Climate Downscaling for Fire Management

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- Part I: Introduction
- Part II: Climate projection
- Part III: Methods – Dynamic climate downscaling
- Part IV: Methods – Statistical climate downscaling
- Part V: Applications

Part I: Introduction

Acknowledgements

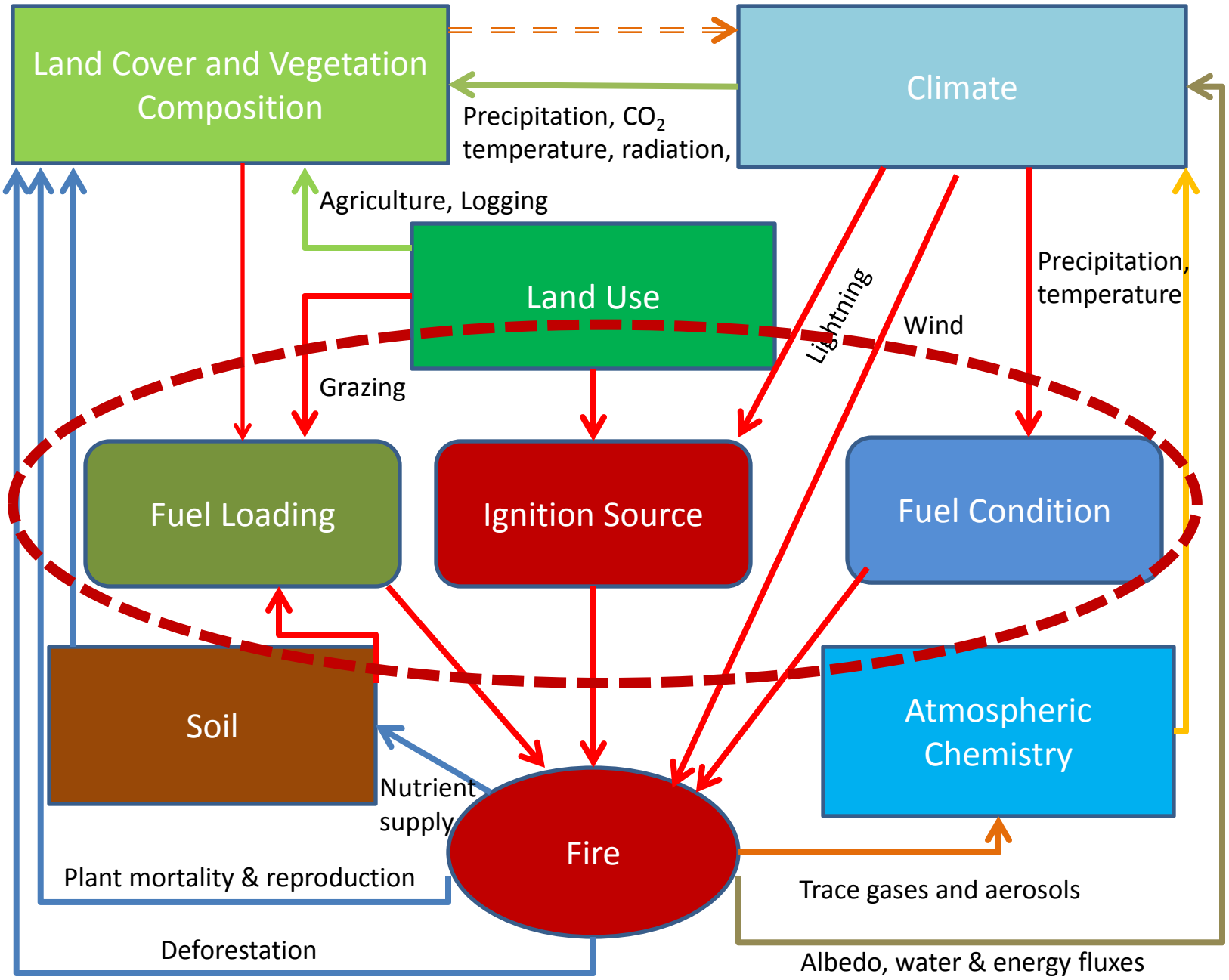
- Joint Fire Sciences Program
- National Fire Program
- FS Research and Development, Southern Research Station

- Disclaimer: The views expressed are those of the authors and do not necessarily represent the position or policy of the Forest Service.

Workshop Outline

- Basics and Introductions
- Climate and Fire Background
- Global Climate Modeling and Downscaling
- ***Break***
- Downscaling Methods-Dynamic
- Downscaling Methods-Statistical
- ***Break***
- Applications and Discussion

(Re-drawn from Spessa et al., 2013)



Information Needs for Down-scaled Climate Data

- Fire Regime
  - Fire management
  - Forest Management
  - Other resources management
- Extreme Events
  - Fire management
  - Forest Management
  - Other resources management
- Fire Season
  - Wildfire risk
  - RxFire window
- Fire Weather
  - Fire behavior
  - Smoke management

Time Scale

- Fire Season
  - Days to weeks
  - Onset
  - Length
  - Fine fuel loading
  - Lightning ignitions
- Fire Regime
  - Years to decades
  - Altered fuels
    - Vegetation growth
    - Vegetation structure
    - Vegetation composition
    - Decomposition
    - Density
    - Fuel loading
    - Fuel connectivity

Pathways for Climate-Altered Fire Regimes

- Changes in fuel loading
- Altered fuel condition
- Changes in ignitions

Changes in Fuel Loading

- More frequent or severe disturbances
  - Pathogens
  - Wind events
  - Snow or ice events
- Altered density or connectivity
- Altered fire regime
- **Many biomes but especially fine-fuel dominated systems (shrub, grass, woodland) and semi-arid forests**

Changes in Fuel Condition

- Length fire season
- Shift in timing of fire season
- More/less or longer/shorter drought cycle
- More/less or longer/shorter wet cycle
- Fire weather conducive to spread (i.e., windiness)
- **Boreal and temperate forests**
  - **High fuel load, multiple ignition sources, but high fuel moisture**

Increased Ignition Sources

- Increased lightning
  - **Semi-arid forests where sufficient fuel but little convective activity causing low lightning**
- Human activity
  - **Wildland-urban interface**
  - **Energy development (i.e., transmission lines)**

Did We Get It Right????

Information Needs for Down-scaled Climate Data

- Fire Regime
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- Fire Weather
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  - Smoke management

So What About Global Climate Modeling and Downscaling ?

Part II: Climate projection

Global Energy Balance

342 W/m^2

Incoming solar radiation

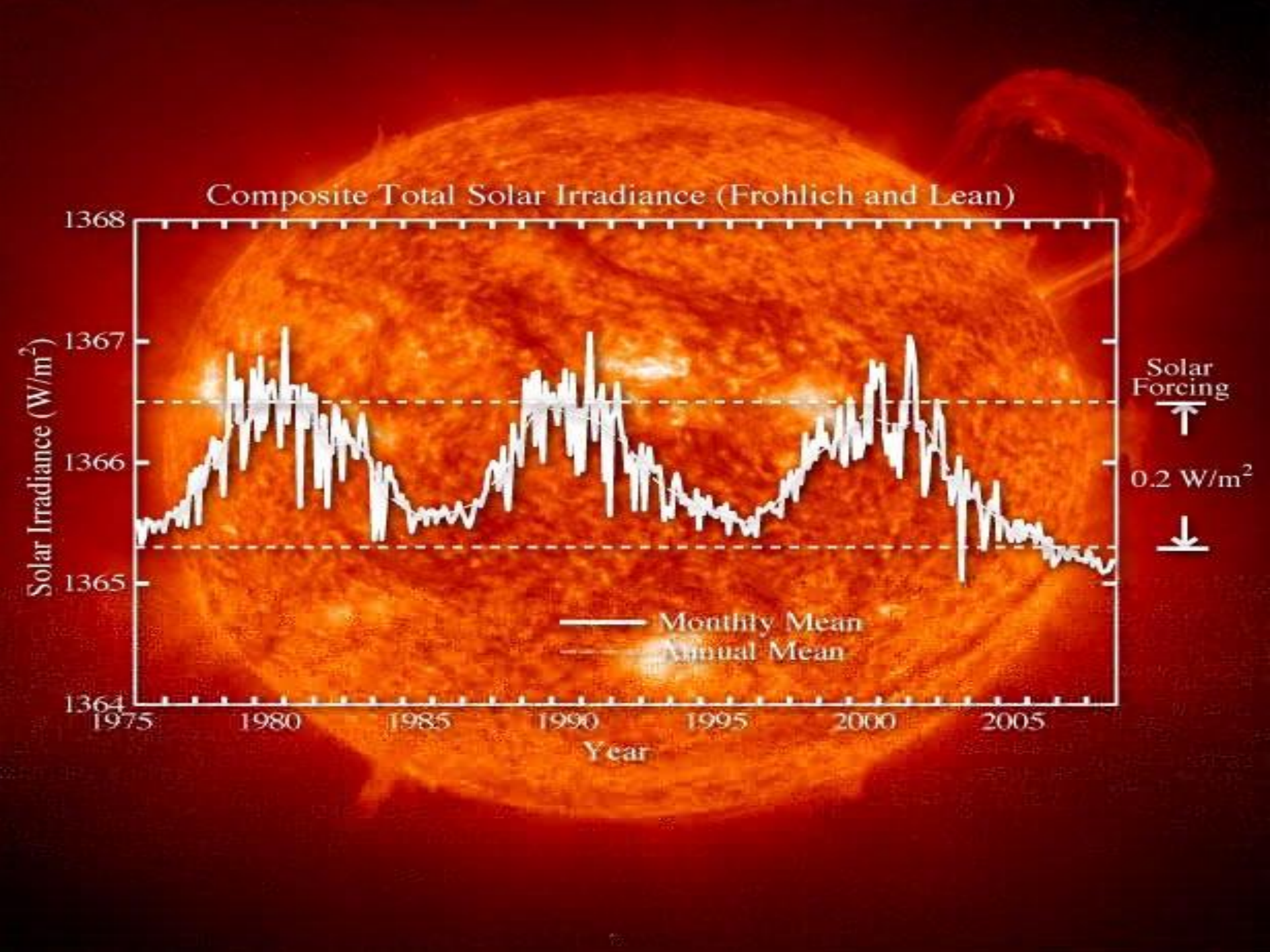
235 W/m^2

Outgoing long wave radiation

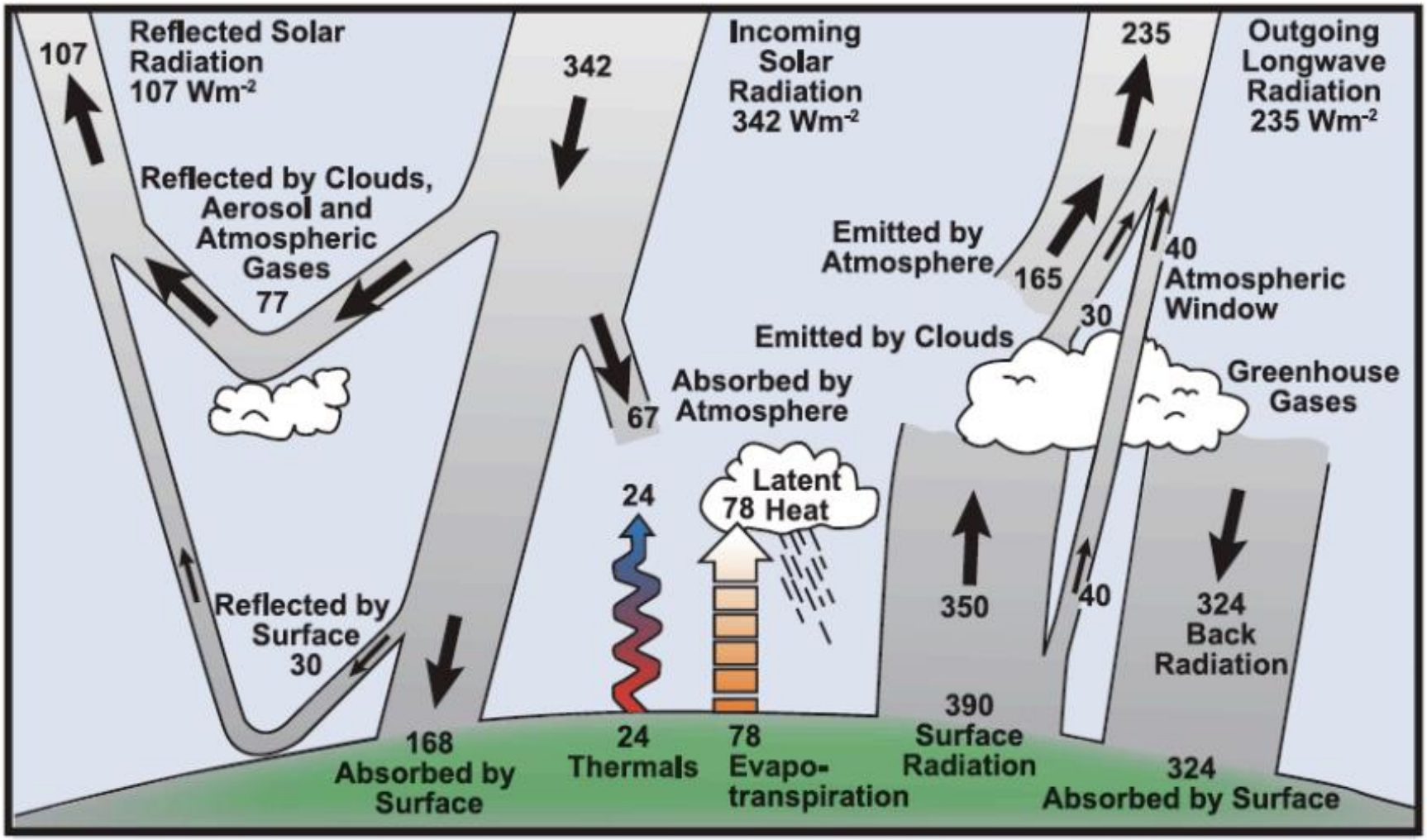
107 W/m^2

Reflected solar radiation

Temperature

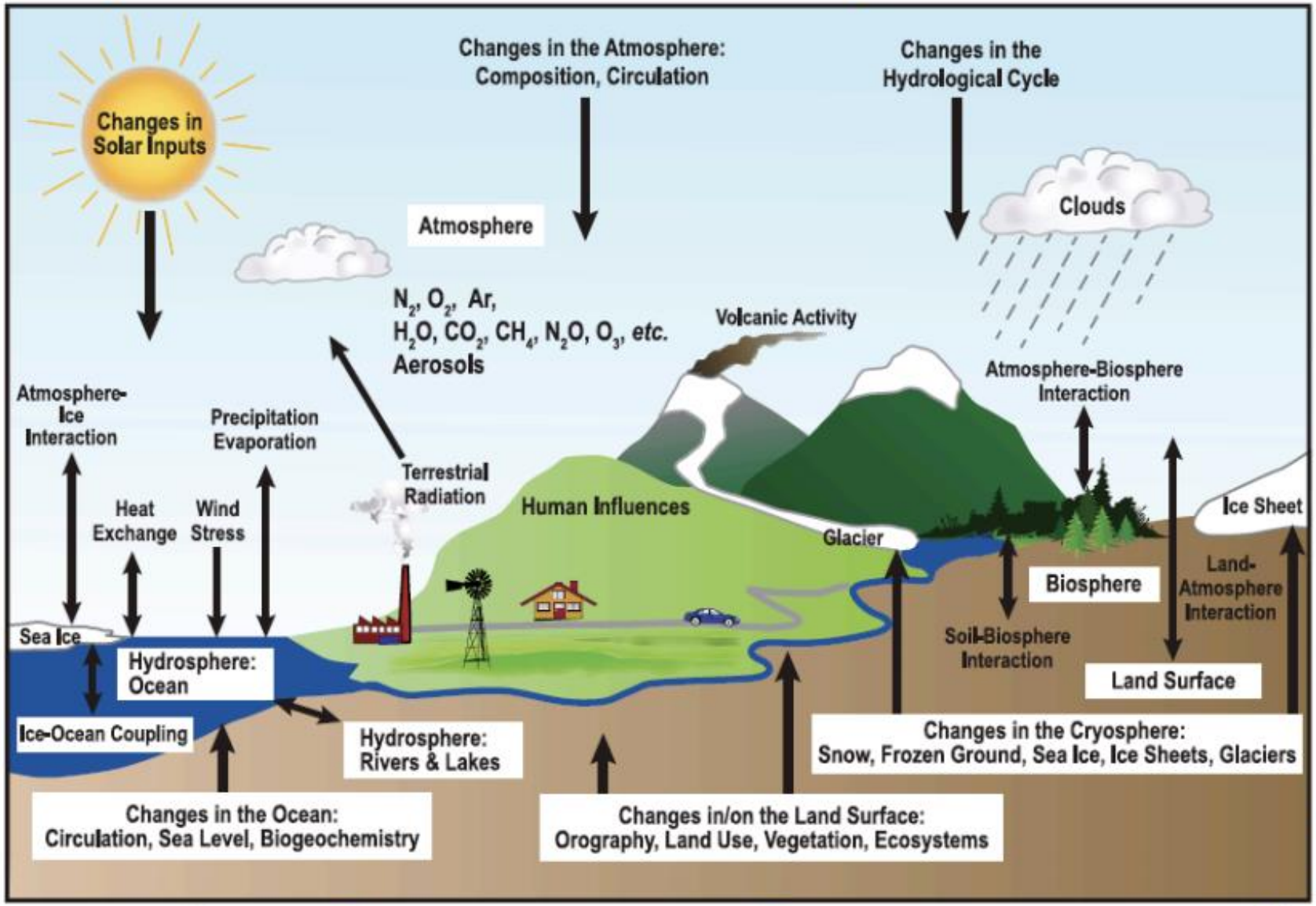

Composite Total Solar Irradiance (Frohlich and Lean)
Solar Irradiance (W/m²)
1368
1367
1366
1365
1364
1975
1980
1985
1990
1995
2000
2005
Year
Monthly Mean
Annual Mean
Solar Forcing
0.2 W/m²

Exchange of Energy in the Climate System

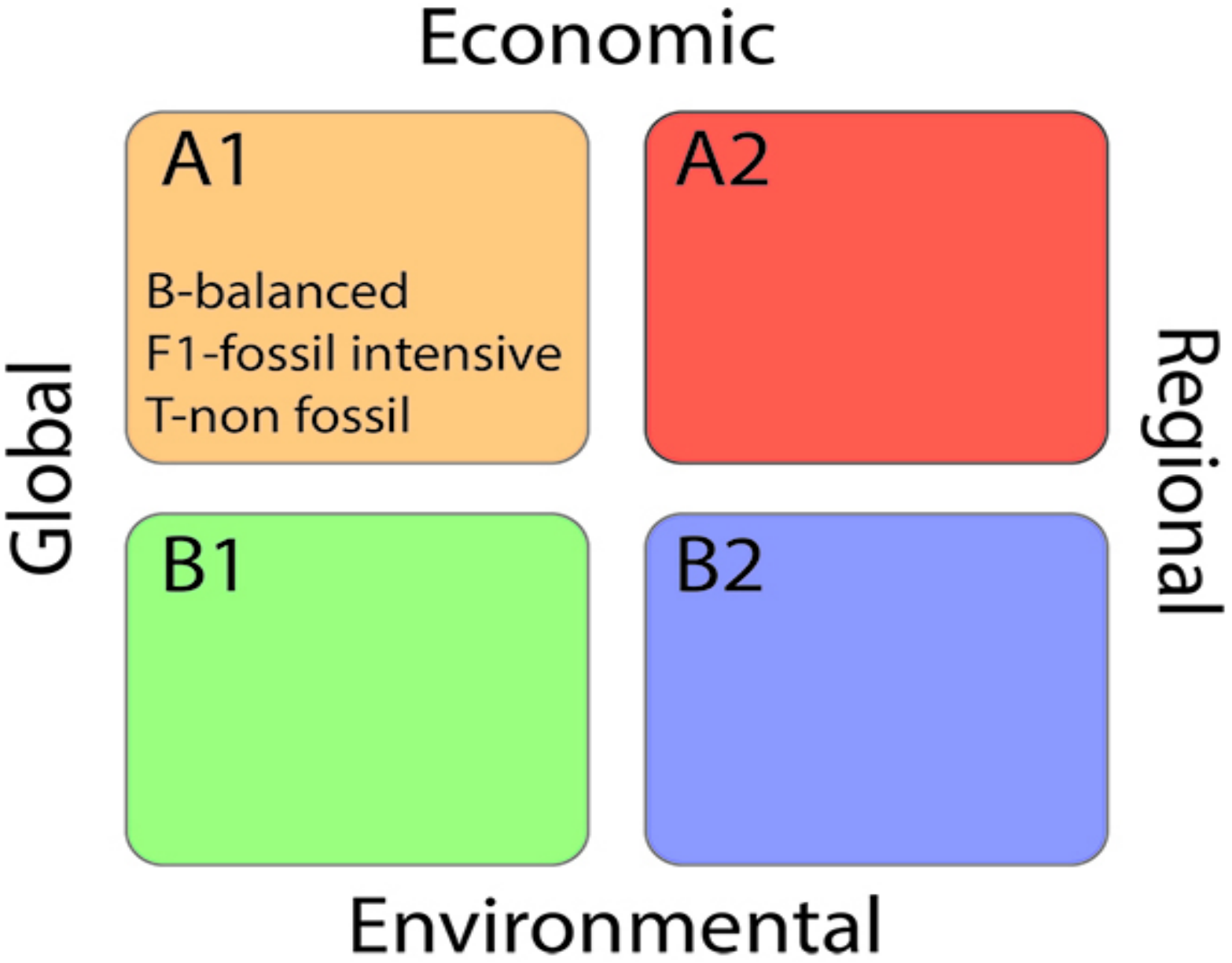


Kiehl & Trenberth, 1997

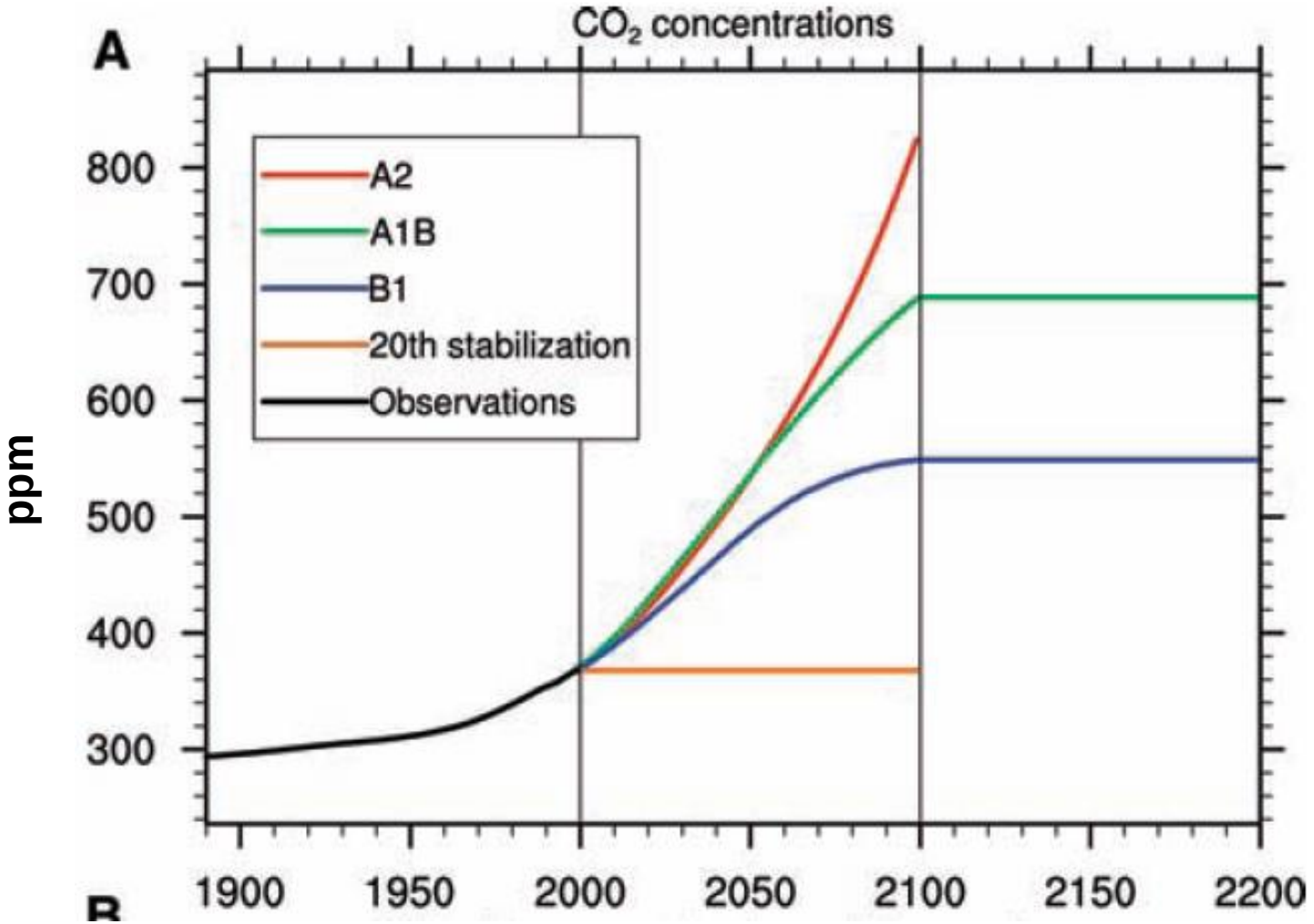
Components of the Climate System



IPCC, 2007

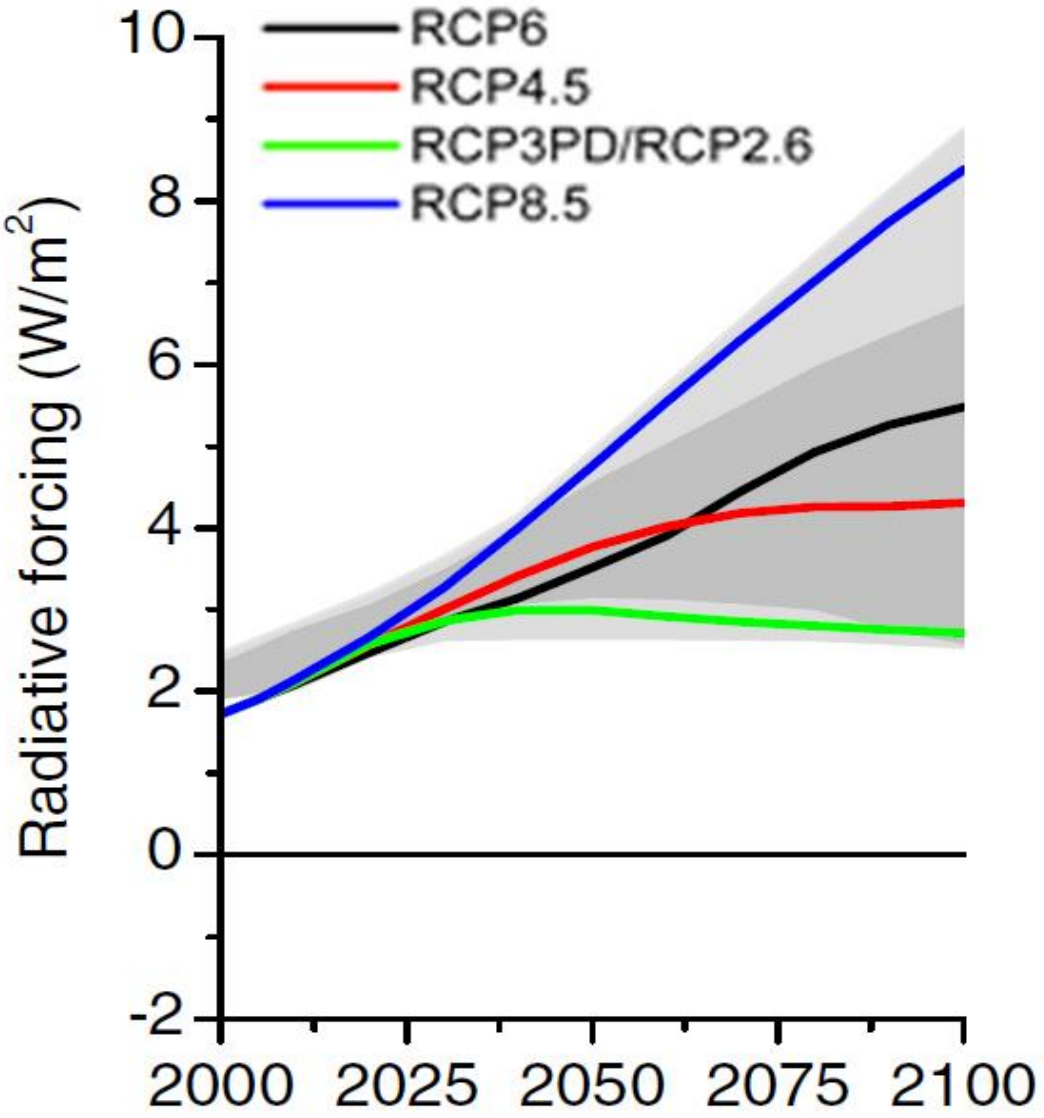

Economic
A1
B-balanced
F1-fossil intensive
T-non fossil
A2
Global
Regional
B1
B2
Environmental

