Regionally-refined, Globally Uniform High Resolution and CAPT Simulations using the Community Atmosphere Model (CAM)

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

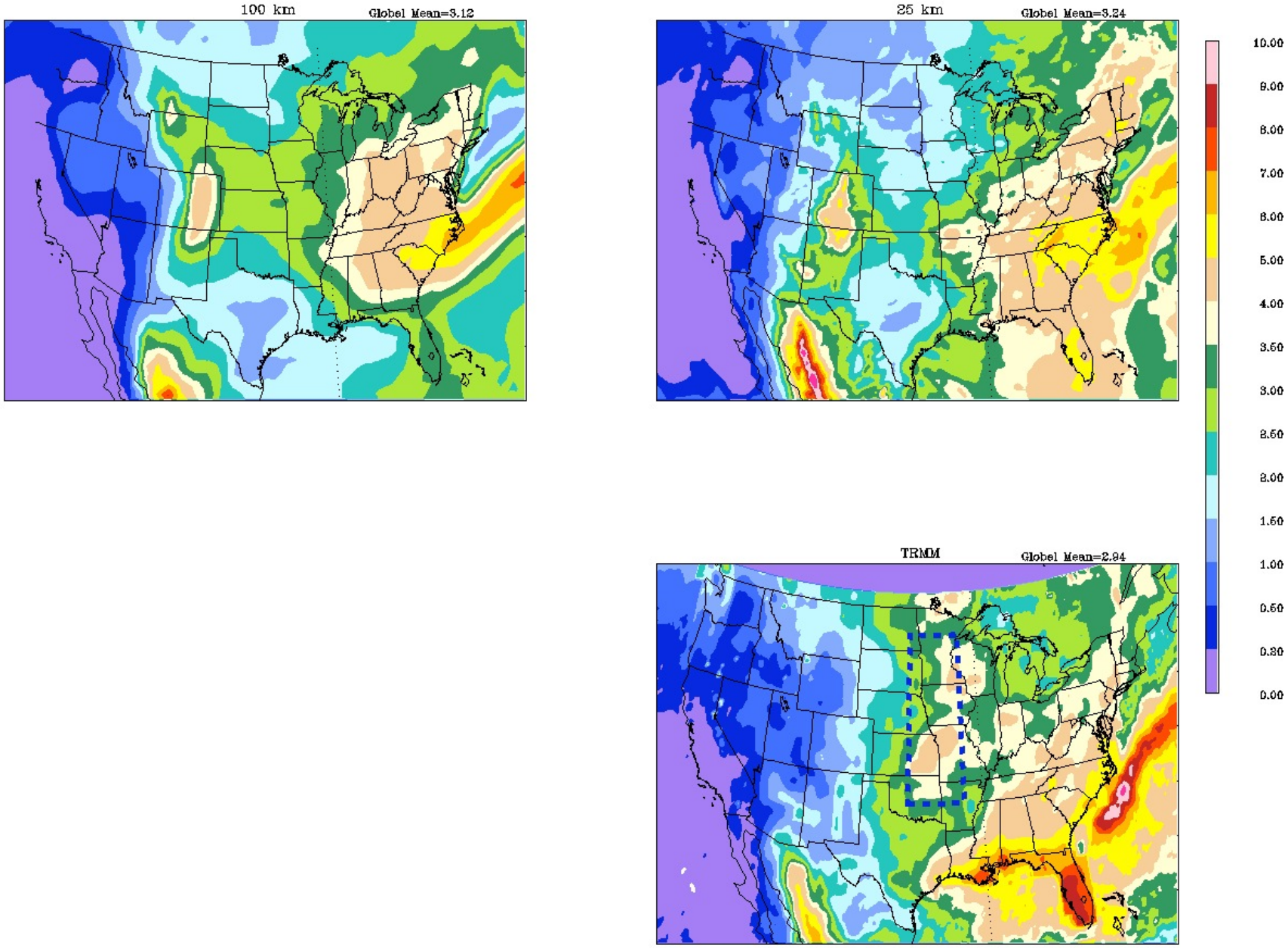
NOAA/DOE High-resolution Workshop, College Park MD, 1 October 2014

Outline

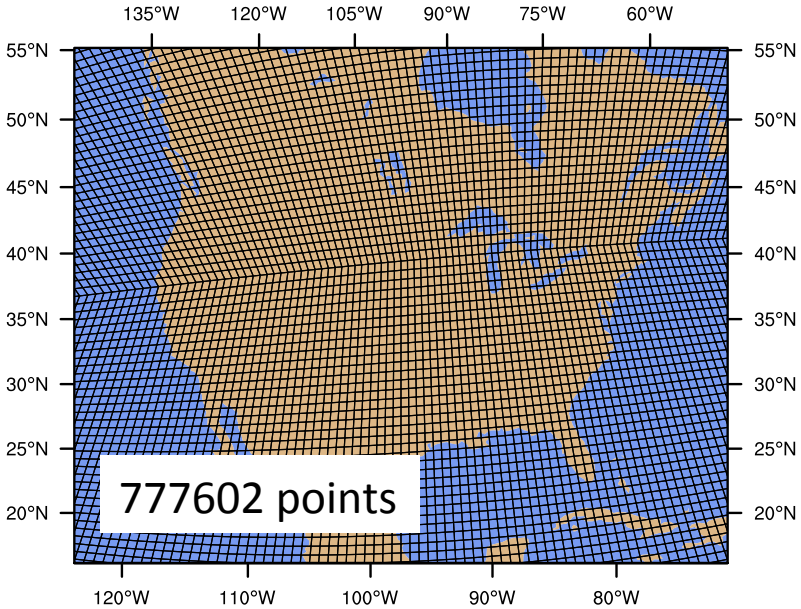
- “Radical” refinement to examine midwest summer precipitation bias
- Persistent topographic biases at High-Resolution
- CAPT runs to examine parameterizations
- Conclusions

Summertime precipitation bias in US Midwest

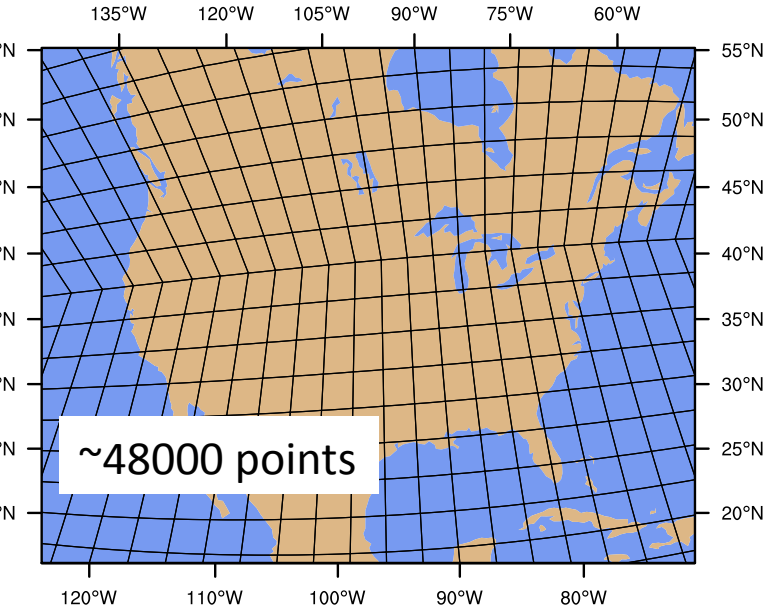
JJA precipitation 2000–2005



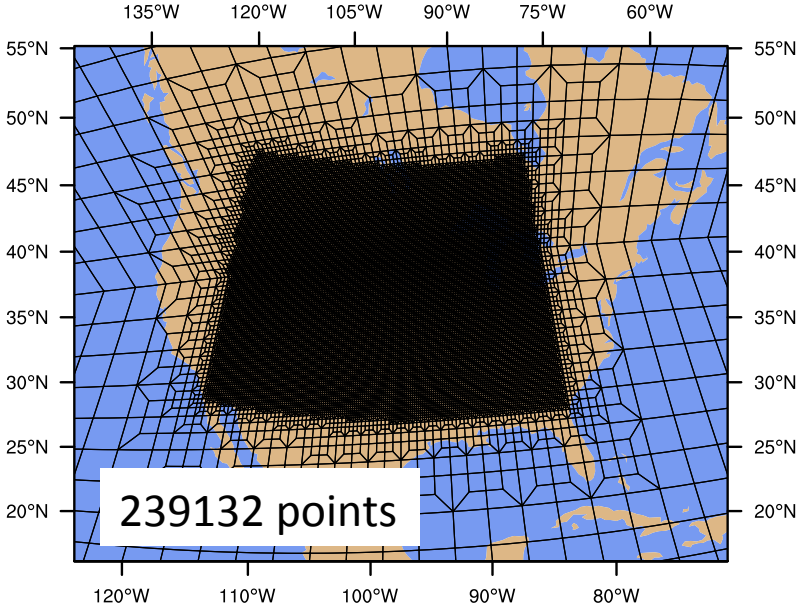
Uniform 25km (ne120)



Uniform 100km (ne30)



100km(ne30) --> 6km(ne480)



Refinement over ~1.5% of globe

Total cost: ~77x over ne30 (~150,000 cpuhrs/SY *roughly comparable to uniform ne120 ΔX~25km)*

Possible objections:

- Refinement is too extreme: *Baroclinic wave test*
- Non-hydrostatic model is needed: *Maybe better, but not critical. Including mass of condensates more important.*

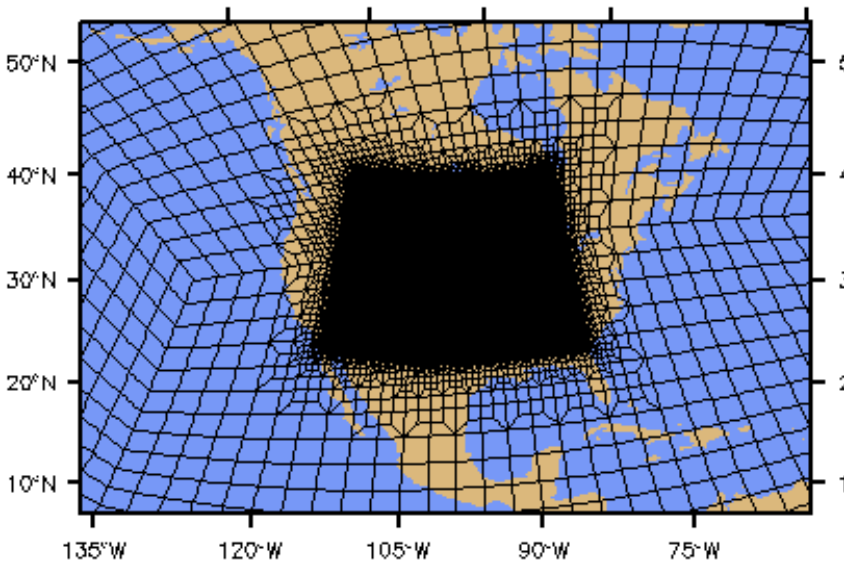
Run design

- 1 month spinup (May 1 – May 31) with nudging everywhere
- 3 months June 1-August 31 - Nudging off over US, but left on elsewhere*
- Year=2000. Working to extend through 2005.

