Climate-Change Science and Policy:
What Do We Know? What Should We Do

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Kavli Prize Symposium
International Cooperation in Science
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Coverage of these remarks

WHAT DO WE KNOW?
- The essence of the challenge
- Five myths & their refutations
- Climate change risks & impacts going forward

WHAT SHOULD WE DO?
- The available options
- How much mitigation, how soon?
- A mitigation supply curve & its implications
- The Obama Administration's strategy

The essence of the challenge

- 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 wrecking the climate its environment needs.

Five myths about the challenge

1. A little global warming can't hurt anything.
2. The Earth is no longer warming anyway.
3. Even if it is, humans aren't the main cause.
4. If there is any danger, it's far in the future.
5. The CRU e-mails and IPCC mistakes have shown that mainstream climate science is deeply flawed.

"Global warming" is a (dangerous) 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

We should call it "global climate disruption".

Why average temperature isn't the whole story

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.

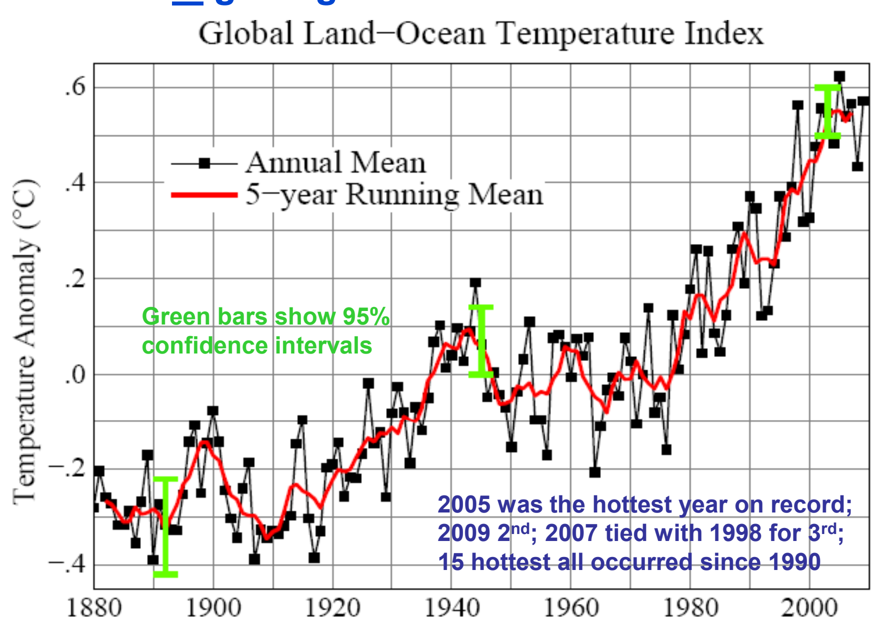
Global average temperature is just an index of the state of the global climate as expressed in these patterns. Small changes in the index → big changes in the patterns.

Can't hurt anything?

Climate governs (so climate disruption affects)

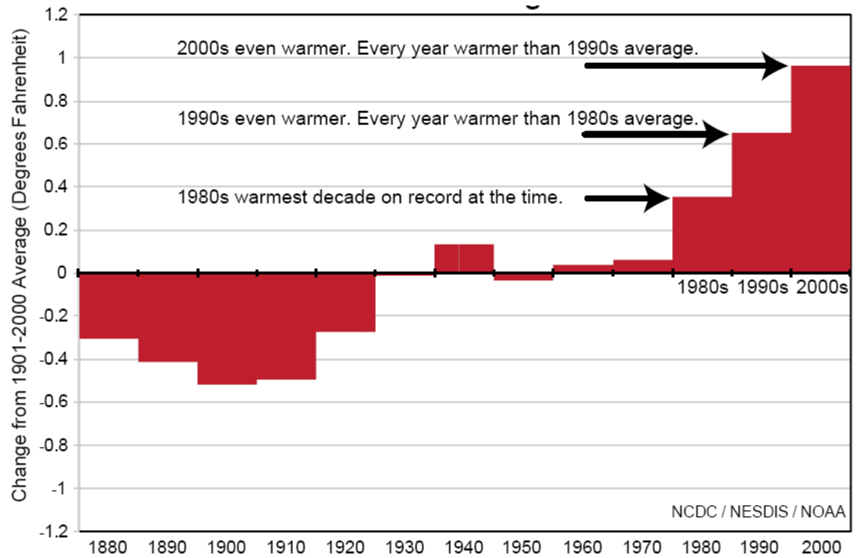
- availability of water
- productivity of farms, forests, & fisheries
- prevalence of oppressive heat & humidity
- formation & dispersion of air pollutants
- geography of disease
- damages from storms, floods, droughts, wildfires
- property losses from sea-level rise
- expenditures on engineered environments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

The Earth is getting hotter



http://data.giss.nasa.gov/gistemp/graphs/

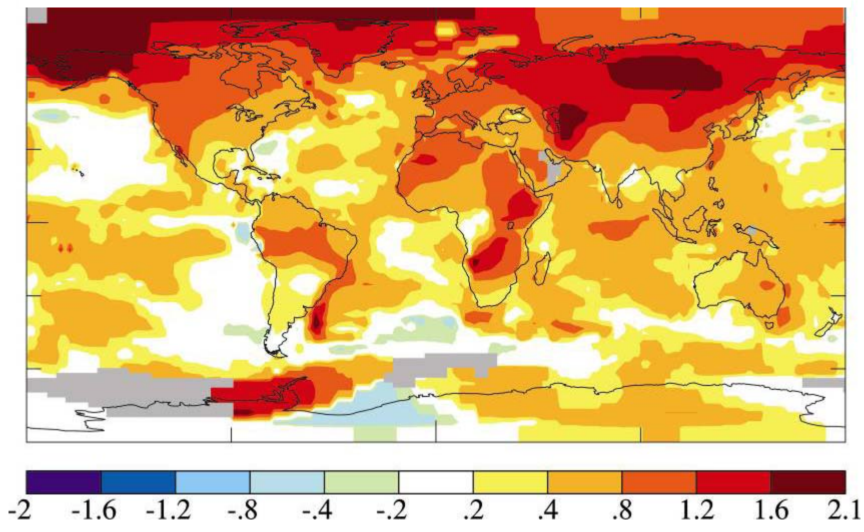
The Earth <u>is</u> getting hotter (continued)