SRES (2000)

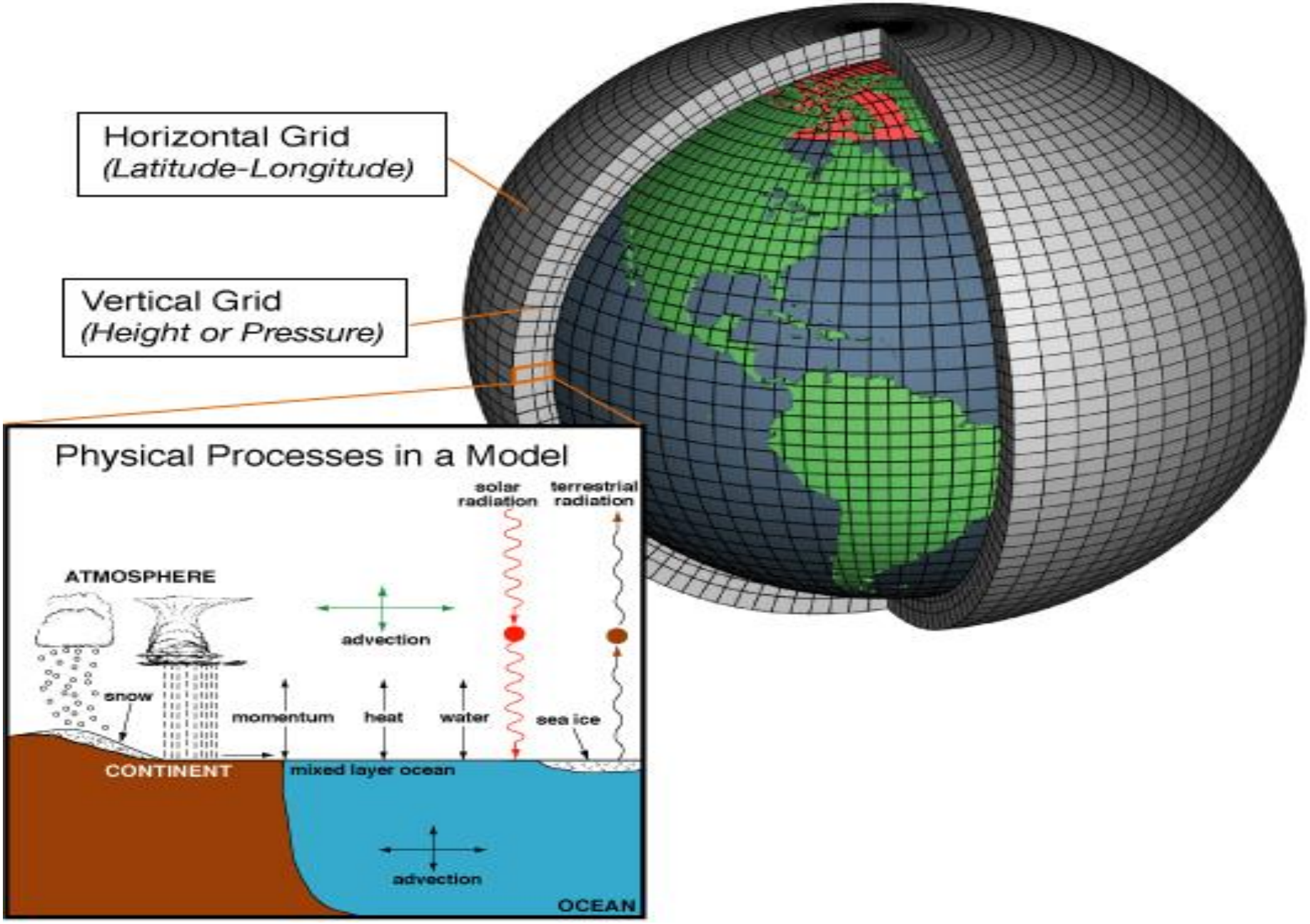


Source: IPCC 2007

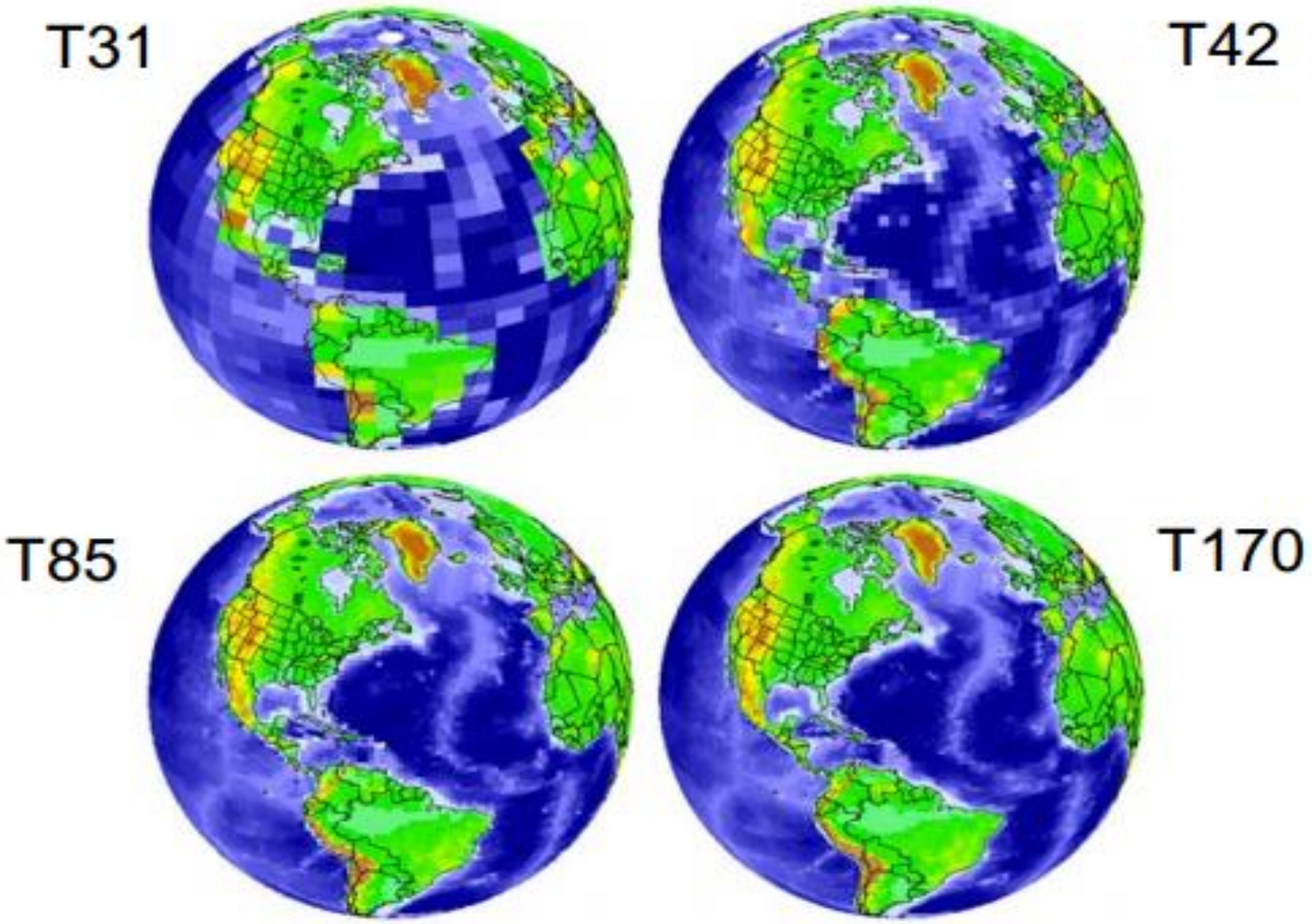
Representative Concentration Pathways (RCP 2013)



Source: IPCC 2013



Source:NOAA - http://celebrating200years.noaa.gov/breakthroughs/climate_model/AtmosphericModelSchematic.png



http://gcep.host.ualr.edu/Archives/2009/2009_Orientation_Files/Art&Science_of_Climate_Modeling_GHAN_GCEP_2009.pdf

Part III: Methods – Dynamic Downscaling

Climate downscaling approaches

- Dynamic approach
  - Regional climate modeling
  - NARCCAP
  - Strength and weakness
- Statistical approach
  - Methods
  - Examples
  - Strength and weakness
- Comparisons (SE)

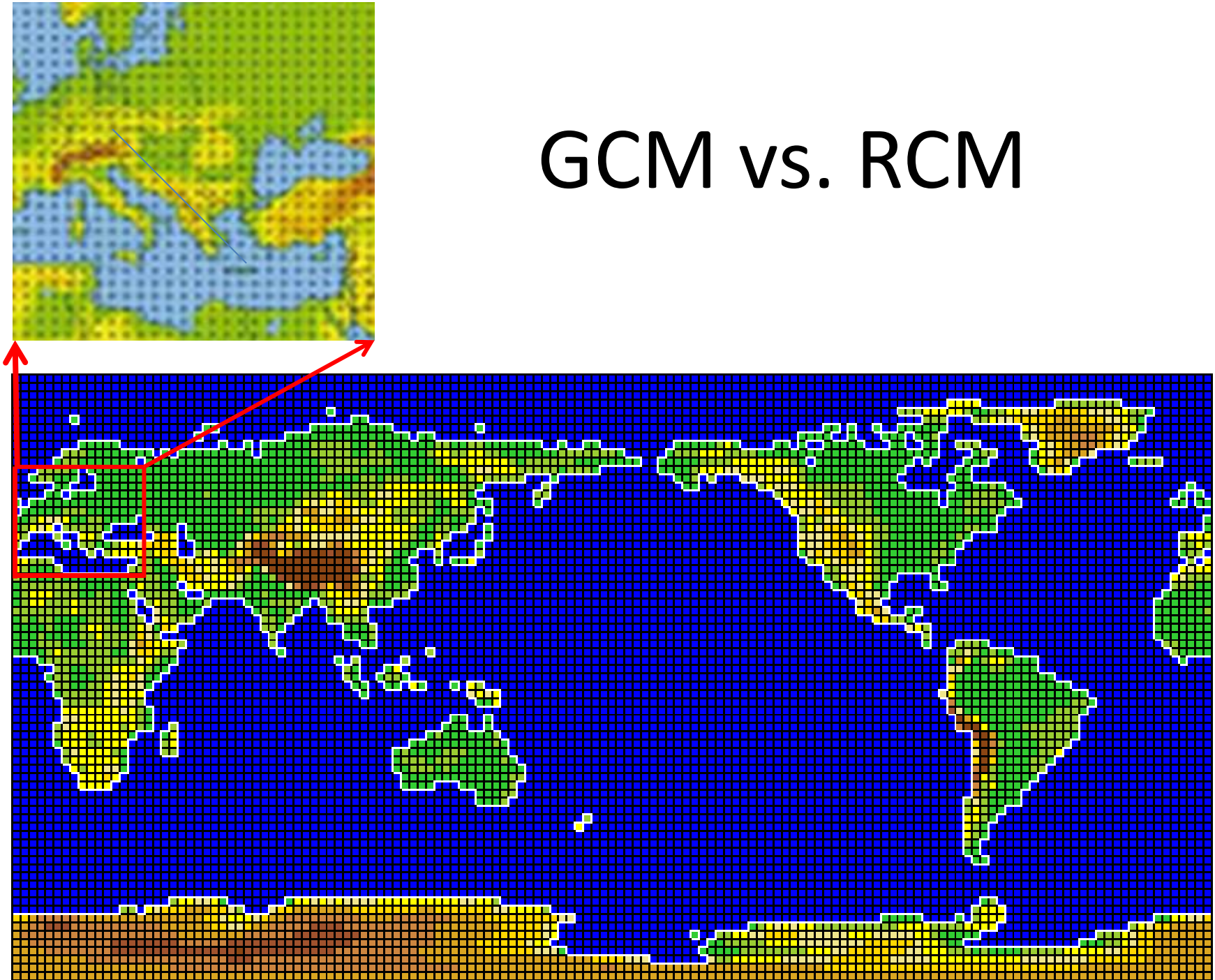
Dynamic downscaling

Utilizes regional climate models (RCMs) to obtain high-resolution regional climate driven by current and future global climate from GCMs

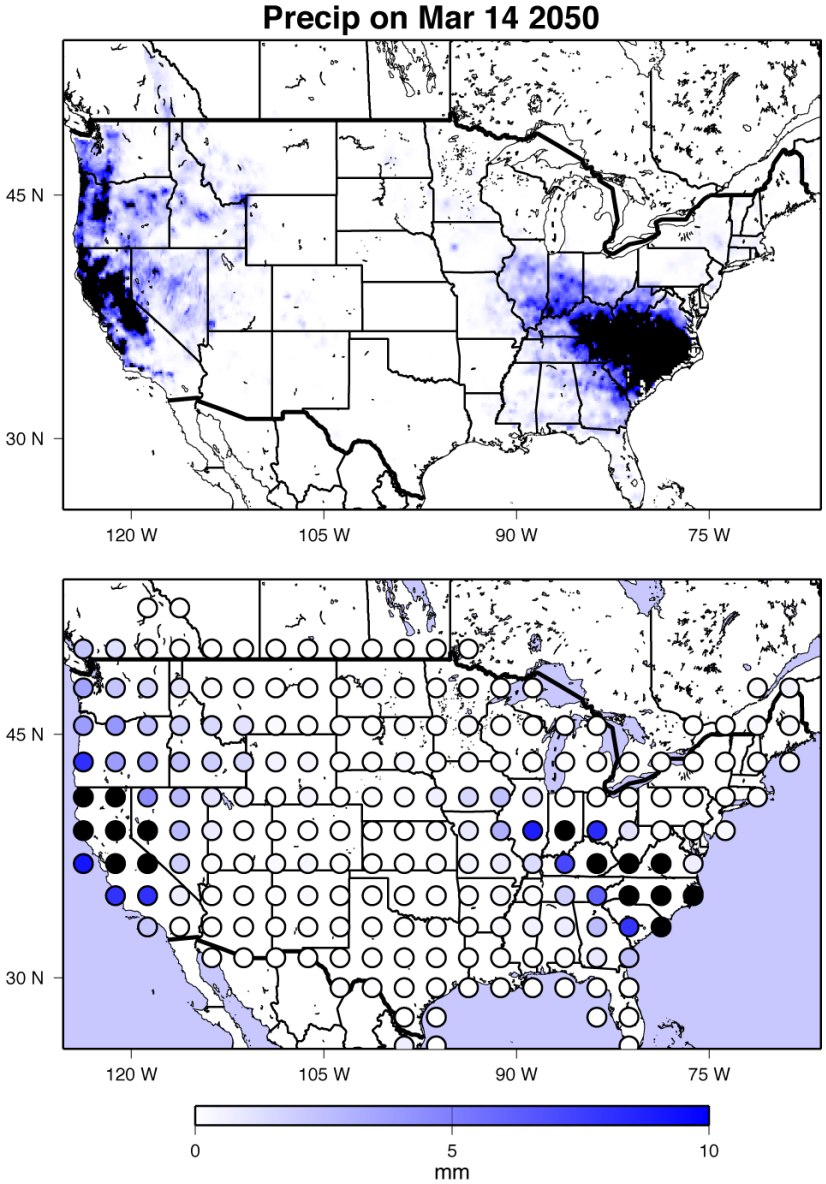
GCM vs. RCM

Regional climate model (RCM)

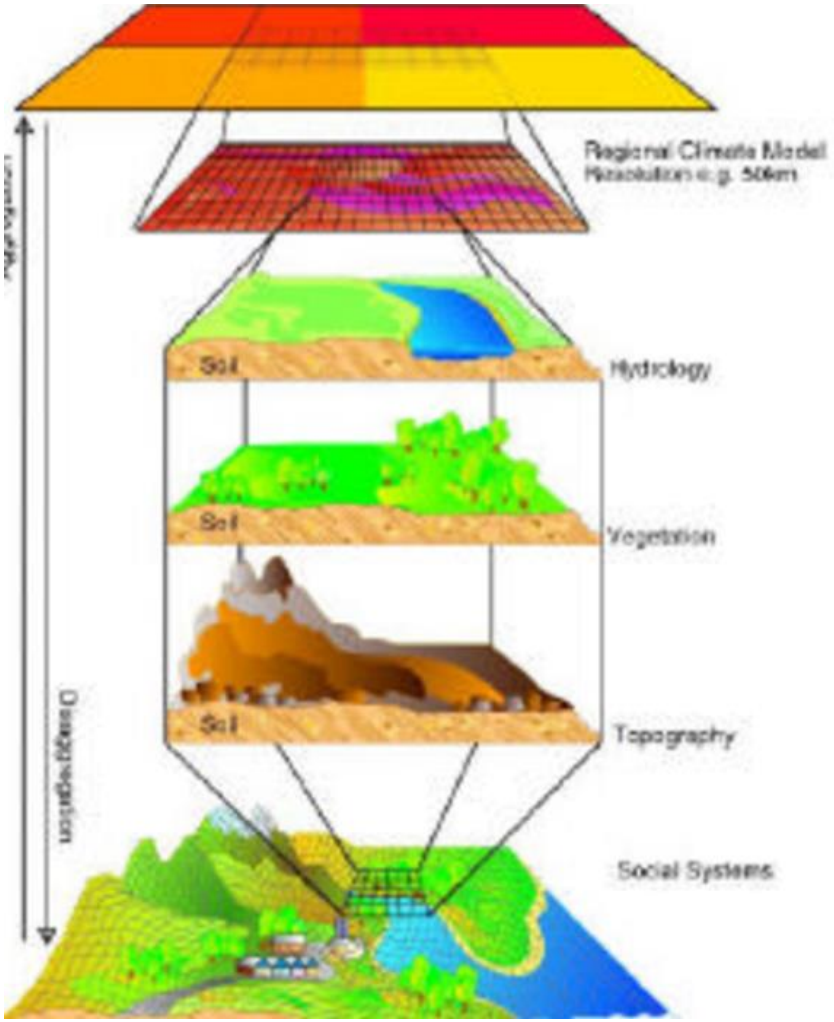
General circulation model (GCM)



Climate downscaling



From Dettinger



(From Elaine Barrow 2001)

GCM

- Climate
- ~100km (cyclone, front)
- GHG Forcing

LAM

- Weather
- ~10km (storm, breeze)
- Initial forcing

Local forcing

- topography
- land cover
- aerosol

RCM

- Climate
- Regional
- ~10 km
- GHG
- Regional forcing

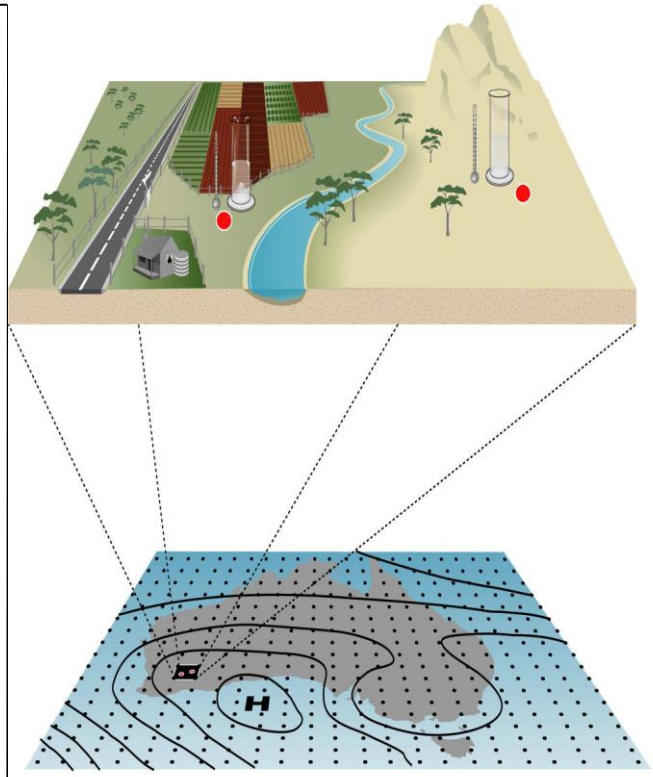


Image source: Met Office

NCAR Regional Climate Model (RegCM)

RegCM (Dickinson, Giorgi, 1989), RegCM2 (Giorgi et al. 1996), RegCM3 (Giorgi et al. 1999)

- *To provide a modeling tool for understanding high-resolution spatial patterns of climatic variability*
- *By incorporating more detailed schemes of important climate processes in MM4/5*
- *Driven by observation (ECMWF /NCEP) or CCM simulations*
- *Coupling with other models (hydrology, ecosystem, air quality, etc.)*

Atmospheric model Component

$$\frac{du}{dt} - \left(f + u\frac{\tan\phi}{a}\right)v = -\frac{1}{a\cos\phi}\frac{1}{\rho}\frac{\partial p}{\partial\lambda} + F_\lambda$$

E-W wind

$$\frac{dv}{dt} + \left(f + u\frac{\tan\phi}{a}\right)u = -\frac{1}{\rho a}\frac{\partial p}{\partial\phi} + F_\phi$$

N-S wind

$$g = -\frac{1}{\rho}\frac{\partial p}{\partial z}$$

vertical balance

$$\frac{\partial\rho}{\partial t} = -\frac{1}{a\cos\phi}\left[\frac{\partial}{\partial\lambda}(\rho u) + \frac{\partial}{\partial\phi}(\rho v\cos\phi)\right] - \frac{\partial}{\partial z}(\rho w)$$

mass

$$c_p\frac{dT}{dt} - \frac{1}{\rho}\frac{dp}{dt} = Q$$

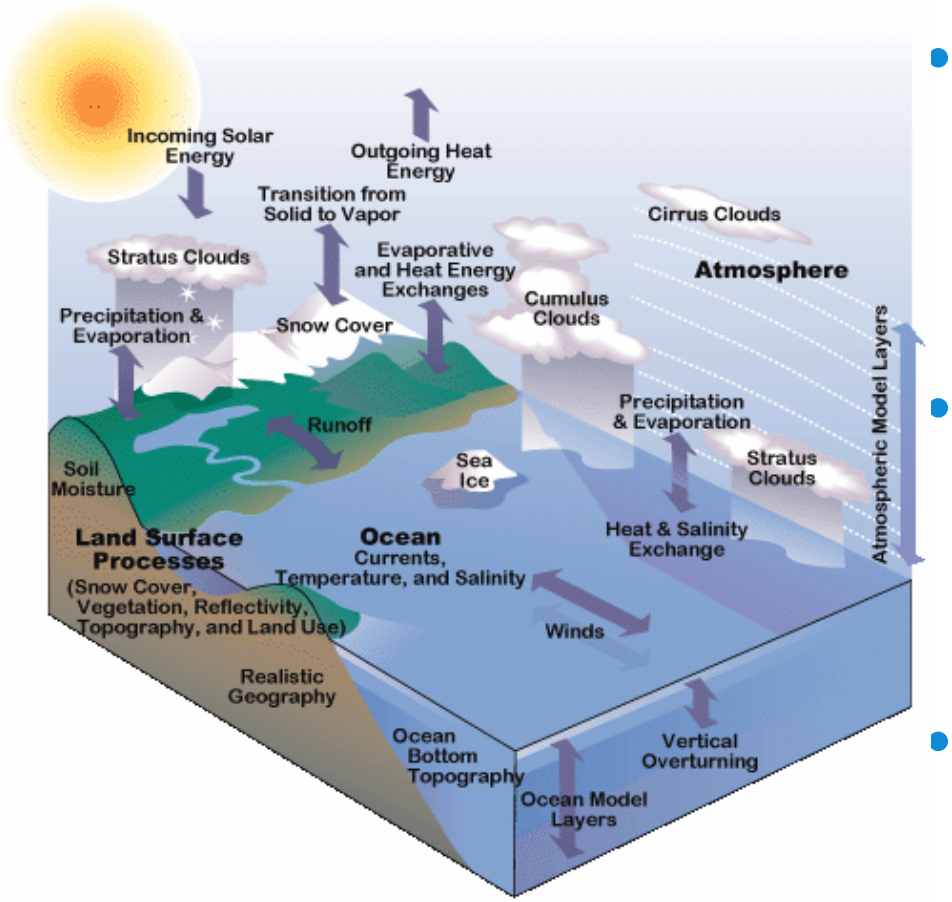
Temperature

$$p = \rho RT$$

Ideal Gas

6 equations for 6 unknowns (u,v,w,T,p,ρ) - Moisture often added as 7th equation

Climate model components and processes



- Radiation
  - as it drives the system each climate model needs some description of the exchange of shortwave and longwave radiation
- Dynamics
  - the movement of energy in the system both in the horizontal and vertical (winds, ocean currents, convection, bottom water formation)
- Surface processes
  - the exchange of energy and water at the ocean, sea-ice and land surface, including albedo, emissivity, etc.
- Chemistry
  - chemical composition of the atmosphere, land and oceans as well as exchanges between them (e.g., carbon exchanges)

Steps

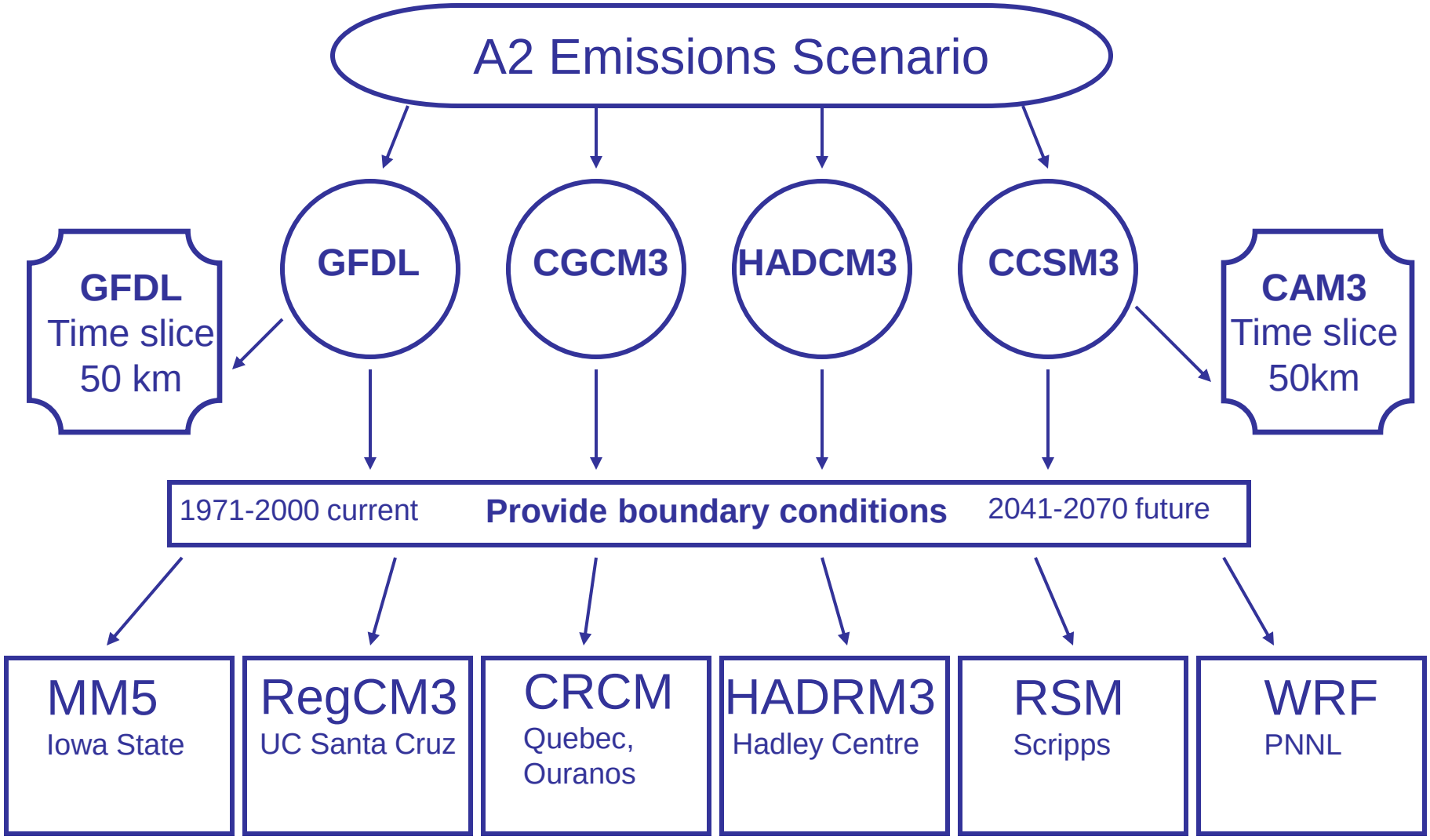
1. Select GCM projections
2. Select RCMs
3. Set RCM domain and resolution
4. Model bias analysis and correction
5. Regional climate projection and analysis
6. Time gap filling
7. Applications

