Who Am I?

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Professor, Jackson Chair in Earth System Science
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Education: BSc and MSc in Meteorology
PhD in Atmospheric Science

Research: Land Surface Modeling, Model Development & Evaluation
Land–Atmosphere Interaction, Climate Modeling, Climate Change and Impacts on Water Resources and Environment

Teaching: Living with a Planet; Earth, Wind and Fire
Physical Climatology; Climate: Past, Present and Future
Hydroclimatology; Land–Atmosphere Interaction Dynamics

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Hours: Friday 12:45-1:45pm or by Appointment
Phone: 471-3824

My Education and Work Places

China	He'nan Province: 16 years	
	Nanjing: 5 years	
	Shanghai: 1 year	
Australia	Melbourne: 3 years	
	Sydney: 4 years	
USA	Tucson: 8 years	
	Austin: 13 years	

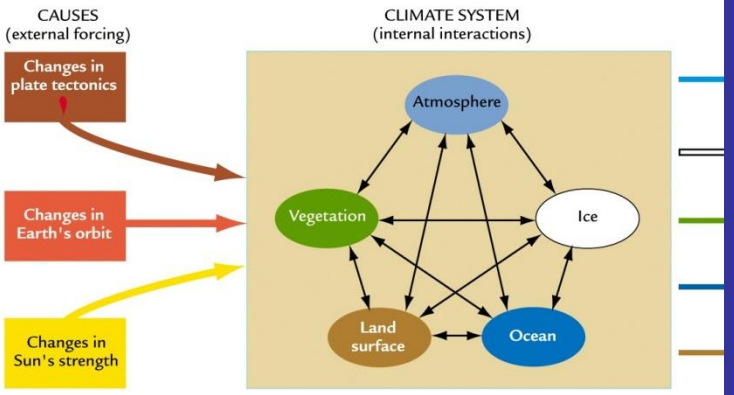
Introduction

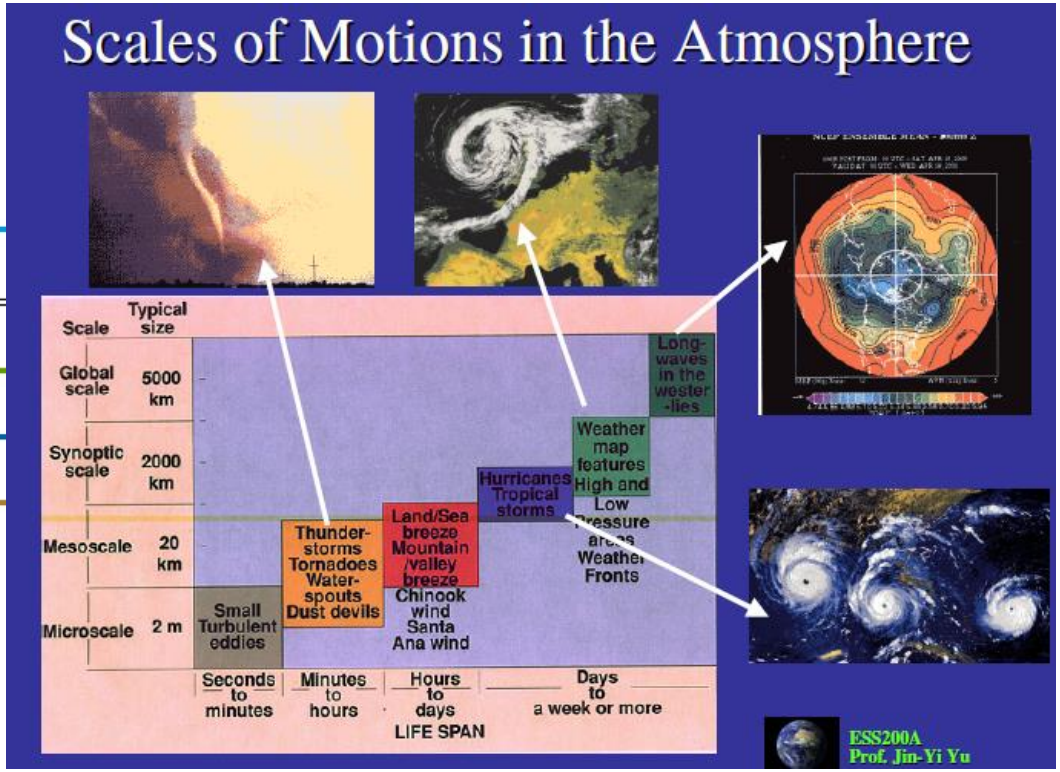
- **The scope of climatology**

  Derived from Greek terms: *klima* + *logos*

  slope (reflecting the early idea that distance from the equator alone drove climate) + study

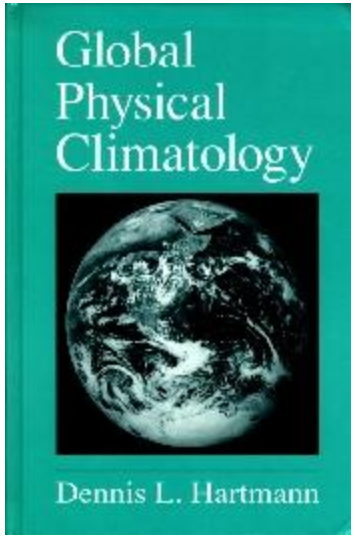
- **Study physical aspects of the interaction of the atmosphere with other spheres (lithosphere, hydrosphere, cryosphere, and biosphere); focusing on large scale (1000-km or above).**



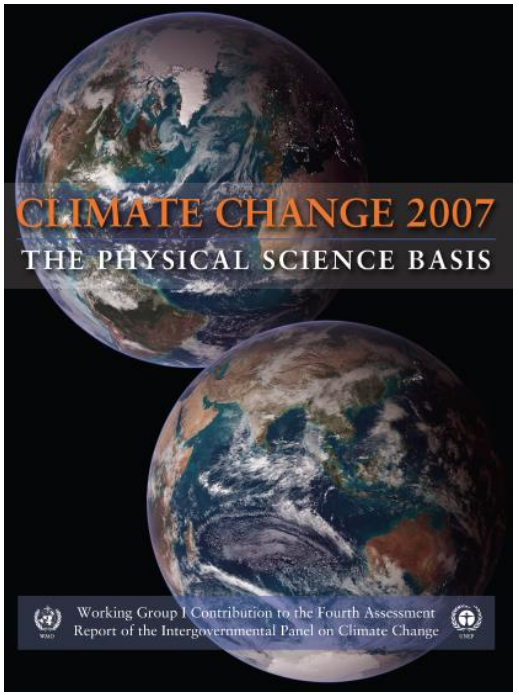


GEO 377P/387H Physical Climatology

- Textbook: Hartmann, 1994.
  Global Physical Climatology
  12 chapters, 411 pp.



- Textbook: IPCC, Climate Change 2007: The Physical Science Basis
  11 chapters, 940+ pp.



