Use of Dynamical Downscaling to Improve Regional Climate Change Projections in the Southwest U.S.

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Water Management and Climate Change in Northern Arizona
Flagstaff, Arizona, 8 June 2011

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Presentation Outline

Motivation for improved climate change projection in the Southwest

Why use dynamical downscaling for climate change projection with a regional climate model and how does it work?

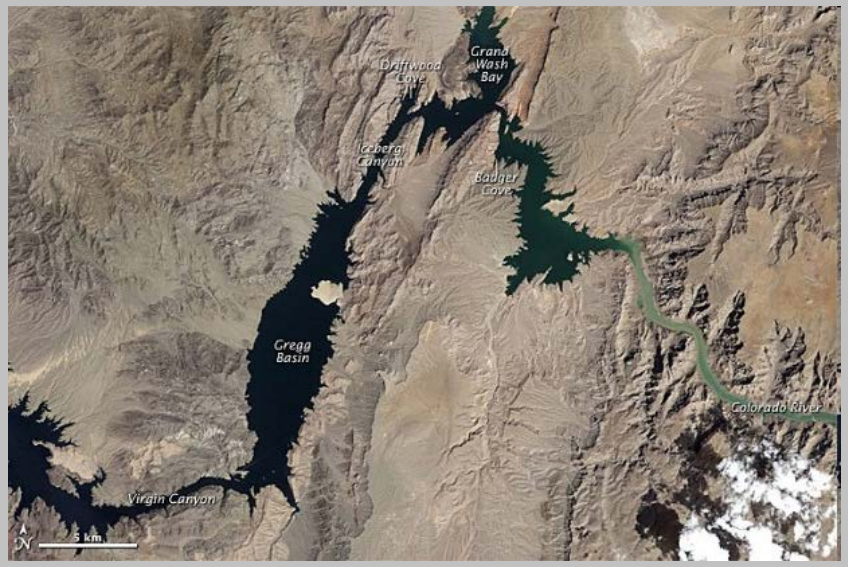
Dynamical downscaling results for select IPCC AR4 models for the cool and warm season: historical performance in late 20th century and climate change projections.

Use of dynamically downscaled data in a hydrologic model for water resource projection

Acknowledgements: Funding provided by NSF, DOE, UA Water Sustainability Program, and local water resource stakeholder partners (Salt River Project, Bureau of Reclamation, City of Phoenix) through the Climate Assessment for the Southwest.

UA Contributors: F. Dominguez, H-I. Chang, C. Carrillo, E. DeMaria, M. Durcek, S. Wi, E. Rivera

What is CURRENTLY HAPPENING to Colorado River reservoirs
This is a primary water source in Arizona!



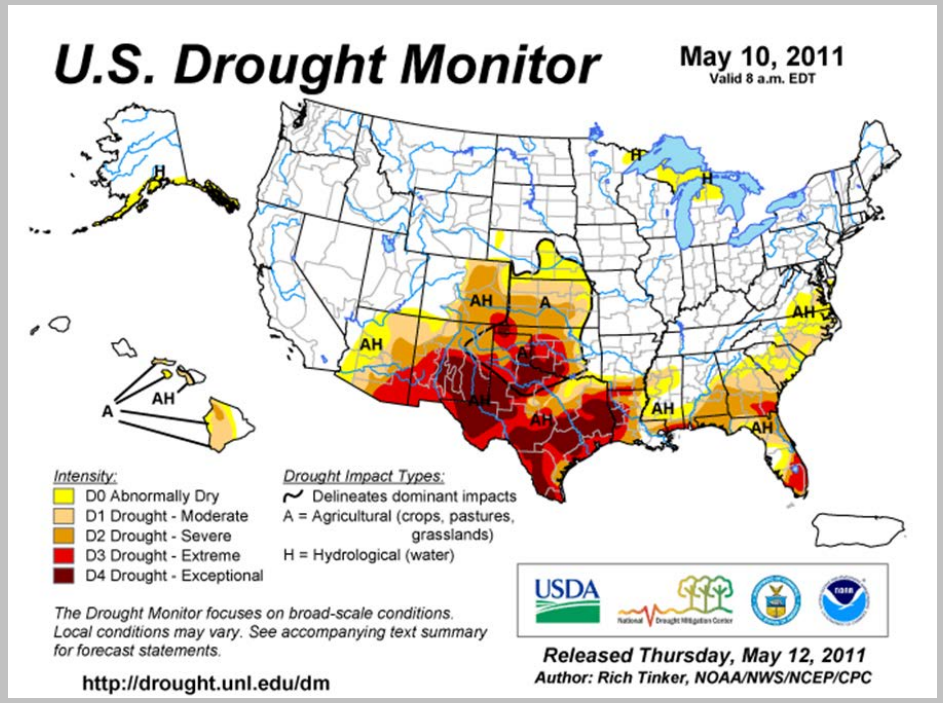
Lake Mead: 1985

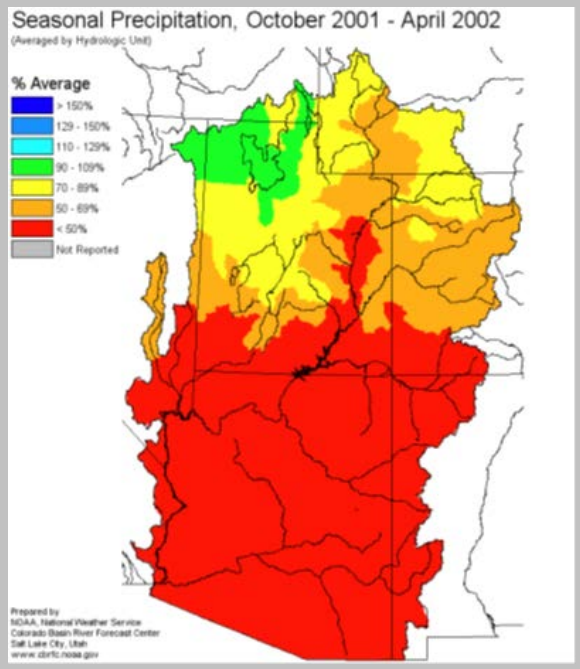
Lake Mead today
At lowest level since 1937

From Arizona Daily Star Article
November 2010

Horseshoe Fire in Chiracahua Mountains
Cochise County, Arizona
Burned nearly 50,000 acres in May 2011

NASA Imagery



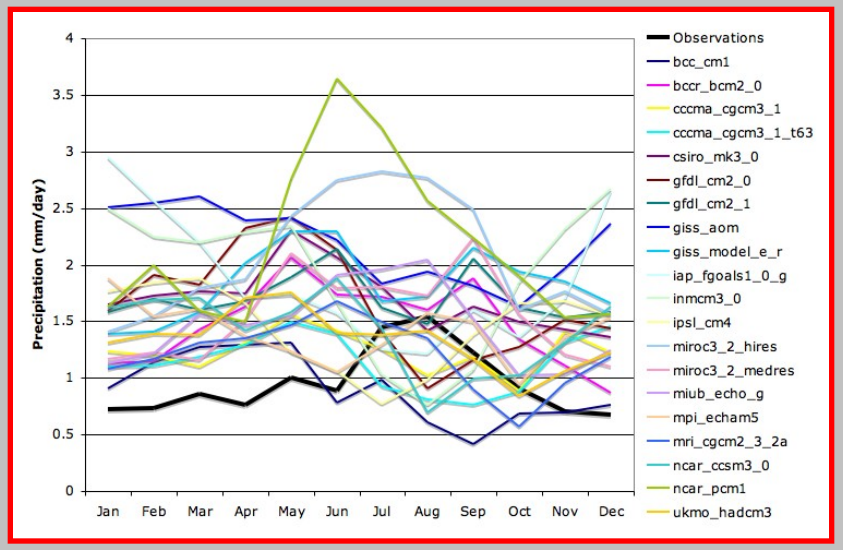


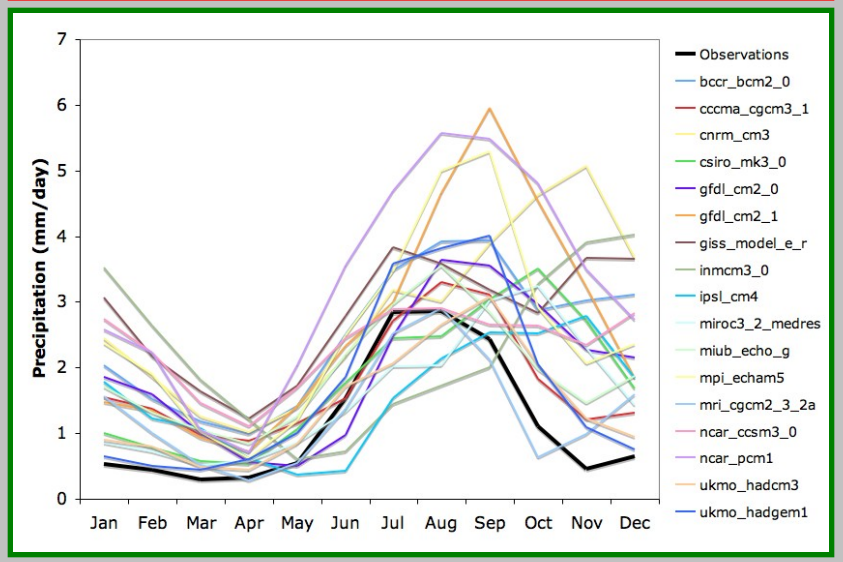
***Dr. John Nielson Gammon, Texas State Climatologist*: 2011 record spring drought in west Texas likely due to the combination of La Niña and climate change (*New York Times* article).**