NARCCAP

North American Regional Climate Change Assessment Program

(narccap.ucar.edu)

Steps 1 and 2: select GCM projections and RCMs



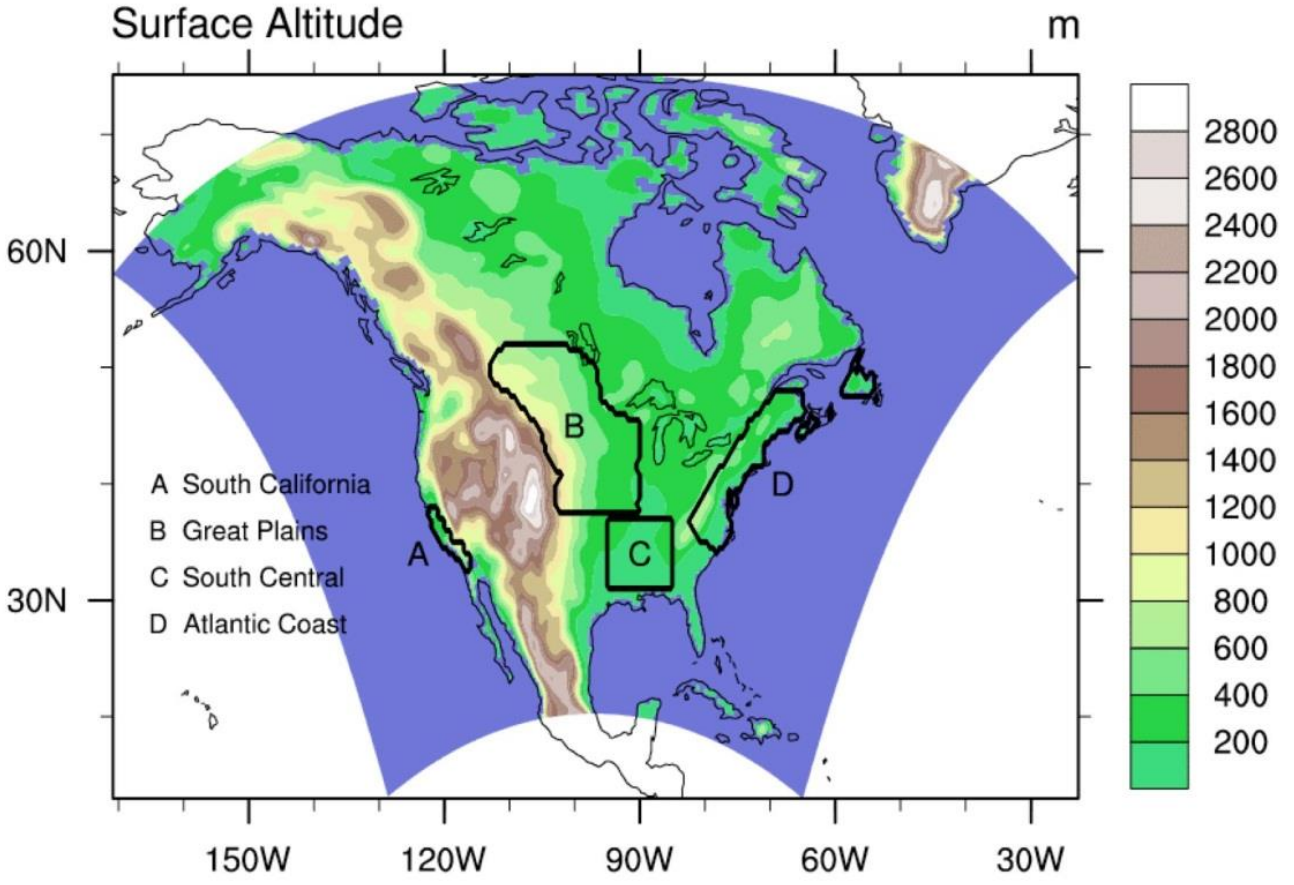
From NARCCAP
(narccap.ucar.edu)

Step 3 Model setup

- Domain
  - **Most of North America**
- Resolution
  - **50 km**
- Periods

  1971-2000,

  2041-2070

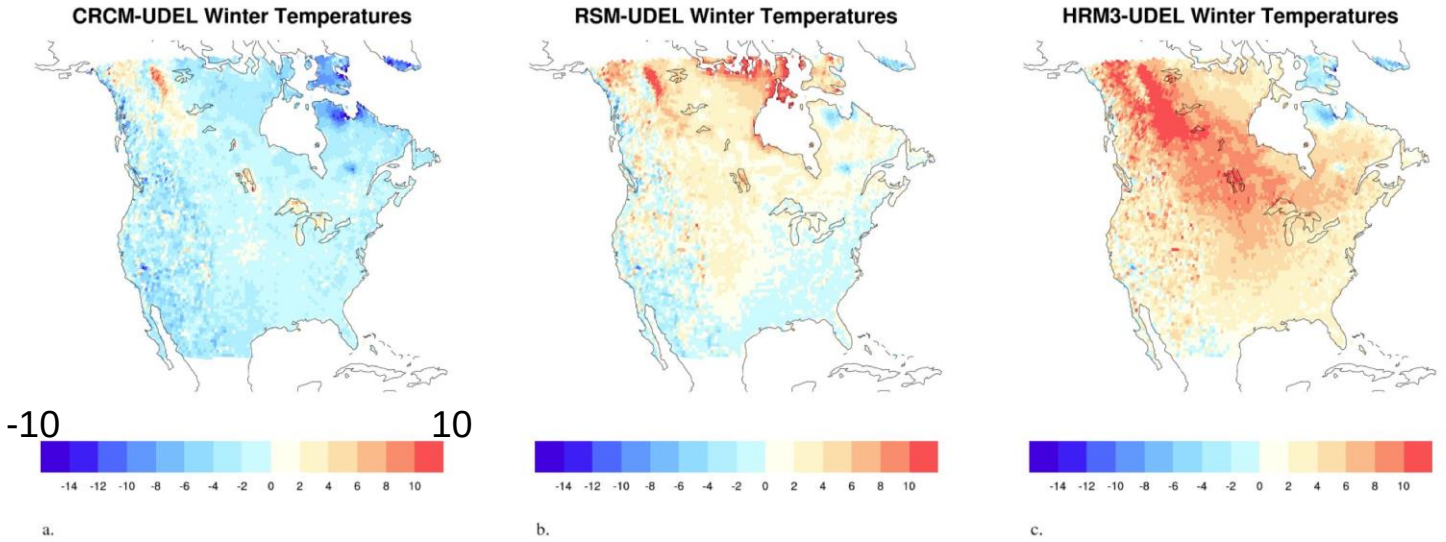


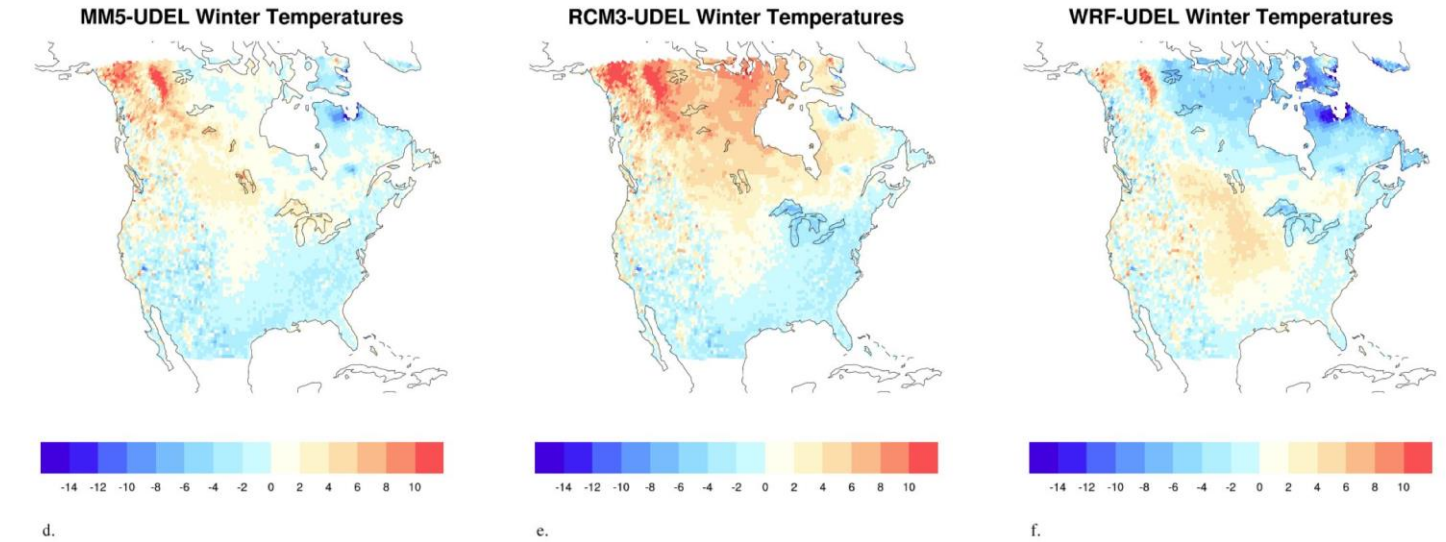
From Gutowski (2011)

Step 4 Model Evaluation

- Period
  - **1980-2004**
- Boundary Conditions
  - **NCEP/DOE reanalysis**
- Data
  - 0.5^{o} gridded observations from Univ. Delaware

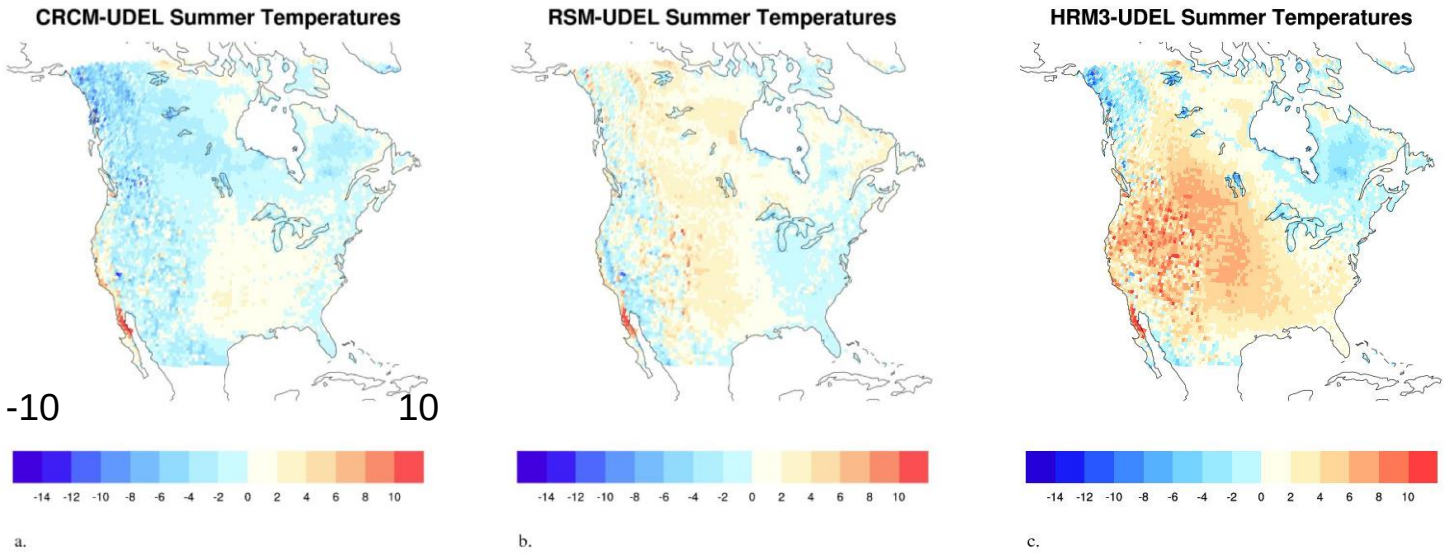
Temperature Bias – DJF

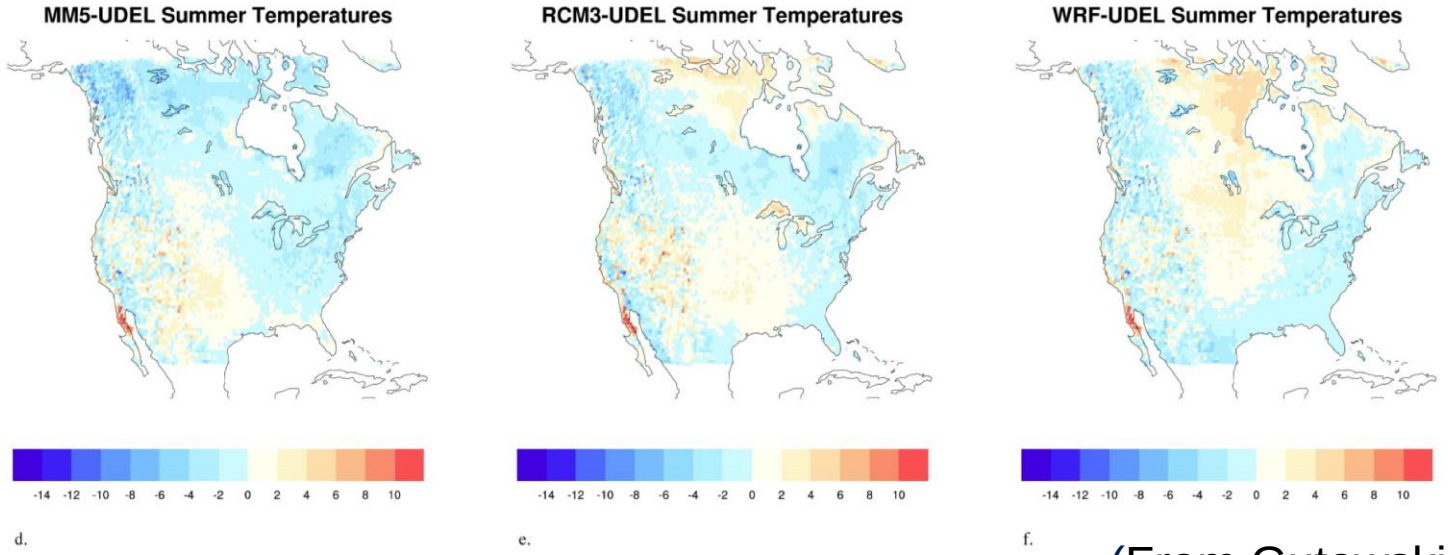




(From Gutowski 2011)

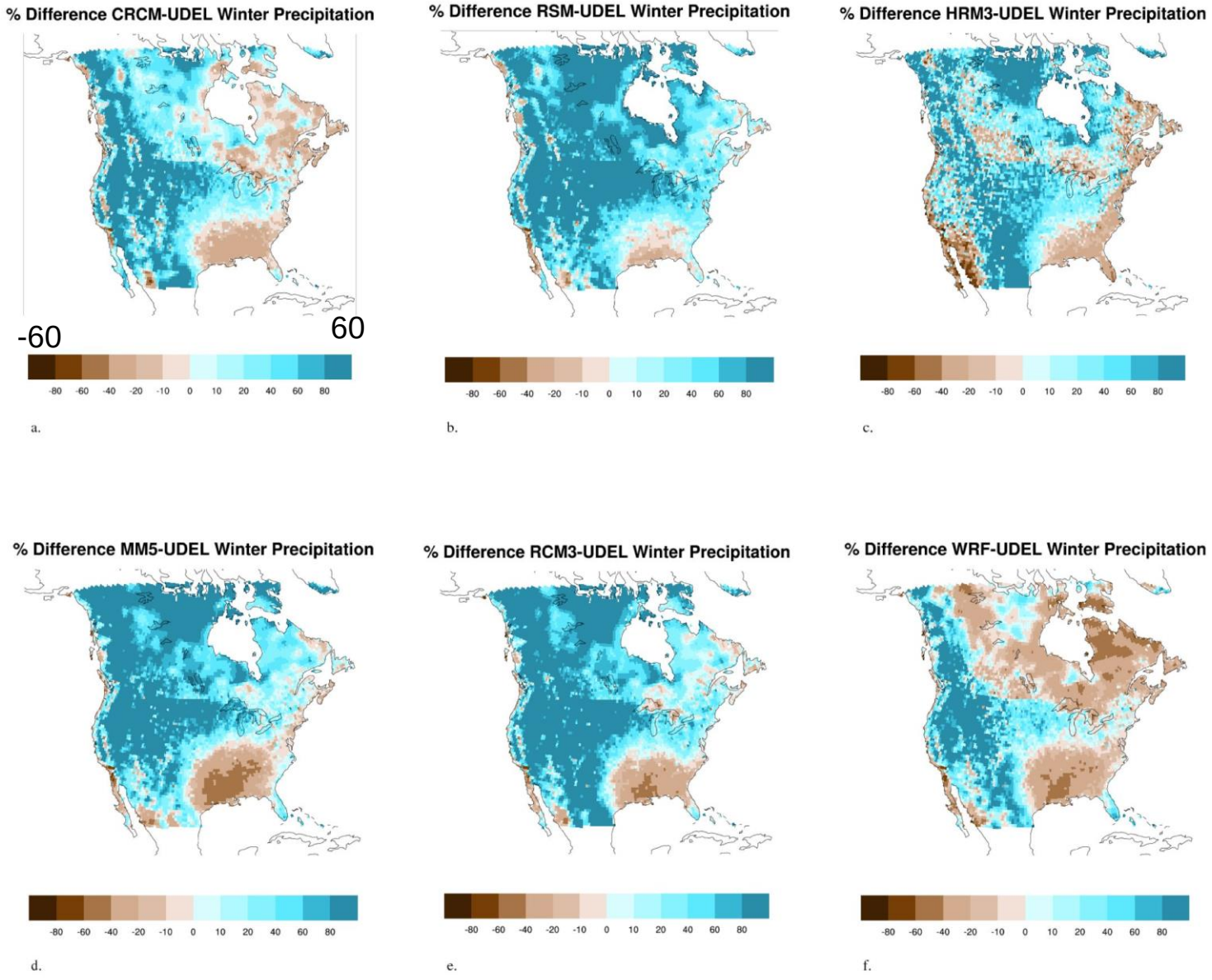
Temperature Bias - JJA





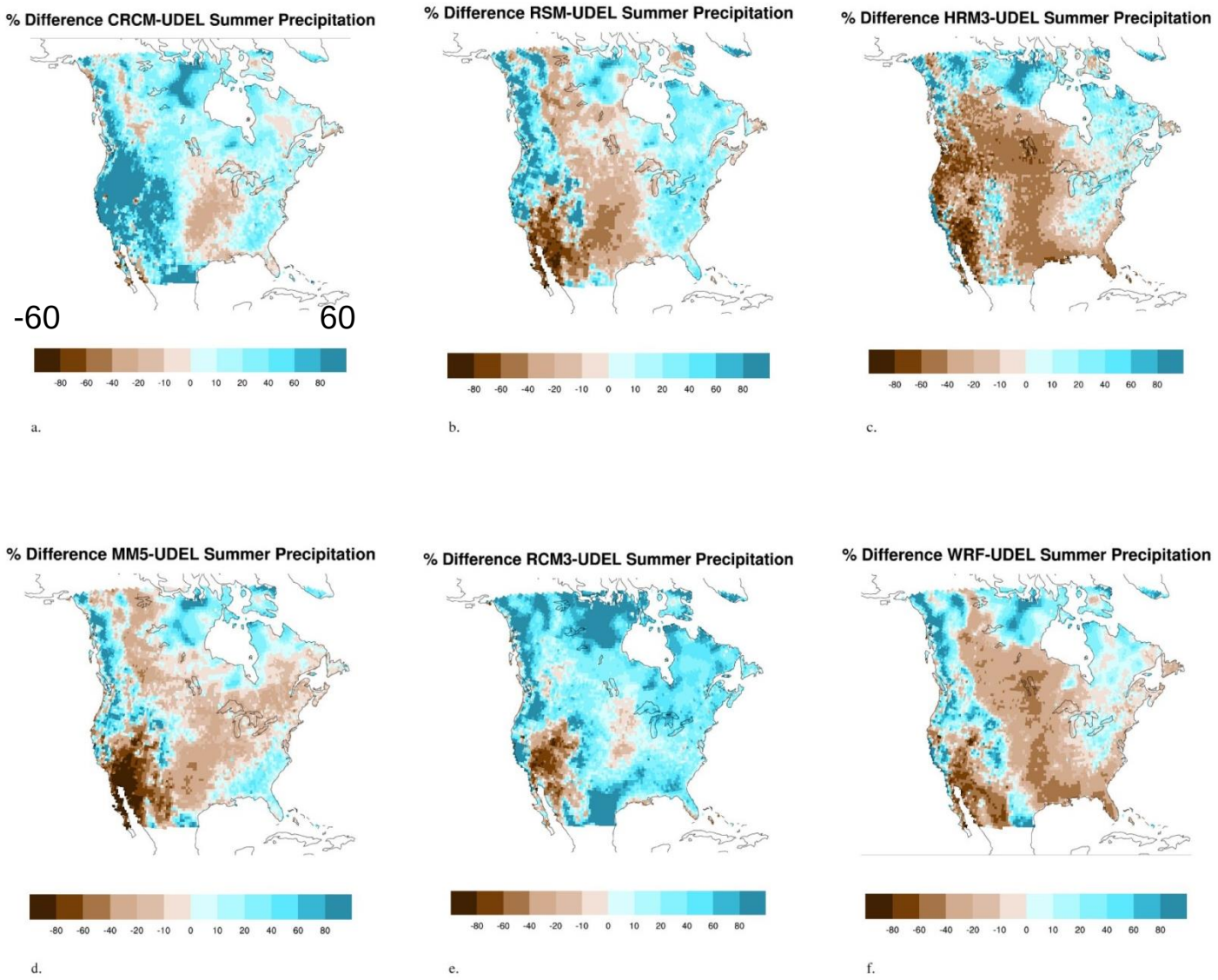
(From Gutowski 2011)

Precipitation Bias (DJF)

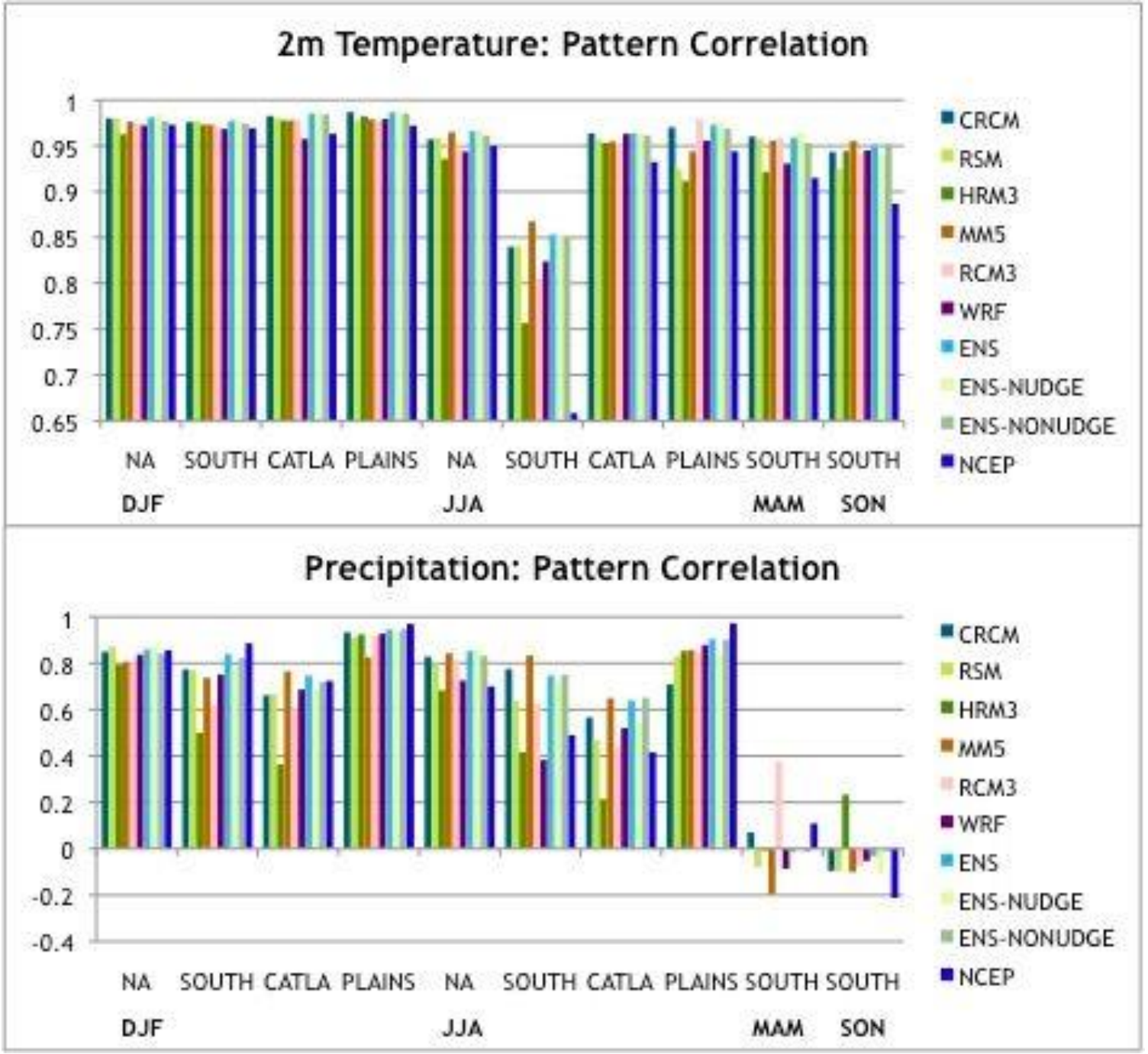


(From Gutowski 2011)

Precipitation Bias (JJA)

