Use of the Weather Research and Forecasting Model Toward Improving Warm Season Climate Forecasts in North America

Christopher L. Castro[1] and Francina Dominguez[1,2]
[1]Department of Atmospheric Sciences
[2]Department of Hydrology
University of Arizona, Tucson, Arizona

ATMOSPHERIC SCIENCES
LIASCIENCE

Hydrology and Water Resources
The University of Arizona

Presentation Outline

Current state and seasonal climate forecasting for warm season

Retrospective CFS Reforecasts

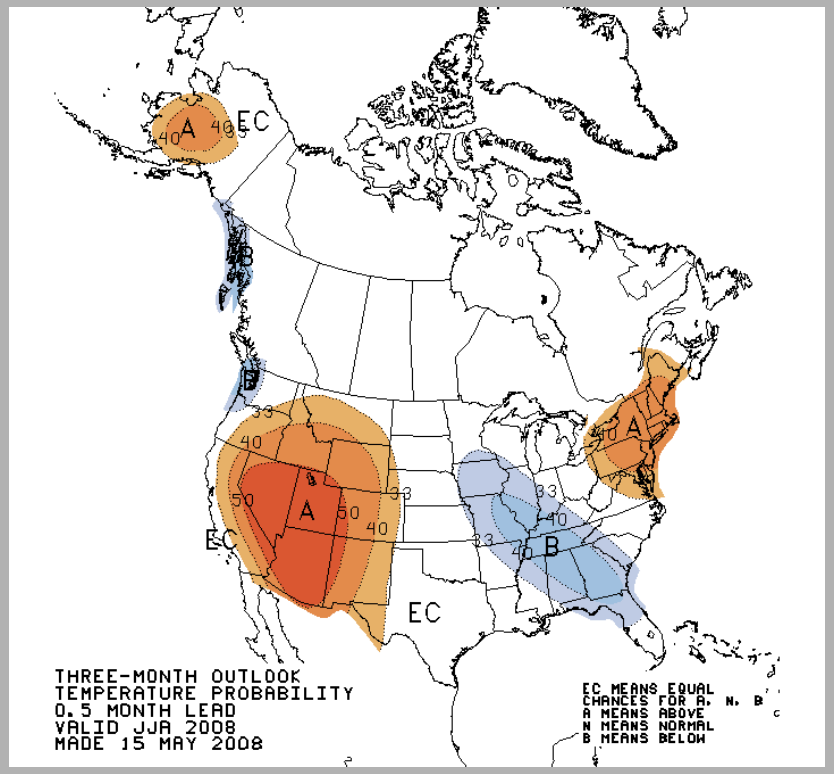
Value added of RCMs in representing warm season climate

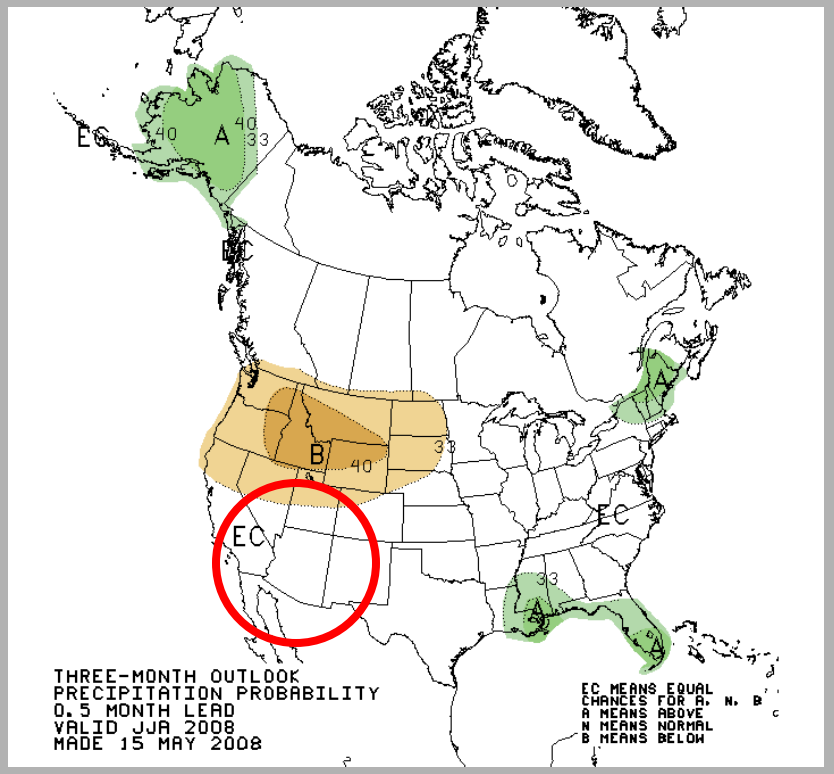
Dynamical downscaling procedure for CFS reforecasts

Preliminary results and ongoing work

What about this year's monsoon????

