

Climate Science and Public Policy From (pre) 1965 to (post) 2015

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Coverage of these remarks

- Context for the 1965 PSAC report to President Johnson: a selective chronology* of major...
 - advances in climate science
 - **skeptical & contrarian counterpoints**
 - **reports for political leaders by official bodies**
- The key scientific understandings that underpin President Obama's Climate Action Plan
- A look ahead: What recent and emerging scientific insights will most influence public perceptions and policy decisions going forward?

*with a major debt to the remarkable history compiled by Dr. Spencer Weart on the AIP website,
<https://www.aip.org/history/climate/index.htm>

Chronology

Earliest understandings of heat trapping by the atmosphere

1824: Joseph Fourier deduces that Earth's surface would be colder in the absence of an atmosphere.

"Remarques Générales sur les Températures Du Globe Terrestre et des Espaces Planétaires." *Annales de Chemie et de Physique* **27**: 136-67.

1861: John Tyndall discovers that water vapor, CO₂, and CH₄ trap heat, while O₂ and N₂ do not.

"On the Absorption and Radiation of Heat by Gases and Vapours..."
Philosophical Magazine **ser. 4, 22**: 169-94, 273-85

1896: Svante Arrhenius estimates that a doubling of atmospheric CO₂ will raise surface T by 5°C.

"On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground." *Philosophical Magazine* **41**: 237-76

Climate science 1900-1950

1900: Knut Ångström argues that atmospheric CO₂ changes will have negligible effect.

"Über die Bedeutung des Wasserdampfes und der Kohlensäures bei der Absorption der Erdatmosphäre." *Annalen der Physik* 4(3): 720-32.

1920s: Anecdotal observations of warming temperatures appear in professional & popular media.

e.g., C.E.P. Brooks, "A Period of Warm Winters in Europe." *Meteorological Magazine*, June 1922, pp. 203-05; C.E.P. Brooks, "The Problem of Mild Polar Climates." *Quarterly J. Royal Meteorological Society* 51: 83-94, 1925.

1938: G.S. Callendar concludes that atmospheric CO₂ increased 10% in preceding 100 years, potentially explaining the observed warming.

"The Artificial Production of Carbon Dioxide and Its Influence on Climate." *Quarterly J. Royal Meteorological Society* 64: 223-40.

Climate science 1900-1950 (continued)

1900-1950: It's widely assumed in the science community, that uptake by ocean & biosphere will prevent atmospheric CO₂ buildup (and, after Callendar's report of an increase, that he is mistaken).

e.g., Alfred J. Lotka, *Elements of Physical Biology*, Baltimore, Williams & Wilkins, 1924 (reprinted as *Elements of Mathematical Biology*, NY, Dover, 1956); G. N. Hutchinson, "Circular Causal Systems in Ecology", *Annals of the New York Academy of Sciences* 50: 221-46, 1948.

It's also widely believed in this period, again contrary to Callendar, that even if CO₂ did increase there would be no effect on temperature because the relevant infrared absorption bands are saturated.

e.g., Richard J. Russell, "Climatic Change through the Ages." In *Climate and Man. Yearbook of Agriculture*, U.S. Department of Agriculture, 1941.

Climate science 1951-65

1956: Gilbert N. Plass shows, with a simple multi-layer calculation, that saturation argument is wrong and CO₂ increases do affect Earth's energy balance.

"Effect of Carbon Dioxide Variations on Climate", *American J. Physics* **24**: 376-87

1957: Roger Revelle shows ocean uptake of CO₂ added to the atmosphere is much slower than thought before.

e.g., with Hans E. Suess, "Carbon Dioxide Exchange between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO₂ During the Past Decades", *Tellus* **9**: 18-27.

1957: A National Academy of Sciences (NAS) report to the Chief of the U.S. Weather Bureau says that "In consuming our fossil fuels at a prodigious rate, our civilization is conducting a grandiose scientific experiment."

Committee on Climatology (T.F. Malone, chair), *First General Report on Climatology to the Chief of the Weather Bureau*.

Climate science 1951-65 (continued)

1958: Charles David Keeling begins definitive time series of atmospheric CO₂ measurements.

"The Concentration and Isotopic Abundances of Carbon Dioxide in the Atmosphere", *Tellus* **12**: 200-203, 1960.

