Climate Change Analysis

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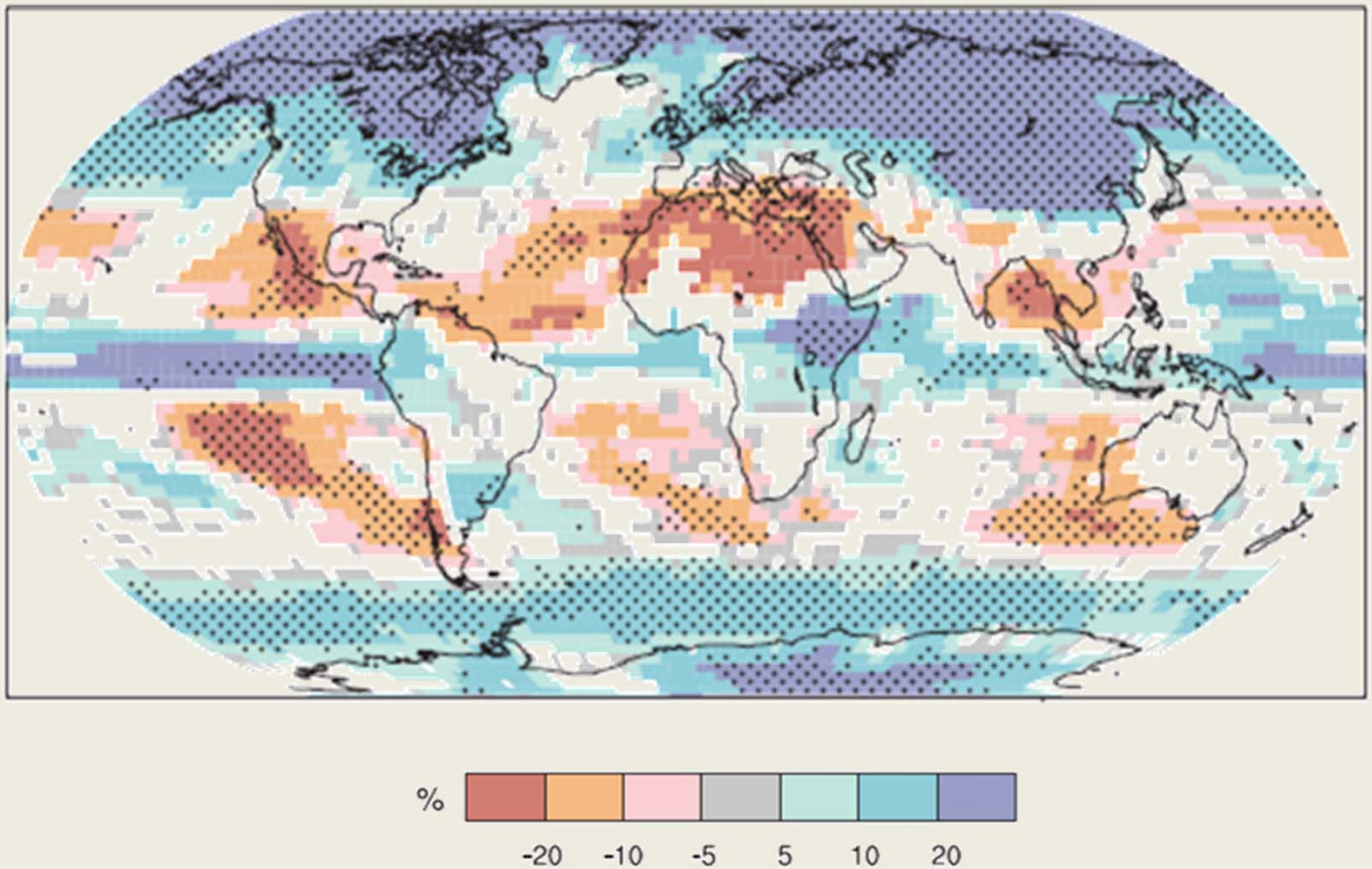
Starting Point: the IPCC

- The IPCC reports provide an overview of observed and projected climate change
- In support of IPCC reports, archives of dozens of Global Climate Model (**GCM**) simulations have been made publicly available in the 5th Coupled Model Intercomparison Project (**CMIP5**) archive.
- GCMs are limited in many ways, but they provide a starting point for regional analysis

