Can Regional Climate Models Improve Summer Climate Forecasts in North America?

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Presentation Outline

Current state and seasonal climate forecasting for warm season

Retrospective CFS Reforecasts

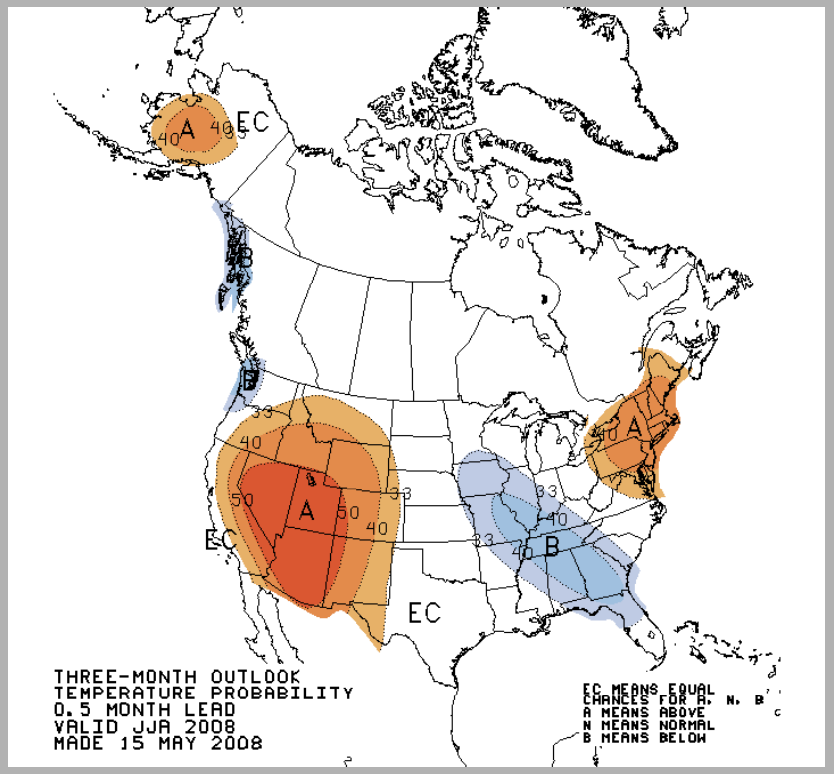
Value added of RCMs in representing warm season climate

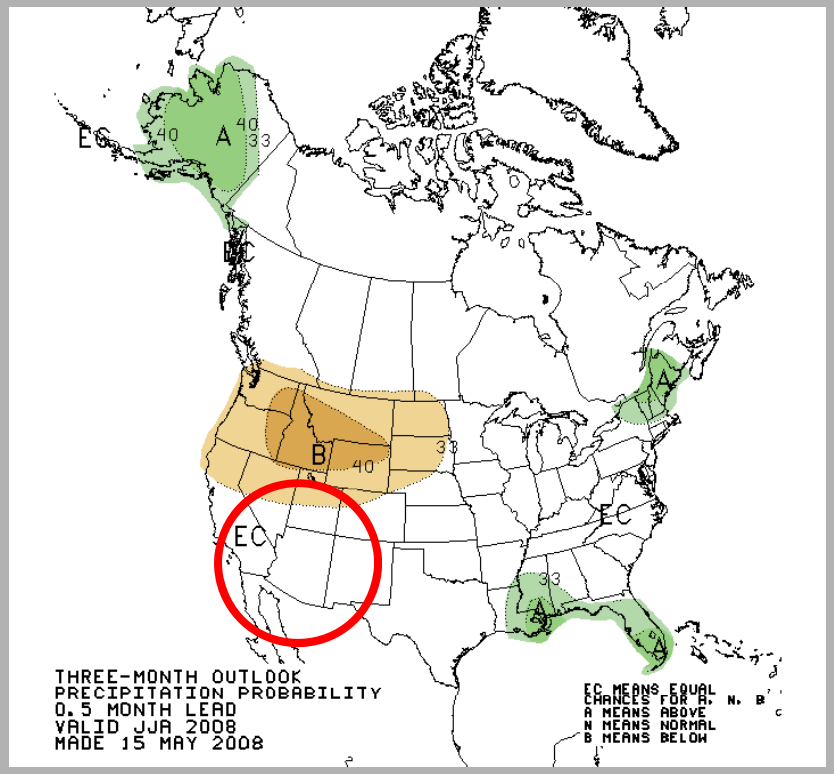
Dynamical downscaling procedure for CFS reforecasts

Preliminary results and conclusions for 1988 and 1993, ongoing work

Acknowledgements: Jae Schemm and Henry Juang from NCEP for CFS data acquisition. Research supported by NSF.

Current state of NCEP seasonal forecasts
Example for previous summer 2008





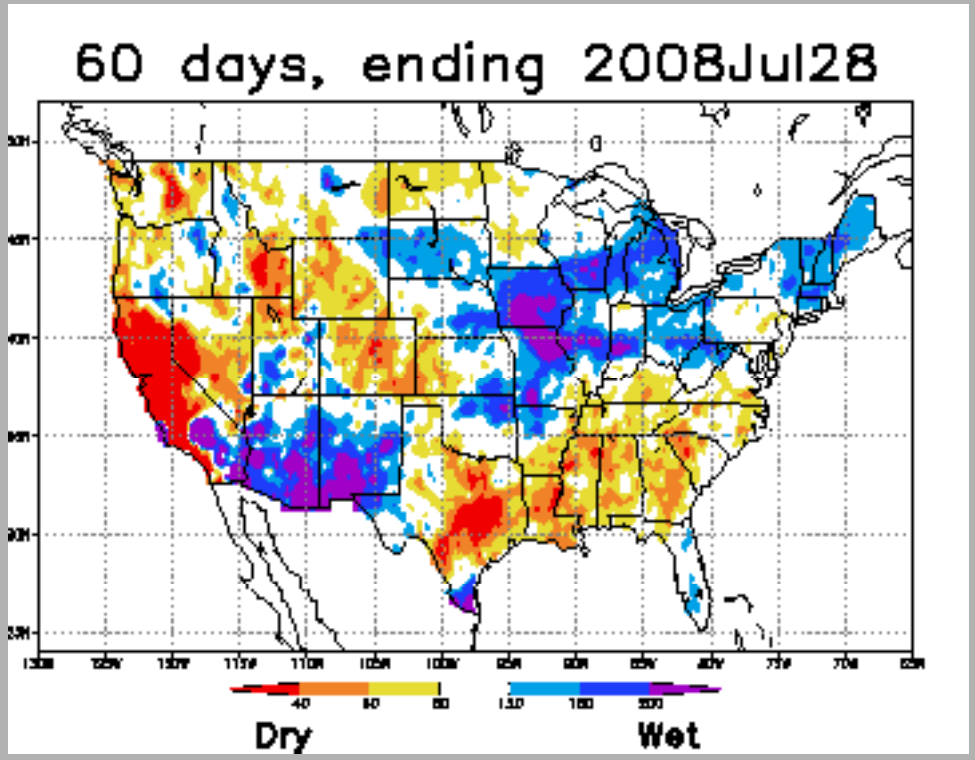
Temperature forecasts are becoming more dominated by long-term trends, probably due to climate change.

