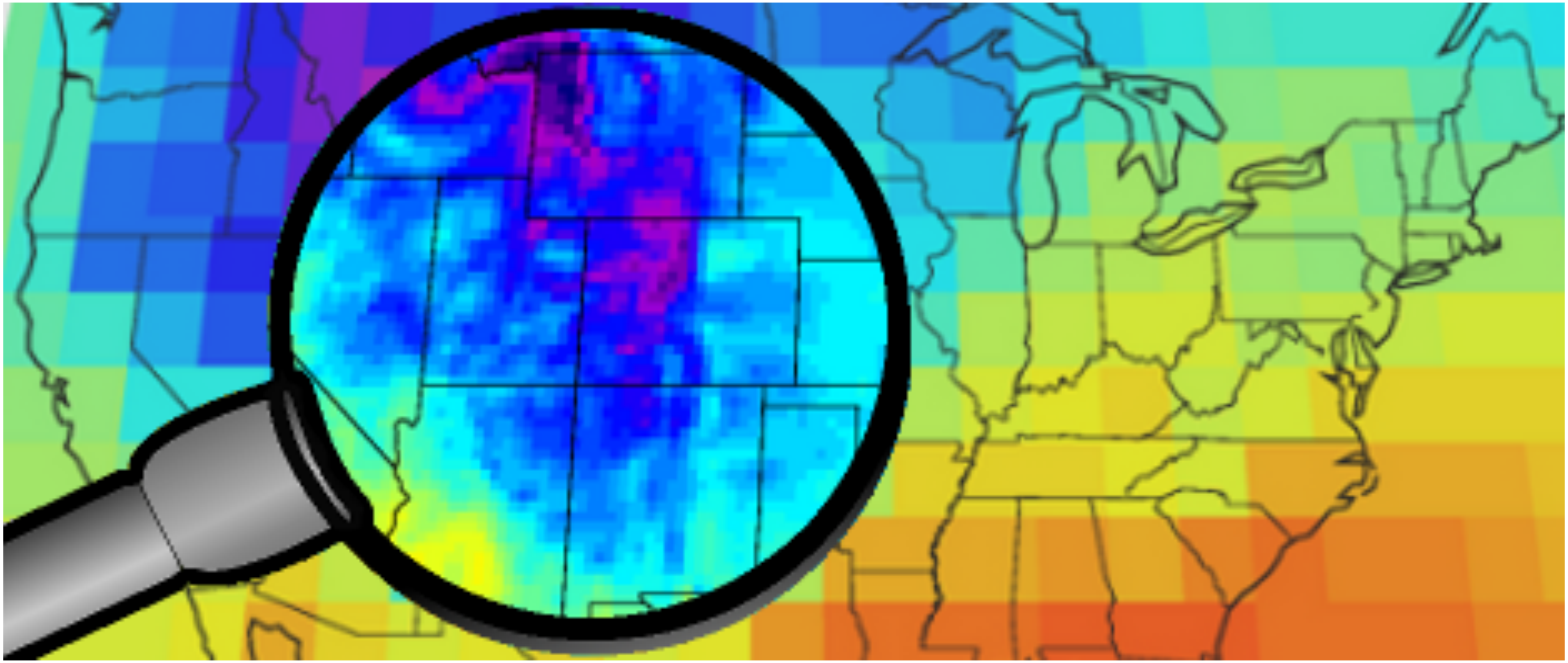
Dynamic Downscaling: Issues and Considerations

Ben Kirtman

University of Miami - RSMAS



Issues and Considerations

- **Regional Thinking**
  - Efficacy/Value Depends on Physical Environment and Variables of Interest
- **There will always be trade-offs between "accuracy" and "credibility"**
- **Methods: Statistical, Global, Global High Resolution, Telescoping Grids, Regional Climate Models**
  - Regional Models Cannot Correct Profound Errors in Large-Scale Forcing (Global Model) – Bias Corrections Necessary
  - Domain Selection – Nesting – Big-Brother Experiment
  - Temporal Resolution
- **Robust Estimates of Uncertainty Required**
  - RCM formulation, Global Model Formulation, External Forcing, NATURAL VARIABILITY
- **Use of Climate Information needs to Drive Modeling Design**
  - Need to do the "Real" Prediction Problem - Verification
- **Much Room for Hybrid Statistical – Dynamic Approaches**

Issues and Considerations

- **Regional Thinking**
  - Efficacy/Value Depends on Physical Environment and Variables of Interest

Methods: Statistical, Global, Global High Resolution, Telescoping Grids, Regional Climate Models

Regional Models Cannot Correct Profound Errors in Large-Scale Forcing (Global Model) – Bias Corrections Necessary

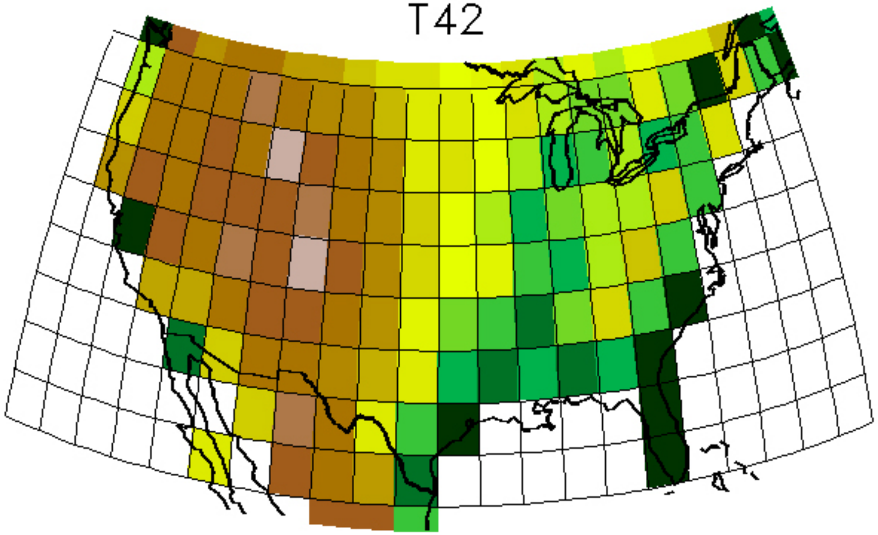
Domain Selection – Nesting – Big-Brother Experiment

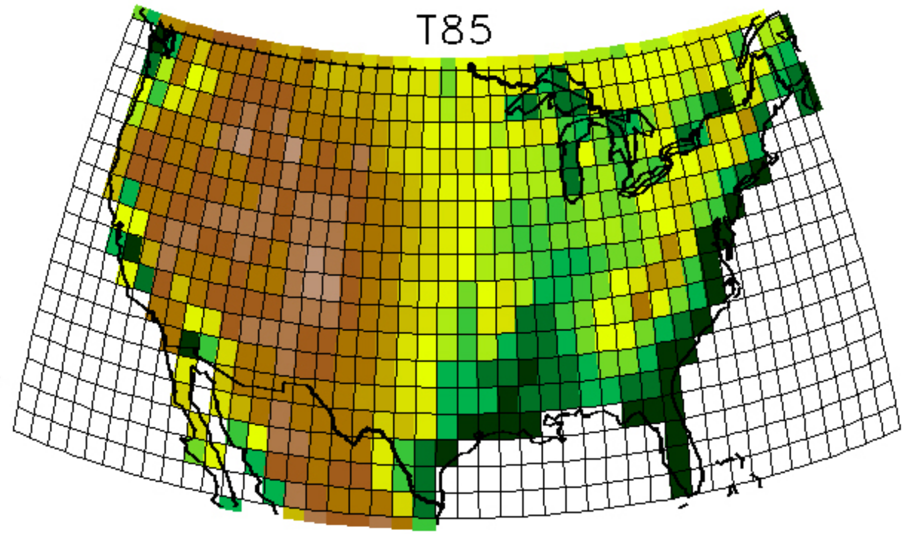
VARIABILITY

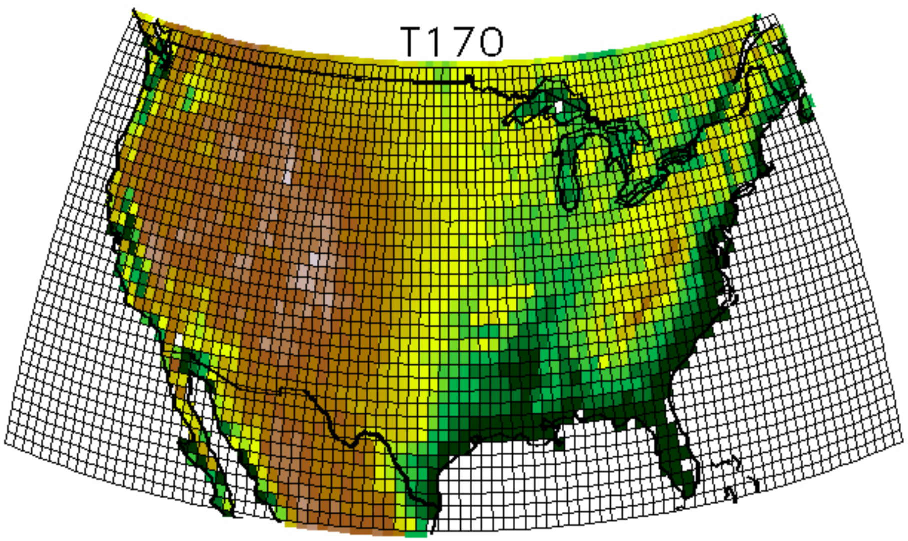
- **Use of Climate Information needs to Drive Modeling Design**
  - Need to do the "Real" Prediction Problem - Verification
- **Much Room for Hybrid Statistical – Dynamic Approaches**

