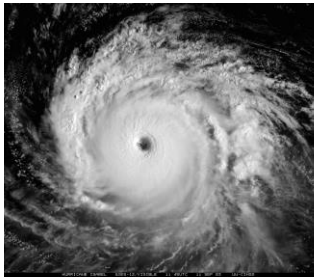
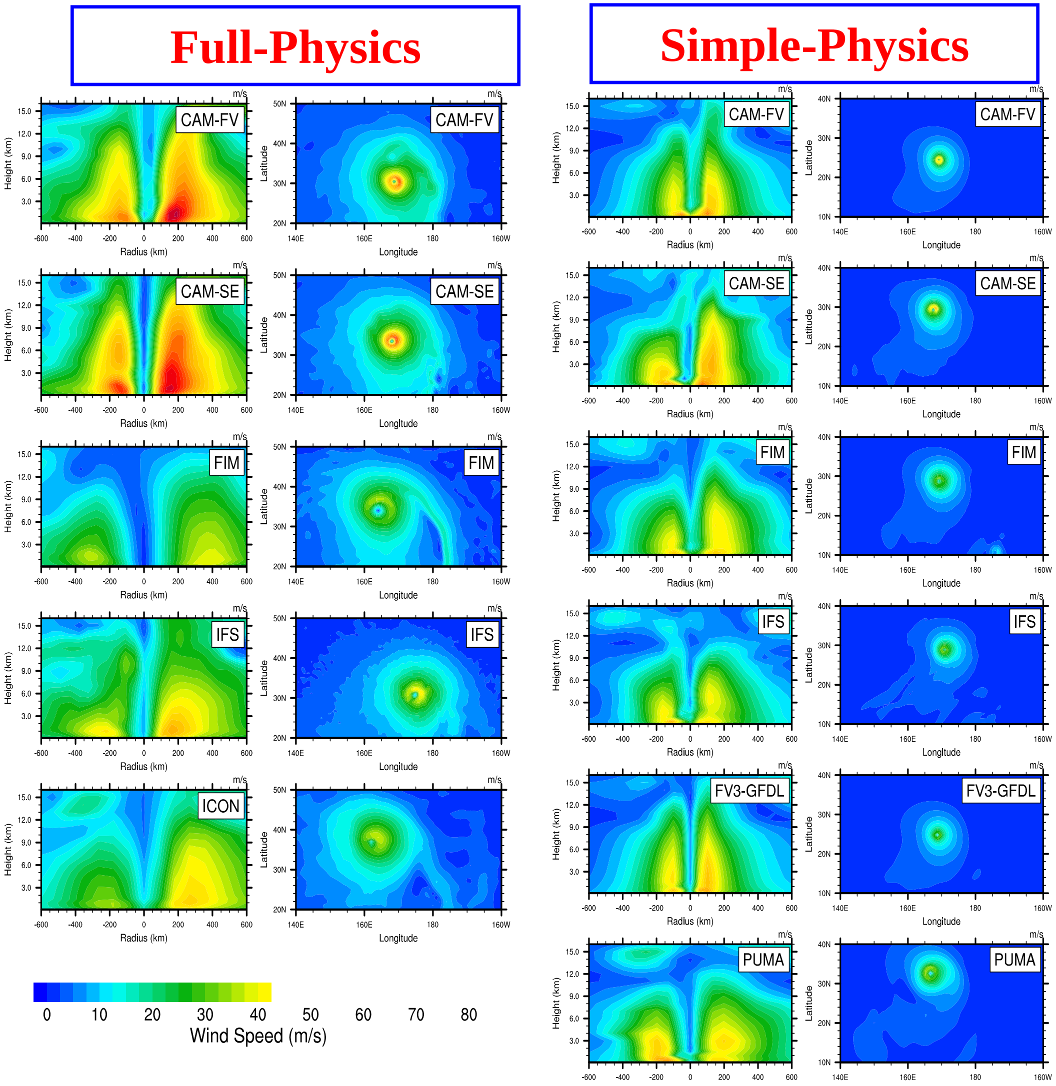
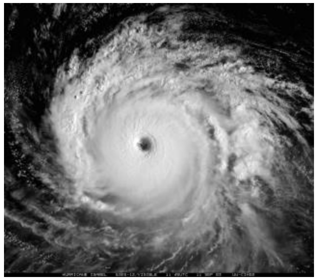


