Precipitation Variability and Diurnal Cycle of Convection-Permitting Deterministic Simulations versus Mesoscale Multi-Physics Ensemble Simulations: A Preliminary Result from the NASA Downscaling Project

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NASA GSFC Code 612

ESSIC UMD

NLDAS Rainfall Diurnal Cycle

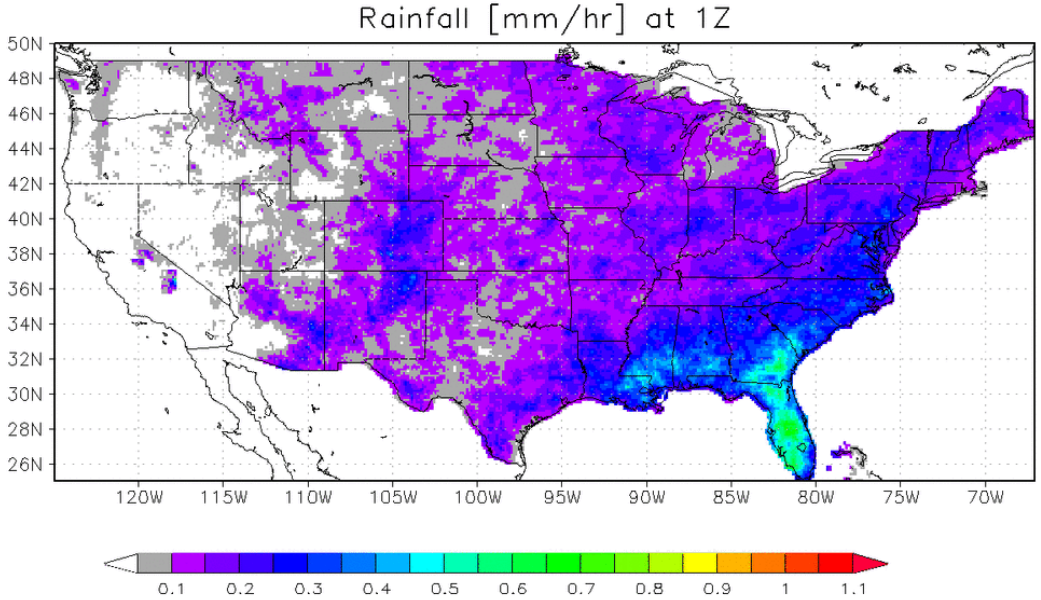
-North American Land Data Assimilation-

NLDAS hourly 0.25deg Precip Data

Hourly Stage II (Radar) values divided by daily Stage II sum to create **hourly temporal disaggregation weights**

Hourly weights applied to daily CPC gauge precip

NLDAS 10-year (1998-2007) JJA Rainfall Climatology



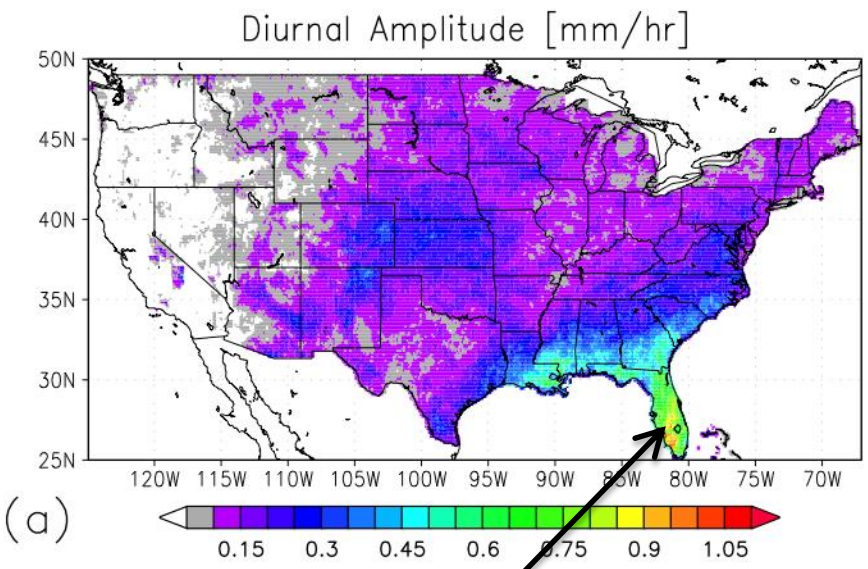
Key Points:

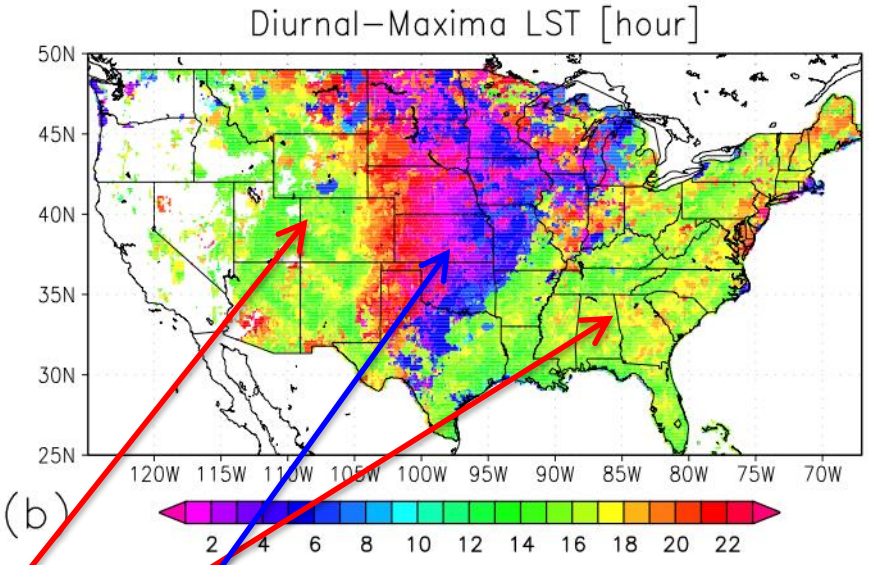
*Stage II Radar precip used only to derive temporal disaggregation weights