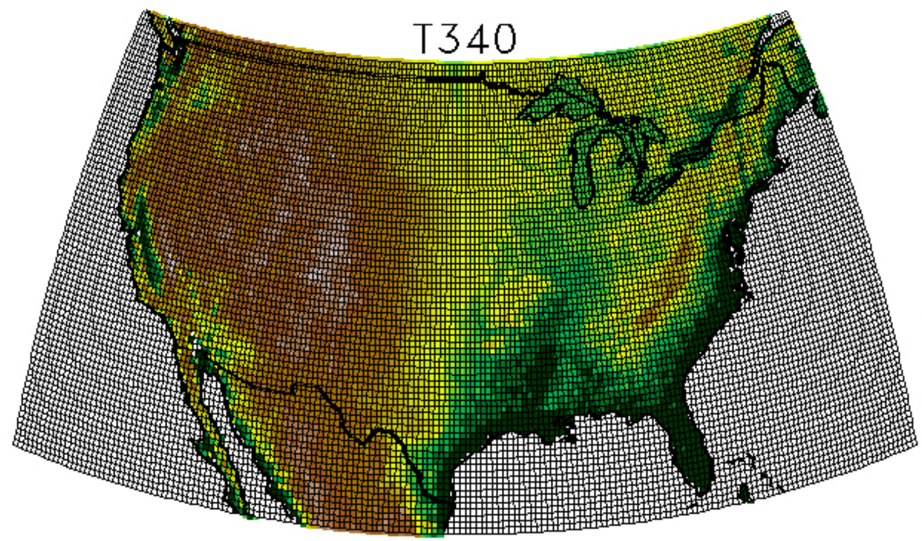
Global Models

AR4-CMIP3 | **AR5-CMIP5**







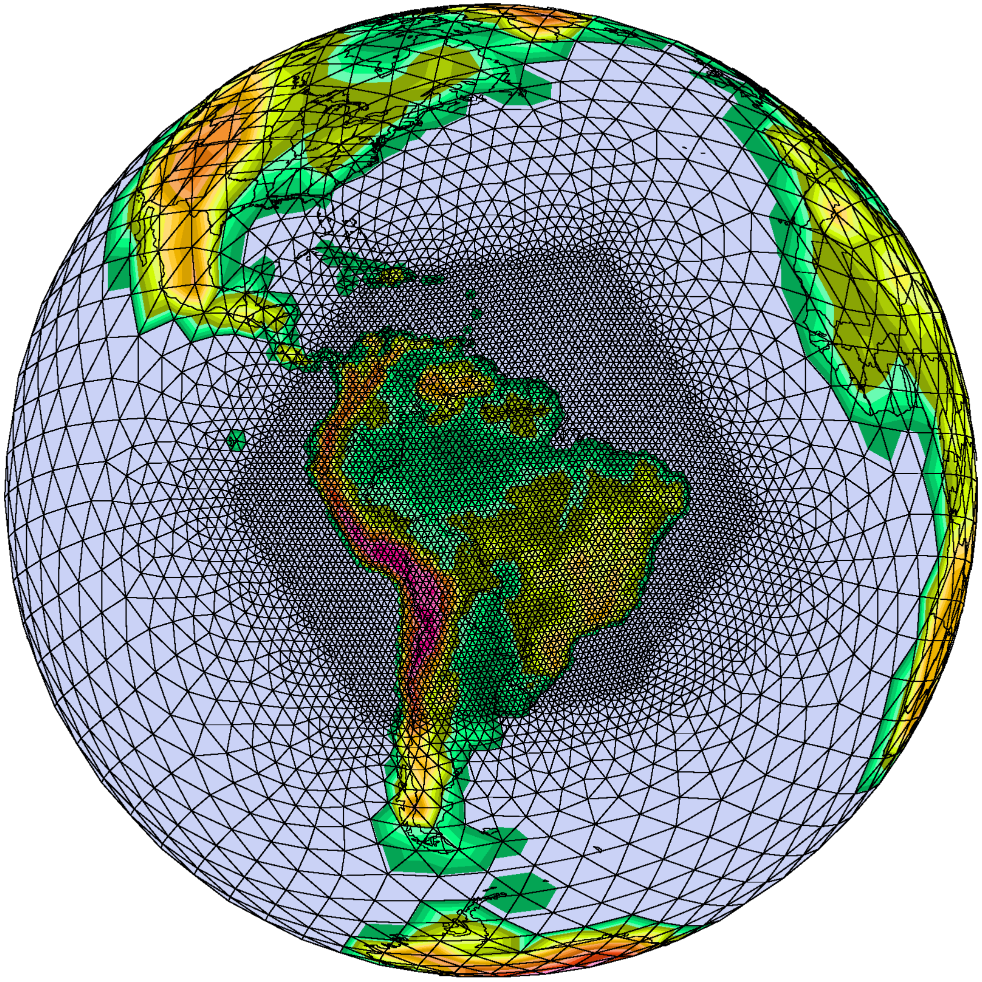


Seasonal Prediction: NMME

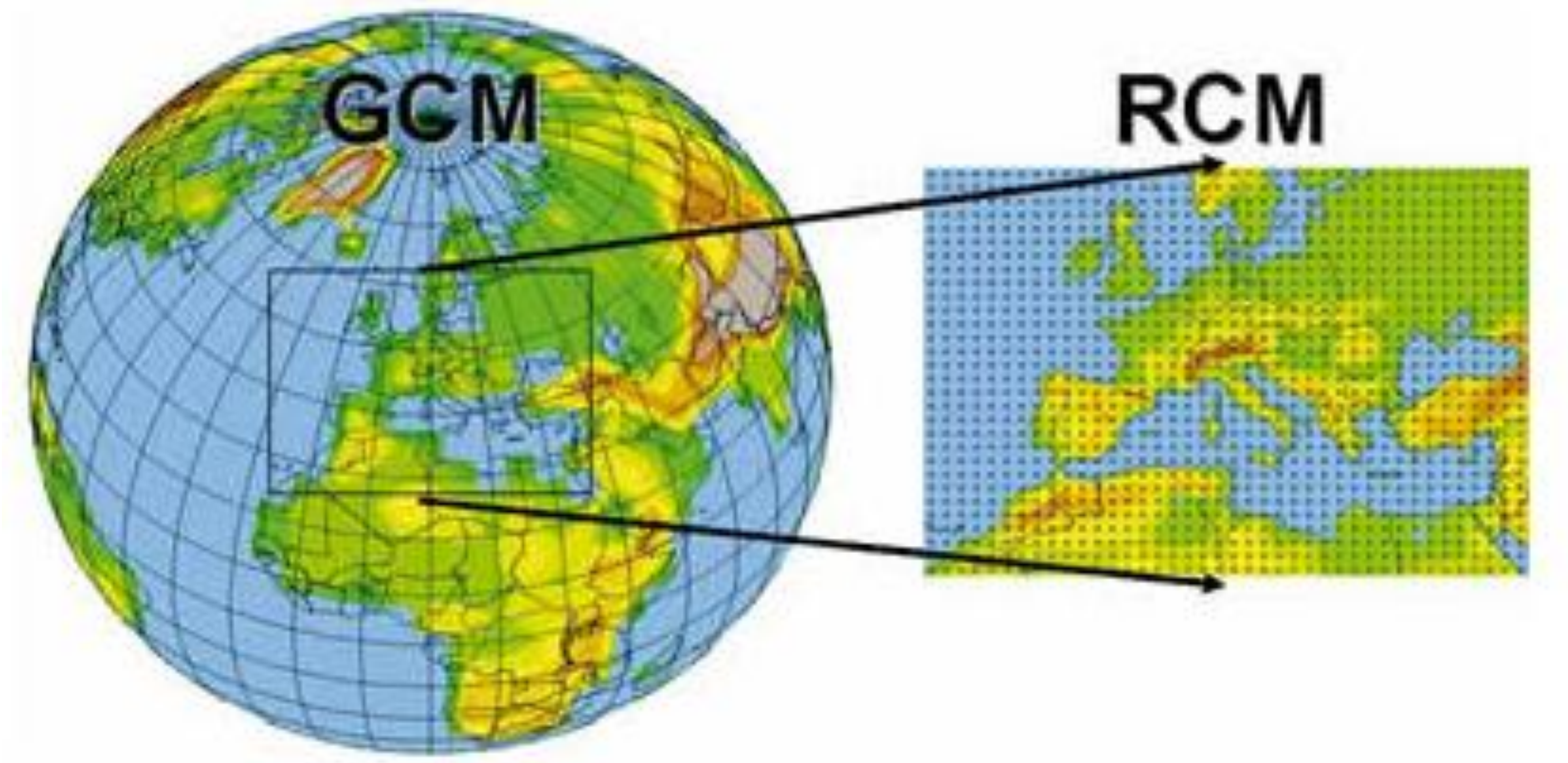
Doable Today: Seasonal + Climate Change

Telescoping Grids

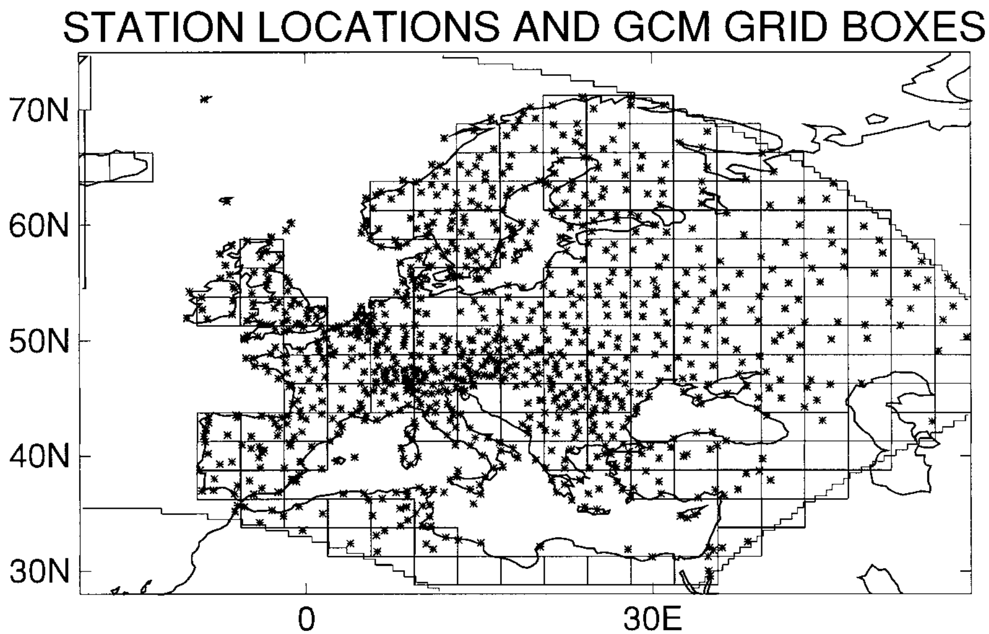
- **Mathematically and Computationally Elegant**
- **Regional Domain Affects Global Domain**
  - **Physical Process Inconsistency**
- **Domain/Boundary Selection Issues**

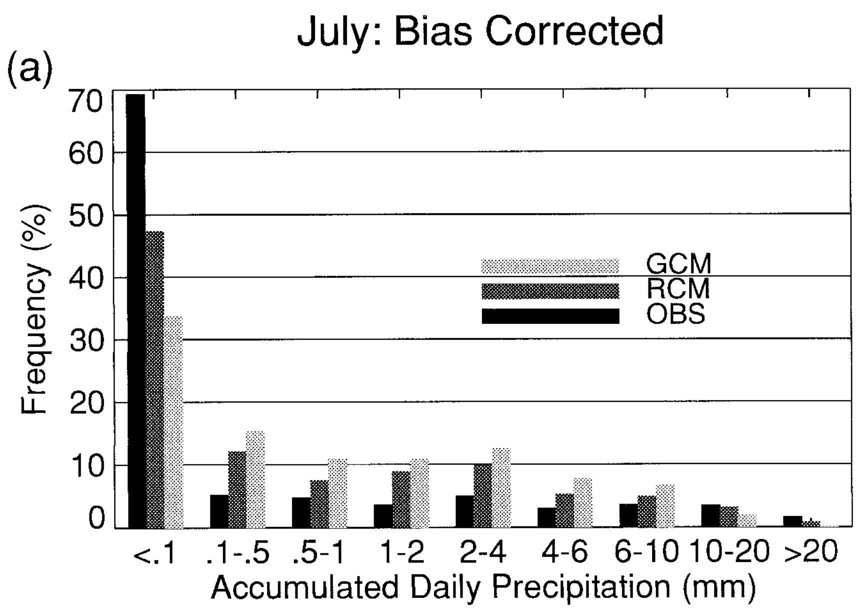


Regional Climate Models



- Computationally Efficient – Easy to Implement
- Regional Scale Model Physics Distinct
- Domain/Boundary/Nesting Selection Issues
- 25-50 km … 2-10 km

