Climate Change: Opportunities in the Greenhouse

Richard B. Alley, Evan Pugh Professor of Geosciences and Associate of the Earth and Environmental Systems Institute,
2010 University Turbine Systems Research Workshop, Penn State

G.Comer Foundation

Please note:

I work for Pennsylvania State University,

And help UN IPCC, NRC, etc.,

But I am not representing them,

Just me.

Energy

- You eat about 2400 Calories per day;
- You use over 240,000 Calories per day;
- Like having 100+ serfs to do your bidding;
- Driving, heating, cooling, pumping, plowing, trucking, flying, cooking…
- Almost all from oil, coal and natural gas (fossil fuels).

Settlers cut almost all Pennsylvania trees, often for fuel, losing all (elk, bison, fisher, mountain lion), or almost all (deer, turkey) large wildlife.

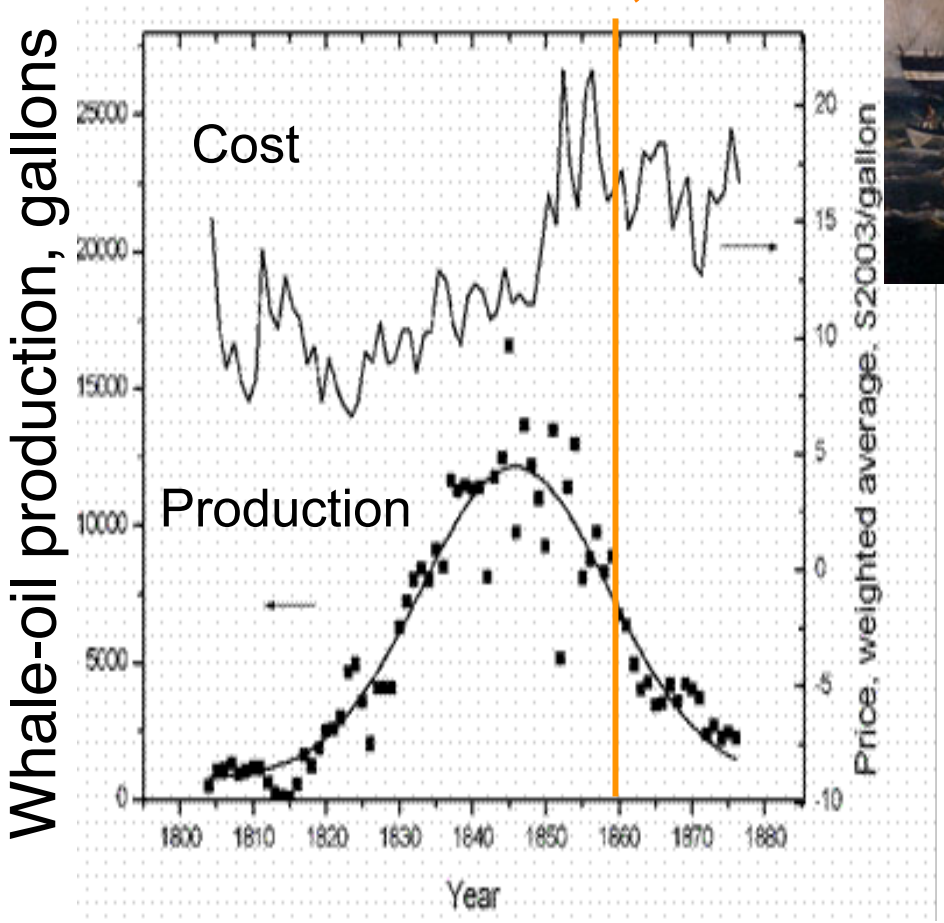
http://www.smithsonianmagazine.com/multimedia/rich-media/0206-forgotten-forest/index.php

http://www.explorepahistory.com/ (Pennsylvania State Education Association)

Penn's Woods-->Pennsylvania "Desert" (**and not just Pennsylvania!**)

Not enough whales to light the evening, so, we drilled for oil…total US whale-oil production in century of 1800s less than 1 day of modern US oil imports!

Drake Well, 1859

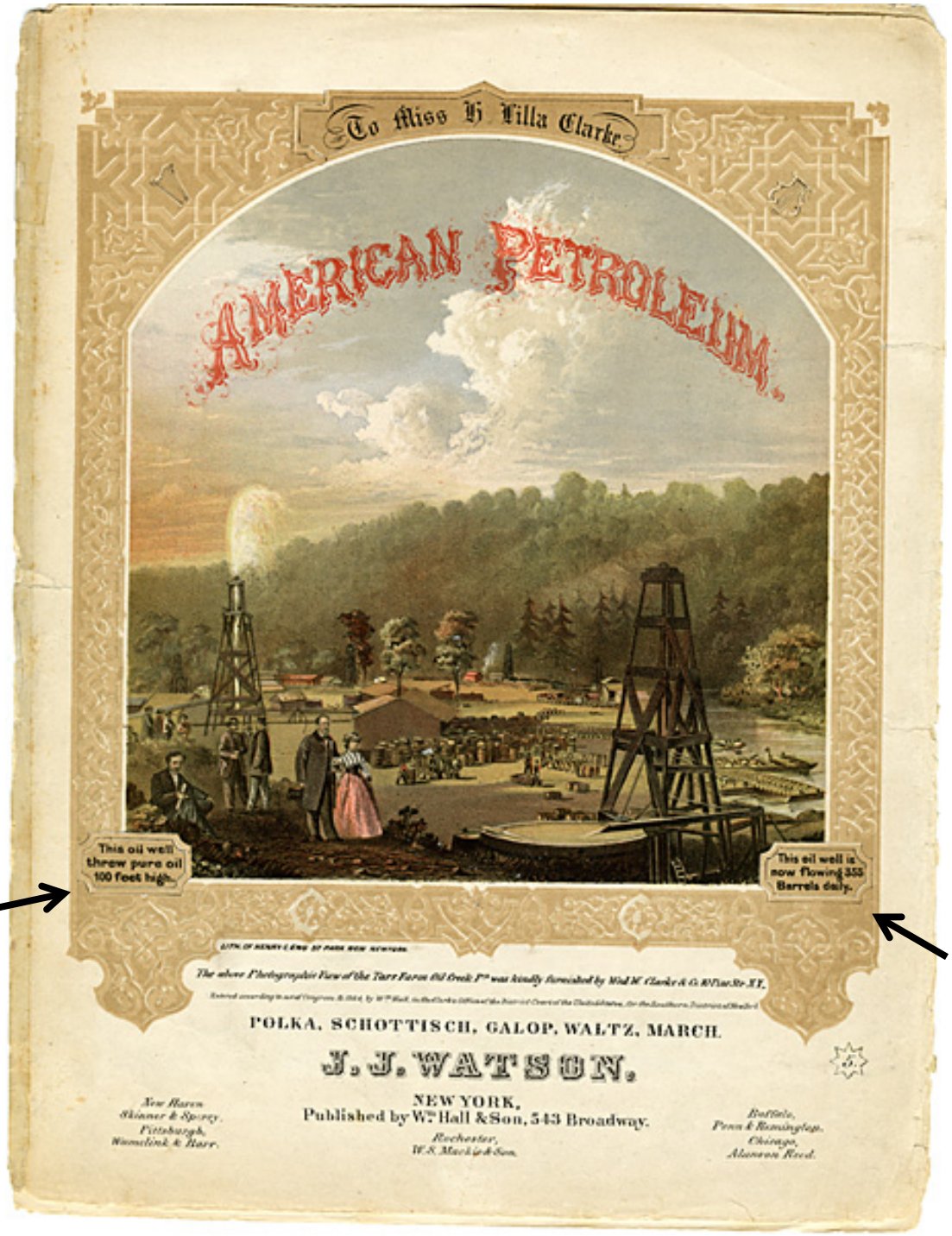


http://www.parks.tas.gov.au/historic/swhaling/offshore.html
Tasmanian Museum and Art Gallery

Whale oil production. Prices and Production over a complete Hubbert Cycle: the Case of the American Whale Fisheries in 19th Century, Aug 2004, Ugo Bardi, ASPO: The Association for the Study of Peak Oil and Gas, and Dipartimento di Chimica - Universita di Firenze,Via della Lastruccia 3, Sesto Fiorentino (Fi), Italy. bardi@unifi.it This document is published in the #45 issue of the ASPO newsletter. (www.peakoil.net) The present version appears at http://www.aspoitalia.net/aspoenglish/documents/bardi/whaleoil/whaleoil.html Data from A. Starbuck, History of the American whale fishery, Seacaucus, N.J. 1878, reprinted 1989

“GRAND BALL GIVEN BY THE WHALES IN HONOR OF THE DISCOVERY OF THE OIL WELLS IN PENNSYLVANIA”, VANITY FAIR, 1861

The **AMERICAN PETROLEUM POLKA**, 1864. Pennsylvania wells.



"This oil well threw pure oil 100 feet high."

"This oil well is now flowing 355 Barrels daily."

Consider transportation:

- Typical U.S. driver buys almost 100 pounds of gasoline per week
- And burning adds O_2 to make about 300 pounds of CO_2
- *(1 gallon of gas weighs about 6 pounds, so 16 gallons is nearly 100 pounds, and each pound of gasoline yields 3.1 pounds of CO_2)*

If car CO_2 came as horse ploppies:

- ~1 pound/mile driven;
- US drivers would cover every road in the country an inch deep every year;
- And you would smell it everywhere.
- Don't even THINK about airplanes…

Now to global warming:

- IF we burn all the fossil fuels before switching to other energy
- AND we put the CO_2 into the air
- THEN we are confident we will change world in ways we don't like;
- Nice to burn and then learn, but for sustainability we must learn faster.

Lincoln's solution…

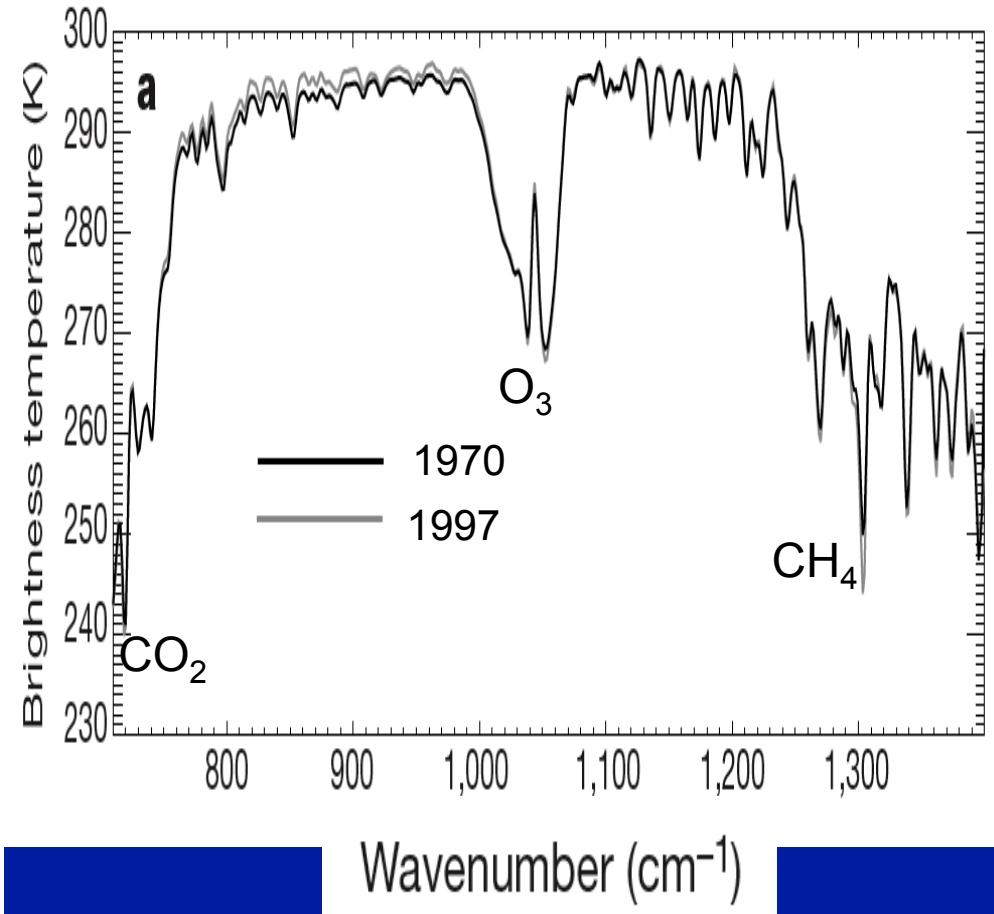
- National Academy of Sciences assesses science for US
- Pres. George W. Bush asked about climate: committee including scientist most likely to write an anti-global-warming-editorial in Wall Street Journal, said:

