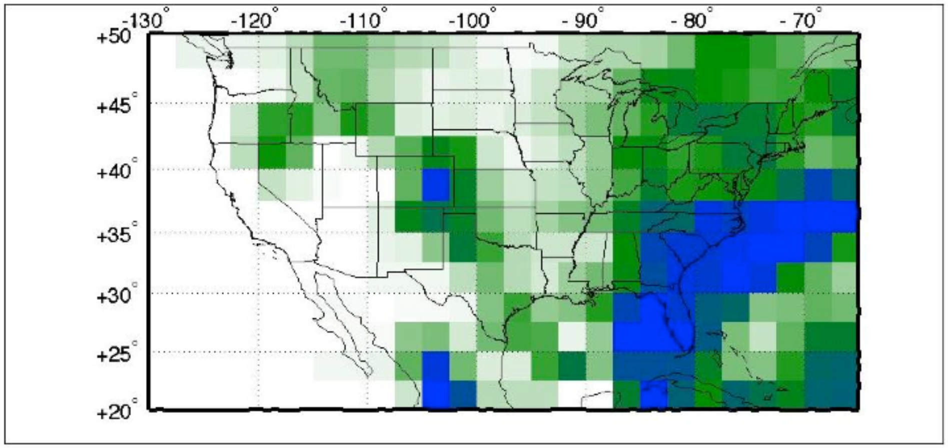
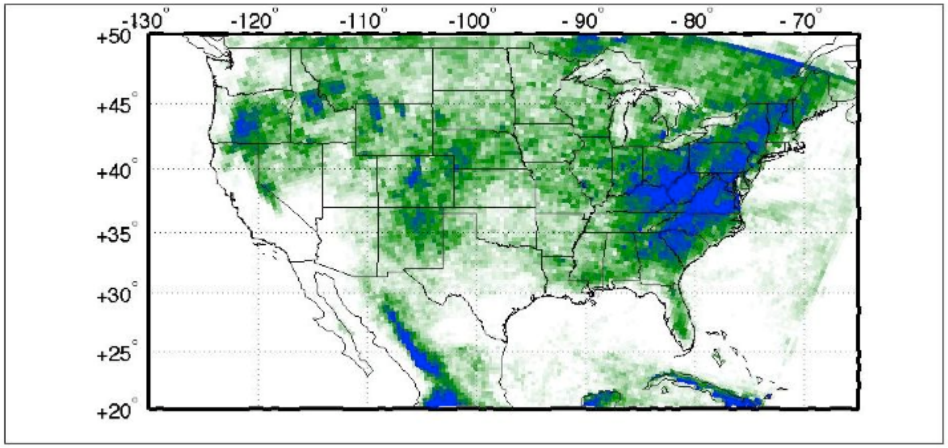
Producing Dynamically Downscaled Information for Climate Change Projection in Arizona





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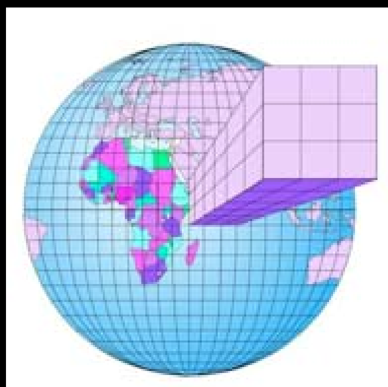
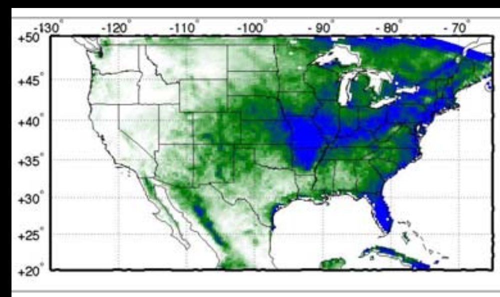
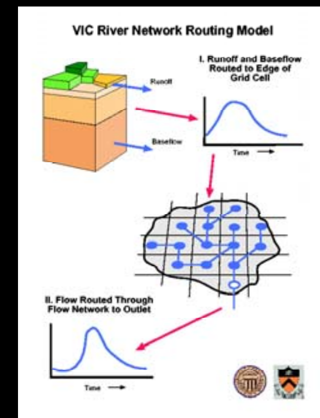
Our goal is to downscale climate model data to an appropriate resolution for hydrological applications.



1. We rely on General Circulation Models (GCMs) to estimate future climate variables



2. These projections are downscaled using either statistical or dynamical methods



3. Downscaled atmospheric fields force the VIC hydrologic model.

4. The outcomes will be used to generate water management data for drought planning, scenarios, modeling, agricultural, tribal activities, etc.

There are basically two approaches to downscale coupled climate model projections :

Statistical Downscaling

Dynamical Downscaling

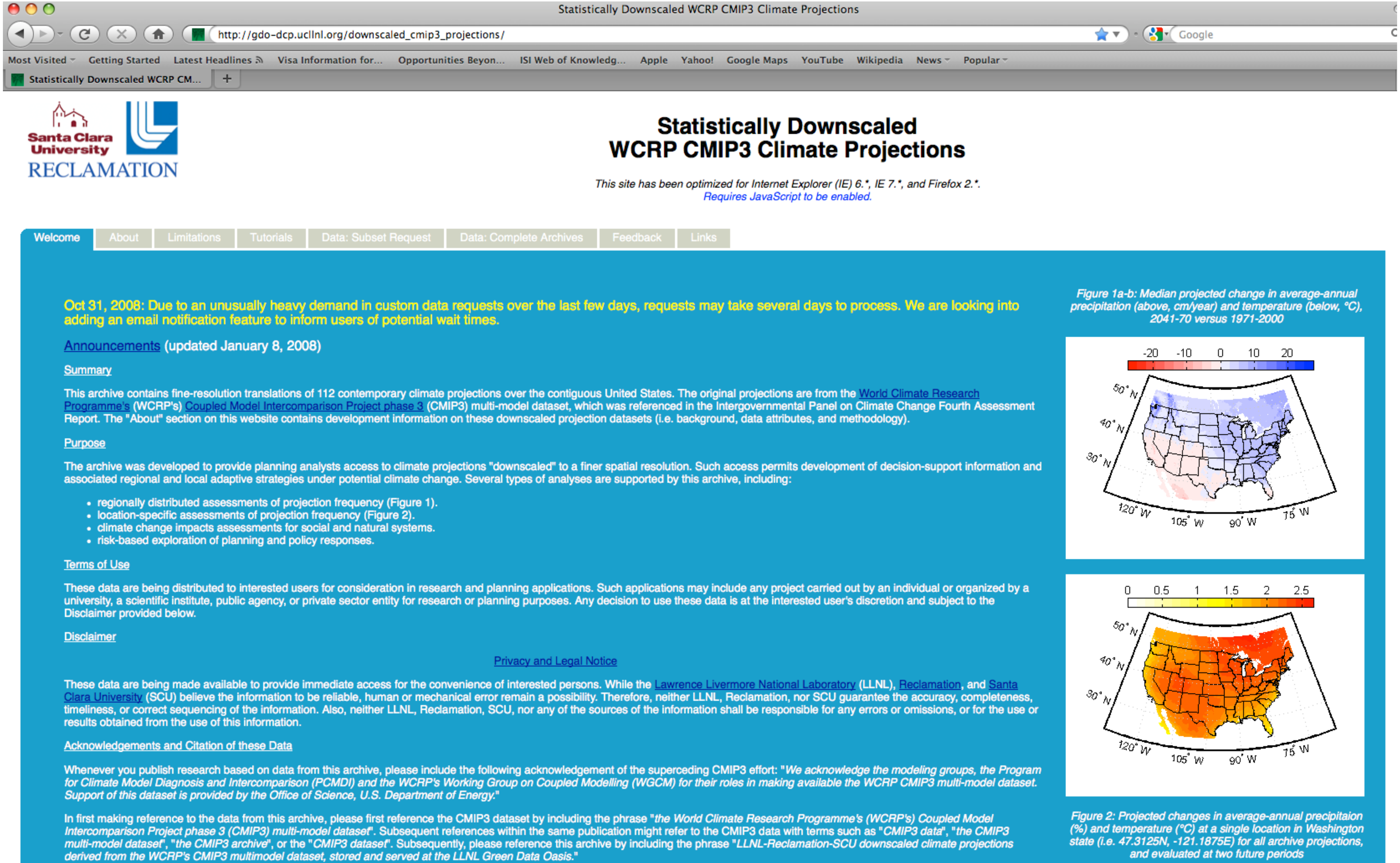
There are basically two approaches to downscale coupled climate model projections :

Statistical Downscaling

These methods assume a relationship between large-scale atmospheric variables (predictors) and local climate variables (predictands).

