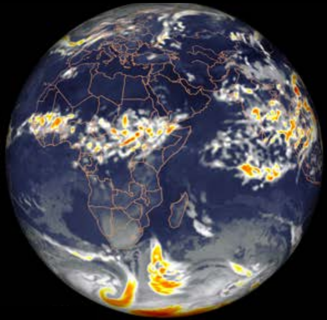
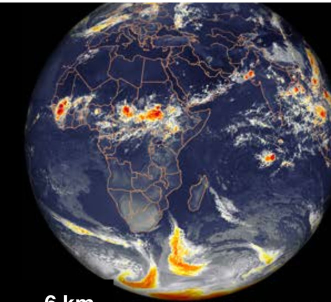
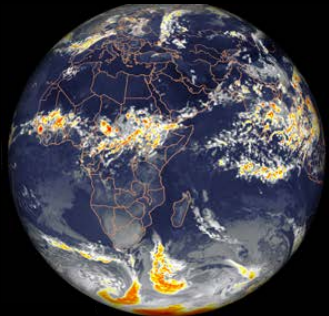
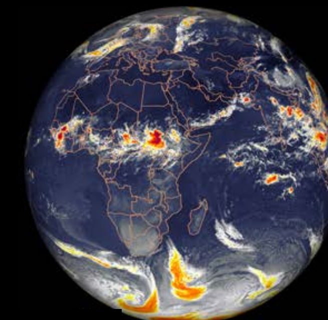

50 km

The diurnal cycle of precipitation and organized convection in a set of global mesoscale simulations with the NASA GEOS AGCM


6 km

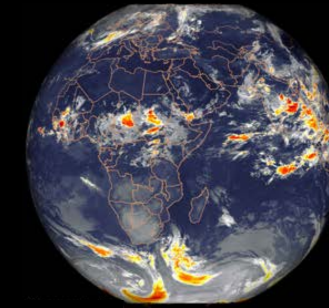

25 km


3 km

Nathan Arnold
Saulo Freitas
William Putman

Global Modeling and Assimilation Office
Goddard Space Flight Center


12 km

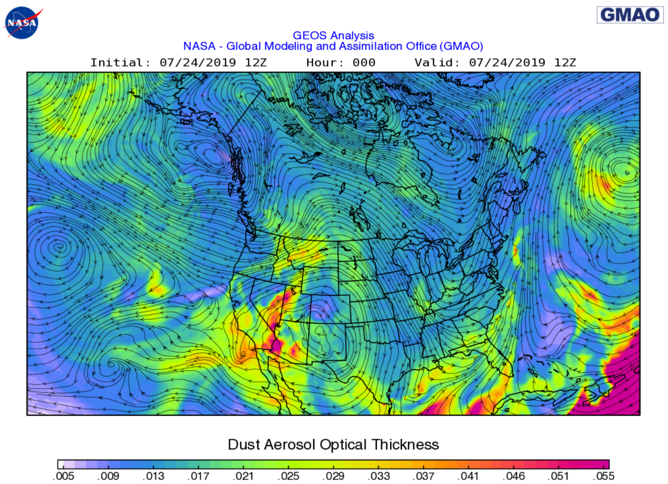

4 km Obs

The Goddard Earth Observing System (GEOS) AGCM

GEOS applications

- 2x daily forecasts (12 km grid)
- Seasonal prediction, contribute to NMME (50 km grid)
- MERRA, MERRA-2 reanalyses (~50 km)
- Global nature runs (3-6 km)

Same executable, different applications.



Model components

- Non-hydrostatic FV3 on cubed sphere
- Grell-Freitas deep convection
  - Scale-aware following Arakawa et al. (2011)
  - Bechtold *et al.* (2014) diurnal closure
- Park and Bretheron shallow convection
- 3-phase 1-moment microphysics (Bacmeister et al. 2006)
- RRTMG longwave and shortwave radiation

Experiments based on DYAMOND protocol

- 40 day integration, from Aug. 1, 2016
- Horizontal grid spacing: 50, 25, 12, 6, 3 km
- 72 levels
- Initialized from MERRA-2

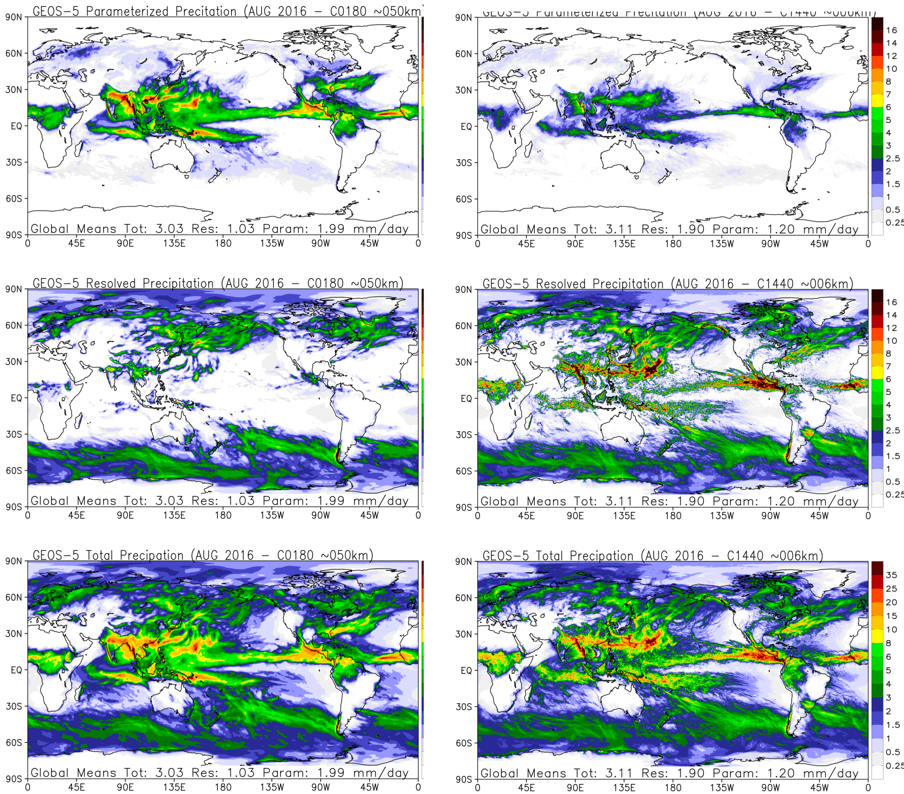
Grell-Freitas (GF) scale-aware precipitation scaling

