Assessing the Goddard Earth Observing System model in non-resolved to convection-permitting regimes

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Abstract

We evaluate the Goddard Earth Observing System (GEOS) modeling and assimilation through a cascade of simulations with increasing horizontal resolution. The GEOS model is driven by the finite-volume cubed-sphere (FV3) non-hydrostatic dynamical core, a set of scale-aware physics package and data assimilation capability. The GEOS model is run for 30-days beginning on 01 August 2016 at seven uniform global resolutions of approximately 200, 100, 50, 25, 12, 6, and 3 km with 72 vertical levels up to 0.01mb. The model physics uses the Grell-Freitas (GF) scale-aware convection scheme to dynamically reduce the role of parameterized deep convection as resolved scale processes in the model take over at higher resolutions. Shallow convection is parameterized following the UW scheme, and cloud microphysics applies a single-moment formulation for rain, liquid and ice condensates. We provide an overview of the scale dependence of precipitation across the spatial scales, geometric characteristics of the simulated cloud fields, and comparison of IR brightness temperature with observations. We also include a look at the capability of GEOS to realistically represent the diurnal cycle of precipitation over global and land only regions across those scales.

Diurnal Cycle of the Precipitation

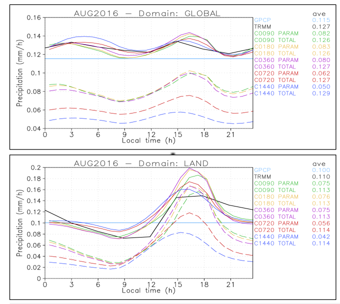


Table 1. GEOS spatial resolutions analyzed

Cubed-sphere resolution	Nominal horizontal grid length
C0048	200km
C0090	100km
C0180	050km
C0360	025km
C0720	012km
C1440	006km
C2880	003km

Figure 1. Diurnal cycle of precipitation from local and remote sensing derived observations (GPCP and TRMM) and NASA GEOS model with the GF scheme across spatial resolutions from C0090 to C1440 (see Table 1 for the nominal grid spacings). Upper and lower panels show AUG 2016 monthly averaged results for global and land spatial domains, respectively. Model results are shown in terms of total precipitation and only from the convection parameterization ('PARAM' with dashed lines) in mm h^{-1}.

Partition between Parameterized and Resolved Precipitation Across Scales

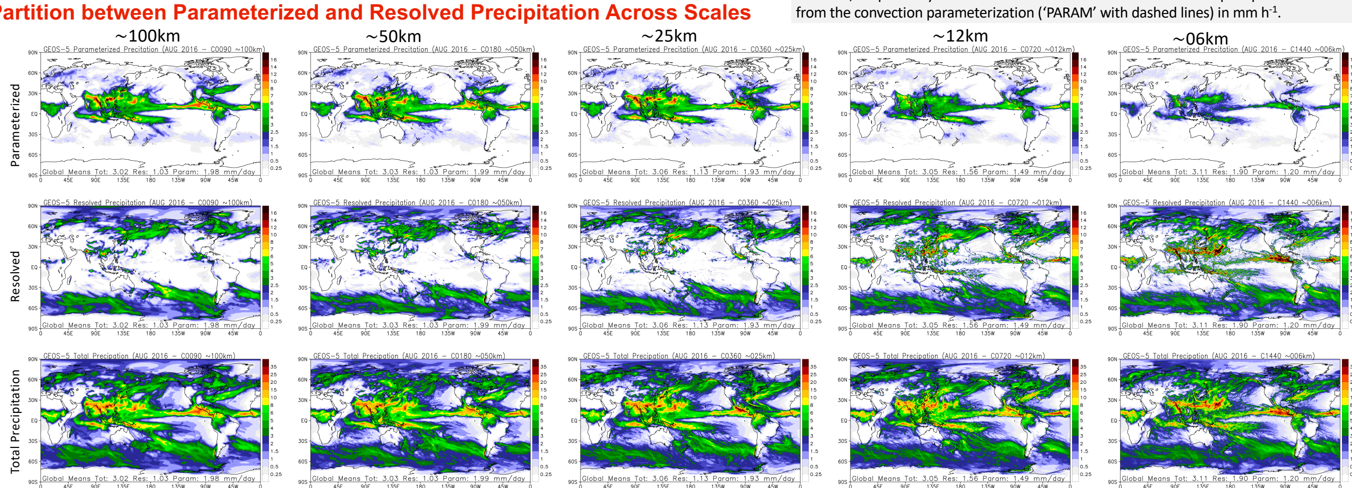
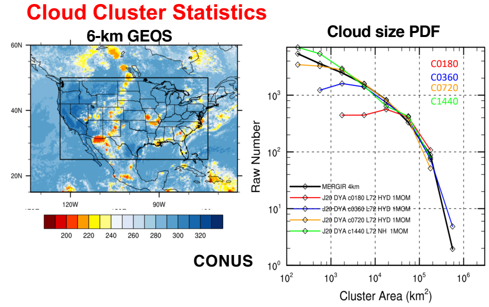
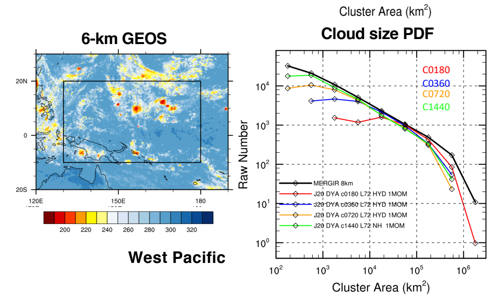