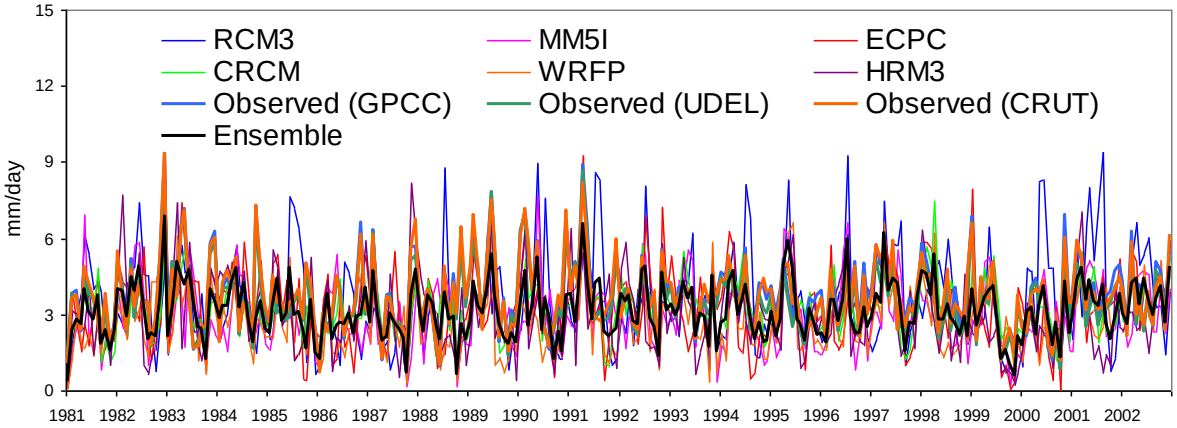


(From Gutowski 2011)

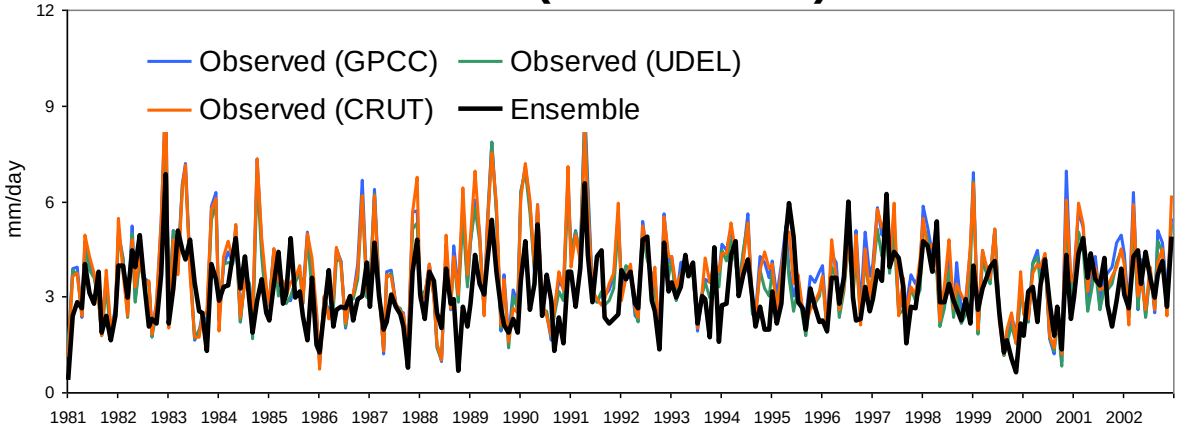


(From Gutowski 2011)

Monthly Time Series - Deep South



Ensemble (black curve)

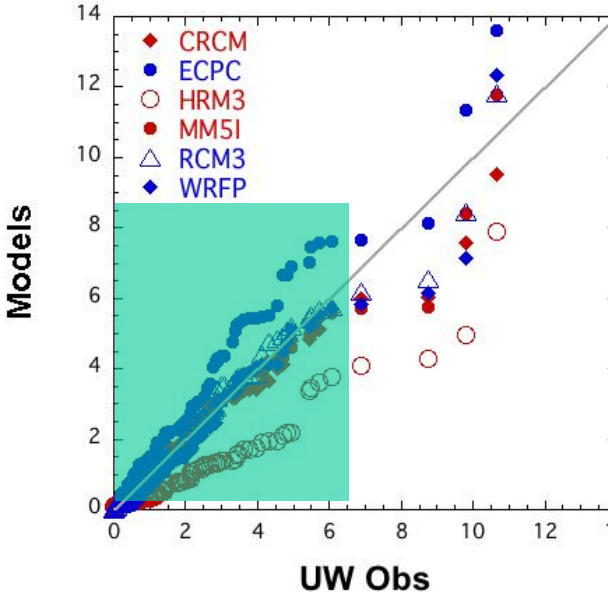


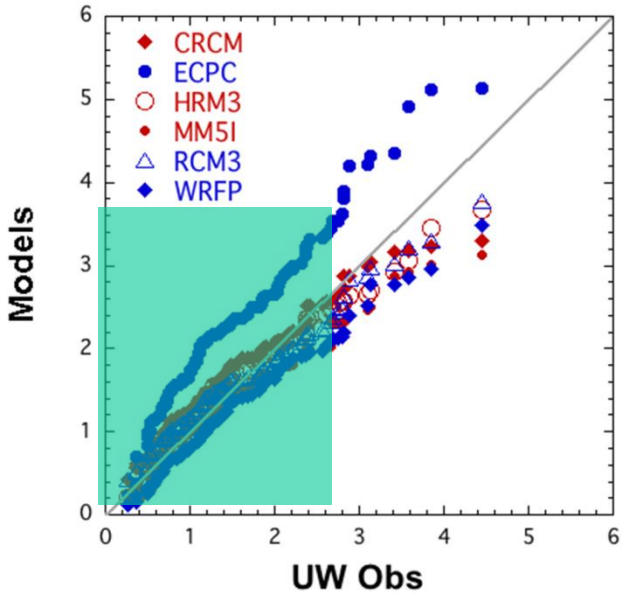
Model	Correlation
HadRM3	0.489
RegCM3	0.231
MM5	0.343
RSM	0.649
CRCM	0.649
WRF	0.513
Ensemble	**0.640**
RSM+CRCM	**0.727**

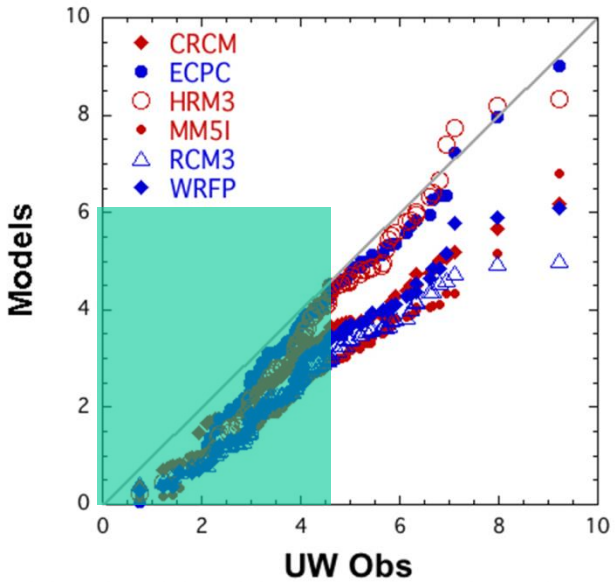
A "mini ensemble" of RSM and CRCM performs best in this region.

(From Gutowski 2011)

Ranked Precipitation – Coastal CA







Coastal CA

Ensemble average of top 10 = 9% smaller than UW

Upper MS

Ensemble average of top 10 = 6% smaller than UW

Deep South

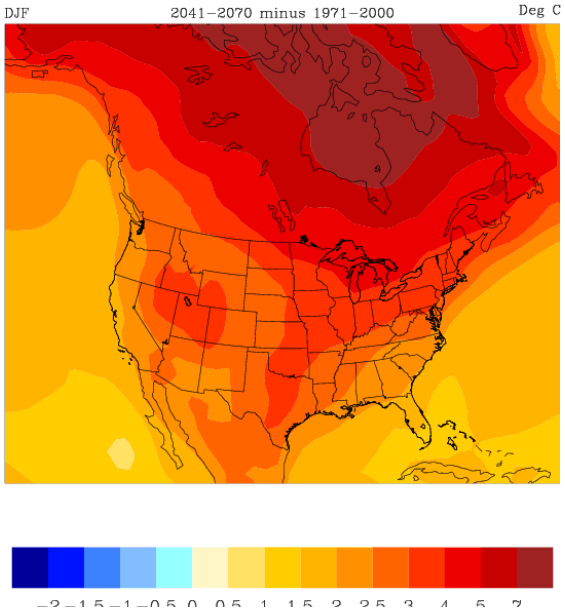
Ensemble average of top 10 = 22% smaller than UW

(From Gutowski 2011)

Step 5: Projections and Analysis

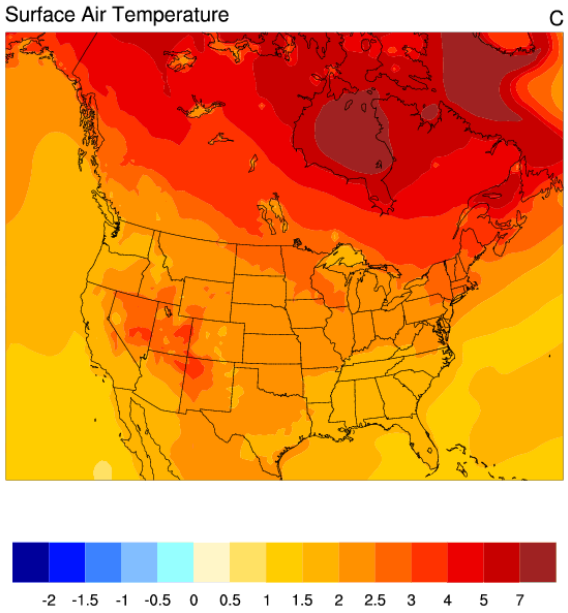
Global - CCSM3

CCSM Change In Seasonal Avg Temp



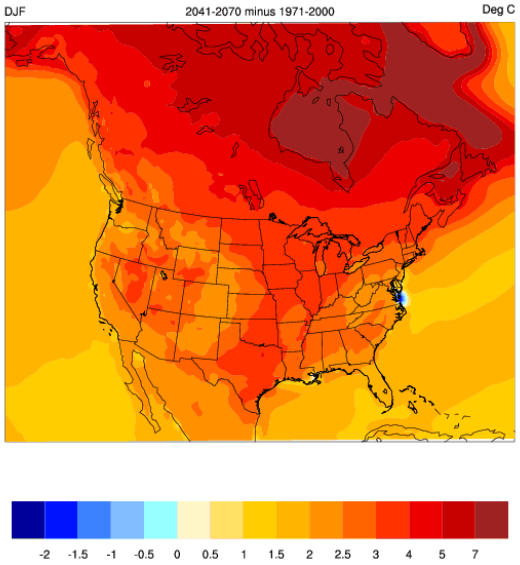
MM5 RCM

MM5I+CCSM Change in DJF Avg Temp



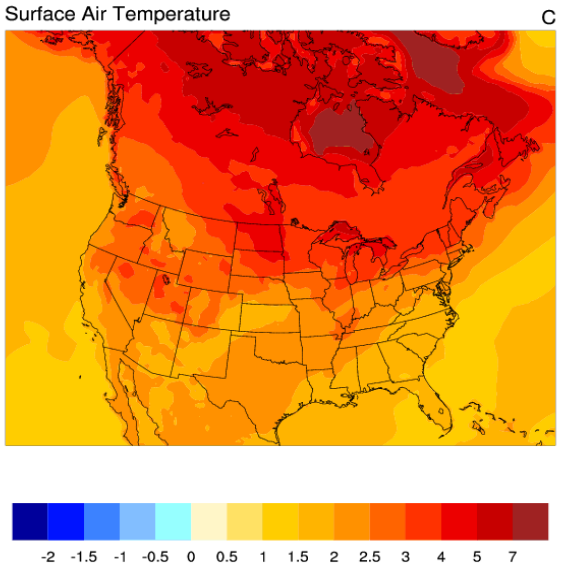
WRF RCM

WRFG+ccsm Change In Seasonal Avg Temp



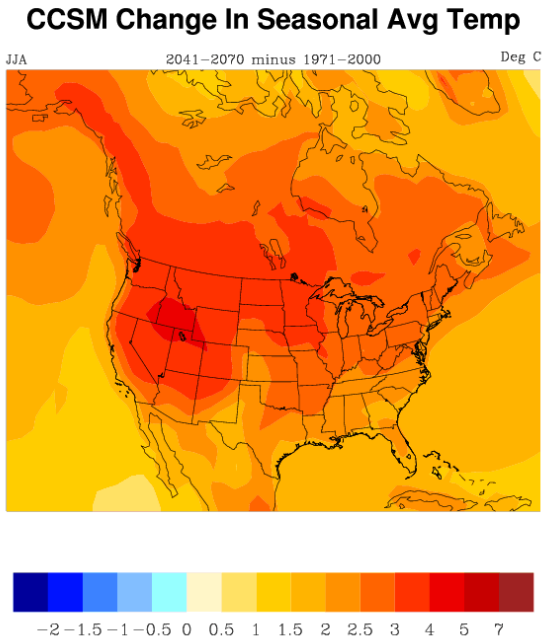
CRCM

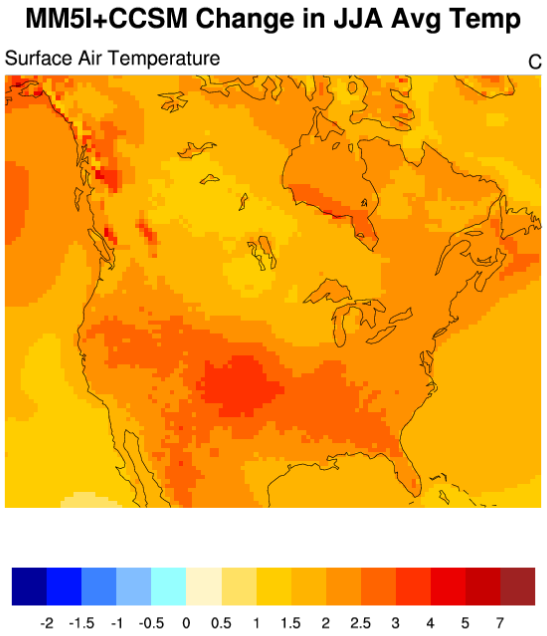
CRCM+CCSM Change in DJF Avg Temp



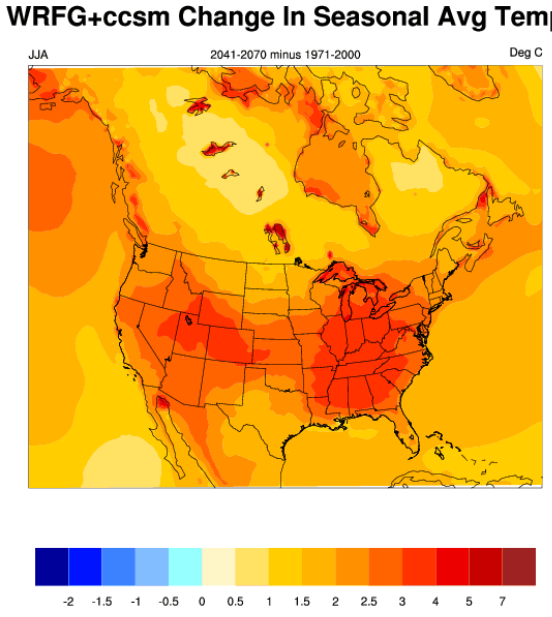
Change in Winter Temperature CCSM3, 3 RCMs

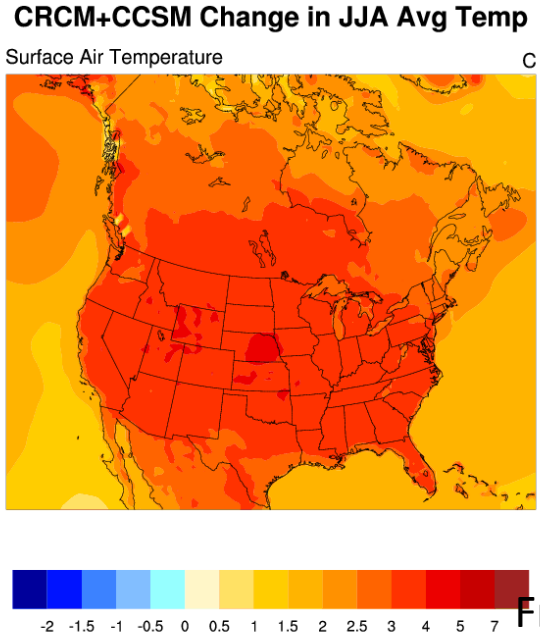
From Mearns 2012





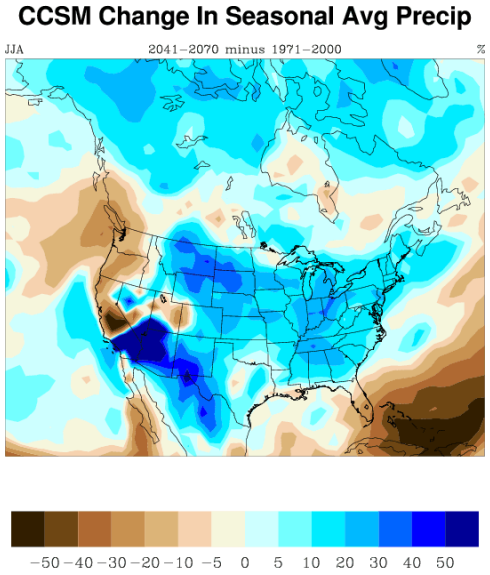
Change in Summer Temperature CCSM-driven

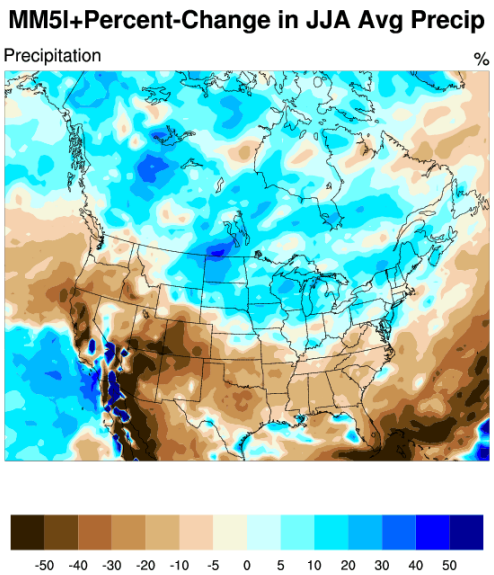




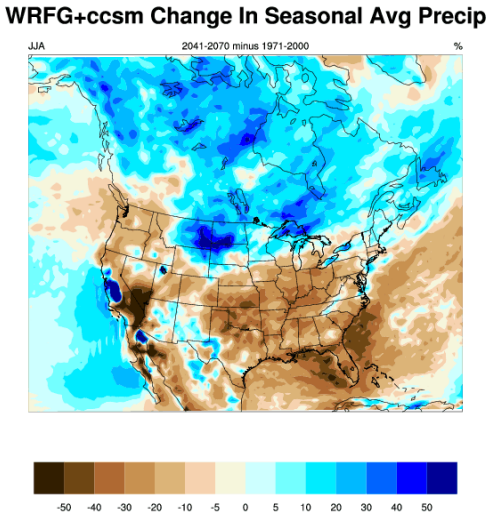
From Mearns 2012

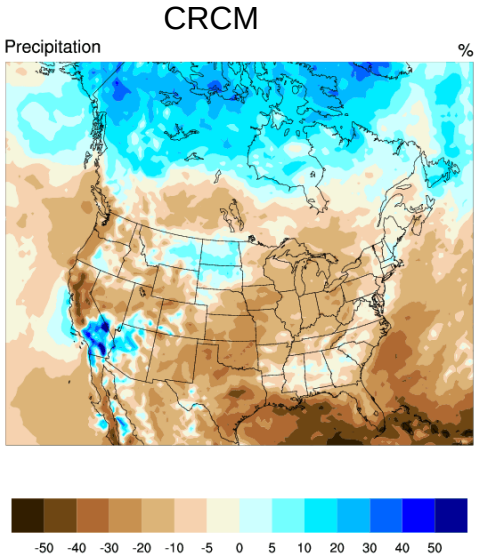
CCSM





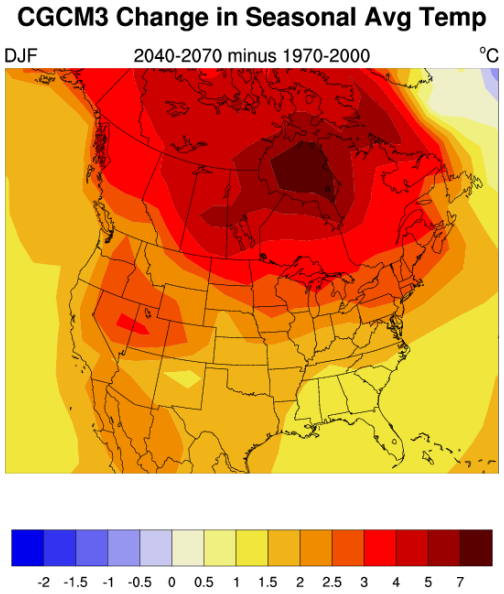
CCSM-driven change in summer precipitation



