

Coping With Climate Change: Issues in Science, Policy, and Communication

John P. Holdren

**Assistant to the President for Science and Technology
and Director, Office of Science and Technology Policy
Executive Office of the President of the United States**



Imperial College

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Overarching questions

About climate-change science:

- What do we know?
- How (and with what confidence) do we know it?
- What more do we most need to know?
- How (and when) can we know it?

About climate-change policy:

- What should we do and when should we do it?

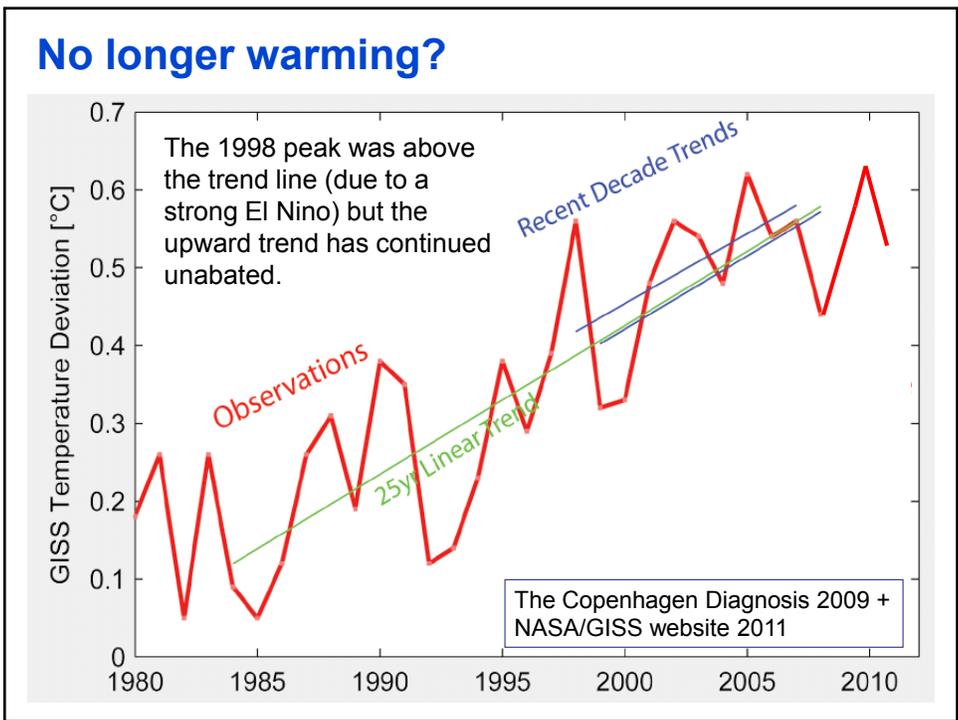
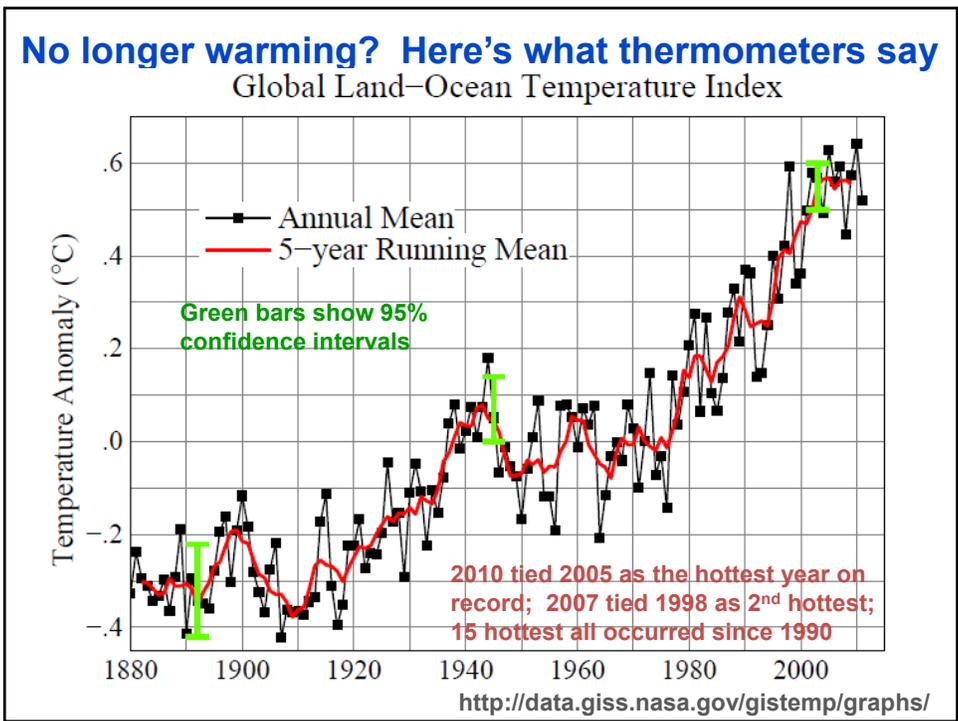
About communication:

- How can we communicate about the science to better inform the answers that publics and policy-makers embrace about what to do and when to do it?

The science questions

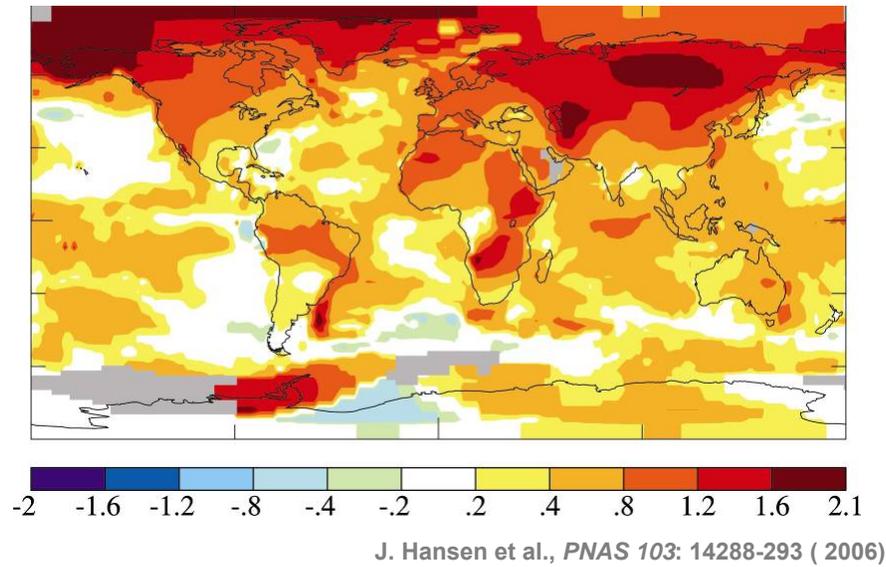
Five myths about the science

1. The Earth stopped warming in the last decade.
2. If it is warming, humans aren't the main cause.
3. A little warming isn't harmful anyway.
4. If there is any danger, it's far in the future.
5. Even if mainstream climate science is right and the need for action therefore is real, doing enough to make a difference is unaffordable.



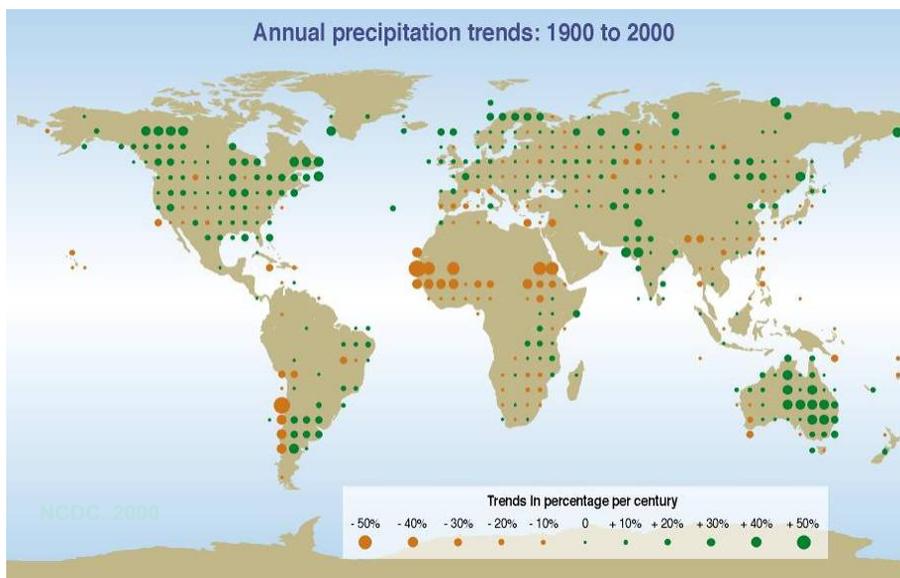
The heating is not uniform geographically

Surface T in 2001-2005 vs 1951-80, averaging 0.53°C increase



Other climate indicators are changing apace

Annual precipitation trends: 1900 to 2000



Most places getting wetter, some drier; Earth wetter overall.