Current state of NCEP seasonal forecasts
Example for previous summer 2008





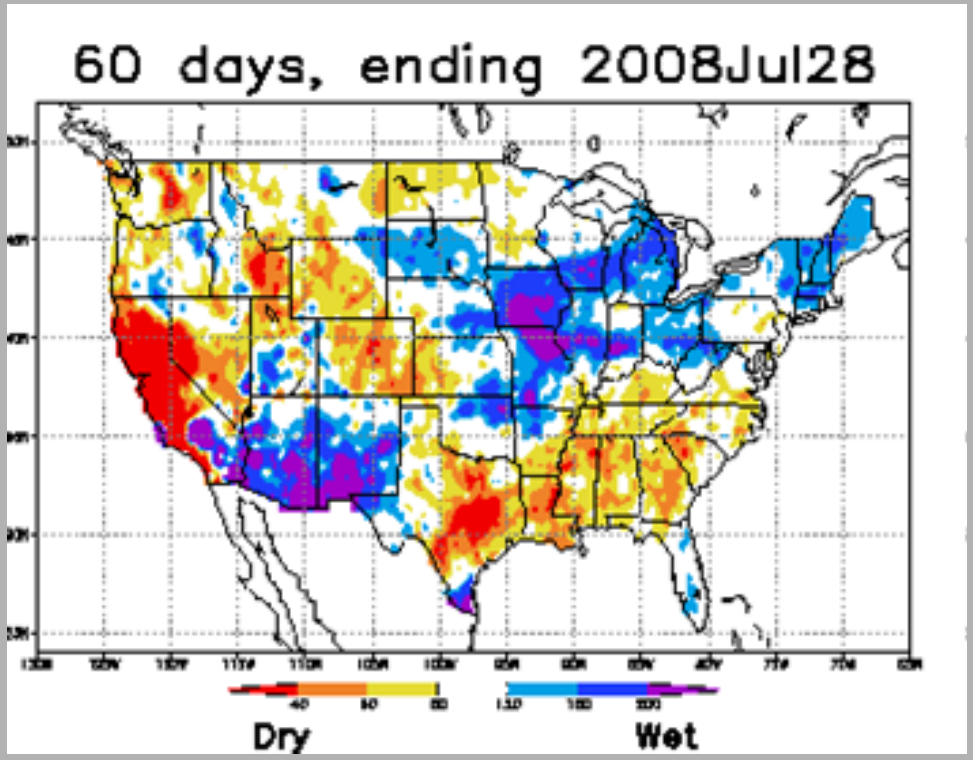
Temperature forecasts are becoming more dominated by long-term trends, probably due to climate change.

“Equal chances” for monsoon precipitation in the Southwest.

http://www.cdc.noaa.gov

Why did last year's monsoon forecast go wrong?

2008 June and July precipitation anomalies



(Climate Diagnostics Center)

Two possible reasons:

Global forecast model did not capture the large scale circulation anomalies that lead to increase rainfall.

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: 1981-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.

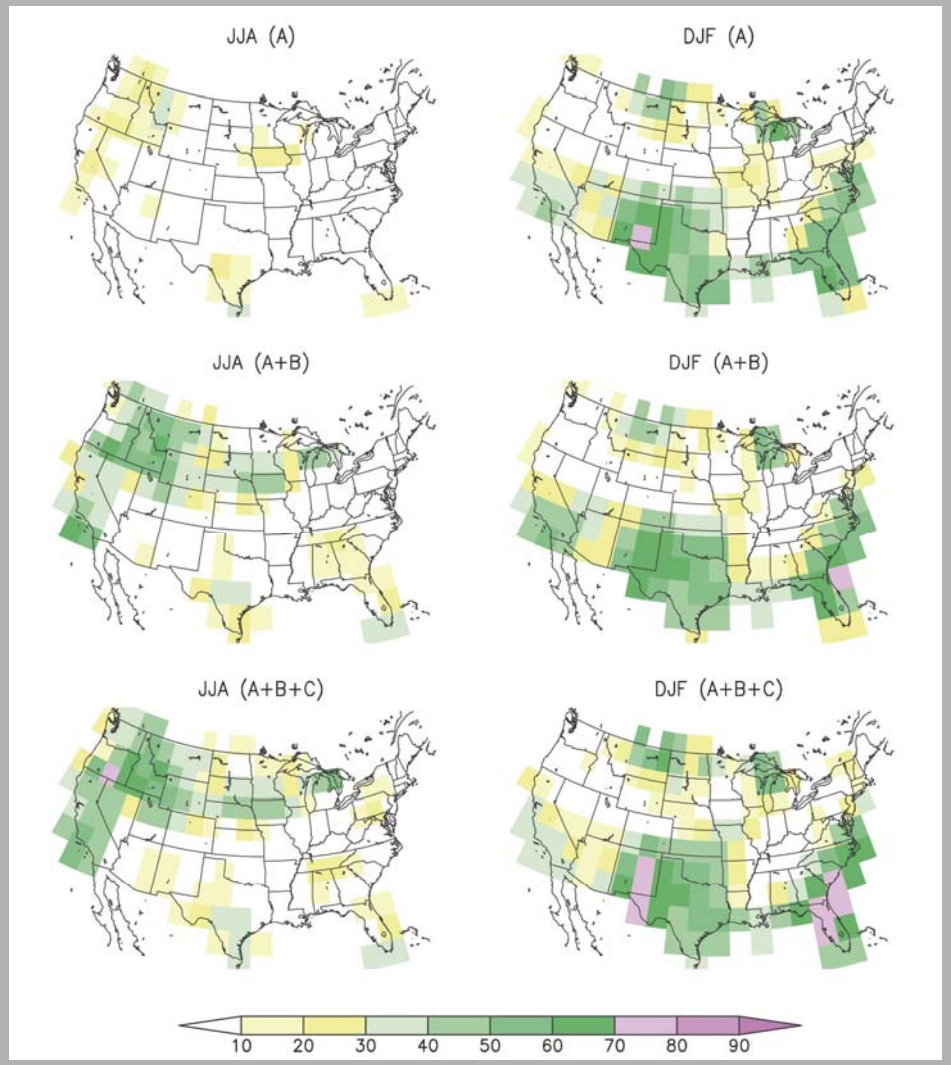
Primary purpose is to evaluate the climatological biases of the model in a hindcast mode for improved operational forecasting.

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.

