Results from NCEP-driven RCMs

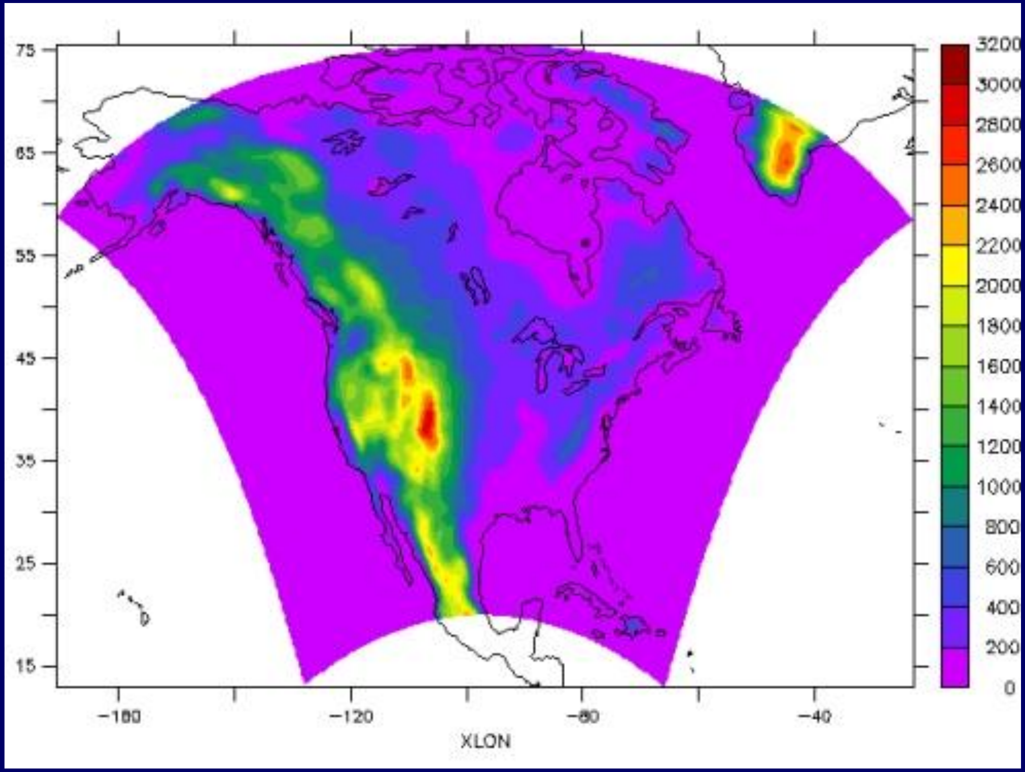
~ Overview ~

William J. Gutowski, Jr. & Raymond W. Arritt
Iowa State University
and
The NARCCAP Team

Simulations Analyzed

MM5 Iowa State/ PNNL	RegCM3 UC Santa Cruz ICTP	CRCM Quebec, Ouranos	HADRM3 Hadley Centre	RSM Scripps	WRF NCAR/ PNNL

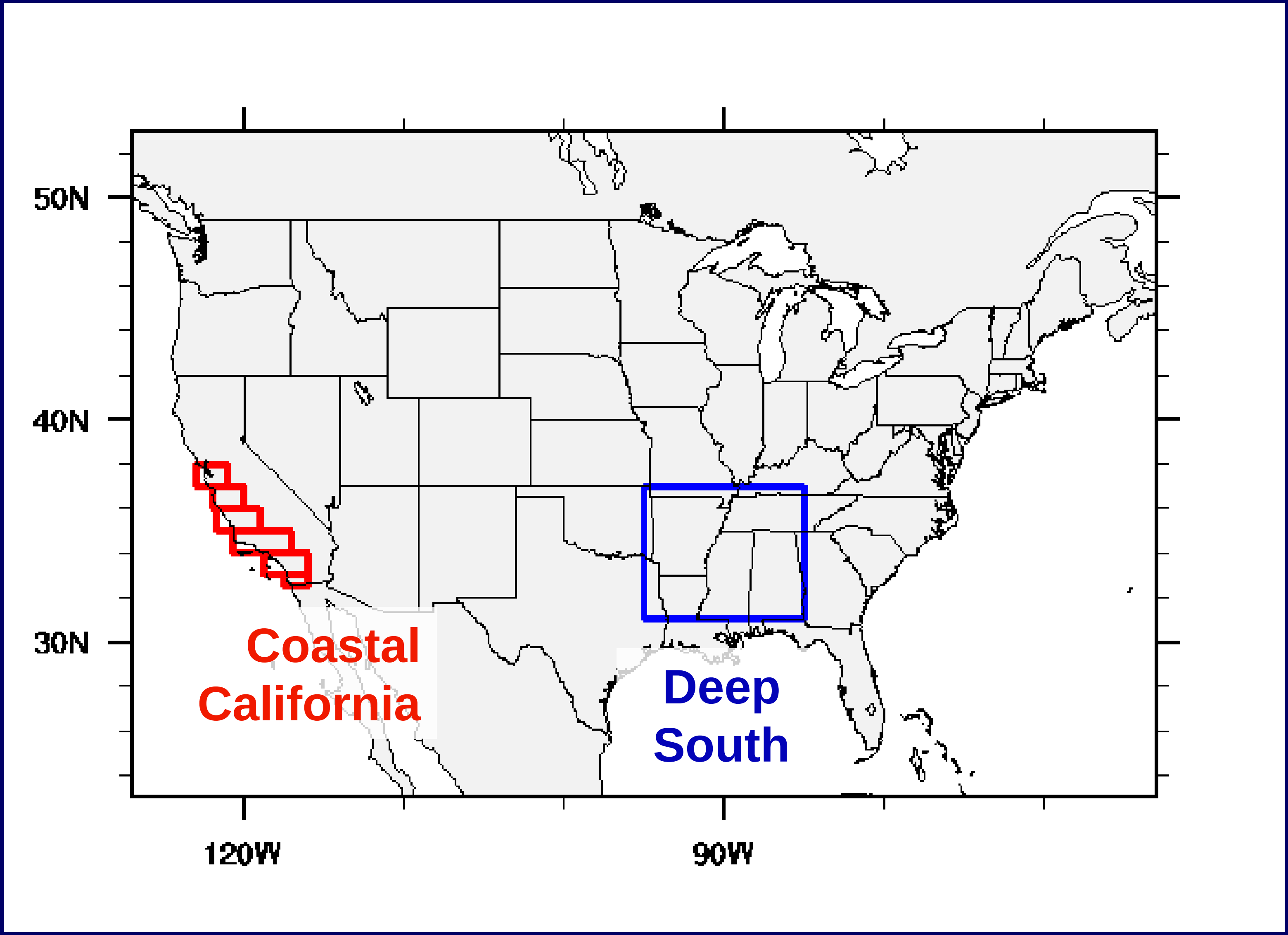
- Domain
  - Most of North America
- Period
  - 1979-2004
- Boundary Conditions
  - NCEP/DOE reanalysis
- Resolution
  - 50 km



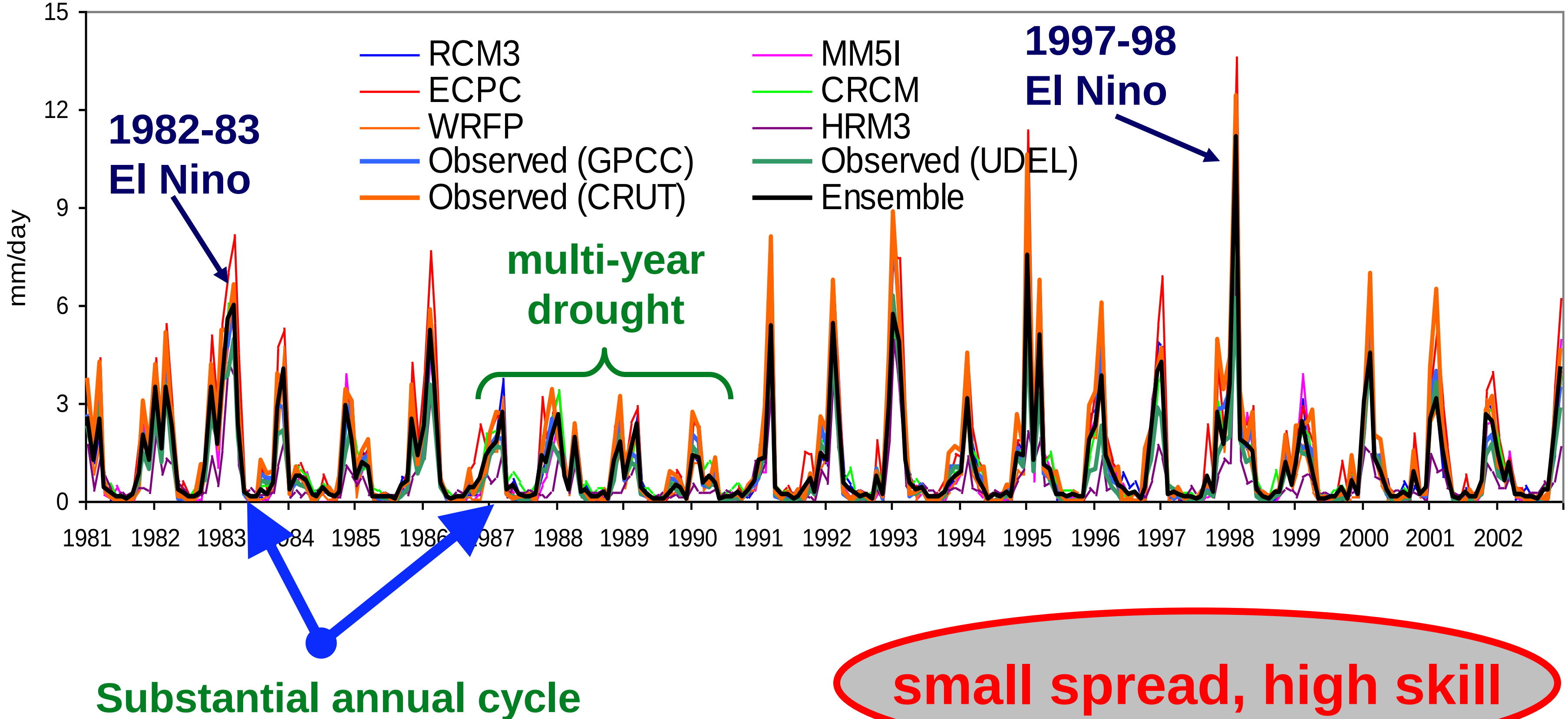
Part I: Interannual Variability

- Results shown for 1981-2002
- Comparison with 0.5º gridded precipitation analysis from the University of Delaware

Precipitation analysis for two regions



Monthly time series of precipitation in coastal California



small spread, high skill

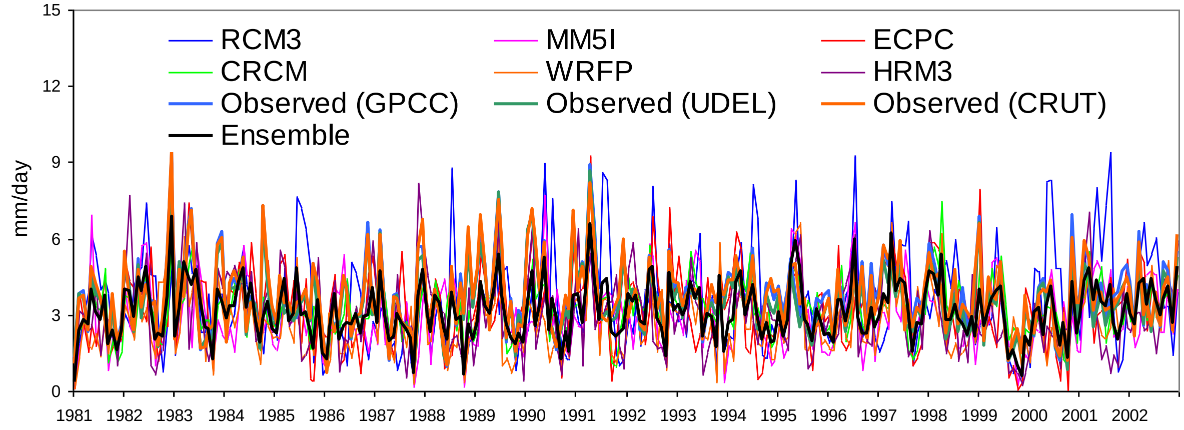
Correlation with Observed Precipitation - Coastal California

Model	Correlation
HadRM3	0.857
RegCM3	0.916
MM5	0.925
RSM	0.945
CRCM	0.946
WRF	0.918
Ensemble	**0.947**

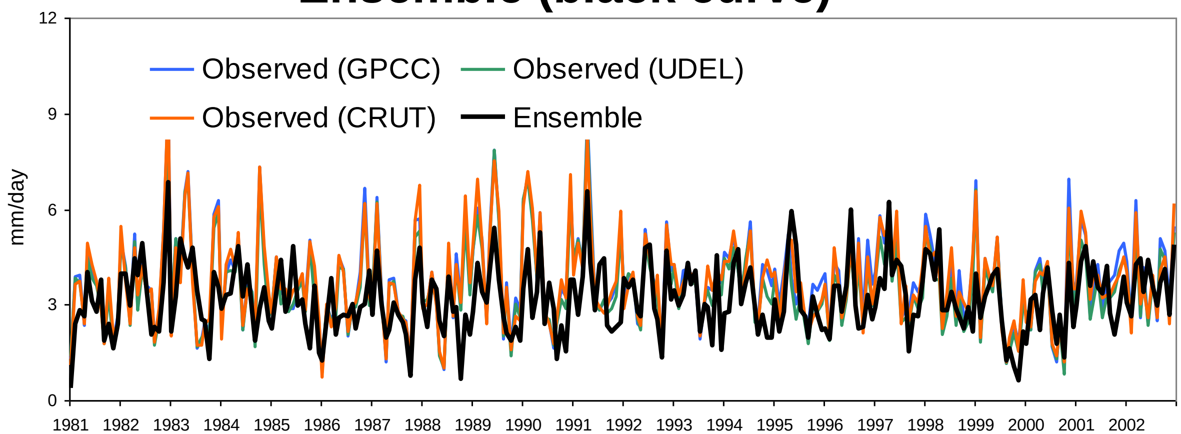
All models have high correlations with observed **monthly time series** of precipitation.

Ensemble mean has a higher correlation than any model

Monthly Time Series - Deep South



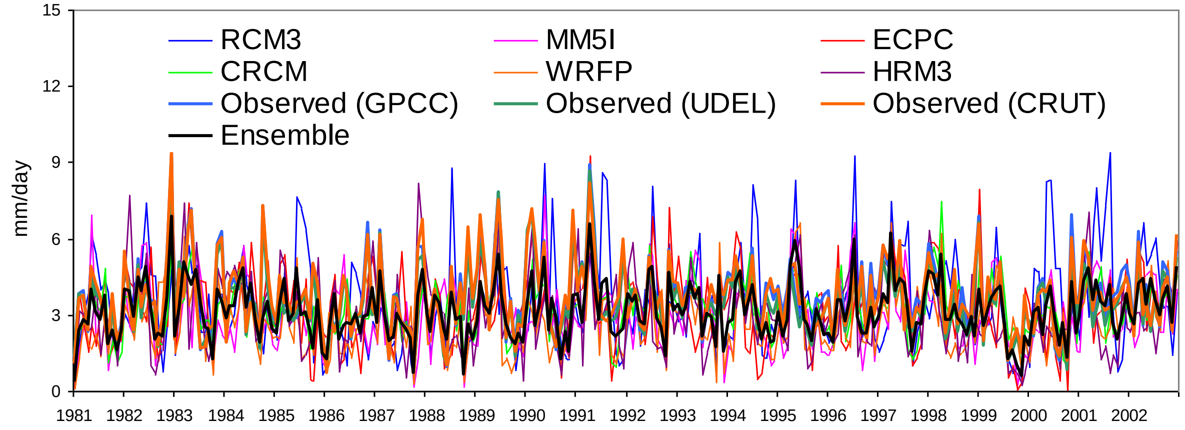
Ensemble (black curve)

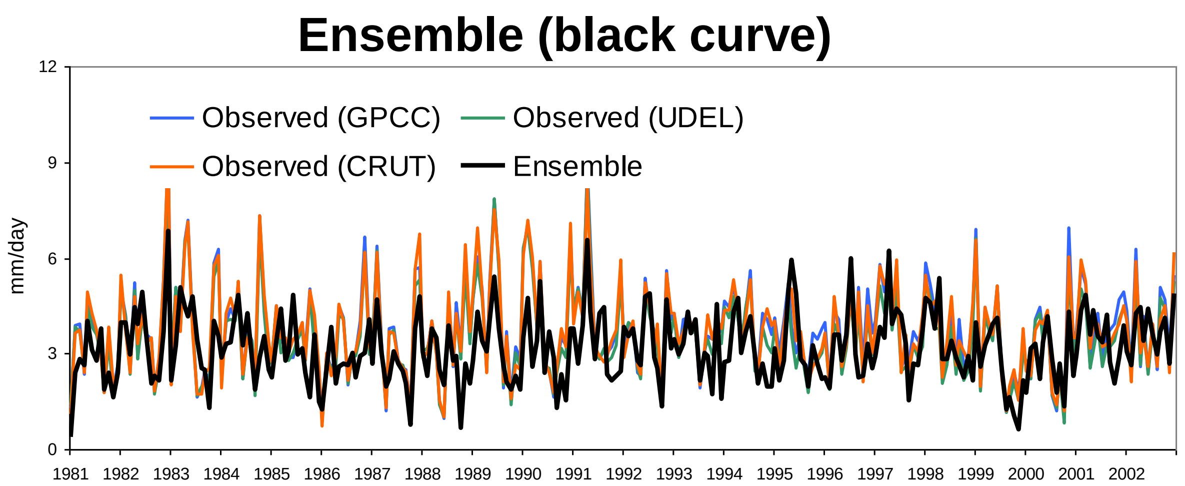


Model	Correlation
HadRM3	0.489
RegCM3	0.231
MM5	0.343
RSM	0.649
CRCM	0.649
WRF	0.513
Ensemble	**0.640**

Two models (RSM and CRCM) perform much better. These models inform the domain interior about the large scale.