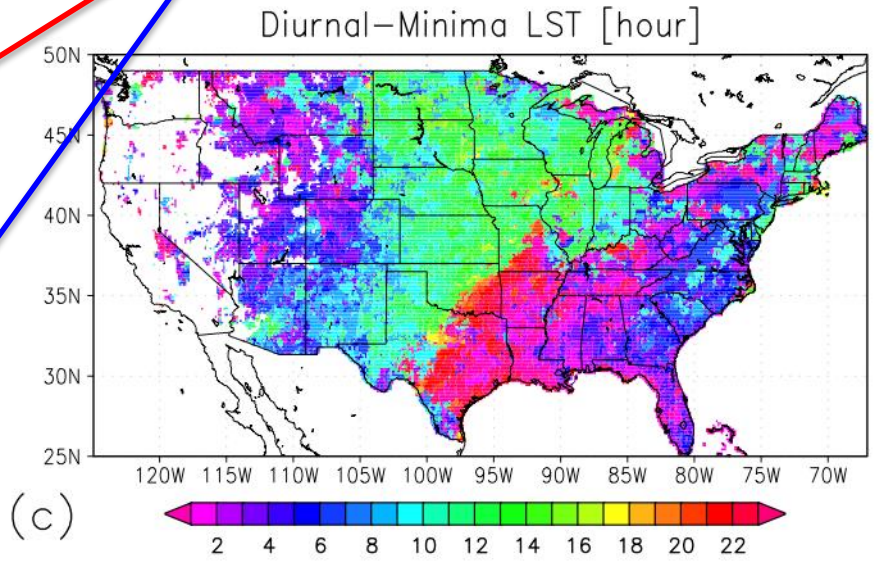
*Sum of hourly CPC precip values equals original daily CPC gauge total

Sampled NLDAS2 rainfall at **each hour** on **1/8-grid CONUS map** over 10-year (1998-2007) JJA period. →Each 1/8 grid has 920 samples per hour.

10-Year Climatology of JJA Rainfall Diurnal Cycle from NLDAS data







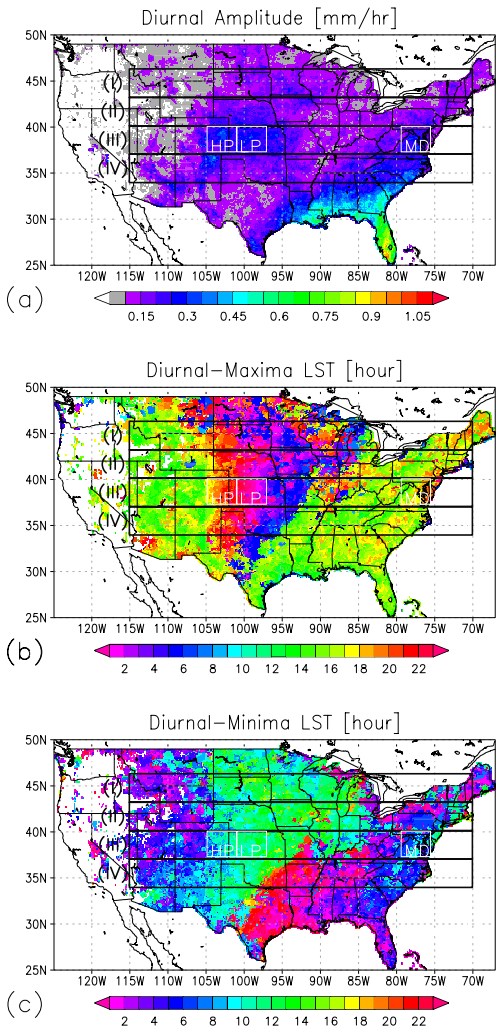
1) Largest diurnal amplitude (P_{max} - P_{min}) appears over Florida.

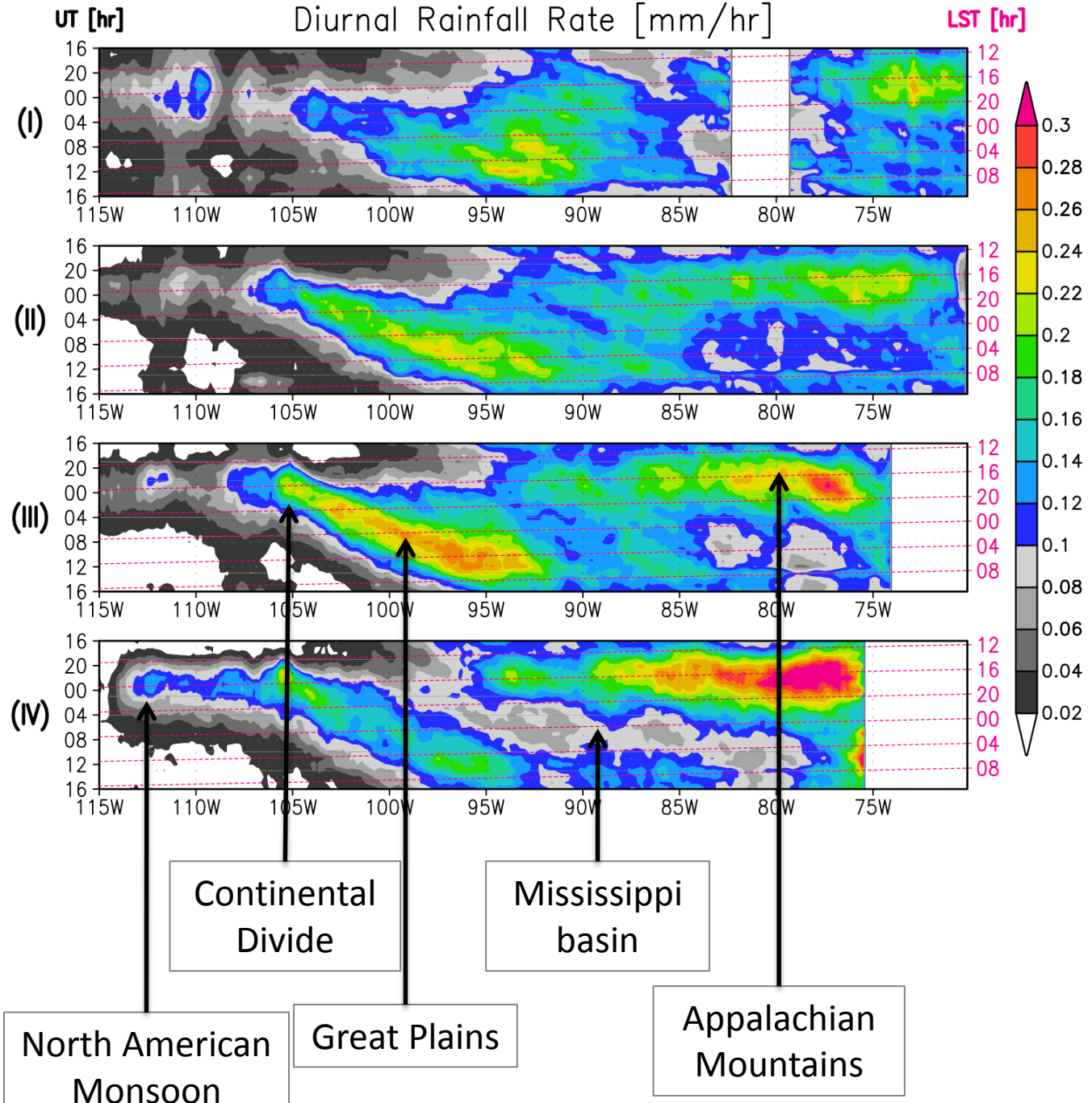
2) Diurnal rainfall cycle is characterized by frequent isolated afternoon thunderstorm.