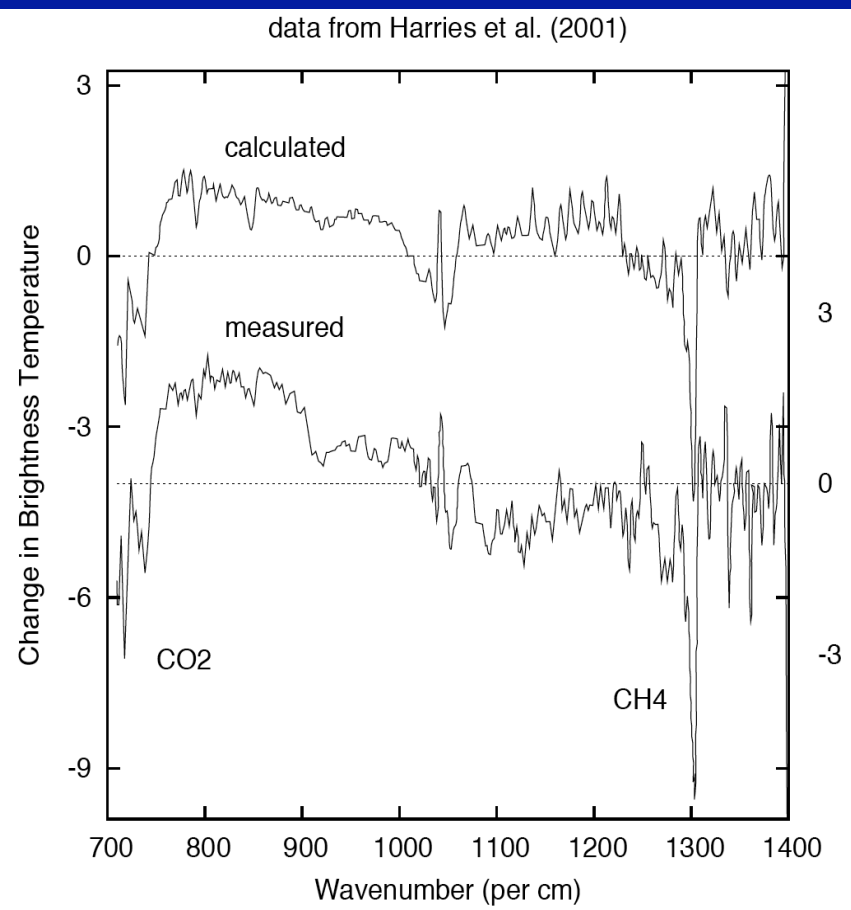
"Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperature and subsurface ocean temperature to rise. Temperatures are in fact rising. The changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability… The committee generally agrees with the assessment of human-caused climate change presented in the IPCC Working Group I (WGI) scientific report"

(p. 1, Climate Change Science: An Analysis of Some Key Questions, Committee on the Science of Climate Change, National Research Council, 2001, National Academy Press, Washington, DC, www.nap.edu)

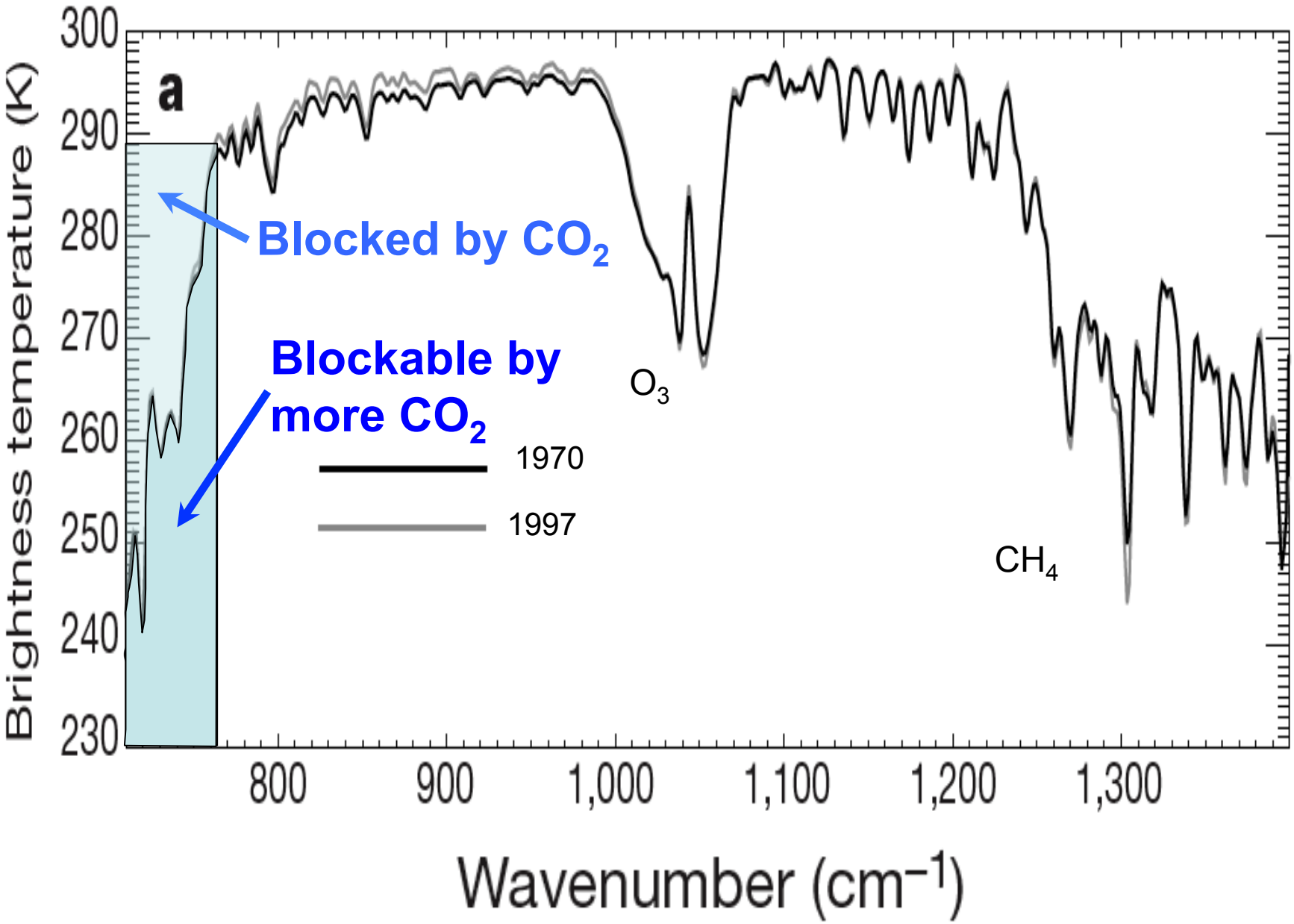
Increased greenhouse effect from CO_2, CH_4, and other gases is observed;

Satellite-measured spectra over central Pacific, 1970-1997:





Harries et al. (2001)


a
Blocked by CO_2
Blockable by more CO_2
1970
1997
O_3
CH_4
Brightness temperature (K)
300
290
280
270
260
250
240
230
800
900
1,000
1,100
1,200
1,300
Wavenumber (cm^{-1})

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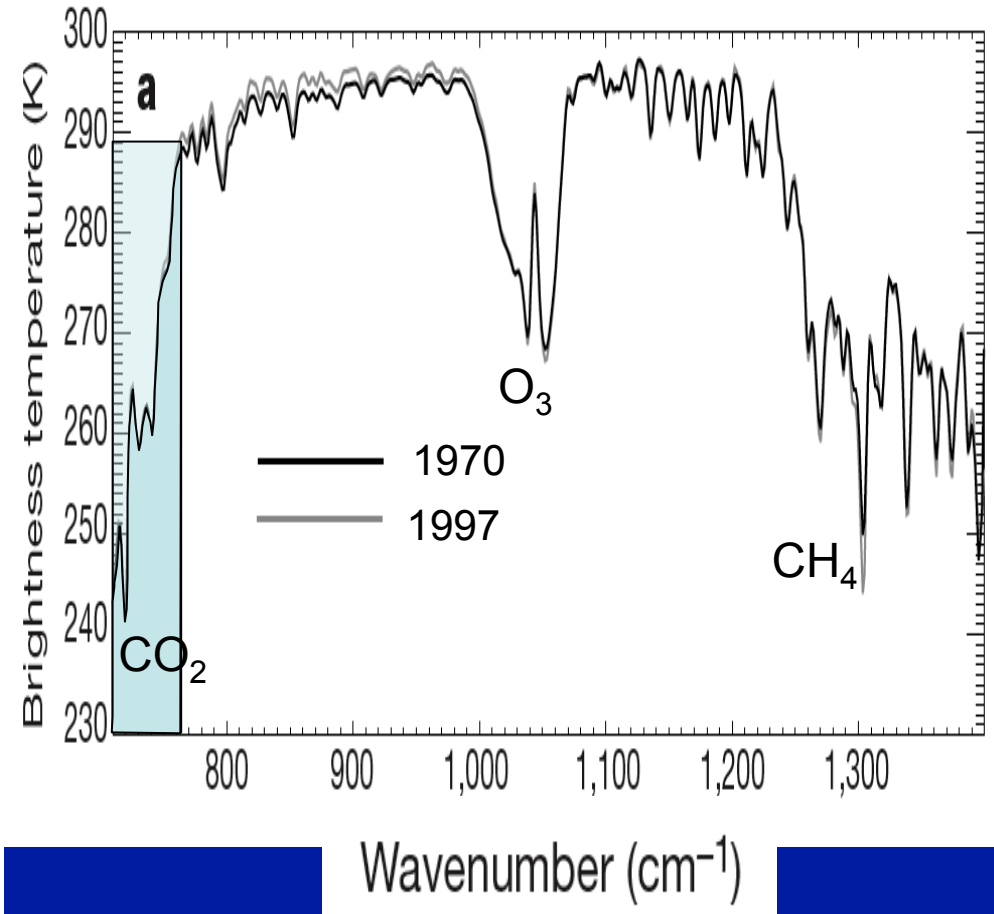
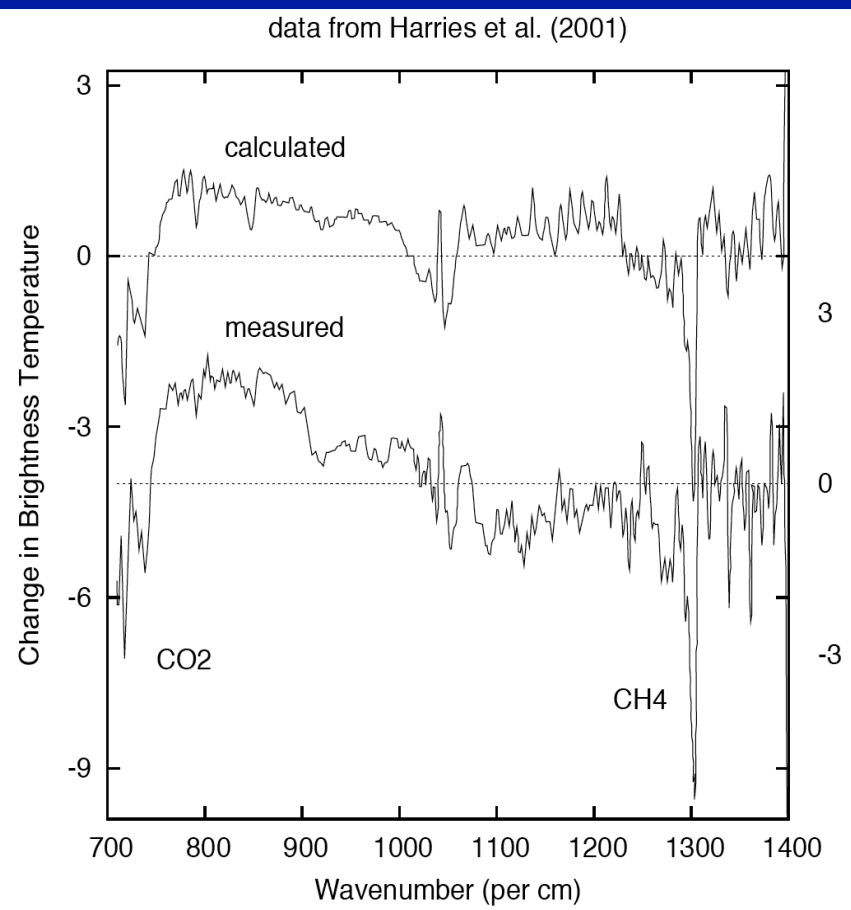
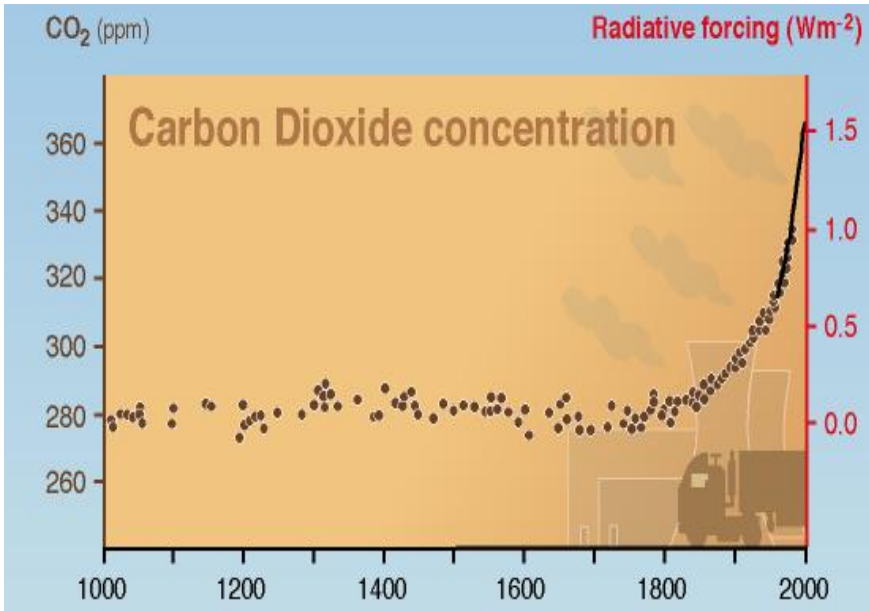
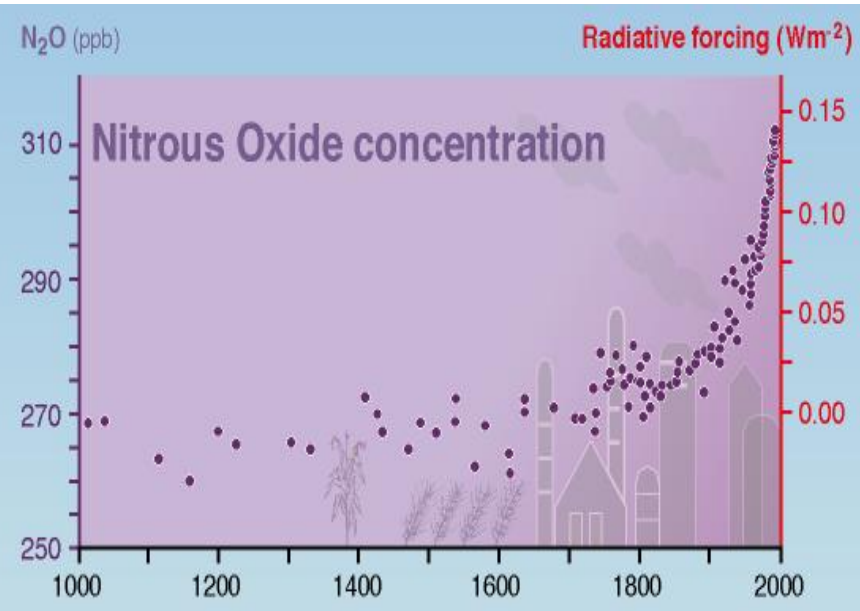