Idealized tropical cyclone experiments of varying complexity: a tool for model development

K. Reed, B. Medeiros, P. Lauritzen, J. Bacmeister & C. Jablonowski

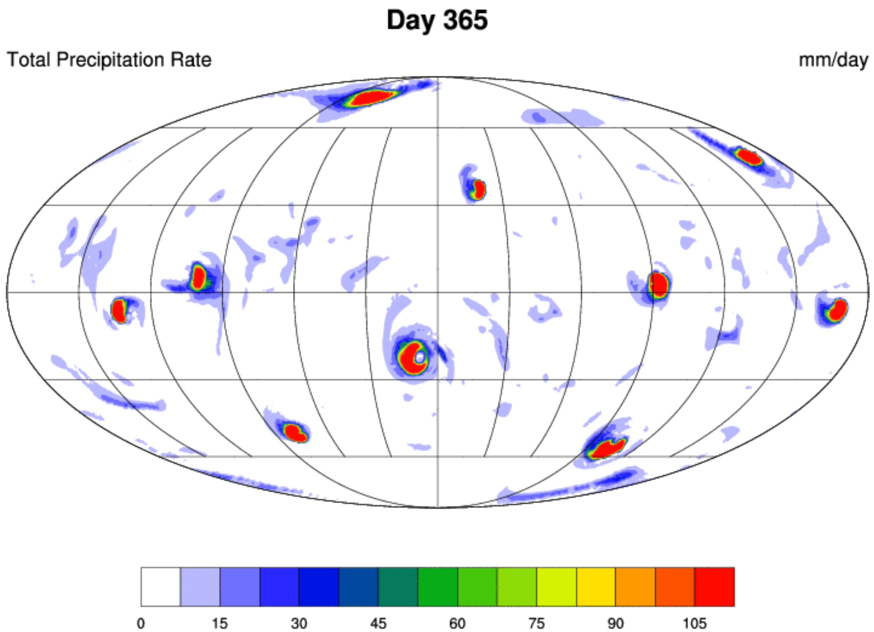
- With increasing computer power comes the capability of routinely running global models at **high horizontal resolutions**.
- This allows the direct simulation of extremes, such as **tropical cyclones**.
- There are many open questions about the ability of model components (i.e. **dynamical core, physics parameterizations and coupling**) to simulate such extremes.
- DCMIP results!