Monthly Time Series - Deep South





Model	Correlation
HadRM3	0.489
RegCM3	0.231
MM5	0.343
RSM	0.649
CRCM	0.649
WRF	0.513
Ensemble	**0.640**
RSM+CRCM	**0.727**

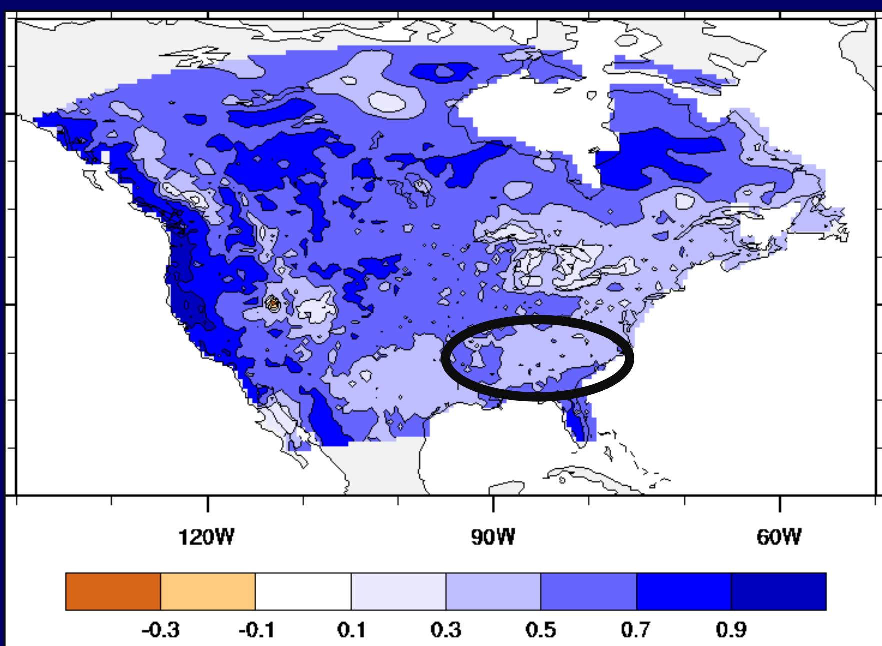
A "mini ensemble" of RSM and CRCM performs best in this region.

Correlation of Monthly Time Series

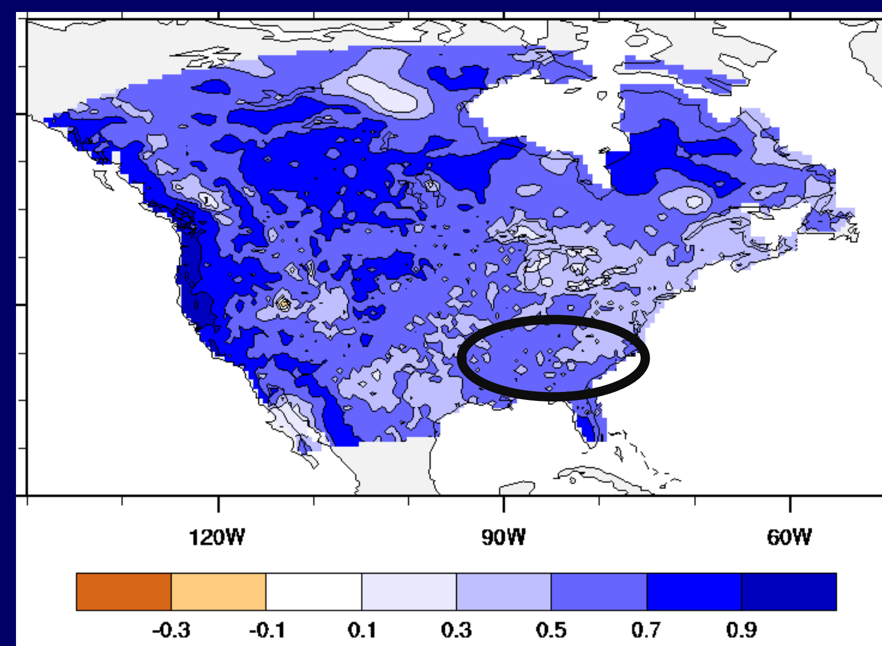
The "mini-ensemble" has better correlation than the full ensemble in the southern and eastern parts of the domain.

Other measures of forecast skill (such as bias) are not necessarily better.

Full ensemble



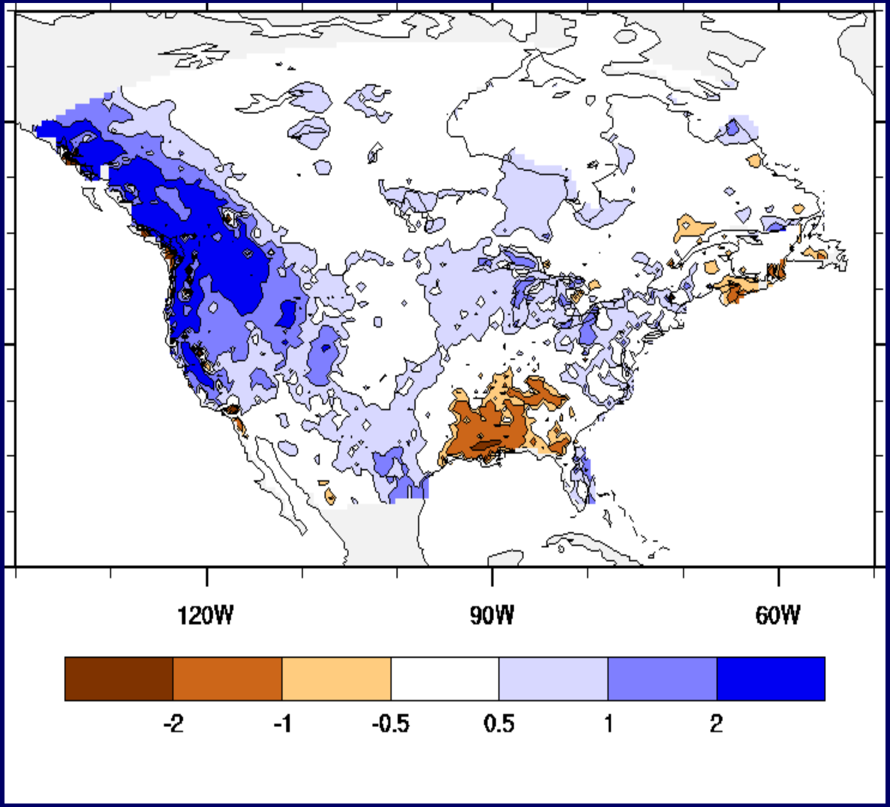
RSM + Canadian RCM



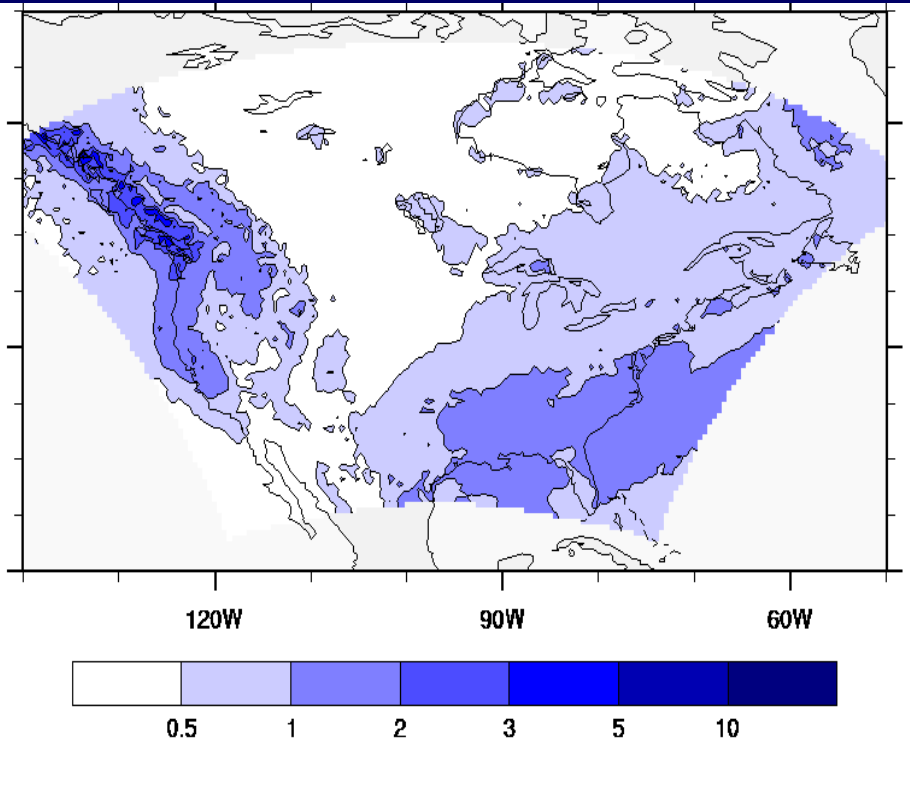
Ensemble error and spread (January)

There are hints of a spread-skill relation but it is not consistent.

Bias

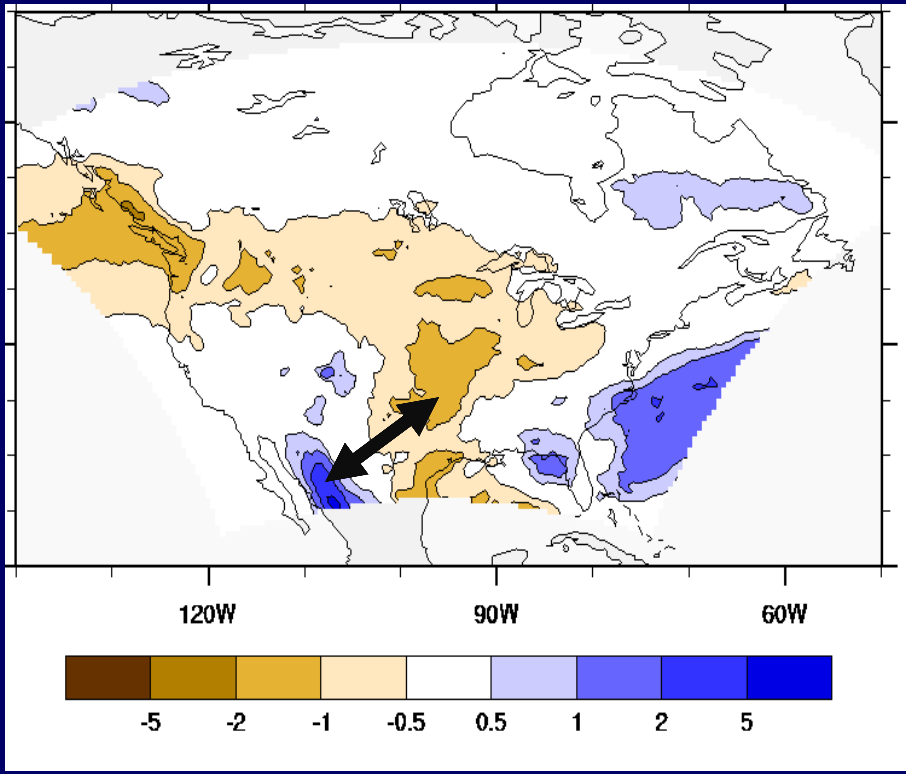


Ensemble spread

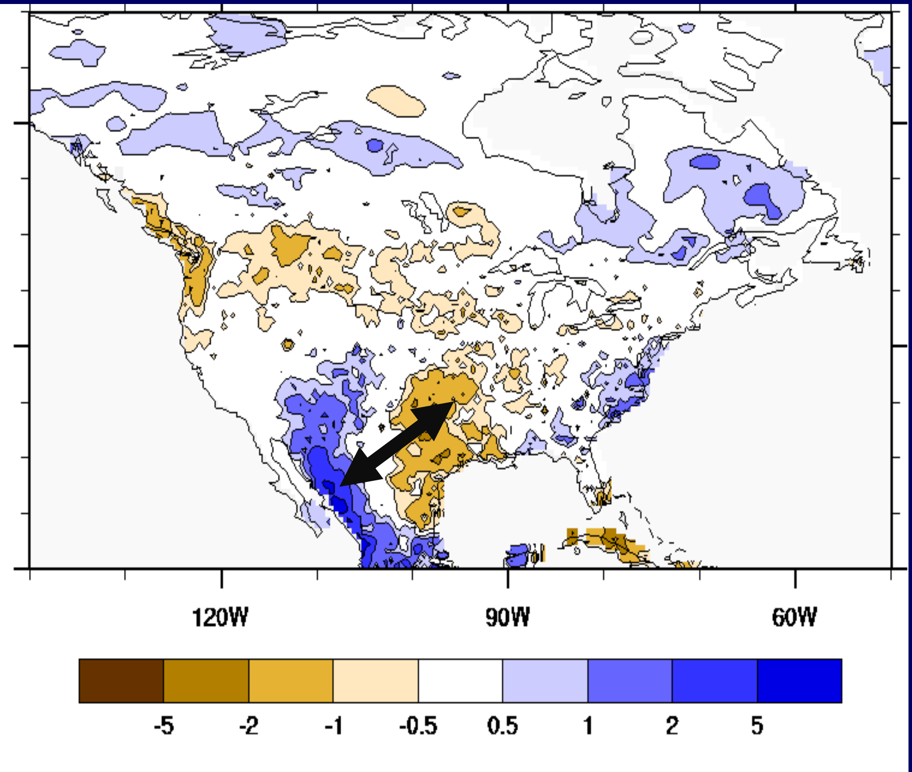


The ensemble reproduces the dipole of June-July precipitation change, but the monsoon does not extend as far north as observed.

ensemble July minus June



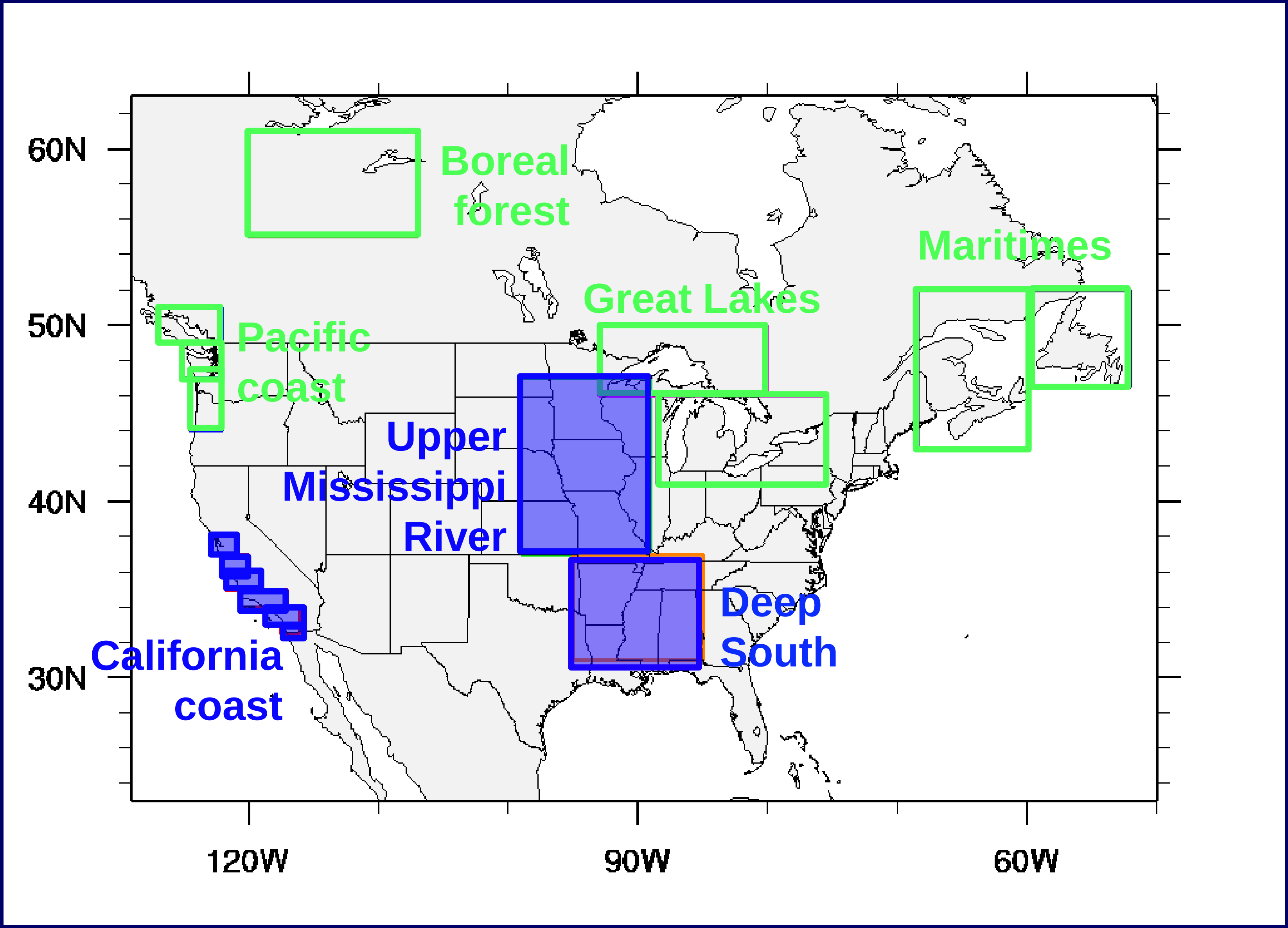
observed July minus June



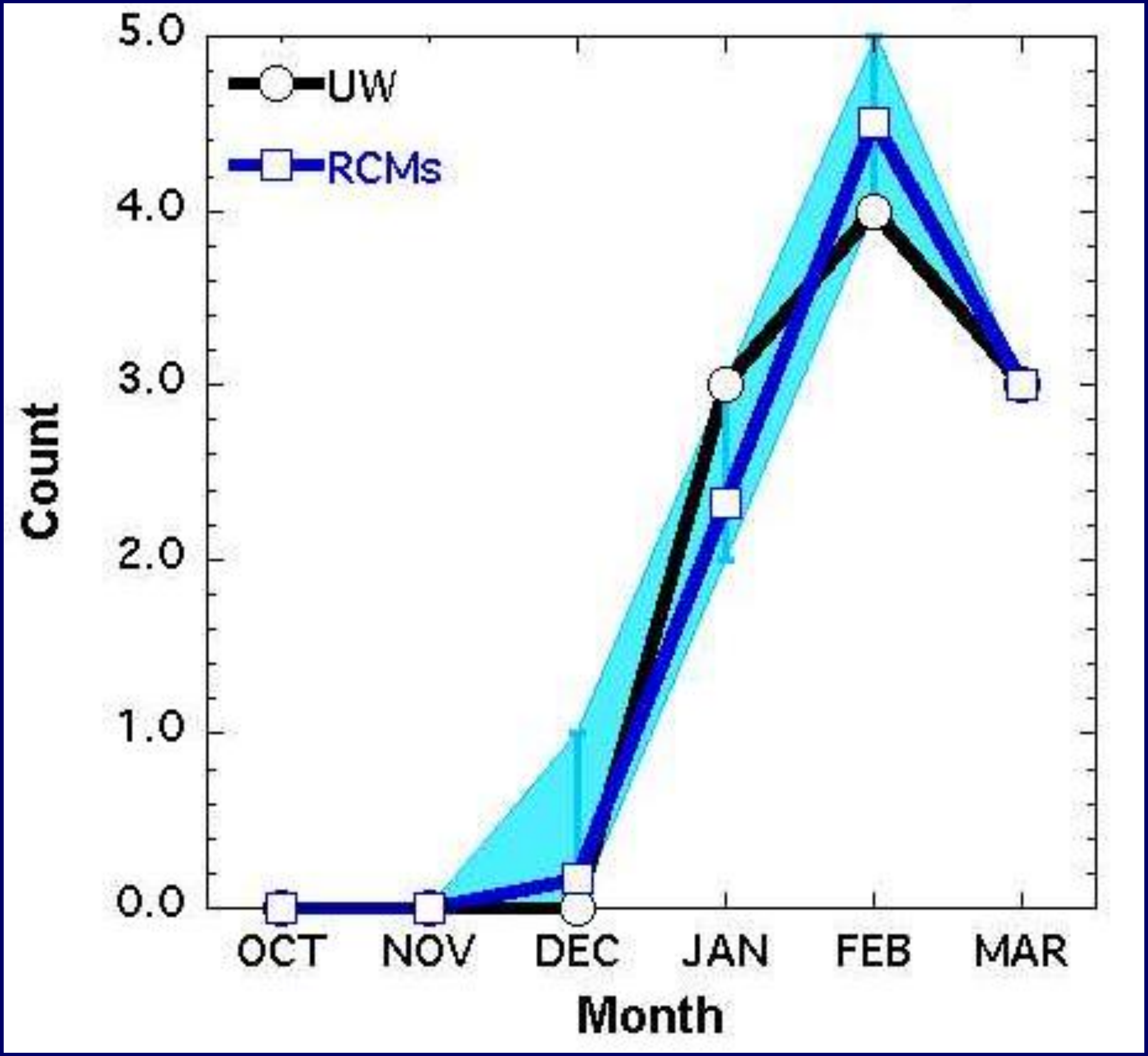
Part 2: Extreme Monthly Precipitation

- Observations
  - ✶ **Precip: University of Washington VIC retrospective analysis**
  - ✶ **500 hPa Heights: North American Regional Reanalysis**
- Comparison period: 1982 -1999
  - ✶ **1979-1981 omitted - spinup**
  - ✶ **UW data end in mid-2000**
- Analysis
  - ✶ **Cold season (Oct-Mar)**
  - ✶ **10 wettest months (top 10%)**