NOAA, State of the Climate 2009, 2010

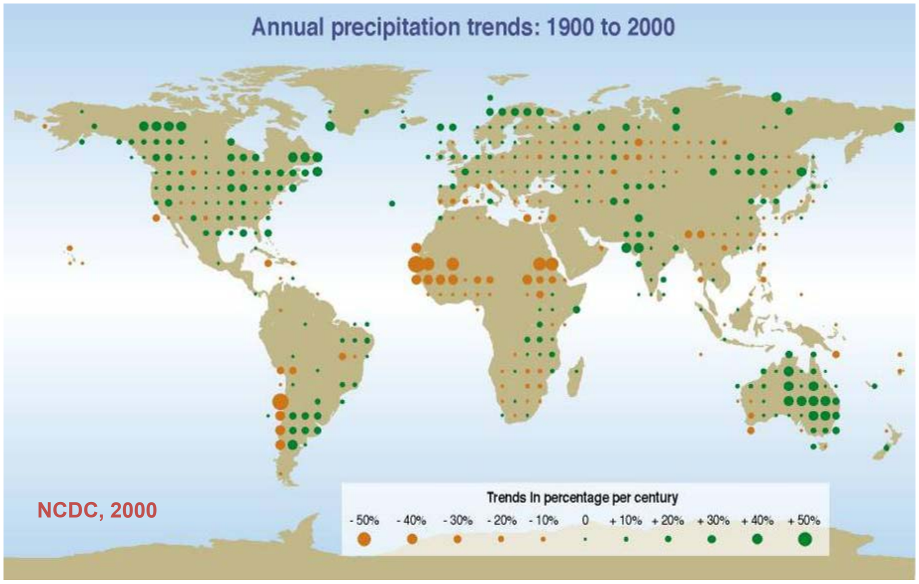
The heating is not uniform geographically

Surface T in 2001-2005 *vs* 1951-80, averaging 0.53ºC increase



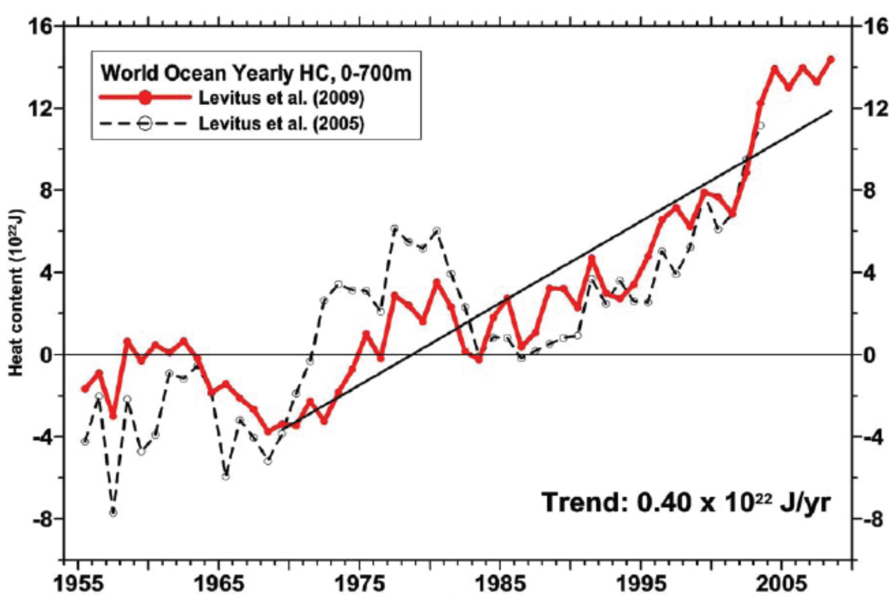
J. Hansen et al., *PNAS 103*: 14288-293 (2006)

Other climate indicators are changing apace



This too is not uniform; most places getting wetter, some drier.

Other indicators: ocean heat content is growing



NAS, America's Climate Choices, 2010

Other indicators: coastal glaciers retreating

Muir Glacier, Alaska

August 1941

August 2004

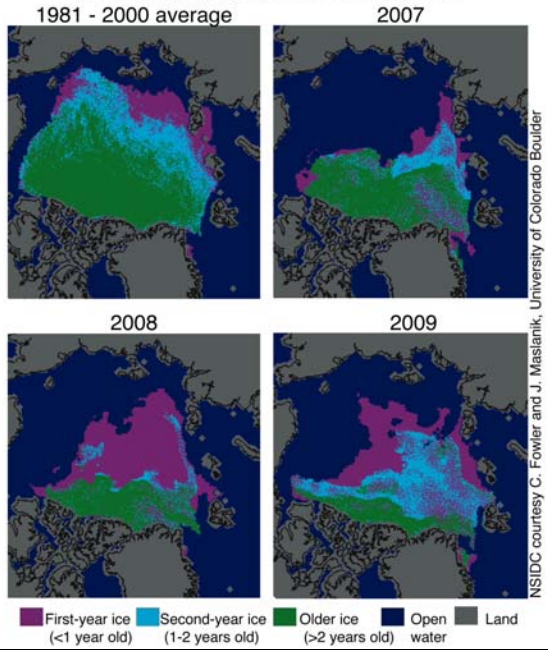
NSIDC/WDC for Glaciology, Boulder, compiler. 2002, updated 2006. *Online glacier photograph database.* Boulder, CO: National Snow and Ice Data Center.

Indicators: mountain glaciers shrinking

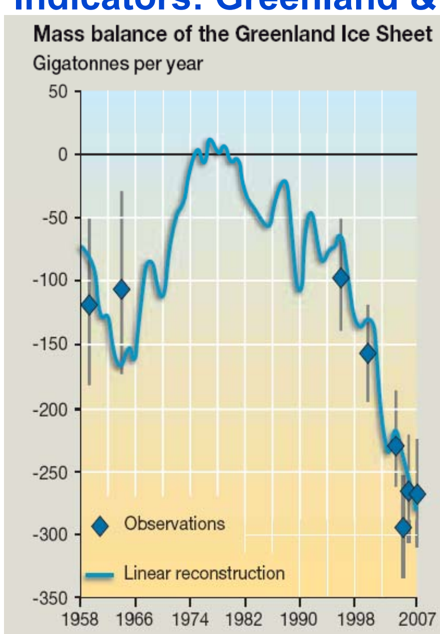
Rongbuk glacier in 1968 (top) and 2007. The largest glacier on Mount Everest's northern slopes feeds Rongbuk River.