- Course website
  http://www.geo.utexas.edu/courses/387h
- Click **Schedules** for lists of lecture topics, reading assignments and homework.
- Click Syllabus for Grading Policy.
- Office hours: Friday, 12:45-1:45pm or by appointment, JGB Room 5.220DA

http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html

Special Report: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)
http://www.ipcc-wg2.gov/SREX/

Chapter 1: Introduction to the Climate System

This lecture discusses:

1. **What are the components of Earth's climate system?**
2. **How does climate variability differ from day-to-day weather?**
3. **What factors drive changes in Earth's climate?**
4. **How does the climate system work?**

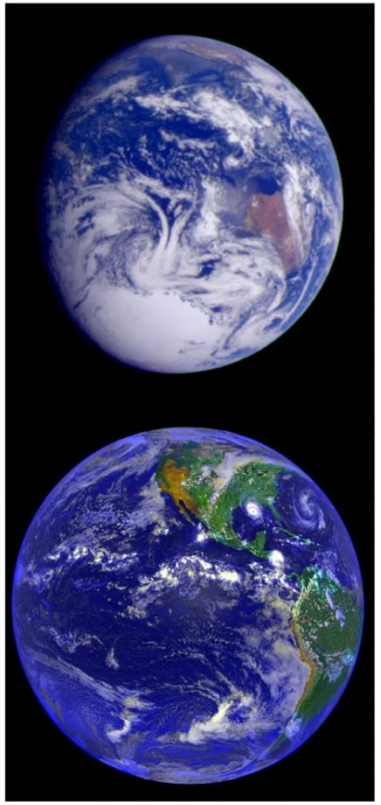
The Habitable Earth

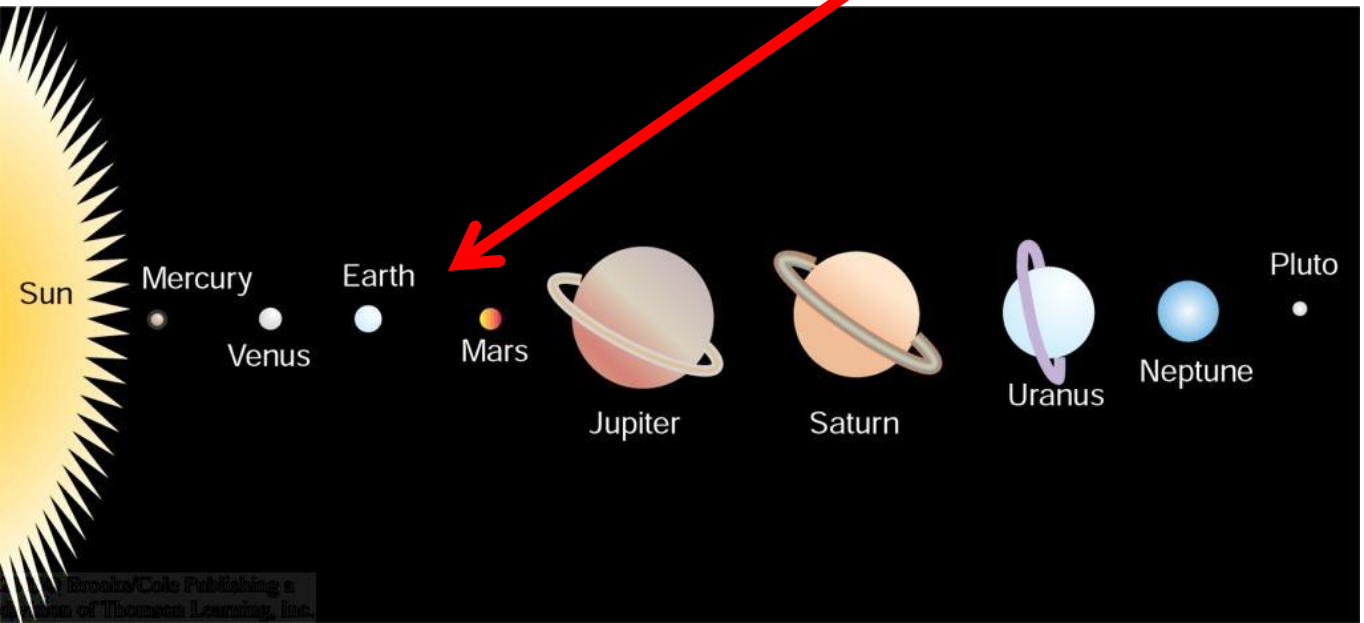
The earth is the only habitable planet in our solar system.

Oceans: 70% of the surface
Land: 30%

Earth's climate is favorable to life.

In the era of population explosion, climate change is critical to human life.





Weather versus Climate

Weather

The condition of atmosphere <u>at a given time and place</u>

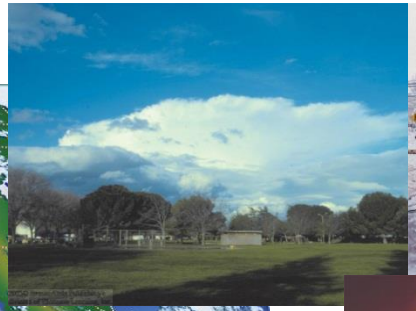
- **Short-term (and large) fluctuations that arise from internal instabilities of the atmosphere**
- **Occurs as a wide variety of phenomena that we often experience**
- **Effects are immediately felt**
- **Social and economic impacts are great but are usually localized**
- **Many such phenomena occur as part of larger-scale organized systems**
- **Governed by non-linear chaotic dynamics; not predictable deterministically beyond a week or two**

