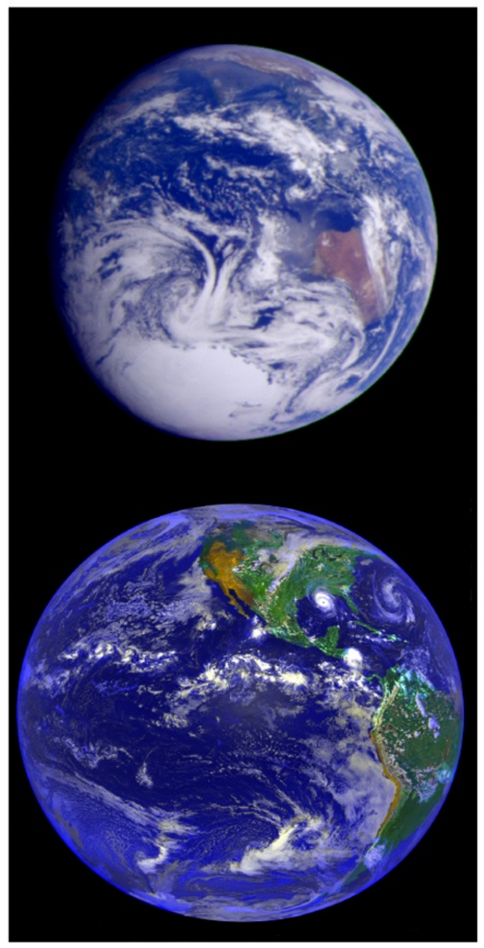
Today's lab

Discussion:

- Climate vs. weather
- Components of the climate system
- Forcing and response
- Response time
- Feedback
- Equilibrium

Earth's Climate &Weather



- Climate
  - Long-term (years and longer) average condition of a region
    - Rainfall or snowfall
    - Snow and ice cover
    - Temperature
- Weather
  - Short-term (hours to weeks) fluctuations

"climate is what you expect; weather is what you get".

Climate vs. Weather

- Definition
- Why do we care about climate?
- How is climate related to weather?
- Climate impacts examples
- Climate change examples

http://www.youtube.com/watch?v=wnjx6KETmi4

Historical Examples of Climate Change?

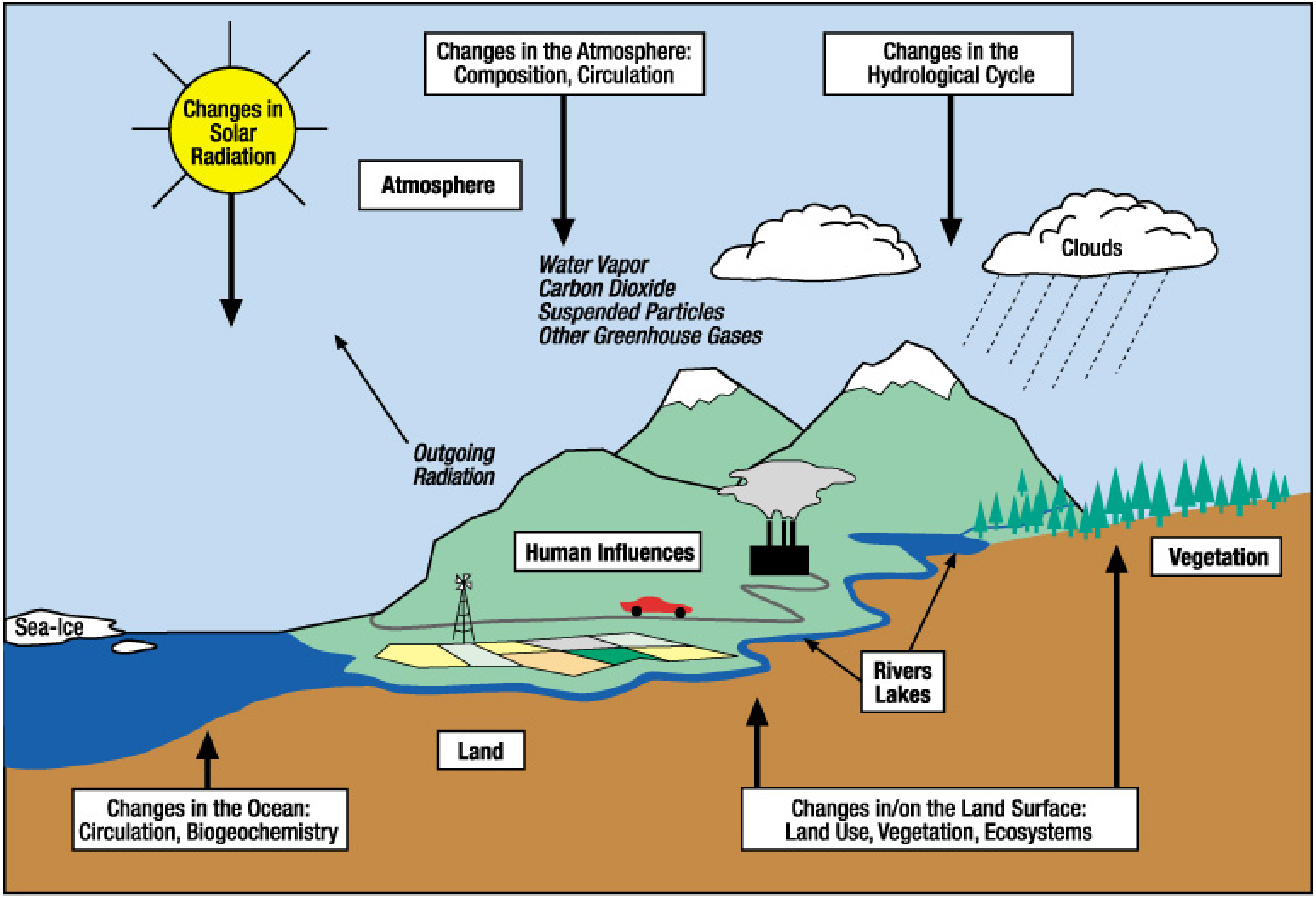
- Advance and retreat of glaciers
  - Alpine glaciers shrunk in 20^{th} century
- Thinning of ice on NW Greenland
  - See *Nature* v. 414, 60-62
- Sea level rise
- El Nino/La Nina oscillations
- Length of growing season in Alaska increased from 1950-2000
- Decrease in Arctic sea ice cover from 1970-2000