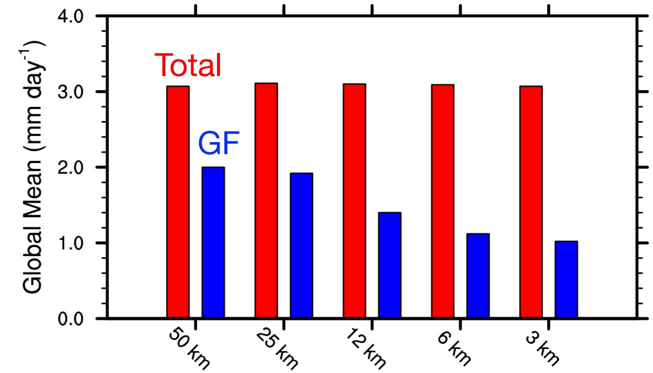
GEOS – 50 km | **GEOS – 6 km**

Parameterized

Resolved

Total





- Total precipitation is ~constant while parameterized convection decreases smoothly.

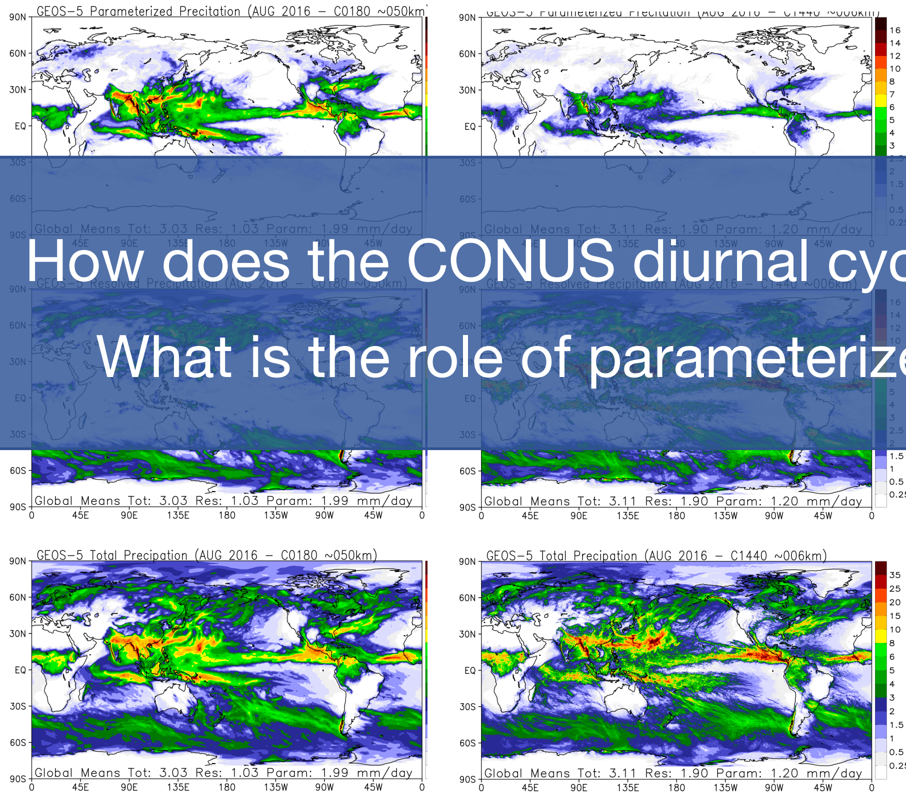
Grell-Freitas (GF) scale-aware precipitation scaling