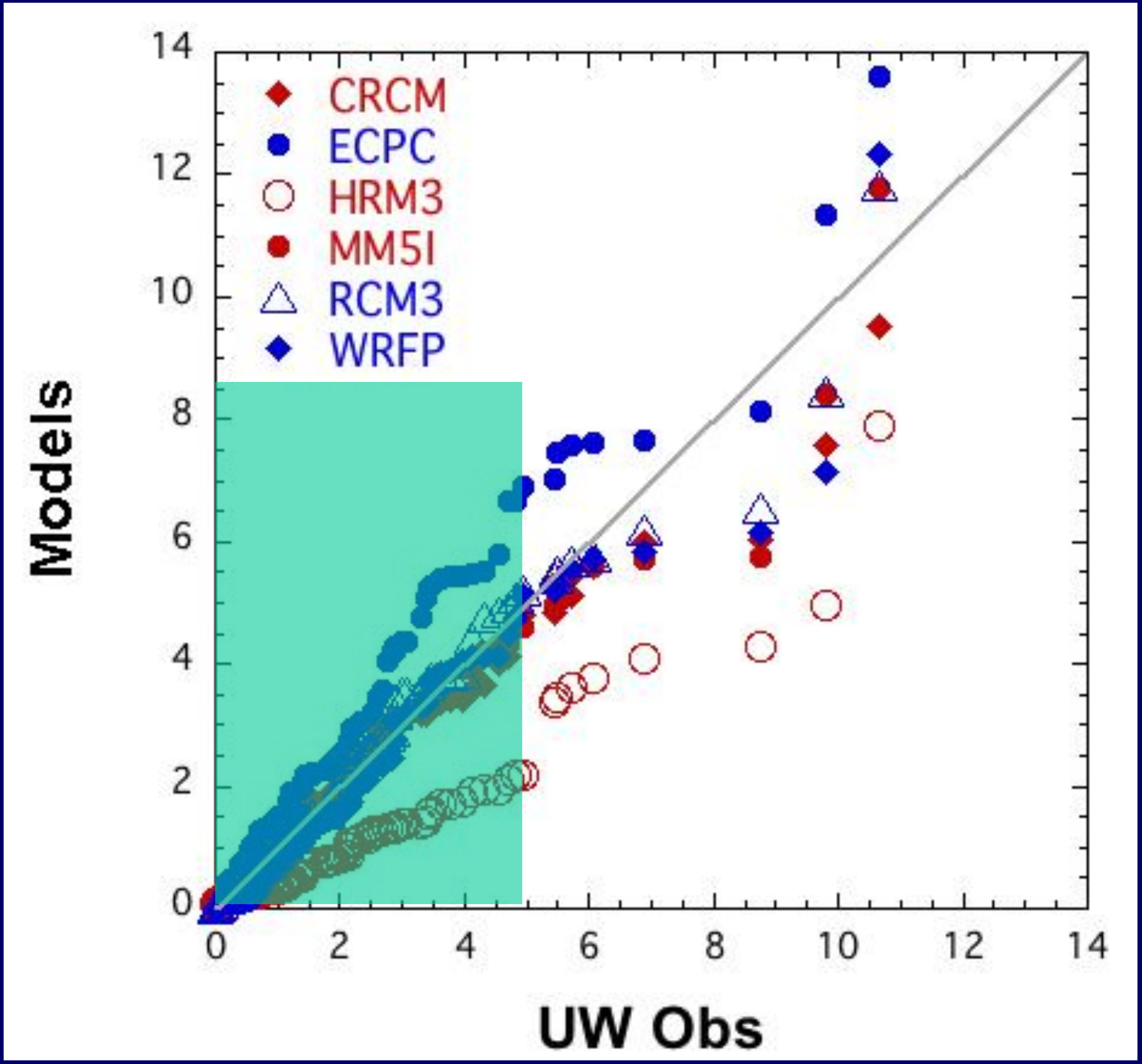
Regions Analyzed



Frequency – Coastal CA

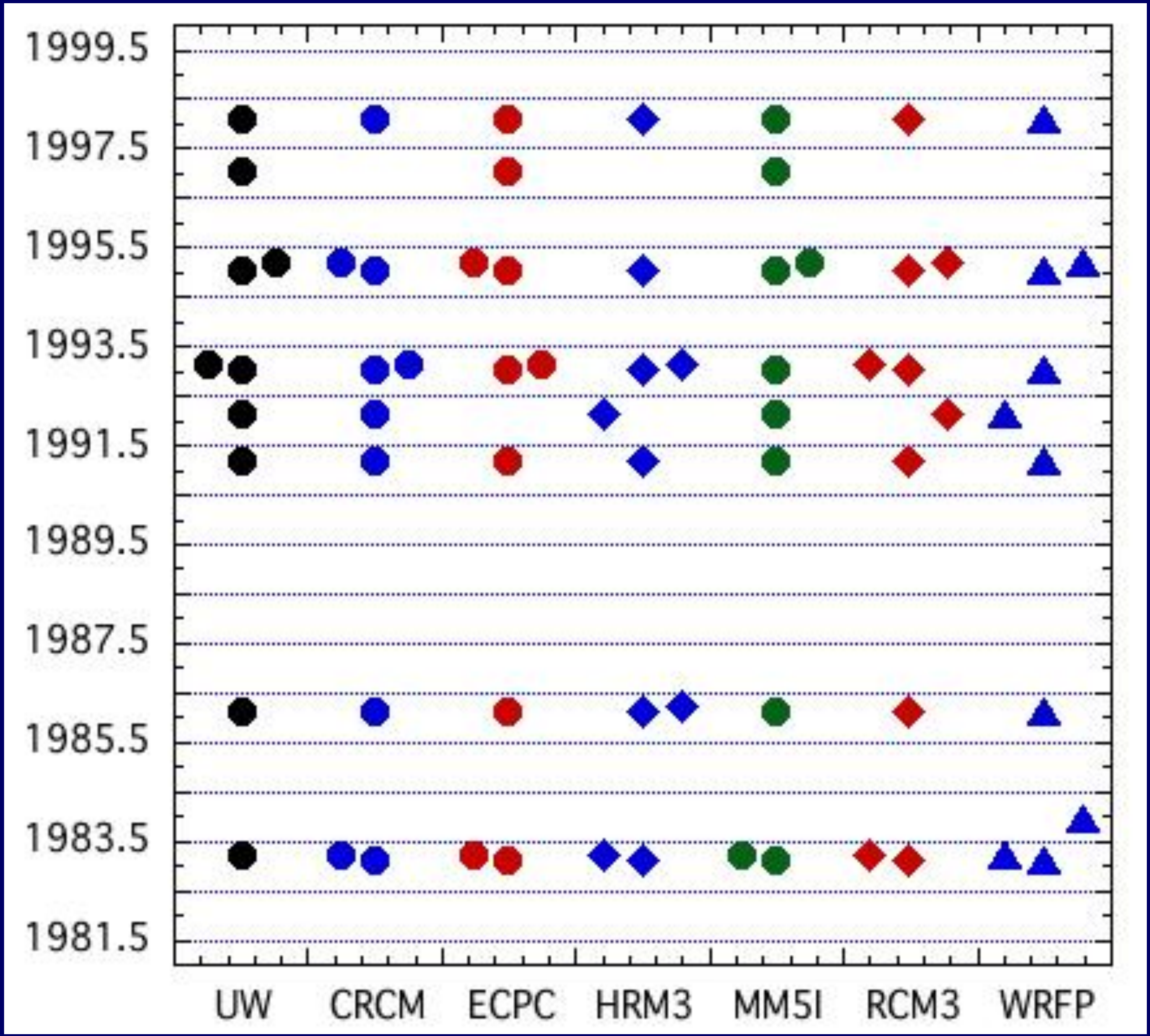


Ranked Precipitation – Coastal CA



Ensemble average of top 10 = 9 % smaller than UW

Interannual Variability – Coastal CA



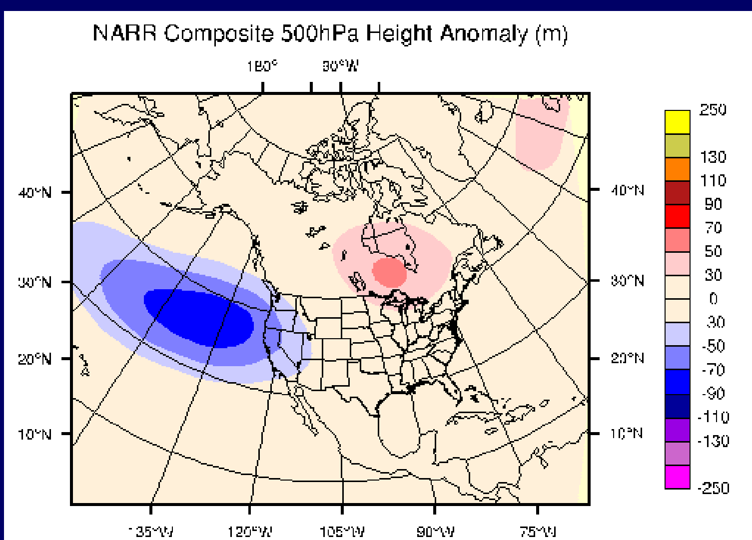
59 of 60 (98%) simulated extremes occur in cold seasons with an observed extreme.

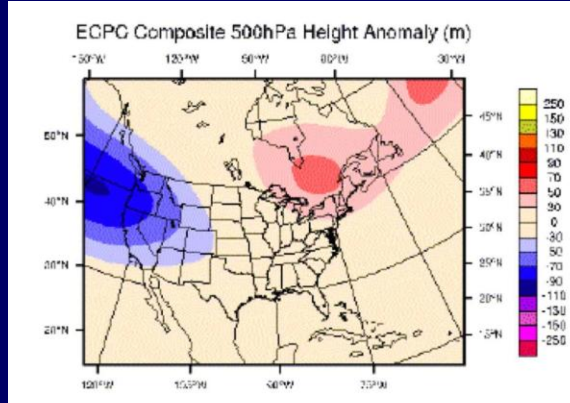
(random chance: 27)