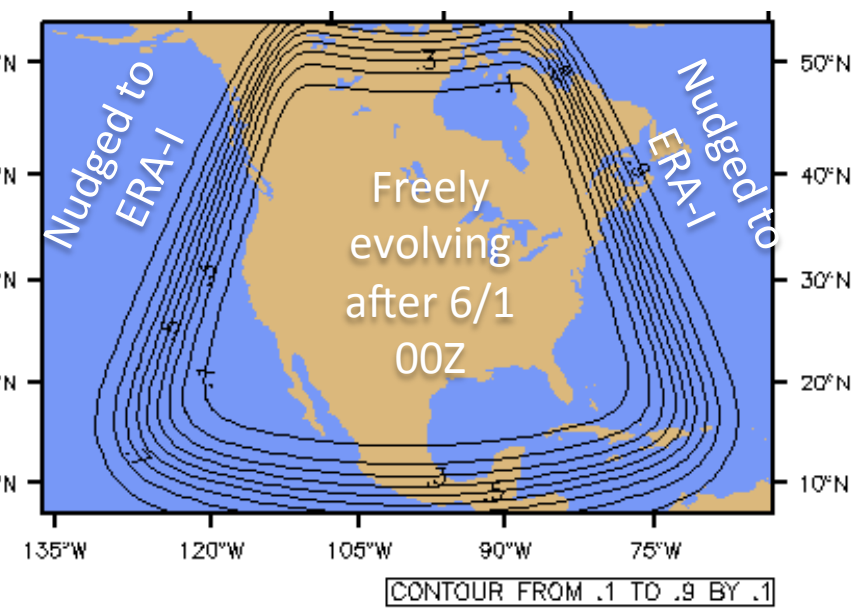
- *Deep scheme (ZM) can be turned off regionally (or globally)*

**Control run with nudging turned off everywhere on June 1*

100km(ne30)➔6km(ne480)



Nudging Window used after June 1

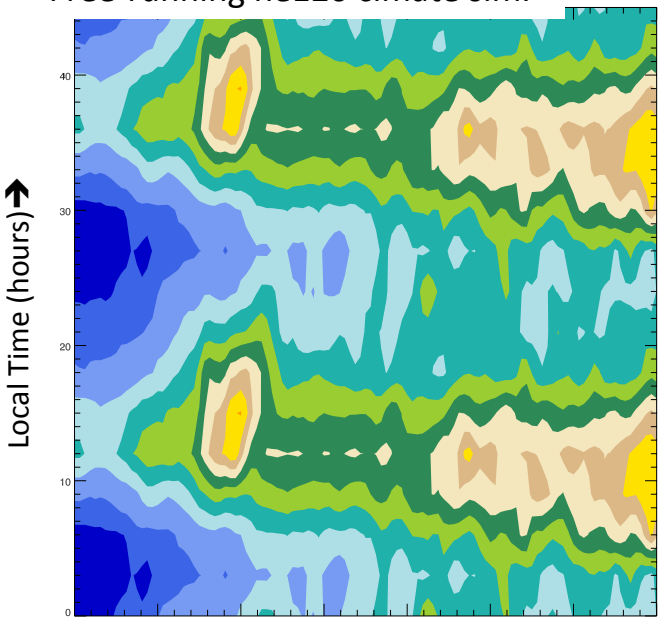


Nudging

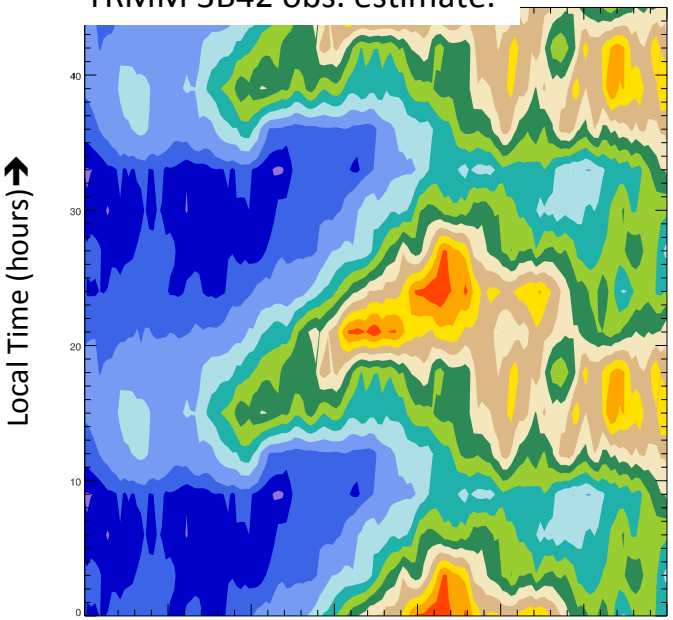
- U,V,T,Q_{sfc} + T-bias correction
- *Others tried, e.g., U,V only. Not discussed here*

Mean diurnal cycle 35N-45N

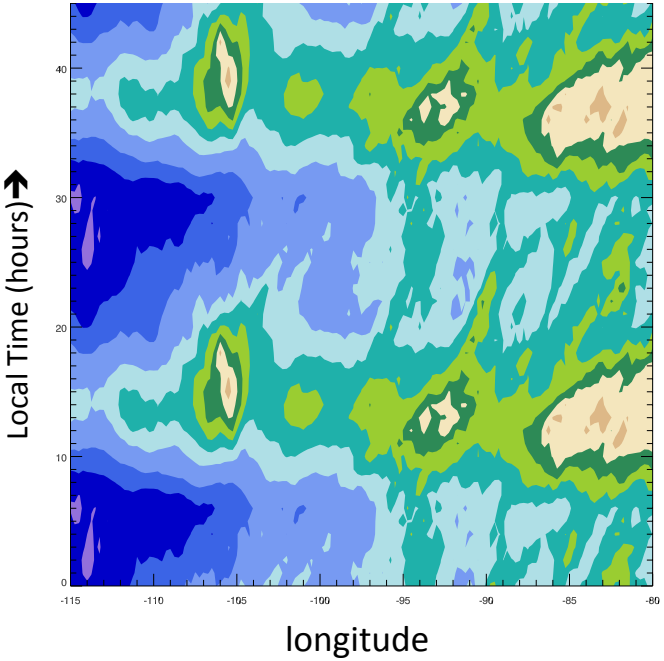
Free-running ne120 clmate sim.



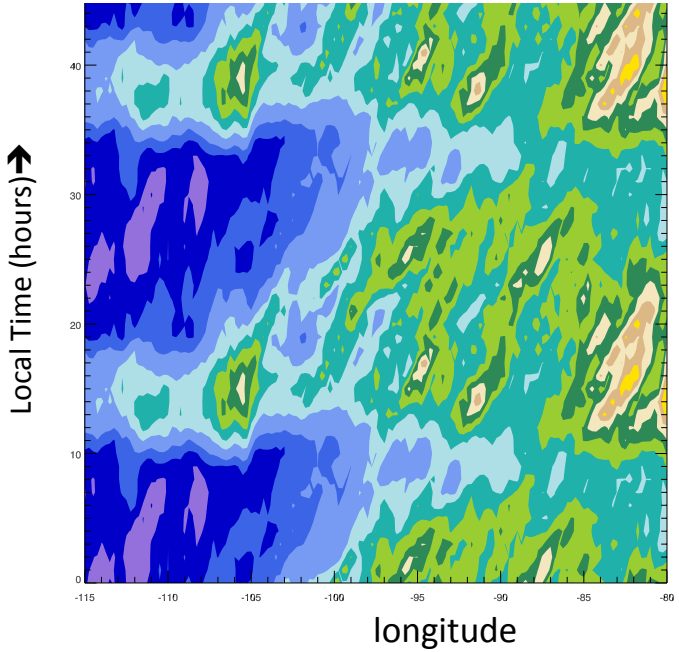
TRMM 3B42 obs. estimate.



6km RR SE mesh with boundary nudging.

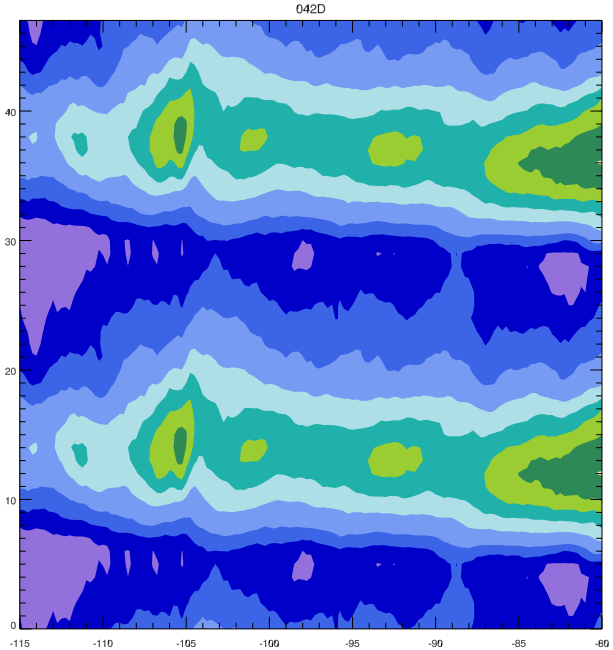


6km RR SE mesh with boundary nudging. ***ZM scheme off***

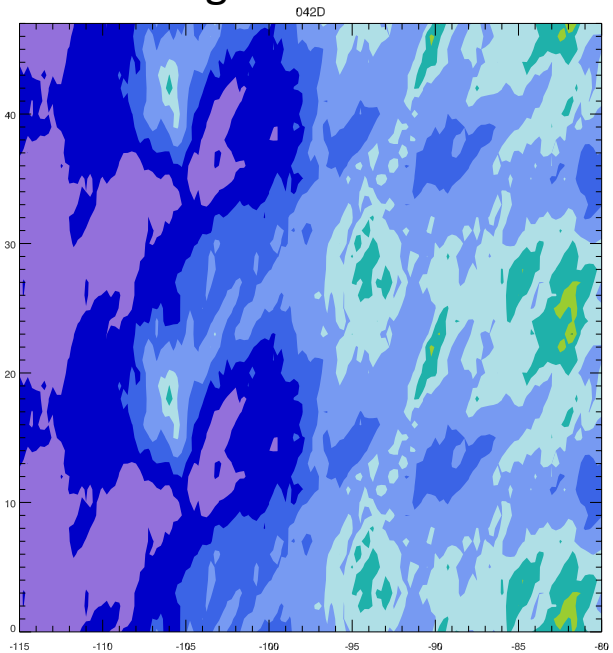


6km RR SE mesh with boundary nudging.