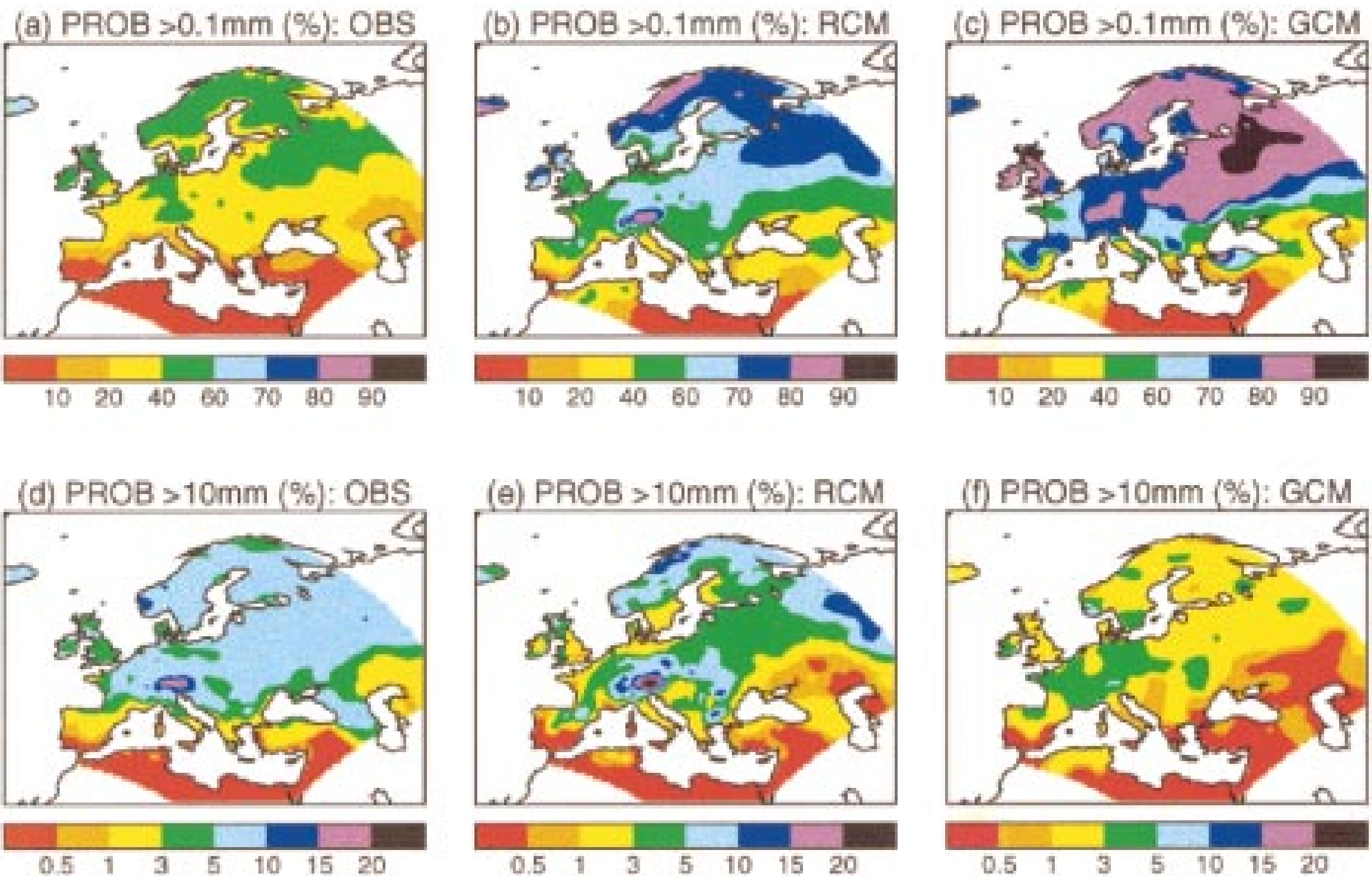




Murphy 1999

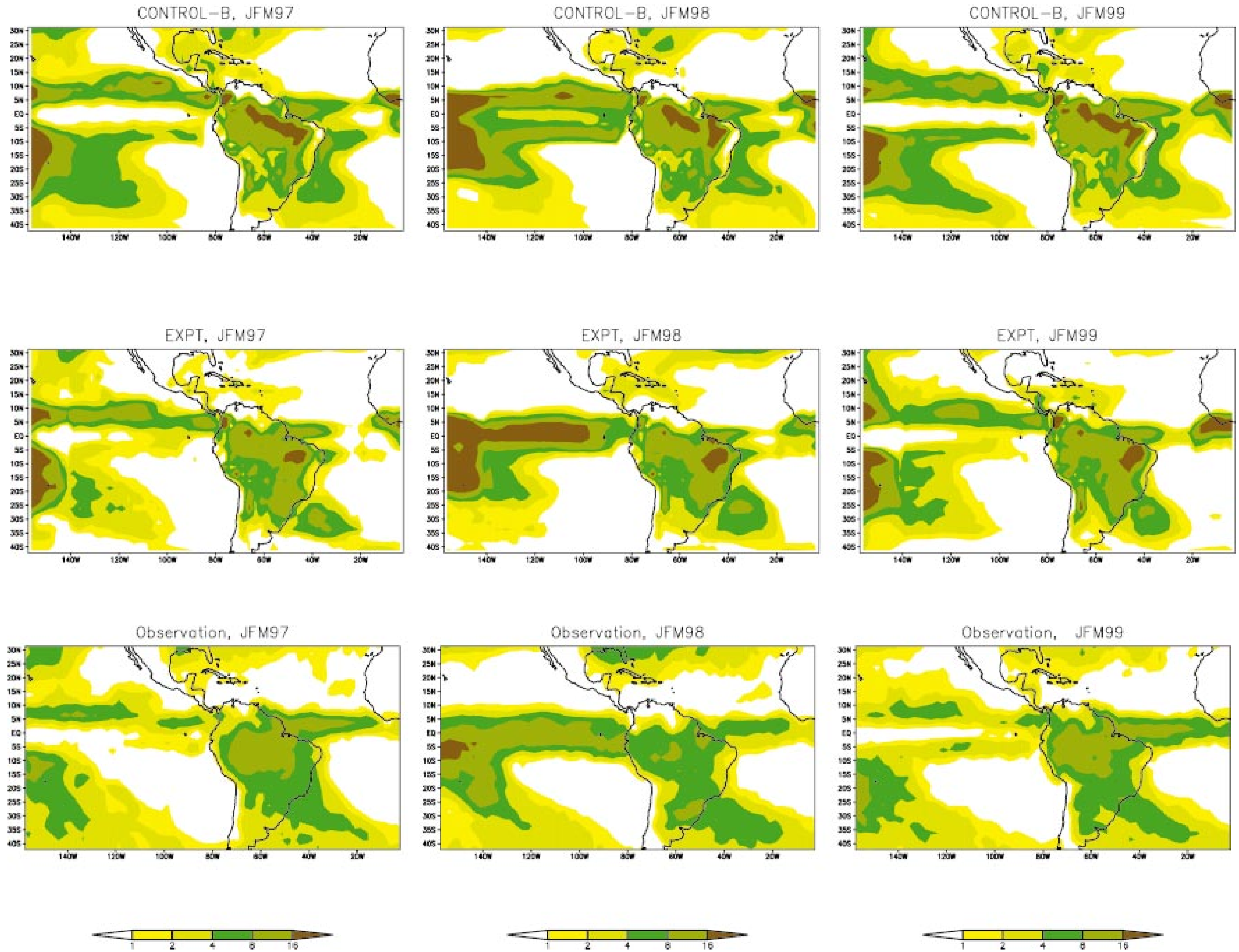
- **Compares Statistical Downscaling vs. Dynamical**
  - GCM has observed climate
  - GCM+RCM
  - Pure Stats
- **Statistical Methods as Good as Either Dynamical Technique**
- **RSM has More "Credibility" but not Necessarily More Skill**
  - Higher Frequencies, Rainfall Distribution
- **Climate Change?**

