The Science in Adaptation

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- Adaptation to the impacts of future climate conditions is place-based
- One cannot adapt solely to the impacts of "climate change" on regional space scales
- When climate is changing, climate variability is changing
- Adaptation requires getting the variability correct
- Our entire current climate enterprise (and planned climate enterprise) is directed toward mitigation and is inadequate for providing the information for adaptation to future climate impacts, e.g. "America's Climate Choices"

1. What is adaptation?

2. Adaptation to what?

    Space scales, time scales

3. What climate information is needed?

4. What climate information is available: The state of climate science for adaptation

    The modes of variability

    Modeling and the IPCC

5. The role of a Climate Service

1. WHAT IS ADAPTATION?

Adaptation is the process of taking actions to ameliorate the adverse impacts of future climate conditions on a system and/or taking actions to take advantage of beneficial impacts of future climate conditions.

►There are adverse impacts on the system of interest because the system is vulnerable (i.e. has latent negative potential)

►There are favorable impacts on the system of interest because the system is opportune (i.e. has latent positive potential)

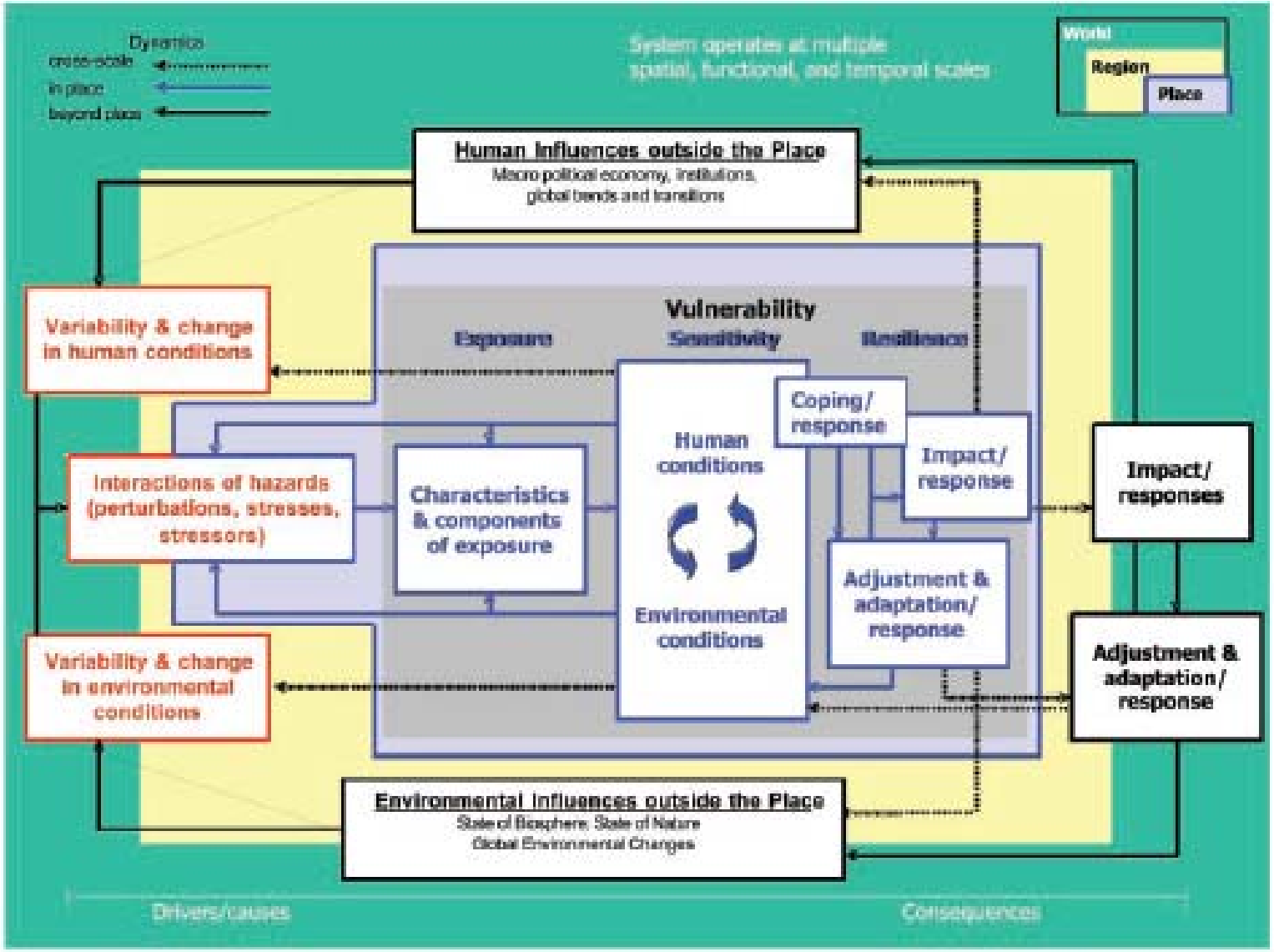
►**Vulnerability or Opportunity can be viewed as the simultaneous action of three separate factors:**

Exposure of the system to climate conditions

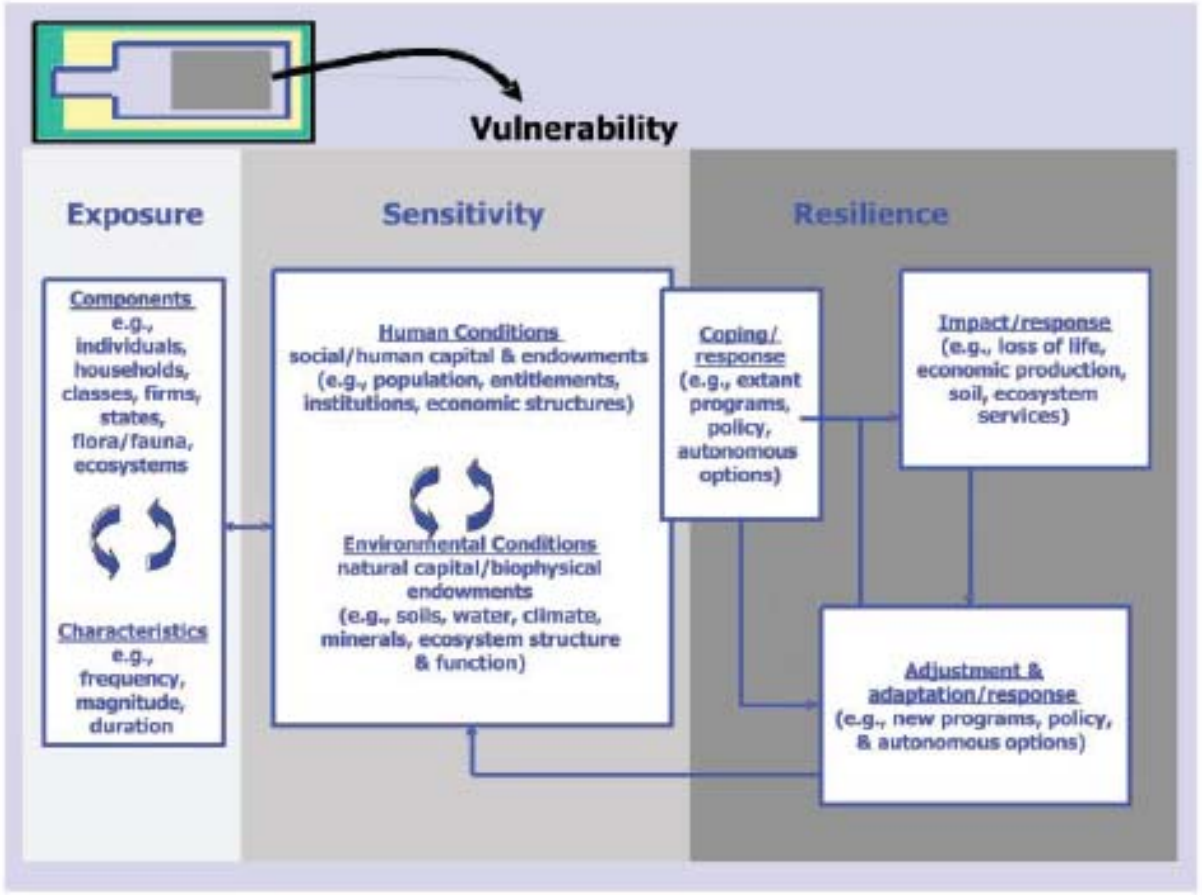
Sensitivity of the system to these conditions