Components of the climate system

Five major components →

Air (atmosphere)
water (hydrosphere)
Ice (cryosphere)
Vegetation (biosphere)
And land (lithosphere)

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

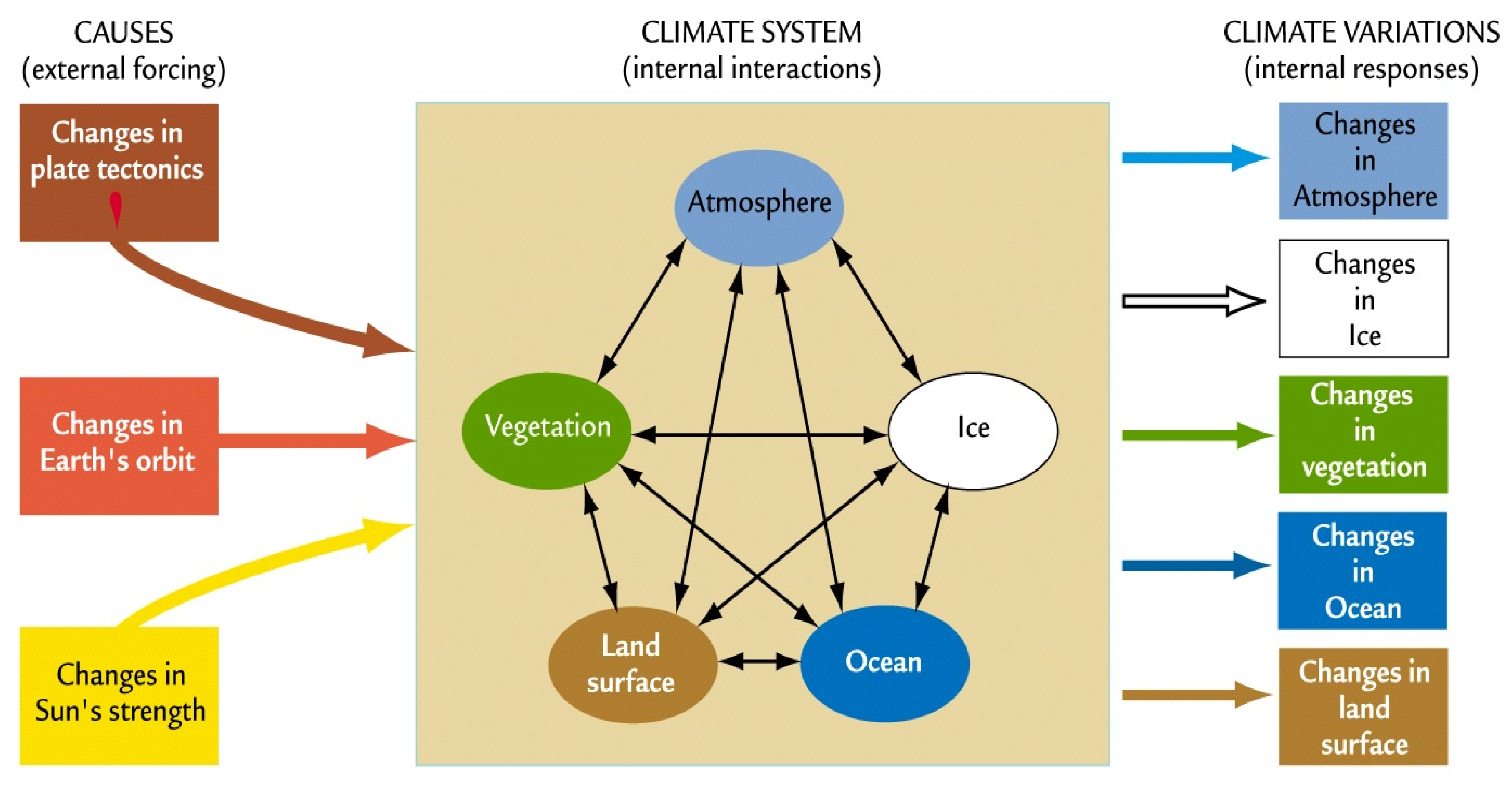
Land and its biomass

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

Human interaction

agriculture, urbanization, industry, pollution, etc.

