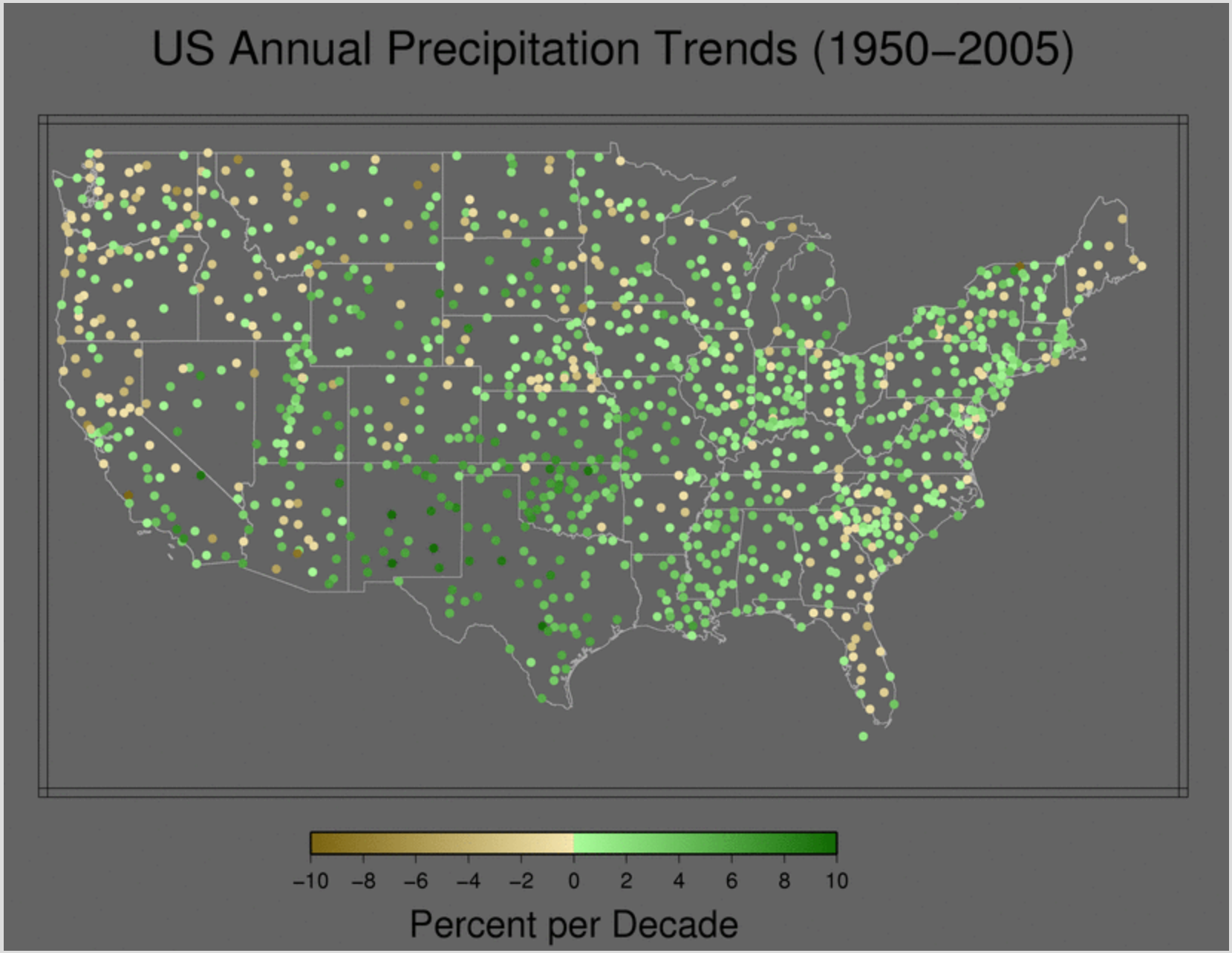
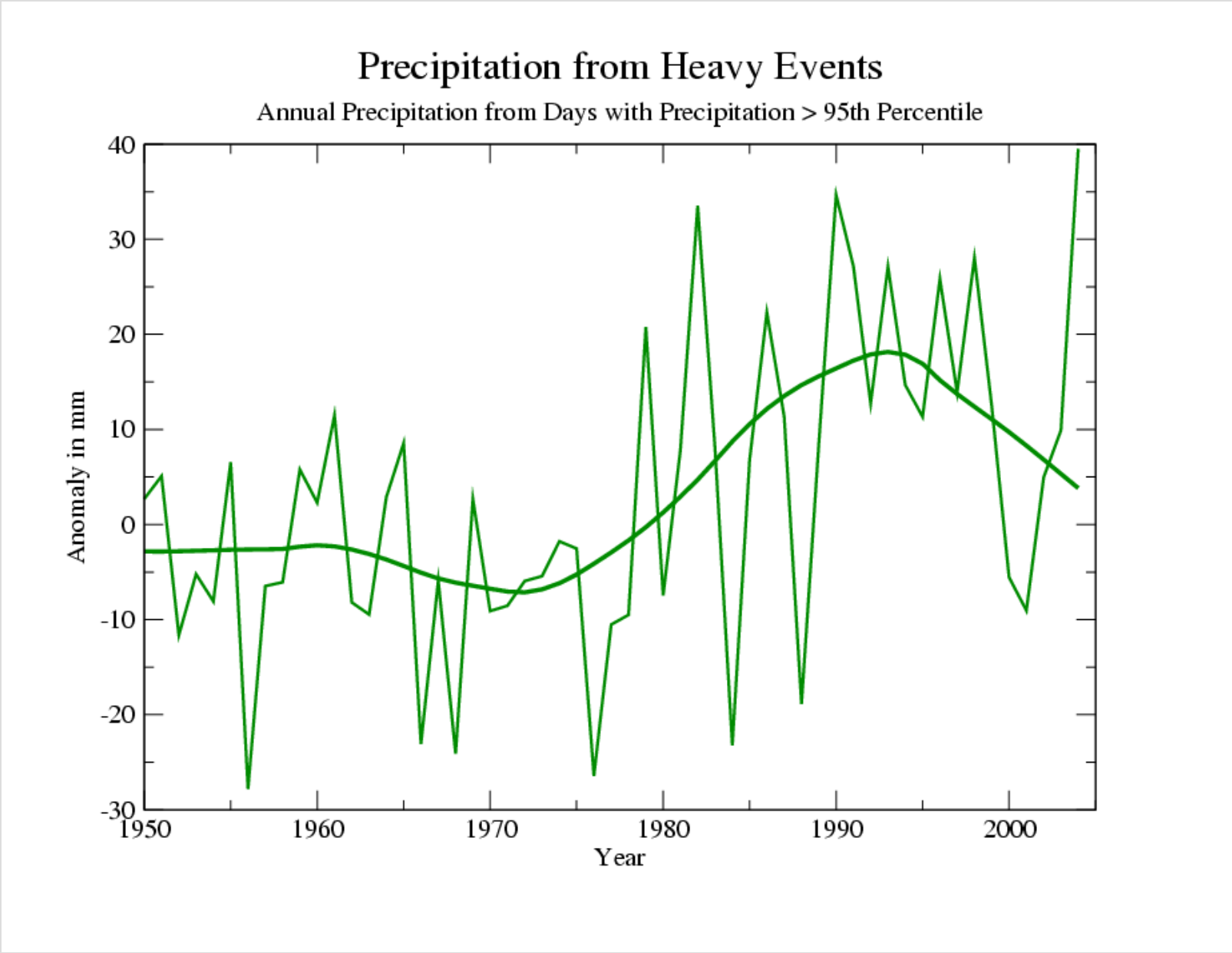
NATS 101
Section 13: Lecture 34

Global Warming
Part II



(National Climate Data Center)



