Climate Science and Public Policy
What Do We Know? What Can We Do?

John P. Holdren
Assistant to the President for Science and Technology
Director, Office of Science and Technology Policy
Executive Office of the President of the United States

Presentation for the
Boston Green Ribbon Commission
9 November 2015

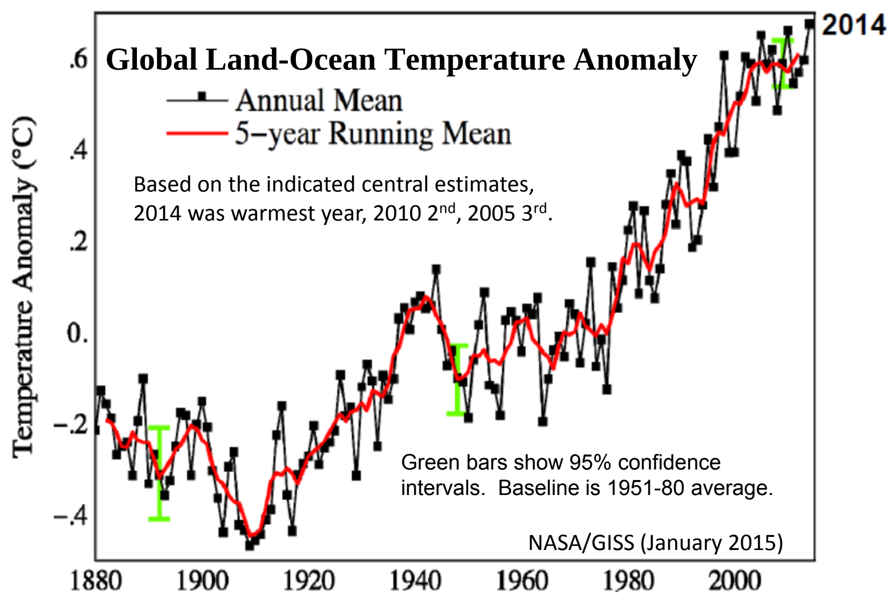
Coverage of these remarks

- What we know about…
  - — how & why climate is changing
  - — what harm it's doing
  - — what's in store
- What we can do
  - — fundamental choices
  - — mitigation & adaptation options
  - — President Obama's Climate Action Plan
  - — next steps domestically & internationally

What We Know

Thermometer records tell us…

Earth's temperature is rising.



Consistent with the thermometer record, observations tell us…

Coastal glaciers are retreating

Muir Glacier, Alaska, 1941-2004

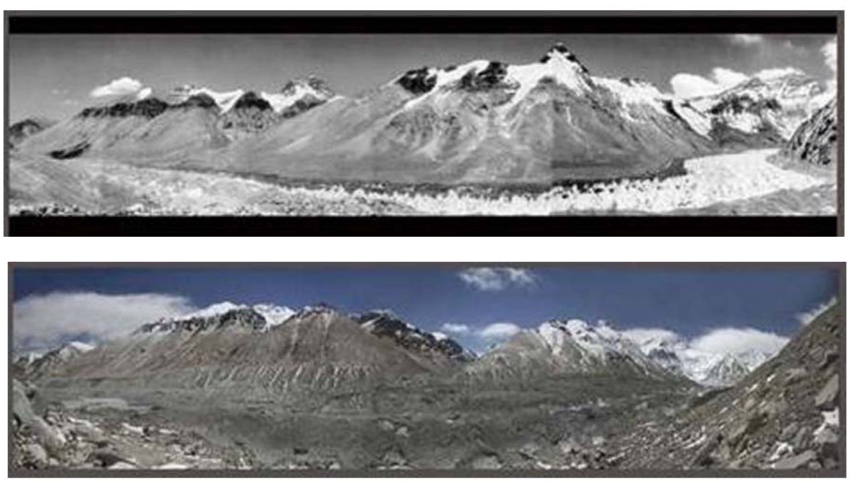
August 1941

August 2004

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

And…

Mountain glaciers are disappearing



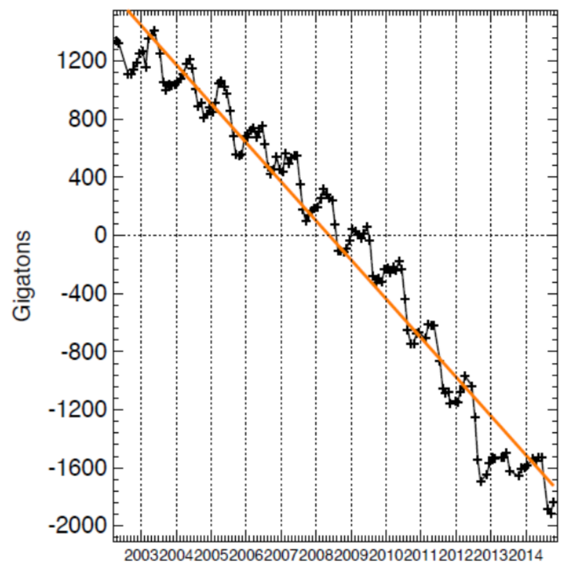
Rongbuk glacier in 1968 (top) and 2007. The largest glacier on Mount Everest's northern slopes feeds the Rongbuk River.

National Snow & Ice Data Center 2010

And…

The Greenland ice sheet is shrinking

Change in Greenland ice mass in the 21st century to date

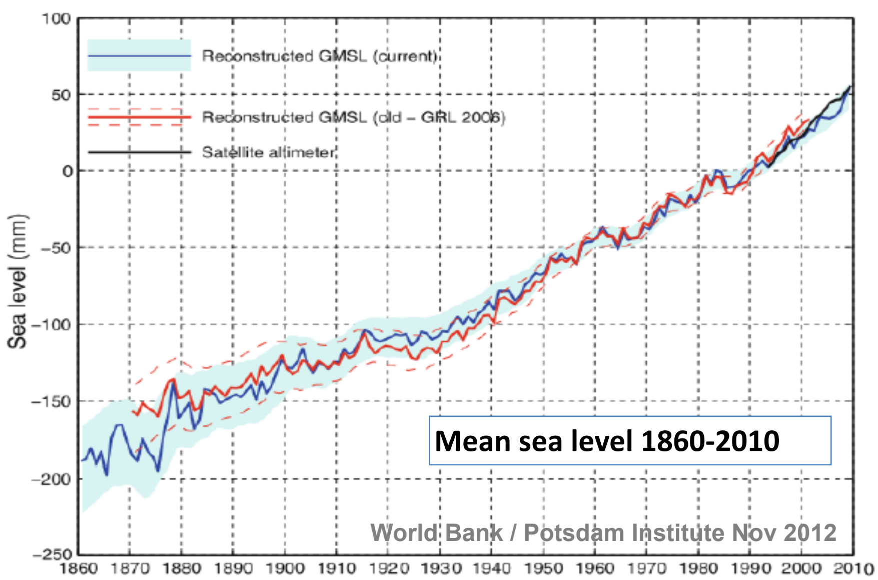


Tonnages referenced to 2009 average

Waleed Abdalati, from GRACE, December 2014

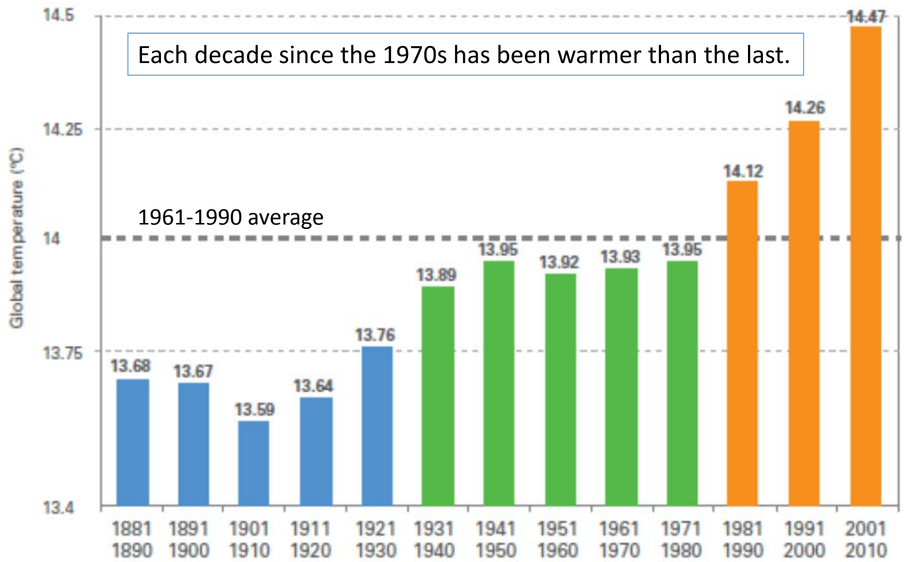
And, because of melting ice and thermal expansion,

Sea level is rising



We also know…

Warning did not "stop in 1998".