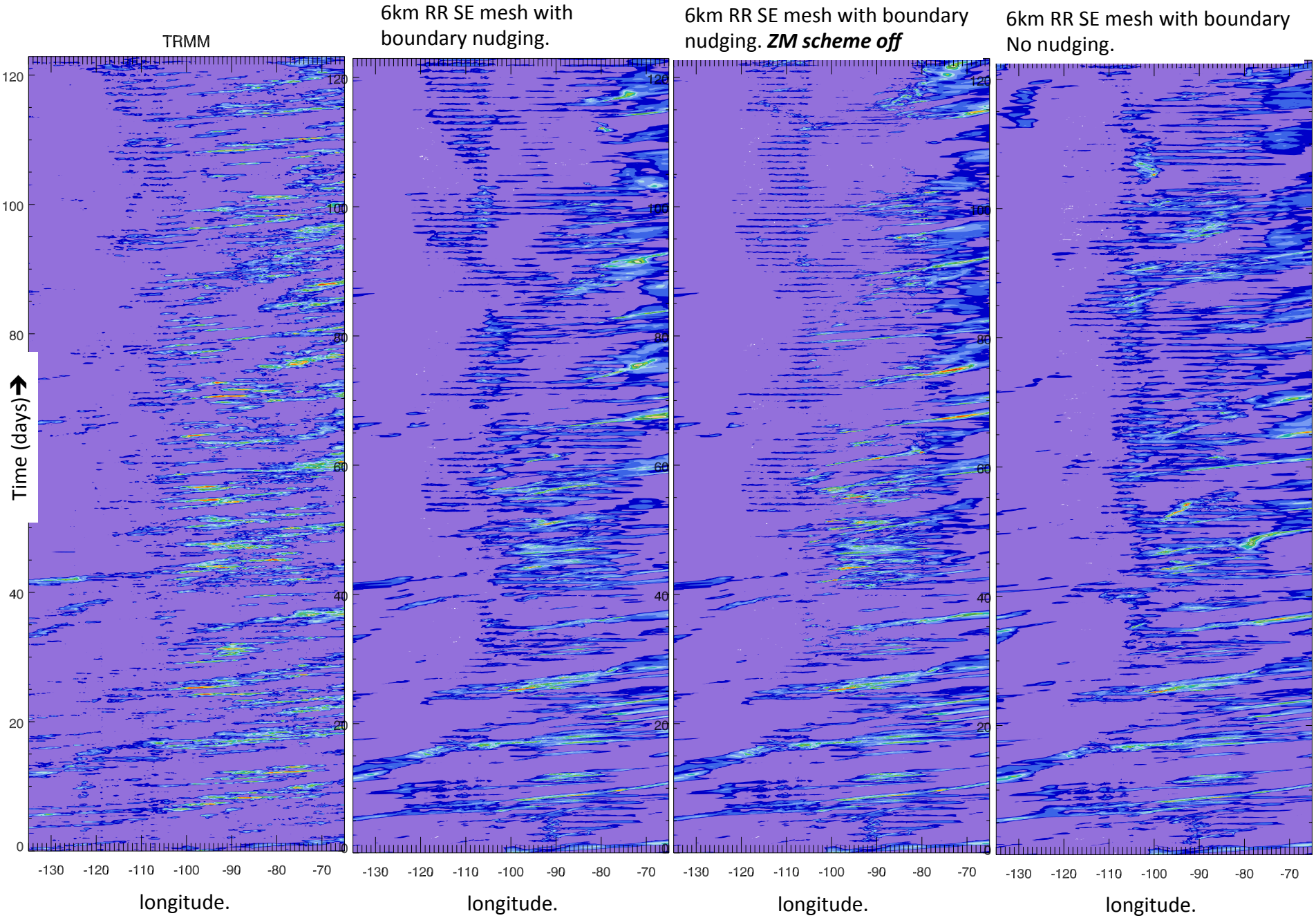
Deep convective rain (ZM)