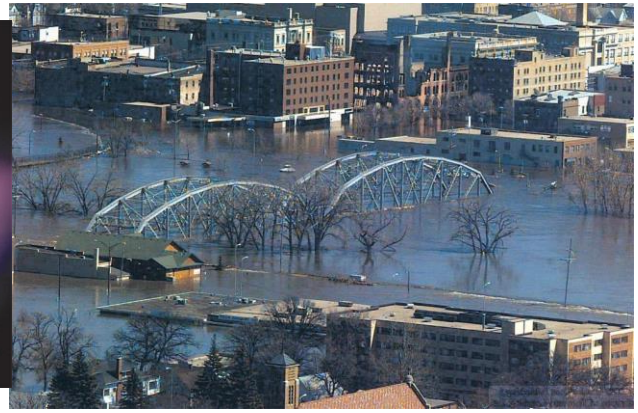
Weather versus Climate

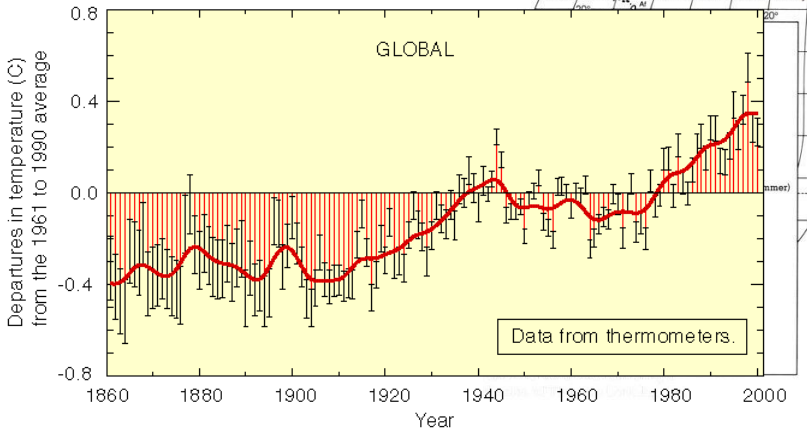
Climate

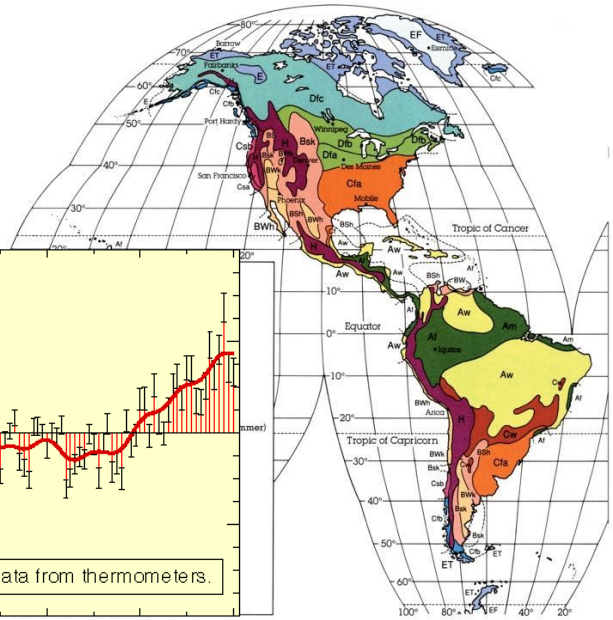
- Defined as the average state of the atmosphere over a finite time period and over a geographic region (space).
- Can be thought of as the "prevailing" weather, which includes the mean but also the range of variations
- The wide range of natural variability associated with daily weather means small climate changes are difficult to detect
- Intimate link between weather and climate provides a basis for understanding how weather events might change under a changing climate
- Climate is what you expect and weather is what you get.
- Climate tells what clothes to buy, but weather tells you what clothes to wear.

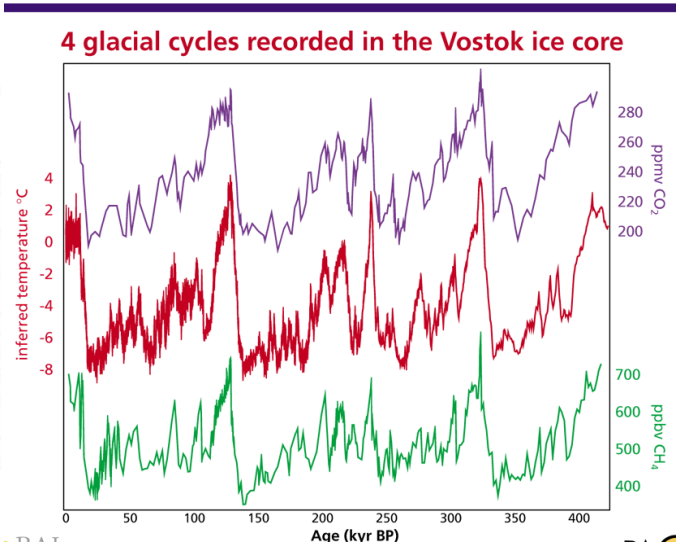
Weather and Climate

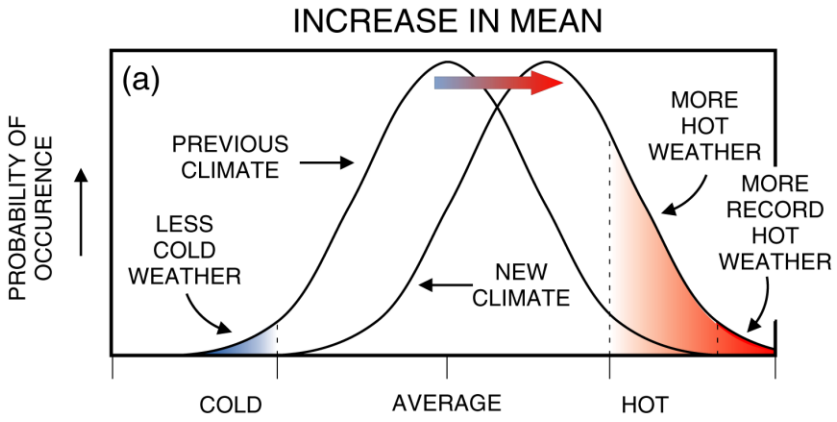












Climate change and its manifestation in terms of weather (climate extremes)