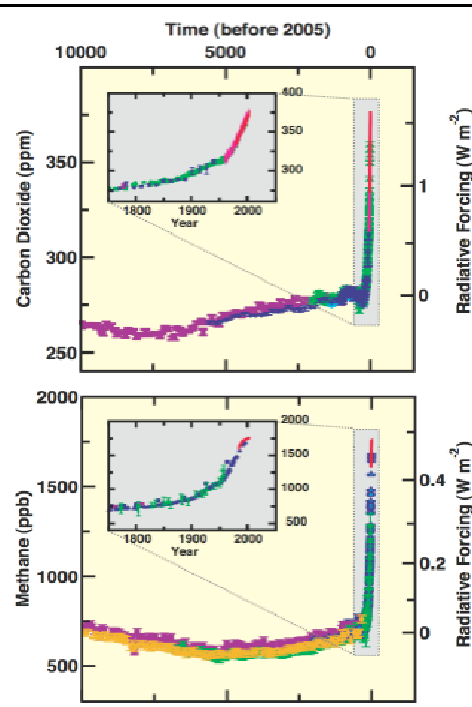
WMO, 2013

We know…

Humans are responsible for the big greenhouse-gas increases since 1750.

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.

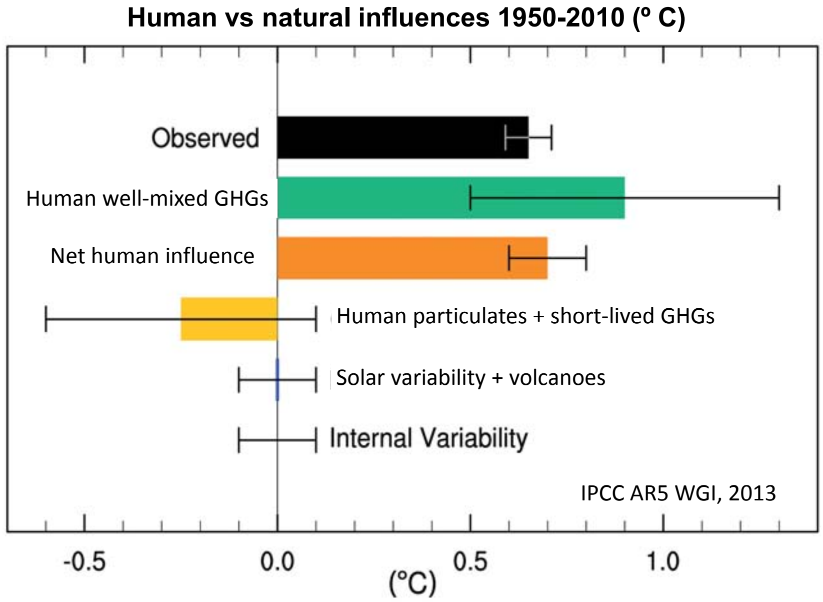
We know humans are responsible for the CO_2 spike because fossil CO_2 lacks carbon-14, and the drop in atmospheric C-14 fraction resulting from the fossil-CO_2 additions is measurable.



IPCC AR4, WG1 SPM, 2007

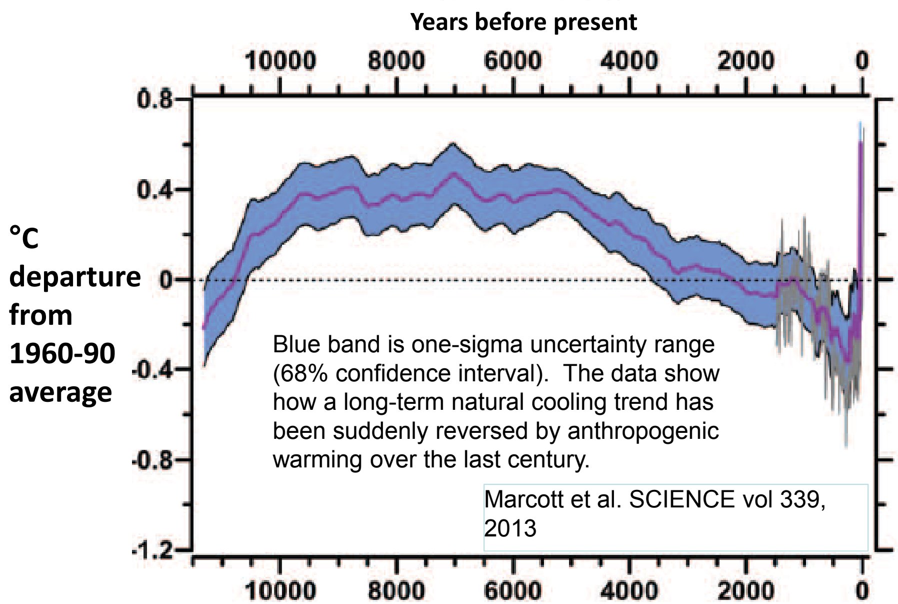
And we know…

The role of these GHG increases in the observed warming.



We also know…

This human influence reversed a long-term cooling.



Climate change is not just about temperature.

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 entails alteration of the patterns.

Global average T is just an index of the state of the global climate system as expressed in these patterns. Small changes in the index correspond to big changes in the system.

The potential impacts of climate change are many.

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

Many such impacts are already occurring.

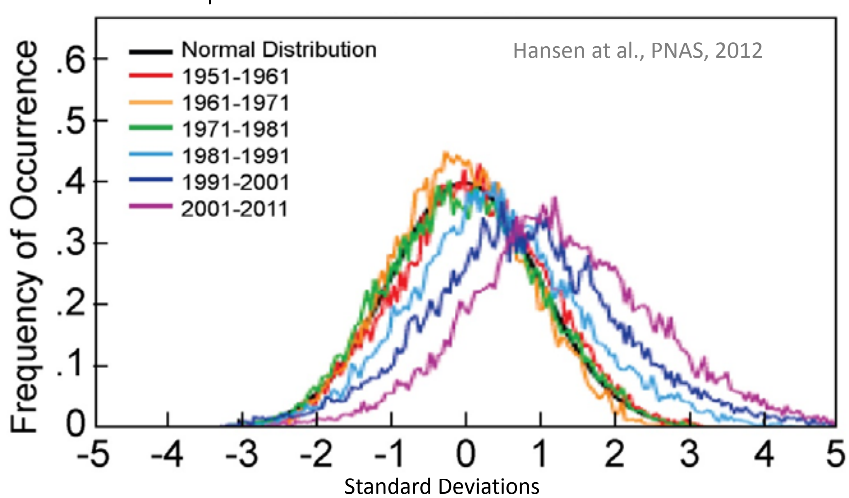
Around the world we're seeing, variously, increases in

- floods
- wildfires
- droughts
- heat waves
- pest outbreaks
- coastal erosion
- coral bleaching events
- power of the strongest storms
- geographic range of tropical pathogens

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

Ongoing impacts: Hotter summers

Probability distribution for Jun-Jul-Aug temperature anomaly on land in the Northern Hemisphere. Baseline normal distribution is for 1951-80.



Portion of Northern Hemisphere land experiencing > 3σ summer heat in a given year increased from 0.1-0.2% in 1951-80 to 10% in 2001-2011—a 50- to 100-fold increase.

