Climate Change 101:
A few basics on climate science and the impacts of climate change

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This morning I will briefly address three questions:

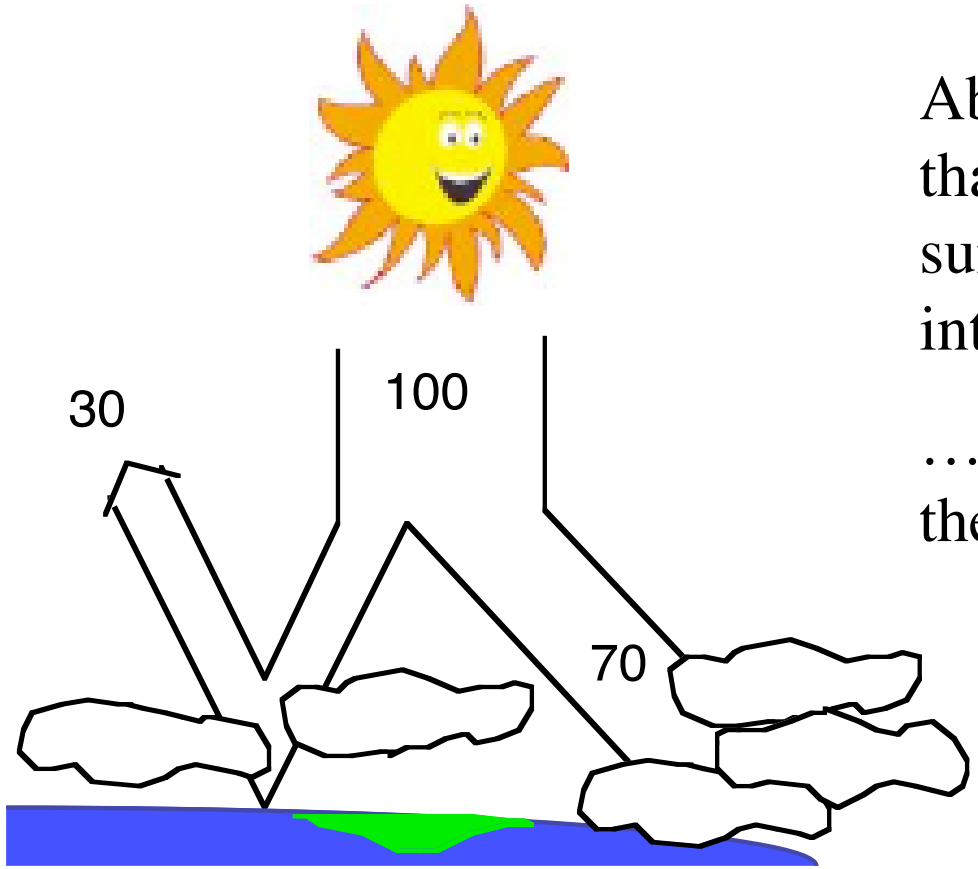
1. What is the basic science behind the issue of climate change?
2. Isn't there enormous uncertainty about climate change?
3. What impacts can we expect to see from climate change?

After which Ed Rubin will talk about controlling emissions from power plants and Lester Lave will talk about controlling emissions from transportation.What can we do to reduce climate change and minimize its adverse impacts?

1. What is the basic science behind the issue of climate change?

Sun-earth system

A quick review



About 30% of the light energy that comes to the earth from the sun is immediately reflected back into space…

…and about 70% is absorbed by the atmosphere and the ground.

But…

…while the atmosphere is transparent to visual light, it is opaque to heat (infrared).

So heat energy gets trapped.

This is termed the "greenhouse effect."

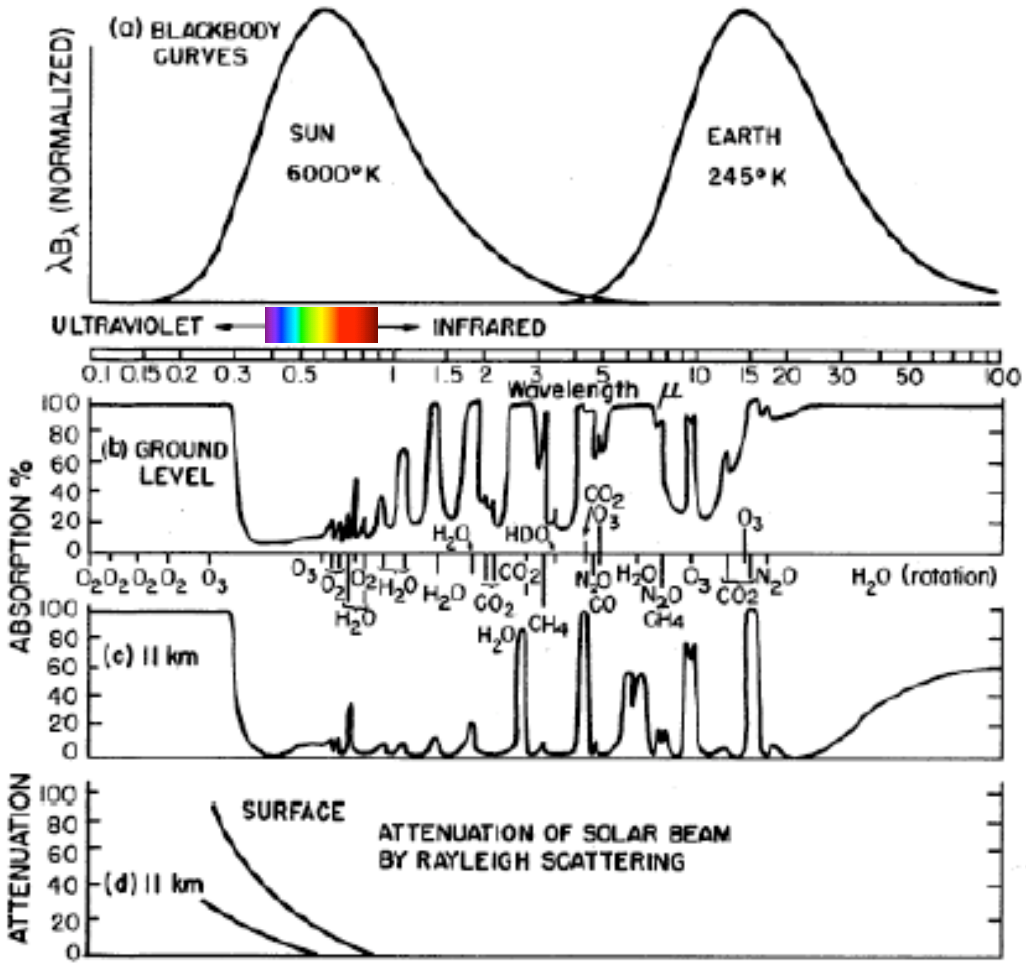
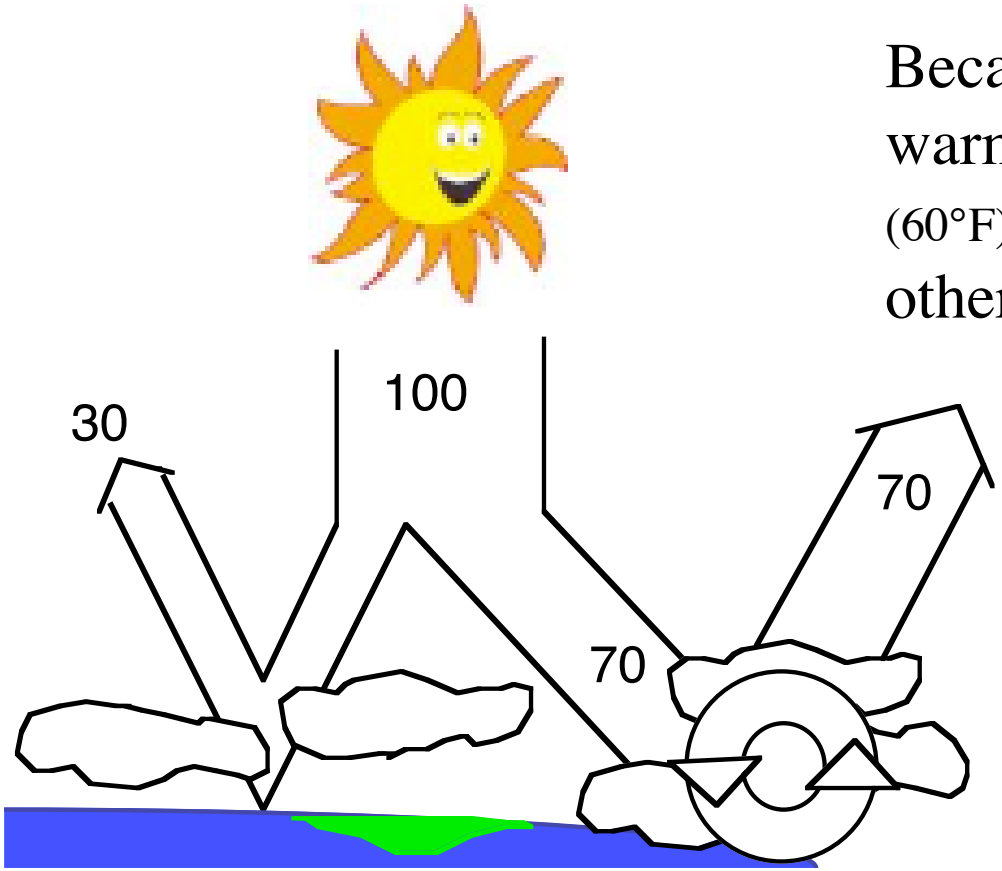


