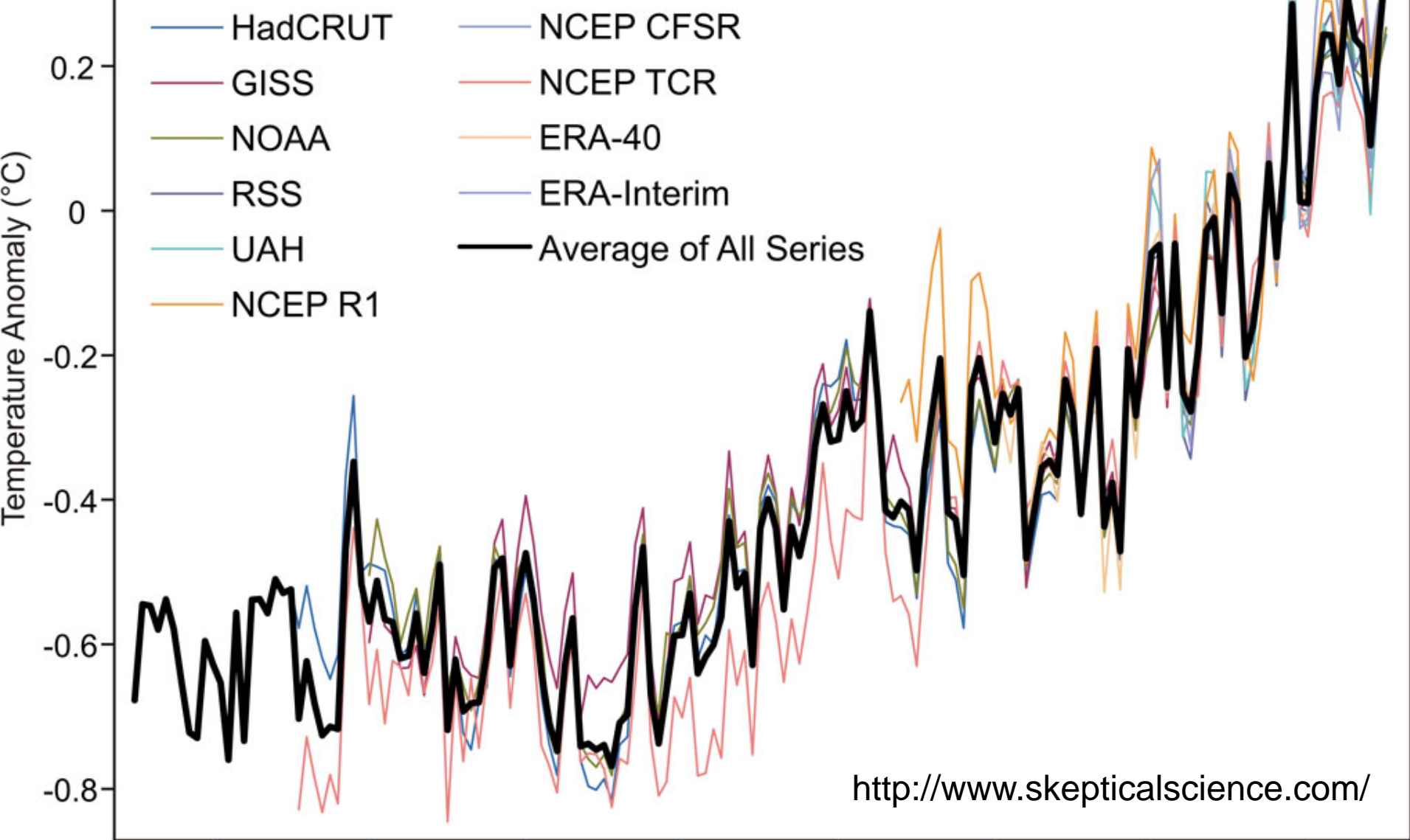


# Various Temperature Measurements

(1990-2000 Baseline)