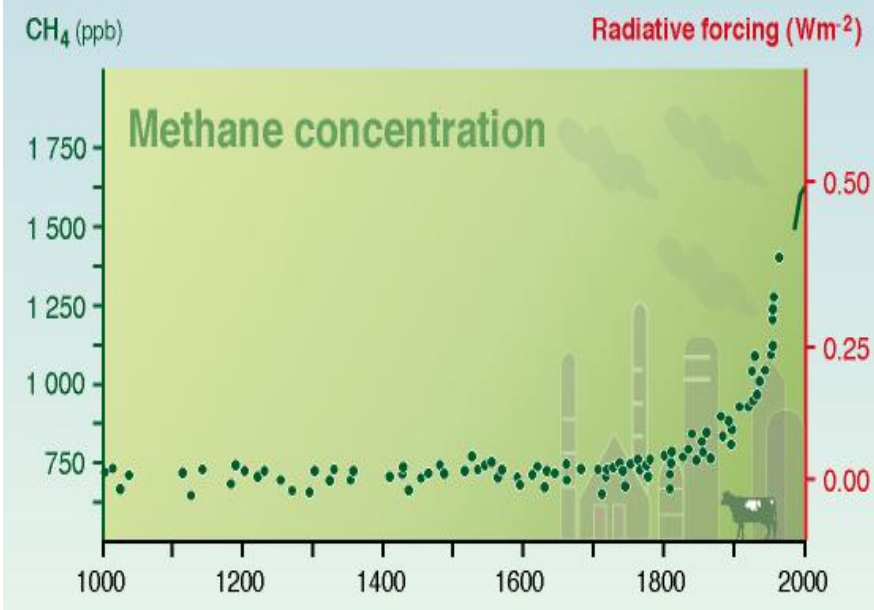


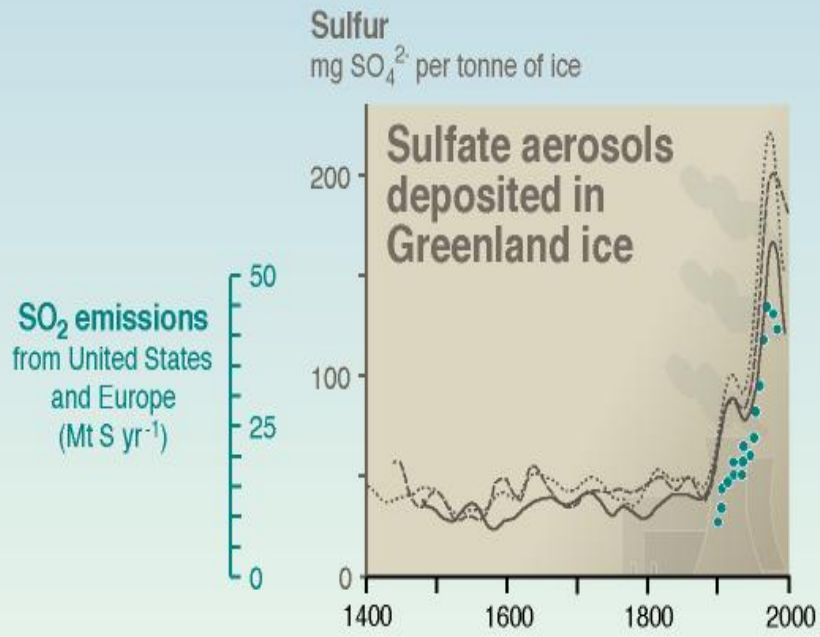
Harries et al. (2001)


CO_2 (ppm)
Radiative forcing (Wm^{-2})
Carbon Dioxide concentration
360
340
320
300
280
260
1.5
1.0
0.5
0.0
1000
1200
1400
1600
1800
2000


N_2O (ppb)
Radiative forcing (Wm^{-2})
Nitrous Oxide concentration
310
290
270
250
0.15
0.10
0.05
0.00
1000
1200
1400
1600
1800
2000

IPCC, 2001


CH_4 (ppb)
Radiative forcing (Wm^{-2})
Methane concentration
1 750
1 500
1 250
1 000
750
0.50
0.25
0.00
1000
1200
1400
1600
1800
2000


Sulfur
mg SO_4^{2-} per tonne of ice
Sulfate aerosols deposited in Greenland ice
200
100
0
1400
1600
1800
2000
SO_2 emissions
from United States and Europe
(Mt S yr^{-1})
50
25
0

Is it our CO_2? Yes

- Bookkeeping: quantitative match between known burning and observed extra CO_2 in system;
- No other possible explanation adequate (volcanic source 1-2% of ours…);
- Air shows fossil fuels responsible:

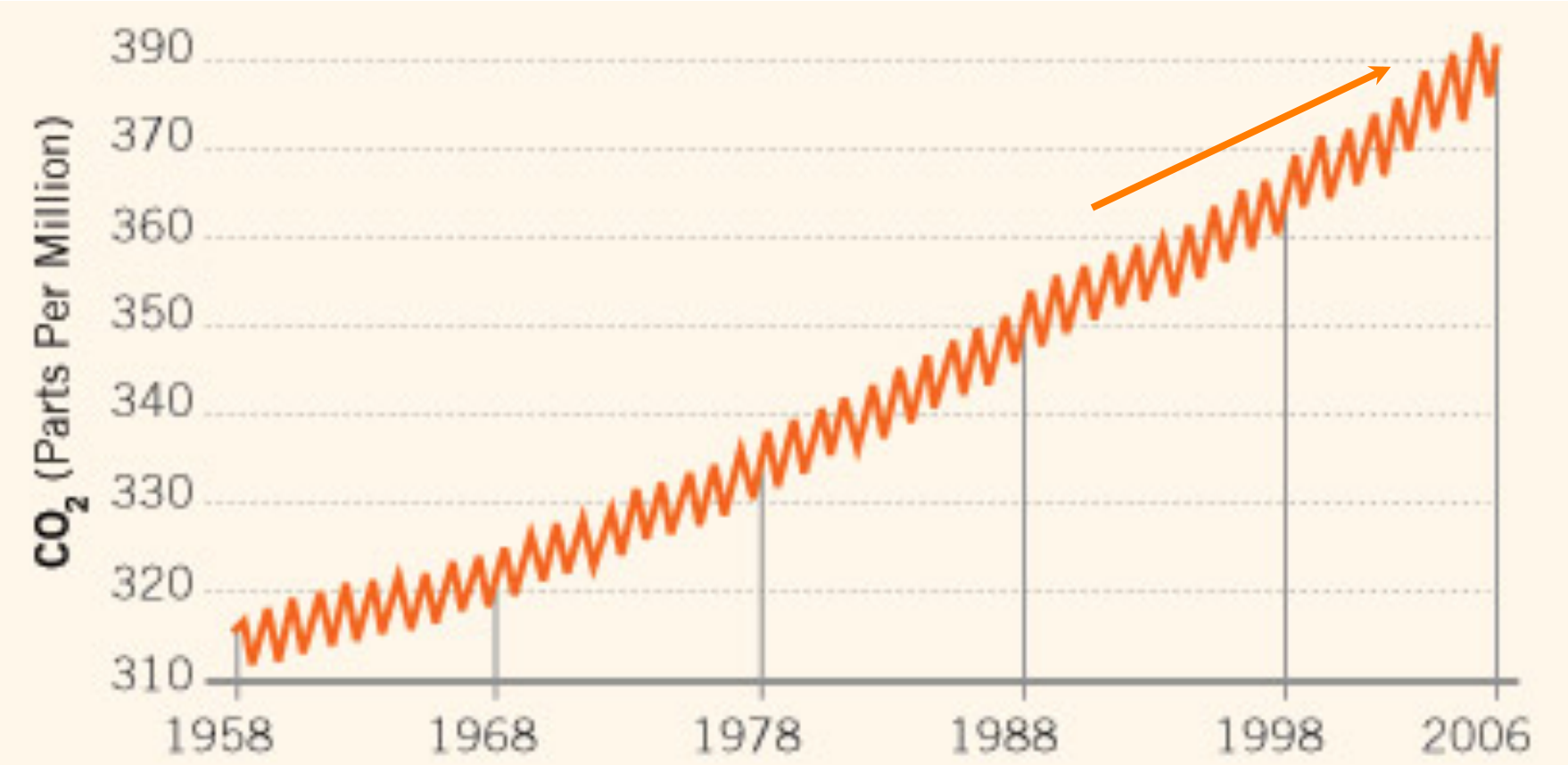
→Atmospheric ^{13}C dilution—extra CO_2 is or was living (not volcanic, dissolved in ocean, etc.)