“Equal chances” for monsoon precipitation in the Southwest.

http://www.cdc.noaa.gov

Why do CFS global model seasonal forecasts have less skill in the warm season?

2008 June and July precipitation anomalies



(Climate Diagnostics Center)

<u>Two possible reasons:</u>

Global forecast model do not capture the large scale circulation anomalies that lead to rainfall anomalies (i.e. incorrect teleconnections)

AND/OR

Global forecast model cannot resolve physical processes related to summer precipitation in the western U.S.

Retrospective Climate Forecast System (CFS) Ensemble Reforecasts

(Saha et al. 2006, *J. Climate*)

Length of CFS reforecast period: 1982-present

For each reforecast year, ensemble of approximately 10-15 produced, generated by different initializations of NCEP Reanalysis 2 at the beginning of each month.

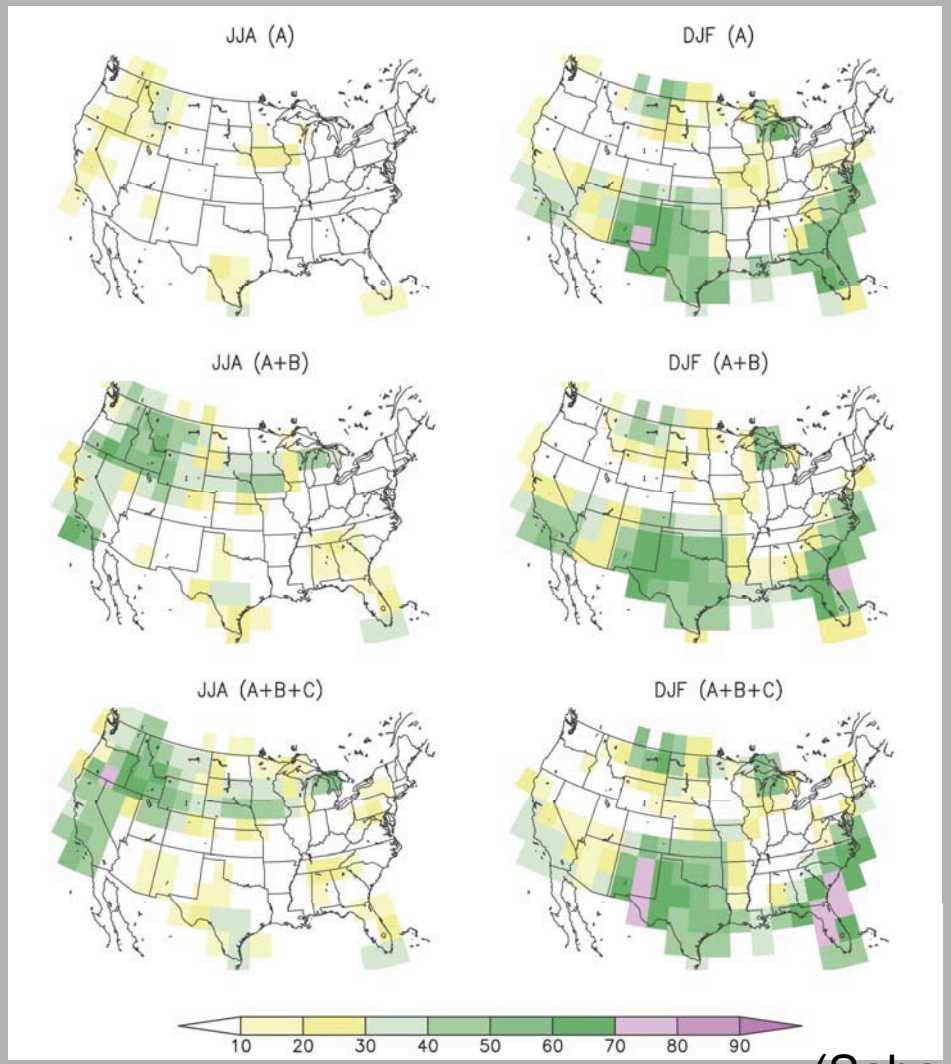
Primary purpose is to evaluate the climatological biases of the model in a hindcast mode for improved operational forecasting.

Additionally these data are being used as lateral boundary forcing for dynamical downscaling of seasonal forecasts.

Multi-RCM ensemble downscaling (MRED): Winter

Our UA NSF-funded research: Summer

CFS Model Anomaly Correlation: precipitation



Winter:

Some skill due to large-scale teleconnection patterns related mainly to Pacific SST forcing.

Summer:

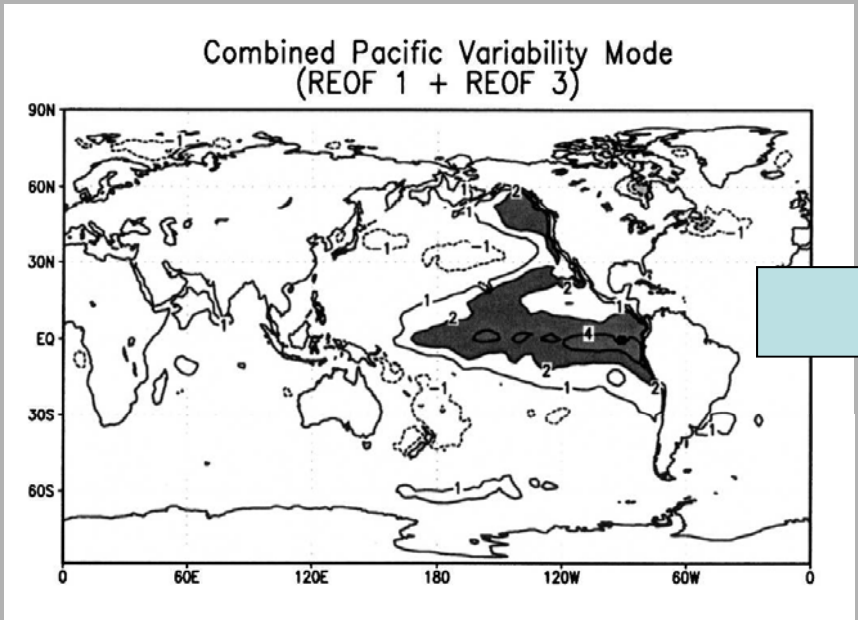
Little skill because of poor representation of convective rainfall processes