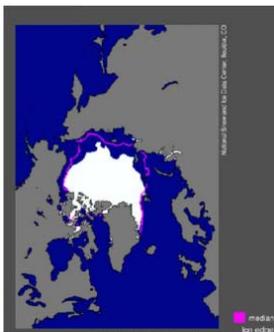
Indicators: glaciers retreating



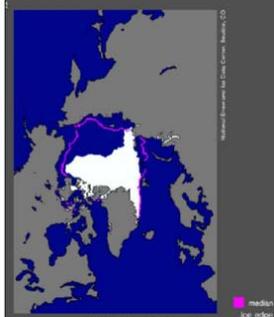
Rongbuk glacier in 1968 (top) and 2007. The largest glacier on Mount Everest's northern slopes feeds the Rongbuk River.

National Snow & Ice Data Center 2010

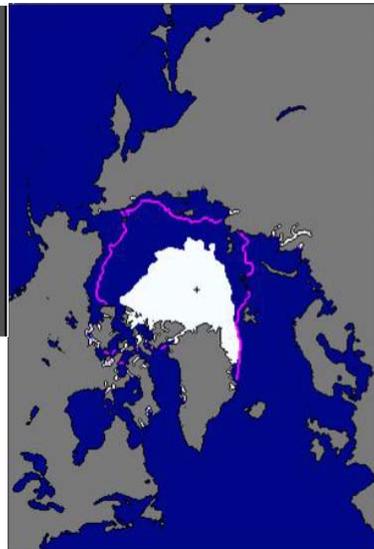
The shrinking Arctic sea ice



September 2005



September 2007

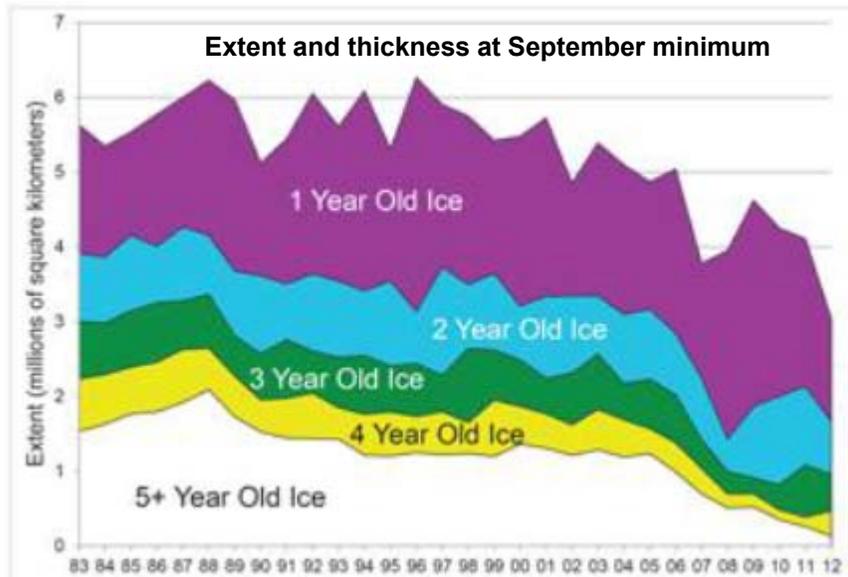


September 2012

The magenta line is the average sea-ice extent at its September minimum from 1979 to 2000. The 2012 extent was by far the lowest since 1979, when satellite observations began.

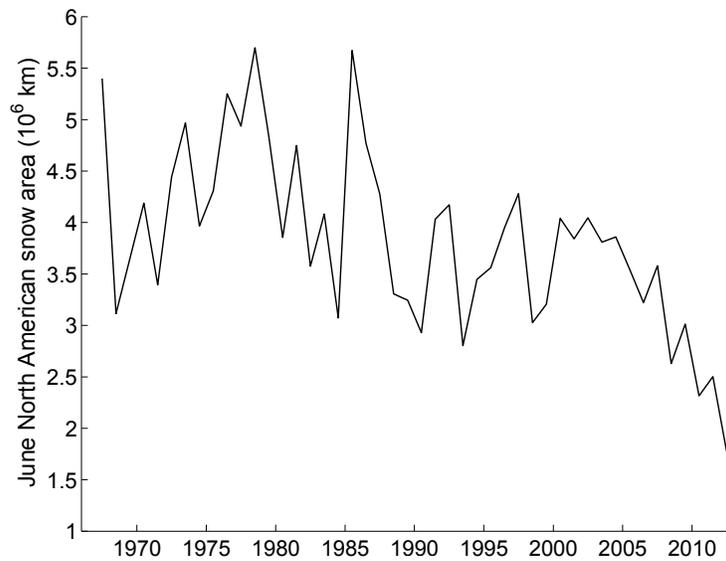
National Ice and Snow Data Center

Arctic sea-ice thickness is shrinking, too.



