Highlights from the 2016 Dynamical Core Model Intercomparison Project (DCMIP-2016)

DCMIP-2016 group photo at NCAR (June 2016)

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Overview

The 2016 **Dynamical Core Model Intercomparison Project** (DCMIP-2016, see also the URL https://www.earthsystemcog.org/projects/dcmip-2016/) shed light on the newest modeling techniques for global weather and climate and models with particular focus on the newest non-hydrostatic atmospheric dynamical cores, their physics-dynamics coupling, and variable-resolution aspects. As part of a two-week summer school held in June 2016 at the National Center for Atmospheric Research (NCAR), a main objective of DCMIP-2016 was to establish an open-access database via the Earth System Grid Federation (ESGF) that hosts DCMIP-2016 simulations for community use from over 12 international modeling groups. In addition, DCMIP-2016 established new **atmospheric model test cases of intermediate complexity** that incorporated simplified physical parameterizations.

The poster presents the results of the three DCMIP-2016 test cases which assess the evolution of an idealized moist baroclinic wave, a tropical cyclone and a supercell. All flow scenarios start from analytically-prescribed moist reference states in gradient-wind and hydrostatic balance which are overlaid by localized perturbations. The poster presents snapshots of the DCMIP-2016 dynamical core simulations and reveals the impact of the moisture processes on the flow fields over 5-15 forecast days. The work demonstrates that idealized test cases are part of a model hierarchy that helps distinguish between causes and effects in atmospheric models and their physics-dynamics interplay. This characterizes and informs the design of atmospheric dynamical cores.

Design of the DCMIP-2016 Test Cases

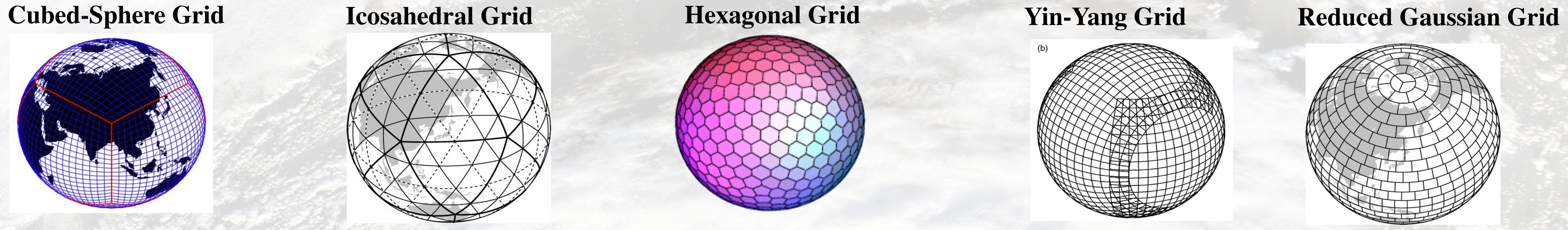
The descriptions of the three DCMIP-2016 test cases and their corresponding Fortran source files are provided in the GitHub repository https://github.com/ClimateGlobalChange/DCMIP2016. In particular, DCMIP added moisture to the Ullrich et al. (2014) baroclinic wave, utilized the Reed and Jablonowski (2011) idealized tropical cyclone test case in combination with the Reed and Jablonowski (2012) "simple-physics" package, and tested the evolution of a supercell on a reduced-size non-rotating planet as described in Klemp et al. (2015). The precipitation processes in all three test cases were represented by a **warm-rain Kessler-type parameterization** (Klemp et al., 2015). In addition, the tropical cyclone test case utilized the "simple-physics" surface fluxes and turbulent mixing in the boundary layer.

The baroclinic wave and the aqua-planet tropical cyclone test case were configured with 30 stretched vertical levels (L30, model top at 44 km). The supercell used 40 equidistant vertical levels with Δz=500 m (model top at 20 km). None of the tests included topography. The horizontal grid spacings shown here were around 110 km (baroclinic wave), 55 and 28 km (tropical cyclone) and 0.5, 1, 2, 4 km (supercell with a reduced Earth radius of 53 km).