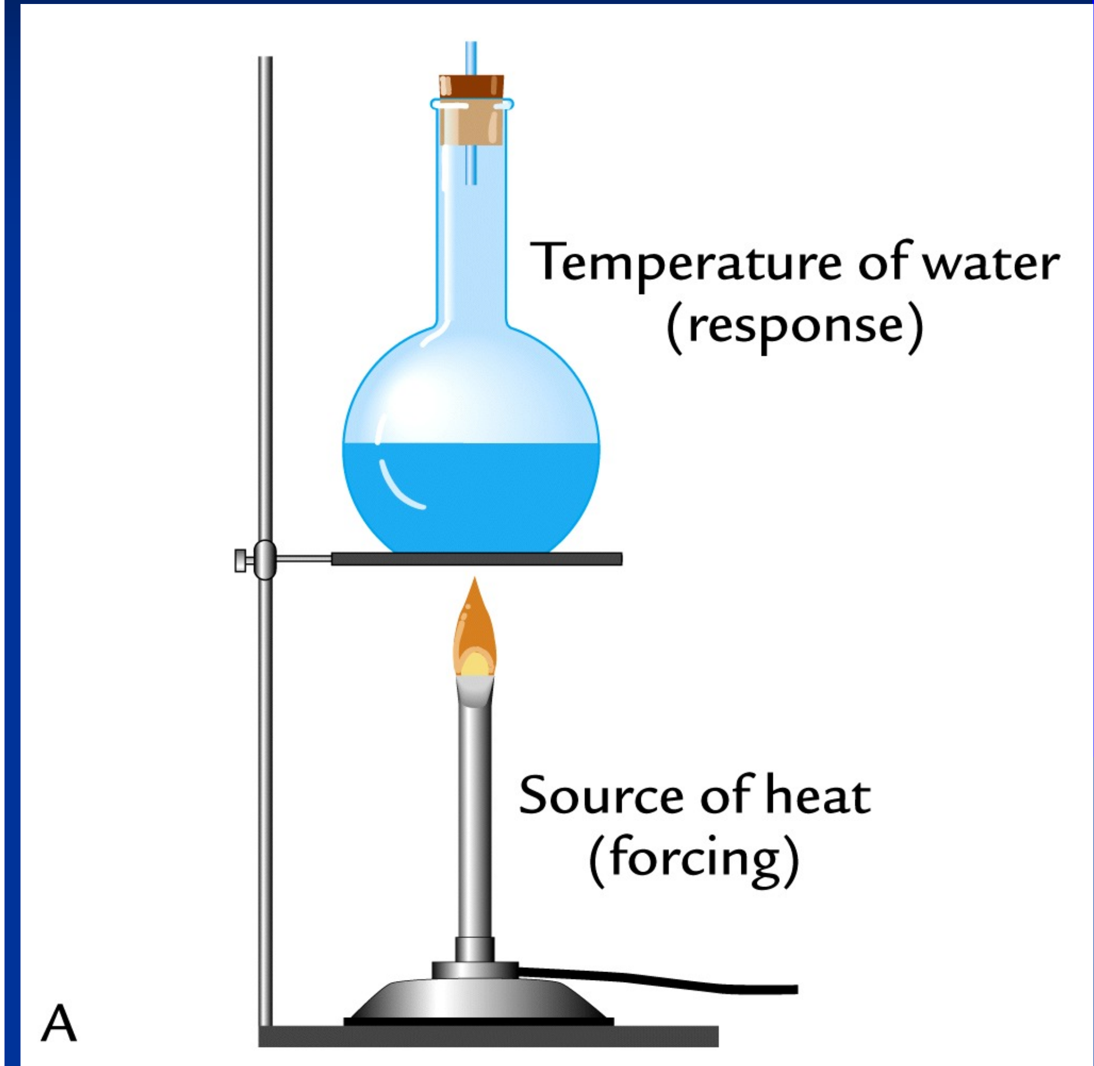
Forcing and response



Forcing – factors that drive or cause changes

Response – the climate change that occurs

Forcing and Response: A Bunsen Burner Experiment



Three major kinds of climate forcing in nature:

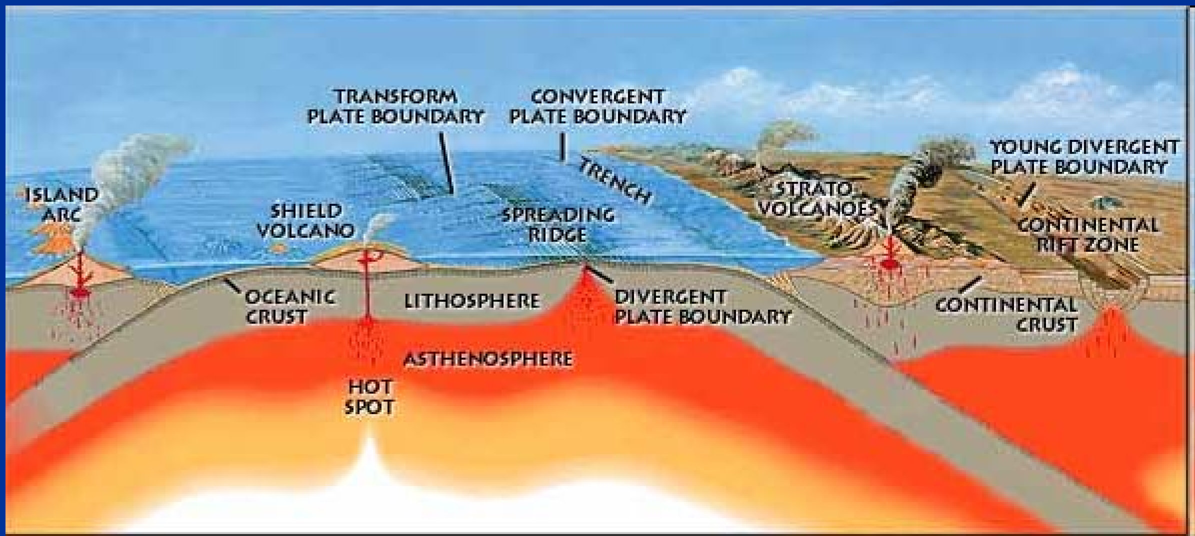
- ✓Tectonic processes
- ✓Earth-orbital changes
- ✓Changes in Sun's strength

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

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

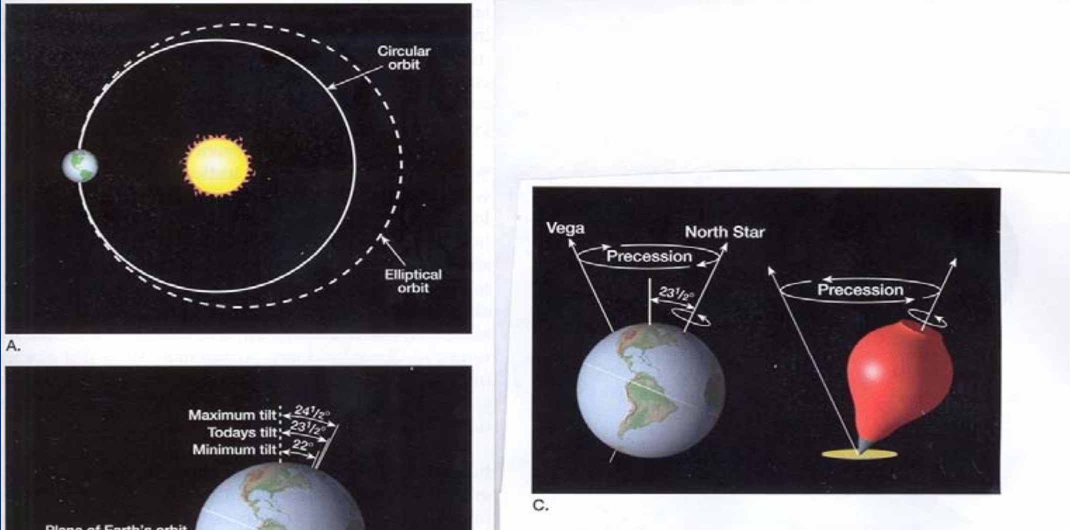
Climate Forcing

- Tectonic Processes
  - Slow movement of plates affects climate only very slowly