Fig. 1. (a) Blackbody emission for 6000°K and 245°K, being approximate emission spectra of the sun and earth, respectively (since inward and outward radiation must balance, the curves have been drawn with equal areas—though in fact 40% of solar radiation is reflected unchanged); (b) atmospheric absorption spectrum for a solar beam reaching the ground; (c) the same for a beam reaching the tropopause in temperate latitudes; (d) attenuation of the solar beam by Rayleigh scattering at the ground and at the temperate tropopause.

Source: Friskin, EOS, 1971.

Sun-earth system…(Cont.)

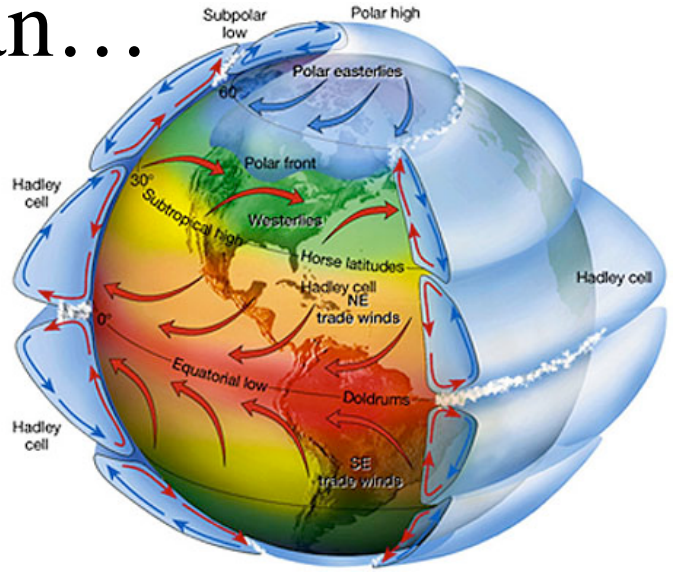


Because of this "greenhouse" warming the earth is 33°C (60°F) warmer than it would otherwise be.

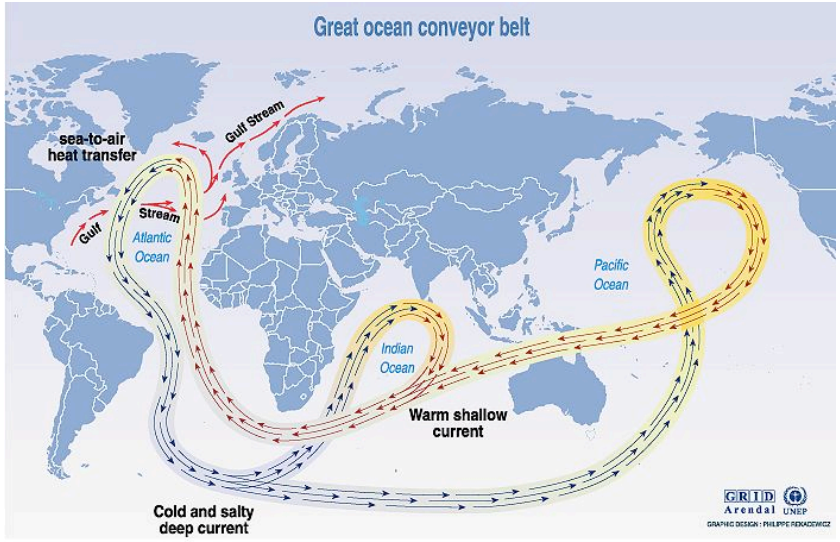
At that warmer temperature, an equilibrium is reached and the same amount of energy is radiated back to space from the top of the atmosphere.

The atmosphere and ocean…

…move energy from the equatorial region toward the poles - about half of the energy is carried by the atmosphere half by currents in the ocean.



Source: NASA

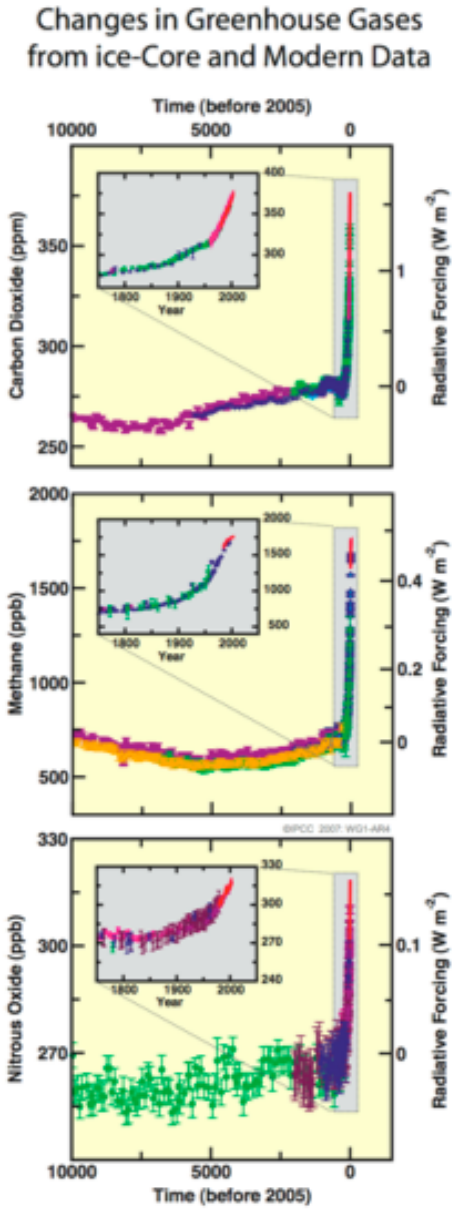


Source: Broecker, 1991, in Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Source: UNEP

Consequences of burning fossil fuel

When people burn coal, oil and gas the carbon in those fuels combines with oxygen in the air, energy is released, and carbon dioxide (CO_2) is created. Much of it remains in the atmosphere for ≥100 yrs. Since the beginning of the industrial revolution, atmospheric concentration has risen by about 30%. The same is true for other "greenhouse" gases such as methane and nitrous oxide.