<http://www.skepticalscience.com/>

# What Occam's razor teaches me about climate change

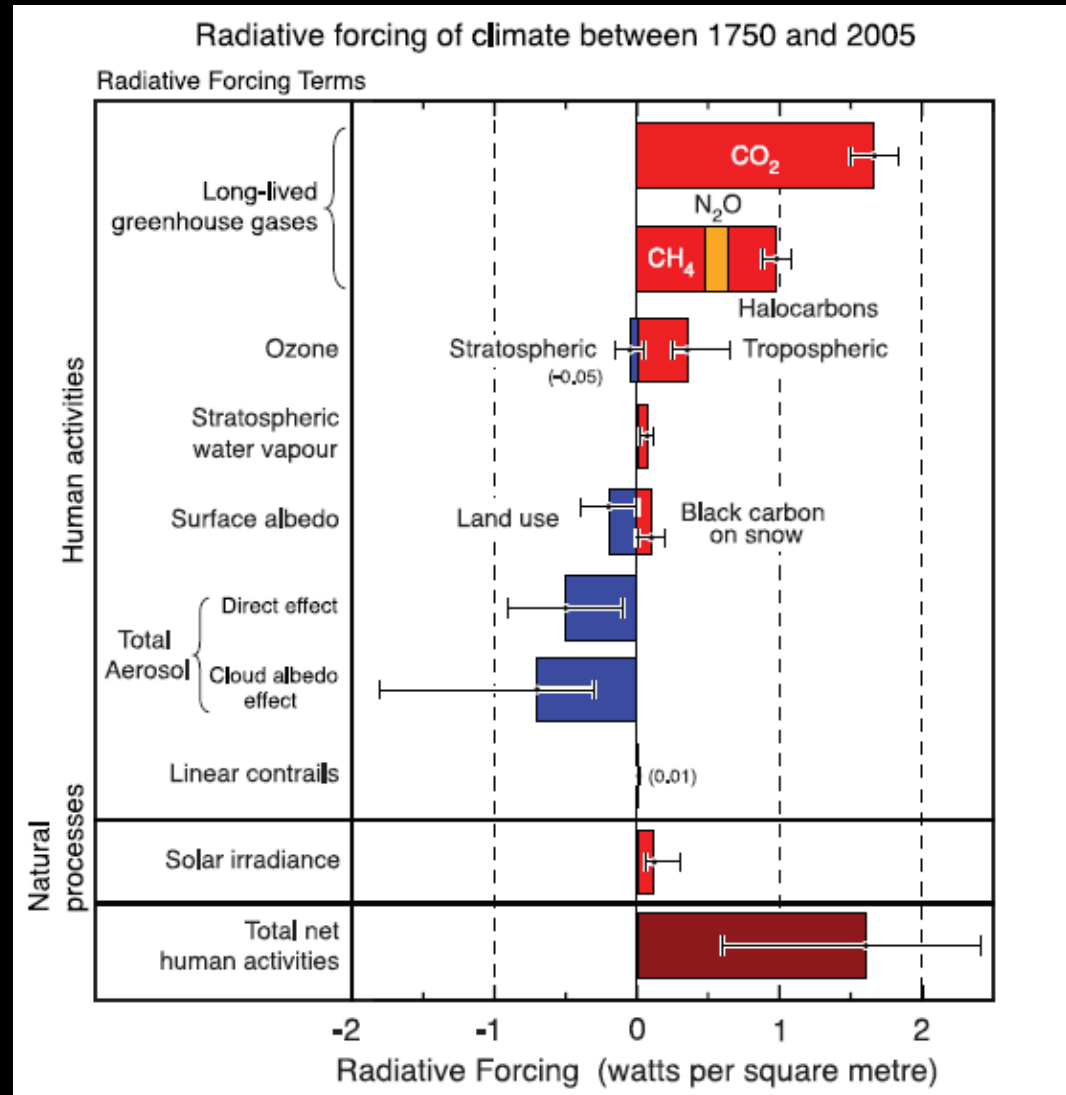
- “Law of succinctness”
- When multiple competing hypotheses are equal in other respects, choose the hypothesis that introduces the fewest assumptions