Climate Forcing

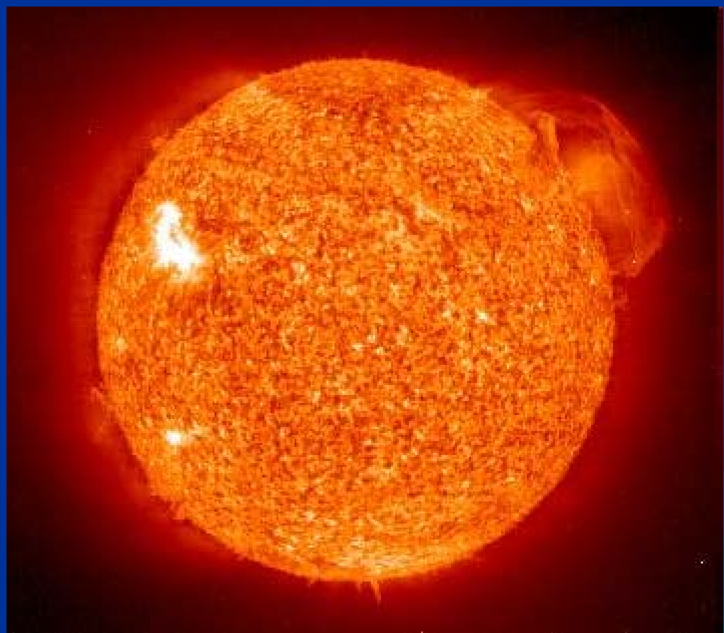
- Earth-Orbital Changes
  - Variations in earth's orbit around the Sun affect the amount of solar radiation received on Earth's surface. Orbital scale changes occur over tens to hundreds of thousands of years.



▲ FIGURE 18.32 Orbital variations. A. The shape of Earth's orbit changes during a cycle that spans about 100,000 years. It gradually changes from nearly circular to one that is more elliptical and then back again. This diagram greatly exaggerates the amount of change. B. Today the axis of rotation is tilted about 23.5° to the plane of Earth's orbit. During a cycle of 41,000 years, this angle varies from 21.5° to 24.5°. C. Precession. Earth's axis wobbles like that of a spinning top. Consequently, the axis points to different spots in the sky during a cycle of about 26,000 years.

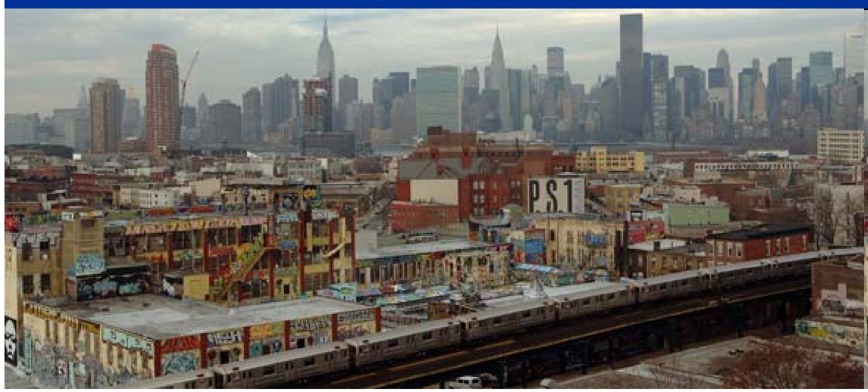
Climate Forcing

- Changes in the Strength of the Sun
  - Affects the amount of solar radiation received on Earth's surface. Can occur on long-term (100's of millions of years) or on short-term (10-1000's years)