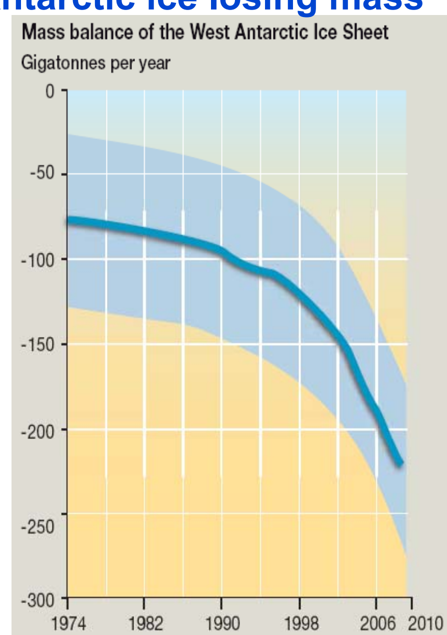
National Snow & Ice Data Center 2010

Indicators: Arctic sea ice shrinking & thinning



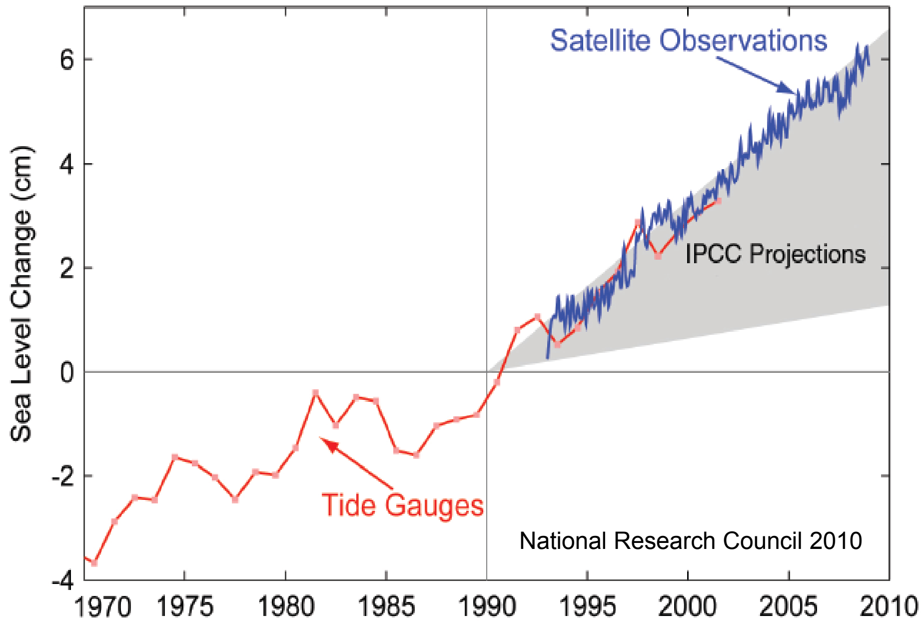
Indicators: Greenland & Antarctic ice losing mass





The Copenhagen Diagnosis, 2009

Indicators: sea level rising



What's known 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.

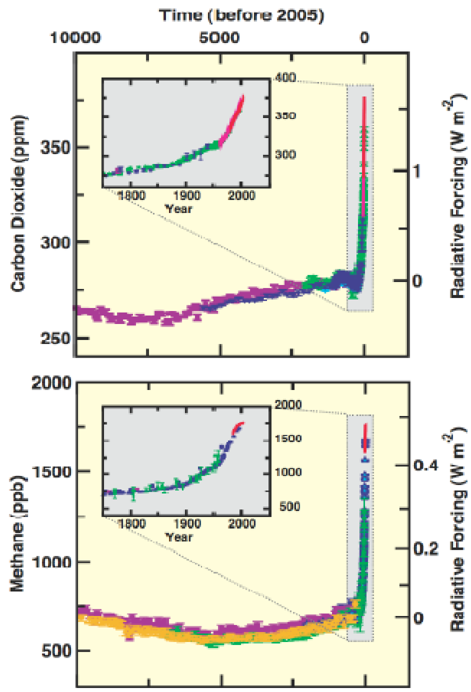
IPCC AR4, WG1 SPM, 2007

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 CO_2 & CH_4 in the past 250 years is extraordinary.

We know humans are responsible for the CO_2 spike because fossil CO_2 lacks carbon-14, and the drop in atmospheric C-14 from the fossil-CO_2 additions is measurable.

IPCC AR4, WG1 SPM, 2007

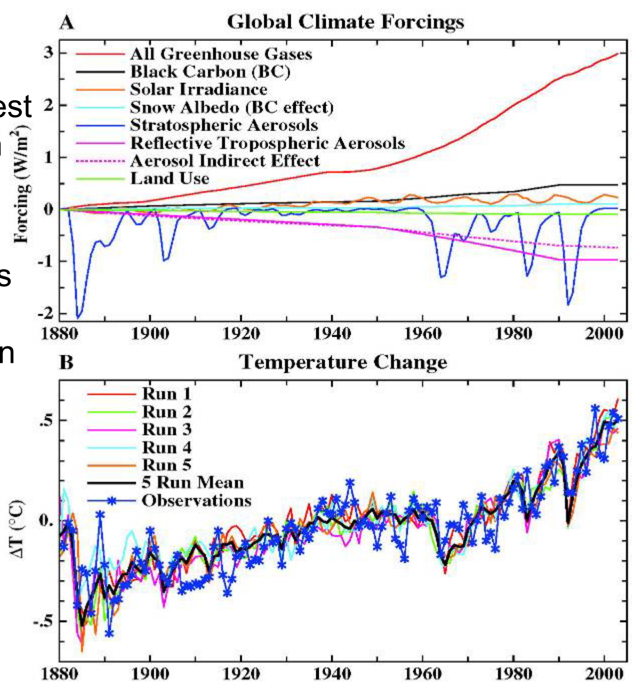


Human influence: the "fingerprint"

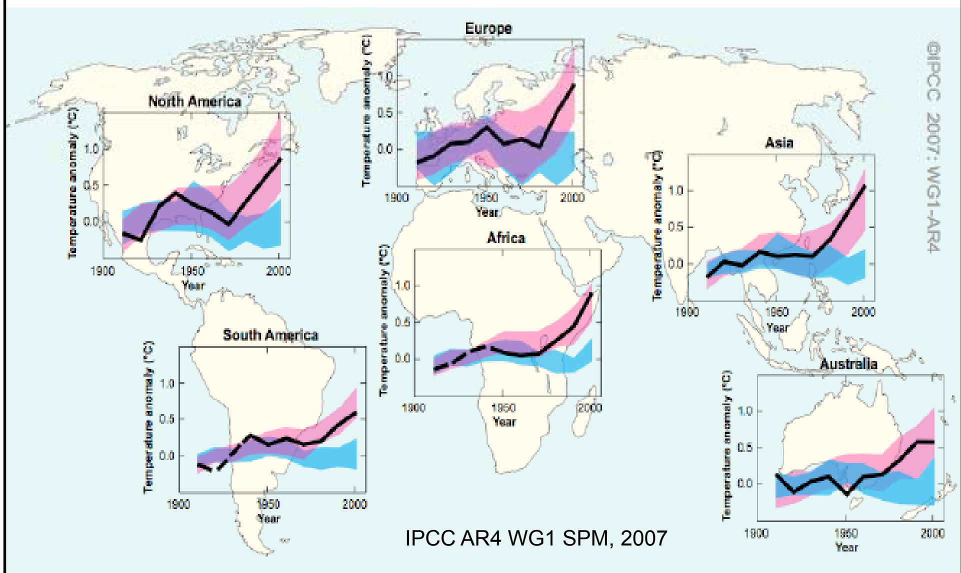
Top panel shows best estimates of human & natural forcings 1880-2005.

