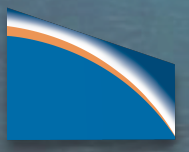
Capturing timescale interactions: Clouds, forecasts and drought

Rich Neale, NCAR

- Are climate models drought prediction 'ready'?
- Progress in climate modeling for modes of variability relevant to S2S
- Dependency on cloud and precipitation processes
- Which characteristics are relevant to skill?

When the Rain Stops: Drought on Sub-seasonal and Longer Timescales

AGCI, September 2018



NCAR

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Orientation

- Global climate models (100km grid separation, mostly)
- Climate or free running simulations
- Mostly NCAR models (CAM3->6): With and w/o an ocean
- Globally uniform representations and settings
- Value judgements have to be made about the most important foci
- Producing a model that would be the most useful for prediction (sub-seasonal/seasonal/decadal)
- Only an atmospheric perspective

- BUT: I had a lot of fun looking at this!

I Lack Focus: The Perils of Global Model Development

Variability

US Summer time precipitation
Madden Julian Osc. (MJO)
Equatorial Wave Variability
ENSO
Indian Monsoon
American Monsoon
Diurnal Cycle
Sub-seasonal Forecasts
Atmospheric blocking
Labrador sea ice

Processes/Parameterizations

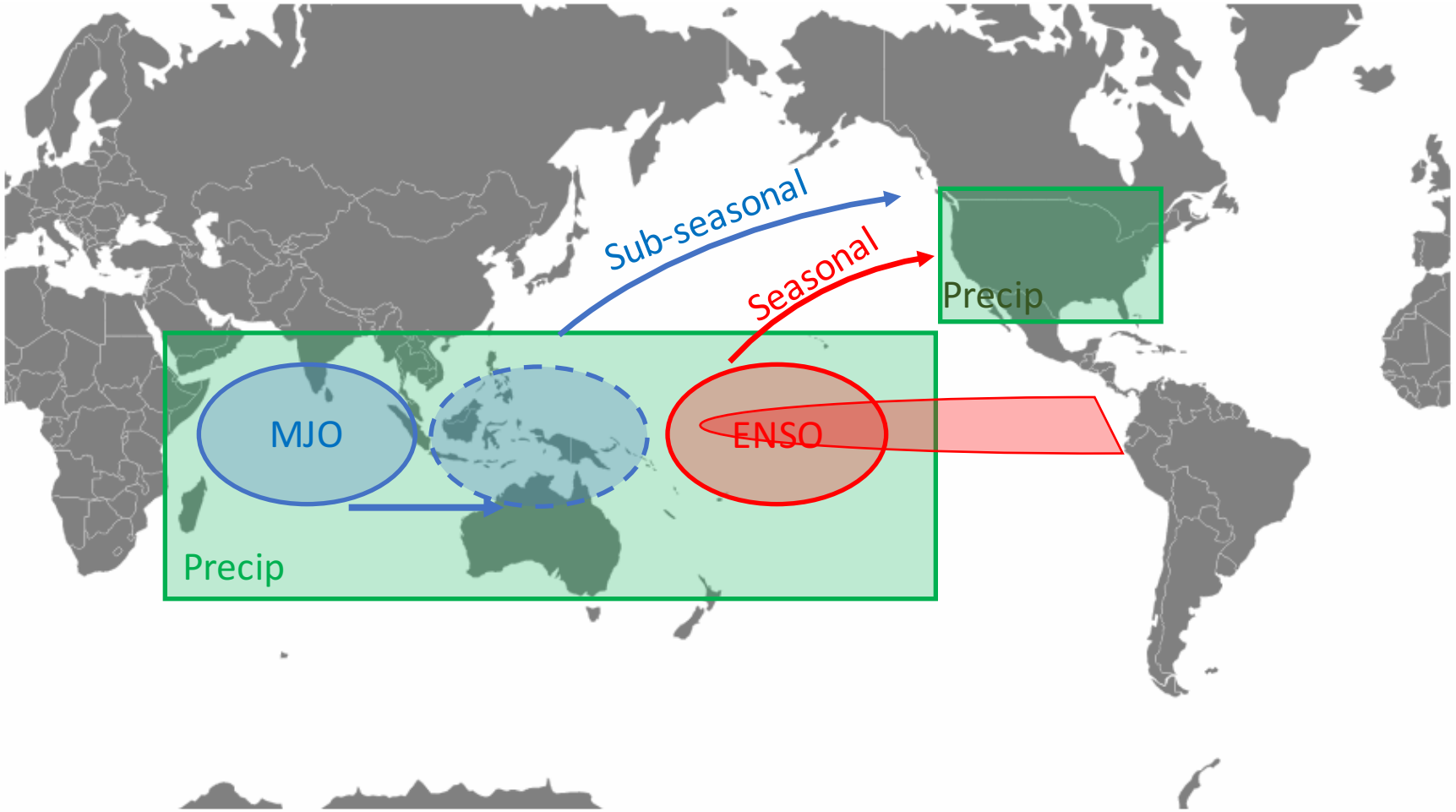
Convection
Boundary layer turbulence
Cloud microphysics
Surface drag
Precipitation over orography

Climate and Change

Climate sensitivity
Cloud feedbacks
Cloud aerosol interactions

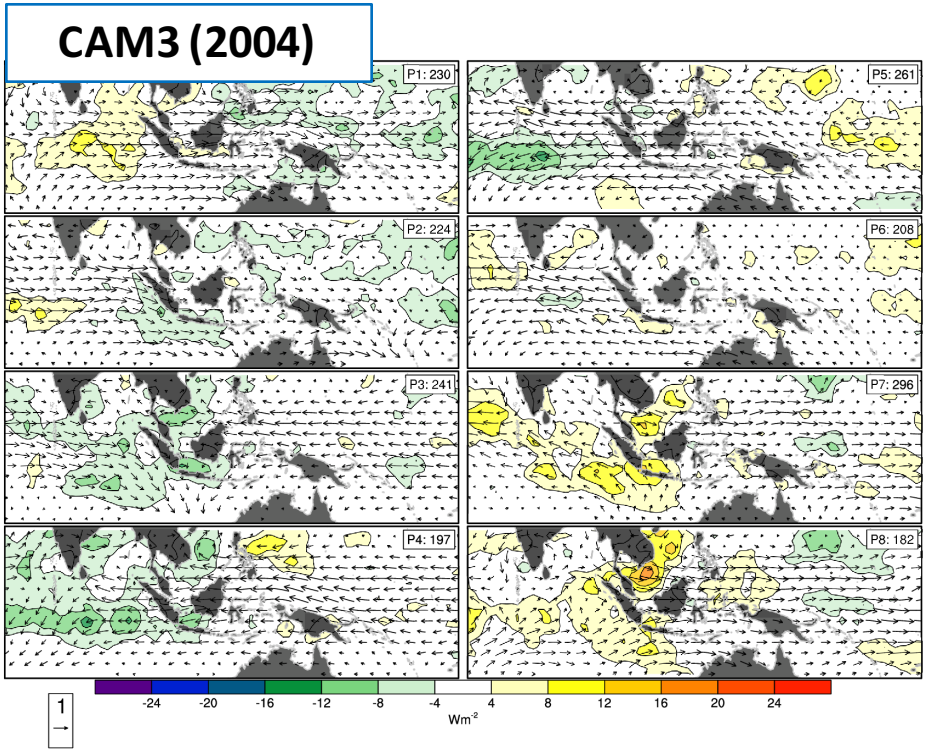
Problems Mostly Related to Precipitation

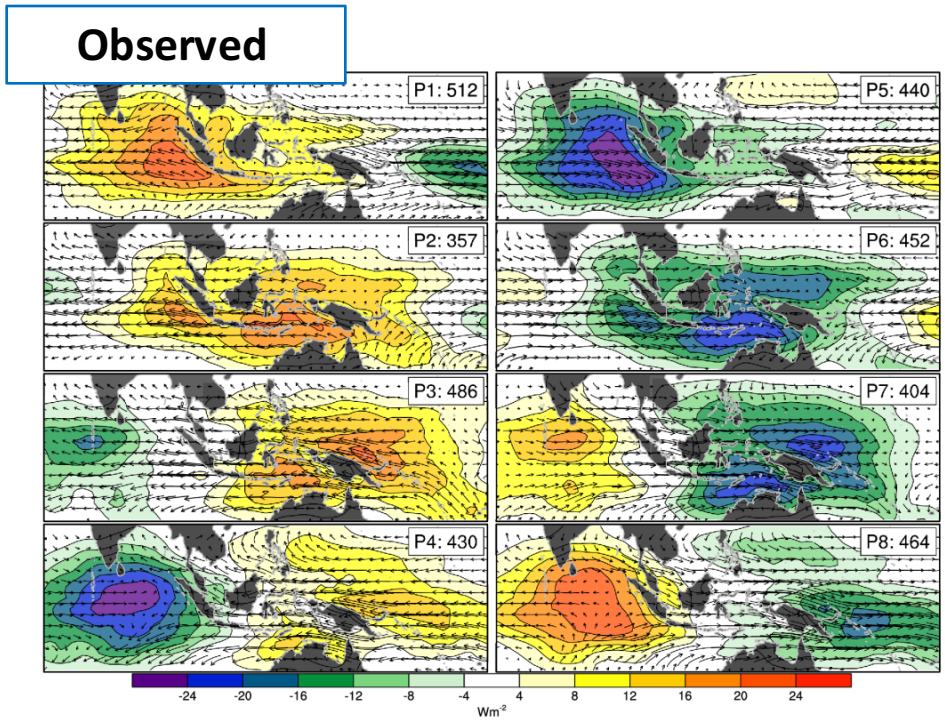
Tropical Sources of S2S Prediction



MJO Progress: Intraseasonal (weeks)

Madden Julian Oscillation (MJO)



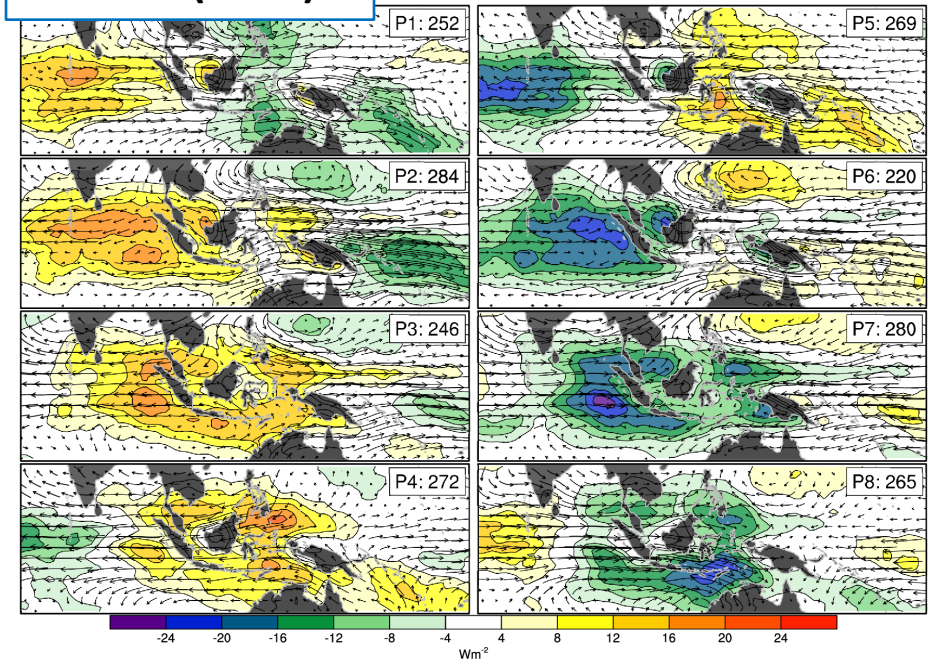


Neale, et al., (2018) Diurnal, Sub-Seasonal and Seasonal Variability in the Community Atmosphere Model, version (CAM6), JAMES, in prep.