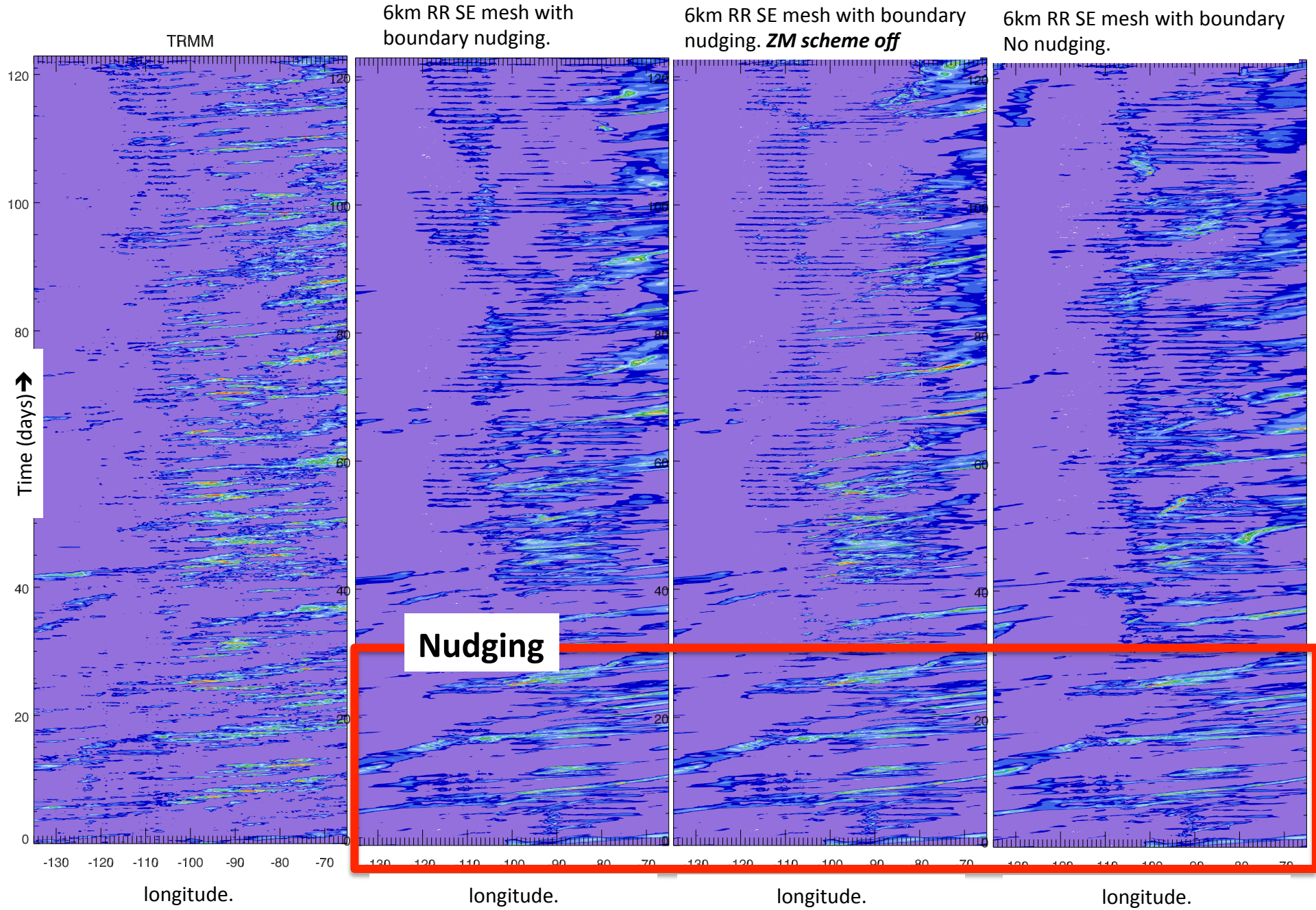
“large scale” rain



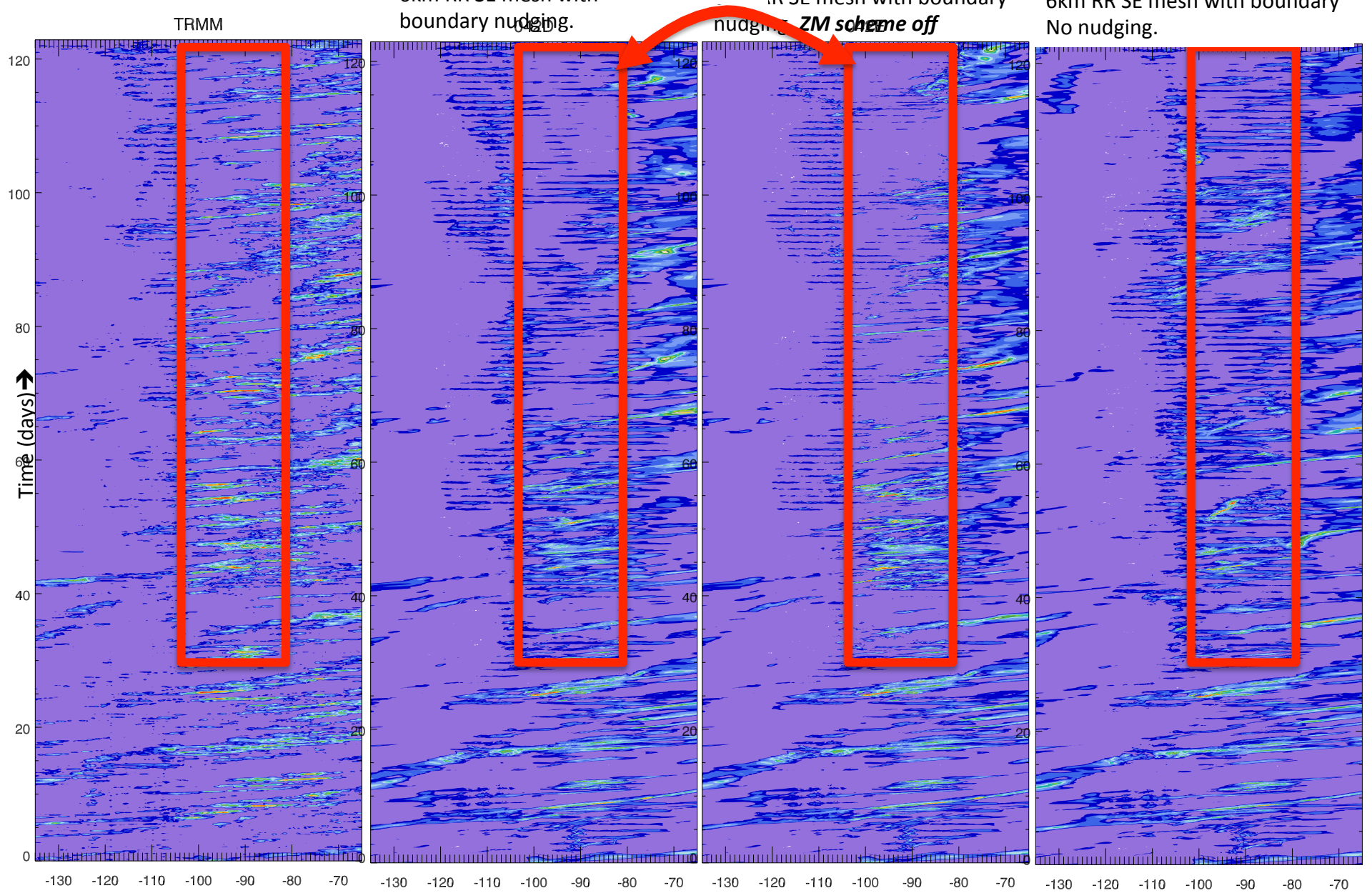
Precipitation Hovmuellers 35N-45N



Precipitation Hovmuellers 35N-45N



Precipitation ellers 35N-45N



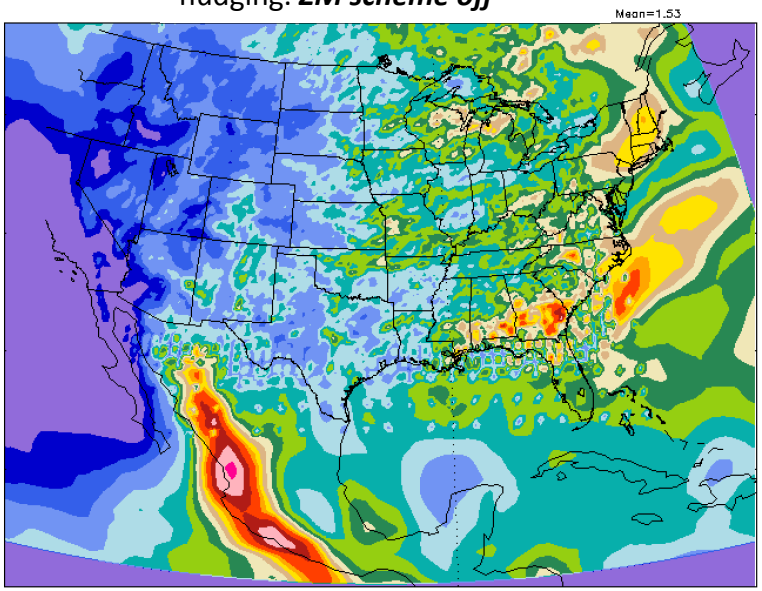
Correlations with TRMM

r=0.43

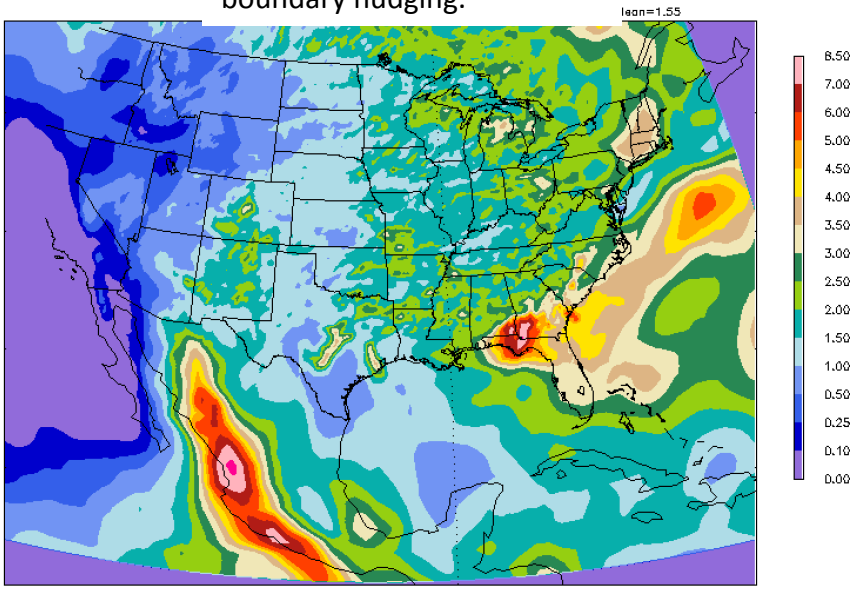
r=0.20

JJA mean precipitation (year=2000)

6km RR SE mesh with boundary nudging. ***ZM scheme off***



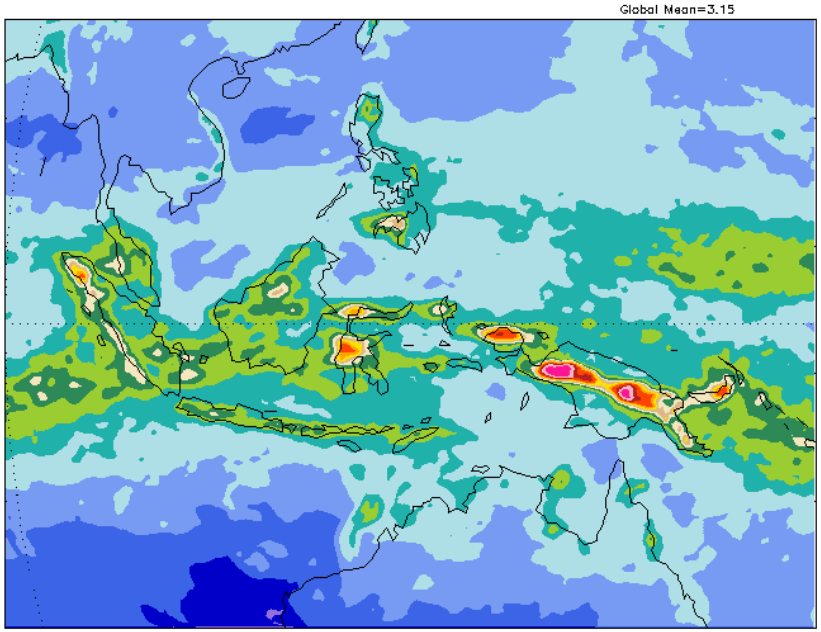
6km RR SE mesh with boundary nudging.



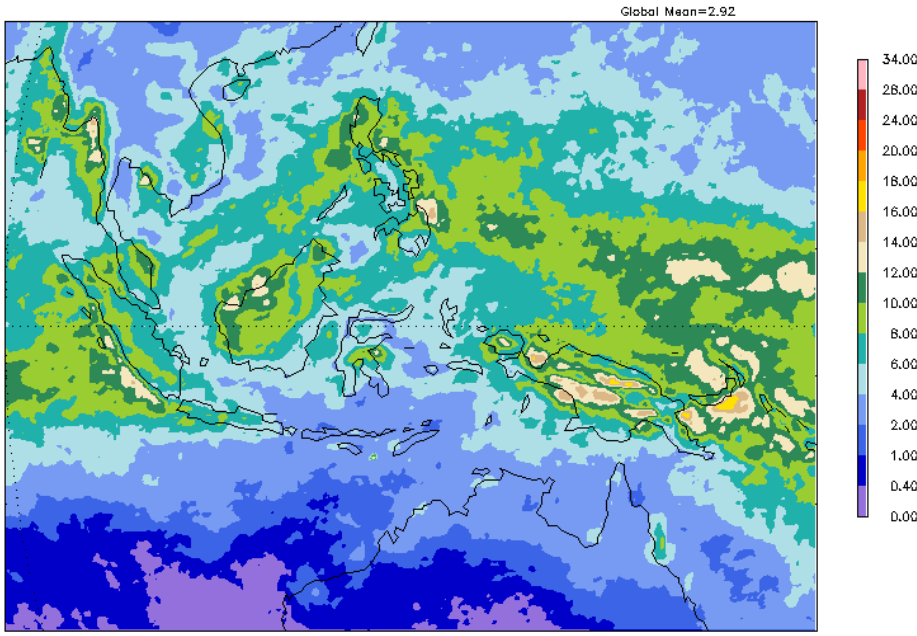
Topographic precipitation biases remain at high-resolution