Adaptive capacity of the system involved

►**Because climate is only one of a number of stressors, and because these stressors vary regionally, adaptation is inherently place-based---on this everyone agrees.**


Dynamics
cross-scale
in place
beyond place
System operates at multiple spatial, functional, and temporal scales
World
Region
Place
Human influences outside the Place
Macro political economy, institutions, global trends and transitions
Vulnerability
Exposure
Sensitivity
Resilience
Variability & change in human conditions
Interactions of hazards (perturbations, stresses, stressors)
Characteristics & components of exposure
Human conditions
Environmental conditions
Coping/ response
Impact/ response
Adjustment & adaptation/ response
Impact/ responses
Adjustment & adaptation/ response
Variability & change in environmental conditions
Environmental influences outside the Place
State of Biosphere, State of Nature
Global Environmental Changes
Drivers/causes
Consequences

(Turner II, et al., PNAS 2003)



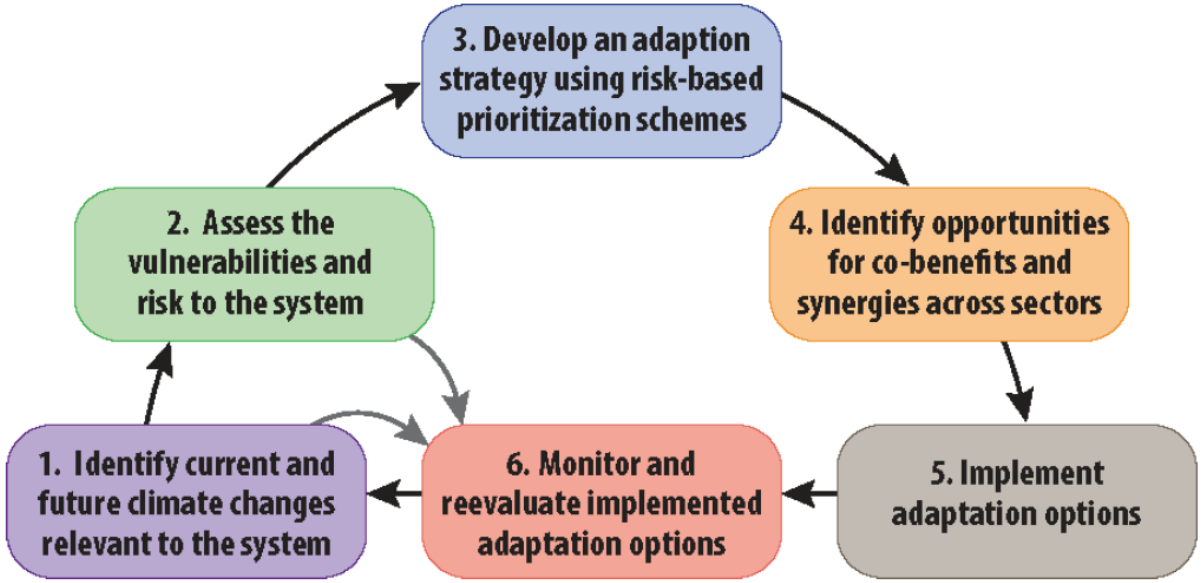
[Note that adaptation was part of the original UNFCC,1992:

> **1. All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall:**
>
> **(b) Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and measures to facilitate adequate adaptation to climate change.**

Note: The UNFCC definition of climate change is:

> **"Climate change" means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.]**

The adaptation process in America's Climate Choices (and most other adaptation schemes) is the process of reducing the vulnerability (or increasing the opportunity) by decreasing the sensitivity or adjusting the adaptive capacity of the system. [These are properties of the system and doesn't really require any climate knowledge. On the other hand, it clearly isn't happening].



“Adaptation to the Impacts of Climate Change” has come to mean just that because of the UNFCC definition—adaptation to those impacts that would not have occurred without anthropogenic forcing of climate.

NRC (2010)

TABLE S.1 Possible options for adapting to climate change that have been identified in the ocean and coastal sector.

Climate Change	Impact	Possible Adaptation Action	Federal	State	Local Government	Private Sector	NGO/Individuals
Accelerated sea level rise and lake level changes	Gradual inundation of low-lying land; loss of coastal habitats, especially coastal wetlands; saltwater intrusion into coastal aquifers and rivers; increased shoreline erosion and loss of barrier islands; changes in navigational conditions	Site and design all future public works projects to take into account projections for sea level rise.	■	■	■		
		Eliminate public subsidies for future development in high hazard areas along the coast.	■	■			
		Develop strong, well-planned, shoreline retreat or relocation plans and programs (public infrastructure and private properties), and poststorm redevelopment plans.		■	■		
		Retrofit and protect public infrastructure (stormwater and wastewater systems, energy facilities, roads, causeways, ports, bridges, etc.).	■	■	■		
		Adapt infrastructure and dredging to cope with altered water levels.	■	■			
		Use natural shorelines, setbacks, and buffer zones to allow inland migration of shore habitats and barrier islands over time (e.g., dunes and forested buffers mitigate storm damage and erosion).	■	■	■		■
		Encourage alternatives to shoreline “armoring” through “living shorelines” (NRC).	■	■	■		
		Develop strategic property acquisition programs to discourage development in hazardous areas, encourage relocation, and/or allow for inland migration of intertidal habitats.	■	■			