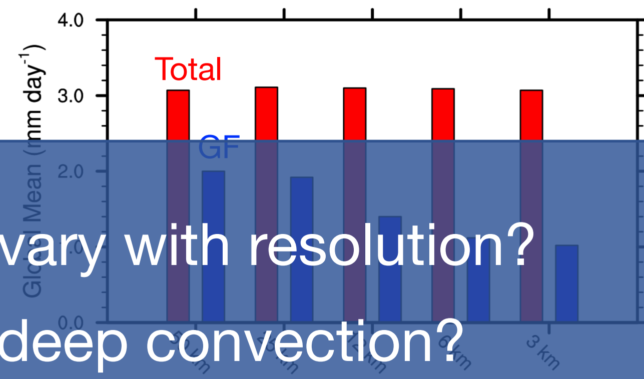
GEOS – 50 km | **GEOS – 6 km**

Parameterized

Resolved

Total



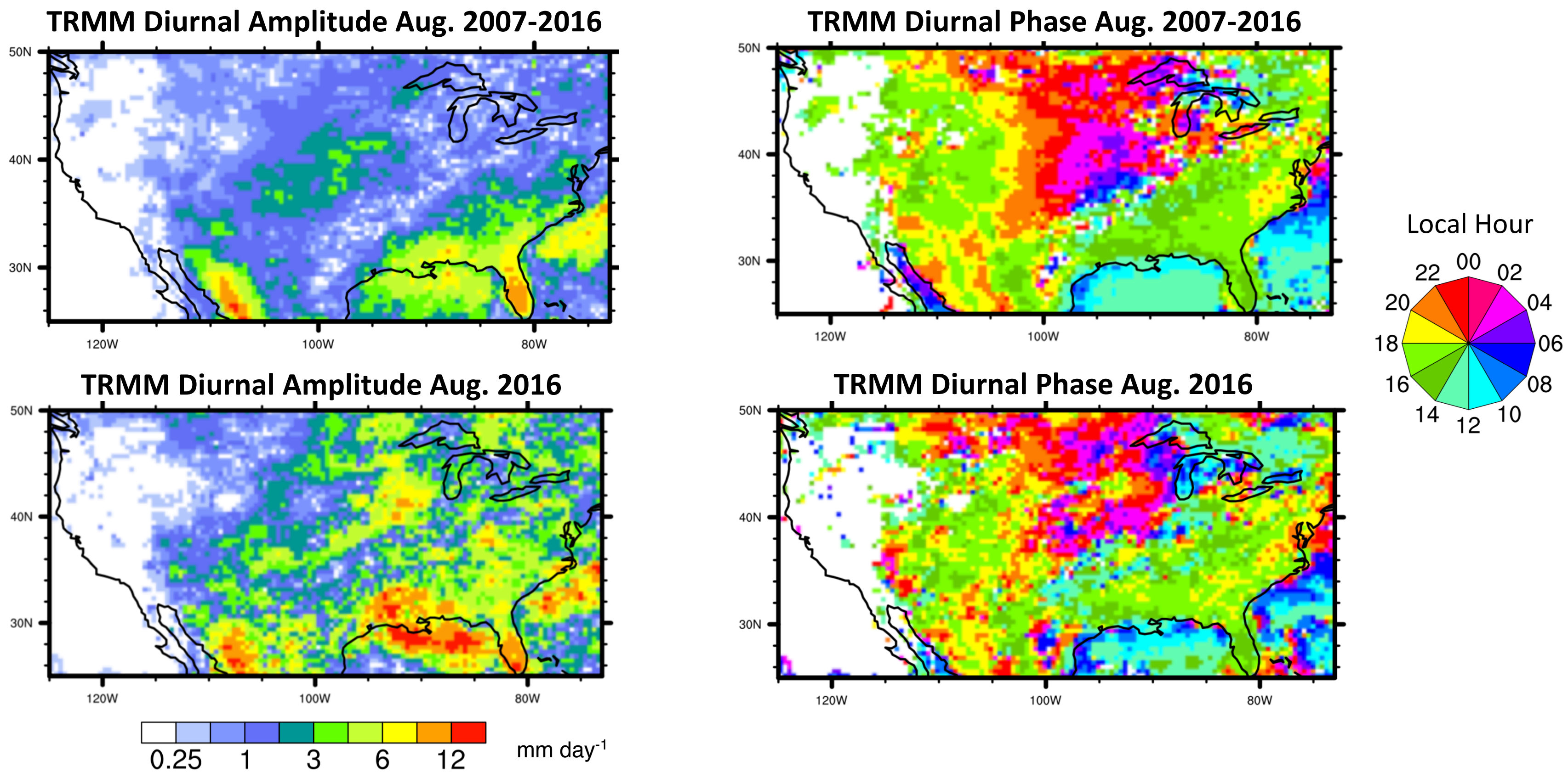


How does the CONUS diurnal cycle vary with resolution?

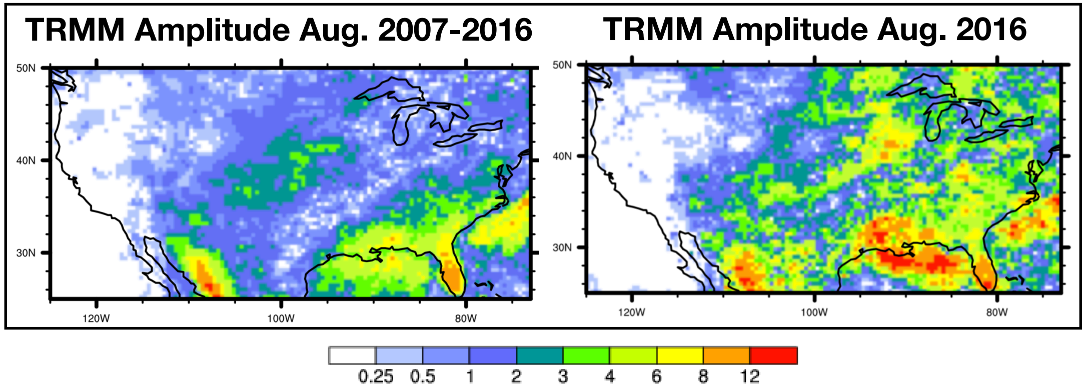
What is the role of parameterized deep convection?

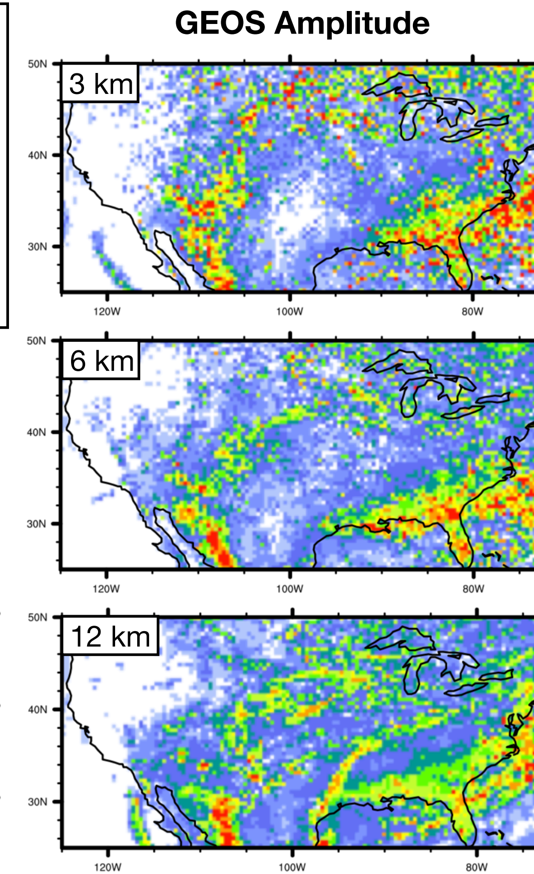
- Total precipitation is ~constant while parameterized convection decreases smoothly.

