

ATMS 321. 2012 May 30 – June 1

Global warming topics

Evidence for global warming in recent decades
Forcings by greenhouse gases and aerosols
Predictions of emissions
Predictions of climate change
Sea-level rise
Glacier-flow contribution to sea level
Impacts
Mitigation
Adaptation

**Climate Change 2007
The Physical Science Basis**

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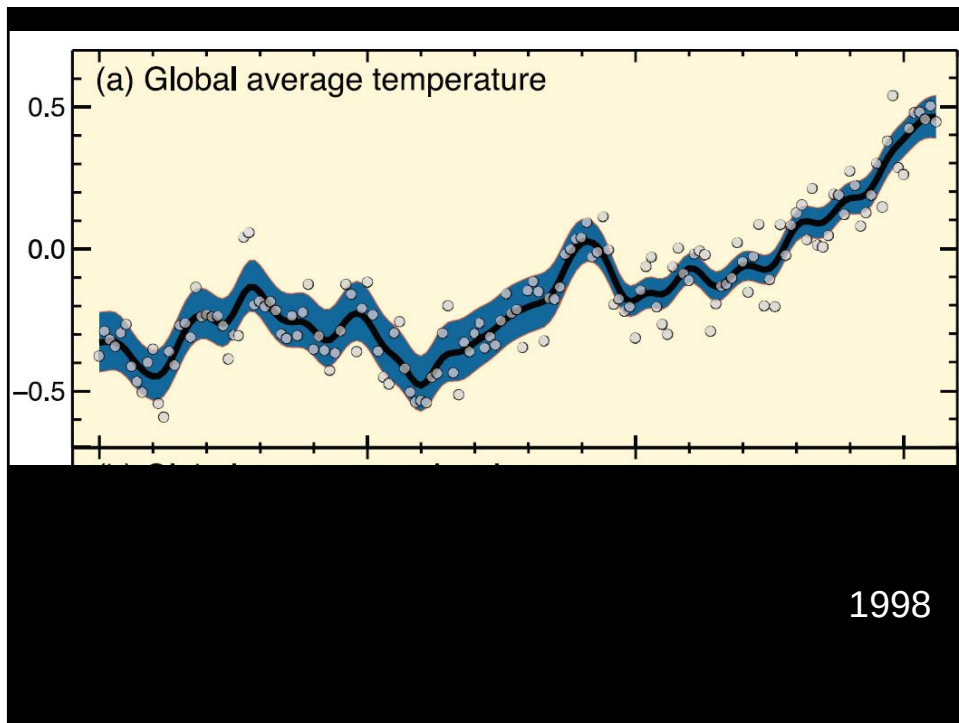
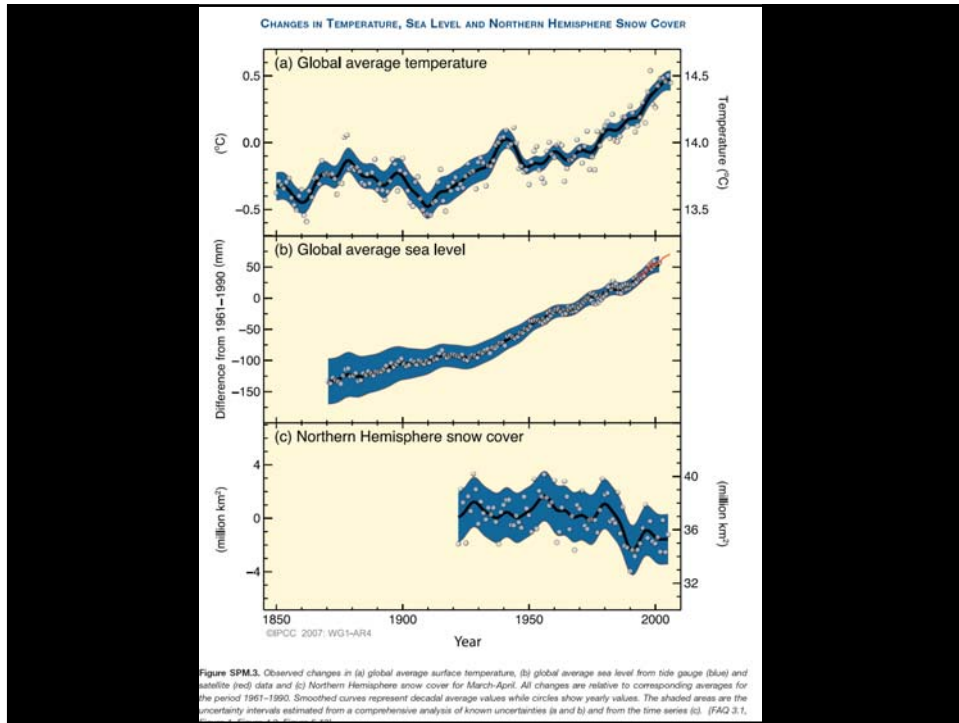
China Meteorological Administration

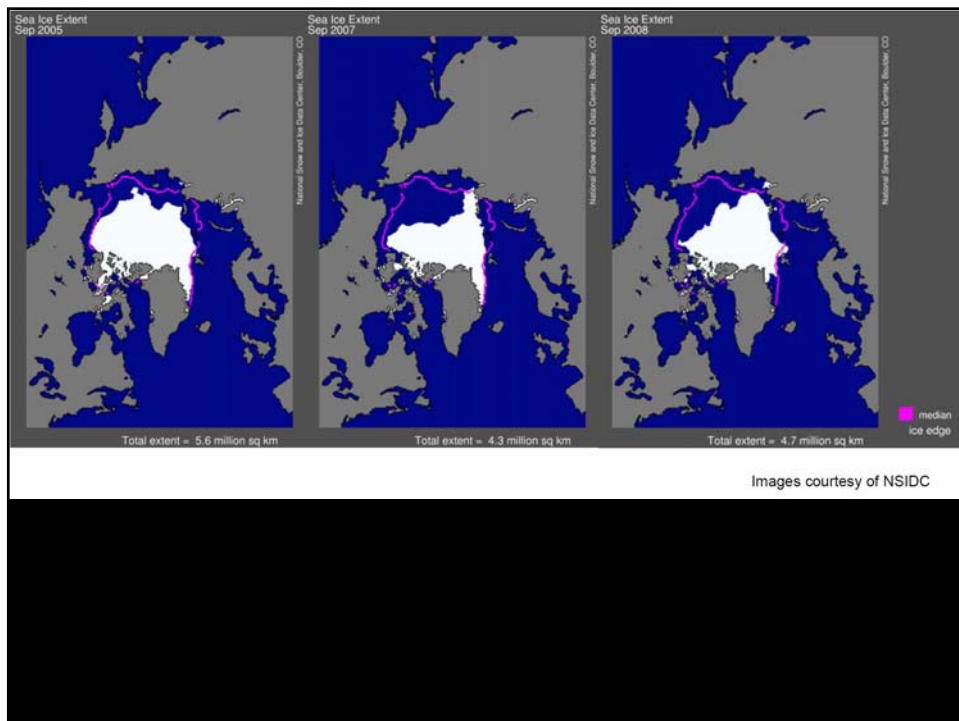
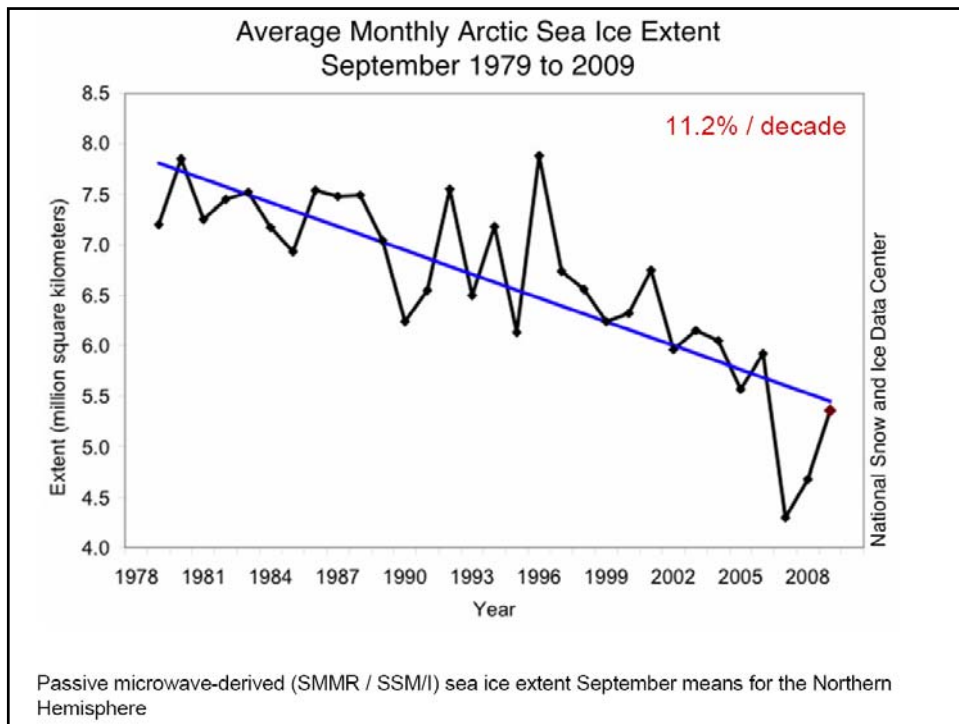
Contribution of Working Group I
to the Fourth Assessment Report of the
Intergovernmental Panel on Climate Change