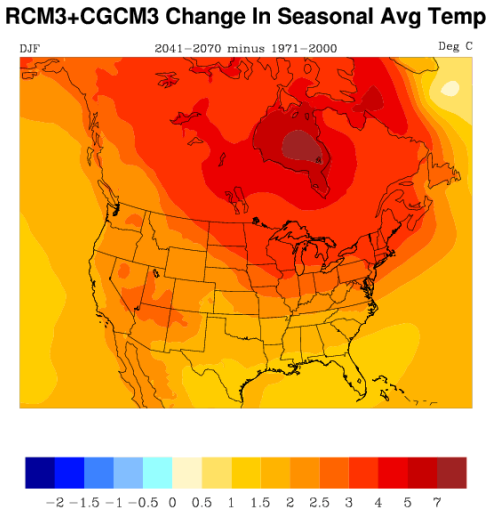


From Mearns 2012

CGCM3 Global Model

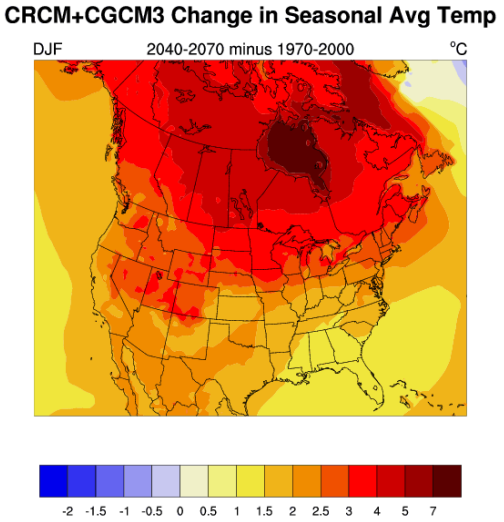


RegCM3

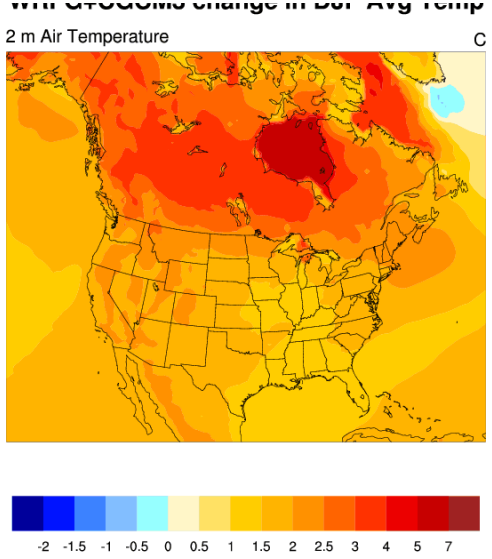


CGCM - driven Change in Winter Temperature

CRCM

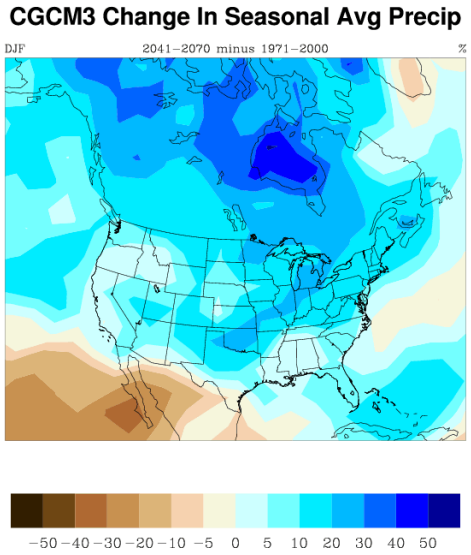


WRFG

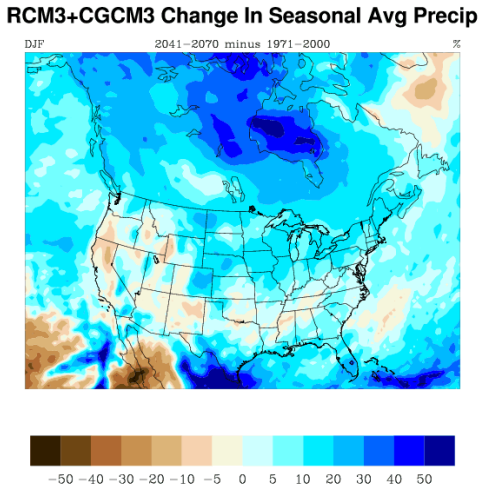


From Mearns 2012

CGCM3 – Global

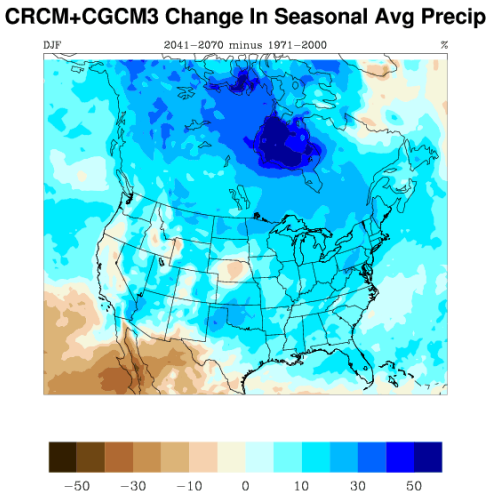


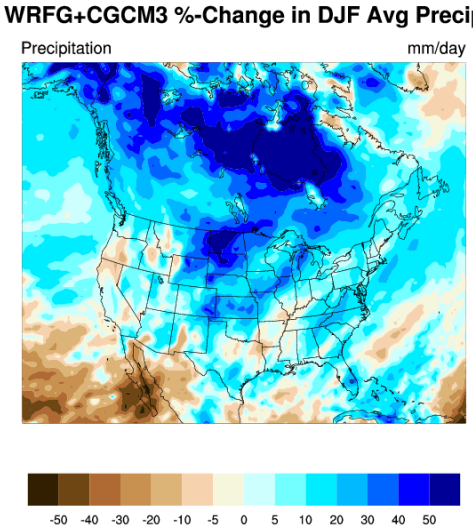
RegCM3



CGCM-driven % Change in Winter Precipitation

CRCM

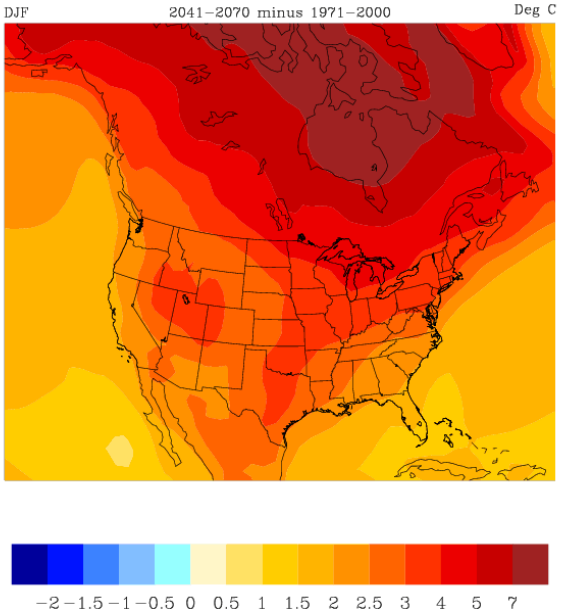




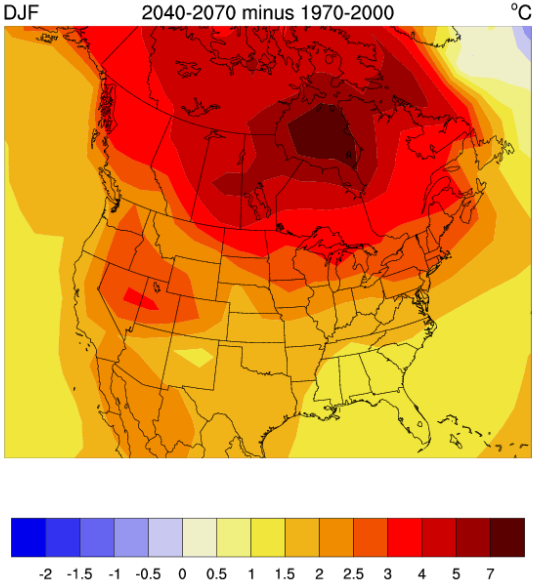
WRFG

From Mearns 2012

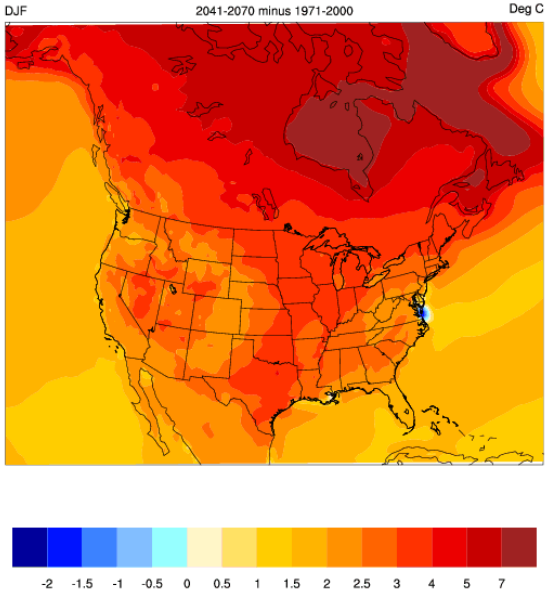
CCSM Change In Seasonal Avg Temp

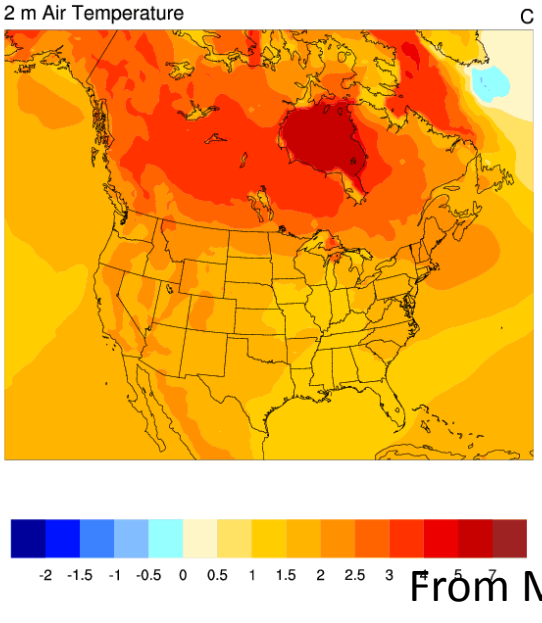


CGCM3 Change in Seasonal Avg Temp



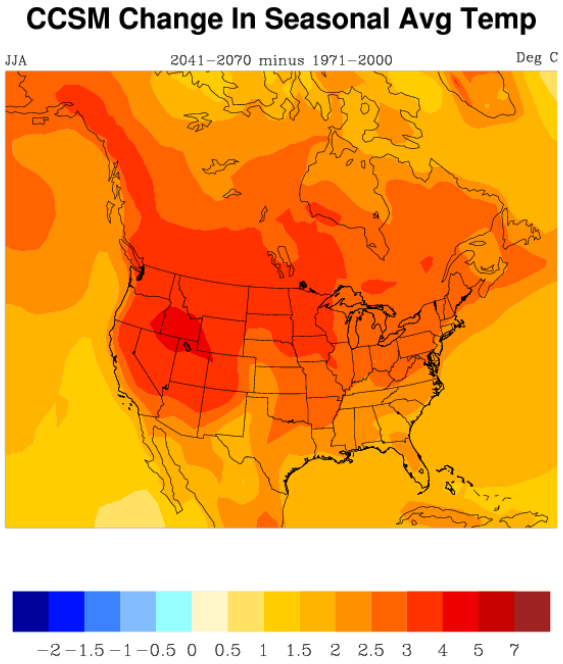
WRF

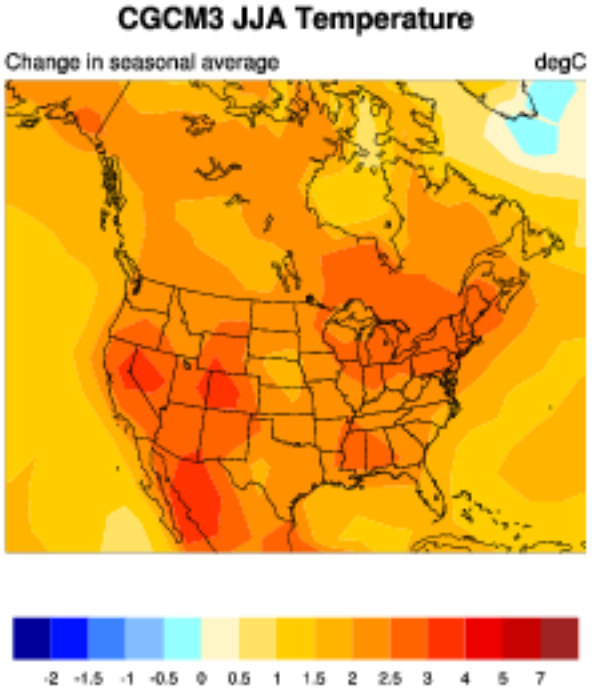


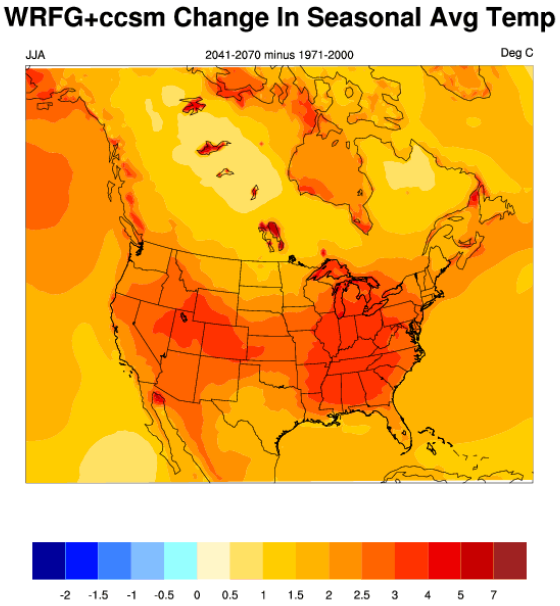


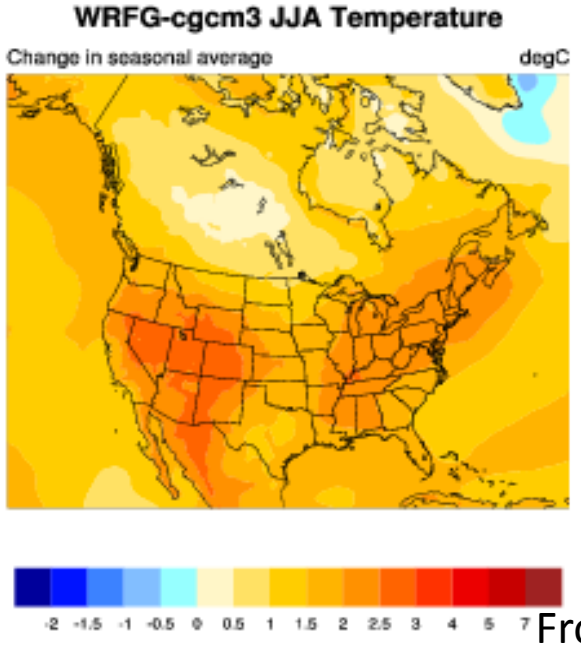
WRF

From Mearns 2012









Change in Summer Temperature WRF

From Mearns 2012

Change in Temperature °C

North Atlantic

	CCSM3			CGCM3		
	Winter	Summer	Annual	Winter	Summer	Annual
CRCM	3.3	2.6	2.7	2.8	2.9	2.7
WRFG	3.4	2.2	2.7	2.1	2.2	2.1
RCM3				3.2	2.6	2.6
MM5I	3.0	2.2	2.5			

Southern Rockies

	Winter	Summer	Annual	Winter	Summer	Annual
CRCM	2.4	3.7	2.6	2.6	3.4	2.8
WRFG	2.6	3.0	2.7	1.9	2.6	2.8
RCM3				2.4	3.4	2.3
MM5I	2.6	2.7	2.5			

From Mearns 2012

Change in Precipitation (%)

North Atlantic

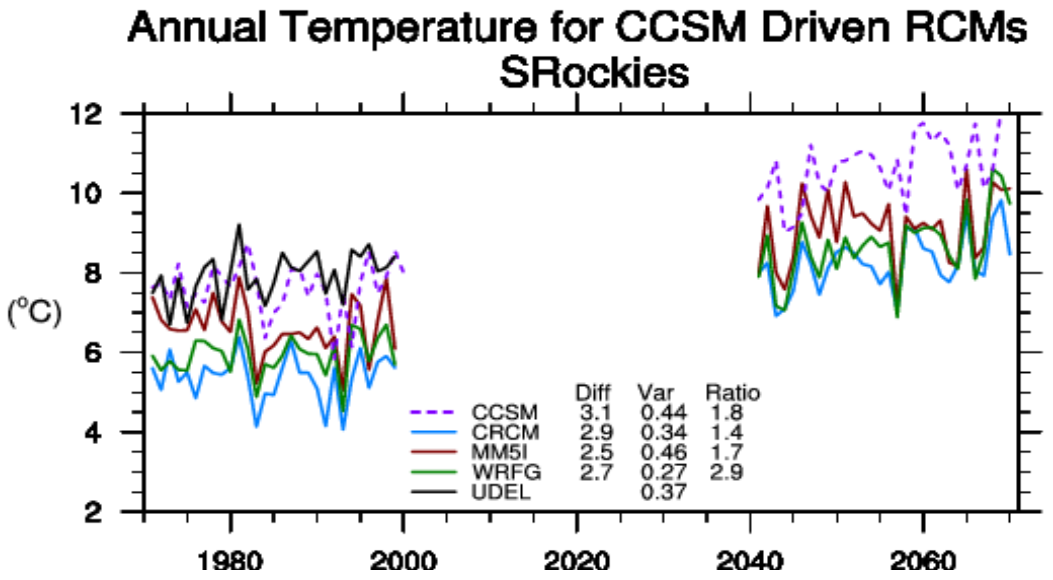
	CCSM3			CGCM3		
	Winter	Summer	Annual	Winter	Summer	Annual
CRCM	12	-5	1	14	-7	5
WRFG	7	7	2	8	-6	7
RCM3				10	-2	4
MM5I	7	4	6			

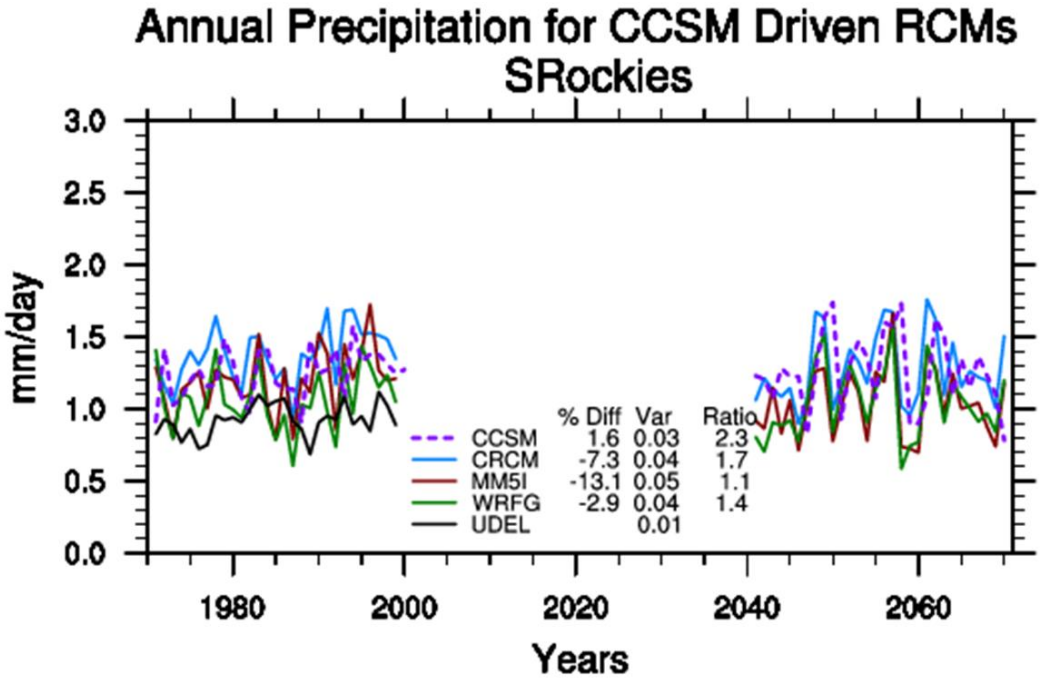
Southern Rockies

	Winter	Summer	Annual	Winter	Summer	Annual
CRCM	1	-15	-8	6	-22	-7
WRFG	8	- 9	- 3	7	-17	-7
RCM3				1	-23	-7
MM5I	1	-50	-15			

From Mearns 2012

Step 6: Time gap filling



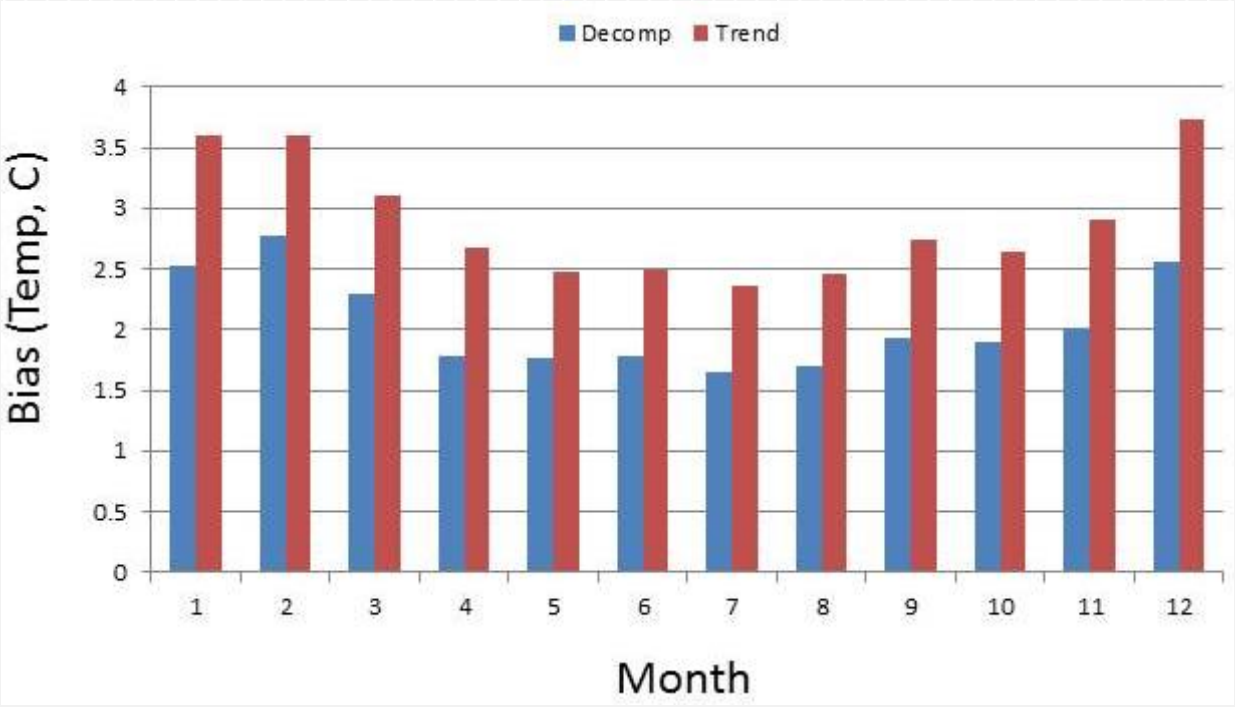


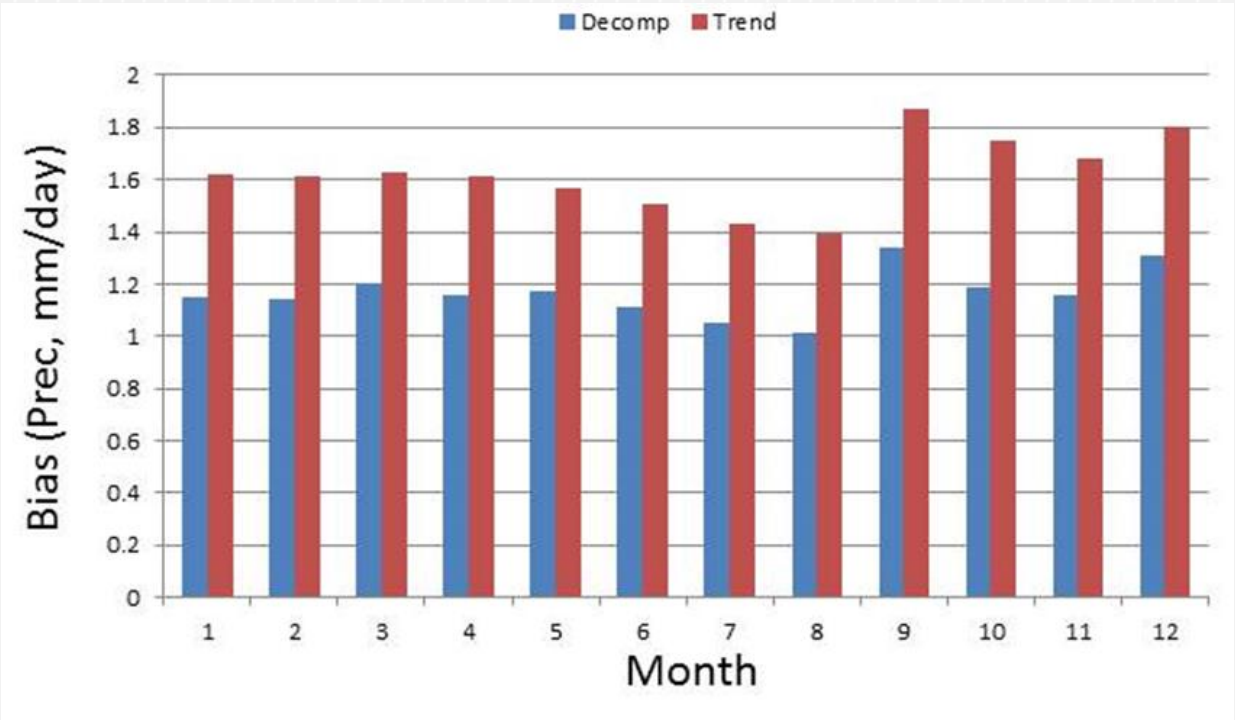
From Mearns 2012

A “repeat-trend” approach (Morales et al. 2007) first assigns current data to the gap period and then adjusts using linear trends between current and future periods.

A “decomposition” approach was proposed. Current and future data series are decomposed using the Fourier transform; The coefficients of each components for the gap period are obtained using weighting averages of current and future coefficients.

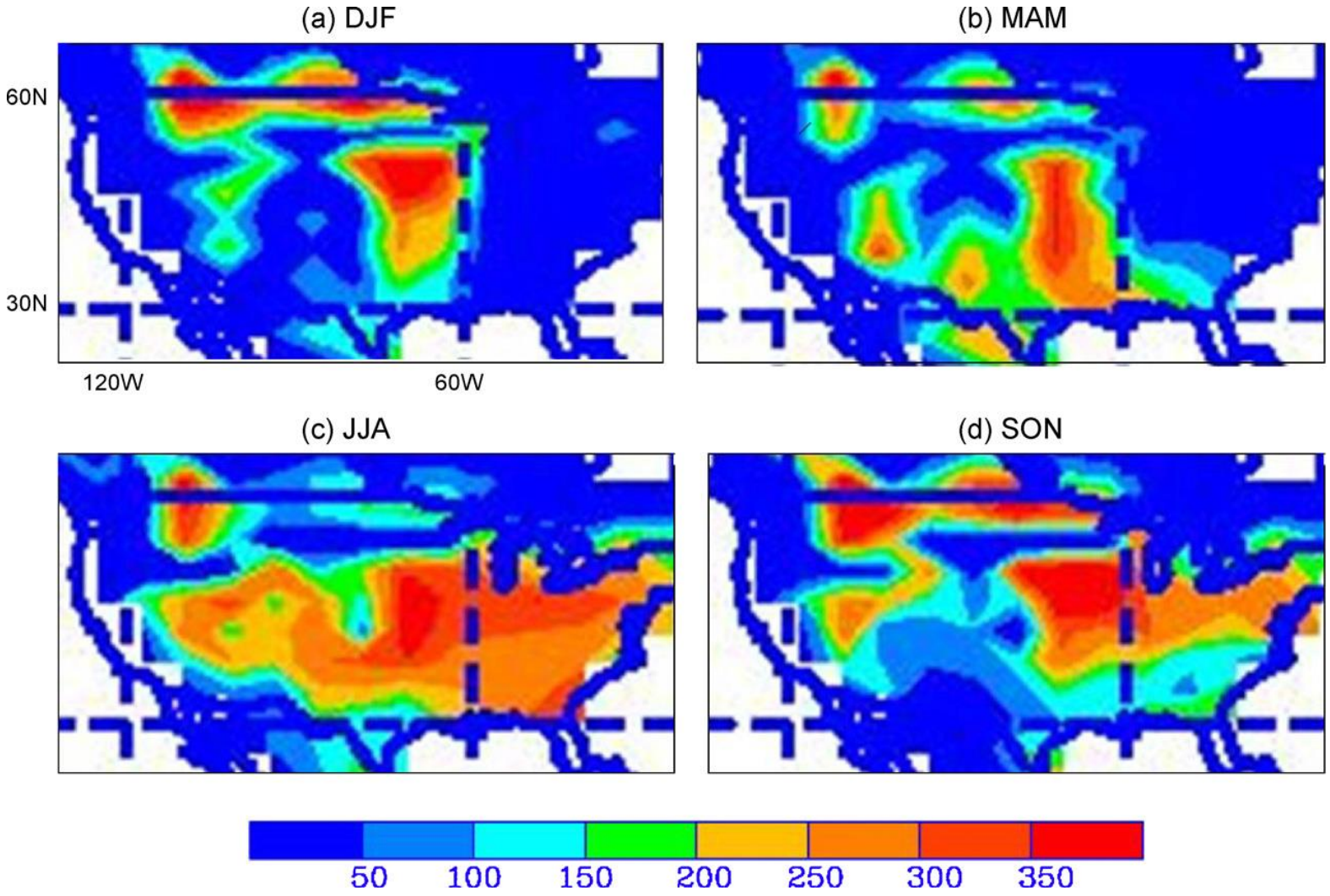
The two approaches were compared for the 50-km data over the contiguous U.S. of HadCM3 A2 projection with the current (1950-1999) and future (2050-2099) periods and the time gap (2000-2049).


Decomp
Trend
Bias (Temp, C)
4
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
Month

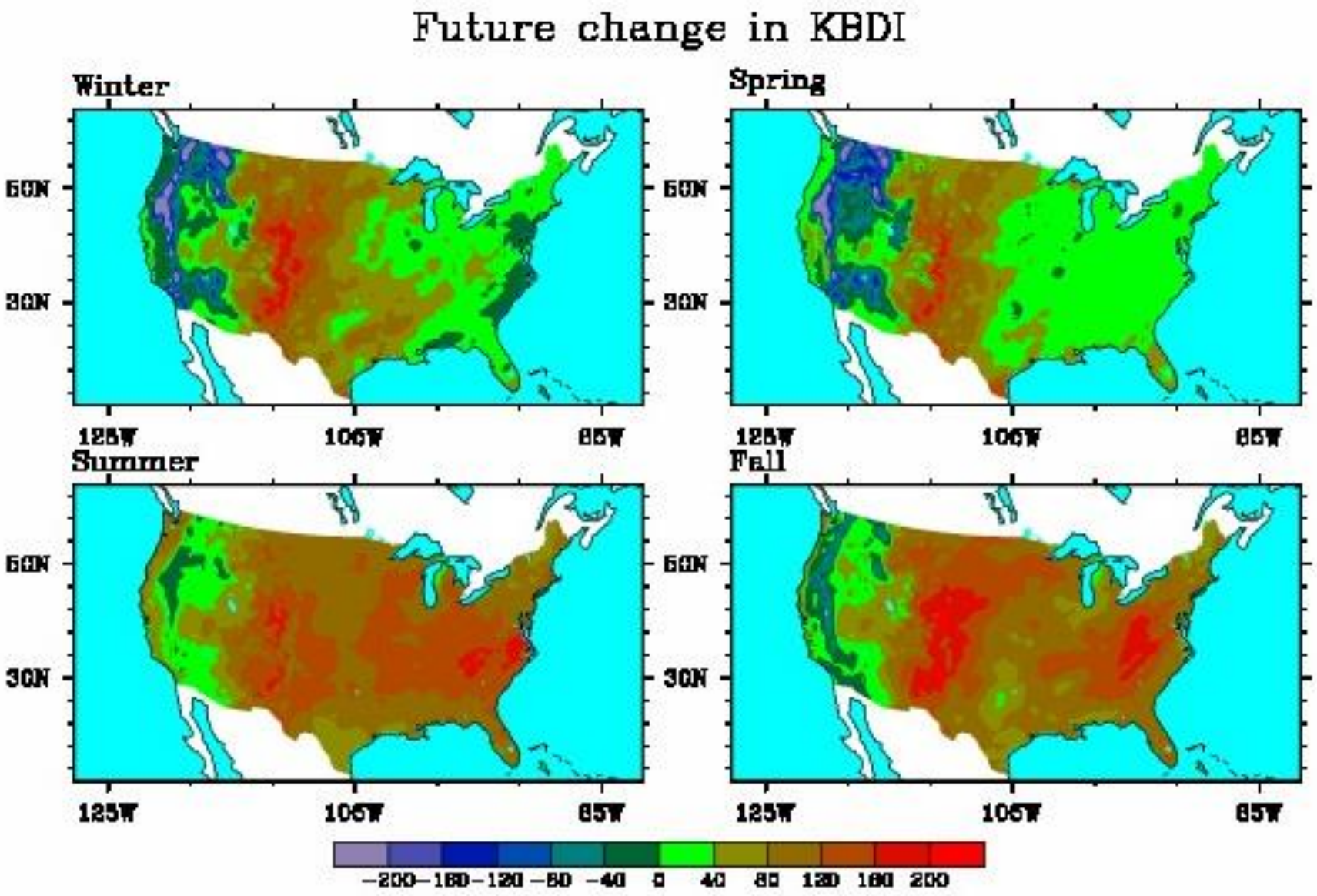

Decomp
Trend
Bias (Prec, mm/day)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10
11
12
Month

Step 7 Applications

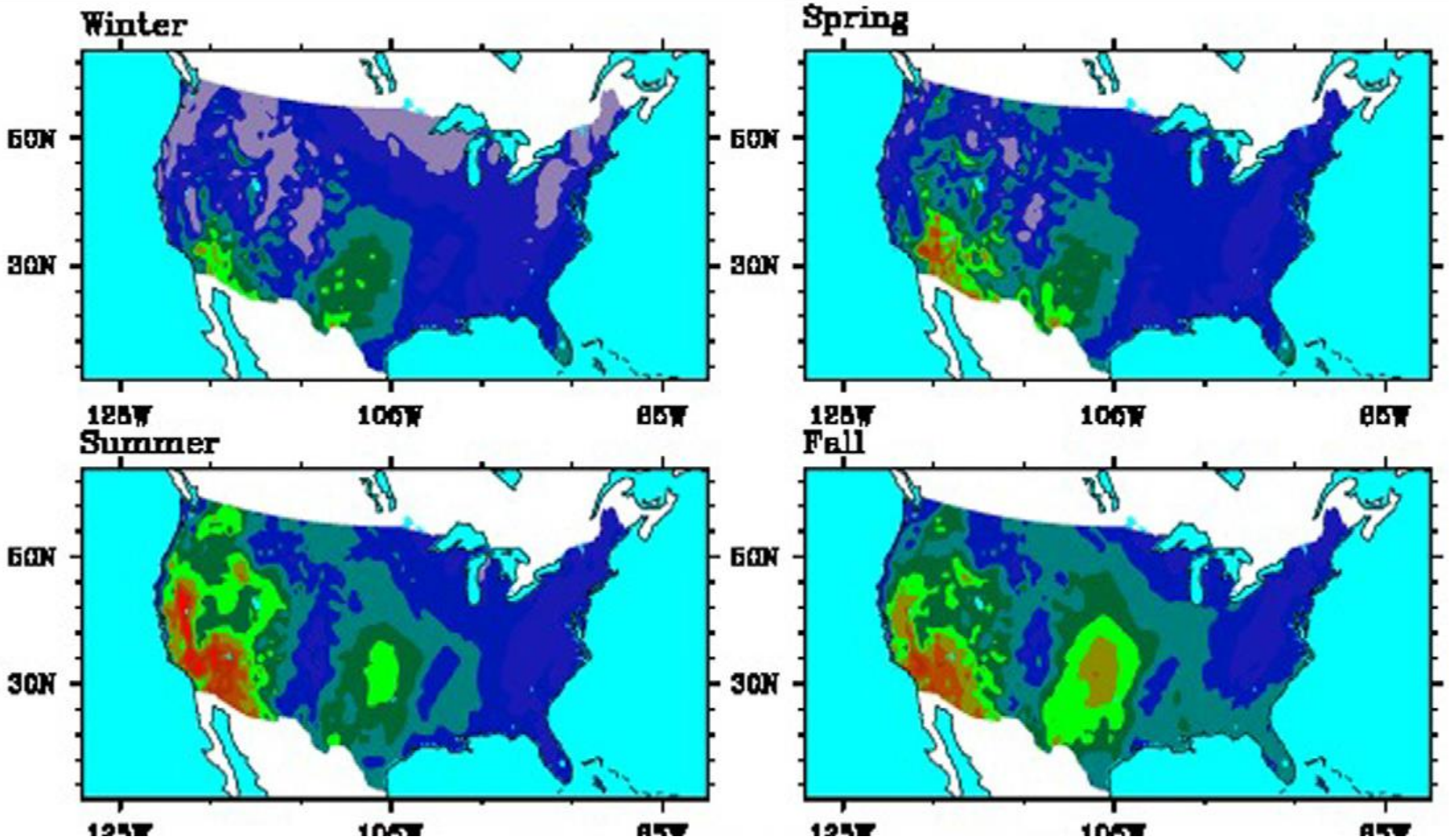
Future KBDI change (HadCM)



Future KBDI change (HRM)



Future Modified Fosberg Drought Index change



Strength	Weakness
Physically consistent (among variables and with GCMs)	Limited by boundary conditions
Multiple variables	Internal instability
Coupled land surface and topography	Computational limitations (space resolution, time gap, CMIP lag)
Extremes (with limited reliability)	RCM dependent

Part IV: Methods – Statistical Downscaling

Statistical downscaling

Utilizes relationships between GCM output and historical data to produce finer spatial and temporal resolution climate data at the regional level.