Observed amplitude and phase of the diurnal harmonic

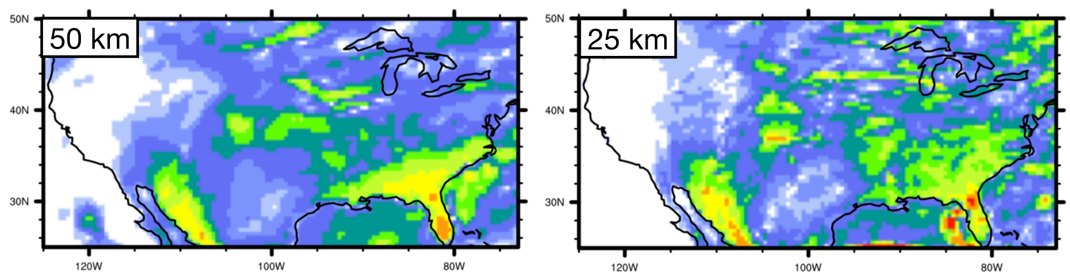


Amplitude of the diurnal harmonic - CONUS





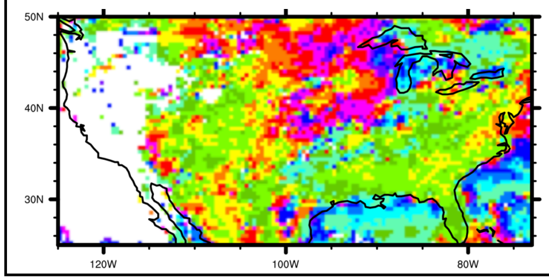
- Model amplitudes more closely resemble the observed climatology, rather than Aug. 2016.
- Model amplitudes increase with resolution.

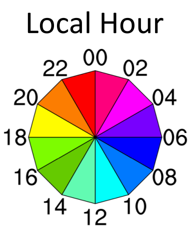


Phase of the diurnal harmonic - CONUS

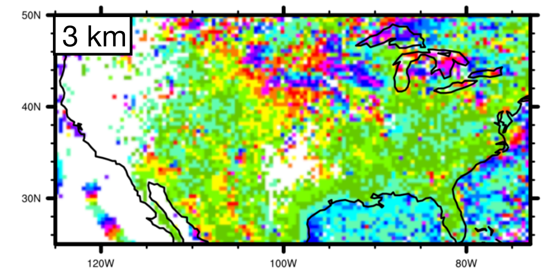
- Phase in good agreement with TRMM over Southeast, ~2 hr early in 3 km case.
- Precip is overly delayed in Mountain West in low resolution cases.
- Great Plains too early in most cases, generally better at high resolution.