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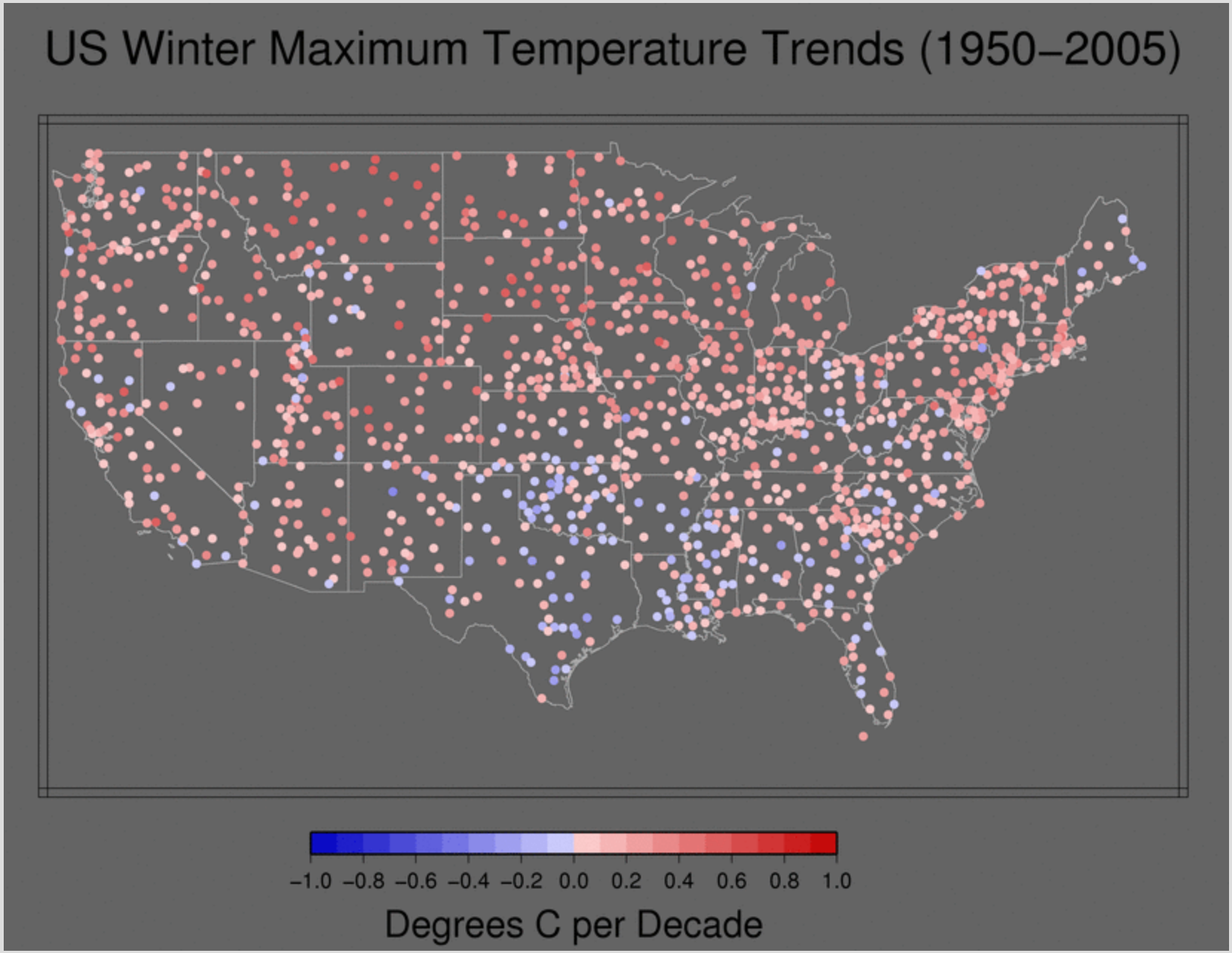

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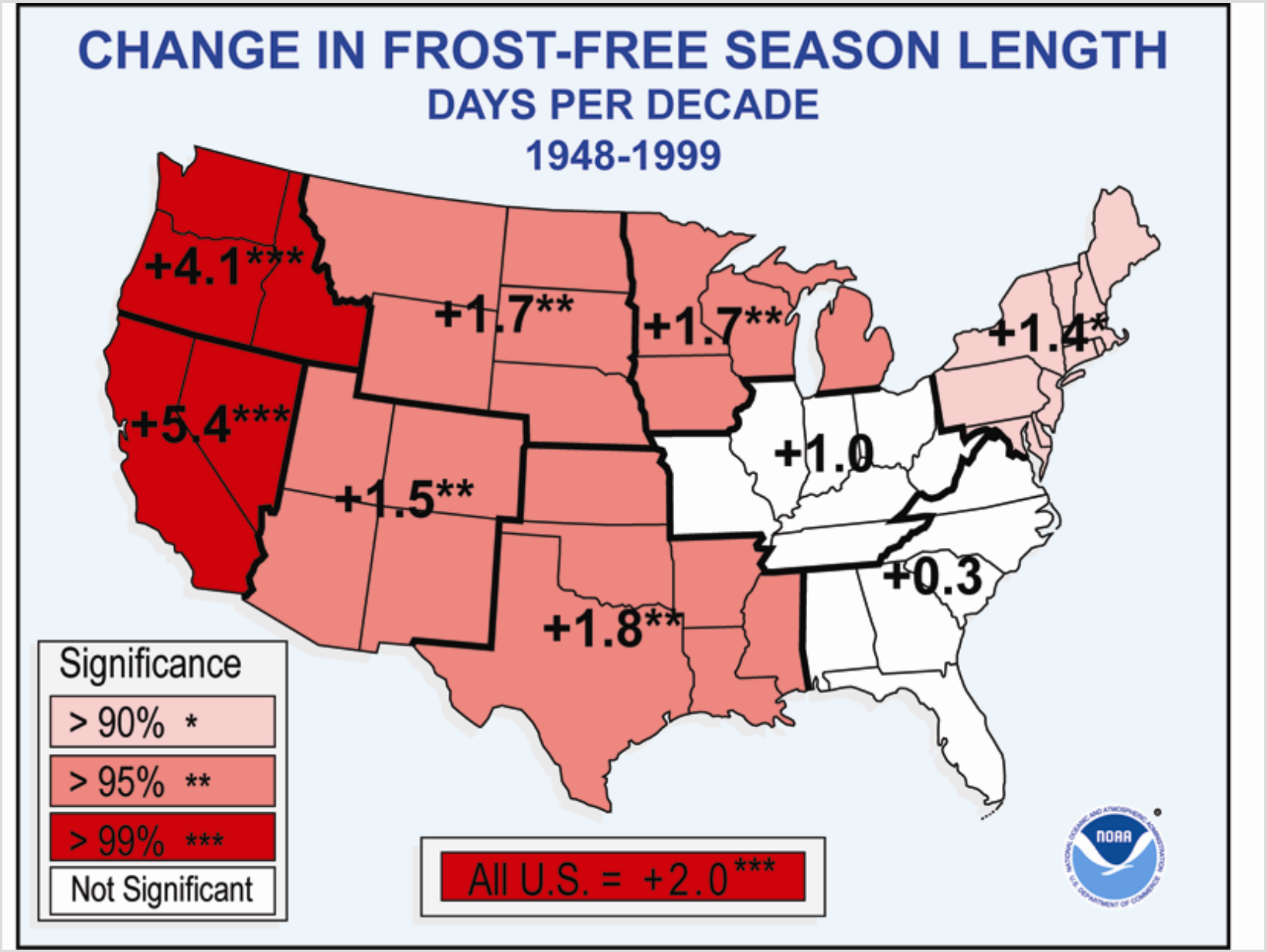

CHANGE IN FROST-FREE SEASON LENGTH
DAYS PER DECADE
1948-1999
+4.1***
+1.7**
+1.7**
+1.4*
+5.4***
+1.0
+1.5**
+0.3
+1.8**
Significance
> 90% *
> 95% **
> 99% ***
Not Significant
All U.S. = +2.0***
NOAA

Conclusion of 2007 IPCC

It is very likely (90%) that anthropogenic activities have caused the observed warming over the past fifty years

Next issues

How can we attribute the recently observed global warming to human activity?

What are the projections for the future?

What are some of the caveats and uncertainties in these projections?

What are some of your thoughts? I'd like to know!

How can the observed global warming be attributed to human activities?

We necessarily have to use a numerical model of the atmosphere and oceans to address this question.

The specific tool is a coupled atmosphere-ocean general circulation model.

IPCC bases its evaluation of present climate and future projections as the average of many different general circulation models from all over the world.