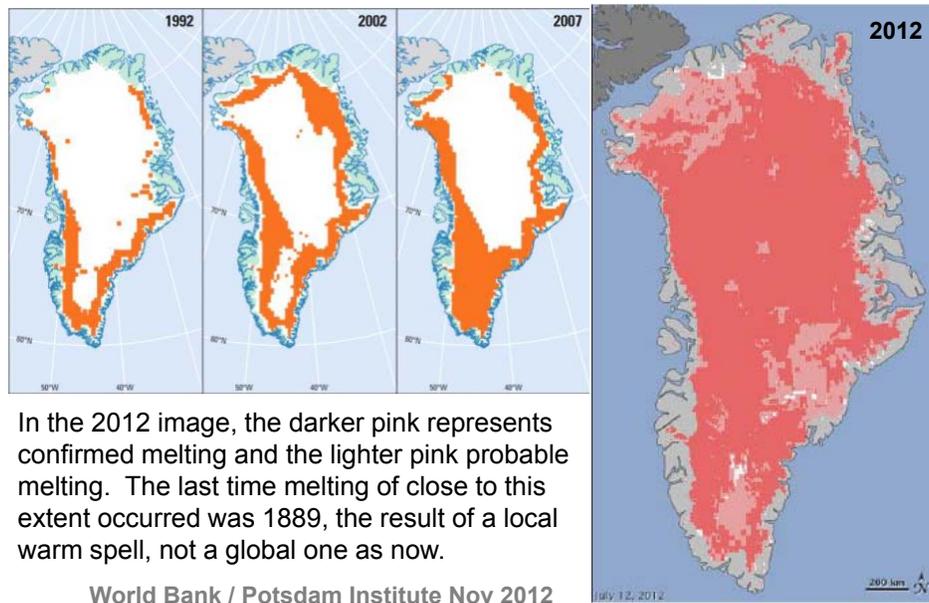
World Bank / Potsdam Institute Nov 2012

North America snow cover in June

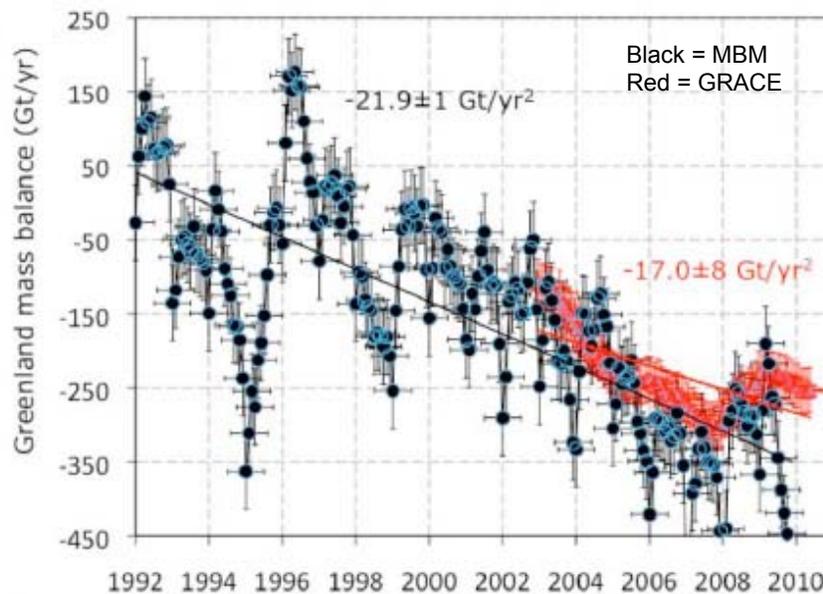


Data from Rutgers University Global Snow Lab

Summer surface melt area on Greenland

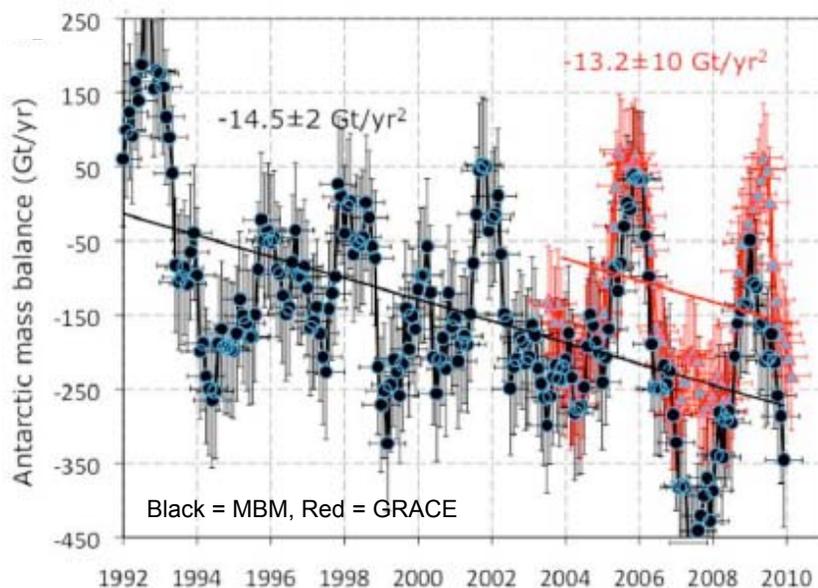


Greenland ice sheet mass balance



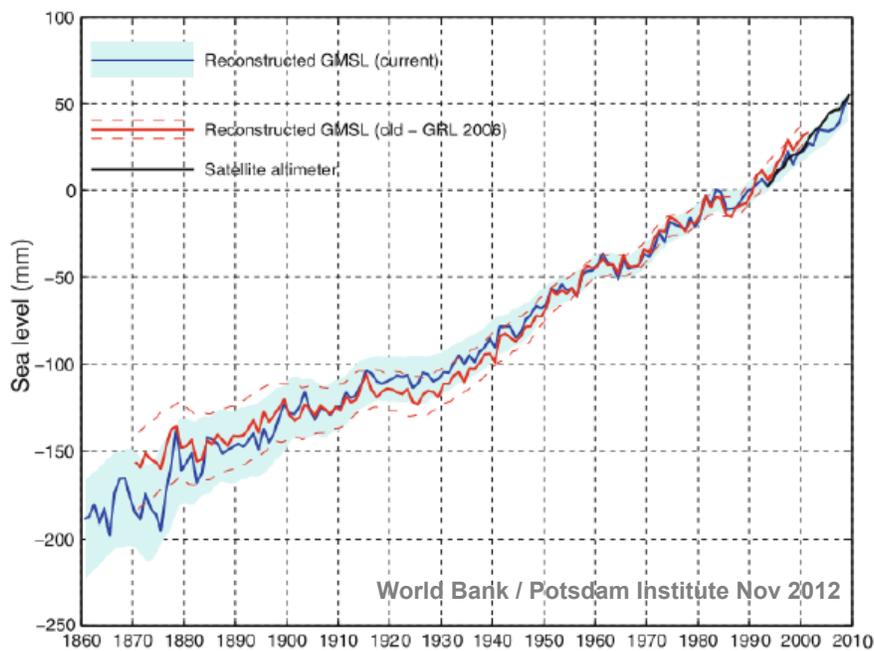
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Antarctic Ice Sheet Mass Balance



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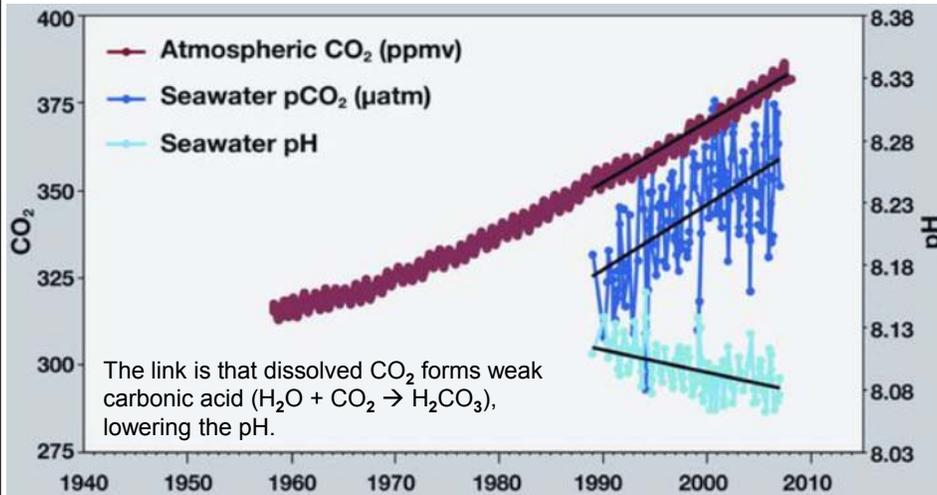
Global mean sea level 1860-2010



World Bank / Potsdam Institute Nov 2012

Atmospheric CO₂ and ocean pH

About 1/3 of CO₂ added to atmosphere is quickly taken up by the surface layer of the oceans (top 80 meters).



World Bank / Potsdam Institute Nov 2012

What do we know about the causes?

Human vs natural influences 1750-2005 (watts/m²)

Human emissions leading to increases in...

atmospheric carbon dioxide	+ 1.7
methane, nitrous oxide, CFCs	+ 1.0
net ozone (troposphere↑, stratosphere↓)	+ 0.3
absorptive particles (soot)	+ 0.3
reflective particles (sulfates, etc.)	- 0.7
indirect (cloud forming) effect of particles	- 0.7

Human land-use change increasing reflectivity - 0.2

Natural changes in sunlight reaching Earth + 0.1

The warming influence of anthropogenic GHG and absorbing particles is ~30x the warming influence of the estimated change in input from the Sun.

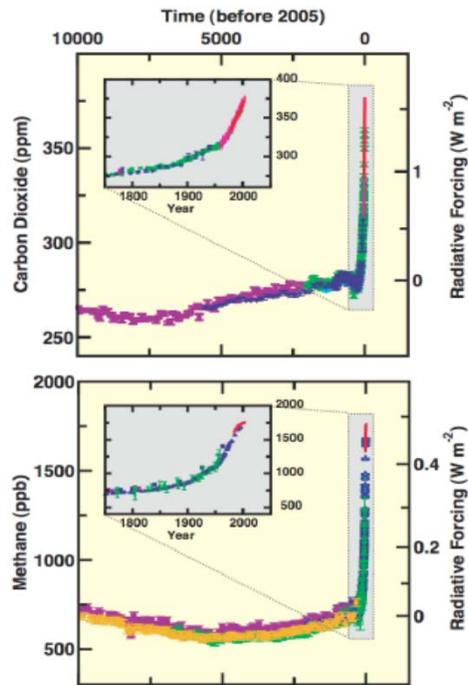
IPCC AR4, WG1 SPM, 2007

The key greenhouse-gas increases were caused by human activities.

Compared to natural changes over the past 10,000 years, the spike in concentrations of CO₂ & CH₄ in the past 250 years is extraordinary.