The DCMIP-2016 Dynamical Cores

Dynamical cores are the central component of every atmospheric General Circulation Model (GCM) and determine the numerical methods, diffusion properties and the computational mesh for the resolved fluid flow. Below, all 12 DCMIP-2016 models are grouped according to their computational grid. The model acronyms are used to label the results below. Almost all dynamical cores are based on the non-hydrostatic equation set, except CAM-SE, DYNAMICO and the CSU model. The latter three utilized the hydrostatic primitive equations.

Cubed-Sphere Grid | Icosahedral Grid | Hexagonal Grid | Yin-Yang Grid | Reduced Gaussian Grid



- **Cubed-Sphere Grid:** **CAM-SE** (NCAR/DoE), **FV3** (NOAA GFDL), **NEPTUNE** (NRL), **TEMPEST** (UC Davis)
- **Icosahedral Grid:** **ICON** (MPI, DWD, Germany), **DYNAMICO** (IPSL, Paris, France)
- **Hexagonal Grid:** **MPAS** (NCAR), **CSU** (Colorado State Uni.), **NICAM** (RIKEN, JAMSTEC, Japan), **OLAM** (Uni. Miami)
- **Yin-Yang Grid:** **GEM** (Environment Canada)
- **Reduced Gaussian Grid:** **FVM** (ECMWF, Reading, U.K.)

