Next-Generation GFDL Climate Model CM4

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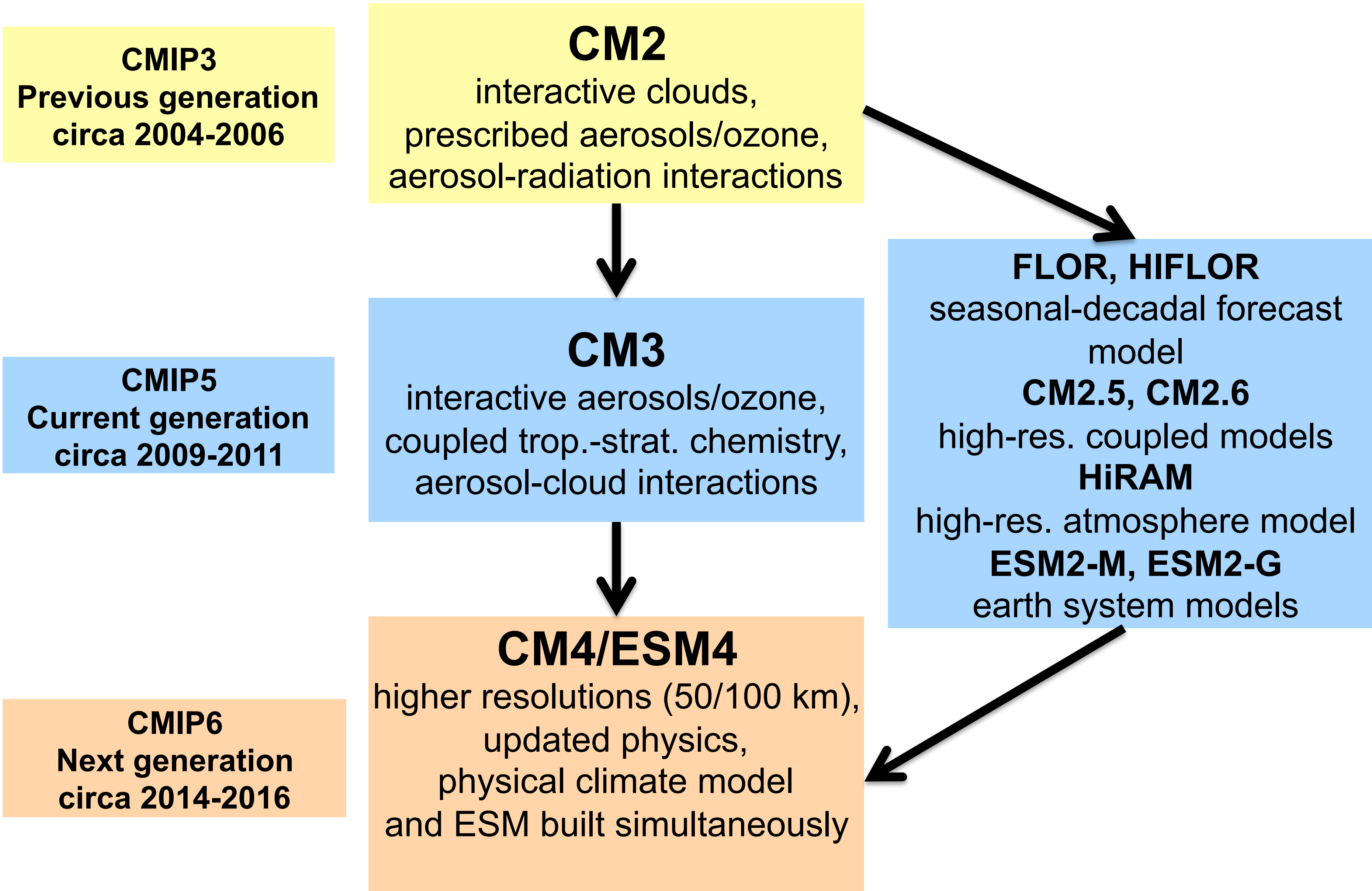
Family tree of recent GFDL models

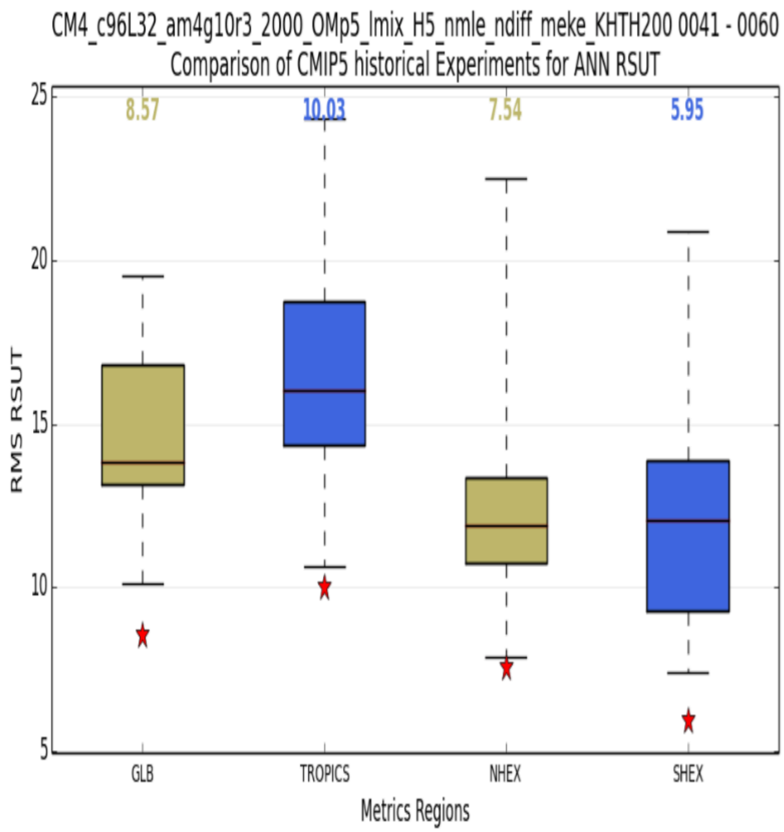


A status report on CM4

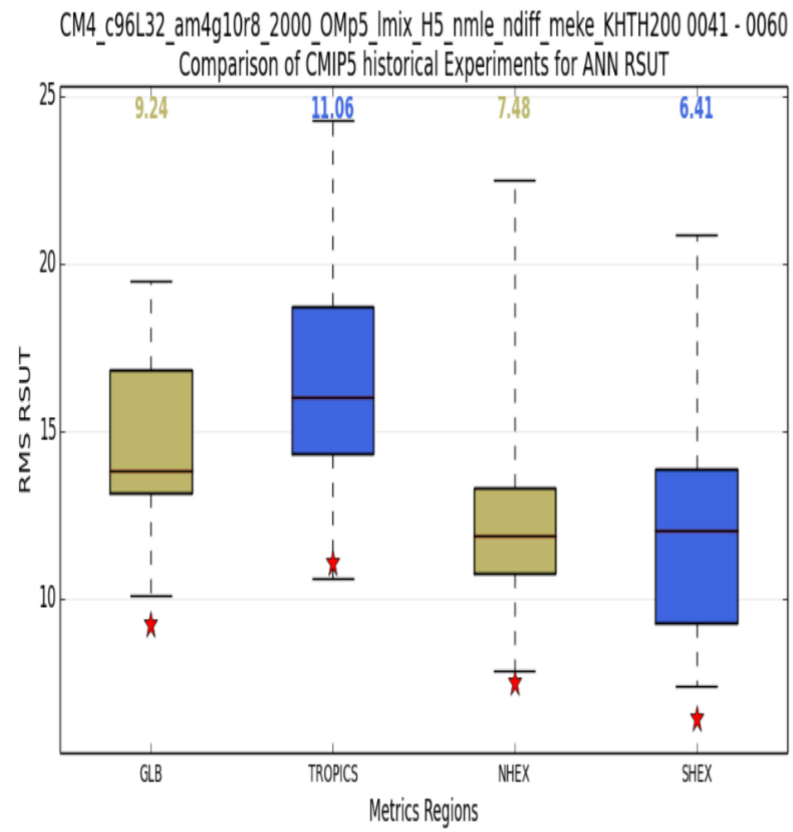
- **FV3 (cubed-sphere, finite-volume) dynamical core** (S.J. Lin)
- **50 or 100 km horizontal resolution, 32 or 48 vertical layers**
- **A new double-plume convection (DPC) scheme** (M. Zhao)
  - Motivated by recent literature and MJO simulation
  - Based on the single bulk plume model used in HiRAM (Bretherton et al., 2004)
  - Additional (deep) plume with entrainment dependent on ambient RH
  - Use quasi-equilibrium cloud work function for closure
  - Cold-pool driven convective gustiness via precipitation re-evaporation
- **"Light" aerosols/chemistry or "full" aerosols/chemistry**
- **MOM6 being built** (A. Adcroft, R. Hallberg)
  - ¼ degree as the primary target
  - Mesoscale eddy parameterizations
  - New mixed layer scheme

Mean climate simulation

RMS error for annual mean reflected SW radiation at TOA (boxplot show statistics from CMIP5 historical experiments)



CM4g10r3 (0041-0060)

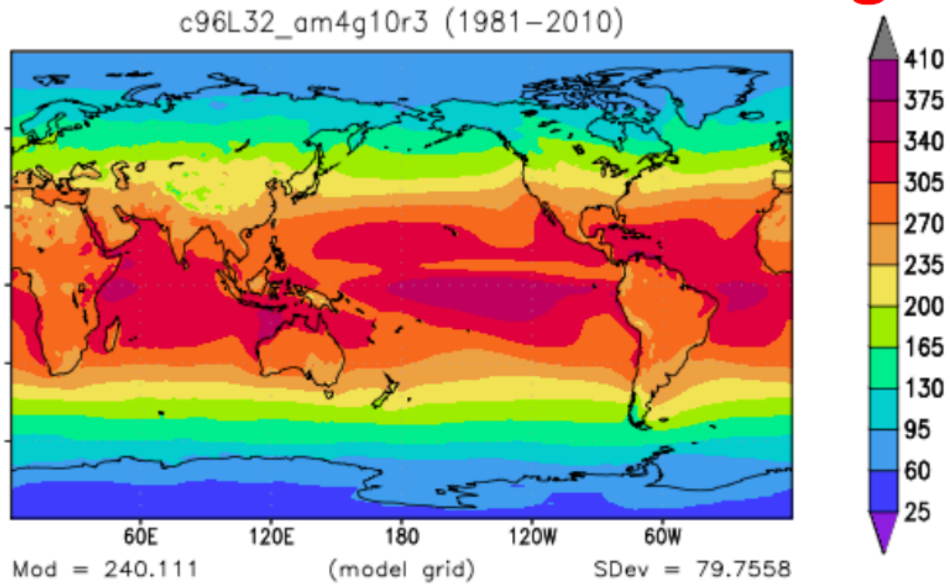


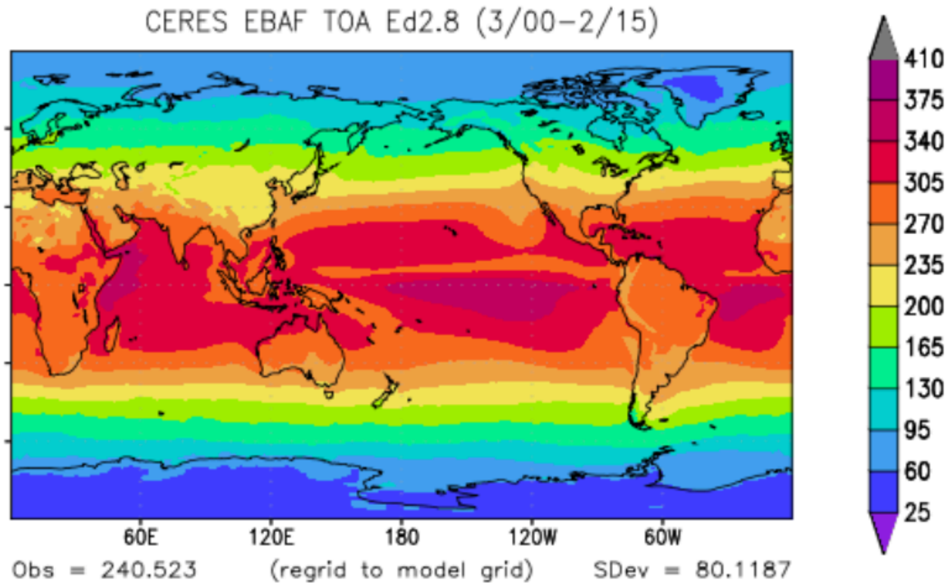
CM4g10r8 (0041-0060)