We know humans are responsible for the CO₂ spike because fossil CO₂ lacks carbon-14, and the drop in atmospheric C-14 from the fossil-CO₂ additions is measurable.

IPCC AR4, WG1 SPM, 2007

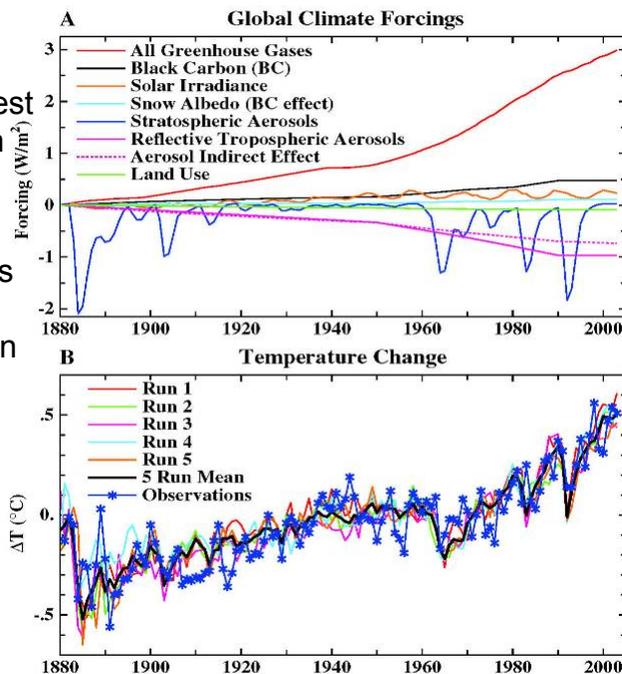


Human influence: the “fingerprint”

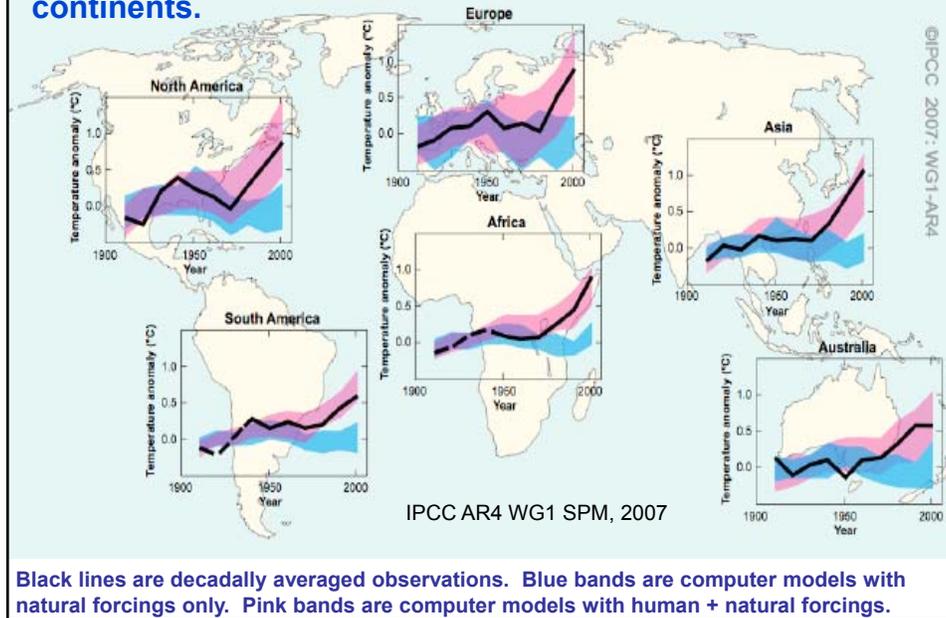
Top panel shows best estimates of human & natural forcings 1880-2005.

Bottom panel shows that state-of-the-art climate model, when fed these forcings, reproduces almost perfectly the last 125 years of observed temperatures.

Source: Hansen et al., Science 308, 1431, 2005.



Geographic pattern is also as predicted for GHG-induced change: Observed ΔT matches modeled results on all continents.



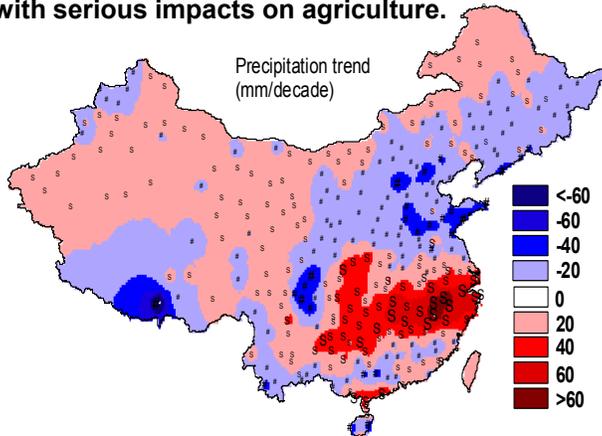
Why worry? What harm can it do?

Climate governs (so altering climate will affect)

- availability of water
- productivity of farms, forests, & fisheries
- prevalence of oppressive heat & humidity
- formation & dispersion of air pollutants
- geography of disease
- damages from storms, floods, droughts, wildfires
- property losses from sea-level rise
- expenditures on engineered environments
- distribution & abundance of species

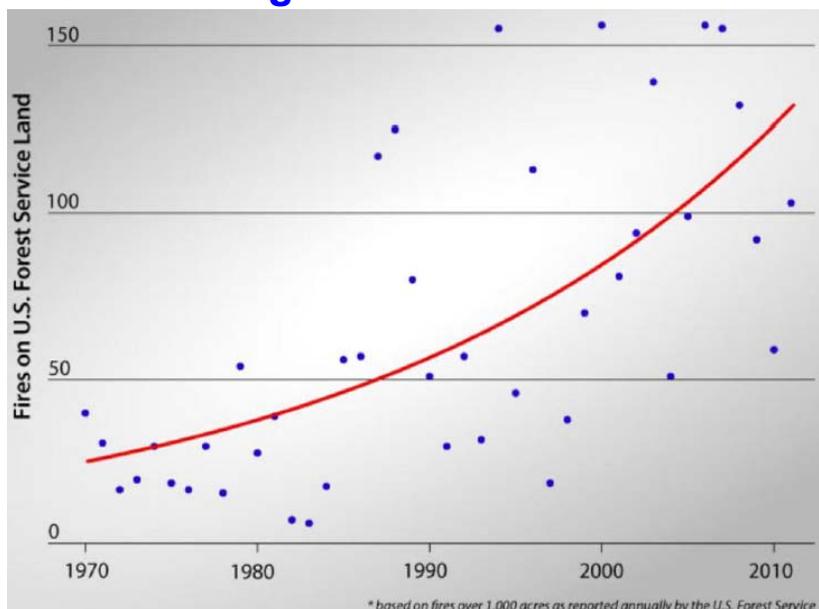
Are we seeing harm? Floods & droughts

30-year weakening of East-Asia monsoon – attributed to global climate change -- has meant less moisture flow South to North over China, producing increased flooding in South, drought in North, with serious impacts on agriculture.