Annual mean precipitation

CAM5 SE ne120

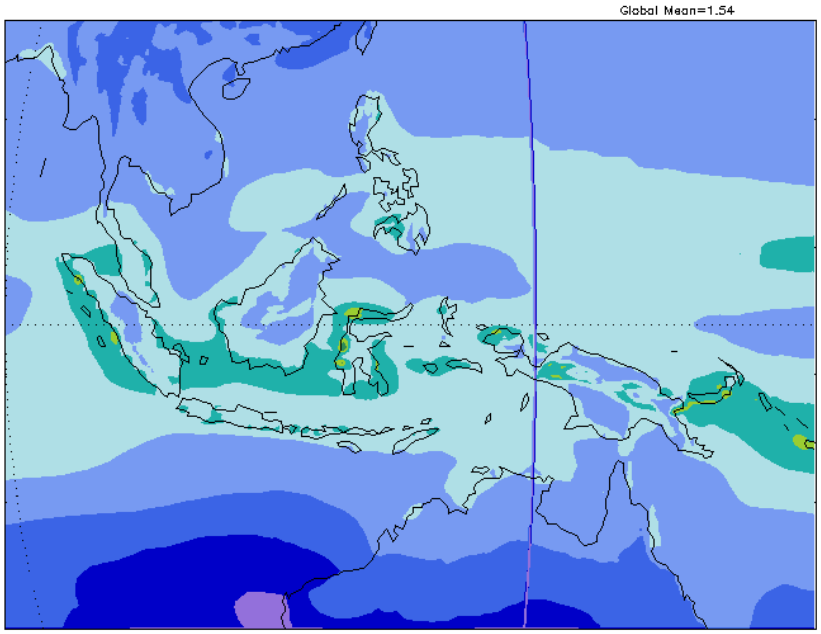


TRMM

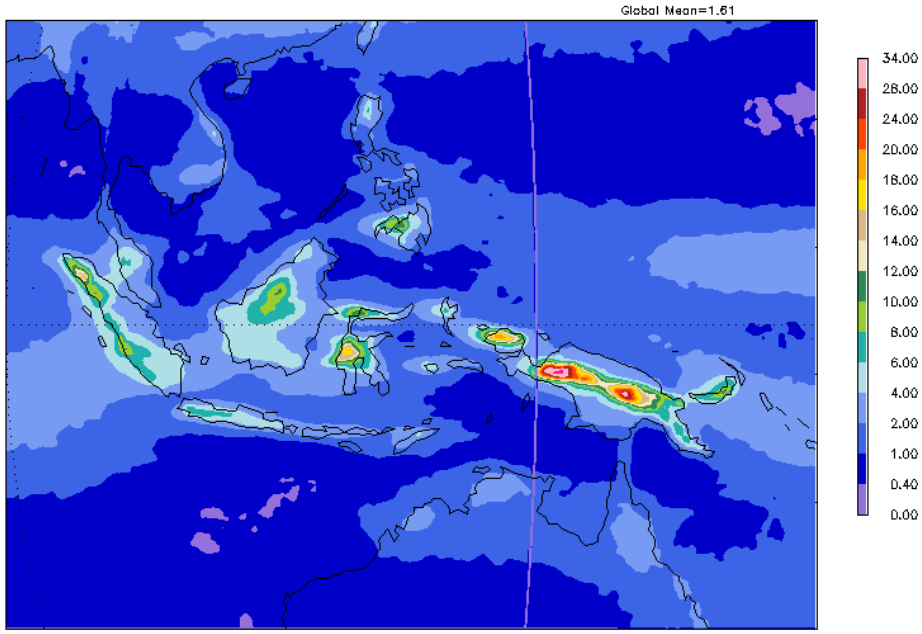


Annual mean precipitation

Convective precipitation

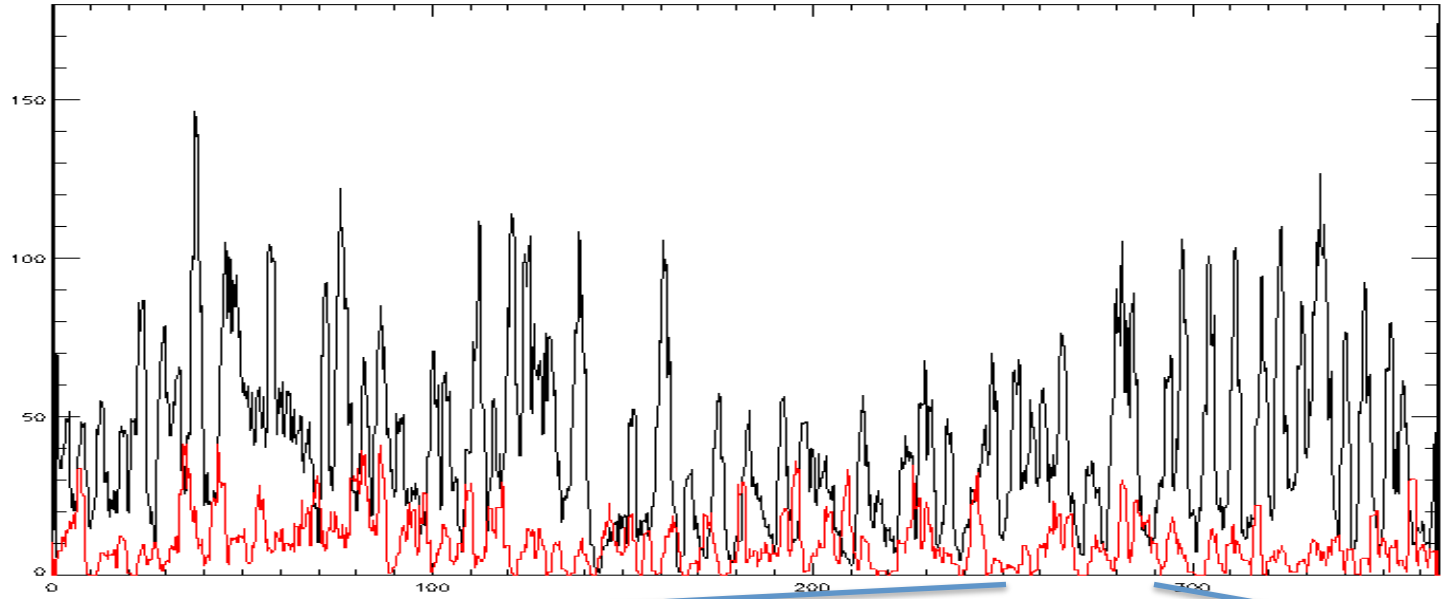


Large-scale precipitation

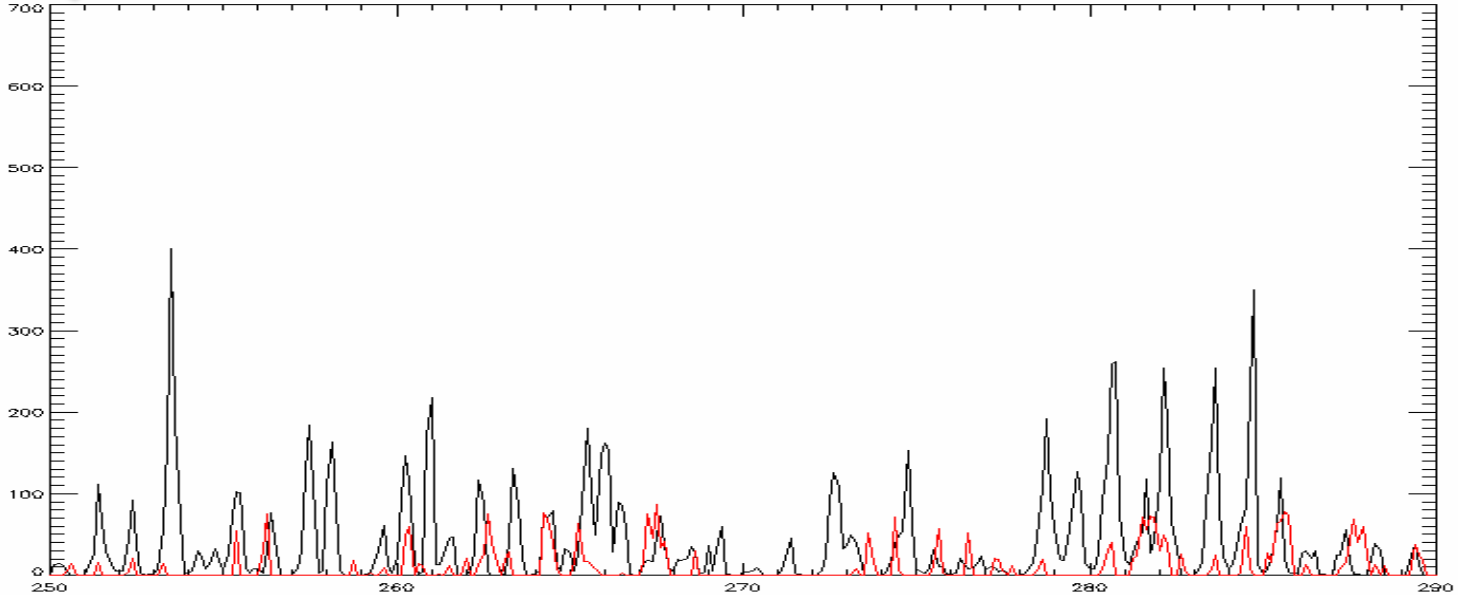


Precipitation time series over Papua/New Guinea highlands

2-day running mean

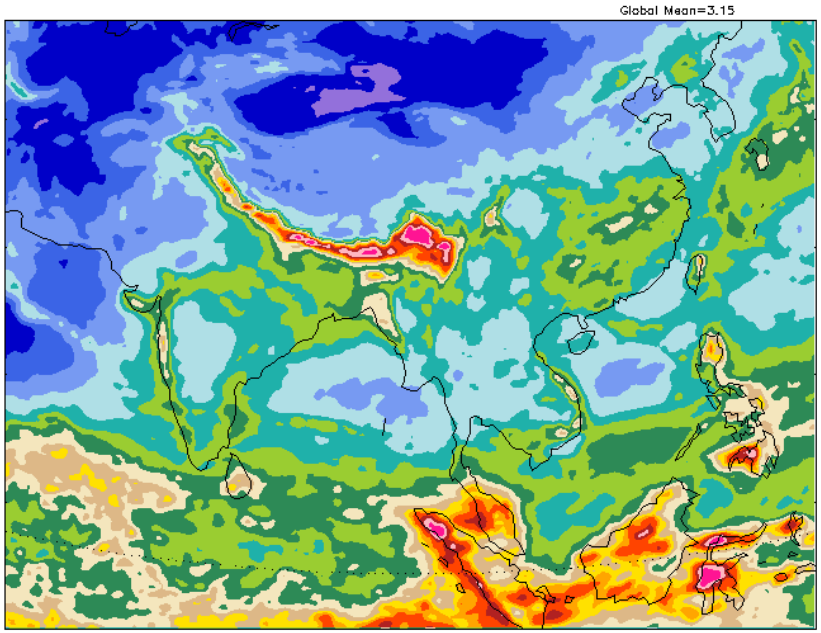


Raw

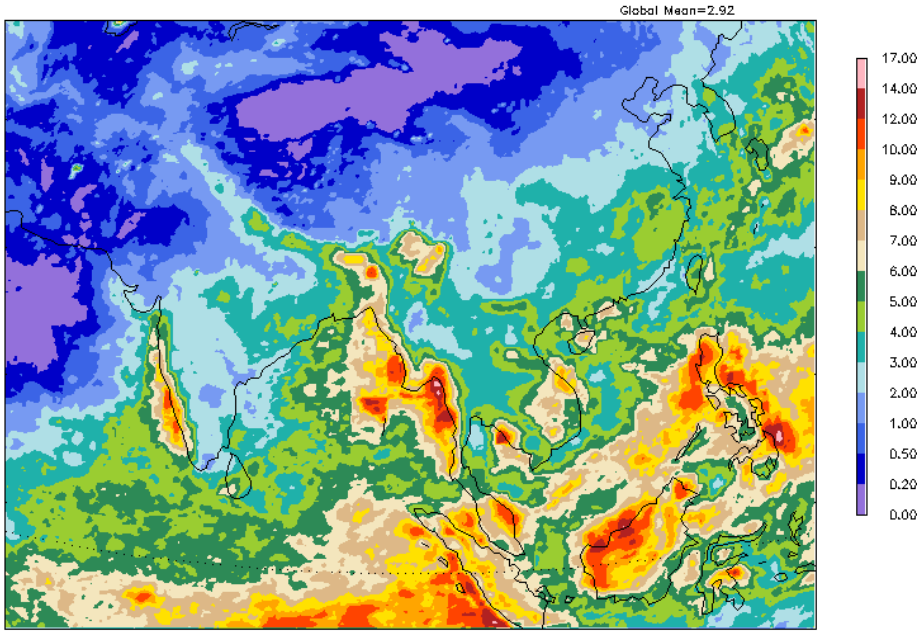


Annual mean precipitation

CAM5 SE ne120

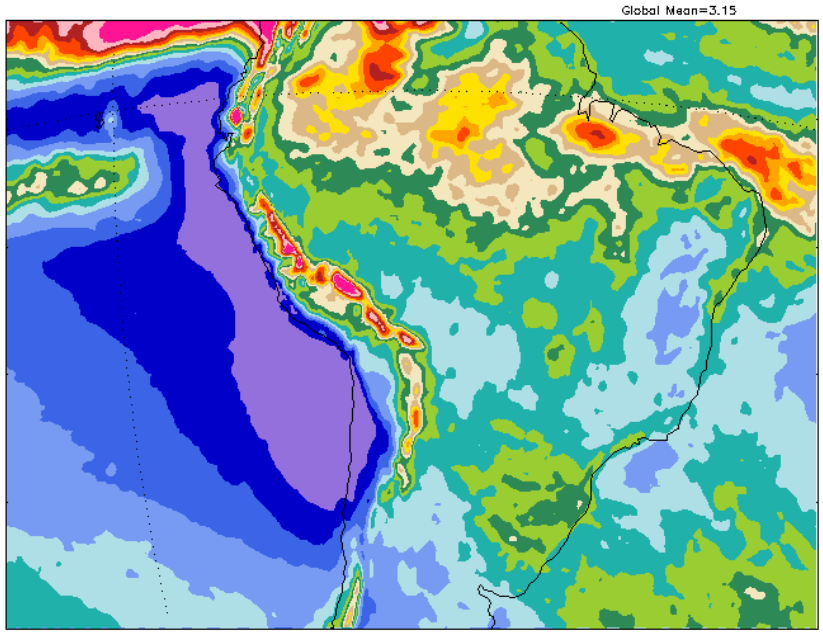


TRMM

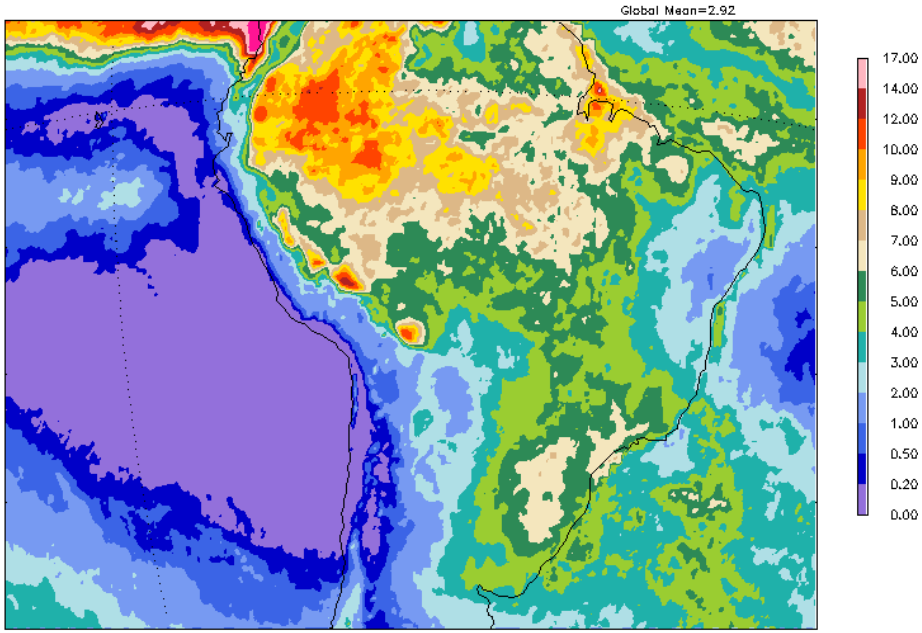


Annual mean precipitation

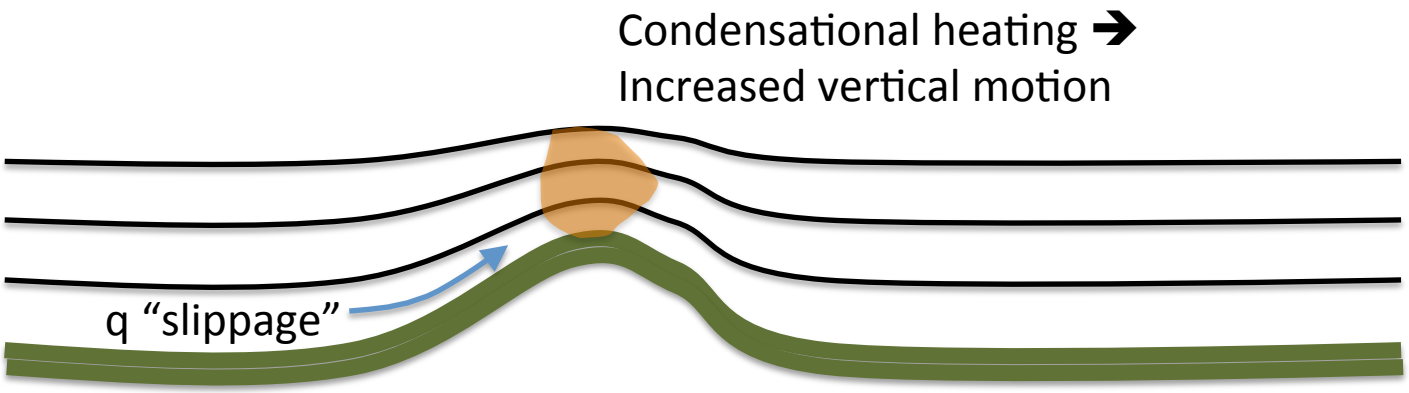
CAM5 SE ne120



TRMM



Causes?