Moist Baroclinic Wave

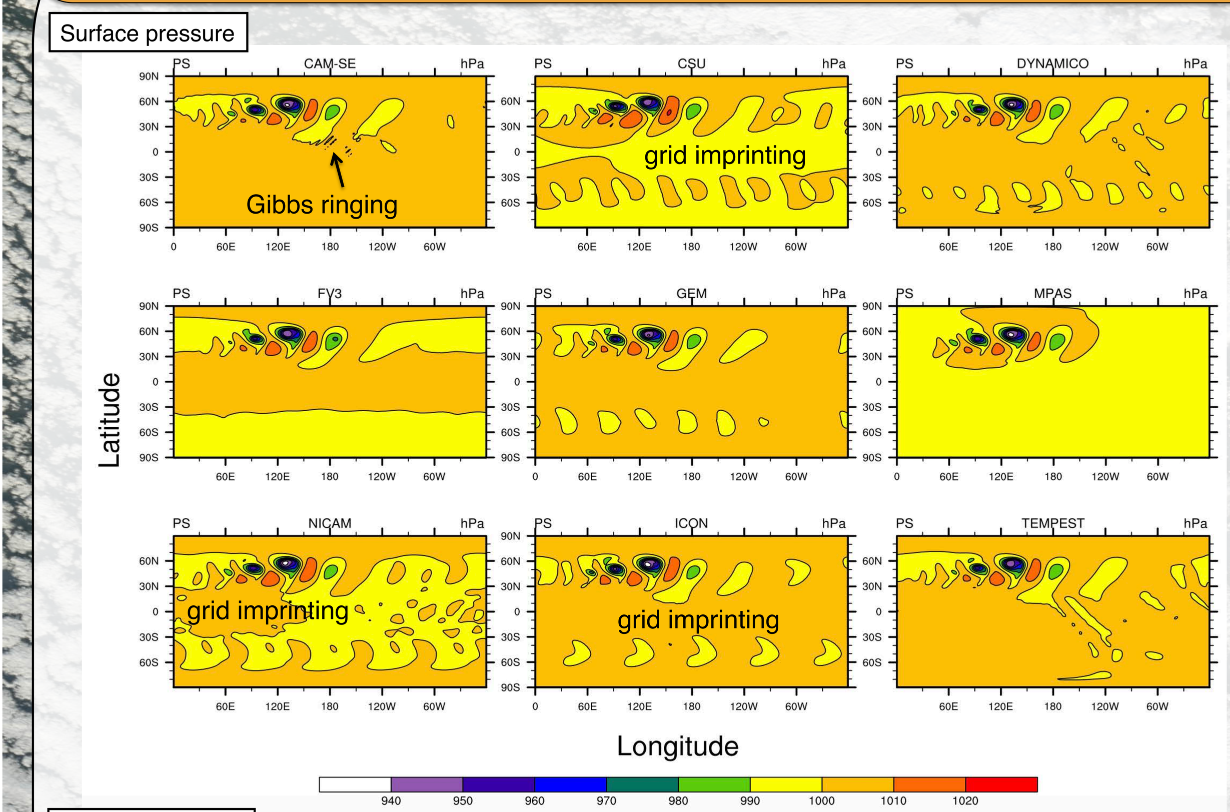
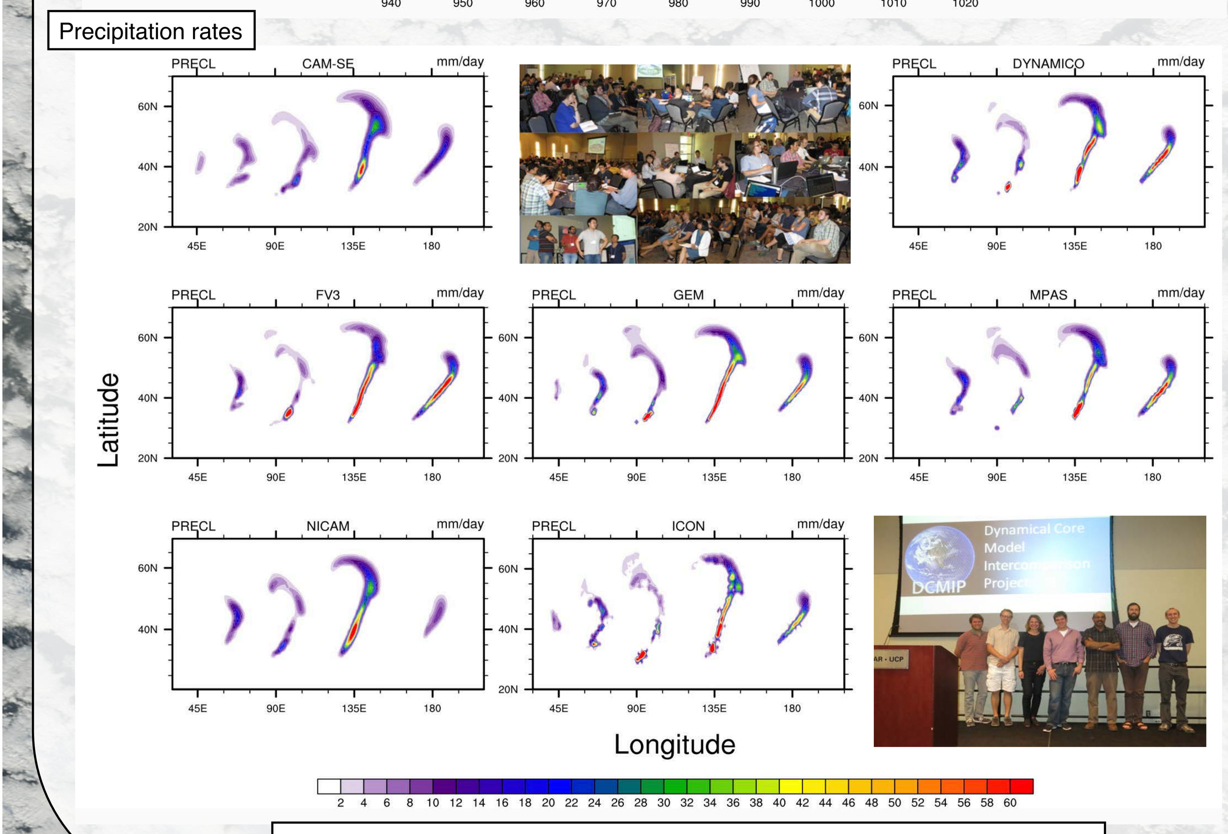


Figure 1: Surface pressure (p_s) at day 10. The initially small wind perturbation has grown into a well-developed baroclinic wave with a sequence of high and low pressure cells. Some models (CSU, NICAM, ICON) show grid imprinting that reflects the underlying computational grid. The spectral element method in CAM-SE experiences mild Gibbs oscillations (noise).