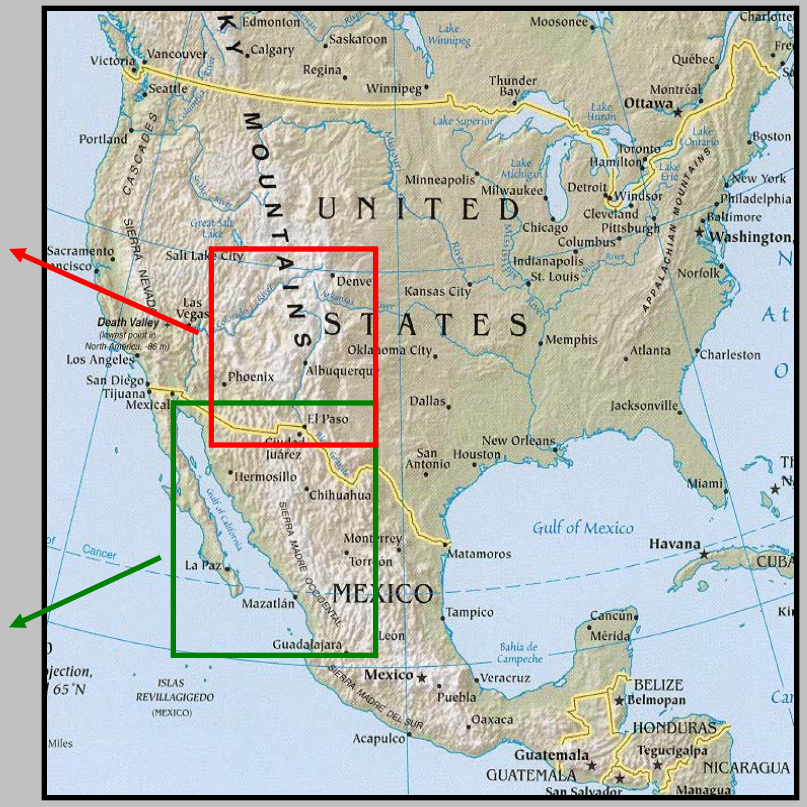
Critical questions therein:

1. **How is natural climate variability interacting with climate change to intensify extremes?**
2. **Can current IPCC-based climate change projections resolve on a regional scale?**

Monthly average historical precipitation from IPCC AR4 models







Historical average of simulations (sres_20c3m) 1970-2000

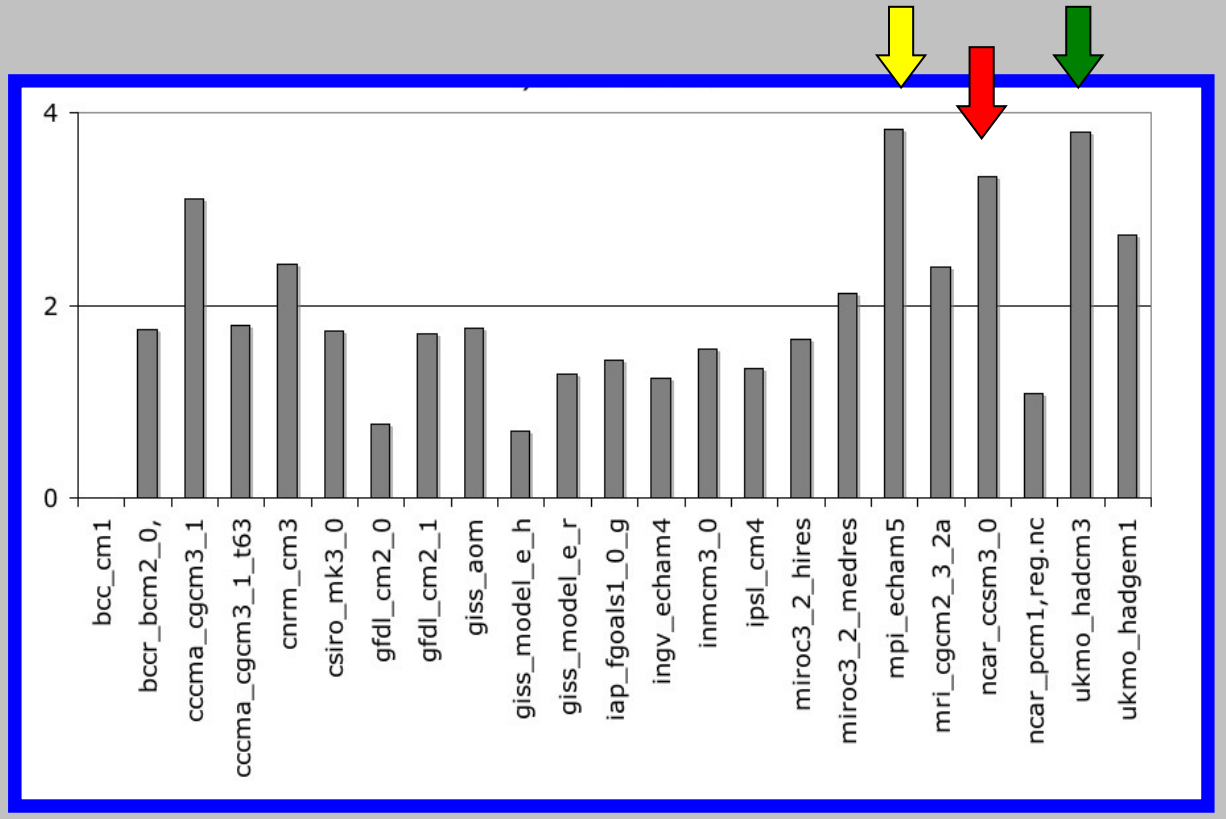
(Francina Dominguez)

Dynamical downscaling of “well performing” IPCC AR4 models for the Southwest

HadCM3: 1968-2070 (completed)

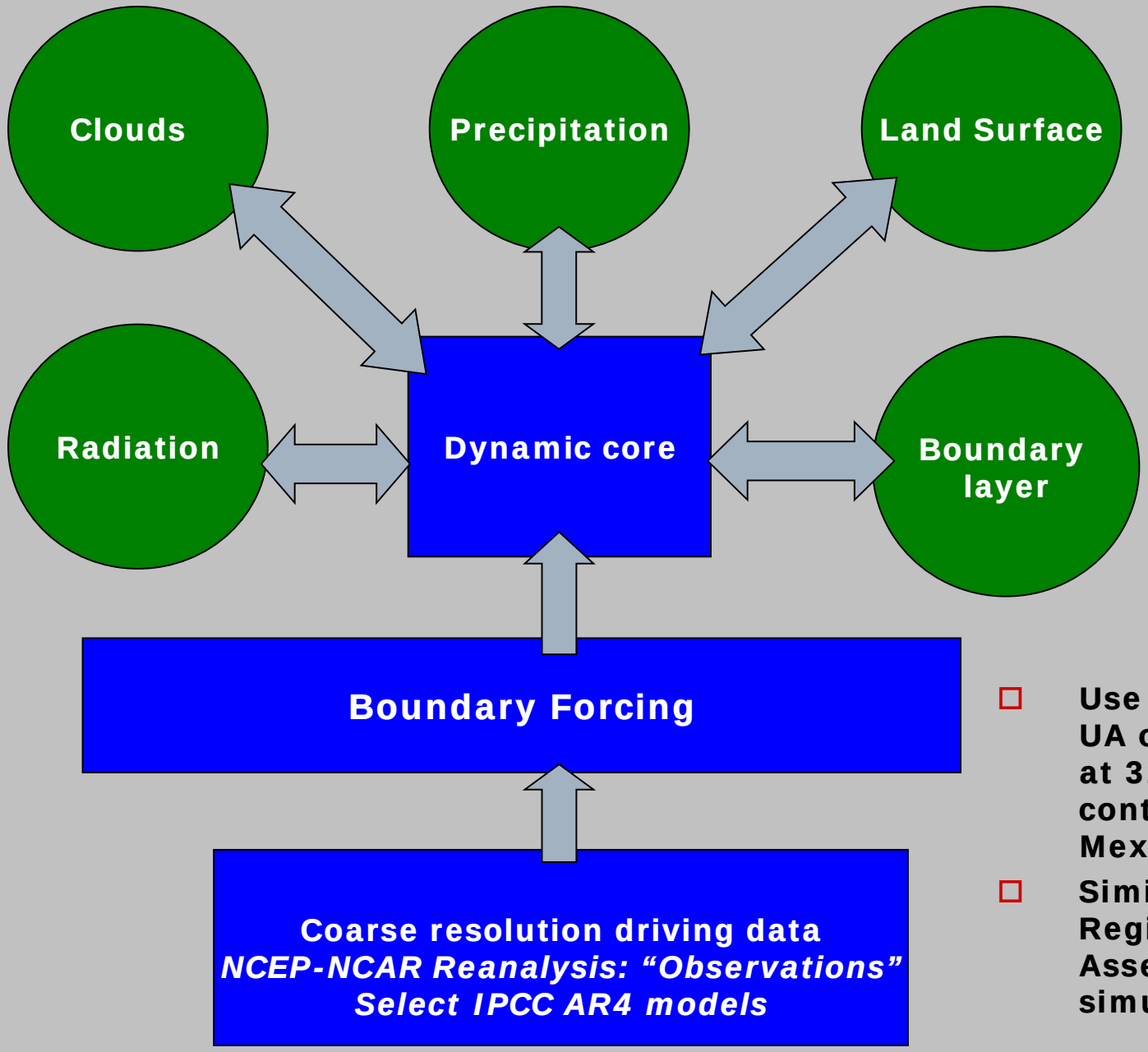
MPI-ECHAM5: 1950-2100 (completed in May)

CCSM: 1950-2100 (still pending)

