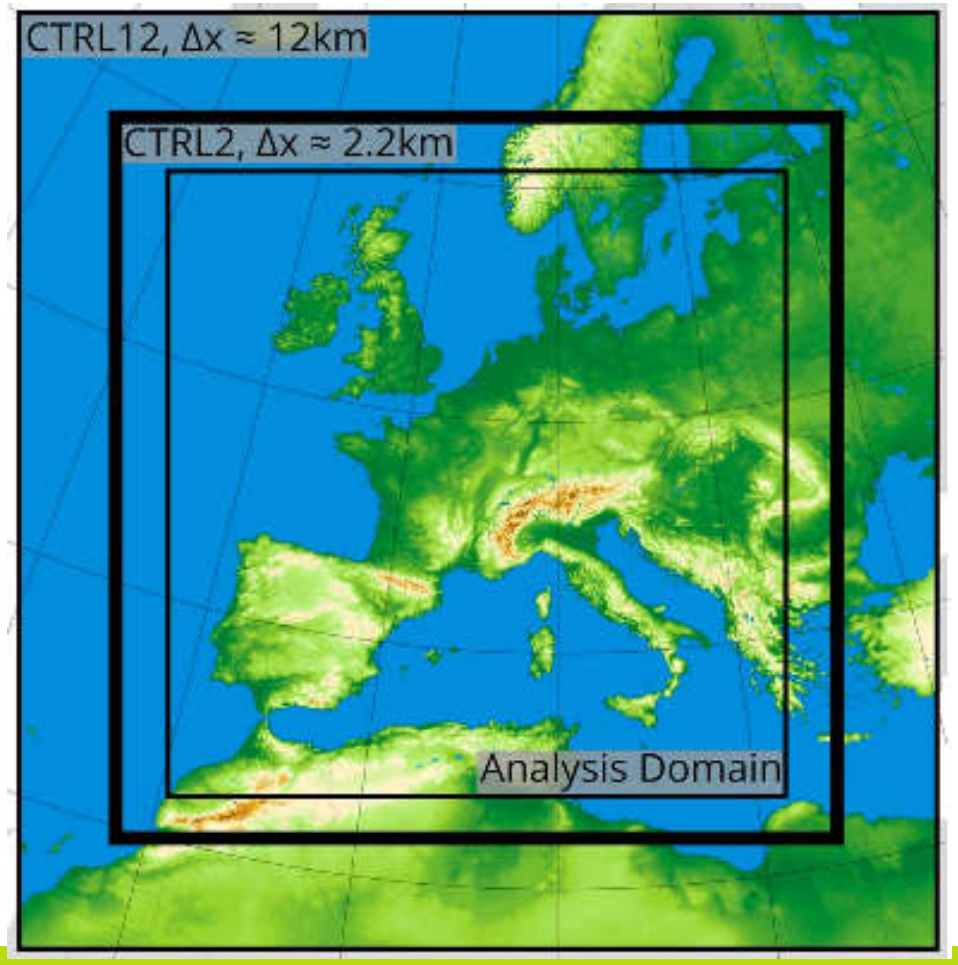
Clausius-Clapeyron (Nikolina Ban)

- Despite the trend towards dryer conditions over Europe, many models project increases of extreme precipitation.
- According to theoretical, observational and modelling studies, the increase in extreme daily precipitation is consistent with the Clausius-Clapeyron rate, i.e. 6-7% per degree of global warming.
- However, for hourly extreme precipitation, some studies have raised the possibility of dramatic increases that amount to 14% per degree warming.
- Compare a present-day simulation driven by ERA-Interim reanalysis (Leutwyler at al., 2017 JGR) with a Pseudo-Global Warming (PGW) simulation to assess climate change effects.

Leutwyler et al. 2017

(Journal of Geophysical Research: Atmospheres)

- Results of a 10-year-long climate simulation at a gridspacing of 2.2 km, covering continental Europe
- COSMO model (run on GPUs) driven by the ERA-Interim reanalysis.
- An assessment of the10-year-long simulation is conducted using a wide range of data sets, including several rain gauge networks (Hourly German and Swiss Precipitation Data Sets), energy balance stations, and a remotely sensed lightning data set.