1963: Conservation Foundation report (with Keeling & Plass among authors) says CO₂ doubling will lead to 4°C temperature rise, with serious impacts.

Implications of Rising Carbon Dioxide Content of the Atmosphere. New York: Conservation Foundation

1965: Edward Lorenz demonstrates chaotic character of weather system and hints at potential for abrupt climate change.

"Lorenz, Edward N. (1965). "A Study of the Predictability of a 28-Variable Atmospheric Model." *Tellus* **17**: 321-333.

The 1965 PSAC report to President Johnson

- The President's Science Advisory Committee under President Lyndon Johnson (chaired by the President's Science Advisor, Dr. Donald Hornig) addresses climate change in the 1965 report of its Environmental Pollution Panel.
- The panel, chaired by statistics expert John W. Tukey, has a CO₂ sub-panel chaired by Roger Revelle and including Dave Keeling.
- Their report concludes that there could be "marked changes in climate, not controllable through local or even national efforts."
- But it gives greater attention to other pollution problems judged to have greater urgency.

Climate science 1966-88

1966: Work on deep-sea sediments by Cesare Emiliani and on deep-sea corals by Wallace Broecker indicates ice ages were caused by orbital variations, showing that large changes can result from small perturbations.

W. Broecker, "Absolute Dating and the Astronomical Theory of Glaciation", *Science* **151**: 299-304, 1966; C. Emiliani, "Paleotemperature Analysis of Caribbean Cores... And a Generalized Temperature Curve for the Past 425,000 Years." *J. Geology* **74**: 109-125, 1966.

1966: An NAS report requested by the government finds that "We are just now beginning to realize that the atmosphere is not a dump of unlimited capacity, but we do not yet know what the atmosphere's capacity is." The report calls for more research (as NAS reports do).

Committee on Atmospheric Sciences Panel on Weather and Climate Modification. *Weather and Climate Modification: Problems and Prospects*.

Climate science 1966-88 (continued)

1970-71: Successive multi-expert, international summer studies (SCEP, MIT, 1970; SMIC, Stockholm, 1971) fail to reach consensus on whether CO₂-induced warming or particulate-induced cooling will prevail in the long run.

Man's Impact on the Global Environment, Study of Critical Environmental Problems, MIT Press, 1970; *Inadvertent Climate Modification*, Study of Man's Impact on Climate, MIT Press, 1971.

1975-76: V. Ramanathan and others show that CFCs, methane, nitrous oxide, and ozone are significant greenhouse gases. Ramanathan calls attention to ice-albedo feedback → differential warming of Arctic.

V. Ramanathan "Greenhouse Effect Due to Chlorofluorocarbons: Climatic Implications" *Science* **190**: 50-52, 1975; W. Wang *et al.* "Greenhouse Effects Due to Man-Made Perturbations of Trace Gases." *Science* **194**: 685-90, 1976.

Climate science 1966-88 (continued)

1976-77: George Woodwell, Richard (Skee) Houghton, and Bert Bolin point to deforestation and other land-use change as additional major sources of anthropogenic greenhouse gases.

G. Woodwell and R. Houghton, "Biotic Influences on the World Carbon Budget", in *Global Chemical Cycles and Their Alterations by Man (Report of Dahlem Workshop, Nov. 1976)*, 1977, pp. 61-72; B. Bolin, "Changes of Land Biota and Their Importance for the Carbon Cycle", *Science* **196**: 613-15, 1977.

1977: An NAS report, reflecting growing scientific consensus that warming by GHGs will dominate cooling by particles, warns of "potentially catastrophic" T increases in the next century or two.

National Academy of Sciences, Geophysics Research Board, *Energy and Climate: Studies in Geophysics*.

1978: Drawing on work by J. Hollin dating back to 1962, John Mercer builds case for warming-induced collapse of West Antarctic Ice Sheet, entraining 5 m of sea-level rise.