Qi Ye, Tsinghua University, May 2006

Are we seeing harm? Wildfires



World Bank / Potsdam Institute Nov 2012

Are we seeing harm? Pest outbreaks

Pine bark beetles, with a longer breeding season courtesy of warming, devastate trees weakened by heat & drought in Colorado



USGCRP 2009

Are we seeing harm? Melting permafrost



Norwegian Polar Institute, 2009

Are we seeing harm? coastal erosion



Courtesy Gary Braasch

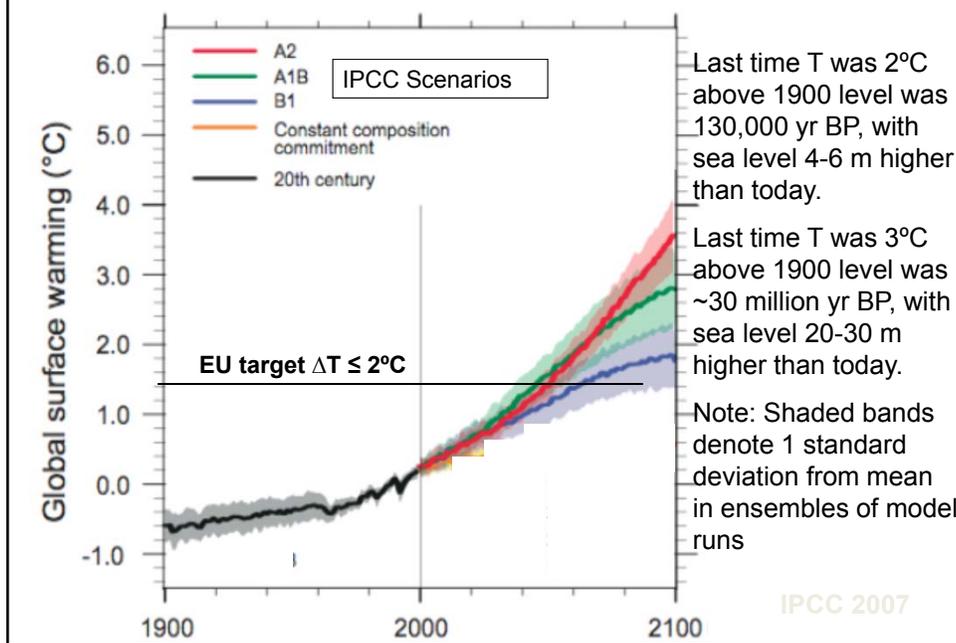
Current harm is widespread

Worldwide we're seeing, variously, increases in

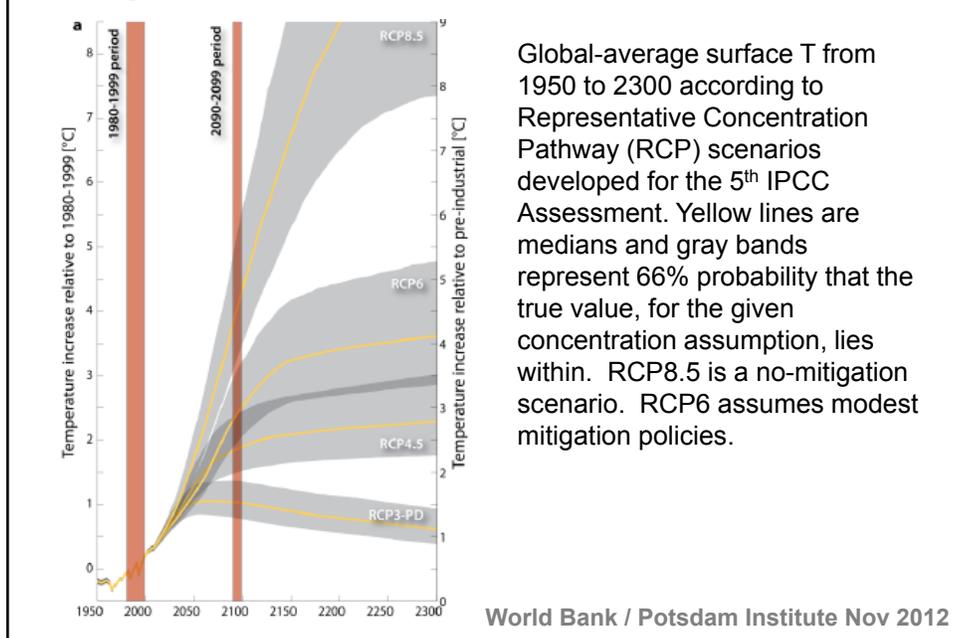
- floods
- wildfires
- droughts
- heat waves
- pest outbreaks
- coral bleaching events
- power of typhoons & hurricanes
- geographic range of tropical pathogens

All plausibly linked to climate change by theory, models, observed "fingerprints"

Much worse lies ahead if “business as usual” persists

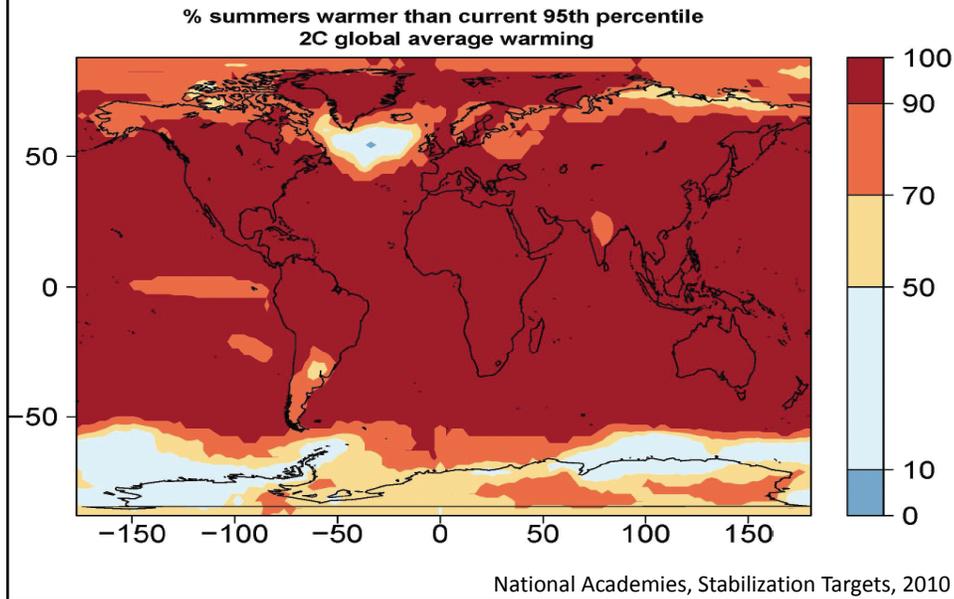


Temperature scenarios to 2300



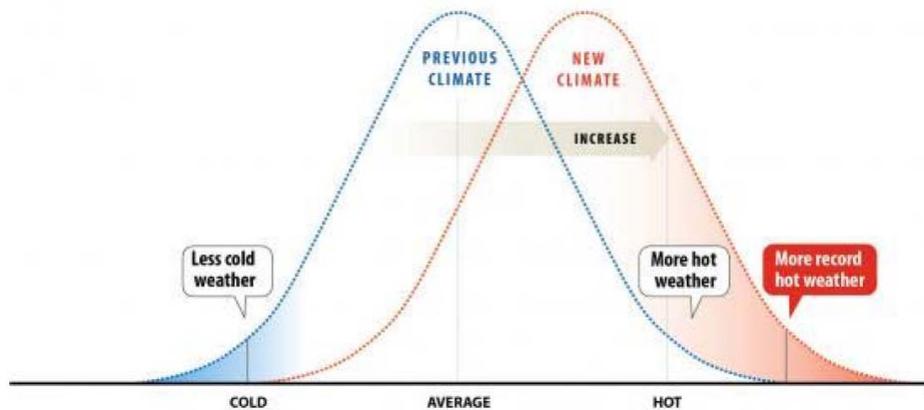
Global-average surface T from 1950 to 2300 according to Representative Concentration Pathway (RCP) scenarios developed for the 5th IPCC Assessment. Yellow lines are medians and gray bands represent 66% probability that the true value, for the given concentration assumption, lies within. RCP8.5 is a no-mitigation scenario. RCP6 assumes modest mitigation policies.