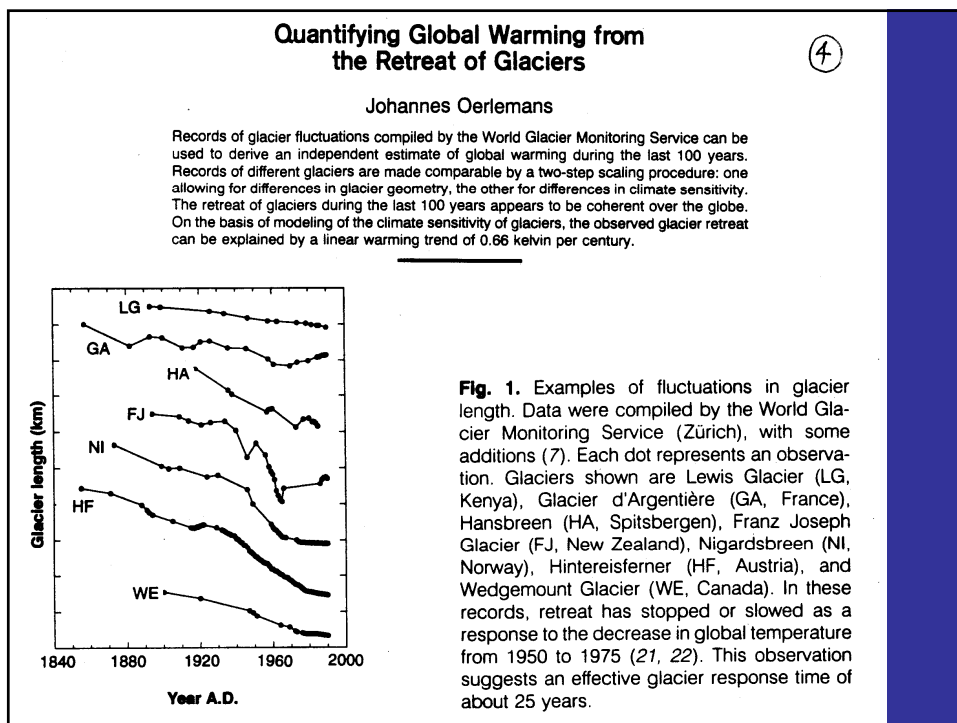
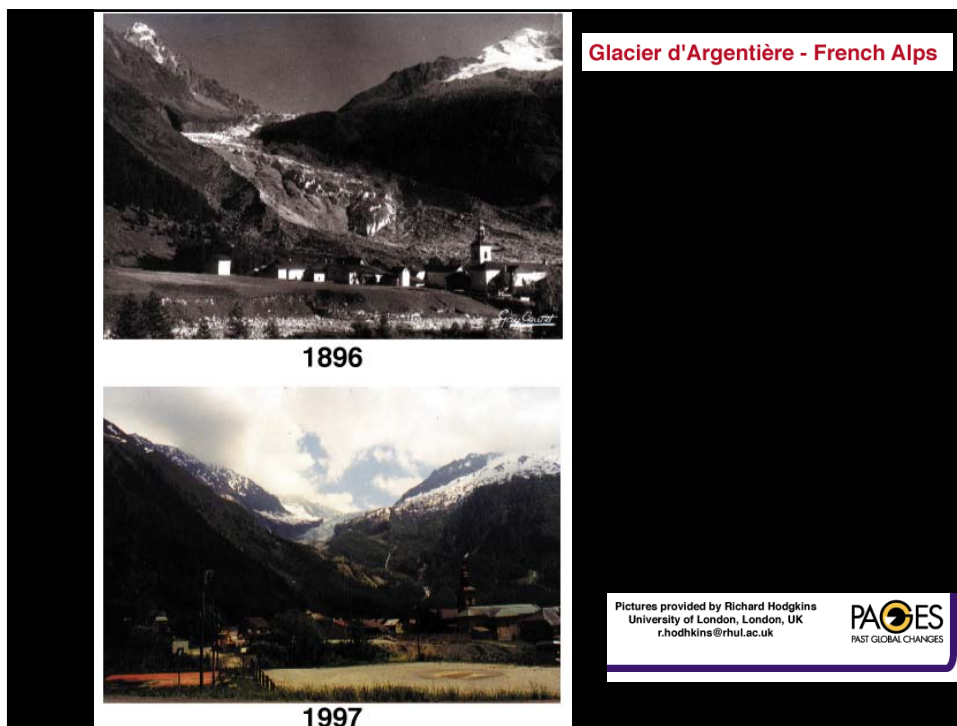
Published for the Intergovernmental Panel on Climate Change