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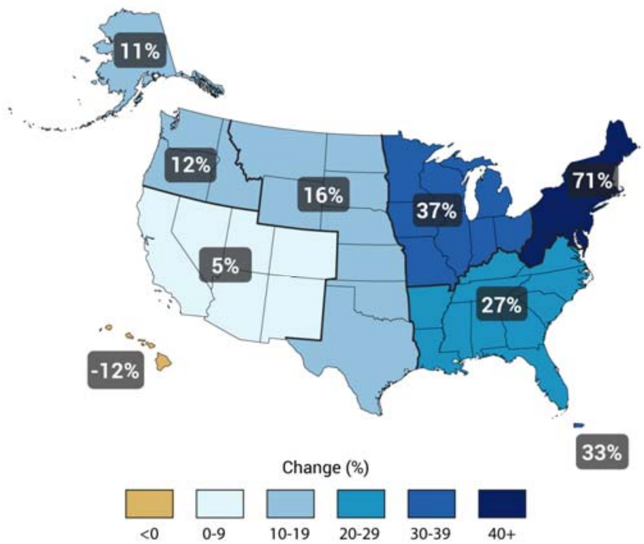
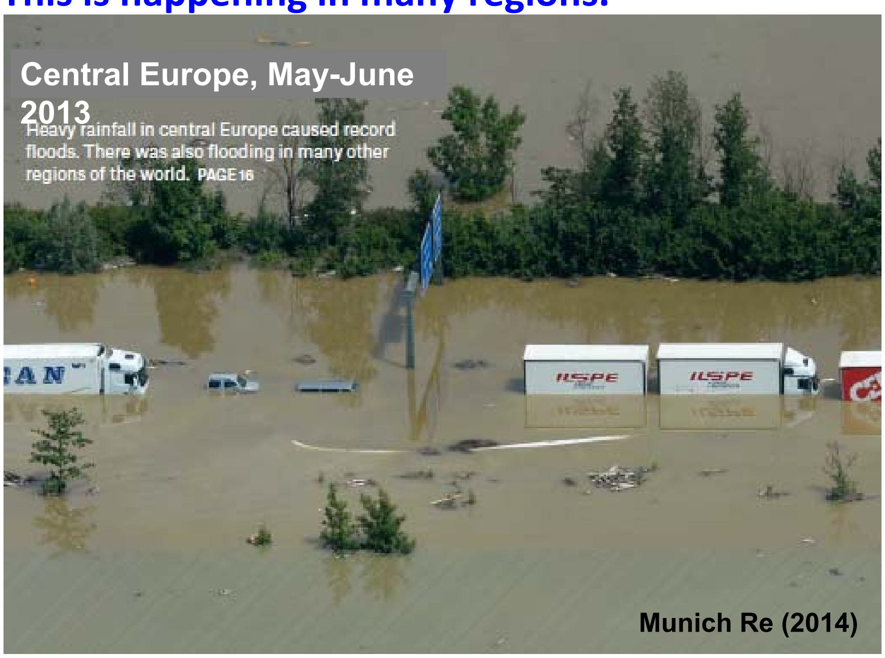
Ongoing Impacts: Torrential rains in the USA



Percentage increase, between 1958 and 2012, in the amount of precipitation falling in the heaviest 1% of precipitation events in each region.

Source: USGCRP, Assessment of Climate Change Impacts in the United States, May 2014

This is happening in many regions.



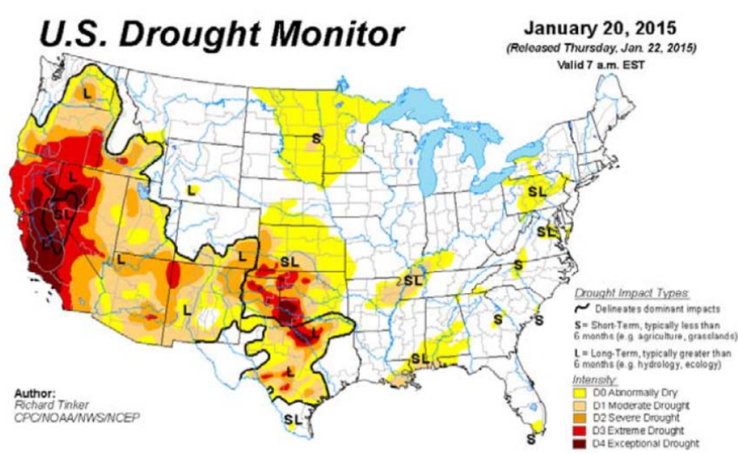
Ongoing impacts: In a wetter world overall, many drought-prone regions are getting more so!

California's Folsom Lake at 17% capacity, 02-02-14

Credit: Ken James / Bloomberg

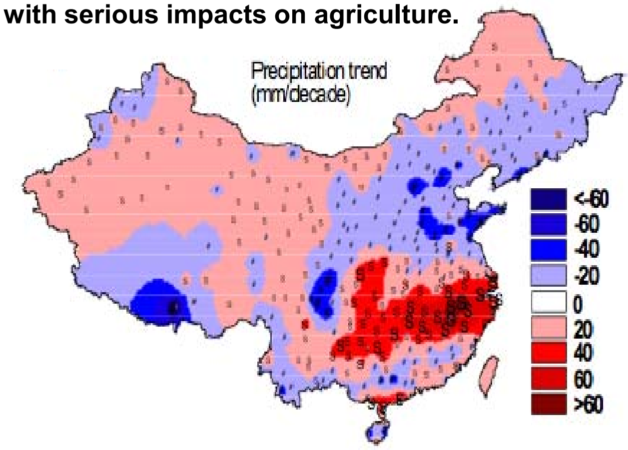
The influence of warming on drought

- Higher temperatures = bigger losses to evaporation.
- More of the rain falling in extreme events = more loss to flood runoff, less moisture soaking into soil.
- Mountains get more rain, less snow, yielding more runoff in winter and leaving less for summer.
- Earlier spring snowmelt also leaves less runoff for summer.
- Altered atmospheric circulation patterns can also play a role.



Ongoing impacts: Floods & droughts in China

An example of how changing circulation patterns can work: 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.

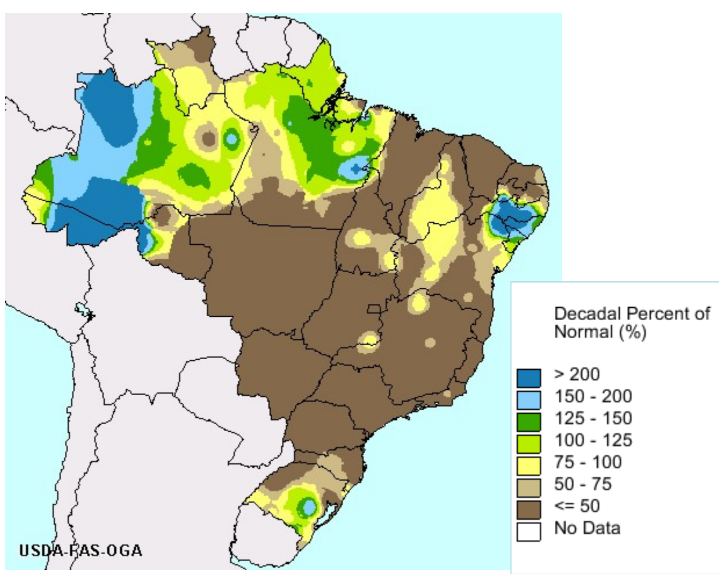


Qi Ye, Tsinghua University, May 2006

Ongoing impacts: Drought in the Amazon

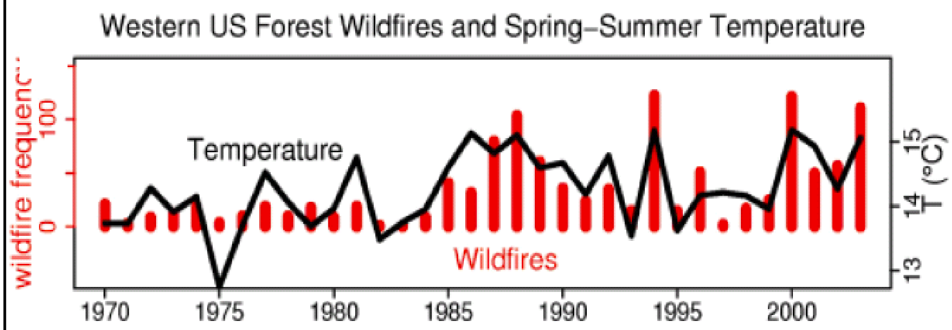
Here, too, changing atmospheric circulation has played a role.