(1) Y0 = f (X0)

known: X0 (GCM), Y0 (local Obs);

unknown: f

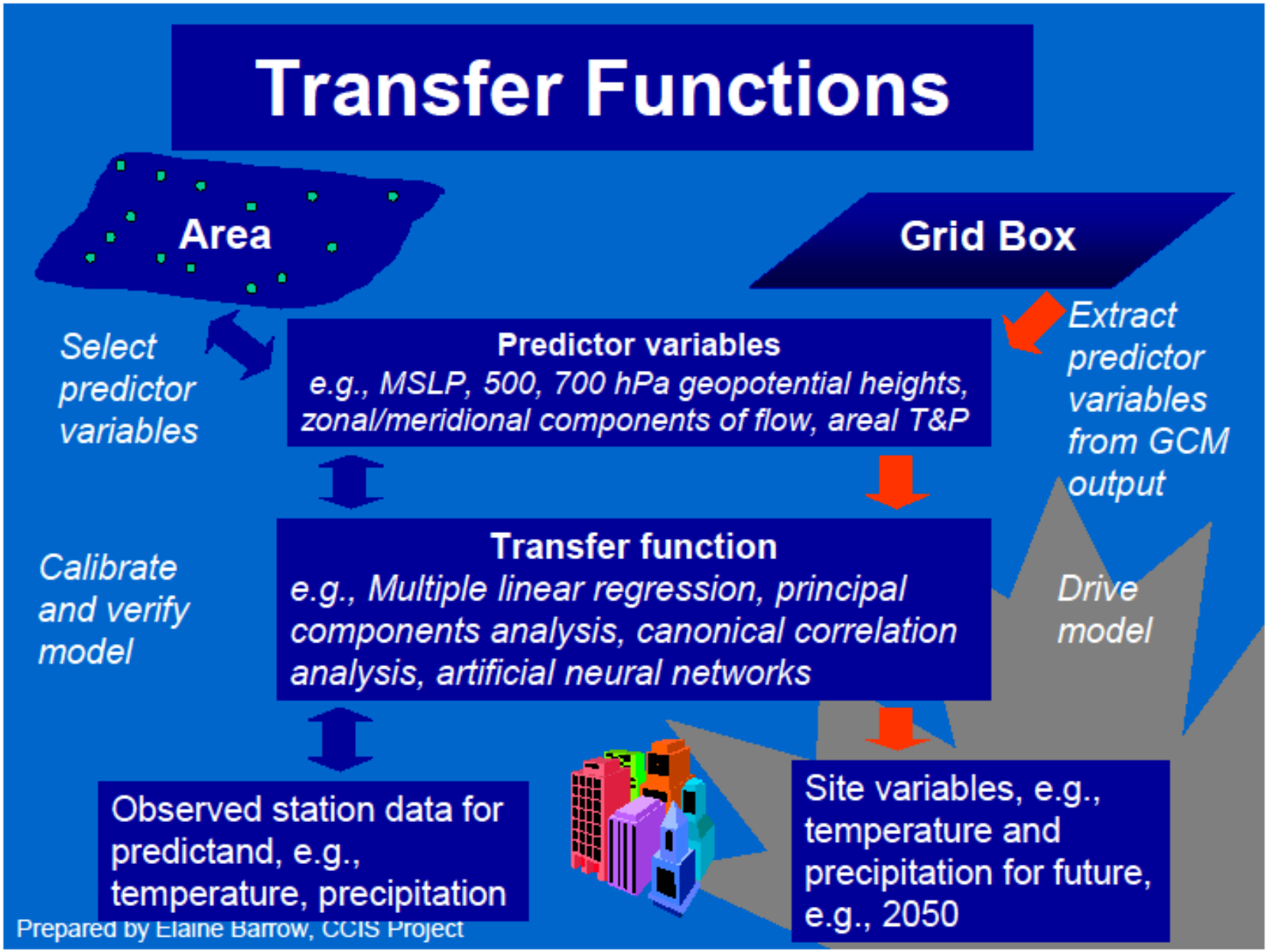
Bias correction?

(2) Y1 = f (X1)

known: X1 (GCM), f;

unknown: Y1(Local)

- Transfer function
- Weather type
- Weather generators


Transfer Functions
Area
Grid Box
Select predictor variables
Predictor variables
e.g., MSLP, 500, 700 hPa geopotential heights, zonal/meridional components of flow, areal T&P
Extract predictor variables from GCM output
Calibrate and verify model
Transfer function
e.g., Multiple linear regression, principal components analysis, canonical correlation analysis, artificial neural networks
Drive model
Observed station data for predictand, e.g., temperature, precipitation
Site variables, e.g., temperature and precipitation for future, e.g., 2050
Prepared by Elaine Barrow, CCIS Project

From Barrow

Weather Typing

Pressure fields from GCM

Identify weather types

Select classification scheme

Calculate weather types

Derive

Relationships between weather type and local weather variables

Drive model

Observed weather variables

Local weather variables for, say, 2050

Prepared by Elaine Barrow, CCIS Project

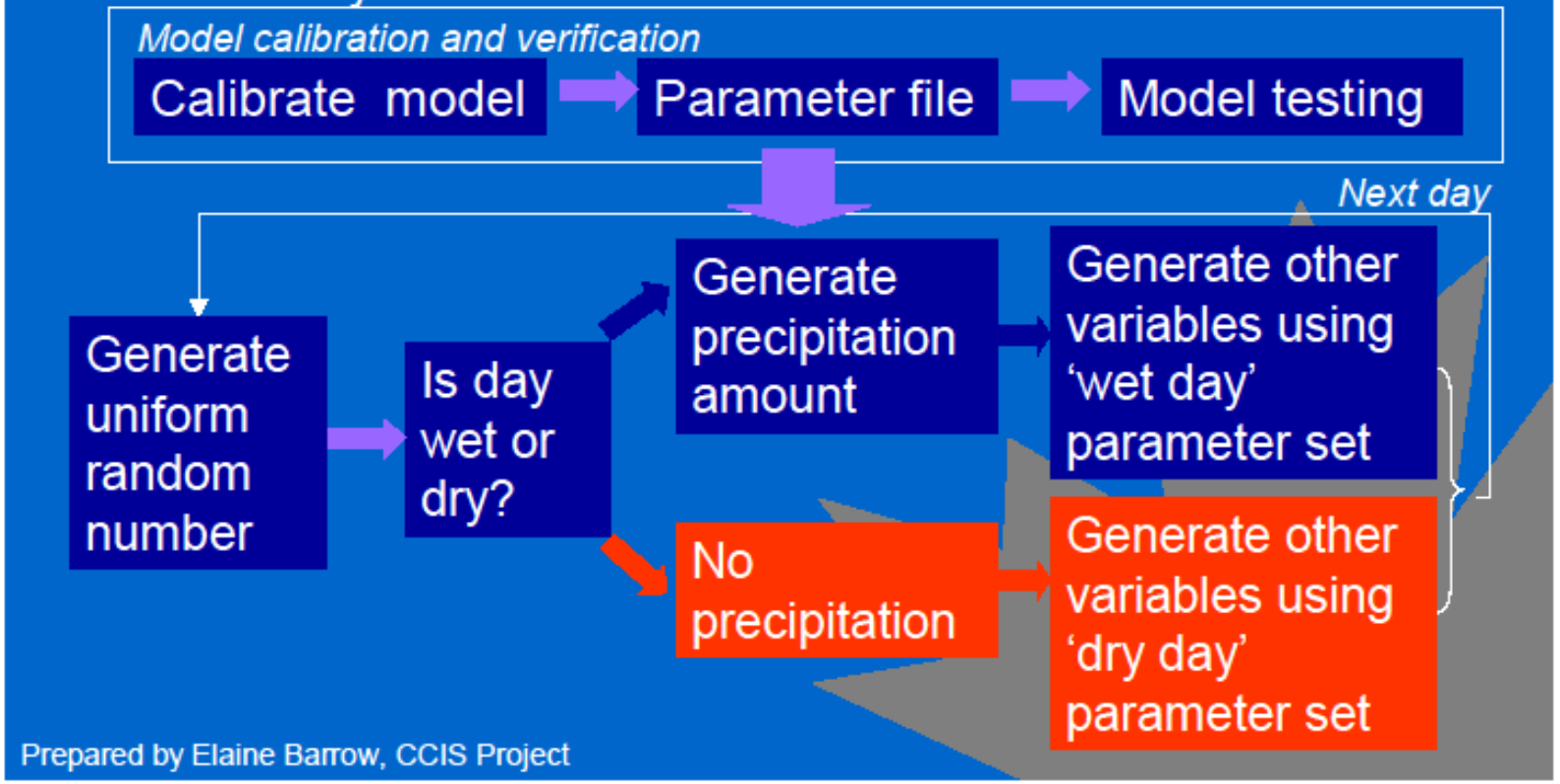
Statistically relate observed station or area-average meteorological data to a weather classification scheme.

Weather classes may be defined objectively (e.g. by PCA, neural networks) or subjectively derived (e.g., Lamb weather types [UK], European Grosswetterlagen)

From Barrow

Weather Generators

Statistical models of observed weather variables, generally at the daily time scale.

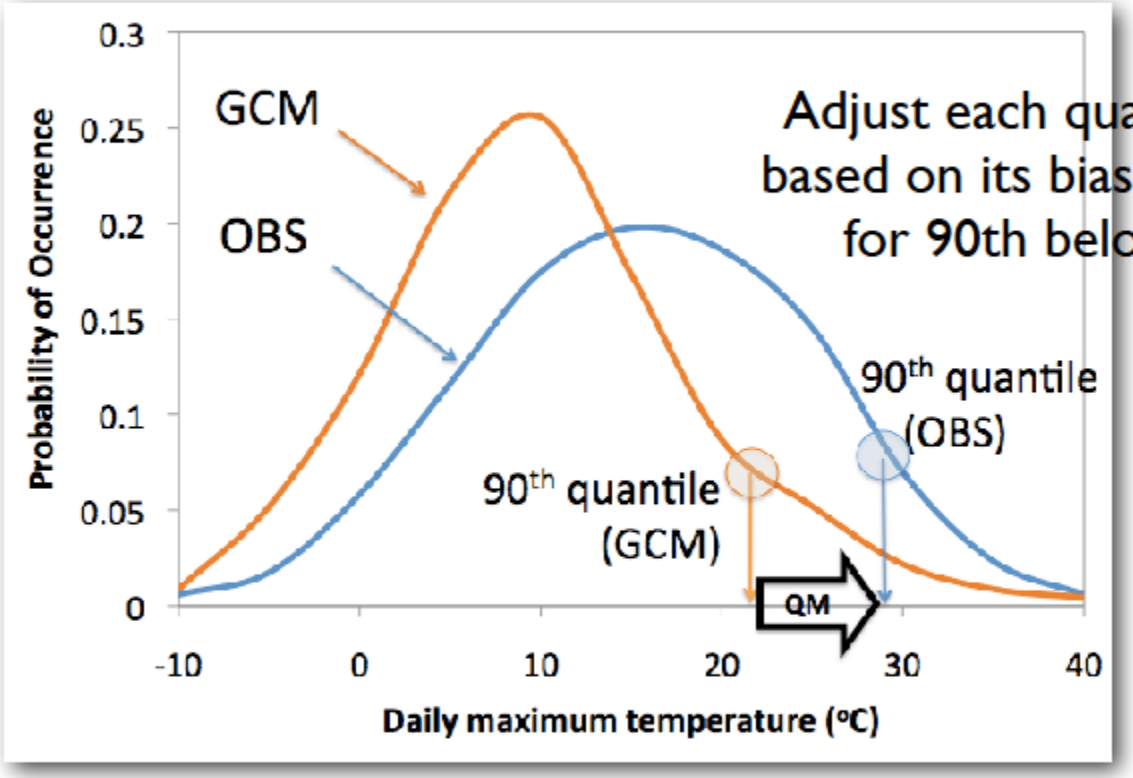


From Barrow

Method	Strength	Weakness
Transfer function	Computationally efficient	Large amount of data
	Easy to produce ensembles	Special knowledge (SVD, ANN)
		Only valid in the data range used for calibration
		May not significant for some variables in future
Weather typing	Meaningful physical linkages between climate on large scale and weather on local scale	Relations between weather and local climate variables may not good at some sites
		Some local climate variables may be not sensitive to large scale climate forcing
Weather generator	Unlimited long time series	Low accuracy, especially for persistent, rare, events, and long-term variaations
	Spatially sparse data	Individual sites without spatial relations.
	Obtain changes in future mean and variability by adjusting WG parameters	

Bias correction

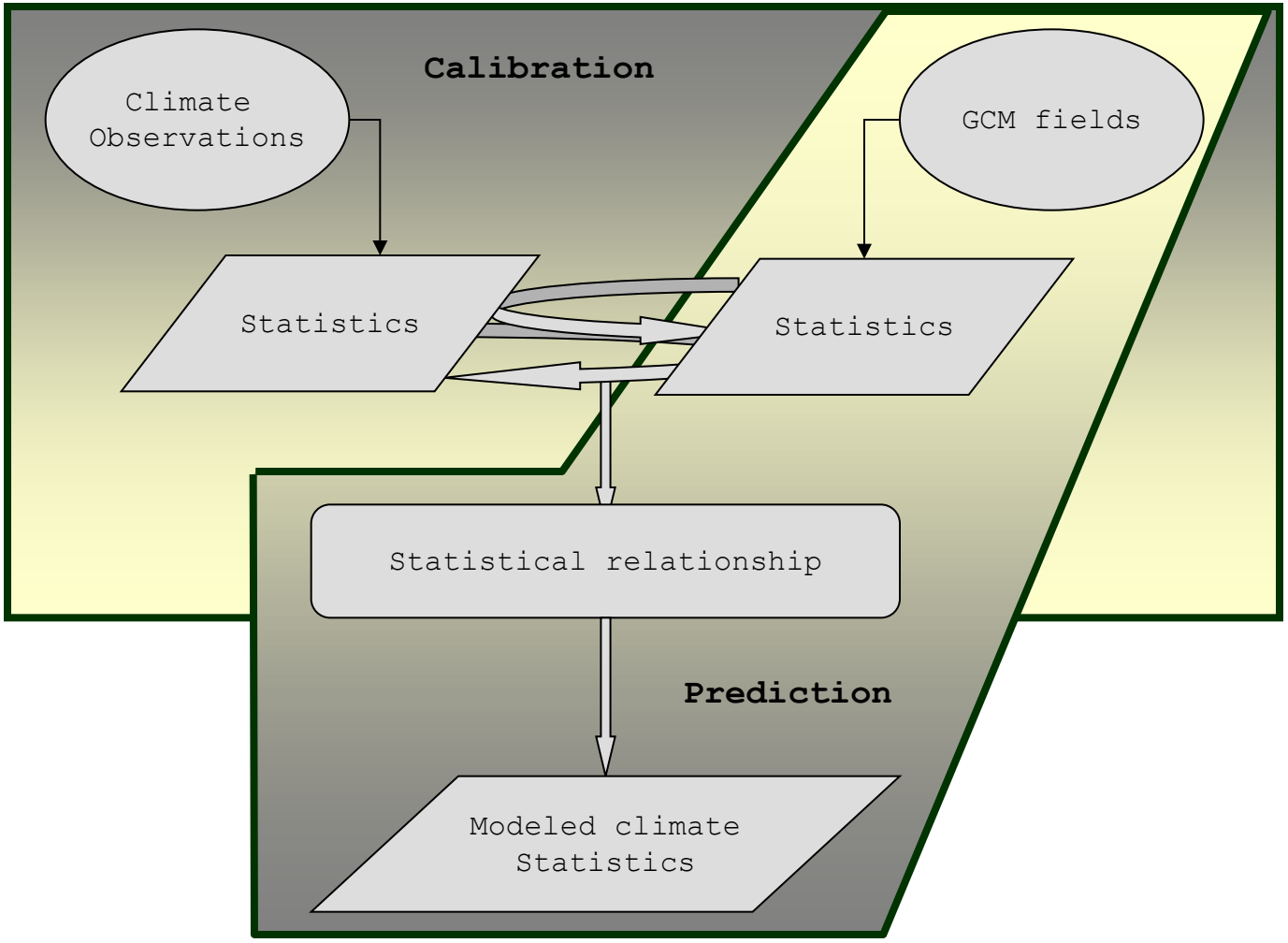
Difference in mean between GCM and observation
GCM values are “mapped” by quantile onto observation



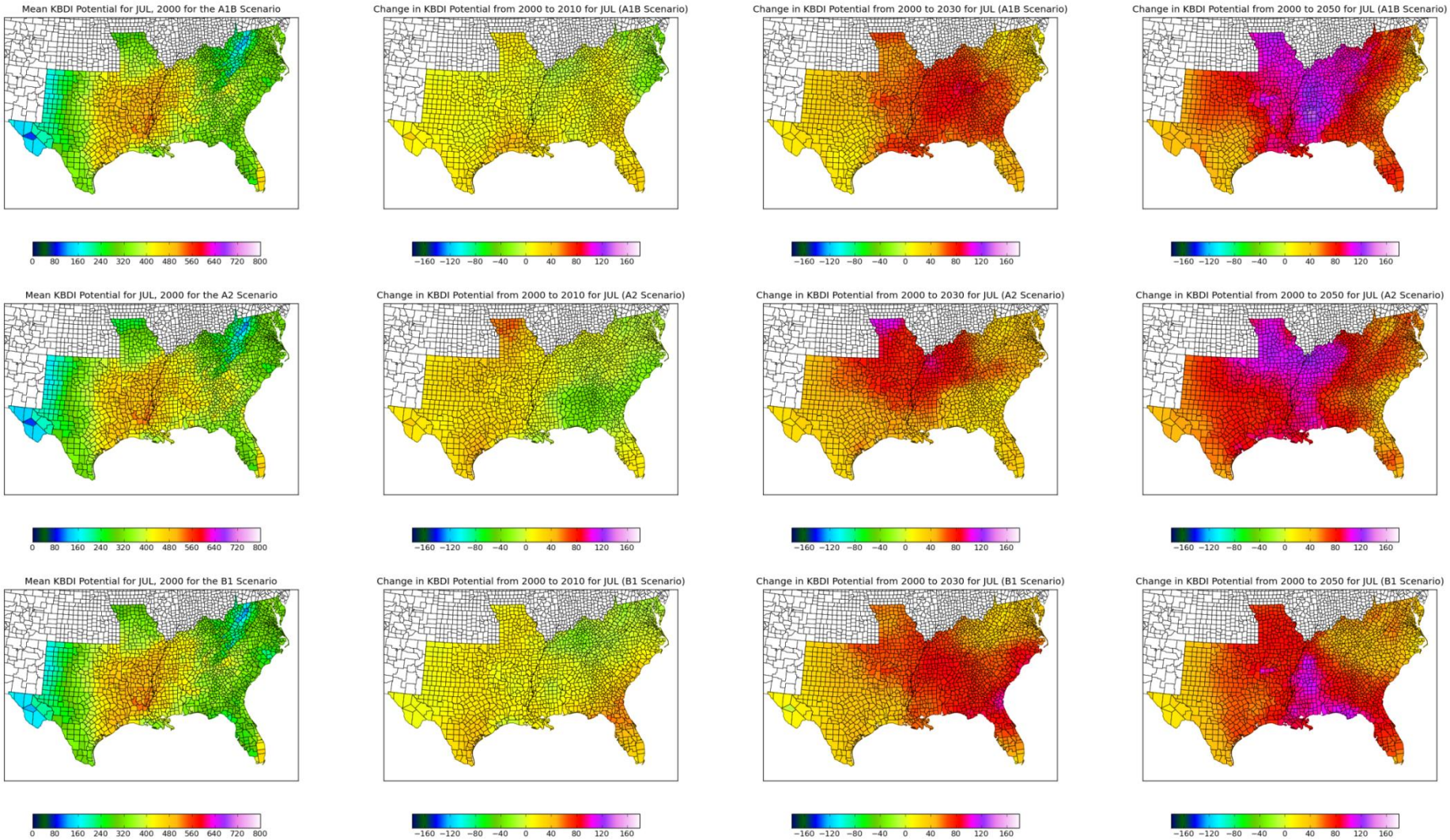
Calculate quantile bias, adjust GCM to obs so can map GCM quantiles onto observed.

[Hayhoe 2010]

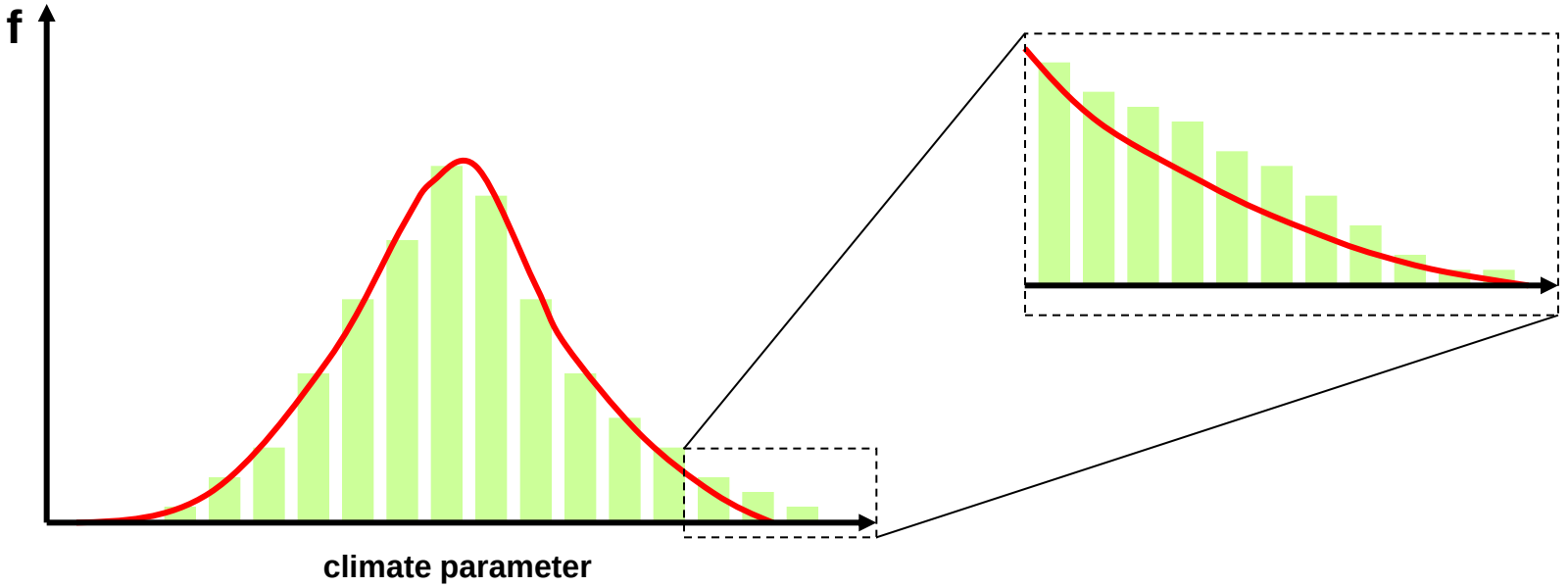
STATISTICAL DOWNSCALING CORRELATION MODELS



2020 2030 2040 2050



Extreme value statistics



Simple linear regression not valid for extremes

III. Extreme value statistics

- **The Generalized Pareto Distribution (GPD) is a useful statistical distribution, since it is a parent distribution for other extreme value distributions (Gumbel, Exponential, Pareto).**

- **The quantile function *x(F)* is given by:**

$$x(F) = \zeta + \alpha \frac{1-(1-F)^k}{k}$$

ζ = location parameter (expectation)

α = scale parameter (dispersion)

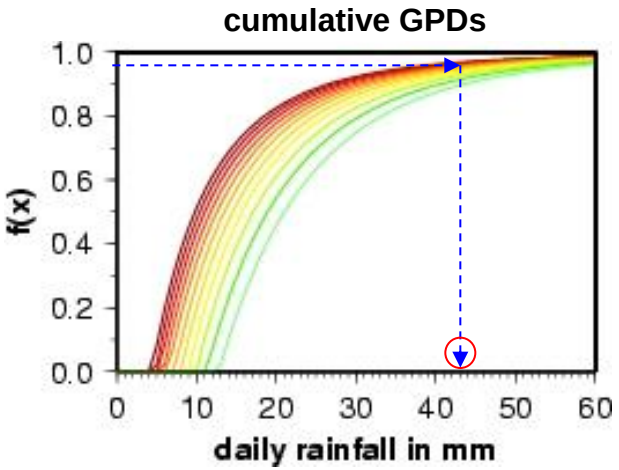
k = shape parameter (skewness)

- **The parameters of the GPD can be estimated by the method of L-moments.**

- **Estimation of T-year return values (RVs):**

$$RV_T = \hat{\zeta} + \hat{\alpha} \frac{1-(1-(1-\frac{1}{T}))^{\hat{k}}}{\hat{k}}$$