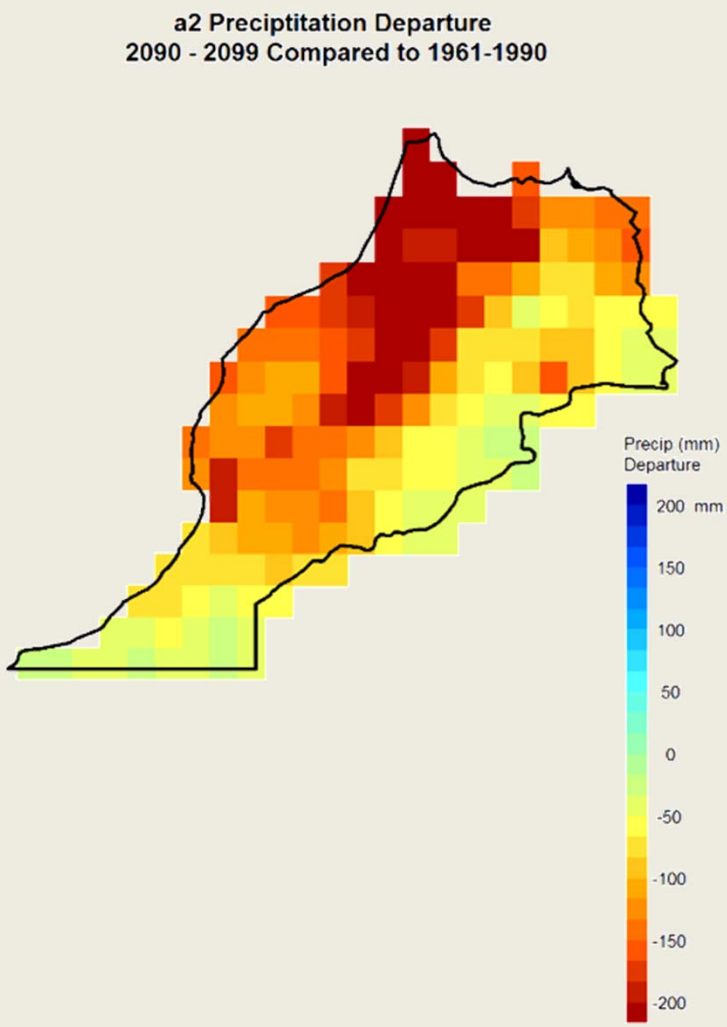
The Projection: hotter and drier

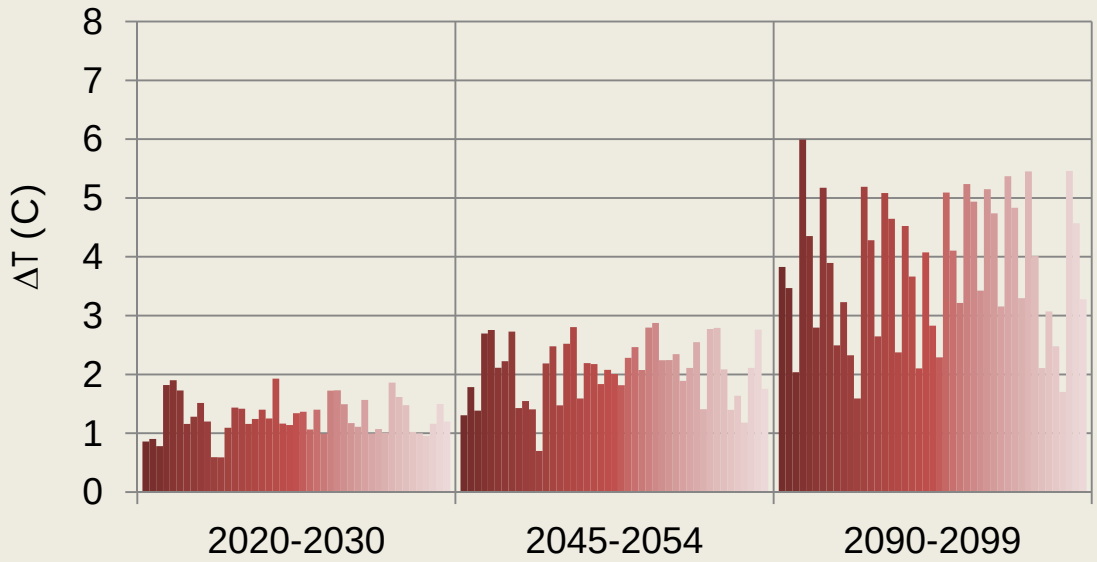
IPCC AR4: 21st C precipitation change, Scenario A1B

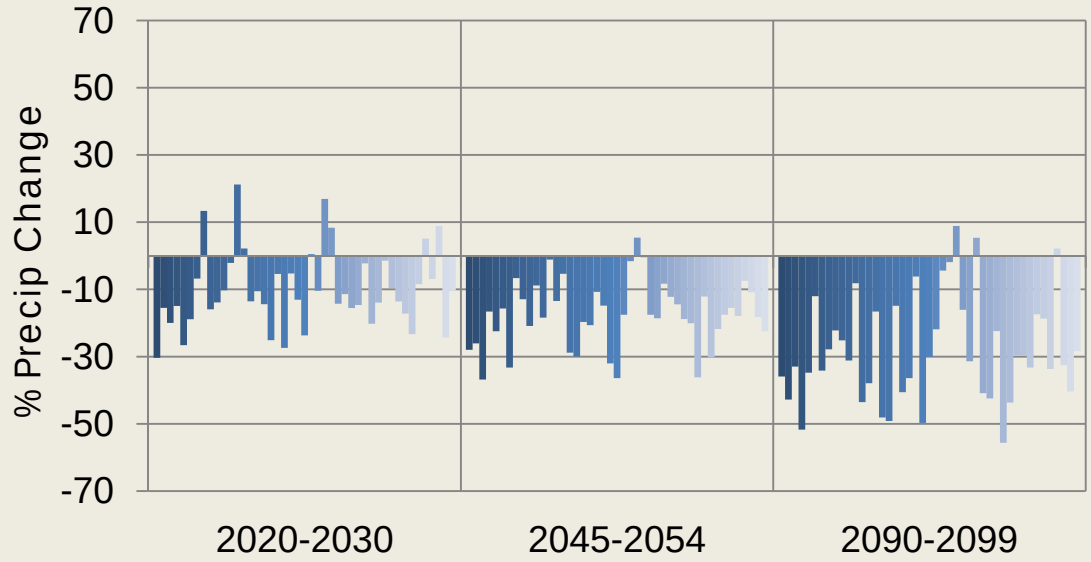


IPCC AR4

Morocco







www.climatewizard.org

Characteristics of GCM Climate Projections

- Large uncertainty
- Coarse spatial resolution
- Precipitation estimates are particularly unreliable
- Limited representation of extremes
- Minimal model evaluation in MENA

Types of Downscaling

- **Statistical downscaling** uses historical observations to draw associations between large scale phenomena and local conditions.

- **Dynamical downscaling** applies regional climate models (RCM) to produce physically-based simulation of fine scale processes.

Types of Downscaling

- **Statistical downscaling**
  - (+) Empirical, computationally efficient, relies on GCMs only for modes of large-scale variability
  - (–) Requires long data records, assumes stationarity, can underestimate variability, generates point-scale predictions

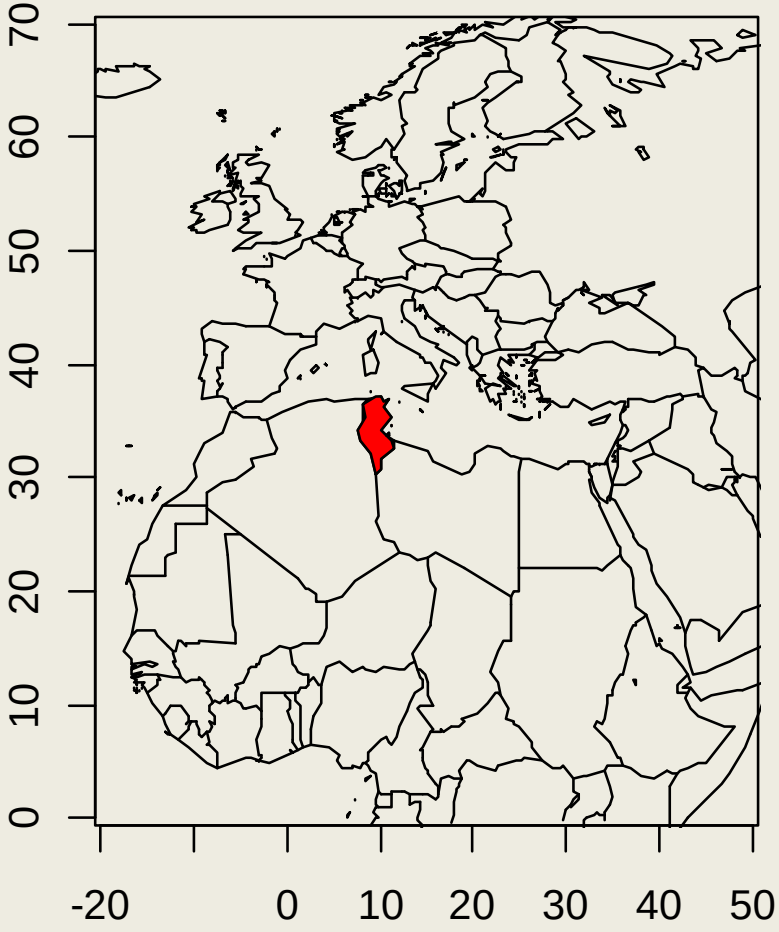
- **Dynamical downscaling**
  - (+) Physically based, allows for nonstationarity*, generates gridded predictions
  - (–) Computationally intensive, requires extensive evaluation, can be difficult to correct biases