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.



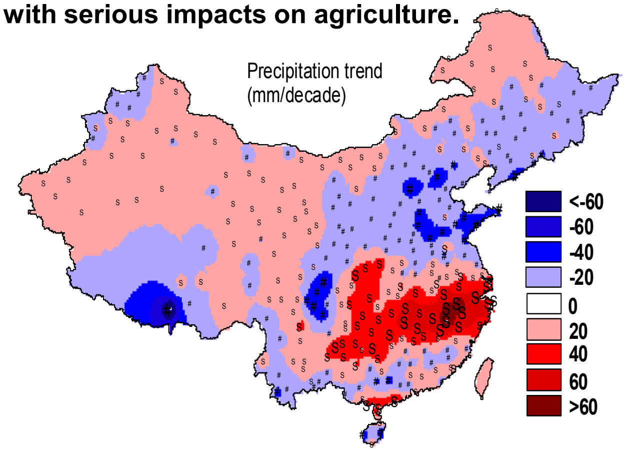
Fingerprint: models match observed ΔT on all continents



Black lines are decadally averaged observations. Blue bands are computer models with natural forcings only. Pink bands are computer models with human + natural forcings.

Are we seeing harm? Floods & droughts

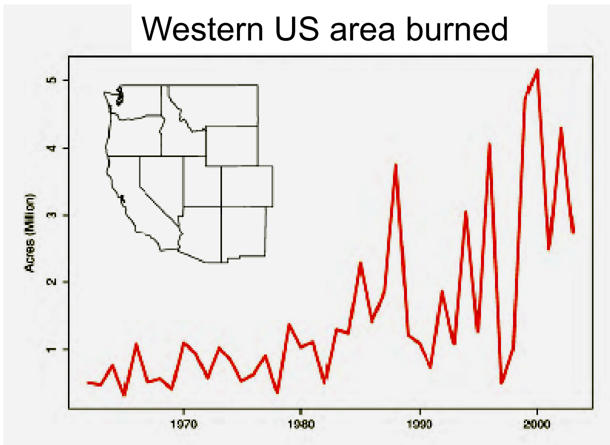
30-year weakening of East-Asia monsoon – attributed to global climate change -- has meant less moisture flow South to North over China, producing increased flooding in South, drought in North, with serious impacts on agriculture.



Qi Ye, Tsinghua University, May 2006

Are we seeing harm? Wildfires

Wildfires in the Western USA have increased 6-fold in the last 30 years. Similar trends are evident in other fire-prone regions.



Source: Westerling *et al.*, SCIENCE, 2006

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

Shishmaref, Alaska; © Gary Braasch

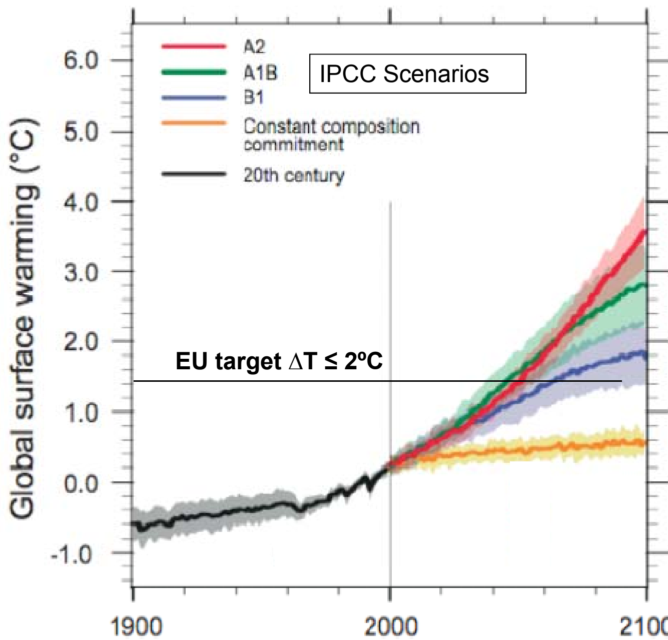
Current harm is widespread

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"

Bigger impacts expected going forward



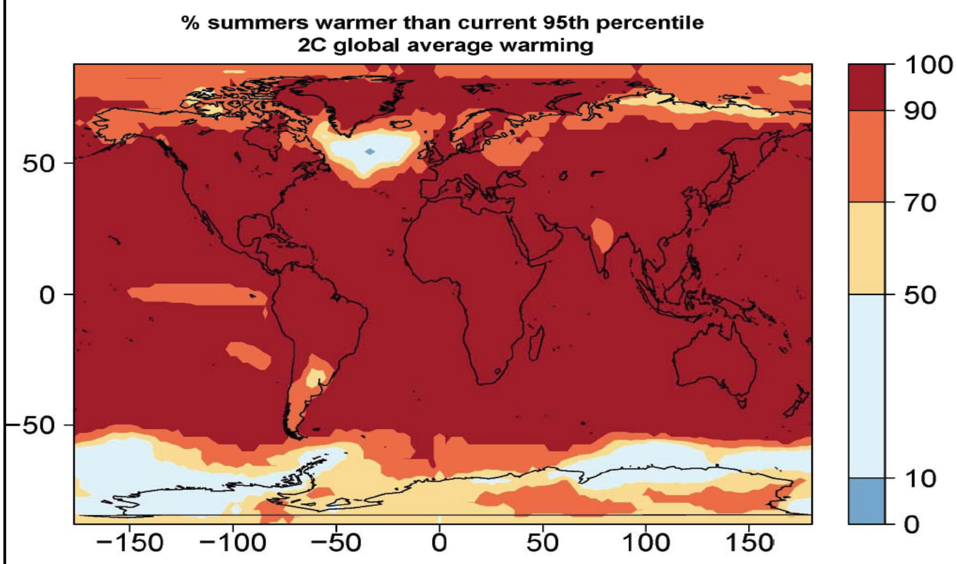
Last time T was 2ºC above 1900 level was 130,000 yr BP, with sea level 4-6 m higher than today.