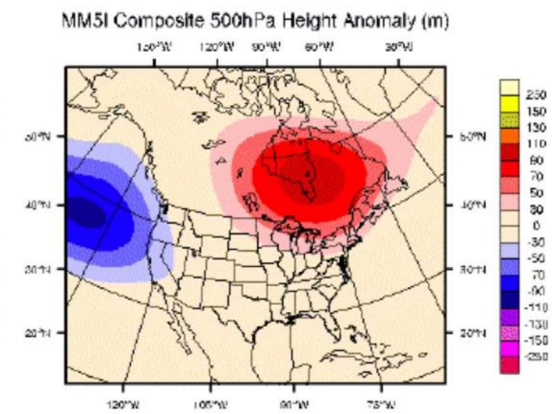
Composite 500 hPa Height Anomalies

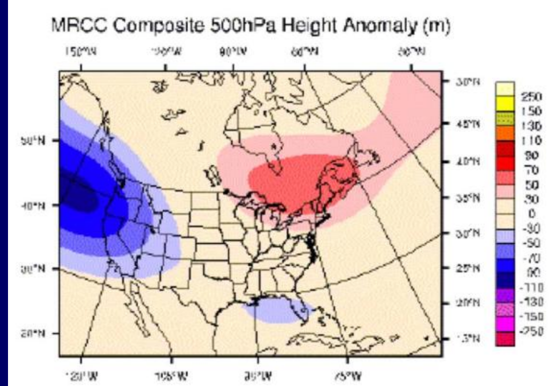
Top 10 Extremes

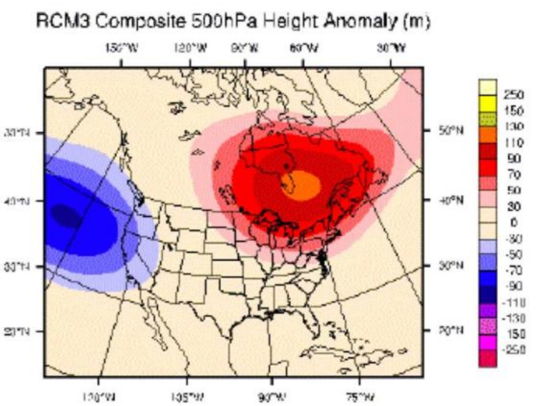
Coastal CA

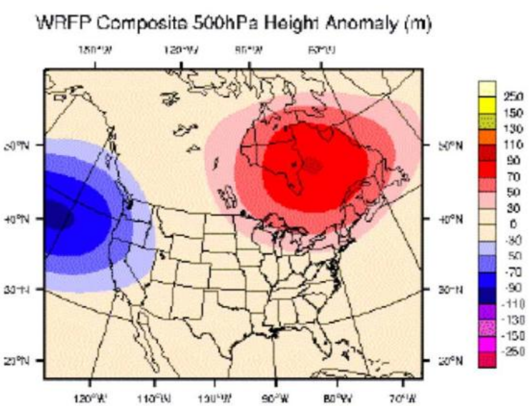




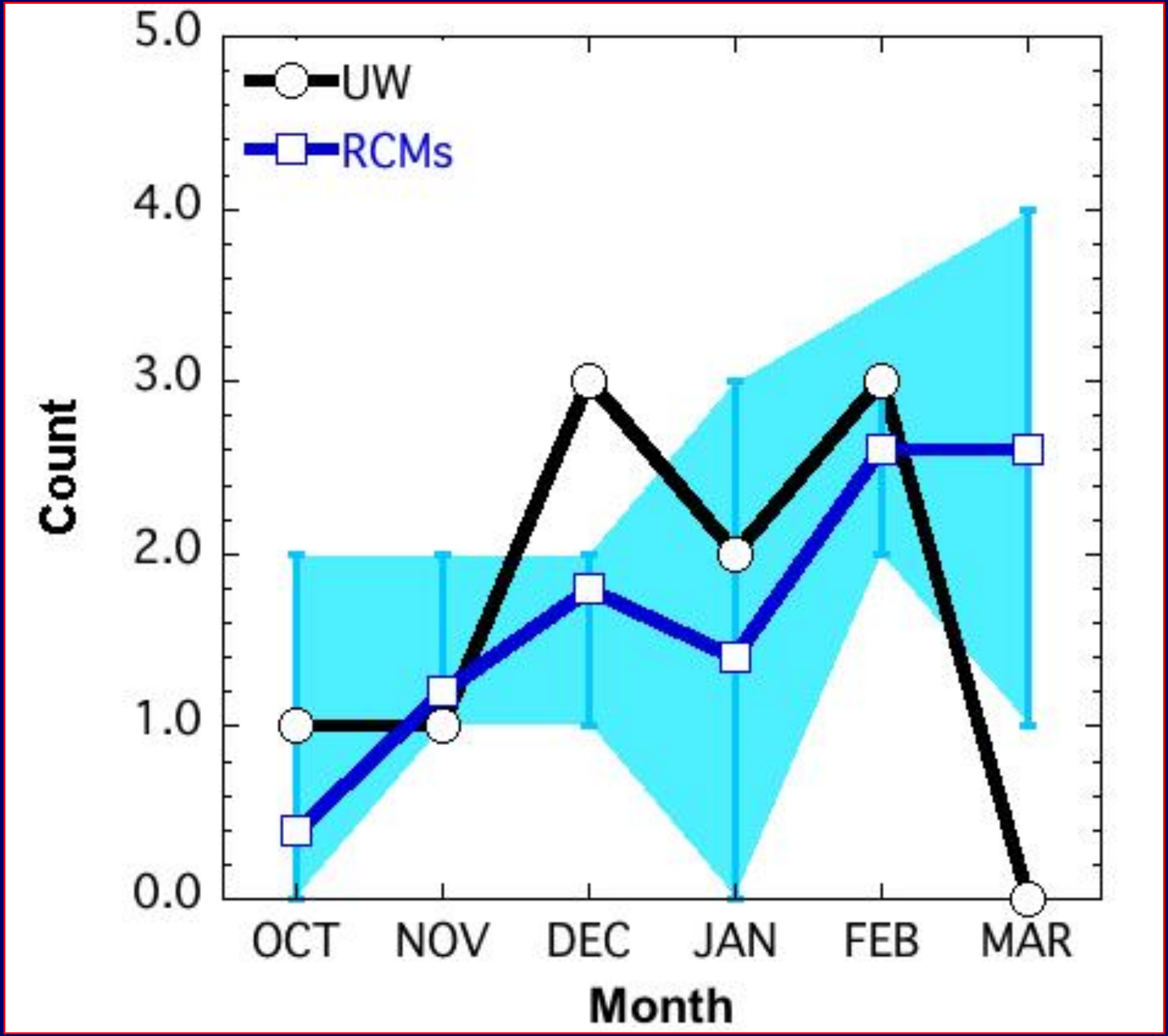




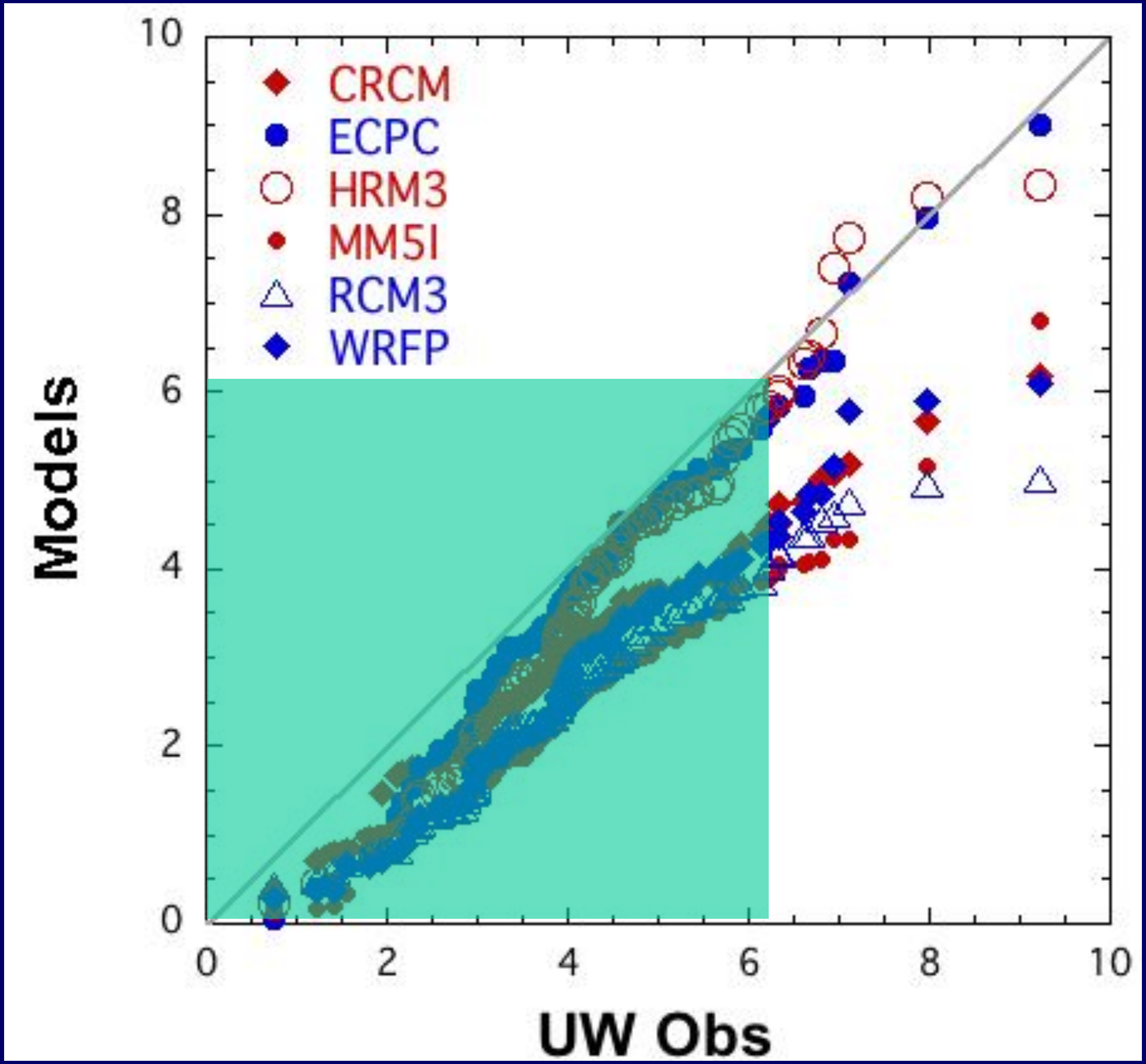




Frequency – Deep South

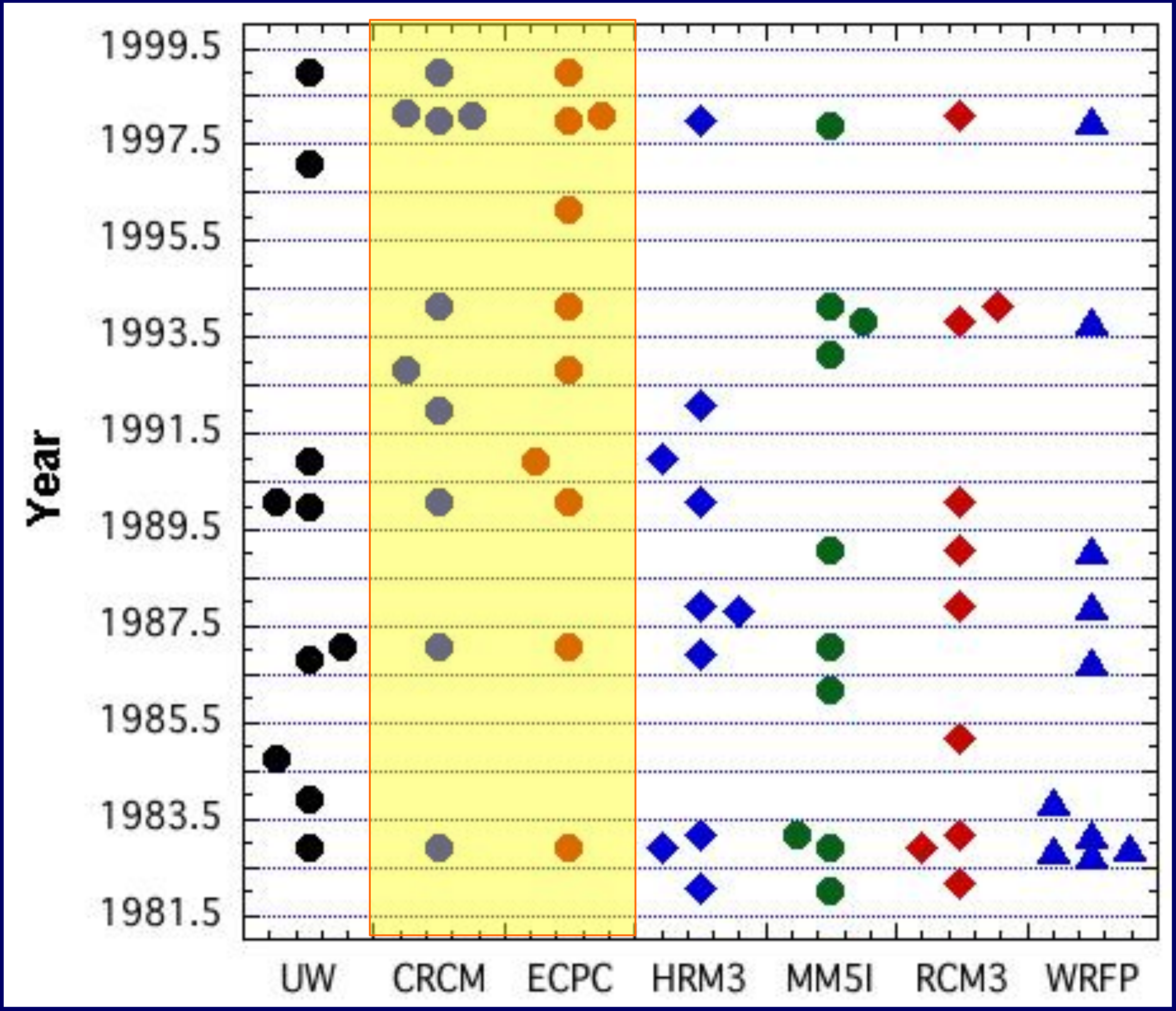


Ranked Precipitation – Deep South



Ensemble average of top 10 = 22 % smaller than UW

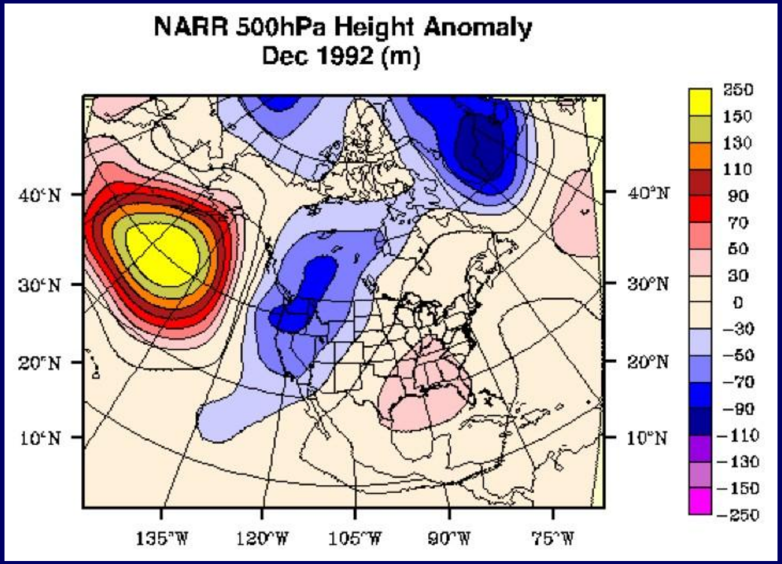
Interannual Variability – Deep South

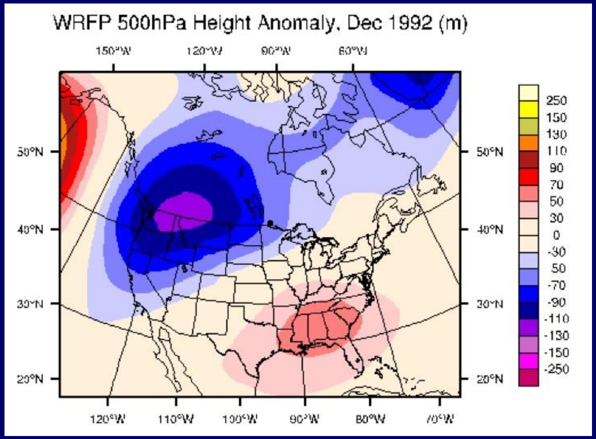


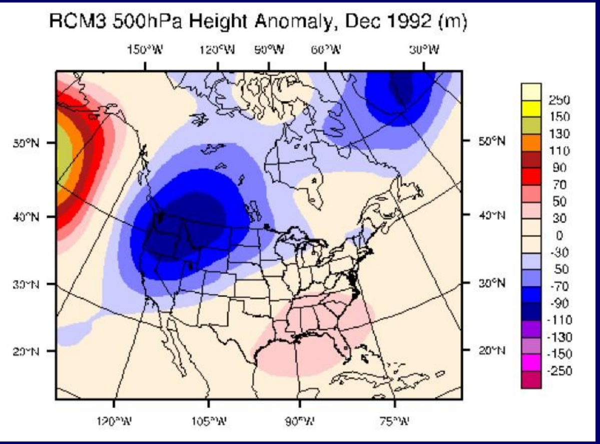
27 of 60 (45%) simulated extremes occur in cold seasons with an observed extreme.

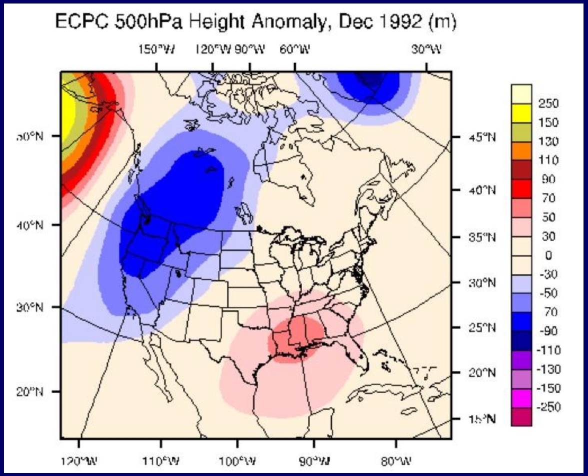
(random chance: 27)

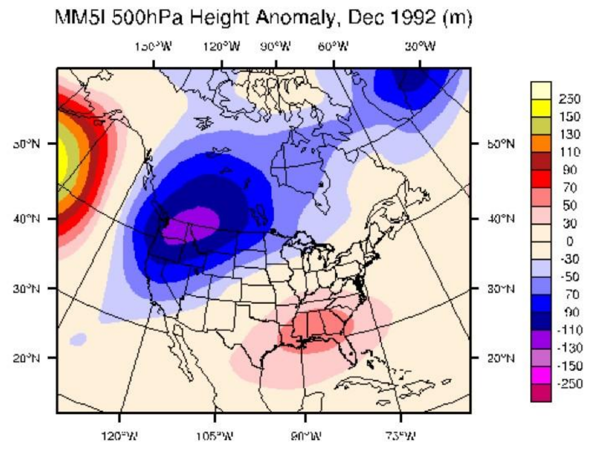
500 hPa Height Anomalies – Deep South Extreme











Summary
Monthly Precipitation

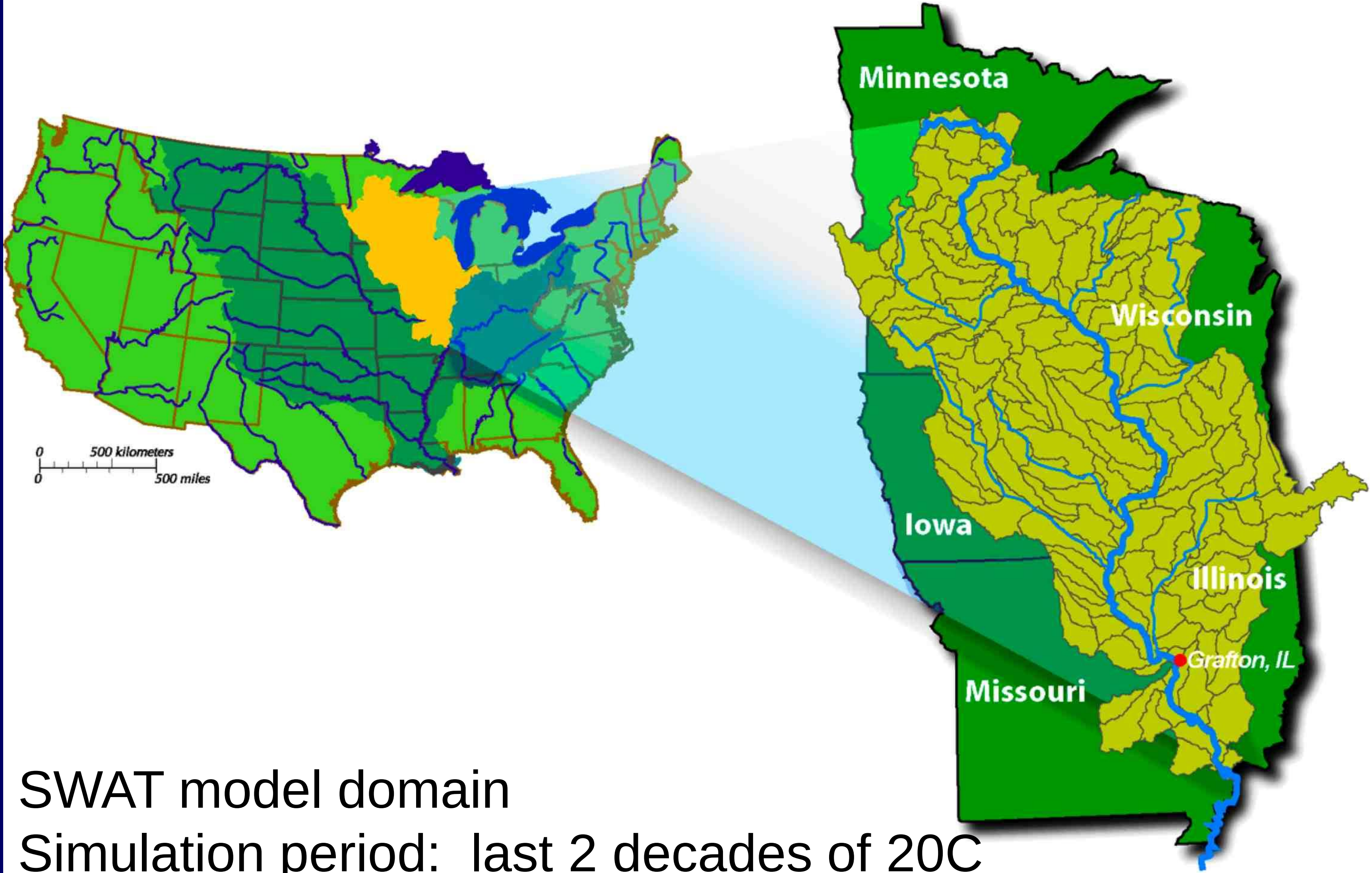
Where there is a substantial periodic cycle:
- Models simulate well the interannual variability
- Models simulate well monthly, regional extremes

Where there is no substantial periodic cycle:
- Models simulate poorly the interannual var. & extremes
- Interior nudging improves interannual variability
- Interior nudging does not help extremes

Thank You!

(www.narccap.ucar.edu)

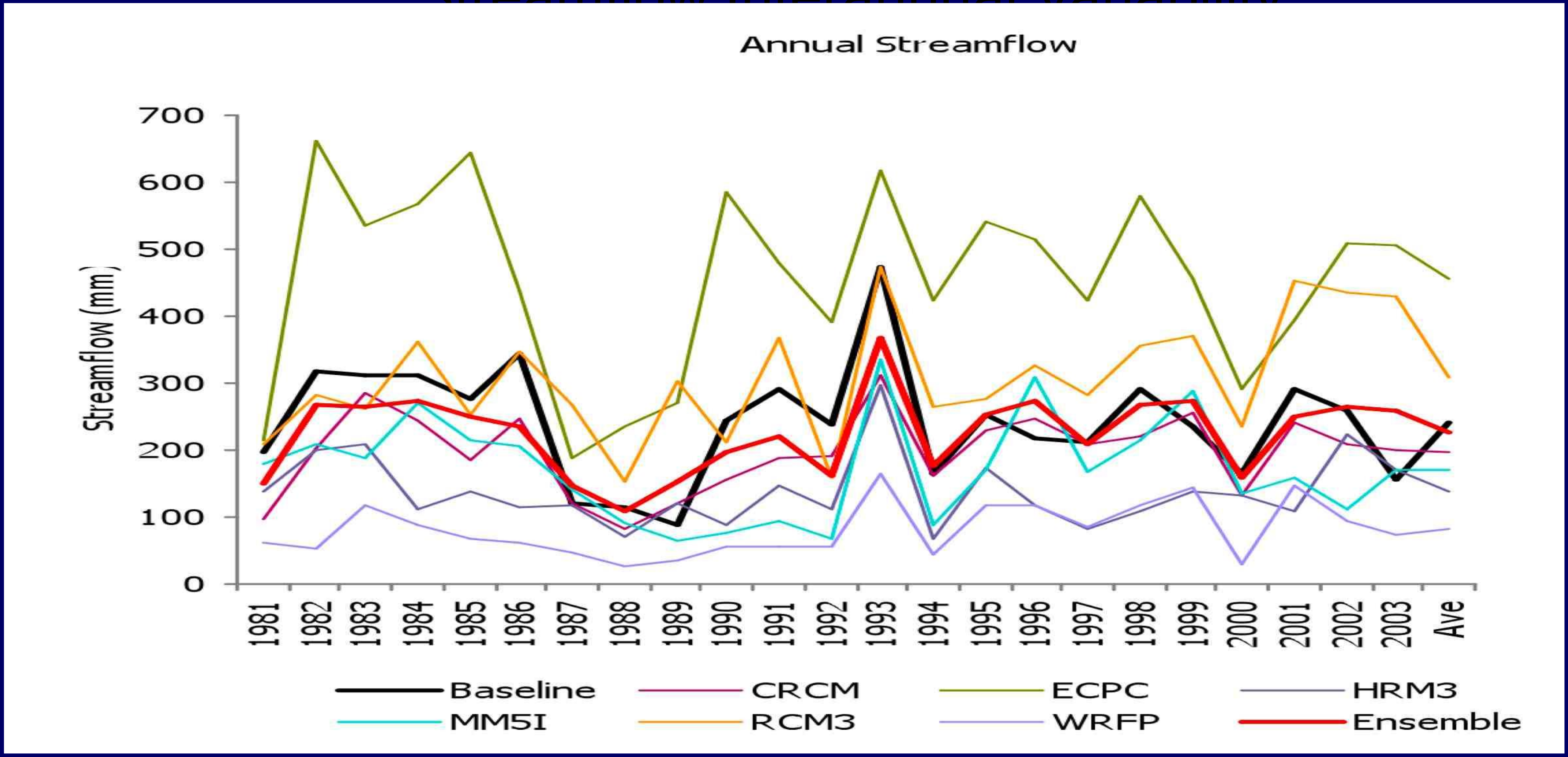
Hydrologic Analysis (Takle et al.)