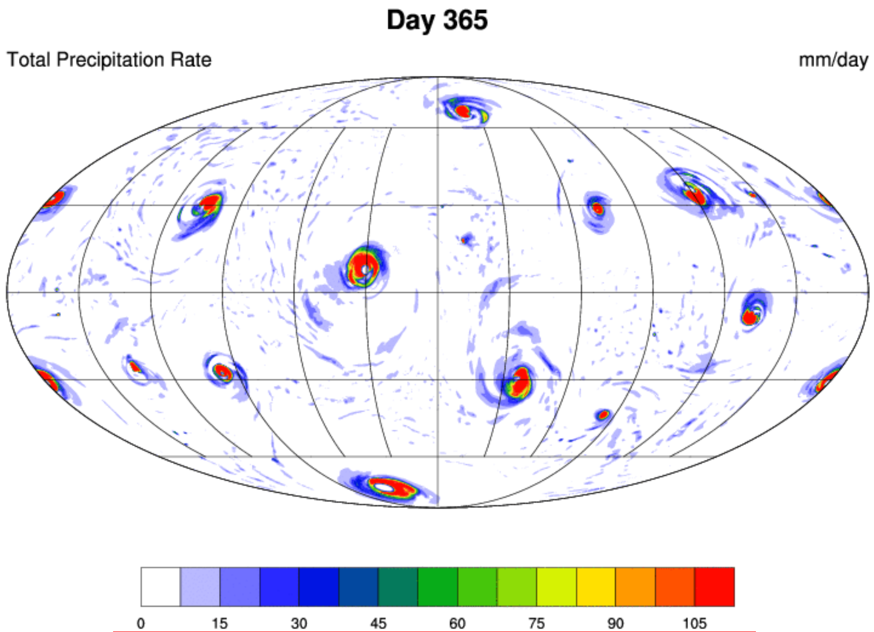


More Complex Testbed: Uniformly rotating RCE World

6-hr Avg. Precipitation (mm/day)

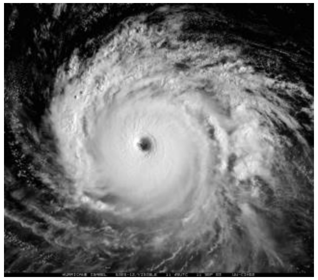


CAM5-SE ne30 (~100 km)



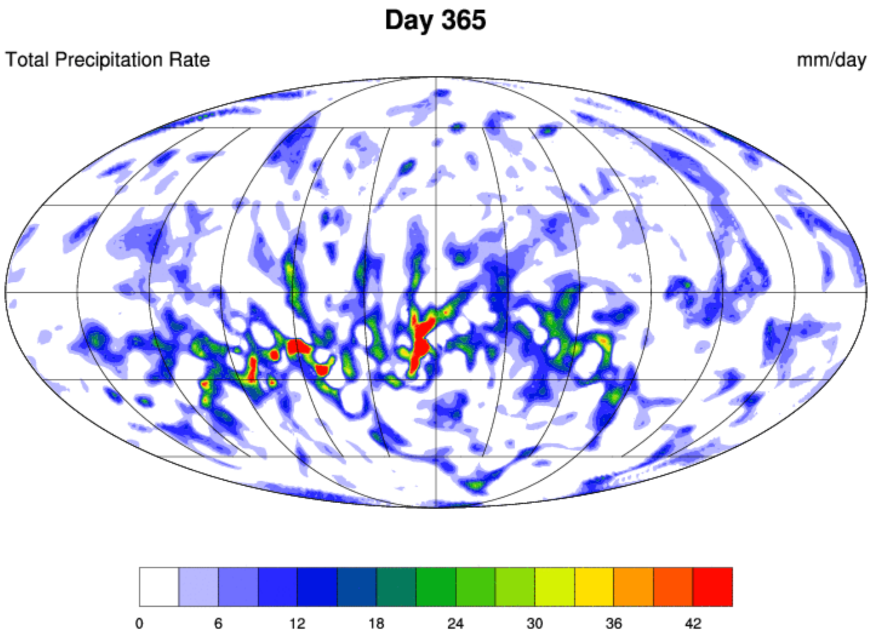
CAM5-SE ne120 (~25 km)

[Corilois set to 10 deg. N]