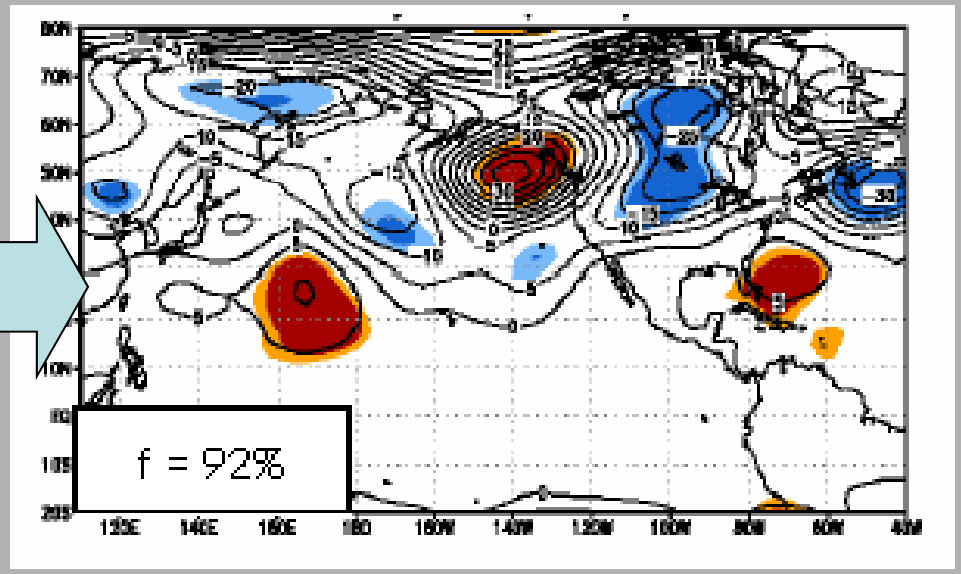
BUT…large-scale teleconnections in early summer may be there…

(Saha et al. 2006)

Early summer teleconnections related to Pacific SST

500-mb height anomalies
(For positive phase of mode)

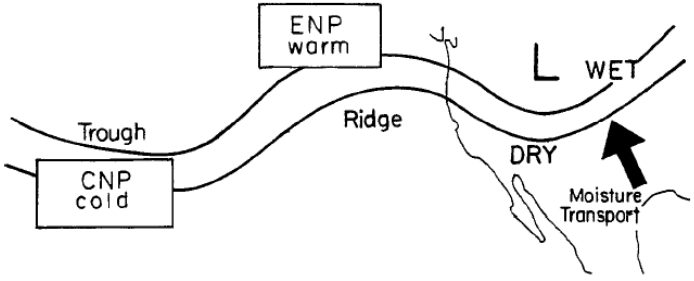




Castro et al. (2007, *J. Climate*)

IF **early summer teleconnetions are present in the seasonal forecast model, dynamical downscaling with a RCM may have great promise to improve a seasonal forecast.**

Monsoon Ridge Position at Onset (Late June, July)



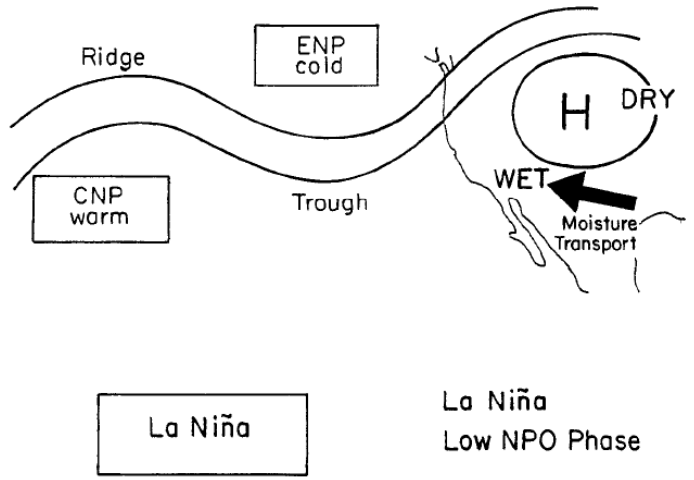


FIG. 14. Idealized relationship of monsoon ridge position and midlevel moisture transport to Pacific SSTs at monsoon onset.

Climatology delayed

Climatology accelerated

(Castro et al., 2001)

Some a priori expectations for RCM dynamical downscaling

A RCM should:

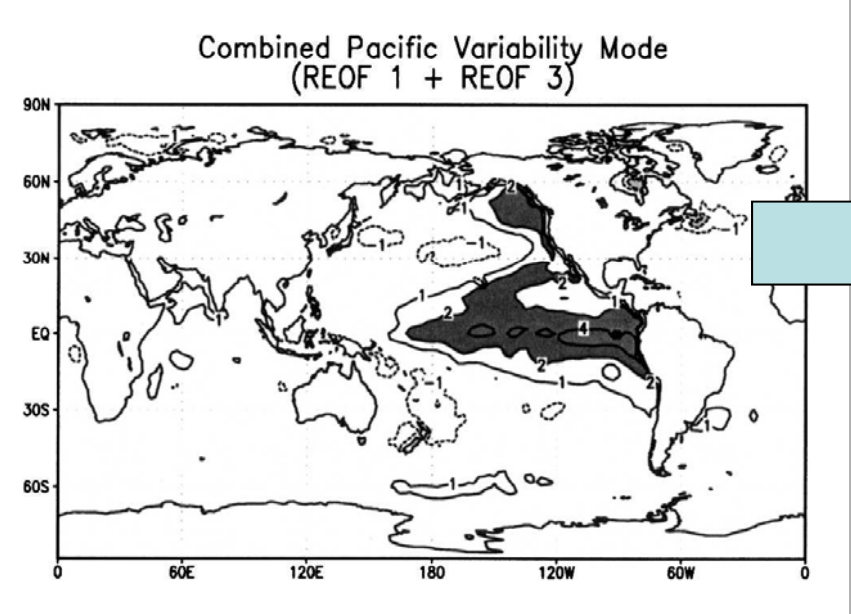
1. **Retain or enhance variability of larger-scale features provided by the driving global model (i.e. those on the synoptic scale)**

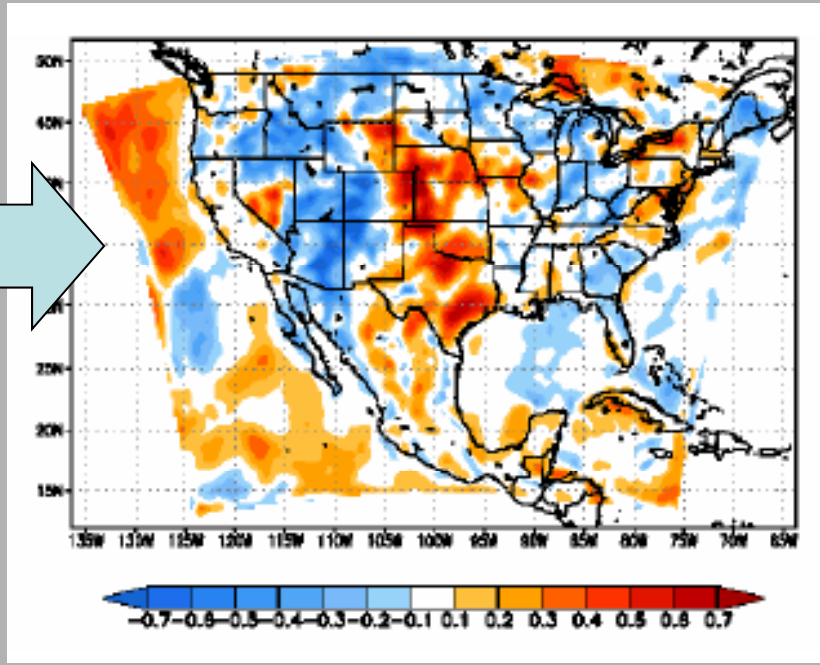
2. **Add information on the smaller scale because of increase in grid spacing, finer spatial scale data (e.g. terrain, landscape) and possibly differences in model parameterized physics.**

3. **Add information that is actually of value, as demonstrated by comparing RCM results with independent metrics**

RCMs capture monsoon interannual variability <u>very well</u> when downscaling retrospective reanalyses

Change in strength of diurnal cycle of convection simulated by a RCM (For positive phase of mode)





Will it work too for dynamical downscaling of CFS seasonal forecasts?