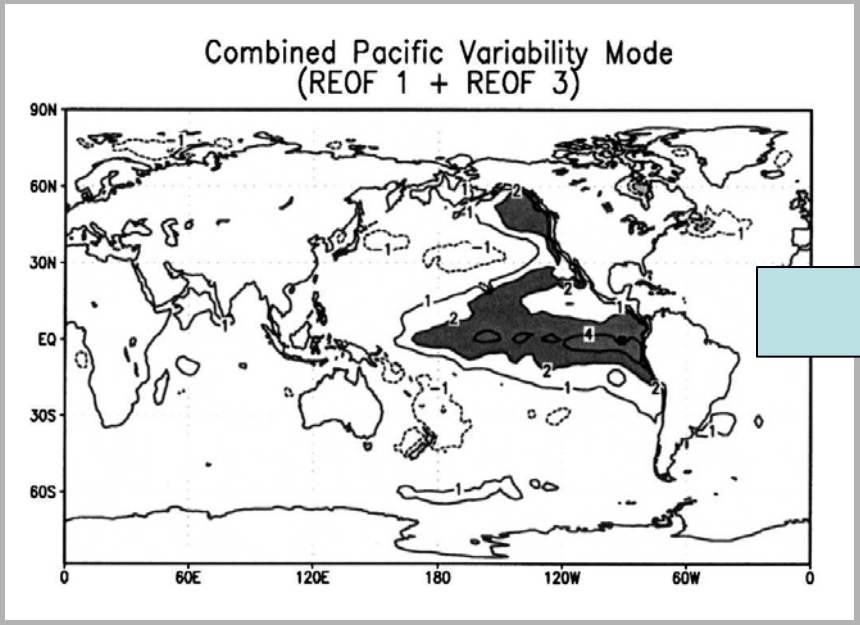
Summer:

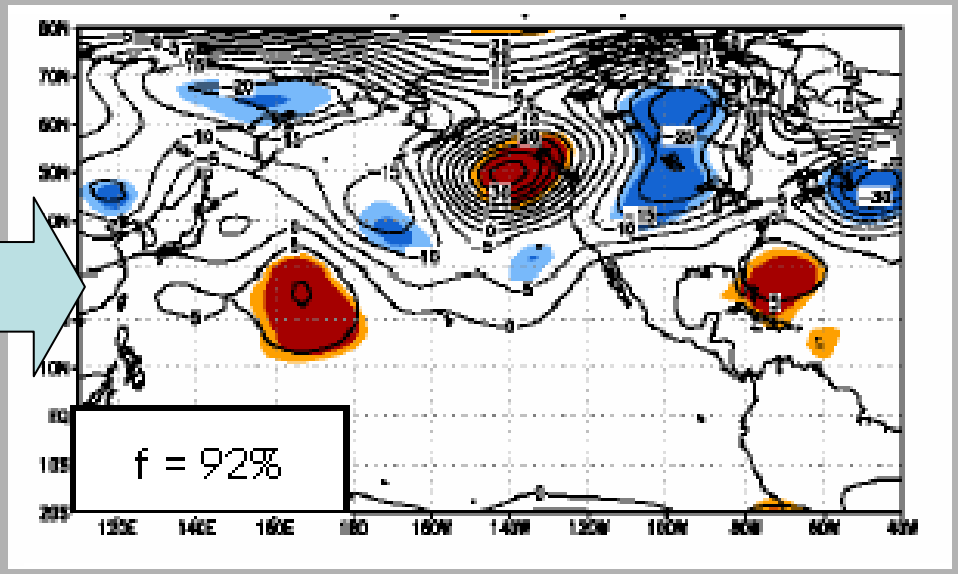
Little skill because of poor representation of convective rainfall processes

BUT…large-scale teleconnections in early summer are probably there!

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)