→Atmospheric ^{14}C dilution--extra CO_2 is from old source (not from modern plants)

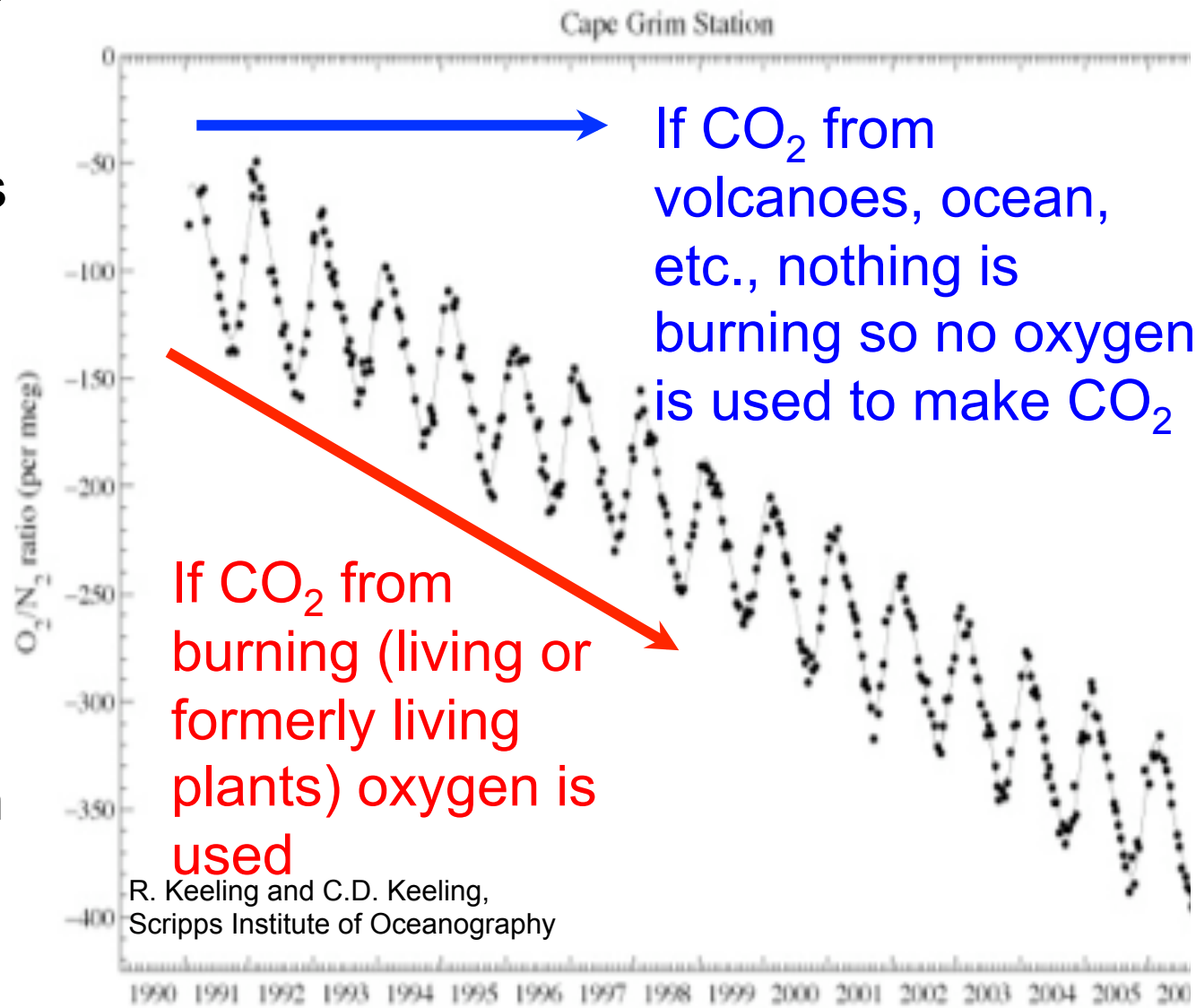
→Atmospheric O_2 drop--excess CO_2 is from burning (not from ocean or volcanoes)

CO_2 is rising. We're burning much fossil fuel (~$1200 each, each year, just to import oil), and we see the CO_2 from our tail pipes in the air and the ocean. Here is the Keeling Curve showing the rise since 1958. The wiggles are the "breathing" of the seasons (spring leaf growth and autumn leaf death).

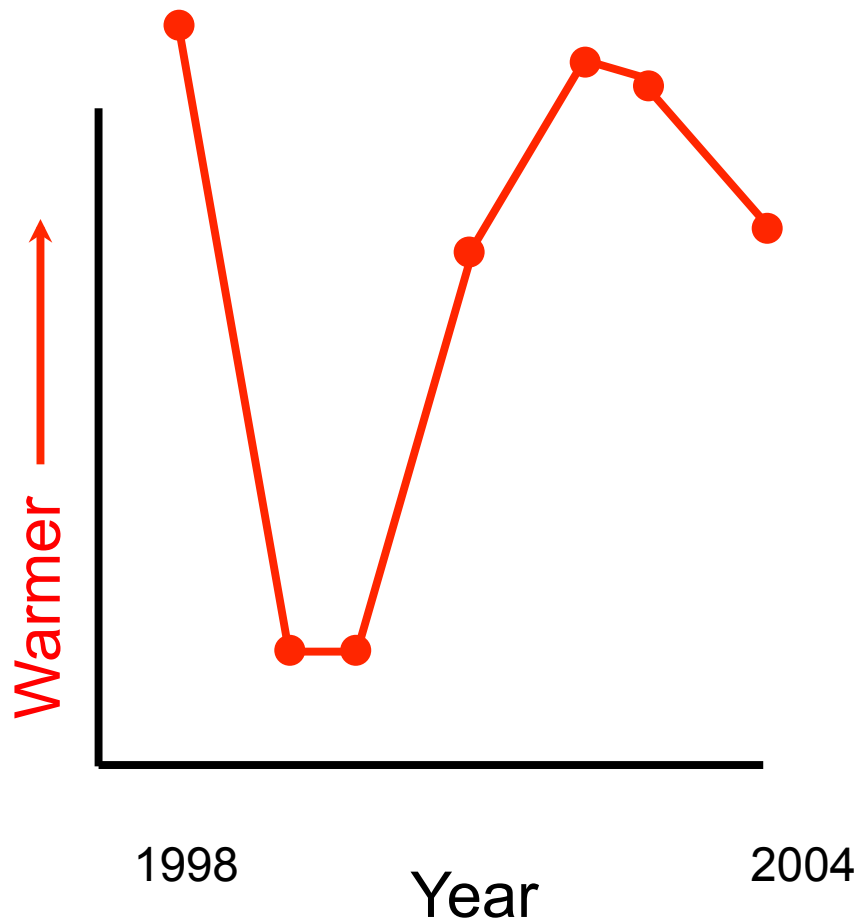
http://www.npr.org/templates/story/story.php?storyId=9885767



It really is our CO_2. What we burn is in the air and the ocean. Tracers in the air confirm this. For example, burning fossil fuels uses oxygen, but volcanoes don't. The drop in oxygen is clear.

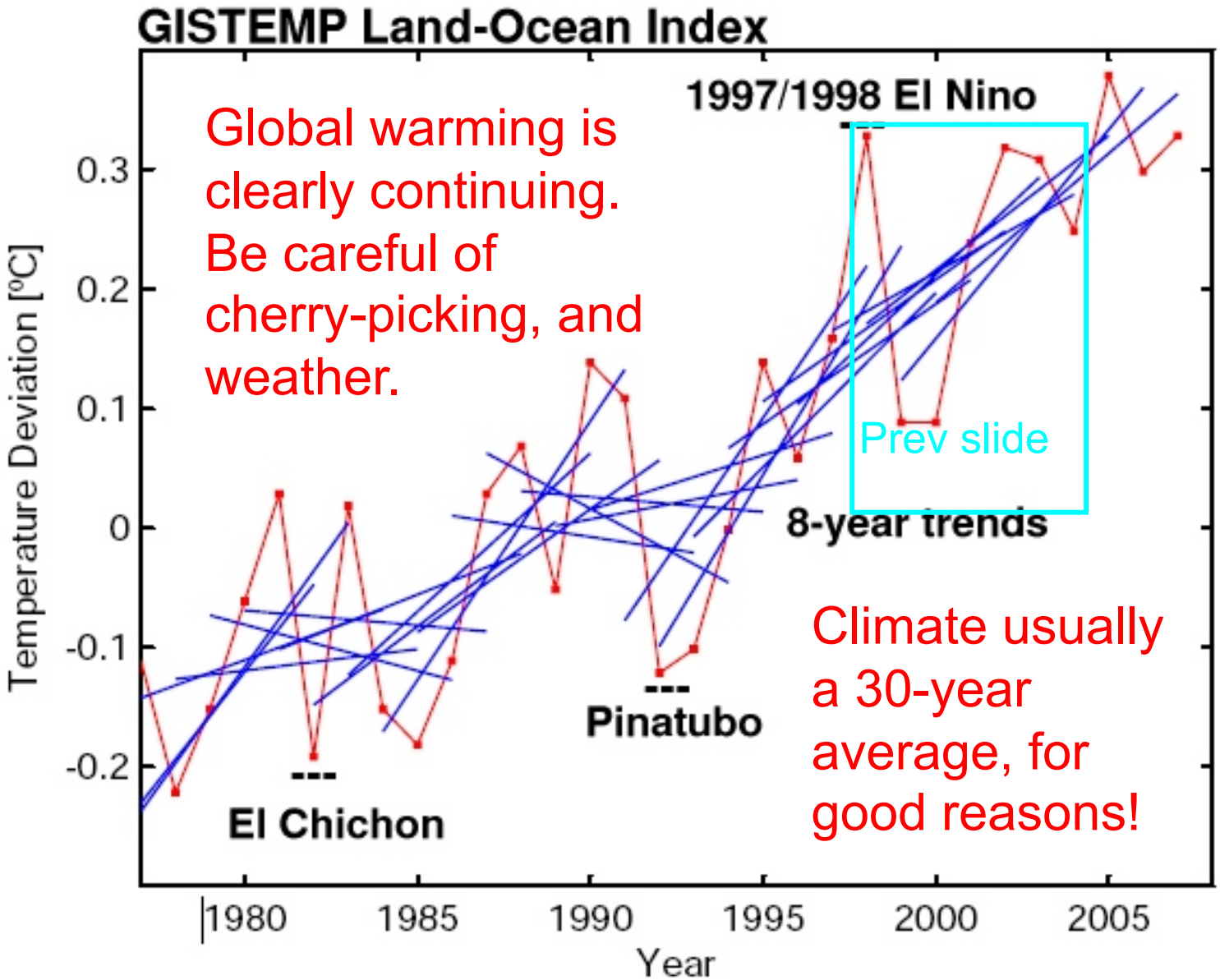


(We'll still be able to breathe!)



There are lots of people who should know better showing short segments of data and claiming that global warming stopped.

In all the global data sets, looking at a long enough interval to give a statistically significant trend shows warming.



Source: Gavin Schmidt, NASA GISS

http://www.realclimate.org/index.php/archives/2008/01/uncertainty-noise-and-the-art-of-model-data-comparison/#more-523

Warming over last century:

- **UNEQUIVOCAL, from cautious IPCC**
- Direct thermometer measurements:

→ In air (including far from cities);

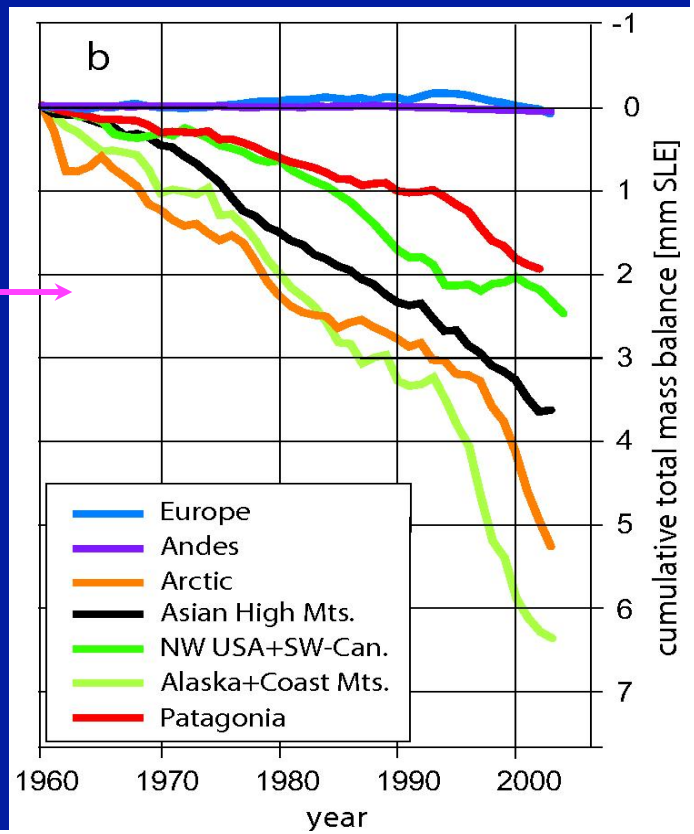
→ In ocean water;

→ In ground;

→ On balloons;

→ From satellites;

- Mass loss from almost all glaciers, including those getting more snow;
- Great majority of biology shifts in direction expected for warming;
- (There still is weather--some people who should know better look at a cool day, week or year and claim warming stopped. Silliness.)