Physics (precipitation) and dynamics are coupled every 1800 s.

Figure 2: Instantaneous precipitation rates at day 10 of selected DCMIP models. Most models develop four organized precipitation bands which are aligned with the low pressure systems (Fig. 1) and their cold fronts. CAM-SE, GEM and ICON show five precipitation bands which highlights the physics-dynamics interplay. The photos show snapshots of the DCMIP summer school and the organizers.

Tropical Cyclone

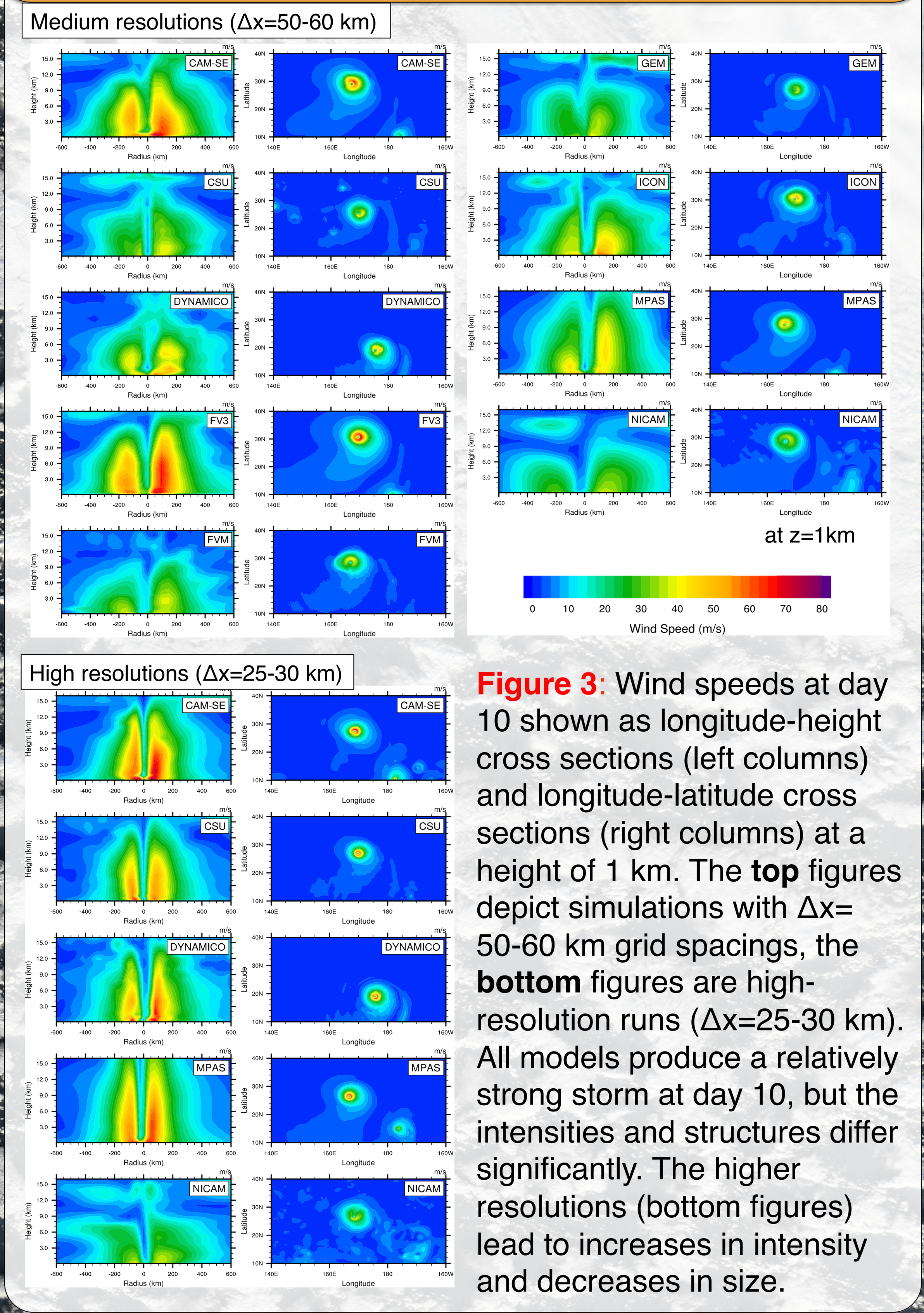


Figure 3: Wind speeds at day 10 shown as longitude-height cross sections (left columns) and longitude-latitude cross sections (right columns) at a height of 1 km. The **top** figures