Source: IPCC FAR WG1, 2007

But, this is all rather abstract…let me try to make it more specific

Consider...

…the Bruce Mansfield power plant (2360 Mw) located on the Ohio River, just west of Pittsburgh.

A plant this size burns the equivalent of about 230 hopper cars (100T each) of coal every day.

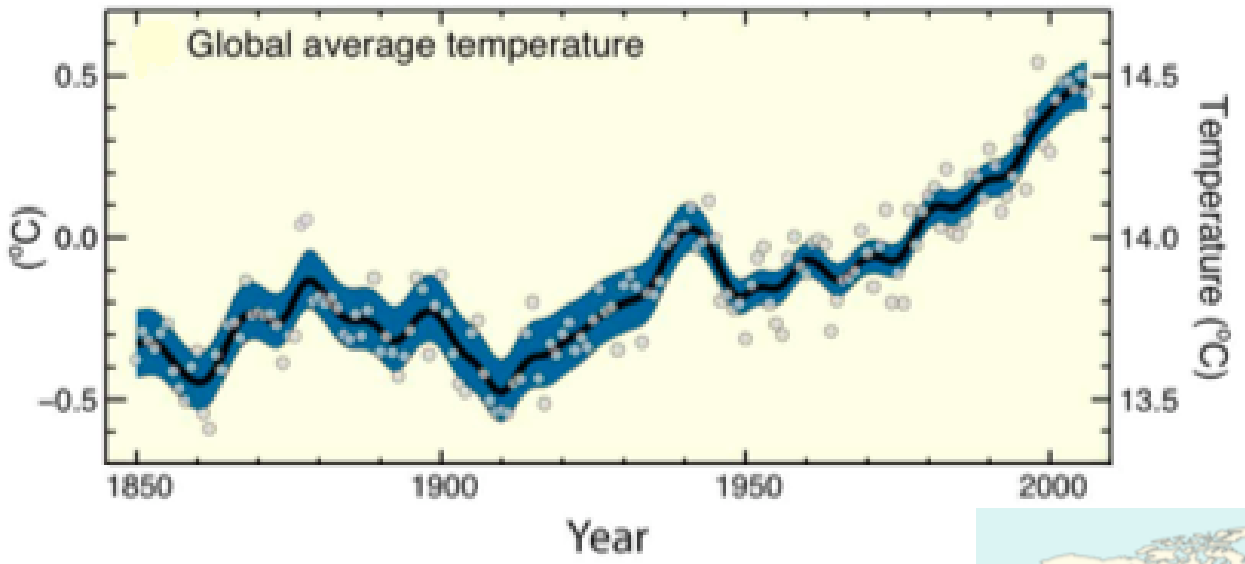
If coal were pure carbon, that would be the same as taking 130 such cars, converting them into invisible CO_2 gas, and releasing them into the atmosphere every day.

Many such plants are operating all over the U..S and the world.

Sources: www.industcards.com/ st-coal-usa-pa.htm and www.battelle.org. Calculations by Jay Apt.

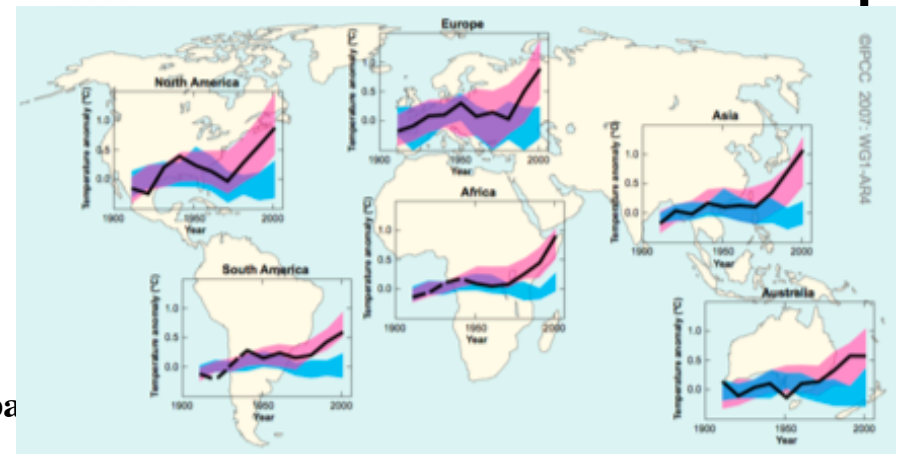
The steady build-up…

…of greenhouse gases (GHGs) in the atmosphere from hundreds of years of industrial activity has produced a corresponding increase in the average temperature of the earth.



Warming over the past 100 years ~1.3°F

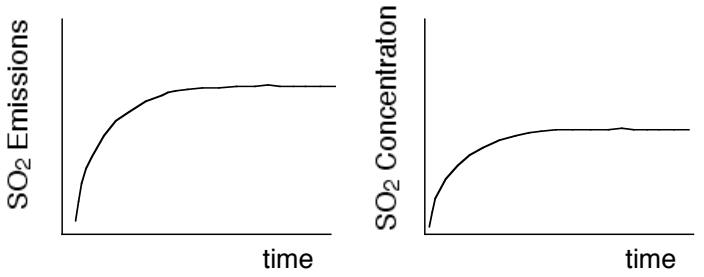
Warming is seen on all the continents:



Source: IPCC FAR WG1, 2007

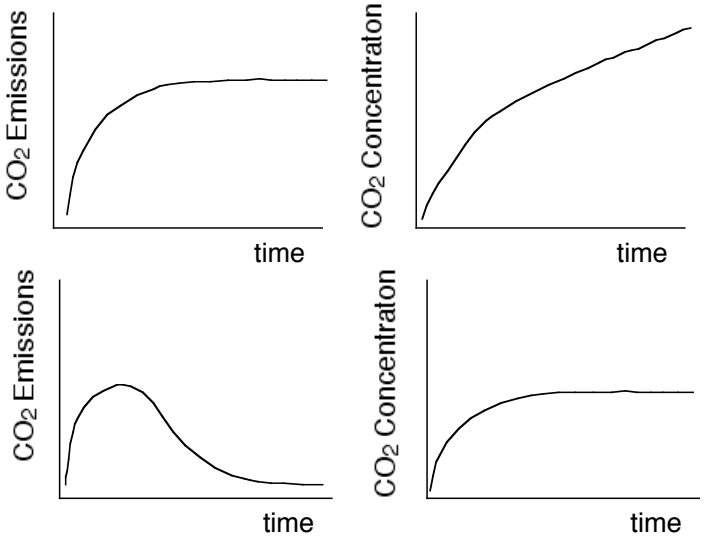
CO_2 is not like conventional air pollutants

Conventional pollutants like SO_2 or NO_x have a residence time in the atmosphere of just a few hours or days. Thus, stabilizing emissions of such pollutants results in stabilizing their concentration.