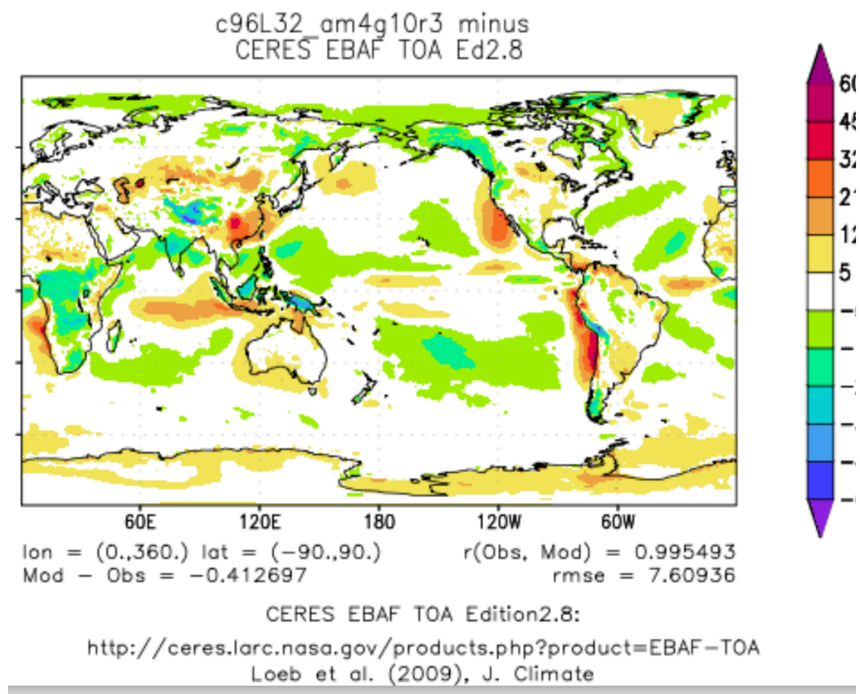
PCMDI metrics from DET

ANN SWABS (W/m²)

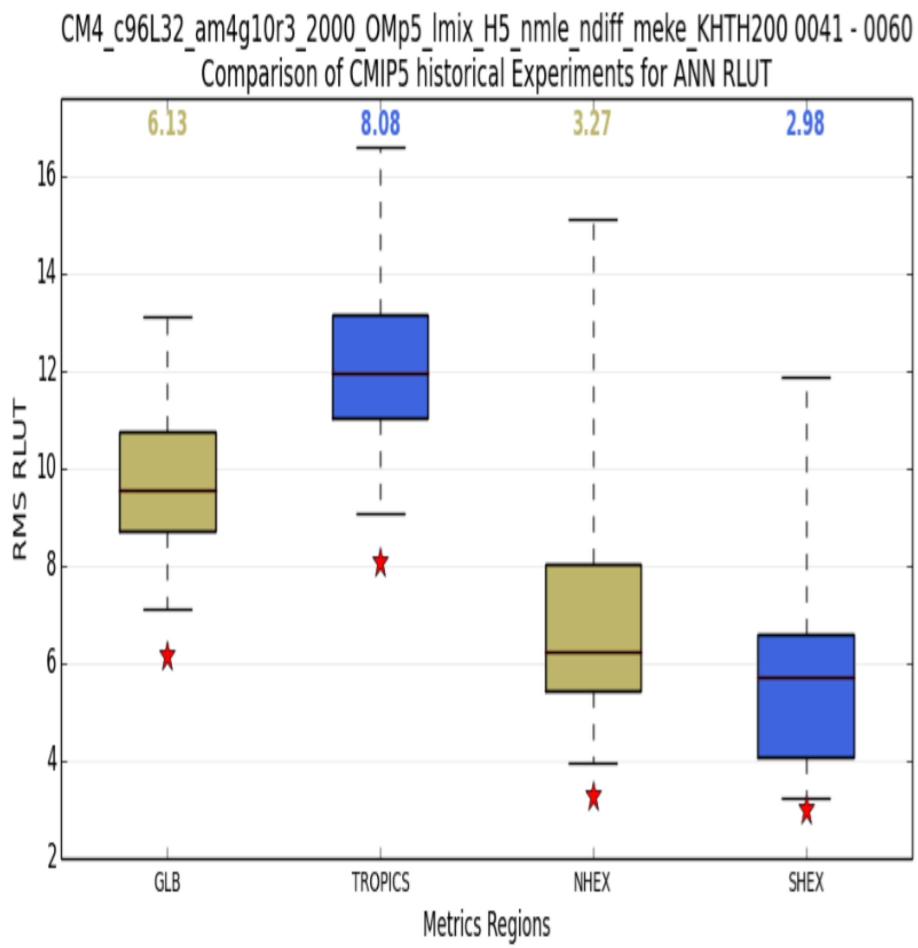
AM4g10r3



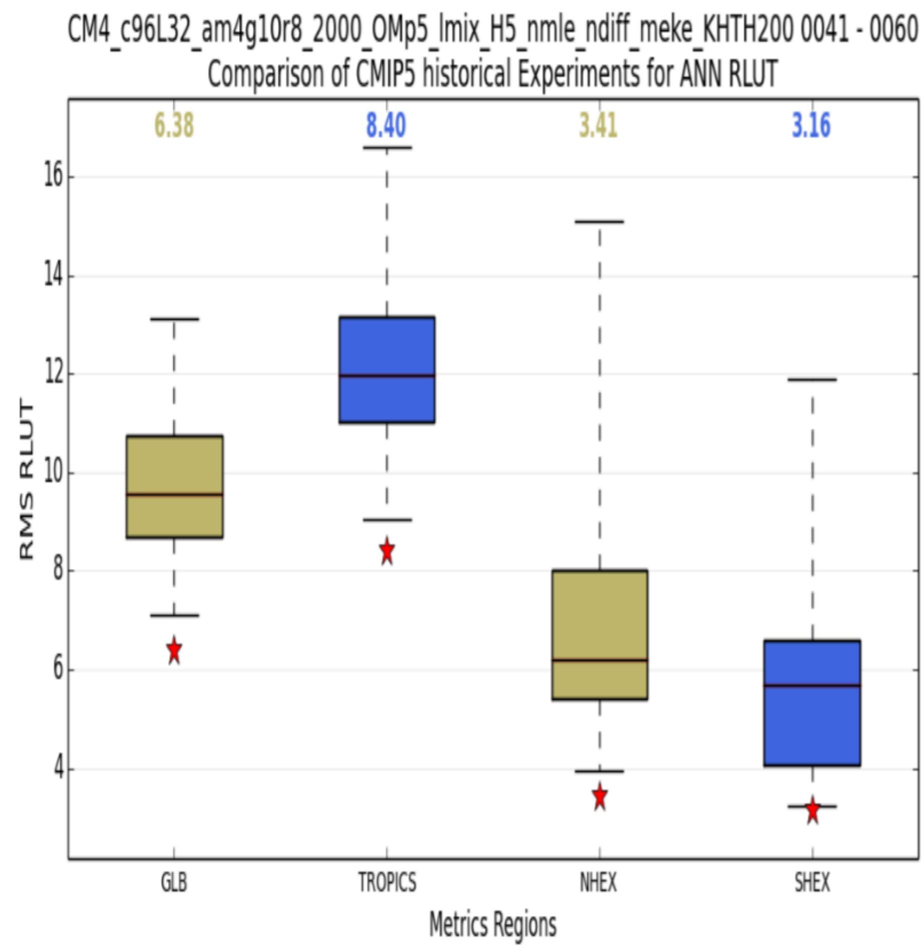




RMS error for annual mean OLR
(boxplot show statistics from CMIP5 historical experiments)



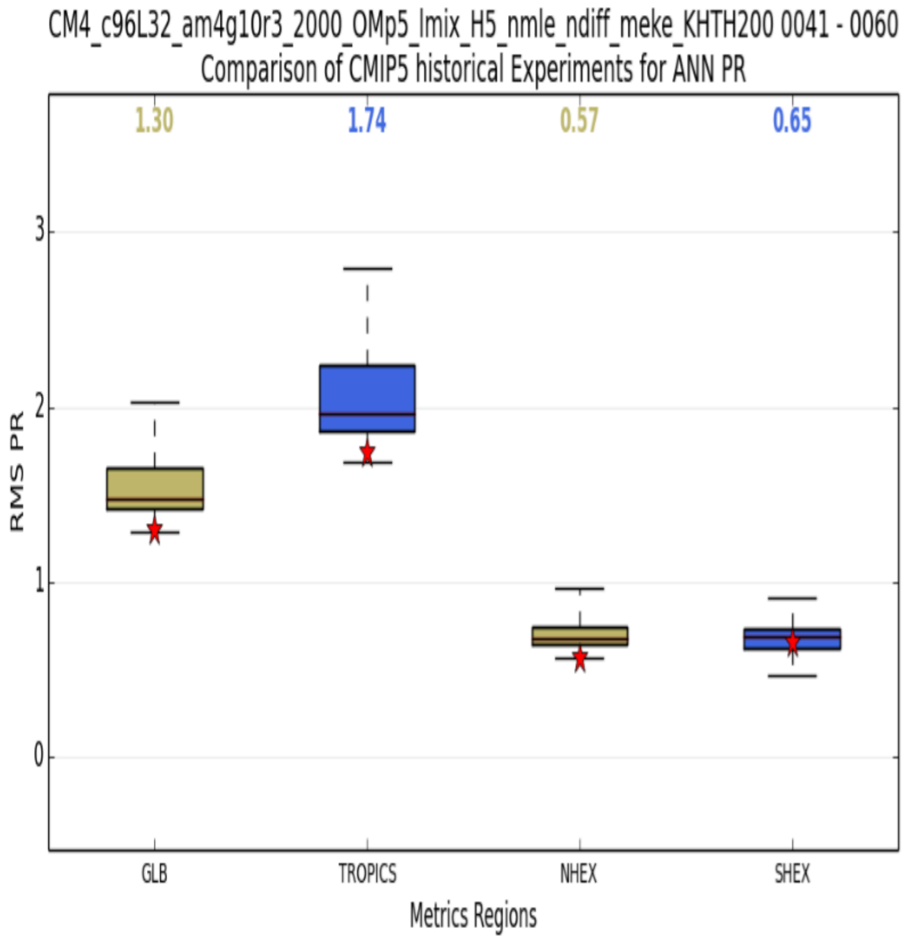
CM4g10r3 (0041-0060)

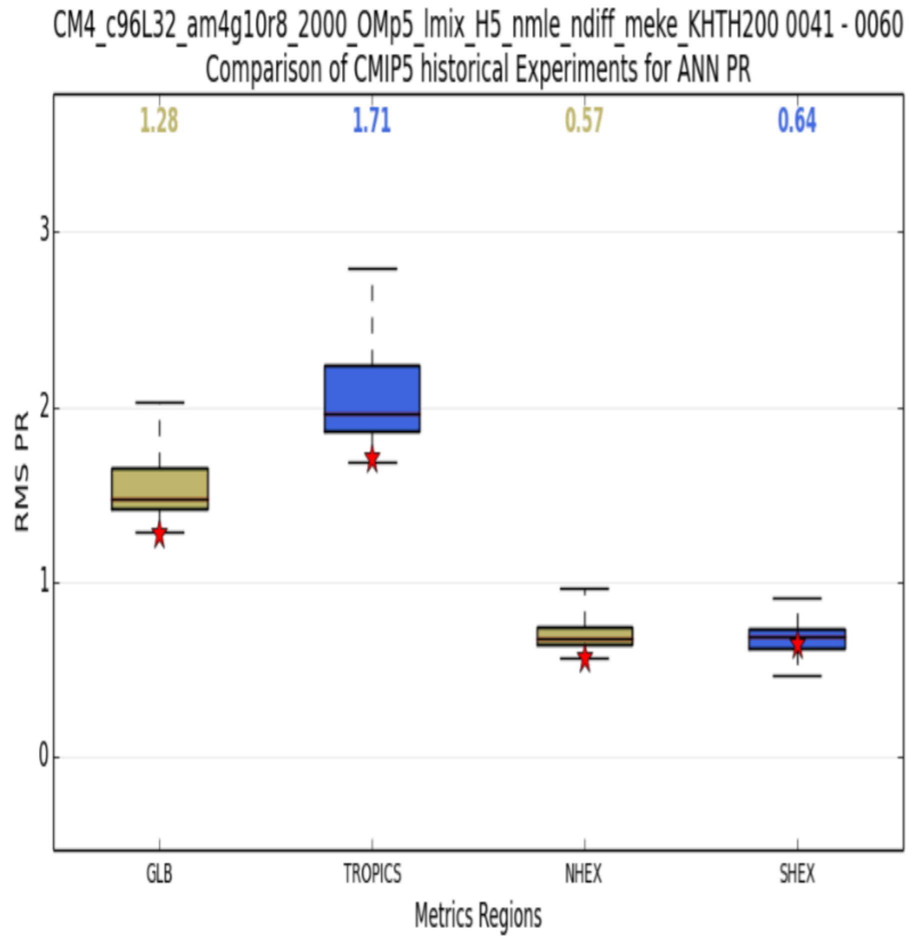


CM4g10r8 (0041-0060)

PCMDI metrics from DET

RMS error for annual mean precipitation
(boxplot show statistics from CMIP5 historical experiments)