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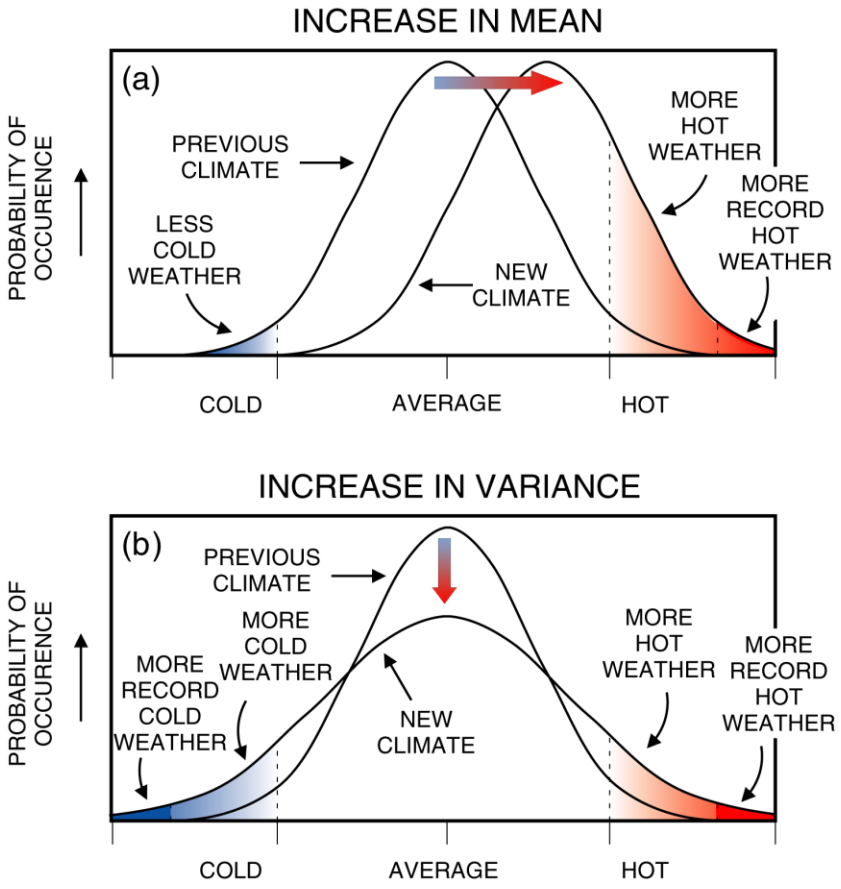
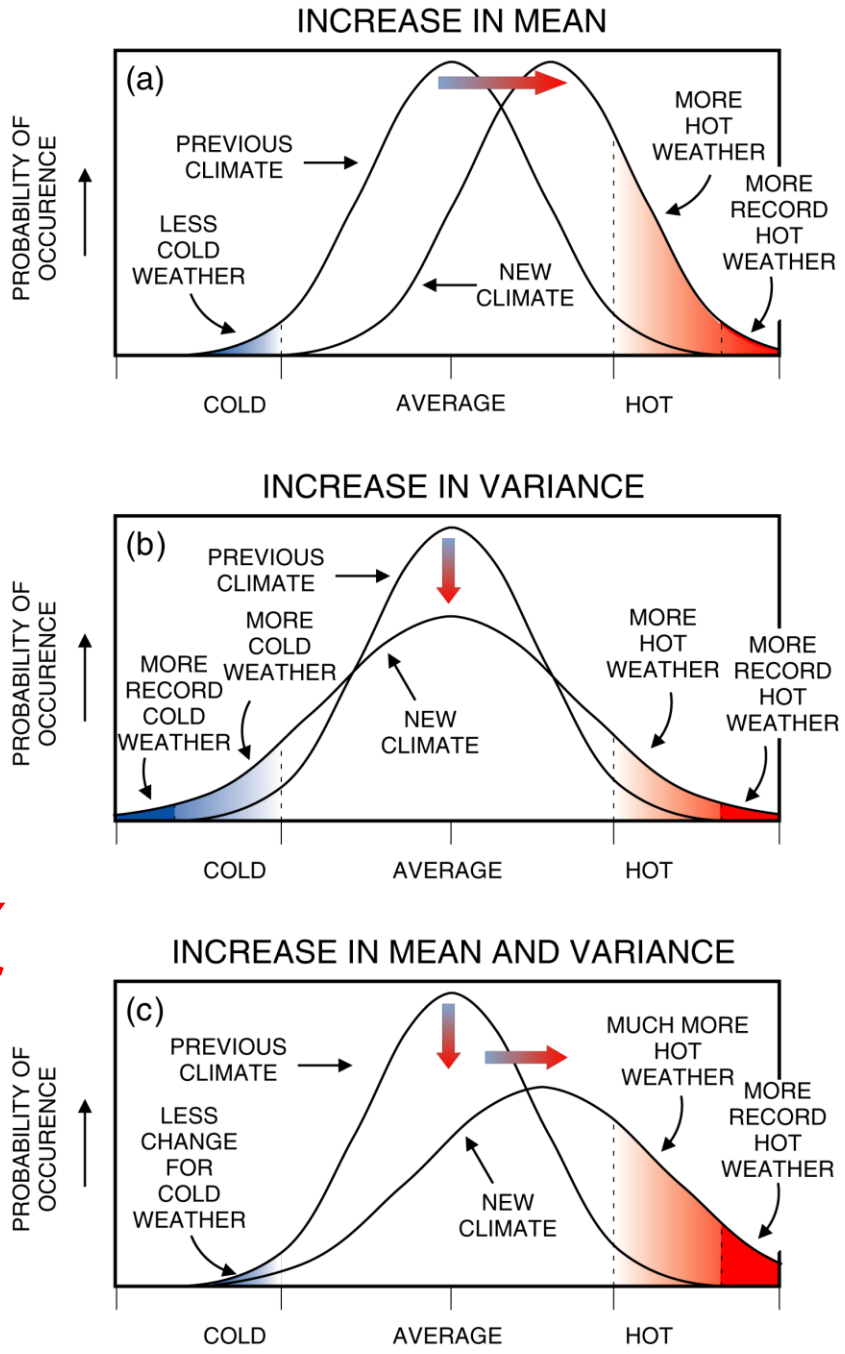
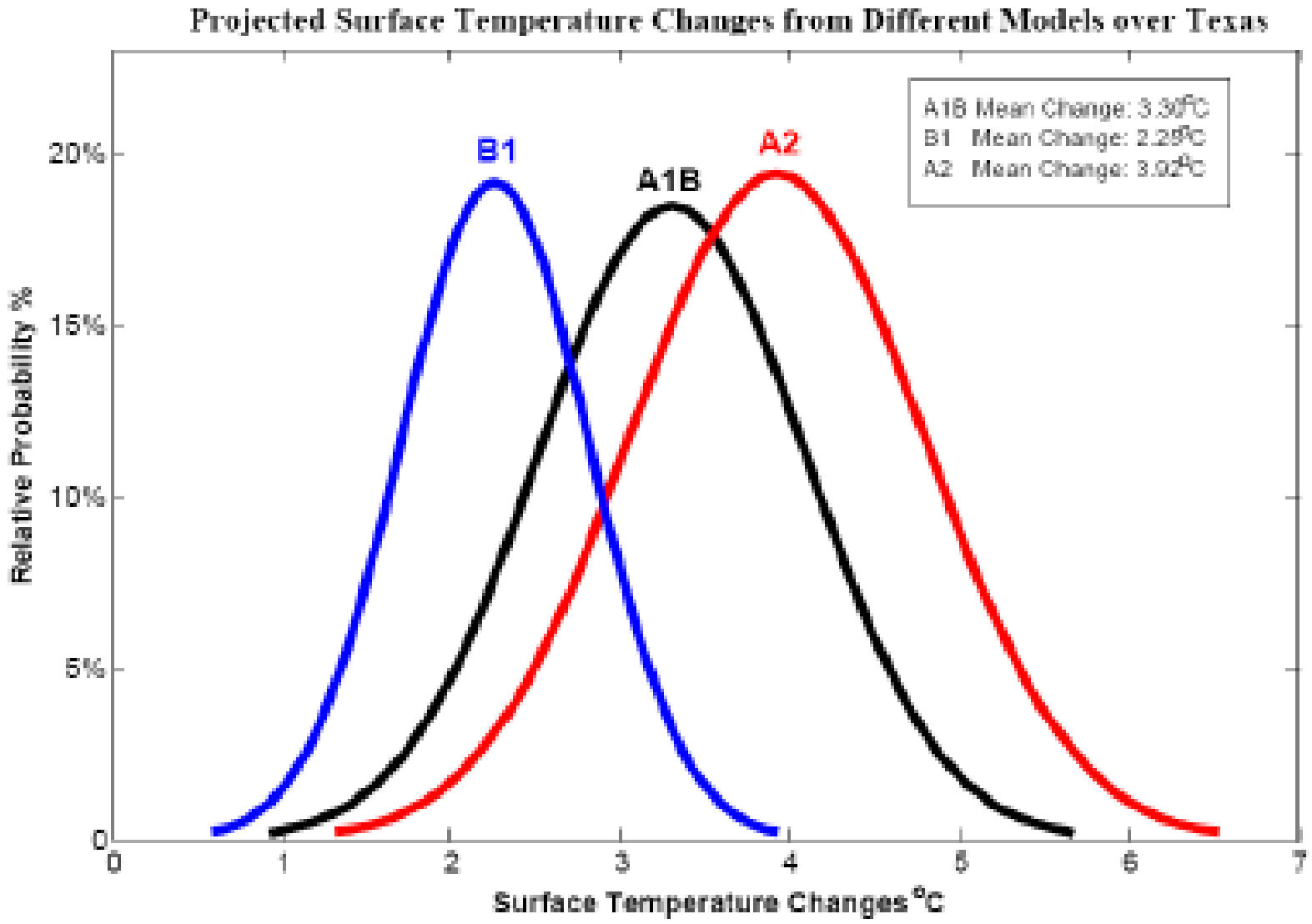