- **Pro : Cheap and computationally efficient.**
- **Pro : Can use many different scenarios, model runs.**
- **Pro : Easily transferable to other regions.**

- **Con : Requires long and reliable observation data.**
- **Con : Depends on choice of predictors.**
- **Con : Assumes stationarity of predictor-predictand relationship.**
- **Con : Cannot account for feedbacks.**



Statistically Downscaled WCRP CMIP3 Climate Projections

http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/

Santa Clara University
RECLAMATION

Statistically Downscaled WCRP CMIP3 Climate Projections

This site has been optimized for Internet Explorer (IE) 6., IE 7.*, and Firefox 2.*.*
Requires JavaScript to be enabled.

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Oct 31, 2008: Due to an unusually heavy demand in custom data requests over the last few days, requests may take several days to process. We are looking into adding an email notification feature to inform users of potential wait times.

Announcements (updated January 8, 2008)

Summary

This archive contains fine-resolution translations of 112 contemporary climate projections over the contiguous United States. The original projections are from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset, which was referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report. The "About" section on this website contains development information on these downscaled projection datasets (i.e. background, data attributes, and methodology).

Purpose

The archive was developed to provide planning analysts access to climate projections "downscaled" to a finer spatial resolution. Such access permits development of decision-support information and associated regional and local adaptive strategies under potential climate change. Several types of analyses are supported by this archive, including:

- regionally distributed assessments of projection frequency (Figure 1).
- location-specific assessments of projection frequency (Figure 2).
- climate change impacts assessments for social and natural systems.
- risk-based exploration of planning and policy responses.

Terms of Use

These data are being distributed to interested users for consideration in research and planning applications. Such applications may include any project carried out by an individual or organized by a university, a scientific institute, public agency, or private sector entity for research or planning purposes. Any decision to use these data is at the interested user's discretion and subject to the Disclaimer provided below.

Disclaimer

Privacy and Legal Notice

These data are being made available to provide immediate access for the convenience of interested persons. While the Lawrence Livermore National Laboratory (LLNL), Reclamation, and Santa Clara University (SCU) believe the information to be reliable, human or mechanical error remain a possibility. Therefore, neither LLNL, Reclamation, nor SCU guarantee the accuracy, completeness, timeliness, or correct sequencing of the information. Also, neither LLNL, Reclamation, SCU, nor any of the sources of the information shall be responsible for any errors or omissions, or for the use or results obtained from the use of this information.

Acknowledgements and Citation of these Data

Whenever you publish research based on data from this archive, please include the following acknowledgement of the superceding CMIP3 effort: "*We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy.*"

In first making reference to the data from this archive, please first reference the CMIP3 dataset by including the phrase "*the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset*". Subsequent references within the same publication might refer to the CMIP3 data with terms such as "*CMIP3 data*", "*the CMIP3 multi-model dataset*", "*the CMIP3 archive*", or the "*CMIP3 dataset*". Subsequently, please reference this archive by including the phrase "*LLNL-Reclamation-SCU downscaled climate projections derived from the WCRP's CMIP3 multimodel dataset, stored and served at the LLNL Green Data Oasis.*"

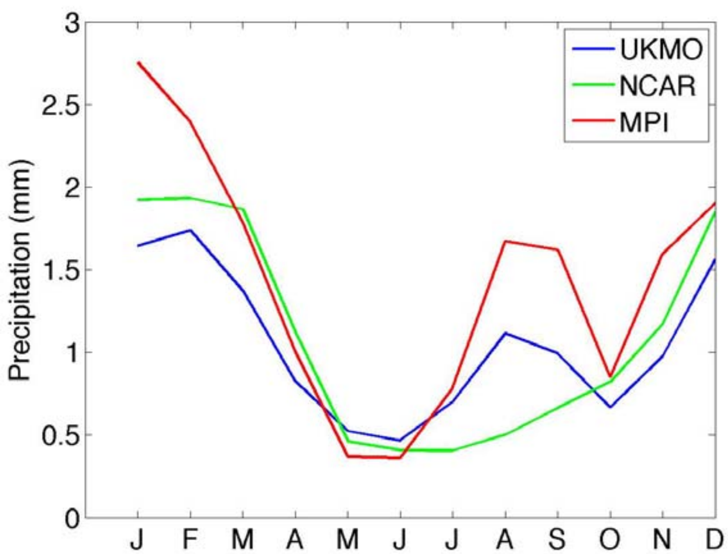
Figure 1a-b: Median projected change in average-annual precipitation (above, cm/year) and temperature (below, °C), 2041-70 versus 1971-2000

Figure 2: Projected changes in average-annual precipitaion (%) and temperature (°C) at a single location in Washington state (i.e. 47.3125N, -121.1875E) for all archive projections, and evaluated at two future periods

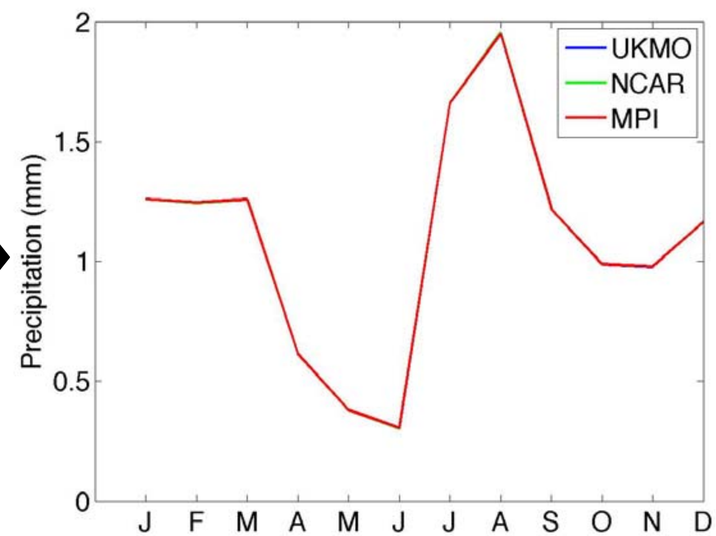
AKA: "Reclamation Data"

Statistical Downscaling

It is important to clarify that the Reclamation Data is Bias Corrected, so the observed climatological mean is matched in the historical data.



Bias Correction



Raw GCM climatology for the three selected models (1950-2000)

“Reclamation” statistically downscaled climatology (1950-2000)

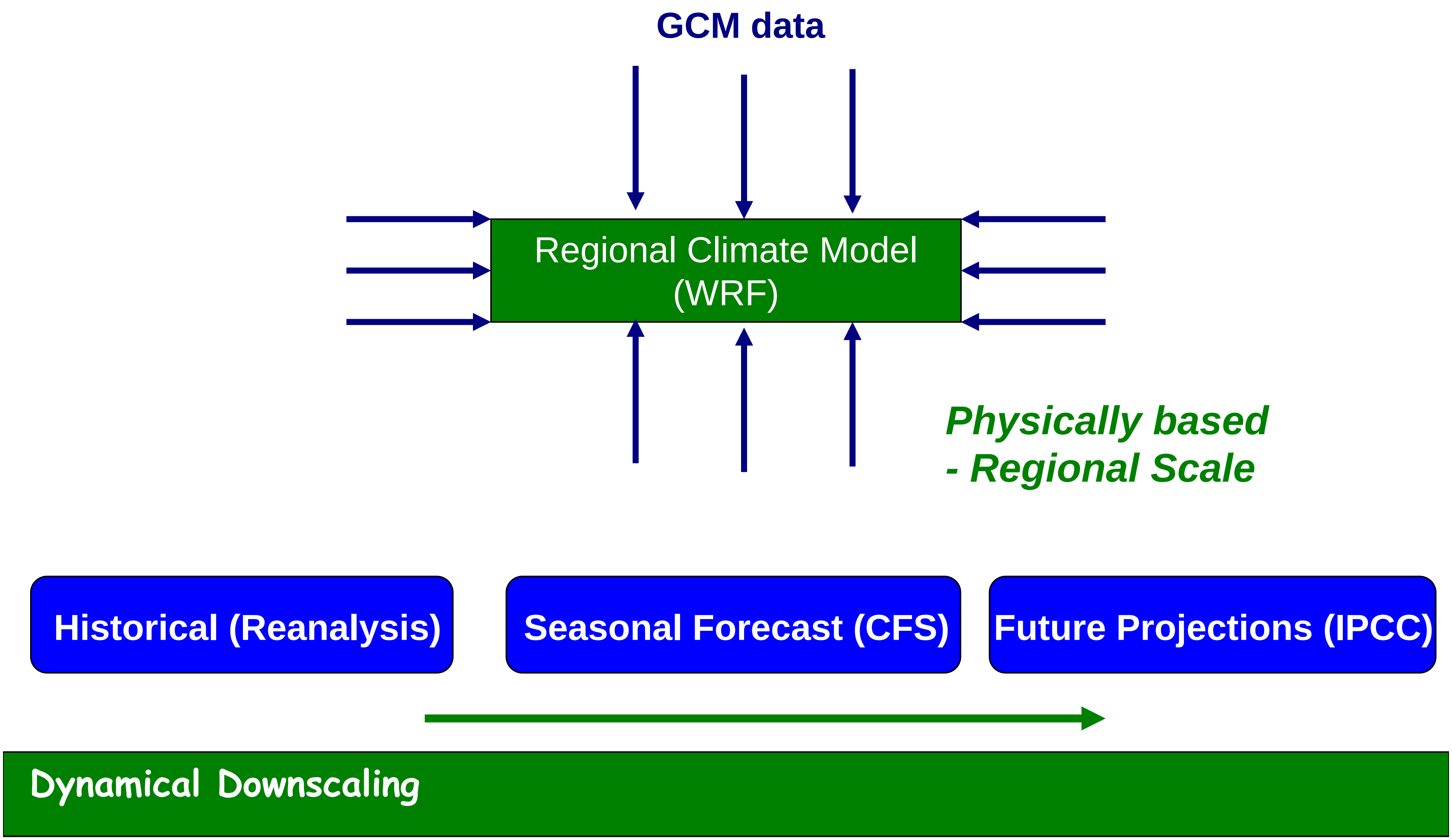
The second downscaling approach is dynamical downscaling.