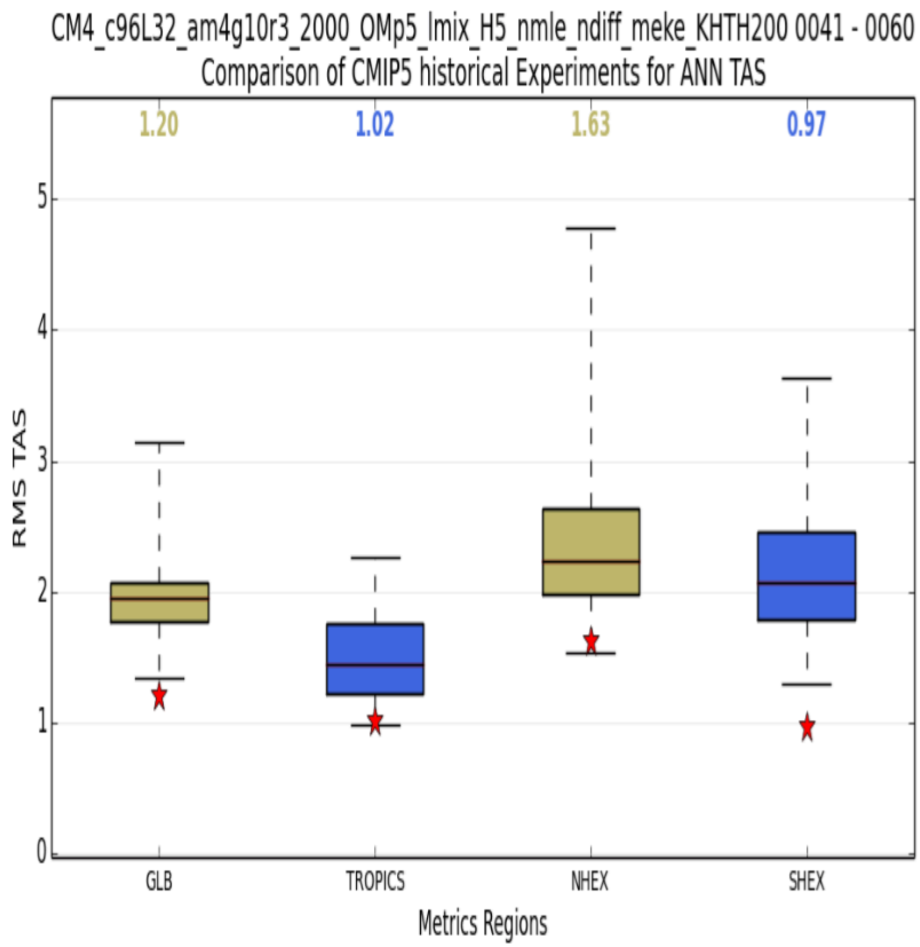


CM4g10r3 (0041-0060)

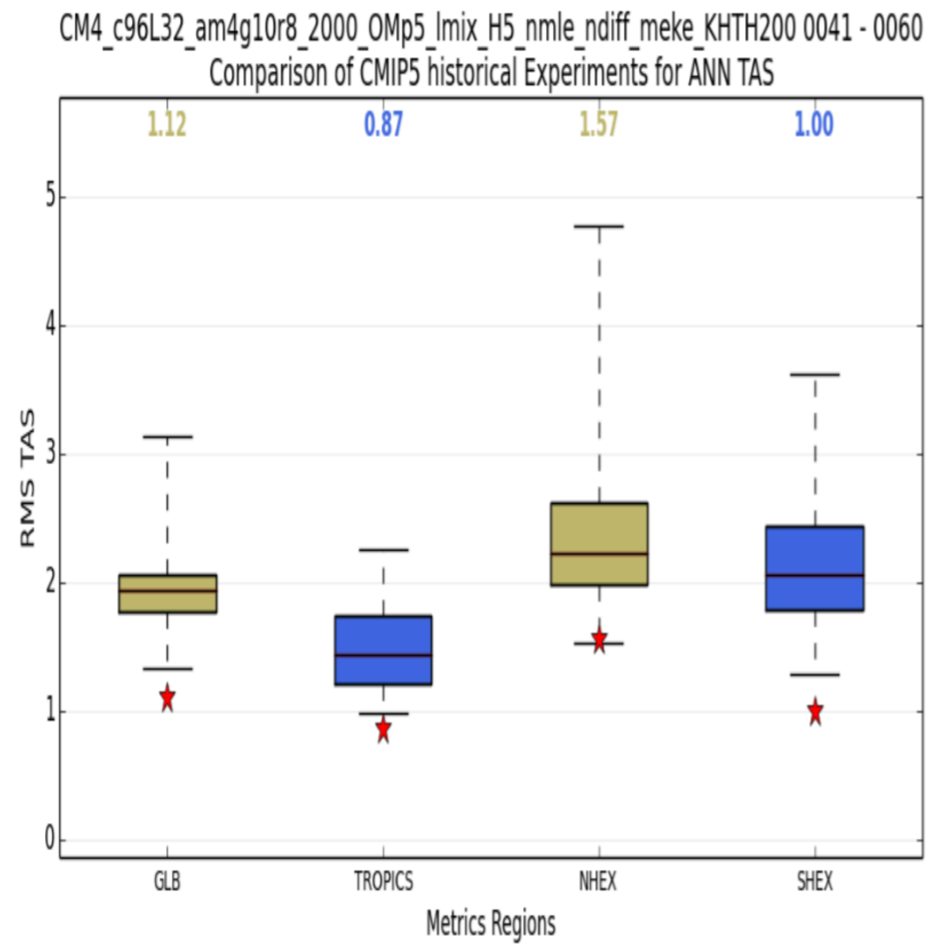
CM4g10r8 (0041-0060)

PCMDI metrics from DET

RMS error for annual mean surface air temperature (boxplot show statistics from CMIP5 historical experiments)



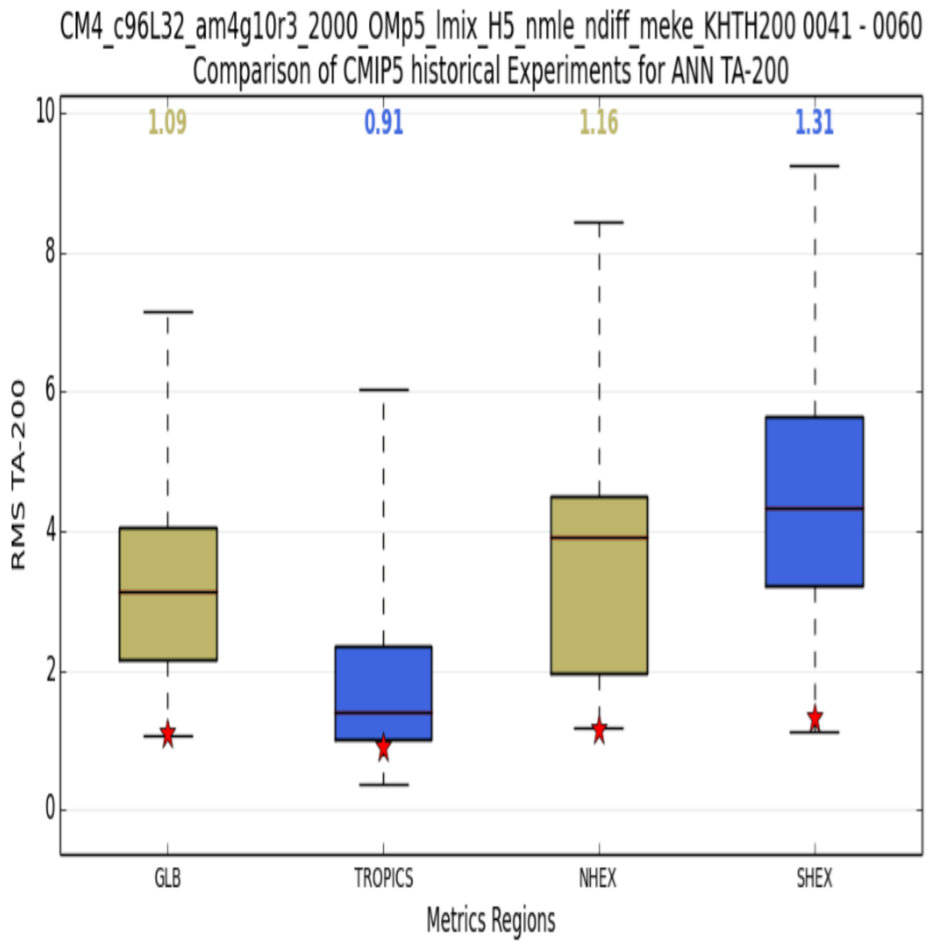
CM4g10r3 (0041-0060)

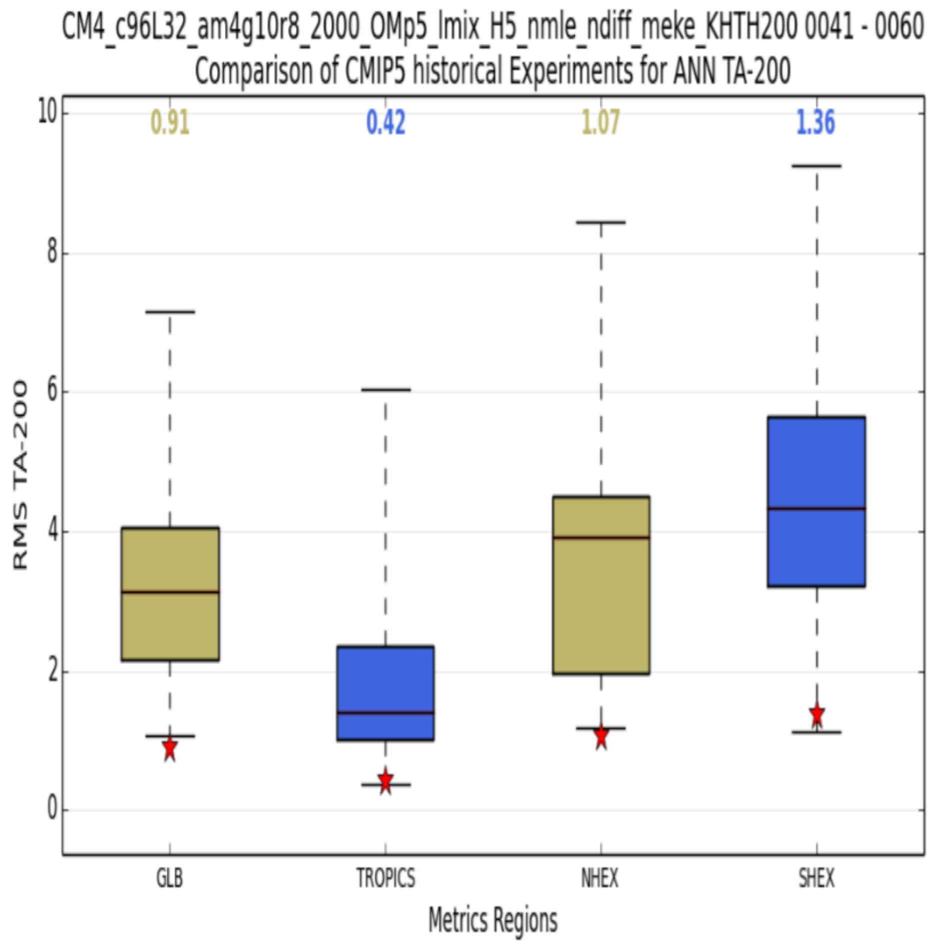


CM4g10r8 (0041-0060)

PCMDI metrics from DET

RMS error for annual mean 200hPa temperature (boxplot show statistics from CMIP5 historical experiments)



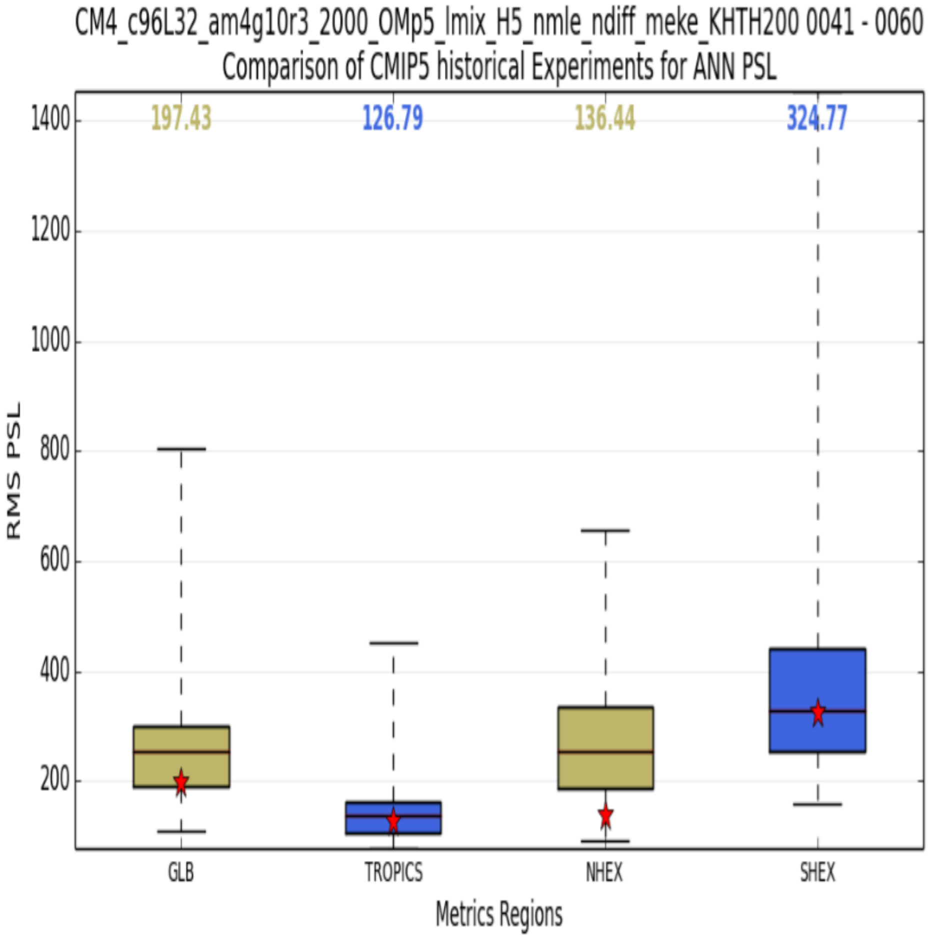


CM4g10r3 (0041-0060)