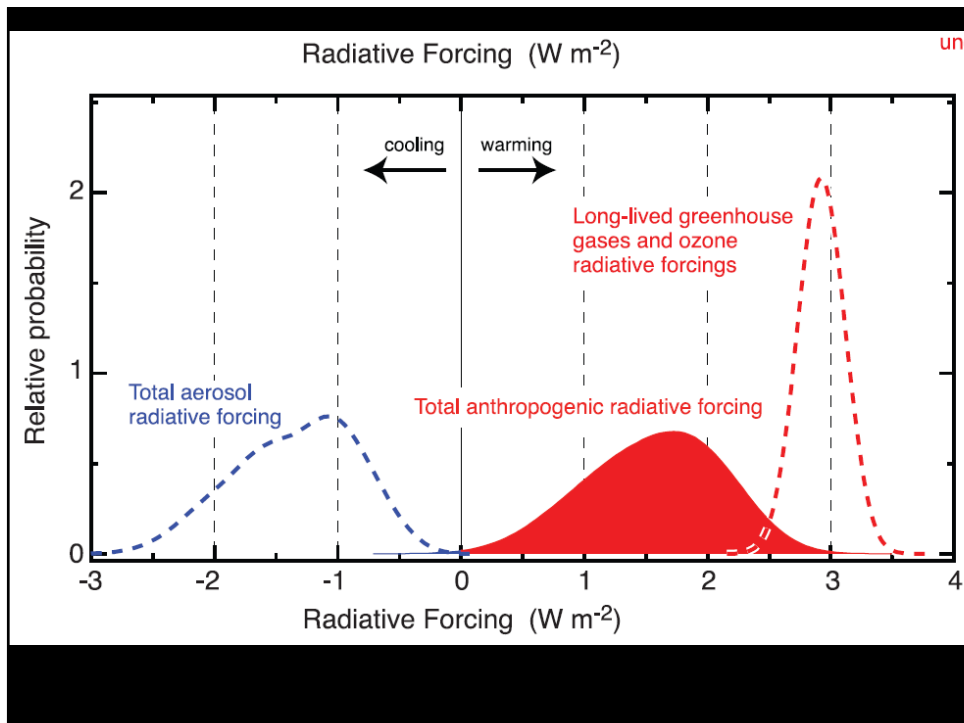
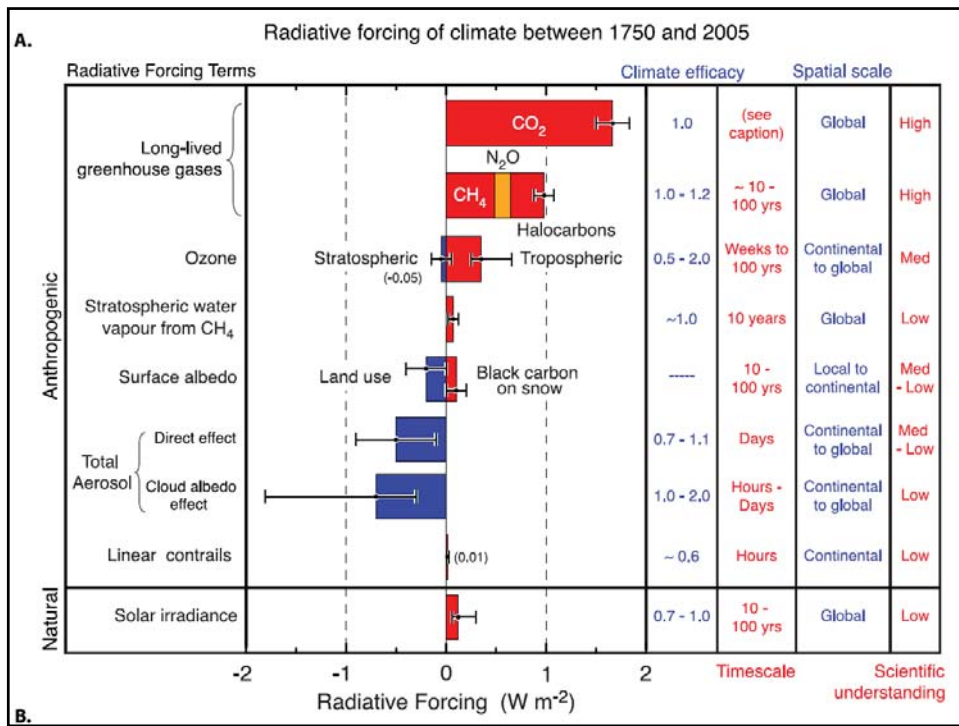
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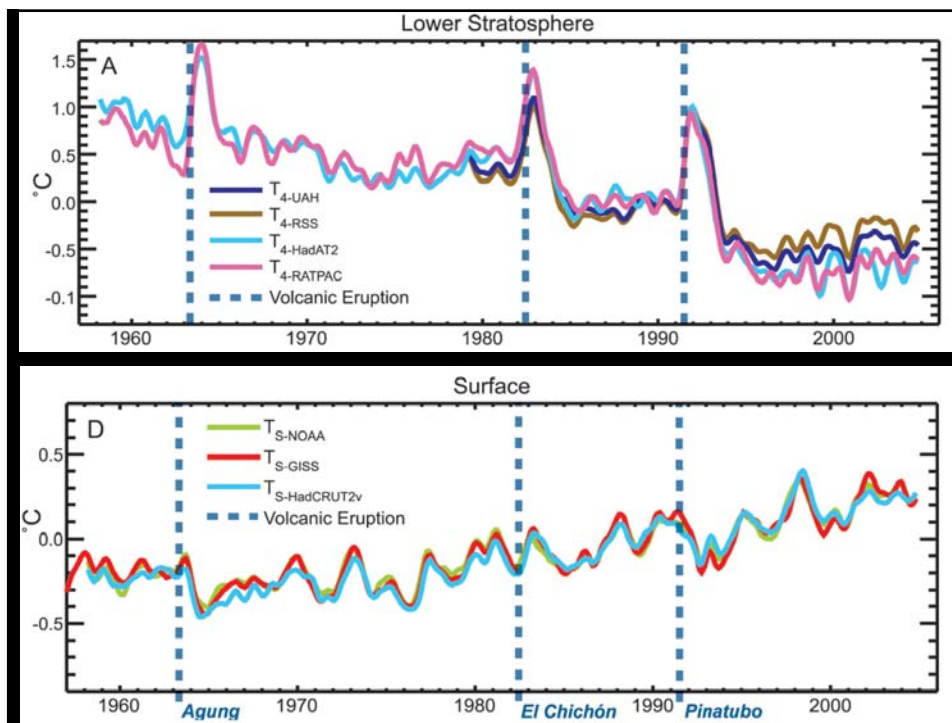


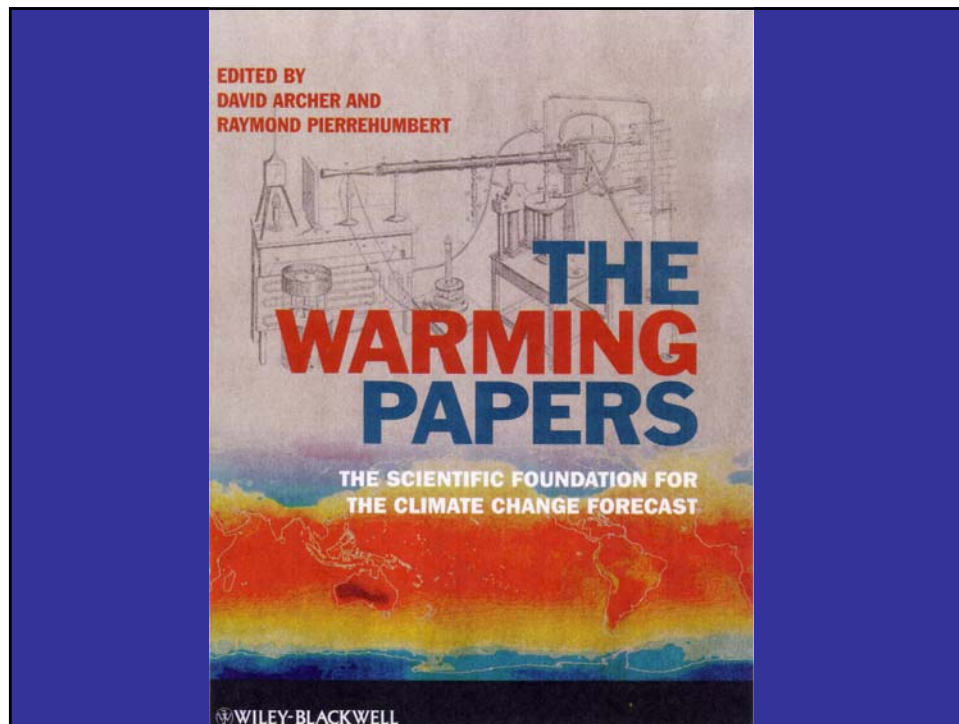


Aerosols. Short lifetime (2 weeks). Concentration in atmosphere is proportional to the *rate* of burning.