2. ADAPTATION TO WHAT?

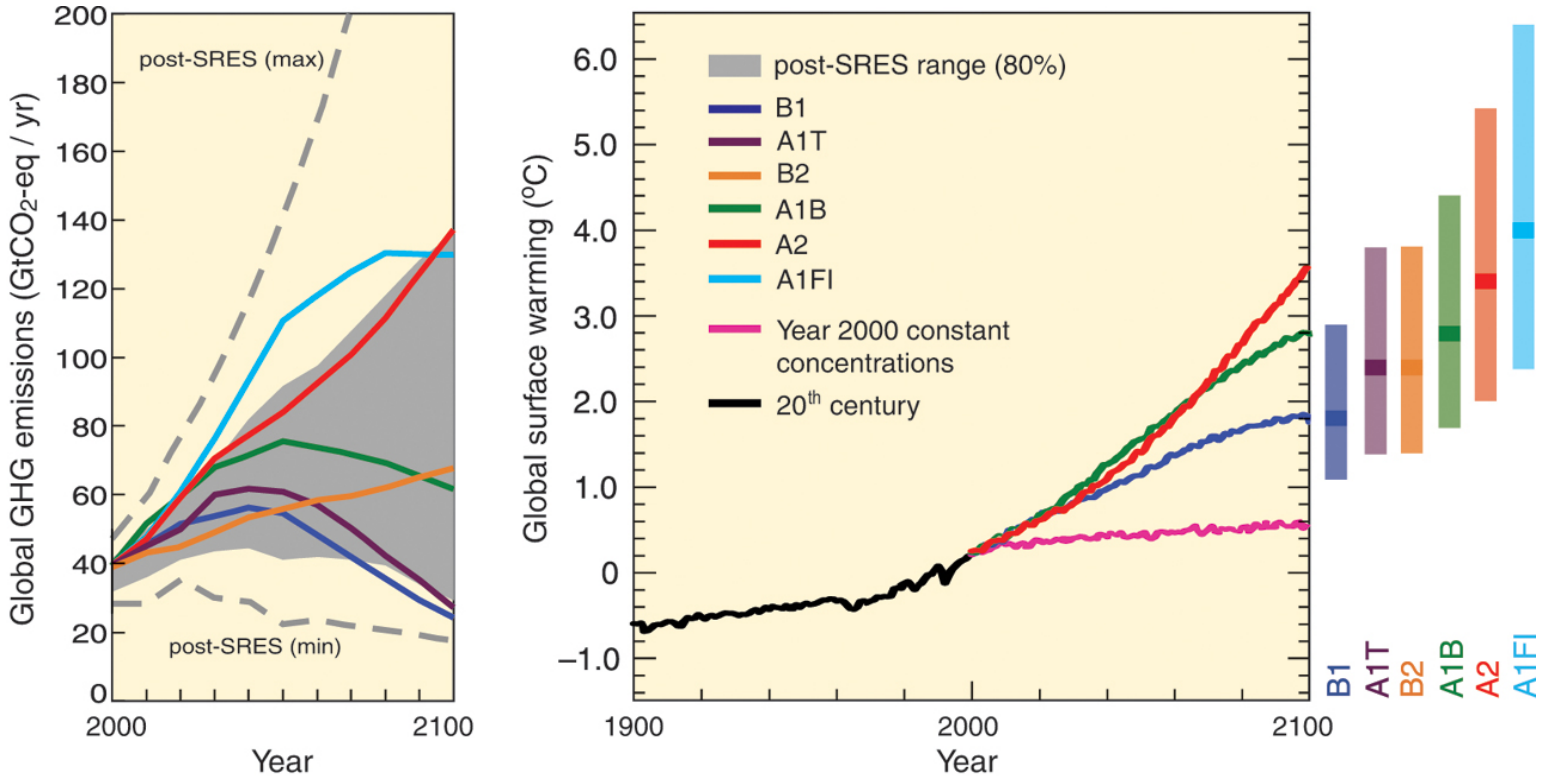
►**The space scale of adaptation is place-based and ranges down to the watershed scale (can be a small as 10km).**

►**Adaptation requires decisions to be made by some agency on some time scale.**

►**There is an intrinsic time scale to the way societies make decisions and this is one year—the time scale on which budgets are formulated and laws are passed.**

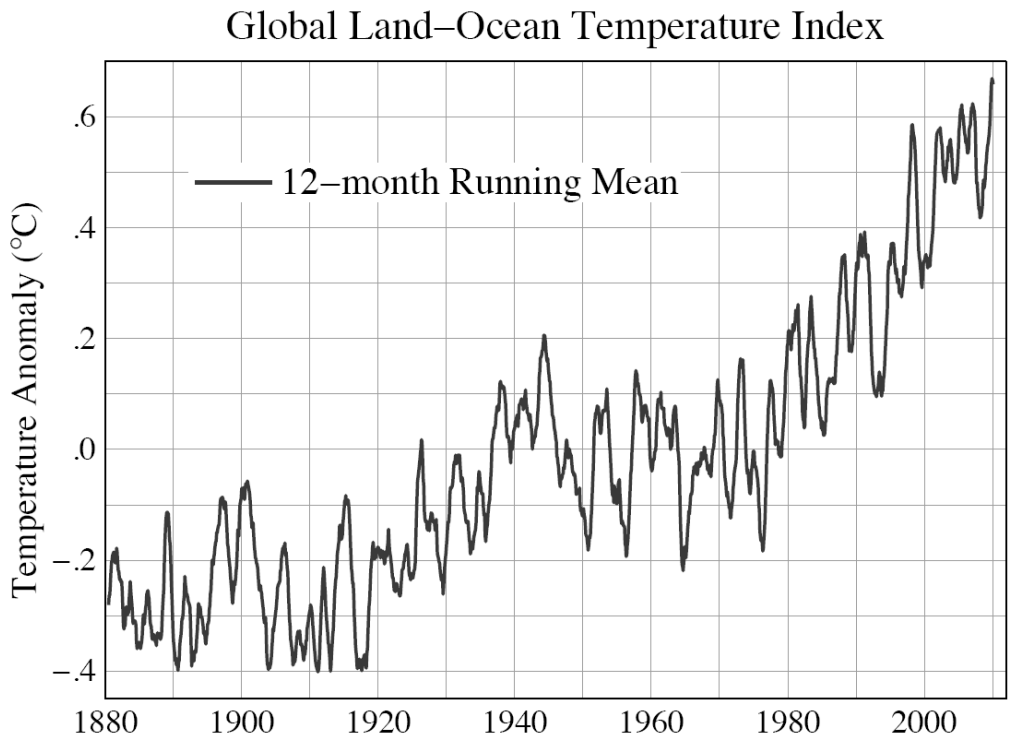
►**The globally averaged surface temperature is useful for mitigation but has little relevance for adaptation.**

When we are presented with a picture for globally averaged surface temperature like,



[IPCC, WG1, 2007]