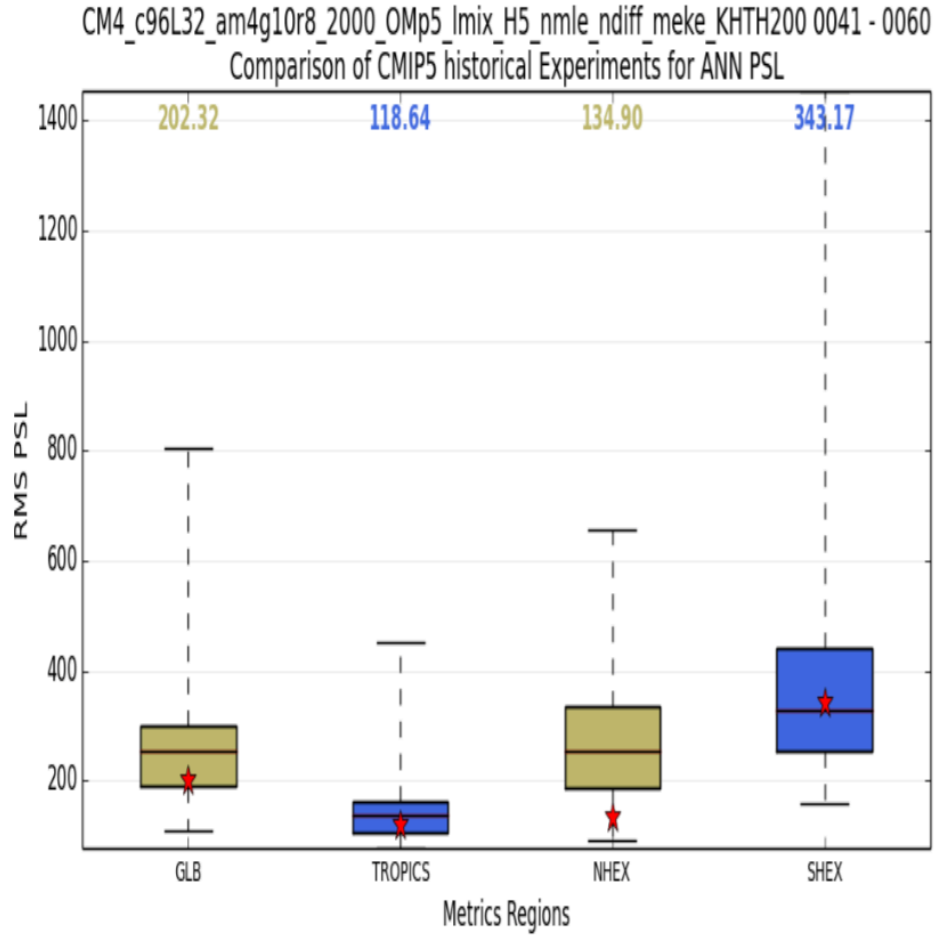
CM4g10r8 (0041-0060)

PCMDI metrics from DET

RMS error for annual mean sea level pressure
(boxplot show statistics from CMIP5 historical experiments)



CM4g10r3 (0041-0060)



CM4g10r8 (0041-0060)

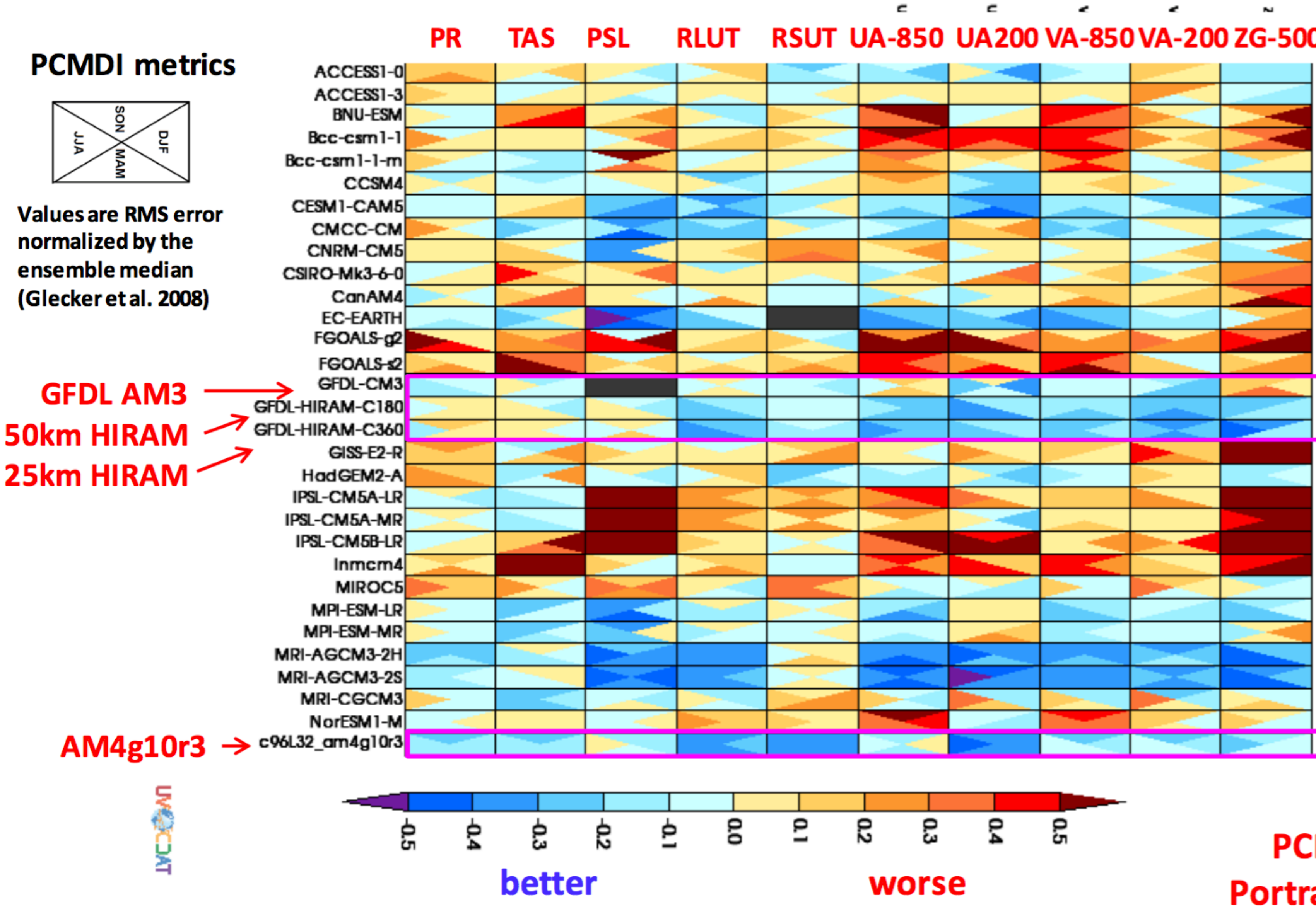
PCMDI metrics from DET

Comparison of AM4g10r3 with CMIP5 models in AMIP simulations

PR: Precipitation; **TAS**: Surface air temperature; **PSL**: Sea-level pressure; **RLUT**: Outgoing LW radiation; **RSUT**: reflected SW radiation at TOA; **UA-850 & UA200**: 850 and 200hPa zonal wind; **VA-850 & VA-200**: 850 and 200hPa meridional wind; **ZG-500**: 500hPa geopotential height.

PCMDI metrics

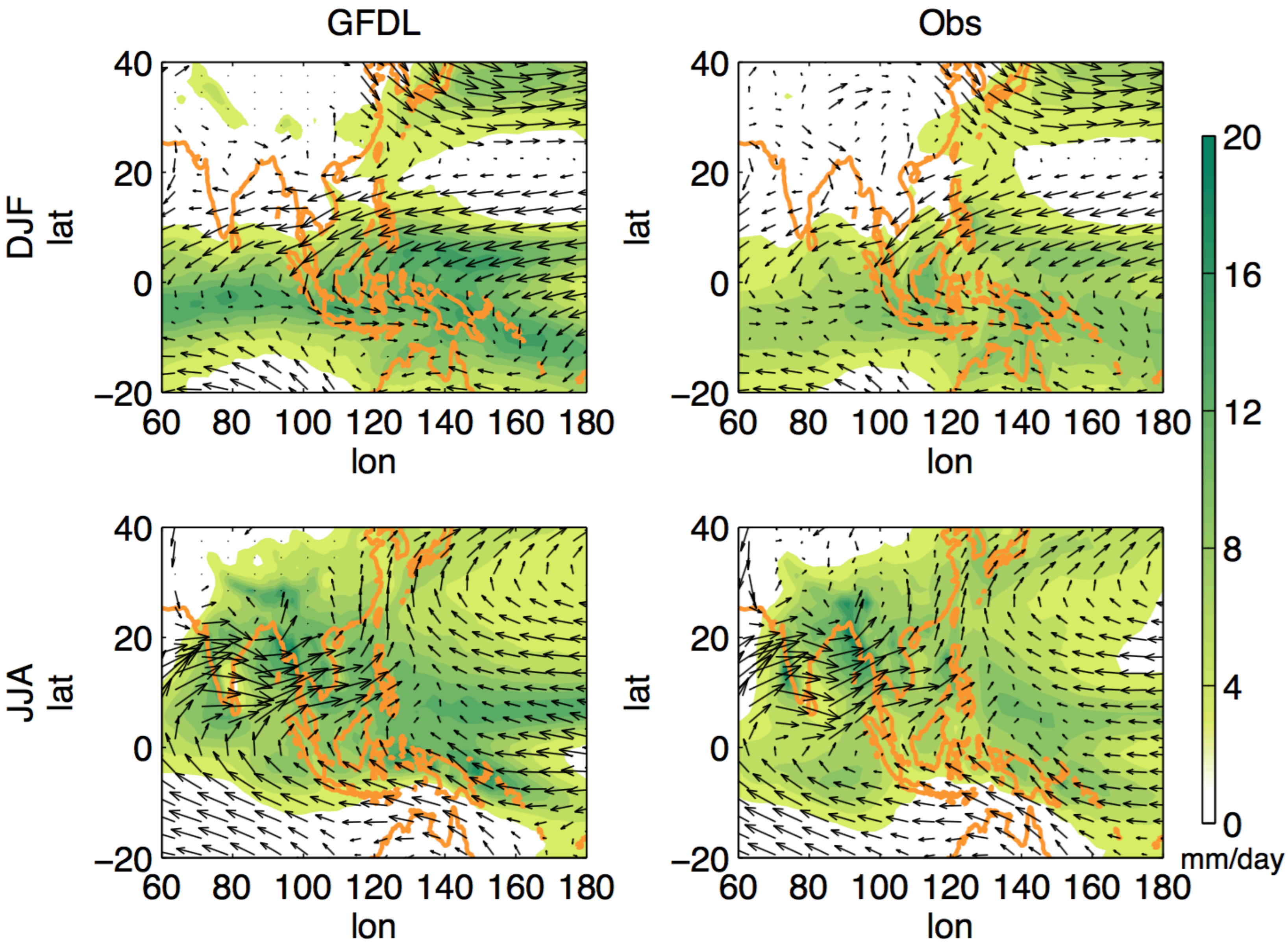
Values are RMS error normalized by the ensemble median (Glecker et al. 2008)