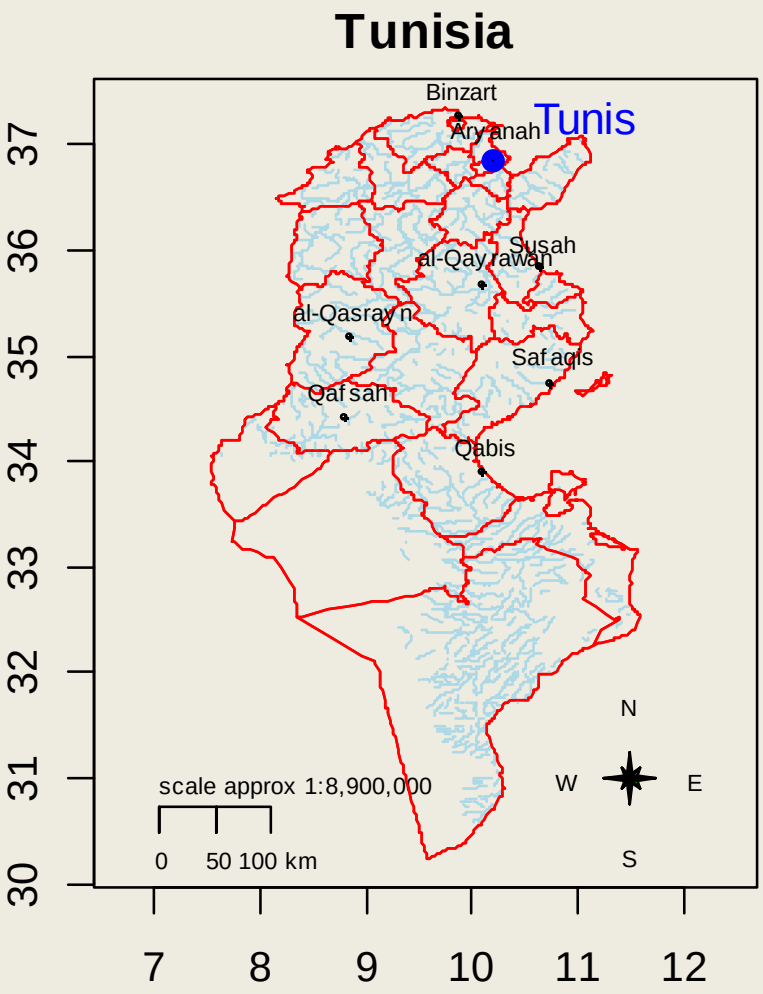
Statistical Downscaling at JHU

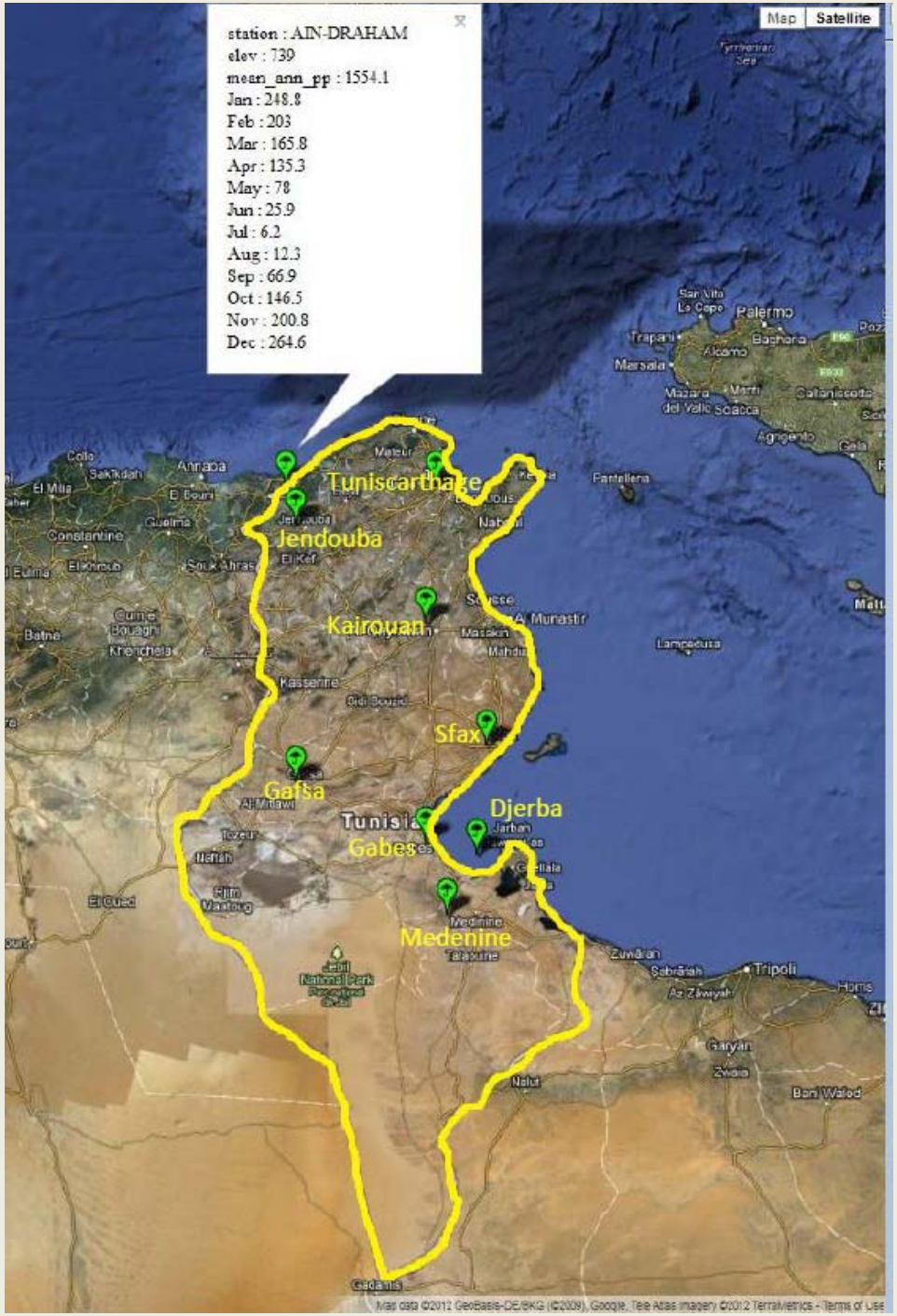
We have focused on:

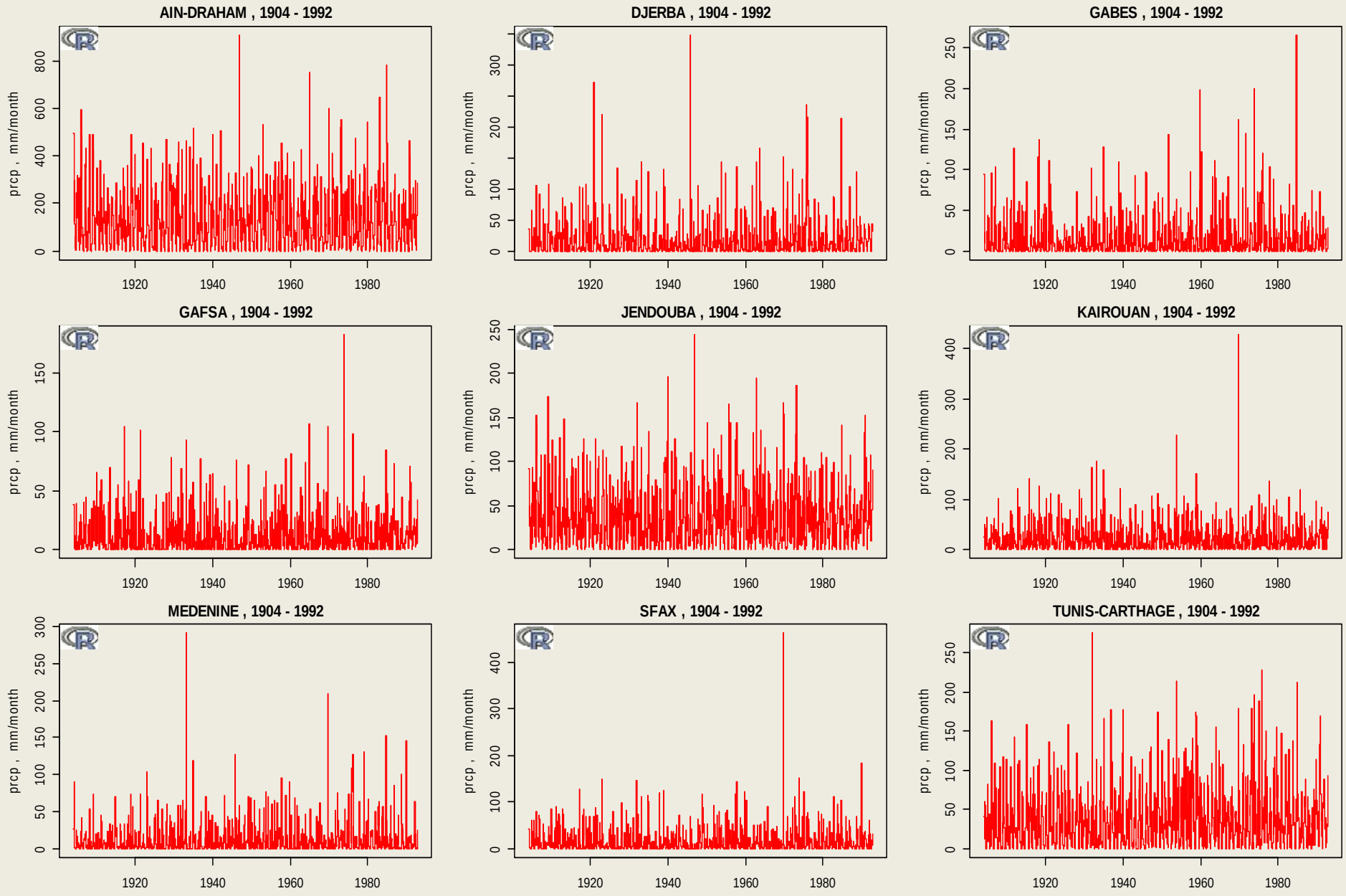
- Understanding observations
- Methods that make use of the full spatial structure of climate variability
- Multiple statistical approaches
- Tools capable of ingesting all CMIP5 data