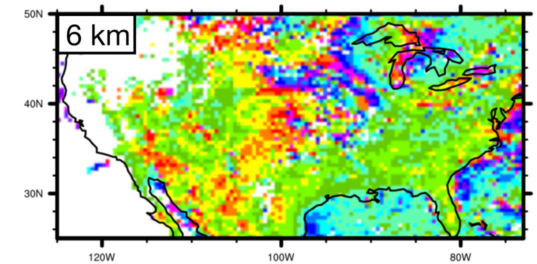
TRMM Phase Aug. 2016

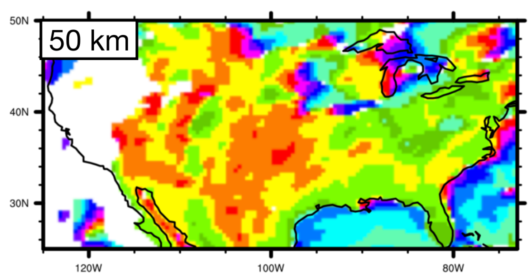


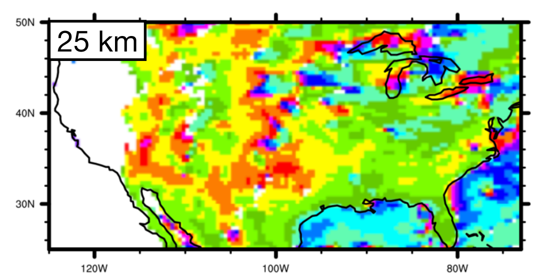


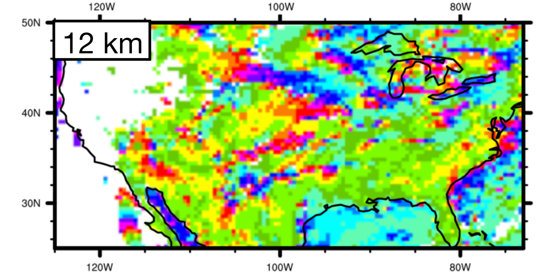
GEOS Phase



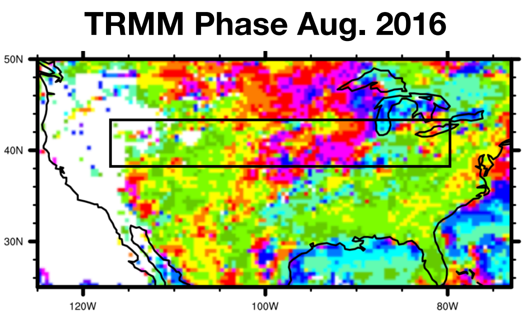


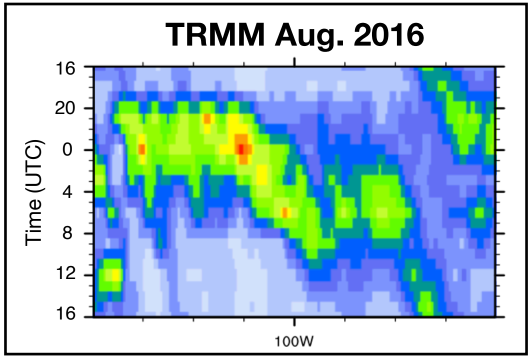




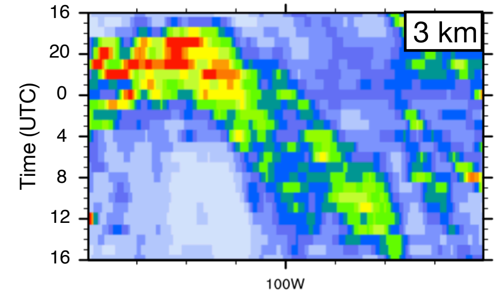


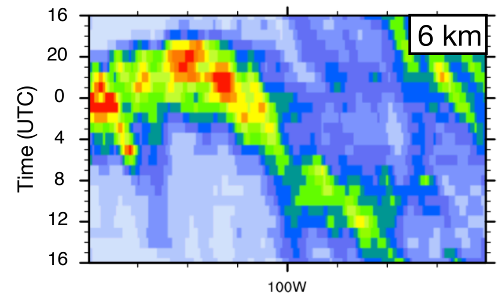
Diurnal propagation over Great Plains



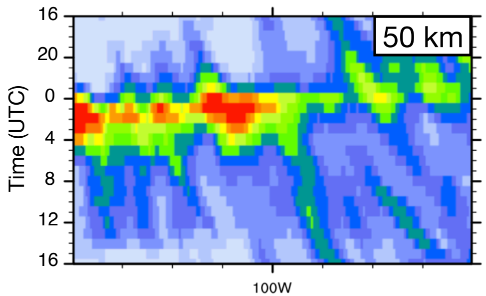


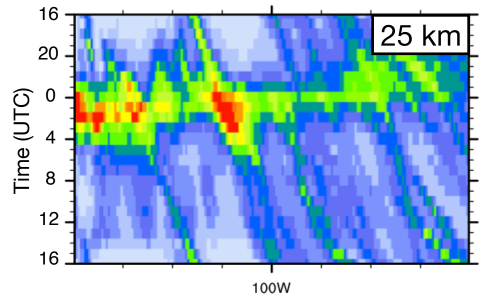
GEOS

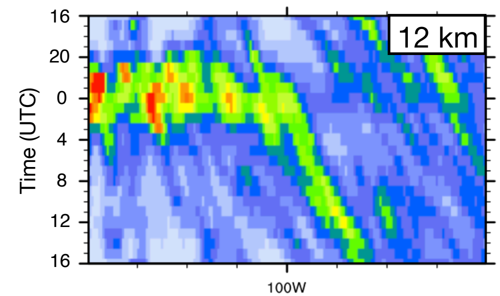




- Propagating systems better represented at dx<25km, with speeds approximately ~14 m/s.
- Analysis based on Liang et al. (2004).