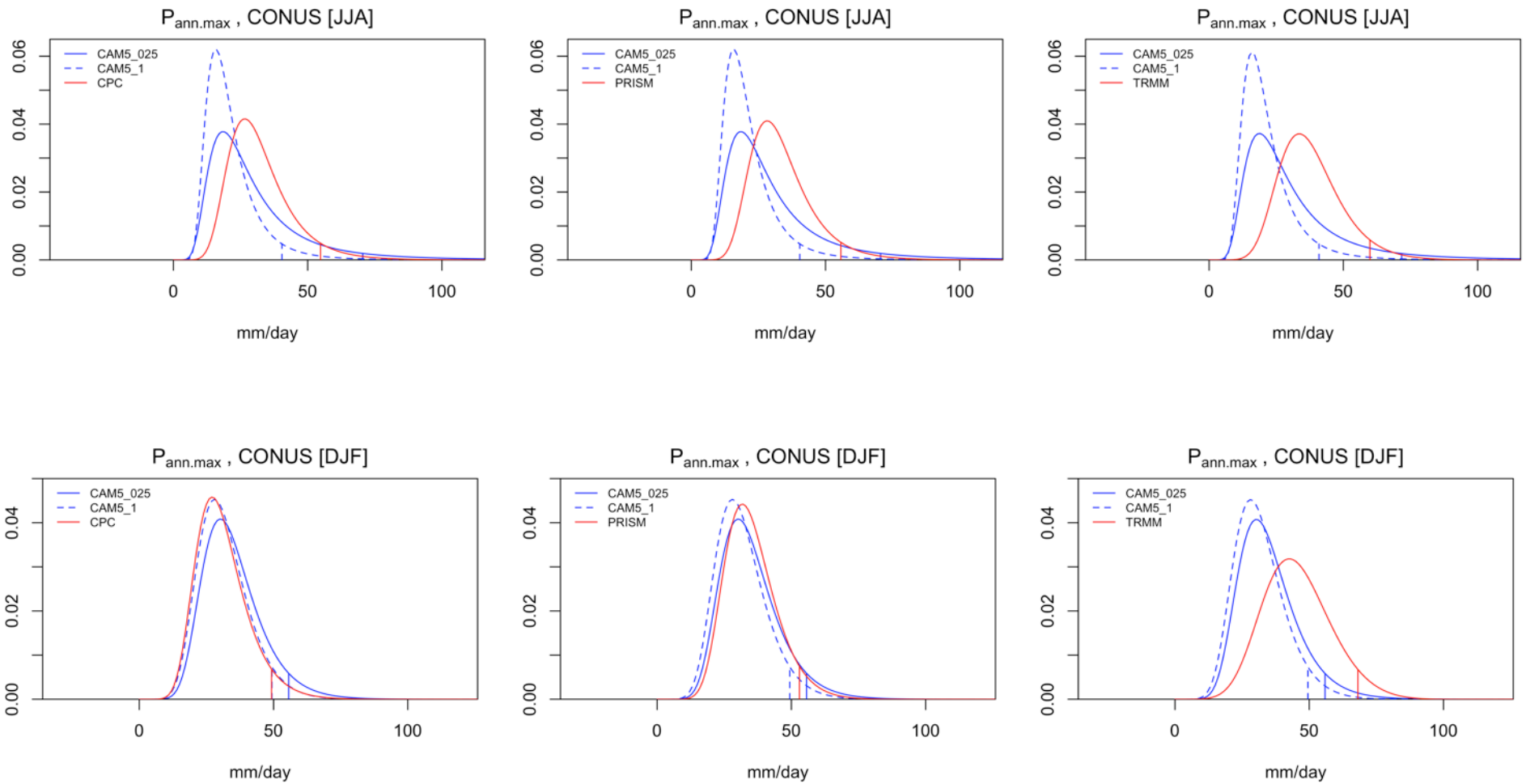


σ-coordinate:

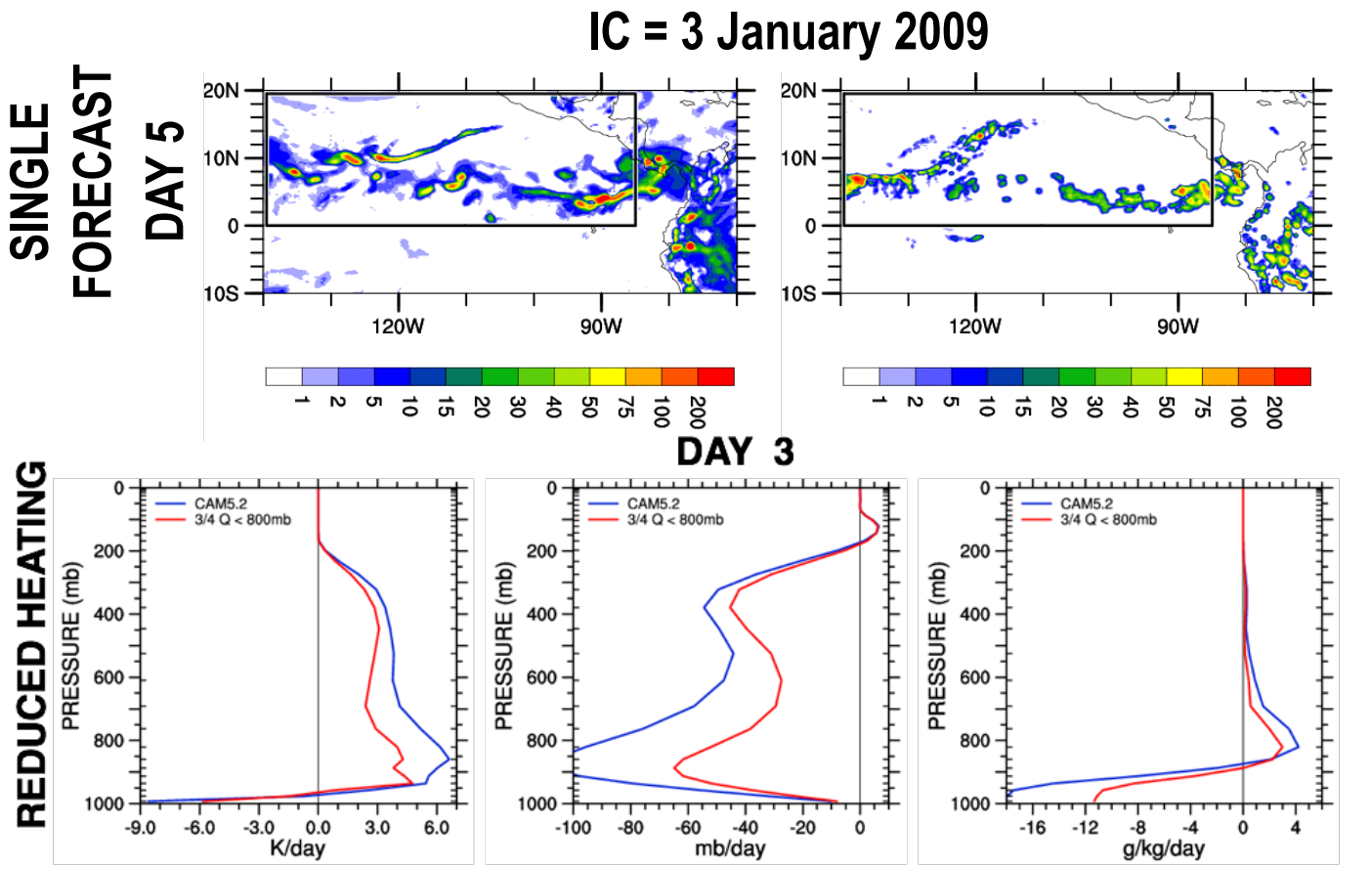
- Implicit/explicit "horizontal" diffusion of q leading to condensational heating at mountain top
- Spurious vertical motion induced by pressure gradient calculation

PDFs of annual maximum daily precipitation rate fitted to GeV dist

Courtesy ***Felipe Tagle***



Diagnosing parameterization errors at high resolution with CAPT



courtesy D. Williamson

Example: high-resolution CAM5 rains too much in E. Pac., traced to feedback between dynamics and physics that is activated because UW shallow convection places heating too low. Artificially raising the heating reduces the bias by removing the feedback.