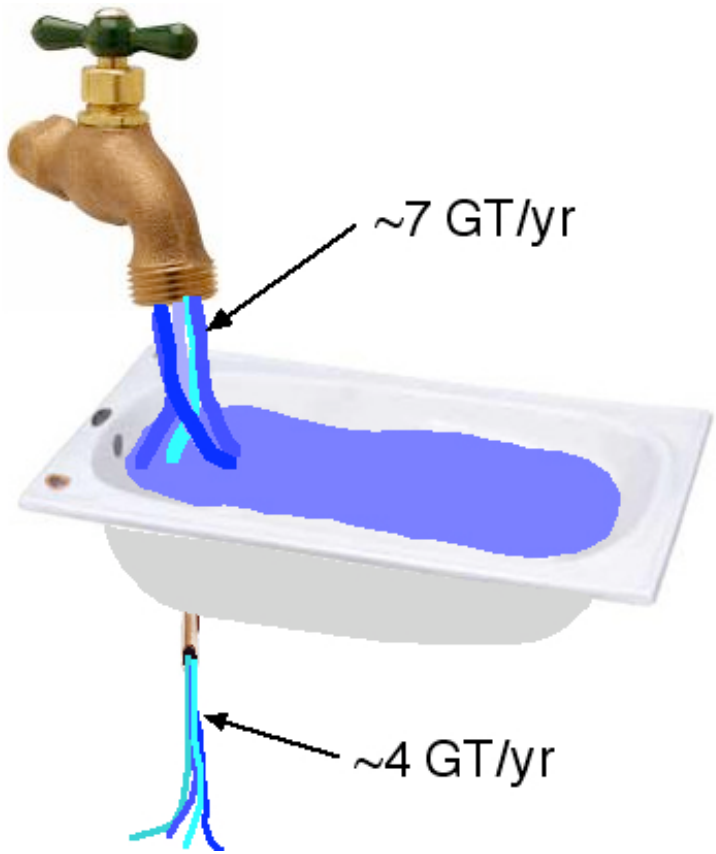
*This is **not** true of carbon dioxide.*

When CO_2 is emitted much of it lasts in the atmosphere for ~100 years. Thus, stabilizing atmospheric *concentrations* of CO_2 will require the world to reduce emissions *by at least 80%*.



A useful analogy is…

…a bath tub with a very large faucet and a much smaller drain:



A key corollary:

China's emissions have now matched those of the U.S. Some argue that until China controls emissions, we should not.

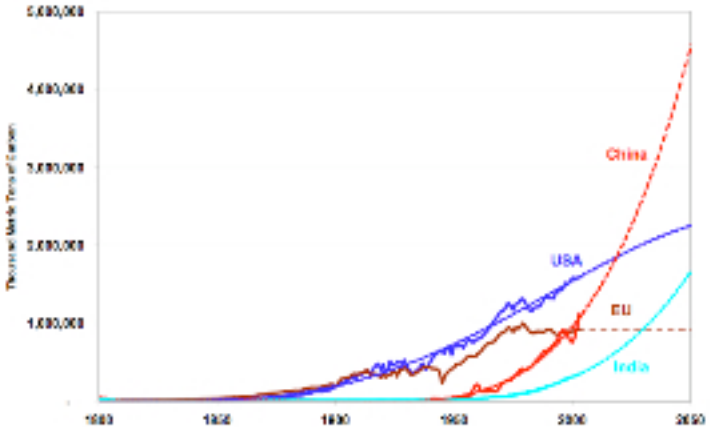
But remember, *concentration* is what matter, and China's

contributions to concentration (red curve and dots) will not equal

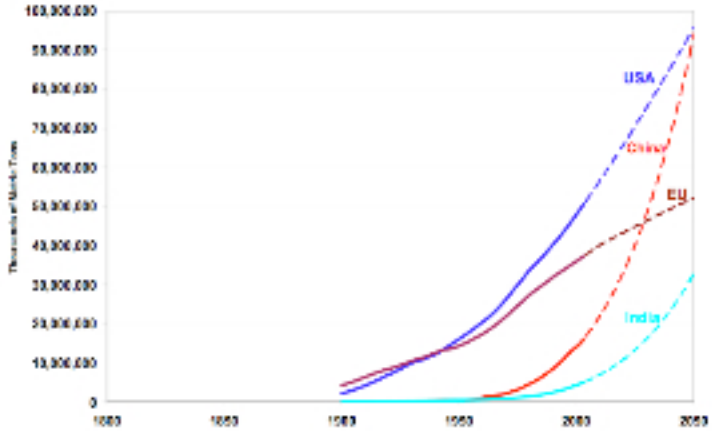
those of the U.S. (blue curve and dots) until mid-century.

AND…even then, in per-capita terms, they will be only ~1/4 of that of the U.S.

Emissions over time



Concentration over time



Plots by J. Apt

Art work by Daniel Marsula, *Pittsburgh Post-Gazette*

2. Isn't there enormous uncertainty about climate change?

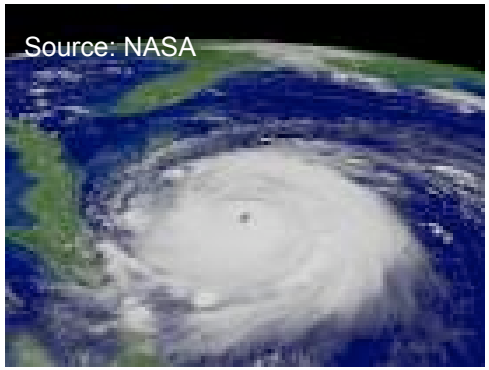
There is ***no*** uncertainty…

…about whether CO_2 and other greenhouse gases (GHGs) are warming the planet and changing the climate. Talk about uncertainty about these issues is largely the result of intentional obfuscation by those with short-term economic interests.

There ***is*** uncertainty about:

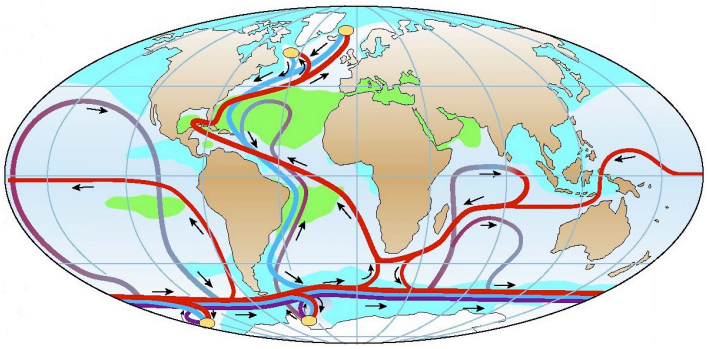
- How much more GHG humans will add to the atmosphere over the next century;
- How much additional warming those additions will produce; and
- The details of many of the changes that will result:
  - In climate, weather and the oceans
  - In natural ecosystems
  - In human activities (agriculture, water, etc.).