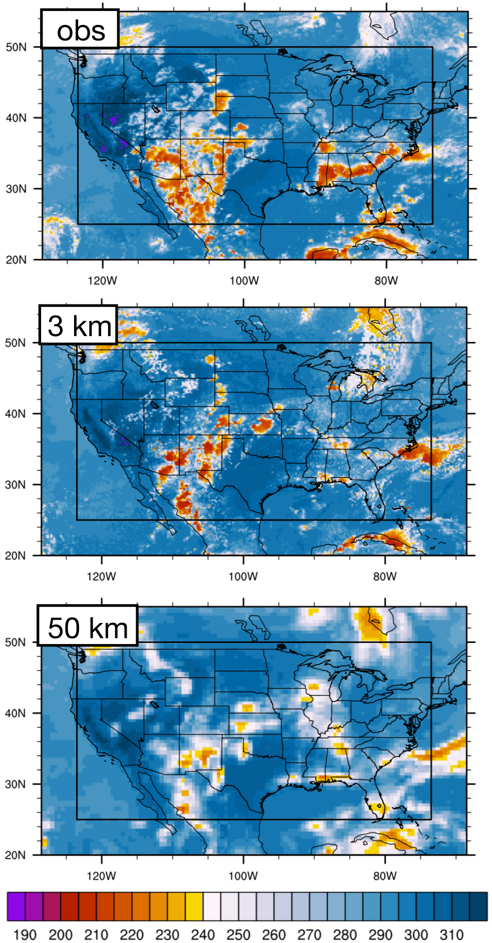


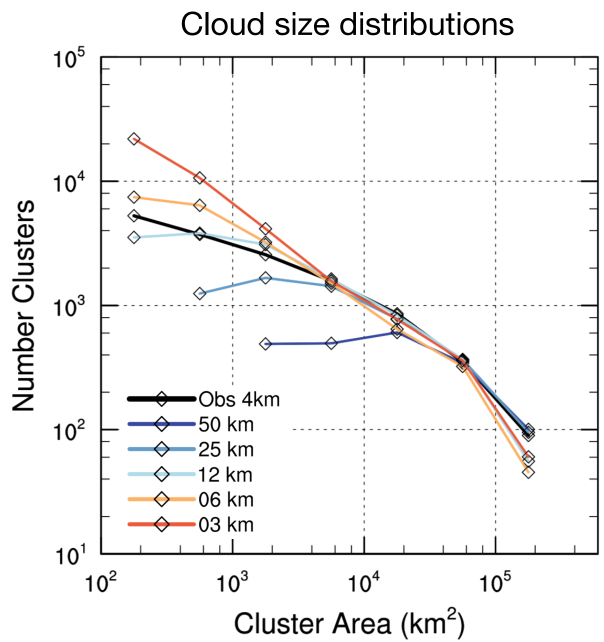


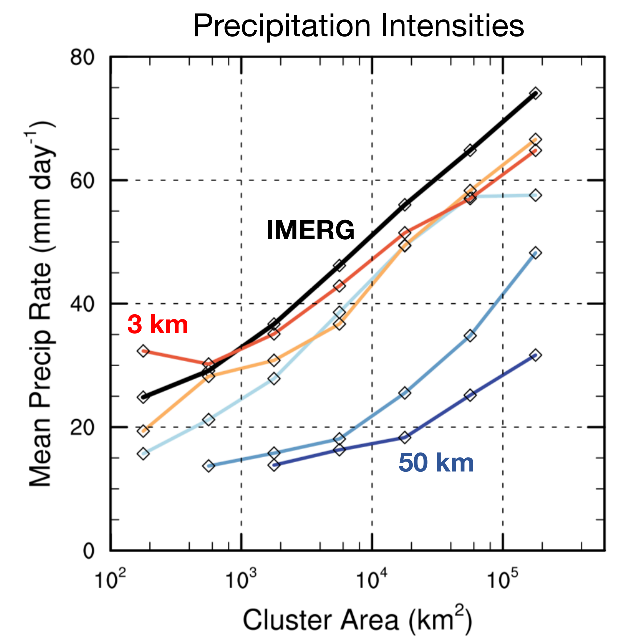


Cloud cluster size distributions

T_b snapshots - Aug 3, 2016

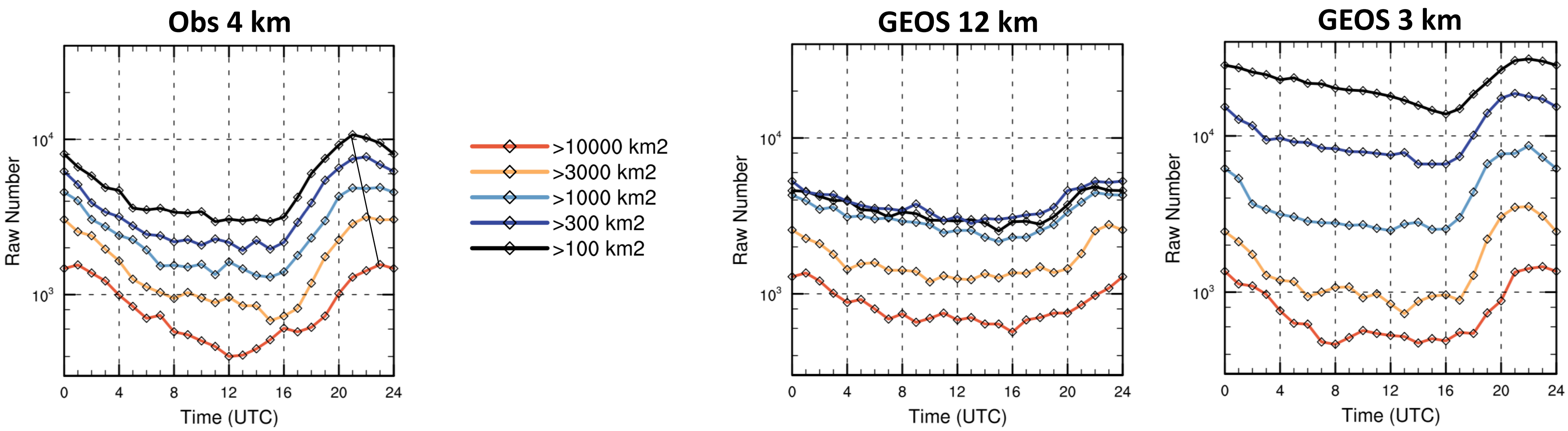






- Clusters defined by $T_b < 230$ K, area > 100 km^2.
- 3 km case overestimates small clusters, but captures precipitation intensity.

Diurnal cycle of cloud size distribution



- 12 km case underestimates amplitude of the diurnal cycle, but this is better represented at 3 km.

- Observed diurnal peak is delayed ~2 hrs for larger clusters, delay is ambiguous in GEOS.