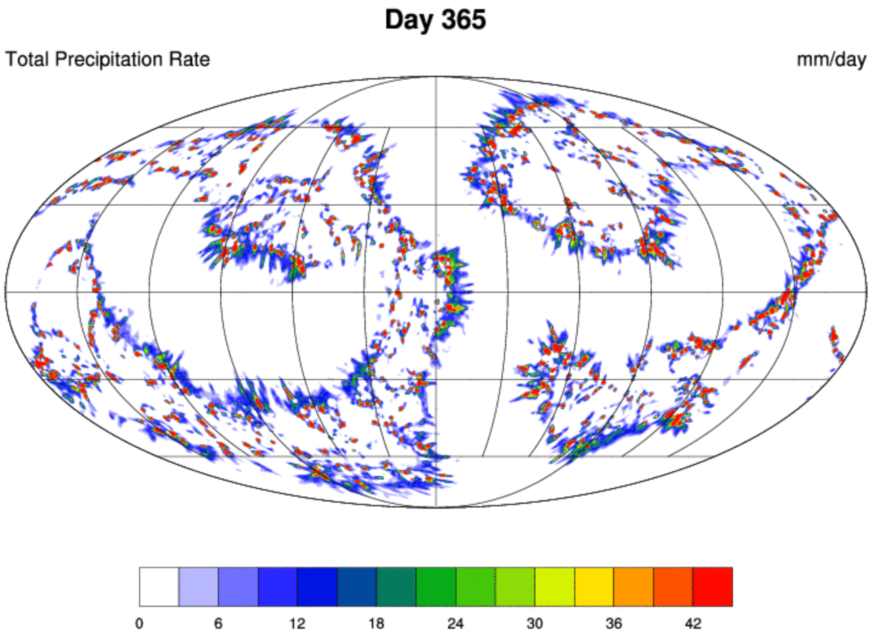


Bonus: Not shown on poster
Non-rotating RCE World

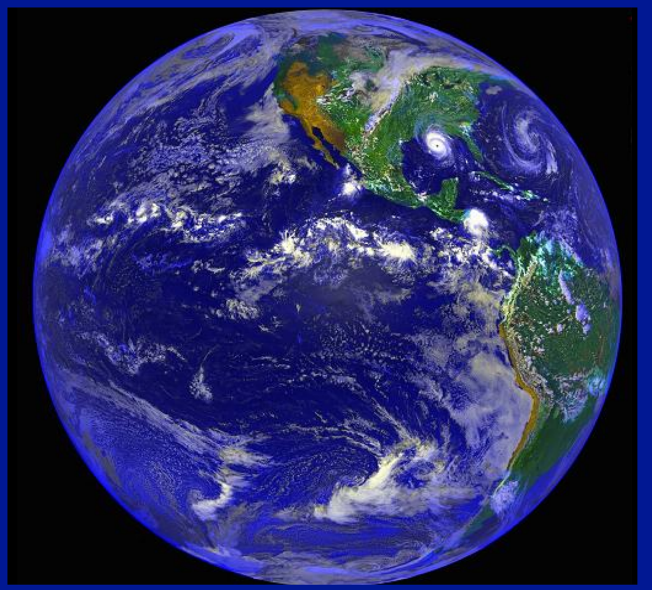
6-hr Avg. Precipitation (mm/day)



ne30 (~100 km)



ne120 (~25 km)



Idealized tropical cyclone experiments of varying complexity: A tool for model development

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Overview

With increasing computer power comes the capability of routinely running atmospheric general circulation models (AGCMs) at high horizontal resolutions (i.e., grid spacing less than 0.5 degrees). Moving to such resolutions requires understanding, and likely improving, the performance of many components of these AGCMs, such as parameterizations of sub-grid scale physics and the interaction of physics and dynamics. The ability of high-resolution AGCMs to simulate tropical cyclones is of particular interest.

The first part of this study involves dynamical core model intercomparisons. This analysis is focused on the evolution of a single, idealized tropical storm and the uncertainties triggered by the choice of model dynamical core formulation in various global models. The second portion of this research takes an initial look at longer-term idealized simulations. In particular, the National Center for Atmospheric Research's Community Atmosphere Model 5 (CAM5) is configured in radiative-convection equilibrium (RCE) to better understand tropical climate and extremes. The RCE setup consists of an ocean-covered earth with diurnally varying, spatially uniform insolation. Configurations with spatially uniform rotation effects are investigated permitting the formation of tropical cyclones. CAM5 is run with the spectral element dynamics package at two horizontal resolutions: a standard resolution of approximately 100 km grid spacing and a high-resolution of approximately 25 km grid spacing. The various model configurations provide useful insights into the simulation of tropical cyclones at high-resolution. The two AGCM setups demonstrate to be unique testbeds for model development.