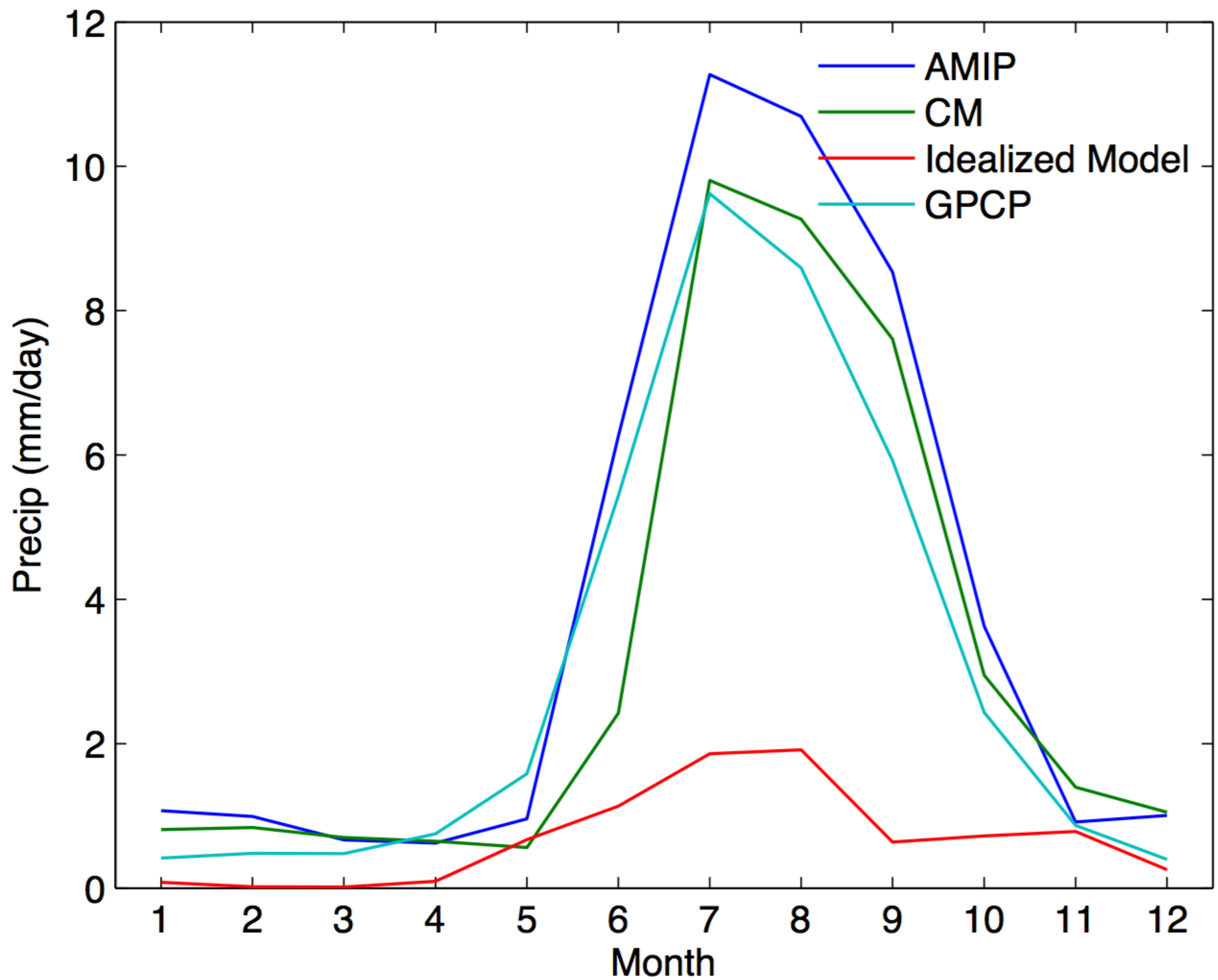
PCMDI Portrait Plot

Monsoon simulation

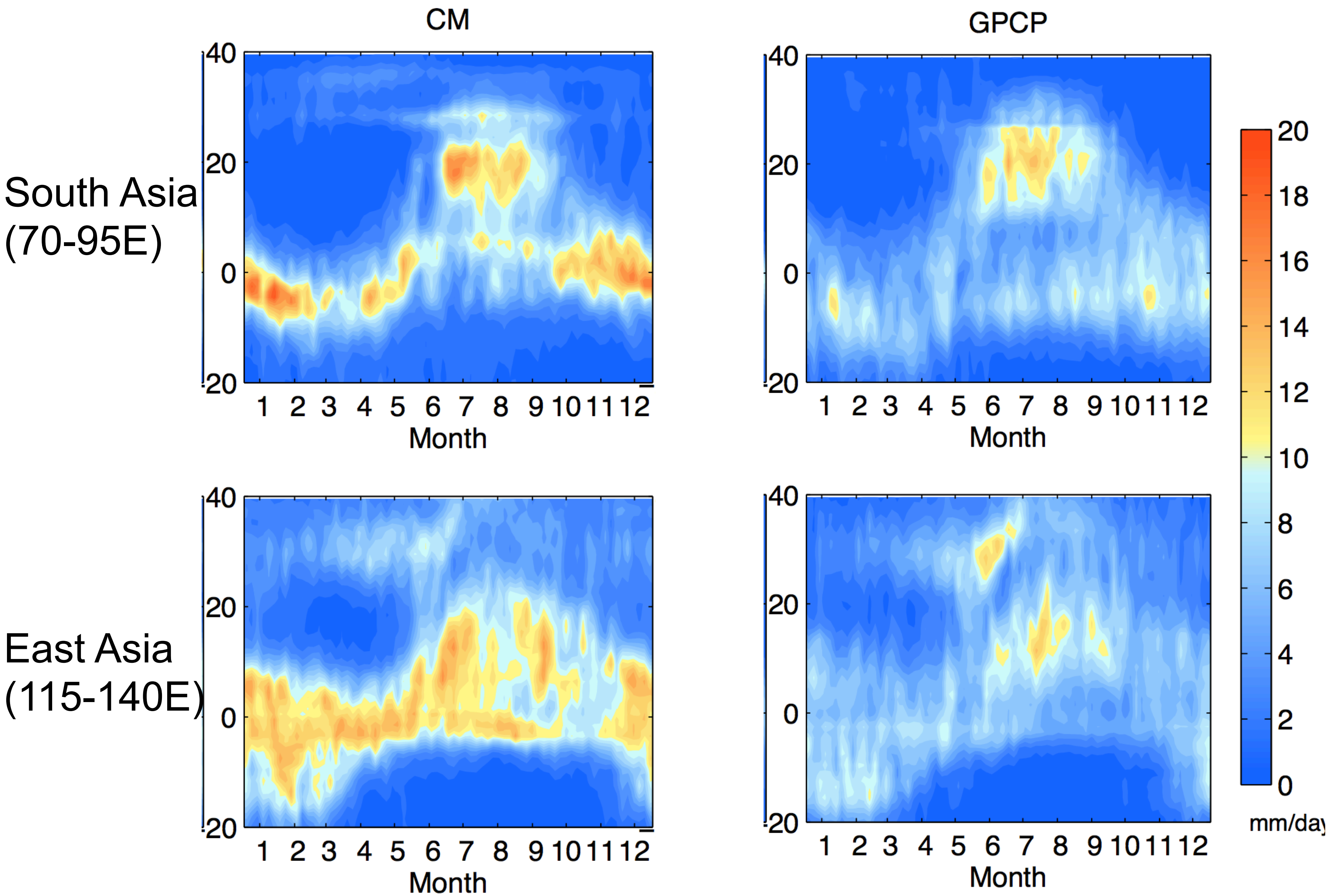
Precipitation (colored shading) and 850-hPa winds



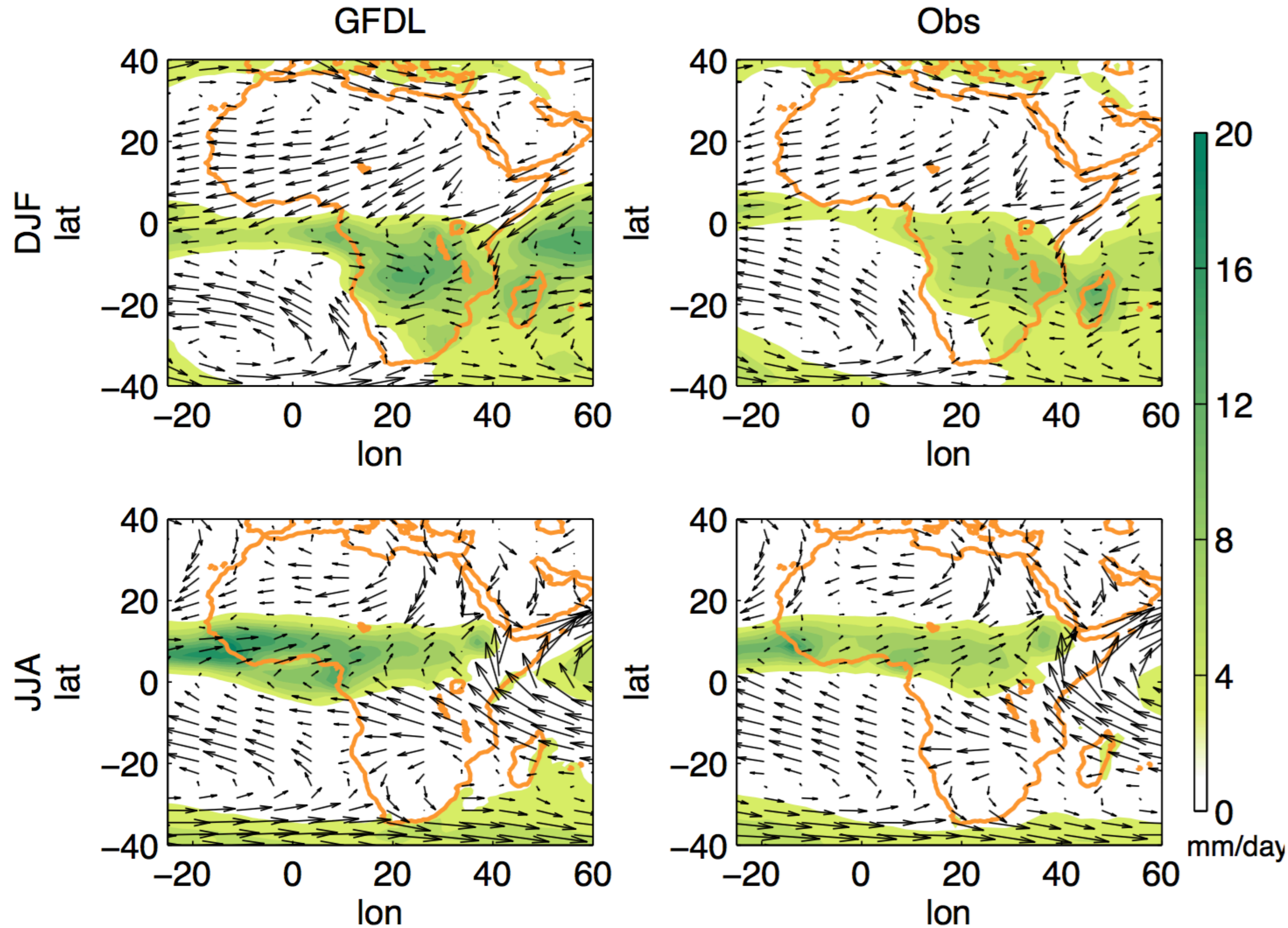
Monthly-mean precipitation over India (10-30N, 70-90E)