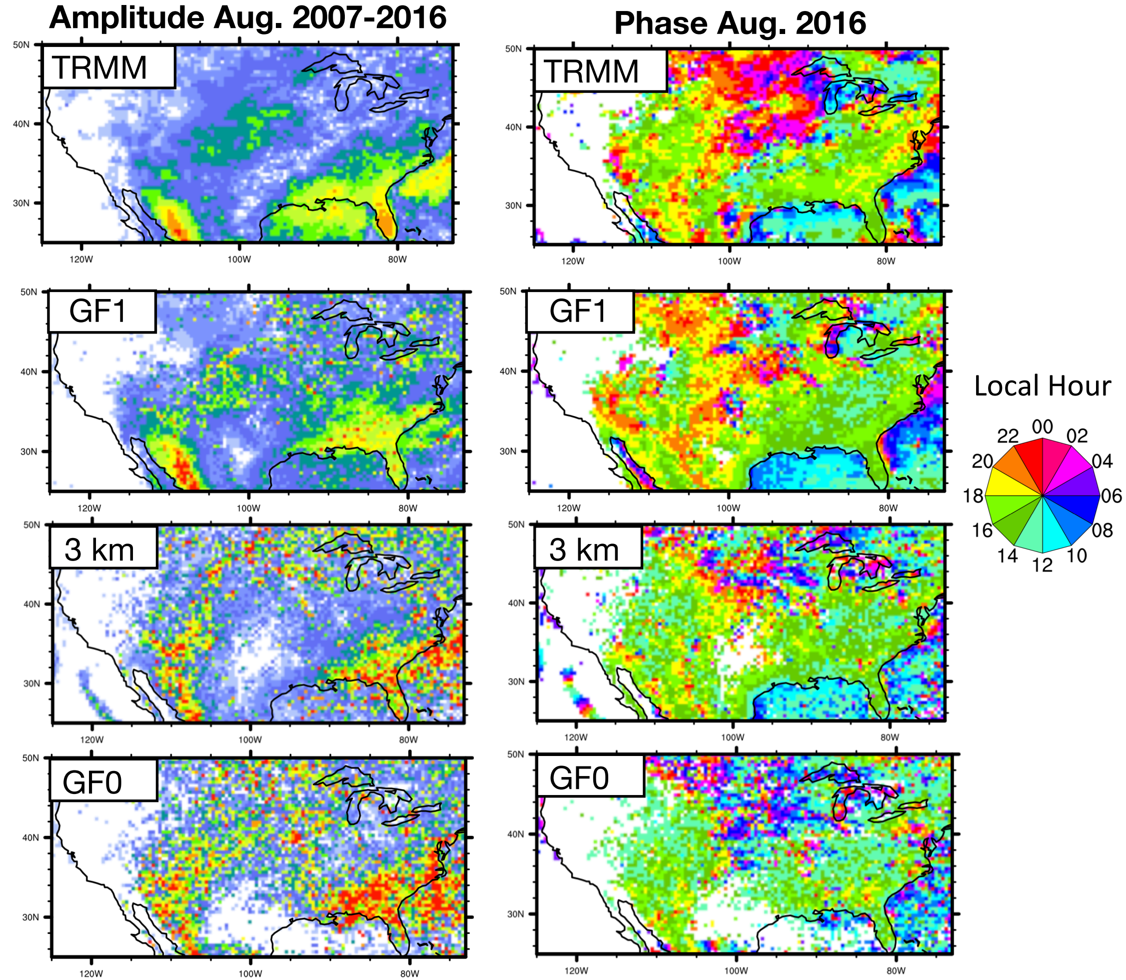
Varying parameterized deep convection strength at 3 km

Two 3 km experiments with Grell-Freitas:

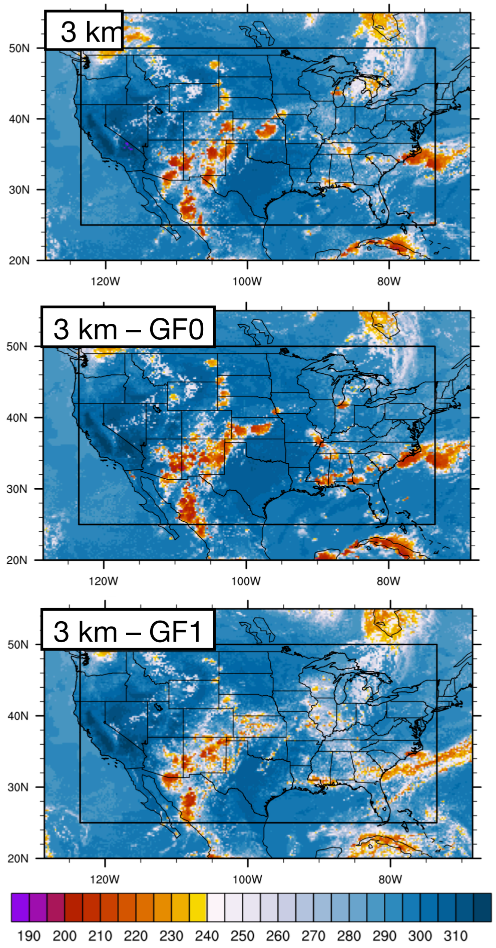
GF0: No parameterized deep convection

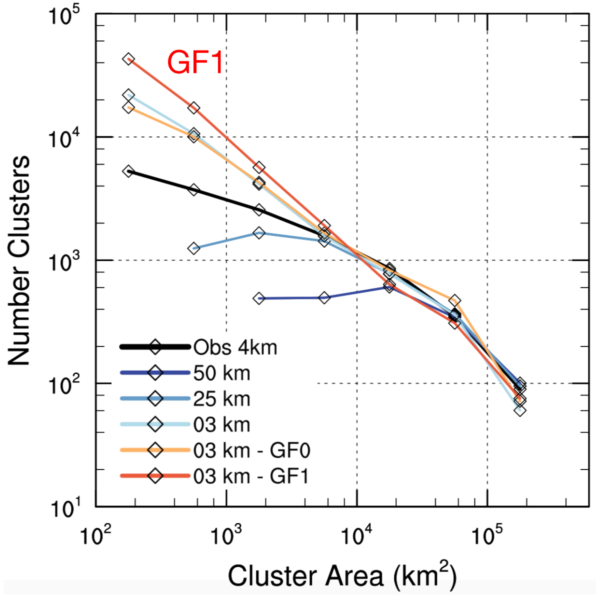
GF1: Scale-awareness turned off, GF at full strength.