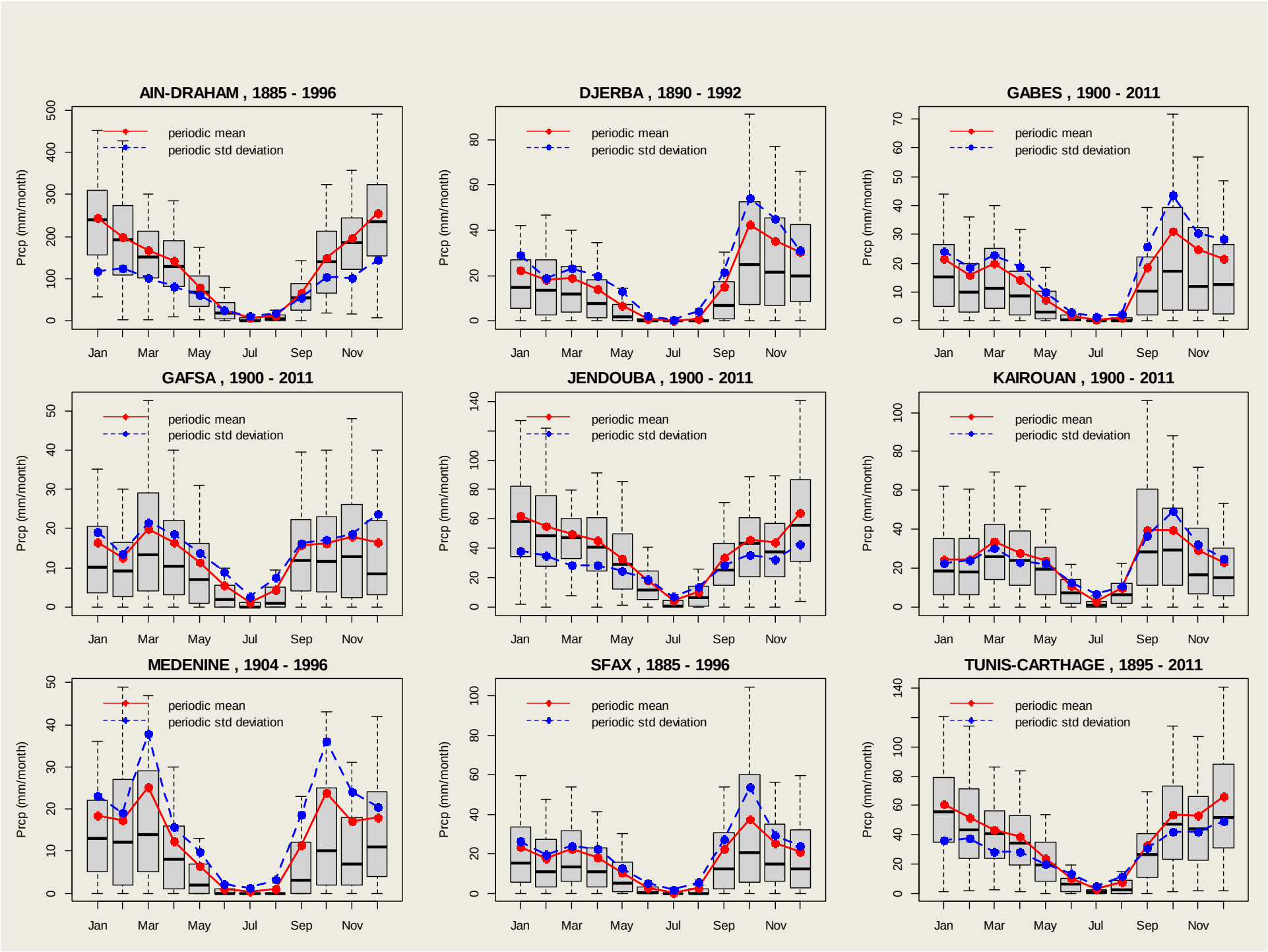
Understanding Observations



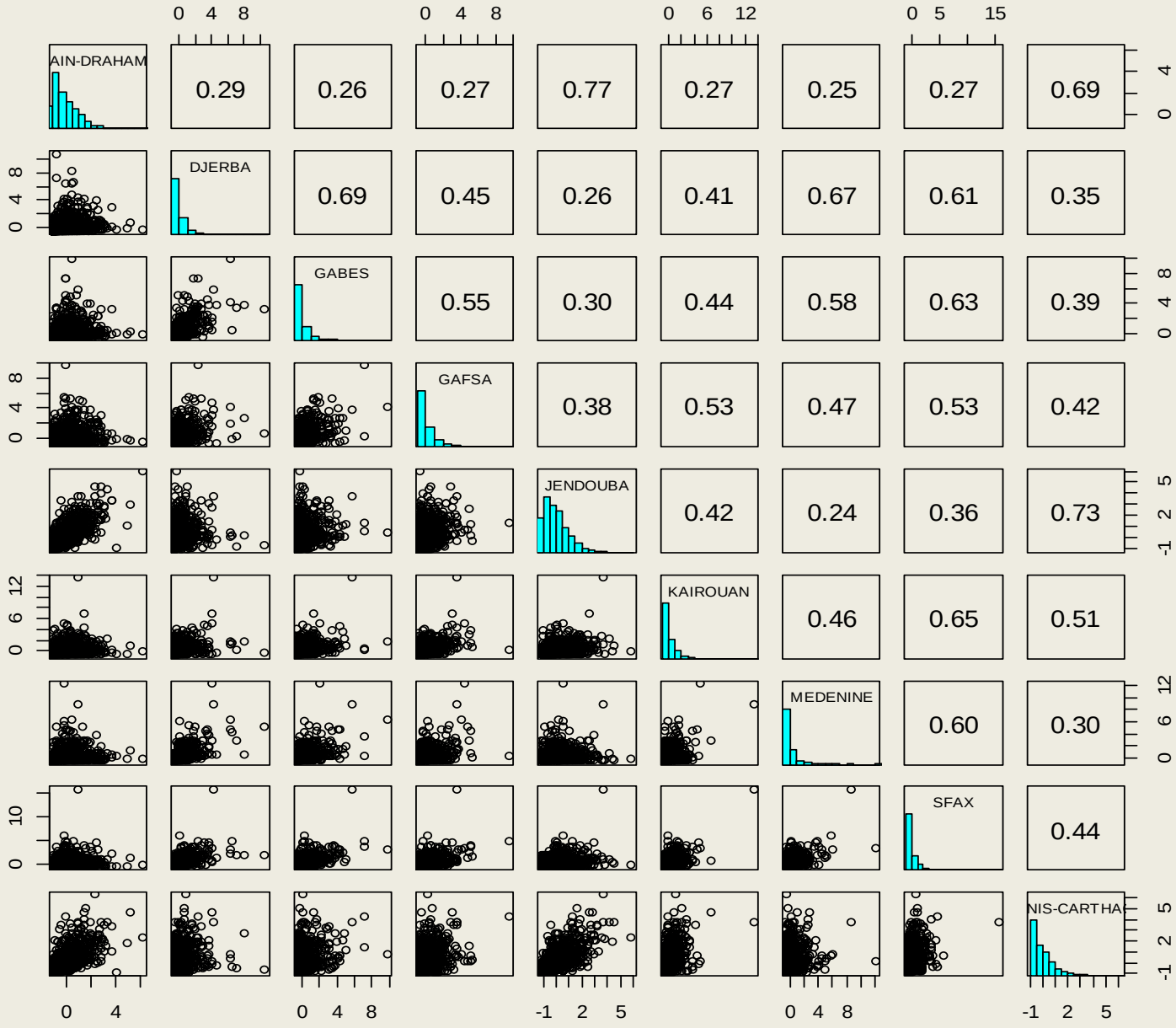



station : AIN-DRAHAM
elev : 739
mean_ann_pp : 1554.1
Jan : 248.8
Feb : 203
Mar : 165.8
Apr : 135.3
May : 78
Jun : 25.9
Jul : 6.2
Aug : 12.3
Sep : 66.9
Oct : 146.5
Nov : 200.8
Dec : 264.6
Map
Satellite
Tuniscarthage
Jendouba
Kairouan
Sfax
Gafsa
Djerba
Gabes
Medenine
Tunisia
Palermo
Tripoli


AIN-DRAHAM , 1904 - 1992
DJERBA , 1904 - 1992
GABES , 1904 - 1992
GAFSA , 1904 - 1992