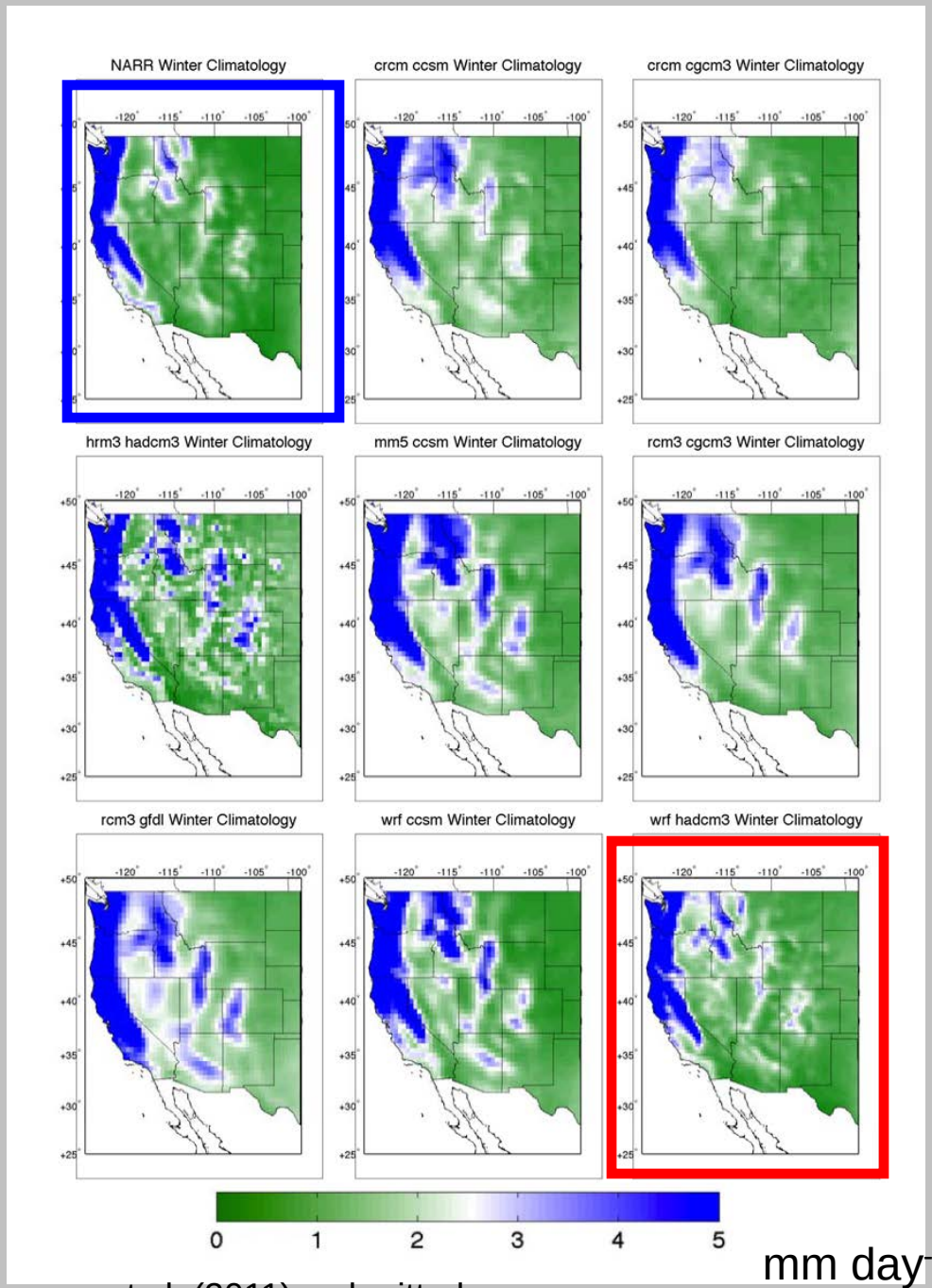


Dominguez et al (2009)

Regional Climate Model Structure



- Use WRF configuration for UA operational forecasting at 32 km grid spacing over contiguous U.S. and Mexico
- Similar to North American Regional Climate Change Assessment (NARCCAP) simulations



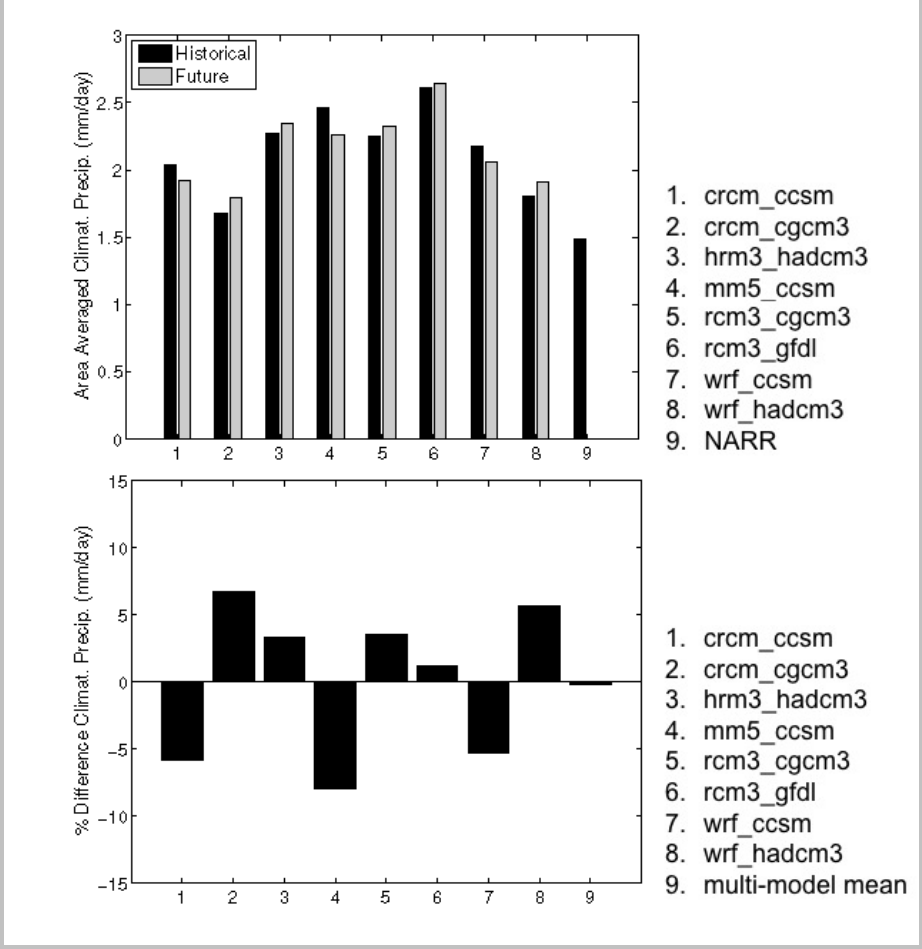
Monthly historical (1968-2000) average precipitation in winter (DJF)

- **NARR Observed**
- **NARCCAP models**
- **WRF-HadCM3**

Extreme event precipitation pattern is very similar

Dominguez et al. (2011), submitted

Historical (1968-2000) and future precipitation (2038-2070) in western U.S.



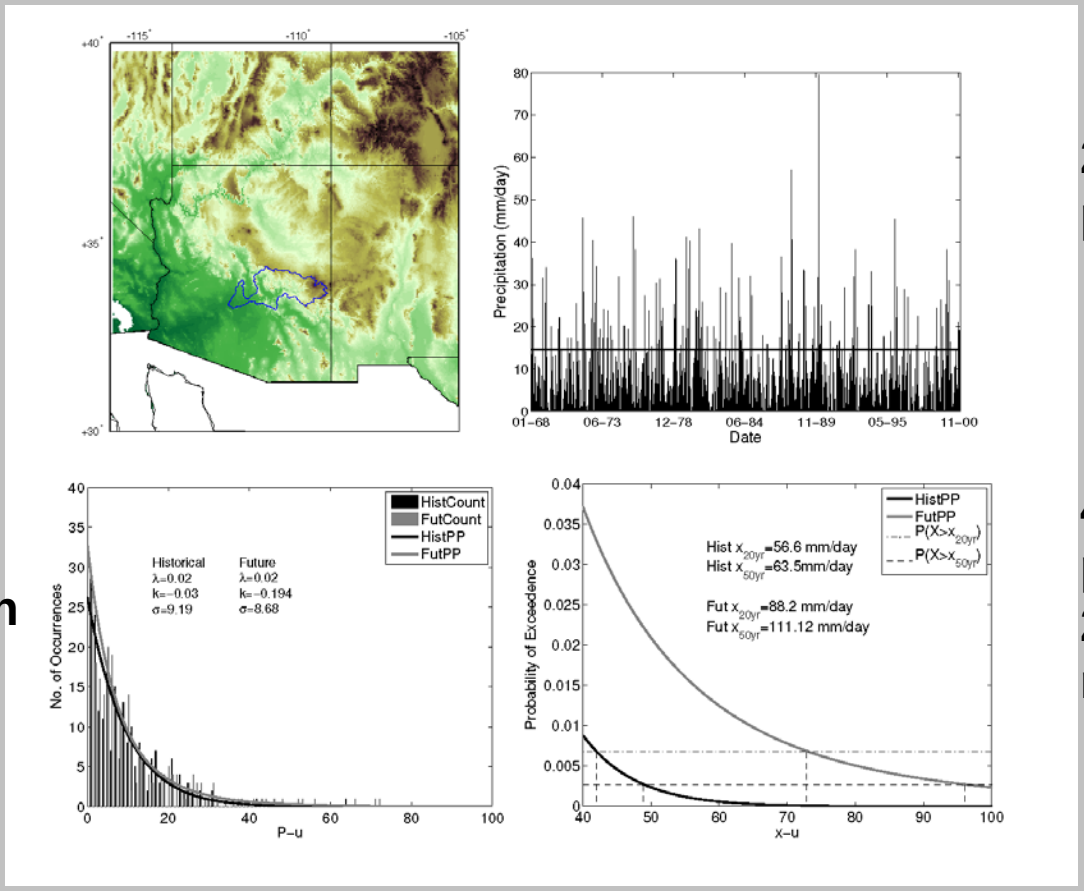
No coherent trend in mean winter precipitation considering all the NARCCAP models, with most in the range of 10% of historical average.

Not surprising, as mean changes dependent on large-scale circulation changes and western U.S. is the transition zone between drying subtropics and moistening high latitudes.