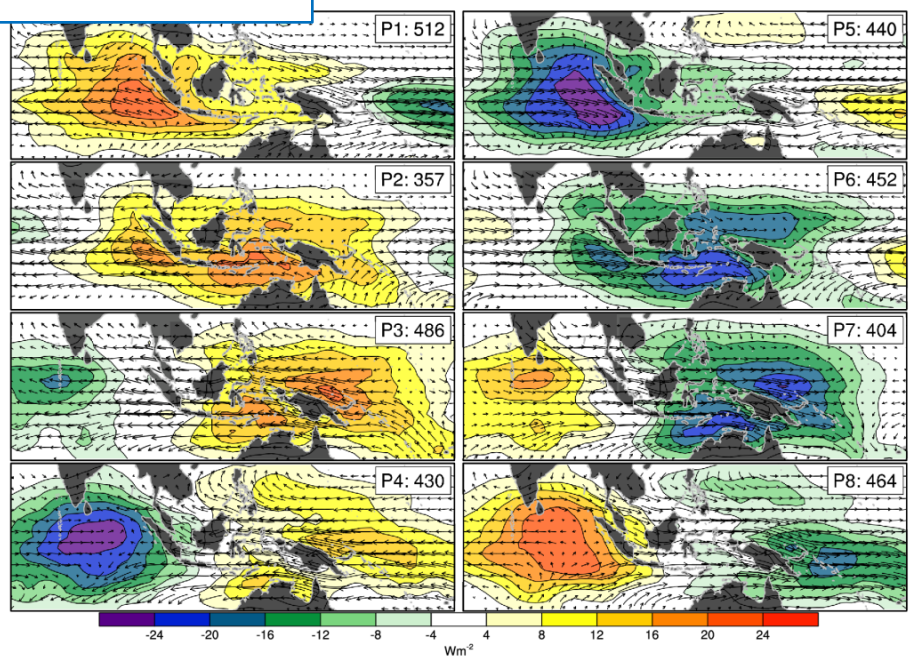
MJO Progress: Intraseasonal (weeks)

Madden Julian Oscillation (MJO) – 30-60 day composite

CAM6 (2018)



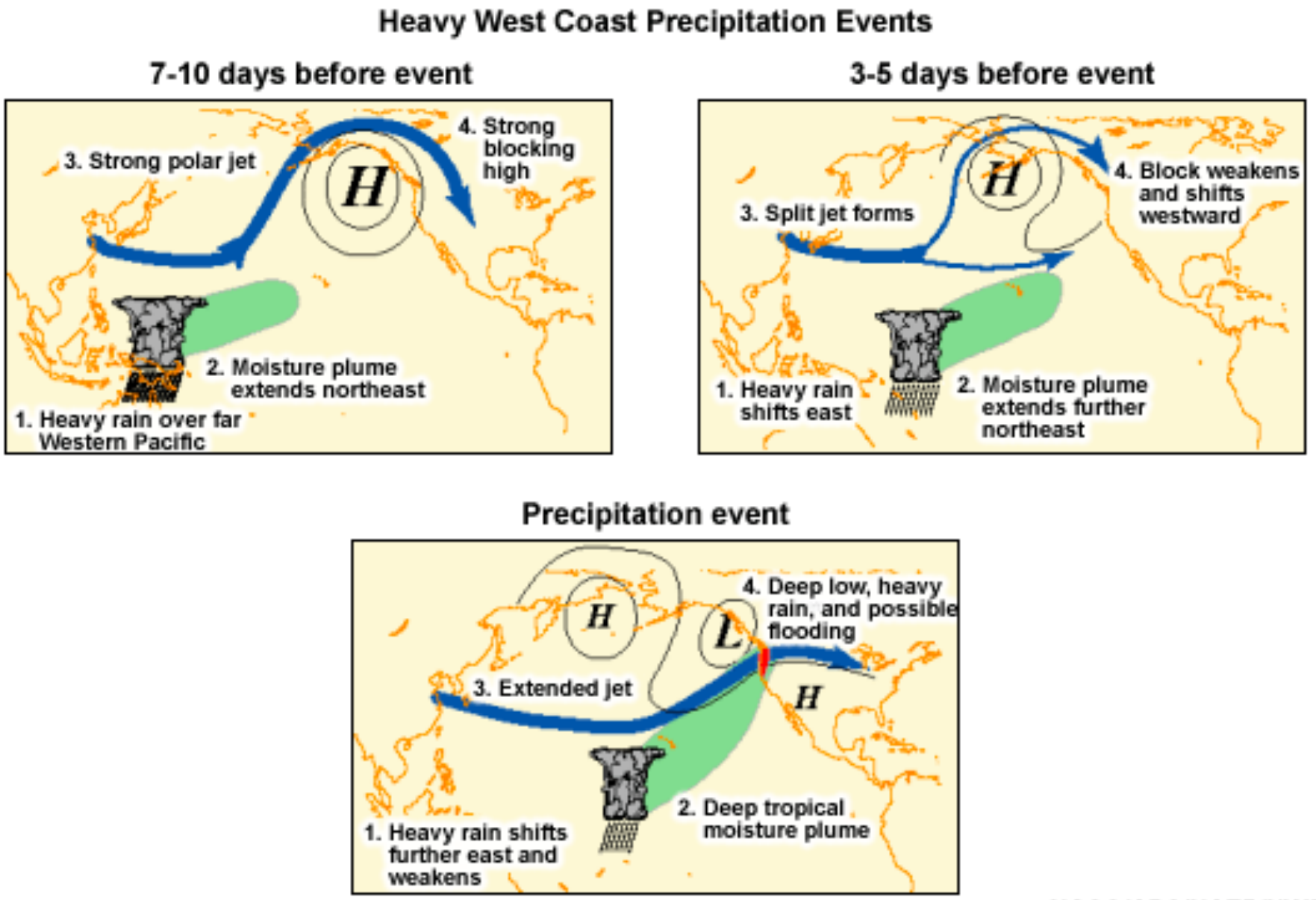
Observed



- Directly linked to changes in convection cloud
- Increase stable-layer sensitivity of convective plumes

Neale, et al., (2018) Diurnal, Sub-Seasonal and Seasonal Variability in the Community Atmosphere Model, version (CAM6), JAMES, in prep.

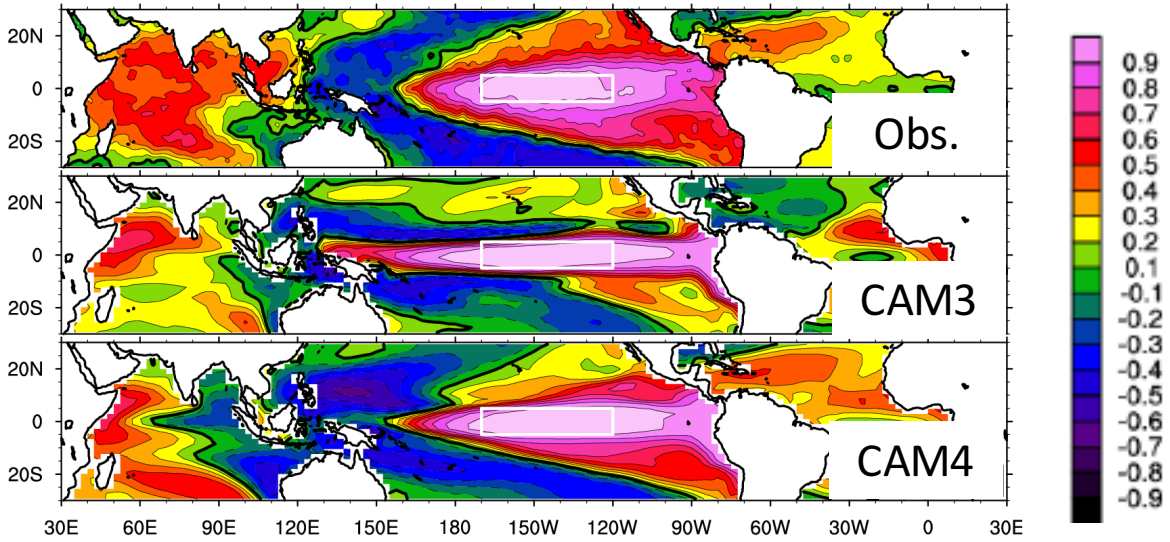
MJO Downstream Sub-seasonal Impacts

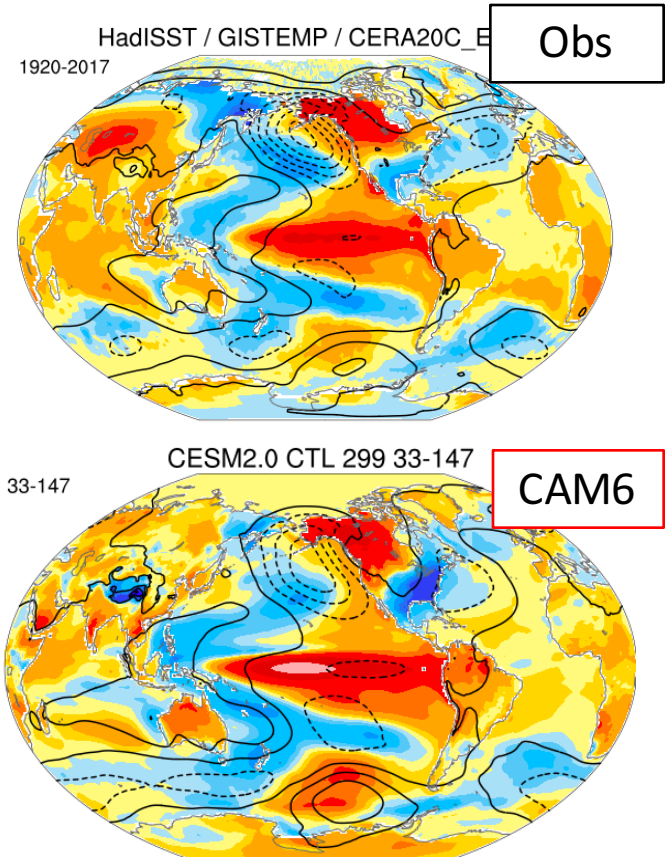


NOAA/CPC/NCEP/NWS

El Nino: Seasonal/interannual (years)