T	**=**	**5a**
q	**=**	**99%**
RV	**=**	**43mm**



dispersion parameter: threshold quantile

Strength	Weakness
Computationally efficient	Data availability and empirical relations
High resolution	Assume relations held for future
Bias control with historical data	Inconsistent among variables
	Limited variables available
	Method dependent
	Extremes

Hybrid approach

Run dynamic downscaling in combination with statistical downscaling

- Run GCM/RCM (dynamic downscaling) to then conduct statistical downscaling using RCM output
- Bias correction to GCM output, then run RCMs

Comparisons for SE

Dynamic

NARCCAP

CLAREnCE10 (COAPS Land-Atmosphere Regional Ensemble Climate Change Experiment) – FSU and USGS

Project)

Hostetler datasets – USGS, Oregon State University

Statistical

Maurer BCSD datasets – U.S. Dept. of Energy

SERAP (Southeast Regional Assessment Project) – Hayhoe, Texas Tech University

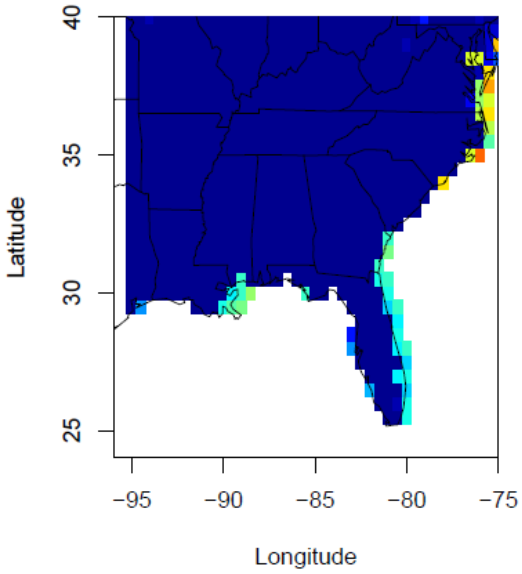
WICCI (Wisconsin Initiative on Climate Change Impacts) – David Lorenz, Center for Climatic Research

From Wootten (2013)

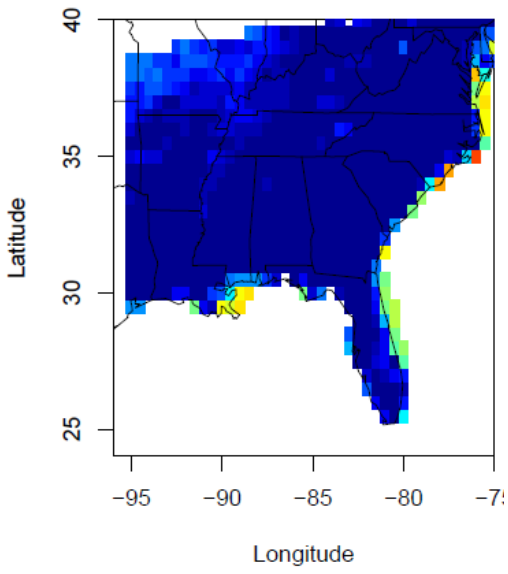
Product	Res	Domain	Temporal	Period(s)	GCM #
Maurer BCSD	12km	Cont. U.S.	Monthly	1950-2099	18
WICCI	11km	E U.S. / S Can.	Daily	1961-2000, 2046-2065, 2081-2100	12
SERAP	12km	Cont. U.S.	Daily	1960-2099	10
CLAREnCE10	10km	SE U.S.	Hourly	1968-2000, 2038-2070	3
Hostetler	15km	W / E NA	3 Hours	1968-199	3
	50km		6 hours	2010-2099	
NARCCAP	50km	NA	3 Hours	1971-2000,	4
			Daily	2041-2070	

From Wootten (2013)

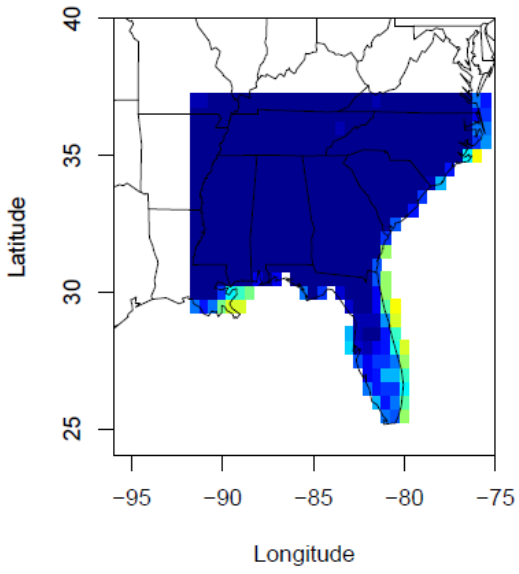
January Mean Monthly Temperature - Bias (C)



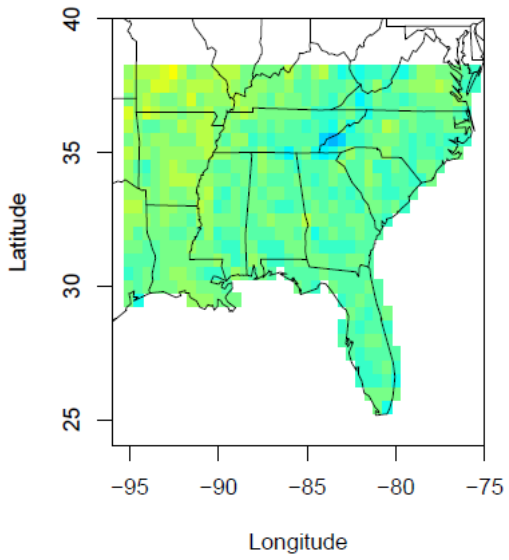
NARCCAP



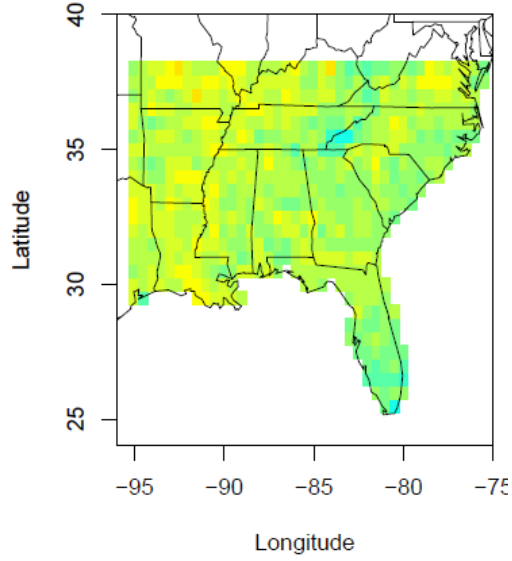
Hostetler



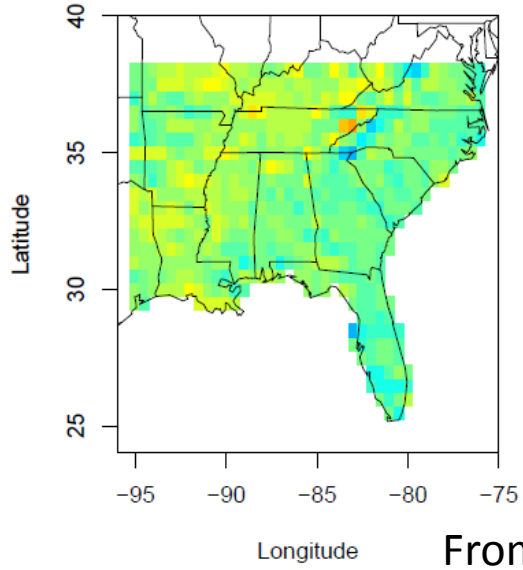
CLAREnCE10



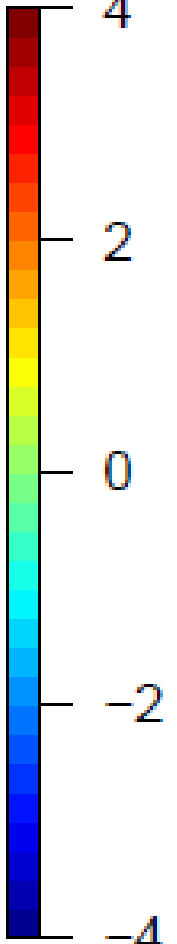
SERAP



Maurer BCSD

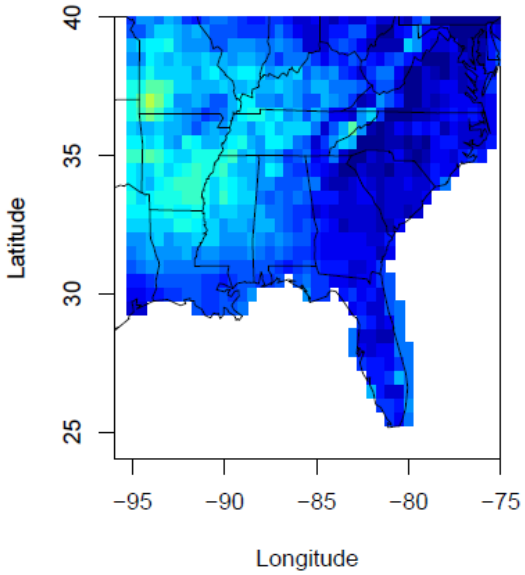


WICCI

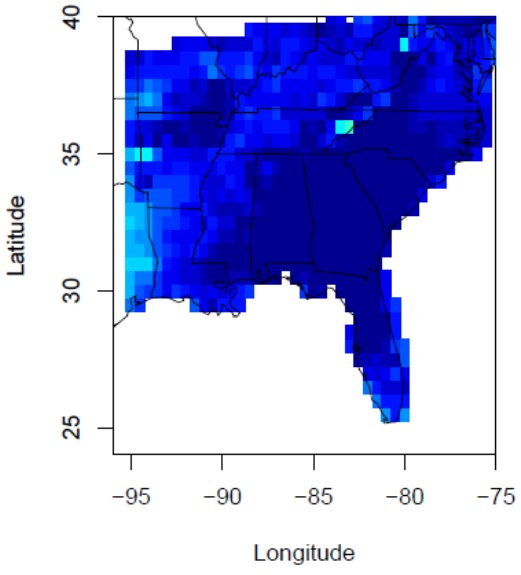


From Wootten (2013)

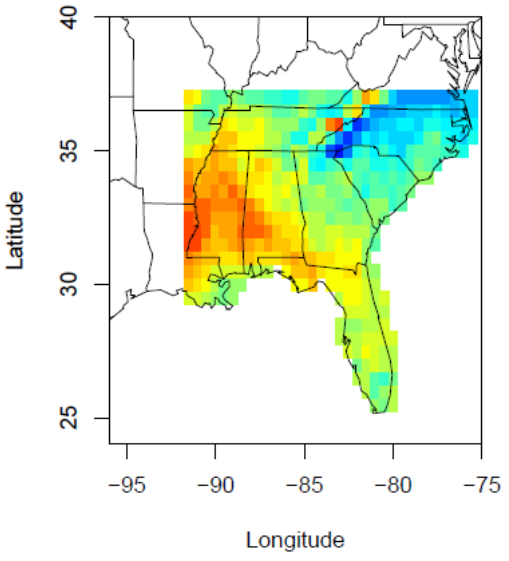
July Mean Monthly Temperature - Bias (C)



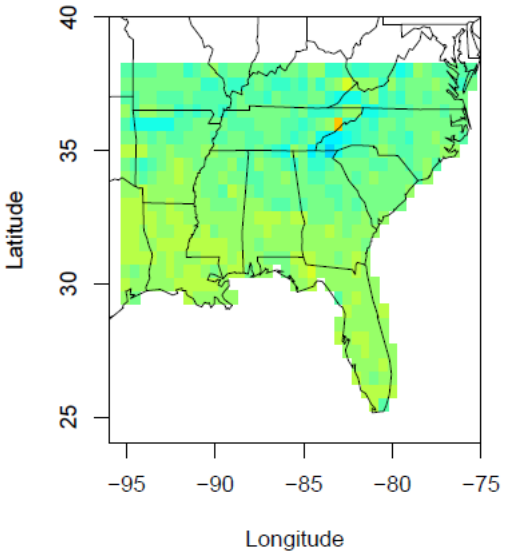
NARCCAP



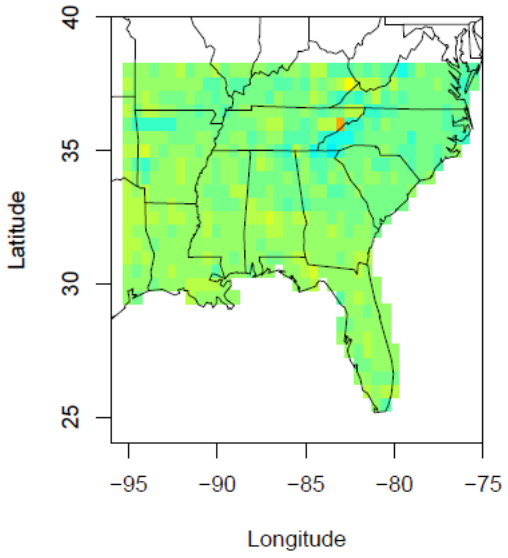
Hostetler



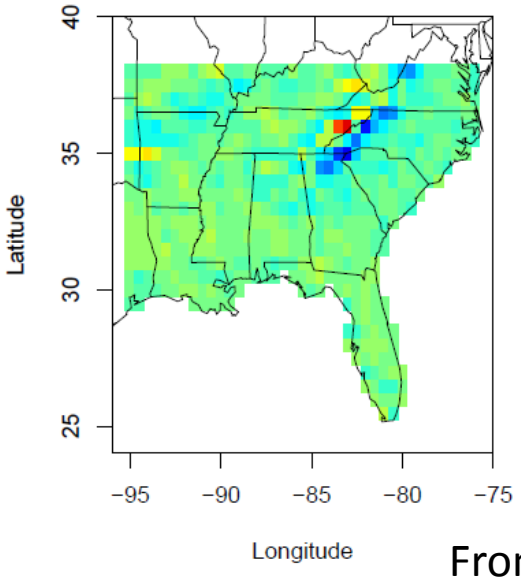
CLAREnCE10



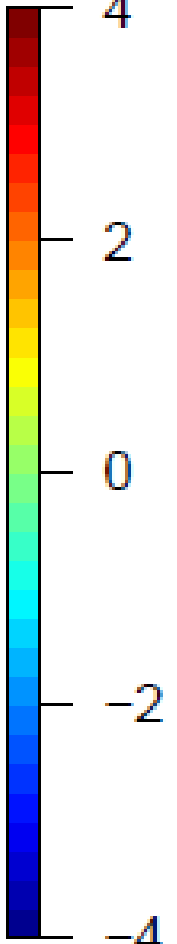
SERAP



Maurer BCSD

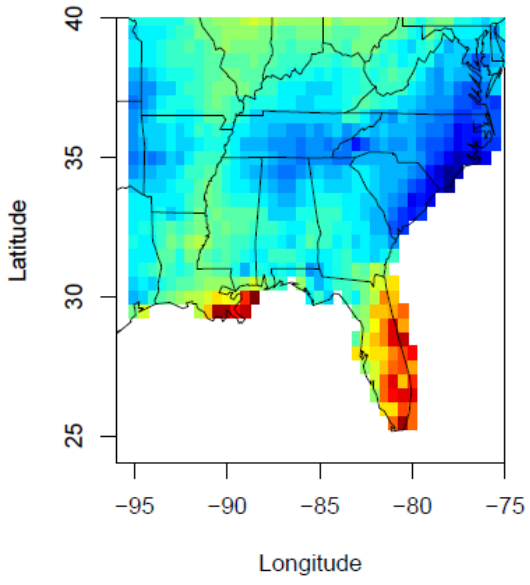


WICCI

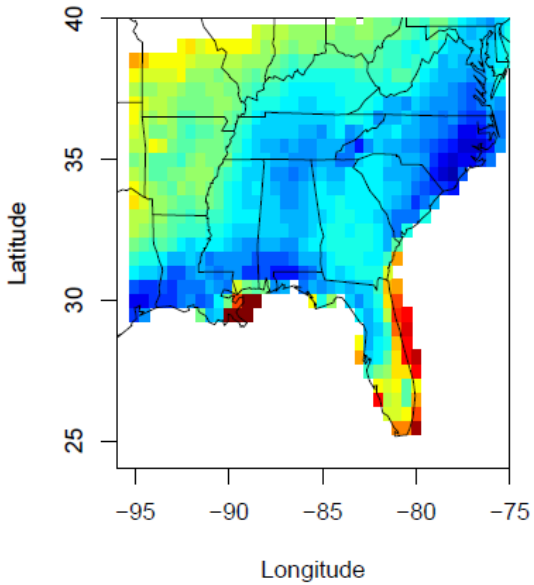


From Wootten (2013)

September Mean Monthly Precipitation - Bias (mm/d)



NARCCAP



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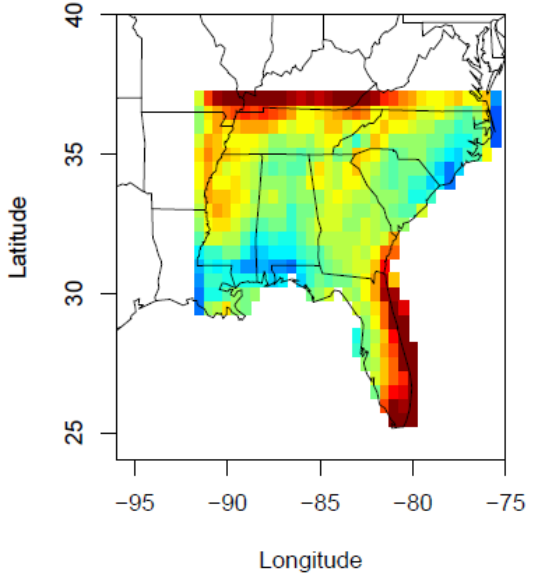
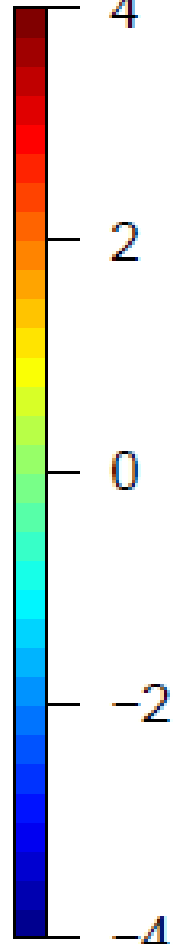
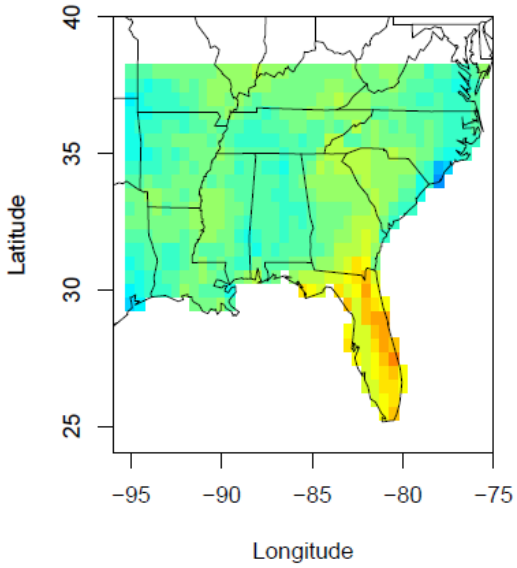
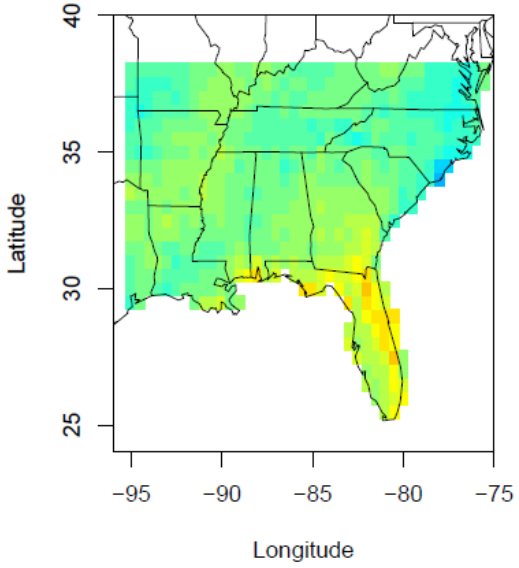


CLARETICE10

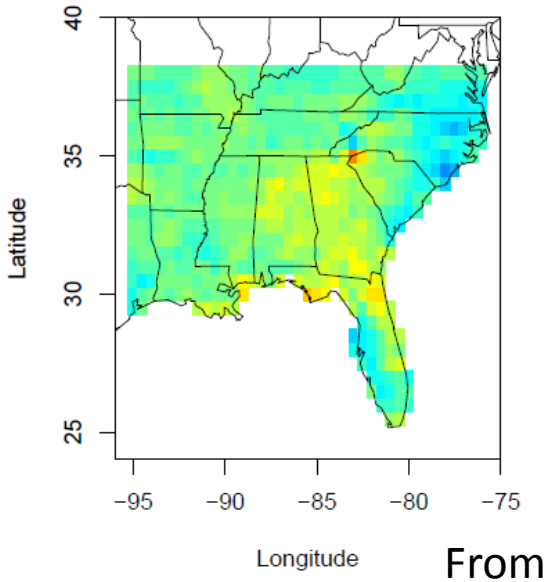




SERAP



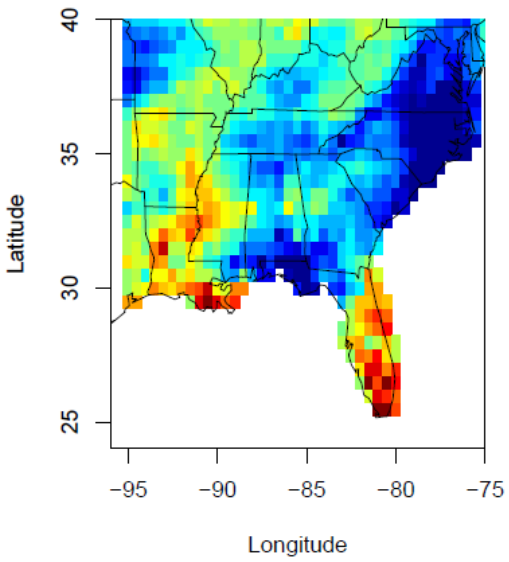
Maurer BCSD



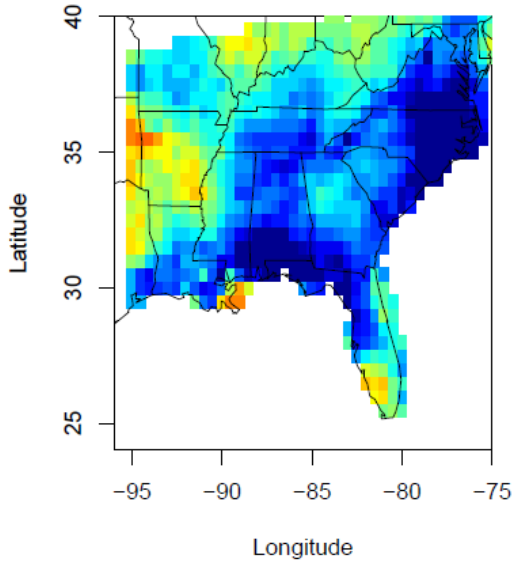
WICCI

From Wootten (2013)

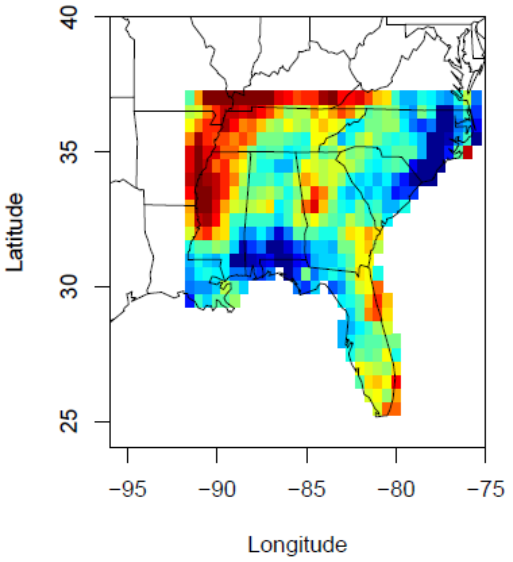
September Mean Monthly Precipitation – Standard Deviation Difference (mm/d)



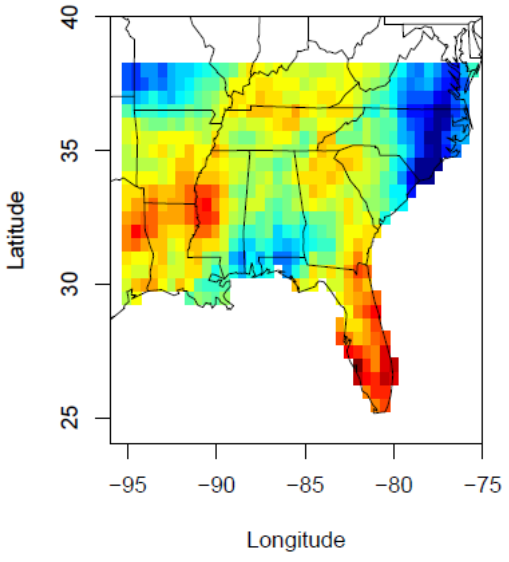
NARCCAP



Hostetler



CLAREnCE10



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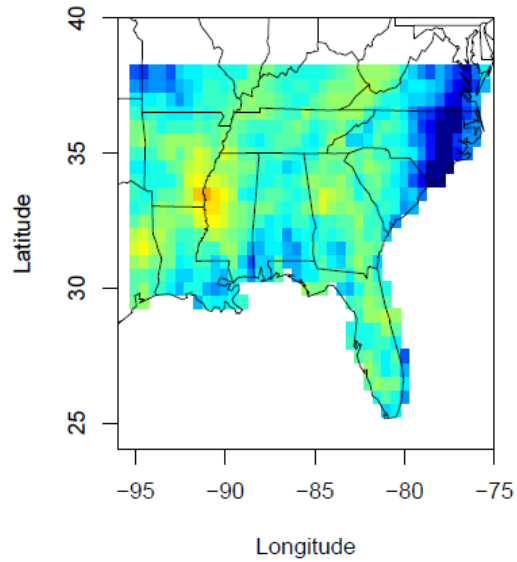
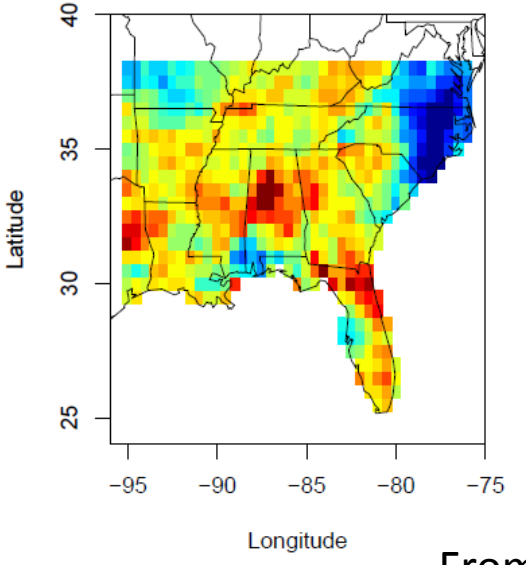
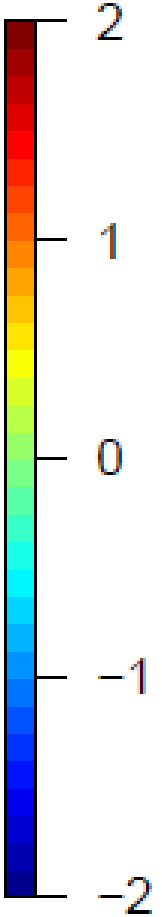