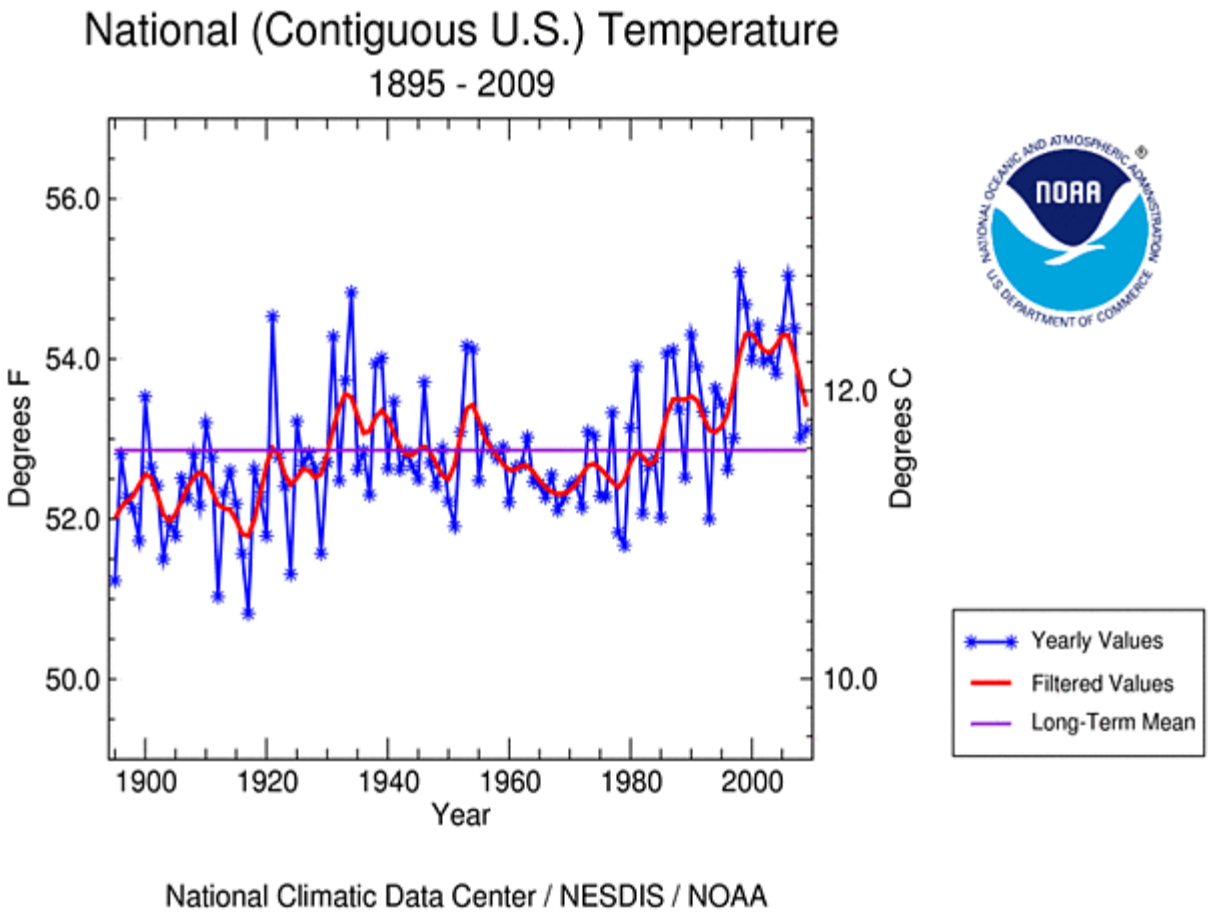
it has a (small) variability implied:



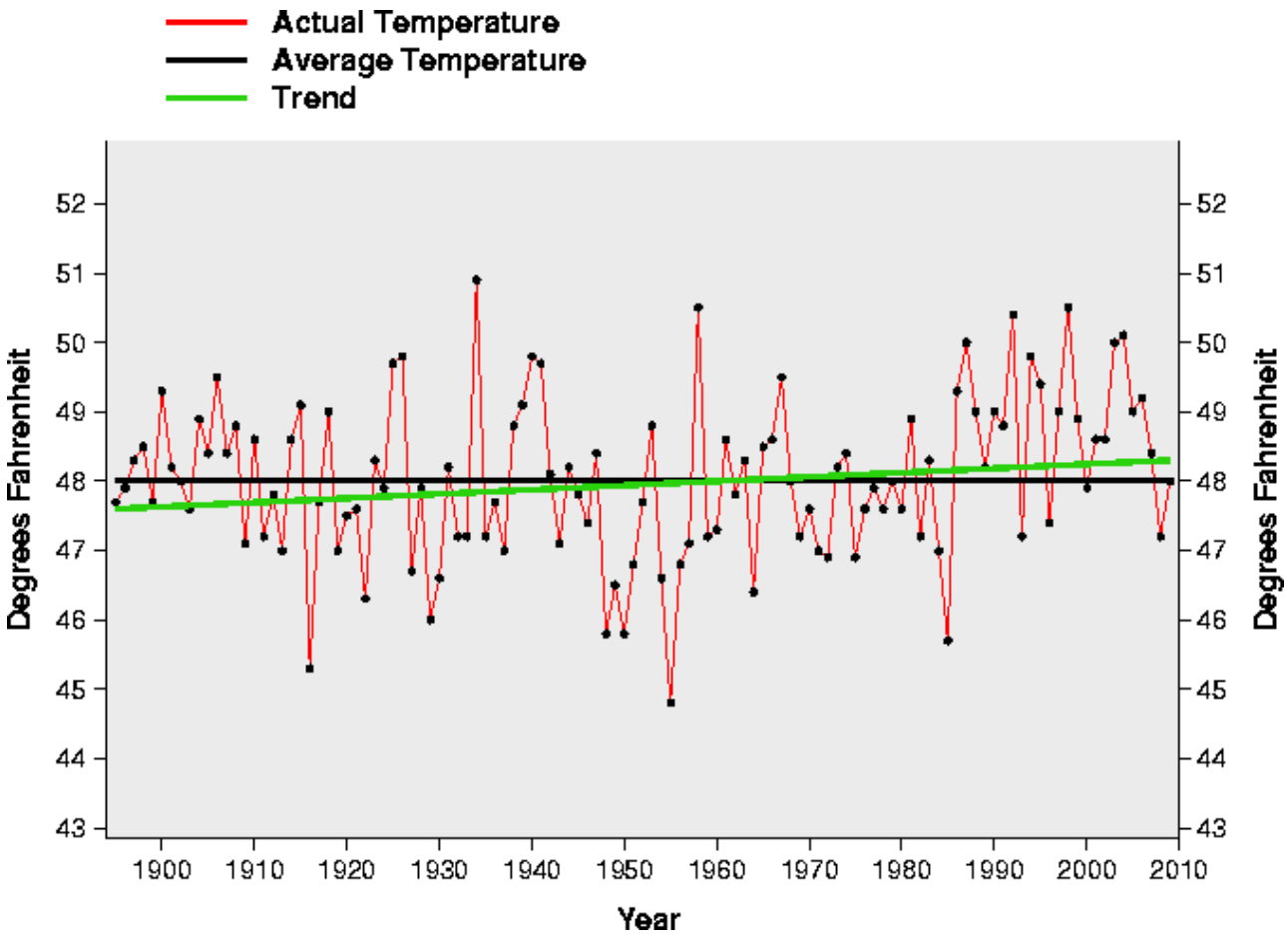
The observations of annually averaged global surface temperature up to July 2010 (NASA GISS: downloaded from http://data.giss.nasa.gov/gistemp/2010july/)