CO₂. Long lifetime (hundreds of years). Concentration in atmosphere is proportional to the *cumulative* amount burned.

So when the burning stops, the sky clears quickly, and we are left with the warming effect of CO₂ but without the cooling effect of aerosols.





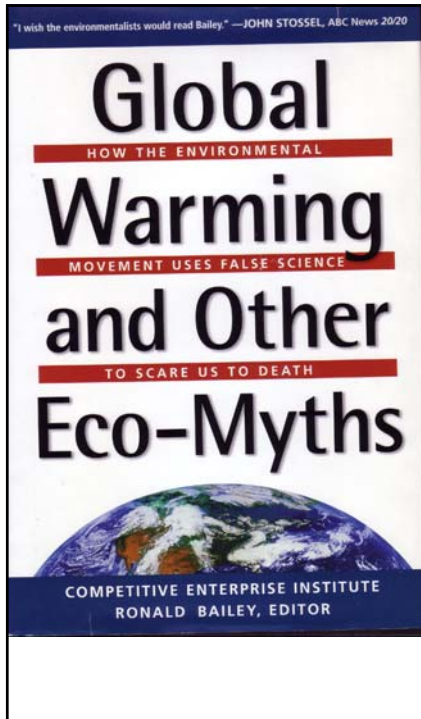
Contribution of Stratospheric Cooling to Satellite-Inferred Tropospheric Temperature Trends

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From 1979 to 2001, temperatures observed globally by the mid-tropospheric channel of the satellite-borne Microwave Sounding Unit (MSU channel 2), as well as the inferred temperatures in the lower troposphere, show only small warming trends of less than 0.1 K per decade (refs 1–3). Surface temperatures based on *in situ* observations however, exhibit a larger warming of ~0.17 K per decade (refs 4, 5), and global climate models forced by combined anthropogenic and natural factors project an increase in tropo-spheric temperatures that is somewhat larger than the surface temperature increase.^{6–8} Here we show that trends in MSU channel 2 temperatures are weak because the instrument partly records stratospheric temperatures whose large cooling trend⁹ offsets the contributions of tropospheric warming. We quantify the stratospheric contribution to MSU channel 2 temperatures using MSU channel 4, which records only stratospheric temperatures. The resulting trend of reconstructed tropospheric temperatures from satellite data is physically consistent with the observed surface temperature trend. For the tropics, the tropo-spheric warming is ~1.6 times the surface warming, as expected for a moist adiabatic lapse rate.

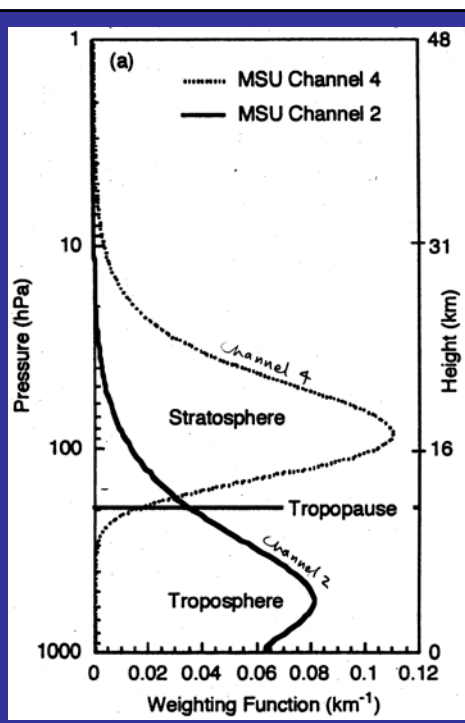
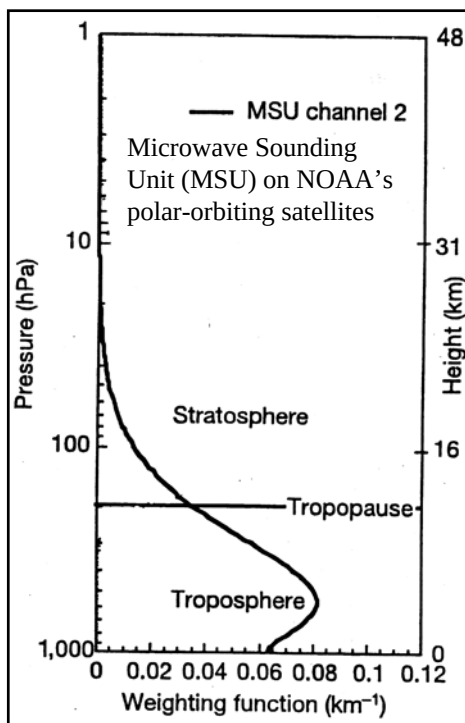
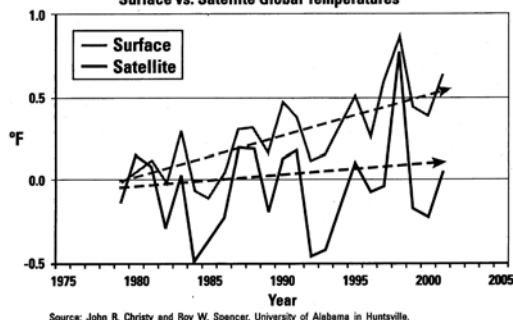