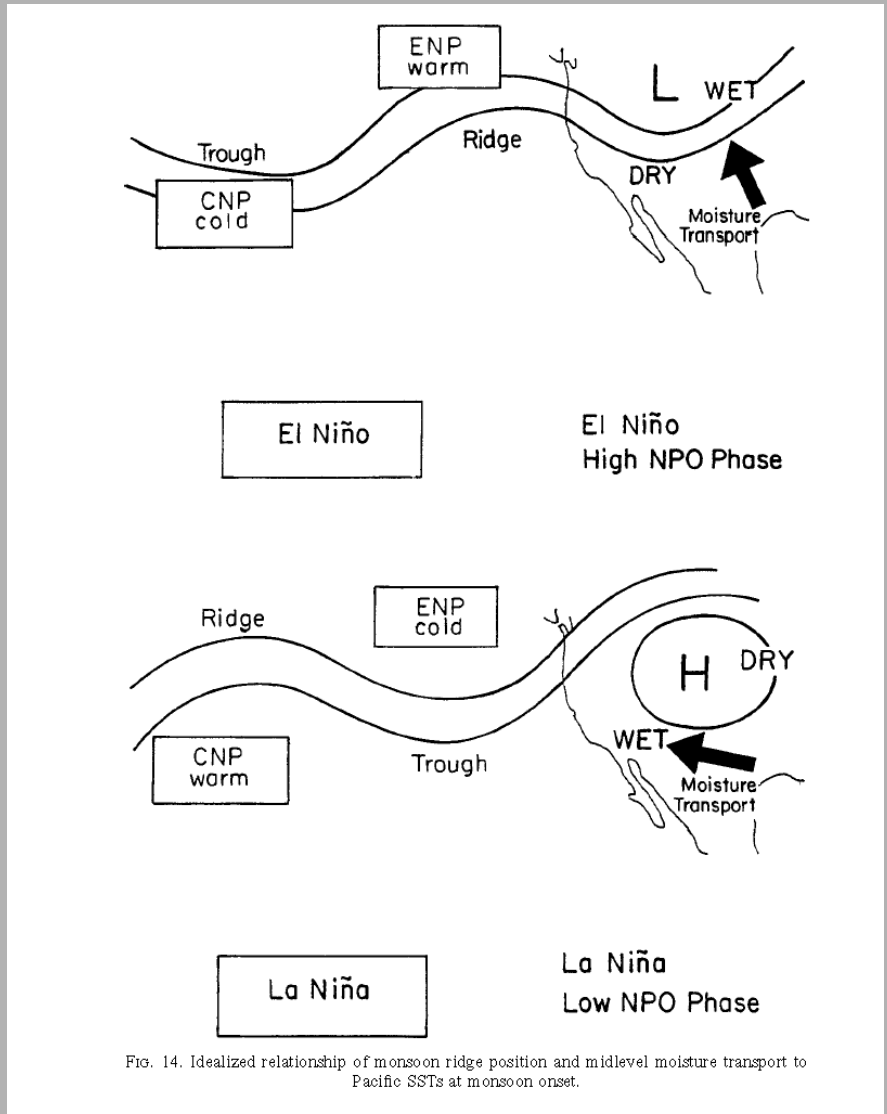


FIG. 14. Idealized relationship of monsoon ridge position and midlevel moisture transport to Pacific SSTs at monsoon onset.

Climatology delayed

Climatology accelerated

(Castro et al., 2001)

Dynamical Downscaling Types
from *Castro et al.* (2005)

	Examples
TYPE 1: remembers real-world conditions through the initial and lateral boundary conditions	**Numerical weather prediction**
TYPE 2: initial conditions in the interior of the model are "forgotten" but the lateral boundary conditions feed real-world data into the regional model	**Retrospective sensitivity or process studies using global reanalyses**
TYPE 3: global model prediction is used to create lateral boundary conditions. The global model prediction includes real-world surface data	**Seasonal climate forecasting**
TYPE 4: Global model run with no prescribed internal forcings. Couplings among the ocean-land-continental ice-atmosphere are all predicted	**Climate change projection**

Some a priori expectations for RCM dynamical downscaling (Type 2 and above)

A RCM should:

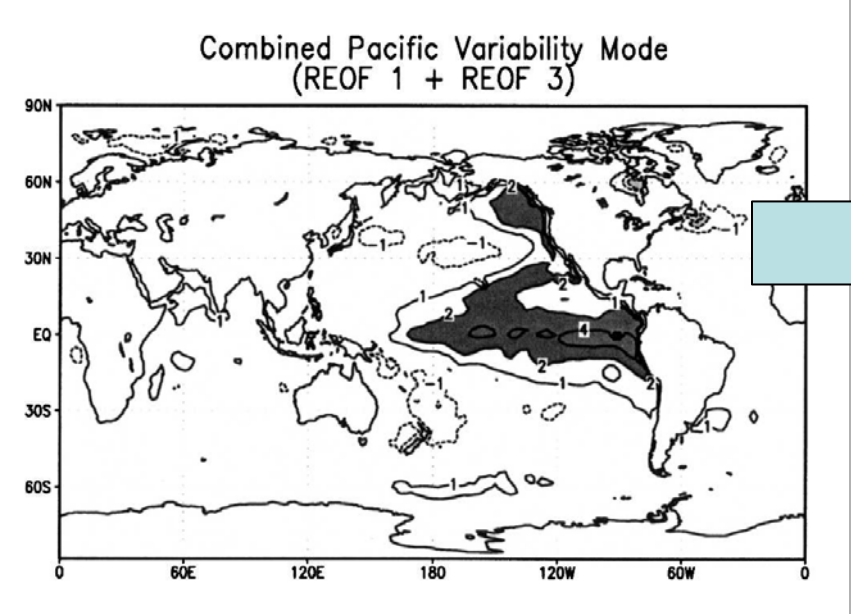
1. **Retain or enhance variability of larger-scale features provided by the driving global model (i.e. those on the synoptic scale)**

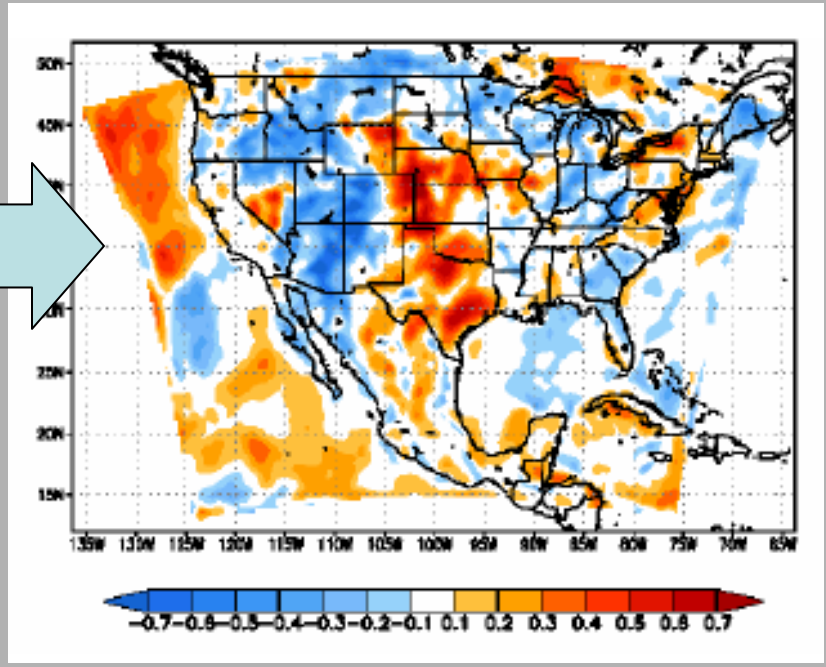
2. **Add information on the smaller scale because of increase in grid spacing, finer spatial scale data (e.g. terrain, landscape) and possibly differences in model parameterized physics.**

3. **Add information that is actually of value, as demonstrated by comparing RCM results with independent metrics (e.g. observations for Type 2)**

RCMs capture monsoon interannual variability <u>very well</u> when downscaling retrospective reanalyses or Type 2 dynamical downscaling

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





Will it work too for Type 3 dynamical downscaling with CFS forecasts?