Structure of atmospheric models

Dynamical Core

Mathematical expressions of

- **Conservation of motion (i.e. Newton's 2nd law $F = ma$)**
- **Conservation of mass**
- **Conservation of energy**
- **Conservation of water**

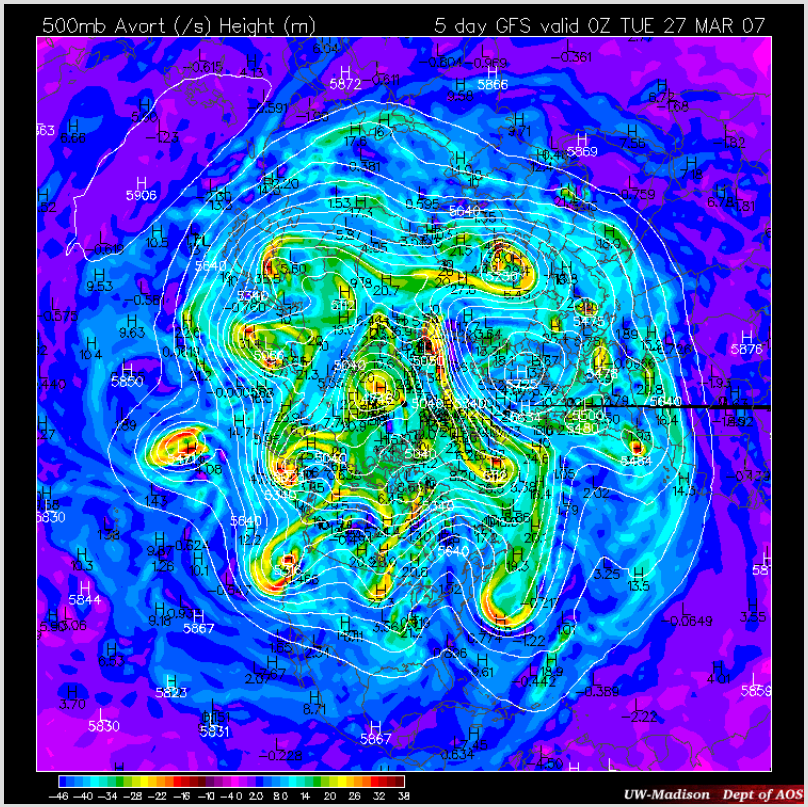
These must be discretized to solve on a grid at given time interval, starting from the initial conditions (analysis).

Parameterizations

One dimensional column models which represent processes that cannot be resolved on the grid, *for example clouds, precipitation, radiation, and land surface processes.*

Called the model "physics"—but it is essentially engineering code.

General Circulation Model (GCM)



Grid spacing = 100s of km

***Definition*: NWP model run over the entire globe**

Utility:

Forecast the evolution of large-scale features, like ridges and troughs.

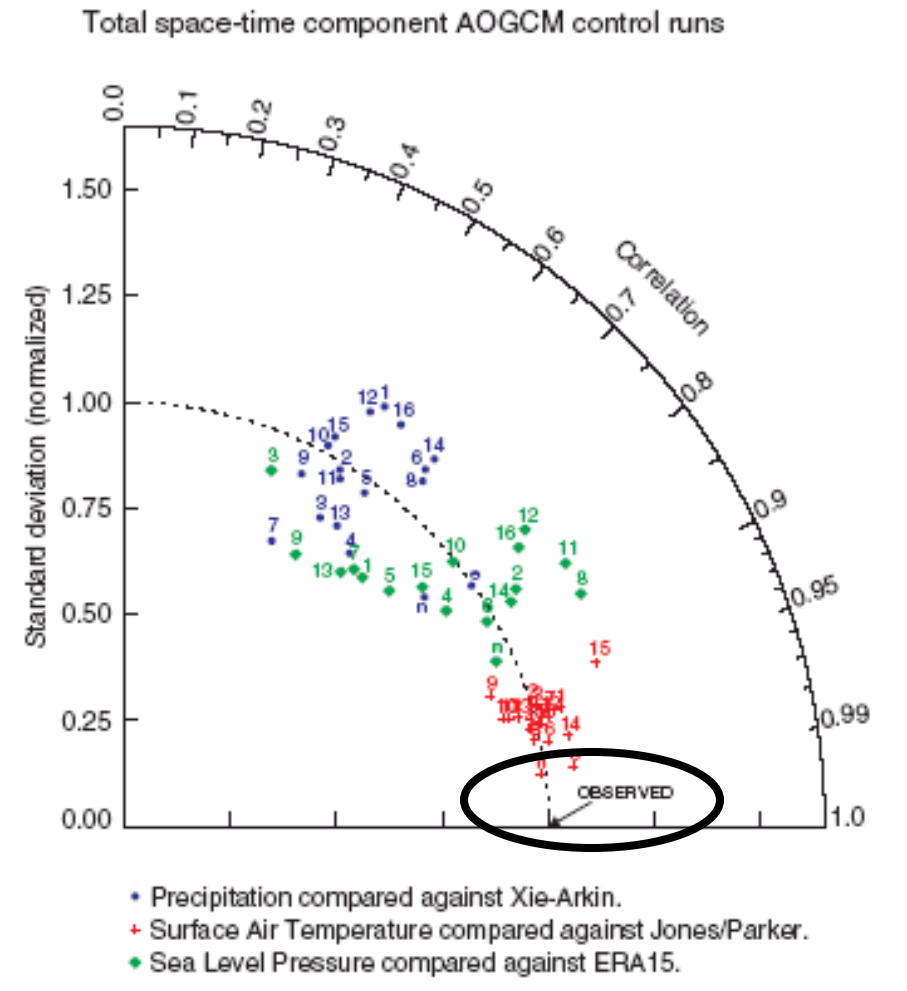
Use to generate long-range weather forecasts (beyond three days), climate forecasts and climate change projections.

Disadvantage:

Can't get the local details right because of course resolution and model physics.

Examples: NCEP GFS, ECMWF

How “good” are GCMs?
A comparison with observations



Temperature is simulated well.

Surface air pressure and winds are not bad.

Precipitation is pretty marginal.

General rule

The more dependent a simulated process is on the physical parameterizations within the model, the more uncertainty there is in the result.

Why is simulating precipitation hard? Arizona monsoon thunderstorms example

Some factors to consider in representing precipitation:

Amount of cloud and cloud condensation nuclei, ice condensation nuclei

Cloud microphysical processes (collision coalescence, ice processes)

Large-scale circulation features (e.g. shortwave disturbances, ridges, troughs)

Terrain differences which lead to storm development

Land surface heterogeneity, like soil moisture and vegetation.

Moisture transport from the Gulf of California and Gulf of Mexico

THESE COMPLEX PROCESES AND DETAILS CANNOT POSSIBLY BE REPRESENTED IN JUST ONE OR TWO GRIDPOINTS OVER ARIZONA!!

Bottom line on utility of general circulation models

General circulation models do have value in getting the "big picture" right on global and continental scales, but not really that great for getting the regional and local scales.

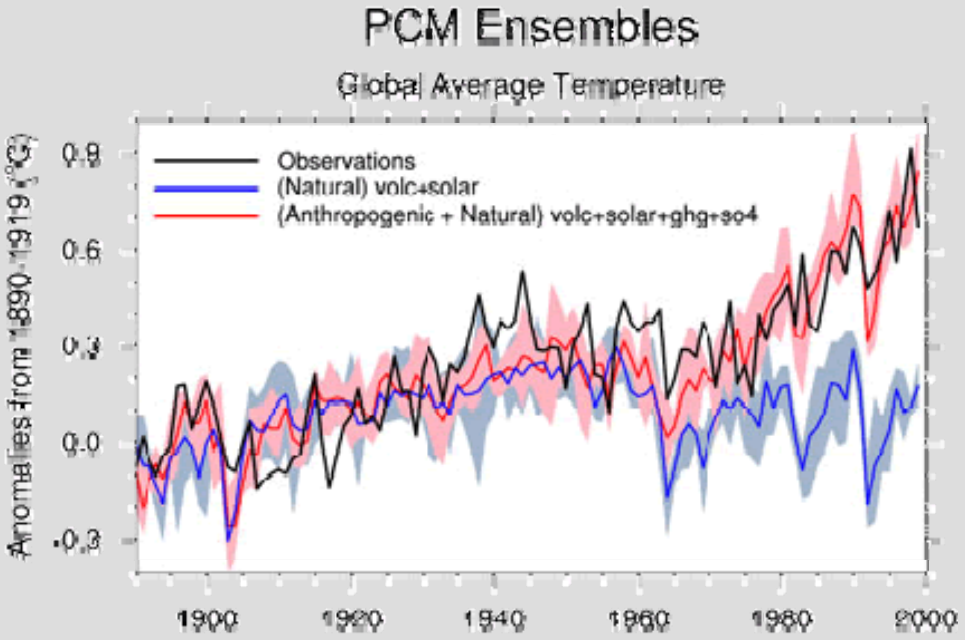
As long as this caveat is kept in mind, (I think) the general circulation model can be a potentially useful tool.