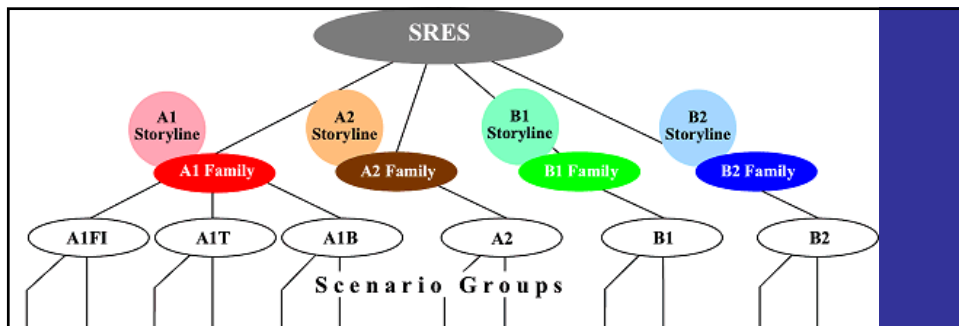
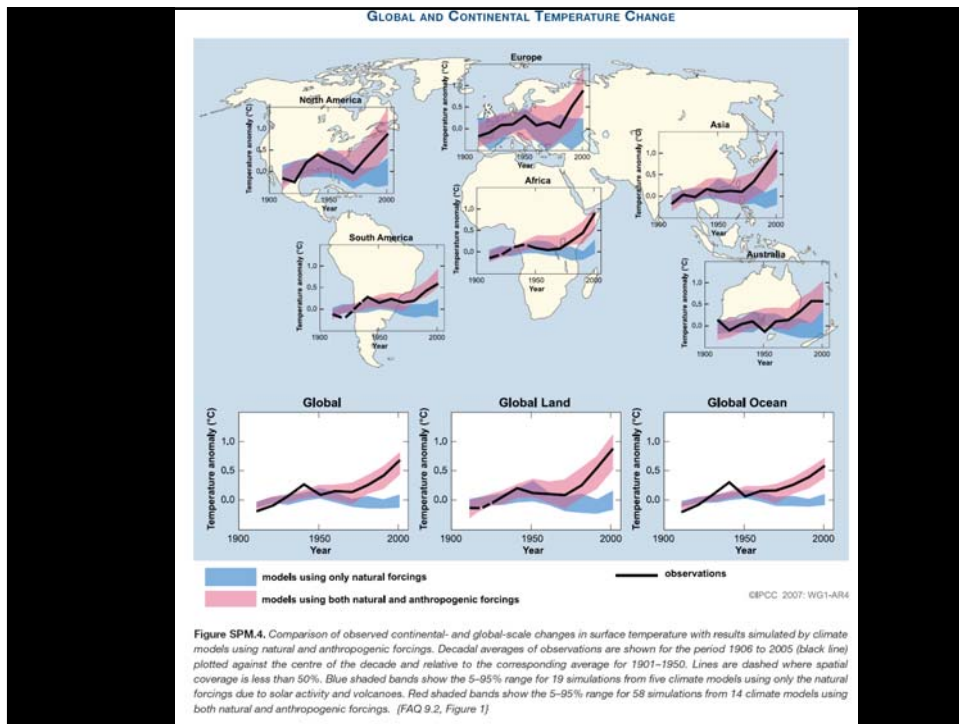
2 THE GLOBAL WARMING FIASCO

ECO-MYTHS DEBUNKED

- There have always been changes in the background climate, such as the recent warming of the global average temperature. (Since 1979, the global temperature trend is a modest $+0.06^{\circ}\text{C}$ increase per decade through March 2002. Note that this increase is only one-third the rate measured by thermometers scattered unevenly across the globe.)
- Carbon dioxide (CO_2) is the lifeblood of the planet, not a pollutant.
- Model projections of climate and weather are scientifically crude at best and should not be used as pretexts for imposing a global energy policy.

Figure 1.3
Surface vs. Satellite Global Temperatures





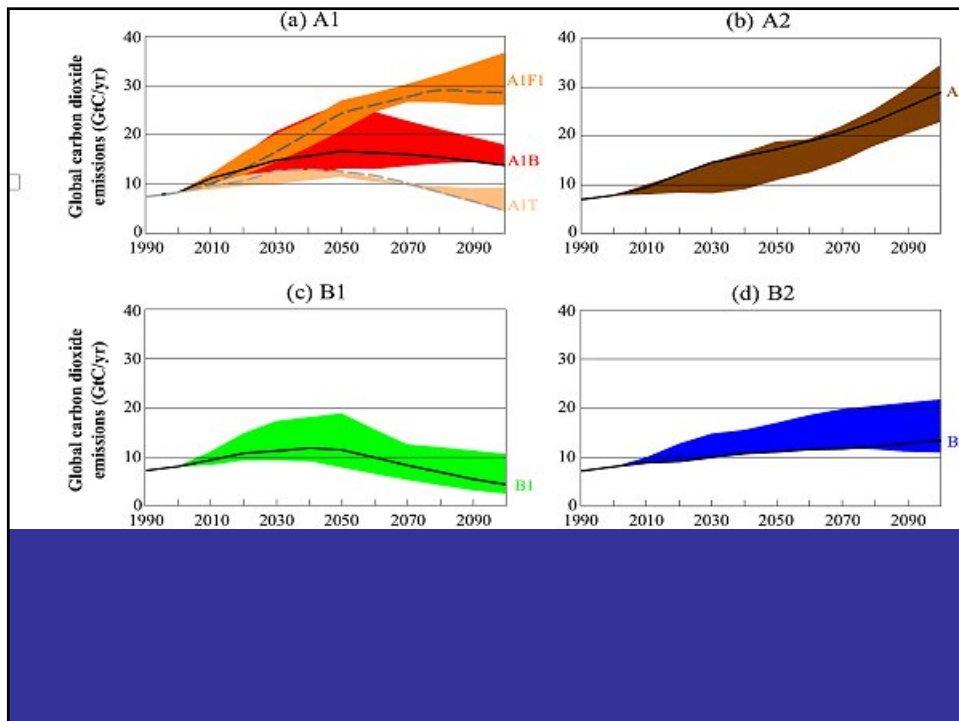
Schematic illustration of SRES scenarios. Four qualitative storylines yield four sets of scenarios called "families": A1, A2, B1, and B2. Altogether 40 SRES scenarios have been developed by six modeling teams. All are equally valid with no assigned probabilities of occurrence. The set of scenarios consists of six scenario groups drawn from the four families: one group each in A2, B1, B2, and three groups within the A1 family, characterizing alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel)

