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=wnjx6KETmi
Historical Examples of Climate Change?

- Advance and retreat of glaciers
  - Alpine glaciers shrunk in 20\textsuperscript{th} century
- Thinning of ice on NW Greenland
  - See *Nature* v. 414, 60-62
- Sea level rise
- El Niño/La Niña 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

1. Changes in Solar Radiation
   - Changes in the Atmosphere: Composition, Circulation
     - Water Vapor
     - Carbon Dioxide
     - Suspended Particles
     - Other Greenhouse Gases
   - Outgoing Radiation
   - Human Influences
2. Changes in the Ocean: Circulation, Biogeochemistry
3. Changes in the Hydrological Cycle
   - Clouds
4. Changes in/on the Land Surface: Land Use, Vegetation, Ecosystems
   - Vegetation
   - Land
   - Rivers
   - Lakes
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
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.
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$_2$O, 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

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<th>Response time (range)</th>
<th>Example</th>
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<td></td>
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<td>Atmosphere</td>
<td>Hours to weeks</td>
<td>Daily heating and cooling</td>
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<td></td>
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<td>Gradual buildup of heat wave</td>
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<td>Land surface</td>
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<td>Warmest beach temperatures late in summer</td>
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<td>Sudden leaf kill by frost</td>
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<td>Slow growth of trees to maturity</td>
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<td>Sea ice</td>
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<td>Late-winter maximum extent</td>
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<td>Historical changes near Iceland</td>
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<td><strong>Slow responses</strong></td>
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<td>Advances/retreats of ice sheet margins</td>
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<td>Growth/decay of entire ice sheet</td>
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</table>
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.

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

![Diagram of positive feedback](image)
Temperature

Carbon dioxide and methane released into atmosphere

Permafrost Thaw
Positive Feedback Cycle

- Surface temperature increases slightly
- Increased evaporation from the oceans
- Enhanced greenhouse effect
- More water vapor in the atmosphere
Feedbacks in the Climate System

- Interactions can produce negative feedback
  - Negative feedbacks reduce the response that would be caused by the forcing
  - Negative feedback suppresses climate change
Cloud Feedback Loop

- Initial Increase
- Earth's Temperature
  - Increase
  - Decrease
- Evaporation
- Solar Energy Absorbed
  - Increase
  - Decrease
- Clouds
  - Increase
- Albedo
  - Increase
Equilibrium
In Equilibrium:

\[ \text{Energy in} = \text{Energy out} \]

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

\[ \text{Energy in} + \Delta E = \text{Energy out} \]

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

\[ \text{Energy in} = \text{Energy out} - \Delta E \]

SAME EQUATION – DIFFERENT INTERPRETATION!