Dominguez et al. (2011), submitted

Computation of precipitation distribution from WRF-HadCM3: Salt River Basin

1. Salt River Basin (blue outline)



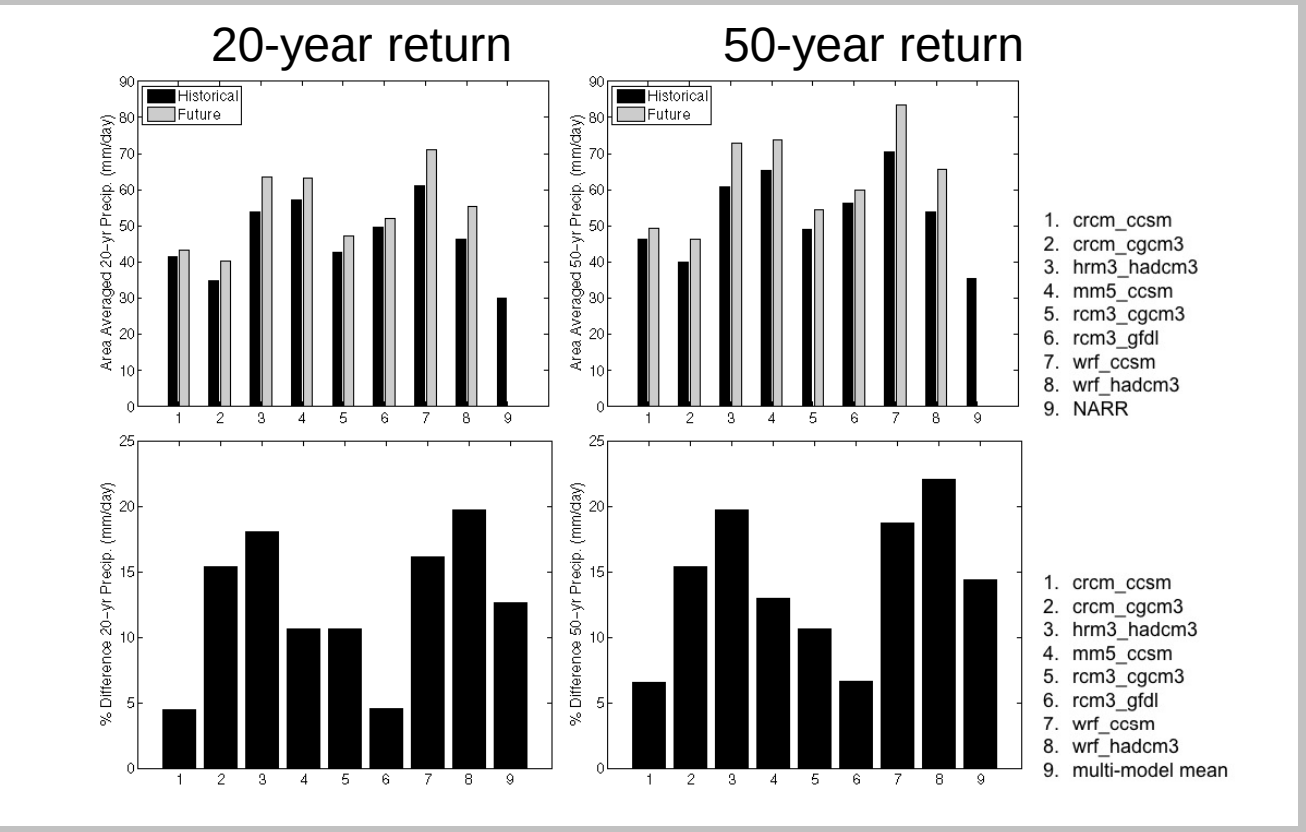
2. Daily precipitation

3. Winter distribution of daily precipitation from generalized extreme value theory

4. Exceedence probability with 20 and 50-yr return periods

Dominguez et al. (2011), submitted

Western U.S. winter extreme event precipitation: historical vs. future



An increase in the precipitation associated with extreme event precipitation is a much more robust result.

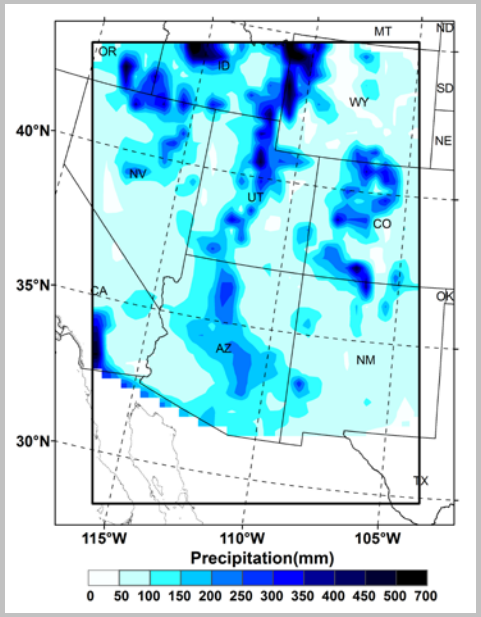
In agreement with observations of the recent historical record.

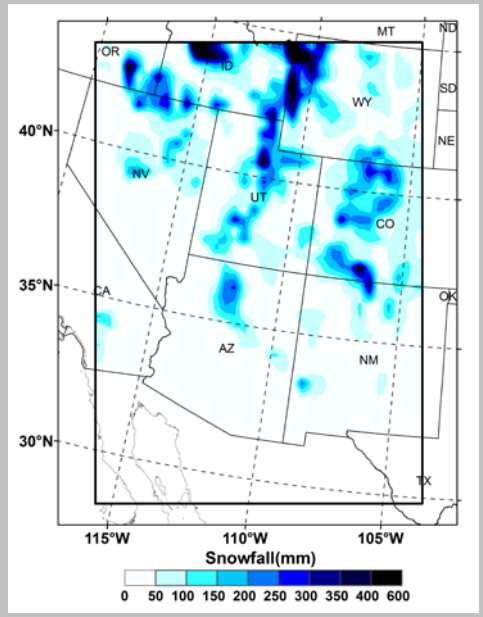
Still LARGE spatial differences among the individual models!

Dominguez et al. (2011), submitted

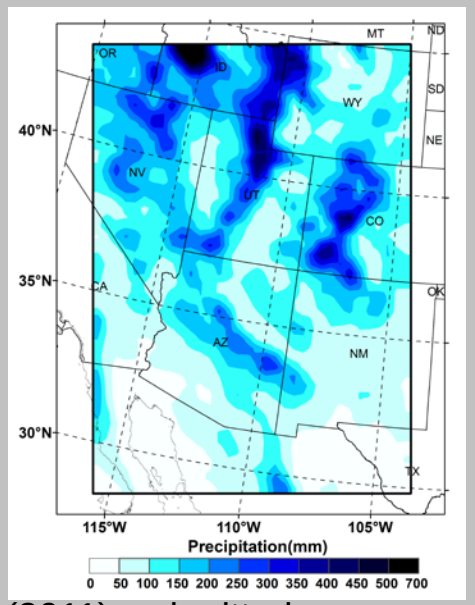
Precipitation ***Snowfall***

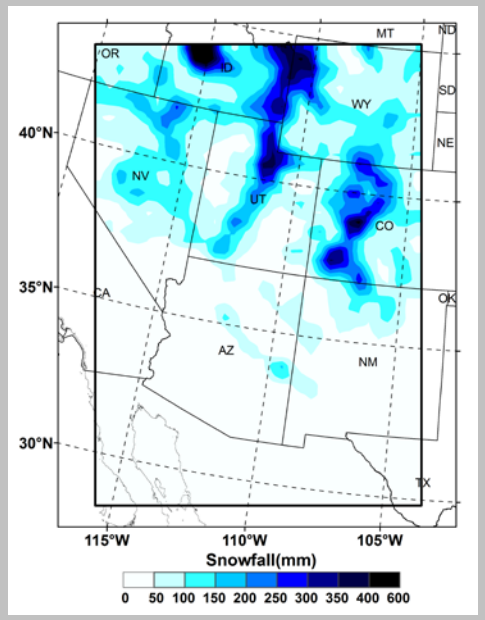
Observed (NARR)





WRF-HadCM3



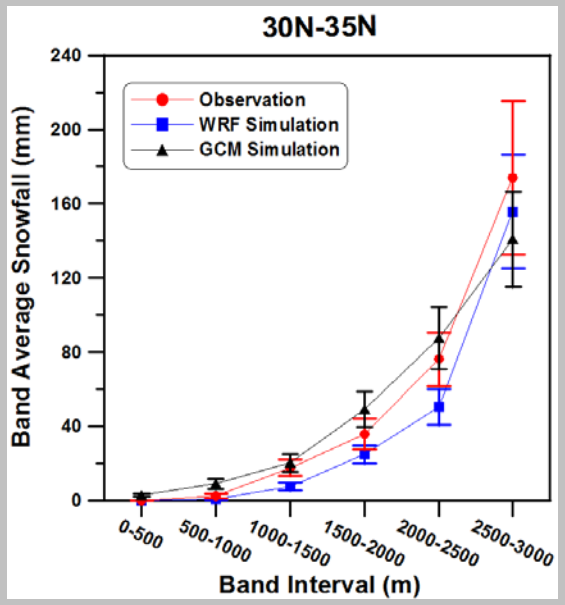


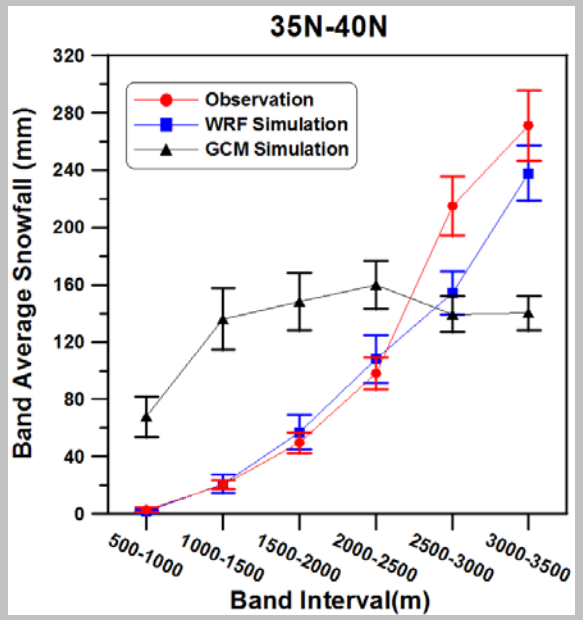
Observed and WRF-HadCM3 winter precipitation and snowfall in

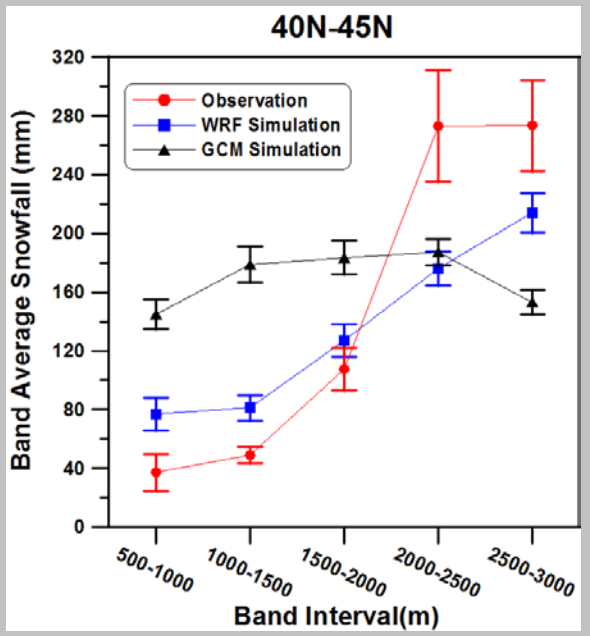
historical period.