Last time T was 3ºC above 1900 level was ~30 million yr BP, with sea level 20-30 m higher than today.

Note: Shaded bands denote 1 standard deviation from mean in ensembles of model runs

IPCC 2007

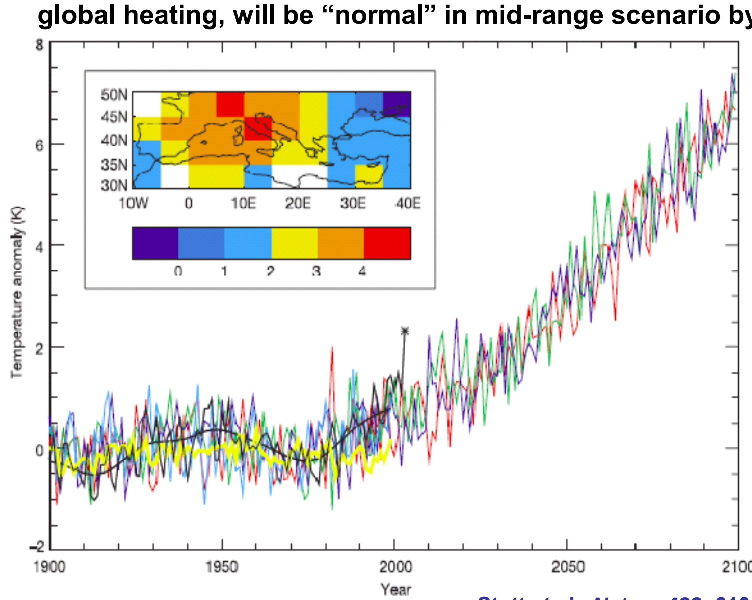
What's expected: Hotter summers



National Academies, Stabilization Targets, 2010

What's expected: Worse heat waves

Extreme heat waves in Europe, already 2X more frequent because of global heating, will be "normal" in mid-range scenario by 2050



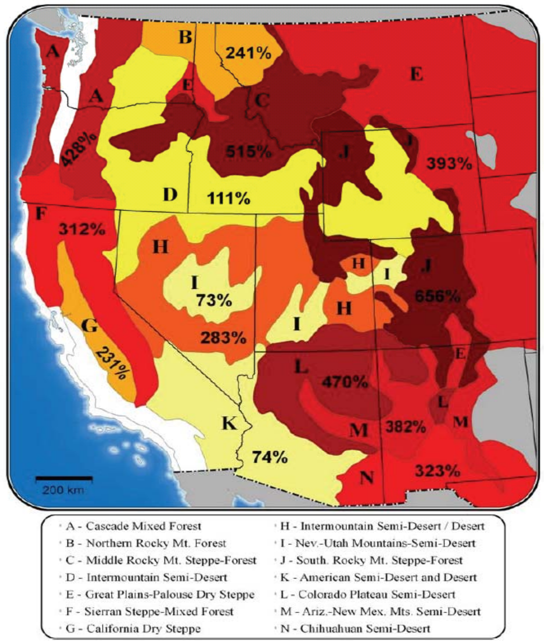
Black lines are observed temps, smoothed & unsmoothed; red, blue, & green lines are Hadley Centre simulations w natural & anthropogenic forcing; yellow is natural only.

Asterisk and inset show 2003 heat wave that killed 35,000.

Stott et al., *Nature 432*: 610-613 (2004)

What's expected: worse wildfires

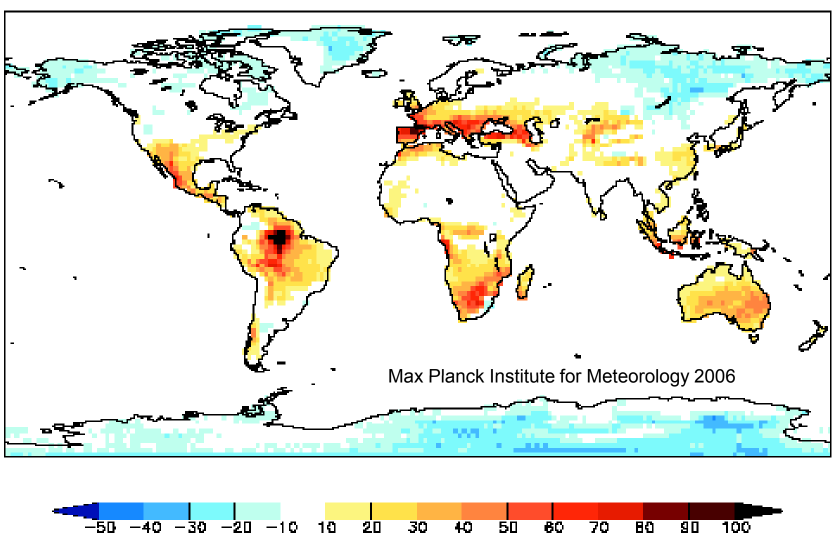
Percentage increases in median annual area burned for a 1°C increase in global average temperature