Figure 2. Parameterized (upper panels), resolved (middle) and total precipitation (lower) averaged over 1-month run for Aug 2016. From left to right, model resolution increases from C0090 (~ 100 km) to C1440 (~ 6 km). The global means of each precipitation in mm/day appears on bottom of each panel. From the left to right, the total precipitation field (lower panel) becomes richer in details with filamentary structures, while preserving the broader pattern and spatial distribution, with the global mean oscillating between 3.02 and 3.11 mm day^{-1}. At low resolution, the parameterized precipitation (upper row) dominates the generation of rainfall, mainly over the tropical region, but gradually reduces its participation as the model resolution increases. The global mean of the parameterized precipitation shows a monotonic decrease from 1.98 mm/day at C0090 to 1.20 mm/day at C1440 resolution.

Cloud Cluster Statistics





- Cloud clusters are identified as contiguous regions with brightness temperature T_b< 230 K.
- Cluster size distributions for GEOS at four horizontal resolutions are compared with the Merged IR 4 km dataset.
- Small clusters are increasingly represented at higher resolutions.
- Larger clusters are persistently under-represented in the Tropics.

Simulated IR Brightness Temperature Across Scales

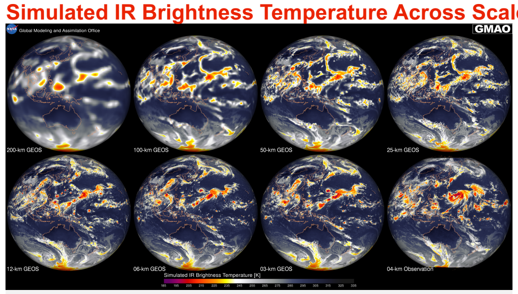


Figure 3. The simulated IR Brightness Temperature from 200 km down to 3 km for 03UTC 04 August 2016. The rightmost figure in the lower row shows the observation by Himawari-8 satellite.

Table 2. Summary of the scale dependence of GEOS precipitation

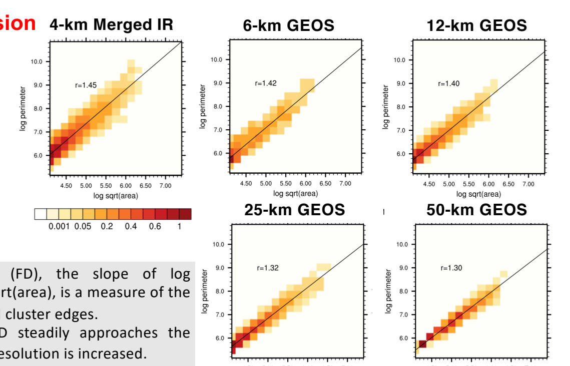
GEOS Model horizontal resolution		Global Mean for Aug 2016		
		Precipitation (mm/day)		Fraction (parameterized /total)
		Parameterized	Total	
C0090	~100km	1.98	3.02	66%
C0180	~ 050km	1.99	3.03	66%
C0360	~ 025km	1.93	3.06	63%
C0720	~ 012km	1.49	3.05	49%
C1440	~ 006km	1.20	3.11	38%
C2880*	~ 003km	1.20	3.37	36%

*only 15 days average

Cloud Fractal Dimension

Table 3. Summary of the fractal dimension

Observation/ GEOS Model	Fraction Dimension
Merged IR 4km	1.45
GEOS 06km	1.42
GEOS 12km	1.40
GEOS 25km	1.32
GEOS 50km	1.30



- Fractal dimension (FD), the slope of log perimeter vs. log sqrt(area), is a measure of the raggedness of cloud cluster edges.
- GEOS simulated FD steadily approaches the observed value as resolution is increased.

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