Description of Model Intercomparison

We utilize a variety of GCMs to trigger idealized tropical cyclone-like vortices over ten simulation days. The initialization of the idealized vortex is built upon prescribed 3D moisture, pressure, temperature and velocity fields (Reed and Jablonowski, 2011). Each GCM is at various stages of development and contains a different dynamical core, which is the central component of every GCM and determines the numerical methods, diffusion properties and computational mesh for the resolved fluid flow. The GCMs are run with either their full-physics or the simple-physics package, or in some cases both. The simple-physics contains selected physical processes that drive tropical cyclones, including parameterizations of large-scale condensation, surface fluxes and boundary layer turbulence (Reed and Jablonowski, 2012). In order to foster model intercomparisons, the simple-physics suite offers a significant reduction in complexity and increased portability when compared to full-physics packages. The GCMs used for this study are:

CAM-FV: NCAR Community Atmosphere Model 5 with the hydrostatic *Finite Volume* grid point-based method on a regular *latitude-longitude* grid.

CAM-SE: NCAR Community Atmosphere Model 5 with a hydrostatic *Spectral Element* method on a *cubed-sphere* grid.

FIM: NOAA hydrostatic global weather prediction model with *Finite Volume* methods on a *icosahedral* grid.

IFS: ECMWF operational Integrated Forecast System with a hydrostatic semi-Lagrangian dynamical core on a reduced *Gaussian* grid.

ICON: MPI and DWD joint *Finite Volume* ICOsahedral Non-hydrostatic General Circulation Model on a *triangular* grid.

FV3-GFDL: GFDL *Finite Volume* dynamical core on a *cubed-sphere* grid.

PUMA: University of Hamburg Portable University Model of the Atmosphere using hydrostatic *spectral* methods on a *Gaussian* grid.

All tests are run with 30 vertical levels (L30) in a *aqua-planet configuration* (Neale and Hoskins, 2000) that consists of an ocean-covered Earth with prescribed radiative forcing and sea surface temperatures (SST). A constant SST of 29ºC is utilized to provide favorable conditions for tropical cyclogenesis. The choice horizontal resolution is dependent upon the model grid but range between 0.5°-0.7° which corresponds to 55-78 km spacing near the equator.