JENDOUBA , 1904 - 1992
KAIROUAN , 1904 - 1992
MEDENINE , 1904 - 1992
SFAX , 1904 - 1992
TUNIS-CARTHAGE , 1904 - 1992
prcp , mm/month
1920
1940
1960
1980

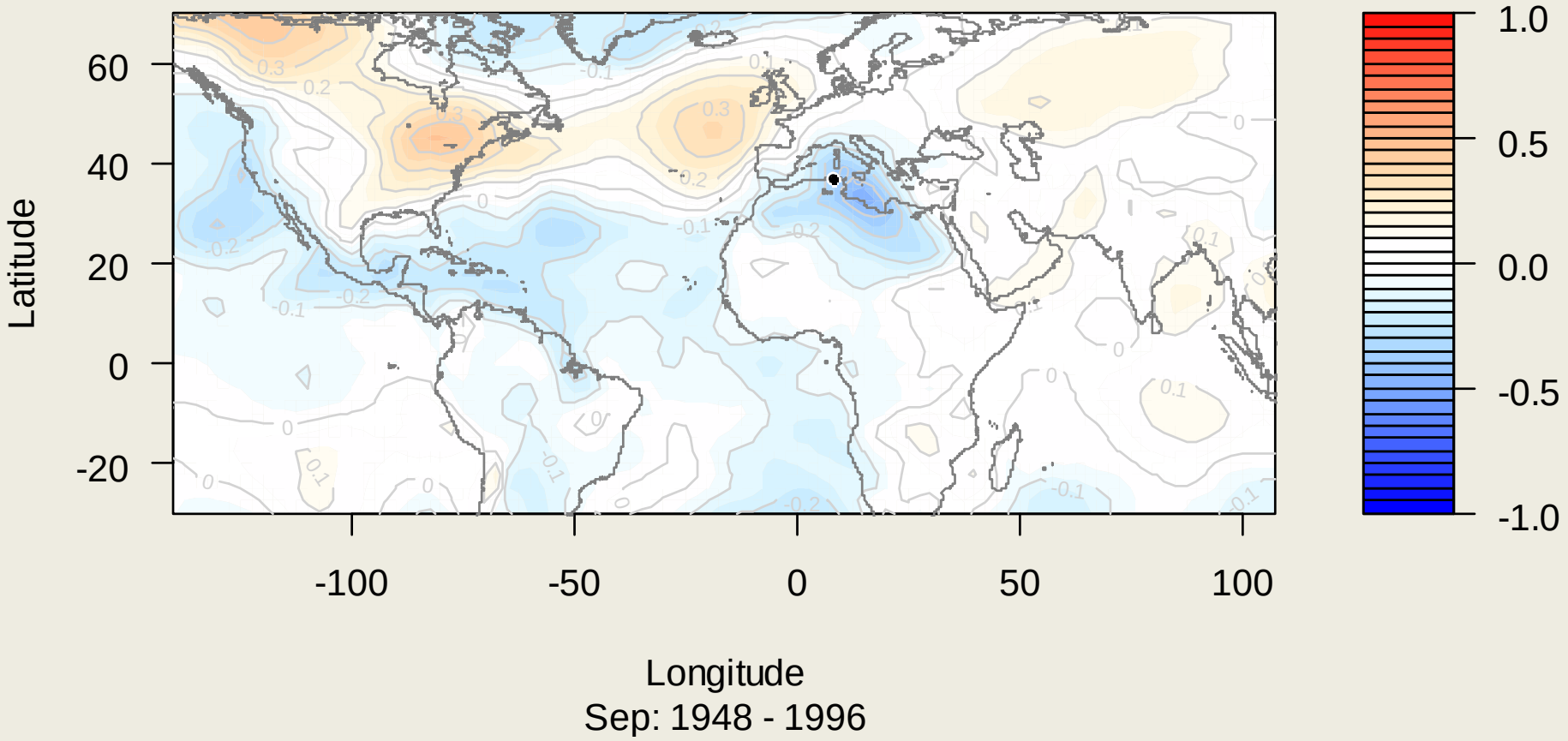

AIN-DRAHAM , 1885 - 1996
DJERBA , 1890 - 1992
GABES , 1900 - 2011
GAFSA , 1900 - 2011
JENDOUBA , 1900 - 2011
KAIROUAN , 1900 - 2011
MEDENINE , 1904 - 1996
SFAX , 1885 - 1996
TUNIS-CARTHAGE , 1895 - 2011
periodic mean
periodic std deviation
Prcp (mm/month)
Jan
Mar
May
Jul
Sep
Nov

