Understanding the Polar Regions in Climate Change

Outline -- What are the Polar Regions Important to Everyone?

- Geography of the Poles
  - Oceans, land, sea ice and ice sheets
- Definition of the Arctic
  - Tilt of the Earth
  - Cause of Seasons
  - Changes in Day Length
  - Seasonal Productivity
  - Links to CO2
- Earth in the Balance
  - Oceans and THC
  - Atmosphere T and P
  - Cryosphere
    - sea ice
    - snow cover/albedo
    - ice and CO2

Continent landmass covered with glacial ice surrounded by Ocean

Deep Ocean surrounded by Land and world’s largest continental shelves

Average depth of the Arctic Ocean is 1038 meters (3407 ft). The deepest point is in the Eurasian Basin, at 5450 meters (17,881 ft). Entire basin is 1.5 x size of the contiguous US

Best known for its ice cover!
Earth’s north pole is in the Arctic Ocean over the deep Eurasian Basin.
60% of the Arctic ocean is underlain by shallow continental shelves – the largest in the world!!

Greenland Ice sheet
If it melted, the water would return to the sea and raise global sea level ~ 6.5 m (21 ft.)
Contrasts in landscapes

Vegetation Contrasts
- Boreal forests of birch, spruce
- Treeline ecotone
- Open Tundra

What makes this a habitable planet? What results from the contrast between the tropics and the poles?

How does the Earth work? What controls changes in the oceans and the atmosphere?
Earth’s has an axial tilt of about 23.44 degrees, always tilted in the same direction throughout the year.

But as the Earth orbits the sun, tilt changes which hemisphere receives more Sunlight causing the Seasons.
• Effect of different angles of sun
  • Summer solstice more concentrated.
  • Winter solstice less concentrated, spread out.
  • Summer solstice hot weather on the way. Winter cooler.

• Winter solstice in northern hem
  • Sunlight conc.
  • Same time,
  • southern hem, sun light is LESS conc.

• Northern hem winter solstice, just the opposite.
  • Recall Dec 21, ~Xmas
  • Australians celebrate Xmas in the summer.
The annual cycle of global radiation (brown line) and surface air temperature (blue line) at a grid cell location in the central Beaufort Sea. Values were drawn from the Arctic Meteorology and Climate Atlas gridded fields for global radiation and two-meter air temperature. http://nsidc.org/arcticmet/factors/

Low latitude oceans are warm and move heat to the poles.
Seasonal Movement of the ITCZ

January
(N. Hemisphere winter)

July
(N. Hemisphere summer)

The great ocean conveyor: of heat and salts

Thermohaline circulation -- warm waters move northward by winds, lose heat to the atm by evaporation, become saltier, cool and sink to deep ocean

Understanding and Projecting the Changes in the Oceanic Conveyor Belt is a Critical Question for Science
The North Atlantic Current provides about 60% of the inflow to the Arctic Ocean, bringing warmer water from the Atlantic Ocean. Some water also moves into the Arctic Ocean from the Bering Sea and the Pacific Ocean, by way of the Bering Strait.

Water flows from the Arctic Ocean into the Pacific and Atlantic Oceans, as well as into a number of surrounding seas. By far, the greatest volume of water leaves the Arctic Ocean through the passage between Greenland and Spitsbergen. The snow and ice that cover the Arctic reflect about 90% of the sun’s energy, so the Arctic is constantly losing heat. However, the ocean currents also exchange heat; currents from the Atlantic bring warm water into the Arctic, while currents traveling southwards discharge cold water.

Sea ice extent in the Arctic has huge image on albedo - reflectivity of Earth Surface
Why the Arctic Warms Faster

A Critical Reason is that:
As snow and ice melt, the darker land and dark blue ocean surfaces that are revealed absorb more of the Sun’s energy.

Timeless Arctic Marine Transport
• Reduced sea ice is very likely to increase marine transport and access to resources.

But...wow!

In 2007, we reached what was predicted for 2070 only a few years ago!

Recent results suggest more snow is falling on top of ice sheet, but it is melting faster than that at the edges. Enough liquid water to fill 51 cubic kilometers in a year (lake 30 miles x 30 miles x 70 feet deep or .005 inches over the world ocean)

Cartoon x-section of ice sheet
We are tracking high end predictions

Thermal expansion greater:
'93-03 data 1.6 m/myr
Not IPCC2007 40±20 cm
Best estimate 80 cm global;
max. 1 m?
Rahmsdorf et al. (2007)

Increase in heat W/m²
Willis et al. (2004)

Global mean sea level observations

Long Beach Island, NJ
Human stabilized

Natural movement

Courtesy N. Pauty
80 cm-1m in 100 yrs with subsidence making it worse in some places

Insurance Rates?
Disaster relief?
Both need forecasting and planning

Greenland (≈ 6 m of sea level) is thinning now
But did not disappear during the last Interglacial

Season changes cause zigzags in CO\(_2\) in Atm. Esp. driven by Northern Hemisphere. In Spring - photosynthesis drops CO\(_2\), in Fall, decomposition causes increase in CO\(_2\)
Monitoring of CO2 and other Greenhouse gases recorded around the world

All get very similar measurements

Why?

Source: Petit et al., 1999

Now at 380 ppm

Source: Petit et al., 1999
There is no analog for the future we face; we need “no regrets” strategies to reduce vulnerability (NAS, 2002).

Summary

- For hundreds of thousands of years, the Earth has imported heat in the tropics and exported heat via the poles maintaining a balance.
- We are certain that as CO2 goes up and down, the temperature of the earth follows.
- The loss of reflective surfaces in the Arctic with increasing global temperatures leads to positive feedbacks that warm the earth even more.
- CO2 is rising fast because of us: Mother Earth is responding.

“NO REGRETS” STRATEGIES (National Research Council Report, 2002)

“...to reduce vulnerability and increase adaptation at little or no cost, by nudging research and policy in directions that will increase the adaptability of systems”

- Energy Policies - to slow climate change
- Ecological Policies -- land use & coastal planning
- Forecasting of weather and weather related events
- Institutions -- water systems, insurance, and statistical data for policy reform

Geological Past and Study of Depositional and Biological Systems of Environmental Change

Strong Science Rational Decision Making Global Environmental Policy