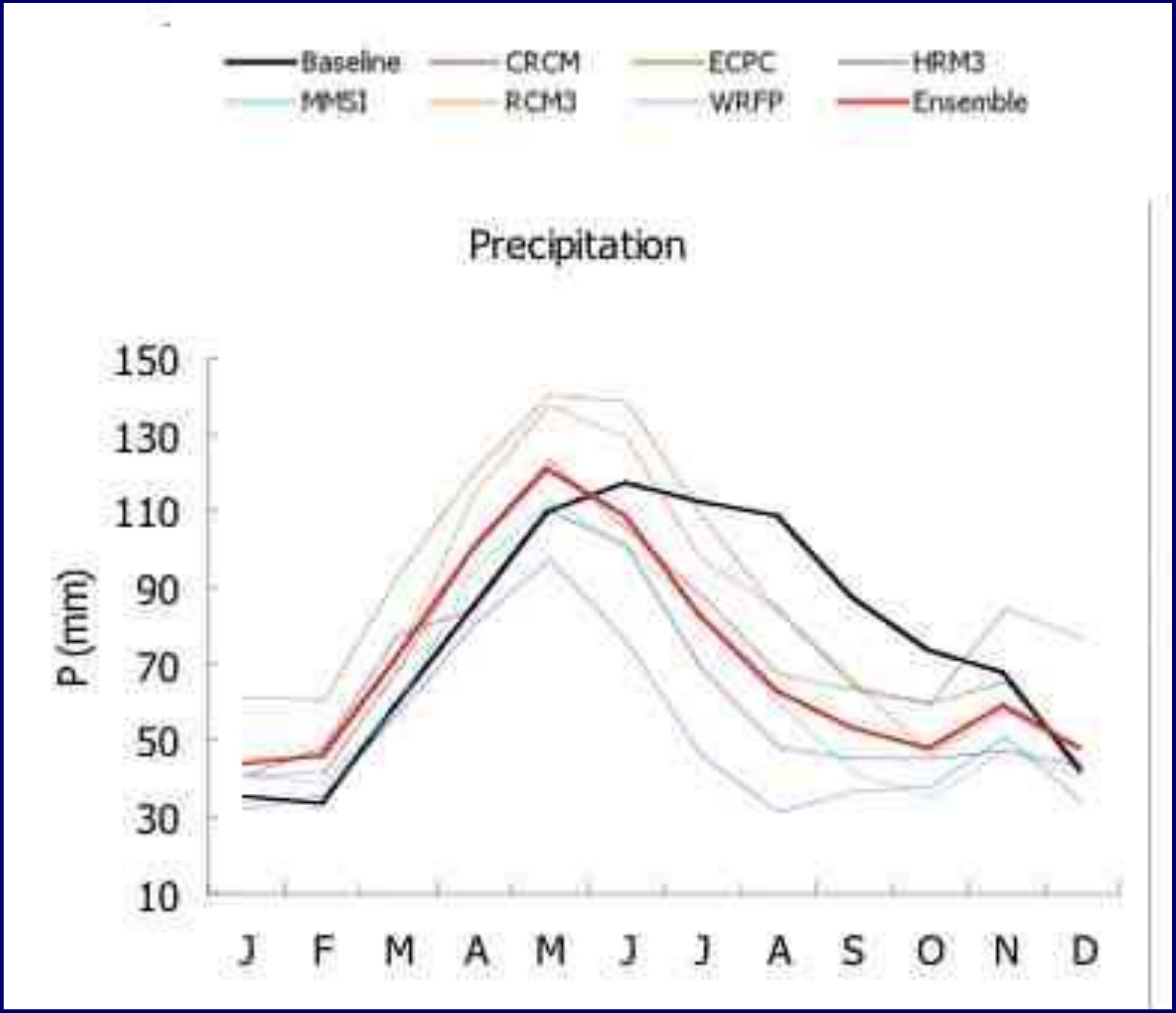
SWAT model domain
Simulation period: last 2 decades of 20C

Hydrologic Analysis (Takle et al.)

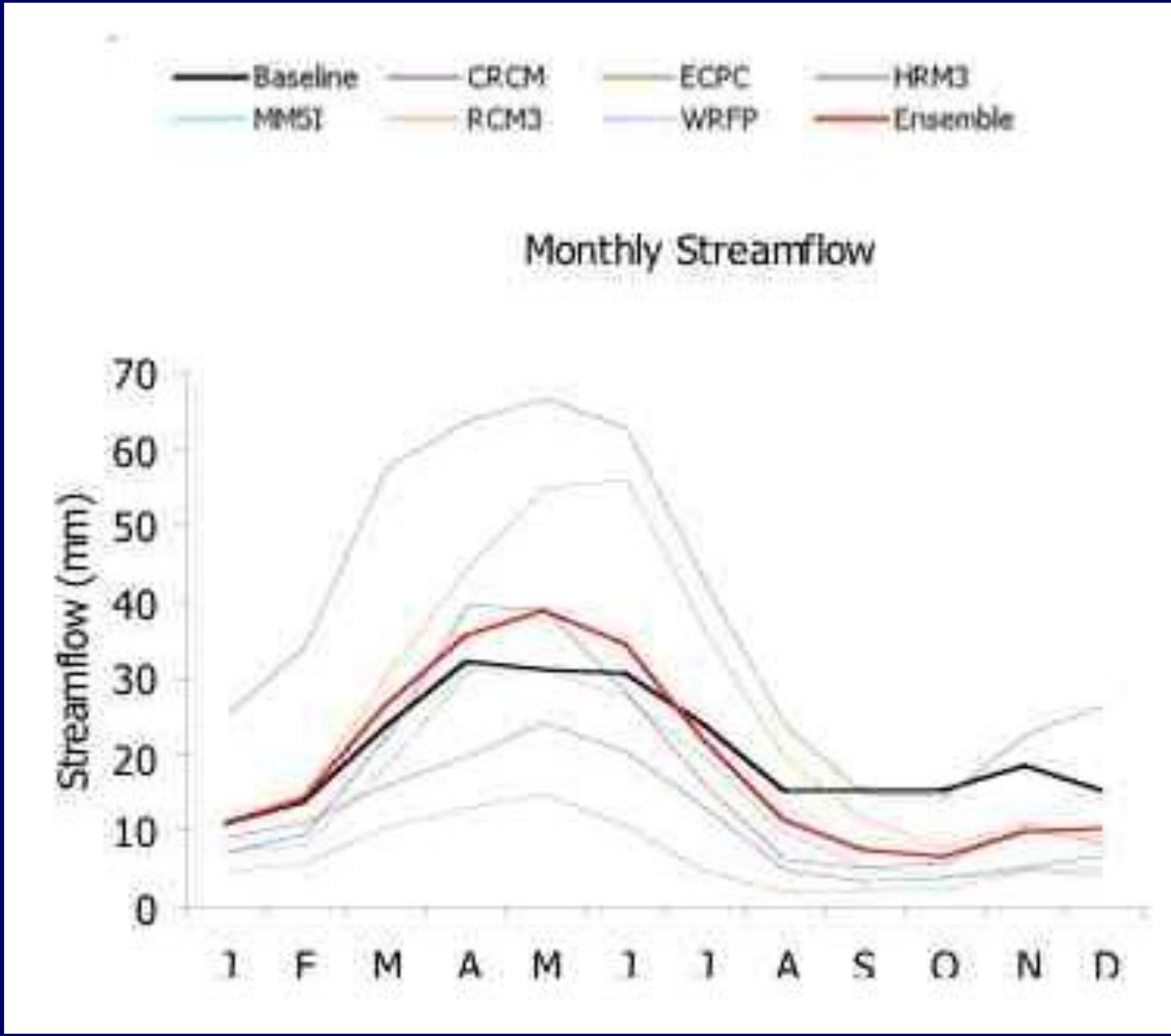
Streamflow Interannual Variability



Hydrologic Analysis (Takle et al.)



Hydrologic Analysis (Takle et al.)



Summary

<u>MONTHLY PRECIPITATION</u>

Where there is a substantial periodic cycle:

- Models simulate well the interannual variability

- Models simulate well monthly, regional extremes

Where there is no substantial periodic cycle:

- Models simulate poorly the interannual var. & extremes

- Interior nudging improves interannual variability

-Interior nudging does not help extremes

<u>UPPER MISSISSIPPI STREAMFLOW</u>

Ensemble replicates well the interannual variability

Annual cycle simulated less well

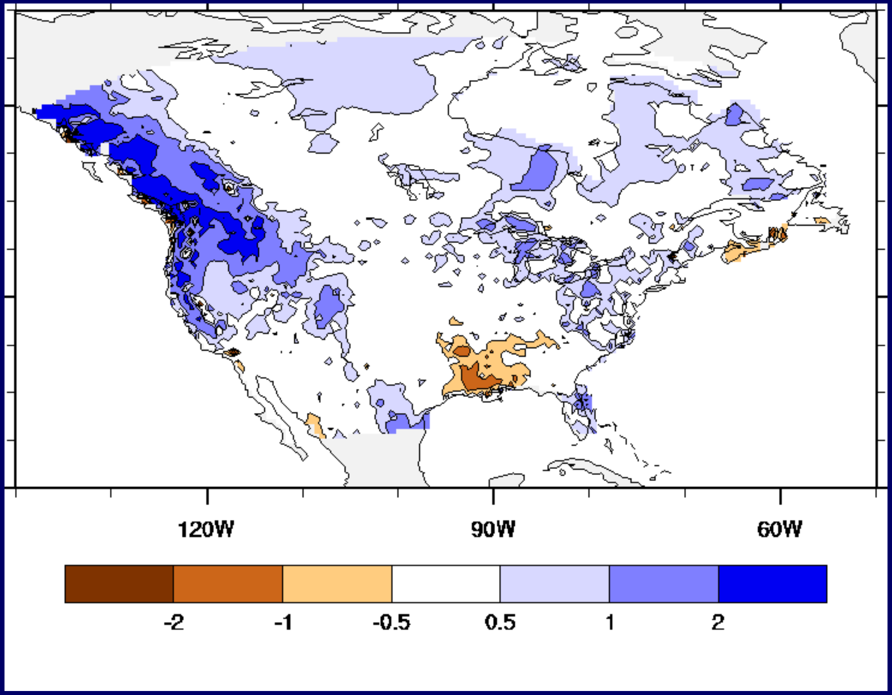
Thank You!

NARCCAP

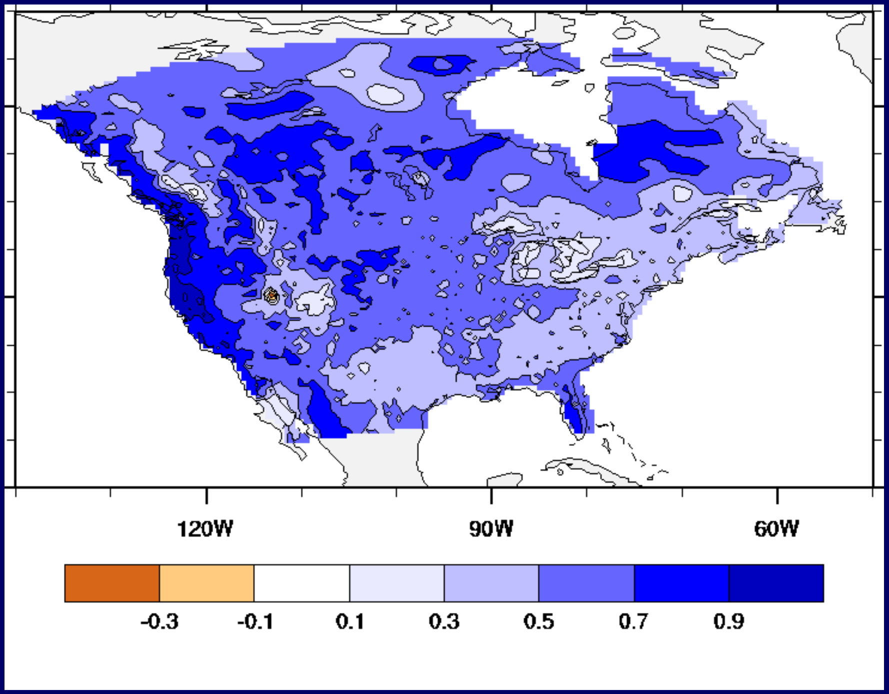
(www.narccap.ucar.edu)

Bias of the ensemble mean and correlation of ensemble monthly time series with observed time series.

Bias



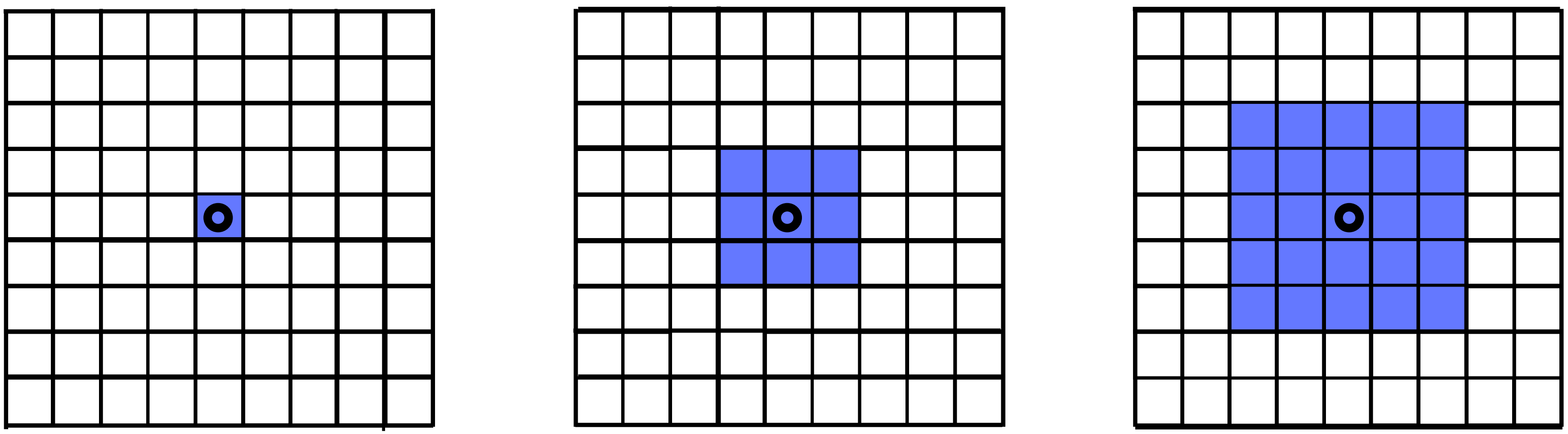
Correlation of monthly time series

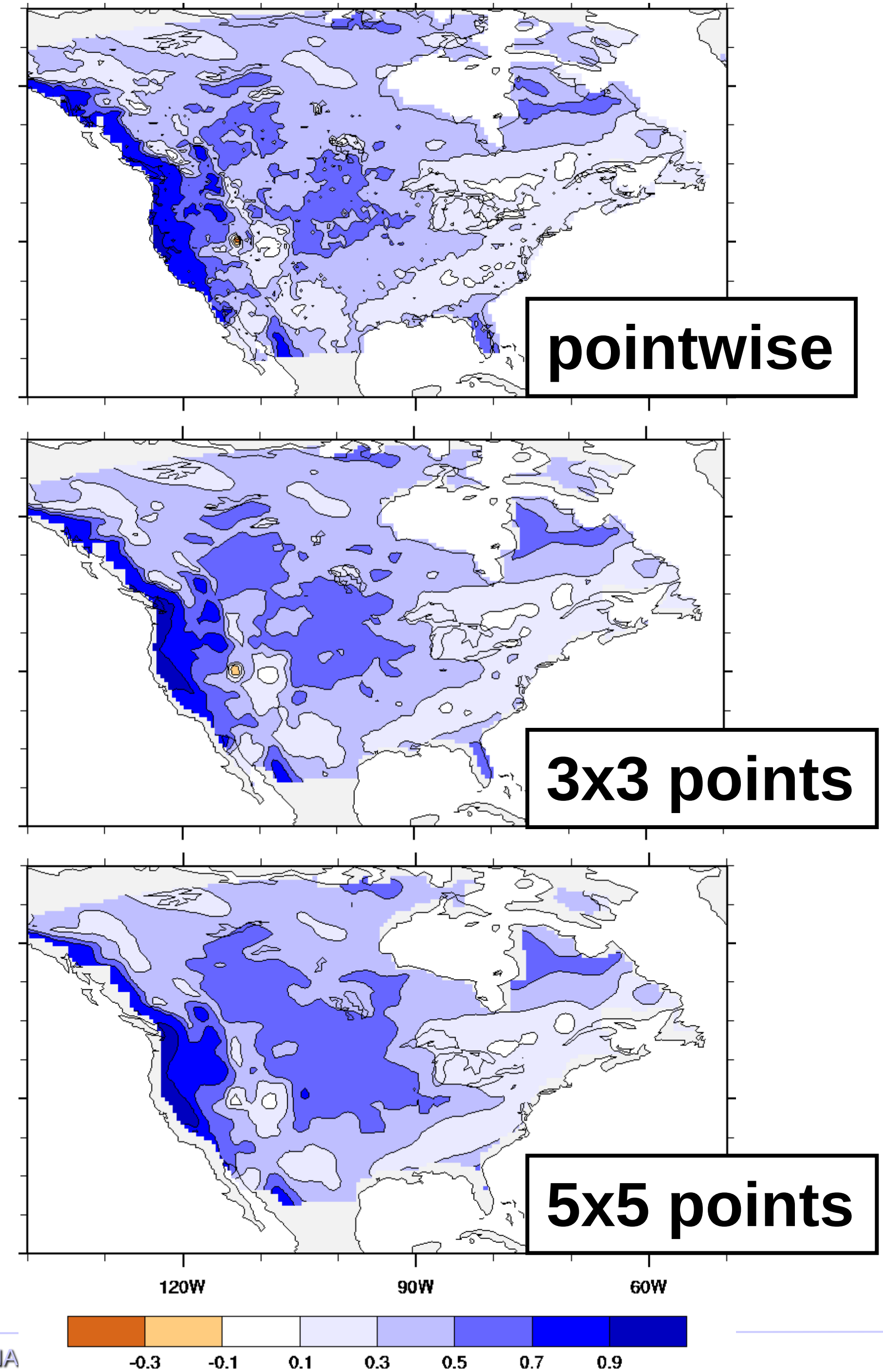


How does spatial aggregation affect prediction skill?