# What Occam's razor teaches me about climate change

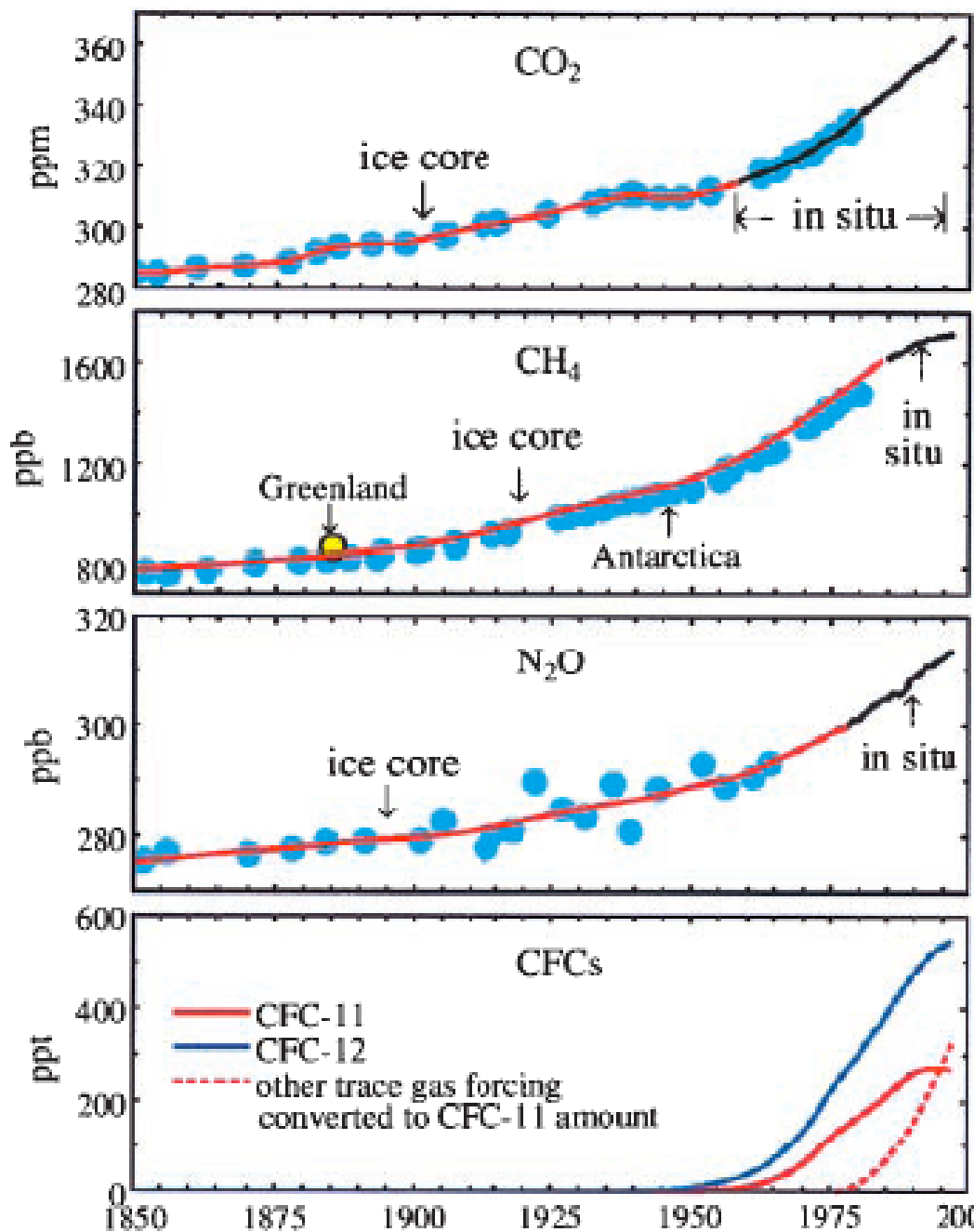
- The simplest model tends to be the right one
- CO<sub>2</sub> is a heat trapping gas
- If you put a heat trapping gas in the atmosphere you expect it to trap heat