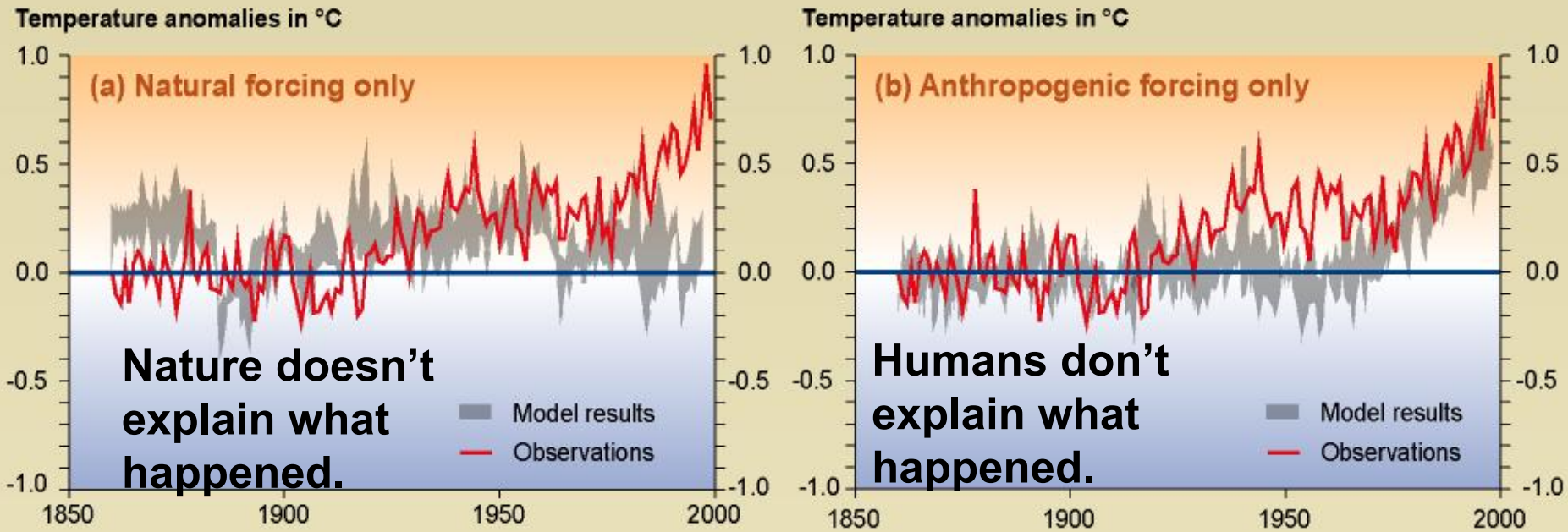
Muir Glacier, Alaska, August 13, 1941, photo by W.O. Field

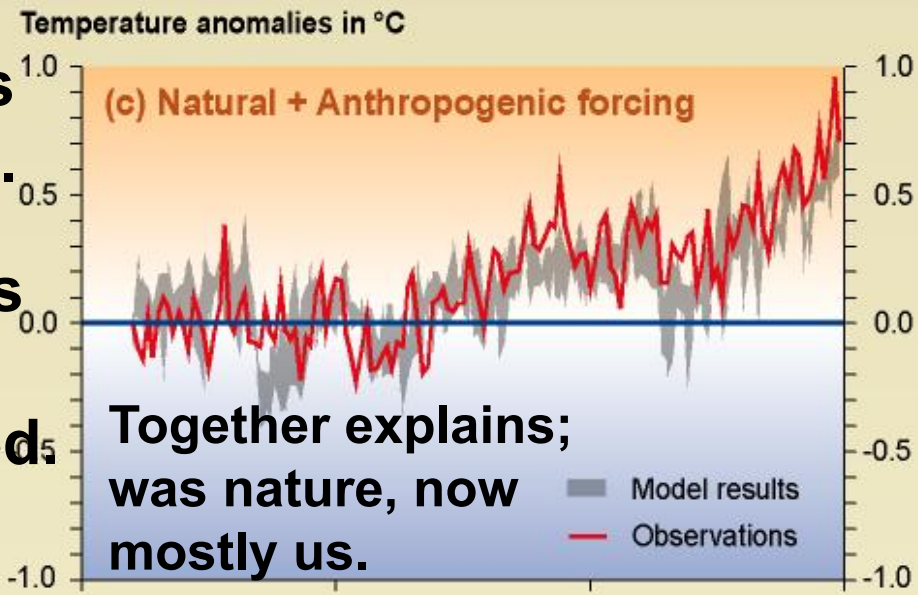
Muir Glacier, Alaska, August 31, 2004, photo by B.F. Molnia

High confidence warming from our CO_2

- PHYSICS: warming influence of rising CO_2 is unavoidable, observable physical reality;
- FORCINGS: Nothing else pushing warming (sun not brightening, cosmic rays not changing, etc.);
- FINGERPRINTS: Quantitative match between modeled and observed warming in time and space if and only if CO_2 included, with mismatch for any other possible cause of warming.

Comparison between modeled and observations of temperature rise since the year 1860

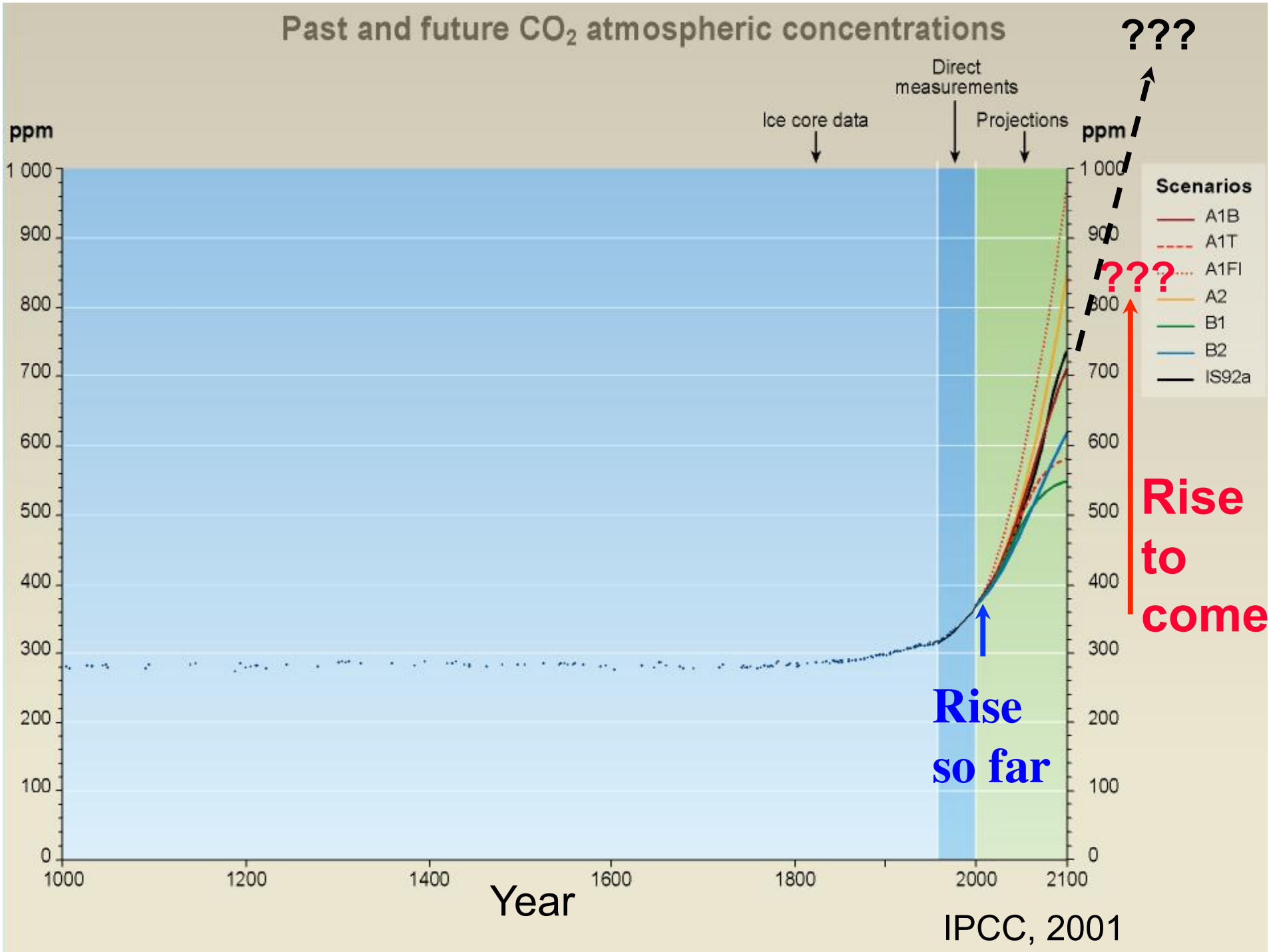




Red shows what happened.

Gray shows what model thinks happened.

IPCC, 2001


Past and future CO_2 atmospheric concentrations
???
Direct measurements
Ice core data
Projections
ppm
ppm
1 000
900
800
700
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
2100
Year
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a
???
Rise to come
Rise so far
IPCC, 2001

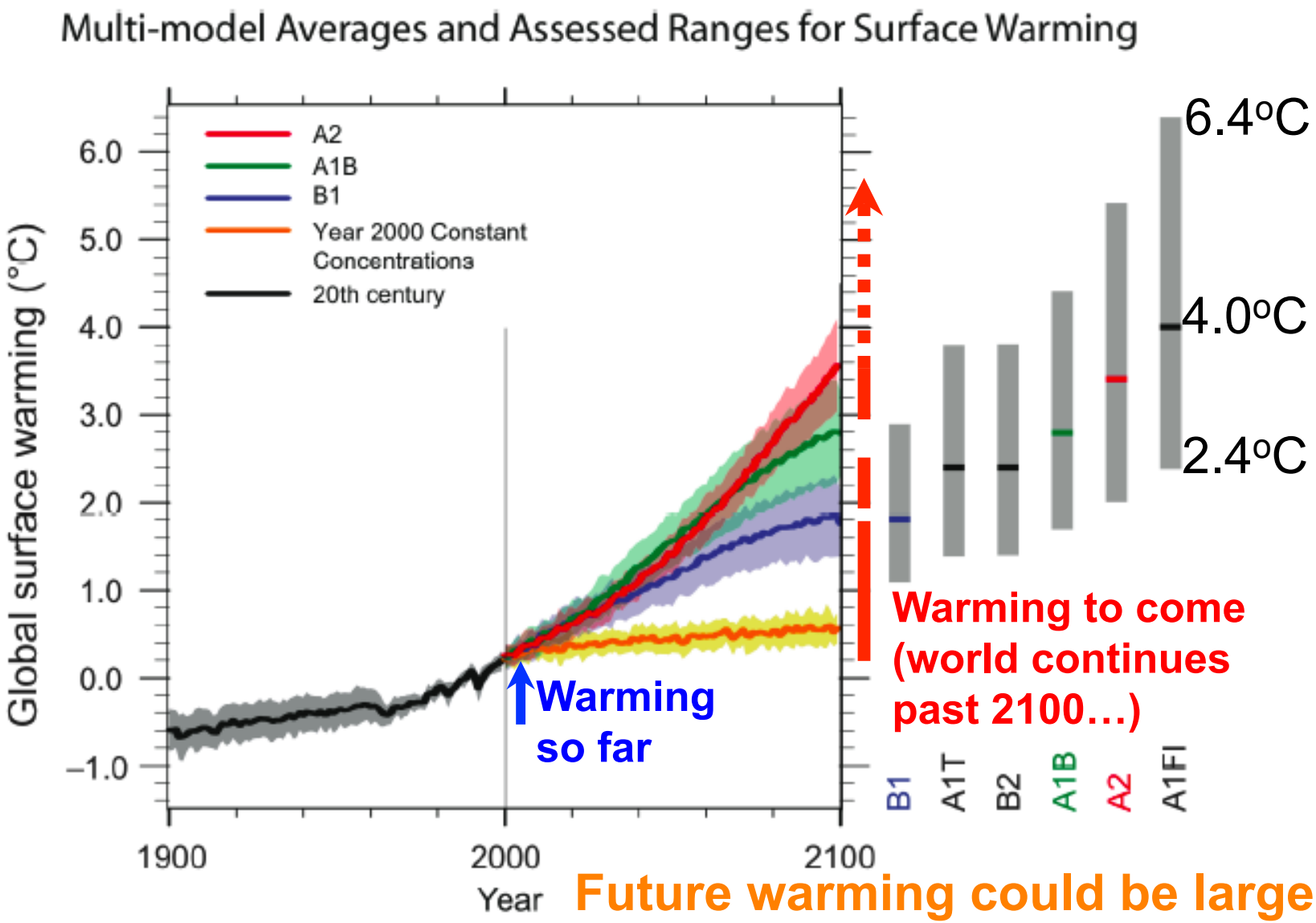


FIGURE SPM-5. Solid lines are multi-model global averages of surface warming (relative to 1980-99) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the plus/minus one standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The gray bars at right indicate the best estimate (solid line within each bar) and the *likely* range assessed for the six SRES marker scenarios. The assessment of the best estimate and *likely* ranges in the gray bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}

Brief summary of impacts:

→Grain-belt drying for crops

→Sea-level rise

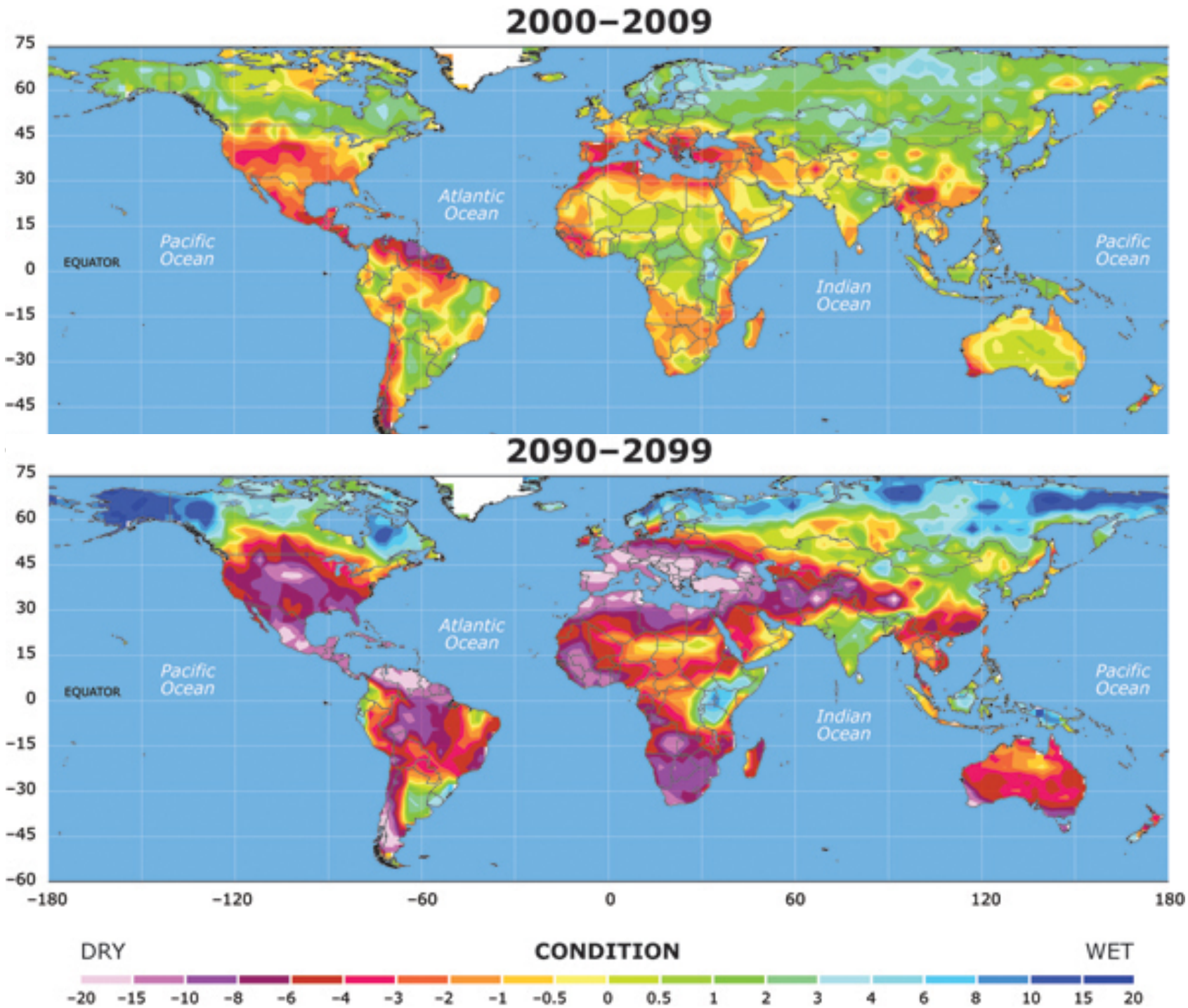
→Tropical diseases no longer frozen

→Loss of unique ecosystems, especially with humans in way of migration

→Tropical cyclones that form likely to become larger (more energy/fuel)

→Tendency for more floods and more droughts (more water in air; faster drying)

Palmer drought severity index: Blue and green= plenty of water for plants.



Dai, A., 2010, Wiley Interdisciplinary Reviews: Climate Change

Economics

- Damages grow to a few percent of world economy per year (1%≈$600 billion);
- Fix ≈1% of world economy per year, after a few decades of serious effort and investment in learning how;
- Economically best to start investing now in heading off warming, then ramp up
- (Well, economically best to start 30 years ago, when science first provided consistent assessed results...)

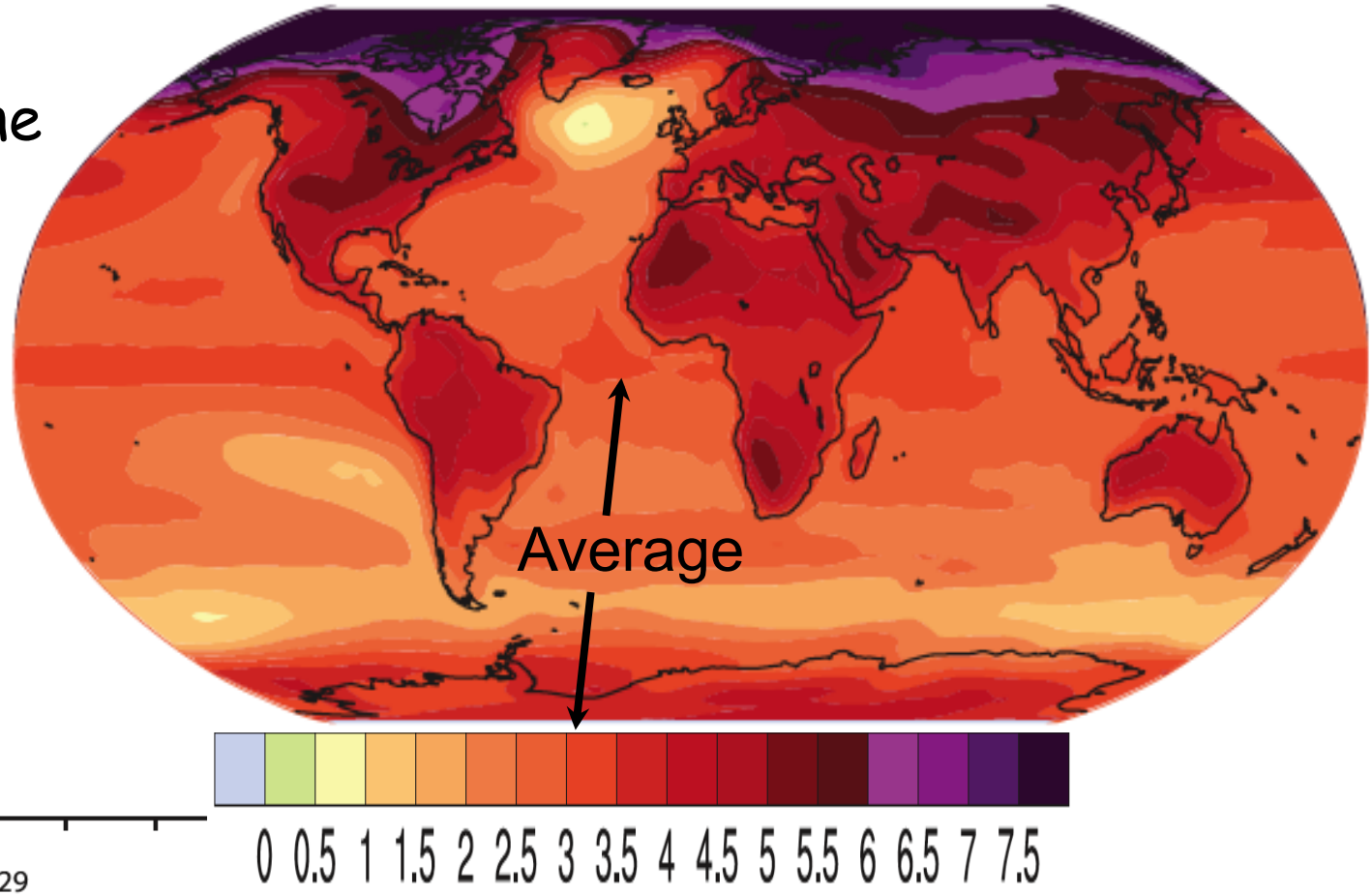
An issue of fairness?

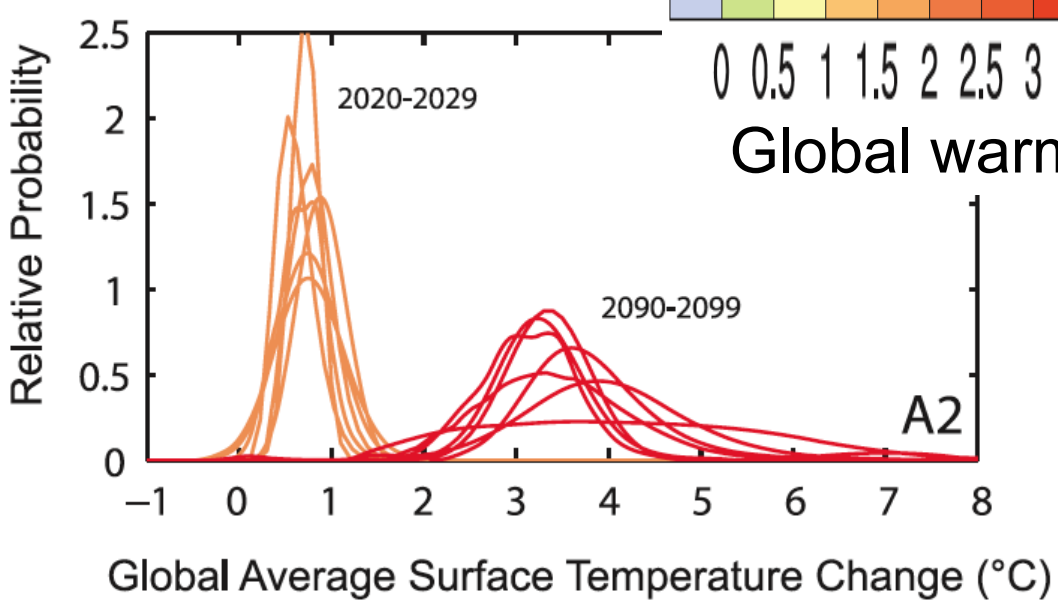
- If you have winter, air conditioners, and bulldozers, a little warming may help economy (too much hurts); if any missing, warming hurts;
- Most warming being caused by people with winter, air conditioning and bulldozers;
- Our emissions hurt others more than us;
- We legally must clean up toilets, some things from smokestacks so others can drink and breathe…

If this picture is wrong, it probably is optimistic:

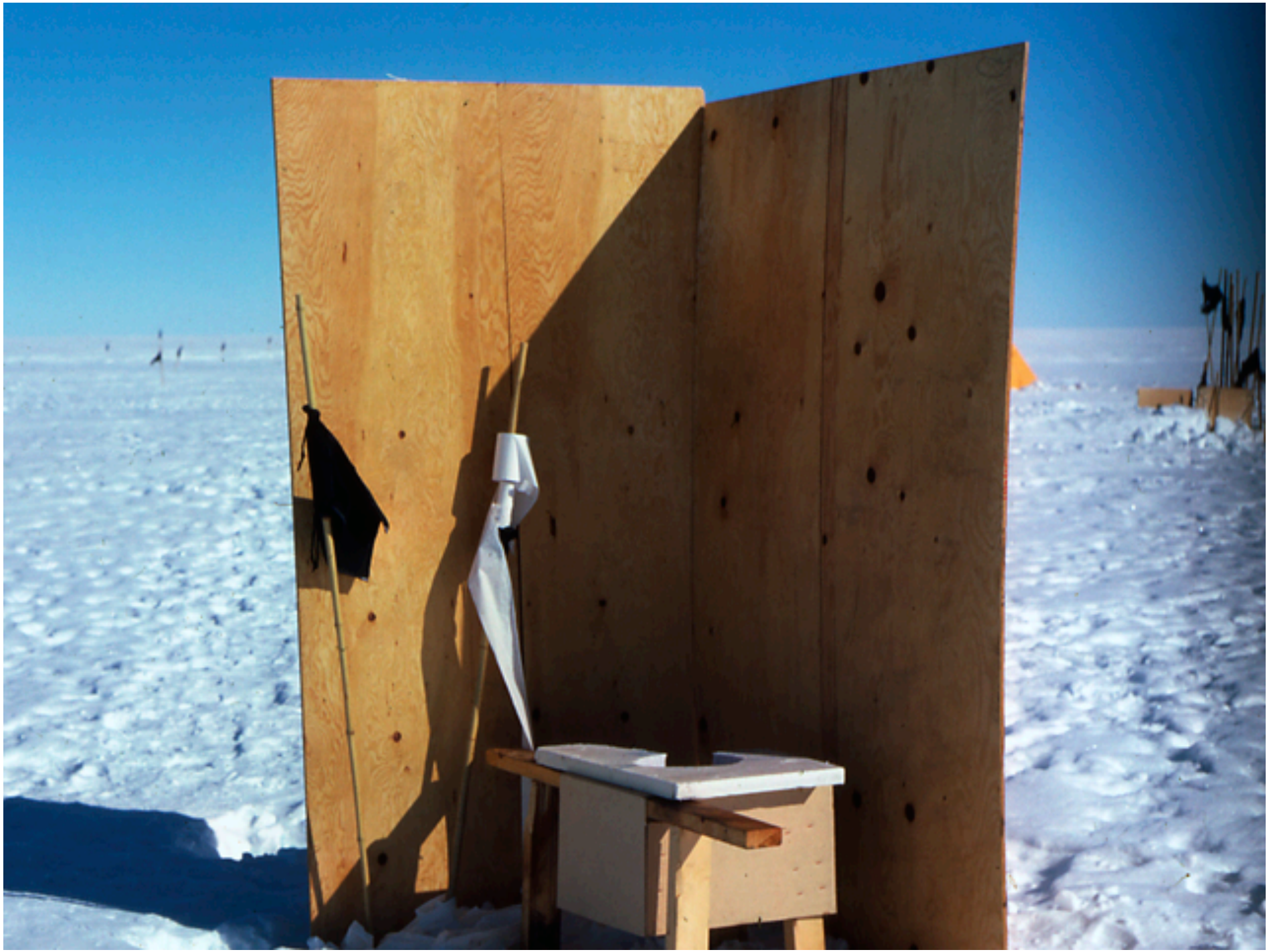
- Models more often underestimate than overestimate past changes (my view of science);
- Projections smooth but world isn't; abrupt changes harder to handle (north Atlantic shutdown, droughts, ice-sheet collapses, etc.);
- Skewed climate sensitivity (typically, estimates of warming give central estimate, possibility of slightly better, slightly worse, or much worse)
- "uncertainties imply a more stringent set of greenhouse-gas controls than are implied by the best-guess case" W. Nordhaus, *Managing the Global Commons*, 1998.