Corr btwn Std Anomalies of Monthly Prcp, Tunisia



Capturing Variability

Corr: slp [Sep] & Prcp [Sep-Sep] @ AIN-DRAHAM



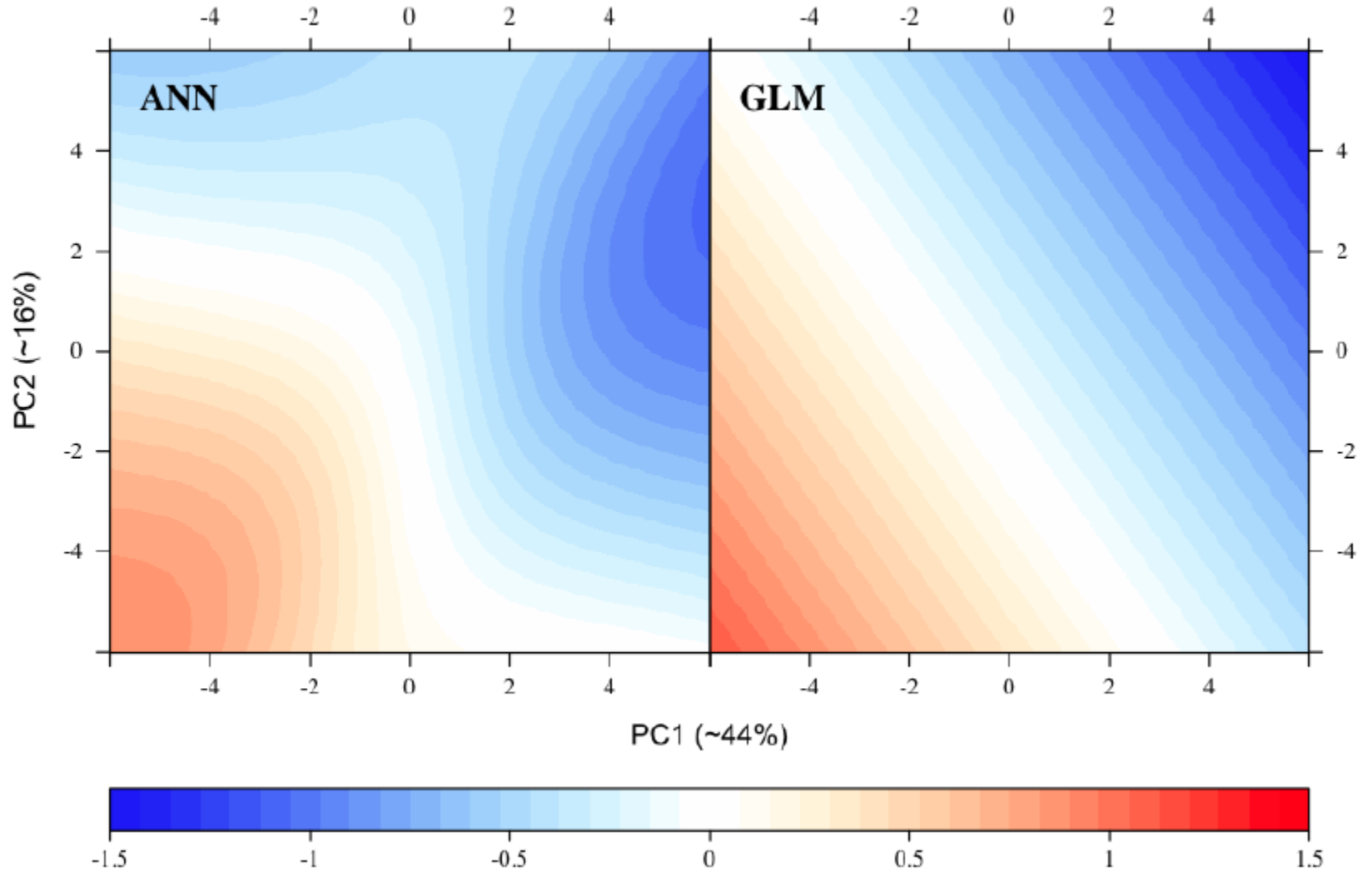
Capturing Variability

- Instead of working with climate indices, we use principal components of SST, SLP, geopotential height, etc.
- Leading PCs of these fields are used as predictors in the statistical model
- Models are fit using reanalysis data and then applied to GCMs

Statistical Approaches

Model	Description
GLM	Full-Covariate Generalized Linear Model
SGLM	Selected Generalized Linear Model based on Stepwise Selection
GAM	Full-Covariate Generalized Additive Model
SGAM	Selected Generalized Additive Model based on Penalized Terms
MARS	Multivariate Adaptive Regression Spline
CART	Classification and Regression Trees Model
BCART	Bagged Classification and Regression Trees Model
BART	Bayesian Additive Regression Trees Model
RF	Random Forest Model
ANN	Artificial Neural Network