Dynamical Downscaling

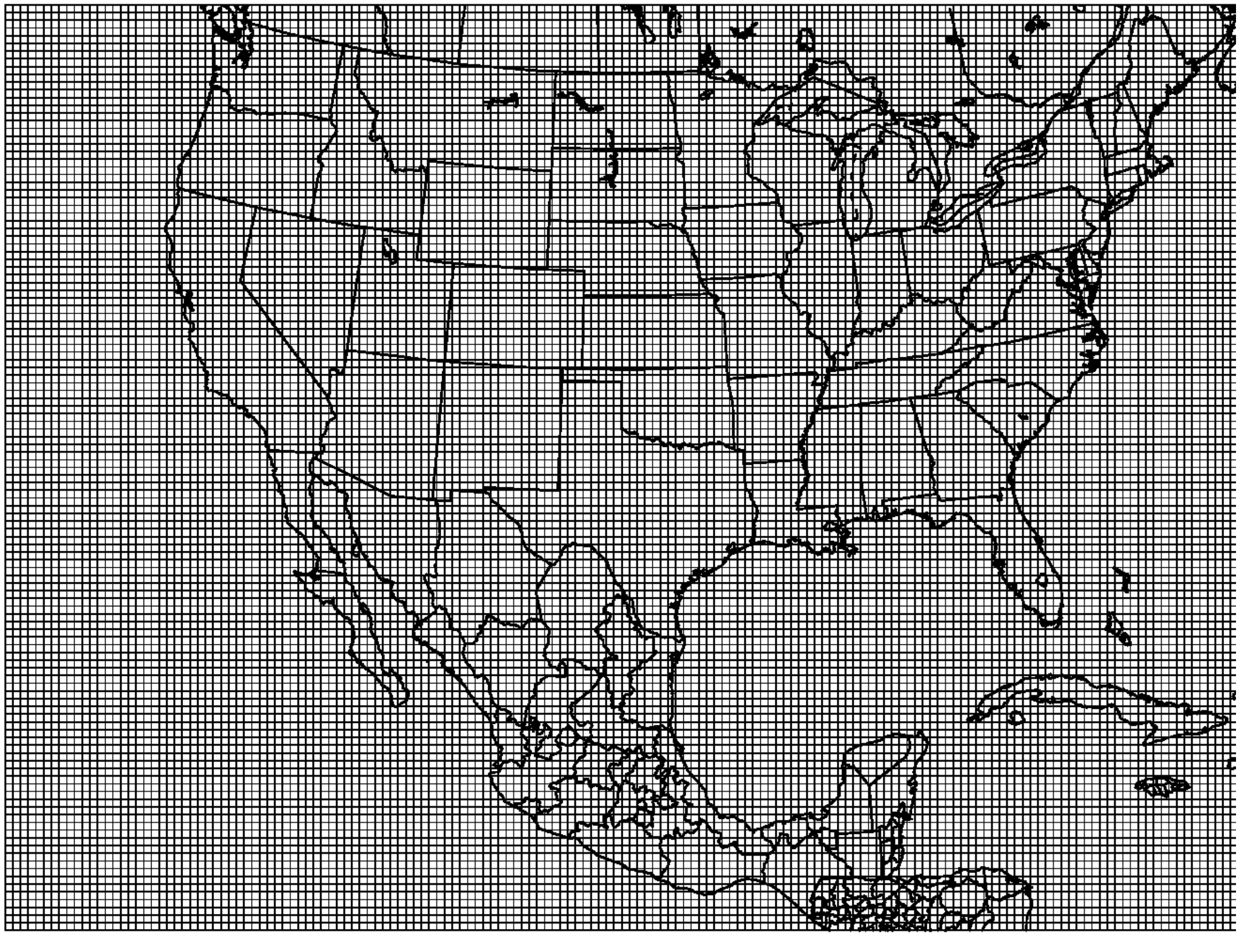
- Pro : Produces responses based on physically consistent processes.
- Pro : Captures feedbacks.
- Pro : Can model changes that have never been observed in historical record.
- Pro : Useful where topographic controls are important.

- Con : Requires significant computational power.
- Con : Limited amounts of models / runs / timescales.
- Con : Dependent on GCM boundary forcing.
- Con : Problems with drifting of large-scale climate.

Use the regional model as a "magnifying lens" to create higher resolution data with identical parameterization options as used for real time WRF UA forecasts…

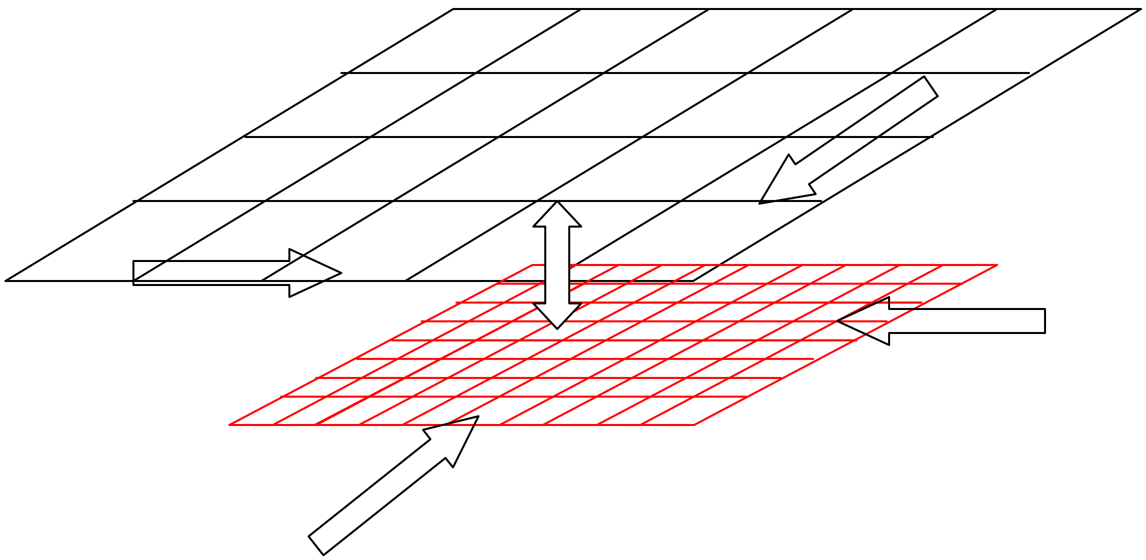


Regional Model Grid (35km grid spacing)



Dynamical Downscaling

GCM not only provides lateral boundary conditions. It is also used to force the interior of the model via a spectral nudging approach…



This helps maintain the appropriate variability in model fields at upper levels and at large scales.