Climate change and its manifestation in terms of weather (climate extremes)

Global warming increases the frequency and intensity of extreme weather events



Climate Change in Texas from WCRP CMIP3



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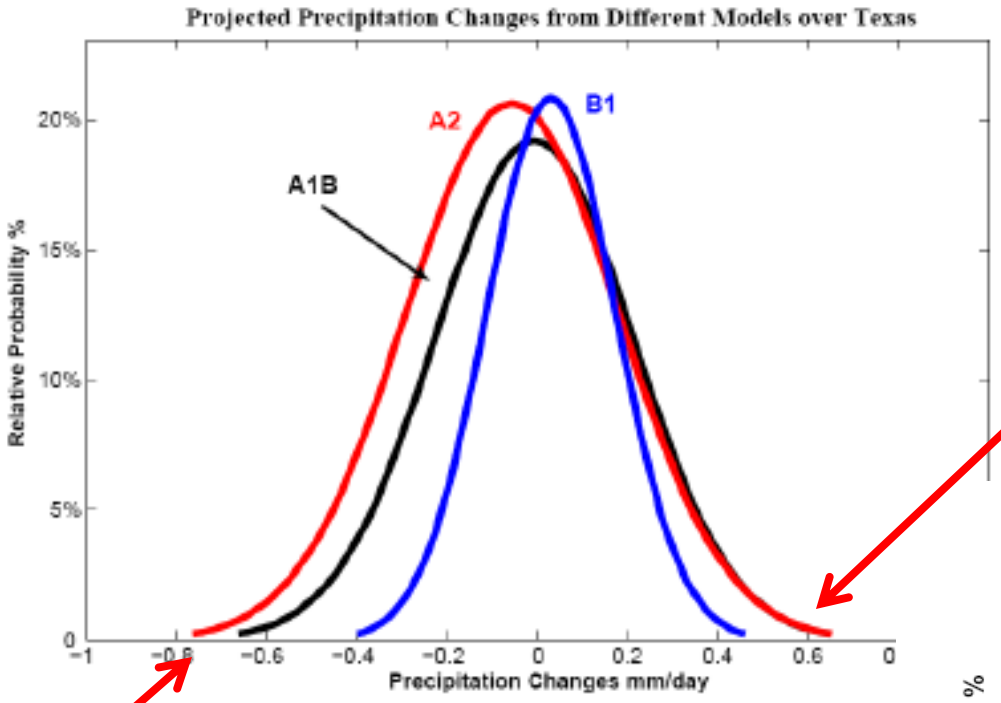
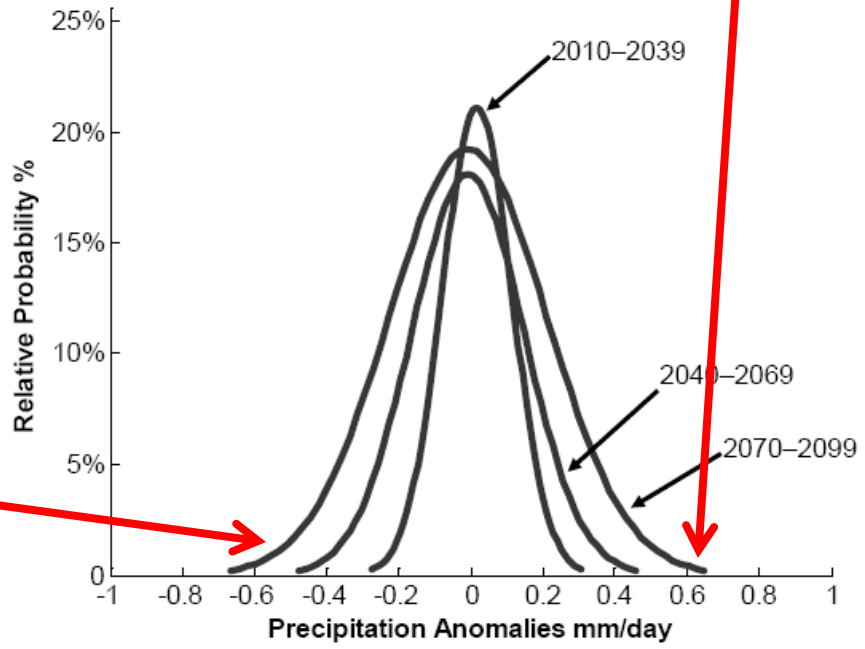


More heavy rainfalls and more floods

More dry periods and intense droughts



Climate versus Weather

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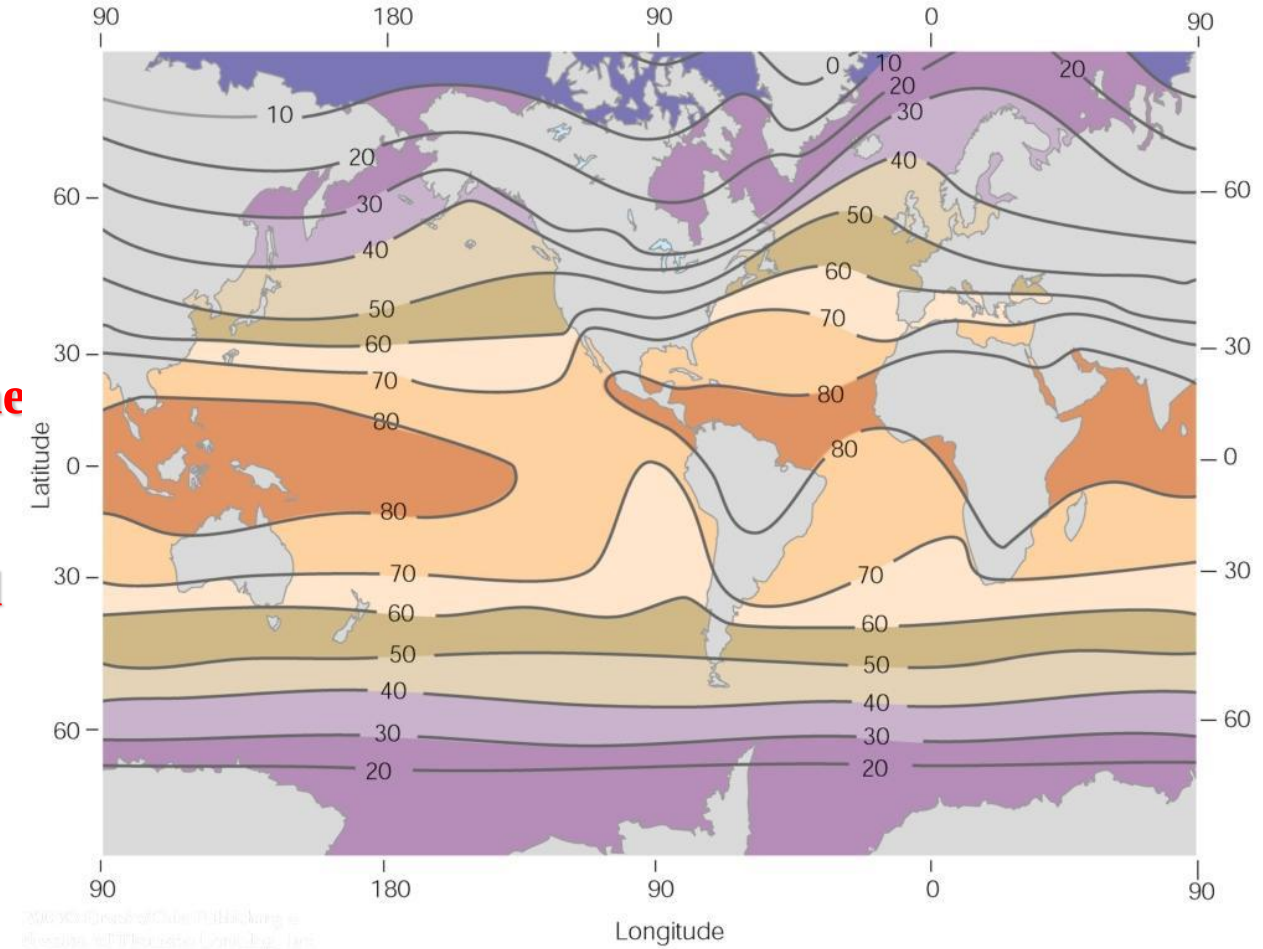
- The wide range of natural variability associated with daily weather means small climate changes are difficult to detect
- Intimate link between weather and climate provides a basis for understanding how weather events might change under a changing climate
- Involves atmospheric interactions with other parts of the climate system and external forcing
- Climate prediction is complicated by considering the complex interactions between, as well as changes within, all components