SST anomalies correlated with Nino3.4 SST anomalies



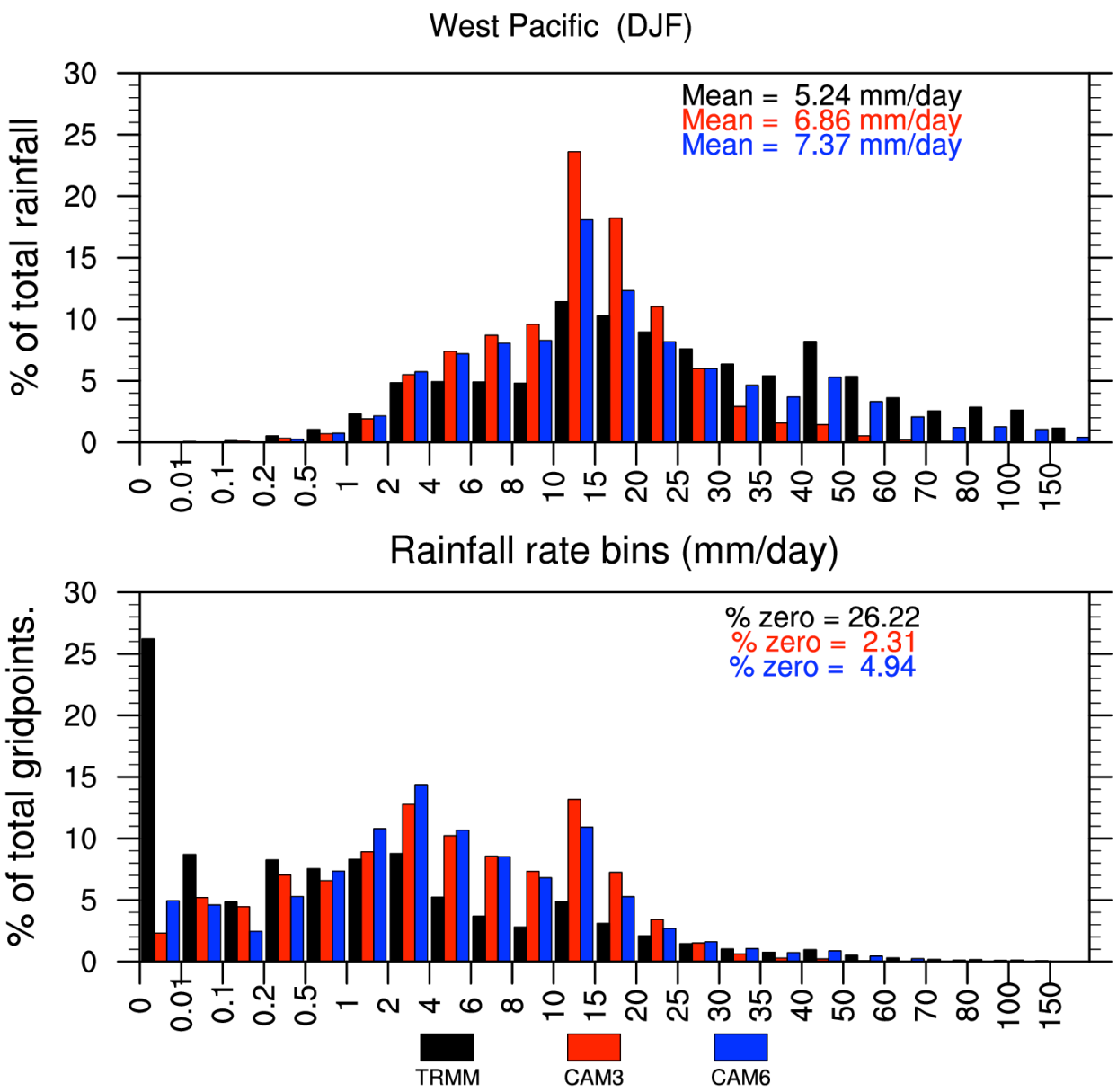


- Directly linked to changes in convection cloud
- In cloud entrainment and momentum transport

Peak nino 3.4 - DJF
SST/Tsurf and PSL (lines)

*Neale, R.B., J.H. Richter, and M. Jochum, 2008: The Impact of Convection on ENSO: From a Delayed Oscillator to a Series of Events. J. Climate, **21**, 5904–5924*

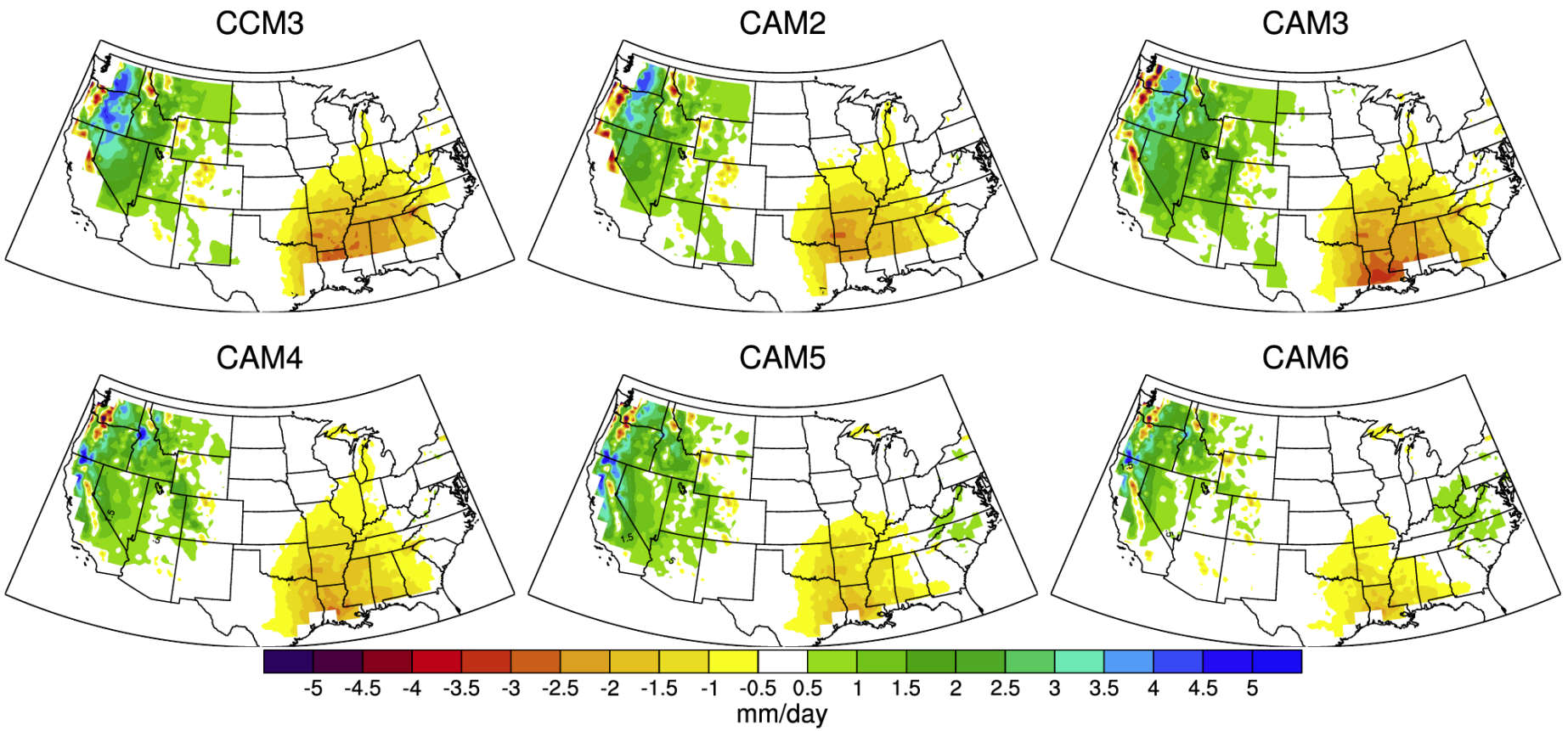
Precipitation Distributions



Daily means (5 years)
100-km resolution
CAM3->CAM6 (15yrs)