Pseudo Global Warming (Schär et al. 1996)

- The PGW simulation is driven by ERA-Interim reanalysis perturbed with the mean annual cycle of climate changes derived from a CMIP5 model.
- In this approach, resulting changes are due to large scale warming and moistening of the atmosphere and due to seasonal circulation changes.
- Consistency with CC was found for all regions except the British Isles…
- While heavy precipitation and winds intensify with warmer climate over mid-Europe, changes in cloud are dominated by reductions in low and medium level cloud due to raised cloud bases.

Severe Weather - Heavy ppn events in SE France (Quentin Fumière)

- The Mediterranean region of France is regularly affected by extreme precipitation that often leads to flash floods.
- The evolution of such events in future climate in terms of occurrence and severity is investigated by comparing a historical simulation (1976-2005) with a future one (2071-2100).
- The study also looked at differences between ALADIN-Climate and AROME-Climate and found large differences over the Alps.

CAPE and CIN in future climate (Kristen Rasmussen)

- CP Climate simulations using the PGW approach looking at changes to convective environments in future climate.
- Results from the analysis show weak to moderate convection will decrease in frequency in future climate whilst strong convection will increase.
- Both CIN and CAPE were found to increase downstream of the Rockies
- Convection could become more intermittent with increased CIN suppressing weak to moderate convection and providing an environment where CAPE can build up to extreme levels resulting in more frequent severe convection.

RELAMPAGO campaign (Lluís Fita Borrell)

- Intensive observational campaign to be carried out over the Córdoba mountains of Argentina during November and December 2018.
- Remote sensing data have shown that the convective systems in subtropical South America are extreme in the present climate: the convective elements within them are the tallest and broadest in the tropics and sub-tropics, satellite proxies for hail are maximized, the systems contain some of the highest lightning flash rates in the world.
- Project focused on measurements of strong convective activity in the area. Collaborating institutions from the U.S.A, Argentina and Brazil.
- A series of different instruments including Mobile Mesonets, Lightning Mapping Arrays, soundings, fixed and mobile radar, lidar, microwave profilers, surface flux measurements.

Conclusions (1)

- The PGW approach is widely used in the CP Climate community as an affordable way of simulating future climate.
- A number of PGW simulations are driven by ERA-Interim reanalysis perturbed with the mean annual cycle of climate changes derived from a CMIP5 model - resulting changes are due to large scale warming and moistening of the atmosphere and due to seasonal circulation changes.
- This contrasts with the Met Office approach of running an ensemble of CP climate projections driven by an ensemble of global climate simulations (HadGEM3-GC3 model, at ~60km) sampling both modelling uncertainty and variability.
- Simulations run over UK with +12 ensemble members allow estimate of uncertainty at km-scale and support UK risk assessment studies.

Conclusions (2)

- According to theoretical, observational and modelling studies, the increase in extreme daily precipitation is consistent with the Clausius-Clapeyron rate, i.e. 6-7% per degree of global warming.
- Results from the Kirsten Rasmussen show weak to moderate convection will decrease in frequency in future climate whilst strong convection will increase. Both CIN and CAPE were found to increase.
- Bigger (increased rain rate and rain area) MCSs in future climate?

Conclusions (3)

- **“Closely cooperating with the numerical weather prediction community that uses CPMs for weather forecasting would accelerate future model developments”.**
- CP Climate community is interested in the same key issues as the NWP community - getting the correct ppn intensity, frequency, duration, sequence and phase.
- Diagnostics for the evaluation of models e.g. CIN/CAPE are of interest to both communities
- CP Climate community is interested in Intensive observational campaigns and also high temporal frequency/ high spatial resolution observational datasets for evaluation.

Conclusions (4)

- The signal to noise ratio when running NWP case studies (or even data assimilation trials) can be large.
- This is a problem when evaluating changes to the model formulation (verification statistics with large error bars and subjective evaluation showing differences of the order of a pair of ensemble members).
- The statistical significance to results that a multi-year climate simulation (or shorter simulations) can bring should be used to complement NWP testing.
- Should lead to increased confidence in the fidelity of model upgrade changes…

Met Office

Questions?

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