What's expected: Hotter summers



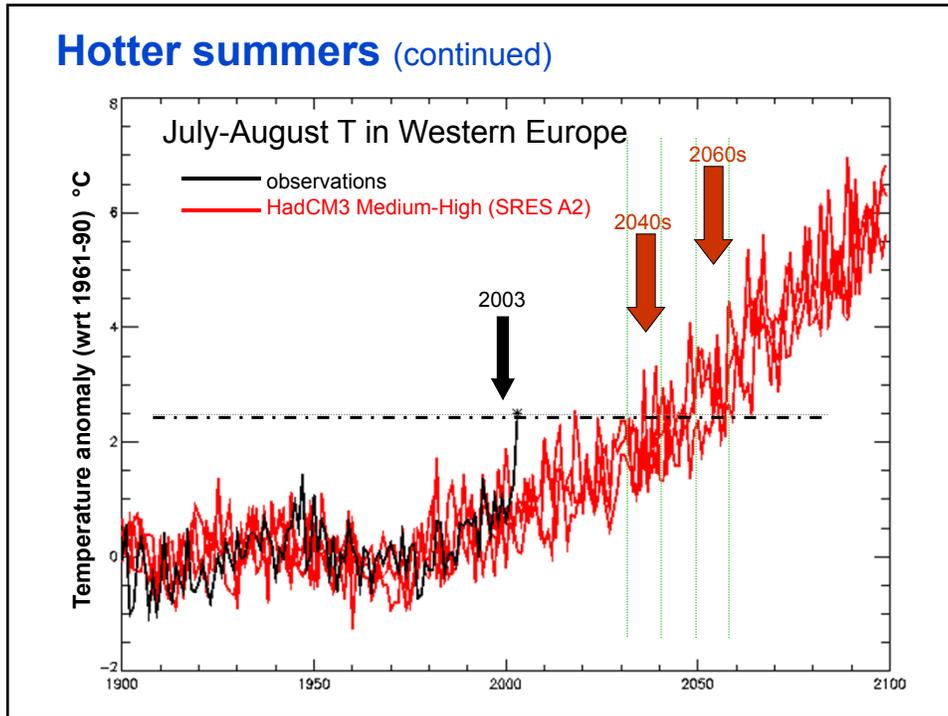
Hotter summers (continued): Why a small increase in average T leads to a big increase in hot weather

Effects of an increase in mean temperature

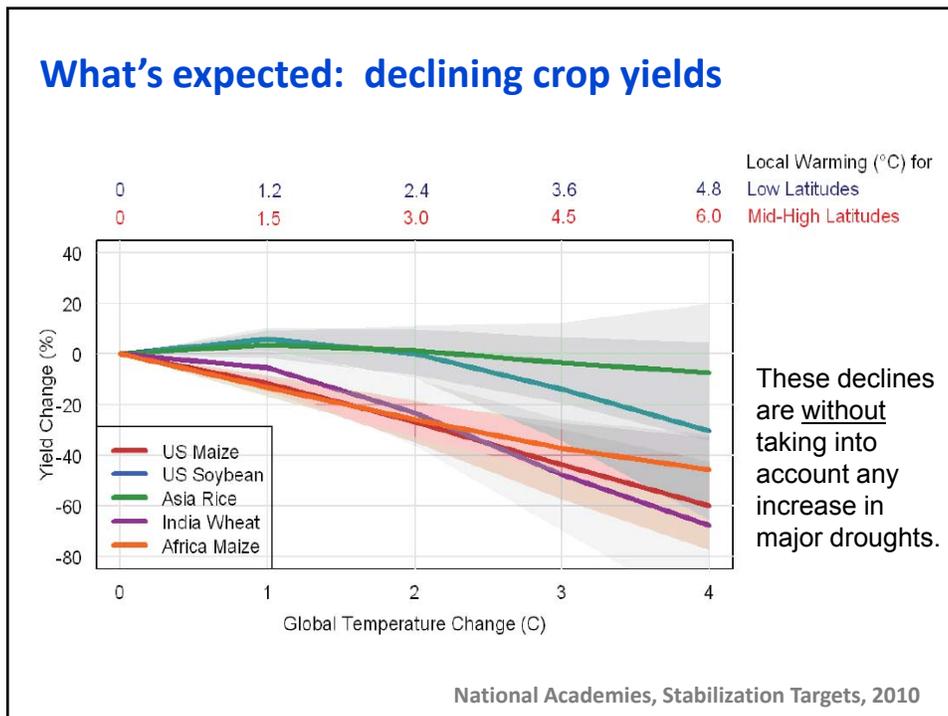


House Resources & Energy Committees Minority Staffs, Sept 2012

Hotter summers (continued)

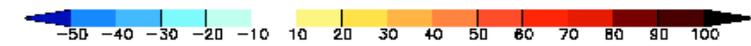
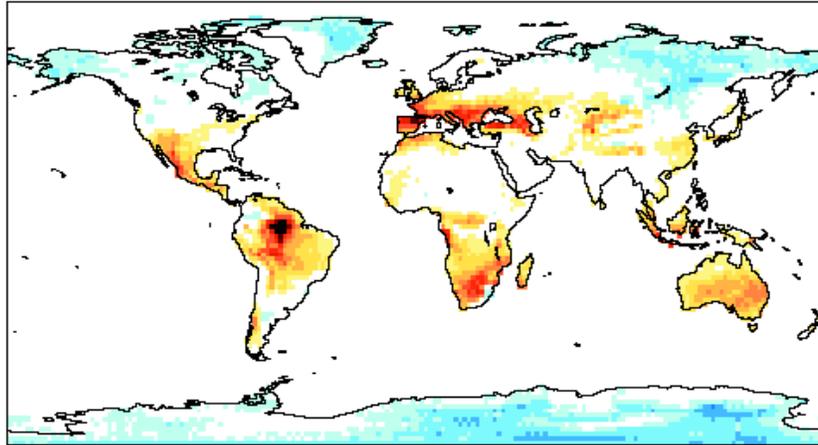


What's expected: declining crop yields



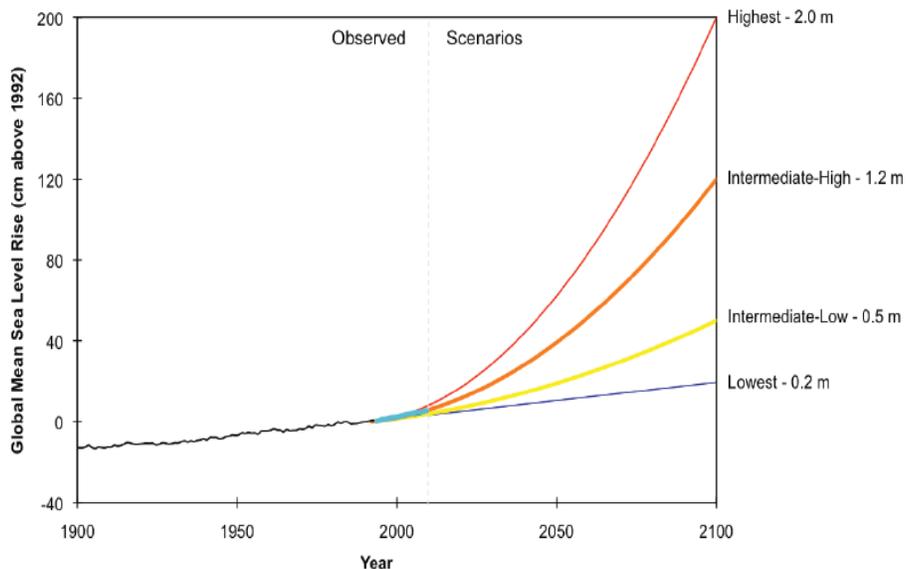
What's expected: worse droughts

Drought projections for IPCC's A1B scenario



Percentage change in average duration of longest dry period, 30-year average for 2071-2100 compared to that for 1961-1990.

What's expected: sea-level rise



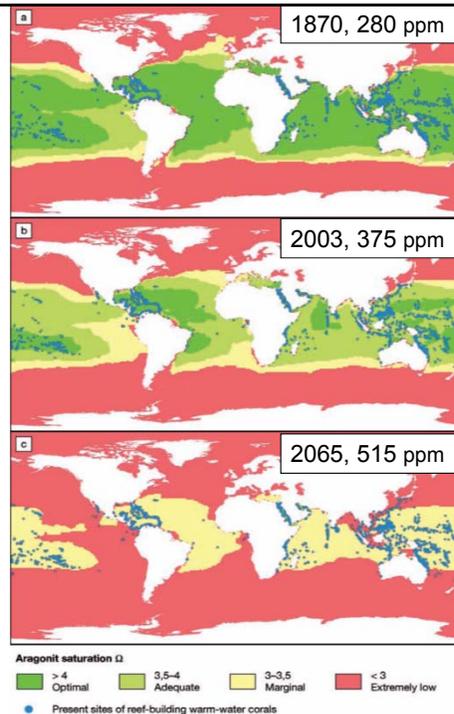
NOAA OAR CPO-1, December 2012

What's expected: continued fall in ocean pH

Increased acidity lowers the availability of CaCO_3 to organisms that use it for forming their shells & skeletons, including corals.

Adverse effects are already being observed.

Coral reefs could be dead or in peril over most of their range by mid to late 21st century.



Steffen et al., 2004

What more do we most need to know?