We are performing different types of Dynamical Downscaling at the UofA using WRF:

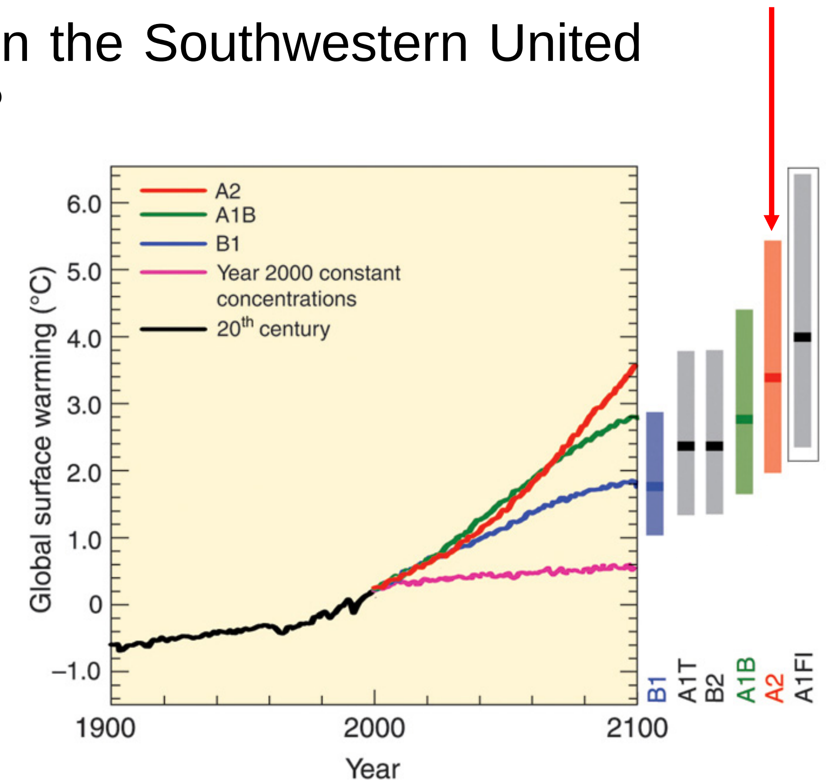
Historical (Reanalysis)	1979-2000	Done this spring
Seasonal Forecast (CFS)	1982-2000	Done Aug. 09
Three IPCC AR4 models for A2 emission scenario	1968-2081	One model done as of this April

Future Projections (IPCC) Using HadCM3

1968-2079

Science Question: How will climate in the Southwestern United States change due to global warming?

Methodology: We use WRF with spectral nudging to downscale 113 (1968-2081) years of SRES A2 data from three "well performing" IPCC models.

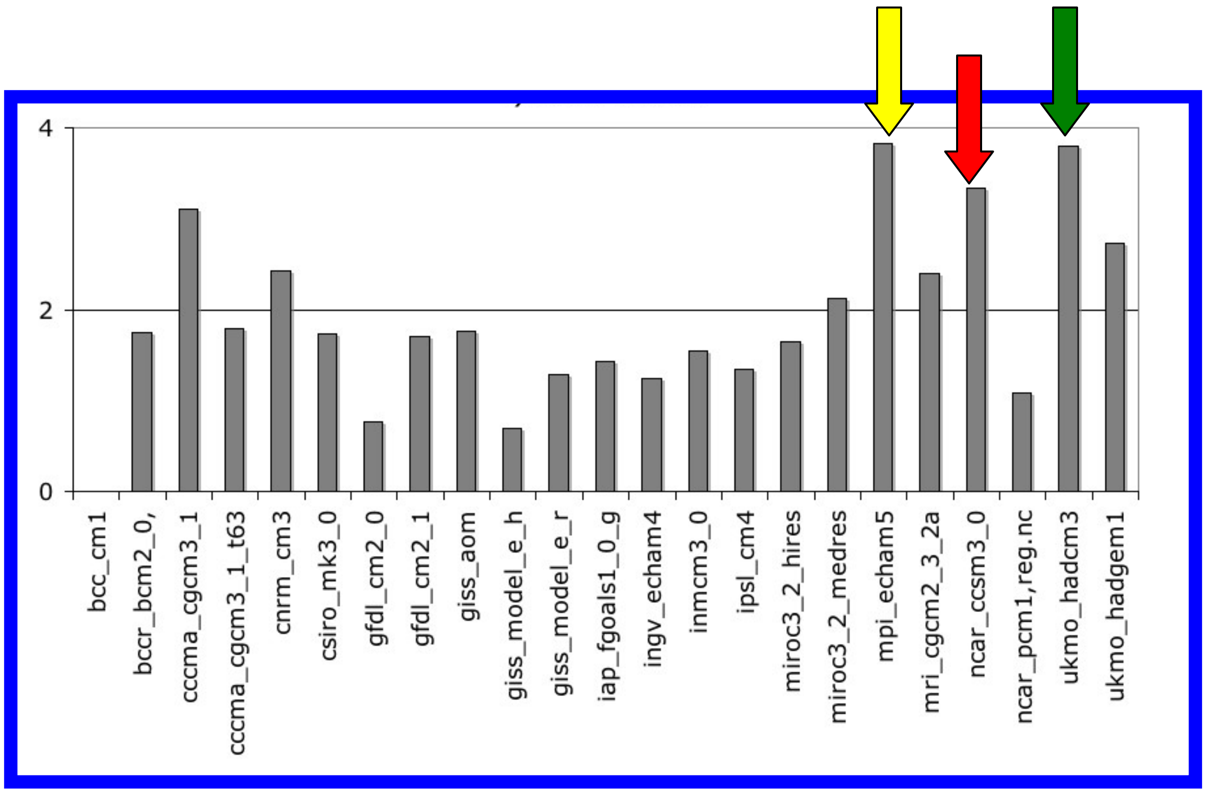


We chose to downscale the **three well performing IPCC AR4 models** that best represent the historical precipitation and temperature climatology in the Southwest and upper atmosphere circulation patterns in the Northern Hemisphere. ***These also have different GCM precipitation projections for Arizona (i.e. include "wet" and "dry" models)***