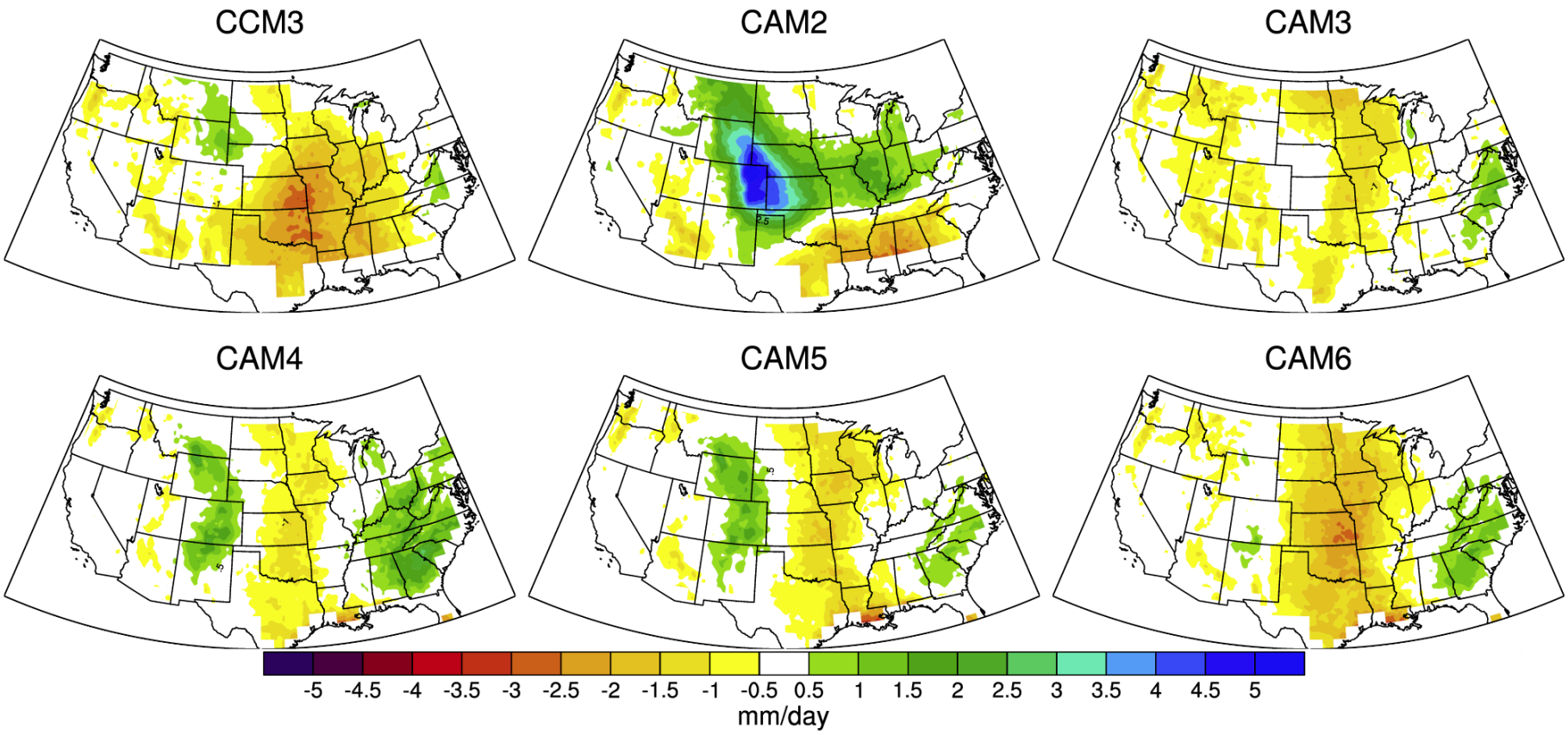
- Too few dry days
- 10-20mm/day drizzle
- Improved wet freq.
- Mutli-scale organization

CAM Mean Precipitation Biases - Winter



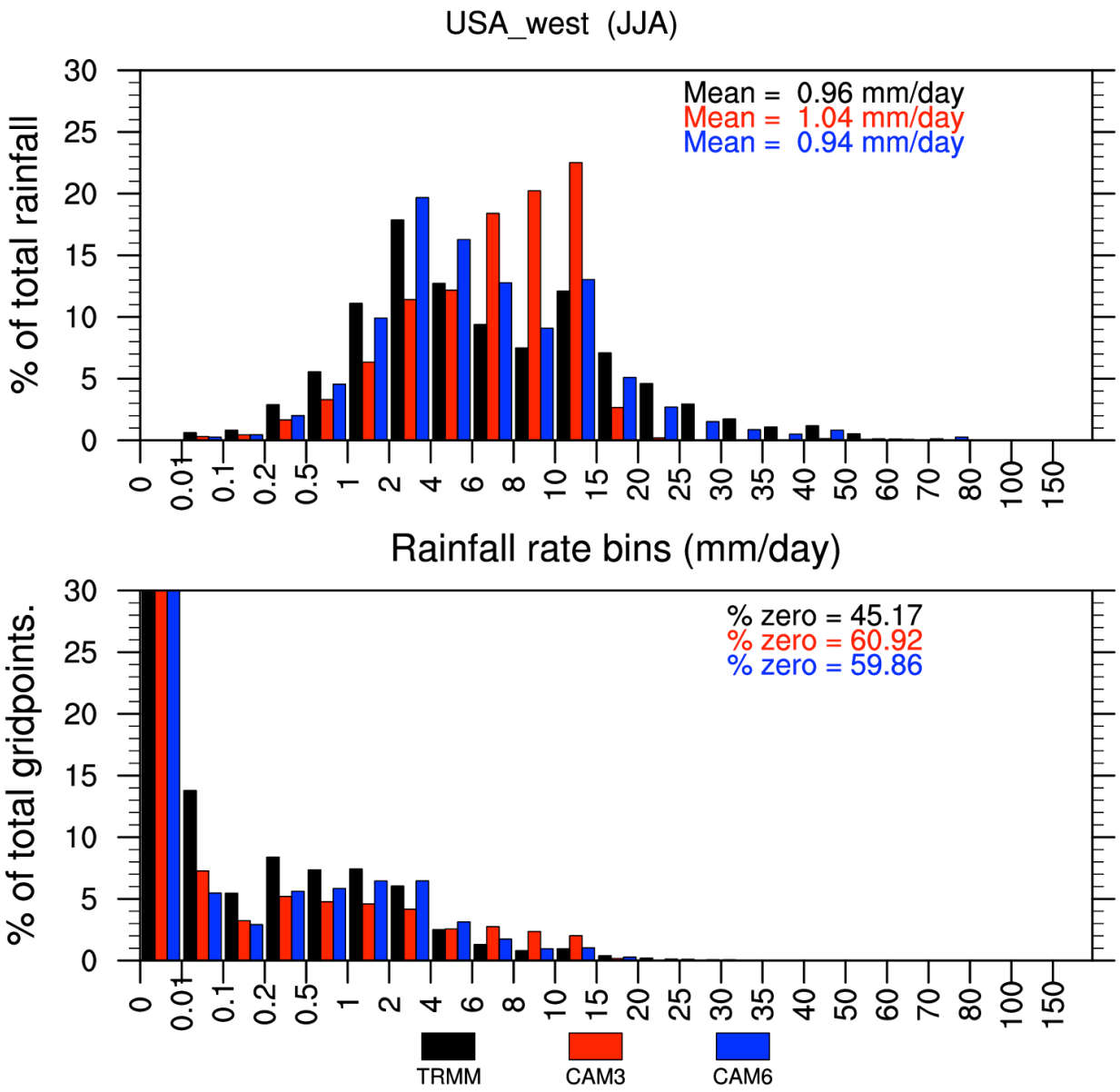
- 20 years (1998-2018)
- Persistent biases across USA
- Bias halved in South-East and West

CAM Mean Precipitation Biases - Summer



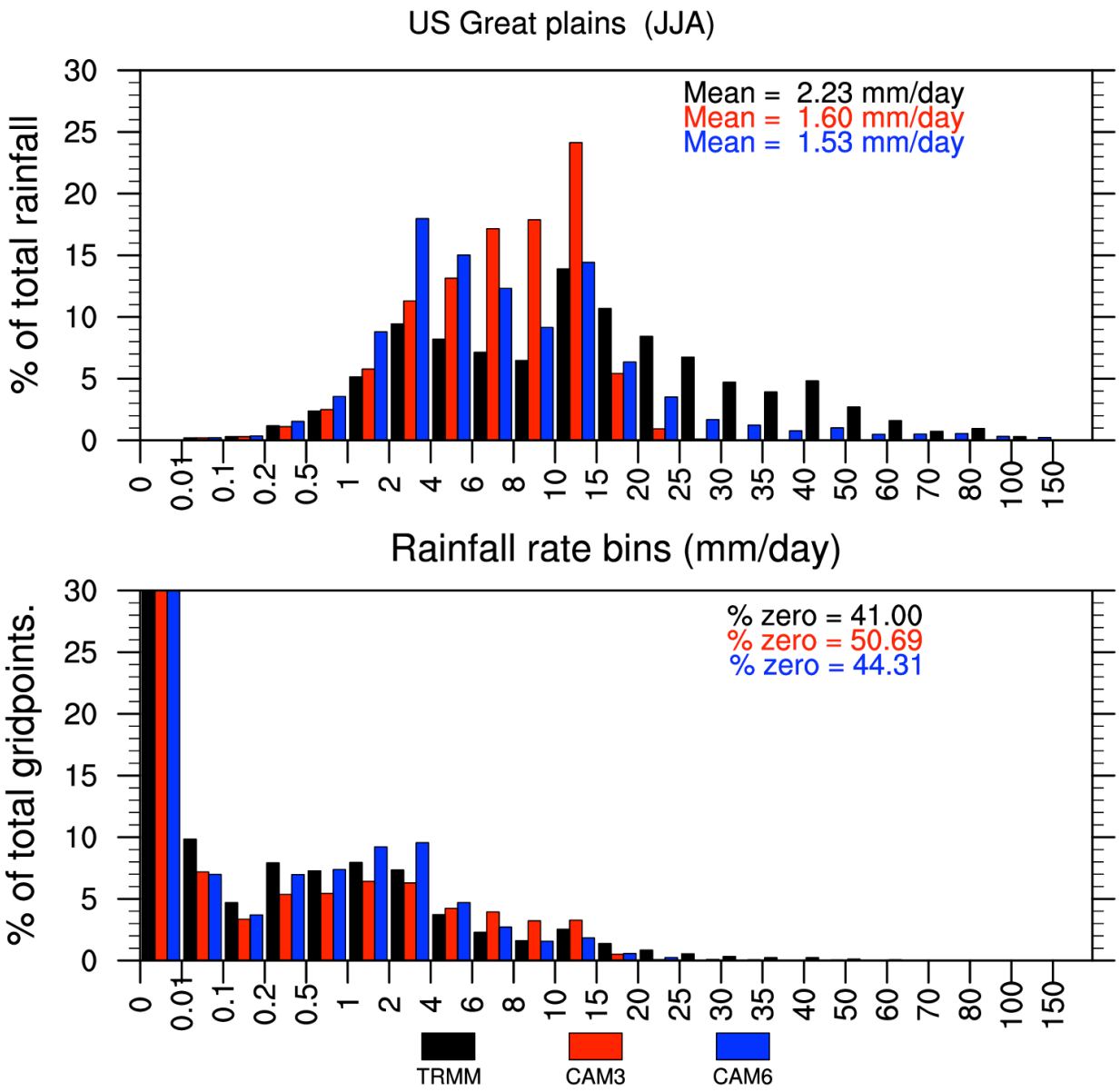
- Mid-west biases have changed over time
- Biases over mid-west have worsened, mountain west improved
- Deficient deep convection
- Lack of organization representation

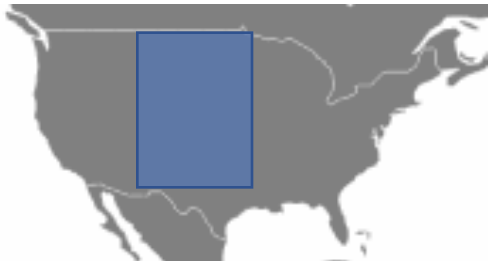
Precipitation Distributions: West



- Too many dry days
- Mid-value rate improvement
- Strong event contributions well captured