# The basic science of the physical causes of the greenhouse effect is very well understood

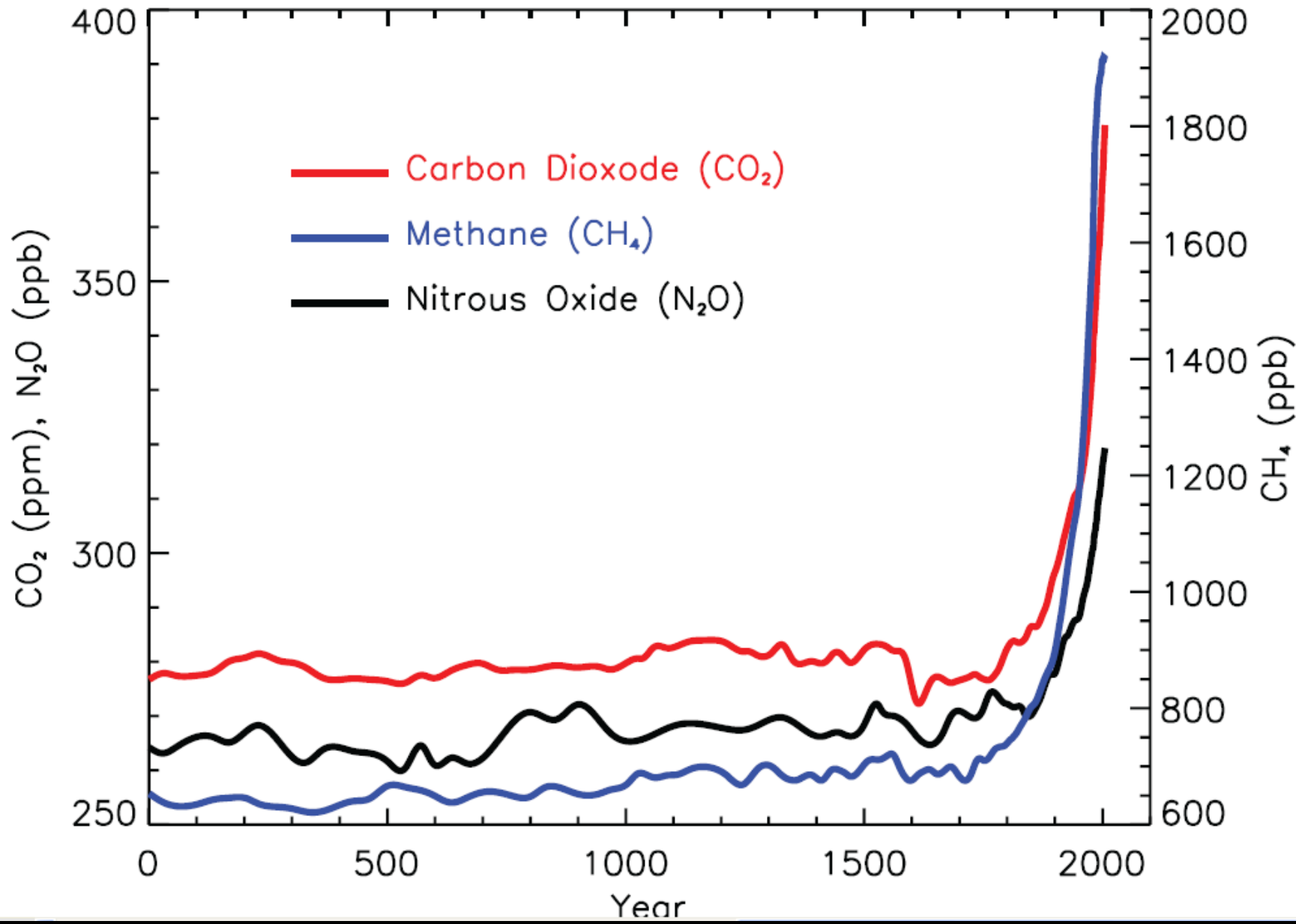
It is physics and physics is easy



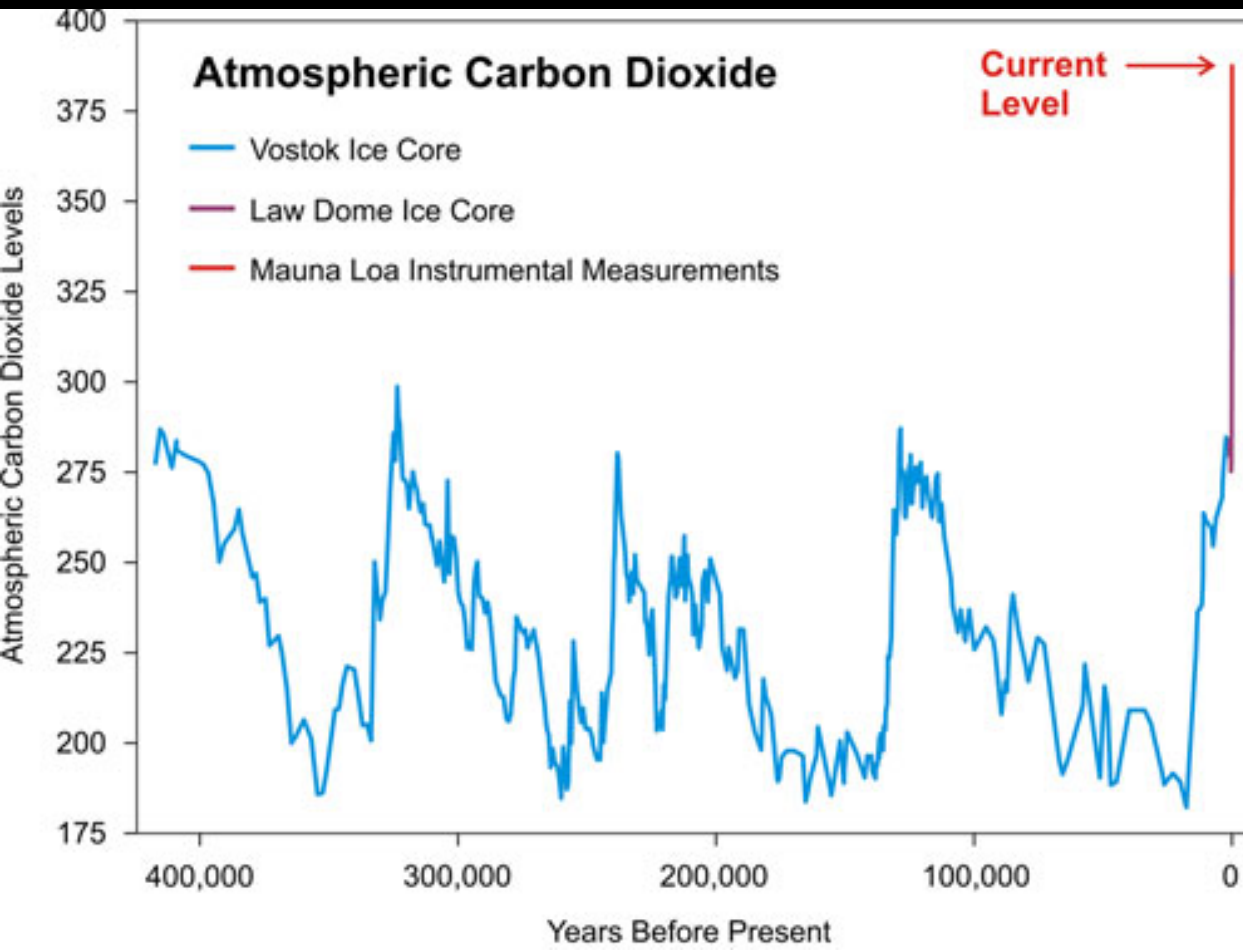