HadCM3: Completely done

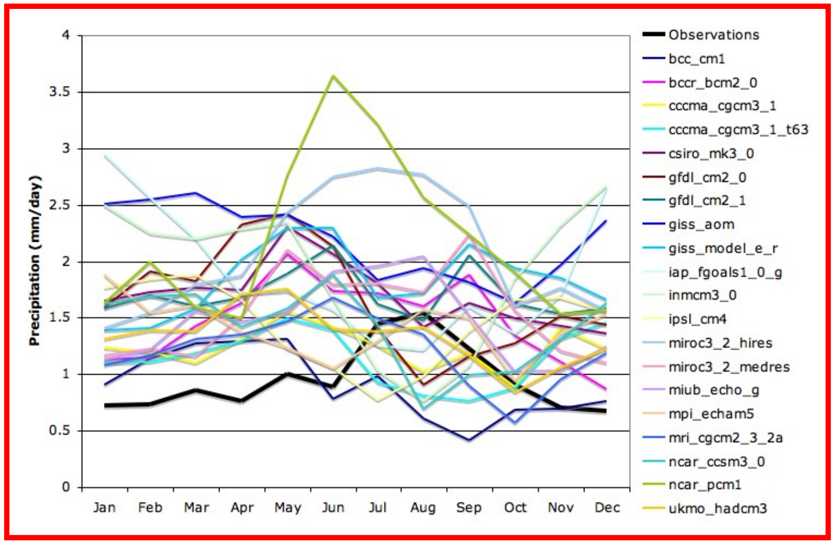
MPI Echam: GCM data being obtained

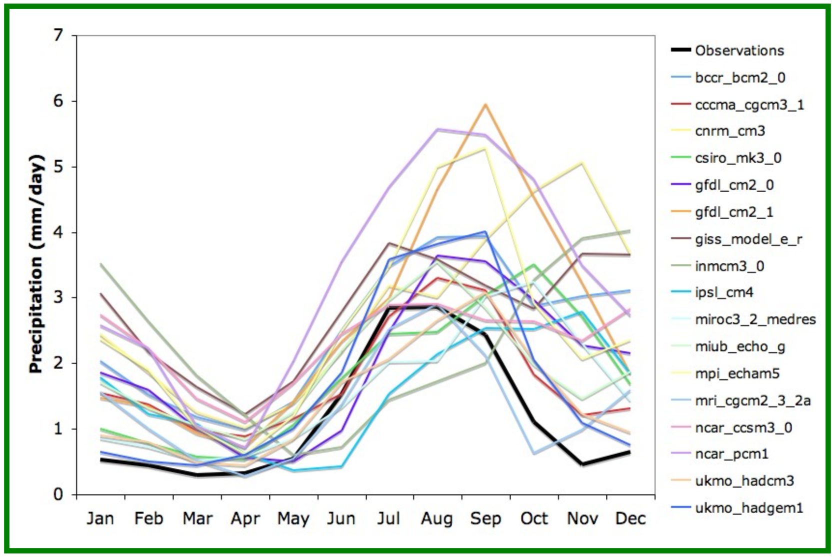
CCSM: Will get these data soon

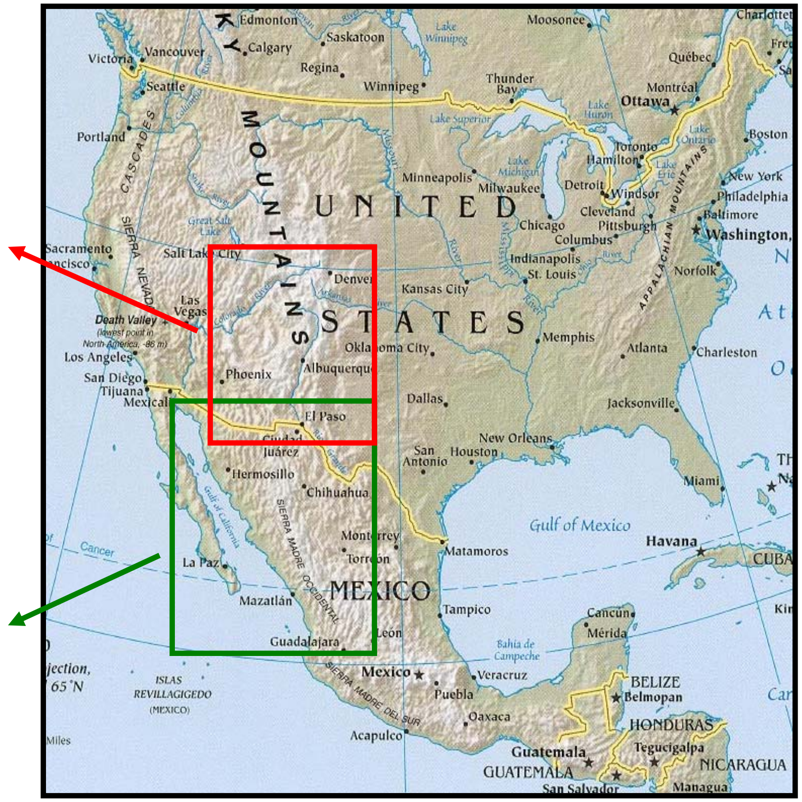


Dominguez et al (2009)

Monthly average precipitation from IPCC models during the previous century





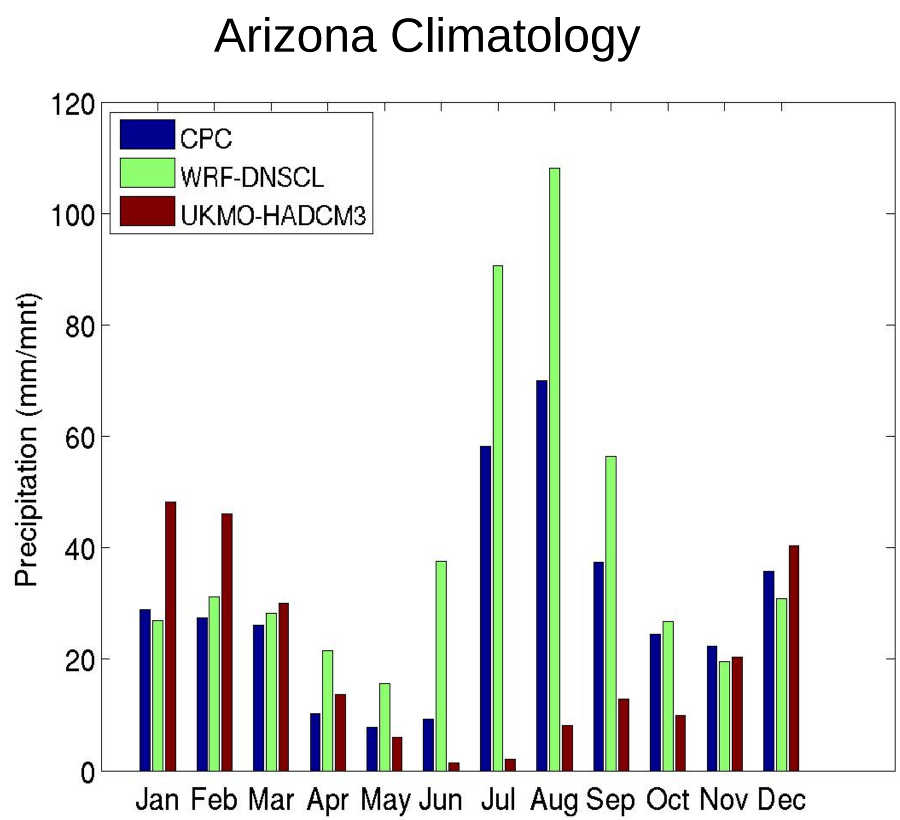


Historical average of simulations (sres_20c3m) 1970-2000

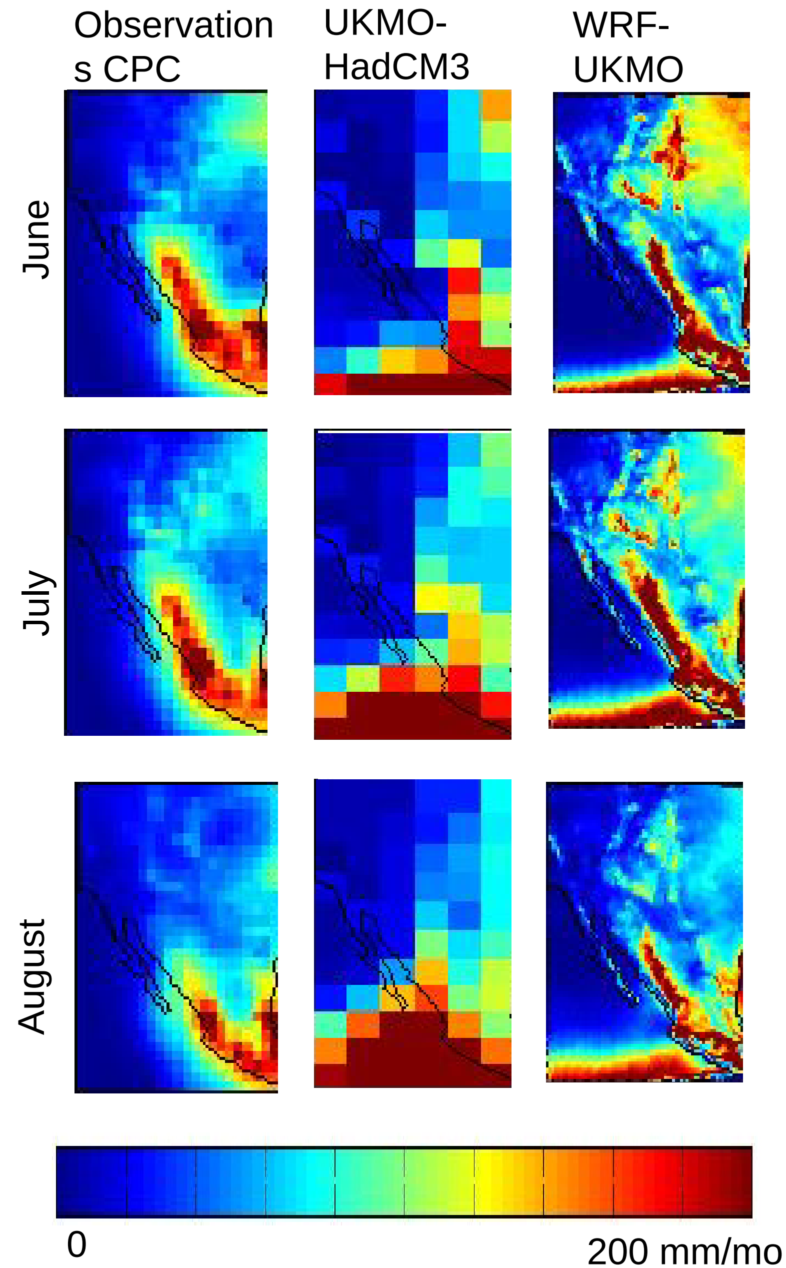
(Francina Dominguez)

Preliminary analysis of results…

1968-2000 monthly climatology shows that WRF represents the timing and intensity of the Monsoon more realistically than the raw model.