3) Diurnal rainfall cycle is characterized by organized propagating Mesoscale Convective Systems (MCSs).

Matsui et al. 2010, GRL

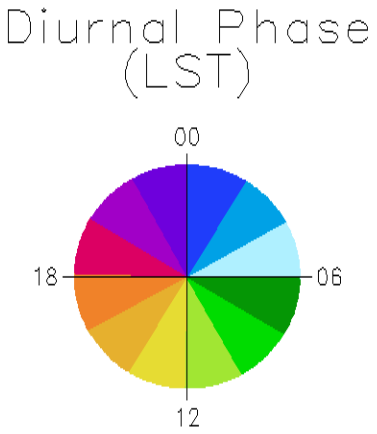
Hovmöller Diagram



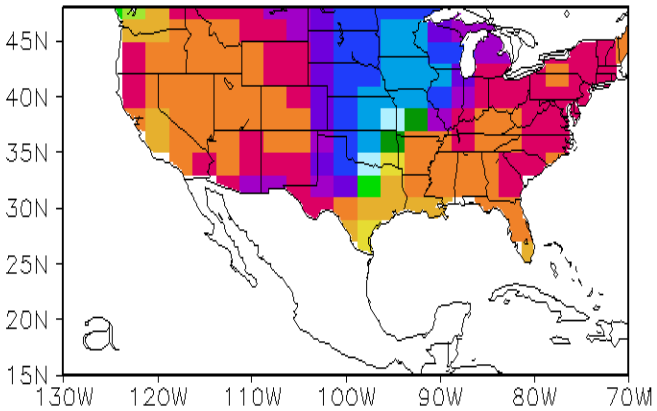


Matsui et al. 2010, GRL

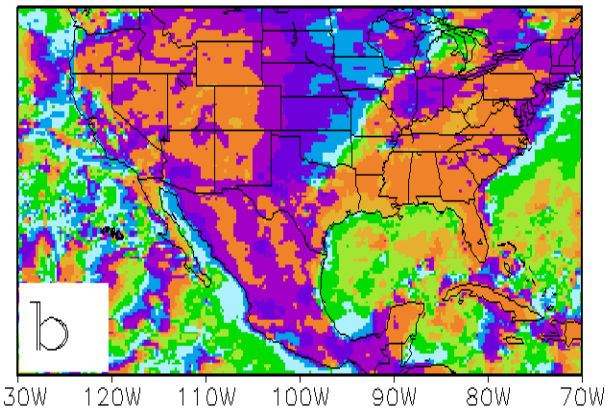
Dreary States in Conventional GCMs



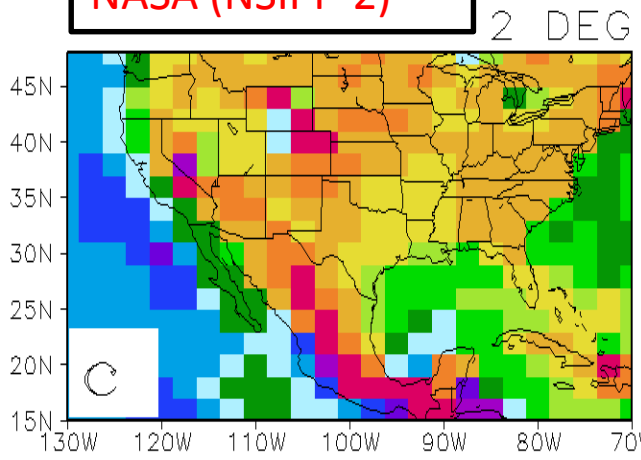
OBS (HPD)



OBS (CMORPH)

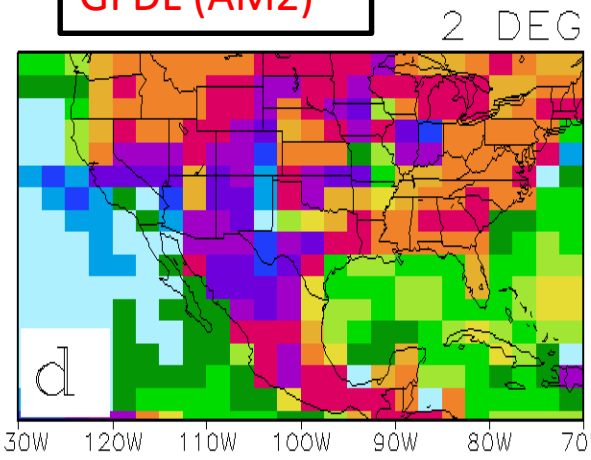


NASA (NSIPP-2)



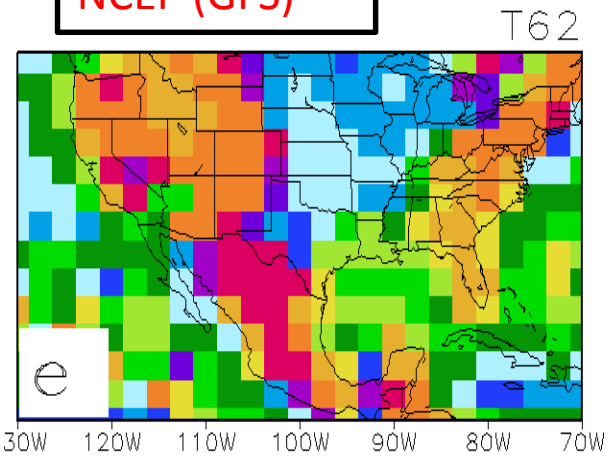
Relaxed Arakawa-Schubert
(Moorthi and Suarez 1992)

