Non Sequitur*

Did you read chapter 31
before coming to class?
A. Yes
B. No

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Weather vs. Climate

- Weather describes fluctuations in temperature, rainfall, etc. over short time scales, and is highly variable (day to day and by season)

- Climate describes the average temperature, rainfall, etc. over long periods of time (many years at least).

- Earth's climate changes naturally over long time scales.

- The current concern relates to climate change thought to be due to human activity.

Which best describes your opinion on global warming?

A. This is just political hype. No action is needed.
B. We should wait until the models are better before we do anything.
C. I'd like beachfront property in Utah. Do nothing and party on!
D. We should invest the $trillions needed to find ways to reduce greenhouse gas emissions.
E. We are already in danger. We should immediately stop driving cars!

The global average temperature of the earth

- The average temperature of the earth depends primarily on
  - The amount of Solar radiation that reaches the Earth
  - The fraction of Solar Radiation that gets trapped in the atmosphere
- At times in the past the Earth has been much cooler and at other times much warmer
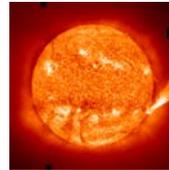
Solar Radiation Reaching the Earth

- Milankovitch Cycles
  - "Ellipticity" of Earth's orbit around the Sun (100,000 yr cycle)
  - Tilt of Earth on its axis (41,000 yr cycle)
  - Precession of Earth on its axis (23,000 yr cycle)
- Tilt and Precession
  - Don't change overall radiation, but can change seasonal extremes in weather.
  - The arrangement of continents is not symmetric. Most of the land is in the northern hemisphere
  - Land and ocean respond differently to seasons (glaciers vs. sea ice)
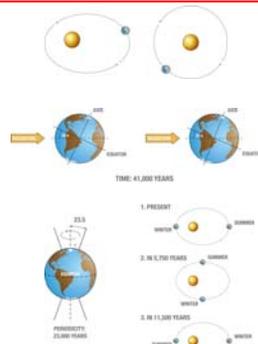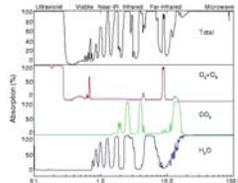

What does the past teach us?

- The orbital cycles are reasonably good predictors of glaciations
  - Orbital eccentricity: 100ky
  - Axial inclination: 41ky
  - Axial precession: 23ky
- According to these cycles, we would predict that we would enter a new ice age sometime "soon" (on the tens of thousands of years time scale)
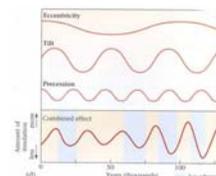
Trapping solar radiation in the atmosphere increases the fraction of solar radiation that is retained

- If you treat the earth and sun as "black" bodies, you underestimate the earth's temperature.
- The (unfortunately named) greenhouse effect is the reason.
  - Infrared light emitted by the earth is absorbed by greenhouse gases (Carbon Dioxide, Methane, Water Vapor)
  - The absorbed energy heats the gases, that then re-radiate—half up and half down
  - The net effect is that energy is trapped in the atmosphere longer, and the planet is warmer than it would be without this effect
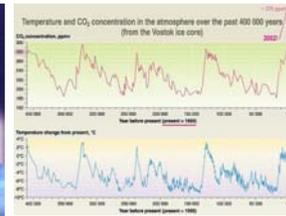

What does the past teach us?
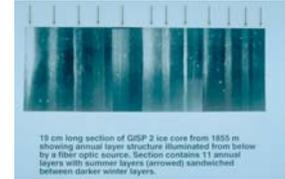
18 cm long section of GISP 2 ice core from 1855 m showing annual layer structure illuminated from below by a fiber optic source. Section contains 11 annual layers with summer layers (arrowed) sandwiched between darker winter layers.
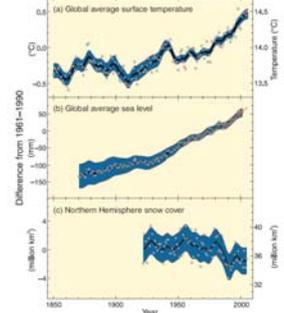
## Historical correlation between temperature and greenhouse gas levels

- So does temperature drive CO_2 or does CO_2 drive temperature?
- Yes.

So what has been happening recently?