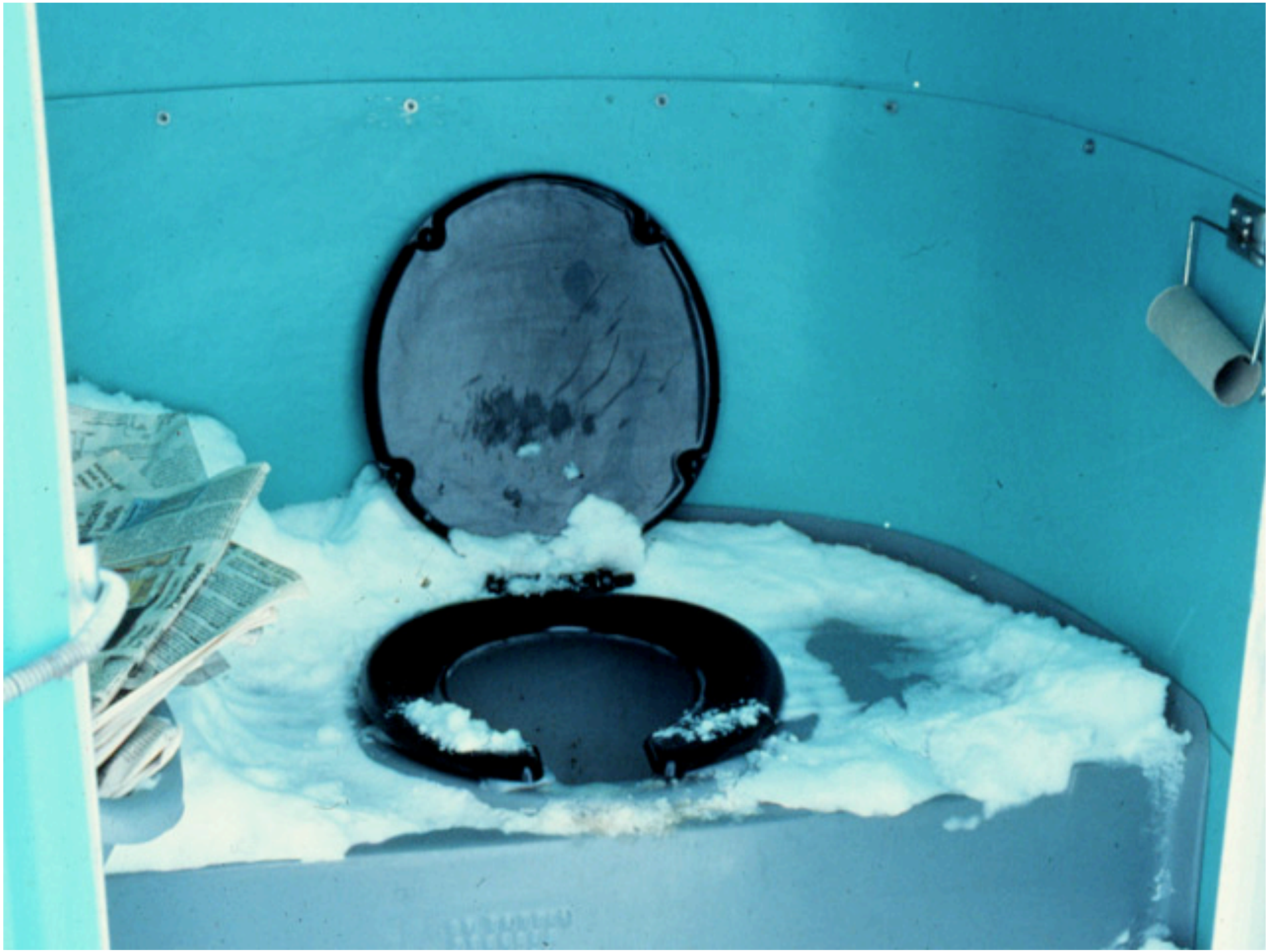
Lake Wobegon: Almost everyone experiences above-average warming (most people live on land, which warms faster than global average).



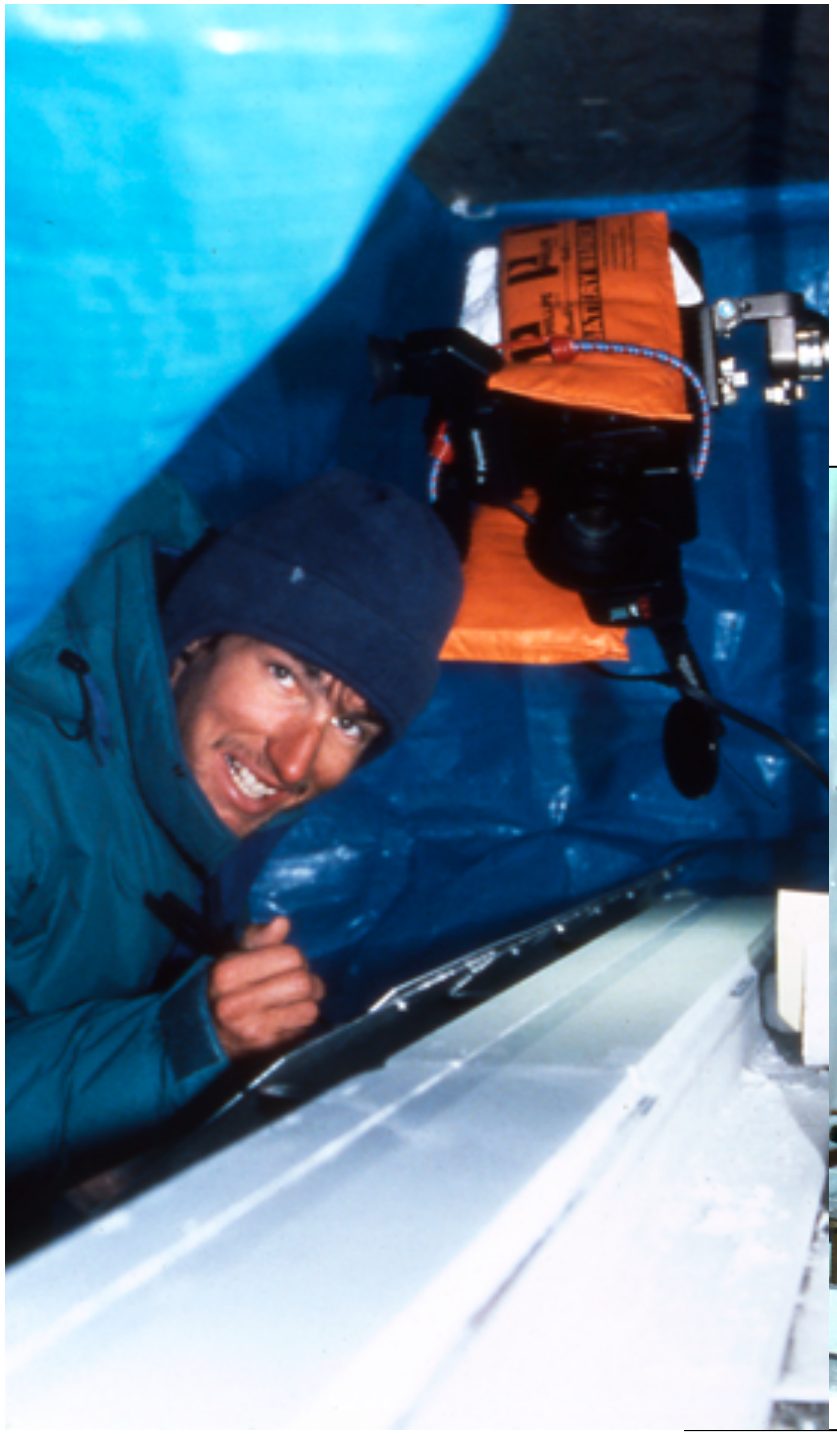


With chance of a little better, a little worse, or a lot worse.

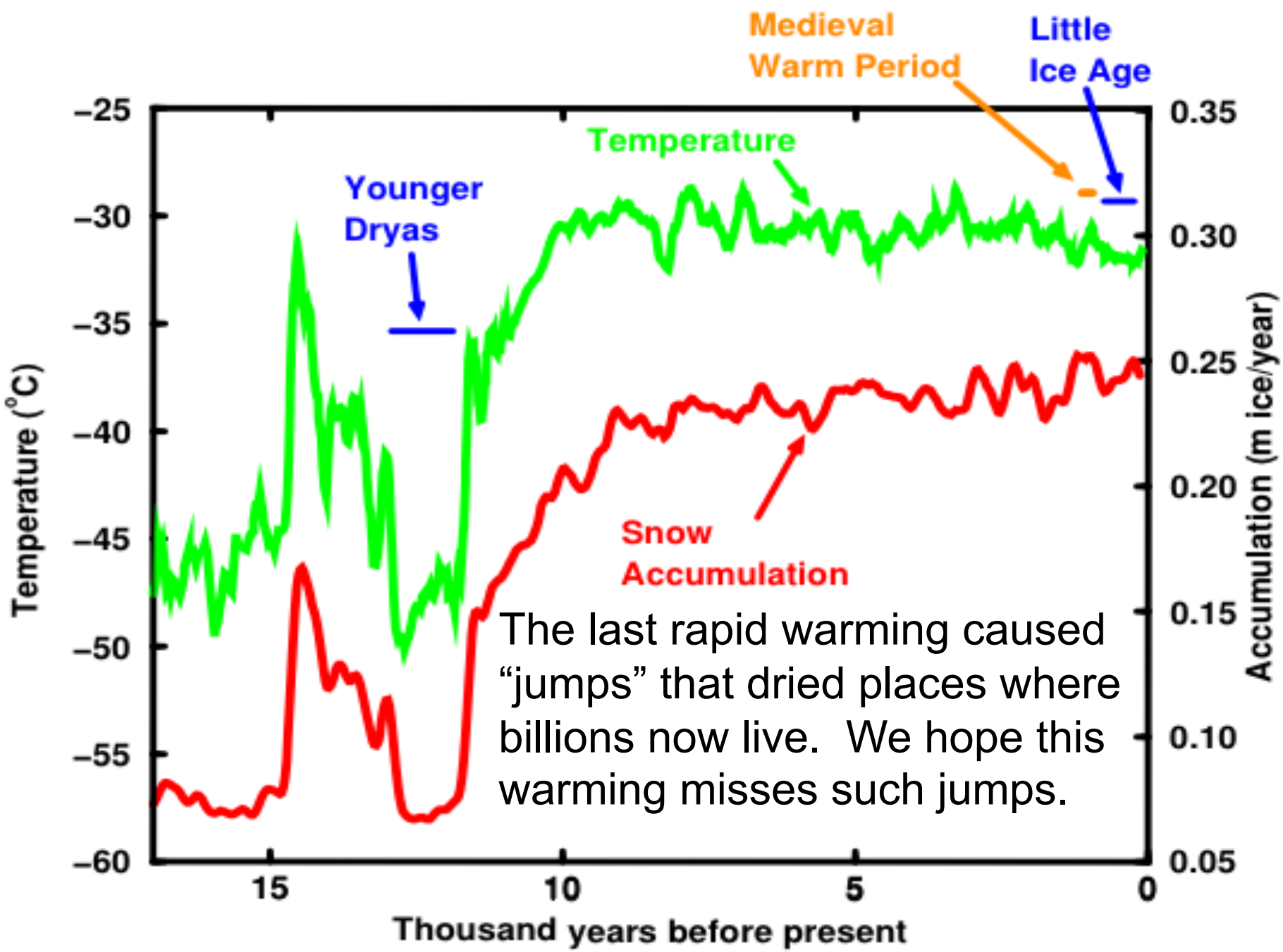




PROJECT
AIR LTD



Penn Staters Kurt Cuffey, Wanda Kapsner studying ice cores, central Greenland (NSF-sponsored GISP2 project)