depict simulations with Δx= 50-60 km grid spacings, the **bottom** figures are high-resolution runs (Δx=25-30 km). All models produce a relatively strong storm at day 10, but the intensities and structures differ significantly. The higher resolutions (bottom figures) lead to increases in intensity and decreases in size.

Supercell on a Reduced-Size Planet

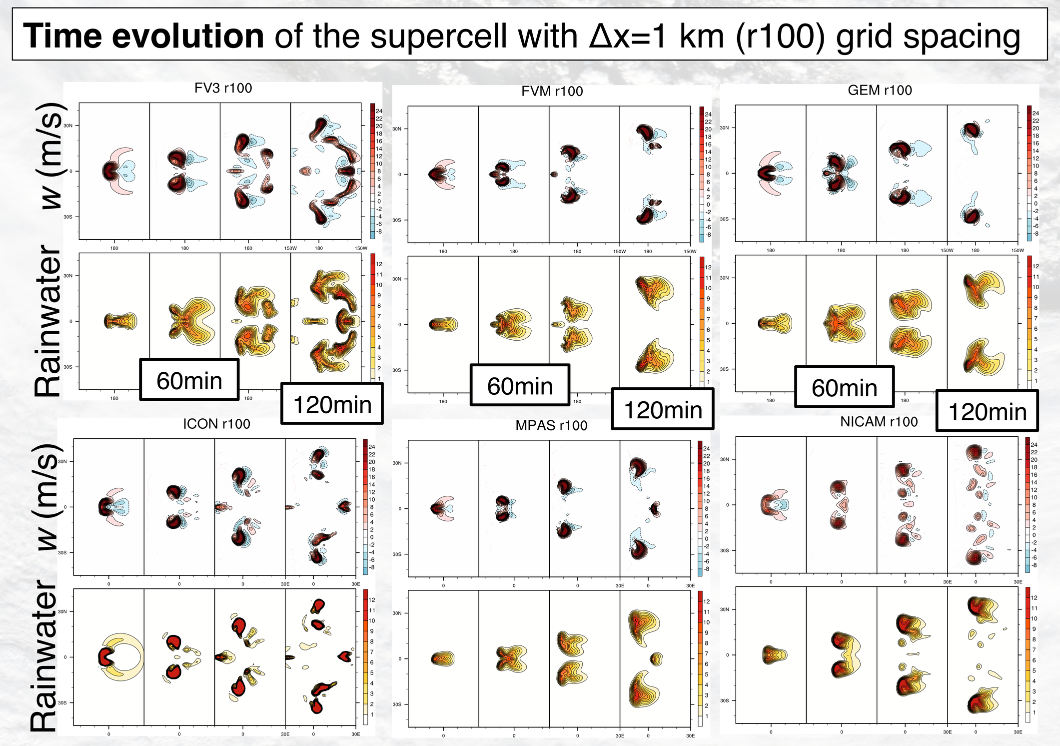


Figure 4: Vertical velocities (m/s, upper rows) and rainwater mixing ratios (g/kg, lower rows) at z=5 km shown after 30, 60, 90 and 120 min. after initialization. All supercells split and move poleward through the second hour, with near-mirror symmetry. The details differ greatly though.