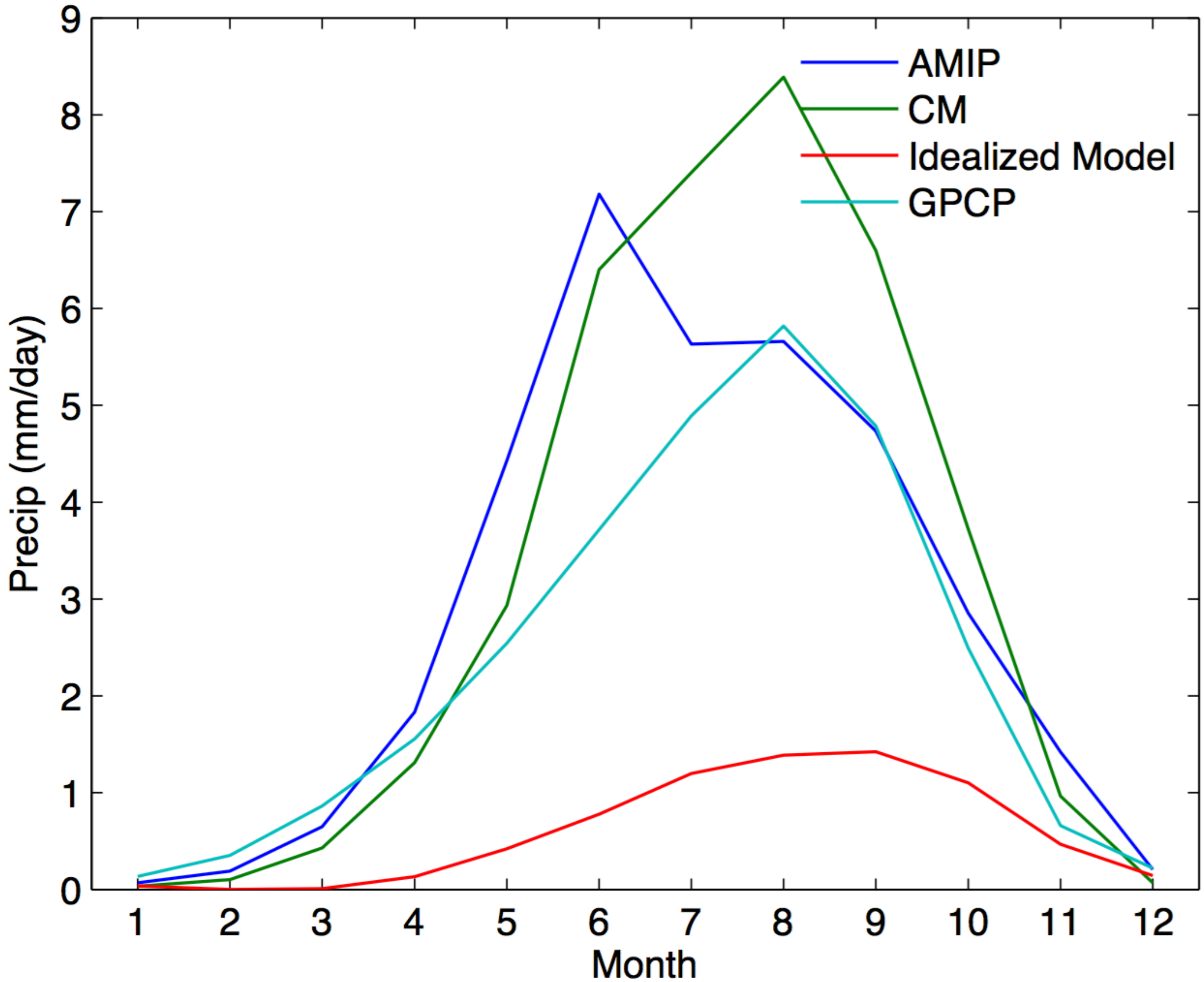
Monsoon onset: pentad precipitation



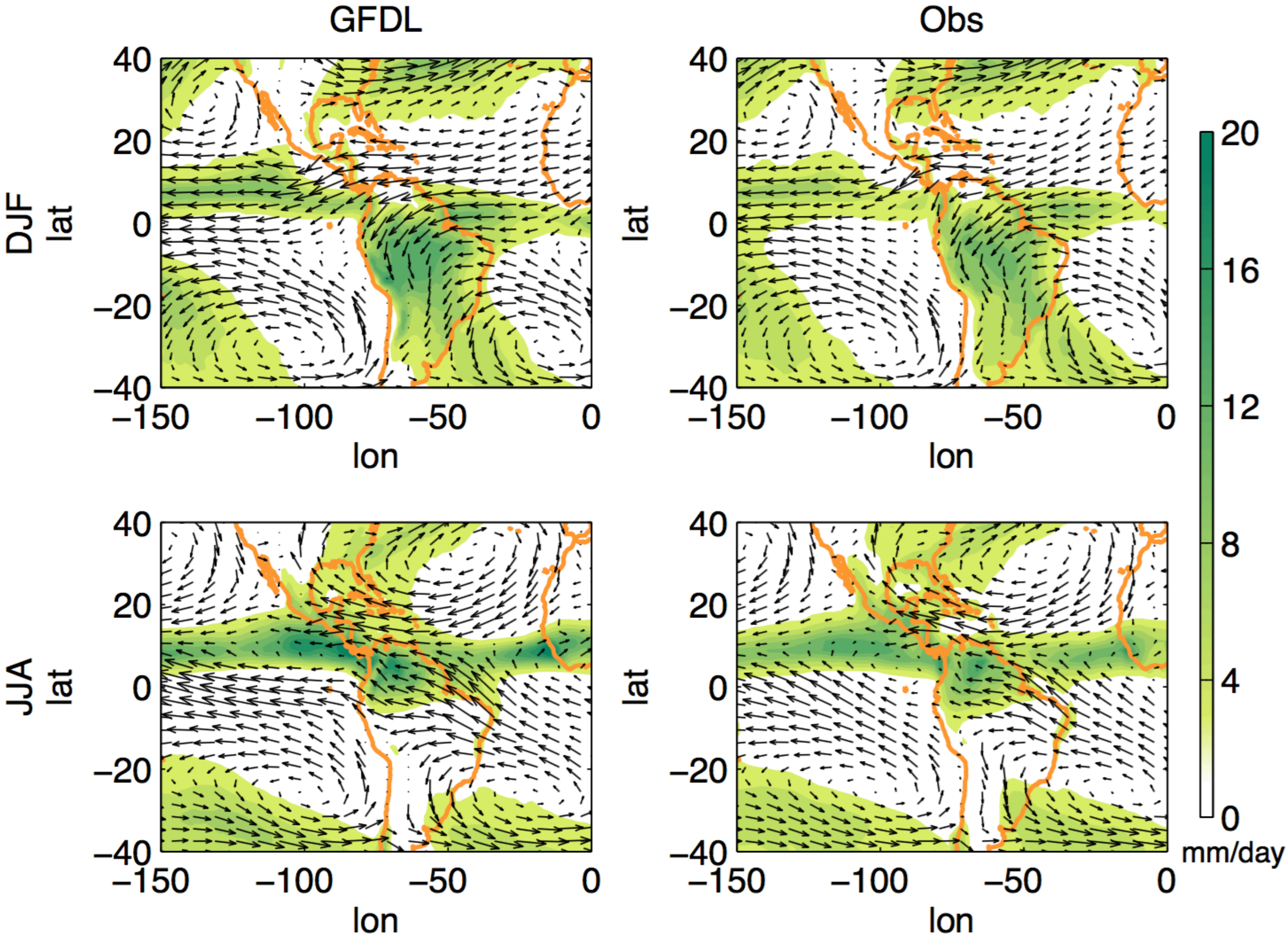
Precipitation (colored shading) and 850-hPa winds

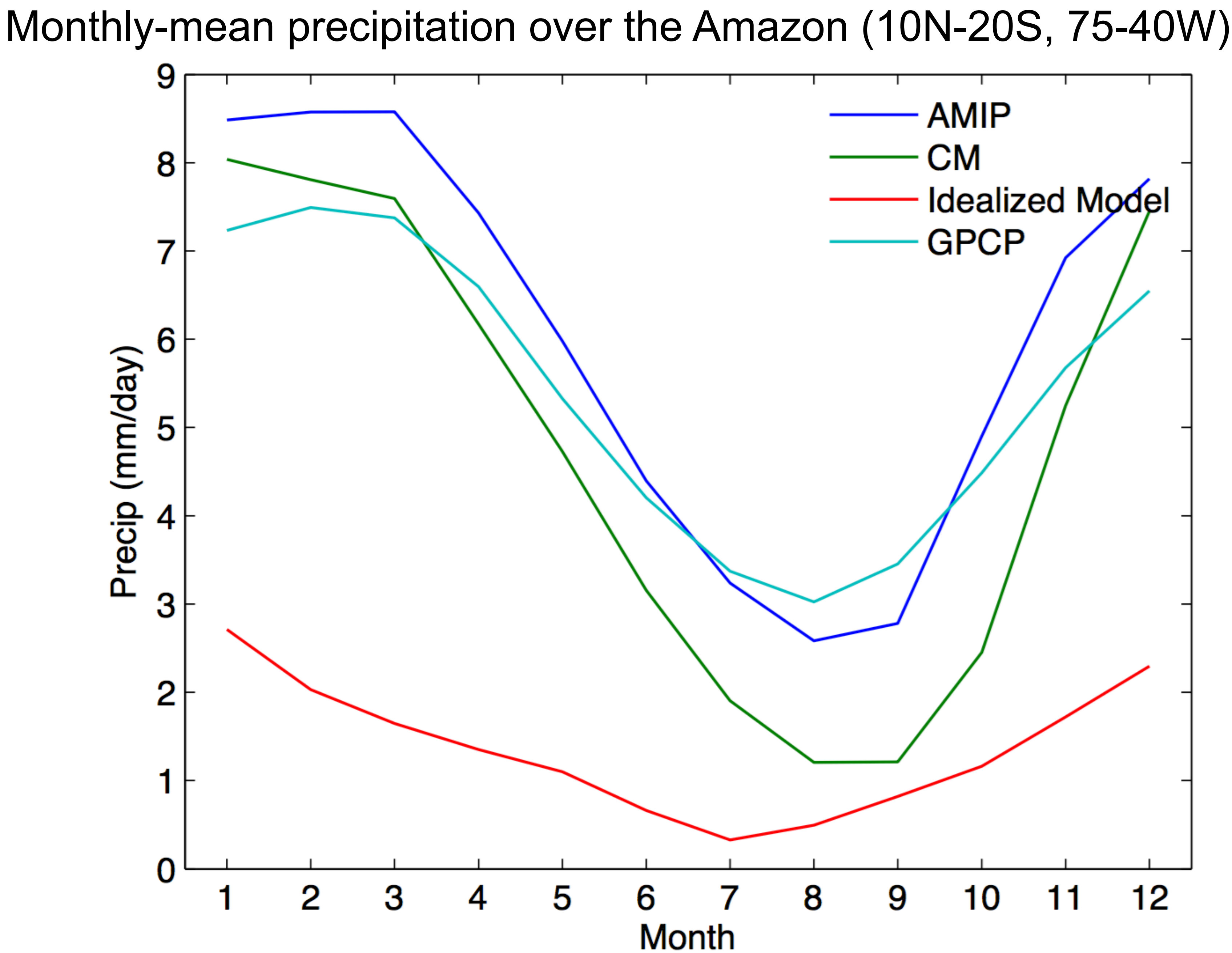


Monthly-mean precipitation over the Sahel (0-20N, 15W-10E)



Precipitation (colored shading) and 850-hPa winds

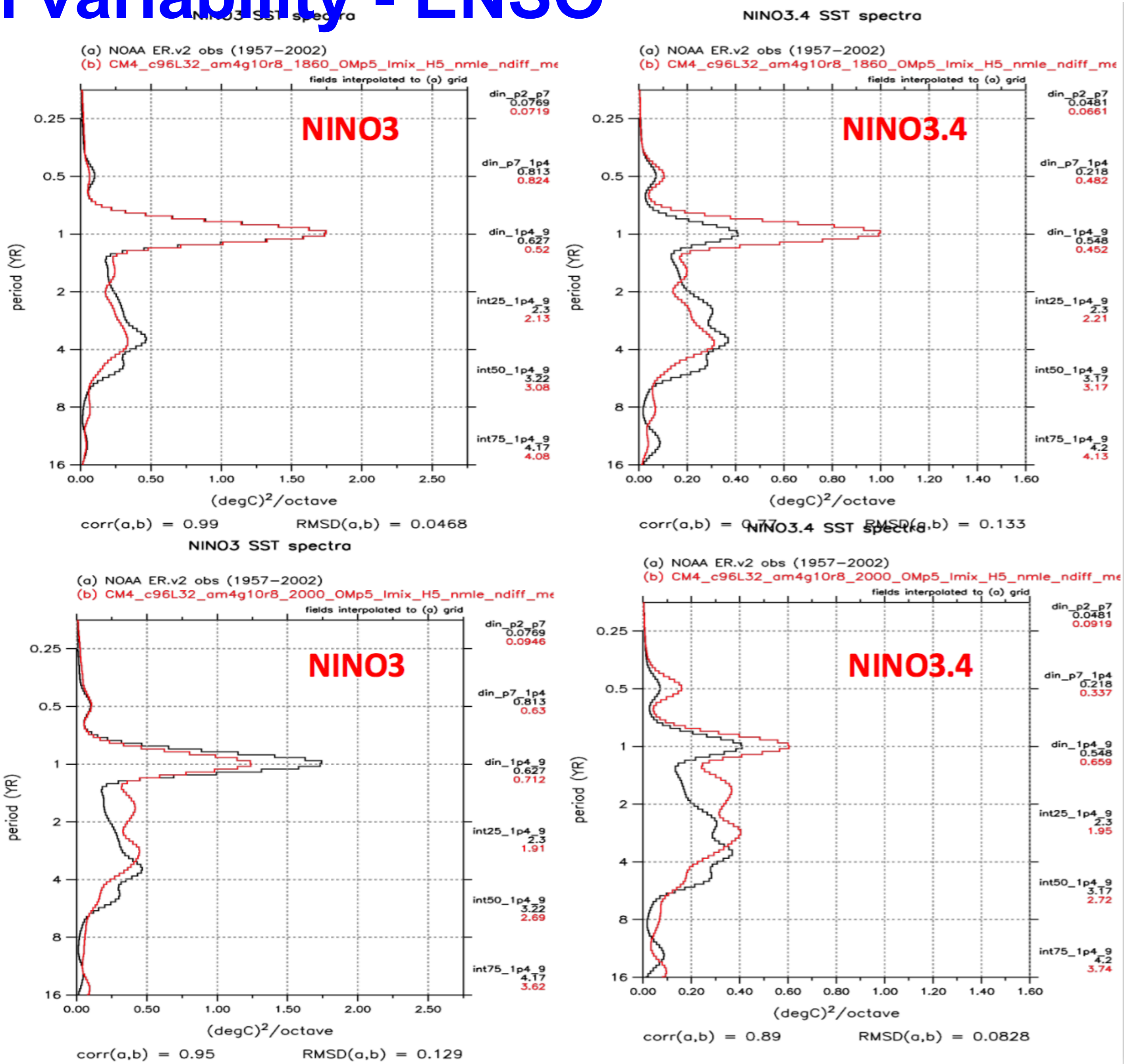



Monthly-mean precipitation over the Amazon (10N-20S, 75-40W)
AMIP
CM
Idealized Model
GPCP
Precip (mm/day)
0
1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
8
9
10
11
12
Month