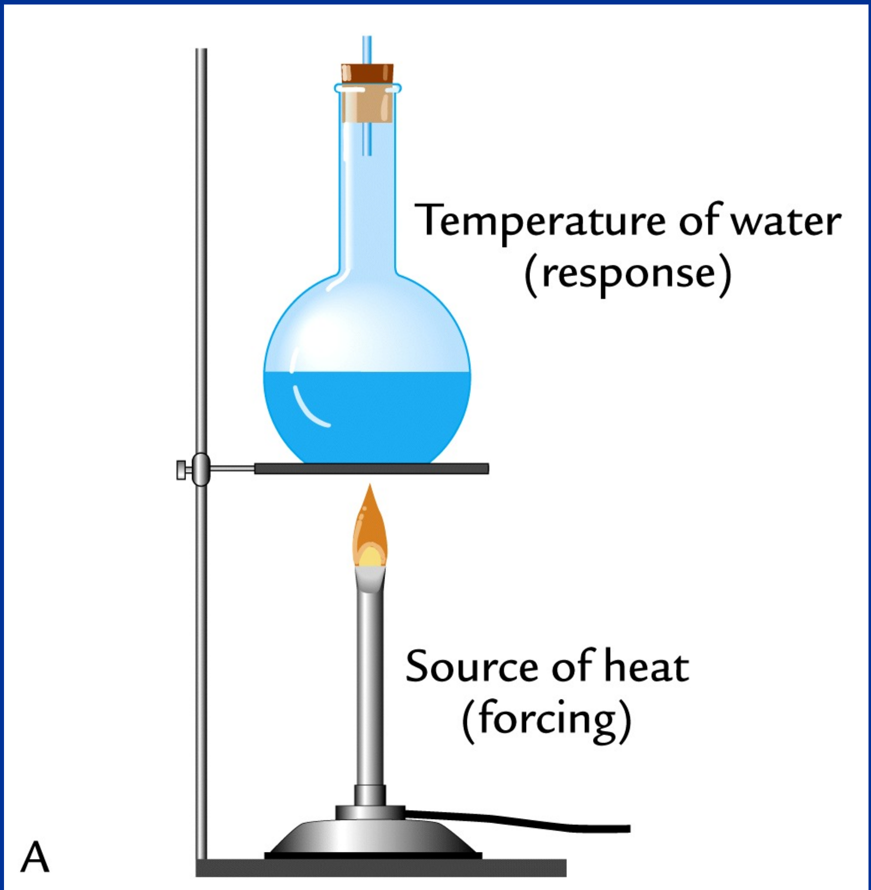
Climate Forcing

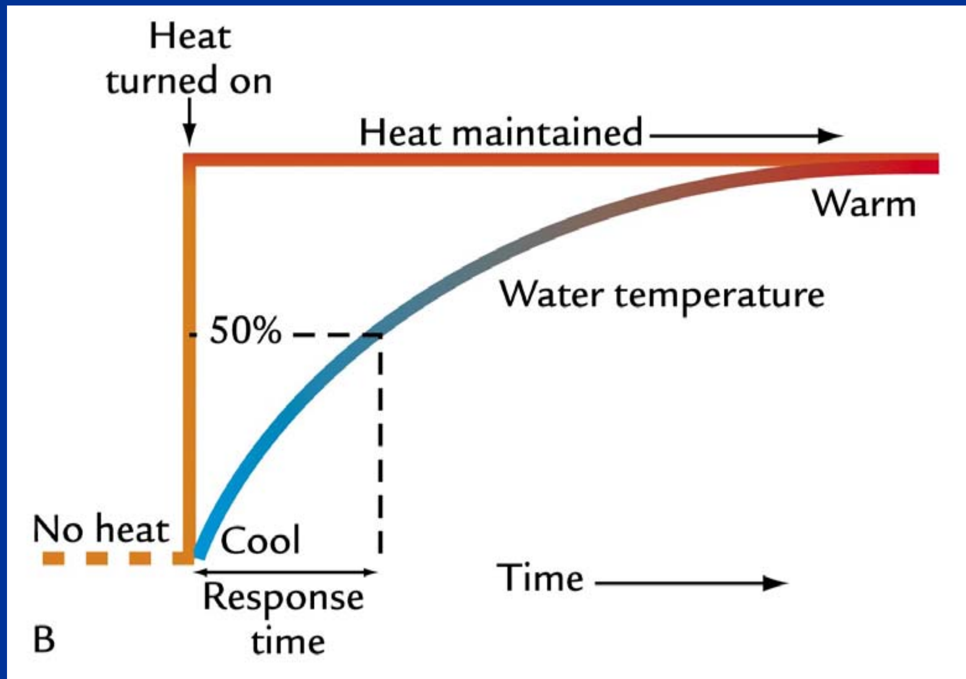
- Anthropogenic Forcing
  - Not part of the natural climate system
  - Affect of humans on climate
  - Byproduct of agricultural, industrial and other human activities
    - Example is addition materials to the atmosphere such as gases (CO_2, N_2O, etc.), sulfate particles and soot.




Response Time

- Time it takes the climate system to react to a change in forcing (reaction time)





Response time = amount of time it takes to get 50% of the way toward equilibrium

Response time

Response Times of Various Climate System Components

TABLE 1.1 Response Times of Various Climate System Components

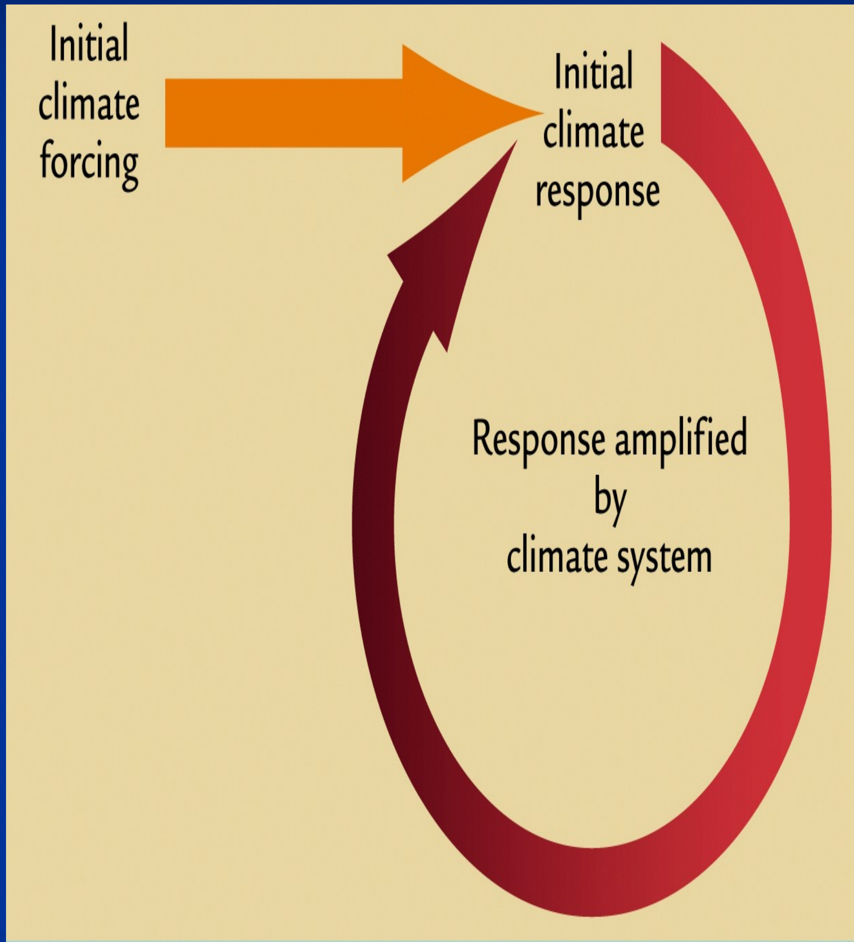
Component	Response time (range)	Example
	Fast responses	
Atmosphere	Hours to weeks	Daily heating and cooling Gradual buildup of heat wave
Land surface	Hours to months	Daily heating of upper ground surface Midwinter freezing and thawing
Ocean surface	Days to months	Afternoon heating of upper few feet 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