National Academies, Stabilization Targets, 2010

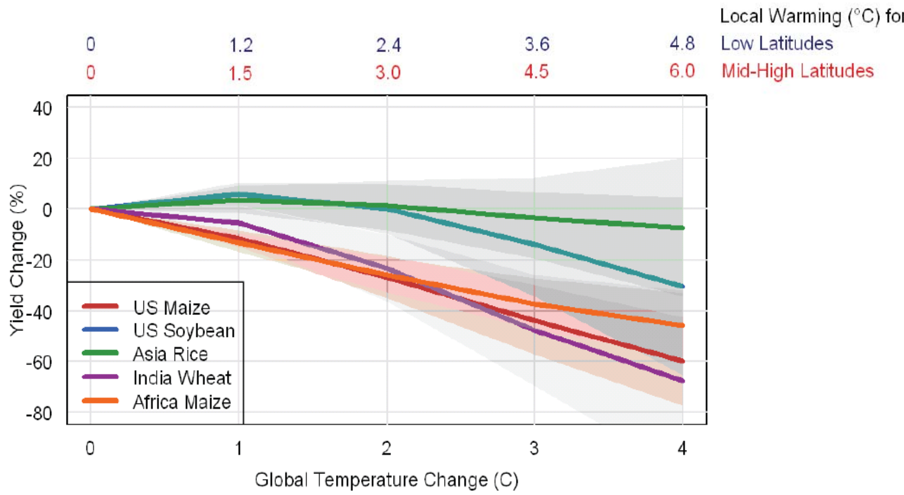
What's expected: worse droughts

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: declining crop yields



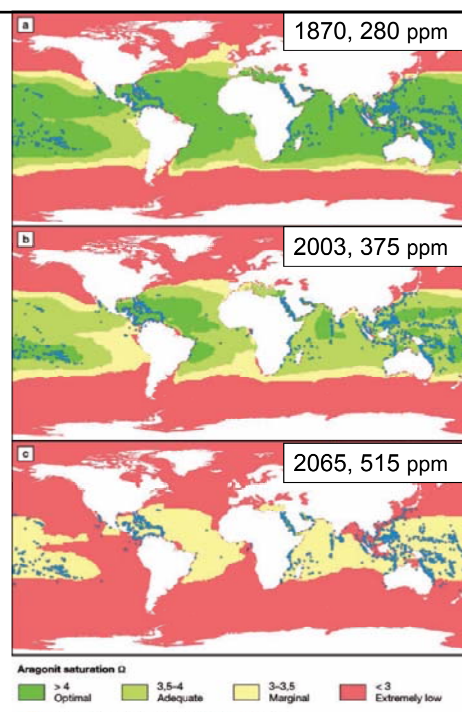
National Academies, Stabilization Targets, 2010

What ‘s expected: falling ocean pH

About 1/3 of CO_2 added to atmosphere is quickly taken up by the surface layer of the oceans (top 80 meters).

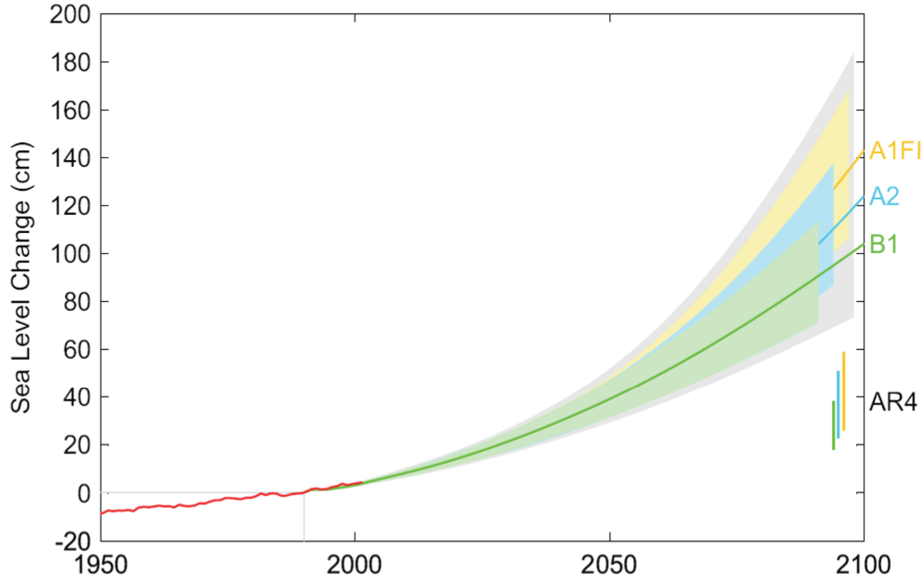
This lowers pH as dissolution of CO_2 forms weak carbonic acid ($H_2O + CO_2 \rightarrow H_2CO_3$).

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



Steffen et al., 2004

What's expected: sea-level rise to 2100



The National Academies, America's Climate Choices, 2010, vol 1

Do recent disclosures about e-mails and IPCC missteps cast doubt on these conclusions?

- E-mails show climate scientists are human, too; more efforts at openness & transparency are warranted
- IPCC missteps show need for increased rigor in adhering to organization's strict review procedures; but errors discovered so far are few & unimportant.
- IPCC isn't the source of scientific understanding of climate, just one of the messengers. Sources are the global community of climate scientists & mountain of peer-reviewed research they've produced over decades.

Recent disclosures (continued)

- Nothing in e-mails or IPCC controversies rises to a level that would call into question the core understandings about global climate disruption.
- All science is contingent; there are always uncertainties & needs for refinement. And there's always a chance that new observations & analyses will not just refine but overturn previous conclusions.
- But such overturnings are extremely unlikely when the body of data & analysis supporting the generally accepted conclusions is extensive & much reviewed.

Recent disclosures (continued)

- Body of data & analysis supporting generally accepted conclusions about climate disruption is immense.
- Because of their relevance to policy choices of great importance, key findings from climate science have been subjected to unprecedentedly extensive peer review.
- It's therefore highly unlikely that new data or insights will alter these findings in a fundamental way.
- Policy makers should not bet the public's welfare against such long odds – i.e., bet that the science is wrong.

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 unmanage-able, enough adaptation to manage the unavoidable.

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

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.

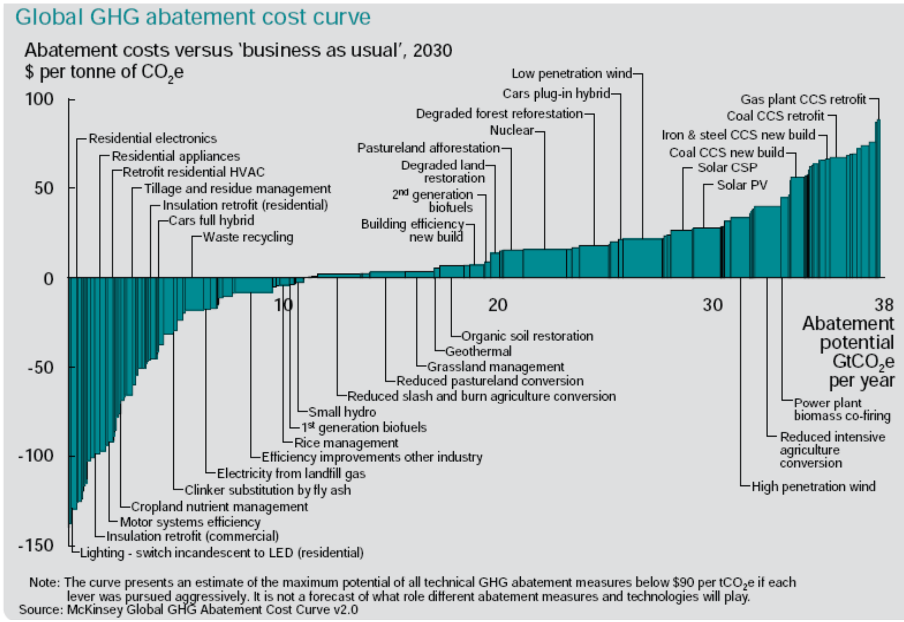
How much, how soon?