GFDL (AM2)



Relaxed Arakawa-Schubert
(Moorthi and Suarez 1992)

NCEP (GFS)



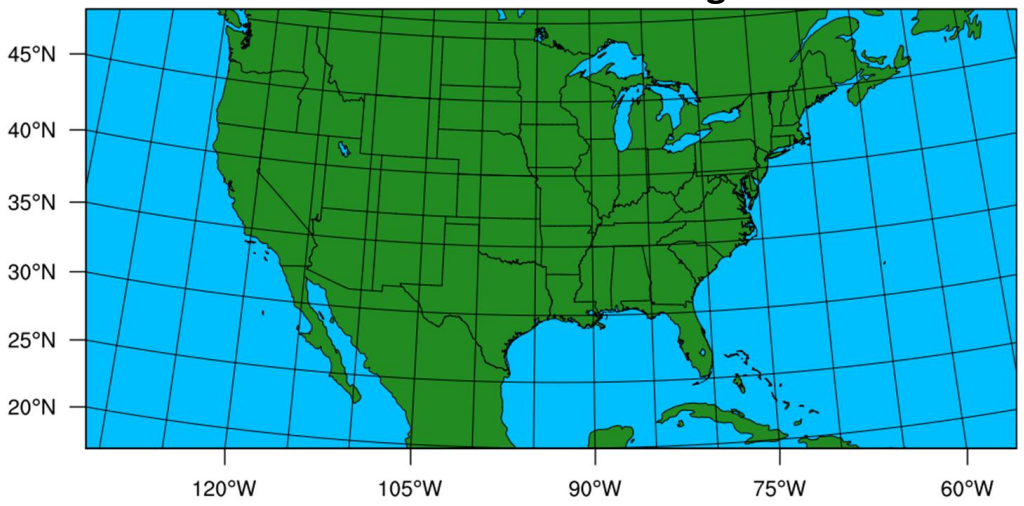
Simplified Arakawa-Schubert
(Grell 1993, Pan and Wu 1994)

Lee et al. 2000

NASA Downscaling Climate Simulation Project

- Regional Climate Model
  - NASA Unified-WRF (NU-WRF) Based on WRF-ARW v3.5.1
- Initial/Boundary Conditions
  - NASA MERRA-2 six-hourly re-analyses over CONUS
- Land Initial Conditions
  - Land Information System (LIS) 10-yr spin-up of Noah LSM
- Nudging (large scale forcing of certain variables to the synoptic scale)
  - Simulations with spectral nudging of p, t, and horizontal winds above the PBL
- Cloud Microphysics
  - GCE 3-ICE with Graupel
- Radiation
  - Goddard 2011
- Planetary Boundary Layer Scheme
  - Mellor-Yamada-Janic
- Land Surface Model
  - Noah LSM

NU-WRF RCM domain configuration



NU-WRF Run List for Rainfall Diurnal Cycle Analysis

Abbreviations	Domain Resolution	Cumulus Parameterization
4km	4km	Grell 3D
12km	12km	Grell 3D
24km G	24km	Grell 3D
24km GO	24km	Grell 3D with native shallow cumulus component
24km GW	24km	Grell 3D with the University of Washington shallow cumulus
24km BO	24km	Betts-Miller-Janjic
24km KO	24km	The new Kain-Fritsch
24km SO	24km	The new simplified Arakawa-Schubert

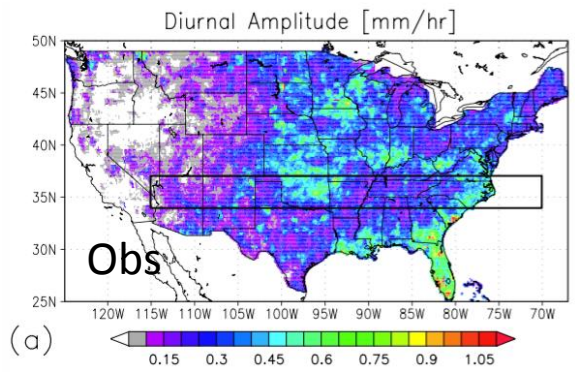
Hourly rainfall rates in all simulations are regridded to NLDAS 0.25 degree

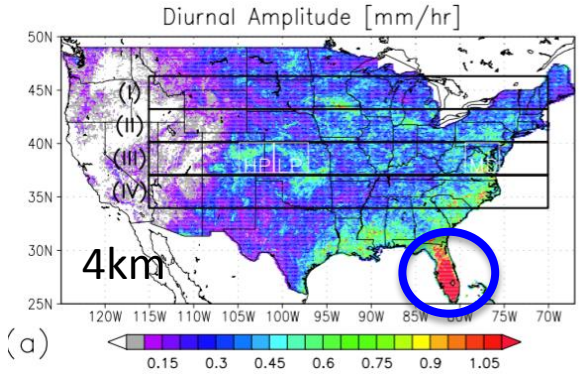
Calculate diurnal characteristics of rainfall in June, July, August of Year2000

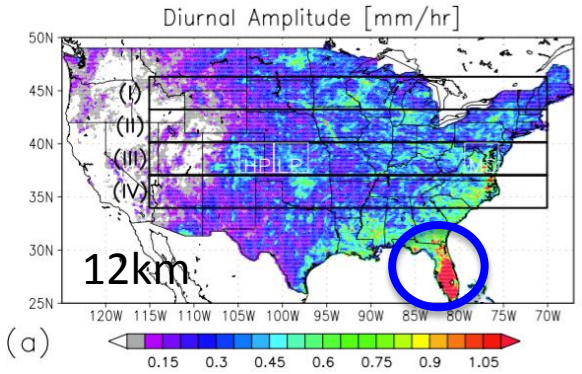
- *How does the regional climate model simulate diurnal precipitation cycle better than traditional global climate models?*
- *How does a convection-permitting regional simulation perform better in comparison with traditional meso-scale simulations?*