Use of WRF for Downscaling of CFS Reforecasts for Warm Season

The version of WRF we use is the Advanced Research WRF (ARW)

Model physical parameterizations consistent with those of the existing WRF NWP System at UA. Use NARR soil moisture as an initial condition.

Summer reforecasts specifically start at the beginning of April, May, or June of the given year. WRF simulations start at beginning of May or June and end in August. Only 3 ensemble members available per initialization period, unfortunately!

Data from NCEP reanalysis 2 is also being dynamically downscaled to assess the performance of the RCM assuming "perfect" boundary forcing.

The domain for these simulations covers the contiguous U.S. with a grid spacing of 32 km.

Spectral nudging

Applied at scales greater than 4Δx of driving global model for winds, heights, temps.

NECESSARY FOR RCM-TYPE SIMULATIONS!

Form of nudging coefficients for a given model variable in spectral domain:

$$\sum_{j=-J_a,k=-K_a}^{J_a,K_a} \eta_{j,k}\left(\alpha^{a}_{j,k}(t)-\alpha^{m}_{j,k}(t)\right)e^{ij\lambda/L_\lambda}\,e^{ik\phi/L_\phi}$$

$\alpha^{a}_{j,k}(t)$ **Fourier expansion coefficients of variable in driving larger-scale model (*a*)**

$\alpha^{m}_{j,k}(t)$ **Fourier expansion coefficients of variable in the regional model (*m*)**

$\eta_{j,k}$ **Nudging coefficient. Larger with increasing height.**

All reforecast downscaling completed as of early September!

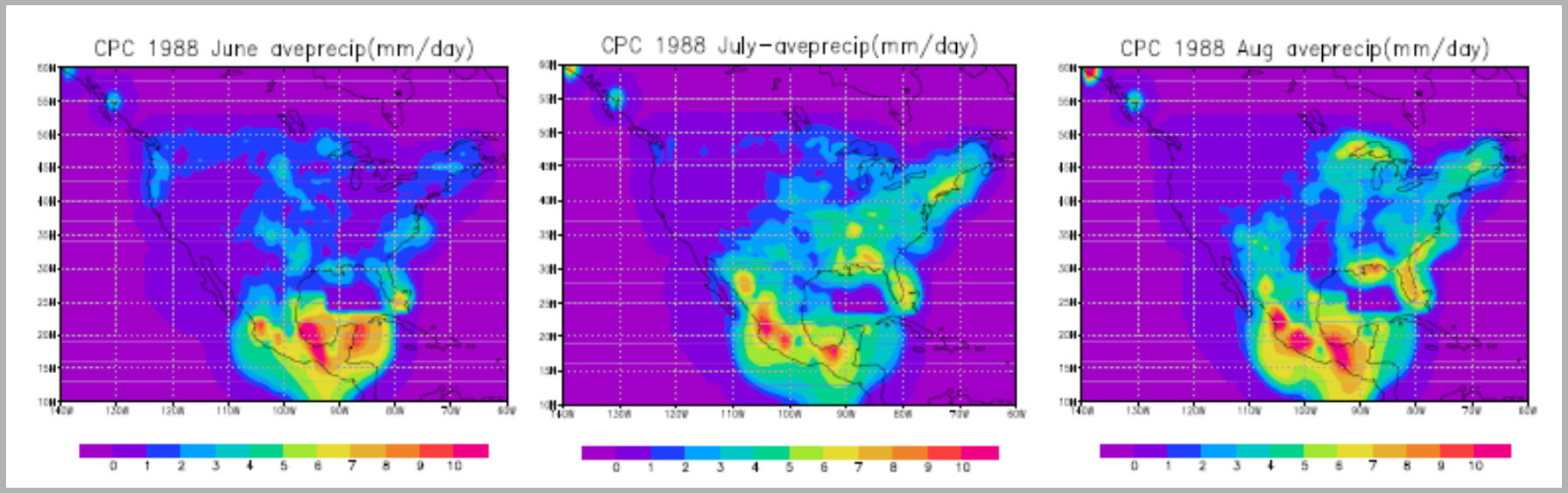
4 Terrabytes worth of data to analyze!!

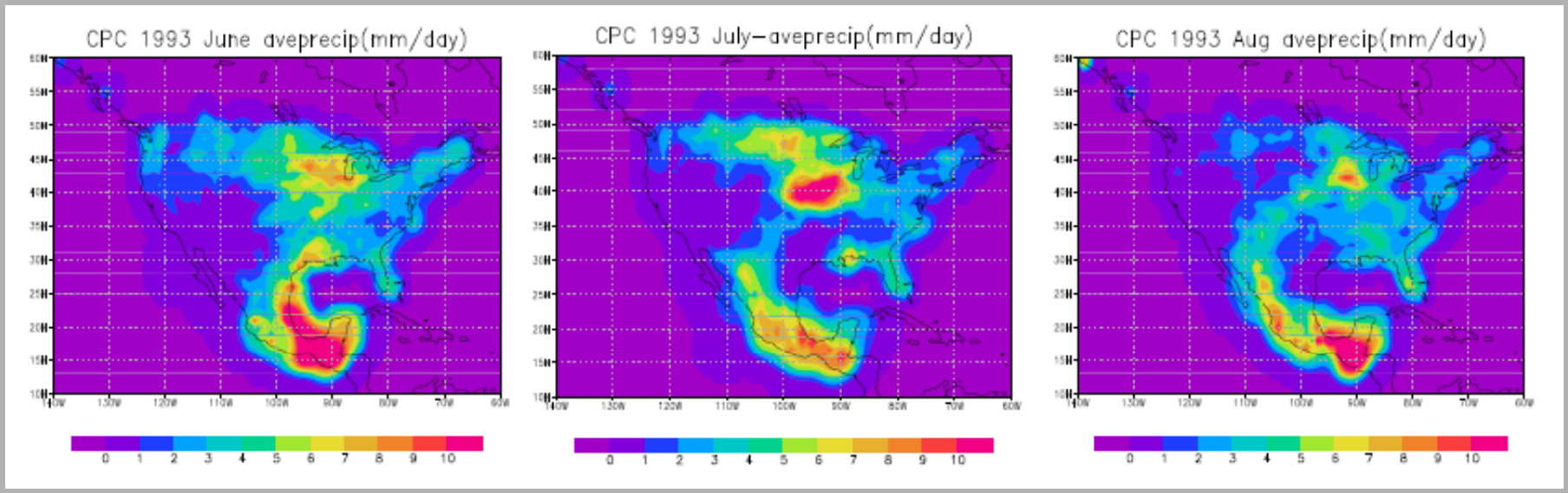
Start with 1988 and 1993

Classic extreme early summer conditions

Capture well-known opposite phase relationship between monsoon and central U.S. precipitation associated with Pacific-SST driven summer teleconnections.