Average both model and observations onto 3x3 or 5x5 grid square areas.

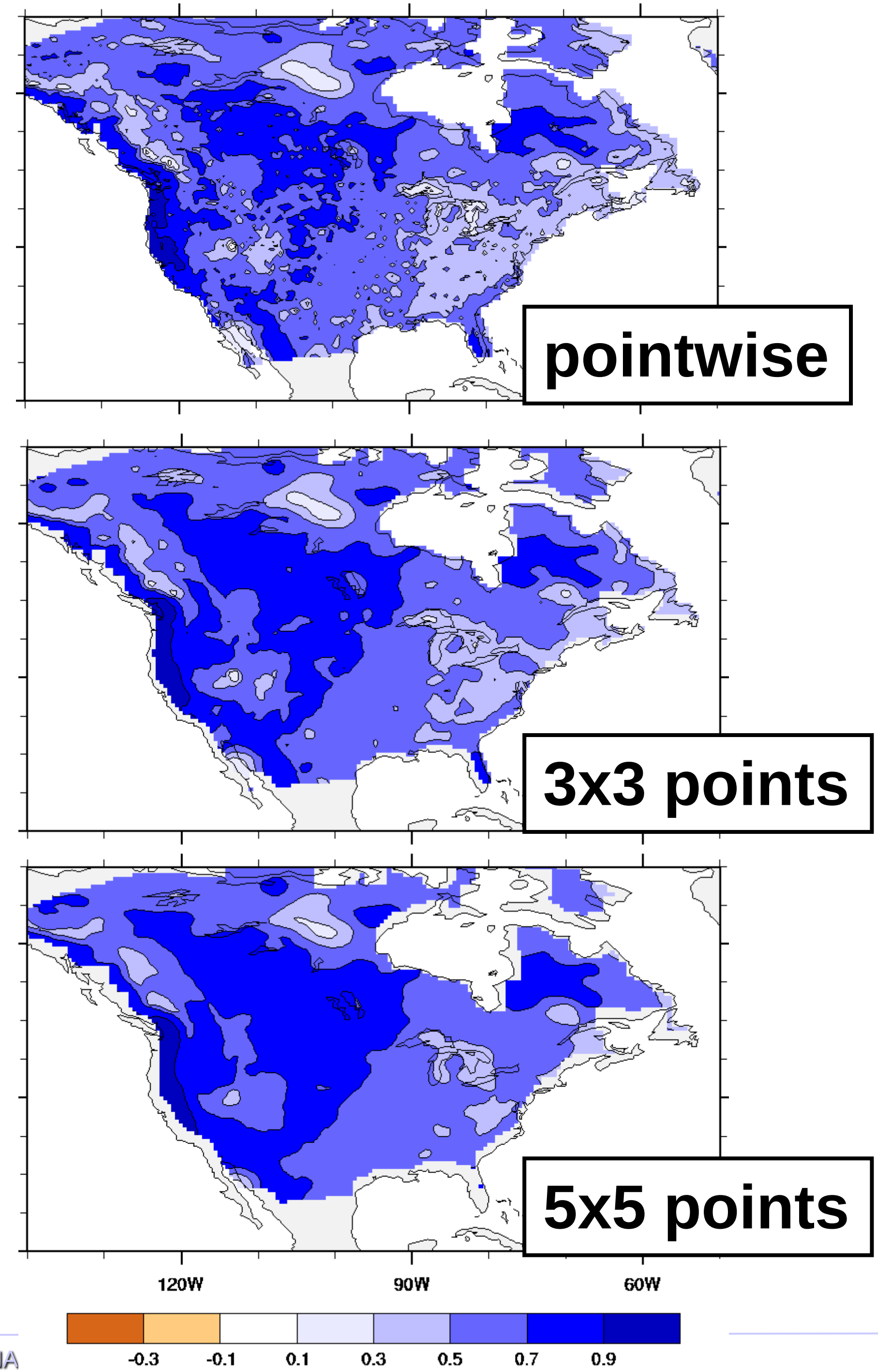
pointwise **3x3** **5x5**





Spatial aggregation tends to improve correlation, but effect differs across the domain.

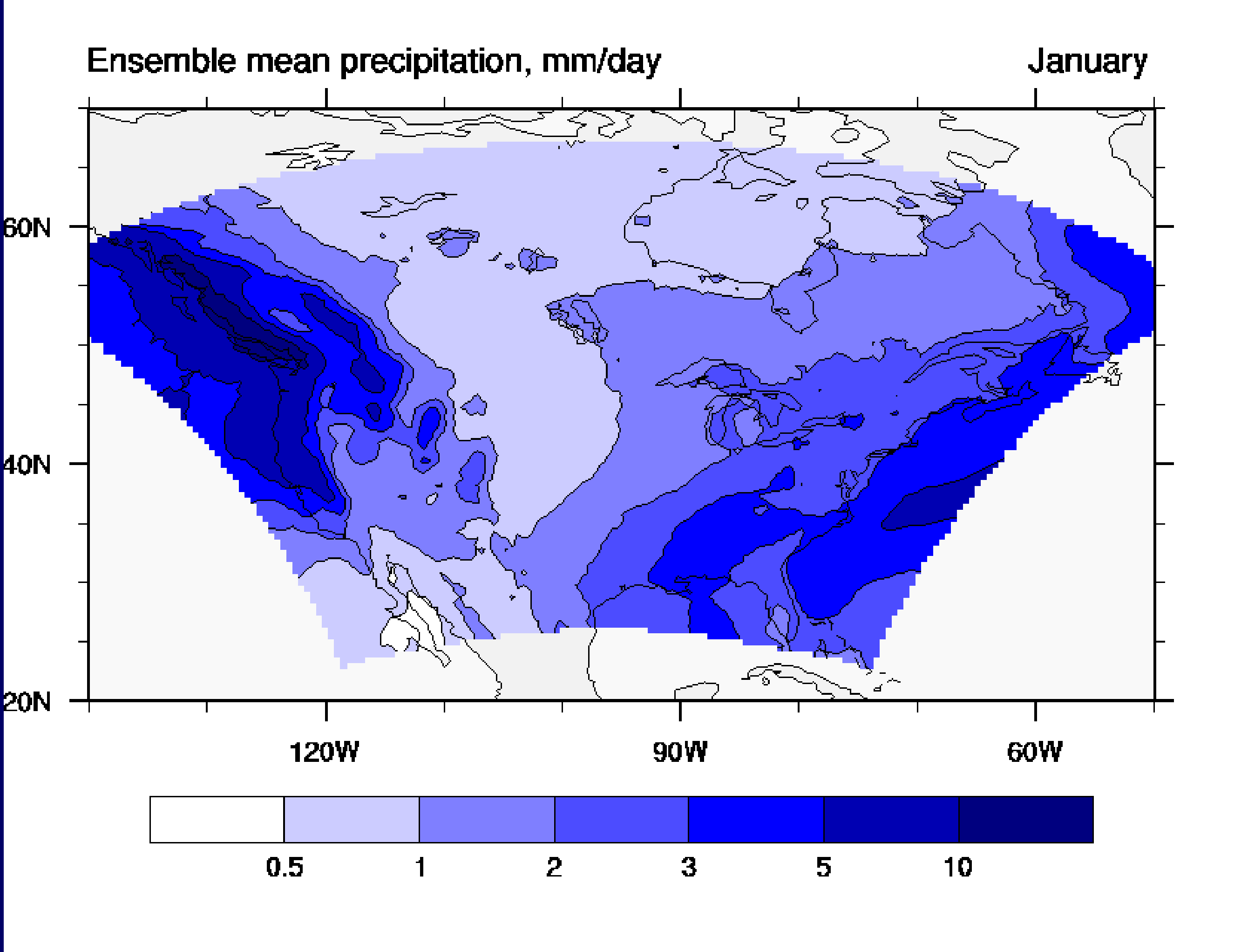
- Differs from model to model (MM5 shown here).
- Aggregation has more effect on individual models than on ensembles.
- Note improvement in central U.S. but not eastern U.S.



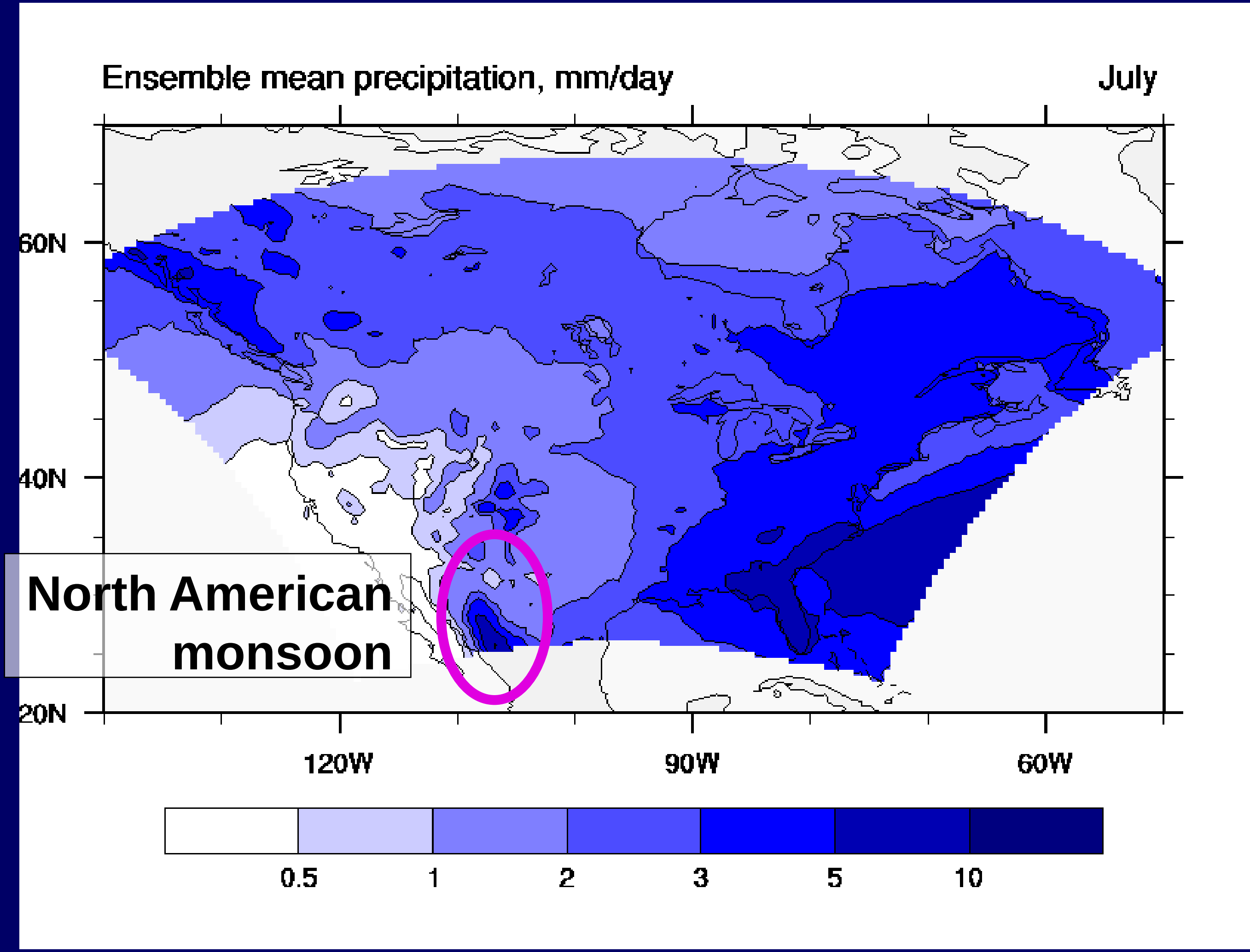
Aggregation has a greater effect on correlation in a model with spectral nudging.

- Canadian RCM shown here.
- Note improvement in eastern U.S.
- **Hypothesis:** Large scales are better represented in a model with spectral nudging, so smoothing out small-scale irregularities produces more improvement.

Ensemble mean precipitation: January

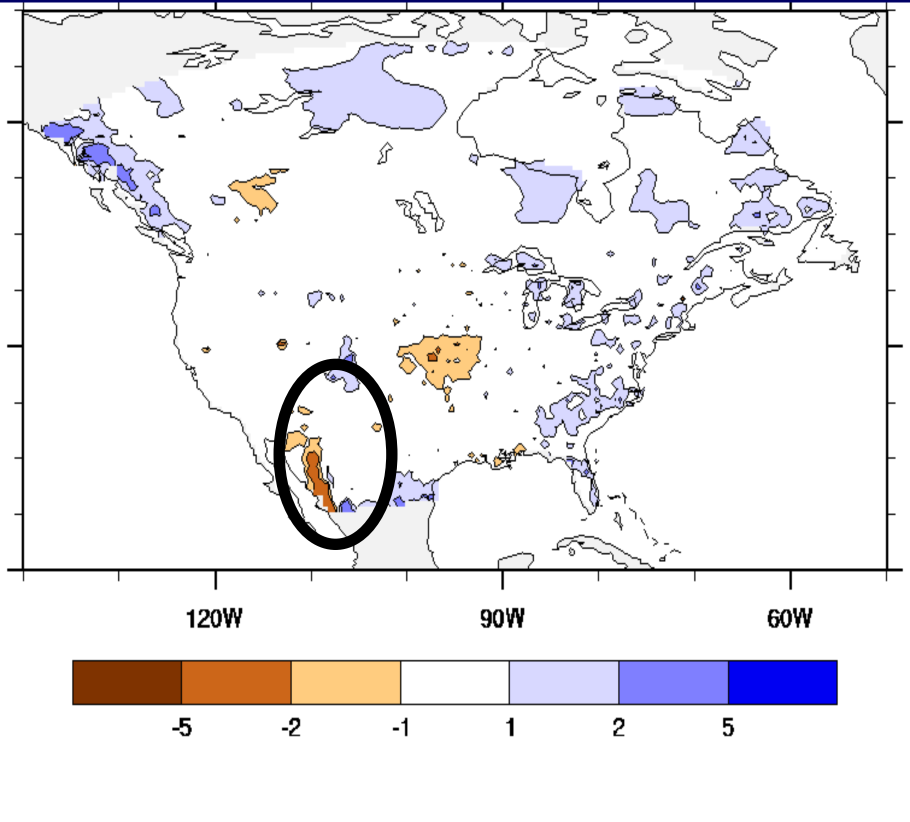


Process oriented evaluation: the North American monsoon

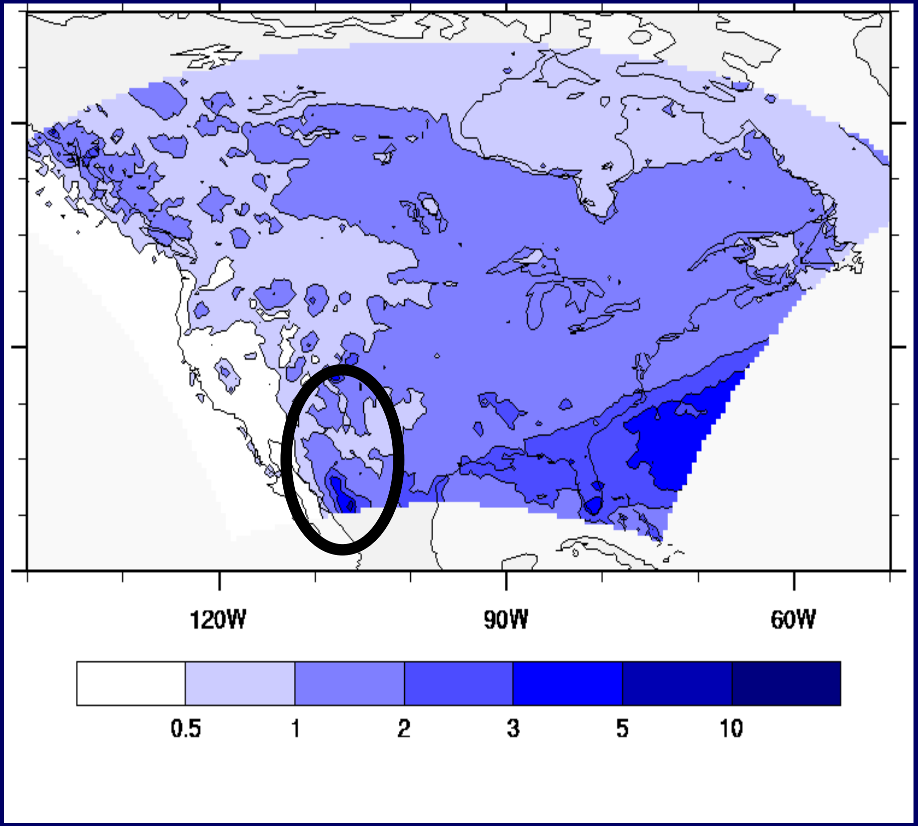


Ensemble error and spread (July)

Bias



Ensemble spread



Analysis of Extremes

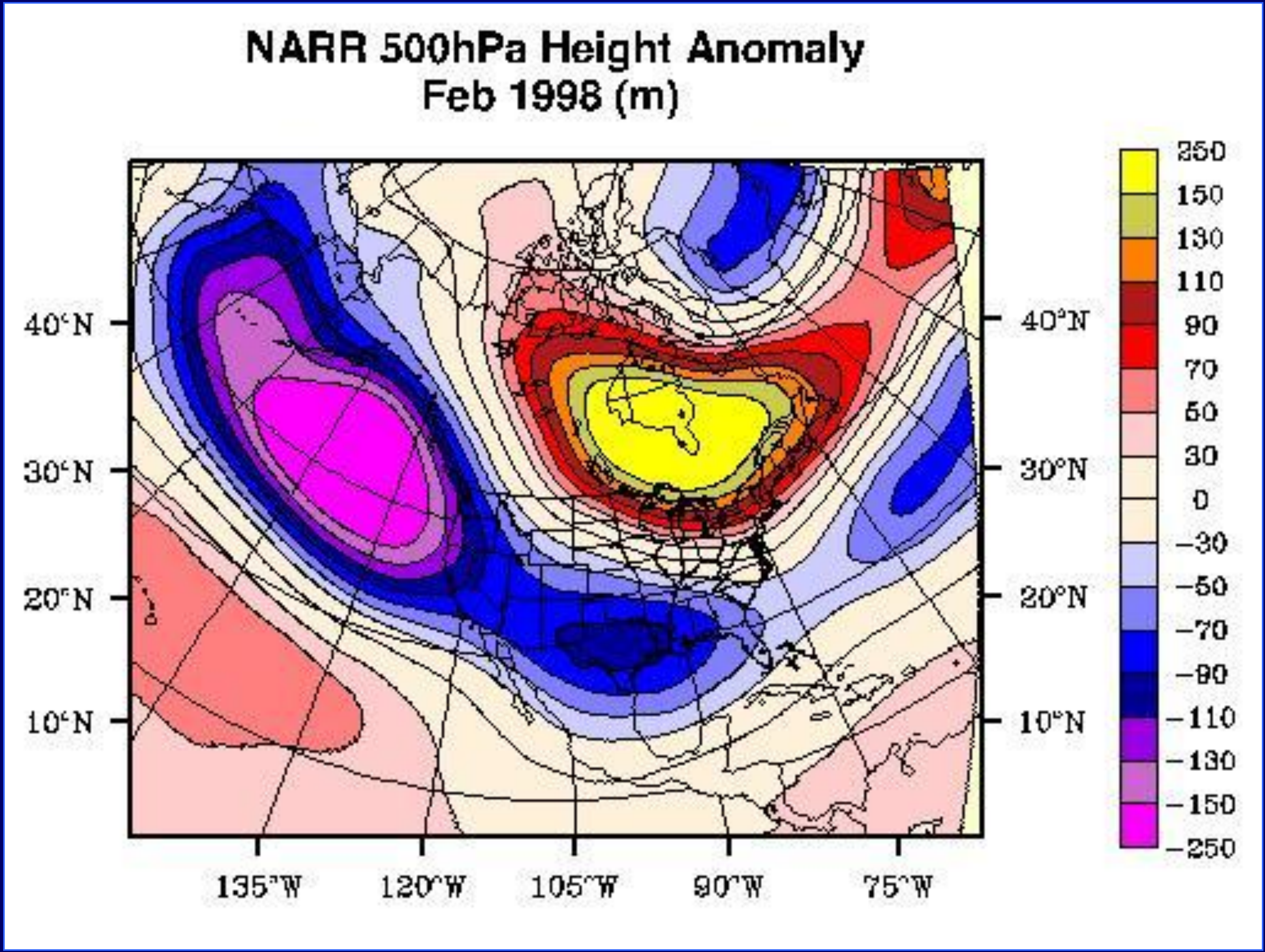
Societal importance, esp. for climate change

Key Question: Do climate models behave like observations?