Statistical Approaches

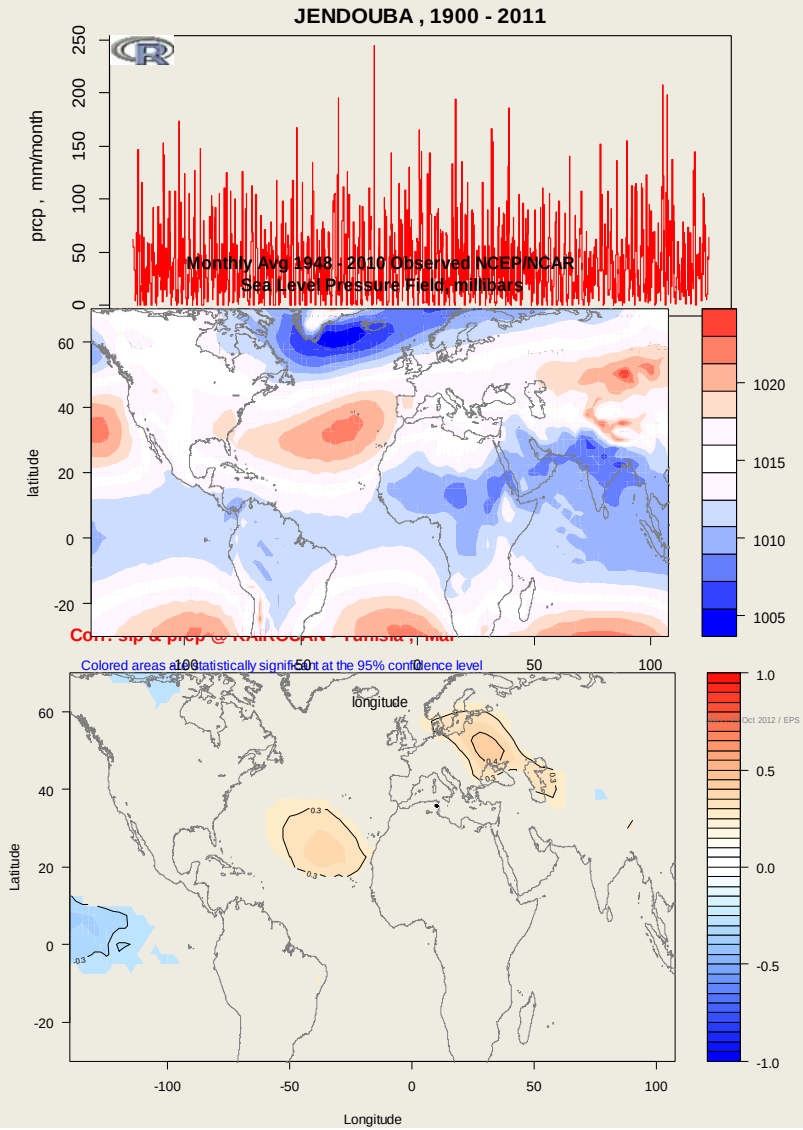


Implementation

1. Obtain long record meteorological station

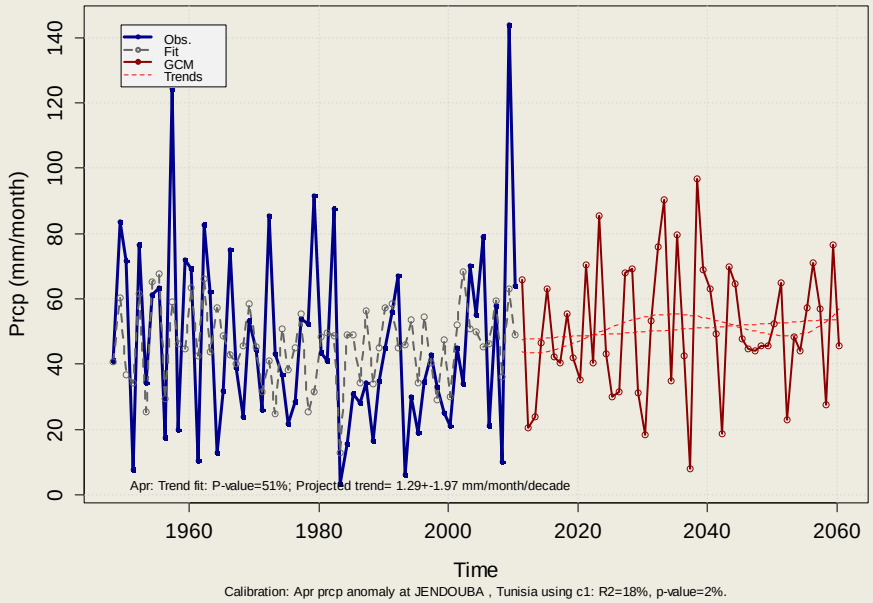
2. Compile large scale variables (SST, SLP, etc.) from reanalysis

3. Derive correlations between large scale and local variables



Implementation

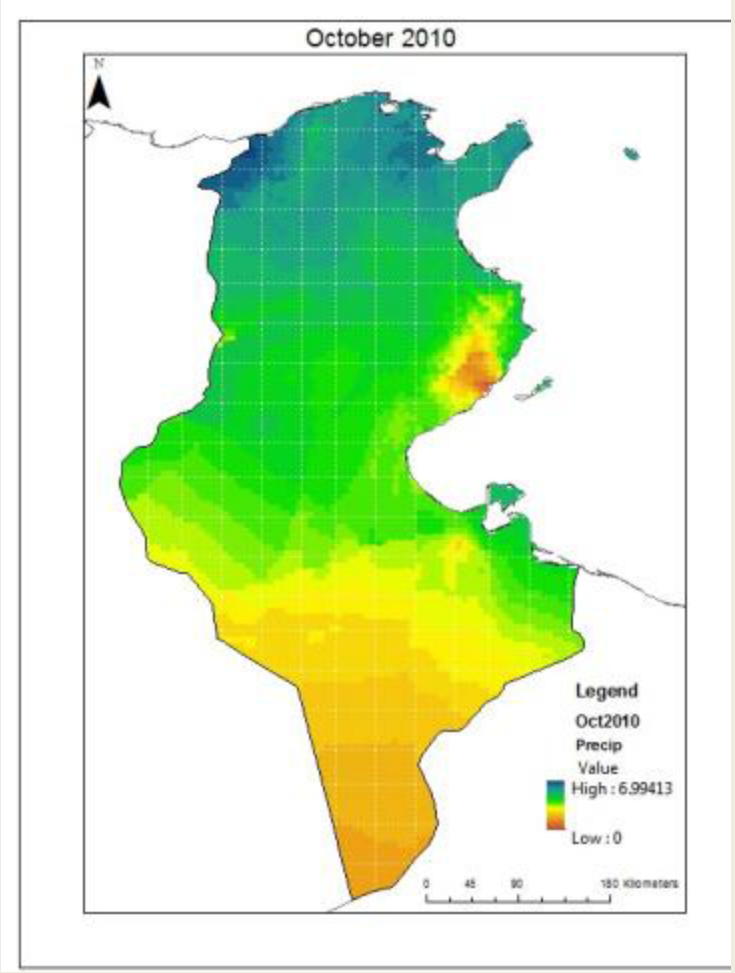
4. Calibrate statistical model and project forward using GCM data



Implementation

4. Calibrate statistical model and project forward using GCM data

5. Perform physically-based interpolation with topographic adjustments

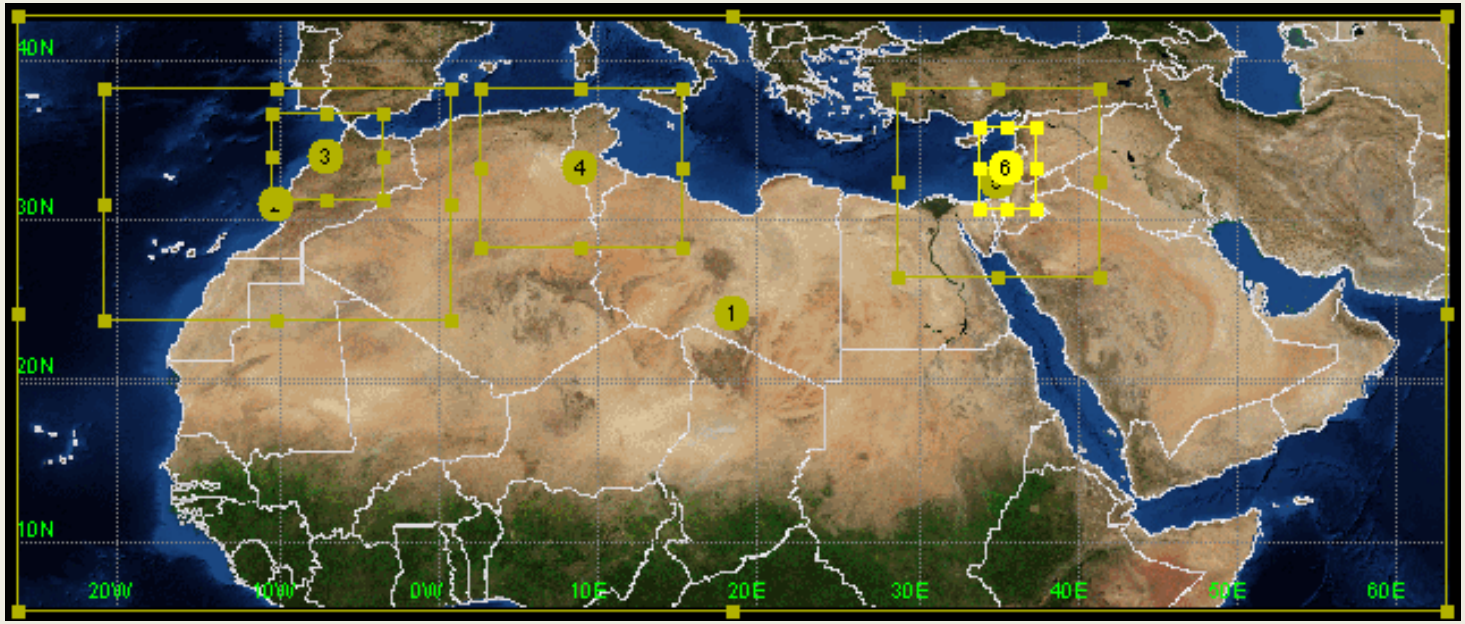


Statistical Downscaling

Summary:

- These techniques use free software and are highly computationally efficient
- They require calibration data from meteorological stations
- Collaborative evaluation and model improvement is critical