GLOBAL Y TO Y VARIATION ≤.3ºC

When we move to smaller space scales, the variability increases:



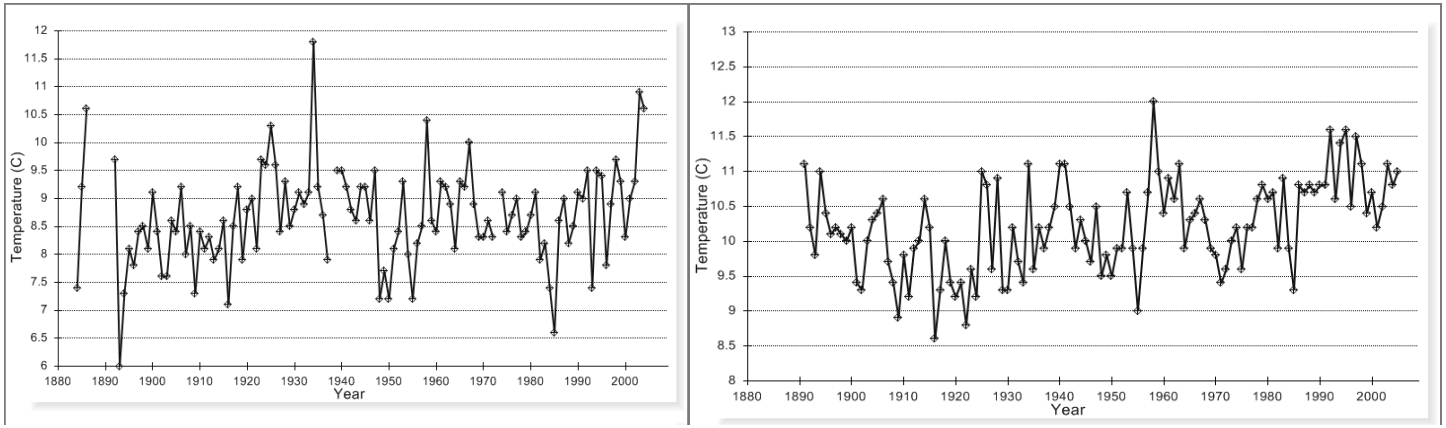
CONTINENTAL Y to Y Variation ~1°C



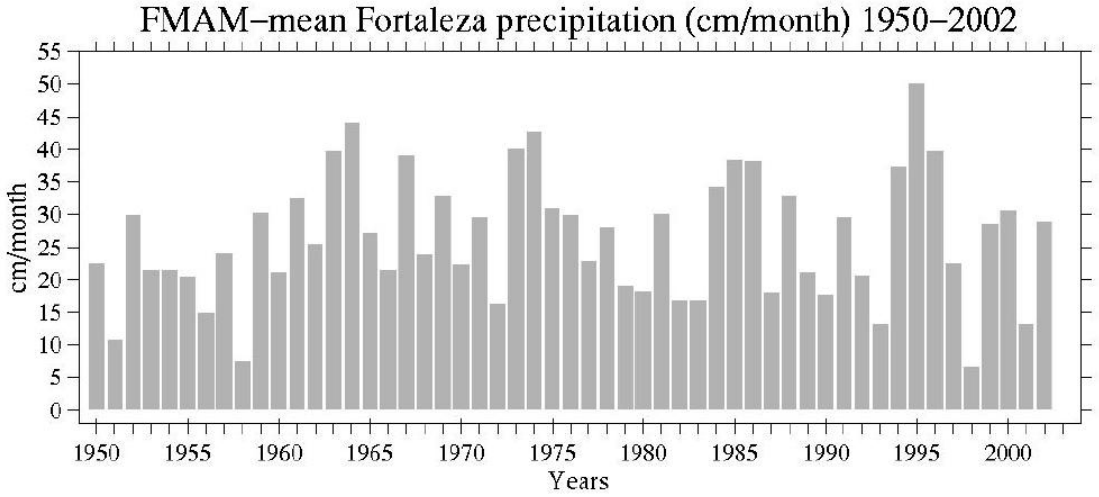
Annual 1901 - 2000 Average = 47.97 degF
Annual 1895 - 2009 Trend = 0.06 degF / Decade

STATE OF WASHINGTON

Y-to-Y variation ~2ºC



Annually averaged surface temperature variations at a single station. Left Panel: Ellensburg, Washington located east of the coastal ranges of mountains in the center of the State of Washington. Right Panel, Aberdeen, on the Pacific Coast of Washington State. Plotted using NOAA NCDC data at site: http://www.appinsys.com/GlobalWarming/climate.aspx.



The year to year variation in rainy season precipitation in Fortaleza, Ceará, Brazil (downloaded from http://jisao.washington.edu/data/brazil/).

That the year-to-year variability increases with decreasing spatial scale means:

- **The 50 or 100 year trends become small compared to the variability**

- **It becomes progressively more difficult to attribute anthropogenic causes to the climate variation**

- **Therefore, if the UNFCC definition of climate change is taken seriously, adaptation to climate change becomes more and more impossible.**

3. WHAT CLIMATE INFORMATION IS NEEDED?

In developing the yearly laws and budgets, and if next year's climate change is likely to be as large as the fifty year trend, two obvious questions arise:

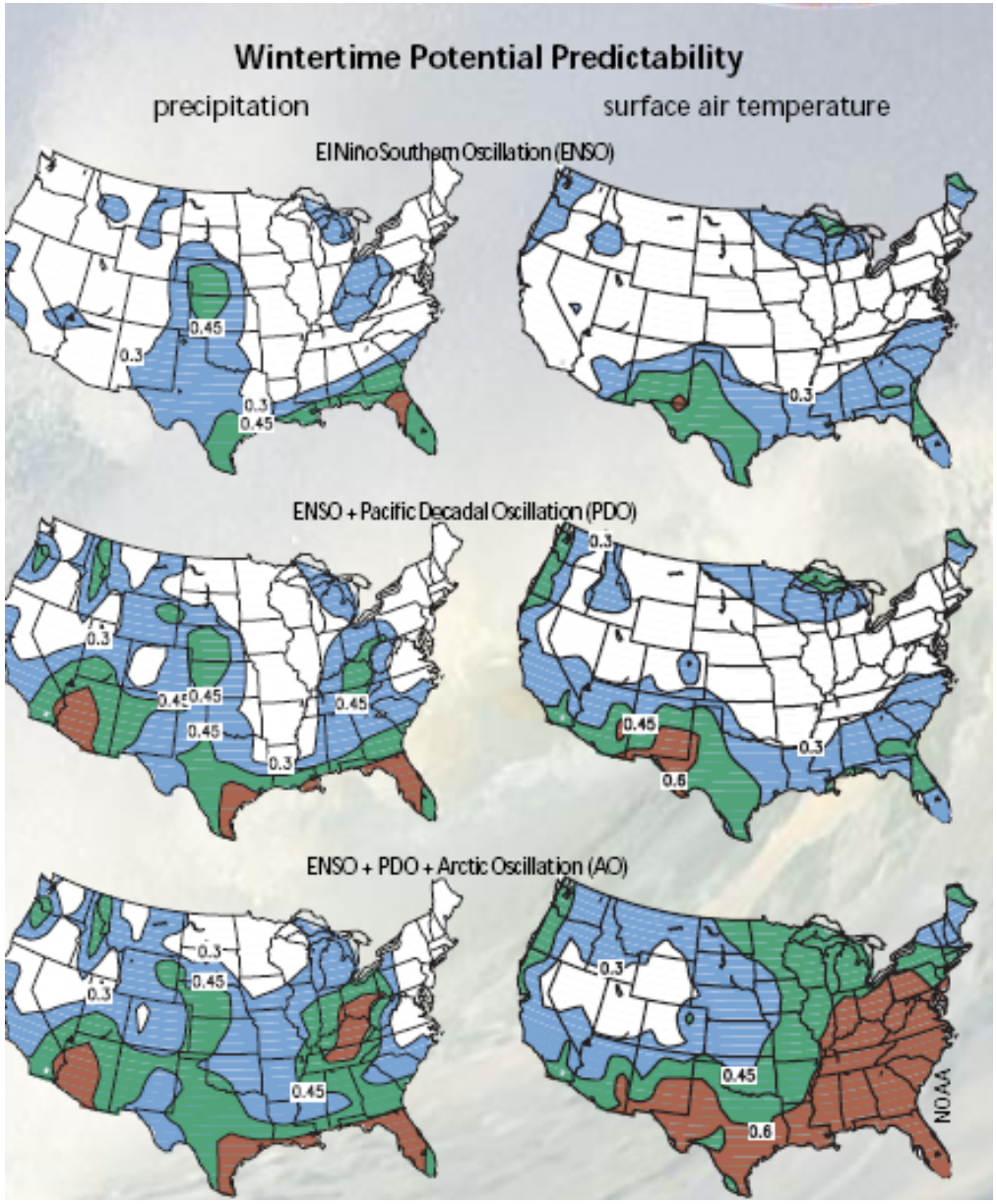
1. **What will the climate be next year (or next few years) in the place?**
2. **How will climate variability in the place change as the world warms?**

1. Adds a prediction component to adaptation which is totally neglected in America's Climate Choices: *Adapting to the Impacts of Climate Change* and in most treatments of adaptation.

[Note: The UN development Program specifically states, as part of its framework for adaptation, that "Adaptation to short term climate variability and extreme events serves as a starting point for reducing vulnerability to longer term climate change."]

2. Requires information about the modes of variability and the stochastic component of climate. Trend plus stationary variability is not the most likely option.

[That nature has graced us with only a handful of climate modes is a gift in this direction: MJO, Annual Cycle including monsoons, NAO, PDO, PNA, AMO. The decadal variation of these modes is especially important.]


Wintertime Potential Predictability
precipitation
surface air temperature
El Nino Southern Oscillation (ENSO)
0.3
0.45
0.3
0.45
0.3
ENSO + Pacific Decadal Oscillation (PDO)
0.3
0.3
0.45
0.45
0.45
0.3
0.3
0.45
0.3
0.6
ENSO + PDO + Arctic Oscillation (AO)
0.3
0.3
0.45
0.45
0.3
0.45
0.6
NOAA

4. WHAT CLIMATE INFORMATION IS AVAILABLE: THE STATE OF CLIMATE SCIENCE FOR ADAPTATION

►We have no climate observing system

►We have no model based monthly analysis of the climate system

►The large scale behavior of the IPCC coupled models is dependable only for scales larger than 5000km (continental scale) and therefore cannot be reliably downscaled dynamically to the regional scale.

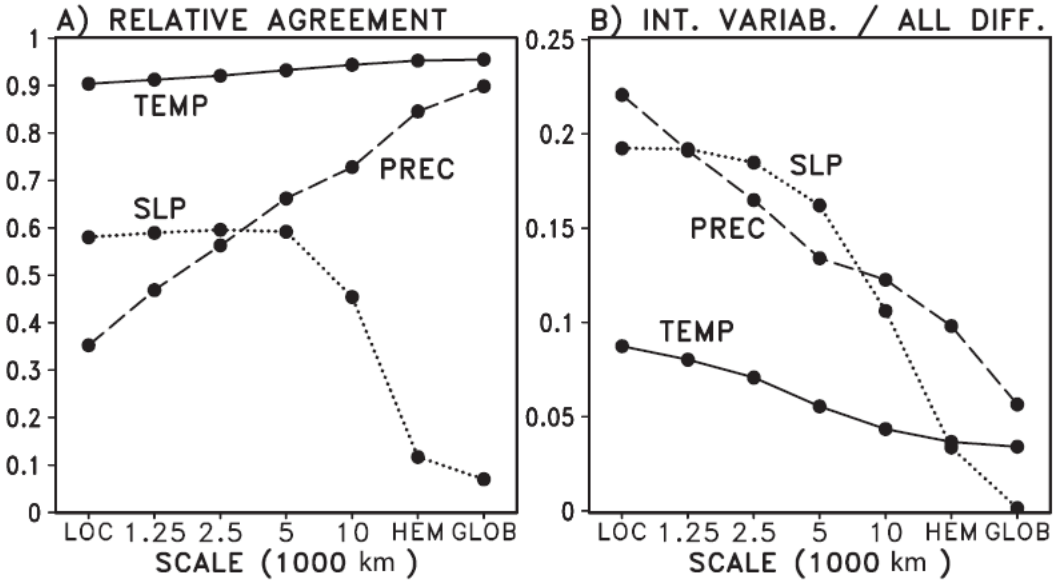
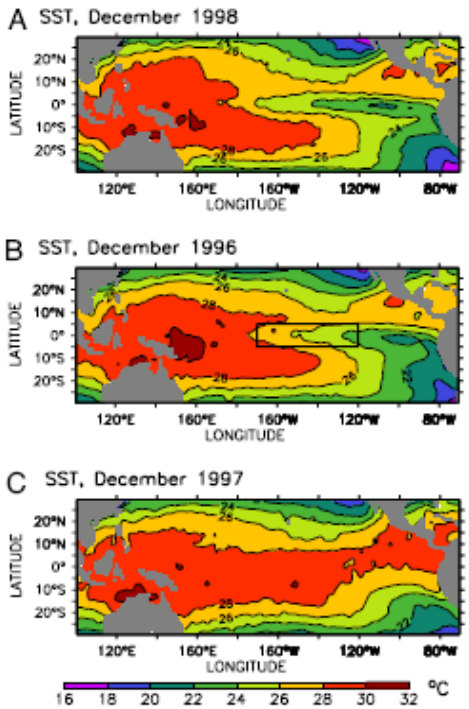