<u>How GCMs are used for global warming problem:</u>

1. **Conduct sensitivity experiments incorporating the various observed forcings to Earth's climate system over the past 100 years. This can establish the attribution of global warming to human activity.**

2. **Test various scenarios to evaluate the "big picture" of how Earth's climate will change in the future.**

Attribution GCM Studies



(Meehl et al., NCAR)

Conduct model experiments incorporating various radiative forcings to the atmosphere.

Control experiment incorporates only the factors which would occur naturally.

Attribution experiment incorporates human factors of greenhouse gases (warm) and aerosols (cool).

***RESULT*: NEED HUMAN FACTORS TO ACCOUNT FOR RECENLTY OBSERVED WARMING, ESPECIALLY AFTER 1980.**

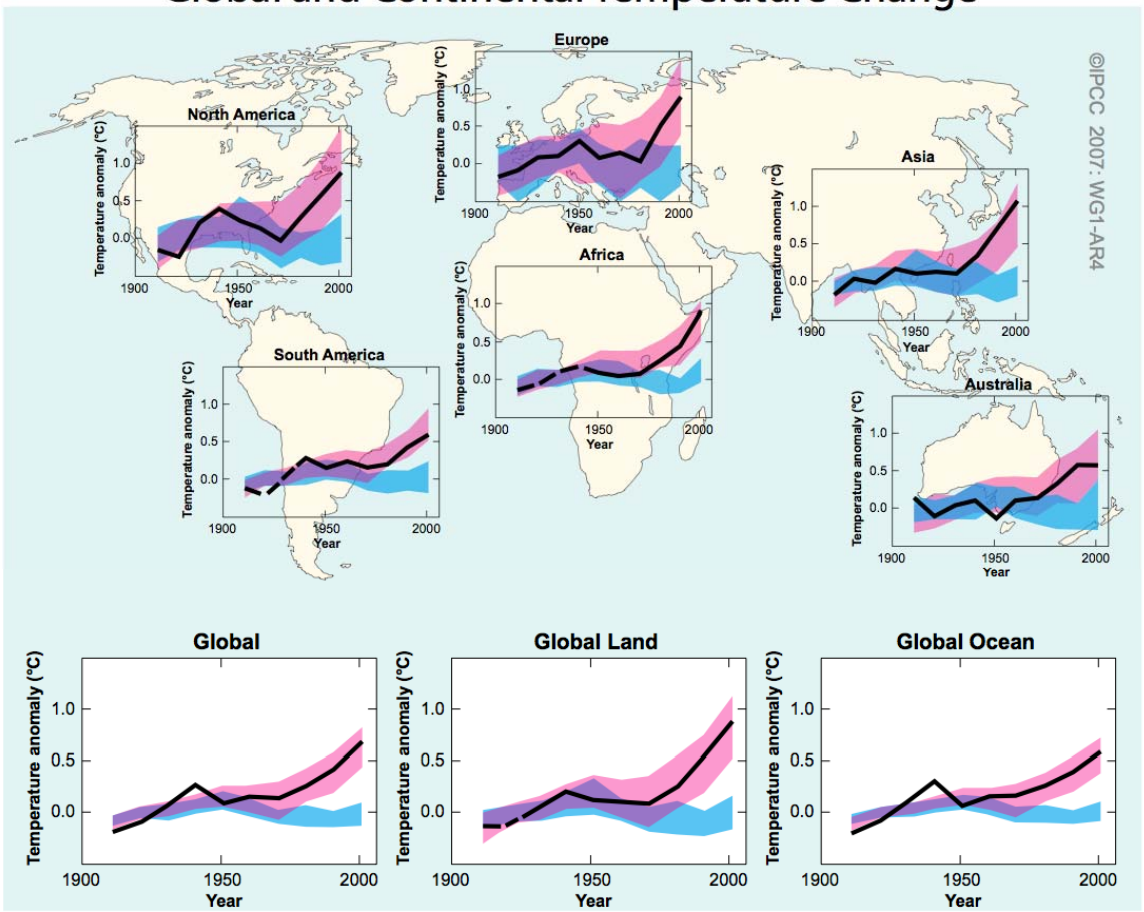
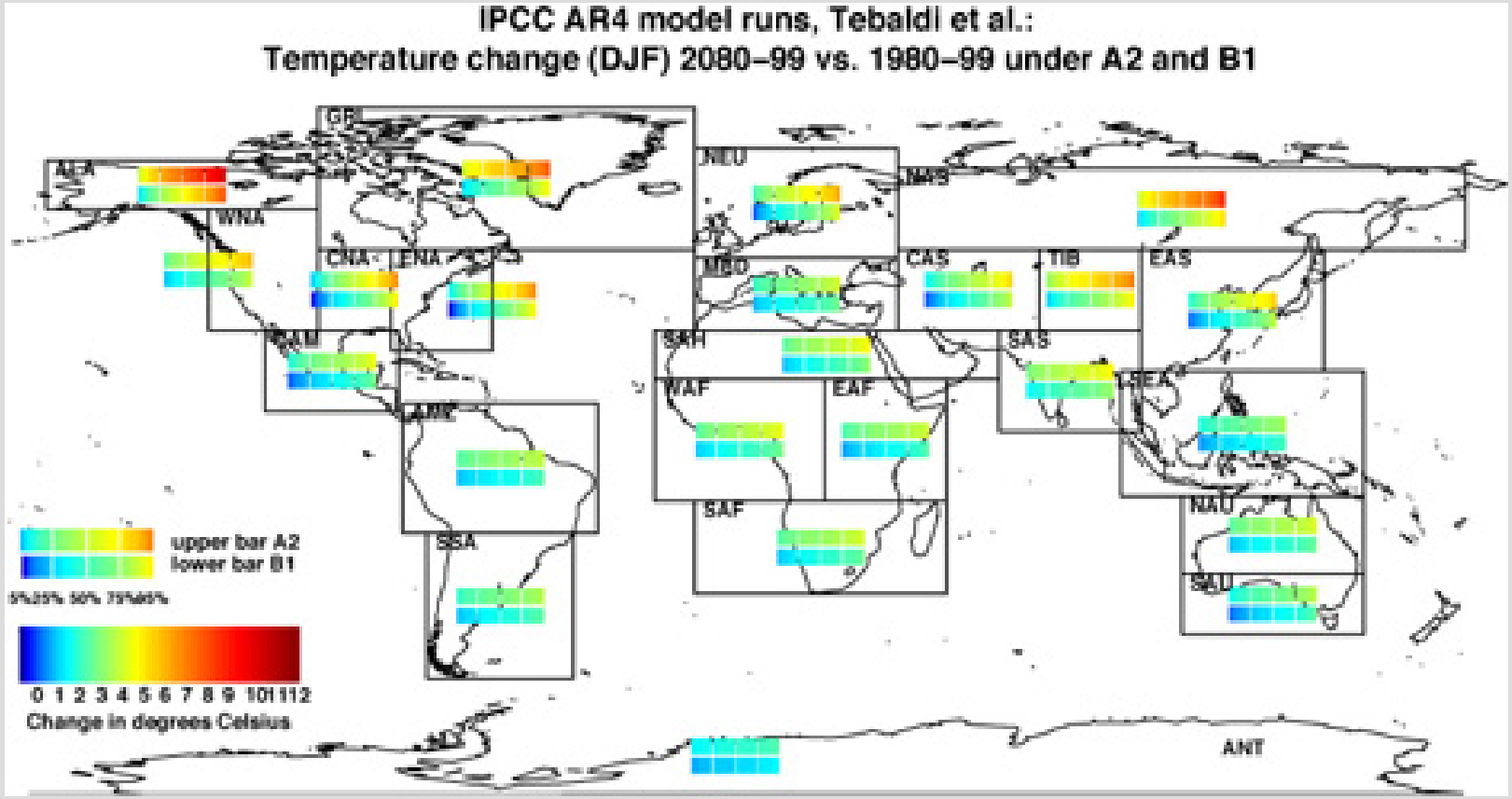