The 2014 drought in Southeastern Brazil affected more than 27 million people and entrained economic losses of at least $5 billion.



Munich Re, 2015

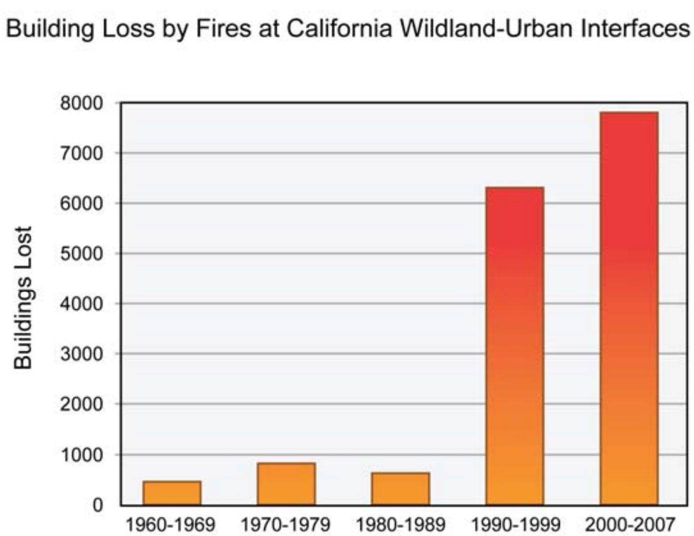
Ongoing impacts: Wildfires are increasing with warming



Fire frequency is correlated with temperature; part of that link works via the reduced soil moisture that goes with higher temperatures.

Westerling et al., SCIENCE, 18 August 2006

Losses to fires at wildland-urban interfaces

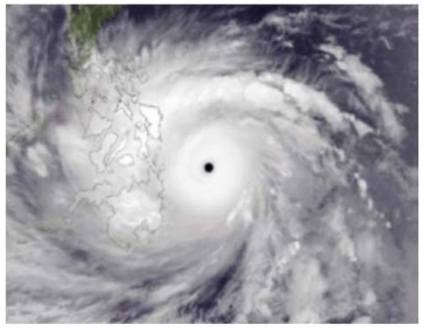


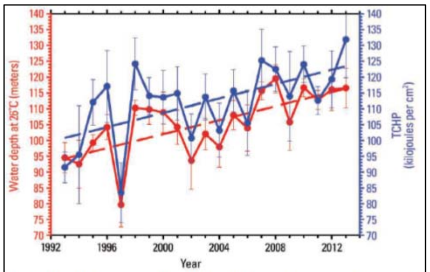
Some of the increase is due to more property at risk, but much of it is the increase in fires.

National Climate Assessment

Ongoing impacts: increasing power of cyclones

Tropical cyclones get their energy from the warm surface layer of the ocean (which is getting warmer and deeper under climate change) and from water vapor in the atmosphere (also going up). In the region that spawned Haiyan—probably the most powerful typhoon to make landfall in modern times—the "Tropical Cyclone Heat Potential" has gone up more than 20% since 1990.

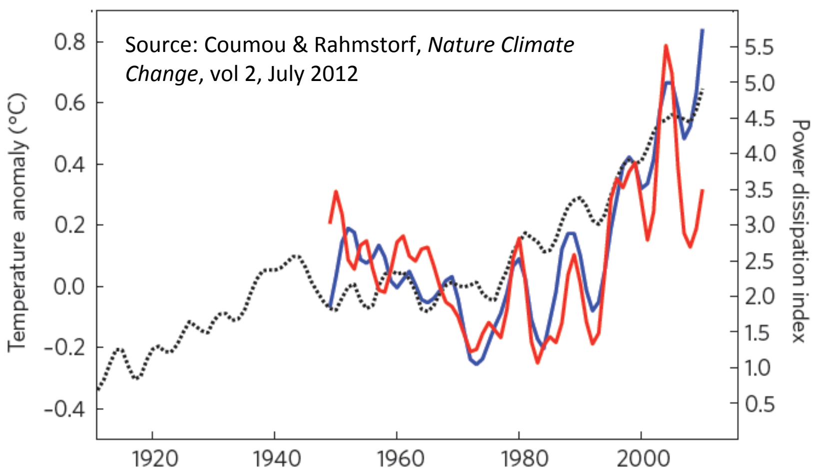




Heated situation. Over 2 decades, a thickening layer of warm water (red) increased the storm-driving heat potential (blue) at the latitudes Haiyan traversed.

Many factors affect the formation and tracks of these storms, but, all else equal, a given cyclone will be more powerful in the presence of a warmer ocean and higher atmospheric water content than it would be otherwise. And the higher local sea level is, the worse the storm surge from any given cyclone will be. Haiyan killed 6,000 people, injured 27,000, and destroyed or damaged 1.2 million homes.

Hurricane power is correlated with sea-surface & air temperatures in the N Atlantic as well

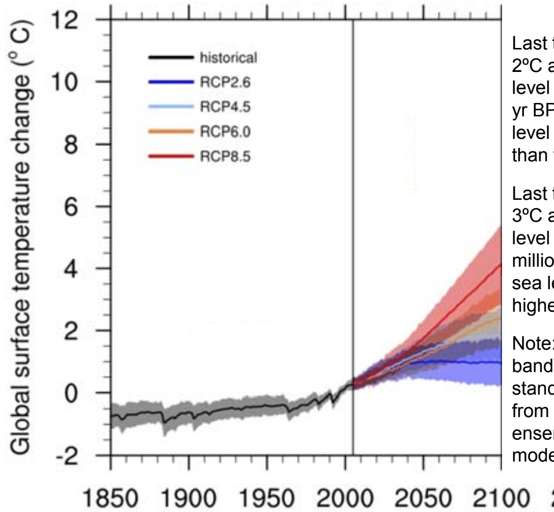


Red line is power dissipation index for N Atlantic hurricanes. Blue line is sea-surface temperature in main development region for these storms. Dotted line is evolution of Northern Hemisphere mean temperature. All data are 6-year running averages.

Something else important that we know is that…

Climate change & its impacts will continue to grow.

Global temperature increases under all IPCC scenarios. It grows for decades because of the long life-time of CO_2 in the atmosphere and the long lag time for the ocean to come into equilibrium with the altered energy balance of the atmosphere.



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

Last time T was 3°C 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

Under the higher emission scenarios, temperatures increase for centuries.

The most worrying recent & emerging insights about future impacts involve…

- Impacts of climate change on human health: heat stress, smog intensity, allergies, pathogens & vectors
- Growing extremes of wet & dry: downpours/floods, droughts, wildfires (T, dryness, pests, lightning)
- Impacts on the coastal zone from the combination of sea-level rise and increasingly powerful storms
- Impacts of rapid climate change in the Arctic both inside and outside the region, including coastal erosion, permafrost melting & methane release, N Hemisphere extreme weather
- Impacts of ocean heating & acidification on marine food webs and commercial & subsistence fisheries

Extremes of heat will become much more prevalent

NATURE CLIMATE CHANGE | VOL 5 | JANUARY 2015 | www.nature.com/natureclimatechange

Dramatically increasing chance of extremely hot summers since the 2003 European heatwave

Nikolaos Christidis*, Gareth S. Jones and Peter A. Stott

NATURE CLIMATE CHANGE | VOL 4 | DECEMBER 2014 | www.nature.com/natureclimatechange

Rapid increase in the risk of extreme summer heat in Eastern China

Ying Sun[1], Xuebin Zhang[2]*, Francis W. Zwiers[3], Lianchun Song[1], Hui Wan[2], Ting Hu[1], Hong Yin[1] and Guoyu Ren[1]