Tropical variability - ENSO

CM4g10r8 1860

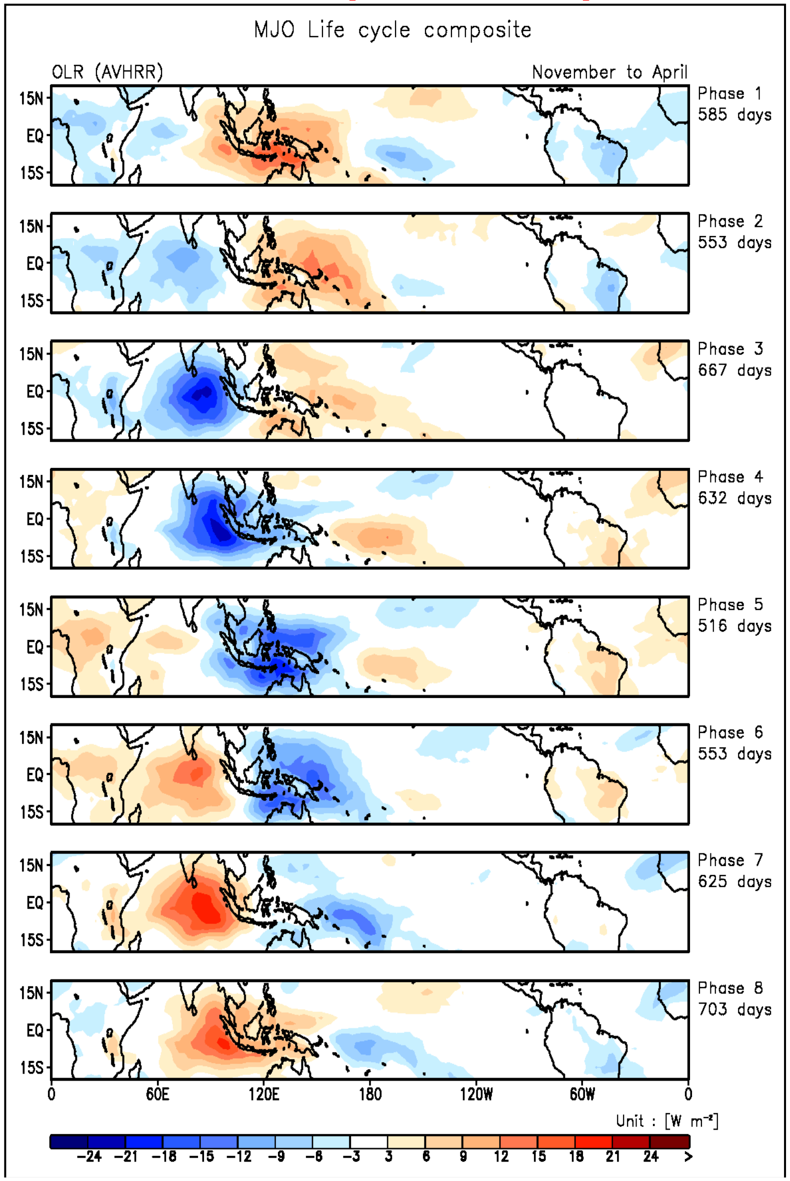
CM4g10r8 2000



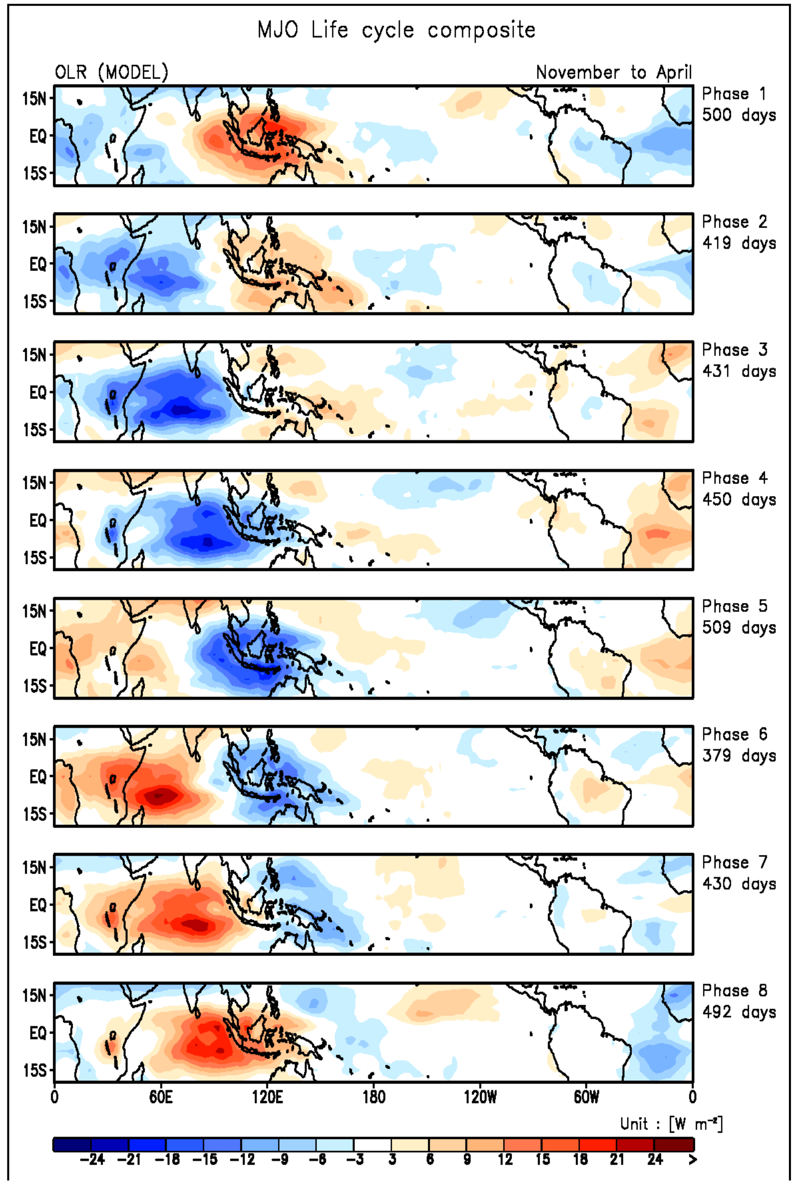
Madden-Julian Oscillation (MJO)

Nov-Apr life cycle composite using US CLIVAR standard diagnostic package

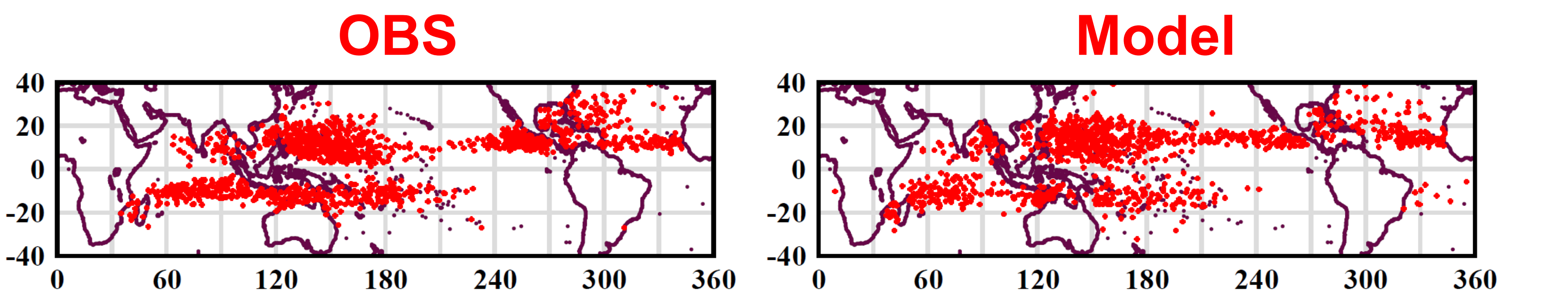
OBS (AVHRR)

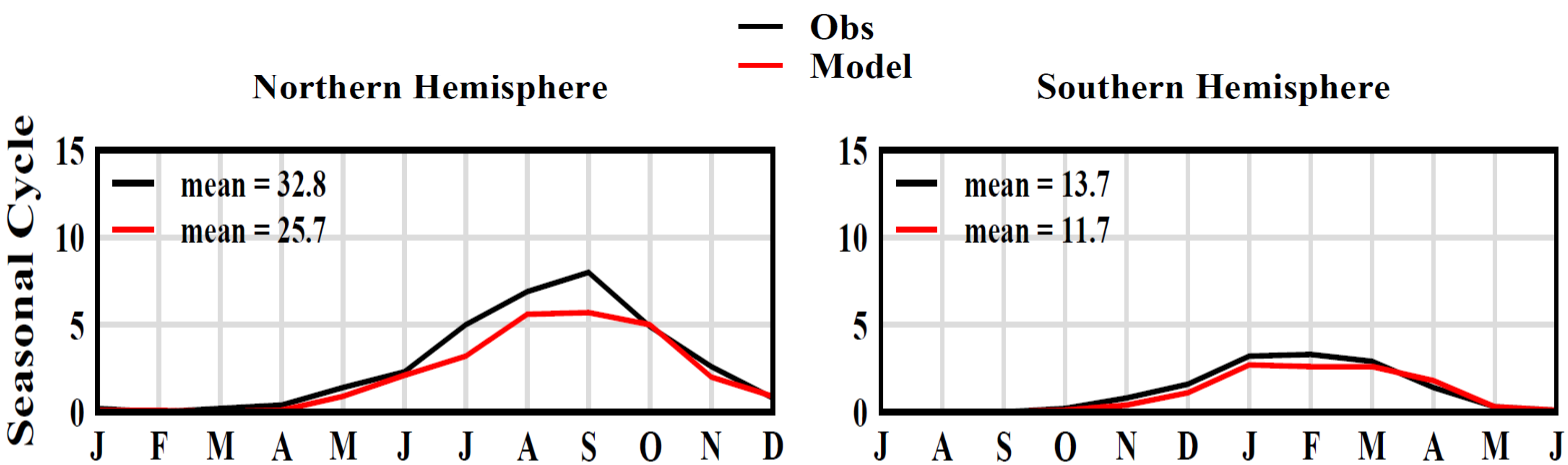


Model



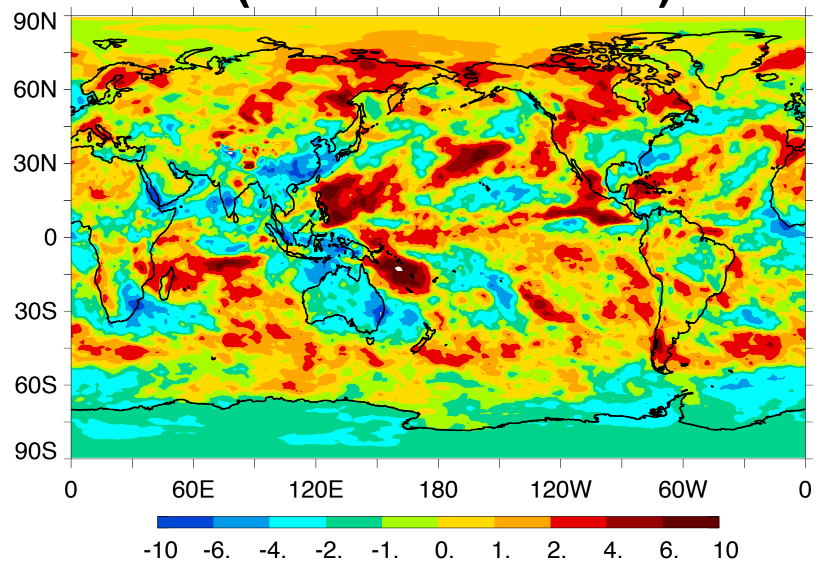
Tropical cyclones



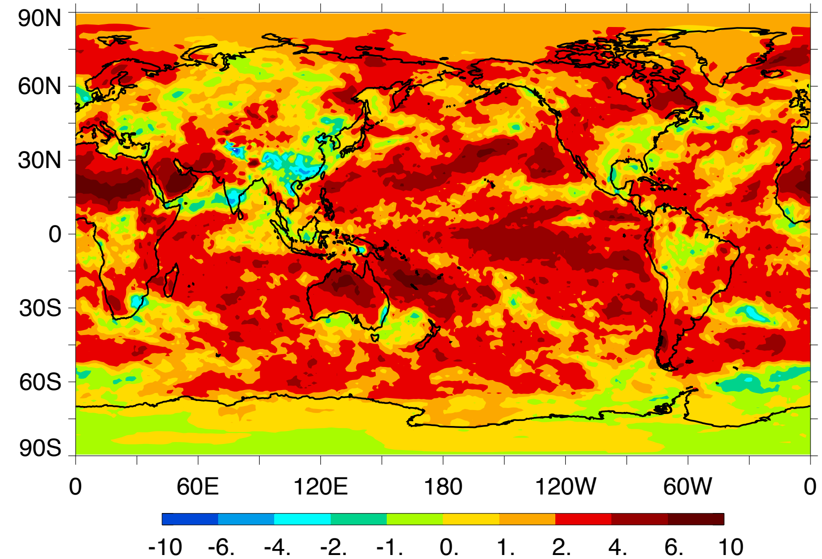


Aerosol forcing (W m^{-2})