- Limiting ΔT_{avg} to ≤2ºC is now considered by many the most prudent target that's still attainable.
  - EU embraced this target in 2002, G-8 & G-20 in 2009
- Just to have a 50% chance of staying below 2ºC
  - developed-country emissions must peak no later than 2015 and decline rapidly thereafter
  - developing-country emissions must peak no later than 2025 and decline rapidly thereafter.

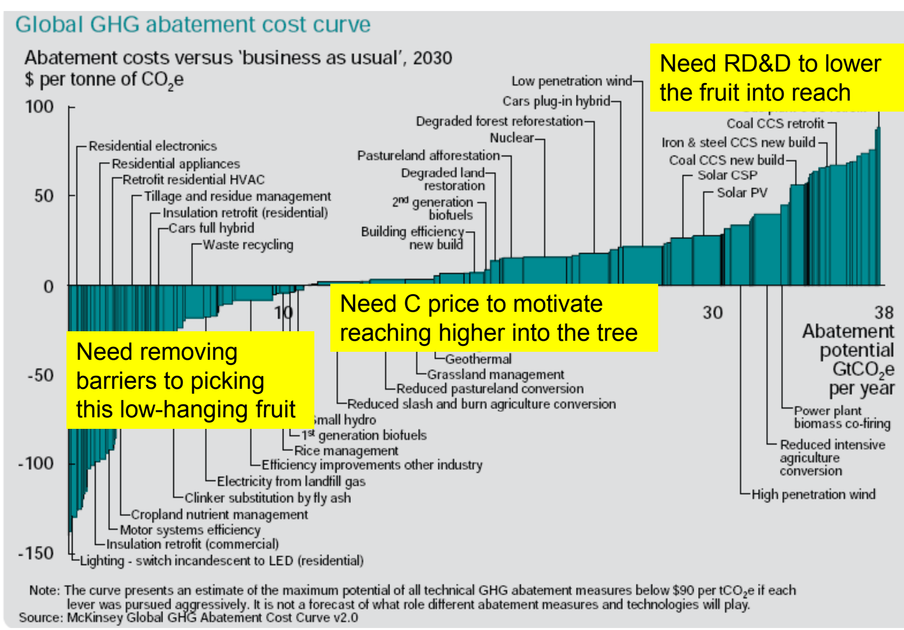
Key mitigation realities

- Human CO_2 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
- Industrialized & developing countries are now about equal in total CO_2 emissions.
- Global energy system can't be changed quickly: ~$15T 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.

Mitigation supply curve for 2030: aiming for 450 ppm CO_2e



Policy needs for the 450 ppm CO_2e supply curve



Is the needed mitigation affordable?

- Rough calculations
  - Paying an average of $100/tC to avoid half of current world CO_2 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 CO_2e 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 Obama administration's strategy

- Promote recognition that problem is real and early action is preferable to waiting
  - The longer we wait, the bigger the damage from climate change & the more rapid the emissions reductions needed to stabilize.
  - Prudent action will be cheaper than inaction or delay.
  - We can reduce costly and risky oil imports and dangerous air pollution with the same measures we employ to reduce climate-disrupting emissions.
  - The needed surge of innovation in clean-energy technologies and energy efficiency will create new businesses & new jobs and help drive economic recovery& growth, maintain global competitiveness.

Obama administration strategy (continued)

- Put climate-change leaders in key positions
- Make climate change a priority for initiatives in departments & agencies
- Revitalize USGCRP & other interagency efforts
- Work with Congress to get comprehensive energy-climate legislation that will put the USA on the needed emissions trajectory with minimum economic & social cost & maximum co-benefits.
- Work with other major emitting countries – industrialized & developing – to build technology cooperation and individual & joint climate policies consistent with "avoiding the unmanageable".

Some key climate-related appointments

- DOE: Secretary Chu
- Interior: Secretary Salazar
- NOAA: Administrator Lubchenco
- EPA: Administrator Jackson
- USGS: Director McNutt
- USAID: Administrator Shah
- CEQ: Chair Sutley
- OECC: Director Browner
- OSTP: Director Holdren
- PCAST: Drs Bierbaum, Molina, Moniz, Schrag

Guidance to agencies

- Executive Order on Federal Leadership in Environ-mental, Energy, & Economic Performance (10-09)
  - "to establish an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions a priority…"
  - designation of agency senior sustainability officers
  - sustainable buildings & acquisition policies
  - targets for GHG reductions in Federal agencies (28% reduction by 2020)

Guidance for agencies (continued)

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

July 21, 2010

THE DIRECTOR

M-10-30

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: Peter R. Orszag
Director, Office of Management and Budget

John P. Holdren
Director, Office of Science Technology Policy

SUBJECT: Science and Technology Priorities for the FY 2012 Budget

Some priorities:

Understanding, adapting to, and mitigating the impacts of global climate change
- Support…an integrated National Climate Assessment of climate change science, impacts, vulnerabilities, & response strategies, including mitigation & adaptation.

Managing the competing demands on land, fresh water, & the oceans for the production of food, fiber, biofuels & ecosystem services based on sustainability &biodiversity
- Support research on integrated ecosystem management approaches

Agency initiatives

- DOE/DOT: $80 billion for clean & efficient energy in ARRA
- DOE: creation of ARPA-E ($400M in 2009-10, $300M proposed for 2011), energy-innovation hubs
- EPA/DOT: first-ever fuel-economy/CO2 tailpipe standards
- NOAA: restructuring to consolidate "climate services" germane to climate-change adaptation
- NASA/NOAA/DoD: FY11 budget restructures NPOESS for success, funds Orbiting Carbon Observatory replacement.