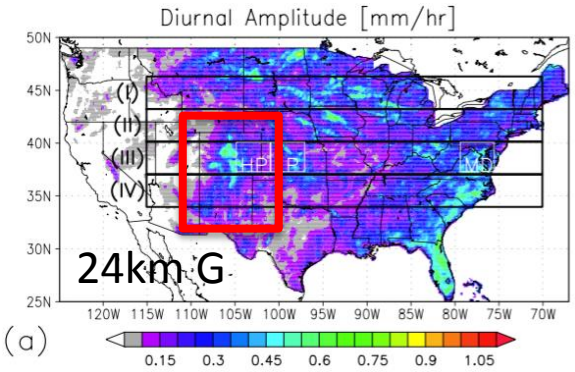
2000 JJA period

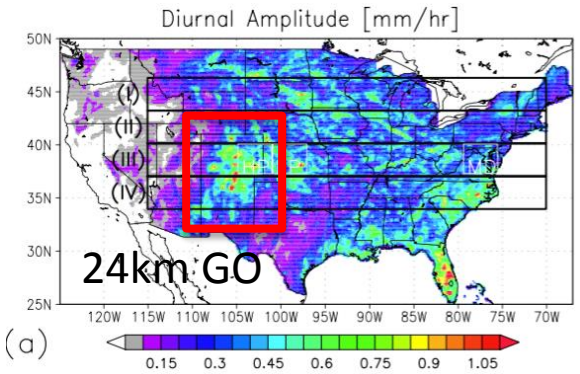
Diurnal Amplitude [mm/hr]