Feedback

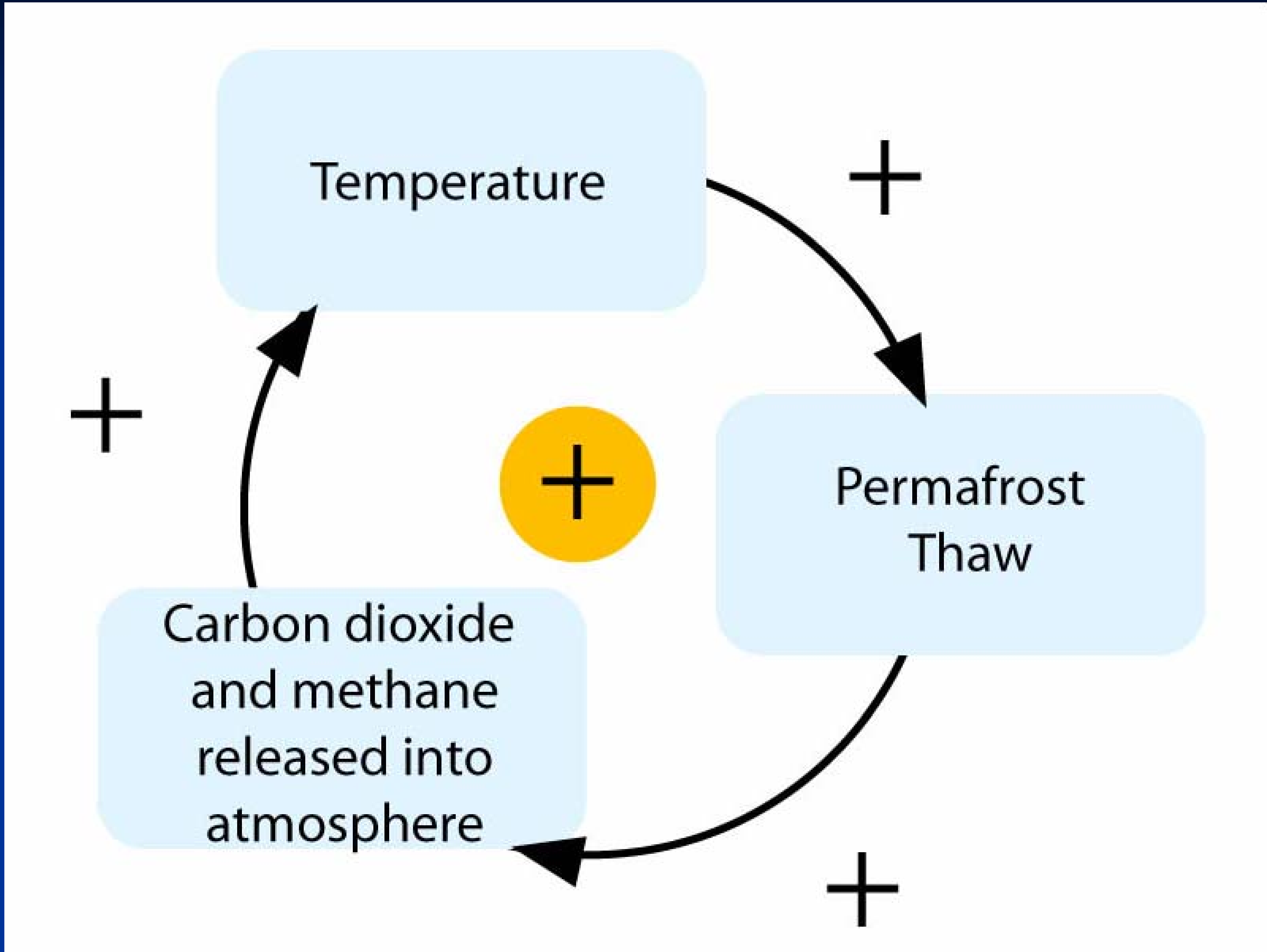
- **Feedback** describes the situation when output from (or information about the result of) an event or phenomenon in the past will influence the same event/phenomenon in the present or future.
- There are many climate feedback mechanisms in the climate system that can either amplify ('positive feedback') or diminish ('negative feedback') the effects of a change in climate forcing
- http://www.bigpicture.tv/videos/watch/371bce7dc