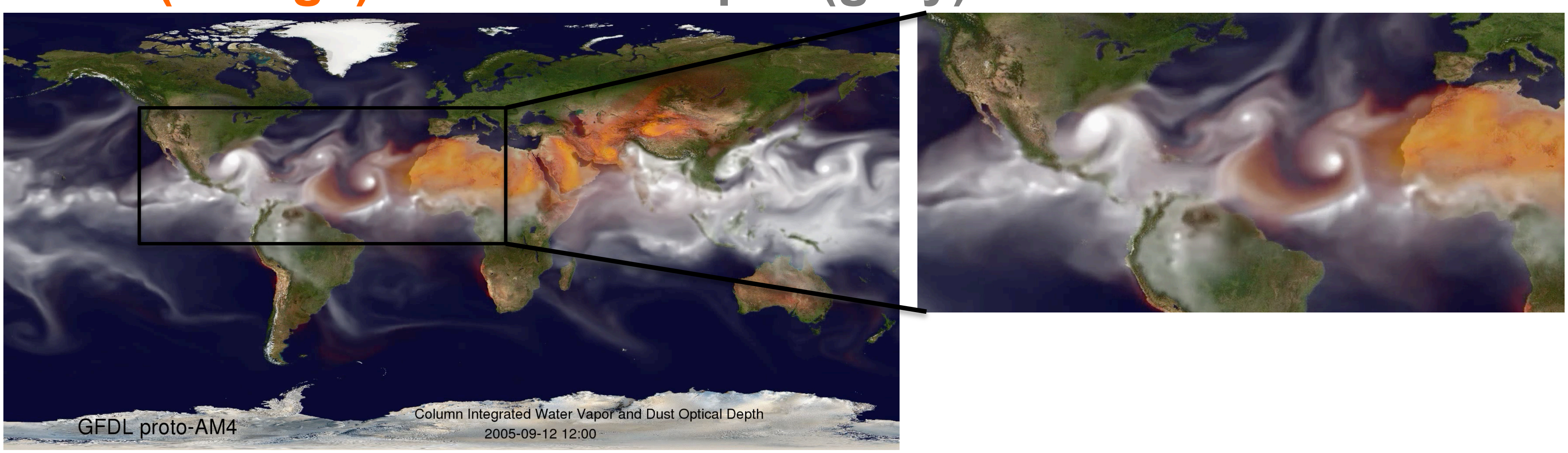
Aerosol (direct & indirect) -0.7



Aerosol & WMGG 2.1

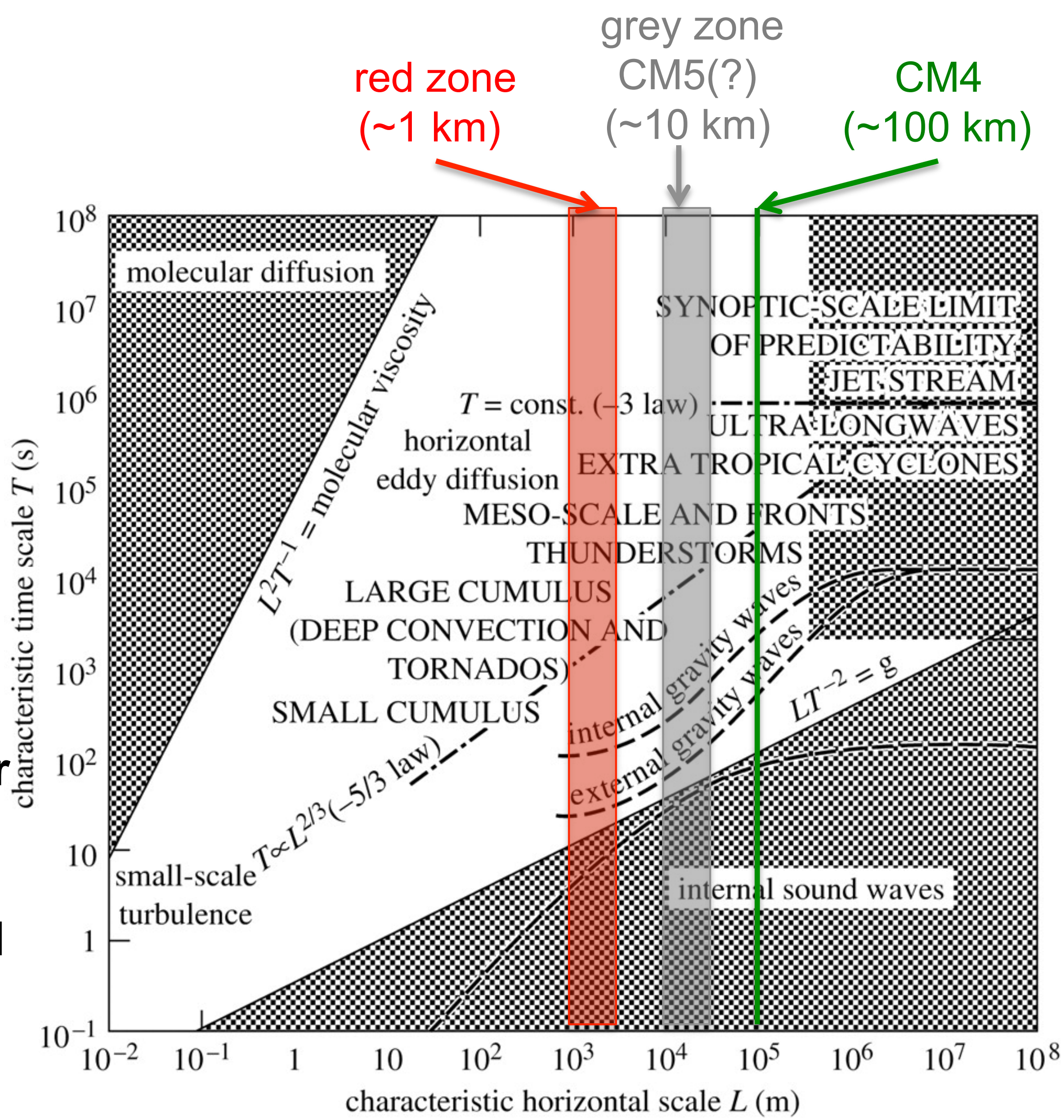


Dust (orange) and water vapor (grey)



Exploring atmospheric physics in the "grey zone" (tens of km)

- **Partially resolved deep convection ("cloud permitting")**
- **Need for re-evaluating existing parameterizations (developed for coarse resolution, resolution-dependence)**
- **Push to the "red zone" (a few km, "cloud resolving") for short (days to months) runs as learning tools**
- **A hierarchy of models (e.g., LES, RCE with regional CRM or GCM physics, high-end global CRM)**
- **Use of simulations, augmented by evaluation and process-level diagnostics, for guiding parameterization development.**

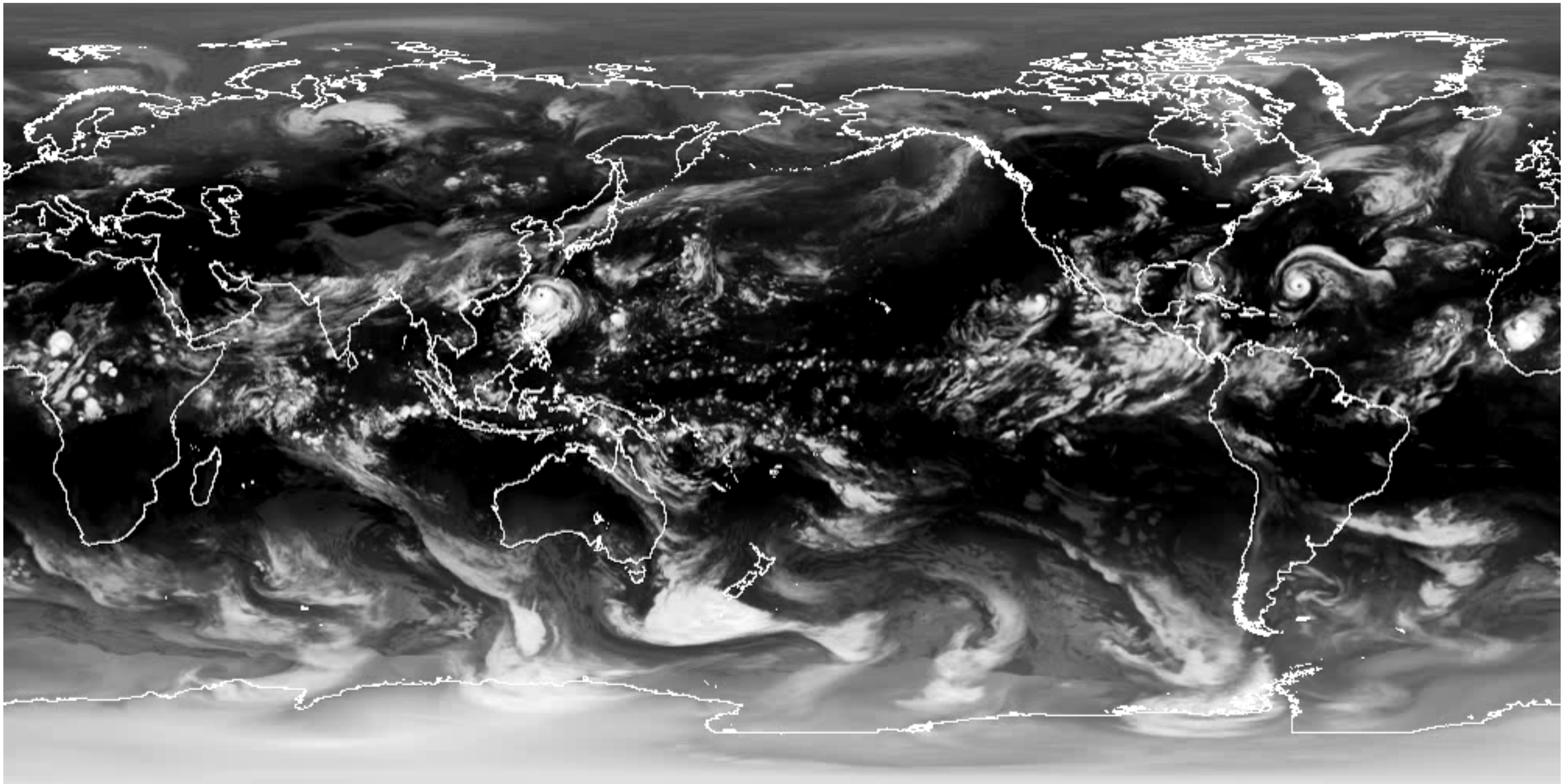


Going back to the NWP root!

Following Smagorinsky (1974)

Weather-climate model simulations

Example 1: Global "cloud-permitting" models (~3.5 km)



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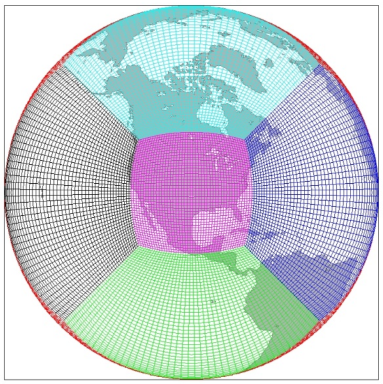
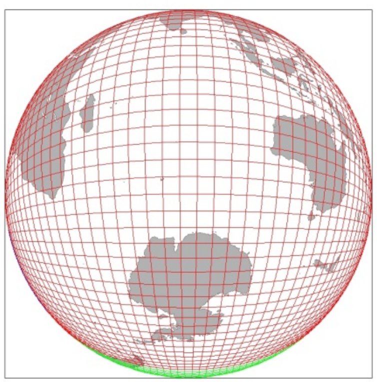
Example 2: Global *regional* cloud-resolving models enabled by grid stretching and nesting (e.g., ~1 km over CONUS)

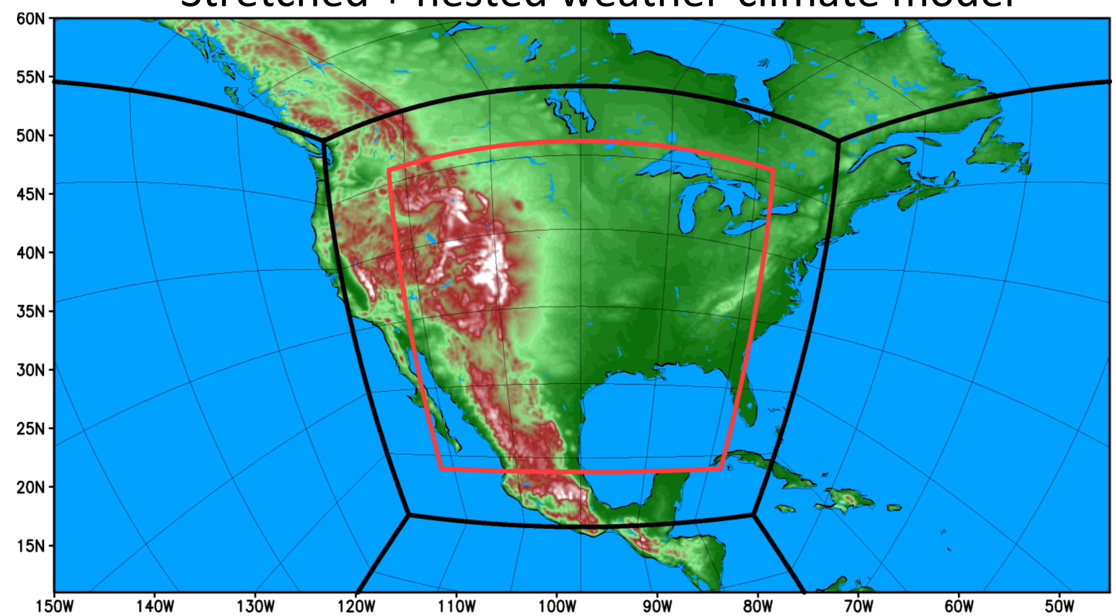
Oklahoma City

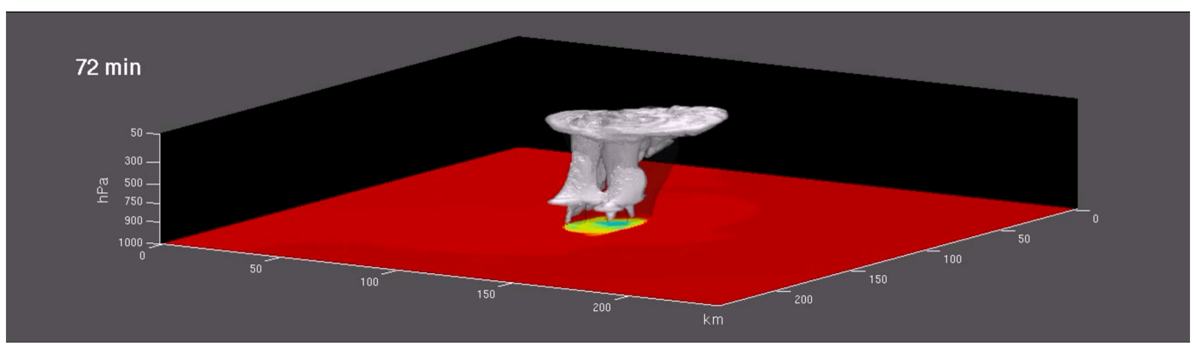


Back side of OKC



Stretched + nested weather-climate model





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Model evaluation and diagnostics

- **Short (days to months) simulations in weather forecast or seasonal prediction mode [as efficient ways to expose model biases]**
- **Process-level diagnostics (moist convection, MJO, mid-latitude cyclones, ...) [spearheaded by the NOAA/CPO Model Diagnostics Task Force]**
- **Comparison with observations (CloudSat, …)**
- **Idealized experiments (aquaplanet, COOKIE, …)**
- **Community-wide efforts (CPT, CFMIP, …)**
- **…**

Goal: Development of physics parameterizations applicable to weather-climate models

Conclusions

- CM4 shows considerable skills in simulating mean climate, monsoon and tropical variability.
- Despite many real challenges, we are excited about **all the new sciences and applications that the high-end weather/climate modeling at GFDL will enable** for many years to come**.**