"West Antarctic Ice Sheet and CO₂ Greenhouse Effect: A Threat of Disaster." *Nature* **271**: 321-2

1979: The “Charney Report”

- Amid controversy over widely different estimates of the temperature increase to be expected from a CO₂ doubling, President Carter’s Science Advisor (geophysicist Frank Press) asks the NAS to study the question.
- A distinguished panel chaired by MIT professor Jule Charney uses the latest general-circulation models (GCMs) from two leading research groups, plus simpler models, to conclude that $\Delta T (2x CO_2) = 3^\circ C \pm 1.5^\circ C$.
- The Charney report also warns that the large heat capacity of the ocean means atmosphere takes decades to come to equilibrium with any given CO₂ concentration, noting that this delay in experiencing impacts may cause society to wait too long to act.

National Academy of Sciences, Climate Research Board (1979). *Carbon Dioxide and Climate: A Scientific Assessment* (Jule Charney, Chair). Washington, DC: National Academy of Sciences

Climate science 1966-88 (continued)

1980: An NAS report on a 5-year study of U.S. energy options pointed to the possibility of a CO₂ doubling by 2040 with a ΔT of 2-3°C, 3-4x more in the Arctic, and the possibility of "extensive and complex changes in precipitation patterns".

Committee on Nuclear & Alternative Energy Systems, *Energy in Transition 1985-2010*

1980-84: Climate scientist Sherwood Idso disputes mainstream consensus that CO₂-induced warming could be catastrophic and argues that CO₂ fertilization effect will “green” the Earth.

"The Climatological Significance of a Doubling of Earth's Atmospheric Carbon Dioxide Concentration." *Science* **207**: 1462-63, 1980; *Carbon Dioxide: Friend or Foe?*, IBR Press, 1982; "The Case for Carbon Dioxide." *J. Environmental Science*, May-June 1984, pp. 19-22.

1983: In the face of Reagan Administration and energy-industry skepticism, White House Office of Science and Technology (OST) commissions another NAS study, which finds “reason for concern, but not panic”.

Carbon Dioxide Assessment Committee, *Changing Climate*.

Climate science 1966-88 (continued)

1983: A more alarming report from EPA comes out a few days before the NAS one, stating that “substantial increases in global warming may occur sooner than most of us would like to believe” with potentially “catastrophic consequences”. Another EPA-issued report that year looks with alarm at sea-level rise.

Environmental Protection Agency, *Can We Delay a Greenhouse Warming?*;
J.S. Hoffman *et al.*, *Projecting Future Sea Level Rise. Report for the US Environmental Protection Agency*, US Government Printing Office.

1985: Analysis of air bubbles in the Vostok (Antarctic) ice core shows that CO₂ and air temperature rose and fell in synchrony through ice ages and interglacials, implying that strong biological and geochemical feedbacks amplified orbital perturbations.

Claude Lorius *et al.*, "A 150,000-Year Climatic Record from Antarctic Ice", *Nature* **316**: 591-96.

Climate science 1966-88 (continued)

1985-86: Ramanathan team concludes non-CO₂ GHGs will bring on warming 2x faster than CO₂ alone. Dickinson and Cicerone find ΔT could reach 5°C or more by 2050.

V. Ramanathan *et al.*, "Trace Gas Trends and Their Potential Role in Climate Change" *J. Geophysical Research* **90**: 5547-66, 1985; Robert Dickinson and Ralph Cicerone, "Future Global Warming from Atmospheric Trace Gases", *Nature* **319**: 109-15, 1986.

1988: James Hansen testifies on a hot summer day, backed by his NASA research group's analysis, that anthropogenic warming is now evident and that its projected continuation will lead to more frequent and/or powerful storms, floods, and heat waves.

J. Hansen, "The Greenhouse Effect: Impacts on Current Global Temperature and Regional Heat Waves", Testimony to U.S. Senate, Committee on Energy and Natural Resources, June 23, 1988; J. Hansen *et al.*, "Global Climate Changes as Forecast by Goddard Institute for Space Studies 3-Dimensional Model." *J. Geophysical Research* **93**: 9341-64, 1988.

Climate science 1989-2008

1989-90: Media and public interest following Hansen's testimony elicits an upwelling of contrarian reactions, arguing variously that

- satellite data call surface temperature measurements into question;
- the Arctic is cooling rather than warming;
- the computer models are flawed in ways that overstate ΔT from a CO_2 doubling;
- even the modeled ΔT 's would not be particularly harmful,
- big swings in Earth's temperature have occurred for millennia for natural reasons; and
- whatever warming has recently occurred was likely caused by changes in the sun's output.