FIGURE SPM-4. Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906–2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {FAQ 9.2, Figure 1}

(IPCC 2007 SPM)

Spatial pattern of simulated warming (Another clue models may be right)

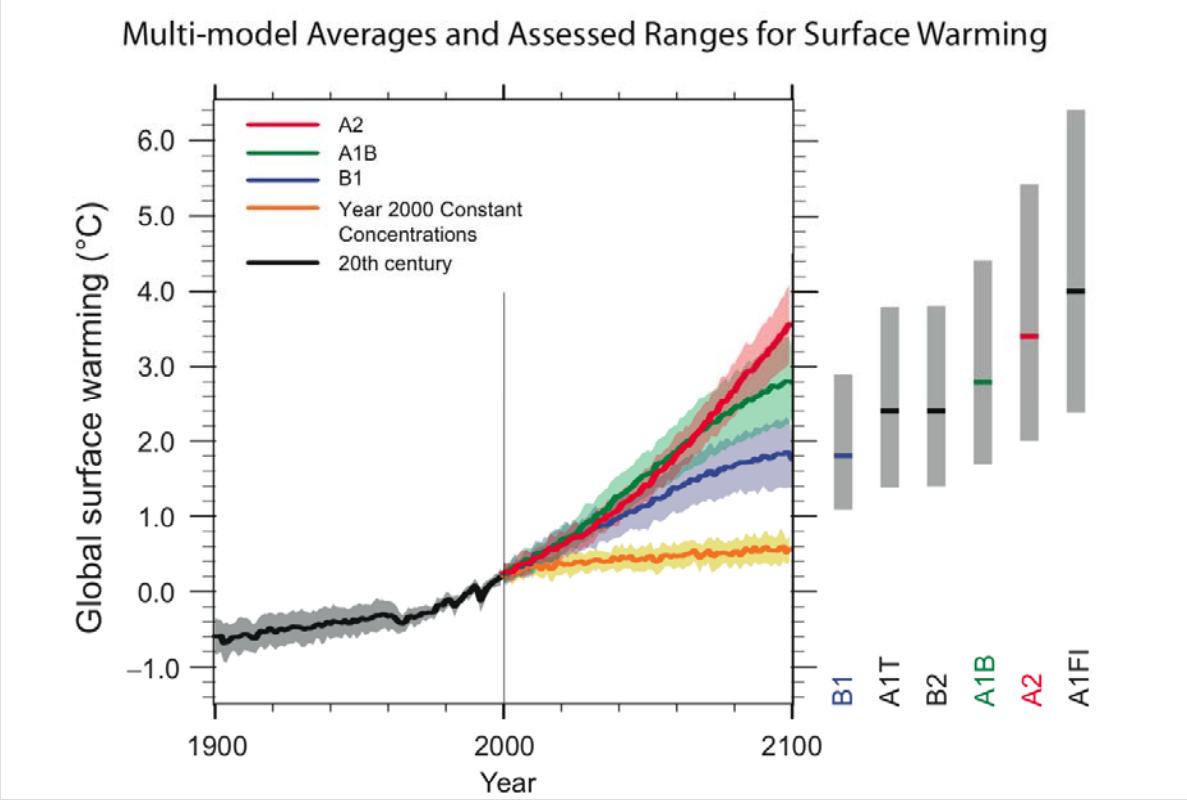


AS IN OBSERVATIONS, GREATEST WARMING OCCURING IN ARCTIC

So if we assume that the general circulation models are “good enough” to get the big picture and establish attribution of recent global warming to human beings, what does the future hold?

Depends on what economic and social choices that WE collectively make.

IPCC Model Scenarios for future global mean temperature

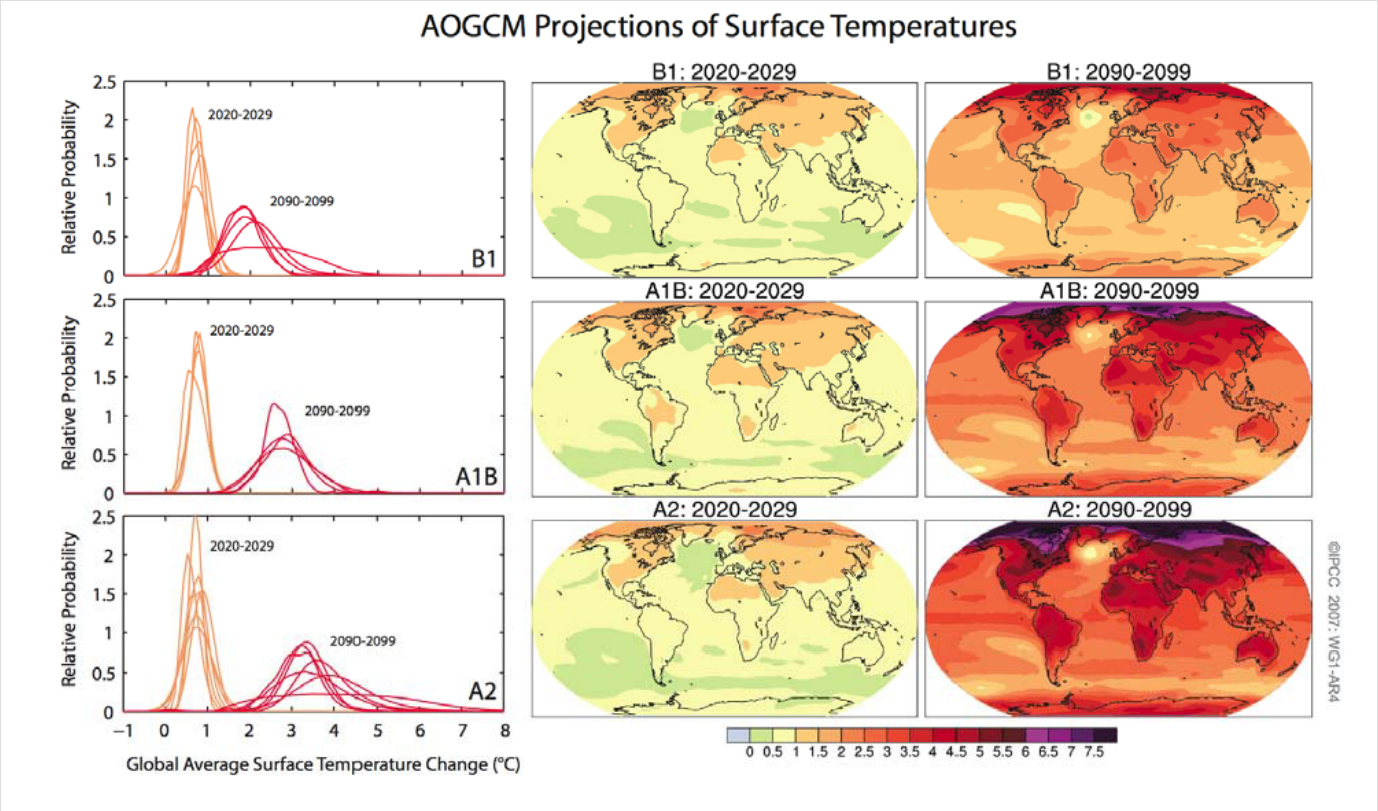


PROJECTED GLOBAL MEAN TEMPERATURE INCREASE OF ABOUT 1.5 - 4°C FROM TODAY.

We are committed to more warming NO MATTER WHAT WE DO.

“Business as usual” IPCC scenarios which assume continued heavy reliance on fossil fuels project the greater amounts of warming after about 2020.