Three examples of uncertainty about climate change detail



1. It is still unclear whether and how climate change may affect the frequency, intensity and track of hurricanes.

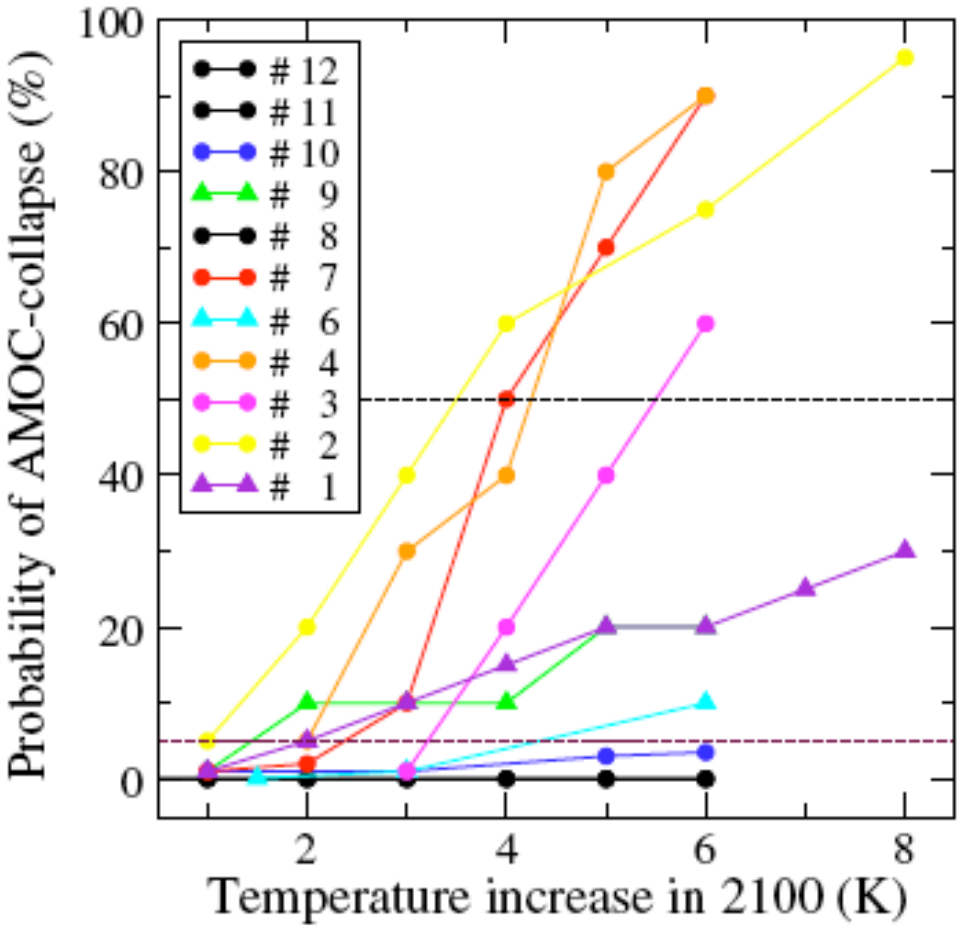
2. It is unclear whether and how much climate change will affect the "ocean conveyor belt" (also known as the AMOC)



Source: Kuhlbrodt et al, 2004.

Among 12 of the world's leading experts there is a great diversity of views.

Collapse was defined as a 90% reduction in strength of the AMOC



Source: Zickfield et al, *Climatic Change*, 2007.

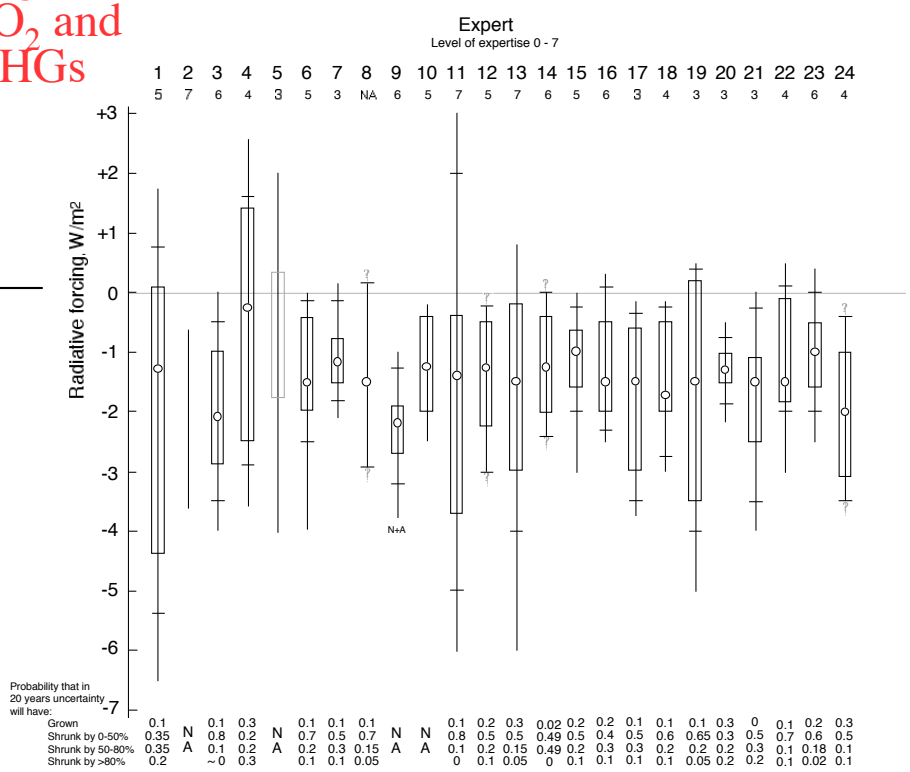
If the AMOC shuts down…

Sources: Google Earth; Great Dixter; Sheffield Park; Sissinghurst; Battle Harbor; and geocities.com

Three examples…Cont.

Best estimate of positive forcing (warming) from CO_2 and other GHGs

3. Fine particles in the atmosphere cause cooling (that offsets some of the warming from CO_2 and other greenhouse gases). The diagram shows estimates made by 24 of the world's leading experts.

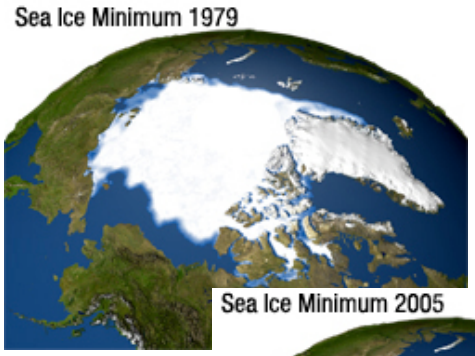


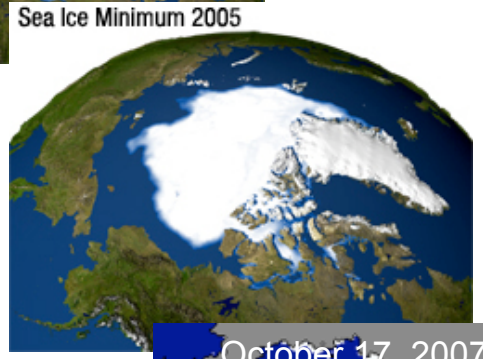
3. What impacts can we expect to see from climate change?