Climatic Controls

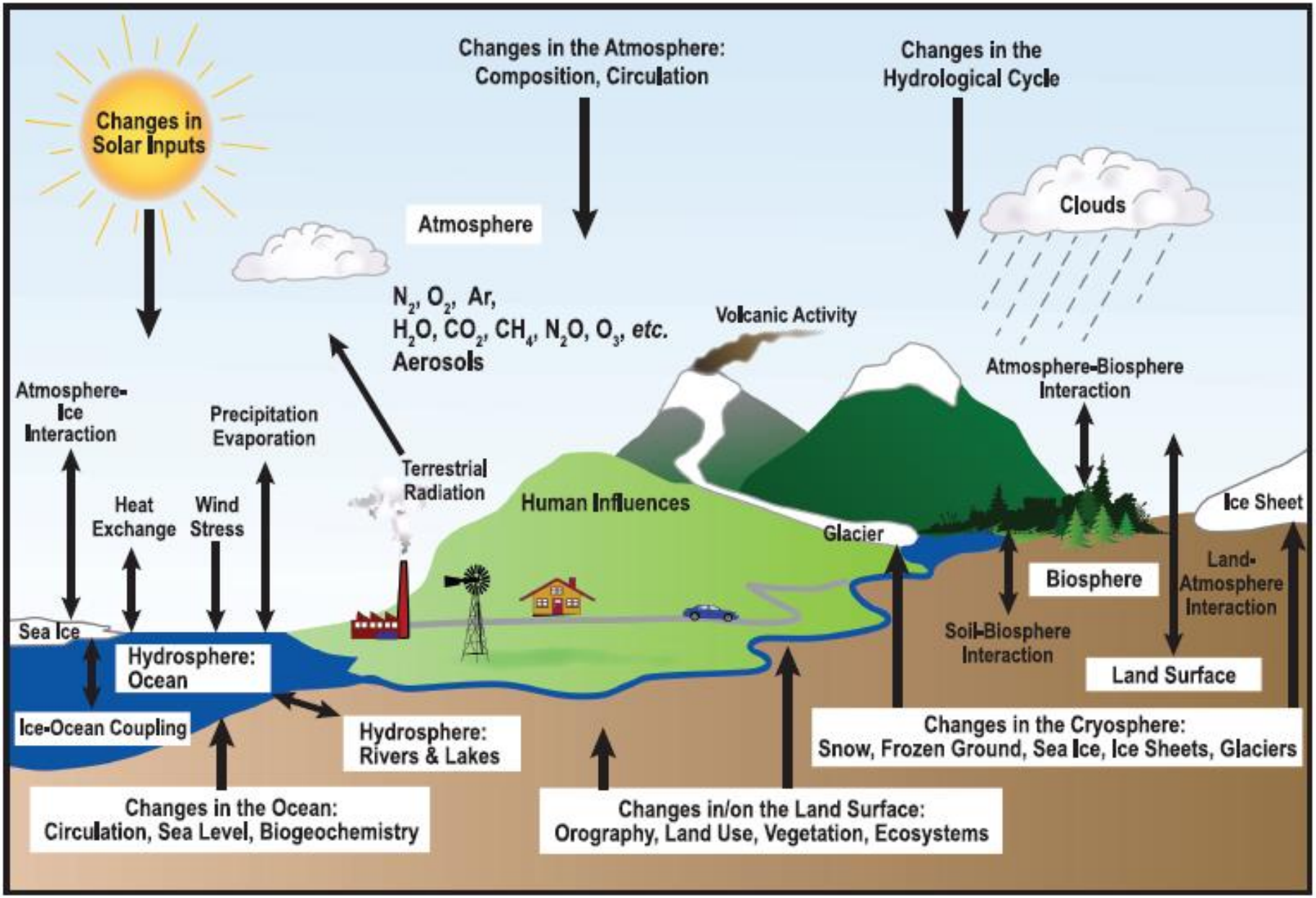
The world's many climates are controlled by the same factors affecting weather,

a) intensity of sunshine and its variation with latitude,
b) distribution of land and water,
c) ocean temperature and currents,
d) mountain barriers,
e) land cover,
f) atmospheric composition.



This map shows sea-level temperatures (°F).

The Climate System Components



Climate System Components

Atmosphere

- Fastest changing and most responsive component
- Previously considered the only "changing" component

Ocean

- The other fluid component covering ~70% of the surface
- Plays a central role through its motions and heat capacity
- Interacts with the atmosphere on days to thousands of years

Cryosphere

- Includes land snow, sea ice, ice sheets, and mountain glaciers
- Largest reservoir of fresh water
- High reflectivity and low thermal conductivity

