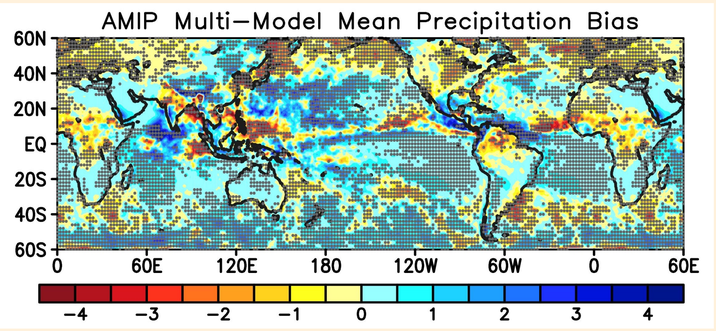
Superior daily and sub-daily precipitation statistics for intense and long-lived storms in global storm-resolving models

Hsi-Yen Ma (ma21@llnl.gov), Steve A. Klein, Jiwoo Lee, Min-Seop Ahn, Cheng Tao and Peter J. Gleckler
Lawrence Livermore National Laboratory

Motivation

Contemporary global climate models suffer from many systematic errors in precipitation simulations. This is usually due to the deficiency in parameterizations (e.g., convection) and coarse model resolutions.



Science Question

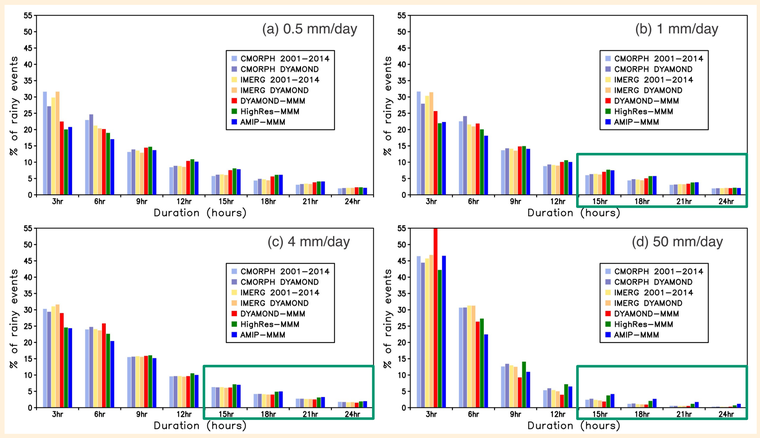
The first-ever model intercomparison project for global models with convection-permitting resolution (dx ~ 2 – 5 km) was first organized, named the DYAMOND initiative (DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains).

What aspects of precipitation simulations are better captured by these DYAMOND models (GSRMs) compared to other CMIP-class models (Δx: 100km → 50km → 4km); What problems remain?

Simulations and Validation Data

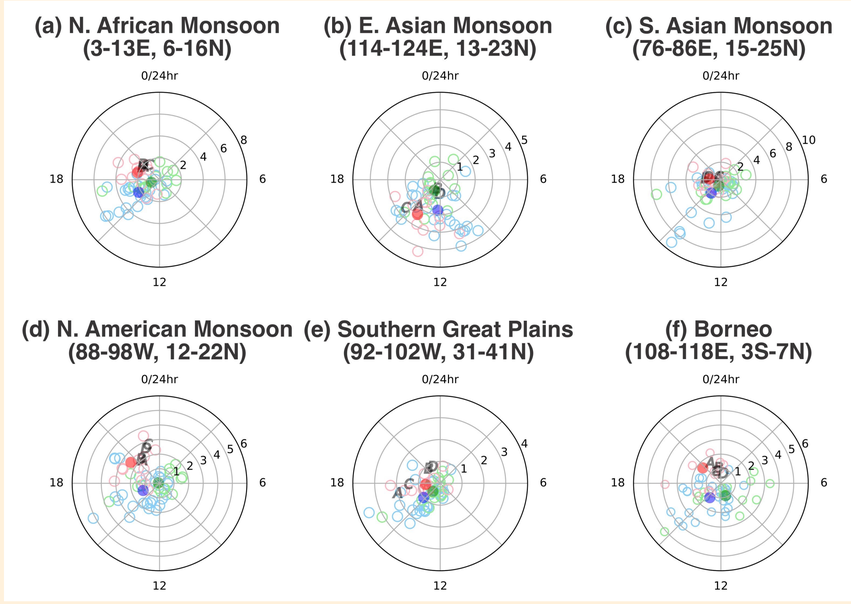
- DYAMOND: 9 models (Δx ~ 4 km), a single 40-day simulation started from 1 August 2016 (boreal summer experiment phase)
- CMIP6/HighRes: 14 models (Δx ≤ 50 km), 2001-2014 (only August), highresSST-present
- CMIP6/AMIP: 28 models (Δx ≥ 100 km), 2001-2014 (only August)
- Observations: 2 satellite datasets: CMORPH, IMERG