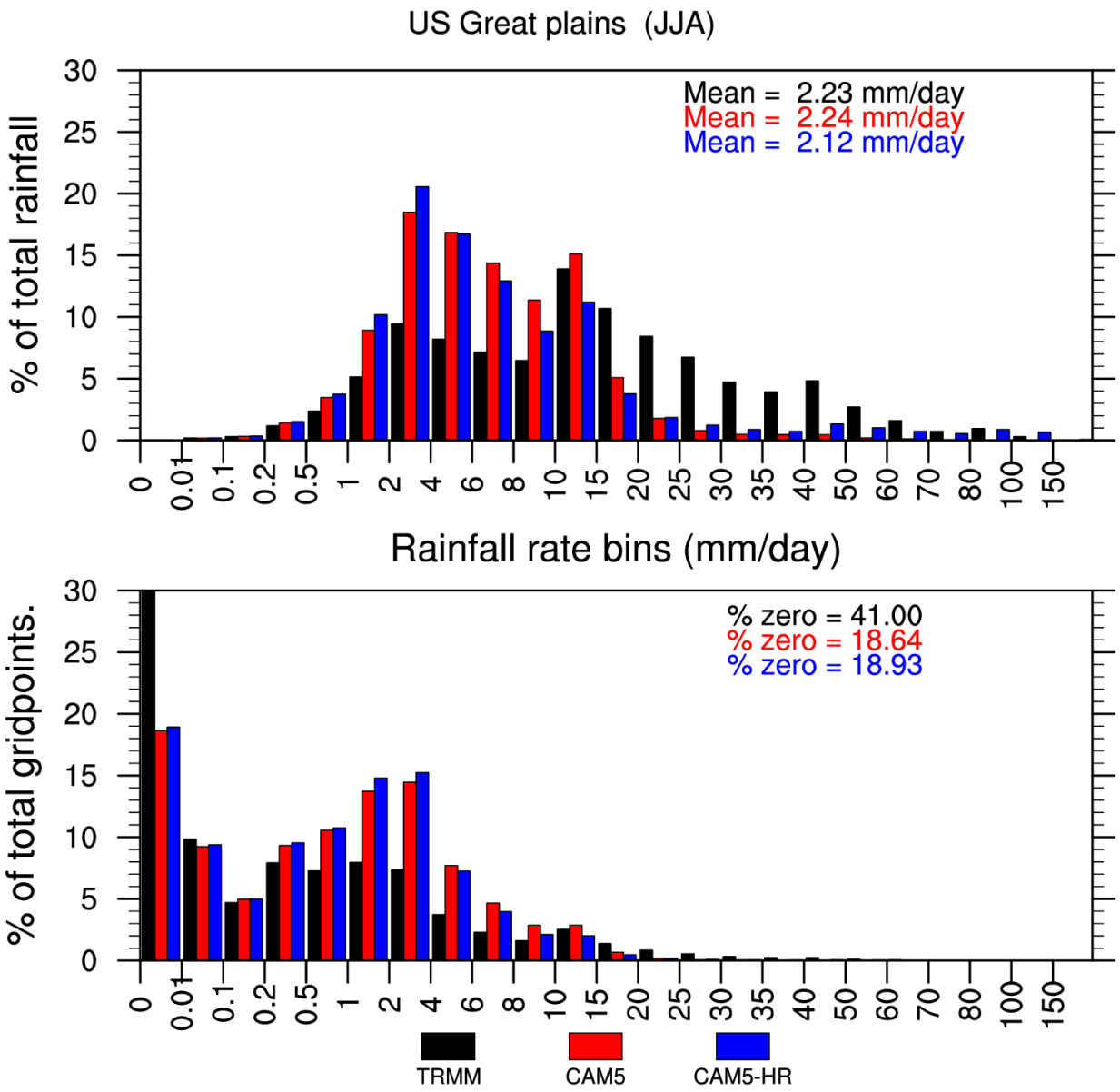
Precipitation Distributions: Plains

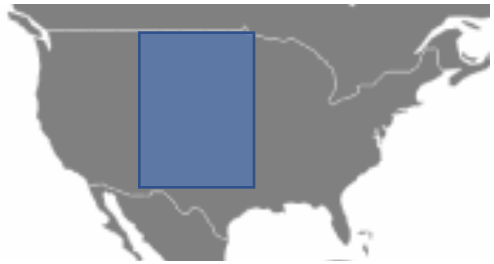




- Similar dry days
- Too few wet days
- Similar to W. USA PDF

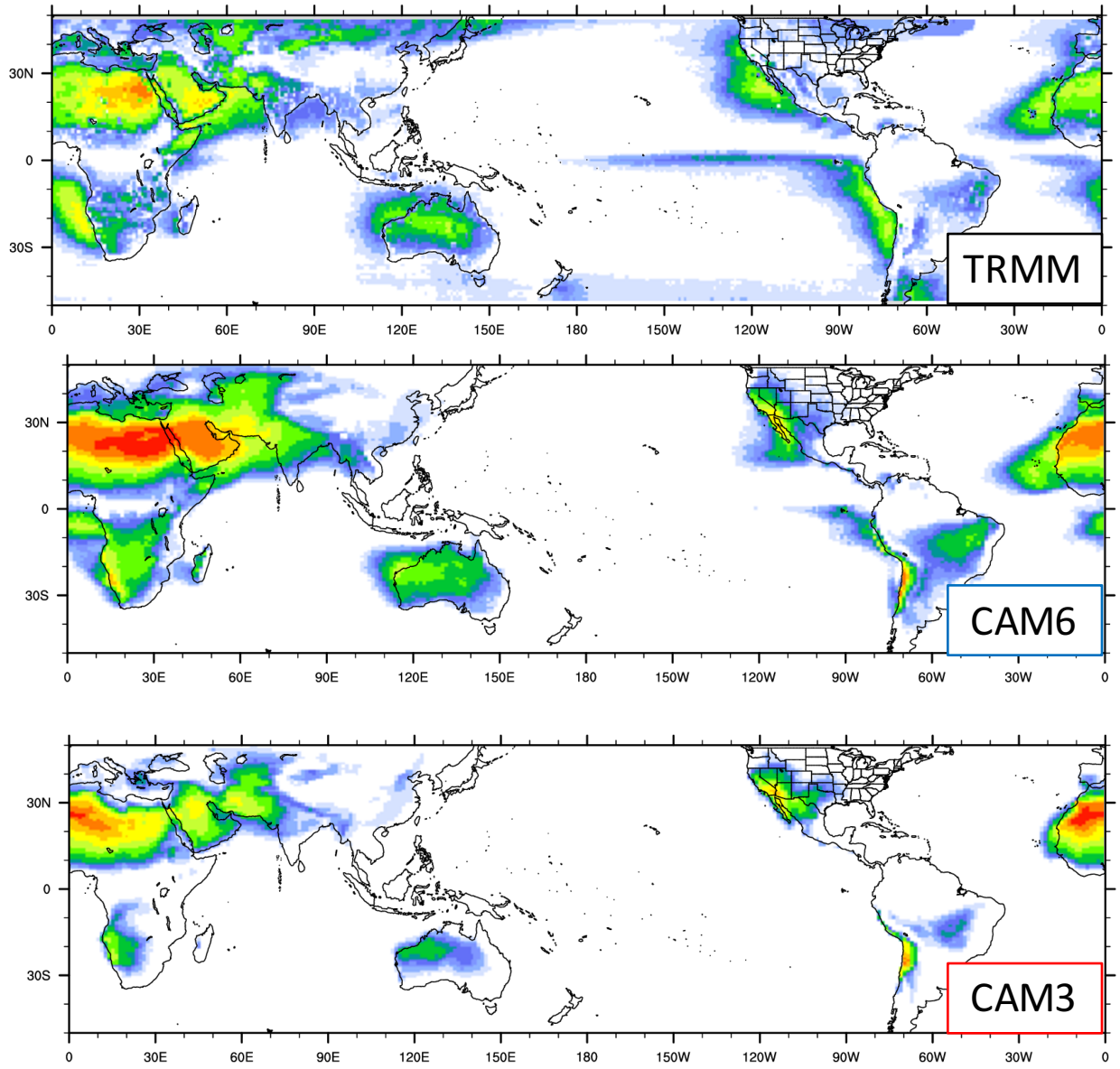
Precipitation Distributions: Resolution?

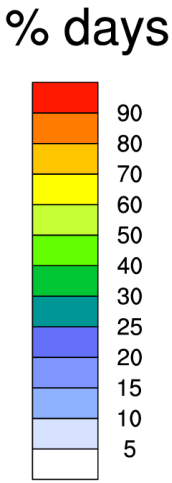




- CAM5 example
- 100km -> 25km (HR)
- Not a factor
- Convective parameterization issues