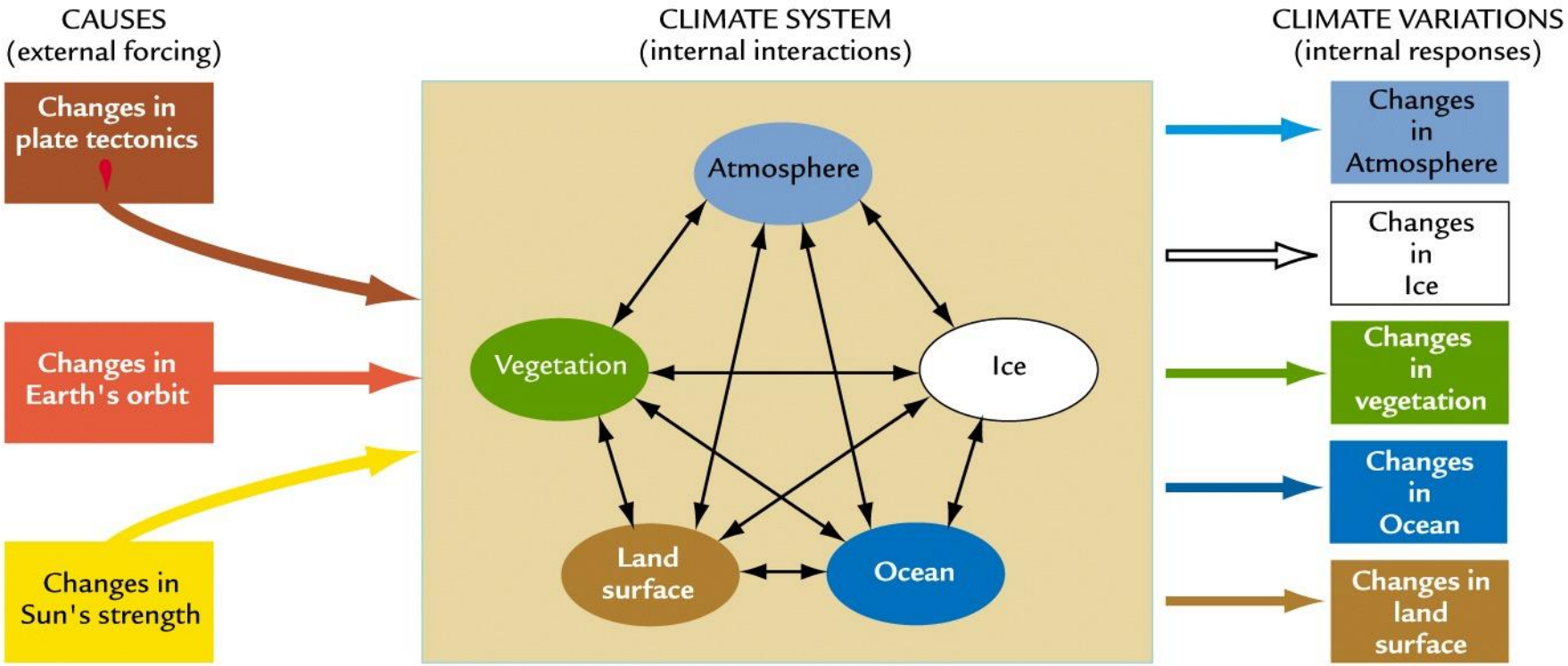
Land and its biomass

- Slowly changing extent and position of continents
- Faster changing characteristics of lakes, streams, soil moisture and vegetation

Human interaction

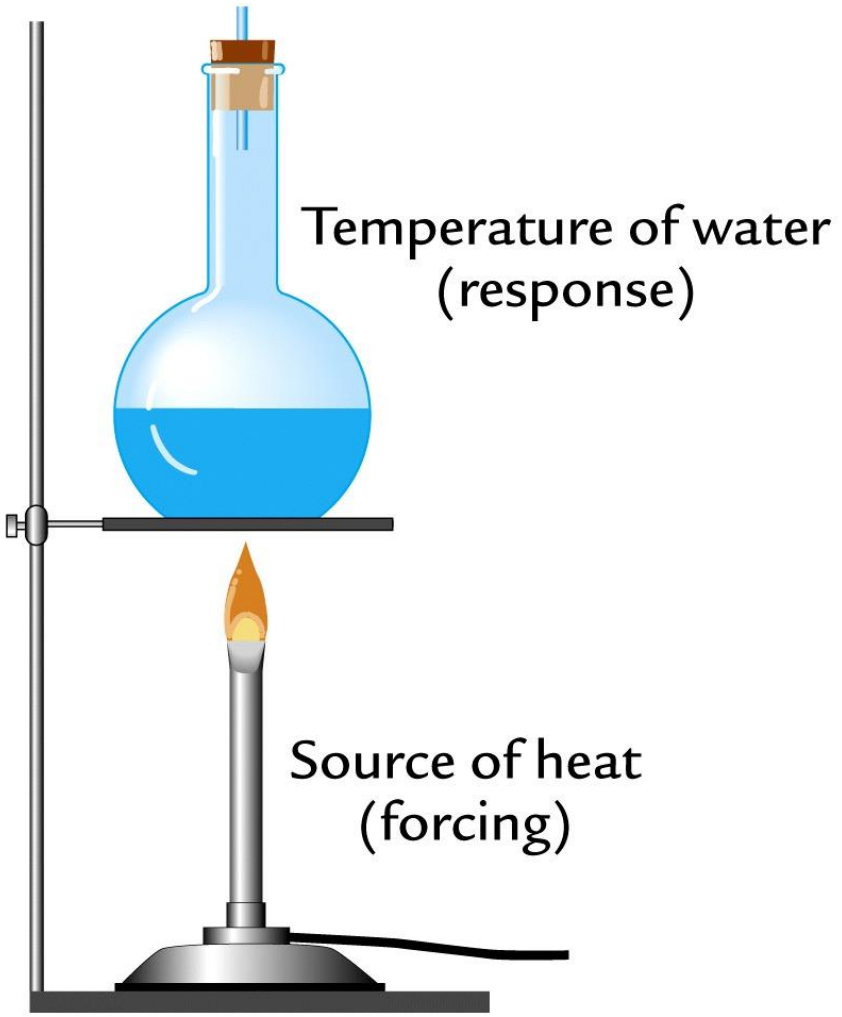
- agriculture, urbanization, industry, pollution, etc.

Climate: Forcing and Response



Input **Machine** **Output**

Forcing and Response: A Bunsen Burner Experiment



A

Three major kinds of climate forcing in nature:

- ✓Tectonic processes
- ✓Earth-orbital changes
- ✓Changes in Sun's strength

- ✓Anthropogenic forcing
  - ✓Urbanization
  - ✓Deforestation
  - ✓Burning fossil fuels
  - ✓Agriculture

Response time depends on "materials" or "components".

Response Times of Various Climate System Components

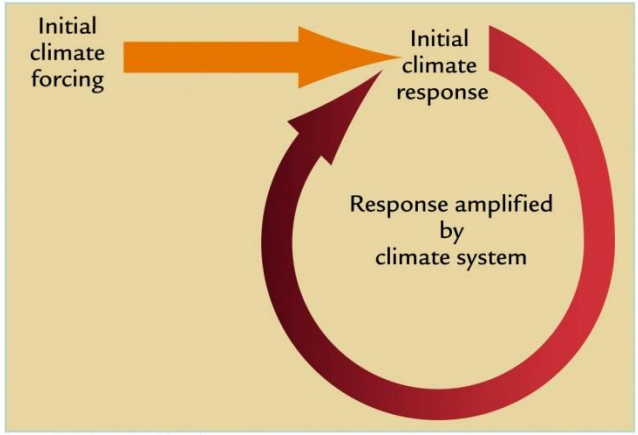
TABLE 1.1 Response Times of Various Climate System Components

Component	Response time (range)	Example
	Fast responses	
Atmosphere	Hours to weeks	Daily heating and cooling Gradual buildup of heat wave
Land surface	Hours to months	Daily heating of upper ground surface Midwinter freezing and thawing
Ocean surface	Days to months	Afternoon heating of upper few feet Warmest beach temperatures late in summer
Vegetation	Hours to decades/centuries	Sudden leaf kill by frost Slow growth of trees to maturity
Sea ice	Weeks to years	Late-winter maximum extent Historical changes near Iceland
	Slow responses	
Mountain glaciers	10–100 years	Widespread glacier retreat in 20th century
Deep ocean	100–1500 years	Time to replace world's deep water
Ice sheets	100–10,000 years	Advances/retreats of ice sheet margins Growth/decay of entire ice sheet