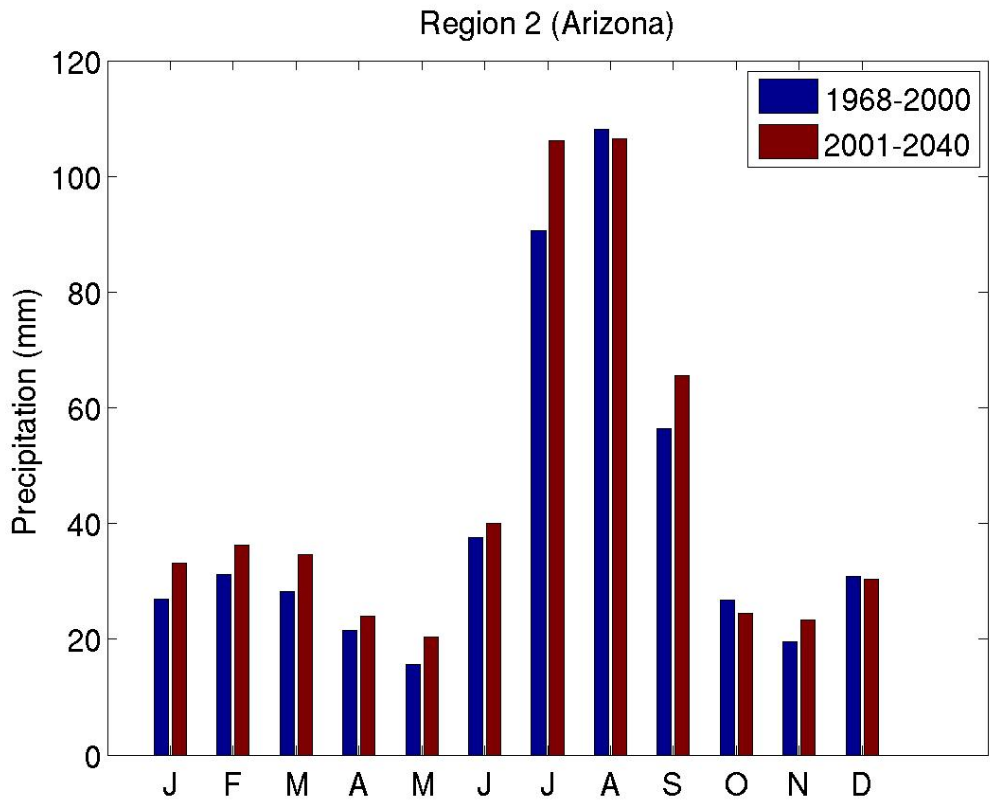


Preliminary analysis of results…



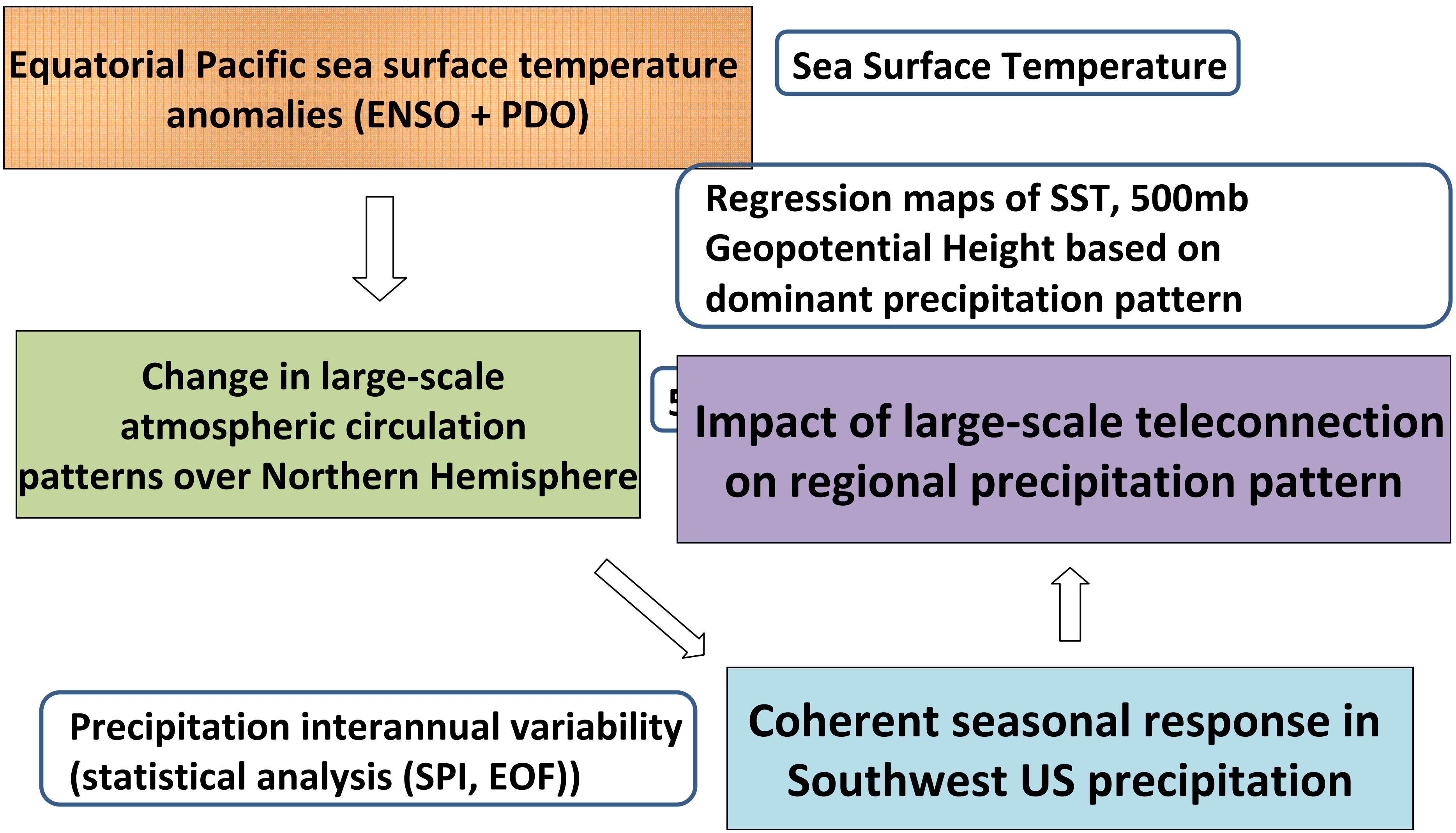
1968-2000 June July and August precipitation climatology of WRF downscaled UKMO-HadCM3 data show a much more realistic spatial representation of the North American Monsoon than the raw model.

Preliminary results of future precipitation show that the 2001-2040 climatology has a generalized higher precipitation – Particularly in July, as compared to the 1968-2000 monthly climatology. Similar results at river basin scale (e.g.Salt, Verde)



We have talked about the climatological analysis, now let’s look at the interannual variability…

Connections between seasonal precipitation variability and large scale teleconnections



Statistical analysis methods:

Precipitation normalization

- Standard Precipitation Index(SPI): Accounts for non-normal distribution of precipitation

Spatial pattern recognition

- Rotated Empirical Orthogonal Function Analysis(REOF)

Relationship of dominant modes of precipitation variability to large-scale forcing factors

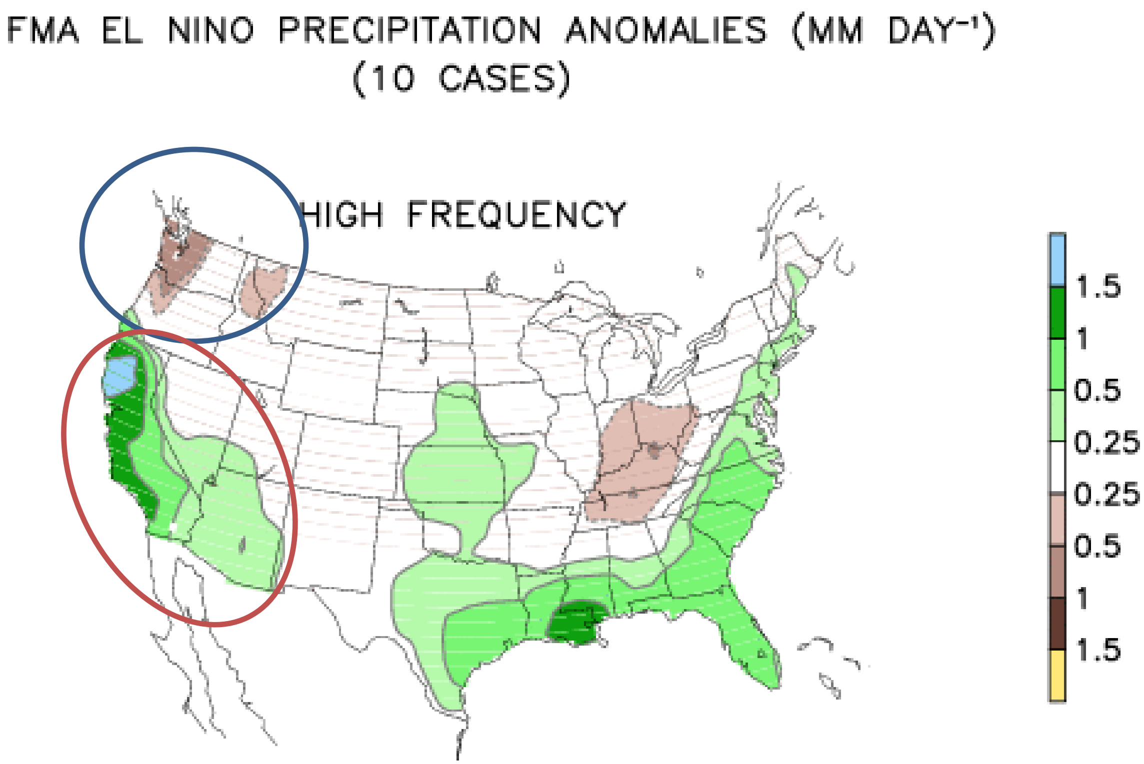
- Regression Analysis between precipitation modes and SST, geopotential height