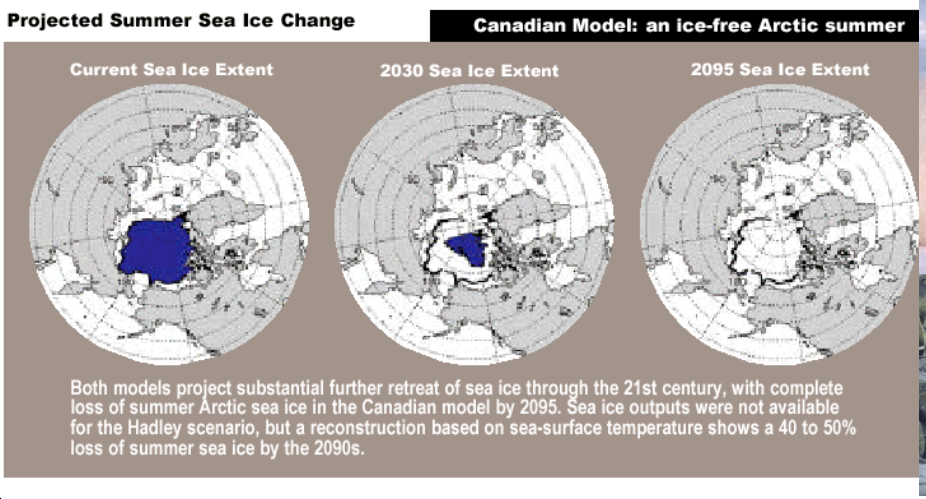
Warming will be…

…greatest at the poles. The extent of summer polar sea ice is already decreasing.

Some models suggest the Arctic Ocean will be ice free in the summer by 2100. Recent experience suggests it may happen even sooner.







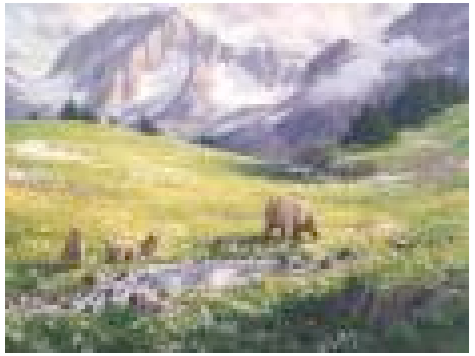
Sources: U.S. National Assessment, Polar Bear International and NOAA, NASA, NSIDC

While the Arctic is vulnerable, so too are…

Small island states and coastal estuaries

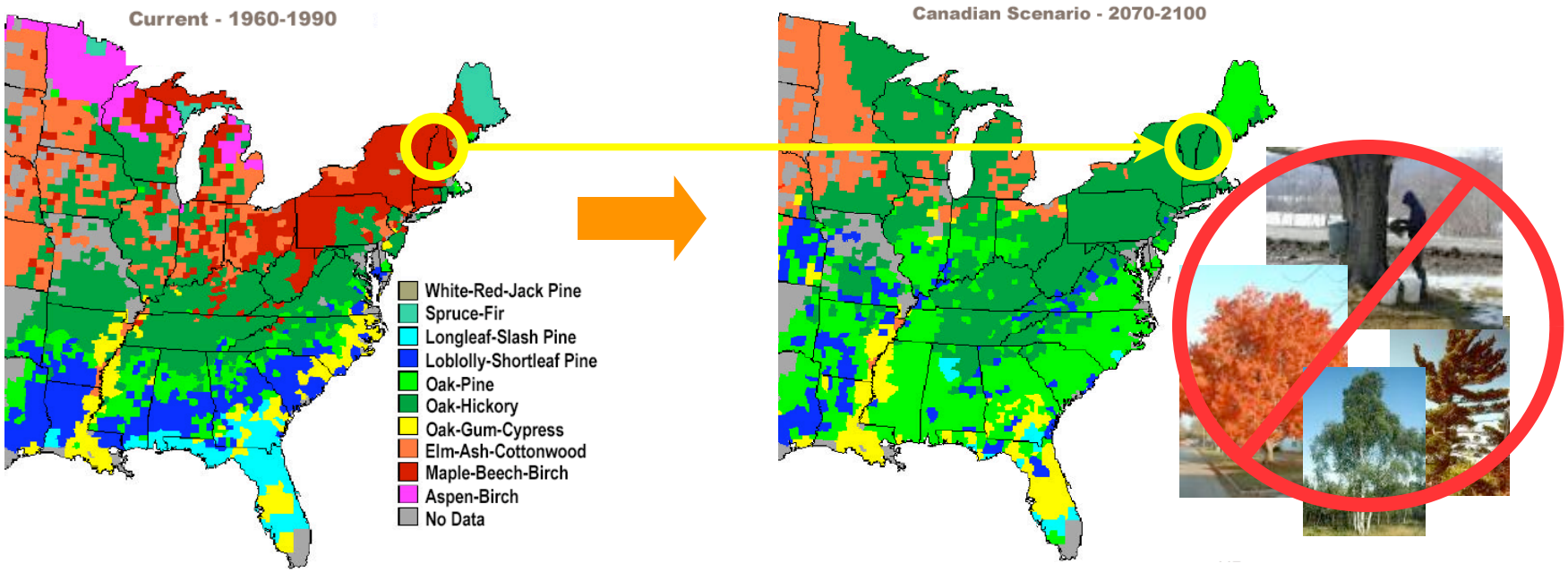
Mangroves

Alpine meadows



Coral reefs

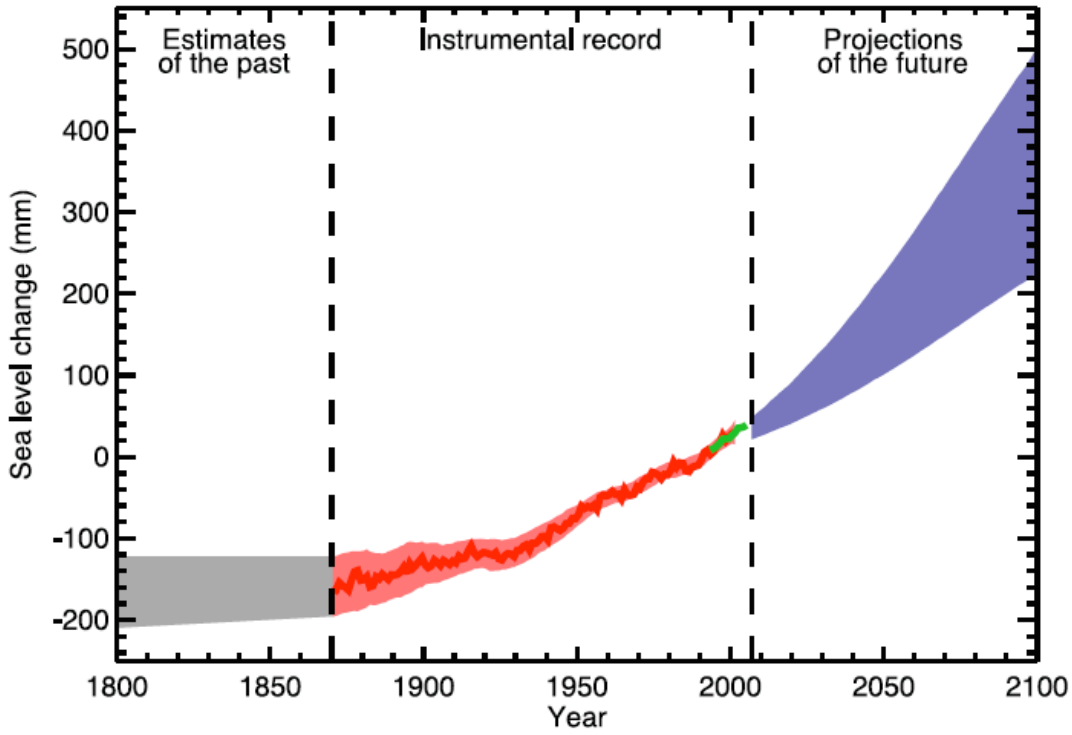
…as well as continental ecosystems that many of us hold dear