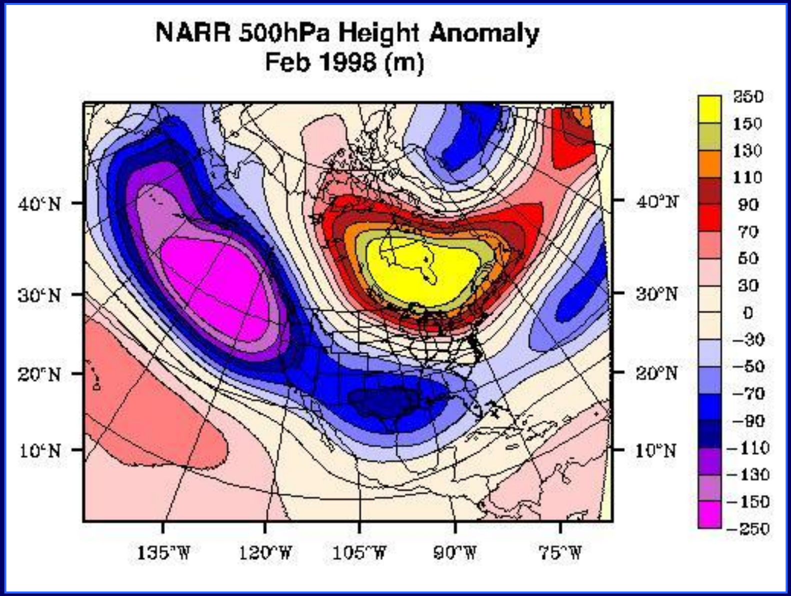
Diagnosis of physical mechanisms

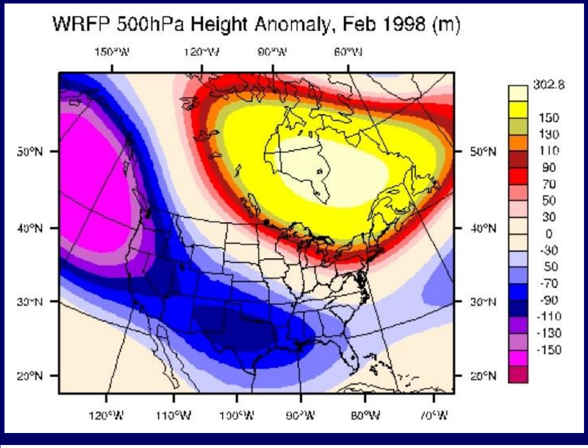
- Necessary for model vs. obs. comparison
- Basis for developing confidence in projections

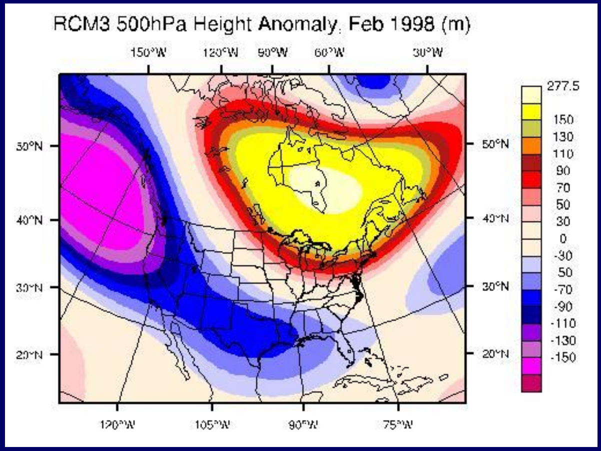
500 hPa Height Anomalies – Coastal CA Extreme

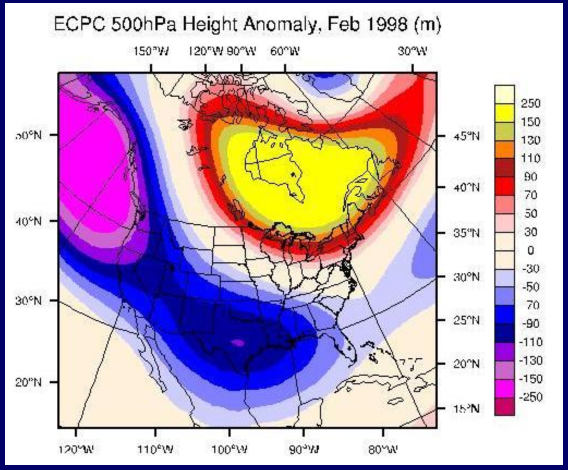


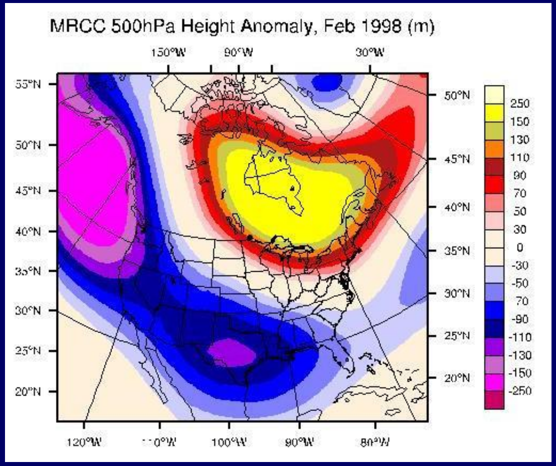
500 hPa Height Anomalies – Coastal CA Extreme