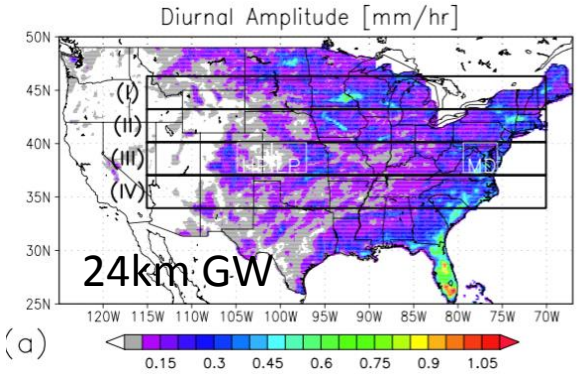


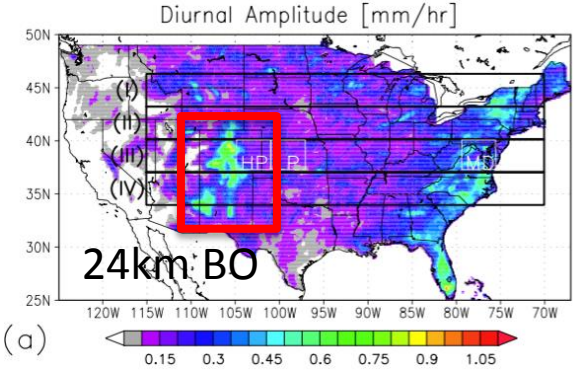


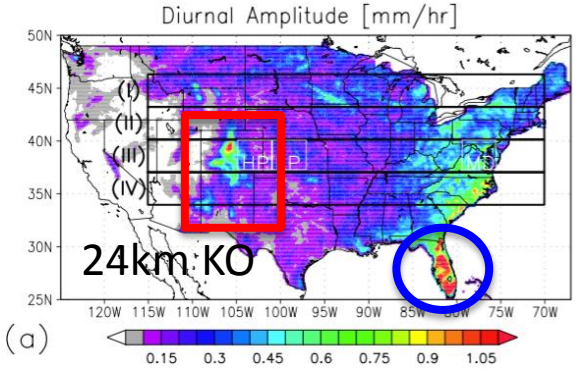


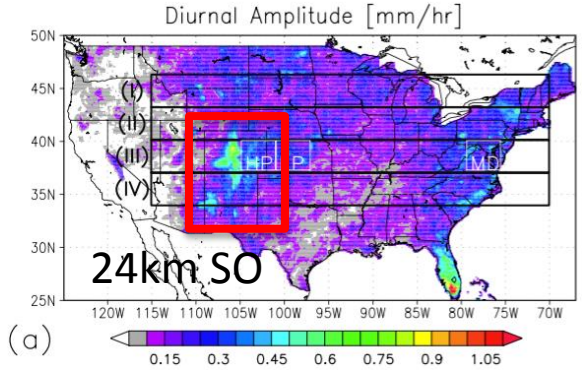






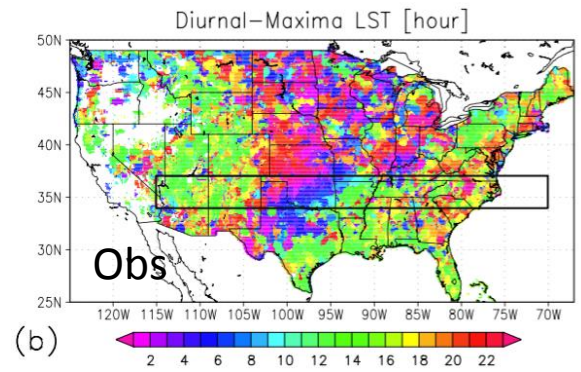


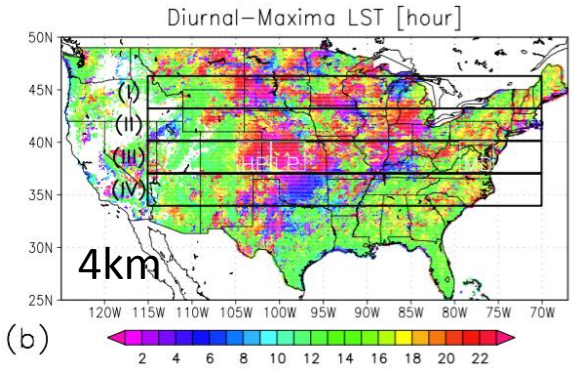


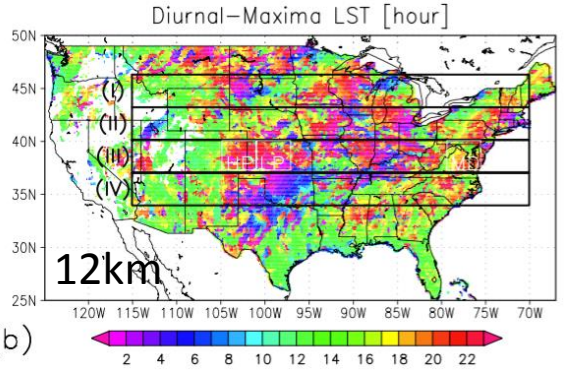


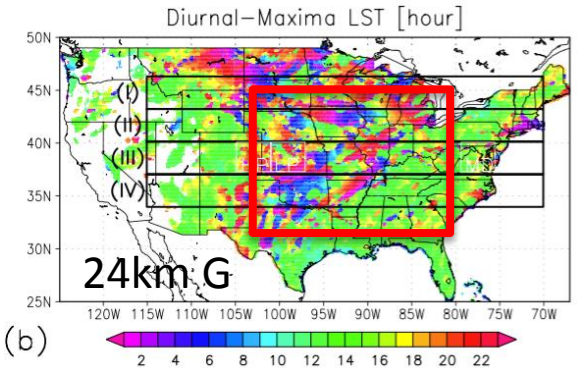
2000 JJA period

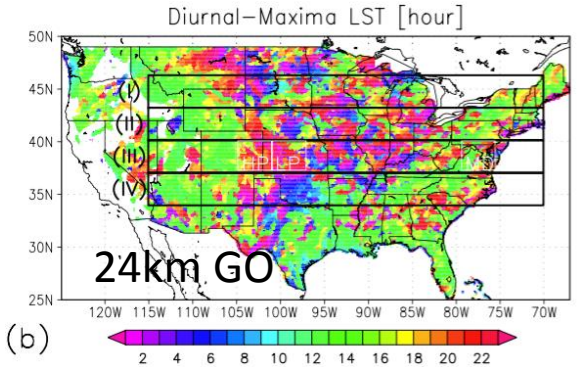
Diurnal-Maxima LST [hour]