IPCC global warming projections



Economic and social change scenario

More “business as usual” scenario

IPCC precipitation projections
NH Winter and summer

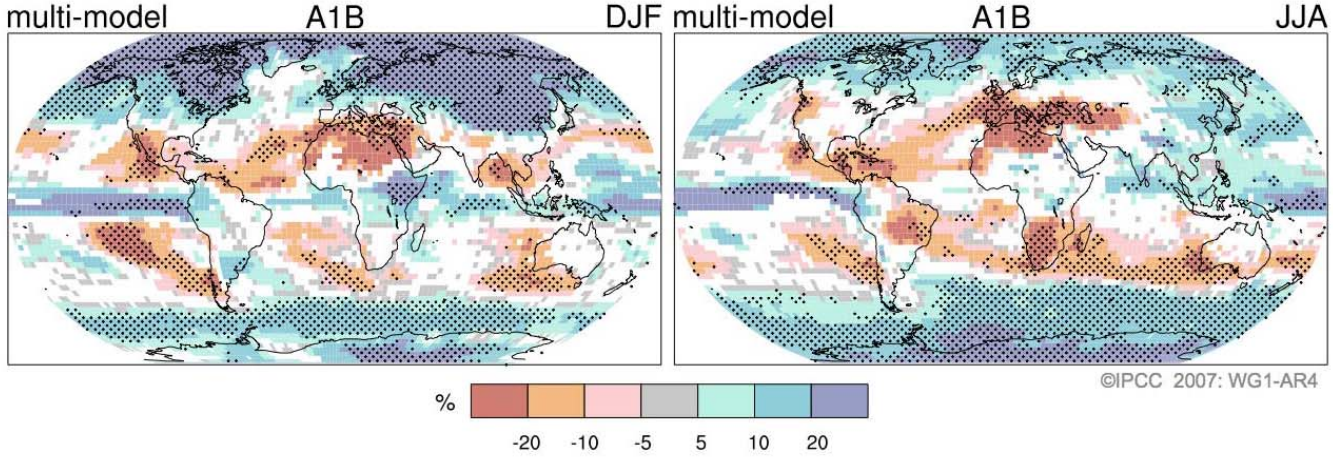


FIGURE SPM-7. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}

Generally less rain in subtropics and more near the poles.

Reflects poleward shift in mid-latitude storm track.

THESE PROJECTIONS ARE MORE UNCERTAIN…

Other major IPCC projections

“VERY LIKELY”

Sea-level rise of (at least) 0.2 to 0.6 m (half a foot to two feet)

Acidification of the ocean

Continued contraction of snow cover and polar ice sheets

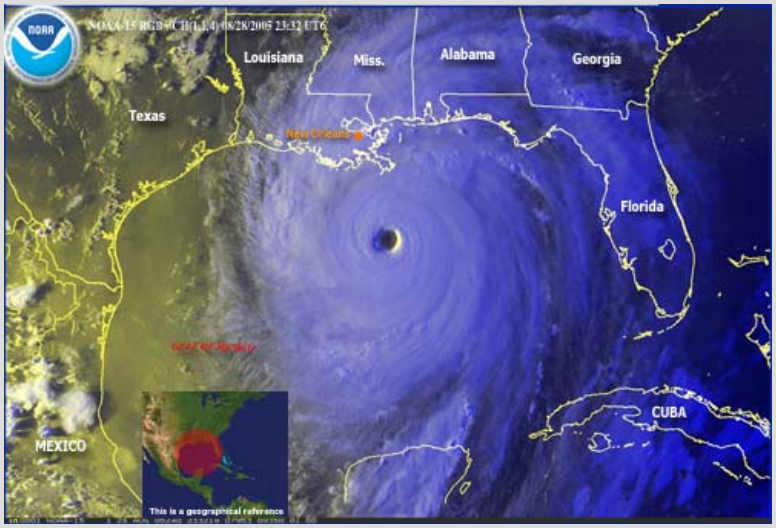
Increase in the number of heat waves and heavy precipitation events

“LIKELY” (more uncertainty)

Slowdown in the Atlantic thermohaline circulation (i.e. Gulf Stream), but not enough to mitigate warming in Europe, for example.

Intensification of tropical cyclones associated with an increase in sea surface temperature.

A note on the hurricane intensity, global warming question…



This is still some (vigorous) disagreement in the meteorological community as to whether the intensity of tropical cyclones has actually increased in recent years. Some studies suggest yes.

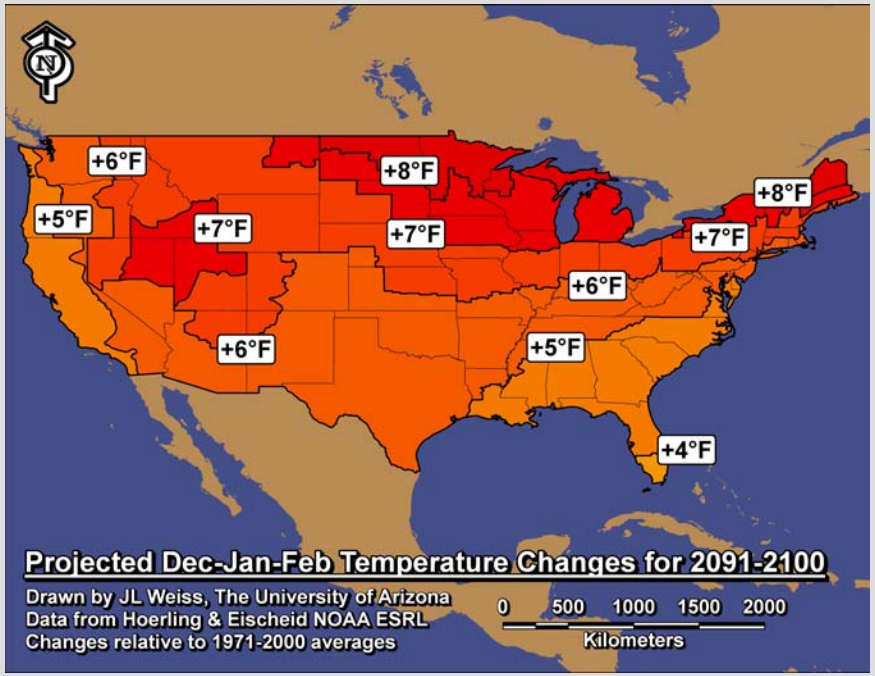
Complex problem because hurricanes are influenced by natural climate variability too.

My opinion: No one single event or hurricane season should be used as conclusive "proof" of global warming.

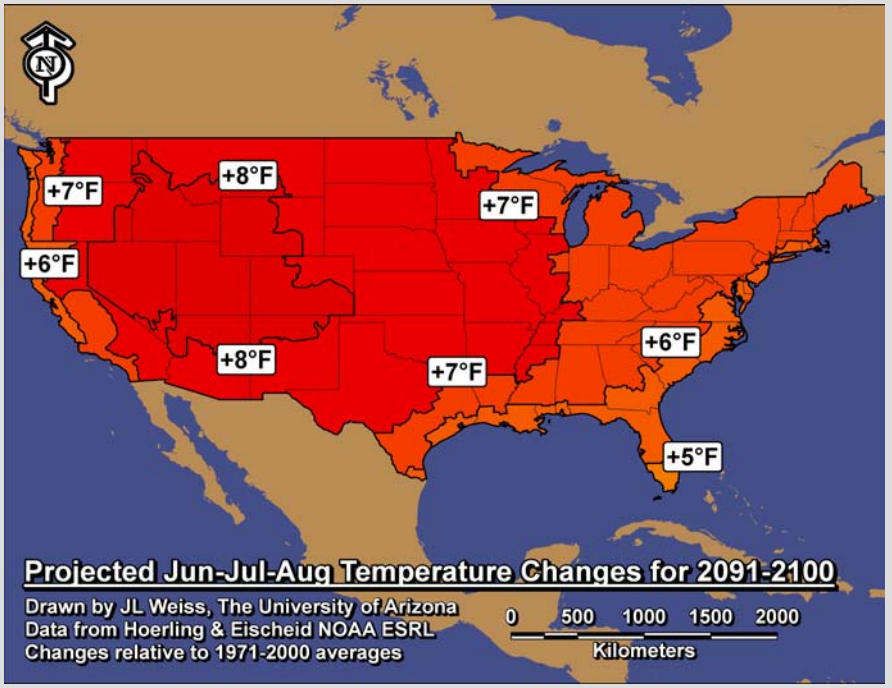
What about the United States and Arizona, in particular?