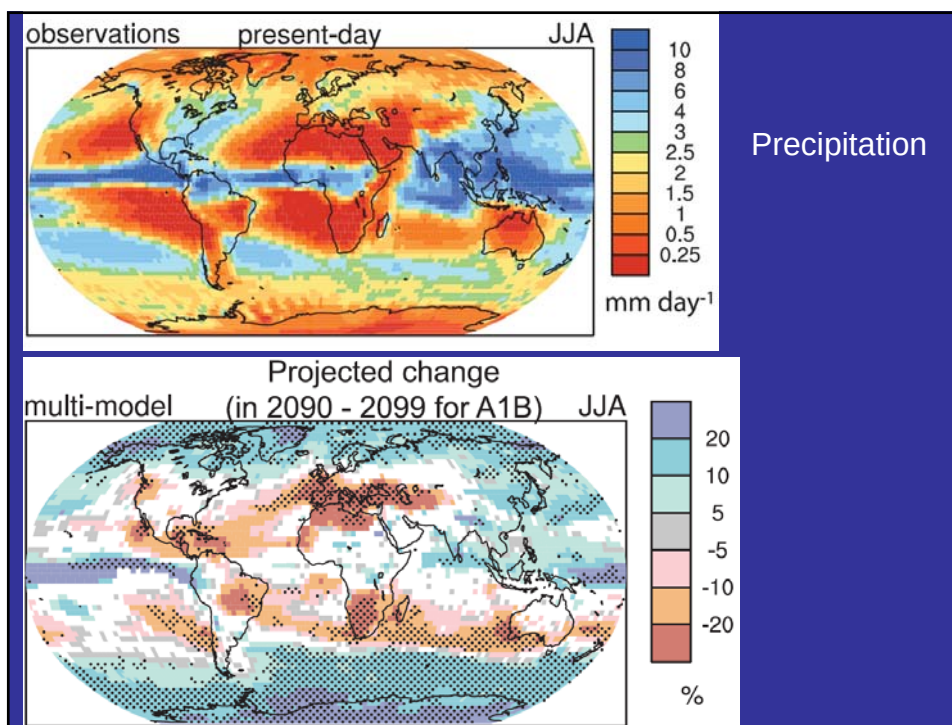
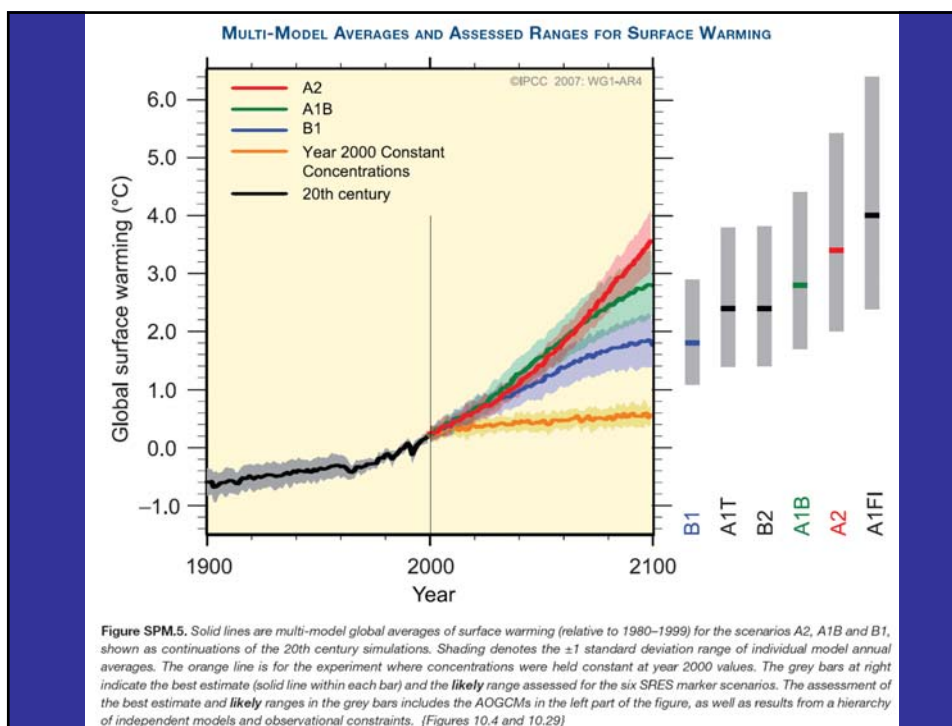
The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

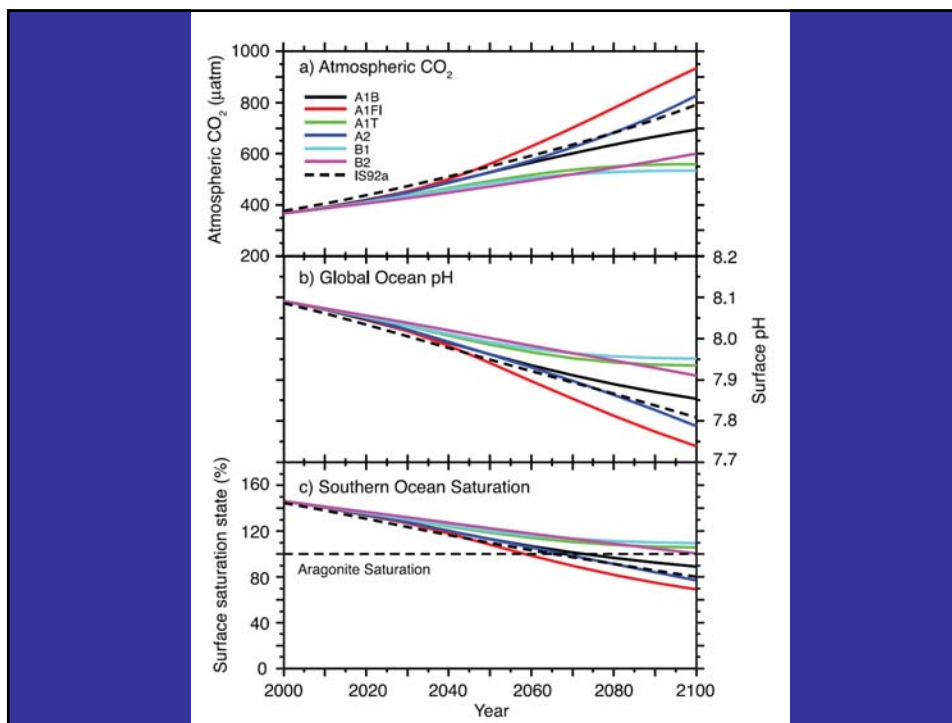
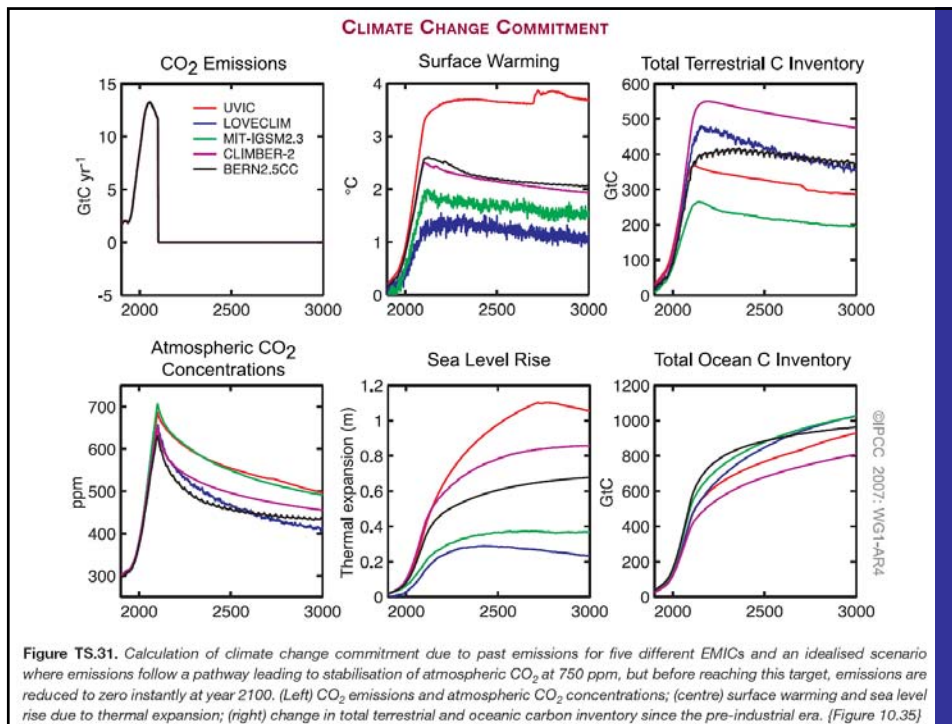
The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.