Figure 10.27. *Statistics of annual mean responses to the SRES A1B scenario, for 2080 to 2099 relative to 1980 to 1999, calculated from the 21-member AR4 multi-model ensemble using the methodology of Räisänen (2001). Results are expressed as a function of horizontal scale on the x axis ('Loc': grid box scale; 'Hem': hemispheric scale; 'Glob': global mean) plotted against the y axis showing (a) the relative agreement between ensemble members, a dimensionless quantity defined as the square of the ensemble-mean response (corrected to avoid sampling bias) divided by the mean squared response of individual ensemble members, and (b) the dimensionless fraction of internal variability relative to the ensemble variance of responses. Values are shown for surface air temperature, precipitation and sea level pressure. The low agreement of SLP changes at hemispheric and global scales*

►**We hypothesize that the ability of IPCC models to get the globally averaged temperature right, but not be able to get the regions right, is because the variability is misplaced in space.**

EXAMPLE—ENSO

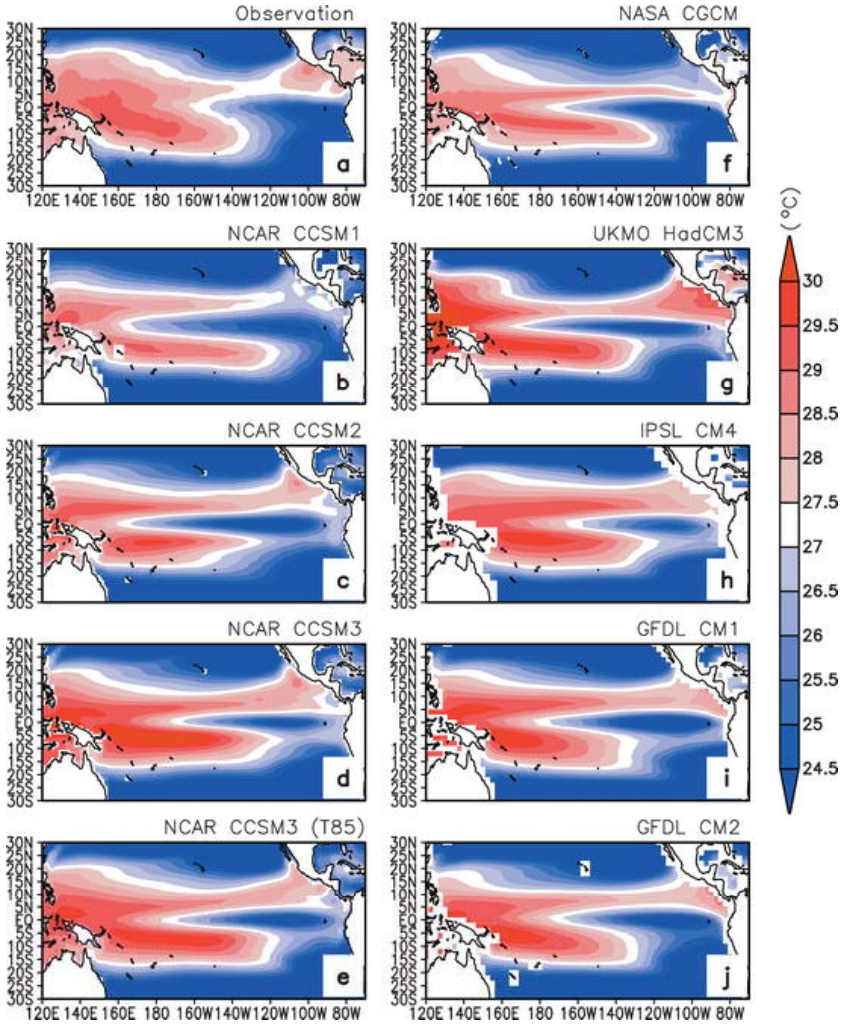


cold

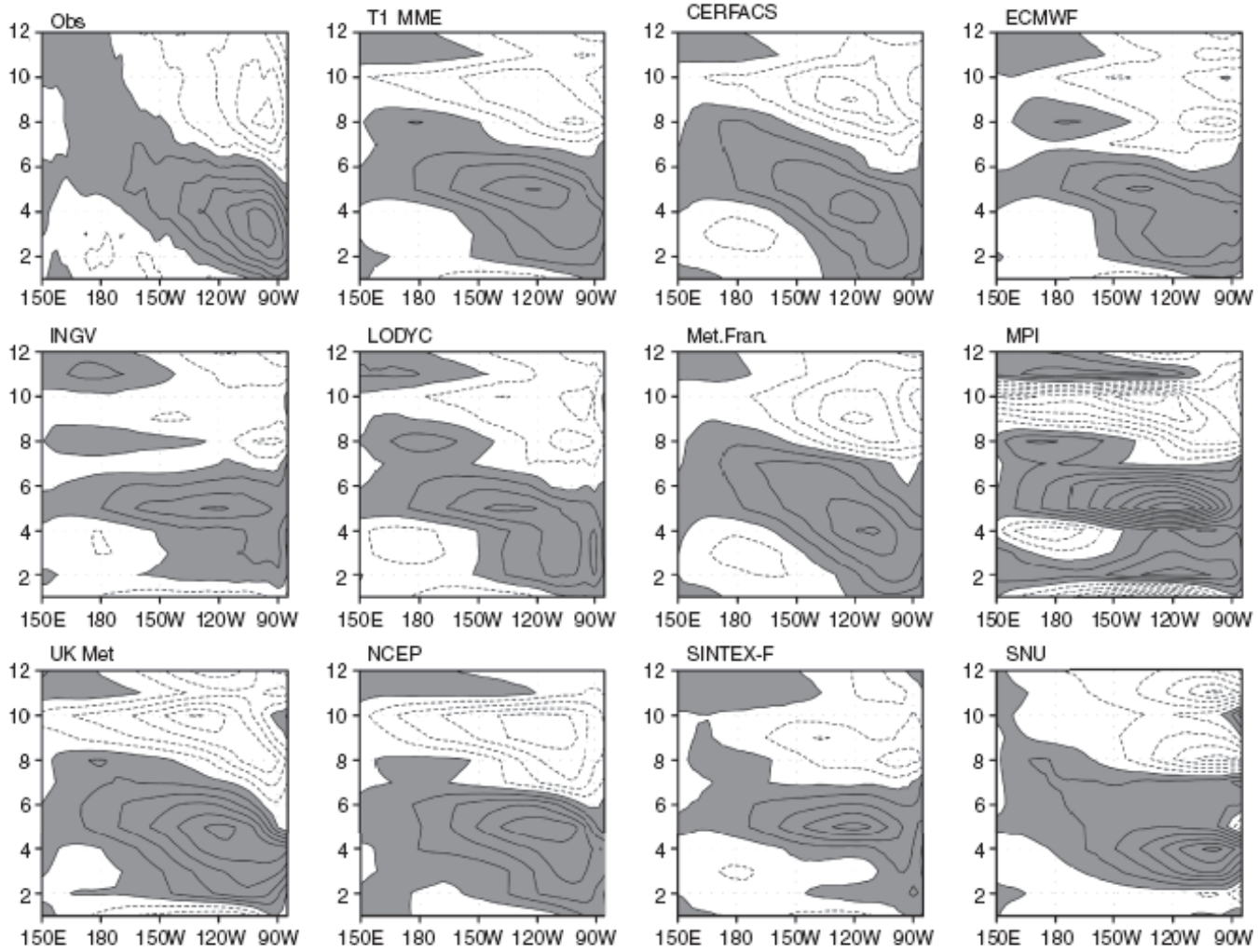
normal

warm

ALL models have a tropical bias in mean and annual cycle



(Sun et al, 2006)



E. K. Jin et al, 2008

►**With the mean climate and annual cycle wrong, the western Pacific heat source is at the wrong place at the wrong time and therefore incorrectly teleconnects to higher latitudes.**

►**The IPCC strategy of building a new model every five years and hoping everything gets better is not the right strategy to solve the bias problem.**