What we look for to assess natural variability in downscaled climate data

GCM: need to capture the SST forcing and associated large-scale circulation pattern

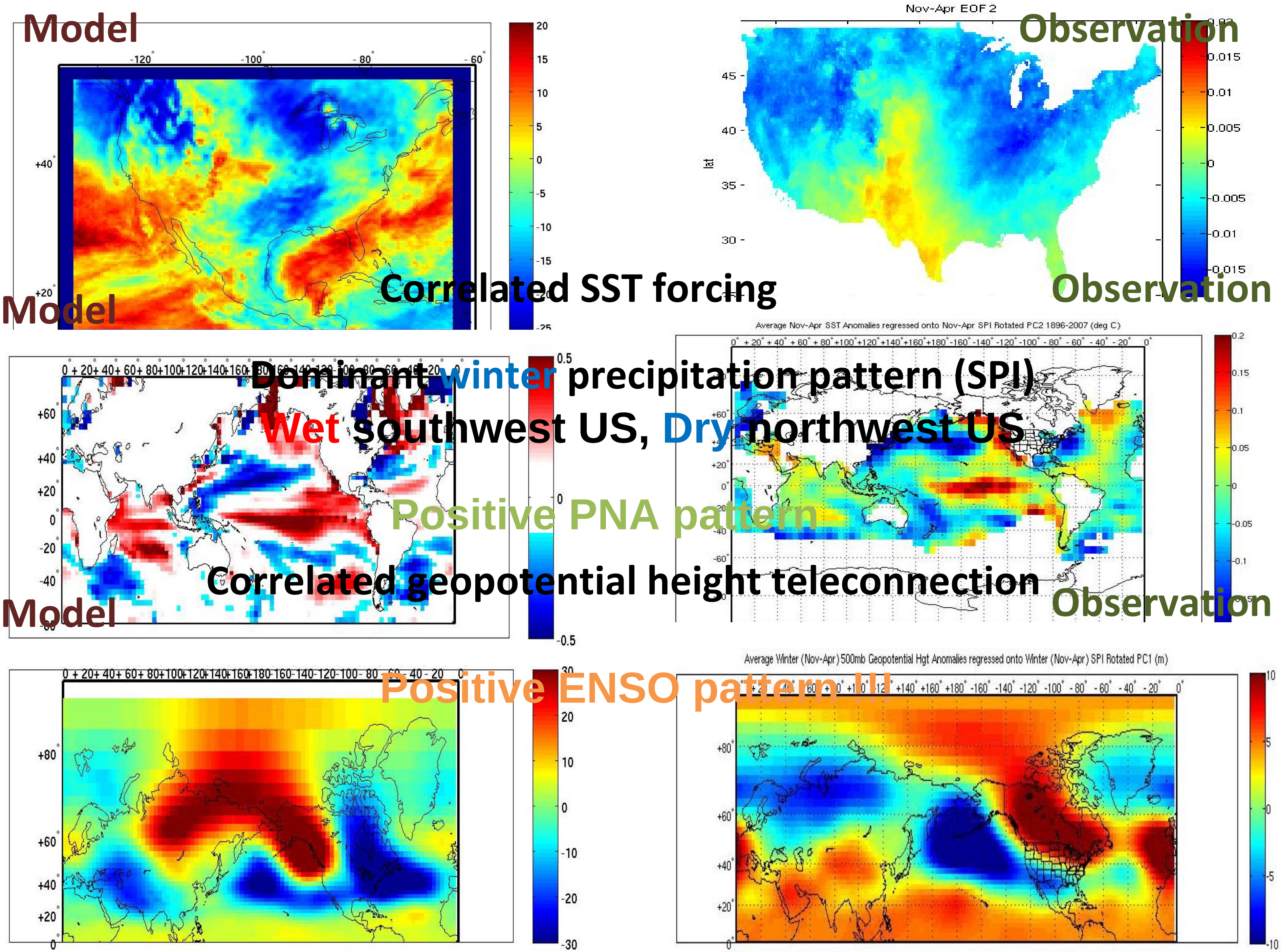
- RCM: need to capture the regional precipitation variability

- Expectations for dynamically downscaled output:
  - Capture Pacific forced interannual variability, which must be seen in the dominant regional precipitation patterns, associated sea surface temperatures and large scale circulation



Typical winter precipitation
anomaly during El Nino year

Source: Climate Prediction Center


Model
Observation
Nov-Apr EOF 2
Correlated SST forcing
Model
Observation
Average Nov-Apr SST Anomalies regressed onto Nov-Apr SPI Rotated PC2 1896-2007 (deg C)
Dominant winter precipitation pattern (SPI)
Wet southwest US, Dry northwest US
Positive PNA pattern
Correlated geopotential height teleconnection
Model
Observation
Average Winter (Nov-Apr) 500mb Geopotential Hgt Anomalies regressed onto Winter (Nov-Apr) SPI Rotated PC1 (m)
Positive ENSO pattern !!!

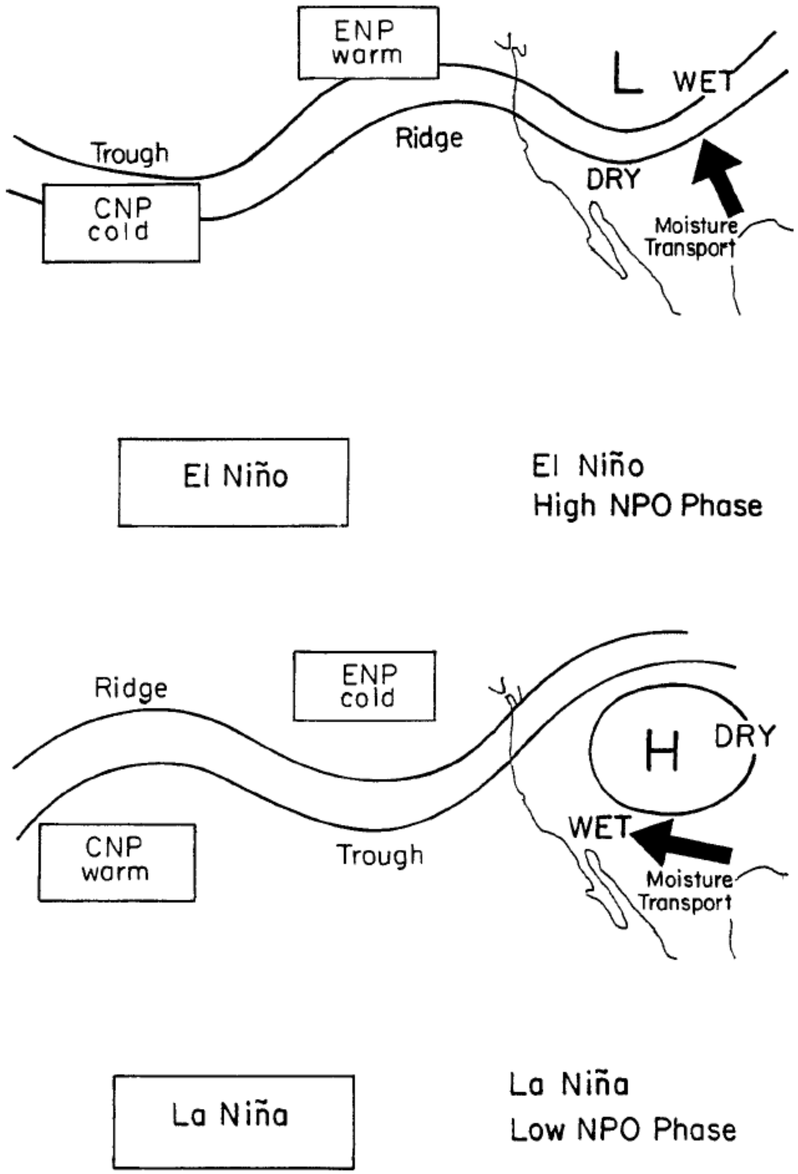
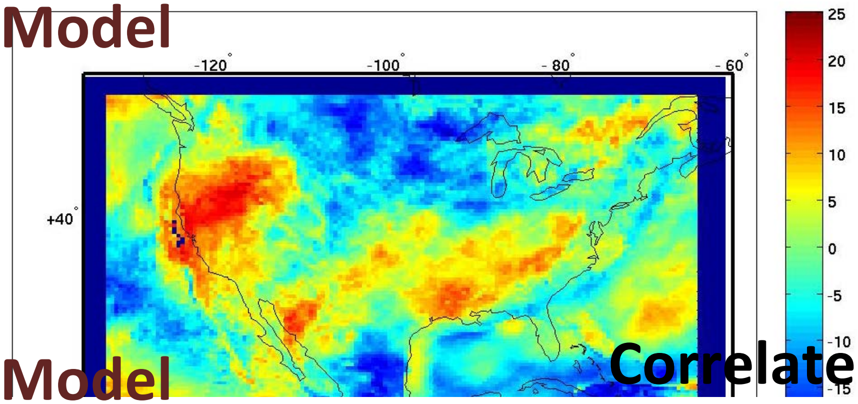


FIG. 14. Idealized relationship of monsoon ridge position and midlevel moisture transport to Pacific SSTs at monsoon onset.