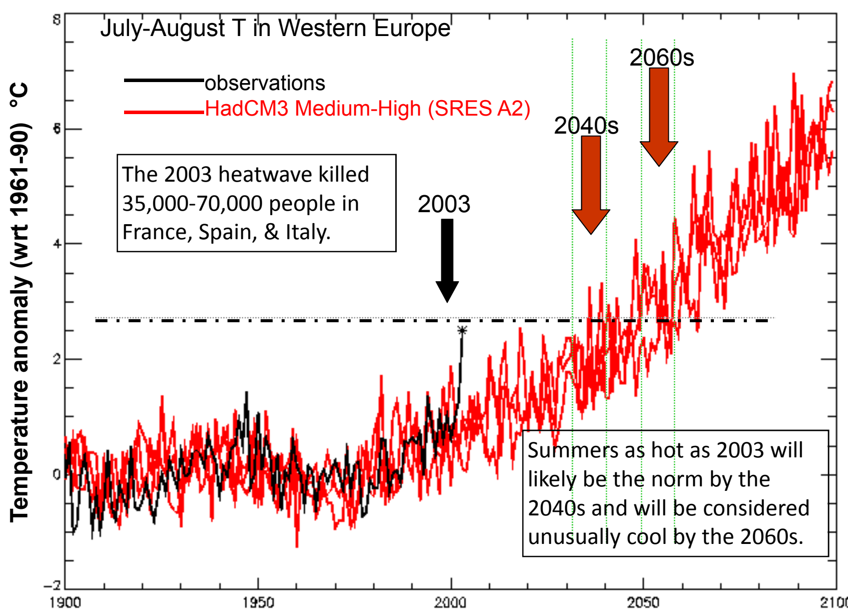
NATURE CLIMATE CHANGE | VOL 5 | JULY 2015 | www.nature.com/natureclimatechange

Future population exposure to US heat extremes

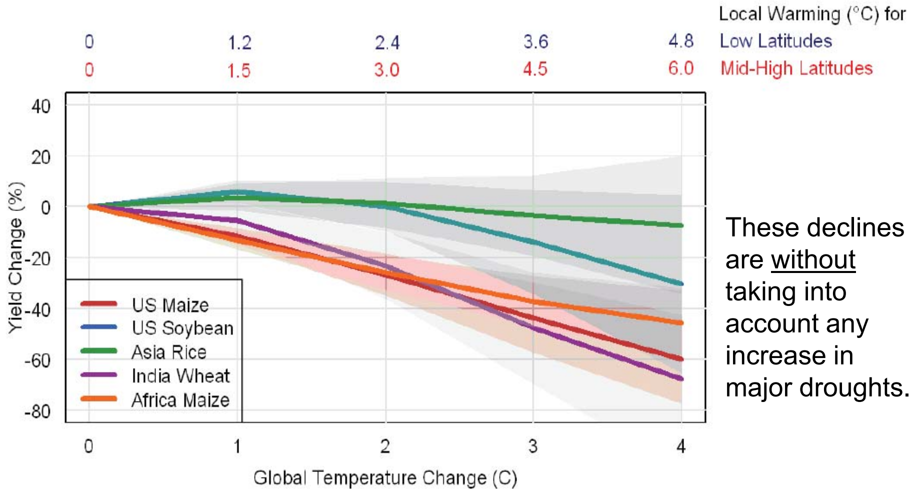
Bryan Jones[1]*, Brian C. O'Neill[2], Larry McDaniel[3], Seth McGinnis[3], Linda O. Mearns[3] and Claudia Tebaldi[2]

Concerning impacts on health

Under BAU, severe heat waves multiply



Yields of staple crops decline with warming.

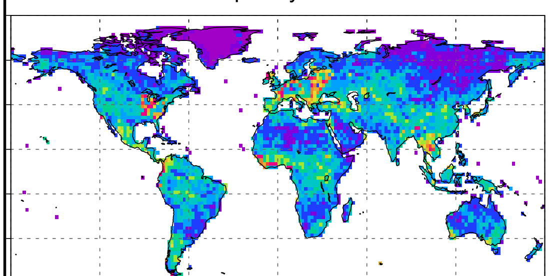


These declines are <u>without</u> taking into account any increase in major droughts.

National Academies, Stabilization Targets, 2010

Multiplying droughts are expected to make it worse.

Frequency of 4-6 month duration droughts (events per 30 years)

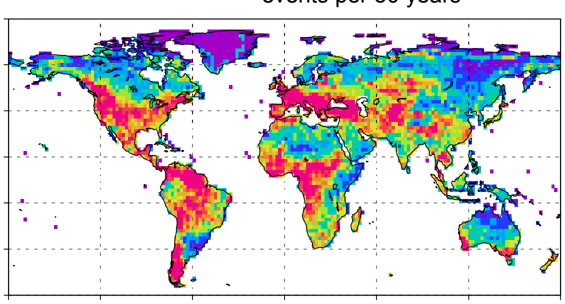


1961-1990

Drought defined as soil moisture below historical 10th percentile value for that calendar month.

events per 30 years

Results shown are the mean of 8 global climate models

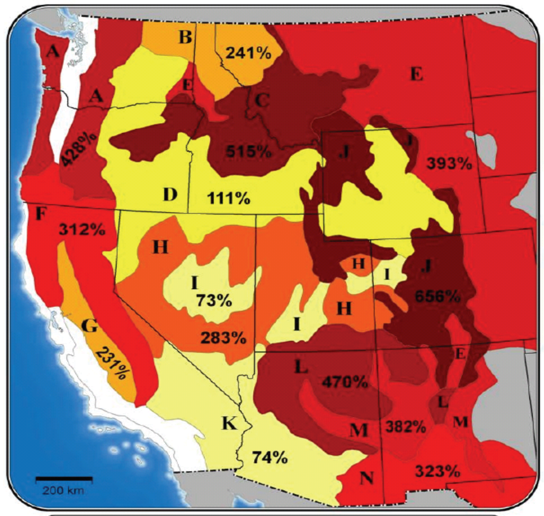


2070-2099, IPCC A2 scenario

Source: Sheffield and Wood 2008 Climate Dynamics (2008) 31:79–105
DOI 10.1007/s00382-007-0340-z

Area burned by wildfires, already up substantially, is destined to go up much more.

Percentage increases shown in median annual area burned are for a 1°C rise in global average temperature, referenced to 1950-2003 averages.



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

National Academies, Stabilization Targets, 2010

Severe storms are expected to multiply

PNAS | October 8, 2013 | vol. 110 | no. 41 | 16361–16366

Robust increases in severe thunderstorm environments in response to greenhouse forcing

Noah S. Diffenbaugh[a,1], Martin Scherer[a], and Robert J. Trapp[b]

SCIENCE 14 NOVEMBER 2014 • VOL 346 ISSUE 6211 851

Projected increase in lightning strikes in the United States due to global warming

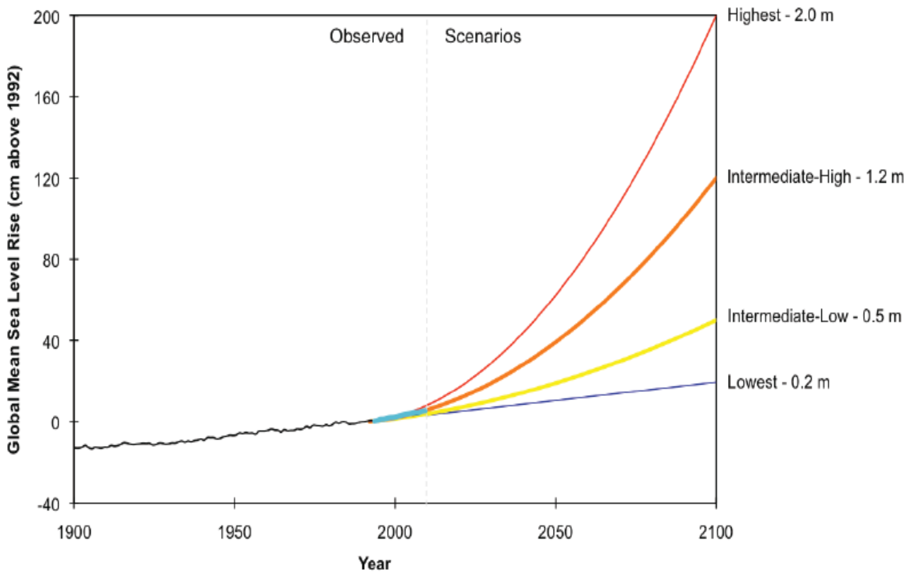
David M. Romps,[1*] Jacob T. Seeley,[1] David Vollaro,[2] John Molinari[2]