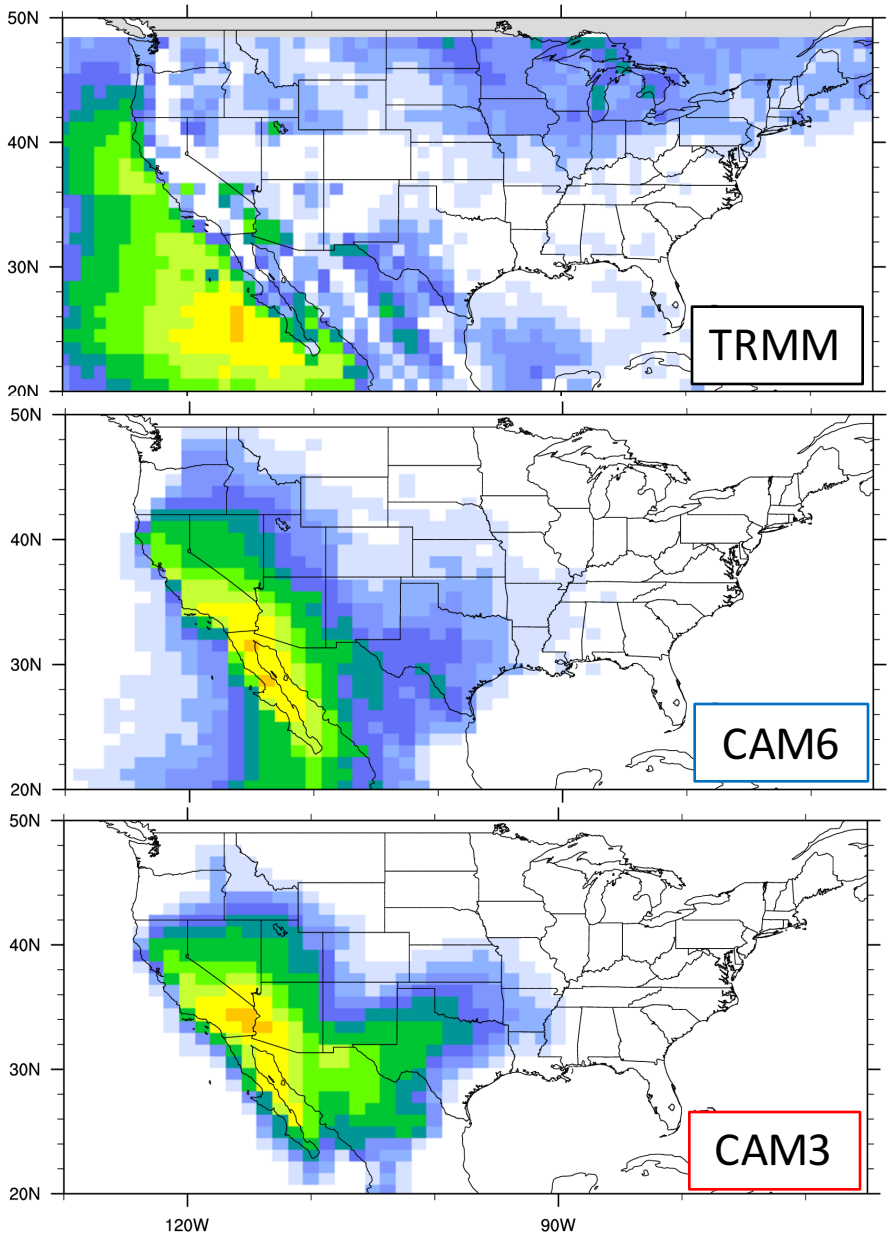
Precipitation >10-day dry, %days

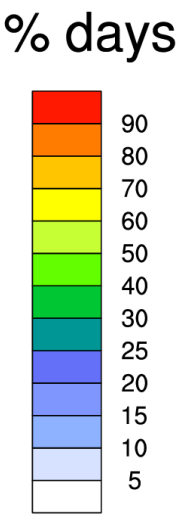




- No model drought over ocean!
- Recent increased dry periods in CAM6
- Too lengthy dry periods in dry regions

Precipitation >10-day dry, %days





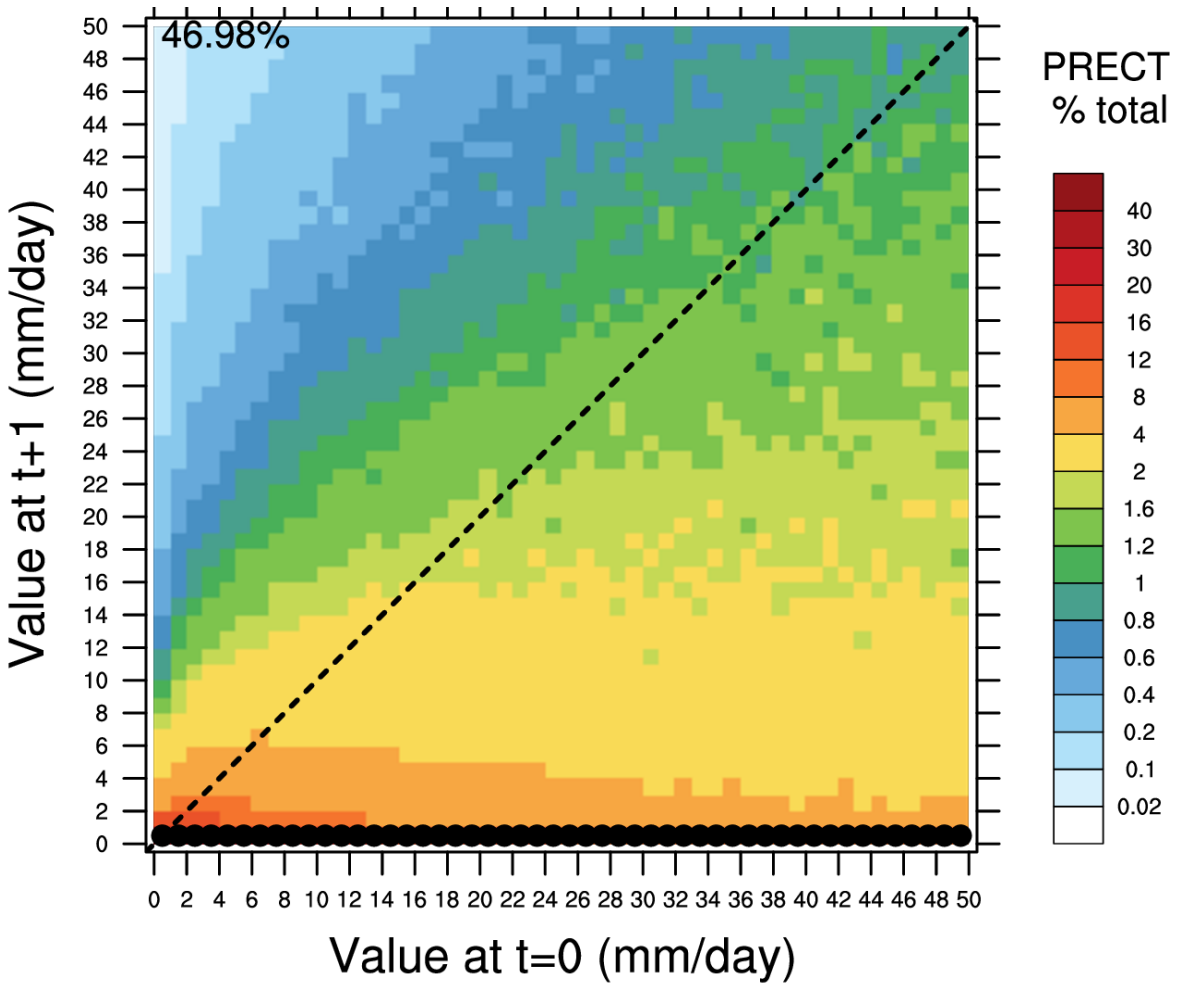
- Large land versus ocean contrast with observations
- Strong California extended dry periods in CAM
- Great lakes dry region missing
- CAM6 dry regions over ocean

Precipitation Succession

How does future precipitation relate to the current time?

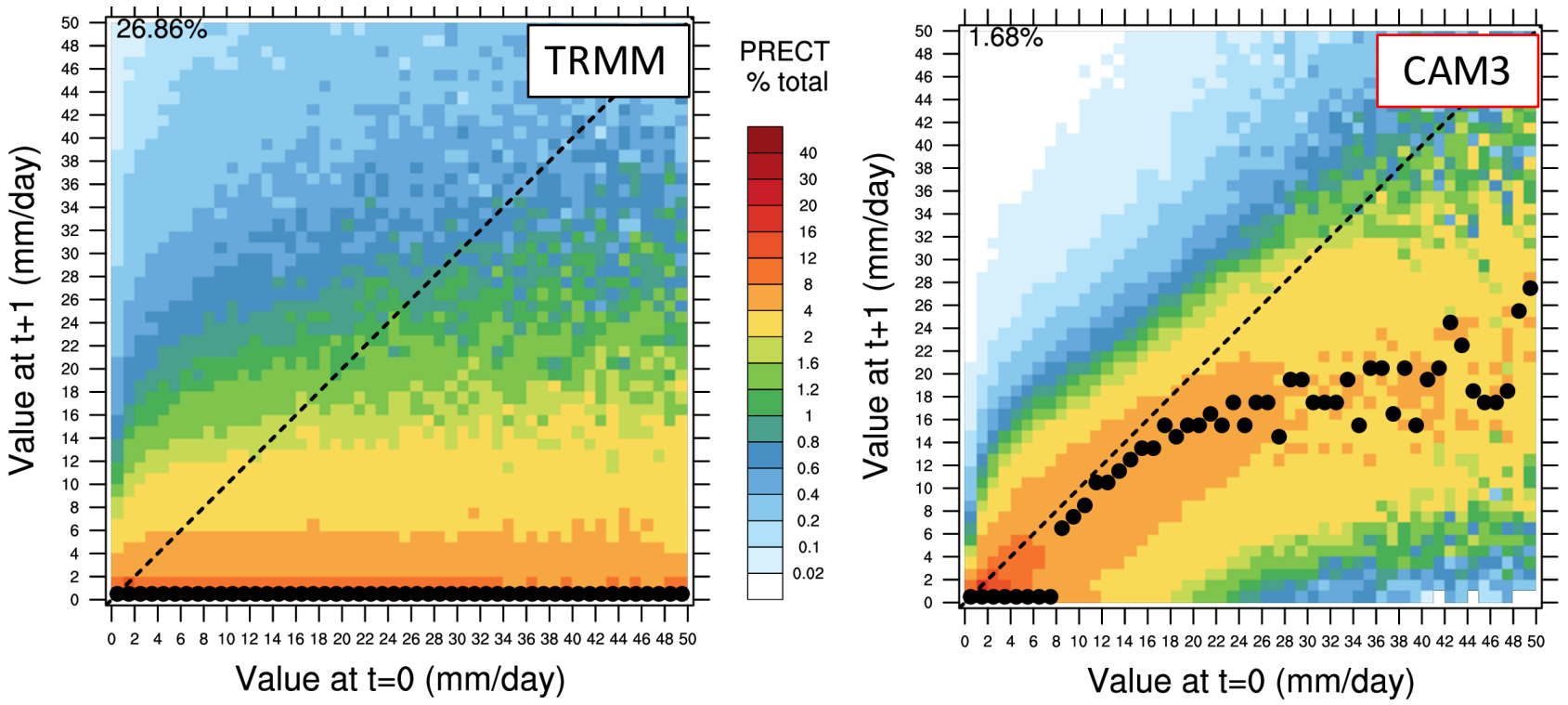
- Total precipitation (mm/day)
- Daily
- 1 deg (~100 km resolution)
- A years worth of data
- USA

- Probability density function (y-axis) of next precipitation rate for each bin (x-axis)