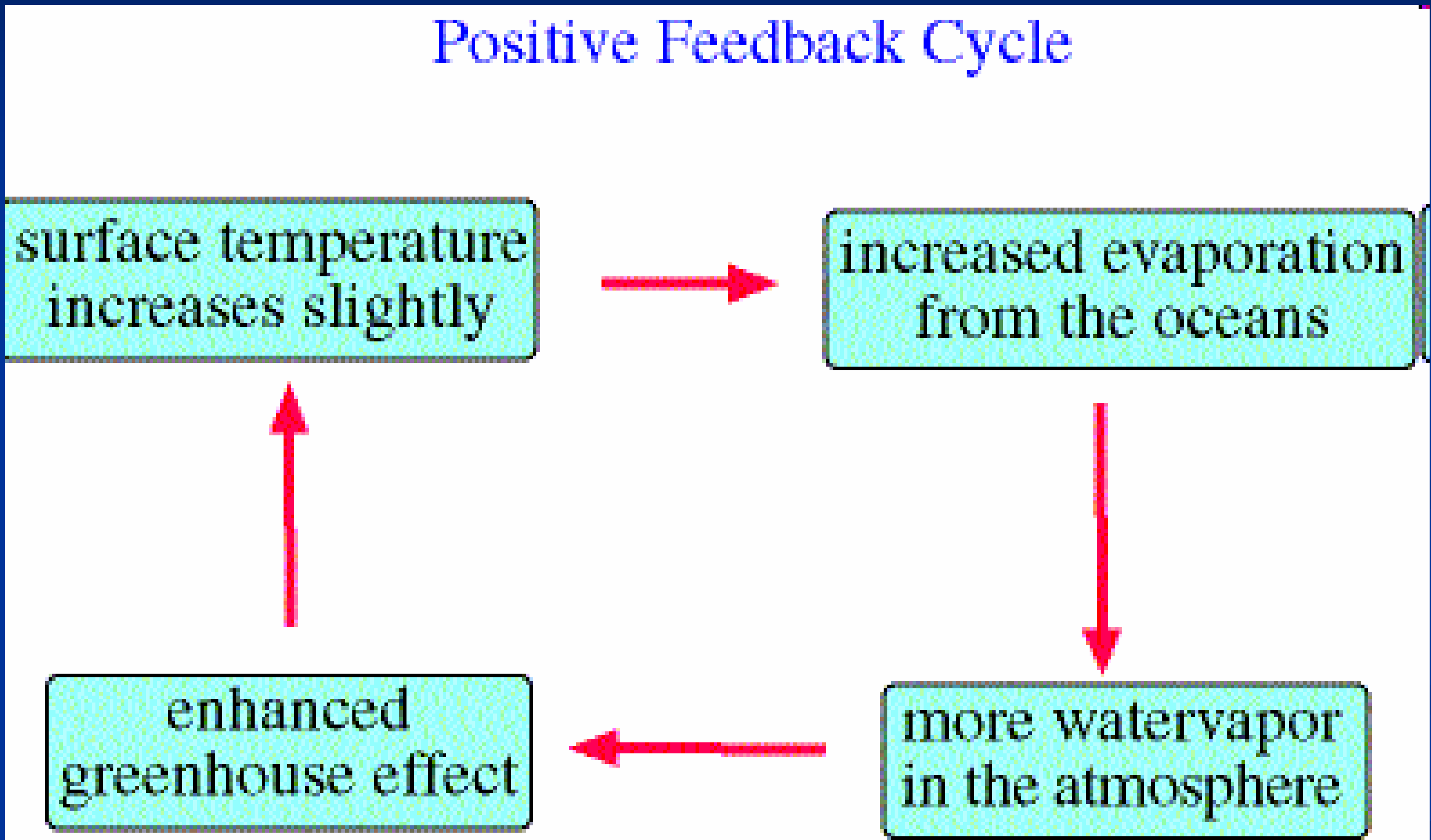
Feedbacks in the Climate System

- Interactions can produce positive feedback
  - Positive feedbacks produce additional climate change beyond that triggered by the initial forcing
  - Positive feedback amplify changes



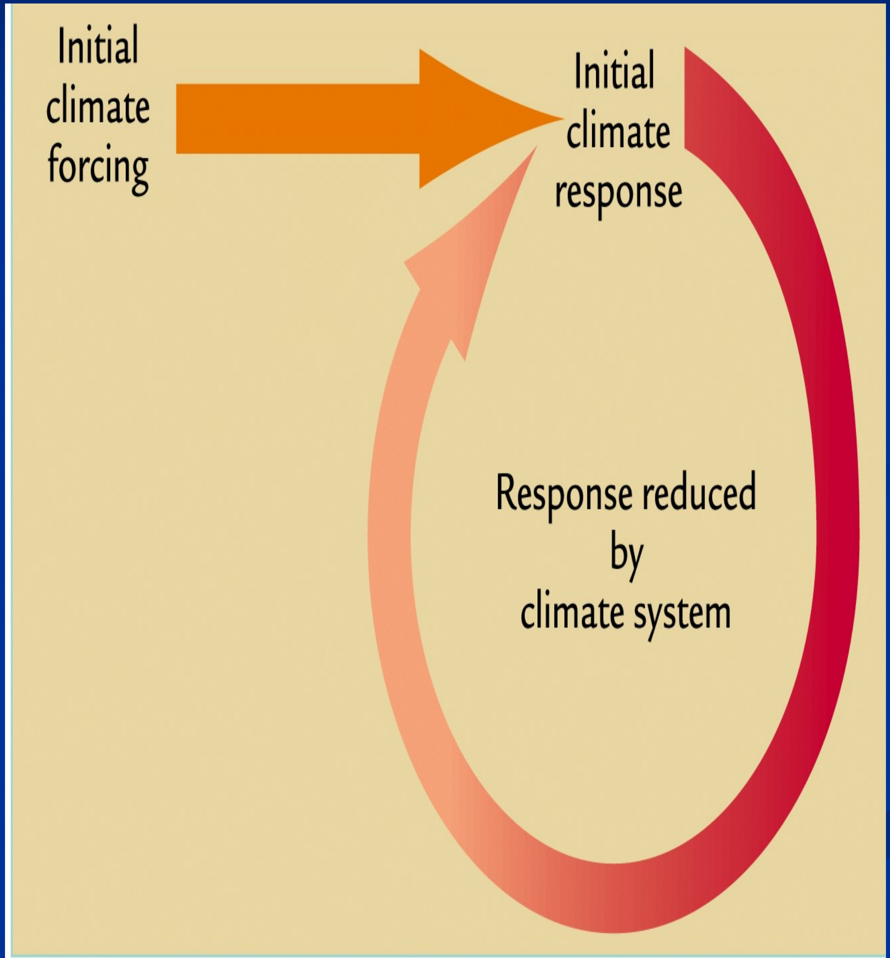
A Positive feedback


Temperature
+
+
+
Permafrost Thaw
Carbon dioxide and methane released into atmosphere
+


Positive Feedback Cycle
surface temperature increases slightly
increased evaporation from the oceans
more watervapor in the atmosphere
enhanced greenhouse effect