Source: U.S.National Assessment

As water warms it expands…

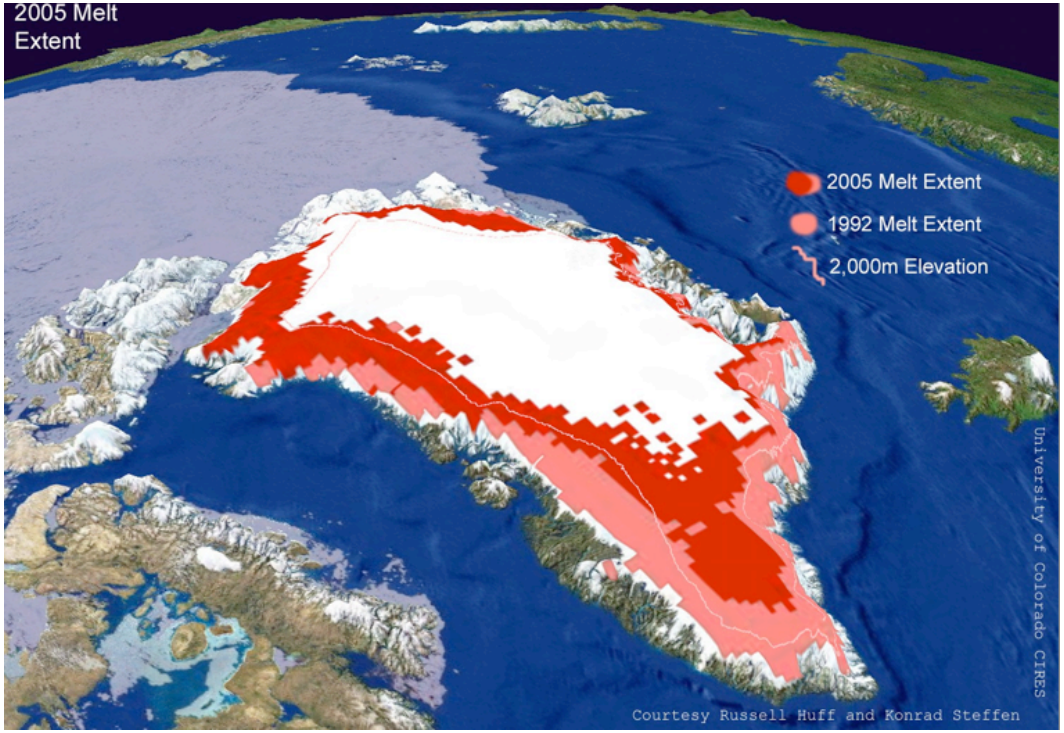
…so both for this reason, and because of melting glaciers, global warming will also produce sea level rise.



Source: IPCC WG1 2007.

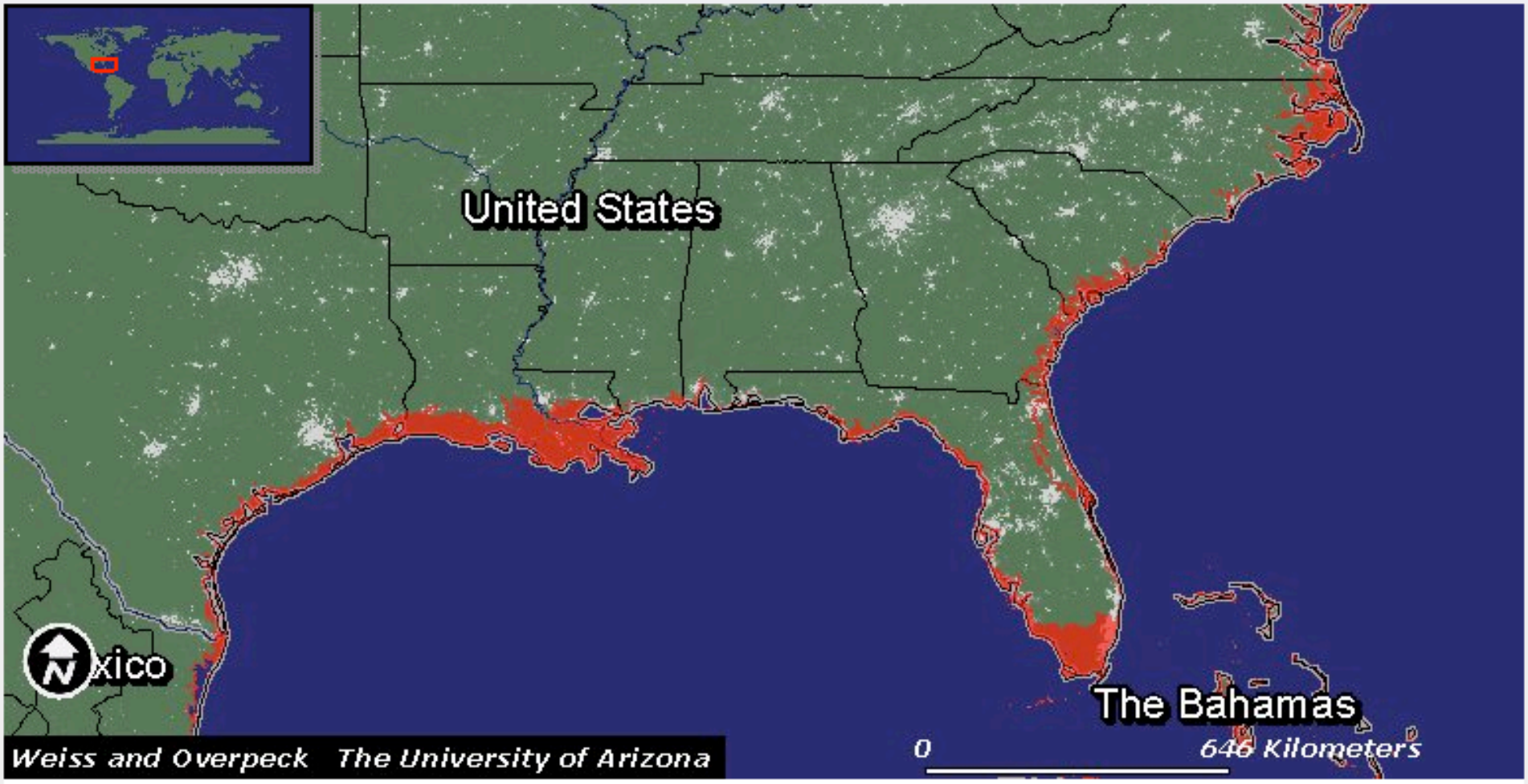
The IPCC estimates may be too small…

…because new studies of Greenland suggest that it is melting more quickly than anyone thought. Greenland ~7m of sea level!