1988 and 1993 JJA Monthly CPC observed monthly rainfall (mm day^{-1})





Preliminary questions

Is WRF spectral nudging necessary to retain the large-scale variability?

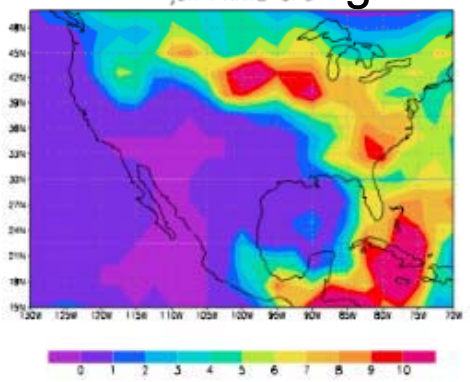
Are large-scale teleconnections there?

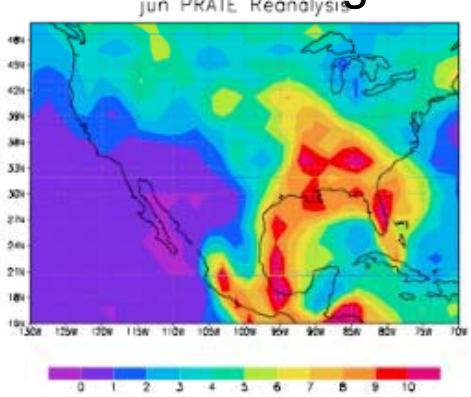
Does downscaling add value to CFS global reforecasts? Of particular interest, are we getting a monsoon in the southwest?