- We have had good thermometers for a while now.
- People on the coast keep good track of the sea level
- Since the early 1900s we have good measurements of snow cover

Current warming is generally greater over continents
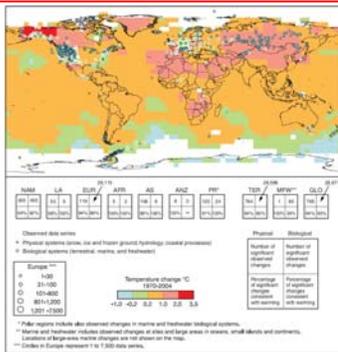
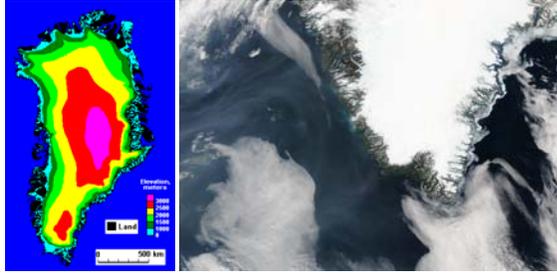## More glaciers are receding than advancing today.

Pasterze Glacier, Austria

1875

2004

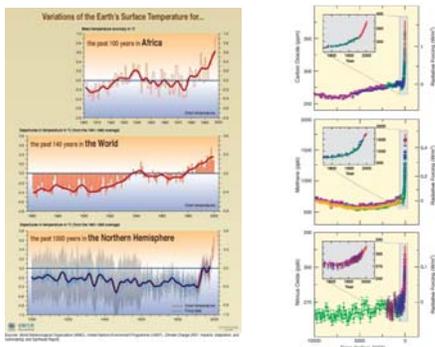## Continental Glaciers seem to be receding

- Example: Greenland

Why do we care?

- What happens to water levels when an ice berg melts?
- What happens when a continental glacier melts?

+ 3 meters
USA: Louisiana

## So are we causing the recent warming? How can we tell?

So are we causing the recent warming? How can we tell?

- The Best Way:
  - Take another earth, run it exactly the same as ours, but don't have people make greenhouse gasses.
  - This approach has some obvious flaws (sigh).
- Since we can't run a physical comparison, we do computer modeling.
  - Run a computer simulation of the whole earth using the laws of physics, chemistry, and geology. Run with and without greenhouse gas emissions and see how things change.
  - In principle this works—but it is awful hard to get the simulation just right.

Example of modeling challenges

- Clouds reflect solar energy before it gets down to where it is absorbed and re-radiated by the earth
  - What happens to cloud cover if you increase temperature?

- Energy is circulated through huge ocean currents driven in large part by desalination of ice forming on the poles.
  - If you change the temperature a little, what happens to ice formation and how does that affect ocean currents?

- These are examples of feedbacks, and these types of questions make modeling the climate very challenging.
  - The things we could control (e.g. CO_2) impact other parameters that we can't through feedback loops.
  - All feedbacks are not completely understood.
  - We have a lot of smart people working on this , and climate scientists indicate that they have a pretty good handle on the issues.

What do the current climate models tell us?
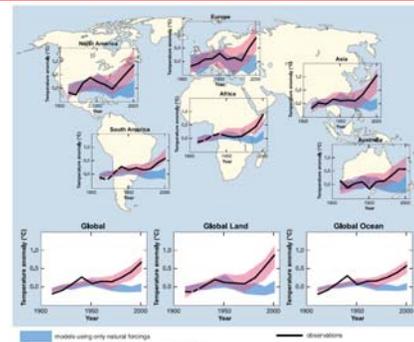
Well, what will happen?

- Very hard to say for certain
- People make predictions, but they are not without their skeptics.
- This is much more complicated than just predicting temperatures. It involves human social and political response as well as physical laws.
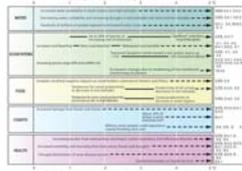
Risk, Cost, & Benefit

- Cost of reducing greenhouse emissions will certainly be hundreds of billions of dollars (more like trillions if we avoid nuclear).
- Certainty of controlling global warming is not 100%
  - Current predictions depend on imperfect models
- Environmental and economic consequences could be truly catastrophic
  - Some say global warming could cause the end of technological civilization
- As voters and consumers, these are **your** issues

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