Wet Day Probabilities



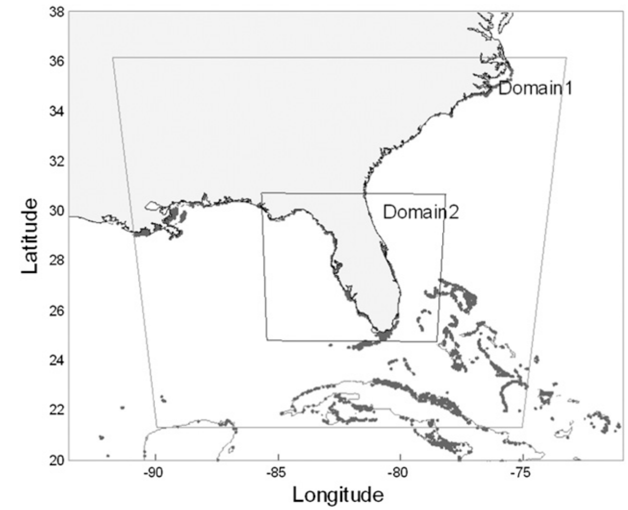
Murphy 1999

Garbage in – Garbage out

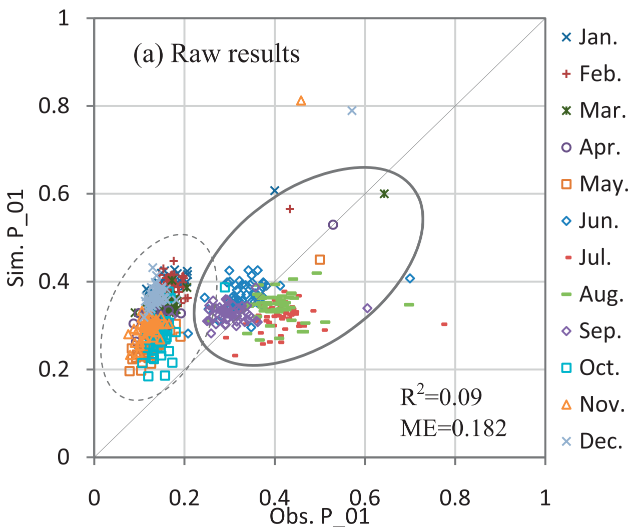


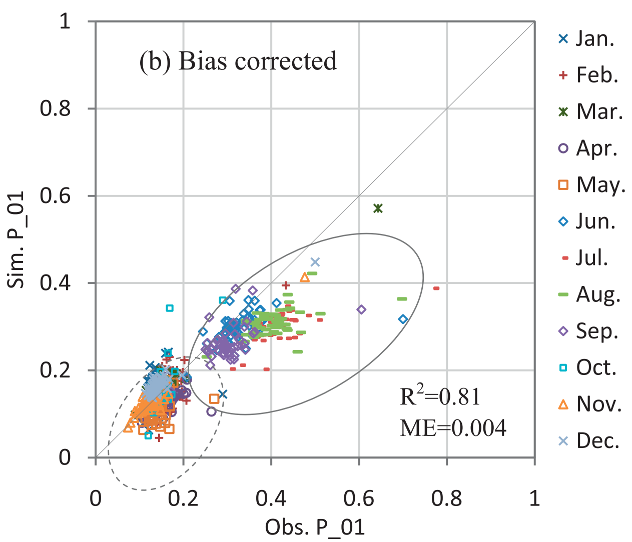
Misra, Dirmeyer and Kirtman 2003

Hwang et al 2011

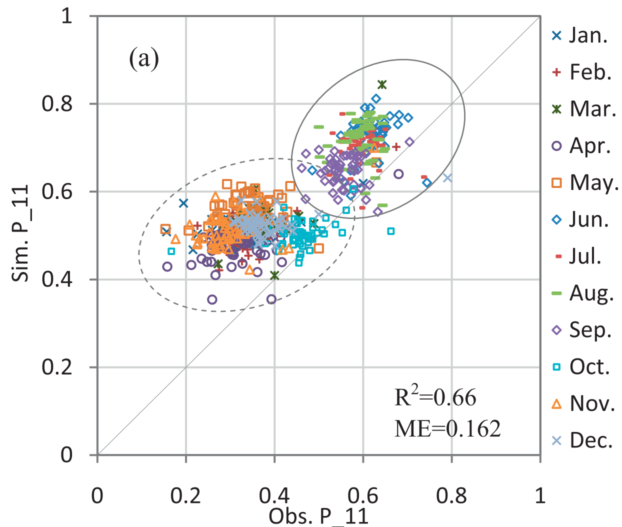


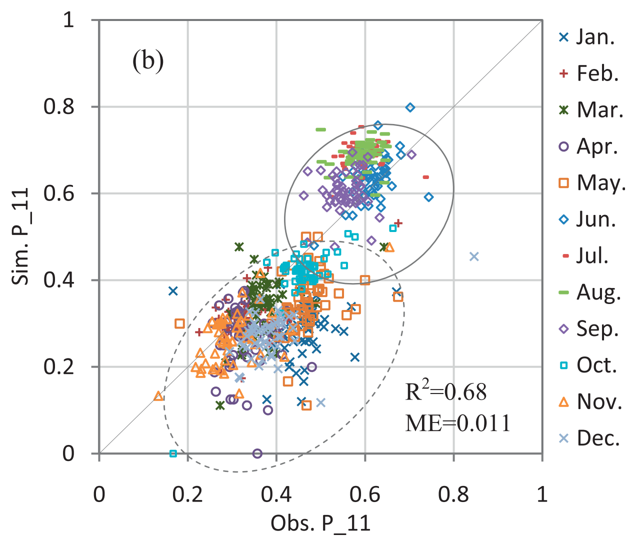
Dry - Wet



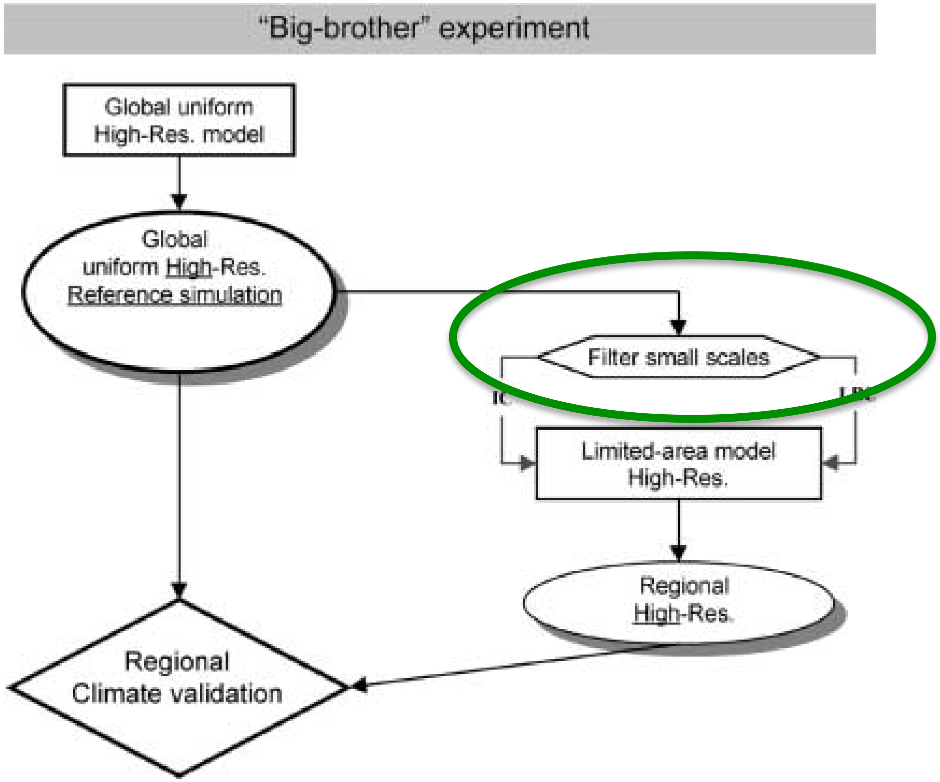


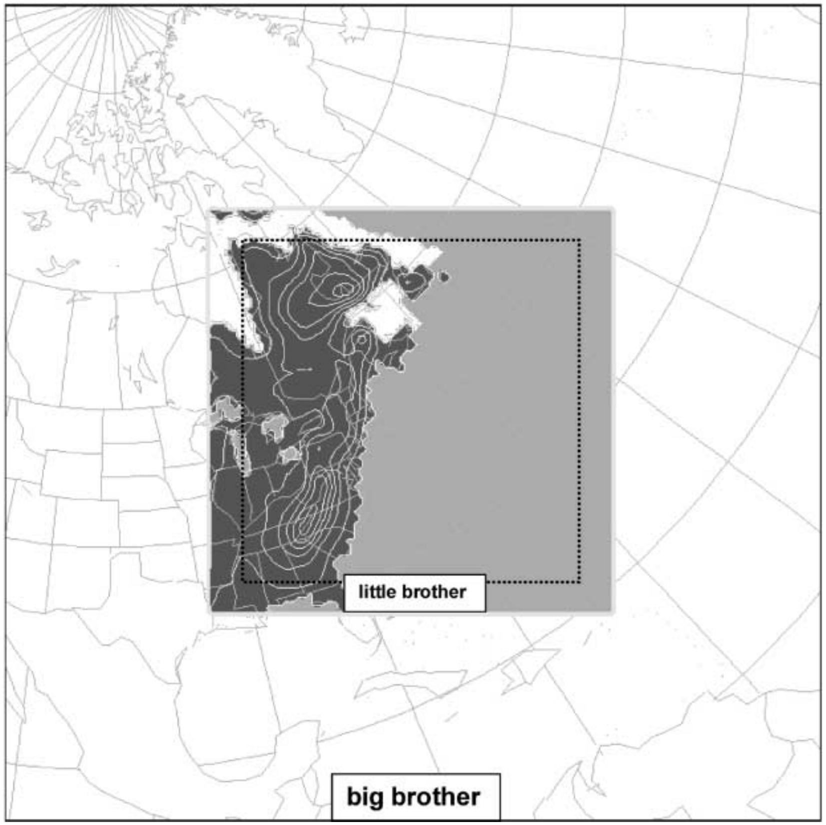
Wet - Wet





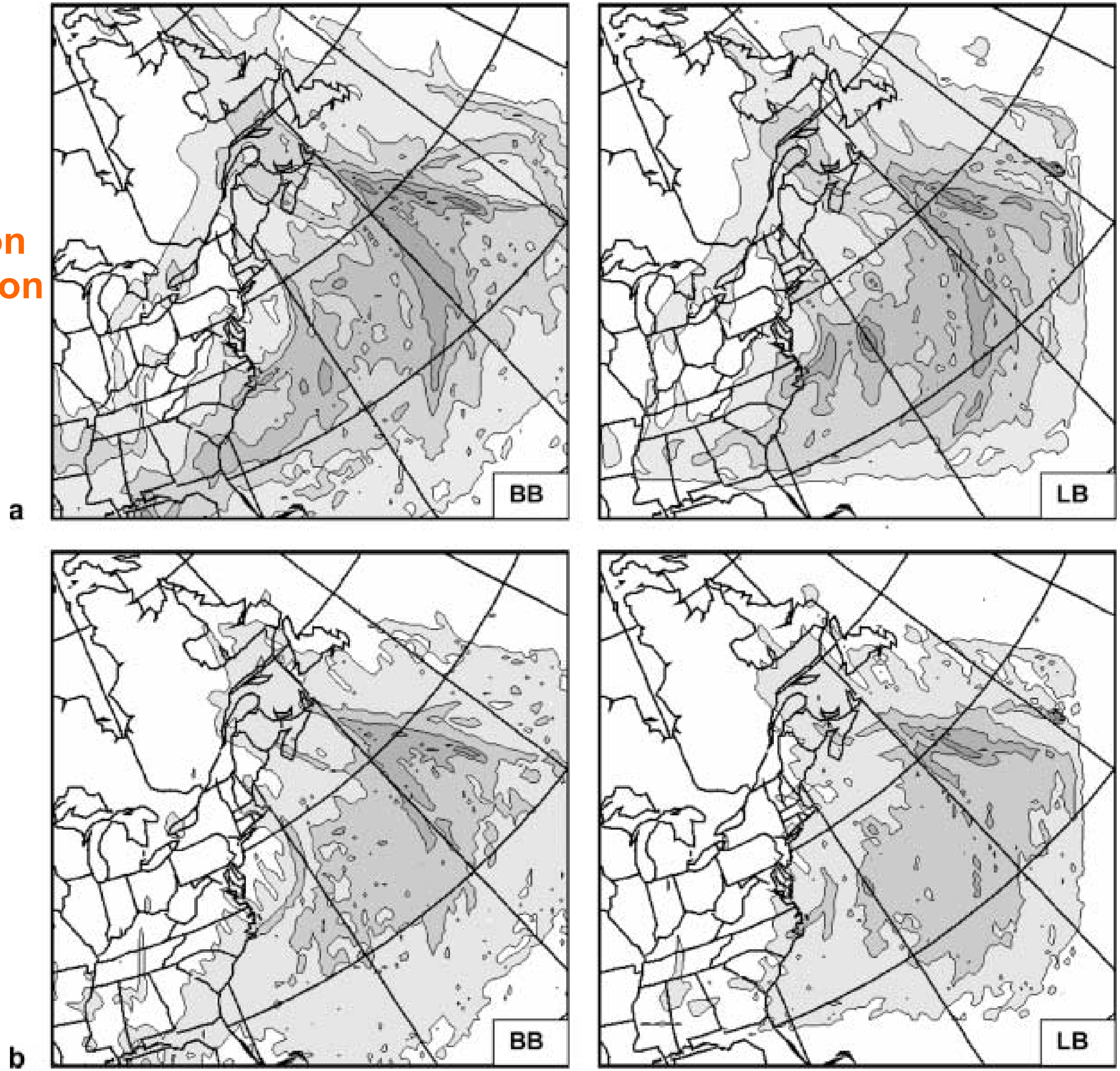
Denis, Laprise et al: Big-Brother Experiment





Total Precipitation Standard Deviation

“Small Scale” Precipitation Standard Deviation



Issues and Considerations

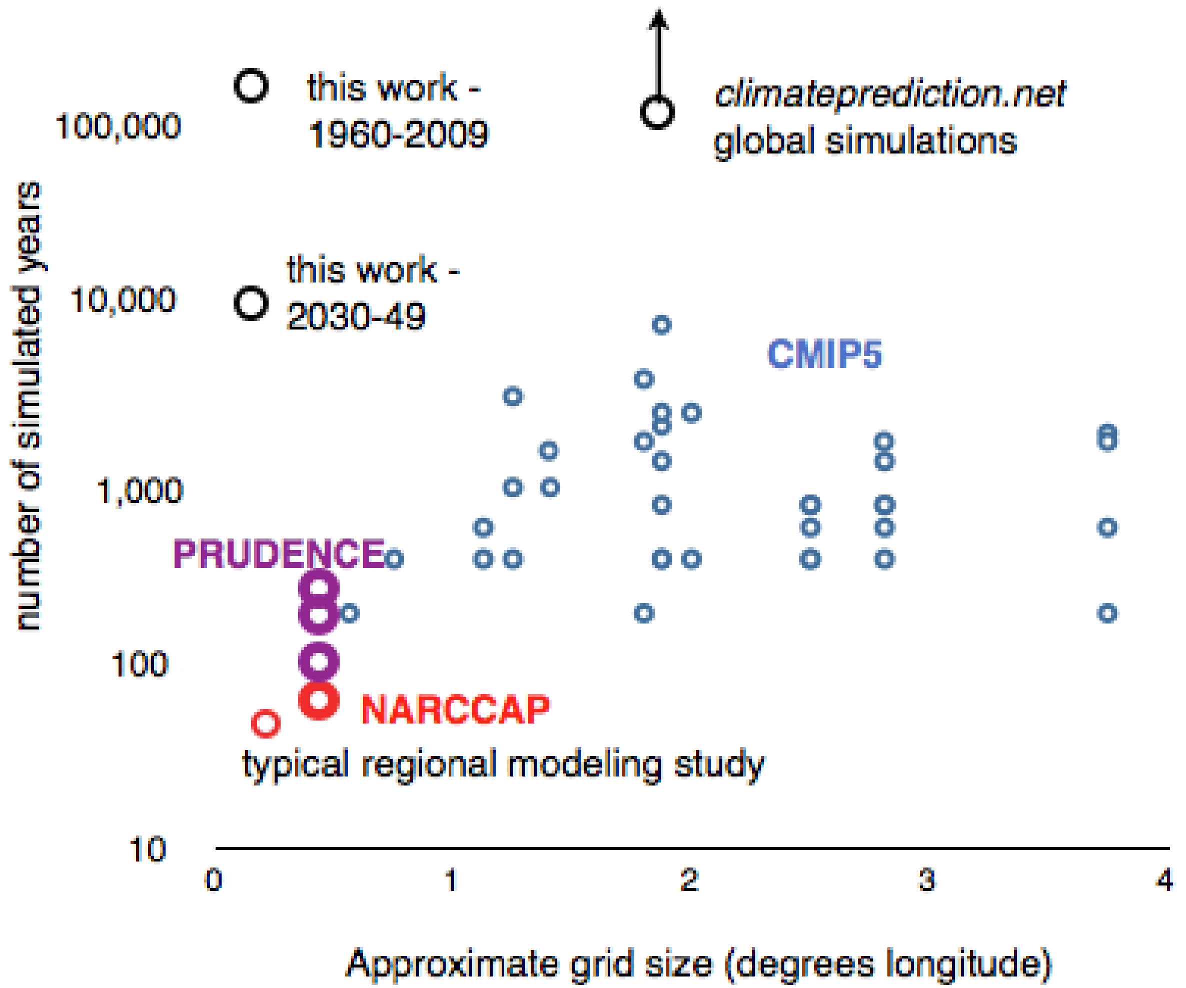
- **Regional Thinking**
  - Efficacy/Value Depends on Physical Environment and Variables of Interest
- **There will always be trade-offs between “accuracy” and “credibility”**
- **Methods: Statistical, Global, Global High Resolution, Telescoping**

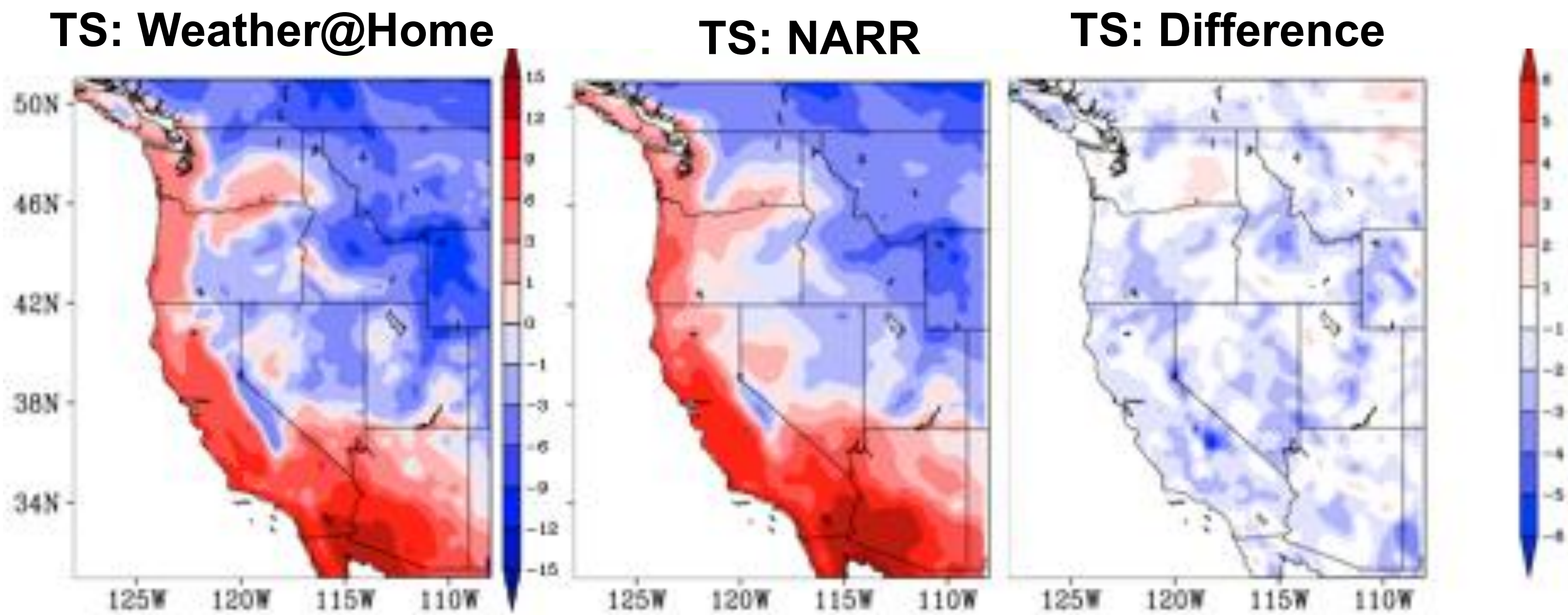
Robust Estimates of Uncertainty Required