Precipitation Intermittency (Duration)



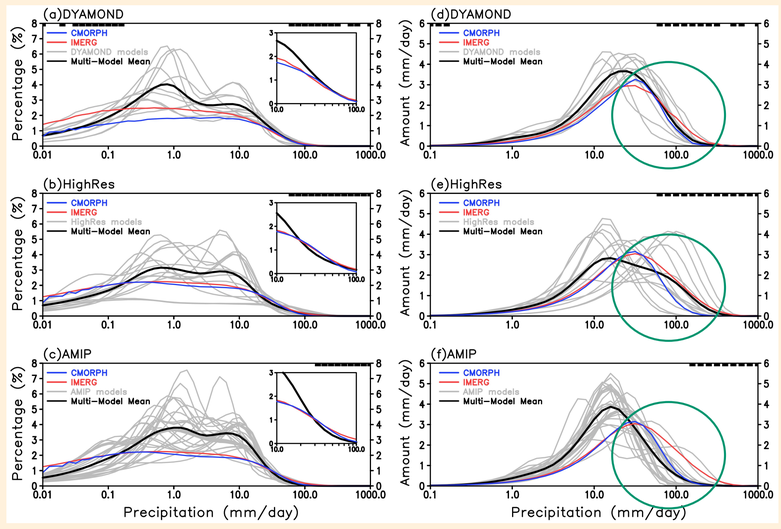
- DYAMOND models show better performance with thresholds of 1, 4 and 50 mm day^{-1} for precipitation events with longer duration (> 12hrs), especially for 50 mm day^{-1} thresholds

Precipitation Diurnal Harmonic Phases and Amplitudes



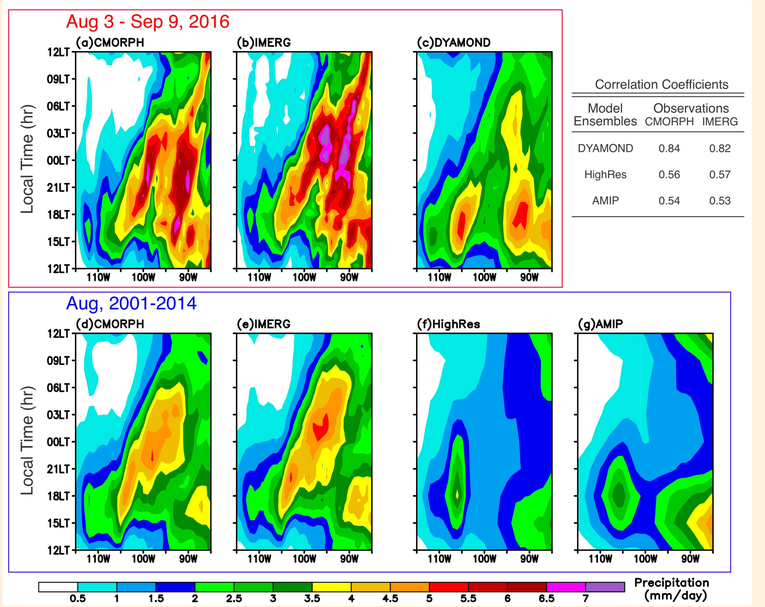
- DYMOND models show substantial improvement in the diurnal cycle phase.
- The diurnal harmonic phases from DYAMOND models are only slightly earlier (~1-2 hours) or very close to observed peak hours.
- HighRes or AMIP show much earlier diurnal phases (~5-10 hours) compared to observations, with peak hours in the late morning or early afternoon over land and early morning over ocean.