- Improved understanding of climate “sensitivity” to human & natural forcings (including effects of particles, clouds)
 - Sensitivity means, in essence, how much average T increases under a doubling of atmospheric CO_2 or its equivalent.
 - Improvements in this understanding will improve predictions.
 - Getting there will require continuing investments in paleo-climatology, basic climate physics, maintaining & improving our constellation of Earth-observation satellites, and running better climate models on faster computers.
- Better regional disaggregation of predicted changes in temperatures, precipitation, storm tracks, ice sheets
 - Requirements for getting there similar to those above

What more we need to know? (continued)

- Better understanding of ecological effects of regional climate changes
 - Including impacts on oceans, crops, domestic animals, wildlife, pests, pathogens
 - This is needed to shape adaptation strategies
 - Requires continuing investments in ecological sciences, major improvements in diversity & density of monitoring networks
- Better integrated assessments combining predictions, mitigation and adaptation options (character, capabilities, costs), social dimensions
 - Requires additional effort in integrated-assessment methods and practice as well as in specifics of mitigation & adaptation options

The policy questions

What should we do?

There are only three options:

- Mitigation, meaning measures to reduce the pace & magnitude of the changes in global climate being caused by human activities.
- Adaptation, meaning measures to reduce the adverse impacts on human well-being resulting from the changes in climate that do occur.
- Suffering the adverse impacts that are not avoided by either mitigation or adaptation.

Concerning the three options...

- We're already doing some of each.
- What's up for grabs is the future mix.
- Minimizing the amount of suffering in that mix can only be achieved by doing a lot of mitigation and a lot of adaptation.
 - Mitigation alone won't work because climate change is already occurring & can't be stopped quickly.
 - Adaptation alone won't work because adaptation gets costlier & less effective as climate change grows.
 - We need enough mitigation to avoid the unmanageable, enough adaptation to manage the unavoidable.

Adaptation possibilities include...

- Changing cropping patterns
- Developing heat-, drought-, and salt-resistant crop varieties
- Strengthening public-health & environmental-engineering defenses against tropical diseases
- Building new water projects for flood control & drought management
- Building dikes and storm-surge barriers against sea-level rise
- Avoiding further development on flood plains & near sea level

Many are “win-win”: They’d make sense in any case.

Mitigation possibilities include...

(CERTAINLY)

- Reduce emissions of greenhouse gases & soot from the energy sector
- Reduce deforestation; increase reforestation & afforestation
- Modify agricultural practices to reduce emissions of greenhouse gases & build up soil carbon

(CONCEIVABLY)

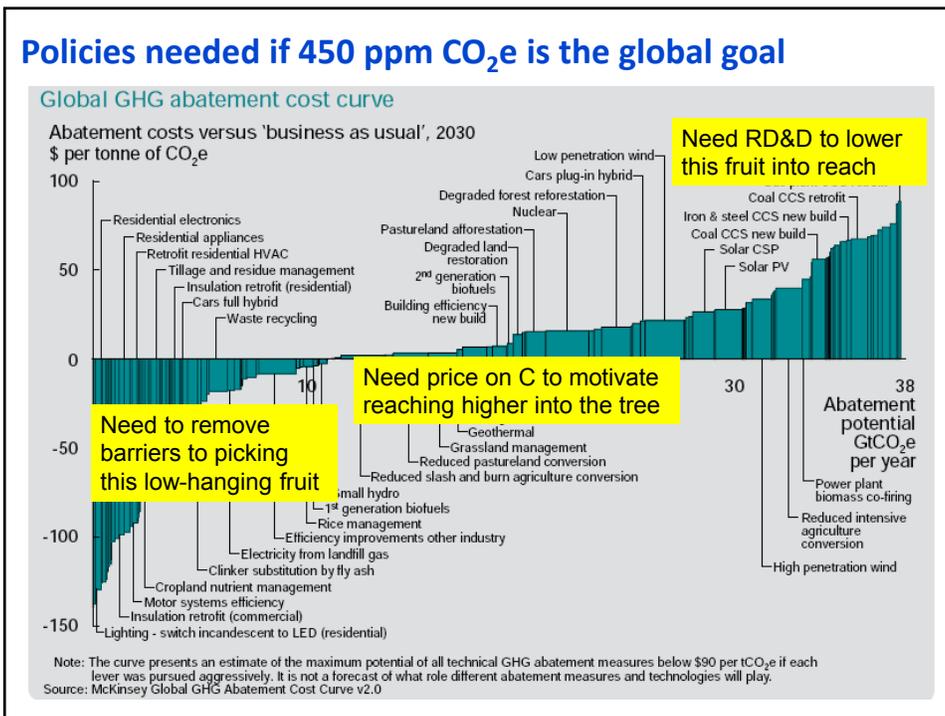
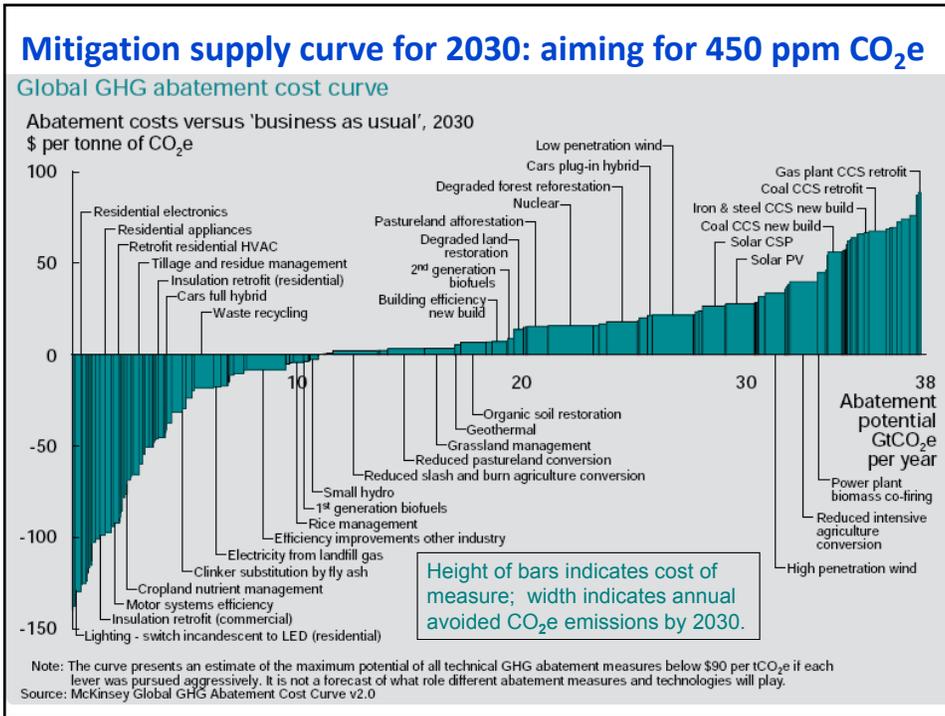
- “Scrub” greenhouse gases from the atmosphere technologically
- “Geo-engineering” to create cooling effects offsetting greenhouse heating

Key mitigation realities

- Human CO₂ emissions are the biggest piece of the problem (50% and growing)
 - About 85% comes from burning coal, oil, & natural gas (which provide >80% of world energy)
 - Most of the rest comes from deforestation & burning in the tropics
- Developing countries now exceed industrialized ones in total CO₂ emissions (but not per capita).
- Global energy system can't be changed quickly: ~\$20T is invested in it; normal turnover is ~40 yrs.
- Deforestation also isn't easy to change: forces driving it are deeply embedded in the economics of food, fuel, timber, trade, & development.

How much mitigation, how soon?

- Limiting ΔT_{avg} to $\leq 2^{\circ}\text{C}$ is now considered by many the most prudent target that still may be attainable.
 - EU embraced this target in 2002, G-8 & G-20 in 2009
- Just to have a 50% chance of staying below 2°C:
 - atmospheric concentration of heat-trapping substances must stabilize at 450 ppm CO₂ equivalent (CO₂e);
 - to get there, developed-country emissions must peak no later than 2015 and decline rapidly thereafter, and
 - developing-country emissions must peak no later than 2025 and decline rapidly thereafter.



Is this much mitigation affordable?