Use of WRF for Downscaling of CFS Reforecasts for Warm Season

The version of WRF we use is the Advanced Research WRF (ARW) developed at NCAR.

Model physical parameterizations in this work are consistent with those of the existing WRF numerical weather prediction system at the University of Arizona (by Mike Leuthold)

Summer reforecasts specifically start at the beginning of May of the given year and last approximately the duration of the warm season (through at least August). 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.

So far…have done test simulations for 1993.

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.**

Preliminary WRF simulation results for 1993 (one ensemble member)

Why 1993 to start?

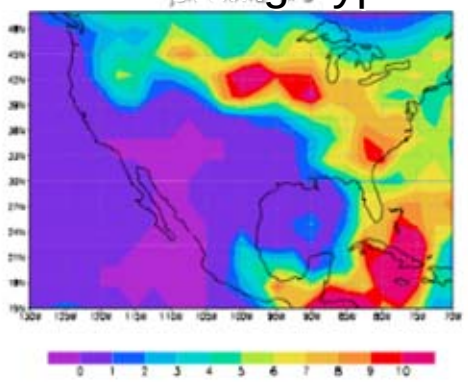
Classic extreme early summer conditions

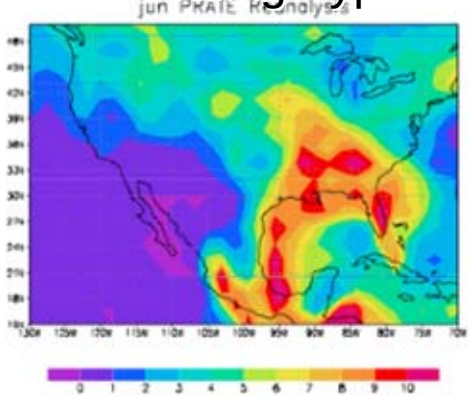
Wet central U.S., dry and delayed monsoon