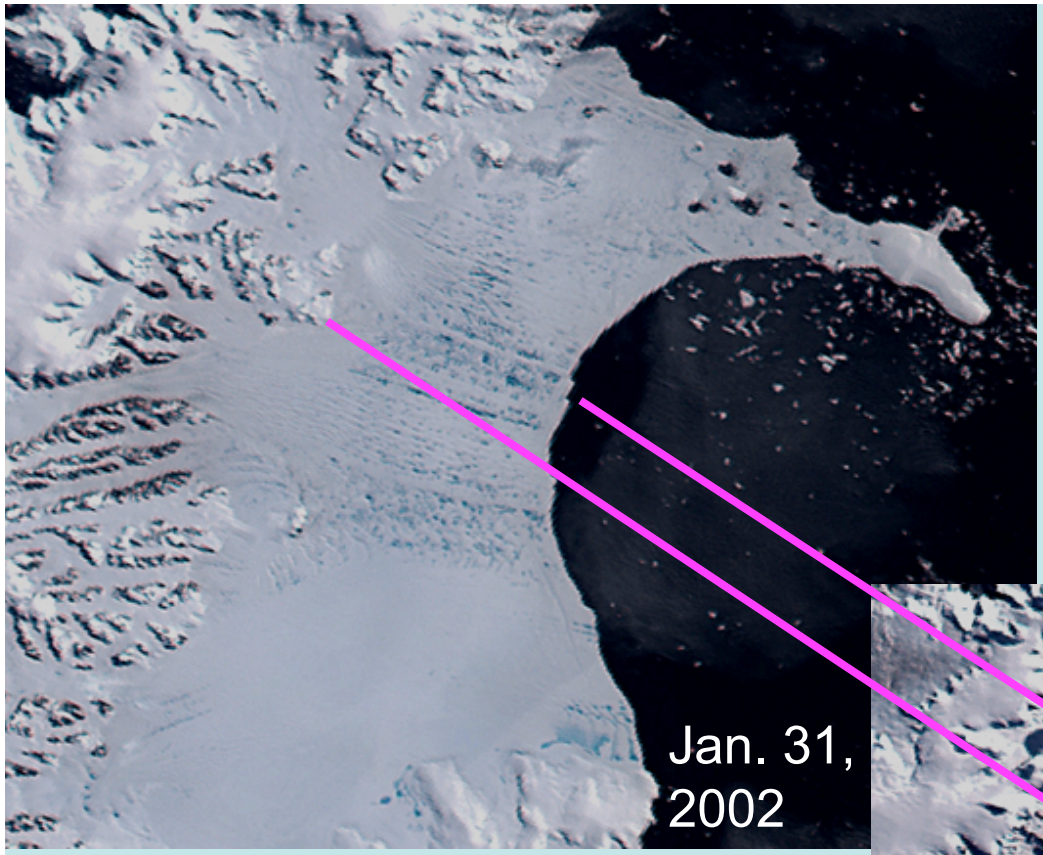


The last rapid warming caused "jumps" that dried places where billions now live. We hope this warming misses such jumps.

NSF US Antarctic Program (Penn Staters Don Voigt, Huw Horgan, Sridhar Anandakrishnan CReSIS

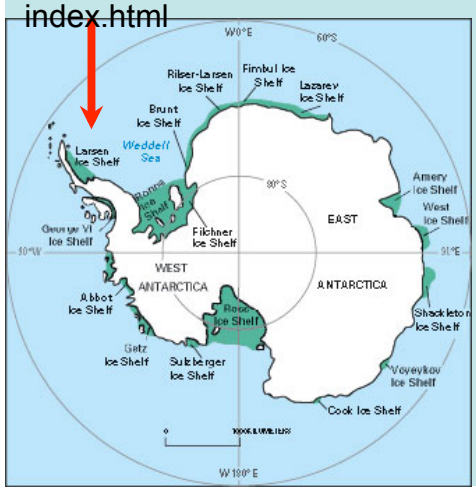
IPCC on ice sheets:

- 2001: much uncertainty, but expected snowfall to rise more than melting, little change in flow, net growth 21st century;
- Then: ice sheets responded to warming by shrinking, with ice-flow accelerations;
- 2007: **"Models used to date do not include…the full effects of changes in ice sheet flow, because a basis in published literature is lacking… understanding of these effects is too limited to… provide a best estimate or an upper bound for sea level rise."**

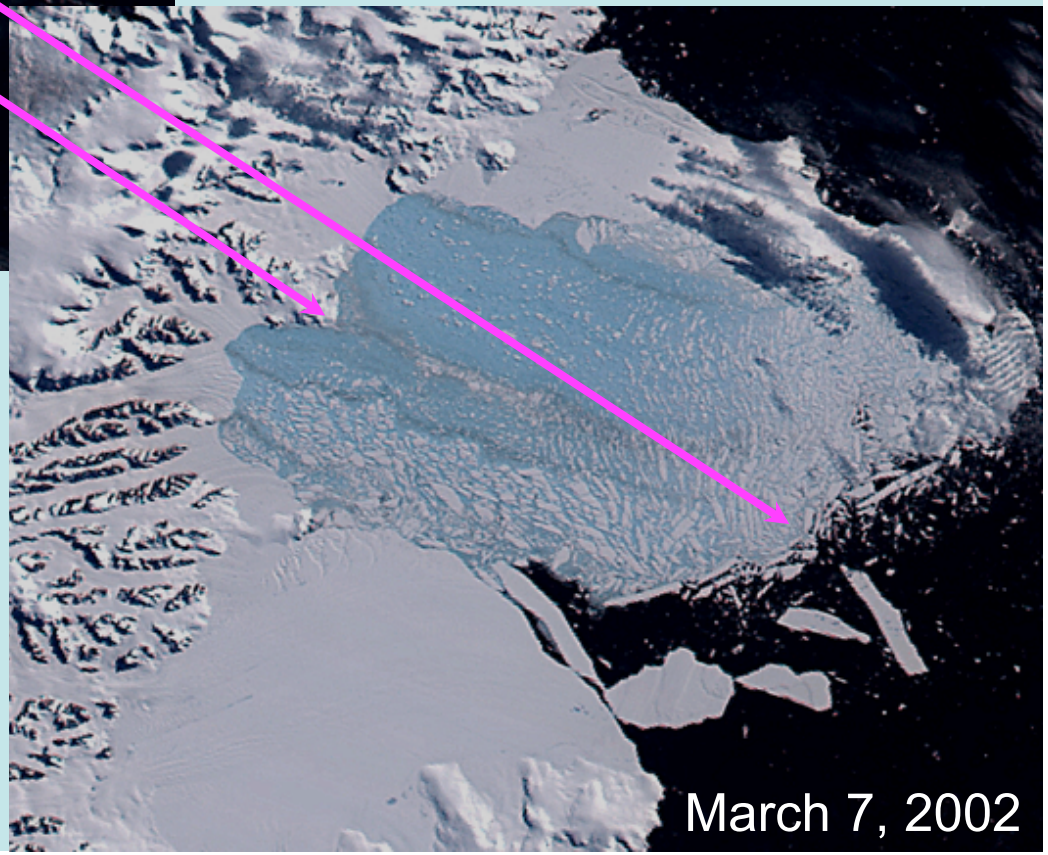


Warming ⟶ ice-shelf collapse in 5 weeks ⟶ 8-fold flow acceleration of tributary glaciers. If this moves south…???

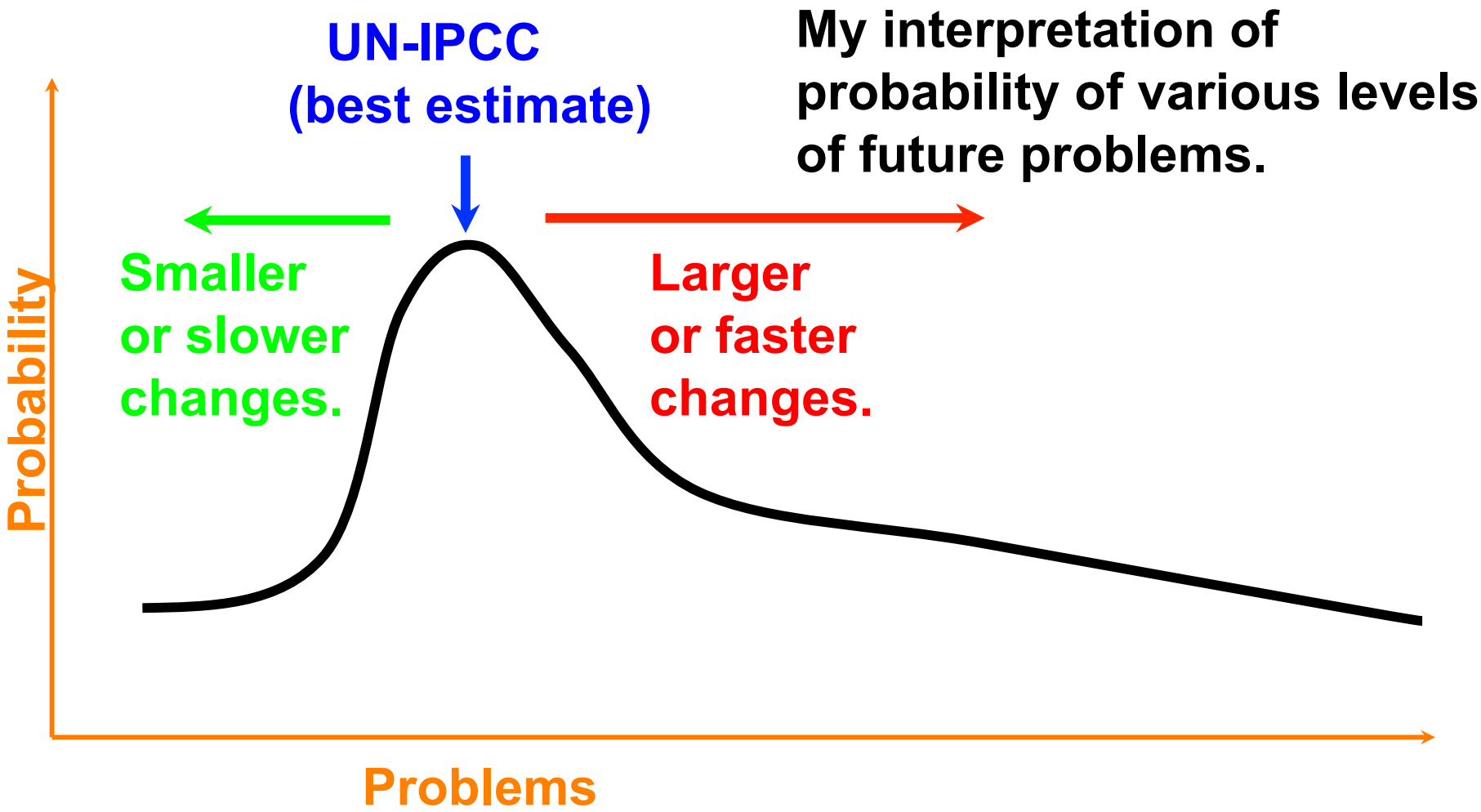
http://svs.gsfc.nasa.gov/vis/a000000/a002400/a002421/index.html



12 mi
20 km



No agreed-upon worst case; maybe 3-4x this rise?
Don't believe this could happen faster than centuries, but we might in decades reach the level that would commit us to this over centuries. Generally NOT in cost/benefit projections.



Most US debate seems to pit "UN-IPCC best estimate" against "smaller or slower changes"; most of the room seems to be in "larger or faster changes".

For Global Warming:

- Physics, history show warming effect of raising CO_2
- This is not opinion or politics, there is no serious alternative to this, it is not called into question by anyone's emails, it is simply science
- Best science says that ignoring this will be more costly than dealing with it
- And, the uncertainties are primarily on the "bad" side—the less you trust climate science, the more you should be worried by global warming
- But, there are lots of ways to deal with it
- If we burn then learn, we will have made life harder for modern poor people and most future people.

Economic Disaster? Scenario 16…

- We tax tobacco to reduce smoking, and alcohol to reduce drinking, and then we tax wages…
- Supplemental EPA Analysis of the American Clean Energy and Security Act of 2009, H.R. 2454, in the 111th Congress, Appendix, 1/29/10;
- Scenario 16–Revenue recycling to reduce labor taxes; all allowances modeled as being returned to households by lump sum in Scenario 2 are instead auctioned and the revenue used to reduce taxes on labor;
- Economy grows faster for next few decades than under business as usual;
- Taxing things we don't want (climate-changing carbon emissions) rather than things we do want (labor) makes economy grow faster.