Frequency and Amount Statistics of Precipitation



- Daily precipitation PDF and amount contribution in the tropics (20S-20N)
- For very intense precipitation (> 25 mm day^{-1}), the precipitation frequencies of DYAMOND MMM are closer to observations while HighRes or AMIP MMM show slightly lower frequencies compared to observations.
- DYAMOND models simulate much better amount contribution, but most models still overestimate amount contribution from less intense precipitation (~ 2 – 25 mm day^{-1})

Propagation of Convection over the US Great Plains

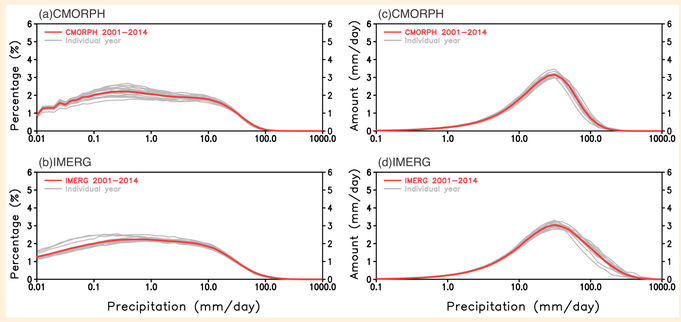


Correlation Coefficients

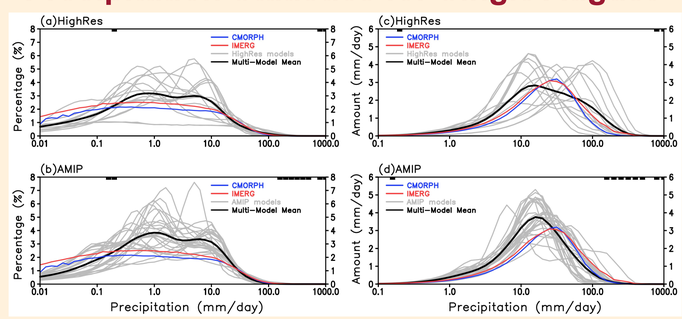
Model Ensembles	Observations CMORPH	IMERG
DYAMOND	0.84	0.82
HighRes	0.56	0.57
AMIP	0.54	0.53

- DYAMOND model ensembles shows capability to simulate the propagation of convection but the precipitation intensity is weaker especially around 00h local time over 100ºW compared to observations.
- Propagation of convection is generally absent in the MMMs of both HighRes and AMIP models.

Interannual Variation of Precipitation Statistics in Observations



Precipitation Statistics for Single August



- Daily and sub-daily statistics are fairly robust even with one single month (August 2014) because the interannual variations are relatively small in both simulations and observations.

Summary

- Daily and sub-daily precipitation statistics from GSRMs and coarser resolution global models are compared to observations
- GSRMs show superior performance for statistics of more intense precipitation events including their diurnal cycle and spatial propagation
- GSRMs are not superior for statistics of weaker or shorter duration precipitation
  - GSRMs still need parameterizations for sub-grid scale processes (e.g., turbulence, radiation, cloud microphysics, aerosols) , which can still contribute to precipitation biases

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References: Ma, H.-Y., Klein, S. A., Lee, J., Ahn, M.-S., Tao, C., & Gleckler, P. J. (2022). Superior daily and sub-daily precipitation statistics for intense and long-lived storms in global storm- resolving models. Geophysical Research Letters, 49, e2021GL096759. https://doi.org/10.1029/2021GL096759.