Maurer BCSD



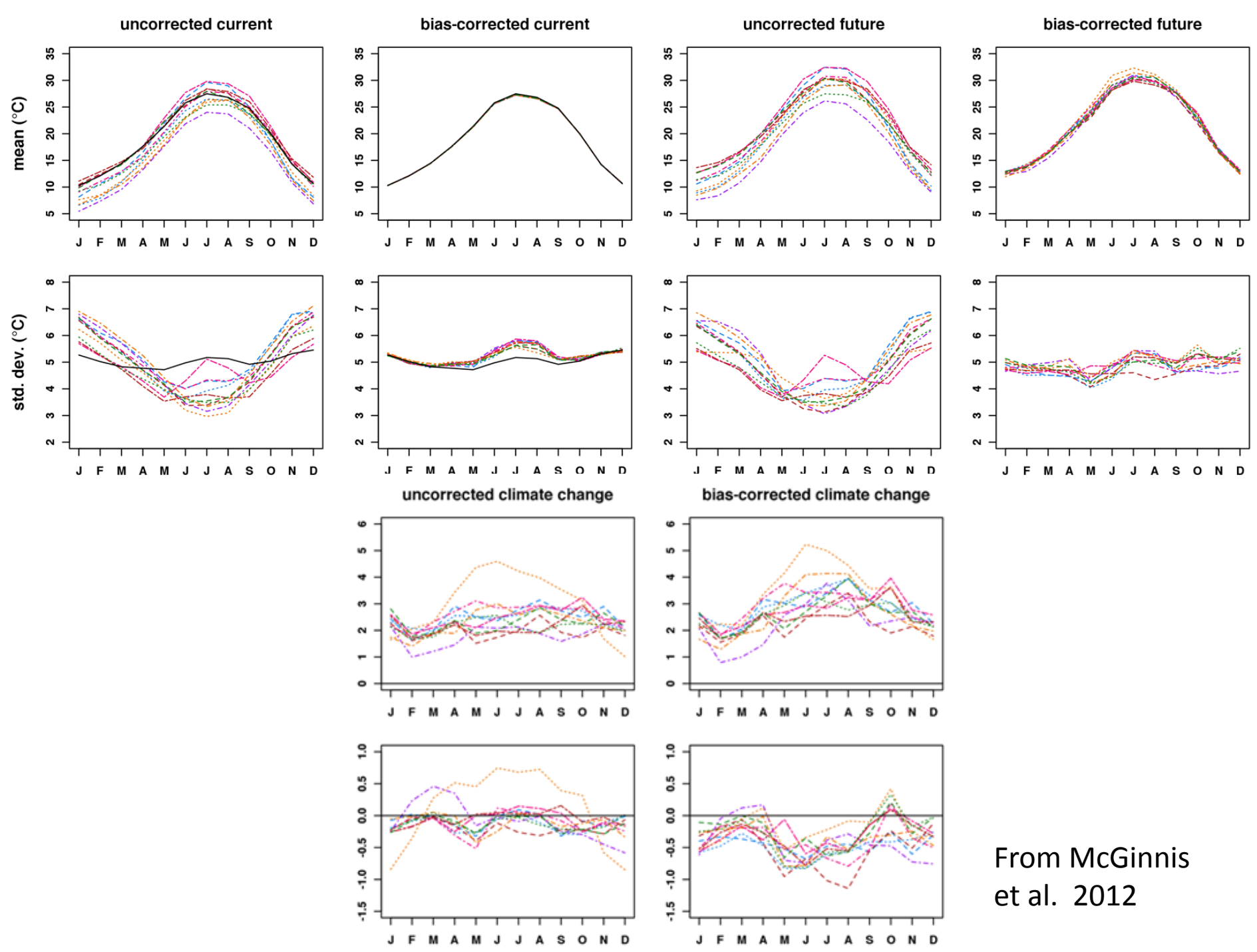
WICCI



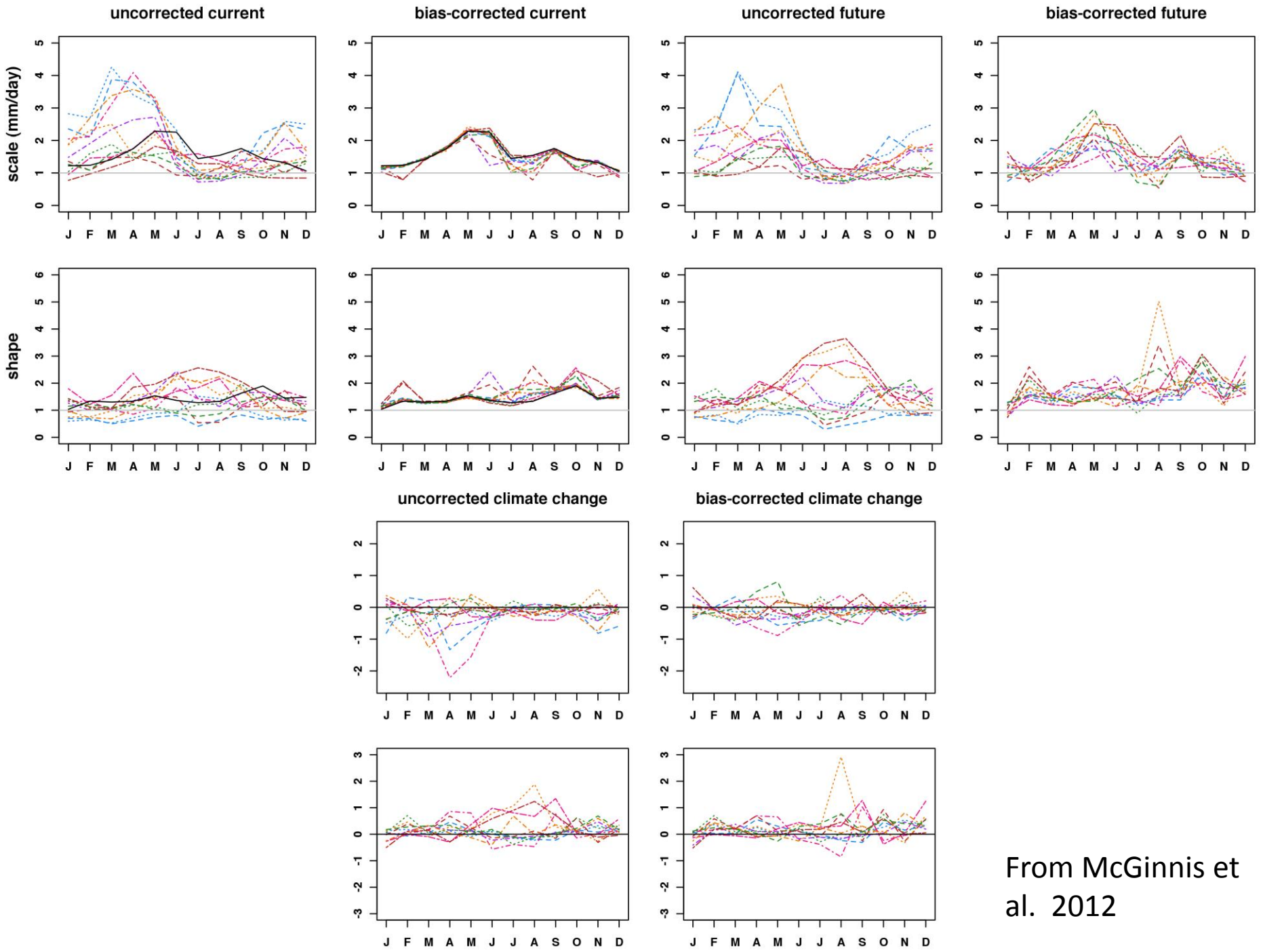
From Wootten (2013)

Bias Correction to DD

- Decompose the monthly average data into climatic regions;
- Fit an appropriate statistical distribution (Gaussian for temperature and gamma for precipitation) to RCM output.
- Bias-correct model output by using quantile mapping (QM) to create a transfer function that adjusts the distribution of model data from the current-climate simulations to match the cumulative distribution function (CDF) of observed data.
- Apply the same transfer function d to output from the future-climate simulations.



From McGinnis et al. 2012



From McGinnis et al. 2012

Part V: Applications

Climate Wizard

- Developed through collaboration between The Nature Conservancy, The University of Washington, and The University of Southern Mississippi, the Climate Wizard enables technical and non-technical audiences alike to easily and intuitively access leading climate change information and visualize the impacts anywhere on Earth.
- http://www.climatewizard.org

Climate Wizard

- Statistical downscaling to 12 km grid
- The method involves …
  - (1) a quantile-mapping approach that corrects for GCM biases, based on observations of 1950–1999
  - (2) interpolation of monthly bias-corrected GCM anomalies onto a fine-scale grid of historical climate data, producing a monthly time series at each 1/8-degree grid cell.

The Nature Conservancy
Protecting nature. Preserving life.™

ClimateWizard

University of Washington
The University of Southern Mississippi

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Analysis Area	Time Period	Map Options	Measurement	Resources
◉ United States ○ Global United States ▼	○ Past 50 Years ◉ Mid Century (2050s) ○ End Century (2080s)	○ Map of Average ◉ Map of Change Compare & Animate Models	◉ Average Temperature ○ Precipitation July ▼	Case Studies Documentation | Developer Data and Map Image Download ClimateWizard Custom Analysis Printer Friendly Version

Future Climate Model

IPCC Fourth Assessment

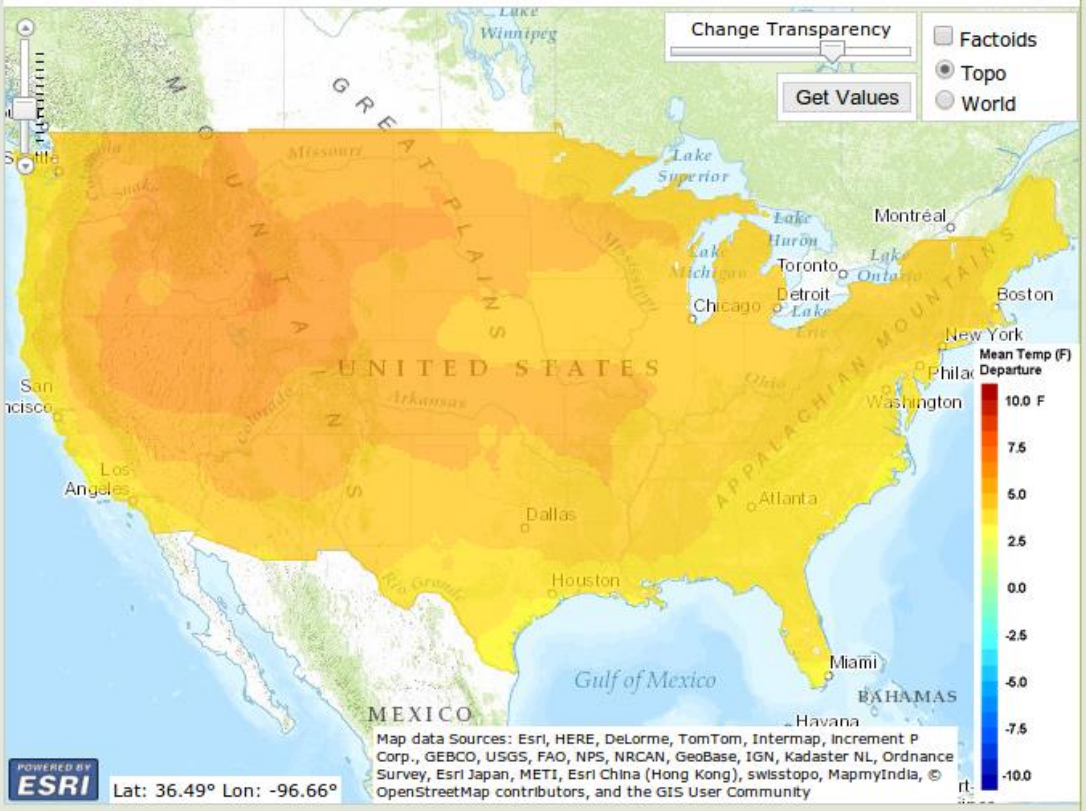
Emission Scenario: High A2 ▼

General Circulation Model: Ensemble Average ▼

50%: This map shows the temperature change projected by the middle model. That is, **half of the models project a greater amount of change, and half of the models project less change** as compared to the 1961-1990 baseline average.

Change in July Temperature by the 2050s

Model: Ensemble Average, SRES emission scenario: A2



Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

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ClimateWizard

University of Washington
The University of Southern Mississippi

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Analysis Area	Time Period	Map Options	Measurement	Resources
◉ United States ○ Global Montana ▼	○ Past 50 Years ○ Mid Century (2050s) ◉ End Century (2080s)	○ Map of Average ◉ Map of Change Compare & Animate Models	○ Average Temperature ◉ Precipitation Annual ▼	Case Studies Documentation | Developer Data and Map Image Download ClimateWizard Custom Analysis Printer Friendly Version

Future Climate Model

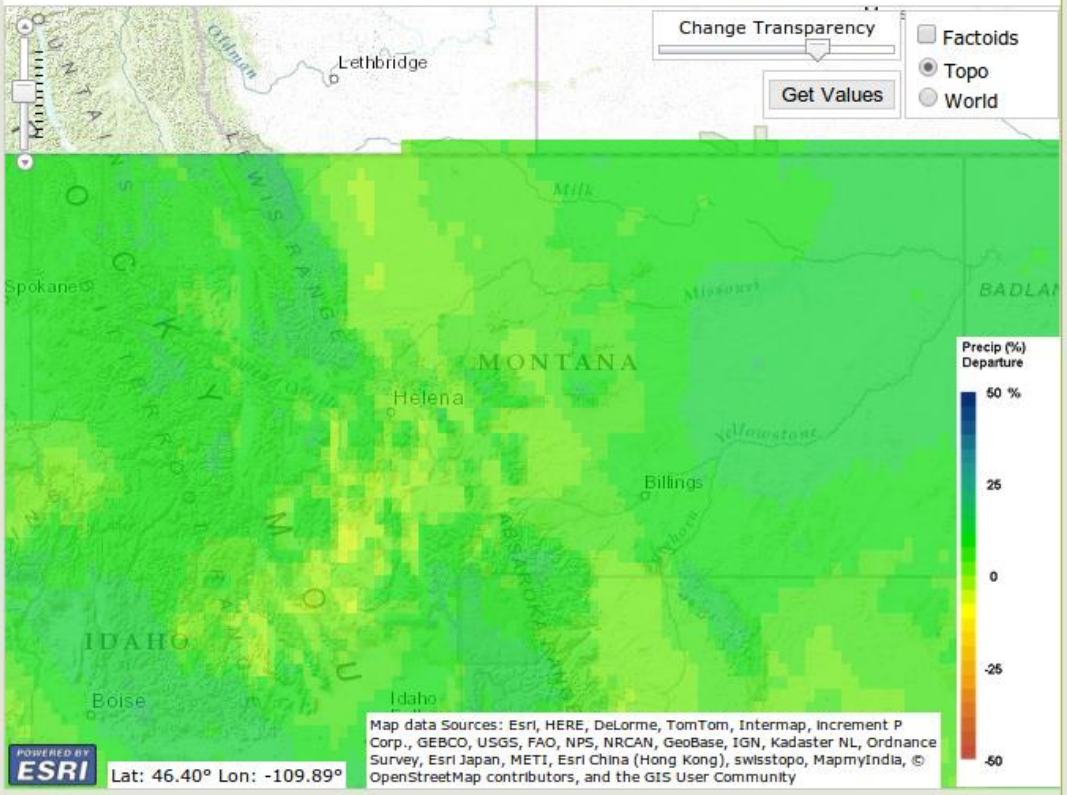
IPCC Fourth Assessment

Emission Scenario: High A2 ▼

General Circulation Model: Ensemble Average ▼

Change in Annual Precipitation by the 2080s

Model: Ensemble Average, SRES emission scenario: A2



50%: This map shows the precipitation change projected by the middle model. **Areas that are blue are projected to increase by at least half of the models, and areas that are yellow to red are projected to decrease in precipitation by at least half of the models.**

Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

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Analysis Area	Time Period	Map Options	Measurement	Resources
◉ United States ○ Global Montana ▼	○ Past 50 Years ○ Mid Century (2050s) ◉ End Century (2080s)	○ Map of Average ◉ Map of Change Compare & Animate Models	○ Average Temperature ◉ Precipitation Annual ▼	Case Studies Documentation | Developer Data and Map Image Download ClimateWizard Custom Analysis Printer Friendly Version

Future Climate Model

IPCC Fourth Assessment

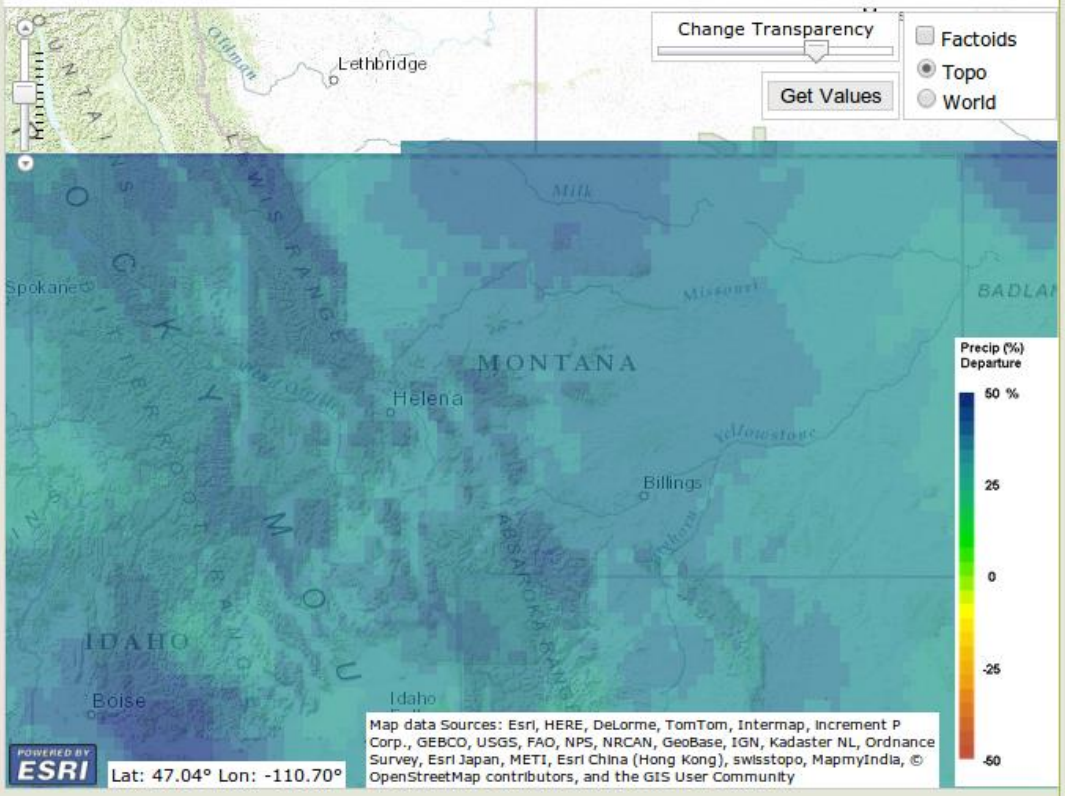
Emission Scenario
High A2 ▼

General Circulation Model
Ensemble Highest ▼

100%: This map shows change projected by the model with the greatest amount of precipitation. **Areas that are yellow to red had complete agreement between all models that precipitation will decrease.** Areas that are blue represent the largest increase in precipitation projected by any of the models.

Change in Annual Precipitation by the 2080s

Model: Ensemble Highest, SRES emission scenario: A2



Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

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Analysis Area	Time Period	Map Options	Measurement	Resources
◉ United States ○ Global Montana ▼	○ Past 50 Years ○ Mid Century (2050s) ◉ End Century (2080s)	○ Map of Average ◉ Map of Change Compare & Animate Models	○ Average Temperature ◉ Precipitation Annual ▼	Case Studies Documentation | Developer Data and Map Image Download ClimateWizard Custom Analysis Printer Friendly Version

Future Climate Model

IPCC Fourth Assessment

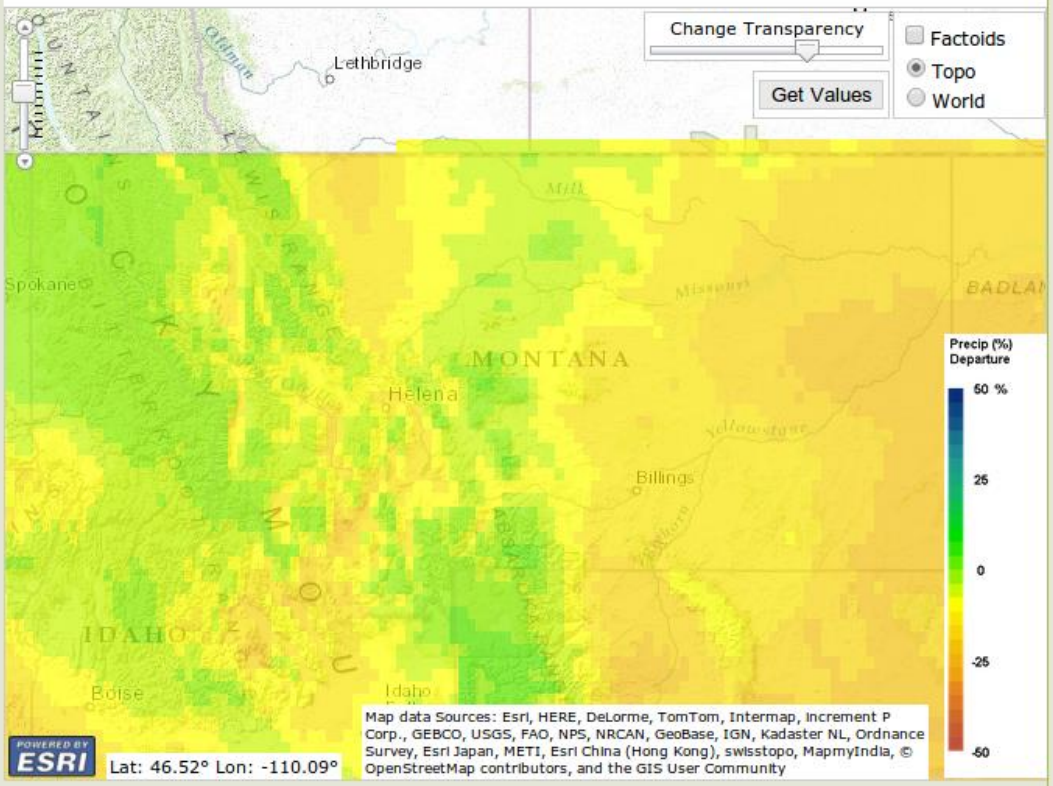
Emission Scenario: High A2 ▼

General Circulation Model: Ensemble Lowest ▼

0%: This map shows change projected by the model with the lowest amount of precipitation. **Areas that are blue had complete agreement between all models that precipitation will increase.** Areas that are yellow to red represent the largest decrease in precipitation projected by any of the models.

Change in Annual Precipitation by the 2080s

Model: Ensemble Lowest, SRES emission scenario: A2



Data Source: Base climate projections downscaled by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Climate Wizard

- Statistical downscaling approaches have several common limitations. These limitations include:
  - (1) underestimation of extremes unless approaches are used to adjust the variance
  - (2) the assumption of stationarity between large-scale and local climate in the future
  - (3) the creation of individual climate predictants (i.e., temperature, humidity, precipitation) that may be physically inconsistent with one another

WorldClim

- WorldClim is a set of global climate layers (climate grids) with a spatial resolution of about 1 square kilometer. The data can be used for mapping and spatial modeling in a GIS or with other computer programs.
- Free Desktop Tool – DIVA-GIS
- http://www.worldclim.org

WorldClim

- Method - thin-plate smoothing spline algorithm implemented in the ANUSPLIN package for interpolation, using latitude, longitude, and elevation as independent variables

WorldClim - Global Climate Data

Free climate data for ecological modeling and GIS

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WorldClim

WorldClim is a set of global climate layers (climate grids) with a spatial resolution of about 1 square kilometer. The data can be used for mapping and spatial modeling in a GIS or with other computer programs. If you are not familiar with such programs, you can try DIVA-GIS or the *R* raster package.

The current version is Version 1.4 (release 3). Please write us if you find any problems.

---> Download data

Information about the methods used to generate the climate layers, and the units and formats of the data. You can find more info in the **preferred citation**:
Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.

Frequently asked question and some 'known issues'.

This dataset is freely available for academic and other non-commercial use. Redistribution, or commercial use is not allowed without prior permission.

Read more

Download

You can download climate data for:

- Current conditions (interpolations of observed data, representative of 1950-2000)
- Future conditions: downscaled global climate model (GCM) data from CMIP5 (IPPC Fifth Assessment)
- Past conditions (downscaled global climate model output)

CMIP5

Downscaled IPPC5 (CMIP5) data

The data available here are climate projections from global climate models (GCMs) for four representative concentration pathways (RCPs). These are the most recent GCM climate projections that are used in the Fifth Assessment IPCC report. The GCM output was downscaled and calibrated (bias corrected) using WorldClim 1.4 as baseline 'current' climate.

The data are available at different spatial resolutions (expressed as minutes or seconds of a degree of longitude and latitude): **10 minutes**, **5 minutes**, **2.5 minutes**, **30 seconds**. The variables included are monthly minimum and maximum temperature, precipitation, and 'bioclimatic' variables.

Bioclim

BIOCLIM

Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. These are often used in ecological niche modeling (e.g., BIOCLIM, GARP). The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). A quarter is a period of three months (1/4 of the year).

They are coded as follows:

BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (* 100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

CMIP5 30-seconds

Downscaled IPPC5 (CMIP5) data at 30 seconds resolution

This page has the data at 30-seconds (of a longitude/latitude degree) spatial resolution (this is about 900 m at the equator). Other spatial resolutions are available.

The data available here are climate projections from GCMs that were downscaled and calibrated (bias corrected) using WorldClim 1.4 as baseline 'current' climate. The file format is GeoTIFF.

Greenhouse gas scenarios: four representative concentration pathways (RCPs)
Time periods: 2050 (average for 2041-2060) and 2070 (average for 2061-2080)
Variables:
tn - monthly average minimum temperature (degrees C * 10)
tx - monthly average maximum temperature (degrees C * 10)
pr - monthly total precipitation (mm)
bc - 'bioclimatic' variables

2050

GCM	code	rcp26	rcp45	rcp60	rcp85
ACCESS1-0 (#)	AC		tn, tx, pr, bi		tn, tx, pr, bi
BCC-CSM1-1	BC	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
CCSM4	CC	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi
CESM1-CAM5-1-FV2	CE		tn, tx, pr, bi		
CNRM-CM5 (#)	CN	tn, tx, pr, bi	tn, tx, pr, bi		tn, tx, pr, bi
GFDL-CM3	GF	tn, tx, pr, bi	tn, tx, pr, bi		tn, tx, pr, bi
GFDL-ESM2G	GD	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	
GISS-E2-R	GS	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi	tn, tx, pr, bi

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  - CRCM+CGCM3
  - ECP2+GFDL
  - HRM3+GFDL
  - HRM3+HadCM3
  - MM5I+CCSM
  - MM5I+HadCM3 NEW!
  - RCM3+CGCM3
  - RCM3+GFDL
  - WRFG+CCSM
  - WRFG+CGCM3

SPONSORS

Data Tables

NARCCAP data is organized into groups based on its spatial and temporal structure: 2-D vs 3-D, daily vs 3-hourly, etc. The groups are listed in the table below. Each variable name links to the corresponding description in the CF Standard Name Table.

Table 1: Daily fields (2-D)

Var.	Long Name	Units	Notes
sic	Daily Average Sea-ice Fraction	1	
spdmax	Maximum Daily 10-Meter Wind Speed	m s-1	
tasmax	Maximum Daily Surface Air Temperature	K	
tasmin	Minimum Daily Surface Air Temperature	K	

Table 2: Primary 3-hourly surface fields (2-D)

Var.	Long Name	Units	Notes
huss	Surface Specific Humidity	kg kg-1	instantaneous
pr	Precipitation	kg m-2 s-1	average
ps	Surface Pressure	Pa	instantaneous
rsds	Surface Downwelling Shortwave Radiation	W m-2	average, positive down
tas	Surface Air Temperature	K	instantaneous
uas	Zonal Surface Wind Speed	m s-1	instantaneous, positive east
vas	Meridional Surface Wind Speed	m s-1	instantaneous, positive north

Table 3: Additional 3-hourly fields (2-D)

Var.	Long Name	Units	Notes
clt	Total Cloud Fraction	1	average

Thanks!