Sherwood Idso, *Carbon Dioxide and Global Change*, IBR Press, 1989; F. Seitz *et al.*, *Scientific Perspectives on the Greenhouse Problem*, George C. Marshall Institute, 1989; Richard Lindzen, "Some Coolness Concerning Global Warming", *Bulletin of the American Meteorological Society* **71**: 288-299, 1990; Roy Spencer and John Christy, "Precise Monitoring of Global Temperature Trends from Satellites", *Science* **247**: 1558-62, 1990.

Climate science 1989-2008 (continued)

1990: First IPCC assessment concludes "the size of warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability."

Intergovernmental Panel on Climate Change, *The IPCC Scientific Assessment*

1991: New NAS report finds "Despite the great uncertainties, greenhouse warming is a potential threat sufficient to justify action now." Recommendations give equal weight to mitigation and adaptation.

National Academy of Sciences, *Policy Implications of Global Warming*

1992: Contributing to a new (post-1988) tradition that any high-profile report taking climate change seriously earns a major contrarian rebuttal, S. Fred Singer and cronies take on the 1990 IPCC report at book length.

S. Fred Singer, ed., *The Greenhouse Debate Continued: An Analysis and Critique of the IPCC Climate Assessment*, ICS Press.

Climate science 1989-2008 (continued)

1993-95: Studies of glacial retreat and ice cores from mountain glaciers in the tropics establish that warming observed in the late 20th century is real and without precedent in recent times.

Lonnie Thompson *et al.* "'Recent Warming': Ice Core Evidence from Tropical Ice Cores", *Global and Planetary Change* **7**: 145-56, 1993; J. Oerlemans, "Quantifying Global Warming from the Retreat of Glaciers", *Science* **264**: 243-45, 1994.

1995: Second IPCC Assessment concludes "The balance of evidence suggests a discernible human influence on global climate."

Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change*

1997: PCAST study for President Clinton on energy-technology innovation summarizes IPCC results, noting that responding to climate change is the most demanding driver of energy R&D.

President's Council of Advisors on Science and Technology, *Federal Energy Research and Development for the Challenges of the 21st Century*

Climate science 1989-2008 (continued)

2001: NAS, asked by President George W. Bush to review IPCC conclusions, endorses IPCC's treatment of the science and states flatly that "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise."

National Academy of Sciences, *Climate Change Science: An Analysis of Some Key Questions*.



Climate science 1989-2008 (continued)

2001: Third IPCC Assessment concludes "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities." Report also warns of "highly damaging future impacts" and "possible severe surprises".

IPCC, *Climate Change 2001: The Scientific Basis*

2005-6: Multiple studies show accelerating ice loss from Greenland, evidence of destabilization of West Antarctic Ice Sheet.

See, e.g., Richard Alley et al., "Ice-Sheet and Sea-Level Changes" *Science* **310**: 456-60, 2005; J. Chen, et al. "Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet." *Science* **313**: 1958-60, 2006

2006: Another NAS study rejects contrarian critiques of Michael Mann's "hockey stick" history of N hemisphere T change over the past millennium, finding that recent temperatures are likely unprecedented in that period.

National Academy of Sciences / National Research Council, National Research Council, *Surface Temperature Reconstructions for the Last 2,000 Years*.

Climate science 1989-2008 (continued)

2007: 4th IPCC Assessment finds that "Most of the observed increase in global average T since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations" and notes that serious impacts are now evident. Other findings include "very likely" continuing increases in extremely hot days, heat waves, and torrential rains; "likely" increases in intensity of tropical cyclones; and a certainty of continuing decreases in ocean pH.

IPCC, *Climate Change 2007: The Physical Science Basis*

2007-8: Evidence accumulates on pace of ice loss from land ice sheets and rate of sea-level rise.

See, e.g., Stefan Rahmstorf et al. "Recent Climate Observations Compared to Projections", *Science* **316**:709, 2007; Rahmstorf, "A Semi-Empirical Approach to Projecting Future Sea-Level Rise", *Science* **315**:368-70, 2007; Eric Rignot et al., "Recent Antarctic Ice Mass Loss from Radar Interferometry and Regional Climate Modelling", *Nature Geoscience* **1**: 106-10, 2008.