- Rough calculations
 - Paying an average of \$100/tC to avoid half of current world CO₂ emissions would cost \$0.5 trillion/yr, under 1% of current GWP (much of it a transfer, not a “loss”).
 - Using McKinsey cost curve for what we’d need to be doing in 2030 to be on 450 ppmv stabilization trajectory shows net cost of only about \$0.1 trillion/yr.
- Current econ models say mitigation to stabilize at 450 ppmv CO₂e probably means 2-3% GWP loss in 2030, 2100 (range 1-5%).
- World now spends 2.5% of GWP on defense; USA spends 5% on defense, 2% on env protection

The communications questions

Q: How can the answers about the science better inform the answers that publics and policy-makers embrace about what to do and when to do it?

A: Through more effective communication and education.

What are the ingredients of more effective communication & education?

- Start with the basics
- Be clear about terminology
- Explain how we know what we know
- Link it to what can be observed
- Link it to listeners' regions and communities
- Focus on how science works, sources of authority & credibility in scientific findings

Starting with the basics

- Without energy there is no economy
- Without climate there is no environment
- Without economy and environment there is no material well-being, no civil society, no personal or national security

The problem is that the world is getting most of the energy its economies need in ways that are imperiling the climate its environment needs.

Terminology: “global warming” is a misnomer

That term implies something...

- uniform across the planet,
- mainly about temperature,
- gradual,
- quite possibly benign.

What’s actually happening is...

- highly nonuniform,
- not just about temperature,
- rapid compared to capacities for adjustment
- harmful for most places and times

A more descriptive term is “global climate disruption”.

Terminology (cont): Weather, climate, disruption

Climate = weather patterns, meaning averages, extremes, timing, spatial distribution of...

- hot & cold
- cloudy & clear
- humid & dry
- drizzles & downpours
- snowfall, snowpack, & snowmelt
- breezes, blizzards, tornadoes, & typhoons

Climate change means disruption of the patterns.

Global average temperature is just an index of the state of the global climate as expressed in these patterns. Small changes in the index → big changes in the patterns.

Observables: Powerful storms (USA, Oct 2010)



This super-storm – the strongest US non-coastal storm on record -- spawned 67 tornadoes over a 4-day period.

Observables: Heat waves (Russia, summer 2010)



© RIA Novosti, Vladimir Fedorenko

Observables: Floods (Australia, 2010-2011)



Record warm sea temperatures contributed to the wettest spring ever in Australia and flooding in Queensland that was the costliest natural disaster in Australia's history.

Observables: Coral bleaching (Carribeau, 2010)



1996 - Healthy

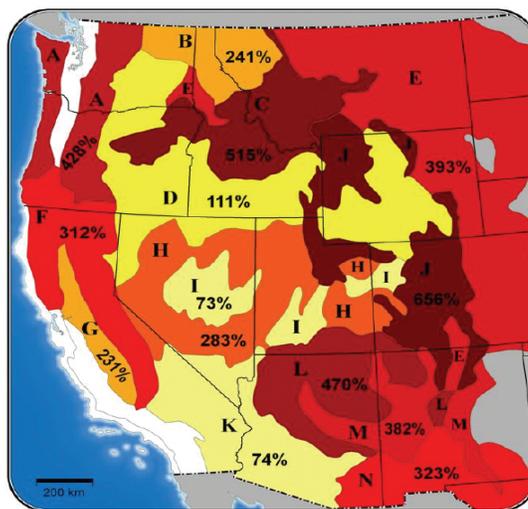
1997 - Bleached

2010 brought the worst coral bleaching since 1998.

Courtesy www.wunderground.com/blog/JeffMasters/

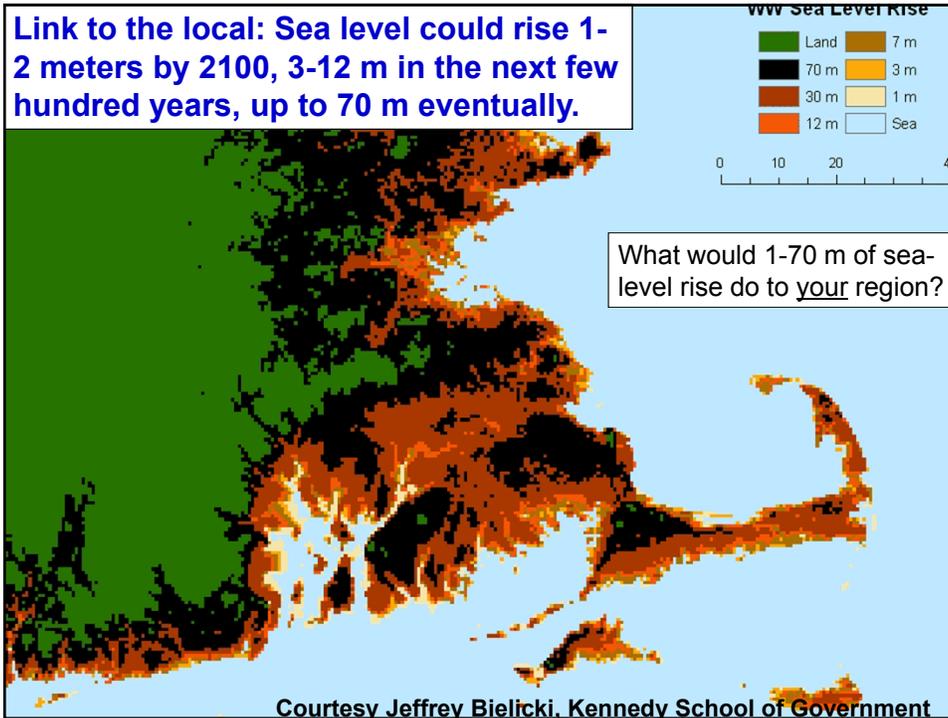
Link to the local: wildfire predictions

Percentage increases in median annual area burned for a 1°C increase in global average temperature



National Academies, Stabilization Targets, 2010

- A - Cascade Mixed Forest
- B - Northern Rocky Mt. Forest
- C - Middle Rocky Mt. Steppe-Forest
- D - Intermountain Semi-Desert
- E - Great Plains-Palouse Dry Steppe
- F - Sierran Steppe-Mixed Forest
- G - California Dry Steppe
- H - Intermountain Semi-Desert / Desert
- I - Nev.-Utah Mountains-Semi-Desert
- J - South. Rocky Mt. Steppe-Forest
- K - American Semi-Desert and Desert
- L - Colorado Plateau Semi-Desert
- M - Ariz.-New Mex. Mts. Semi-Desert
- N - Chihuahuan Semi-Desert



How science works

UNCERTAINTIES ARE TWO-SIDED

- Yes, it could be that the climate changes occurring under a continuation of BAU would be less disruptive, and the adverse impacts on human well-being less severe, than the scientific-mainstream best estimates contained in the reports of the Intergovernmental Panel on Climate Change (IPCC) and other authoritative bodies.
- But it could also turn out that the climate changes under business as usual would be more disruptive, and the impacts on human well-being more severe, than the “consensus” estimates suggest. (Recent results suggest this is more likely than the reverse.)

How science works (continued)

BURDEN OF PROOF

- The “skeptics” routinely brandish some single contrary piece of evidence or analysis -- often a newly reported one that has not yet been subjected to the scrutiny of the scientific community -- and declare that this new result invalidates the mainstream view.
- That’s not how science works. Contrary results appear regularly in all scientific fields. But when a strong preponderance of evidence points the other way (as in the case of climate-change science), isolated apparent contradictions are given due scrutiny but not, initially, very much weight.
- That’s because it’s far more likely that the “contradiction” will turn out to be explainable as a mistake, or otherwise consistent with the preponderance of evidence, than that the preponderance of evidence will turn out to have been wrong.

How science works (concluded)

PRUDENCE

- All science is contingent. It is always possible that persuasive new evidence and analysis will come to light that will change the mainstream view.
- But the greater the consistency and coherence of the existing body of evidence and analysis, the lower the likelihood that the principal conclusions derived from it will be overturned.
- The consistency and coherence of the evidence and analysis supporting the mainstream view of climate-change risks embodied in the reports of the NAS & IPCC are immense.
- Policymakers, on whose decisions the preservation and expansion of the public’s well-being depends, are gambling against very long odds if they bet that the mainstream position is wrong. This is not prudent.



<http://www.ostp.gov>