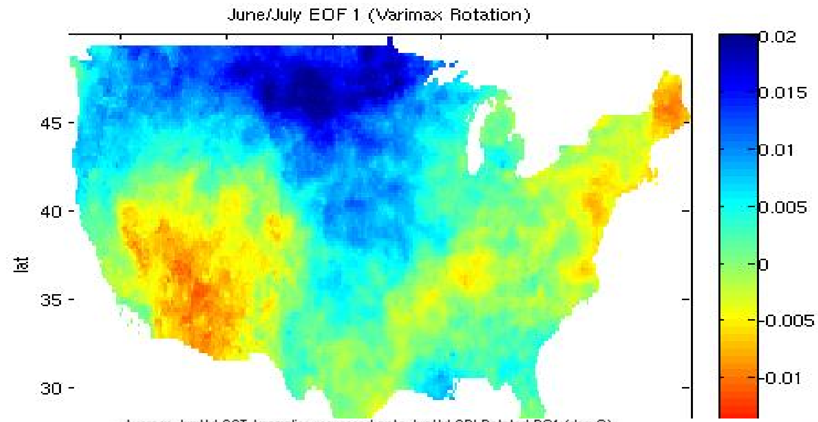
Early summer teleconnection patterns (late June, early July)

(Castro et al., 2001)

Model



Correlated SS



Model

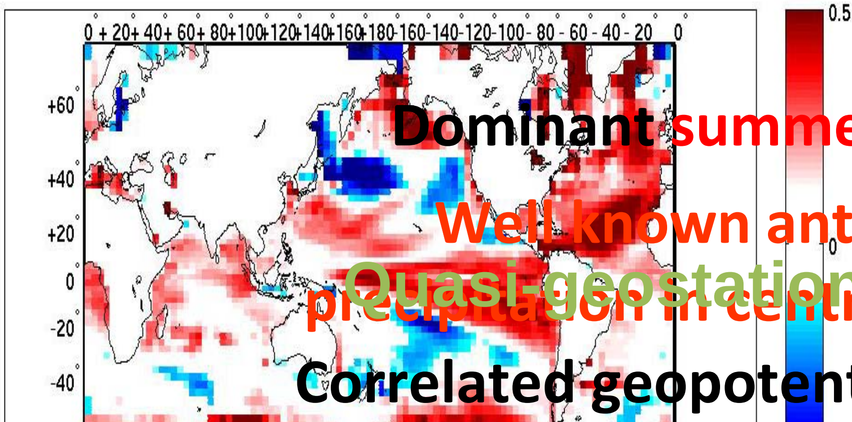
Dominant summer pr

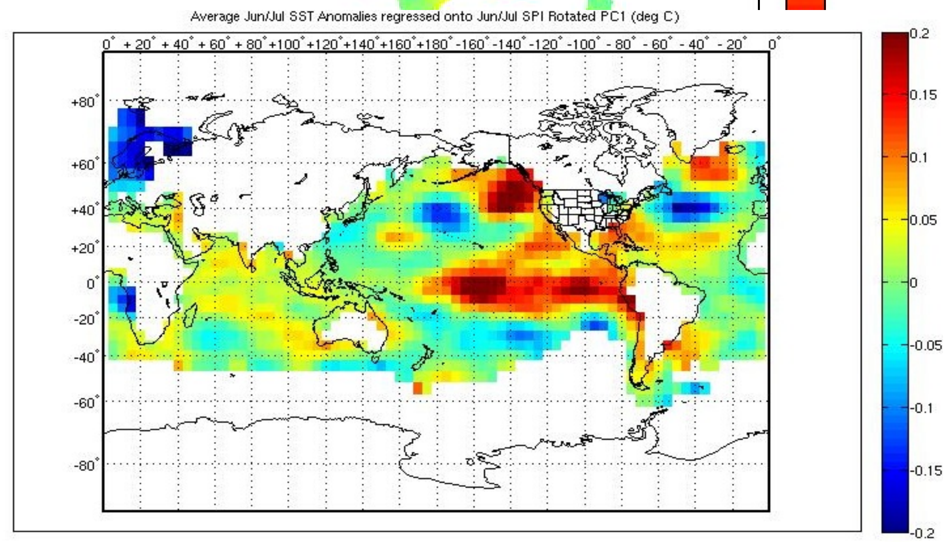
Well known anticyc

Quasi-geostationary

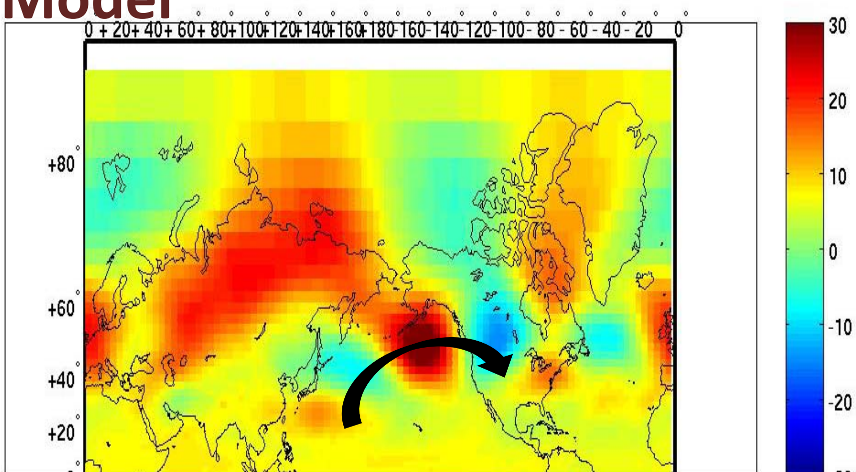
precipitation in central

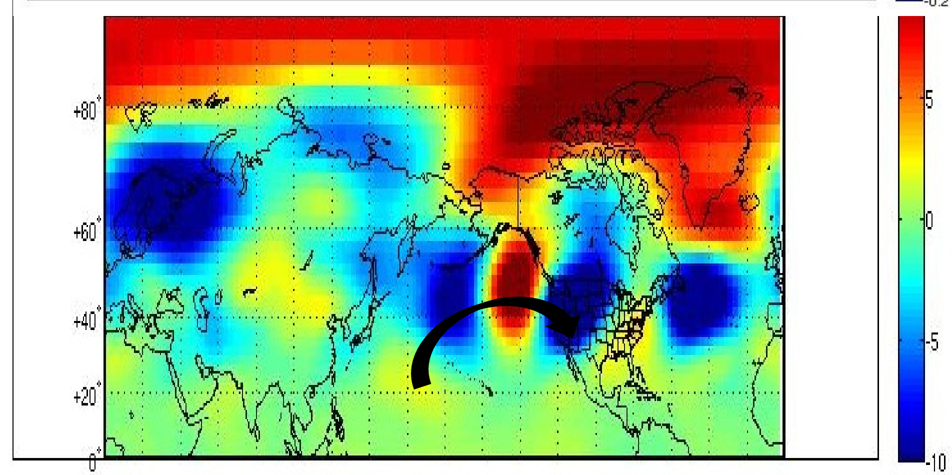
Correlated geopotential





Model





RCM with dynamically downscaled GCM data is able to capture:

- Seasonal precipitation variability (winter and summer)
- Large-scale forcing corresponds to the dominant precipitation pattern
  - ENSO pattern
  - Stationary patterns in the atmospheric circulation both in winter and summer
    - Quasi-geostationary Rossby wave (different driving mechanisms for winter and summer)

The regional model is adding substantial value to the representation of the interannual variability of the driving global model.

Conclusions

1. Dynamical Downscaling of HADCM3 data has been finalized. Current working on two more IPCC AR4 models

2. Climatological analyses show clear improvements when compared to raw GCM data.

3. In the dynamically downscaled WRF HADCM3 interannual variability is well captured for both summer and winter seasons.

Also did not have time to discuss warm season seasonal forecasts—but similar promising results!