Idealized Tropical Cyclone Comparison

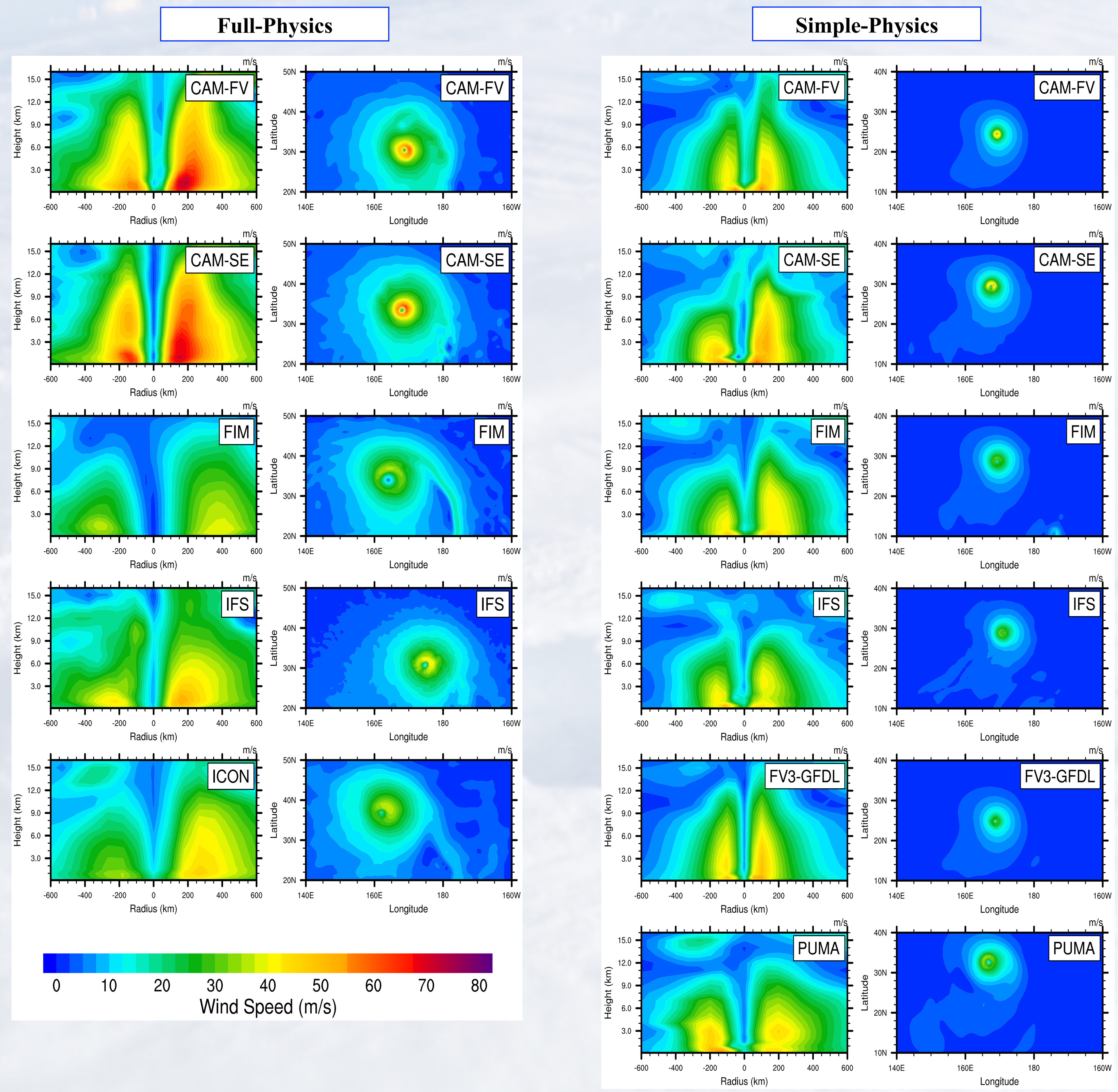

Figure 1: Snapshots of the idealized cyclone simulations at day 10 with various GCMs. Results from full-physics and simple-physics simulations for each global model are shown (see labels). **Left Column of each figure:** wind magnitude for a vertical cross section through the center latitude of the vortex as a function of the radius from the vortex center. **Right column of each figure:** magnitude of the wind at 100 m. In both the full-physics and simple-physics simulations there are significant differences in the intensity and structure of the simulated tropical cyclone amongst the multi-model ensemble. The simple-physics simulations exhibit similar differences amongst the models that are observed in the full-physics simulations, likely resulting from the dynamical core.