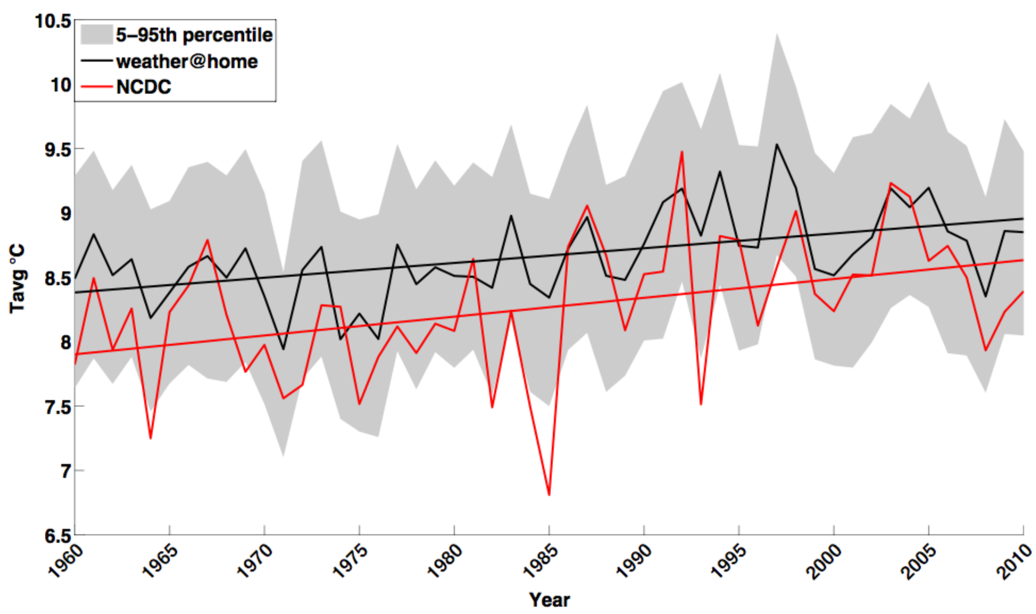
RCM formulation, Global Model Formulation, External Forcing, NATURAL VARIABILITY

- **Use of Climate Information needs to Drive Modeling Design**
  - Need to do the “Real” Prediction Problem - Verification
- **Much Room for Hybrid Statistical – Dynamic Approaches**

Mote et al. 2015: Weather@Home Quantifying Uncertainty

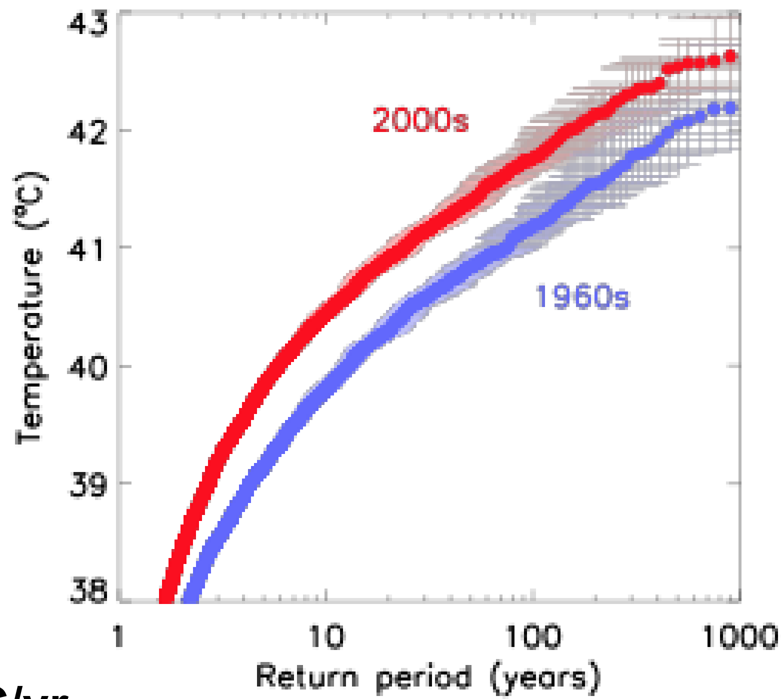




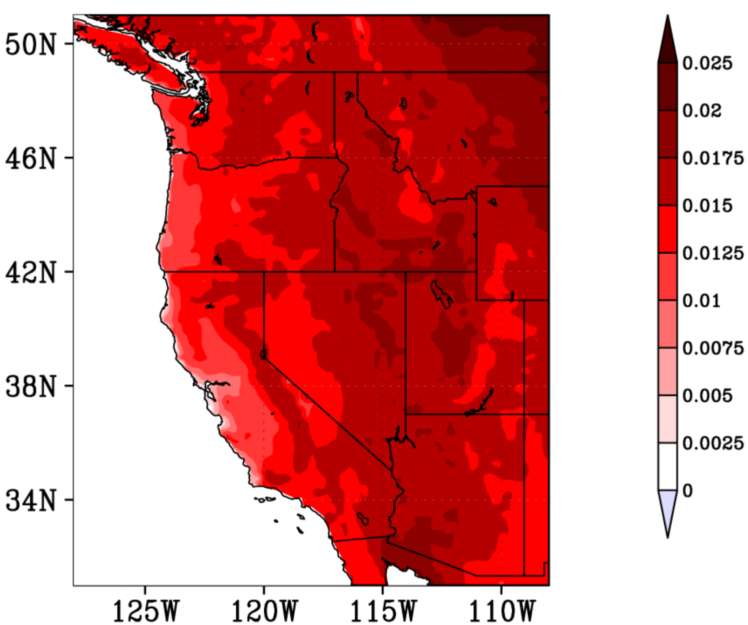


Mote et al. 2015

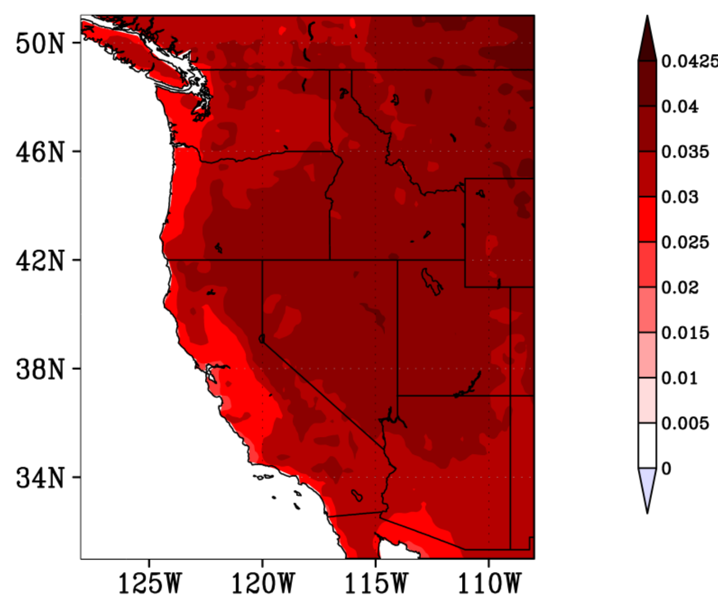
Mote et al. 2015



Ts Trend 1960-2009 C/yr



Ts Trend Future - Past C/yr



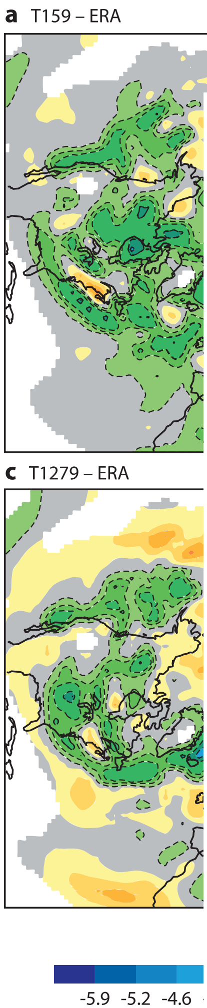
Global High Resolution Example: Athena Project

Table 1. Project Athena experiments.

	Resolution	Grid Size	# Cases	Time Period	Data Volume	Comments
NICAM		7 km	8*	103 days	639 TB	21 May - 31 Aug 2001-2009 * unable to complete 2003
IFS 13-month Hindcasts	T159	125 km	48	395 days	0.7 TB	1 Nov - 30 Nov (next year) 1960 - 2007
	T511	39 km			7 TB	
	T1279	16 km			41 TB	
	T2047	10 km	20		51 TB	
IFS 103-day Hindcasts	T159	125 km	9	102 days	0.03 TB	21 May - 30 Aug 2001 - 2009 (a la NICAM)
	T511	39 km			0.3 TB	
	T1279	16 km			2 TB	
	T2047	10 km			6 TB	
IFS 10-Member Ensembles (Summers)	T511	39 km	6	132 days	2.7 TB	21 May-30 Sep Selected years
	T1279	16 km			17 TB	
IFS 10-Member Ensembles (Winters)	T511	39 km	6	151 days	3.2 TB	1 Nov - 31 Mar Selected years
	T1279	16 km			20 TB	
IFS AMIP	T159	125 km	1	47 years	0.6 TB	1961 - 2007
	T1279	16 km			38 TB	
IFS Time Slice	T159	125 km	1	47 years	0.6 TB	2071 - 2117
	T1279	16 km			38 TB	
Total					874 TB	

Kinter et al. 2013

Cyclone Track Density



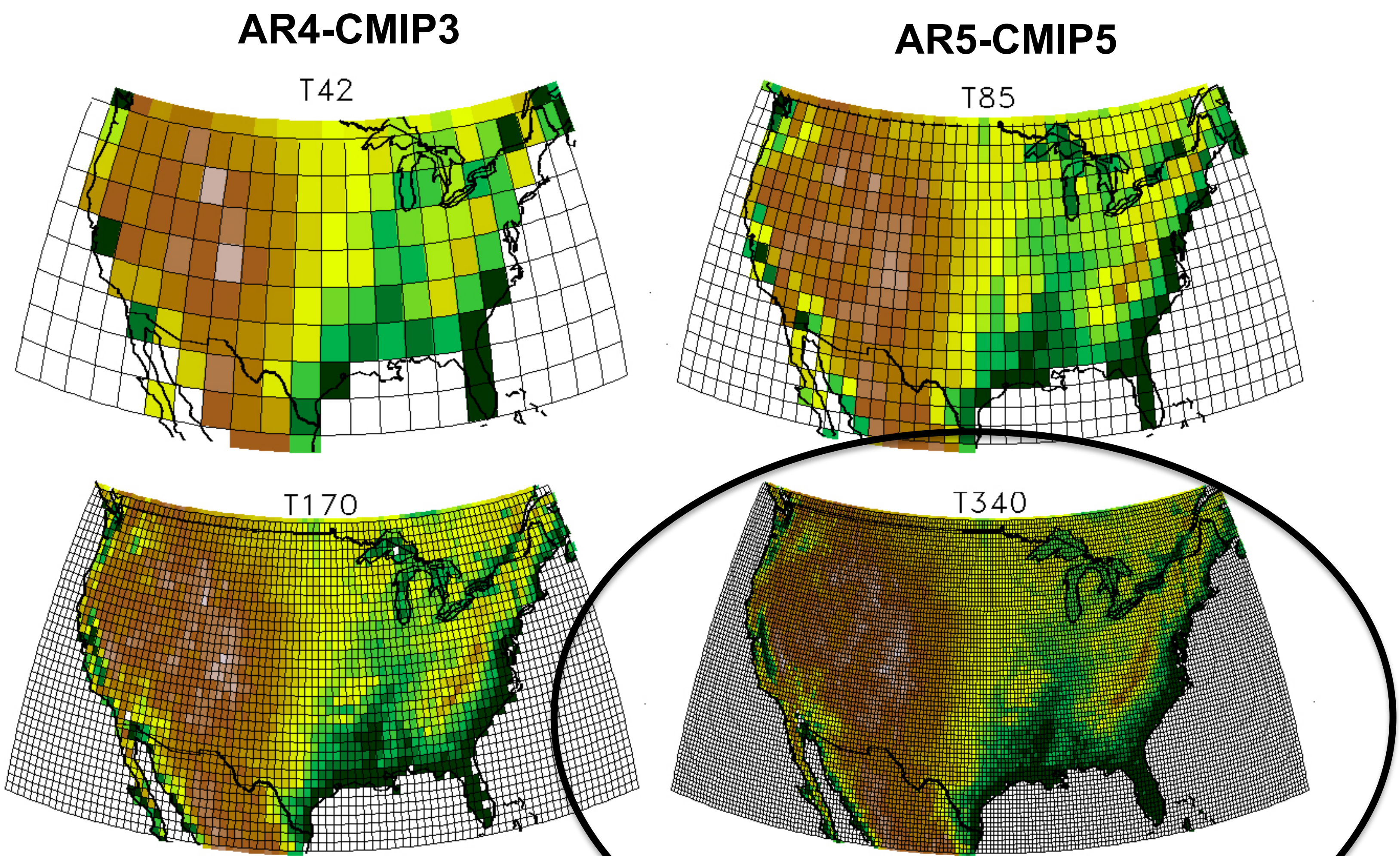
Tropical Cyclone Intensity

TABLE 3. Mean convective/large-scale precipitation (mm day^{-1}) integrated over different domains. Results are based on boreal winters (DJF) of the period 1989–2007 (1989–2006) for 13-month (AMIP style) integrations.