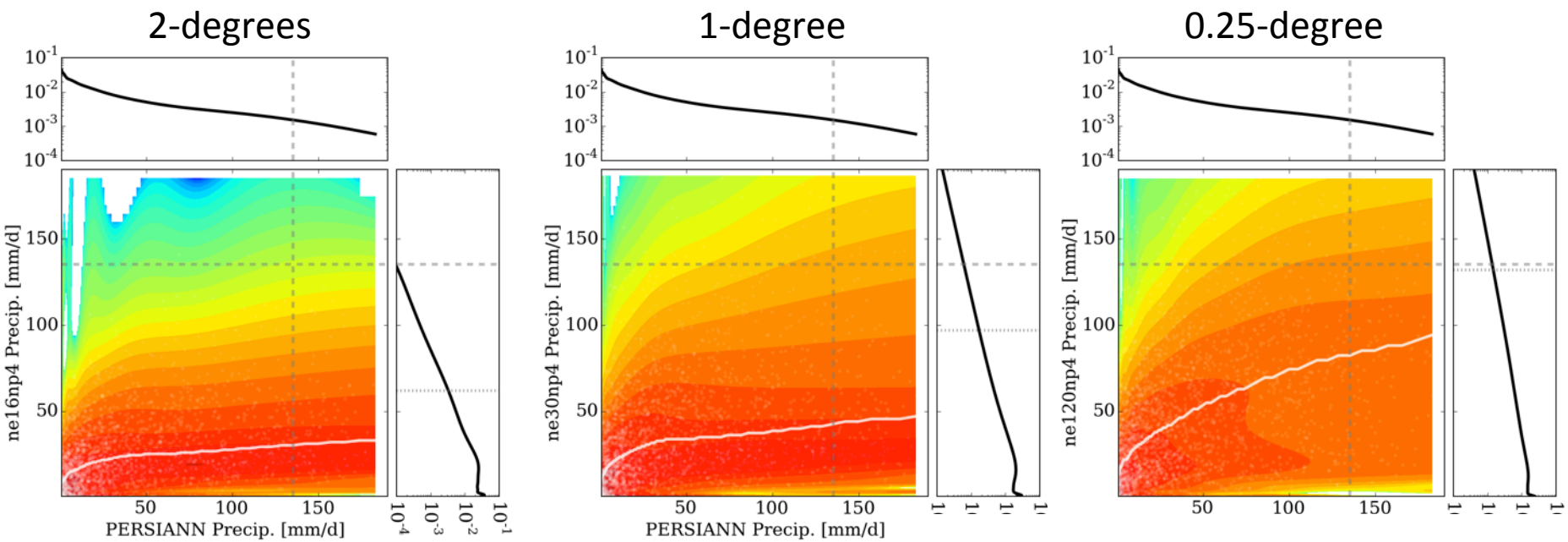
Parameterizations Tested by CAPT

DEEP CONVECTION
- Unified Convection (UNICON)
- Mapes-Neale Convective Organization
- Neale Entrainment Limiter
- G. Zhang (2005) Convective Closure
- Zhang-McFarlane selected settings
- Xie-Zhang Convective Trigger

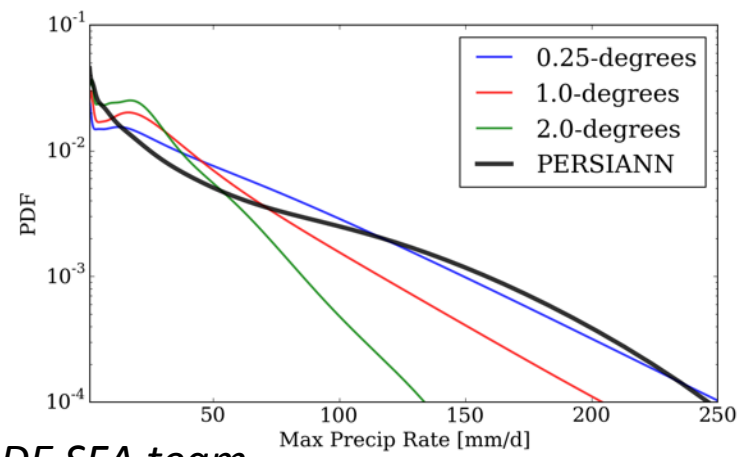
CLOUD MICROPHYSICS
- Morrison and Gettelman Version 2
- G.Zhang MG microphysics in convection
- Gettelman ice/mixed-phase cloud physics
- Liu ice cloud physics
- Phillips ice nucleation
- Bergeron Process / Rain-freezing temperatures
- Cloud Droplet Nucleation Parameterizations (4)
- Autoconversion Parameterizations (5)

OTHER
- Cloud-Layers Unified By Binormals (CLUBB)
- RRTMG Radiation Code
- U. Washington PBL/ShCu

Scrutinizing the fidelity of extremes at high resolution with hindcasts



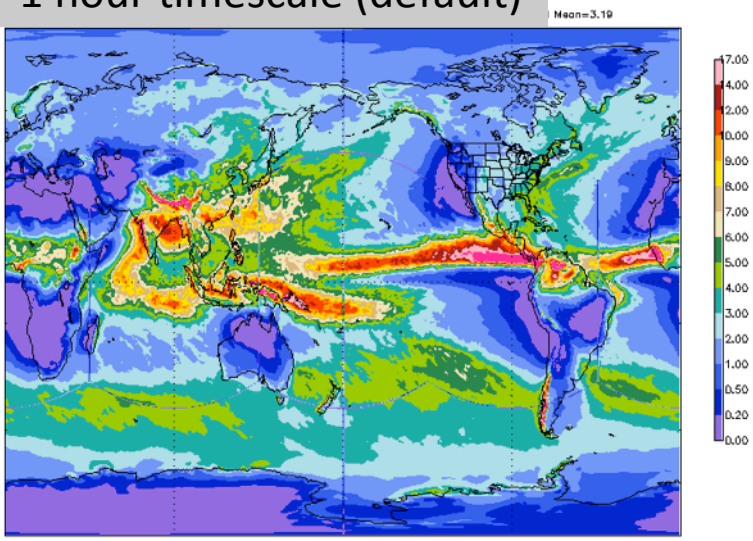
Notice that the precip PDF approaches observations at high resolution (right), but that the model systematically produces too little precip in conditions that produce the most extreme events in reality.



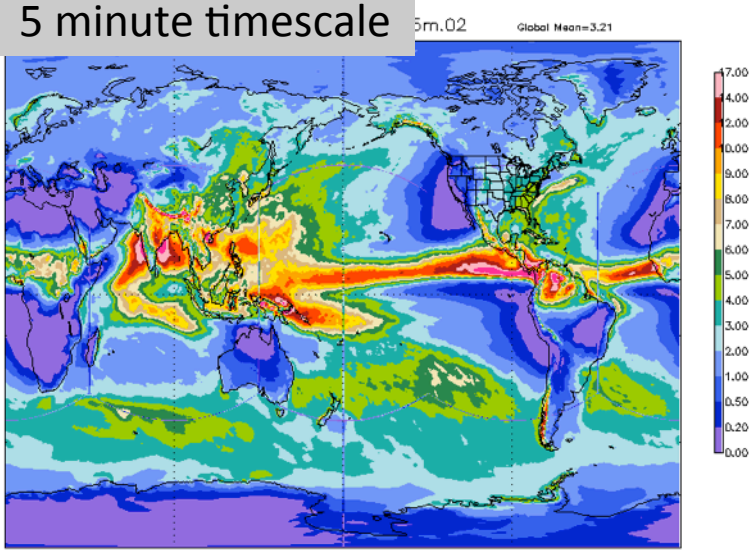
Slide from O'Brien et al. (2015 for JAMES) and the CASCADE SFA team.

Total precipitation

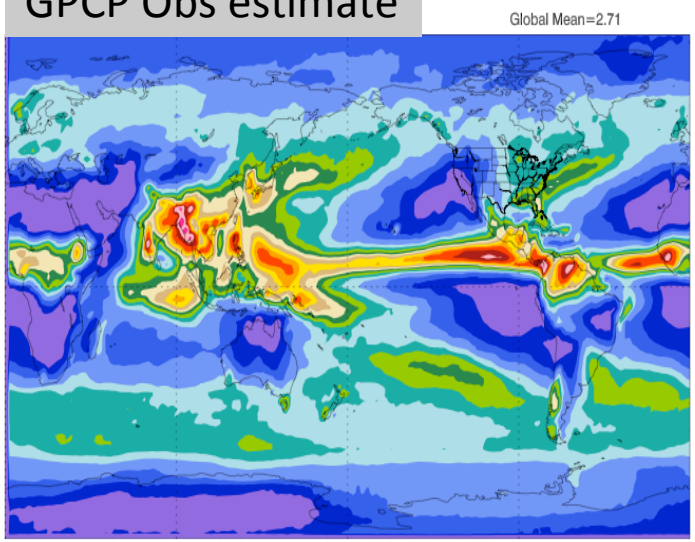
1 hour timescale (default)