CFS member Downscaling

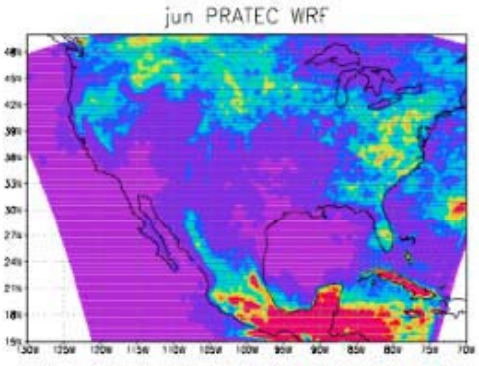
NCEP Reanalysis: Downscaling

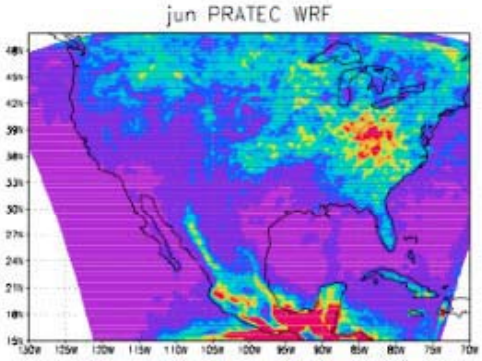
Original Global model



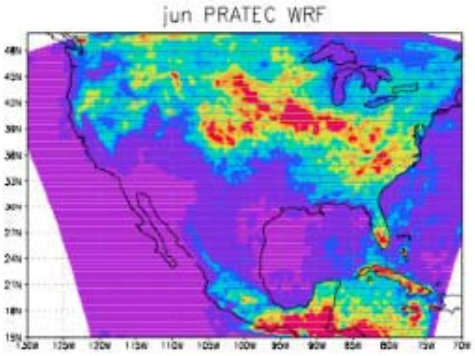


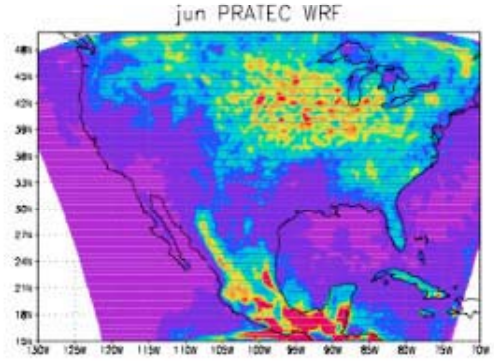
WRF Lateral boundary nudging only





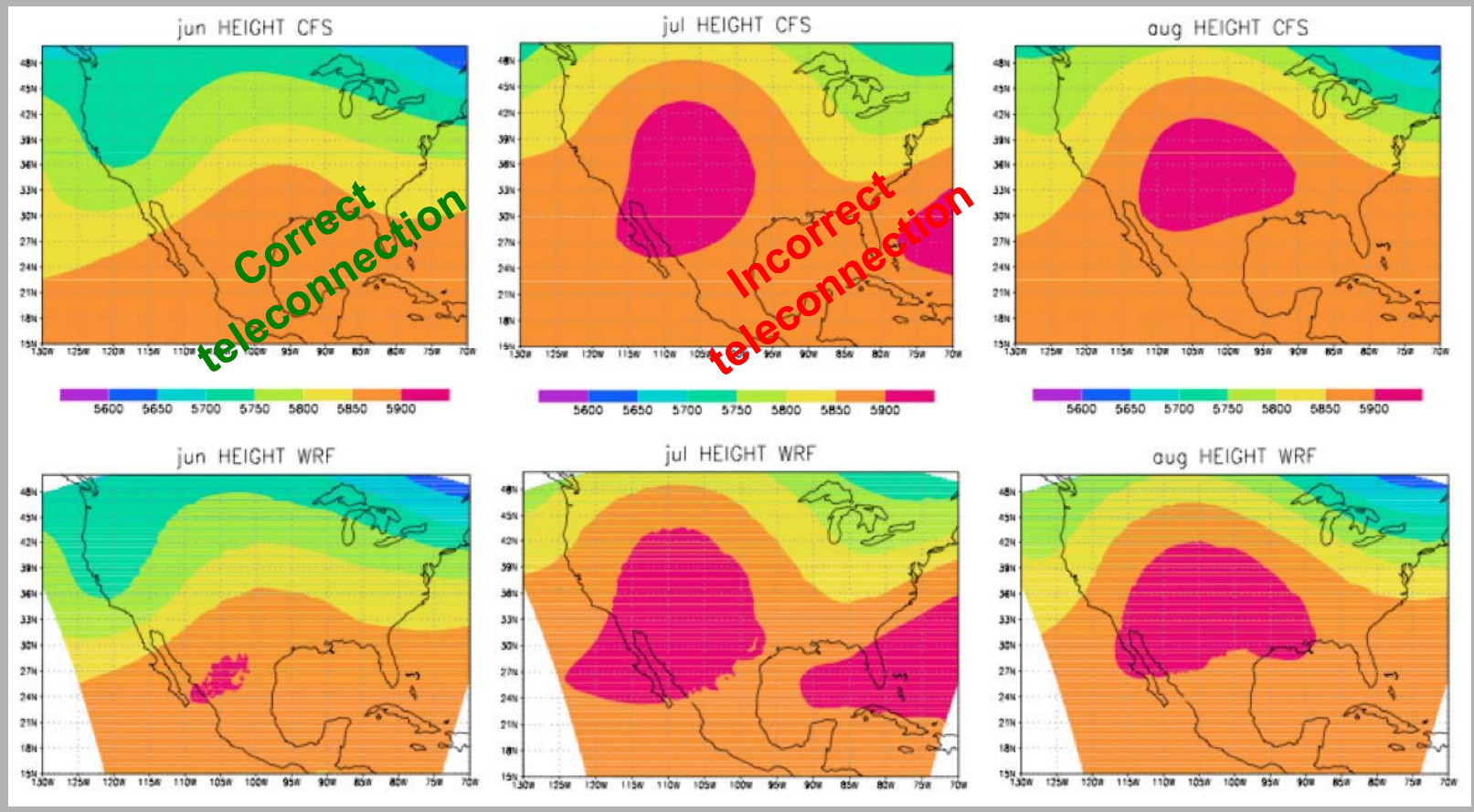
WRF Spectral nudging



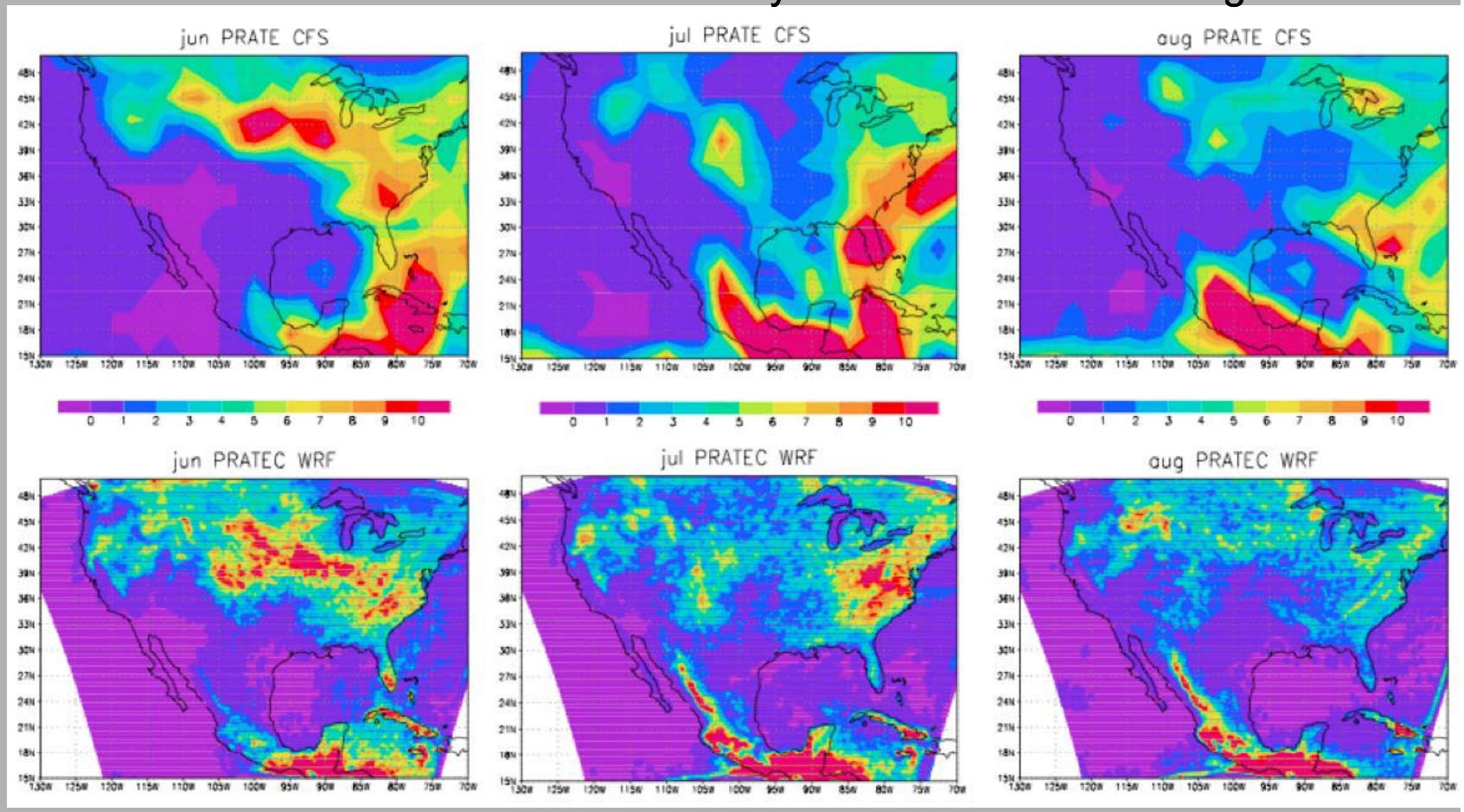


June precipitation solutions (mm day^{-1})