Wi et al. (2011), submitted

Latitudinally-averaged snowfall vs. elevation for historical period

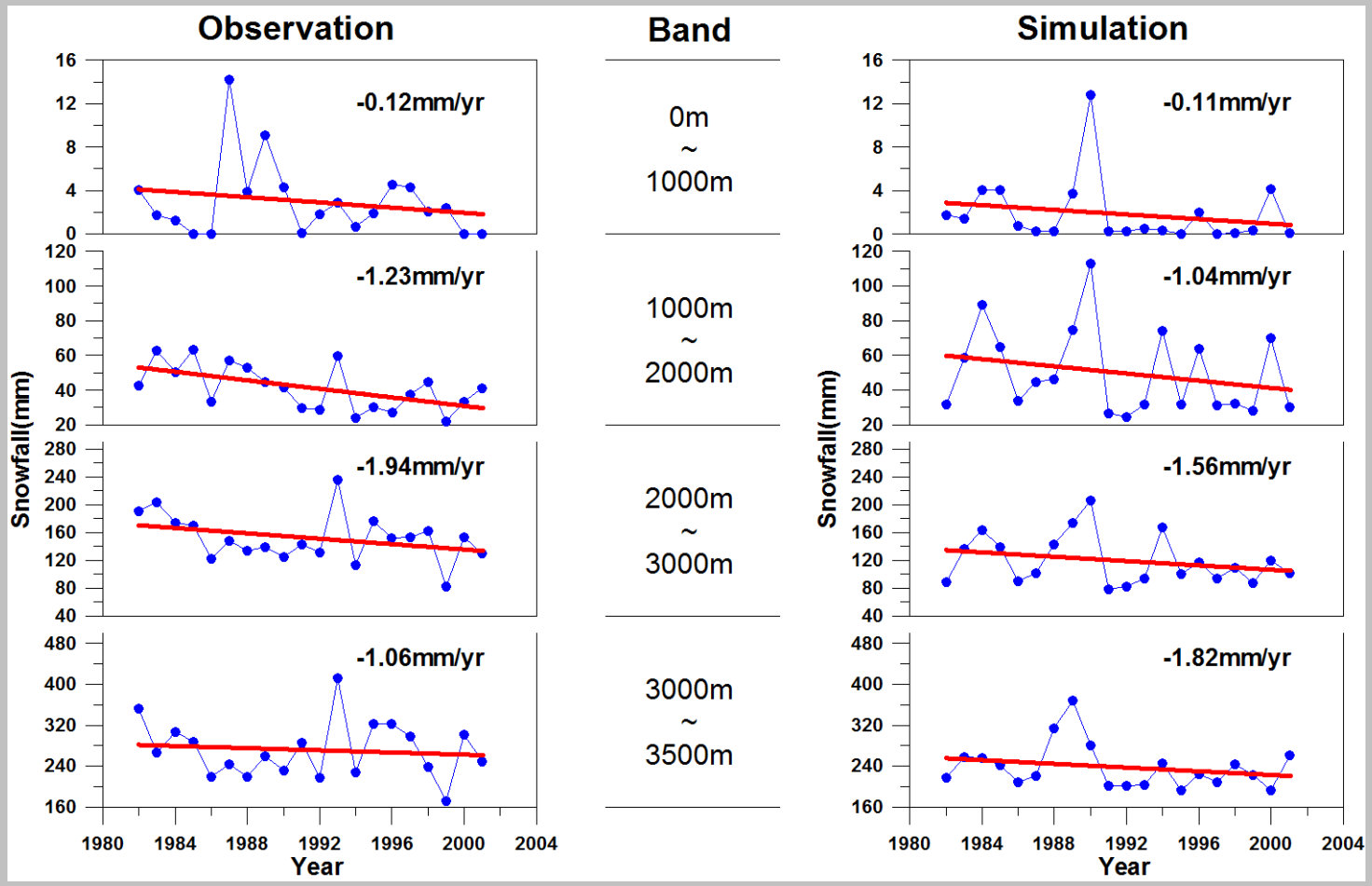






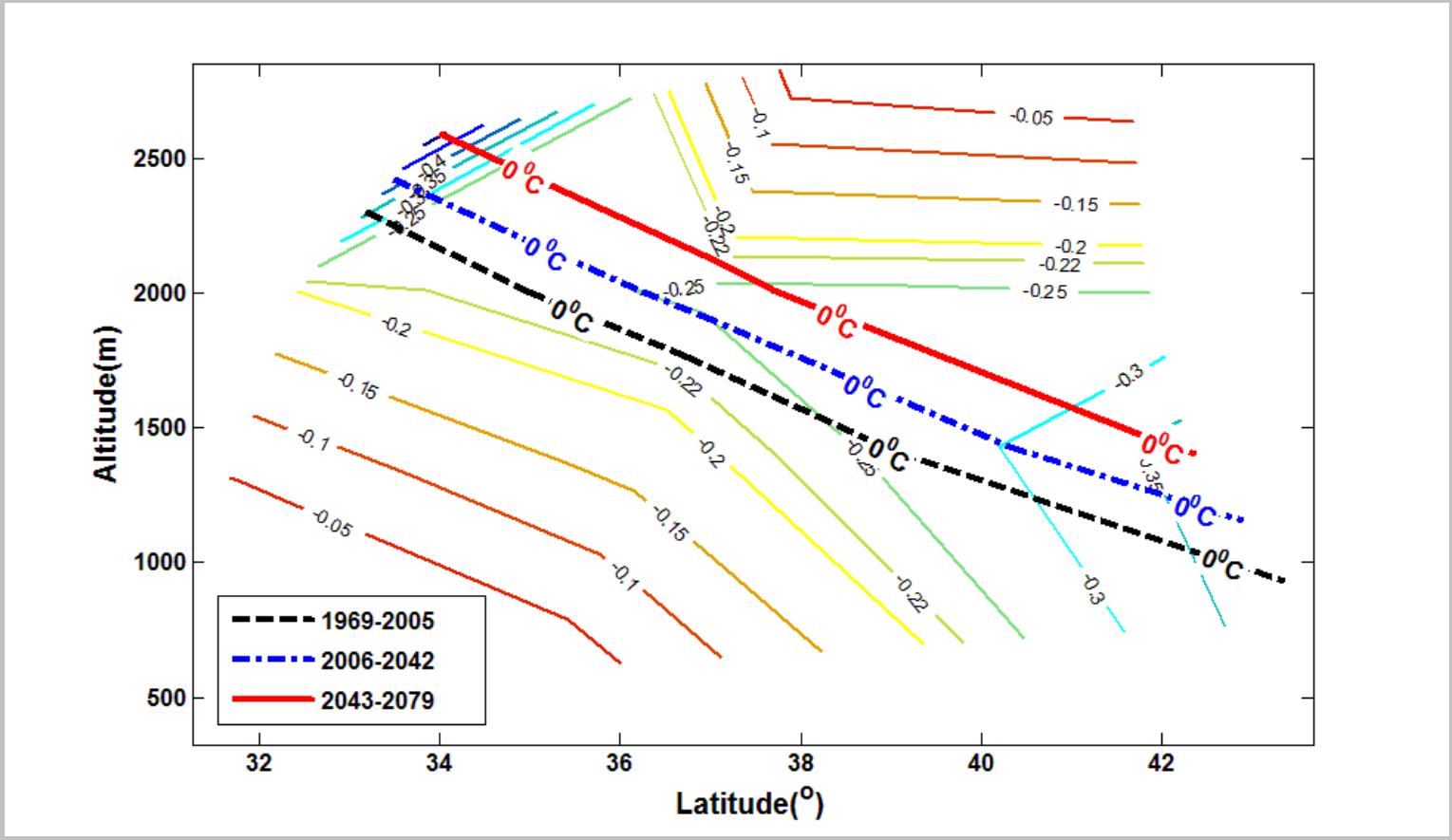
Wi et al. (2011), submitted

Latitudinally-averaged snowfall during historical period as a function of elevation: SNOTEL observations vs. WRF-HadCM3