Region	T159	T511	T1279	T2047
13-month integrations				
15°S–15°N	3.54/1.03	3.57/1.13	3.52/1.23	3.46/1.29
20°–90°N	1.01/1.10	1.06/1.18	1.05/1.20	1.05/1.23
20°–90°S	1.21/1.10	1.18/1.29	1.17/1.35	1.17/1.39
AMIP-style integrations				
15°S–15°N	3.56/1.01	—	3.55/1.24	—
20°–90°N	1.04/1.10	—	1.08/1.20	—
20°–90°S	1.20/1.11	—	1.20/1.37	—

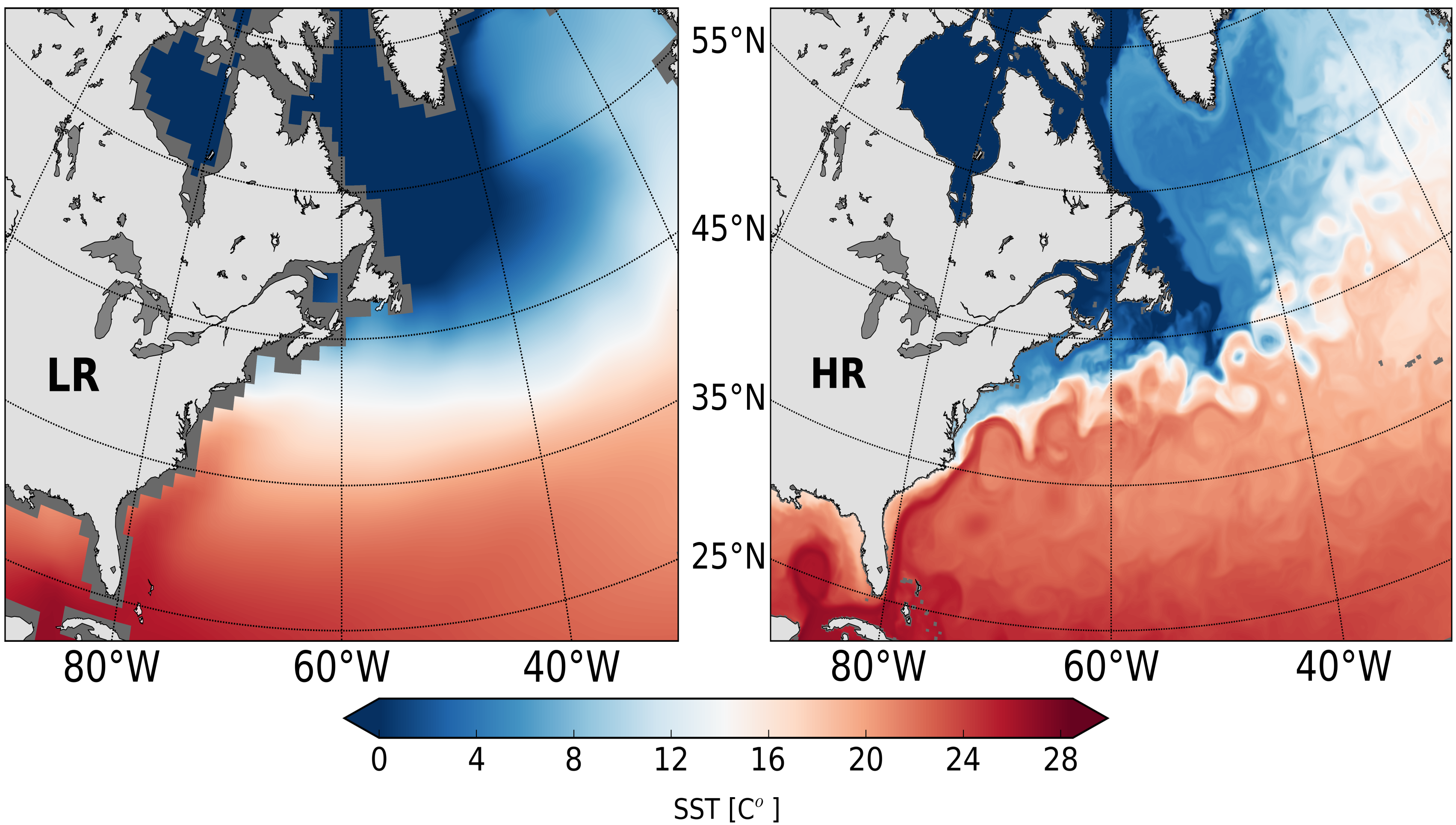
Kinter et al. 2013

Global High Resolution
Example: Resolving Ocean Eddies

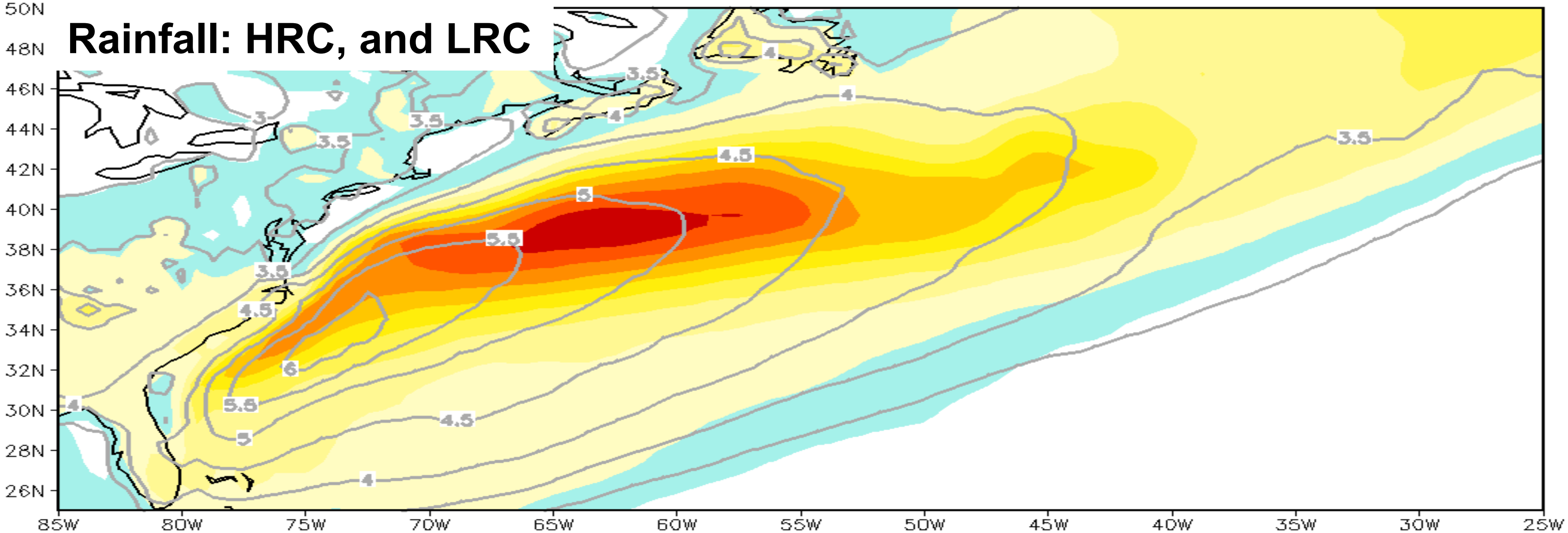


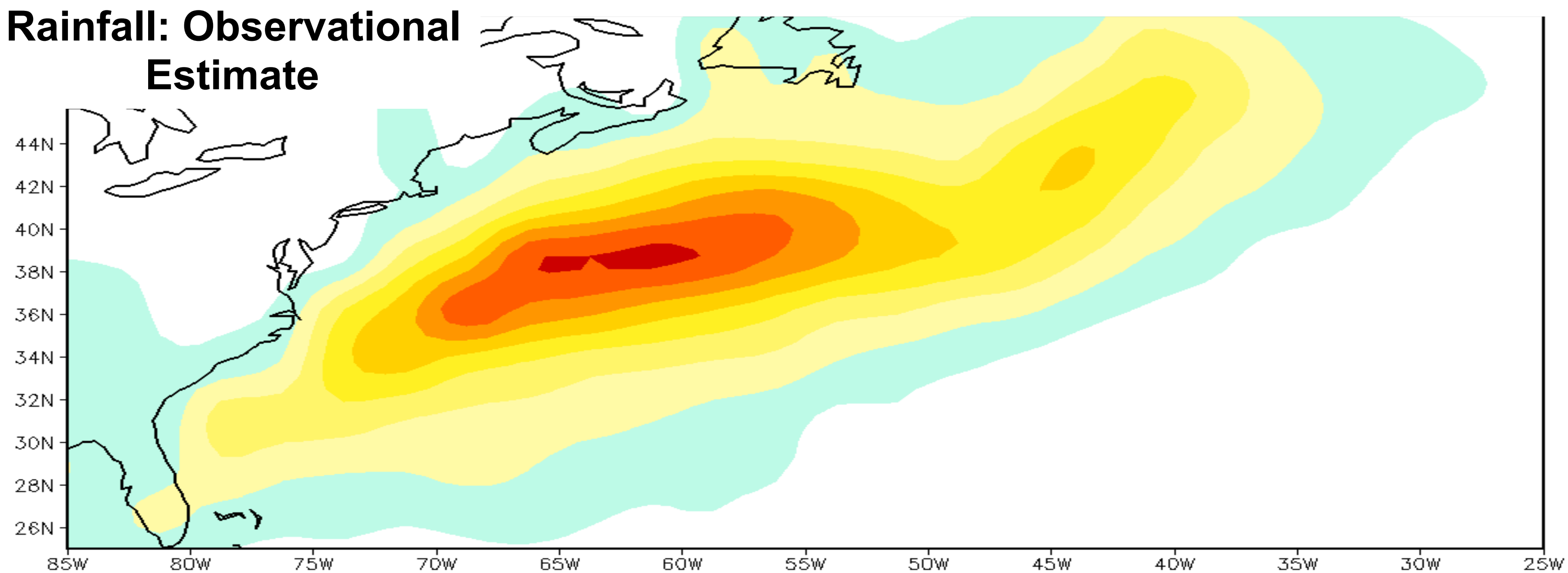
Seasonal Prediction: NMME **Doable Today: Seasonal + Climate Change**