CFS member
Downscaling Type 3

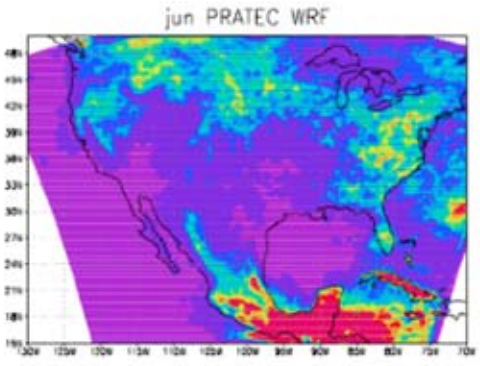
NCEP Reanalysis:
Downscaling Type 2

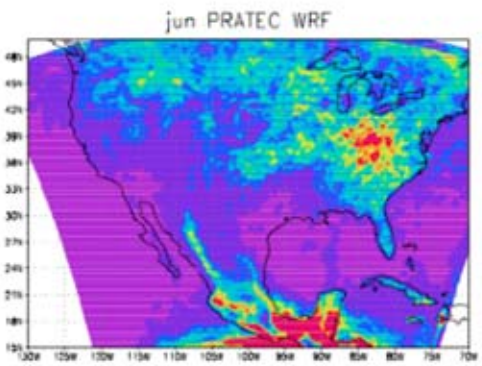
Original
Global model



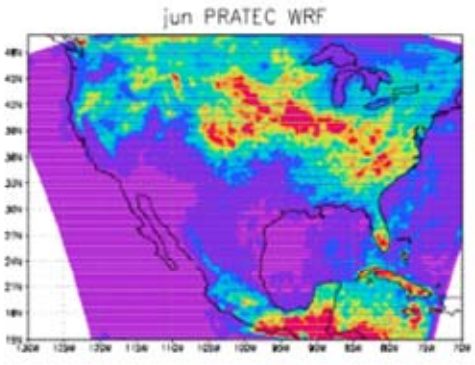


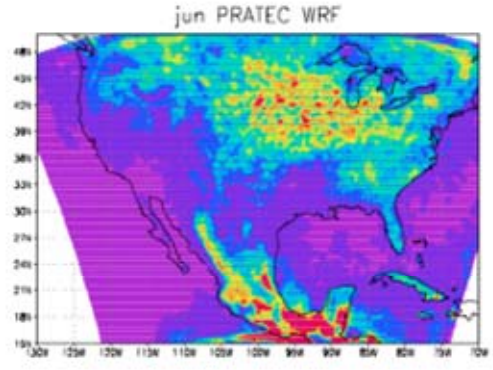
WRF
Lateral boundary
nudging only





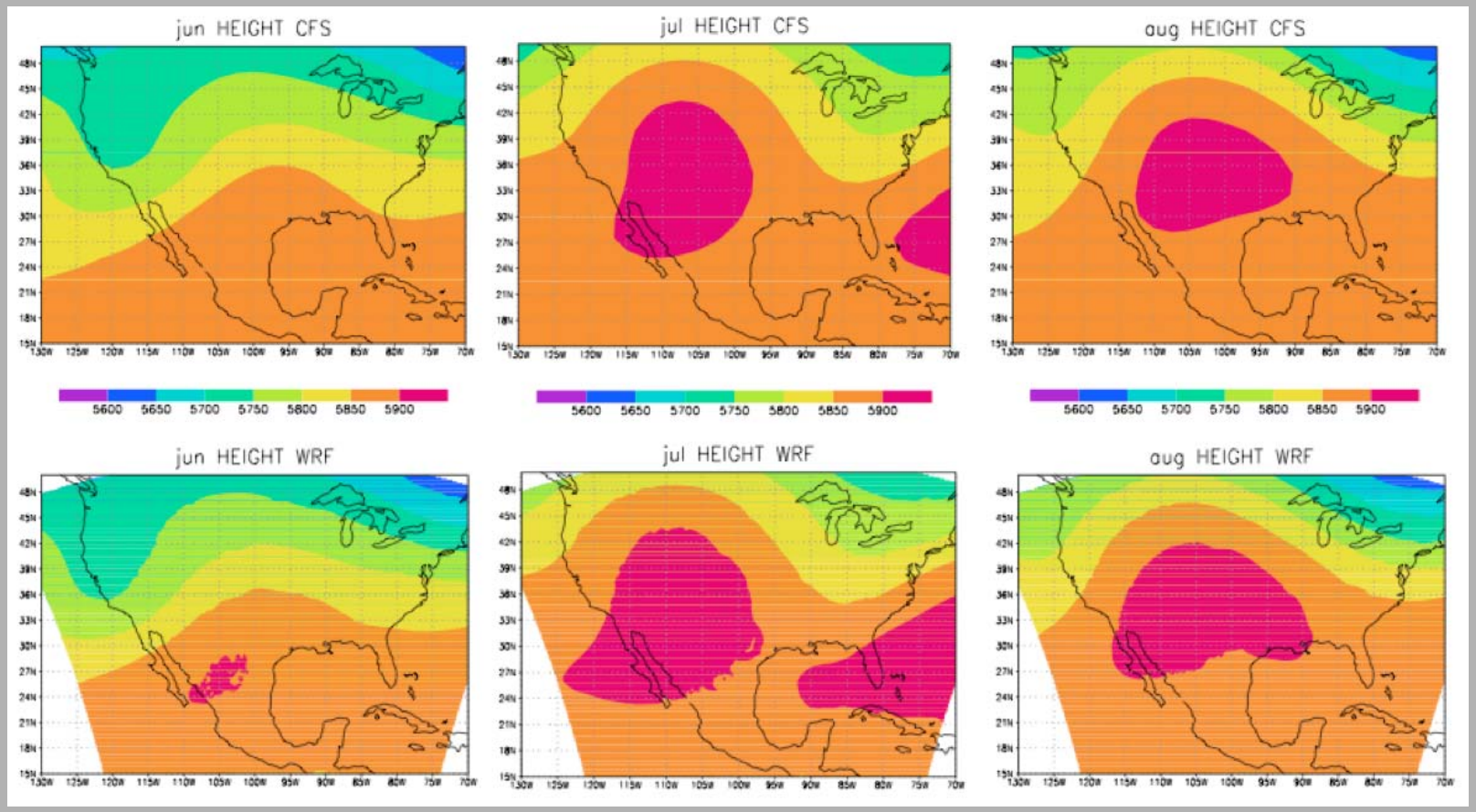
WRF
Spectral nudging



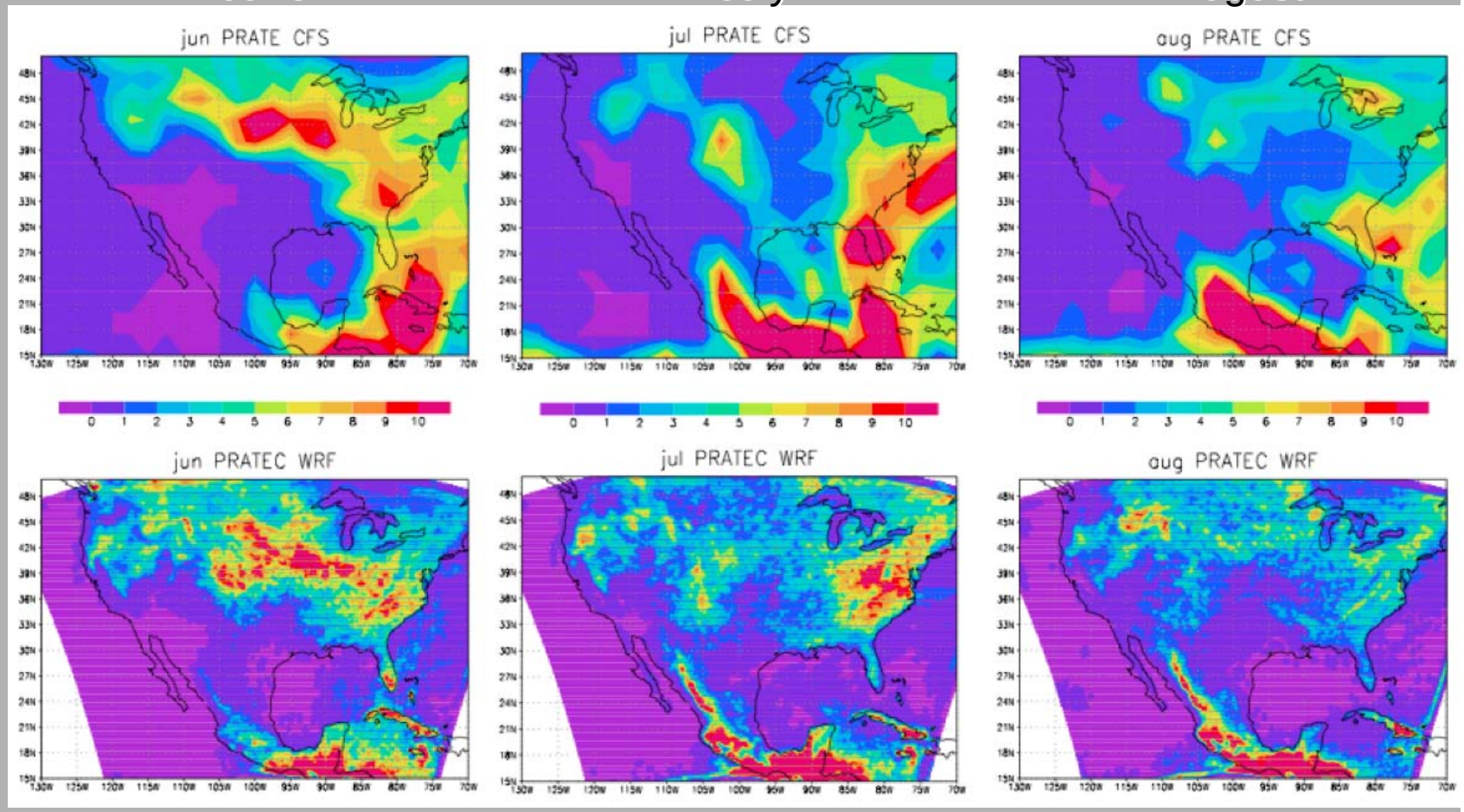


June precipitation solutions (mm day^{-1})

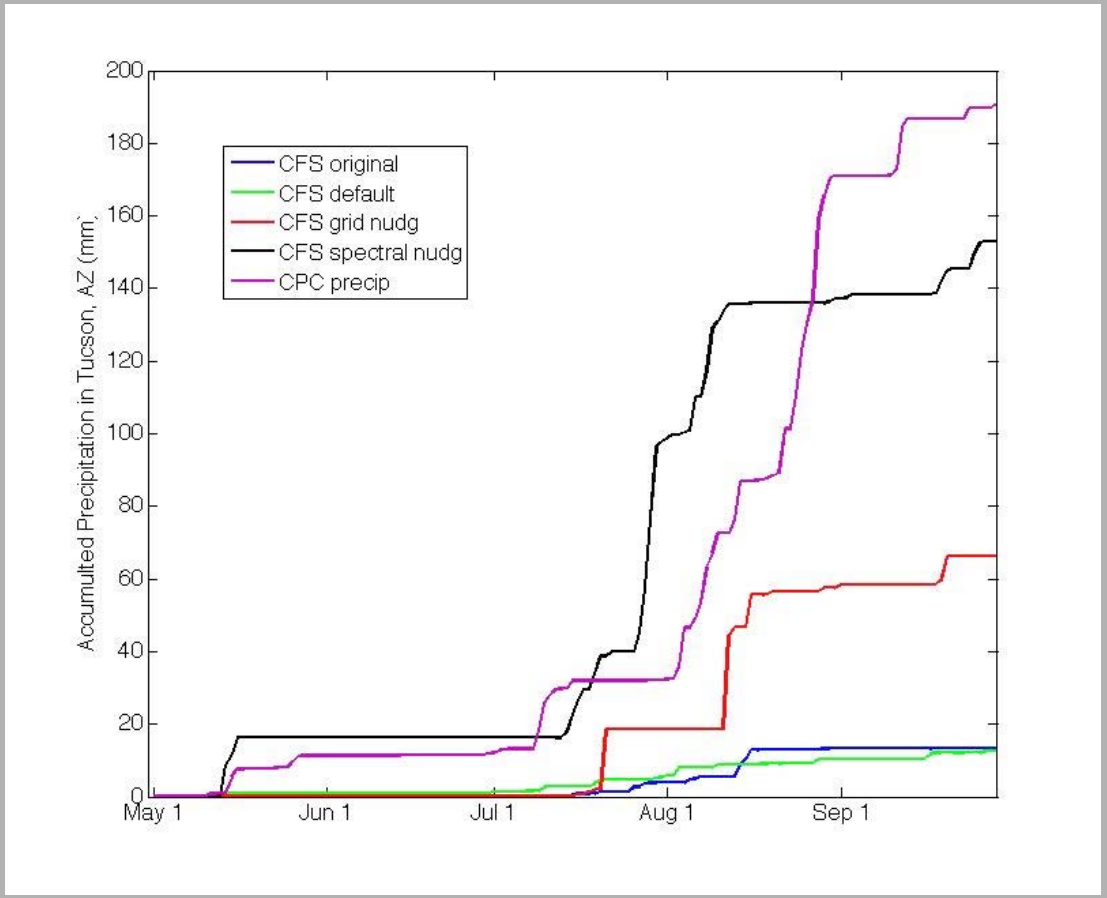
1993 Summer 500-mb heights (m)
Original CFS vs. WRF Downscaled



1993 Summer Precipitation (mm day^{-1})
Original CFS vs. WRF Downscaled



1993 Summer precipitation Tucson, AZ



WRF downscaled simulation with spectral nudging gives best result!

Original CFS model HAS NO MONSOON!

Preliminary Results and Ongoing Work

Provided that the regional model is able to retain the variability in the large-scale circulation fields, WRF used a RVM can potentially add significant value to representation of the warm season climate. This is primarily realized by an improved representation of convective precipitation.

Results appear to validate the hypothesis posed by Castro et al. (2007) that RCMs (in Type 3 and 4 dynamical downscaling) can add value to the representation of the warm season climate provided the driving global model produces reasonably accurate teleconnection patterns and these are retained in the RCM.

We are currently downscaling the entire CFS reforecast period with WRF using the same methodologies described here. After that, regular RCM forecasts for the warm season…eventually.