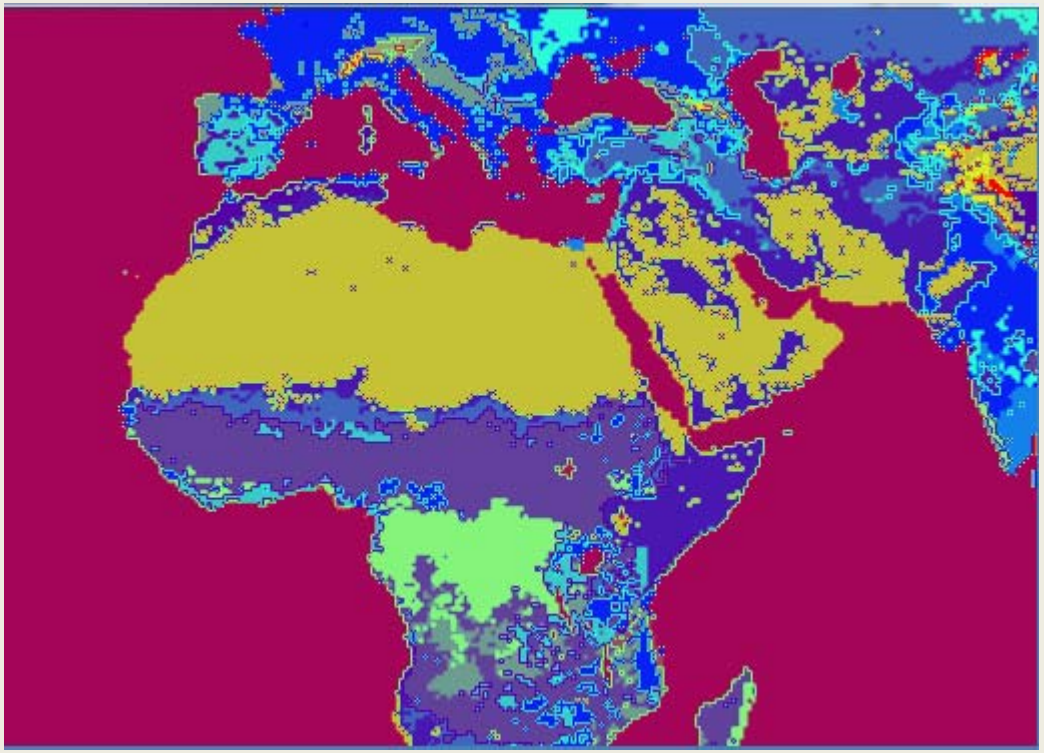
Dynamical Downscaling: WRF



- Physically-based predictions at high resolution
- Respond to GCM boundary conditions
- Models must be evaluated under current conditions
- High powered computers required

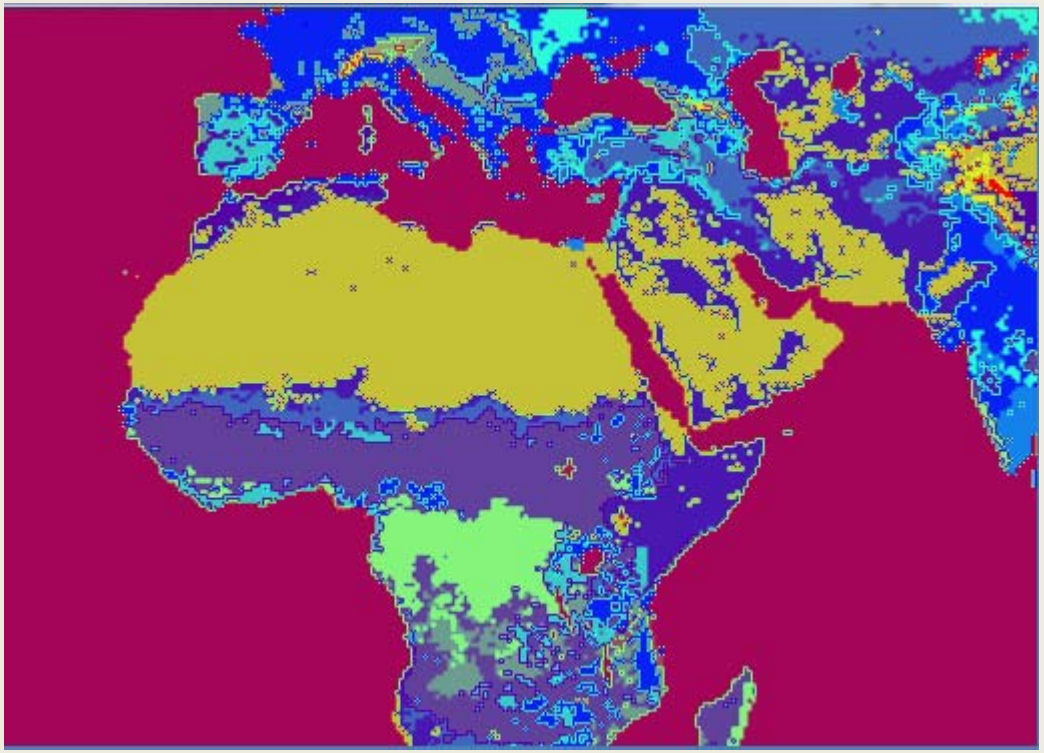
MENA “mother” domain

- 45km resolution
- Includes tropical Africa for Nile studies
- Includes Indian Ocean for Arabia/Levant studies



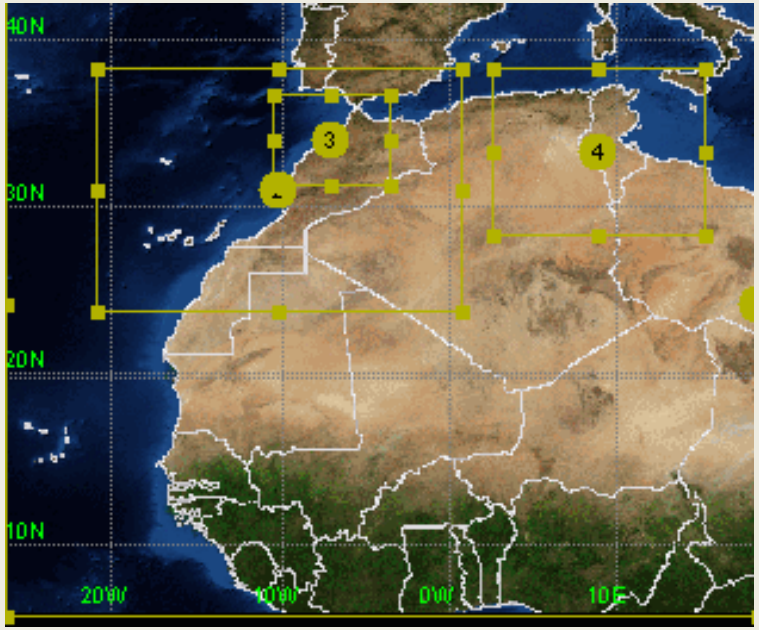
MENA “mother” domain

- Baseline 1990-2005
- Future simulations using MIROC5, CCSM4, and CM3 for 2030-2045
- Additional future period TBD



Dynamical Downscaling

- Outputs of JHU WRF simulations can be made available for impacts studies
- It is also possible to nest down to higher resolution over Morocco
- If you want to run your own WRF simulations we can train on CMIP5 to WRF tools



Questions:

- Are any of these climate analysis tools of interest?
- If so, would you send participants for training at JHU or ICBA?