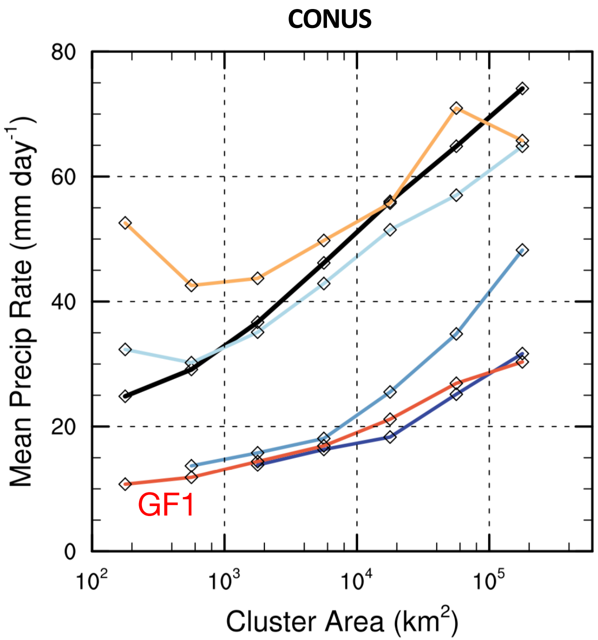
- Parameterized deep convection tends to reduce amplitude of the diurnal cycle in the Southeast, smooth field.
- Tends to realistically delay precipitation in the Mountain West, and reduce excessive delay over Great Plains.



Varying parameterized deep convection strength at 3 km



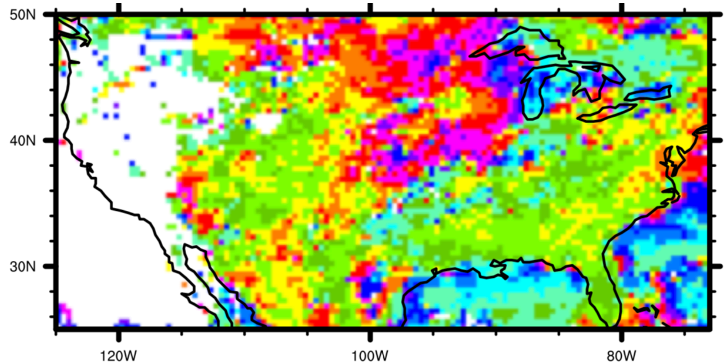


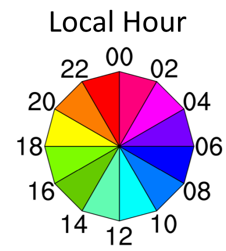


- Non-scale-aware Grell-Freitas (GF1) worsens bias toward small clusters and reduces precipitation intensity.

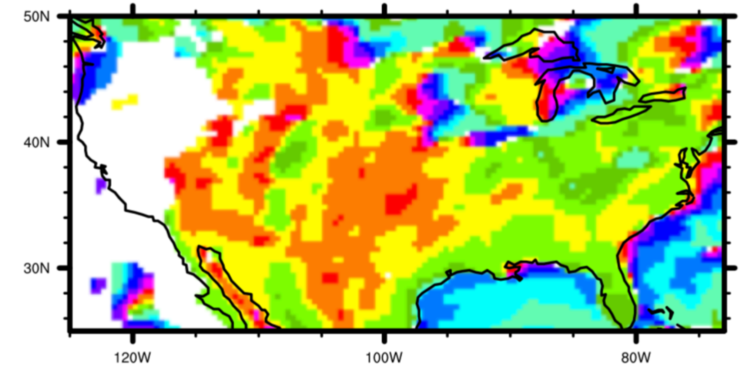
Impact of the diurnal closure in Grell-Freitas convection

TRMM Phase Aug. 2016

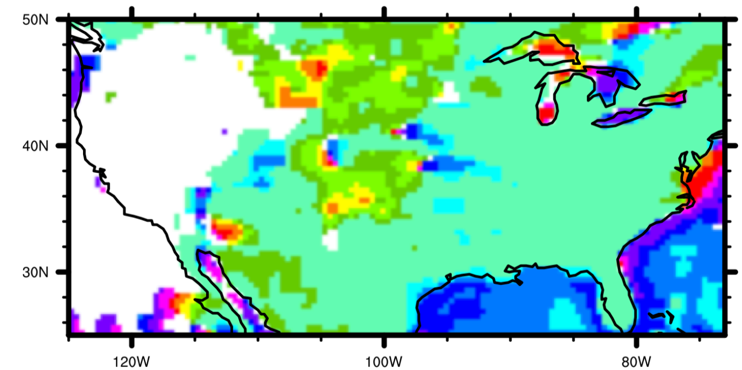




GEOS - 50 km, with diurnal closure



GEOS – 50 km, diurnal closure off



- The reasonable diurnal phase at 50 km is largely due to the non-equilibrium closure of Bechtold et al. (2014)

$$A = \int_{zb}^{zt} \frac{g}{c_p \overline{T}} \frac{\eta(z)}{1+\gamma} [h_u - \overline{h}] dz \qquad A_{avail} = A - \tau_{BL} \frac{\partial A_{BL}}{\partial t}$$

Summary and conclusions

- We evaluated the diurnal cycle of precipitation and cloud size distributions over CONUS in 40-day global runs with the GEOS model, with grid spacing from 100 km to 3 km.
- The simulated pattern of diurnal amplitude more closely resembles the climatology than the specific month of August 2016.
- All resolutions capture the diurnal phase over the Southeast, while low resolutions (dx>=25km) are too delayed over Mountain West.
- High resolution cases dx<=12km better capture diurnal phase over Great Plains, likely due to better representing propagating systems.
- High resolution cases overestimate small cloud clusters, but cluster rainfall intensity improves steadily with resolution.
- The Bechtold et al. closure in Grell-Freitas significantly improves phase.
- 3 km case with full parameterized convection (non-SA) improves diurnal phase but worsens bias toward small cloud clusters, and reduces precip intensity.
- Experiments with 132 levels, different microphysics, and other options are available.

We invite collaborations to study these simulations in more detail!

Nathan Arnold nathan.arnold@nasa.gov