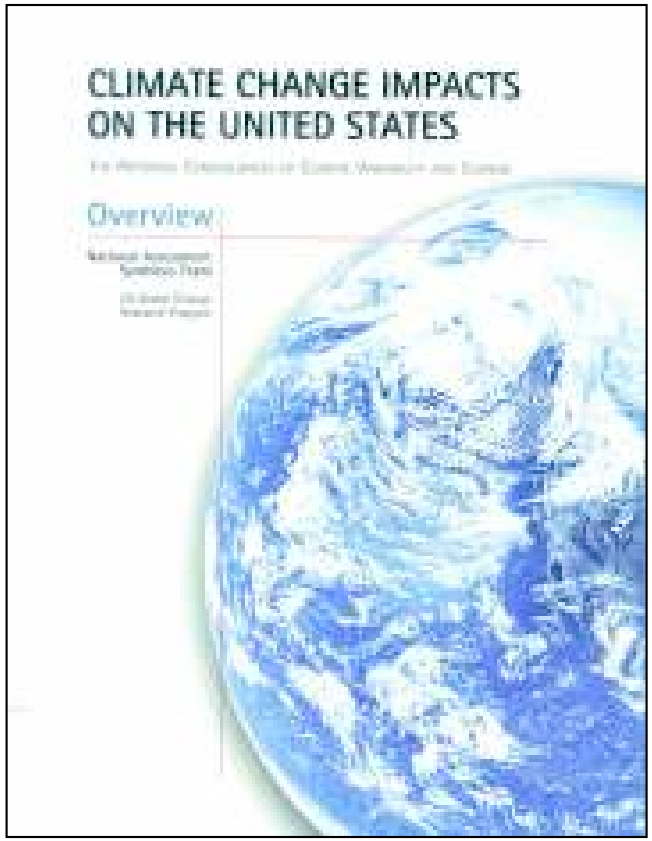
Source:http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise.htm

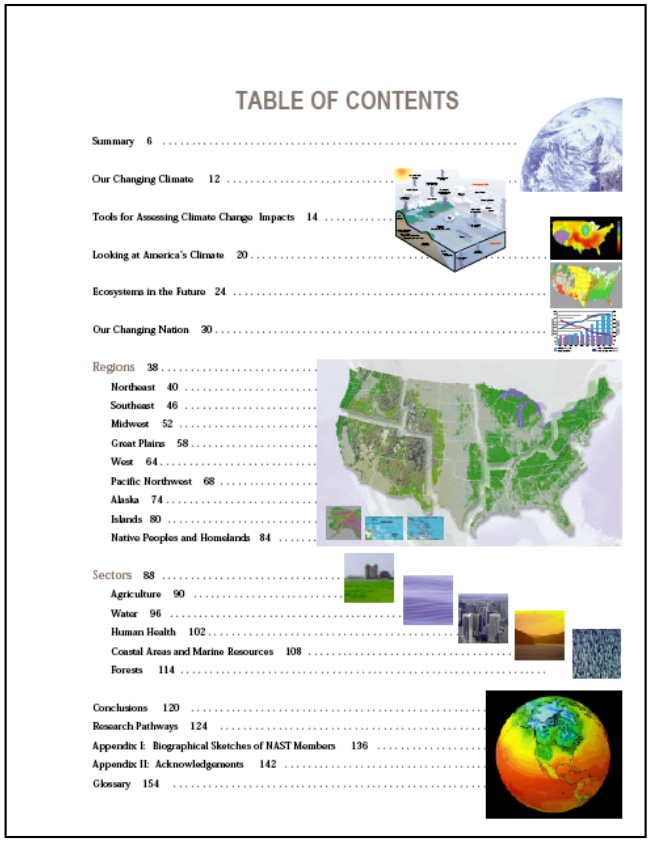
3 meters of sea level rise:



Source:http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise.htm

The US National Assessment





Available on line at:
http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm

Or from Cambridge University Press

IMPACTS OF CLIMATE CHANGE

It is very likely that the US will get substantially warmer. Temperatures are projected to rise more rapidly in the next one hundred years than in the last 10,000 years. It is also very likely that there will be more precipitation overall, with more of it coming in heavy downpours. In spite of this, some areas are likely to get drier as increased evaporation due to higher temperatures outpaces increased precipitation. Droughts and flash floods are likely to become more frequent and intense.

PERMAFROST AREAS

It is very probable that rising temperatures will cause further permafrost thawing, damaging roads, buildings, and forests in Alaska.

FORESTRY

Timber inventories are likely to increase over the 21st century. Hardwood productivity is likely to increase more than softwood productivity in some regions, including the Southeast.

SPECIES DIVERSITY

While it is possible that some species will adapt to changes in climate by shifting their ranges, human and geographic barriers, and the presence of invasive non-native species will limit the degree of adaptation that can occur. Losses in local biodiversity are likely to accelerate towards the end of the 21st century.

WATER SUPPLY

Reduced summer runoff, increased winter runoff, and increased demands are likely to compound current stresses on water supplies and flood management, especially in the western US.

ISLANDS

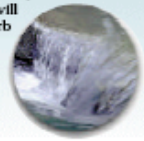
Sea-level rise and storm surges will very likely threaten public health and safety and possibly reduce the availability of fresh water.

CORAL REEFS

Increased CO_2 and ocean temperatures, especially combined with other stresses, will possibly exacerbate coral reef bleaching and die-off.

FRESHWATER ECOSYSTEMS

Increases in water temperature and changes in seasonal patterns of runoff will very likely disturb fish habitat and affect recreational uses of lakes, streams, and wetlands.



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FOREST ECOSYSTEMS

Forest growth is likely to increase in many regions, at least over the next several decades. Over the next century, tree and animal species' ranges will probably shift in response to the changing climate. Some forests are likely to become more susceptible to fire and pests.

COASTAL ECOSYSTEMS

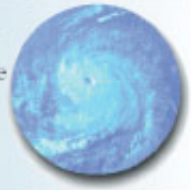
Sea-level rise is very likely to cause the loss of some barrier beaches, islands, marshes, and coastal forests, throughout the 21st century.

AGRICULTURE

The Nation's food supply is likely to remain secure. The prices paid by consumers and the profit margins for food producers are likely to continue to drop.

EXTREME EVENTS

It is very likely that more rain will come in heavy downpours, increasing the risk of flash floods.



HUMAN POPULATIONS

Heat waves are very likely to increase in frequency, resulting in more heat-related stresses. Milder winters are likely to reduce cold-related stresses in some areas.

COASTAL COMMUNITIES AND INFRASTRUCTURE

Coastal inundation from storm surges combined with rising sea level will very likely increase threats to water and sewer systems, transportation and communication systems, homes, and other buildings.

RARE ECOSYSTEMS

Alpine meadows, mangroves, and tropical mountain forests in some locations are likely to disappear because the new local climate will not support them or there are barriers to their movement.

Source: US National Assessment

Acknowledgments

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The opinions expressed are our own.