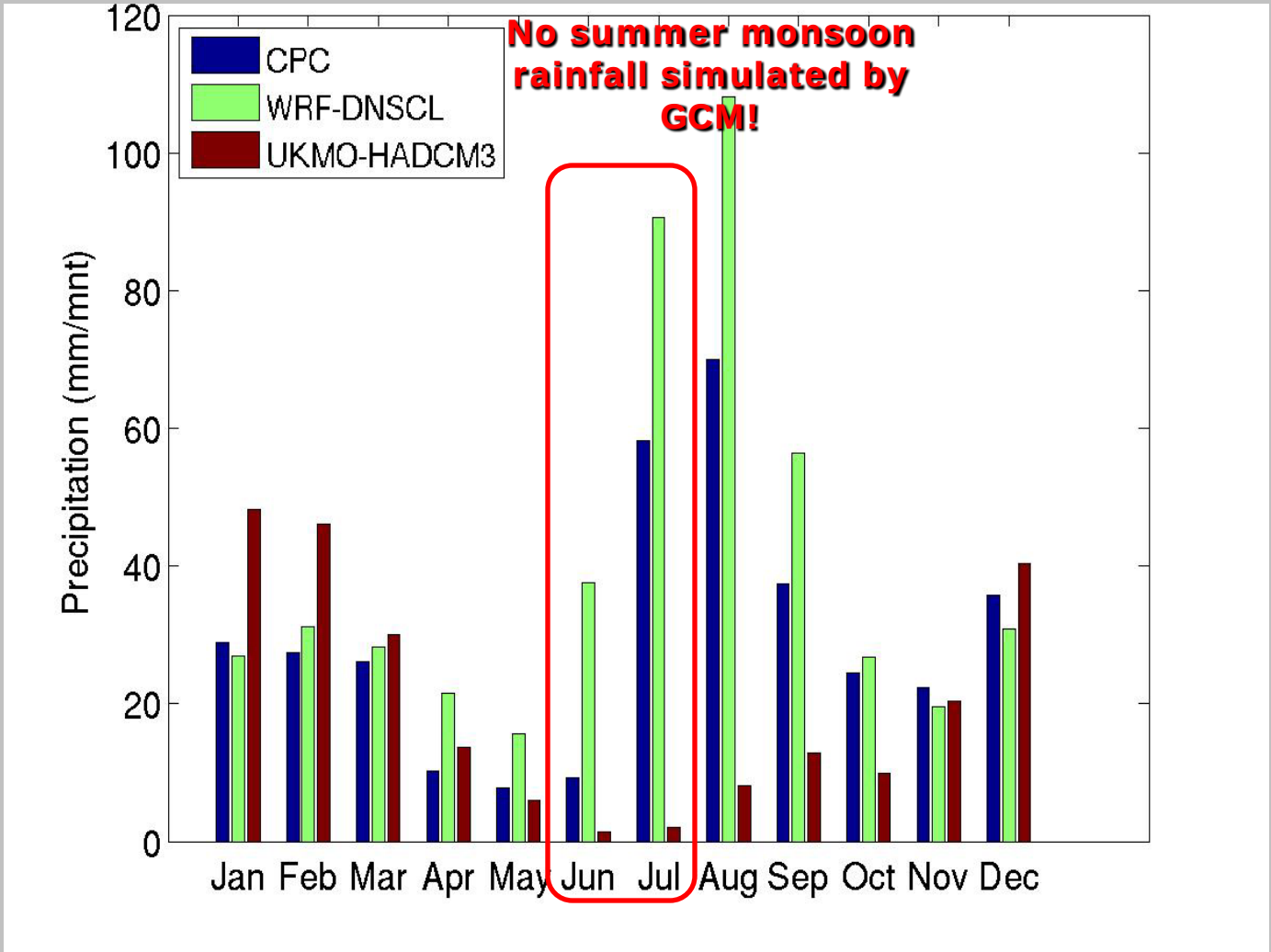
Wi et al. (2011), submitted

WRF-HadCM3-simulated trends in snowfall and changes in the freezing line as a function of latitude and elevation



Wi et al. (2011), submitted

Annual precipitation climatology for Arizona



Monsoon Interannual Variability
Remotely forced teleconnections and land surface feedback

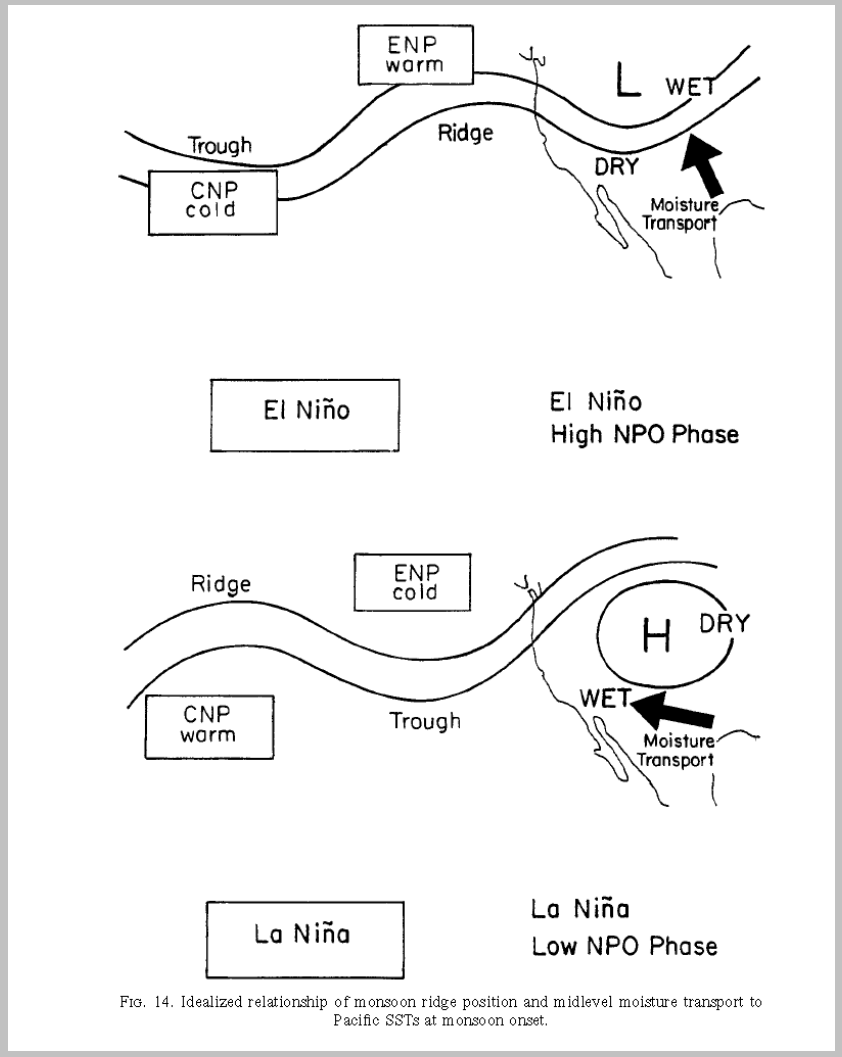


FIG. 14. Idealized relationship of monsoon ridge position and midlevel moisture transport to Pacific SSTs at monsoon onset.

Climatology delayed

Climatology accelerated

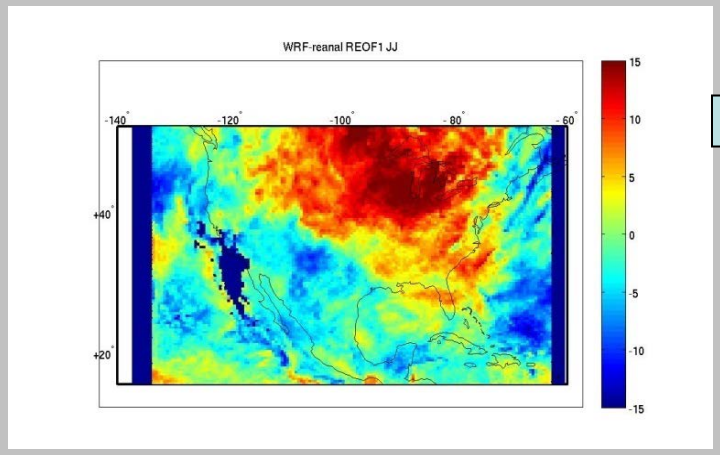
(Castro et al. 2001)

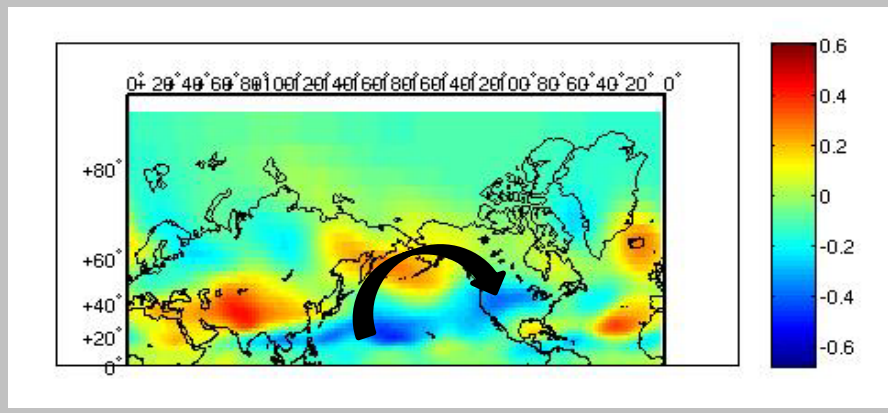
Dominant Mode of JJ downscaled SPI and relationship to 500-mb height anomalies