50 km Atmos + 100 km Ocean **50 km Atmos + 10 km Ocean**



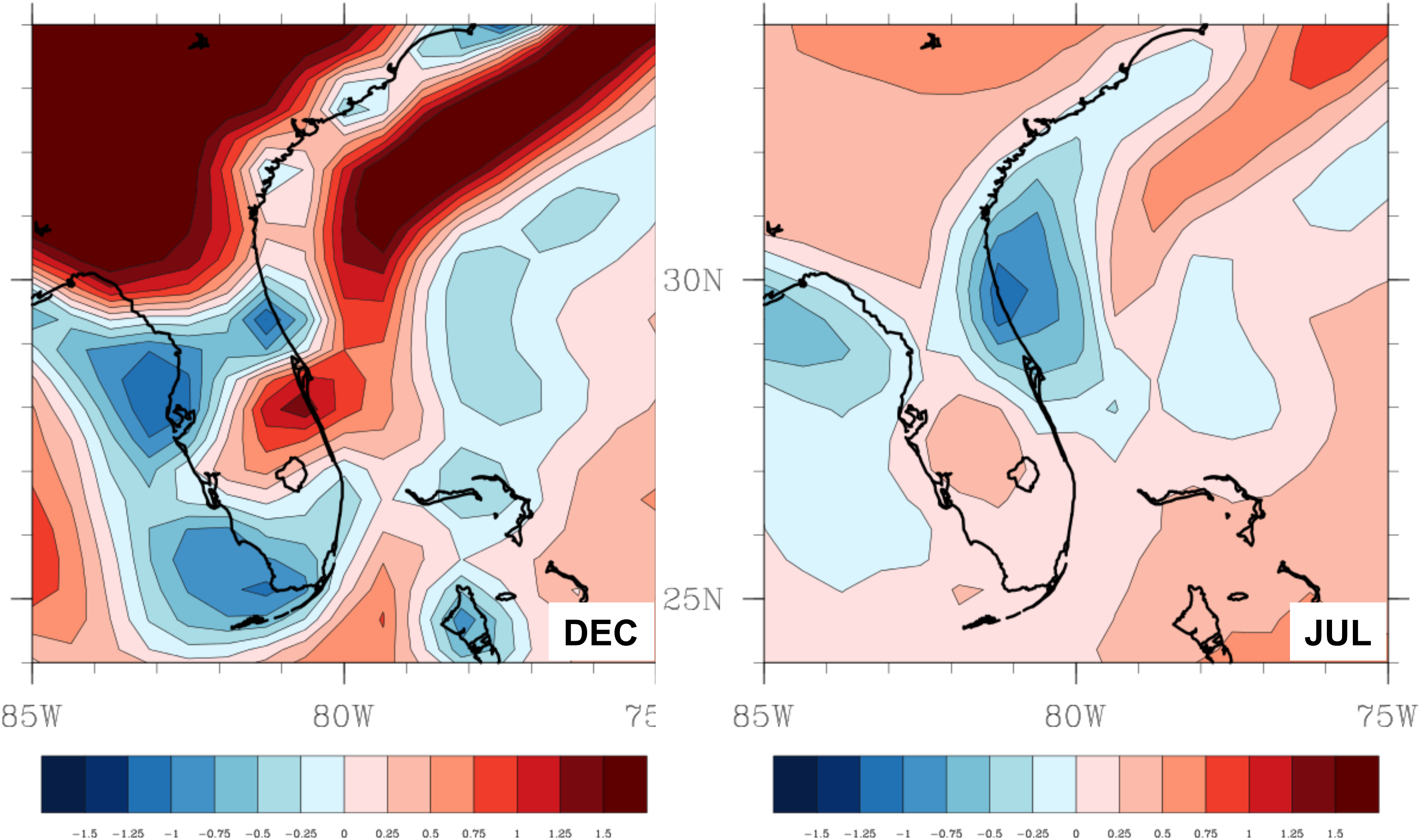
Kirtman et al. 2012



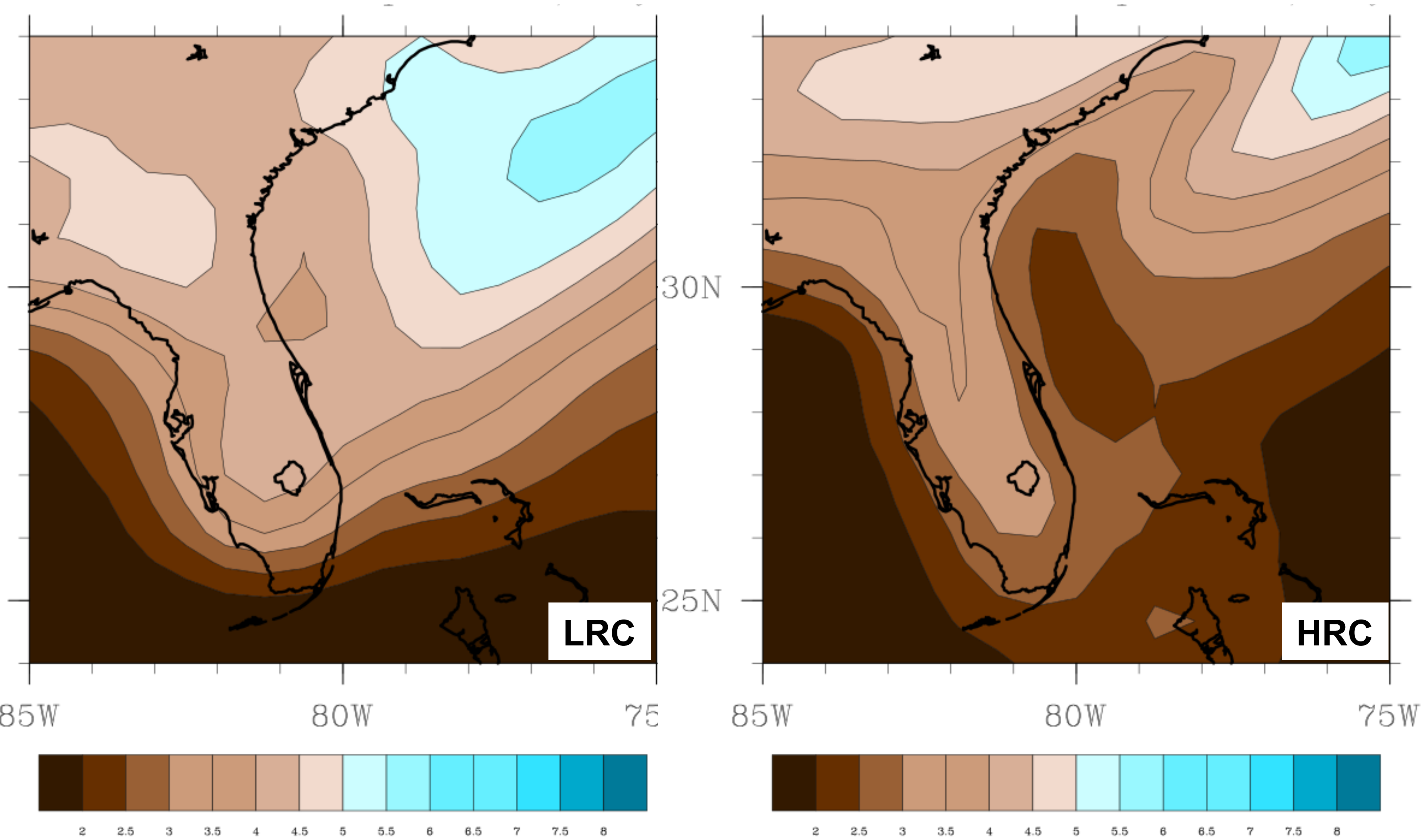


Kirtman et al. 2012

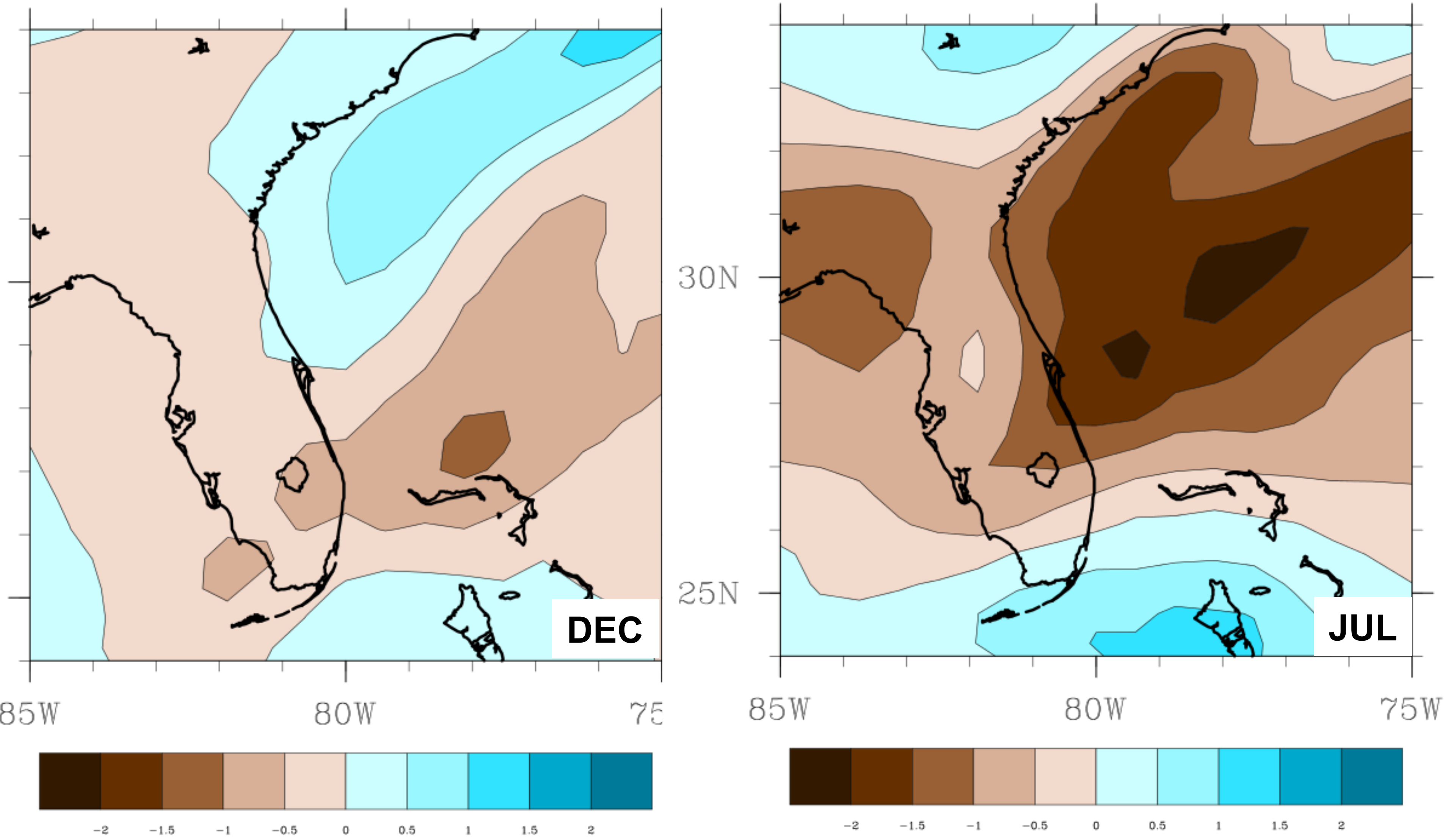
Climatological Surface Temperature Difference
HRC-LRC



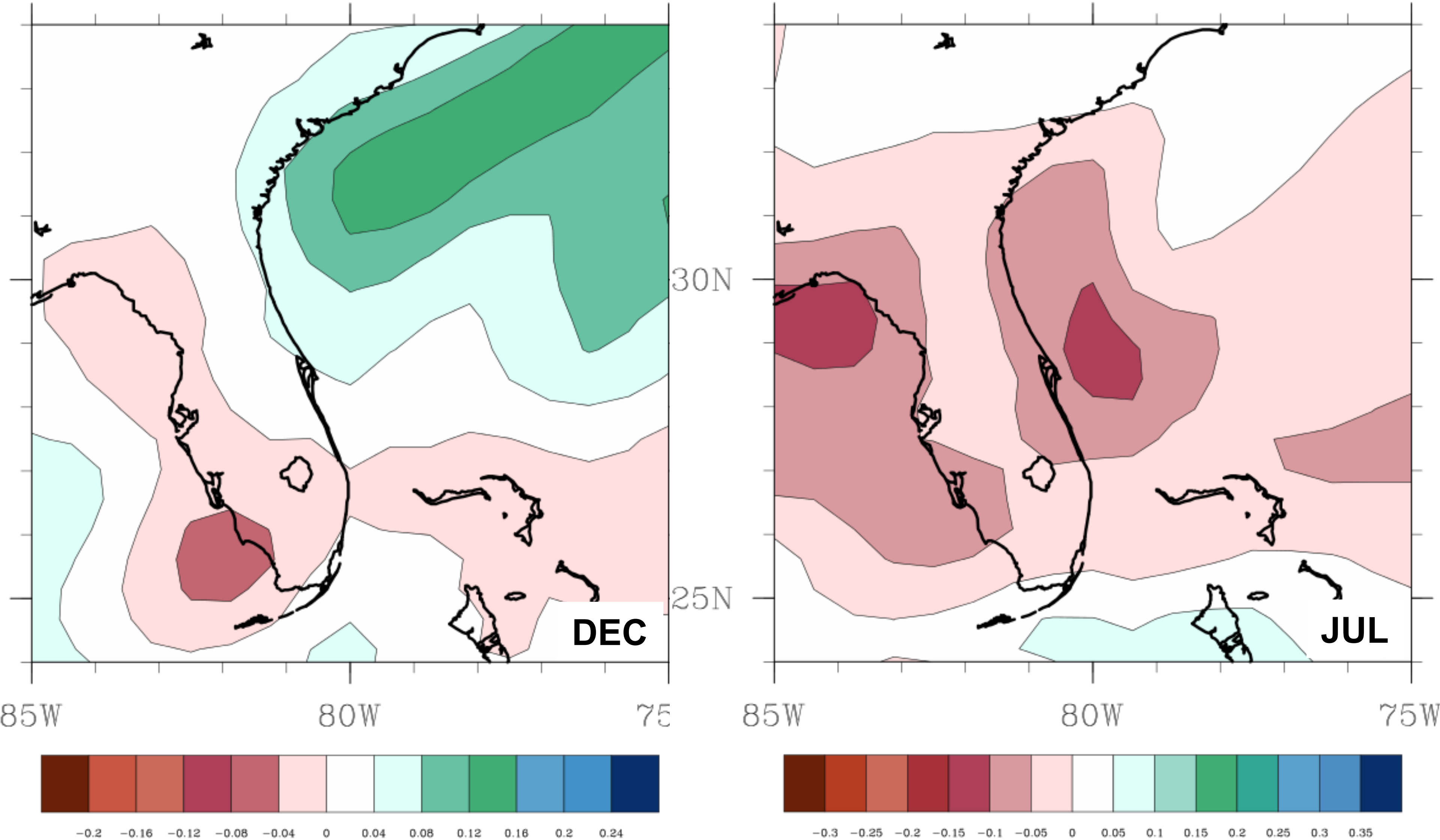
July Climatological Convective Precipitation
LRC vs. HRC