12610–12615 | PNAS | October 13, 2015 | vol. 112 | no. 41

Increased threat of tropical cyclones and coastal flooding to New York City during the anthropogenic era

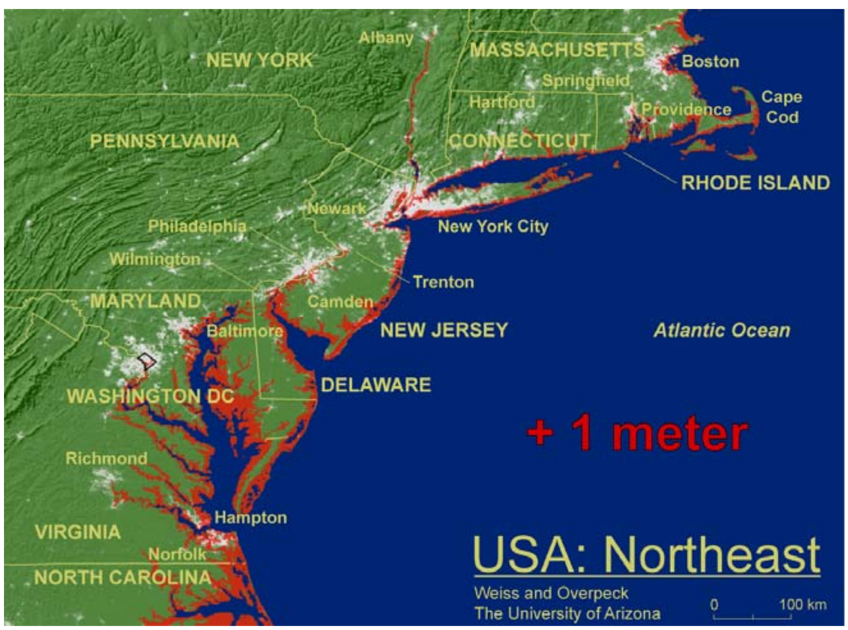
Andra J. Reed[a,1], Michael E. Mann[a,b], Kerry A. Emanuel[c], Ning Lin[d], Benjamin P. Horton[e,f], Andrew C. Kemp[g], and Jeffrey P. Donnelly[h]

Sea level could rise 1-2 meters from 2000 to 2100.



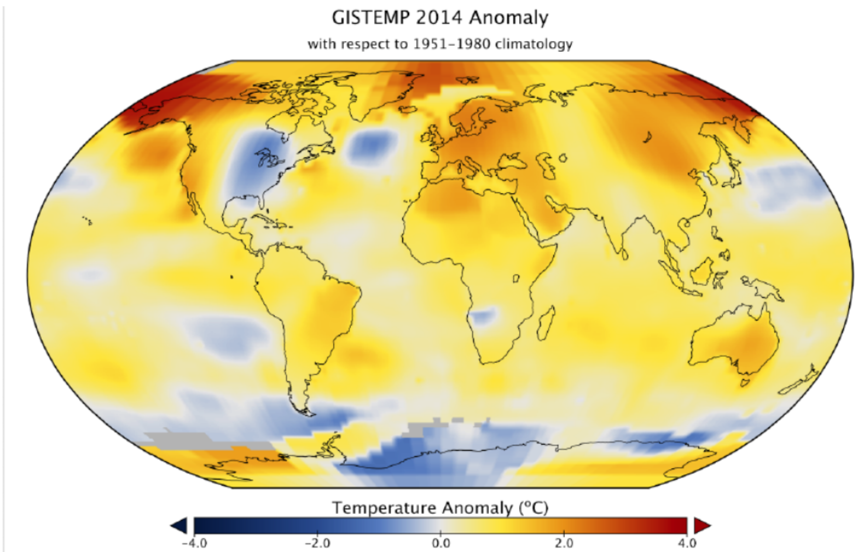
NOAA OAR CPO-1, December 2012

Sea level: Flooded area with 1 meter rise



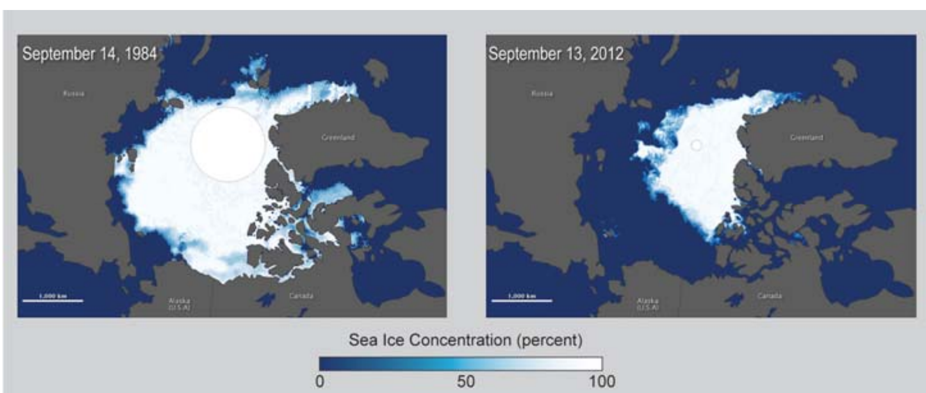
Rapid climate change in the Arctic

Arctic temperatures are changing 2-4x faster than the global average.



NASA, 2015

Arctic sea ice is shrinking



GlobalChange.gov
U.S. Global Change Research Program

Coastal erosion is imperiling settlements.

Courtesy Gary Braasch

Permafrost is thawing

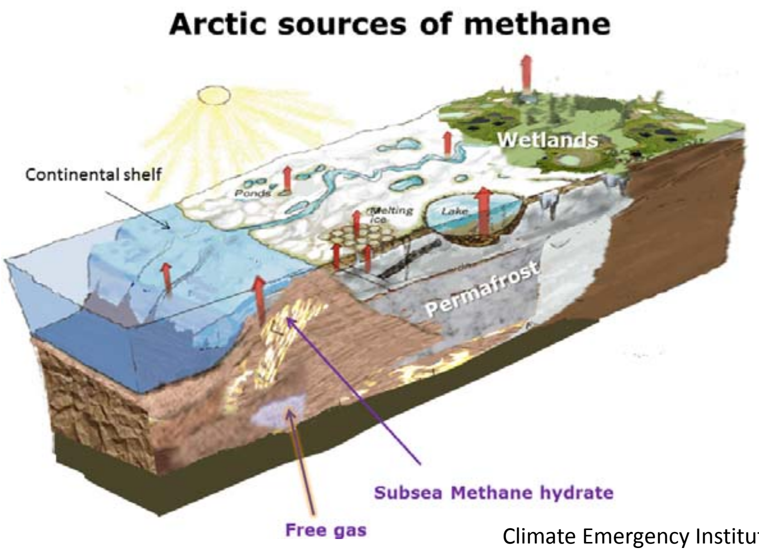
Norwegian Polar Institute, 2009

Vast tracts of the Arctic are burning

Bogus Creek fire, near Aniak, Alaska, June 2015

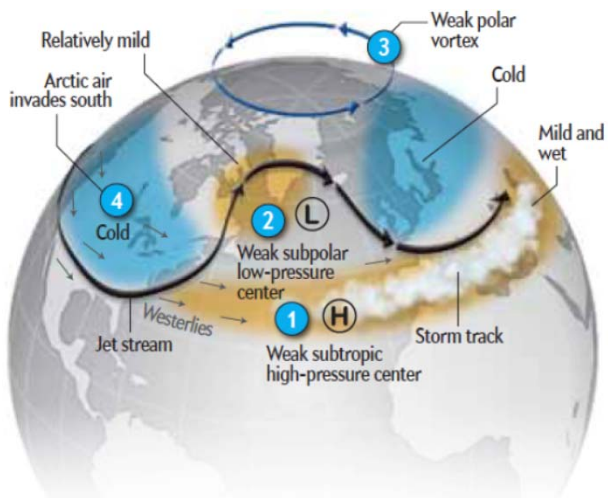
Courtesy of Nicky Sundt, WWFUS. Photo by Matt Snyder, Alaska Division of Forestry.