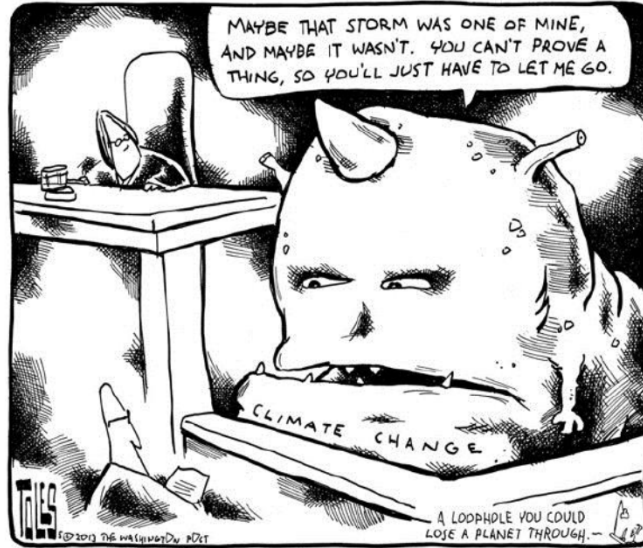
Climate science 2009-2015

- Release of the second National Climate Assessment (2009) and the third (2014) provide increasingly detailed, geographically & sectorally disaggregated information about ongoing and projected impacts of climate change in the United States.
- 2010 NAS report entitled "Climate Stabilization Targets" provides detailed portrayals of a wide range of expected U.S. and global impacts, as a function of emissions trajectories, on time frames of decades to millennia.
- Nov 2010 PCAST report for President Obama on accelerating pace of change in energy technologies states that "The best science suggests that dramatic reductions in CO₂ emissions need to start this decade in the industrialized world, and with little delay in the emerging economies as well, to mitigate the risk of major consequences."
- A 5-volume, Congressionally mandated NAS study of "America's Climate Choices" released in 2010 and 2011 surveys the science, mitigation and adaptation options, and decision-making.

Climate science 2009-2015 (continued)

- A **contrarian chorus that "global warming stopped in 1998"** is resoundingly refuted in the peer-reviewed literature: natural and human-influenced variability cause ups and downs in rate of T increase on time scales of years to decades, but every decade since the 1970s has been warmer than the last.
- Mar 2013 PCAST letter report for President Obama on strategy for addressing climate change in his 2nd term offers detailed recommendations, most of which end up in his Climate Action Plan.
- Oct 2013 5th IPCC assessment concludes that "It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century.
- Studies indicate that long-term sea-level rise commitment is 2+ m per °C of global T increase; big uncertainty is the rate.
- Analyses linking global climate change and more frequent and/or more intense weather-related extremes—downpours & snow blizzes, floods, heat waves, droughts, wildfires, powerful tropical storms—become increasingly robust.

Powerful storms are caused by the interaction of multiple factors, so one can't say climate change caused a particular one. But climate change is increasing the power of some of the strongest ones.



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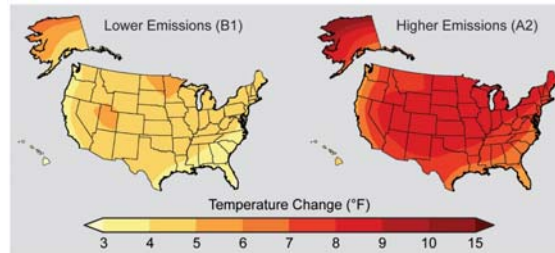
Key Scientific Understandings Underpinning President Obama's Climate Action Plan

Understandings underpinning the CAP

1. Earth's climate is changing at a pace and in a pattern that is not explainable by natural influences.
2. The dominant cause of the changes is an increase in the atmospheric concentrations of CO₂ and other heat-trapping gases, as well as black carbon, caused primarily by fossil-fuel burning and land-use change.
3. With global T about 0.9°C above pre-industrial, these changes are already causing significant harm to life, health, property, economies, and ecosystems.
4. The harm will continue to grow for decades—in the case of sea-level rise, centuries—because of long atmosphere → ocean and even longer atmosphere/ocean → ice equilibration times and because of inertia in society's energy system and land-use practices.