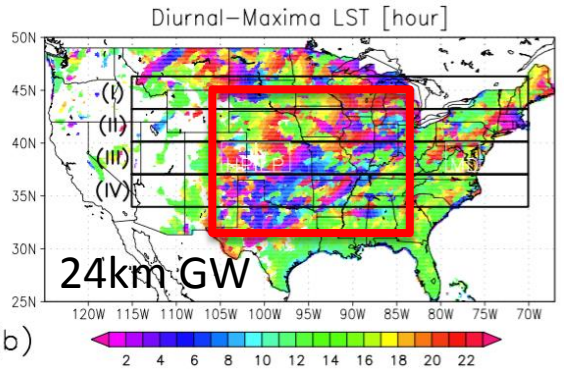


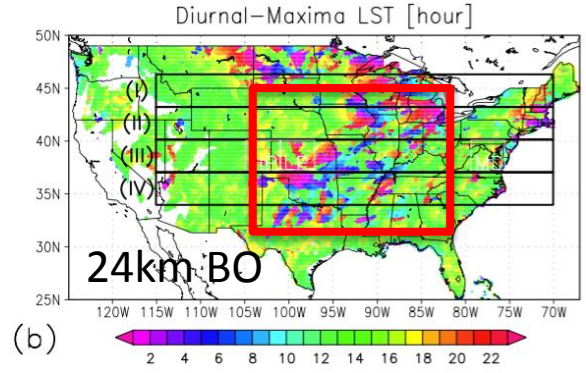


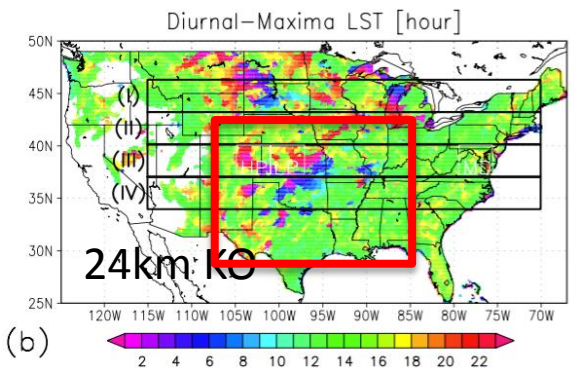


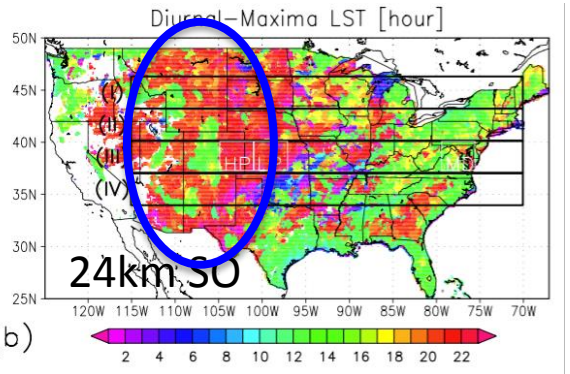






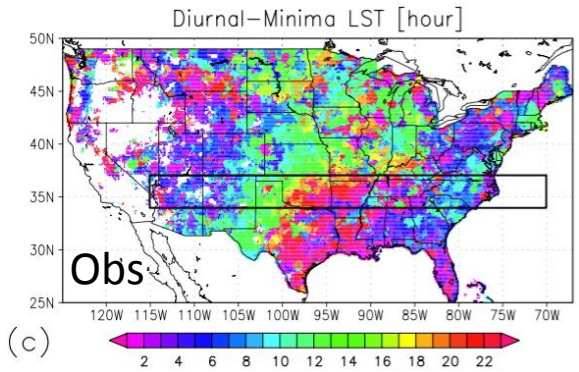


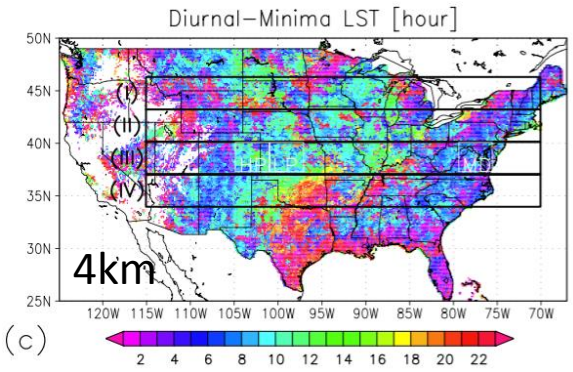


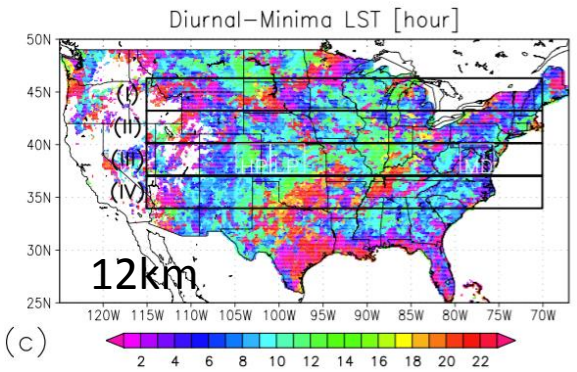


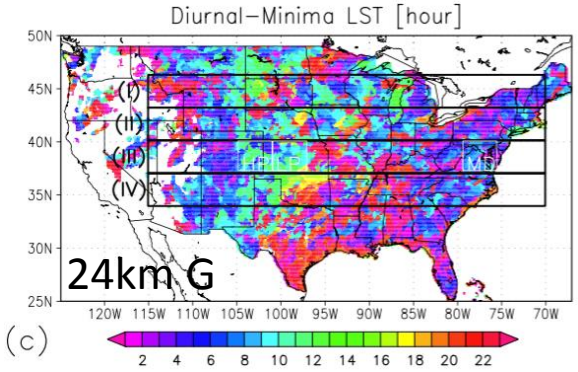
2000 JJA period

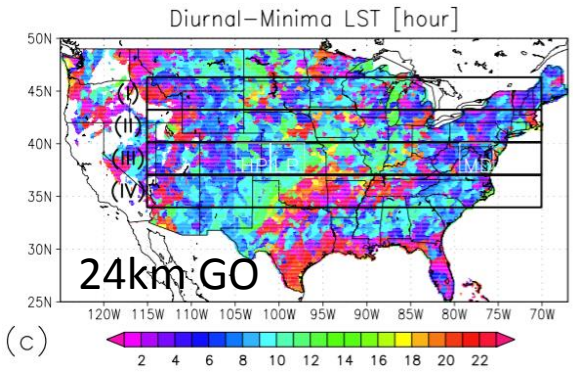
Diurnal-Minima LST [hour]