Climatological Convective Precipitation Difference HRC-LRC



Climatological Convective/Total Precipitation Difference HRC-LRC



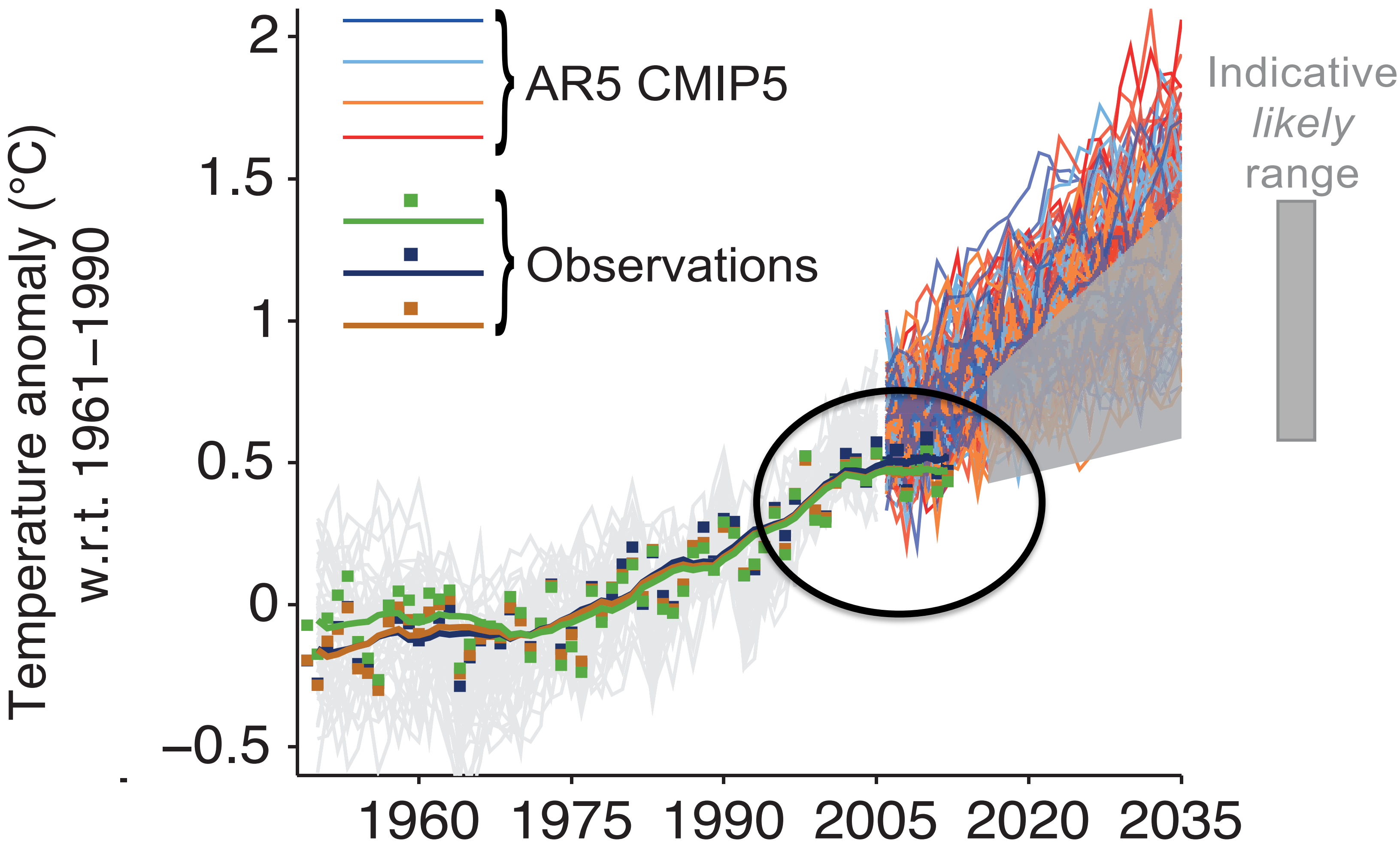
Issues and Considerations

- **Regional Thinking**
  - Efficacy/Value Depends on Physical Environment and Variables of Interest
- **There will always be trade-offs between "accuracy" and "credibility"**
- **Methods: Statistical, Global, <u>Global High Resolution</u>, Telescoping**

Robust Estimates of Uncertainty Required

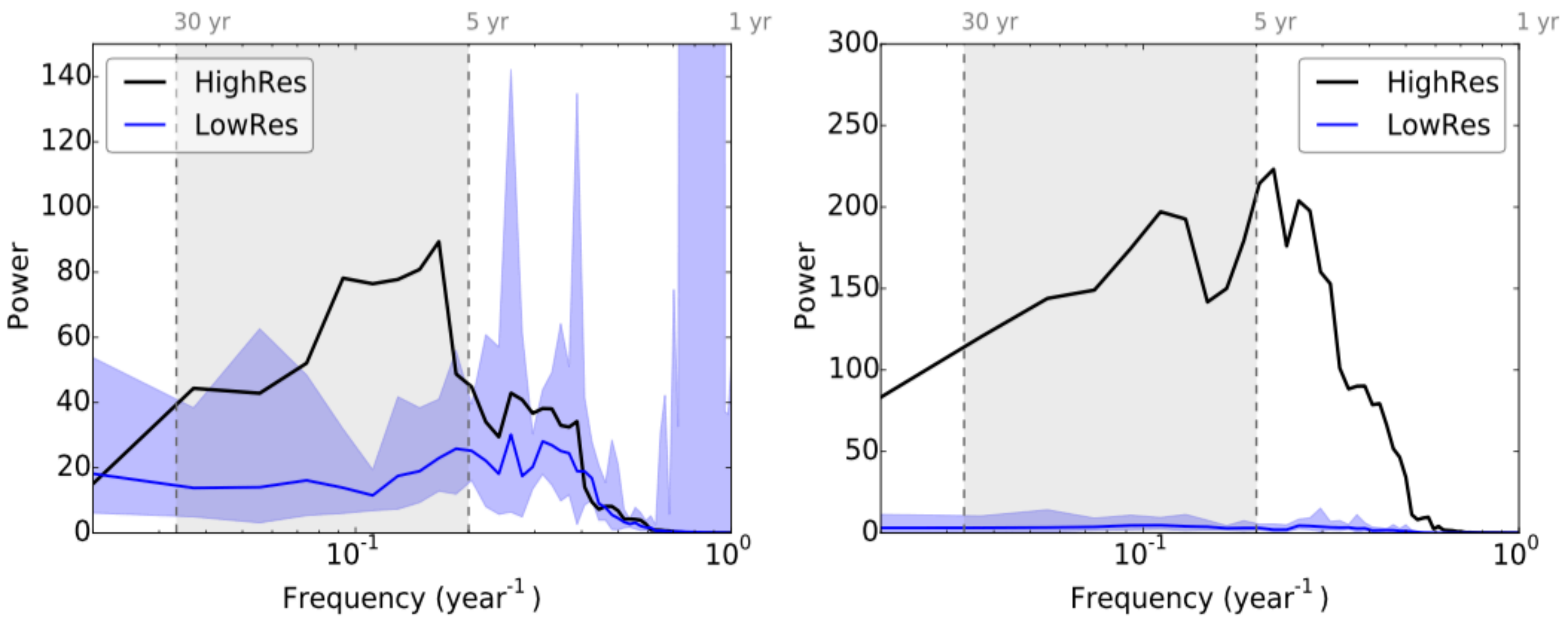
RCM formulation, Global Model Formulation, External Forcing, <u>NATURAL VARIABILITY</u>

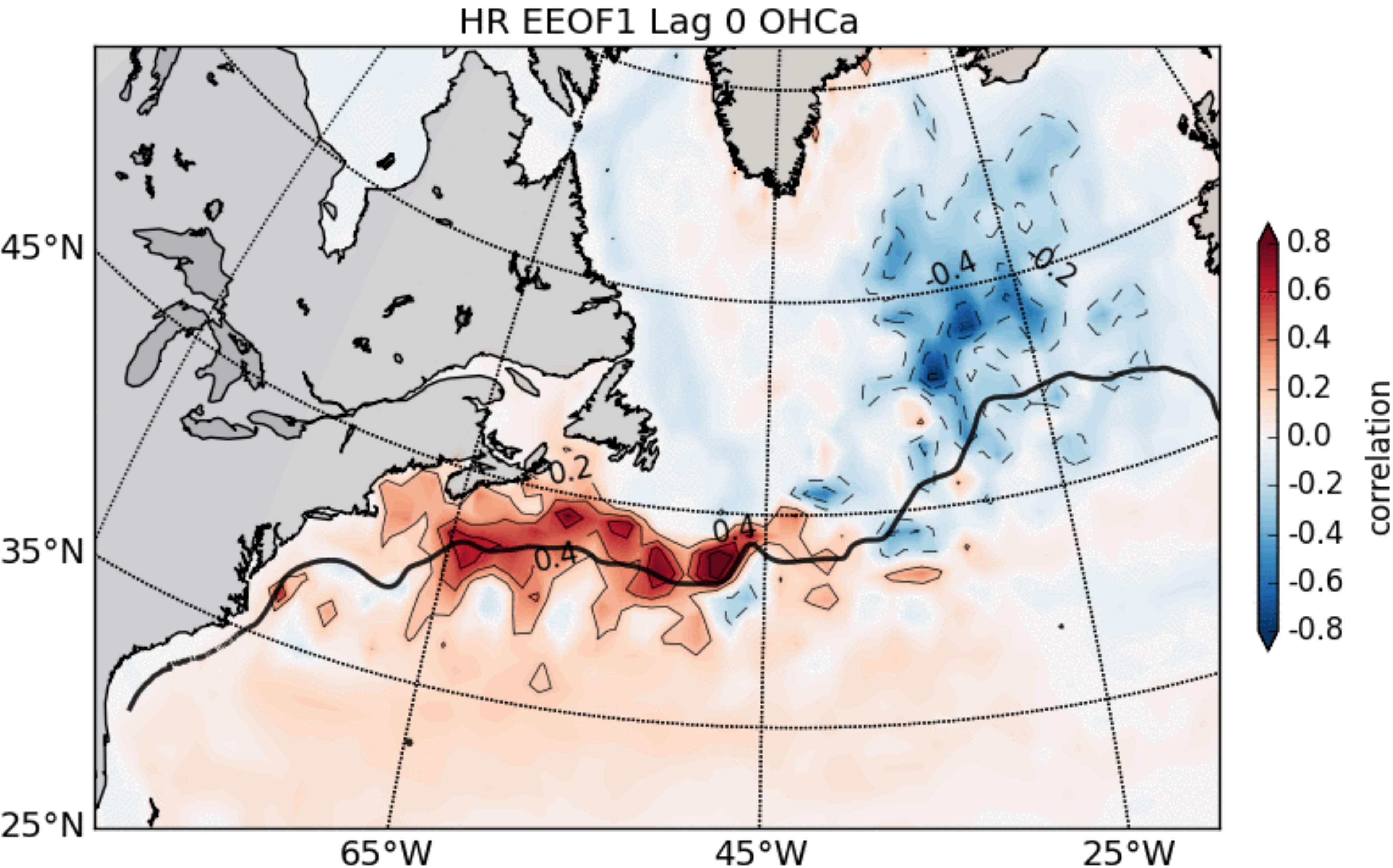
  - Need to do the "Real" Prediction Problem - <u>Verification</u>
- **Much Room for Hybrid Statistical – Dynamic Approaches**



Temperature anomaly (°C)
w.r.t. 1961–1990
AR5 CMIP5
Observations
Indicative
likely
range
2
1.5
1
0.5
0
−0.5
1960
1975
1990
2005
2020
2035

Power Spectra: Jet Position, Ocean KE




HR EEOF1 Lag 0 OHCa
45°N
35°N
25°N
65°W
45°W
25°W
0.2
0.4
0.4
-0.4
-0.2
correlation
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8

Issues and Considerations

- **Regional Thinking**
  - Efficacy/Value Depends on Physical Environment and Variables of Interest
- **There will always be trade-offs between "accuracy" and "credibility"**
- **Methods: Statistical, Global, <u>Global High Resolution</u>, Telescoping Grids, Regional Climate Models**
  - Regional Models Cannot Correct Profound Errors in Large-Scale Forcing (Global Model) – Bias Corrections Necessary
  - Domain Selection – Nesting – Big-Brother Experiment
  - Temporal Resolution
- **Robust Estimates of Uncertainty Required**
  - RCM formulation, Global Model Formulation, External Forcing, <u>NATURAL VARIABILITY</u>
- **Use of Climate Information needs to Drive Modeling Design**
  - Need to do the "Real" Prediction Problem - <u>Verification</u>
- **Much Room for Hybrid Statistical – Dynamic Approaches**