David Archer, 2009:
The Long Thaw

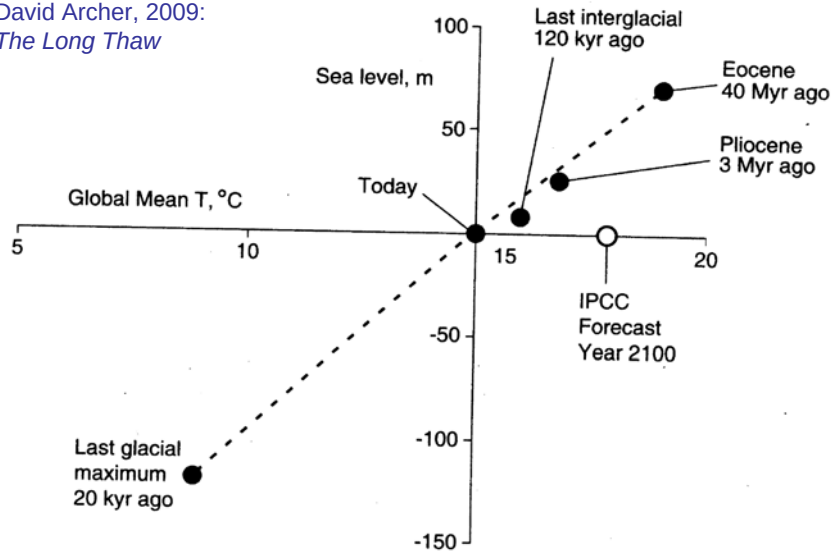
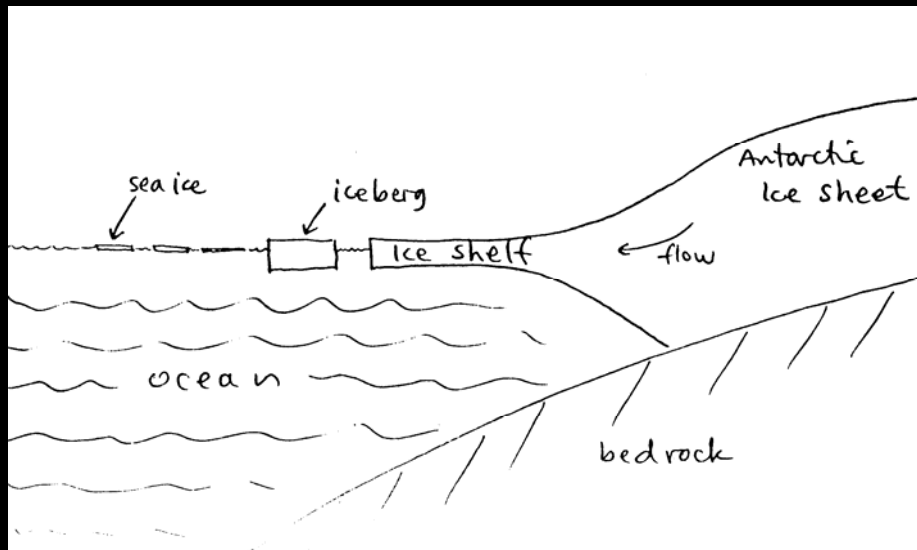


FIGURE 17. Covariation of sea level with global average temperature in the geologic past, compared with the IPCC forecast for sea level rise by the year 2100.



Ice-sheet processes

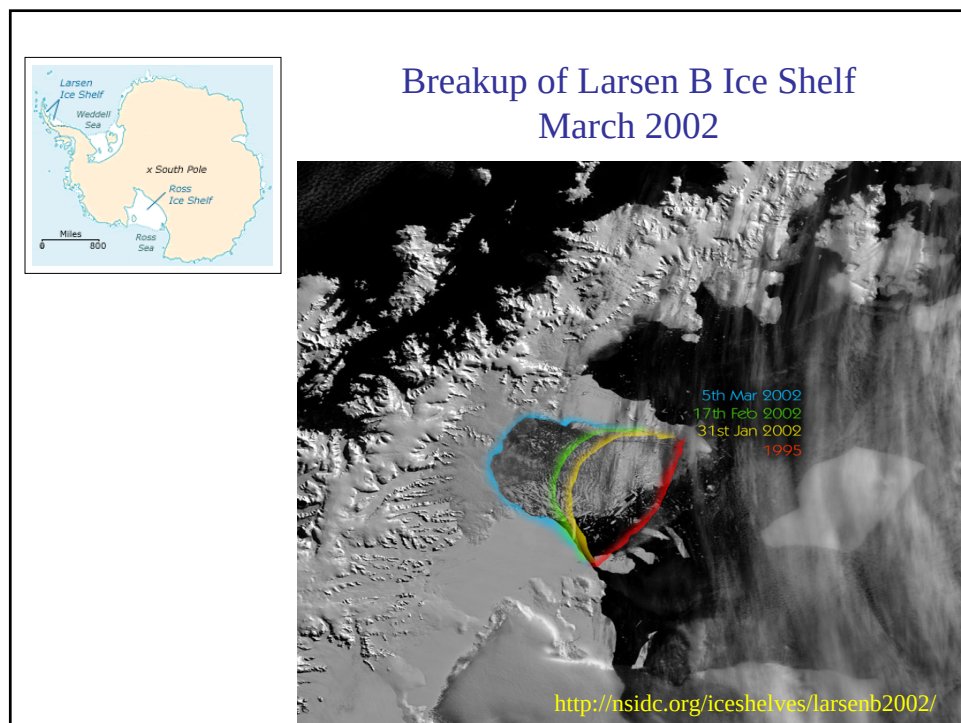
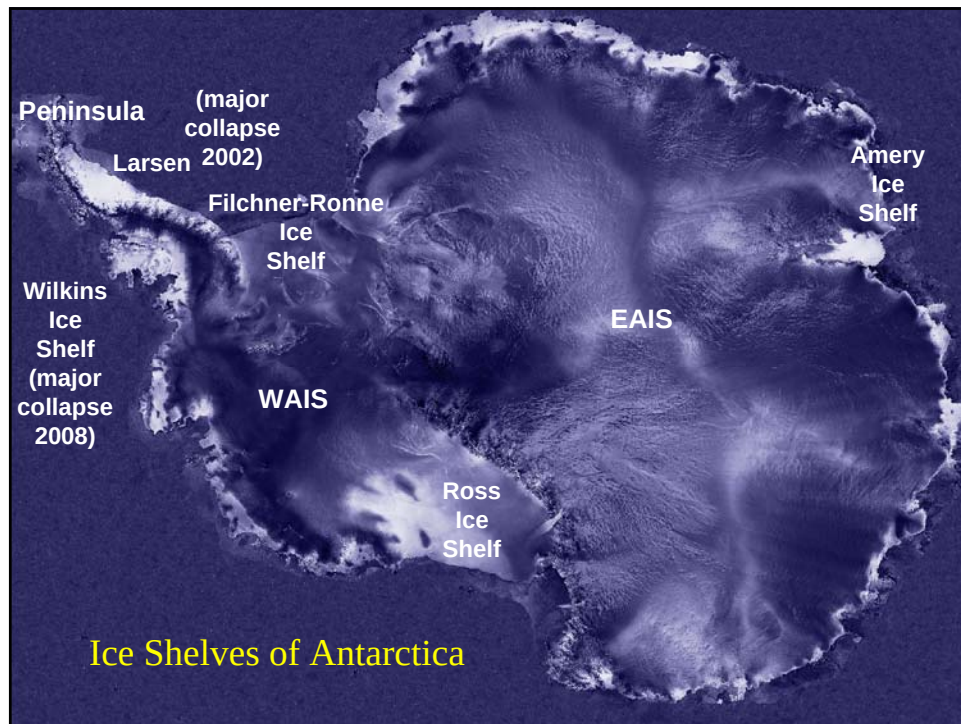
Meltwater from the surface percolates down, lubricates bed and allows sliding.

Surface melting on an ice shelf fills crevasses with water, propagates crack downward.

Breakup of ice shelf removes buttressing, allowing faster glacier flow.

Warm ocean water under ice shelf melts ice shelf from below. Thinning reduces sidewall friction, causing faster flow and further thinning, allowing seawater to intrude farther inland (if bedrock slopes downward inland).