1993 Summer 500-mb heights (m)
Original CFS vs. WRF Downscaled
(May initialization, one ensemble member)

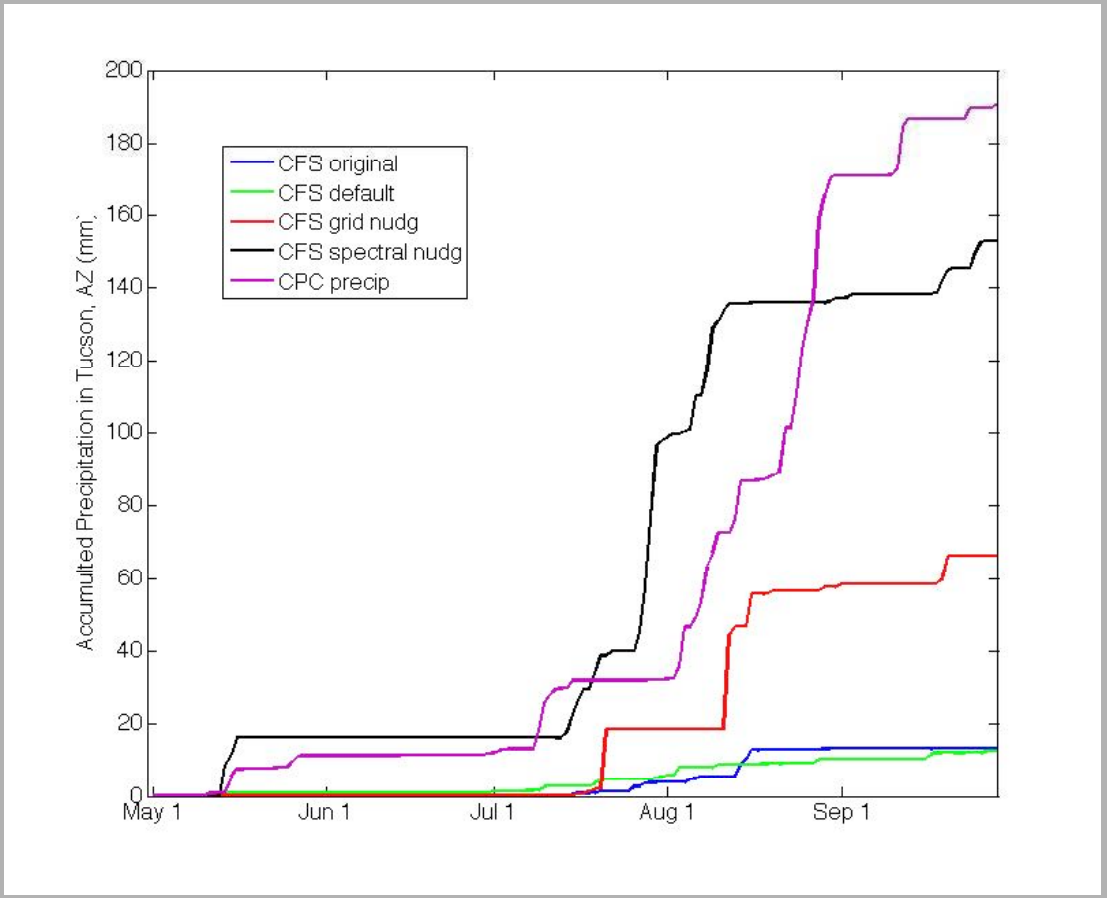


1993 Summer Precipitation (mm day^{-1})
Original CFS vs. WRF Downscaled
May initialization, one ensemble member



1993 Summer precipitation Tucson, AZ

Single CFS ensemble member initialized in May

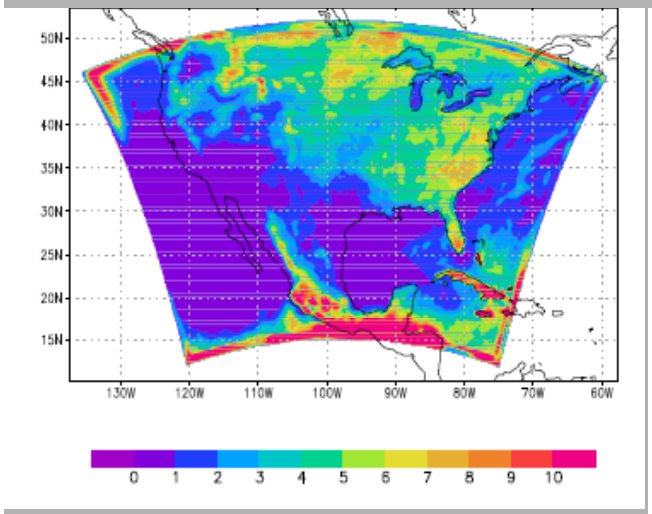


WRF downscaled simulation with spectral nudging gives best result!

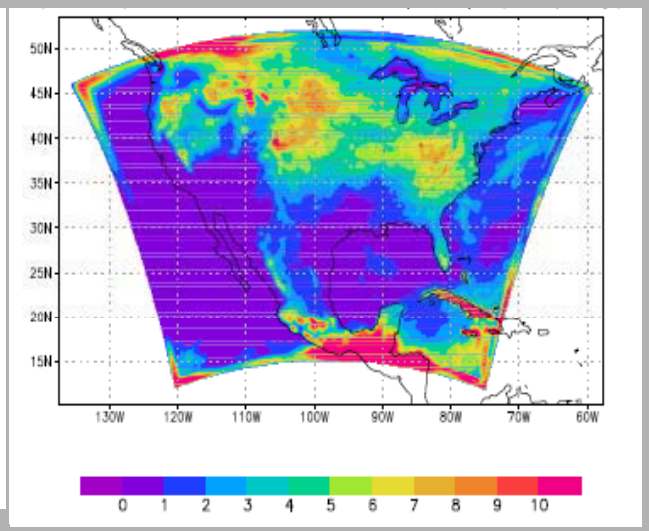
Original CFS model HAS NO MONSOON!

WRF-CFS ensemble precipitation
3 members per initialization
June 1988 (mm day^{-1})

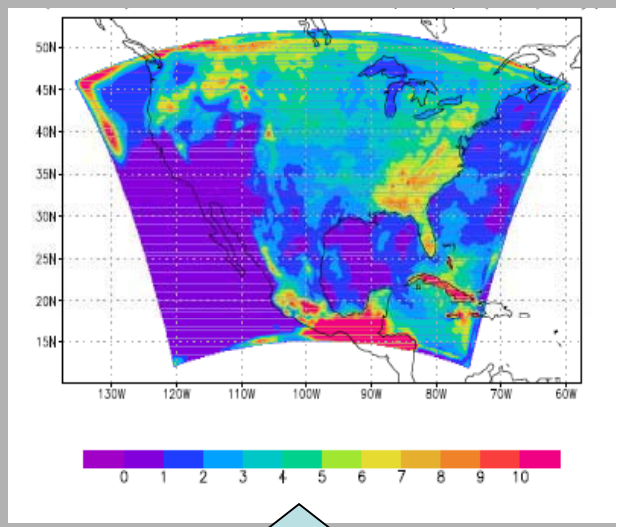
April initialization



May initialization



June initialization

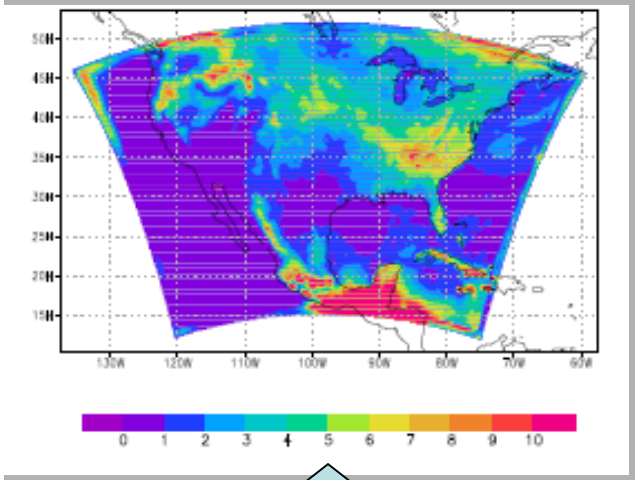


Too wet in the central U.S.

Driest simulation in central U.S. and closest to reality

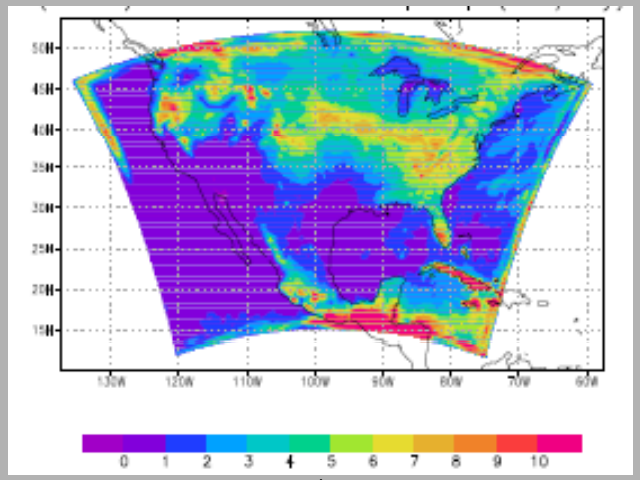
WRF-CFS ensemble precipitation
3 members per initialization
June 1993 (mm day^{-1})