Evolution of Idealized Tropical Cyclone

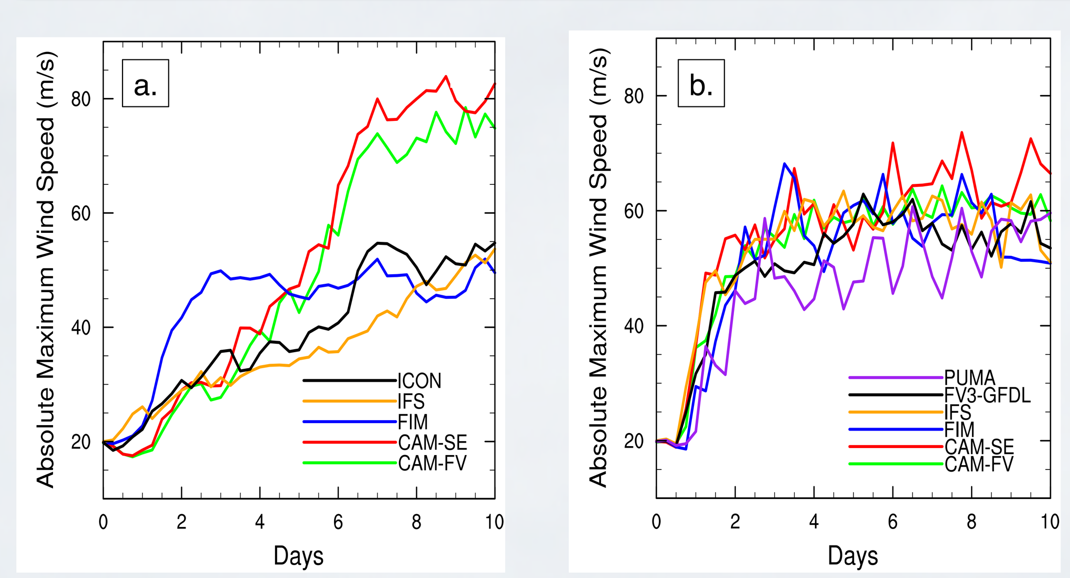

Figure 2. Time evolution of the maximum wind speed throughout the 10-day simulation for the GCMs run with their (a.) full-physics and (b.) simple-physics. The evolution and final intensity of the storm varies depending upon the choice of GCM. The uncertainties amongst the GCMs are reduced, but still exist, in the simple-physics simulations.

Introduction of RCE World Testbed

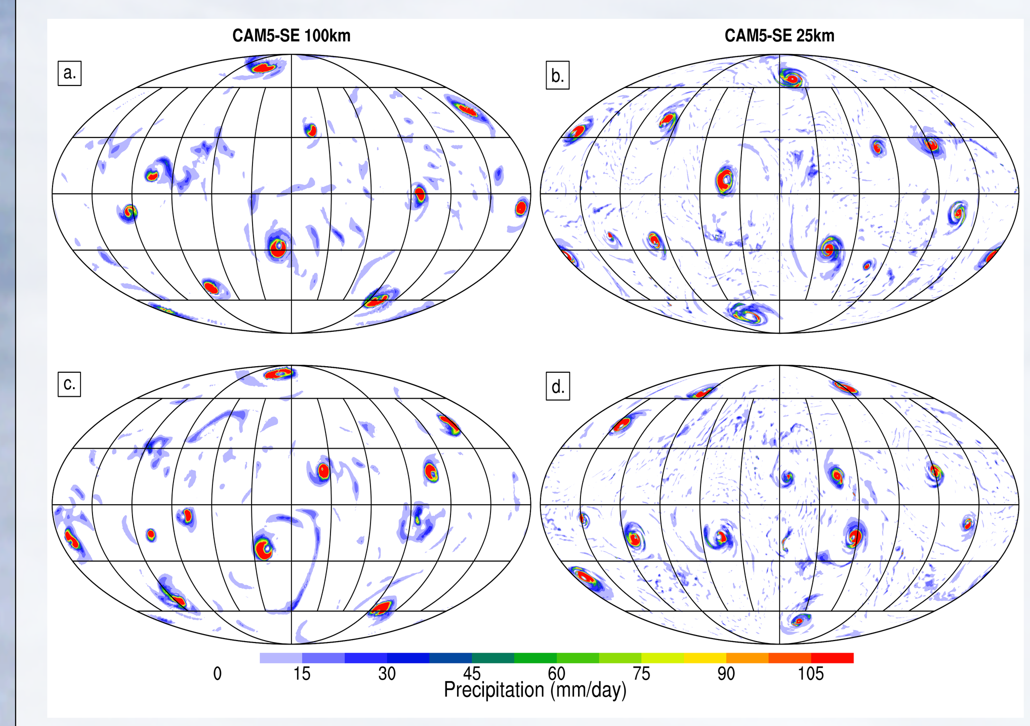

Figure 3: Snapshots of 6 hourly averaged total precipitation (mm/day) for the RCE world tropical cyclone simulations with CAM5-SE at (a. & c.) 100 km and (b.& d.) 25 km horizontal resolution. There is a 10 day difference between the top and bottom rows. The setup simulates between 11-14 tropical cyclones on the globe at any given time with a slight sensitivity to resolution.