Release of methane from the warming Arctic risks acceleration of warming globally.



Climate Emergency Institute, 2015

A weakened polar vortex and wavier jet stream are affecting mid-latitude weather.

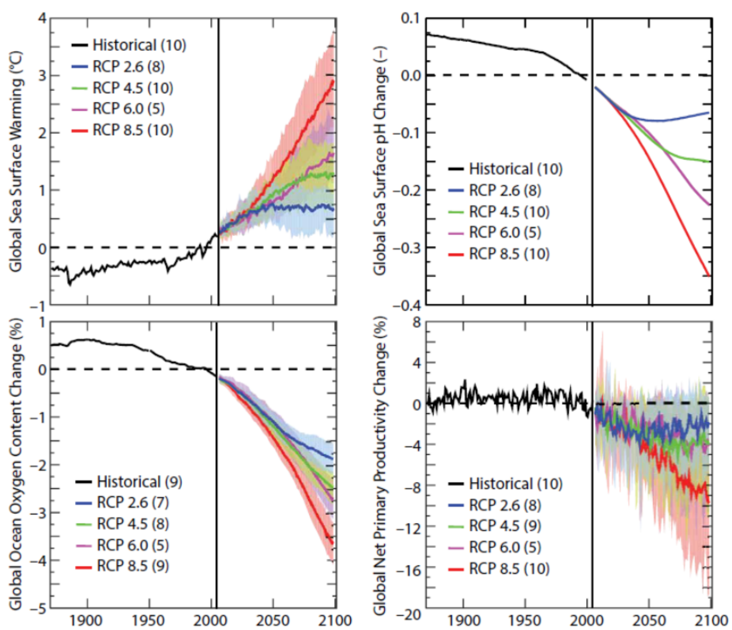


The collision of cold Arctic air with the moisture-laden air over a warmed Atlantic was responsible for the extreme snowfall in the Northeast last winter.

Graphic by XNR Productions

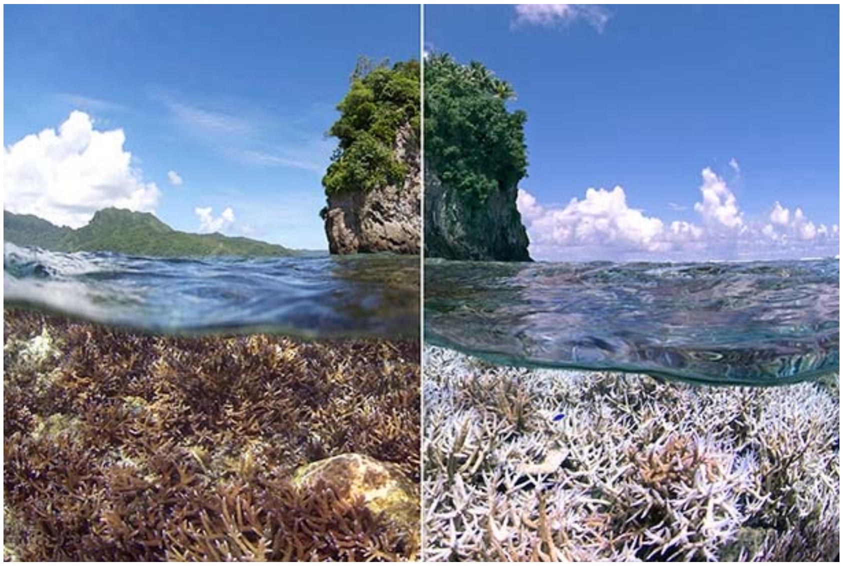
Scientific American blog, January 2014

Oceans: A warming world challenges productivity.



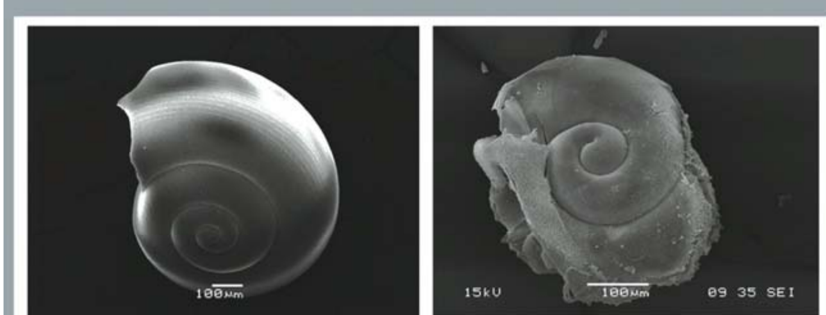
Doney et al, Oceanography March 2014

Warming waters → coral bleaching



Western Samoa, December 2014 left, February 2015 right (NOAA)

Acidification → hard times for critters with shells



Pteropods, or "sea butterflies," are eaten by a variety of marine species ranging from tiny krill to salmon to whales. The photos show what happens to a pteropod's shell in seawater that is too acidic. On the left is a shell from a live pteropod from a region in the Southern Ocean where acidity is not too high. The shell on the right is from a pteropod in a region where the water is more acidic. (Figure source: (left) Bednaršek et al. 2012[e] (right) Nina Bednaršek).

NCA Highlights 2014

The future of corals in an acidifying ocean

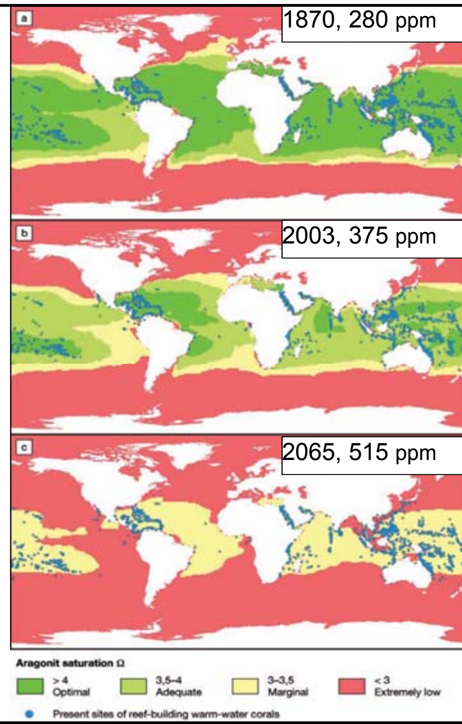
Widespread adverse effects of acidification were already being observed in the early 2000s.

The expanding yellow and red ocean areas are marginal and unsuitable, respectively, for supporting coral reefs.

Blue denotes current areas of reef-building warm-water corals.

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

Steffen et al., 2004



Commercial & subsistence fisheries are at risk

Sciencexpress / sciencemag.org/content/early/recent / 29 October 2015

Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery

Andrew J. Pershing,[1*] Michael A. Alexander,[2] Christina M. Hernandez,[1†] Lisa A. Kerr,[1] Arnault Le Bris,[1] Katherine E. Mills,[1] Janet A. Nye,[3] Nicholas R. Record,[4] Hillary A. Scannell,[1,5‡] James D. Scott,[2,6] Graham D. Sherwood,[1] Andrew C. Thomas[5]

PNAS | **September 1, 2015** | vol. 112 | no. 35 | **10823–10824**

Shifting patterns in Pacific climate, West Coast salmon survival rates, and increased volatility in ecosystem services

Nathan J. Mantua[1]

Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Santa Cruz, CA 95060

What We Can Do

Policy options: What are our choices?

There are only three:

- 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 and societal disruption that are not avoided by either mitigation or adaptation.