April initialization



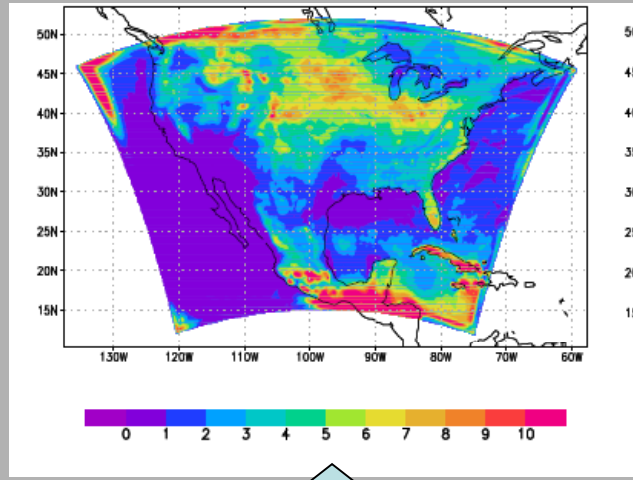
Driest in central U.S

May initialization



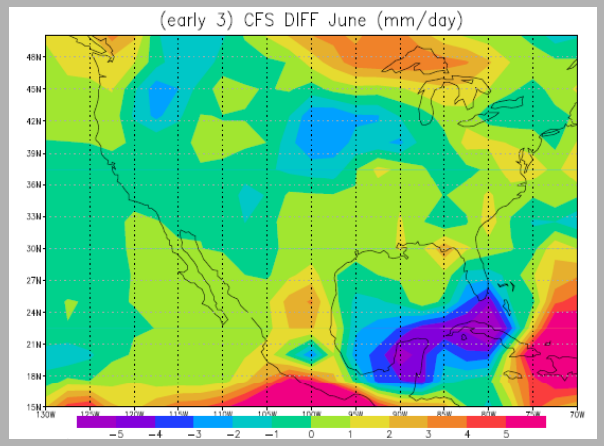
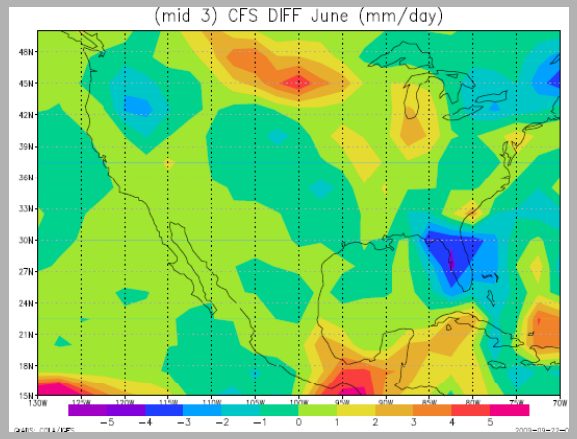
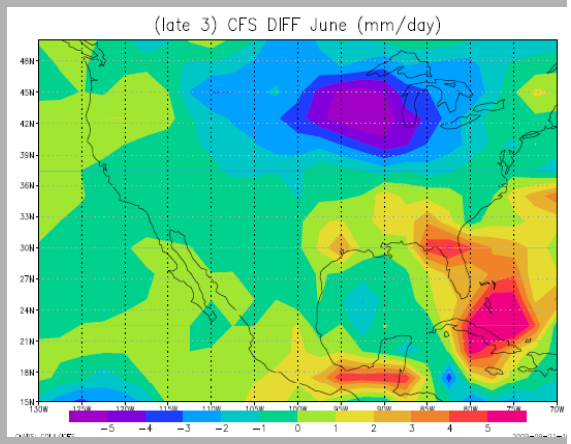
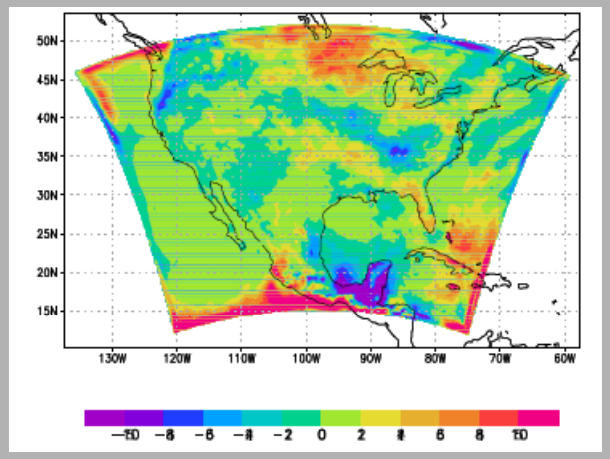
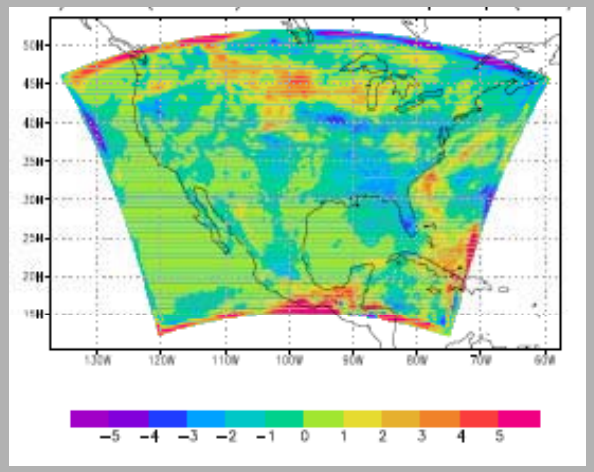
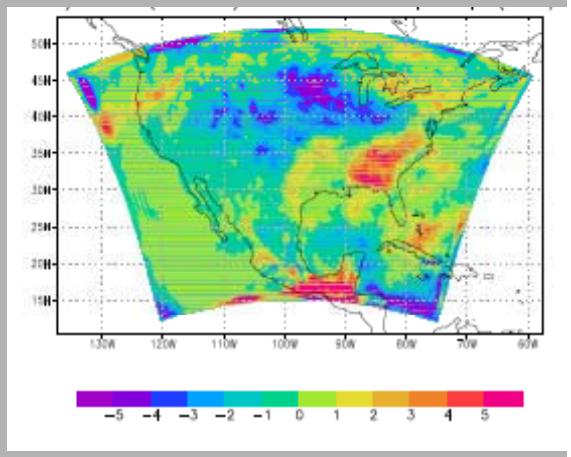
Wetter in central U.S.

June initialization



Wettest in central U.S. and closest to reality

1988 – 1993 June precipitation differences (mm day^{-1})

	April initialization	May initialization	June initialization
CFS			
WRF-CFS			

The coherent continental-scale pattern of precipitation anomalies associated with the early summer teleconnection patterns do not appear until June initialization.

Preliminary Results and Ongoing Work

1. If a RCM retains variability in the large-scale circulation fields from the driving global model through spectral nudging, it can potentially add value warm season forecasts. This is primarily realized by an improved representation of convective precipitation.

2. Provided #1, RCMs can add value to the representation of the CFS warm season climate provided the driving global model produces reasonably accurate teleconnection patterns.

3. CFS may have the large-scale teleconnections responsible for interannual variations in early summer rainfall. Results so far show better representation of teleconnections for CFS initializations closer to the forecast verification time.

   Entire suite of WRF-CFS simulations currently being analyzed…expect to have this completed and reported in the literature by sometime next year.