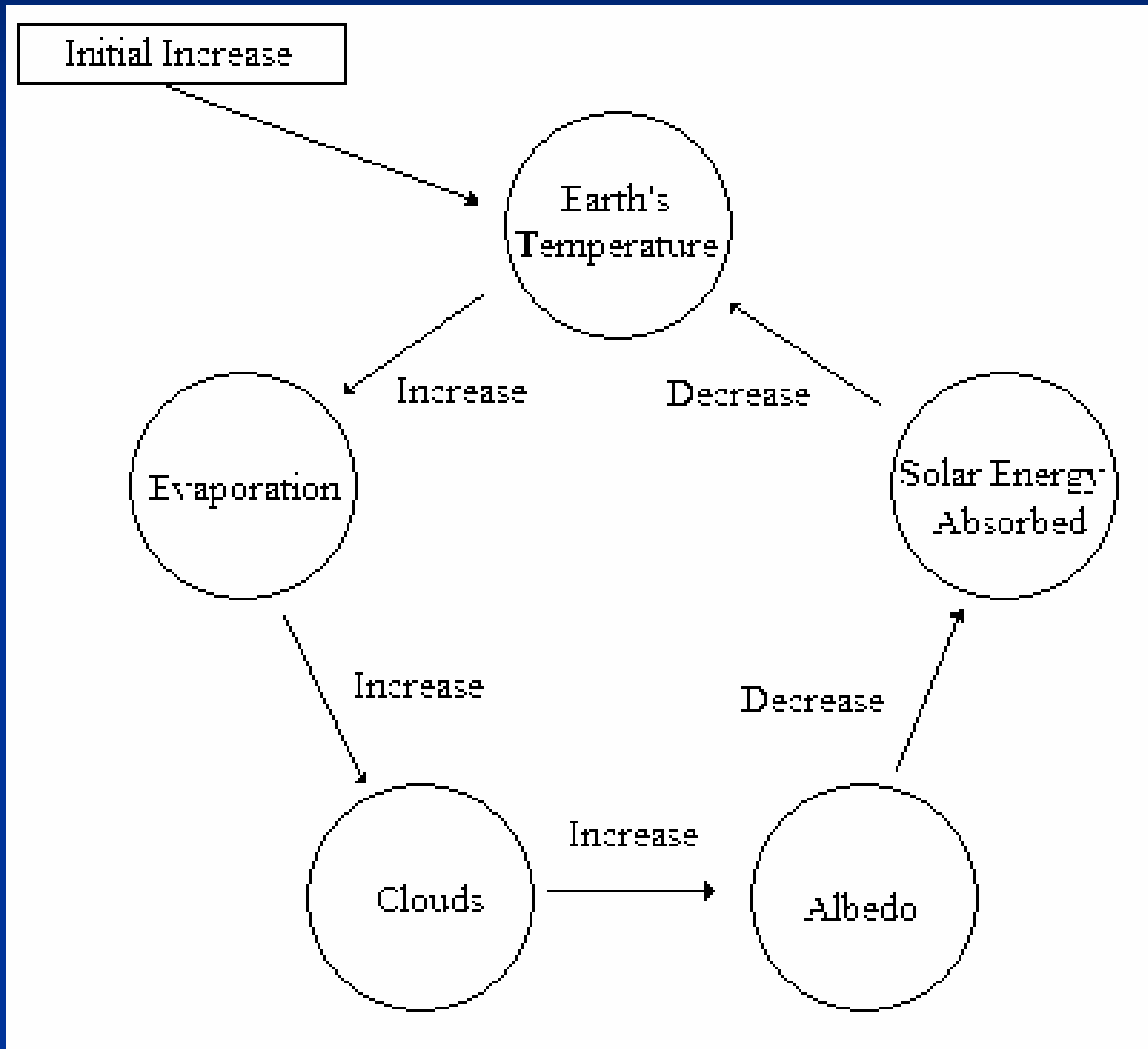
Feedbacks in the Climate System

- Interactions can produce negative feedback
  - Negative feedbacks reduce the response that would be caused by the forcing
  - Negative feedback suppress climate change

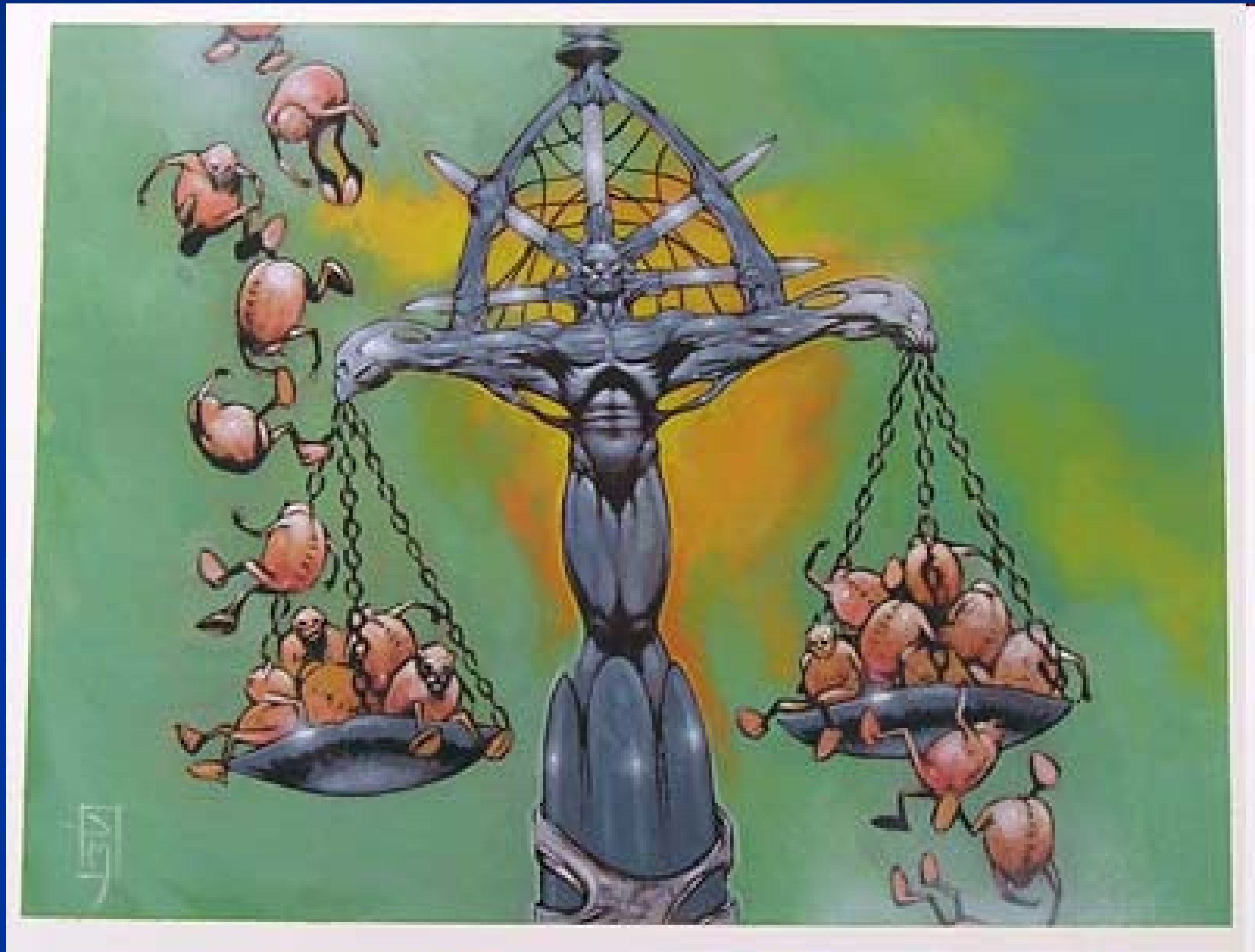


B Negative feedback

Cloud Feedback Loop



Equilibrium



In Equilibrium:

Energy in = Energy out

If we force the climate by adding additional energy in (ΔE) our equation would be

Energy in + ΔE = Energy out

If we force the climate by reducing the energy out by an amount (ΔE) our equation would be

Energy in = Energy out - ΔE

SAME EQUATION – DIFFERENT INTERPRETATION!