RCE Word Tropical Cyclone Intensity

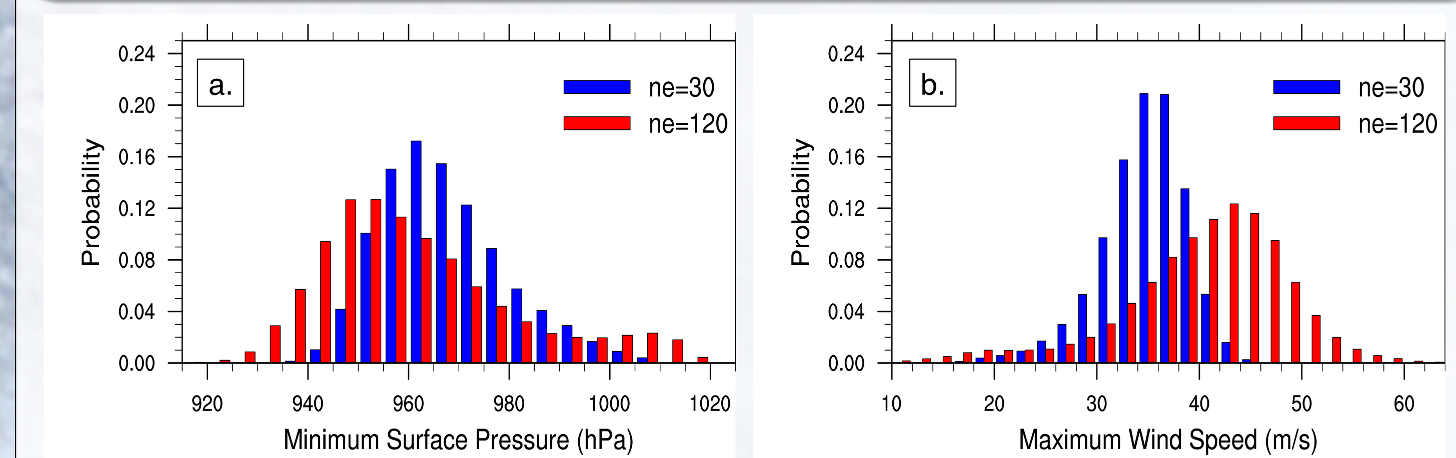

Figure 4: Comparison of the probability density functions for the intensity of RCE tropical cyclones using (a.) minimum surface pressure and (b.) maximum wind speed. As the resolution increases from 100 km (ne=30) to 25 km (ne=120) the intensity of the cyclones increase.

Results/Conclusions

- While uncertainties due to different physics packages and their tuning factors are widely recognized, the uncertainties due to the choice of the dynamical core are not.
- The single, idealized tropical cyclone test with both the full-physics and simple-physics reveals these uncertainties in the evolution, intensity and storm structure.
- Due to its portability and reduced complexity the simple-physics package has the potential to identify the causes and effects of the dynamical core design choices.
- In the RCE world simulations there appears to be preferred regime with 11-14 tropical cyclones on the globe at any time. There are differences in the storm intensities, but not as substantial as seen with the full AMIP simulations (not shown).

References

Neale, R. B. and B. J. Hoskins (2000): A Standard Test for AGCMs Including their Physical Parametrization: I: The Proposal, Atmos. Sci. Letters, 1, 101-107.

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Reed, K. A. and C. Jablonowski (2012), Idealized tropical cyclone simulations of intermediate complexity: a test case for AGCMs, *J. Adv. Model. Earth Syst.*, 4, M04001, doi:10.1029/2011MS000099.