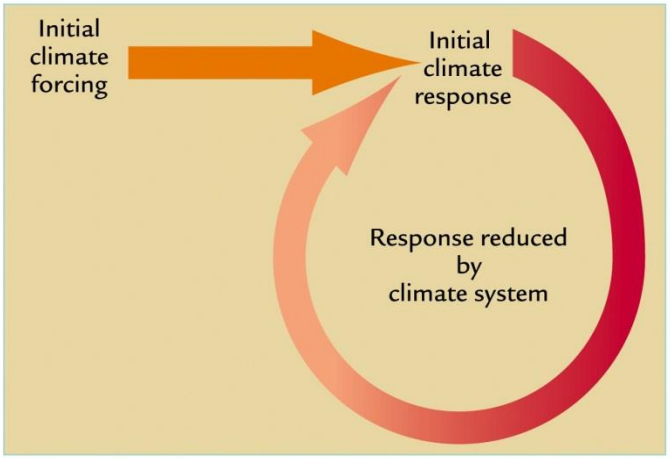
Feedbacks

A feedback is a mechanism whereby an initial change in a process will tend to either reinforce the change (positive feedback)

or weaken the change (negative feedback).



A Positive feedback



B Negative feedback

Example of a positive feedback

Think about the polar regions:

Example of a positive feedback

More energy retained in system

Warm temperatures

Ice and snow melt

Albedo decreases
Less solar energy reflected

If this were the only mechanism acting, we'd get a runaway temperature increase

Example of a negative feedback

More energy
retained in system

Warm temperatures

More evaporation
More clouds

Example of a negative feedback

More energy retained in system

Warm temperatures

More evaporation
More clouds

Albedo increases
More solar energy reflected

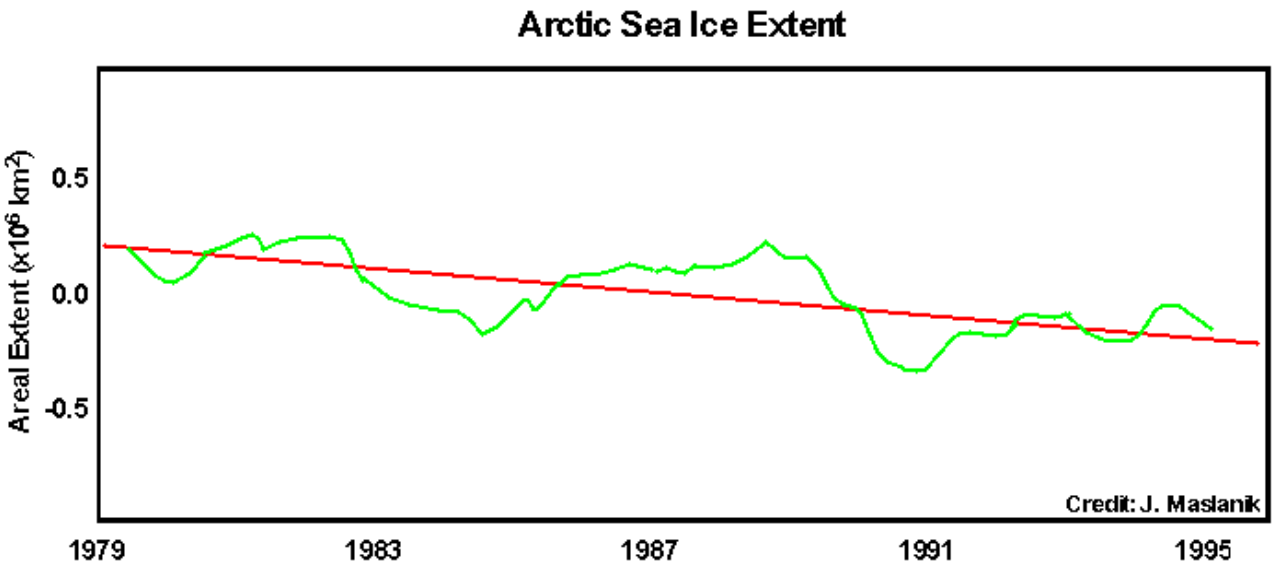
Another Positive Feedback

More energy retained in system

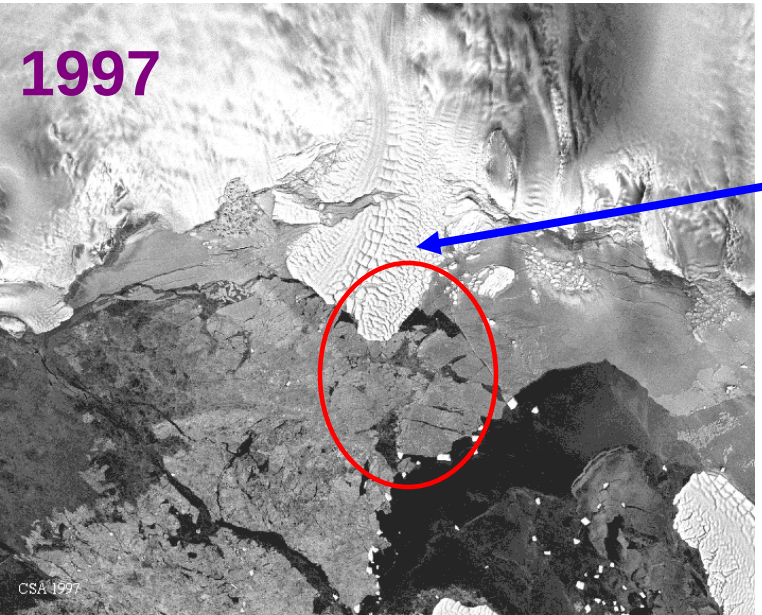
Warm temperatures

More evaporation
More clouds

More longwave energy absorbed

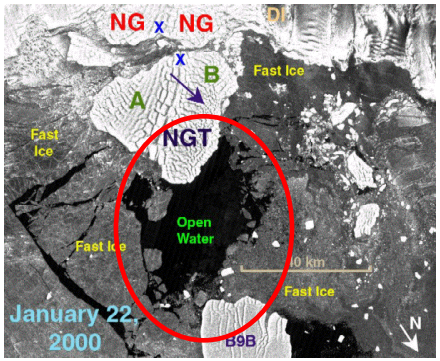


Snow and ice albedo feedbacks in the polar regions are to blame for the large changes already observed.



Ninnis Glacier Tongue Antarctica

2000



Mechanisms of Climate Variability and Change: External versus Internal Forcing

External

- Changes in the Sun and its output, the Earth's rotation rate, Sun-Earth geometry, and the slowly changing orbit
- Changes in the physical make up of the Earth system, including the distribution of land and ocean, geographic features of the land, ocean bottom topography, and ocean basin configurations
- Changes in the basic composition of the atmosphere and ocean from natural (e.g., volcanoes) or human activities

Internal

- High frequency forcing of the slow components by the more rapidly varying atmosphere
- Slow variations internal to the components
- Coupled variations: Interactions between the components

Factors that influence the Earth's climate