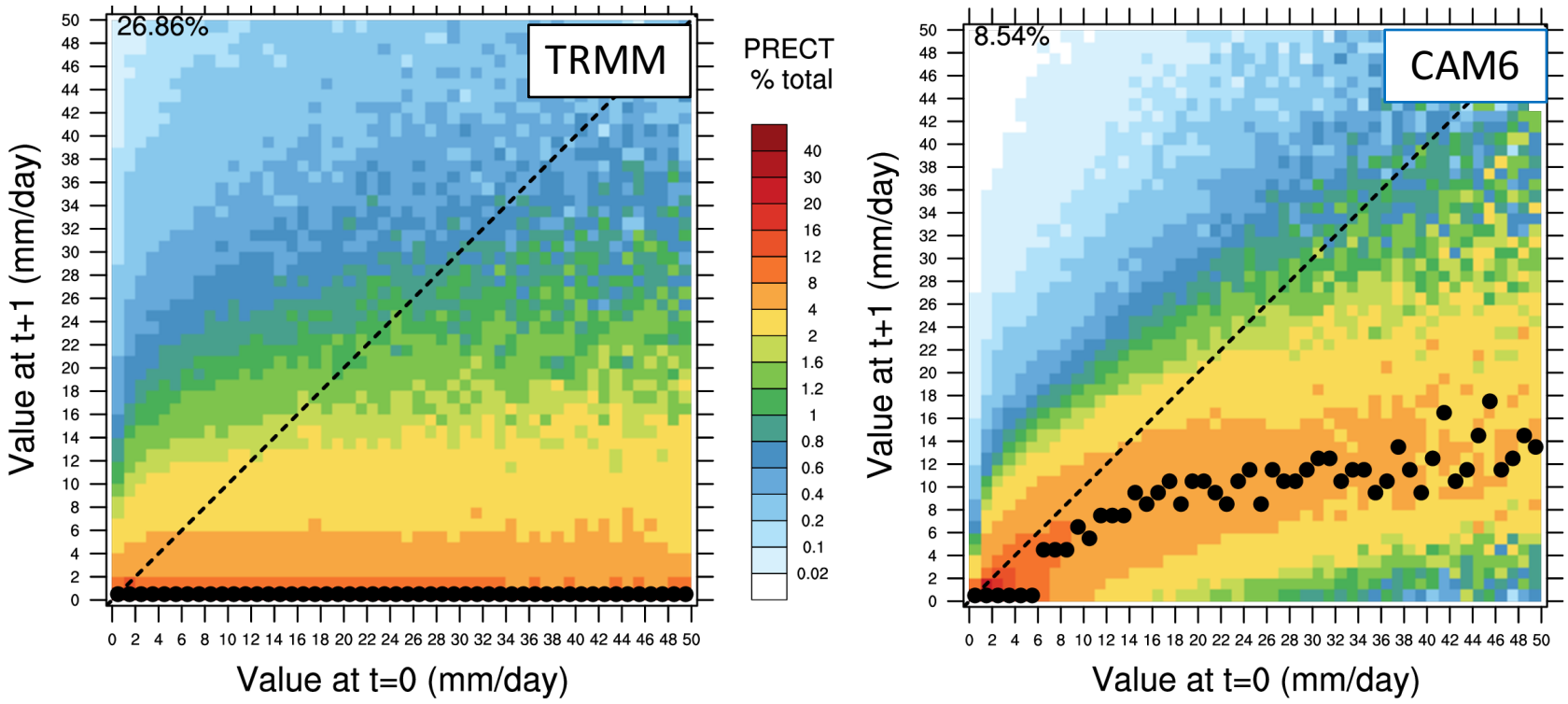
Klingaman, N. P., Martin, G. M., and Moise, A.: ASoP (v1.0): a set of methods for analyzing scales of precipitation in general circulation models, Geosci. Model Dev., 10, 57-83, https://doi.org/10.5194/gmd-10-57-2017, 2017.

Rate Succession



- They're more than a bit different !!
- Zero followed by zero rainfall is much less frequent
- It is most likely that the +1 day rainfall rate is the same is the initial rate
- e.g., Persistent in time
- This model can simulate a soup of precipitation in space and time
- Other models (e.g., CMIP5) can give similar distributions

Rate Succession



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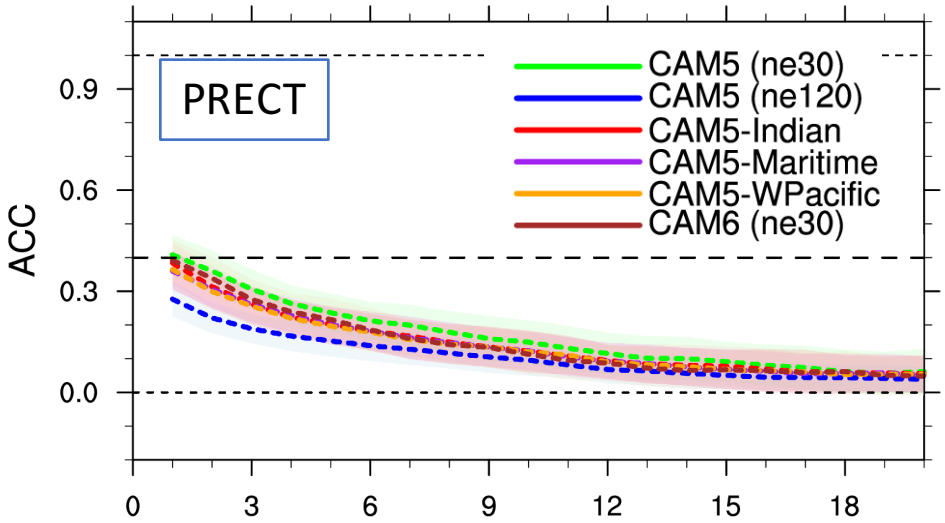
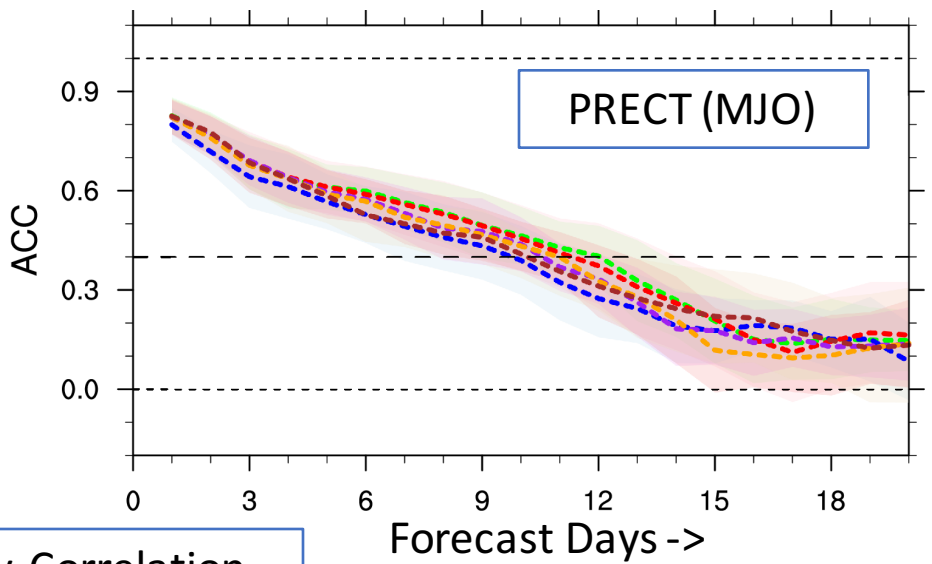
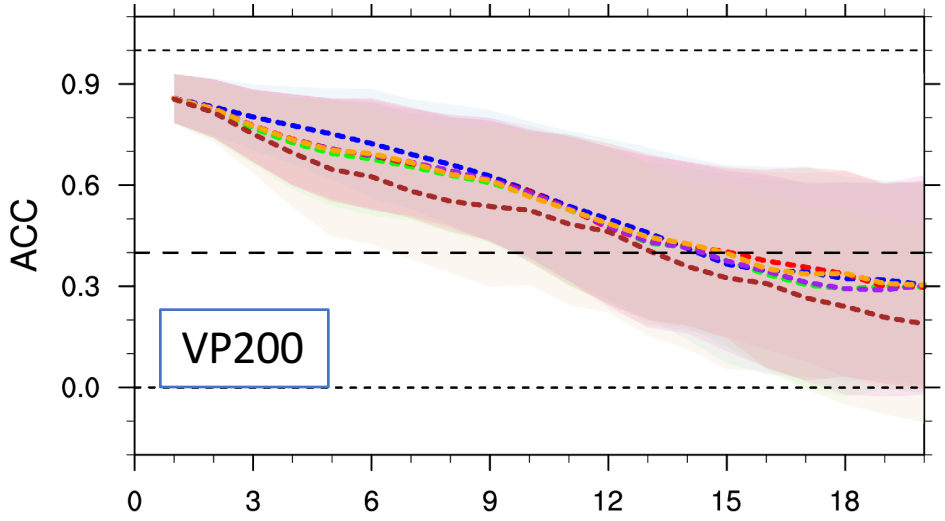
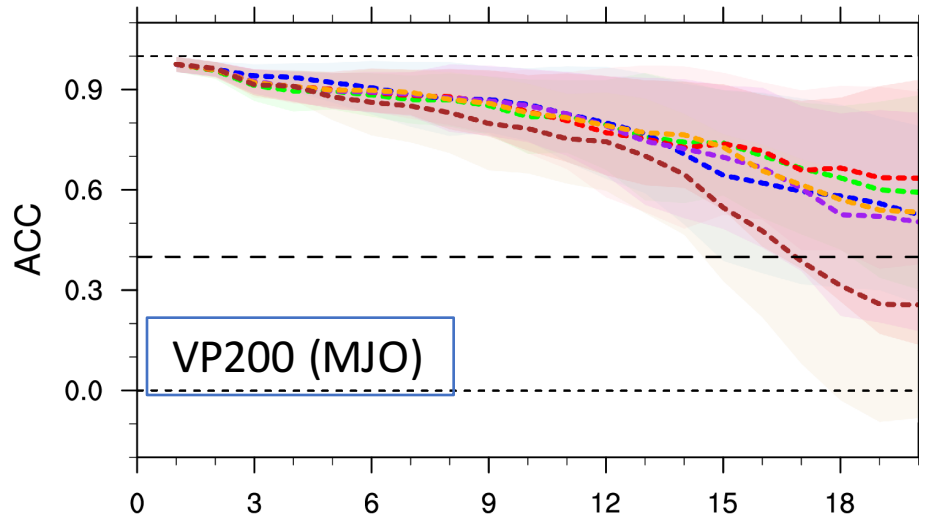
Hindcasts: A good start?