Dominant Precipitation Mode

500-mb Height Anomaly

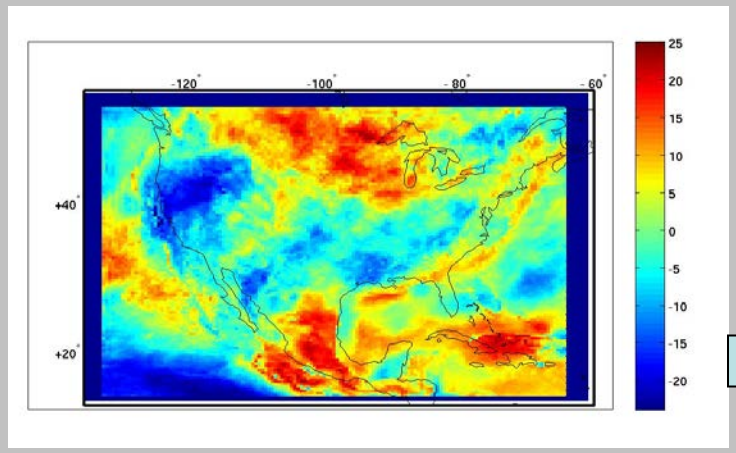
WRF-Reanalysis

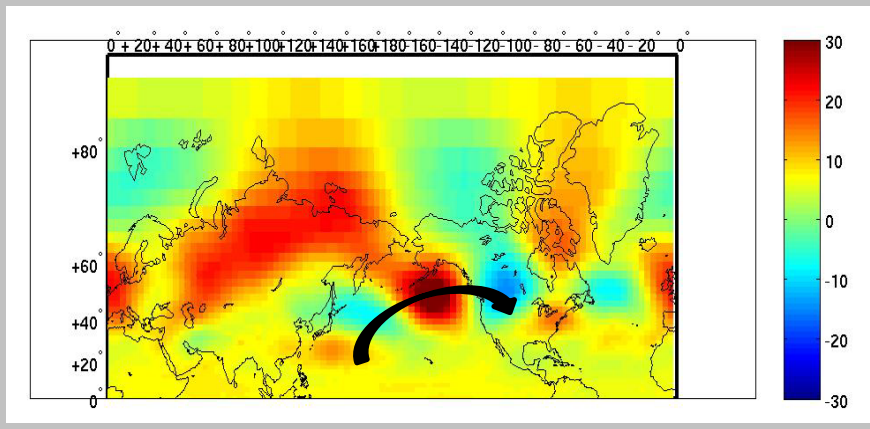




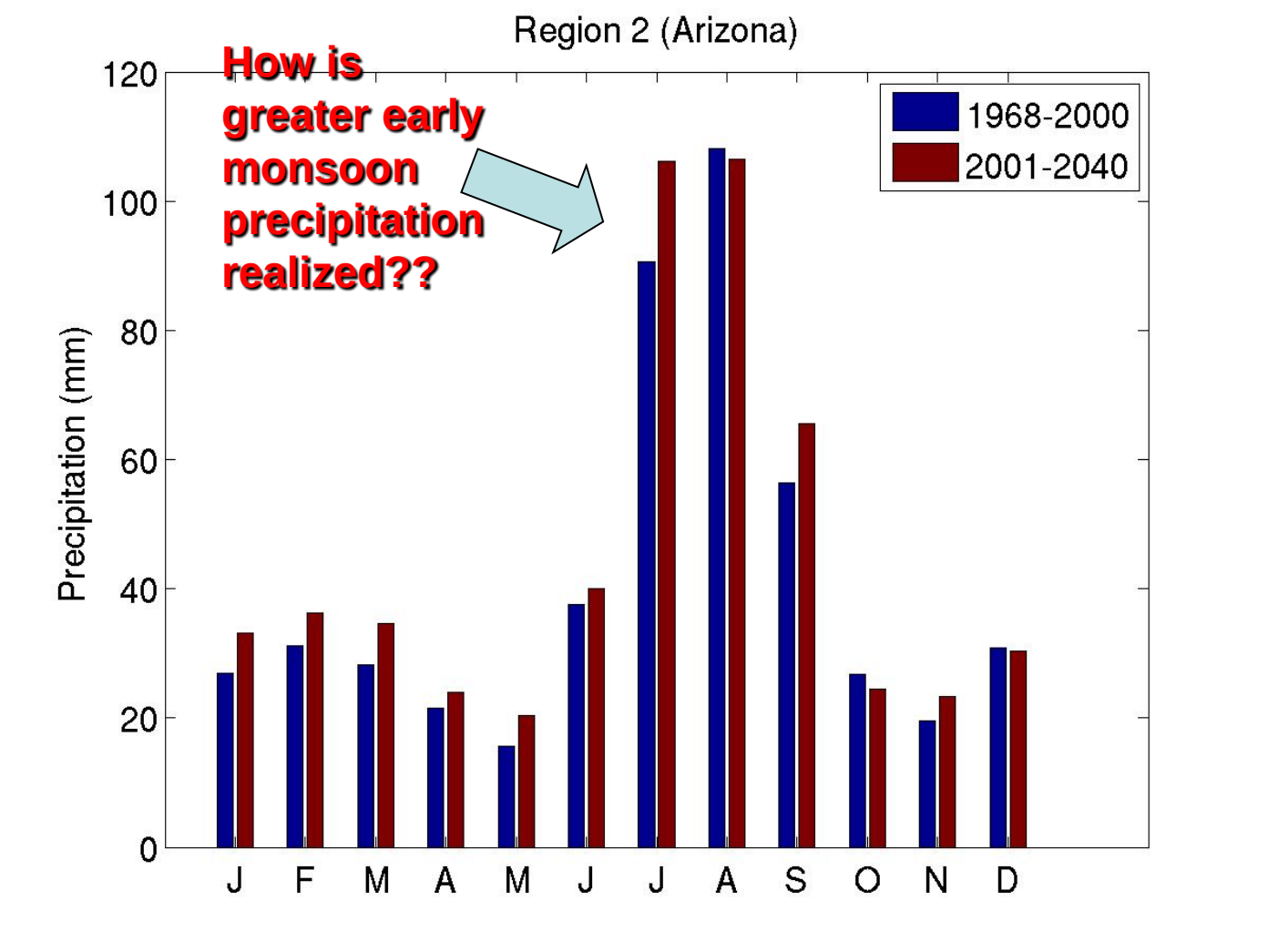
Principal Component Regression

WRF-HadCM3

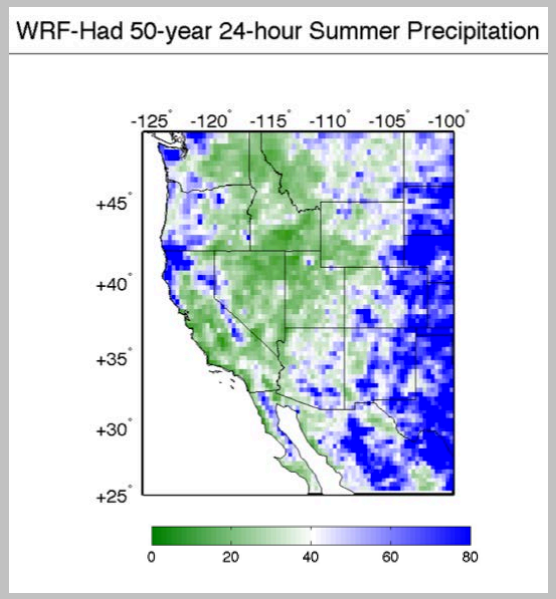




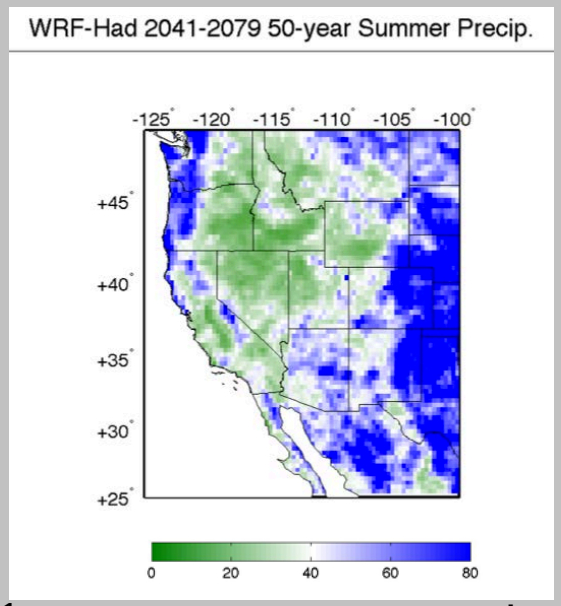
Change in WRF-HadCM3 dynamically downscaled precipitation in Arizona



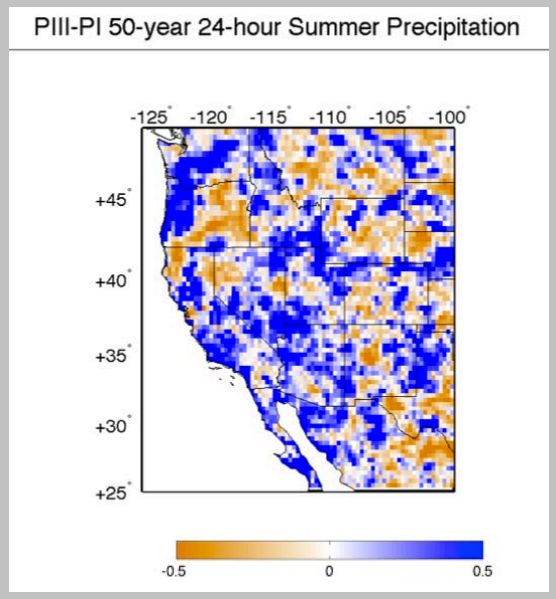
50-year WRF-HadCM3 summer precipitation events: historical vs. future



mm day^{-1}



mm day^{-1}



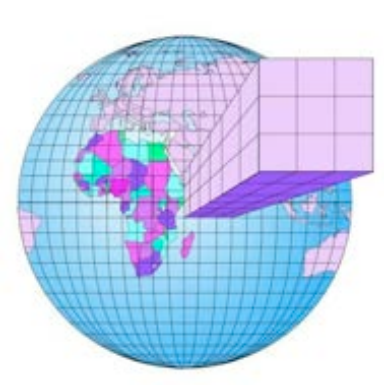
% change

Generally, an increase in warm season precipitation intensity tied to the terrain forced thunderstorms.

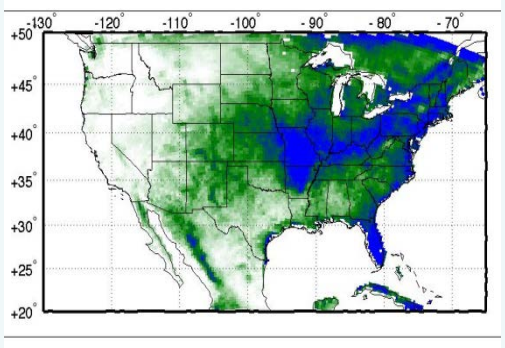
My opinion: Hotter and drier before monsoon onset, the wetter and more severe weather once monsoon arrives. Arrival modulated by natural variability (ENSO,PDO). We're actively working on this….

Multi-model schematic:

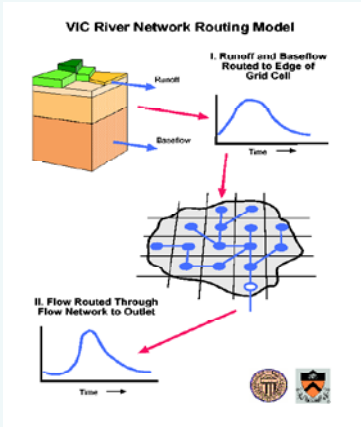
not a straight forward process!