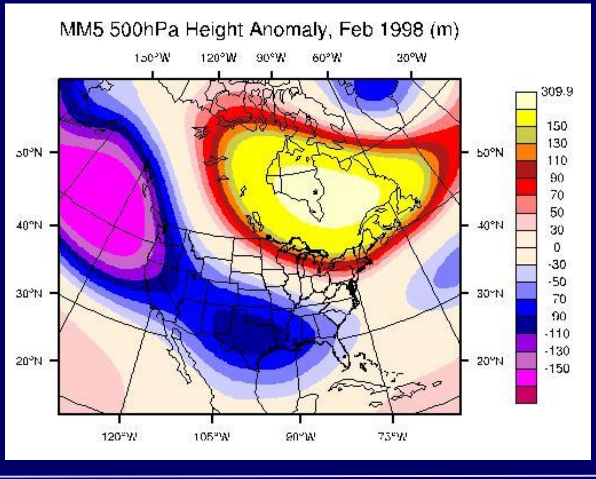




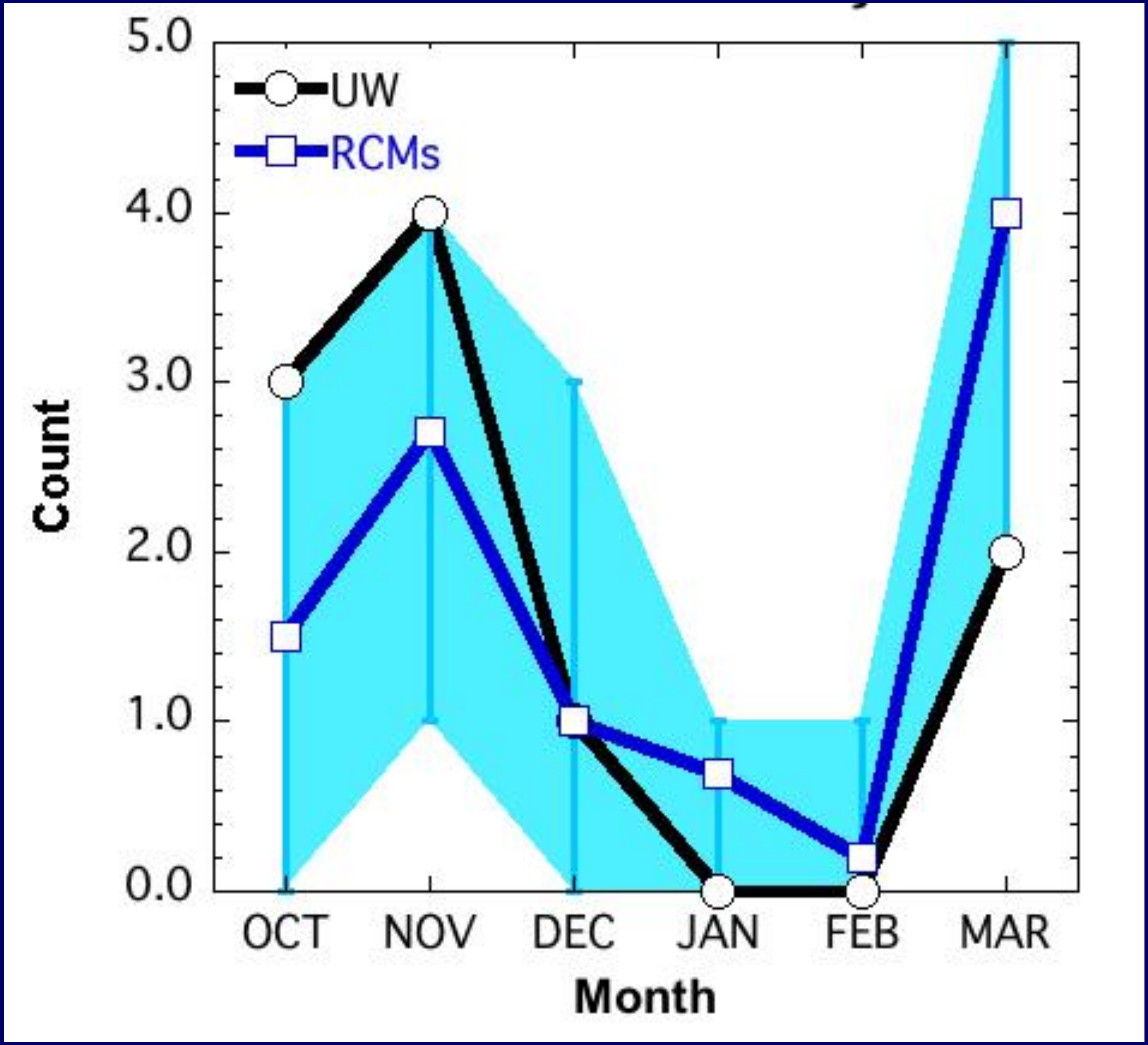




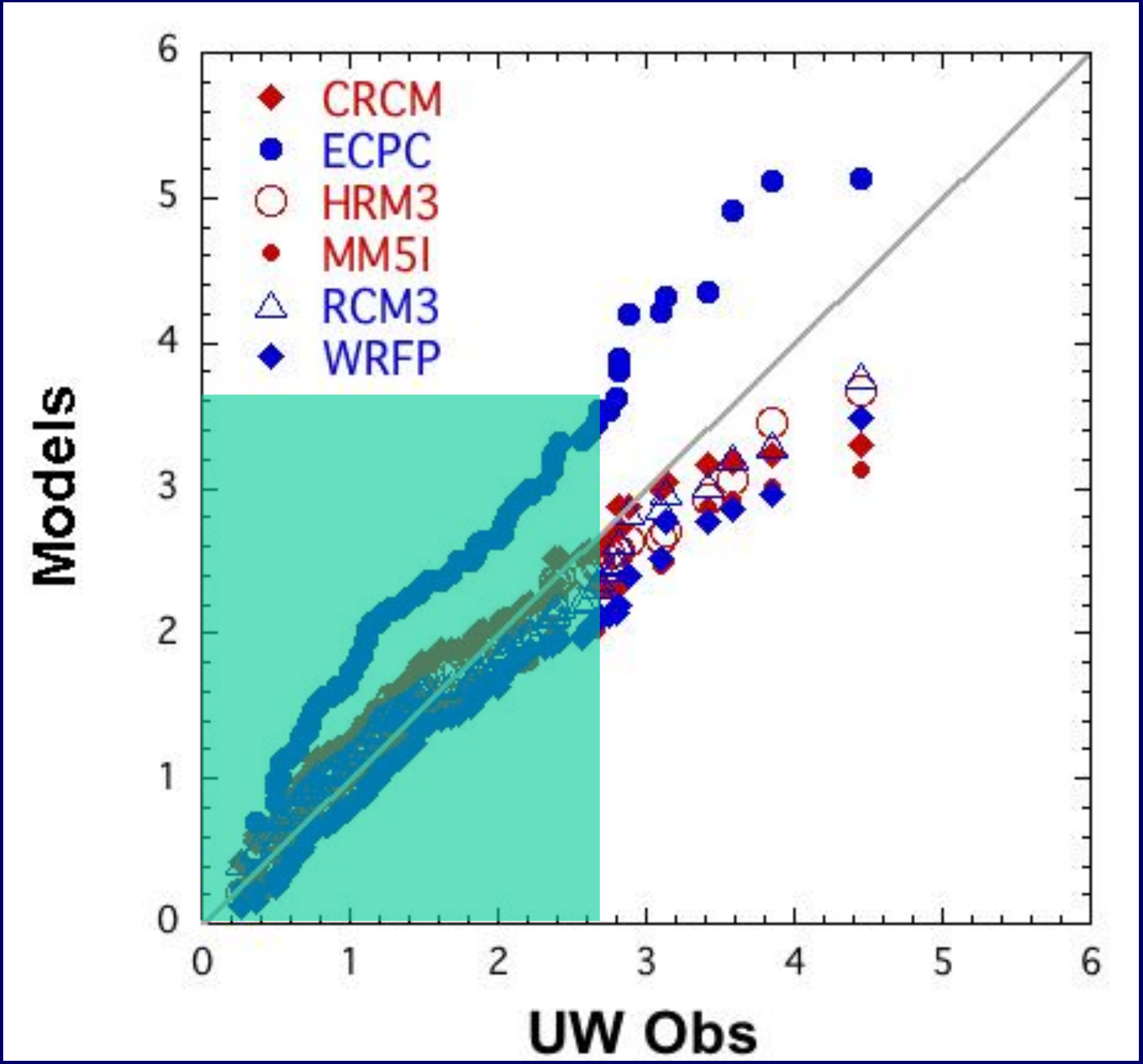




Frequency – Upper MS

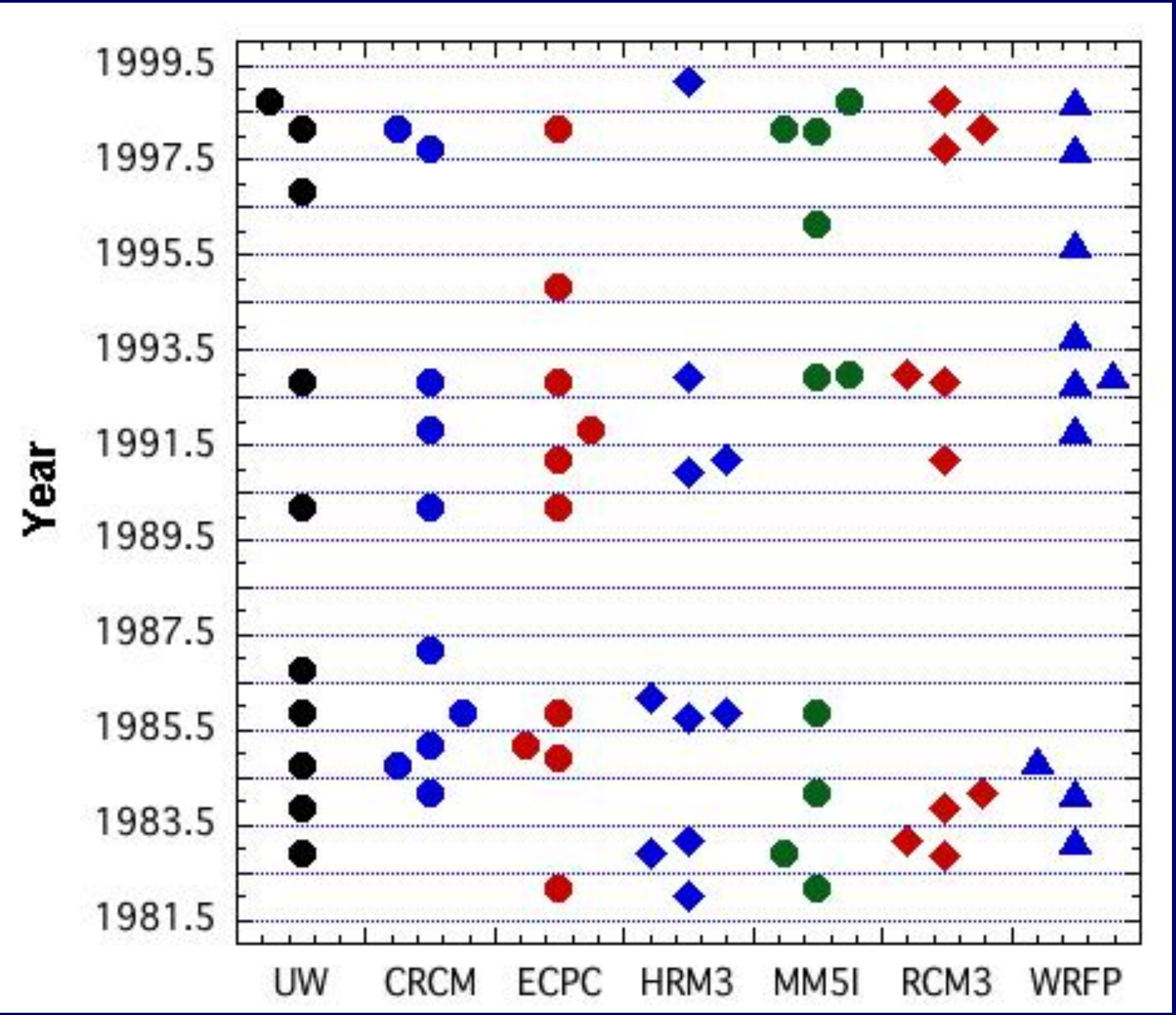


Ranked Precipitation – Upper MS



Ensemble average of top 10 = 6 % smaller than UW

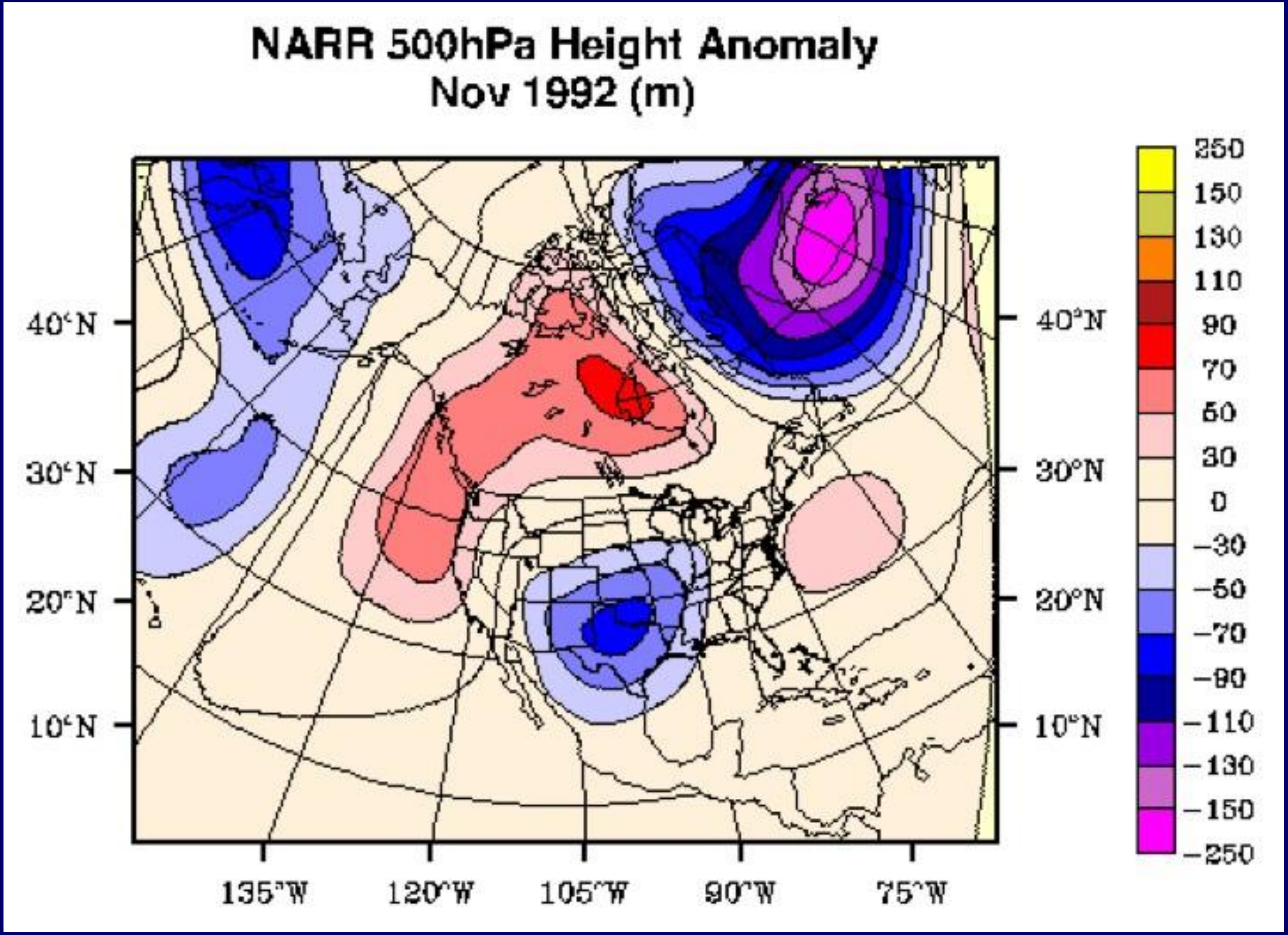
Interannual Variability – Upper MS



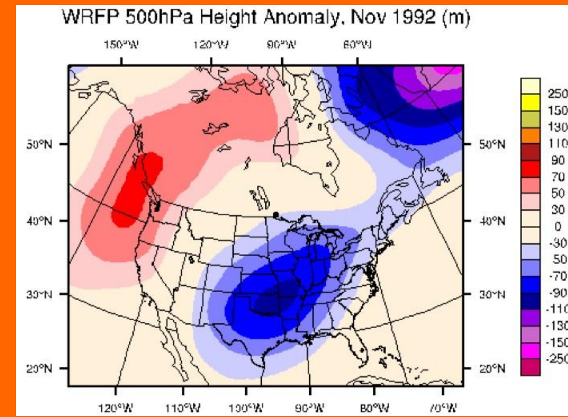
46 of 60 (77%) simulated extremes occur in cold seasons with an observed extreme.

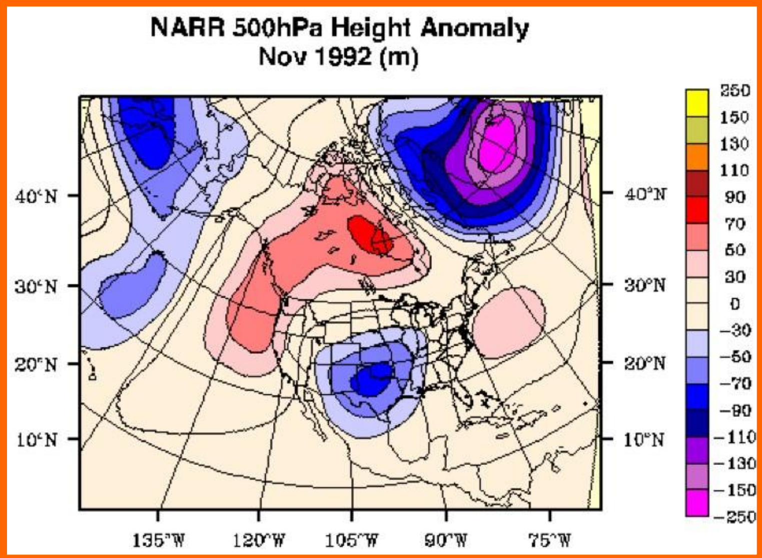
(random chance: 33)

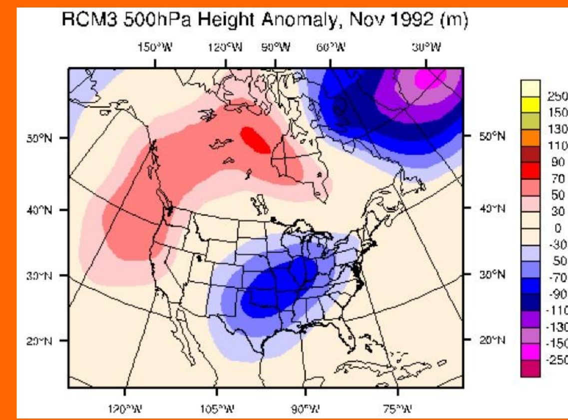
500 hPa Height Anomalies – Upper MS Extreme

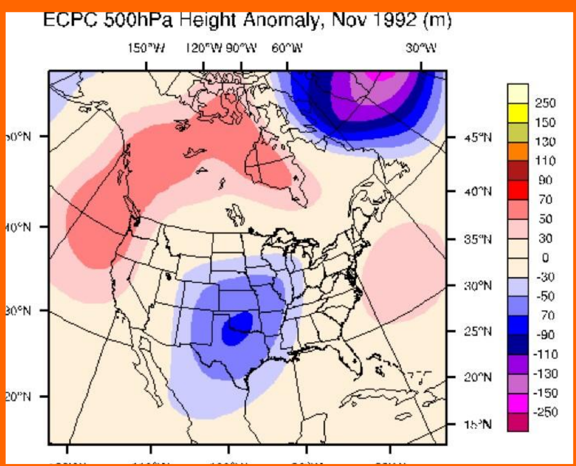


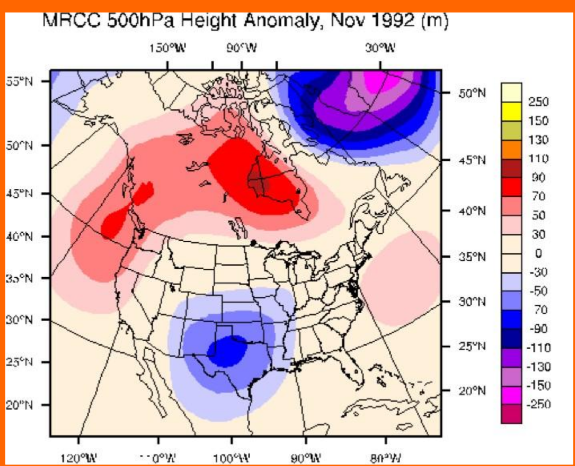
500 hPa Height Anomalies – Upper MS Extreme

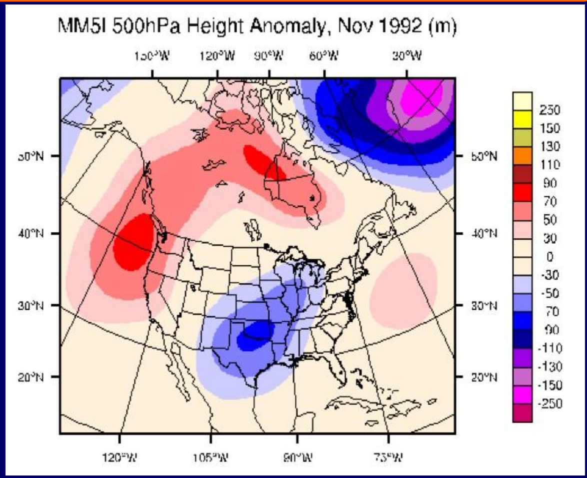










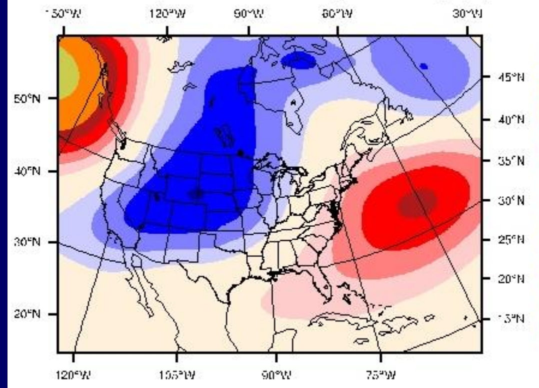


Composite 500 hPa Height Anomalies

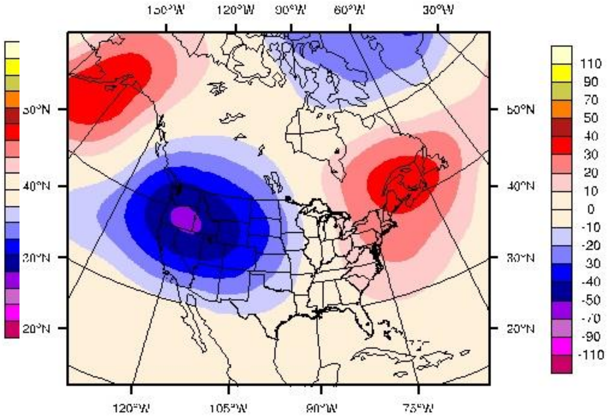
Top 10 Extremes

Upper MS

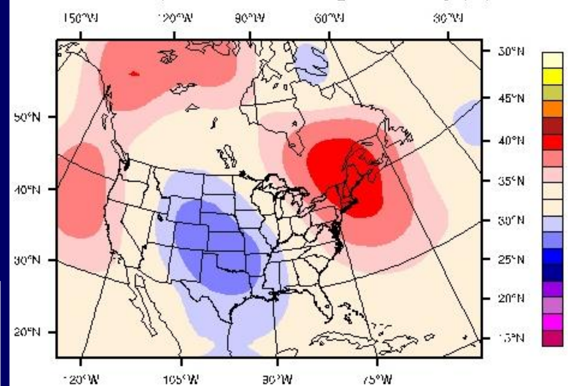
ECPC Composite 500hPa Height Anomaly (m)



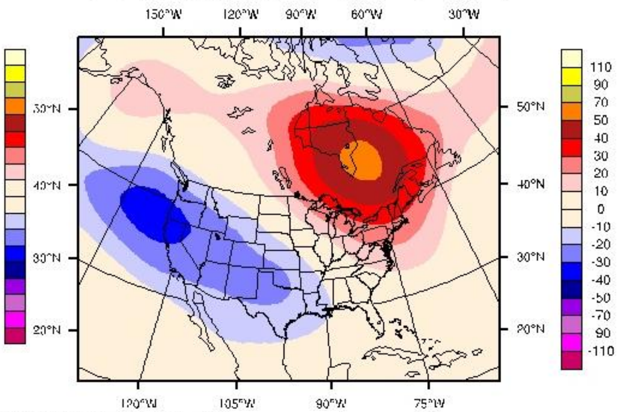
MM5I Composite 500hPa Height Anomaly (m)



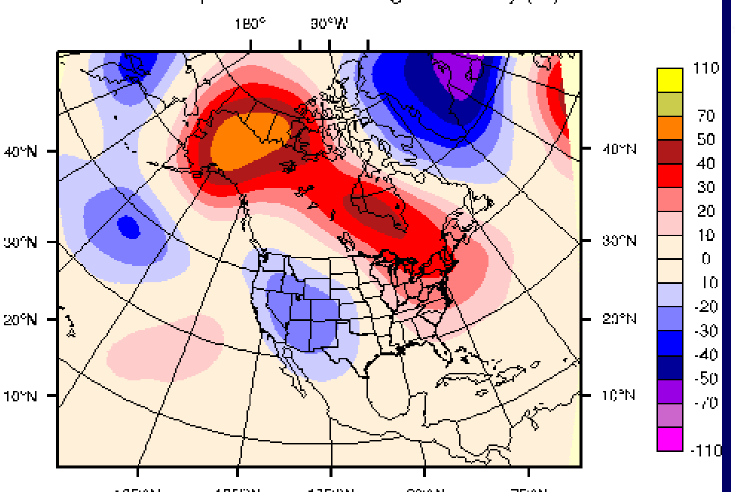
MRCC Composite 500hPa Height Anomaly (m)



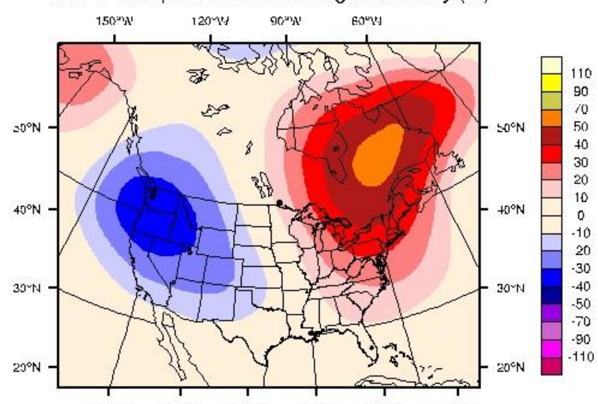
RCM3 Composite 500hPa Height Anomaly (m)



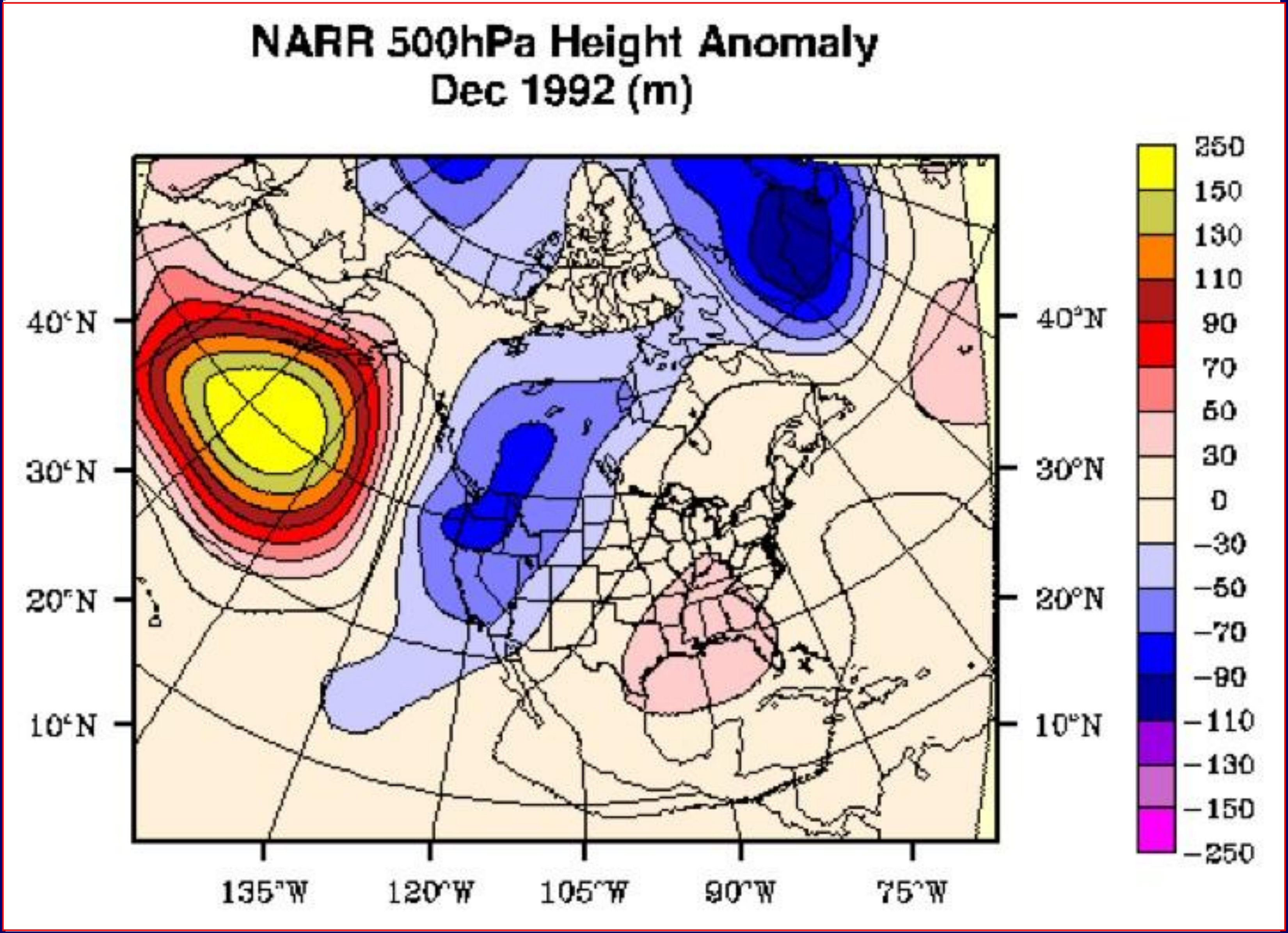
NARR Composite 500hPa Height Anomaly (m)



WRFP Composite 500hPa Height Anomaly (m)



500 hPa Height Anomalies – Deep South Extreme



Correlation:
Monthly Observations and Ensemble Mean