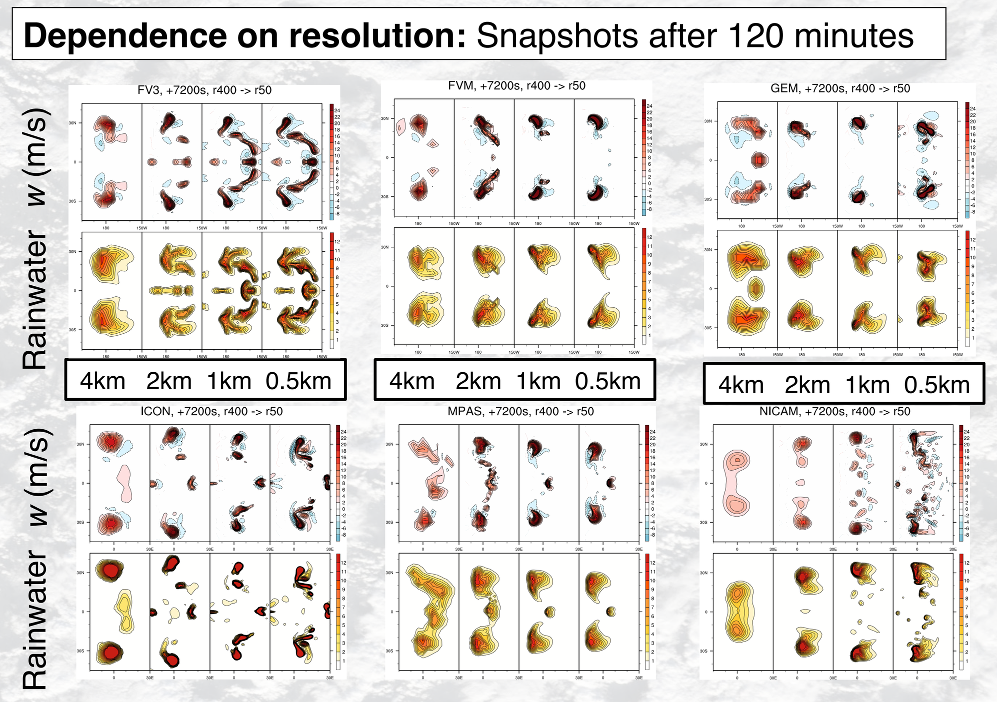


Figure 5: Vertical velocities (m/s, upper rows) and rainwater mixing ratios (g/kg, lower rows) at z=5 km shown after 120 minutes for four decreasing grid spacings. Some models appear to be structurally converged, others do not. This characteristic is highly dependent on the diffusion mechanisms in the dynamical cores.

DCMIP Highlights and Conclusions

- DCMIP **systematically evaluates dynamical cores**, e.g. in dry or small-earth configurations, or with simplified physical parameterizations and moisture. It reveals how the **numerical design choices and model diffusion impact the flow field**.
- Meanwhile, DCMIP has been conducted in 2008, 2012 and 2016. It serves as an **educational** (summer school) forum and **research** (model intercomparison) **platform**.
- Many newly-developed DCMIP test cases have now become **a community standard** for the evaluation of dynamical cores.
- Idealized model configurations, such as DCMIP, are part of a **GCM hierarchy** and give easier access to an improved understanding of the dynamical core and its interaction with physical parameterizations.

References

DCMIP-2016 project page: https://www.earthsystemcog.org/projects/dcmip-2016/

DCMIP-2016 github repository: https://github.com/ClimateGlobalChange/DCMIP2016

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