5. THE ROLE OF A CLIMATE SERVICE

►**A Climate Services identifies, produces, and delivers authoritative and timely information about climate variations and trends and their impacts on built and natural systems on regional, national, and global space scales.**

►**In order to produce the best possible climate information, the CS must do *all* of the following:**

a. Develop and maintain a climate observing system

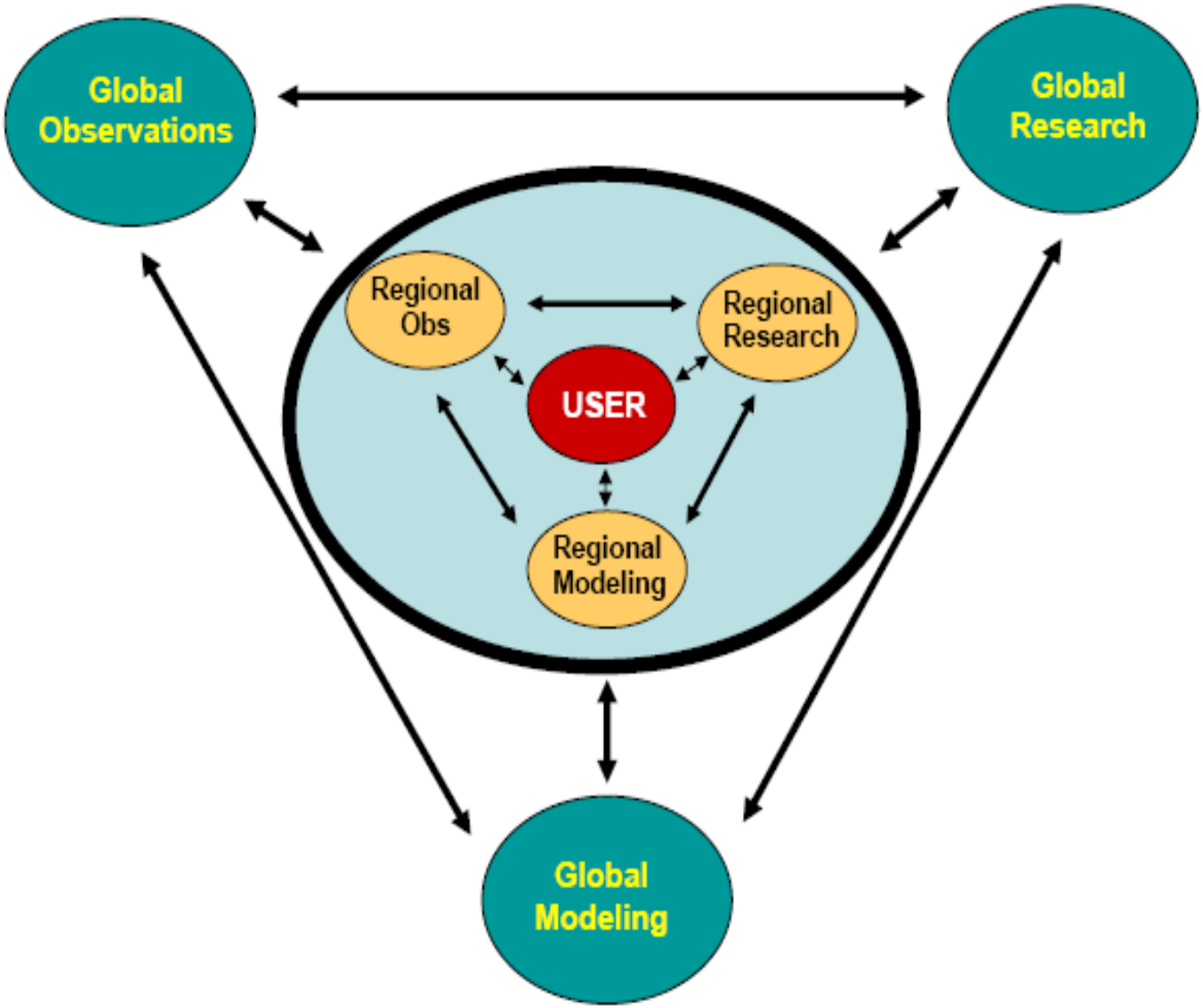
b. Develop the best possible climate prediction models

c. Produce a monthly analysis of the entire climate system using the best possible coupled climate model

d. Produce and disseminate useful products on a regular and systematic basis for public and private use

e. Have access to or directly contract for the research and development needed to accomplish a, b, c, and d.

The CS basically is an operational unit of government with the responsibility of a,b,c,d,e treated as a *system*.


Global Observations
Global Research
Regional Obs
Regional Research
USER
Regional Modeling
Global Modeling

6. CONCLUSIONS

►**The future comes one year at a time so adapting to the near term has to be part of the overall problem of adapting to the long term.**

►**Prediction of next year's climate in the place is a neglected part of current thinking about adaptation.**

►**Adaptation requires more stringent climate information than mitigation and this information can only be delivered by an operational Climate Service.**

►**Adaptation should be a national responsibility whether or not there is global warming—this is especially true in less developed countries.**