Projected U.S. warming in IPCC models (reduced emissions scenario)

WINTER

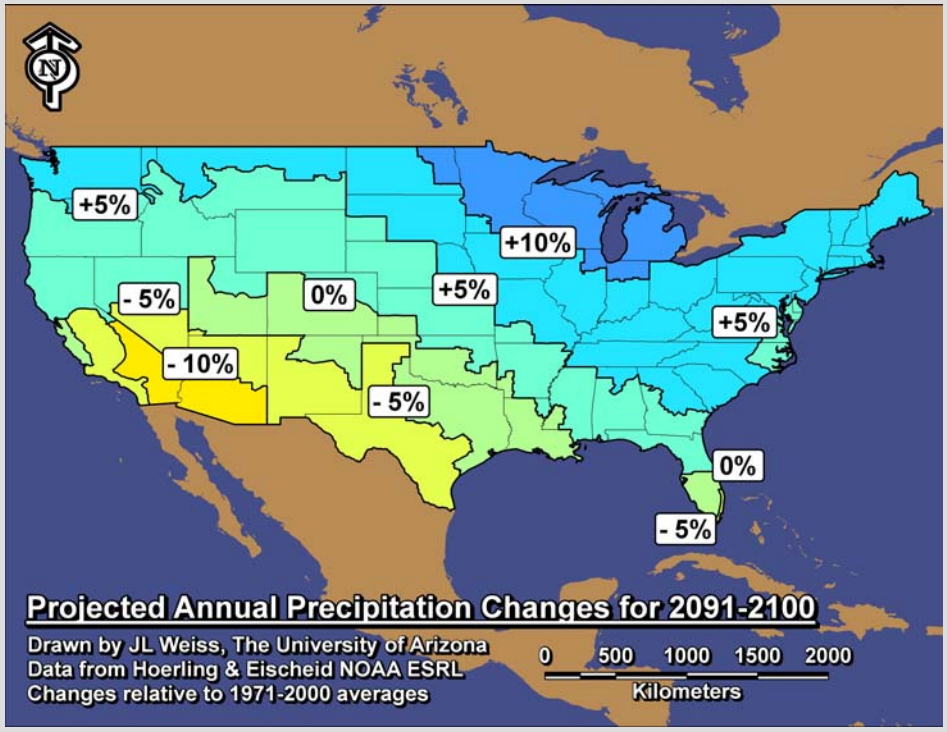


SUMMER



Western part of the United States warms more—consistent with currently observed trends over the past twenty years or so.

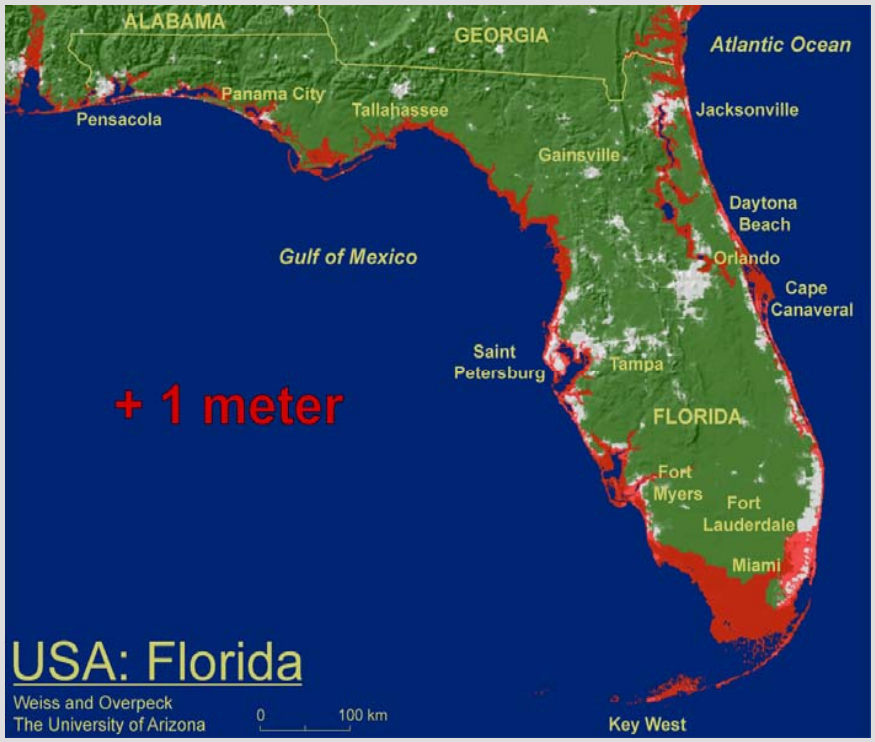
Projected U.S precipitation changes in IPCC models

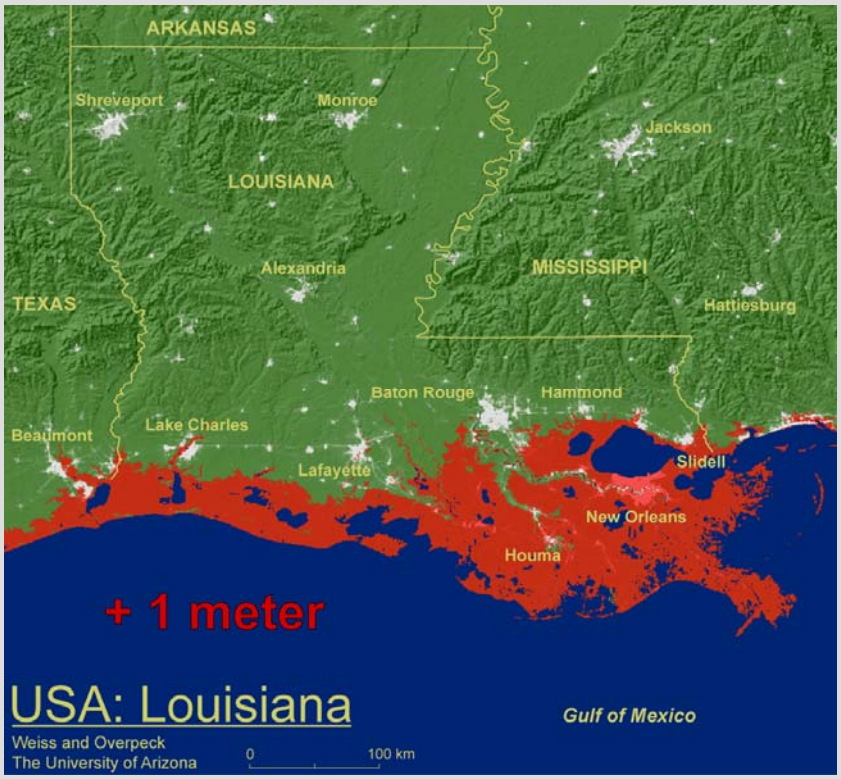


Southwest U.S. may be hard hit—but precipitation projections are more uncertain

BIG CAVEAT: Representation of summer rainfall processes, like the summer monsoon in Arizona

What a meter rise in sea level might do…





(Univ. of Arizona)

LARGE Uncertainties remain!