Dynamical downscaling



Bias correction



1. Global Climate Models (GCMs) (2.5° resolution)

2. Regional climate model (RCM) simulations (35km resolution

3. VIC hydrologic model watershed simulations (1/8 degree resolution)

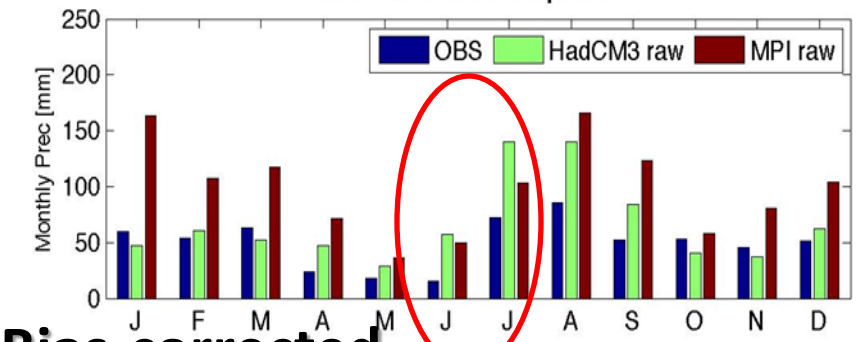
Ultimate goal: long-term reliable future water management data for drought planning for water resource management, agriculture and natural hazards, i.e. floods, severe weather, wildfire

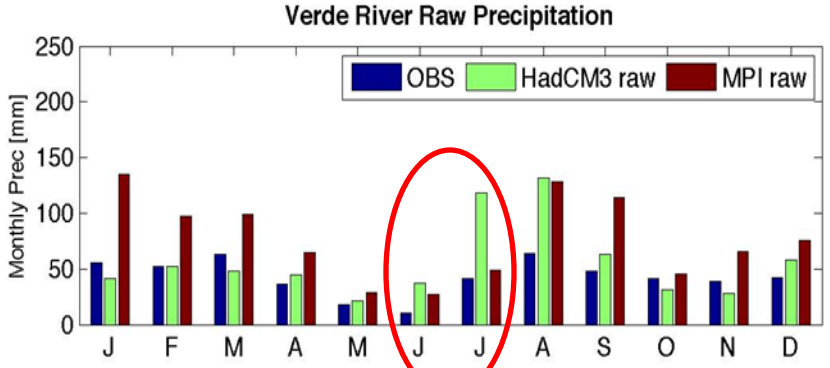
Preparing RCM data for VIC

RCM precipitation and temperatures were:

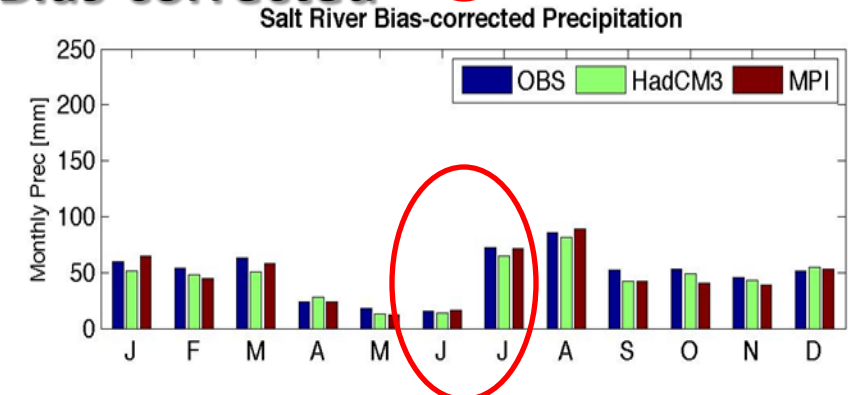
- rescaled to a 1/8 degree grid using an area weighted average
- Bias-Corrected using a Quantile method*

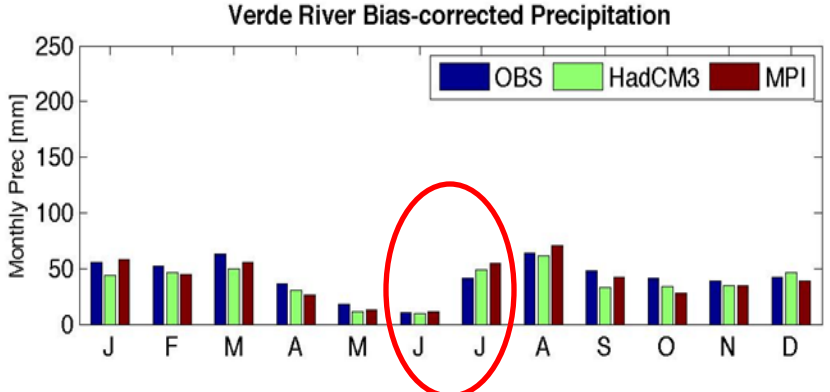
Raw



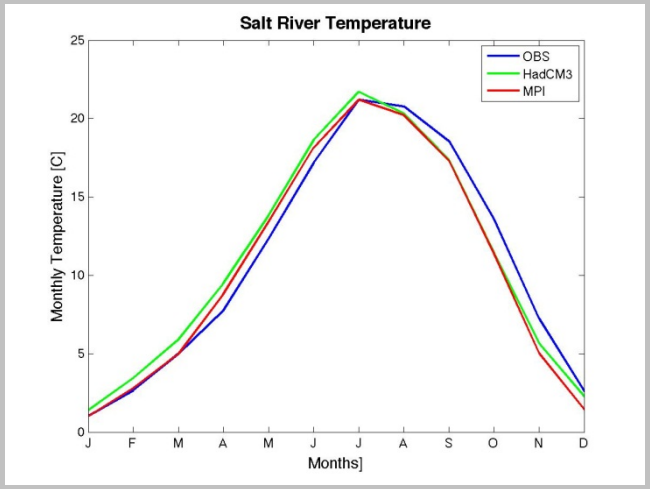


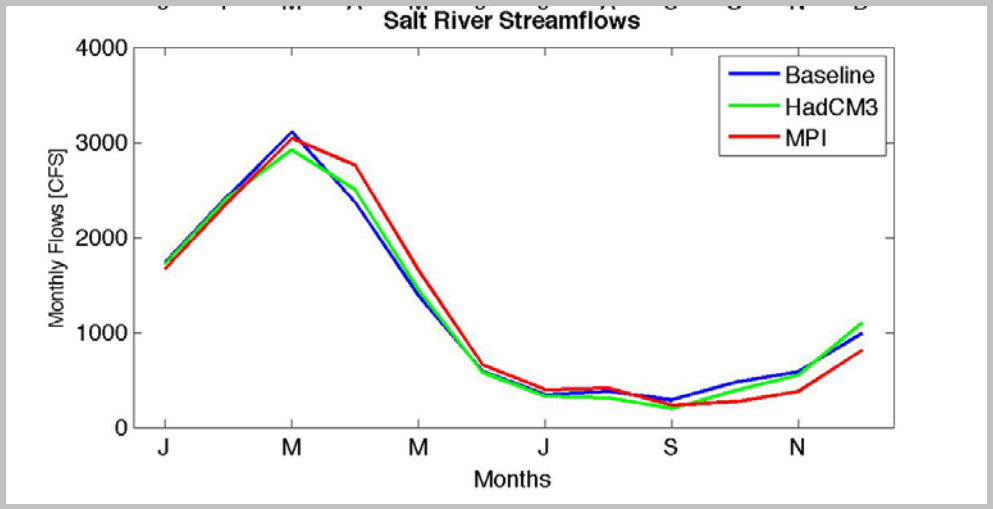
Bias-corrected

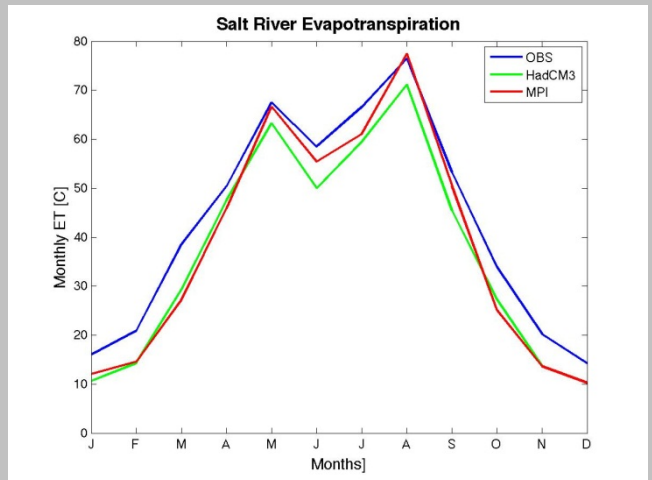


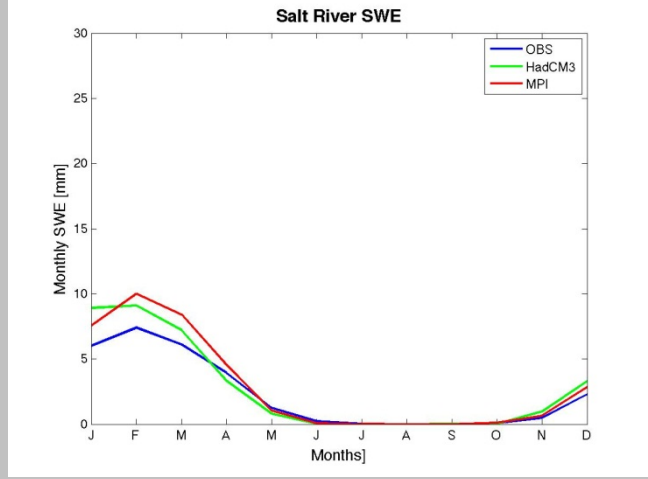


Hydrology model result: Salt River Basin (50 year climatology, monthly average)









Concluding points

Current global model climate change model for the Southwest are spatially inadequate and misrepresent important physical processes—therefore their projections may be wrong.

Dynamical downscaling adds value to climate change projections because a regional model can better represent the land surface influences on precipitation processes: orgraphically forced snowfall in winter, monsoon thunderstorms in summer.

What do dynamically downscaled projections suggest so far?

- **<u>Winter:</u> Precipitation does not significantly change, but is more intense precipitation. Less snowfall, especially in the Southwest. Greatest changes occur with the shift of the freezing line with elevation.**
- **<u>Summer:</u> More precipitation in general with greater severity of thunderstorms.**

Regional climate model data are near a spatial scale adequate for water resource projection with a hydrologic model, appropriately accounting for individual model bias.