Agency initiatives (continued)

- DOI: restructuring to develop Climate Change Response Centers and Landscape Conservation Cooperatives, Carbon Storage Project
- EPA: "endangerment finding" that CO_2 imperils health & welfare, allowing regulation as a pollutant
- DOT-HUD-EPA: Partnership for Sustainable Communities

Revitalizing broad interagency efforts

- The "Green Cabinet"
  - Secretaries of Energy, Interior, Agriculture, Transportation, HUD, Labor; EPA Administrator; SBA Administrator; CEQ Chair; OSTP Director; chaired by OECC Director Browner
- National Science & Technology Council (NSTC)
  - Committee on Environment and Natural Resources (CENR) – chaired by Abbott, Lubchenco, Anastas – being repurposed as Committee on Environment, Natural Resources, <u>and Sustainability.</u>
- Climate-Change Adaptation Task Force
  - Co-chaired by OSTP, CEQ, NOAA, with senior representation from all relevant agencies
- The US Global Change Research Program

The US Global Change Research Program

- Created by the Global Change Research Act
- Purpose *"coordination of a comprehensive and integrated United States research program which will assist the Nation and the world to* ***understand, assess, predict, and respond*** *to human-induced and natural processes of global change."*
- Response includes both mitigation and adaptation
- 13 participating Federal departments & agencies
- Administered by the USGCRP subcommittee of the Committee on Environment & Natural Resources of the National Science and Technology Council

USGCRP: strengthening the science core

- Regional Climate Prediction – downscaling GCMs to understand how local conditions will change
- Precipitation – reducing model uncertainty, particularly regarding the formation and dynamics of clouds
- Ice – increasing knowledge of basal processes and ice shelf dynamics
- Aerosols – understanding how sulfates, black carbon, sea salt and dust affect temperature and rainfall
- Paleoclimate – resolving questions about proxy data and improving temperature reconstructions, especially prior to 1500

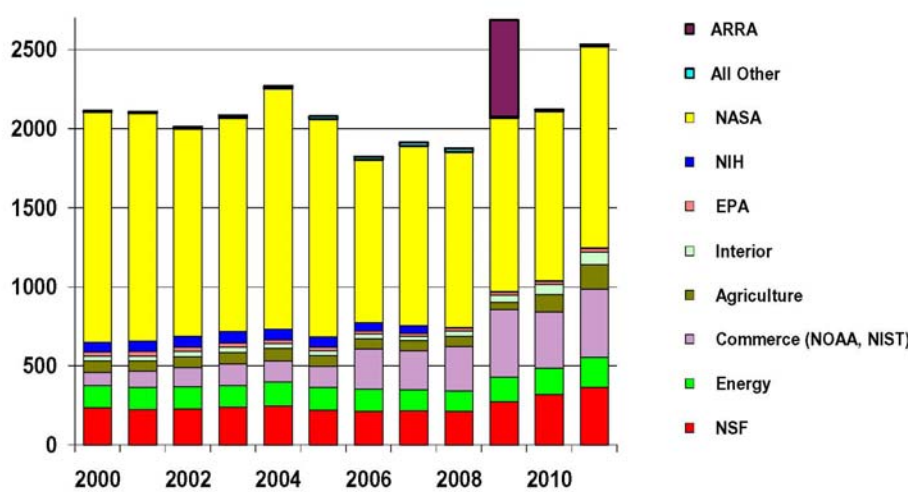
USGCRP: New emphases

- Adaptation Research
  - Integrating human dimensions -- economics, management, governance, behavior, and equity
  - Interdisciplinary research that takes into account the interconnectedness of the Earth system
- Integrated Assessments
  - Engaging localities and sectors to aggregate information into a national picture of climate impacts
  - Gathering information on the "demand-side" of the adaptation problem, where people live and work, to reorient research and observation investments
  - Providing information and capabilities needed by those experiencing impacts

USGCRP: New emphases (continued)

- Climate Services
  - o Providing analysis and assessment that is ongoing, science-based, user-responsive, and relevant to all levels of interest, e.g., local, regional, national and international
  - o Communicating climate change information to users
- Plus – coordination among Science, Adaptation, & Mitigation

USGCRP: budget rising



AAAS 2010

New studies & assessments

- The National Assessment of Climate Change
  - Sits under the USGCRP and shares its new emphases;
  - Leadership: Kathy Jacobs, Director (OSTP), Tom Karl (NOAA), Tim Killeen (NSF)
- Continuing interagency / science community focus on climate-change adaptation
  - OSTP/CEQ/NOAA Task Force
  - National Adaptation Summit (May 2010) launched community-wide effort to develop a National Adaptation strategy with science goals, data strategy, metrics, interaction with state & local planners, publics

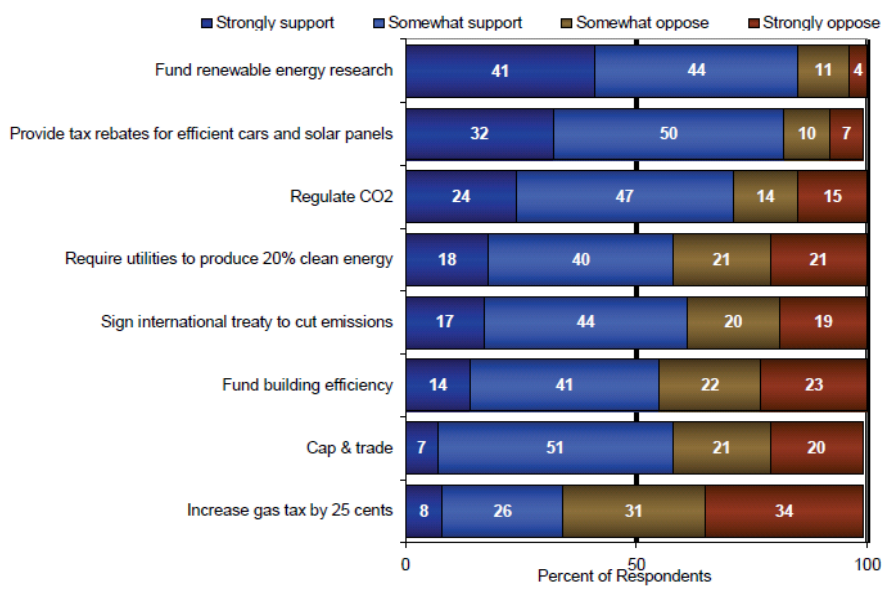
International engagement

- Personal engagement of President Obama to salvage a respectable outcome from Copenhagen COP-15
- Climate-change a priority in revitalized ministerial-level Commissions on Science & Technology Cooperation (with Brazil, China, India, Japan, Korea, Russia), and in US-Russia Bilateral Presidential Commission
- DOE ramping up bilateral cooperation on clean-energy technology with China and other international partners

National climate-change legislation

- President Obama was emphatic that new US energy legislation should include climate, above all a price on carbon emissions.
- The climate component was reluctantly & temporarily abandoned because of insufficient support in the US Senate.
- We will try anew in the next Congress; in the meantime, EPA is moving ahead to control greenhouse gas emissions by regulation.

Americans still support taking action (Jan 2010 poll)



The National Academies, America's Climate Choices, 2010, vol 4