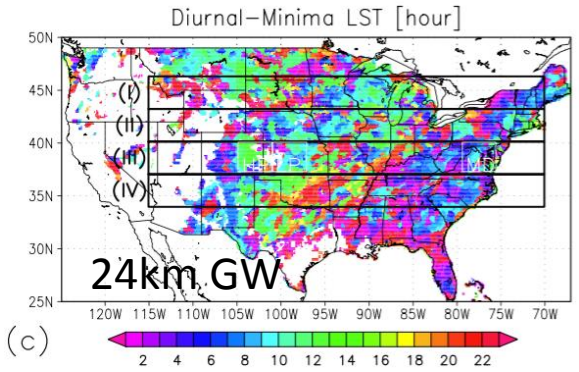


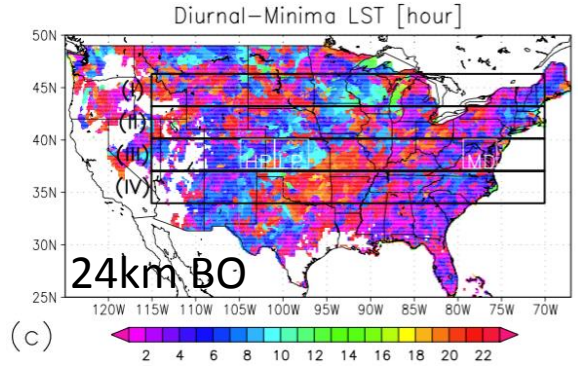


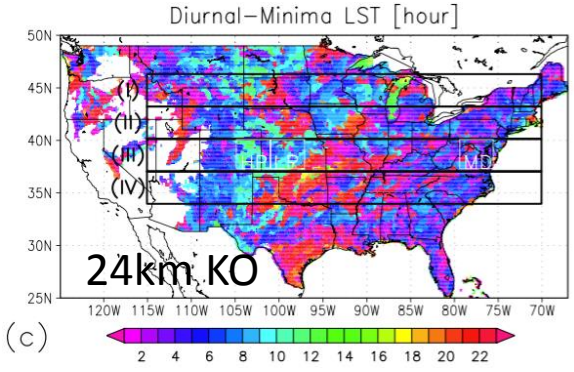


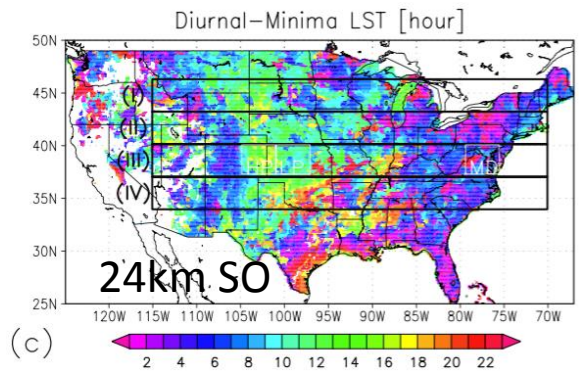




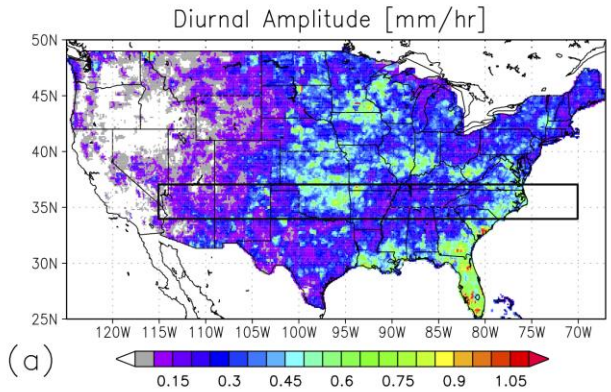


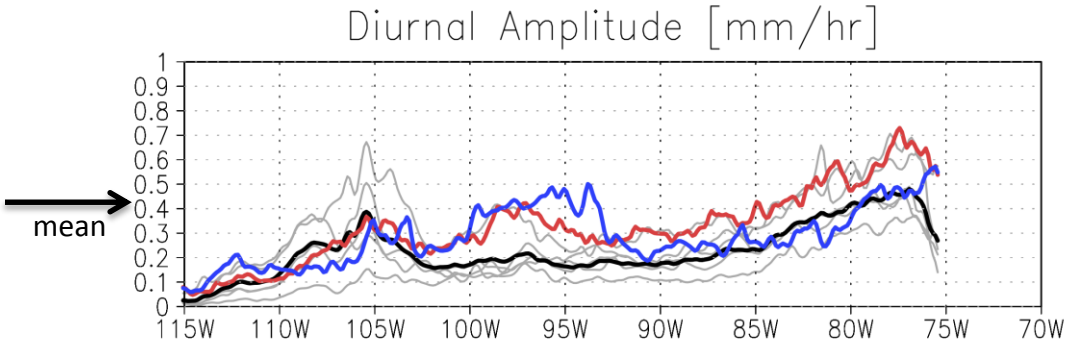


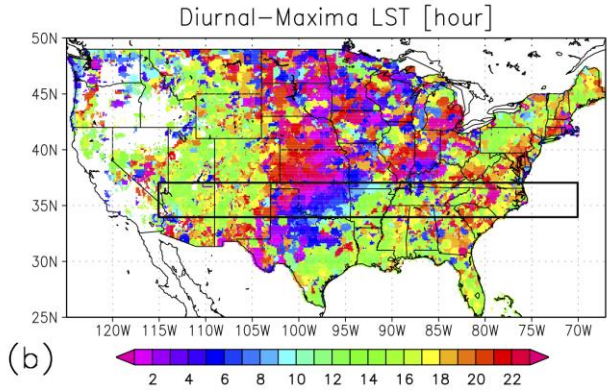


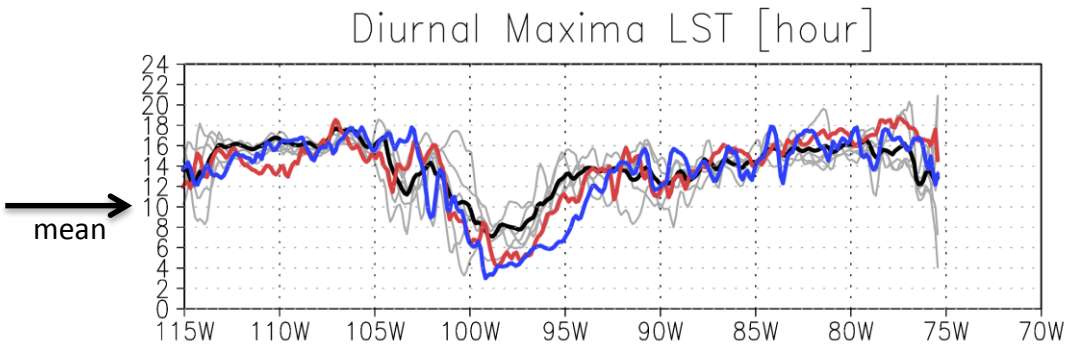


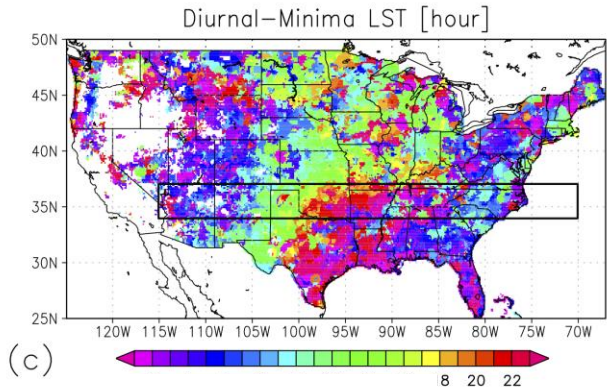
Comparison: 4km run and 24km ensemble mean

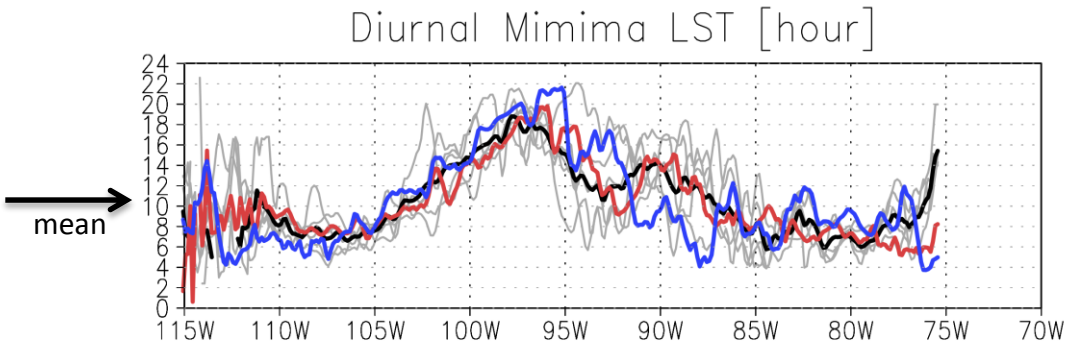












NLDAS Y2000

– OBS – 4km_Run – 24km_Ensemble, – 24km_Ensemble_Mean

Summary

- The 4km deterministic run generally performed better than 24km runs, except for overestimation over the coastal regions of Southeast and Florida: this could be biases in particular physics combination (microphysics + dynamics) of this study, so it could be suppressed by tuning some parameters.
- An ensemble mean of the 24km runs showed a much better performance than individual runs, and global climate model (e.g., Lee et al. 2000). The poor performance over the Continental Divide and Great Plains was not sufficiently improved.
- CPU cost (CPU cores × clock time) of the **4km run is about 300 times greater** than that of a 24 km run. Thus 24km ensemble approaches are worthy of consideration as a low-cost alternative for simulating rainfall diurnal variability by a regional climate model. (*But not sure about climate sensitivity runs associated with propagating meso-scale convection system*.)
- 24km grid spacing will be used by next-generation super high-resolution global climate models. So, the problems and findings could be similar and useful.

Future work

- Extend analysis for multiple years
- The analysis of 12km GEOS-5 GCM run

Acknowledgements for NASA downscaling project members

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Steven Pawson	GSFC	Linda Mearns*	NCAR
William Putman	GSFC	* External Advisors	
Brent Roberts	MSFC		

ANY QUESTIONS?