The science underpinning the CAP (continued)

5. The amount of future harm to be expected will be much smaller if we take prompt, strong, evasive action than if we don't.



Data are change in average air T from 1970-99 to 2070-99, under low and high global emissions. (NCA, 2014)

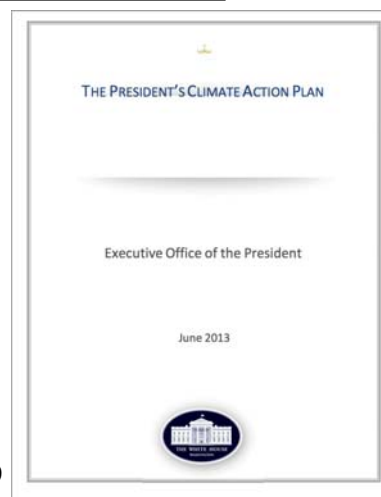
6. The cost of the needed evasive action is very likely to be much smaller than the cost to society from future change in the absence of the needed action. (This is true even without counting co-benefits of both mitigation and adaptation measures.)

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>

Further on 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 that allows appropriate specificity in designing a plan; and
- the recognition that any U.S. plan must include a component designed to bring other countries along.

The Recent & Emerging Science Insights Most Likely to Influence Public Perceptions & Policy Decisions Going Forward

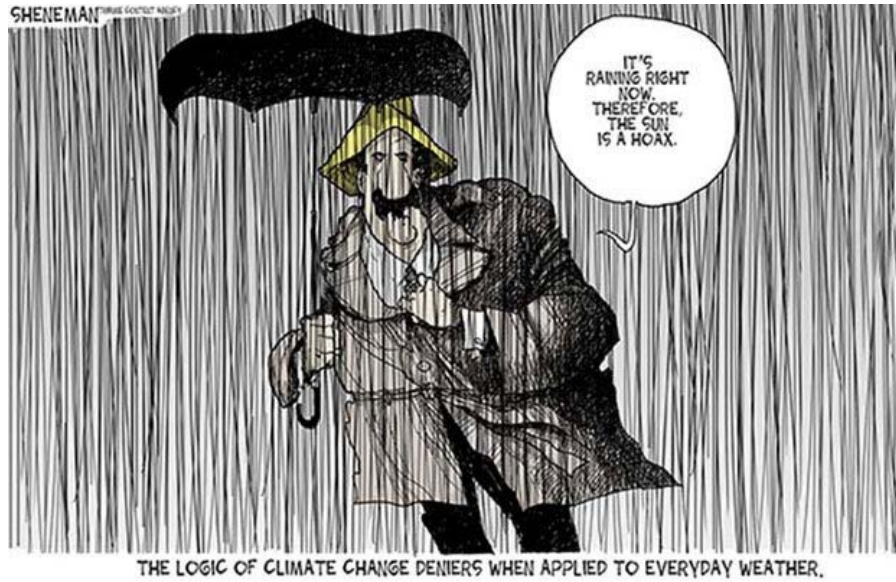
Influential recent/emerging insights

- Impacts of climate change on human health: heat stress, smog intensity, allergies, pathogens & vectors...
- Growing extremes of wet and dry: downpours/floods, droughts, wildfires (T, dryness, pests, lightning)
- Impacts outside the Arctic of accelerated climate change in the Arctic: N Hemisphere extreme weather; methane releases from tundra, permafrost, seabed
- Intersection of sea-level rise and increased storm intensity / storm surges
- Impacts of ocean heating & acidification on marine food webs and commercial & subsistence fisheries
- Other impacts on ecosystem dynamics: tropical forests, coral reefs, biodiversity/extinctions

The immediate path forward

- Defend the requests for clean-energy RD³, geosciences, and Earth observation in the President's FY16 Budget.
- Ensure EPA's Power Plant Rules are finalized.
- Improve the coverage, usability, and user base of the Climate Data Initiative and Climate Resilience Toolkit.
- Build the public-private-global partnership for boosting resilience in developing countries announced at the 09-14 UN Climate Summit.
- Maintain momentum toward a comprehensive, equitable, ambitious climate agreement in Paris.
- Implement the President's Climate Education and Literacy Initiative to ensure continuing public support for all of the above.

And miss no opportunity to rebut the contrarians!



<http://www.ostp.gov>