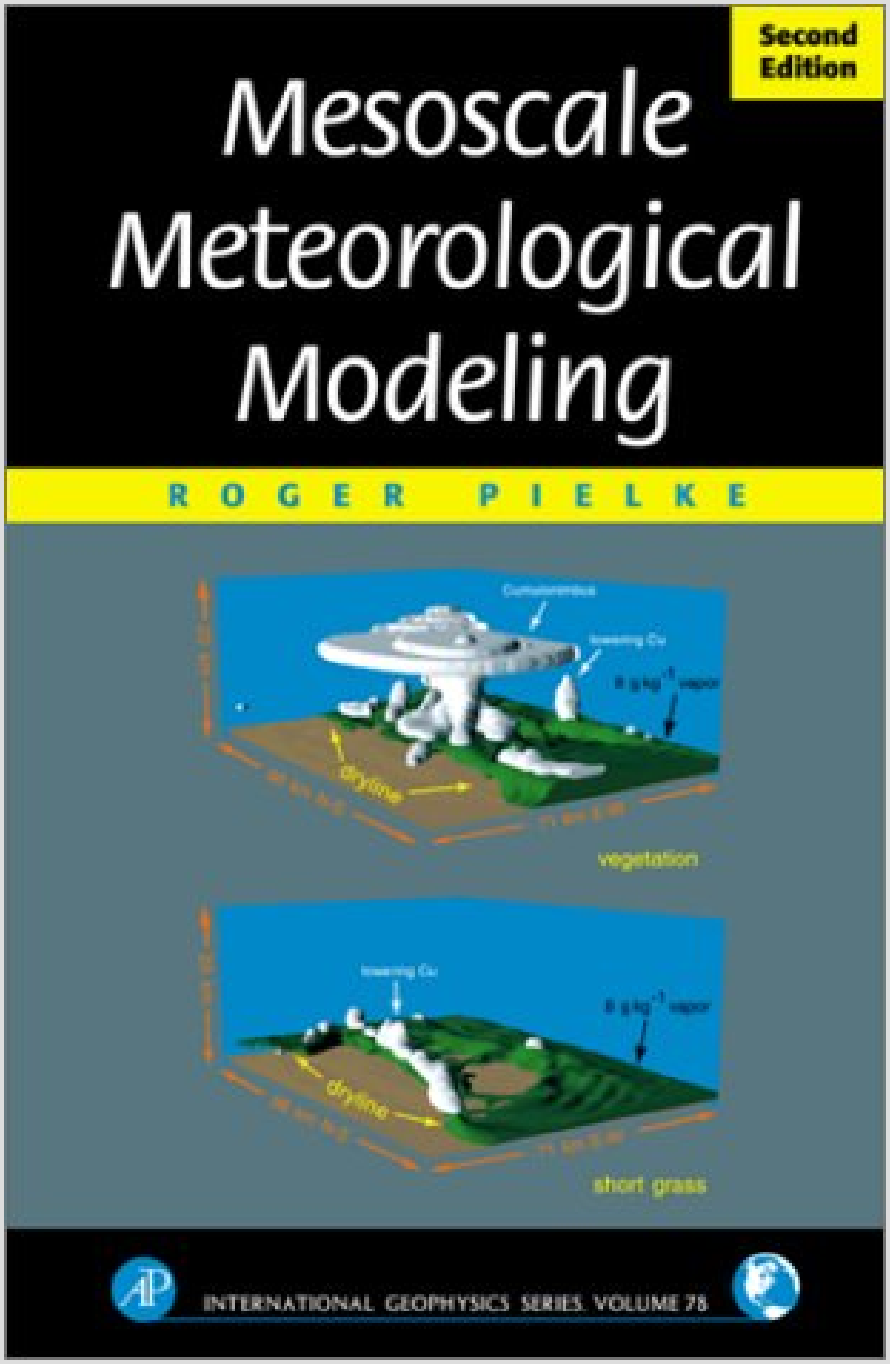
Climate change projections may be very different with higher resolution models.

How may global warming influence natural climate variability? For example, would there be a greater frequency of El Niños?

Are there feedbacks in the climate system which we don't know about and are not represented in models? Are all the known feedbacks being represented correctly?

What are the roles of other human-caused factors which may also contribute toward climate change. These may actually be more important on the regional and local scale than greenhouse-gas associated global warming

- **Changes in land use due to urbanization, agriculture**
- **Atmospheric aerosols due to local pollution**
- **Deforestation**



Changes in land use matter too!

Model simulation of a Great Plains thunderstorm with human current vegetation due to agricultural activity.

Same simulation with natural shortgrass prairie vegetation.

A more sensible approach?

Vulnerability paradigm: **Assesses ALL the potential factors which may influence climate change and variability for a given location (both natural and anthopogenic).**

Example: **New Orleans is vulnerable to strong hurricanes due to a variety of natural and anthropogenic factors, which range from local to global**

Inadequate levee system
Loss of wetlands in southern Louisiana
Natural variability of hurricanes (e.g. Camille in 1969)
A city built basically below sea level
Growth in population
Possibly stronger hurricanes due to global warming

Potential consequences of global warming?

Well, on the balance, it's probably not a good thing.

Archeological evidence indicates that rapid climate shifts may cause societal disruption or collapse, like in the Mayan and Anasazi civilizations.

Geologic record indicates some mass extinctions on Earth likely associated with rapid climate change too.

Potential Consequences of Global Warming

Sea Level Rise –
Ocean Thermal Expansion –
Coastal Flooding

?

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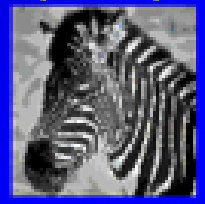
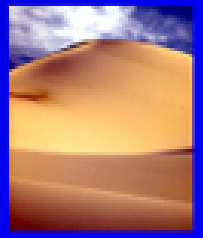
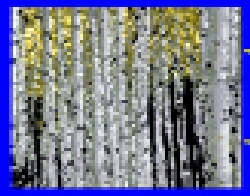


Changes in Climate Zones

Increasing Atmospheric Temperatures





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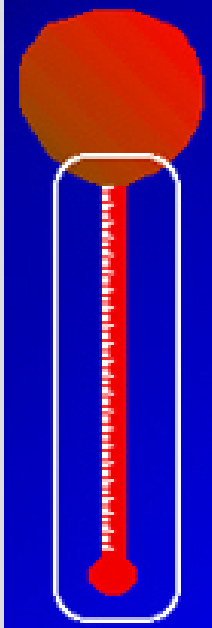
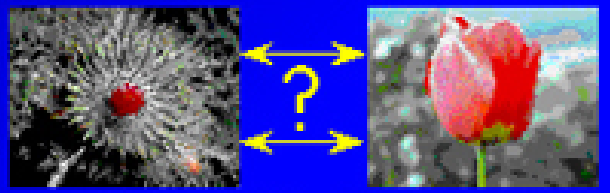
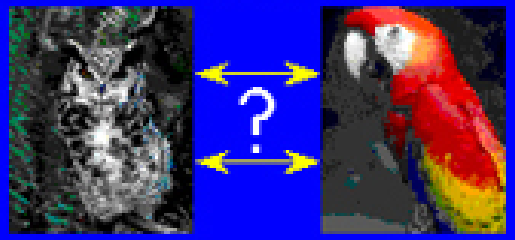


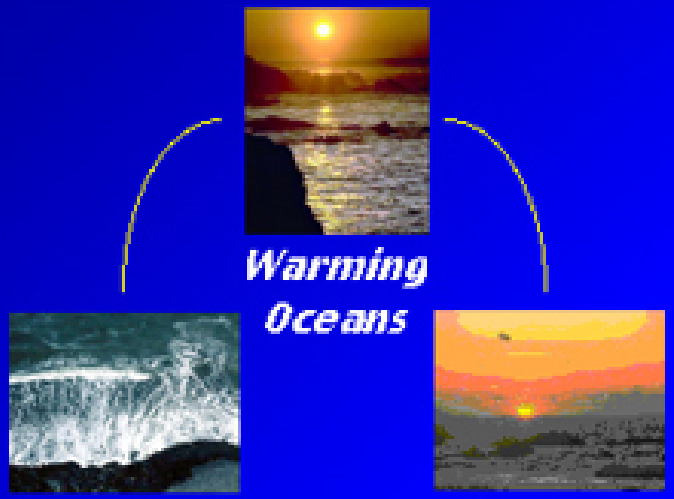
CG Figure-46a

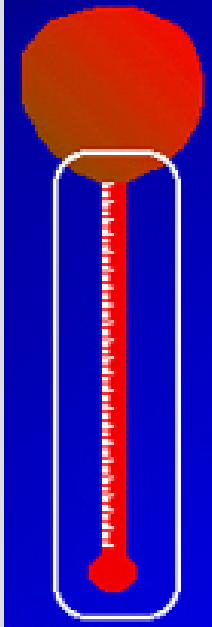
Potential Consequences of Global Warming (cont.)



Unexpected Changes in Biodiversity







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