Also dynamically downscaling IPCC GCM data (Type 4) for climate change projection purposes…didn't talk about it here.

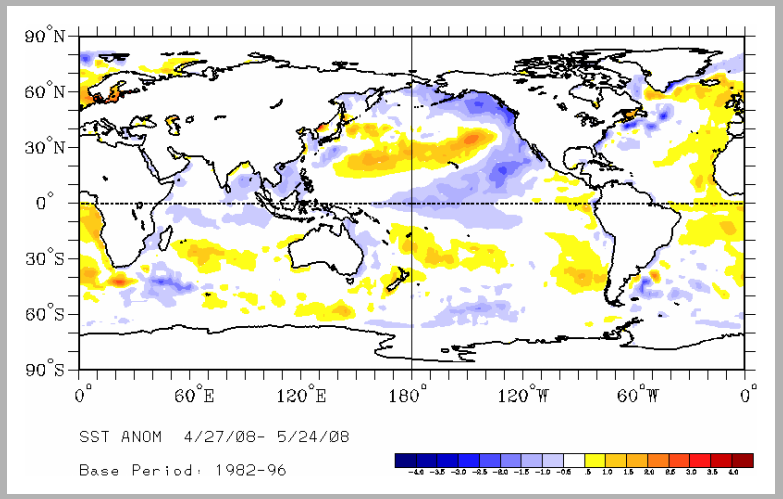
What about this year's monsoon??

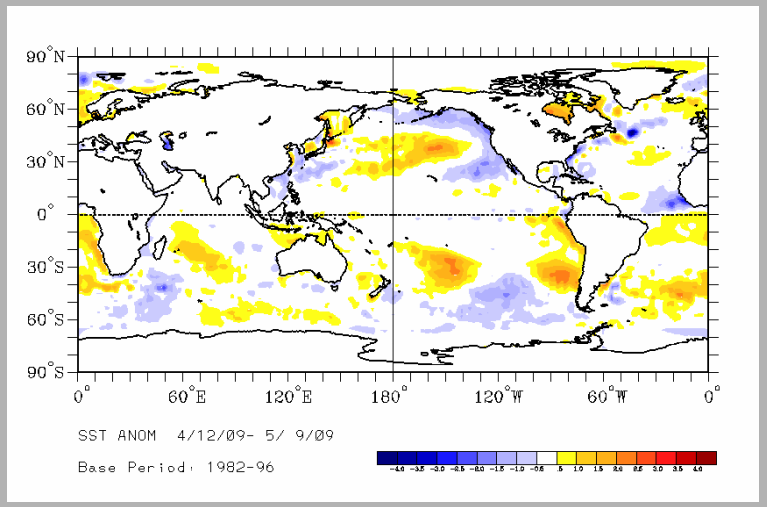
Preview of my comments later this week at monsoon web briefing…

This year is very similar to 2008
Este año es muy parecido al 2008

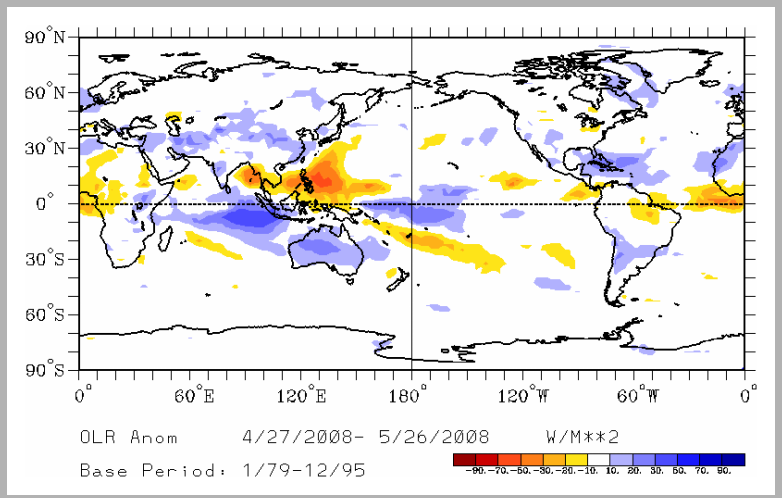
2008 **2009**

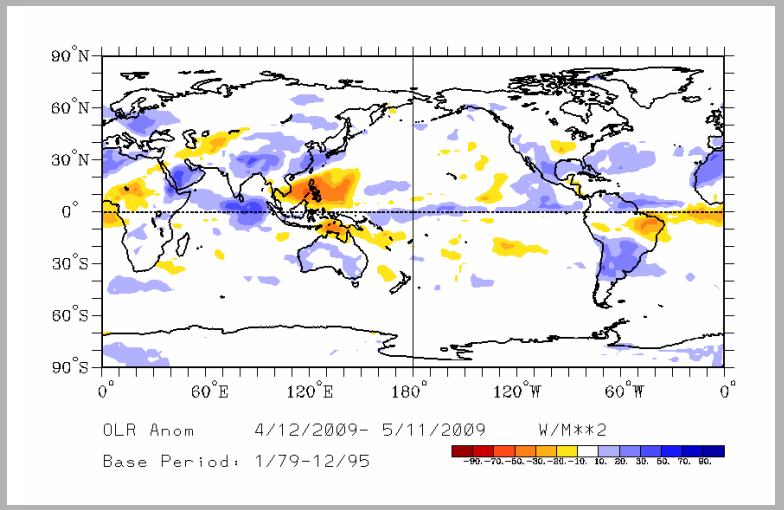
SST Anomalies
Anomalias de TSM





Tropical convection
Convección en los trópicos





I agree with the CPC Forecast

Estoy de acuerdo con el Prognóstico del CPC