Tropics: 30N-30S

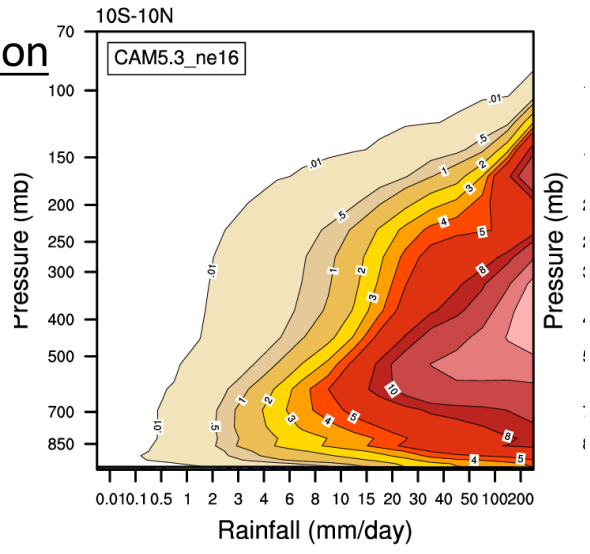




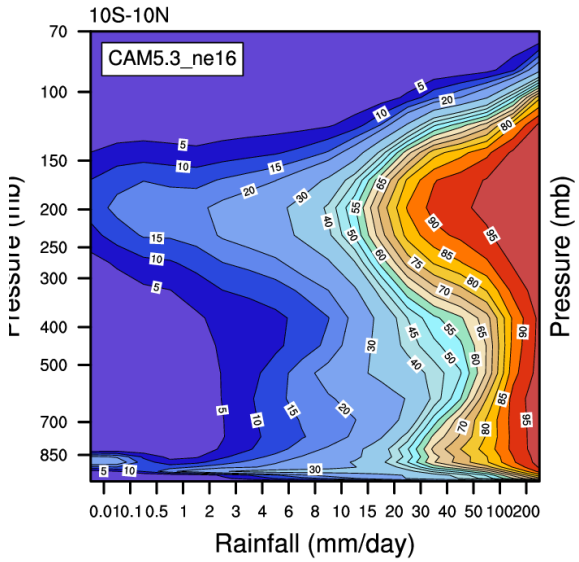
Summary

- Models may now be good enough for some useful S2S prediction
- Precipitation processes on multi timescales are still lagging
- Drought epochs are present in the model
- Are characteristics important for skill?
- Global modeling has tradeoffs for resolution, processes, regional requirements that have to be considered
- Drought relevant precipitation/clouds/convection diagnostics

Convection

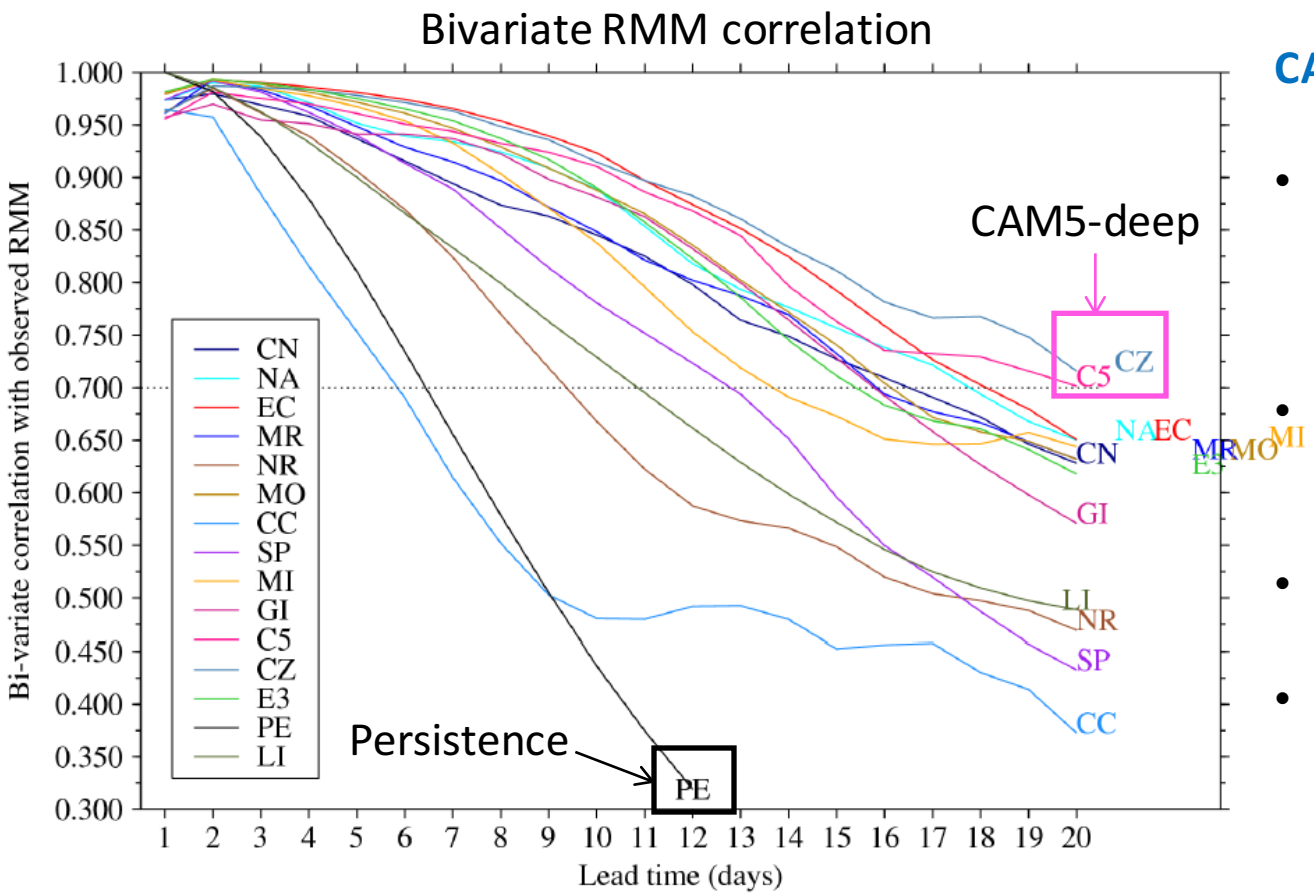


Relative Humidity



Thanks!

CAM Hindcast Skill



CAPT Simulations

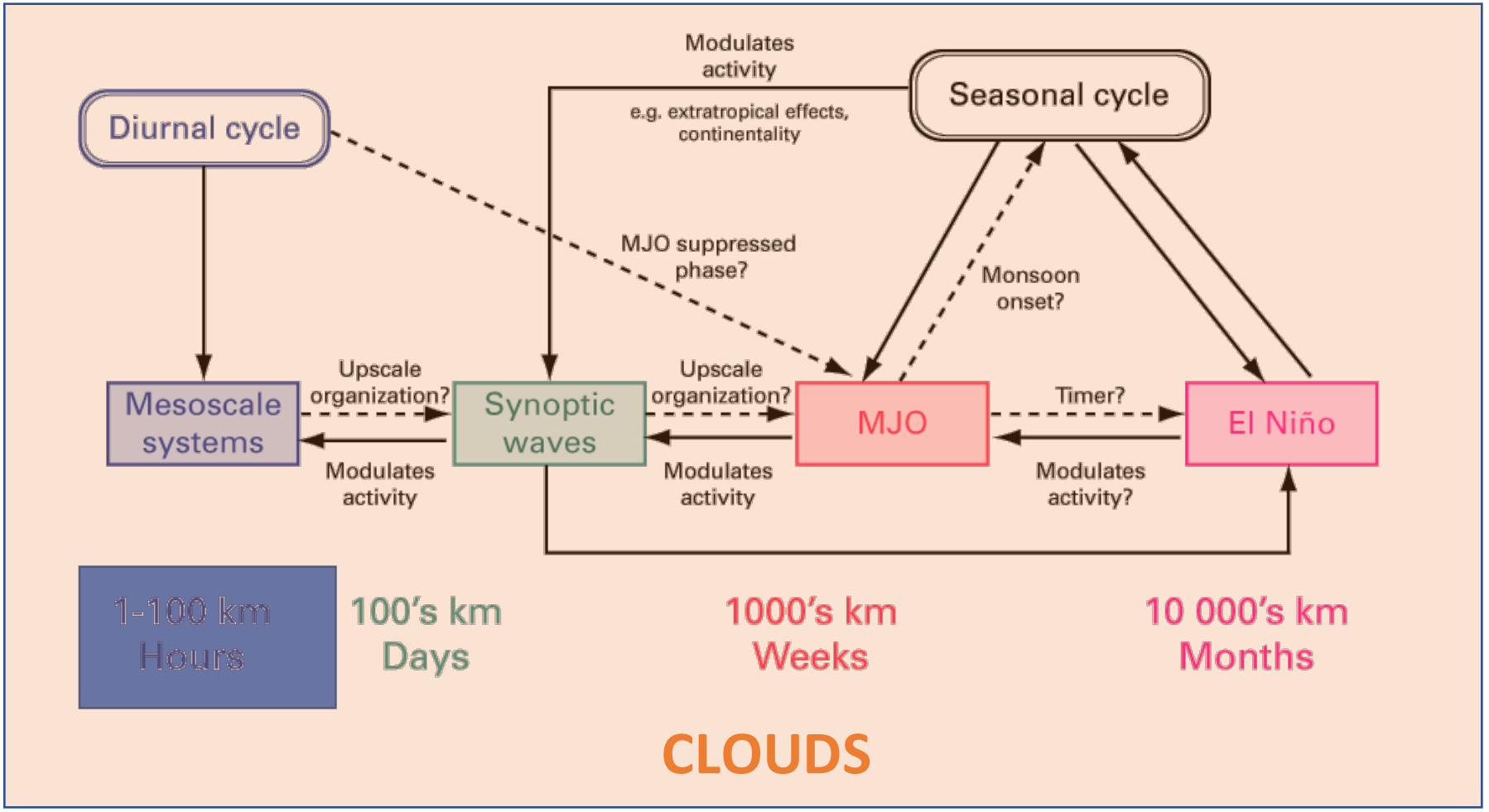
- Mean of daily forecasts During MJO-DYNAMO Campaign(2011-12)
- Combined bivariate mode of MJO variability (RMM)
- CAM5-deep only models to retain skill out to 20 days
- In contrasts to AMIP simulations!

Klingaman et al., 2015

- Droughts are at least intra-seasonal and longer in timescale
- Yet cloud scales are much shorter generally < 1 day
- Is there any direct linkage between these timescales
- Understanding how models perform at these short timescales is key to improving drought prediction and simulation on all timescales
- Local and non-local influences
- Tropical precipitation->large-scale heating from clouds
- US precipitation->no heating from clouds
- Climate model perspectives

- This is a drought prediction conference
- I don't do prediction
- BUT I do make and look at many past prediction from the perspective of improving intra-seasonal prediction
- We have to get everywhere right in a global model
- We get MJO/ENSO improvements from processes that act on the small scales
- I know nothing about stakeholders
- BUT what does this tell us about Flash Droughts ???

CAM Hindcast Skill



Representation of clouds and cloud processes (rain) is a key ingredient for prediction