Concerning the three…

- 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…

- Developing heat-, drought-, and salt-resistant crop varieties
- Strengthening public-health & environmental-engineering defenses against tropical diseases
- Preserving & enhancing "green infrastructure" (ecosystem features that protect against extremes)
- Preparing hospitals & transportation systems for heat waves, power outages, & high water.
- 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.

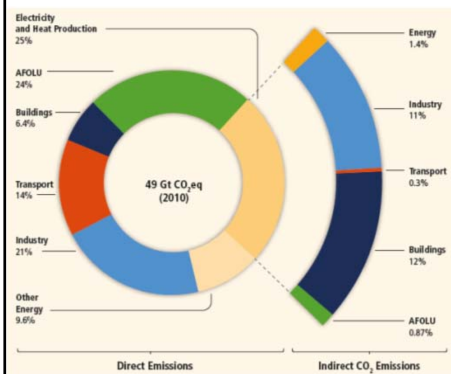
How much mitigation, how soon?

- Limiting ΔT_{avg} to ≤2ºC 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, UNFCCC in 2010
- To have a >50% chance of staying below 2ºC:
  - atmospheric concentration of heat-trapping substances must stabilize at around 450 ppm CO_2 equivalent (CO_2e);
  - 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;
  - global emissions in 2050 must be <half of those in 2005.

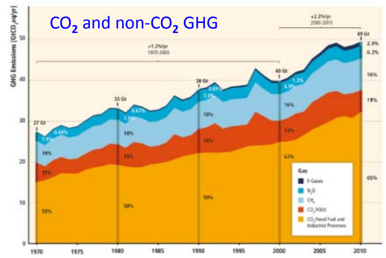
Mitigation: Everybody must play.

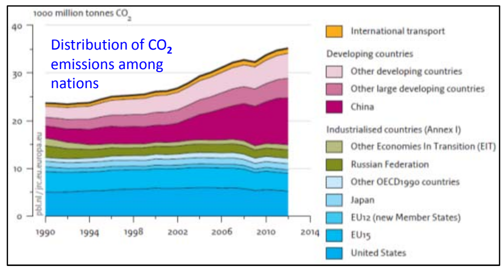
Adequate mitigation will require addressing most heat-trapping substances across most emitting sectors in most countries.

Sectoral sources of global GHG emissions



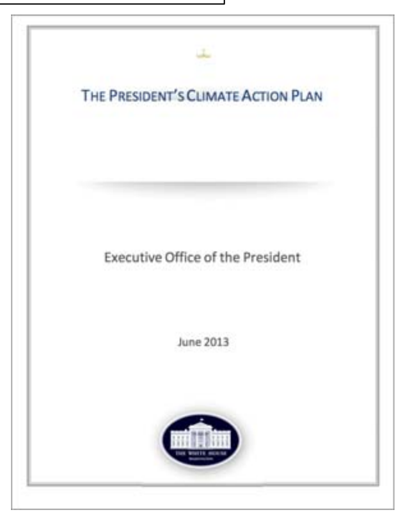
CO_2 and non-CO_2 GHG





Choosing action: President Obama's Plan

Georgetown University, June 2013



- Cutting carbon pollution in America (mitigation)
- Preparing the United States for the impacts of climate change (adaptation)
- Leading international efforts to address climate change

http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

How science shaped the CAP

The key understandings from climate science provided:

- the motivation for seeking to develop a cost-effective plan to reduce those impacts;
- the sense of urgency for doing so now rather than waiting;
- the awareness that such a plan must include both mitigation and adaptation;
- the knowledge of the sources of the offending emissions and the character of society's vulnerabilities to provide appropriate specificity in designing a plan; and
- the recognition that any U.S. plan must include a component designed to bring other countries along.

Principal ingredients of the CAP: Mitigation

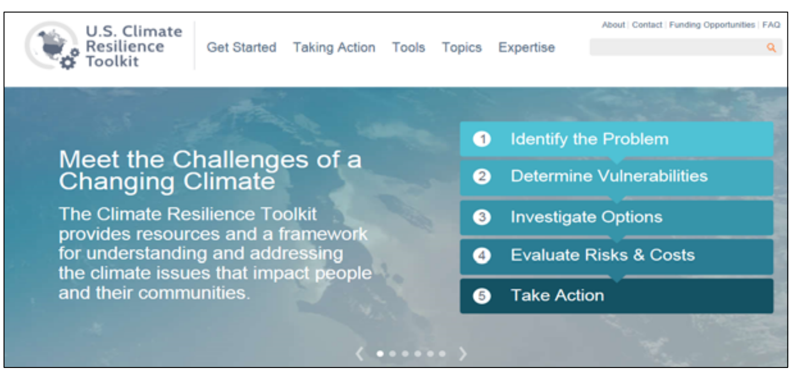
- Reducing carbon pollution from power plants
  - standards for cutting CO_2 from new power plants (Sept 2013)
  - and from existing power plants (June 2014)
- Reducing other greenhouse gases
  - interagency strategy to reduce methane emissions (March 2014)
  - EPA proposal on hydrofluorocarbons (July 2014)
  - 2025 target to reduce methane emissions form the oil and gas sector by 40-45% from 2012 levels along with various actions to reduce methane emissions going forward, including EPA regulation (January 2015)
- Accelerating U.S. leadership on clean energy
- Doubling down on energy end-use efficiency
- Building a 21st-century energy infrastructure

Principal ingredients of the CAP: Adaptation

- Directing agencies to support climate preparedness/resilience
  - All agencies to develop & implement plans for integrating climate preparedness/resilience into their missions, policies, programs, investments, and grants. (Plans released 10-14.)
- Establishing internal & external task forces on resilience
  - Interagency Council on Climate-Change Preparedness & Resilience (~30 Federal agencies); established (11-13)
  - State, Local, & Tribal Leaders Task Force on Climate Preparedness & Resilience (26 elected officials from across the country; delivered recommendations to the Administration 11-14.)
- Managing flood, drought, and wildfire risks
  - Drought Resilience Partnership (11-13); USDA Agriculture Hubs (2-14); USDA/DOI Wildland Fire Strategy (4-14); HUD Urban Resilience Competition (6-14); Flood Risk Standard (1-15).

Ingredients of the CAP: Adaptation (continued)

- Mobilizing science and data for climate resilience
  - —Climate Data Initiative (03-14)
  - —3rd U.S. National Climate Assessment (05-14)
  - —U.S. Climate Resilience Toolkit (11-14)



toolkit.climate.gov

Ingredients of the CAP: International

- Enhancing bilateral engagement
  - — U.S-China Joint Announcement in Nov. 2014 (with national targets, new joint research & demonstration projects)
  - —Engagement with Mexico, Brazil, India, Indonesia to encourage their INDCs.
- Enhancing multilateral engagement
  - — **G-20:** Agreement to phase out fossil-fuel subsidies and to develop a methodology for a voluntary peer-review process (09-13).
  - — **UN:** Pursuit of strong agreement in Paris in December 2015; commitments & partnerships on international assistance for preparedness/resilience (09-14).
- Mobilizing clean-energy and preparedness finance
  - —$3B US contribution to Green Climate Fund; US-German Global Innovation Lab for Climate Finance

The path forward in the United States

- Defend the requests for clean-energy RD^3 and for Earth observation in the President's FY16 Budget.
- Finalize EPA's Power Plant Rules.
- Improve the coverage, usability, and user base of the Climate Data Initiative and Climate Resilience Toolkit
- Strengthen partnerships across Federal-state-local governments, private sector, civil society
- Implement the President's Climate Education and Literacy Initiative to ensure continuing public support for all of the above.
- Elect a President in 2016 who will continue and build on President Obama's climate-change program.

The path forward internationally

- Build the public-private-global partnership for boosting resilience in developing countries announced at the 09-14 UN Climate Summit.
- Continue to push toward a comprehensive, equitable, forward-leaning climate agreement in Paris.
- Begin to plan for the challenges of the steep declines in global emissions that will be needed after 2030.
- To that end, substantially ramp up global research, development & demonstration of the improved and new clean-energy technologies that such cuts will require.

EXECUTIVE OFFICE OF THE PRESIDENT OF THE UNITED STATES
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

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