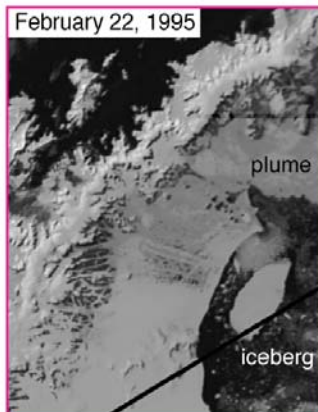


Breakup of Larsen B Ice Shelf, March 2002



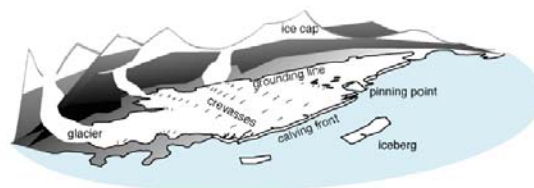
NSIDC

February 22, 1995

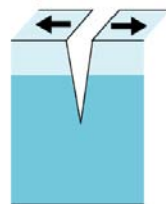


(courtesy of C. Hulbe, Portland State Univ.)

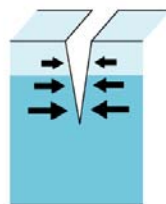
ice shelf disintegration events



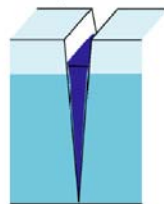
1. tensile stress
opens crevasse



2. lithostatic stress
limits crevasse depth



3. water pressure
deeper crevasse

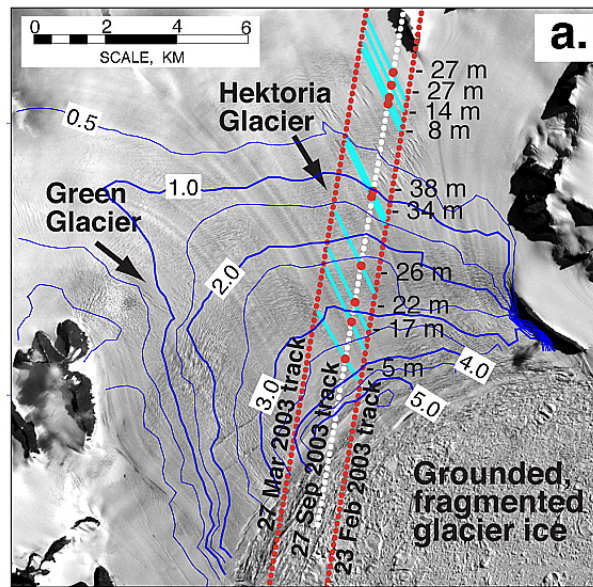


Release of Back Pressure

After Larsen B
collapse ..

Speedup in m/day
— 2.0 —

Surface lowering
along track
e.g. 34 m



(Scambos et al. 2004; GRL, 31)

Impacts, mitigation, adaptation

Impacts: Effects of climate change on humans and other species

Mitigation: Prevent global warming or slow the rate of warming.

Adaptation: Accept that climate change will happen; learn to live with it.

Adaptation to sea-level rise: 3 stories

Netherlands (a rich low-lying country)
population 17,000,000

Tuvalu (a small Pacific nation of atolls)
population 11,000

Bangladesh (a poor low-lying country)
population 150,000,000

**Netherlands Battens Its Ramparts
Against Warming Climate**

(National Geographic News, 2005)

Dutch authorities have raised the height of the Pettener seawall several times since 1976, when it stood only half as tall, trying to keep ahead of storms and coastal erosion. But it may not be tall enough yet.

With half of its territory below sea level—and much of the rest threatened by coastal or river flooding—the Netherlands is taking climate change very seriously.

Global warming is expected to cause the seas to rise by somewhere between four inches (ten centimeters) and three feet (one meter) during this century, while increased rainfall may enhance the flood risk for low-lying towns and cities behind the Dutch sea defenses.

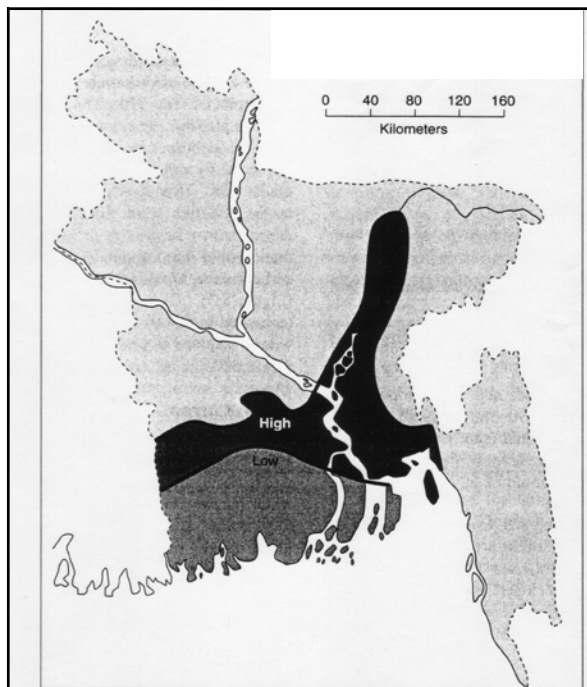
The Dutch expect to invest an extra U.S. \$10 billion to \$25 billion in flood and sea defenses over the next century, and are already drafting plans to upgrade dikes, pumping stations, and seawalls.

A decade ago, Dutch authorities started studying their options for dealing with not only sinking land, but rising

seas, more powerful storms, and ever larger floods. Government engineers considered several strategies, including a plan to simply surrender large parts of the country to the sea. The most cost-effective plan was selected: strengthen the existing defenses and pumping stations, at a cost of \$19 billion to \$25 billion. $\downarrow$ 15 per person per year

"These are enormous figures if you had to spend them all at once, but we're able to spread it out over 50 to 100 years," says John de Ronde of the National Institute for Coastal and Marine Management in The Hague, which prepared the estimates. "And it's relatively simple for us to cope with sea-level rise because we already have [U.S. \$2.5 trillion worth of] existing infrastructure."

"If you really have to start from scratch and build all of this infrastructure, you'd probably have to consider giving the land to the sea," he says. It's a situation low-lying regions from Bangladesh and the Marshall Islands to southern Louisiana and the Florida Everglades may soon be facing.



Impact of low (0.5 m) and high (3 m) sea-level rise in Bangladesh (From Broadus

Bangladesh

(area 80% of
Washington State)

Year	Population
1975	80 million
2007	150 million
2050	230 million

Predicted impacts of climate change in Washington State

Pacific Northwest has a “Mediterranean” climate: dry summer, wet winter.

Natural water storage in mountain snowpacks
Artificial water storage behind dams on rivers

Water stored in winter is used for irrigation in summer.

Warming: Rain instead of snow in winter, runoff instead of storage.

Mitigation

1. Reduce the *sources* of CO₂
 - a. Switch to non-carbon fuels
 - b. Improve energy efficiency(both would result from a carbon-tax)
2. Enhance the *sinks* of CO₂
 - a. Reforestation
 - b. Fertilize of ocean
 - c. Capture CO₂ emissions and *sequester* them
 - (1) before they enter the atmosphere (“clean coal” technology)
 - (2) after they enter the atmosphere (“air capture” technology)
3. Counter the warming with artificial cooling (geoengineering)