5 minute timescale



GPCP Obs estimate

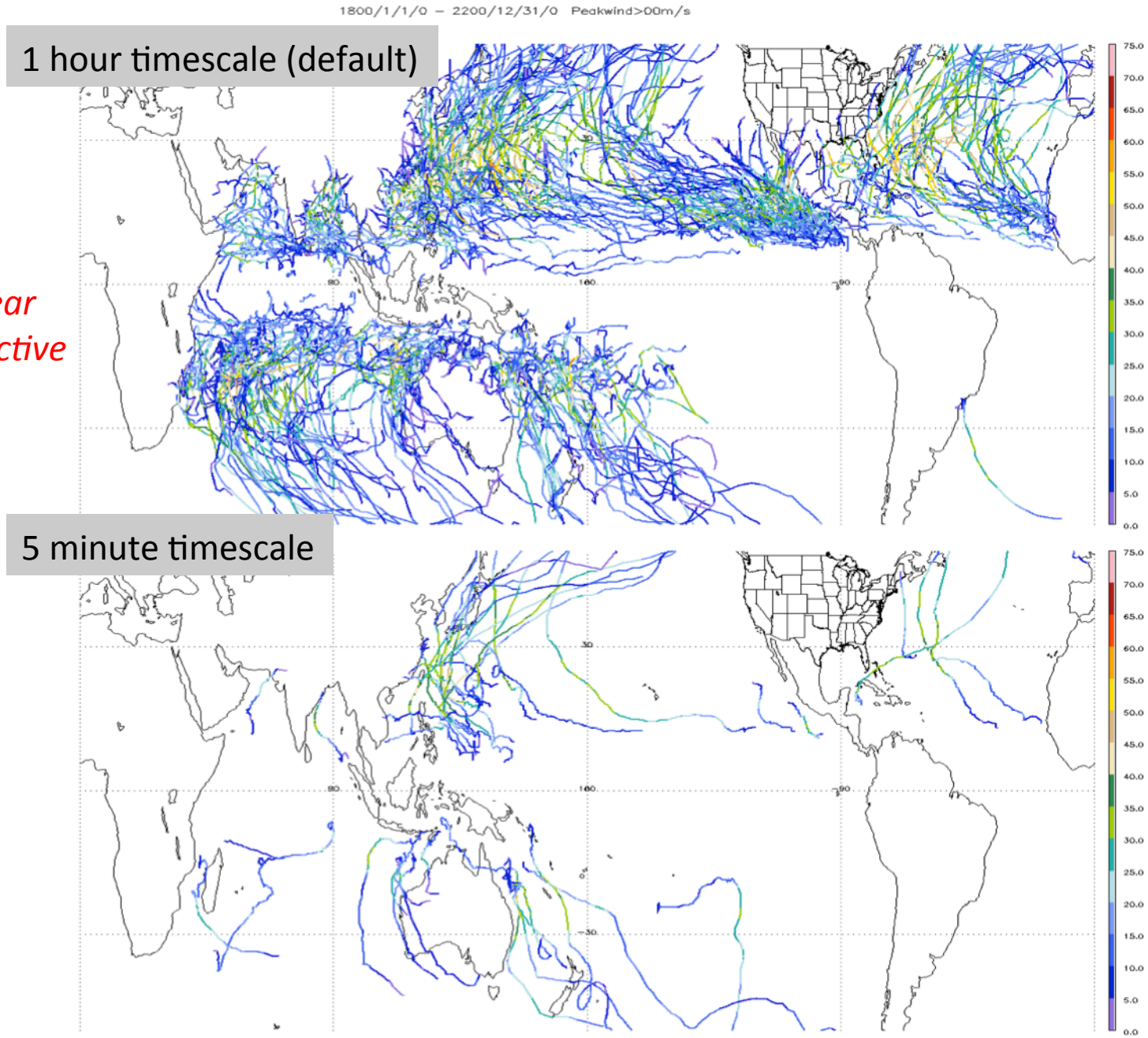


Seasonal mean patterns appear to improve somewhat with shorter convective timescale

Simulated TC tracks 2000-2005

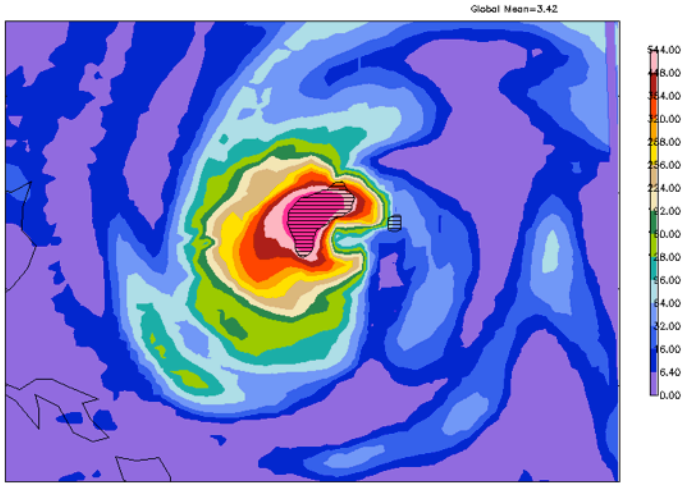
But …

Hurricanes disappear with shorter convective timescale

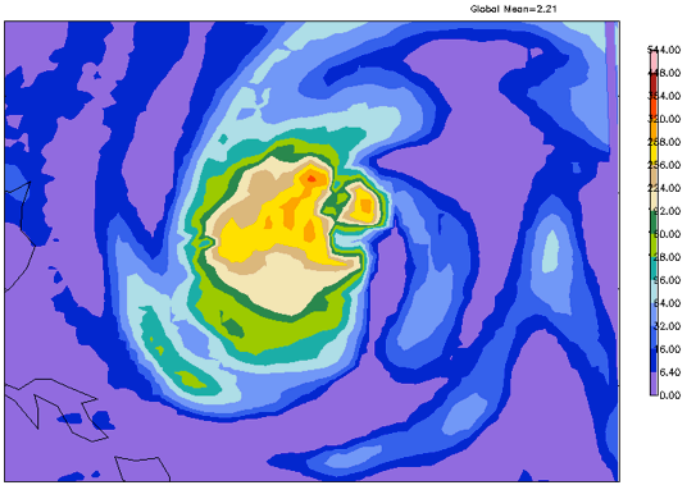


Even with 5-min time scale, TC cores are dominated by large-scale

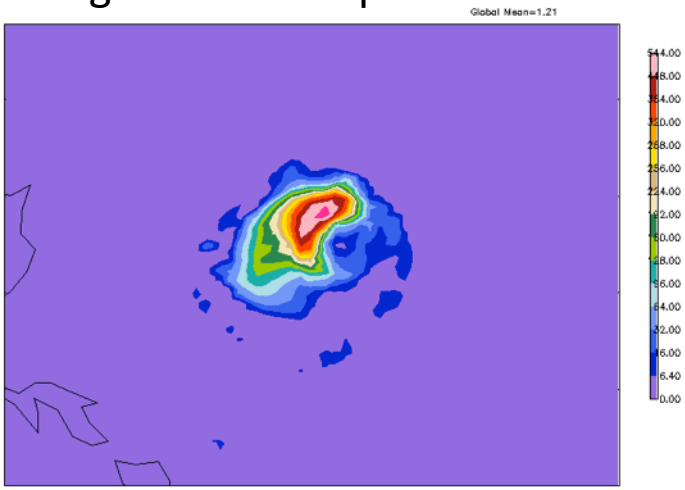
Total Precipitation



Convective Precipitation

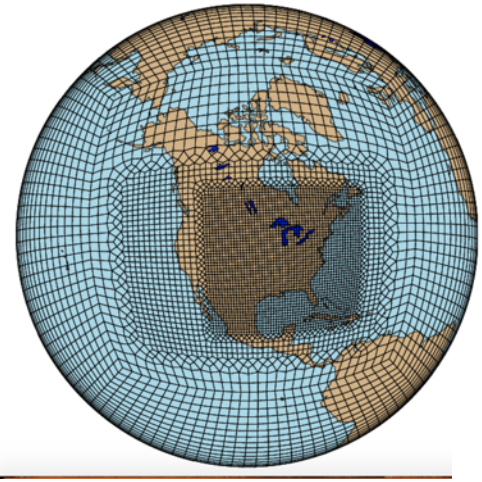
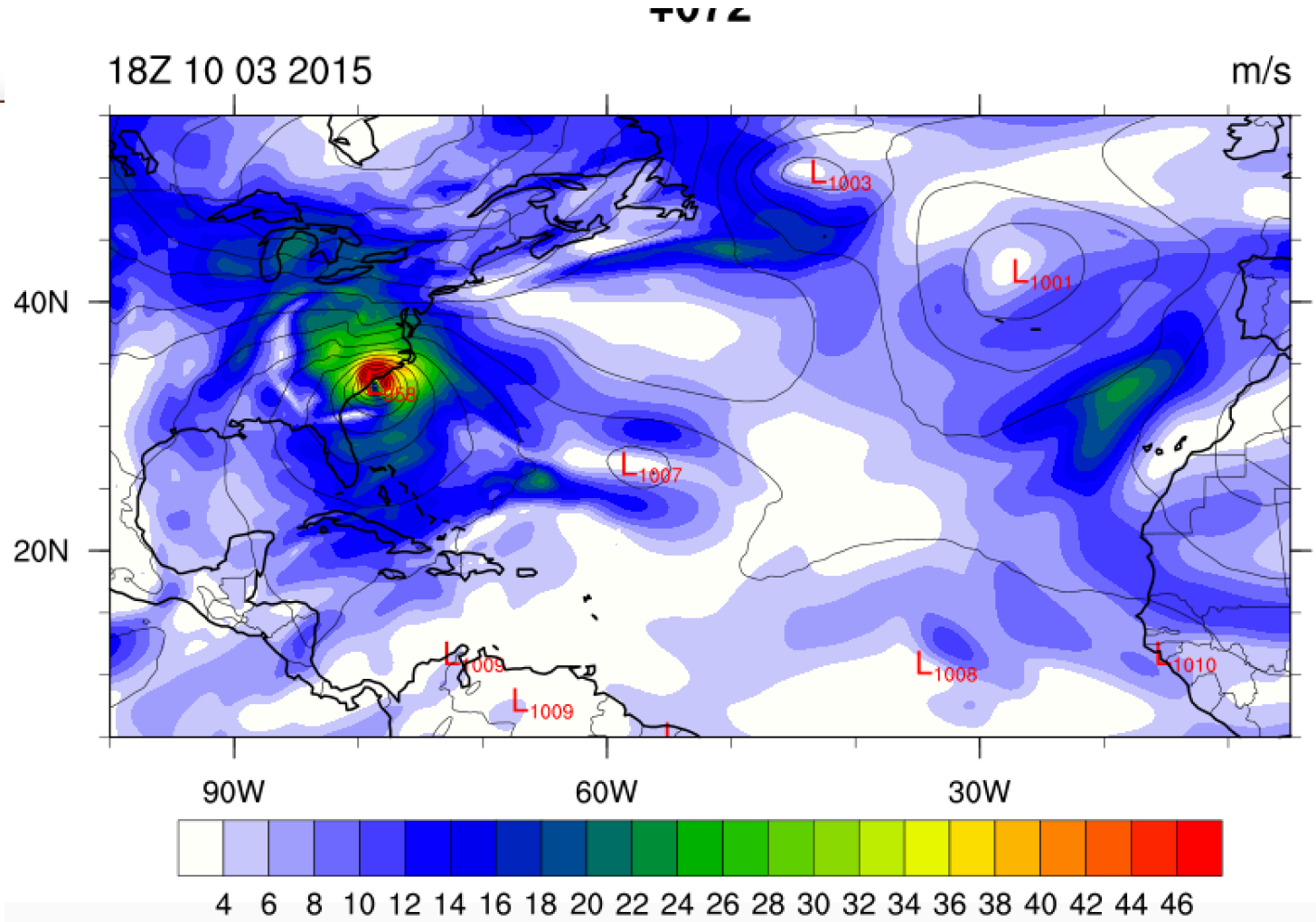


Large-Scale Precipitation



Summary and Future Work

- Parameterized convection plays a surprisingly large role in 6km simulations
  - Large-scale precipitation has approximately correct diurnal cycle, but parameterized convection is always nearly 180° out of phase
  - Shutting off ZM improves diurnal cycle
- Boundary nudging substantially improves correlations with TRMM – *planetary/synoptic scale matters*
  - Correlations similar in runs with and without ZM
- Substantial biases in warm season orographic precipitation remain at high resolution



Joaquin Forecast using RR CAM-SE
(Colin Zarzycki ASP PostDoc)