# Greenhouse Gas Mixing Ratios



Concentrations of Greenhouse Gases from 0 to 2005

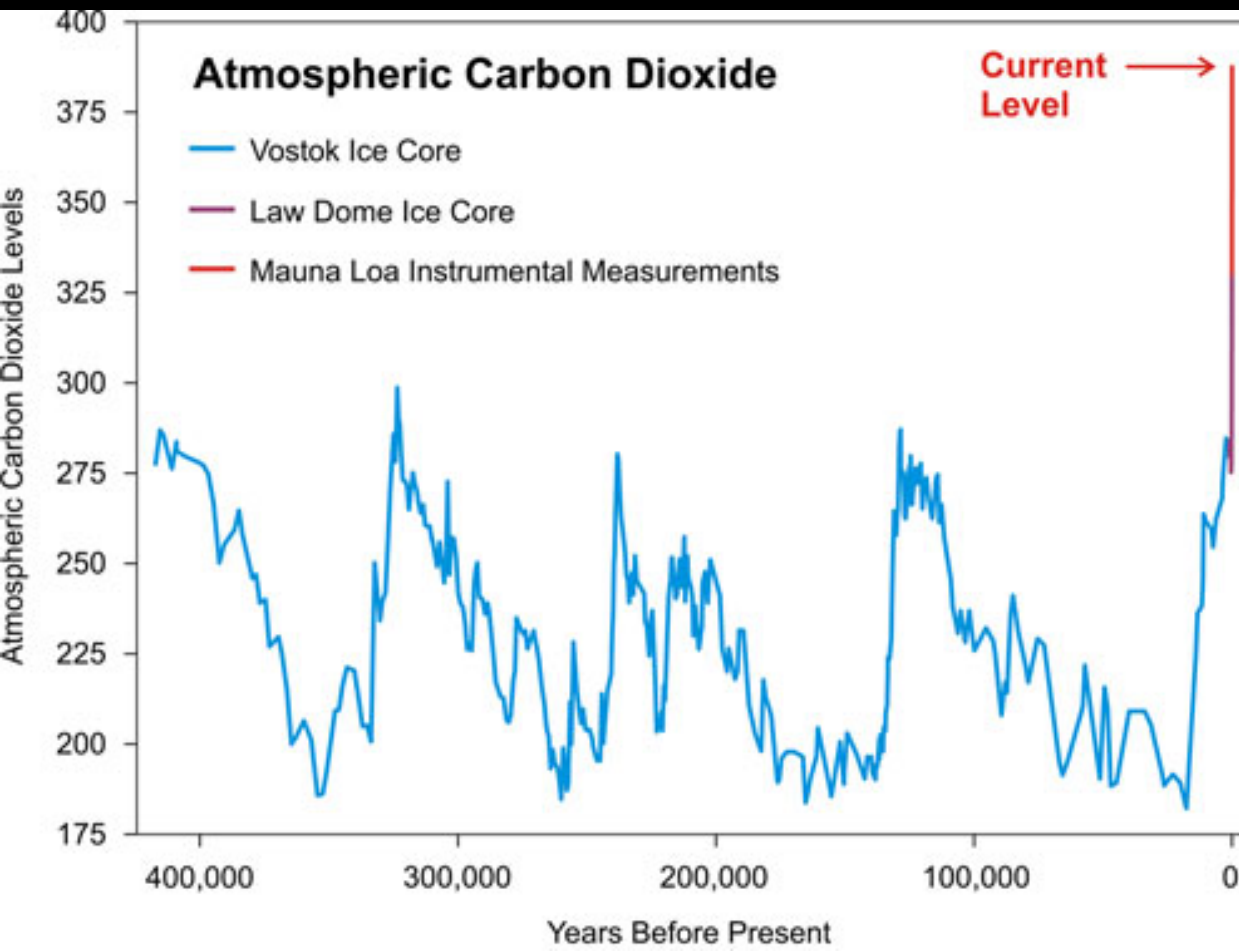


# Ice Cores Preserve the History of Atmospheric CO<sub>2</sub> and climate over the recent ice ages



Data from Petit et al., 1999

# Ice Cores Preserve the History of Atmospheric CO<sub>2</sub> and climate over the recent ice ages



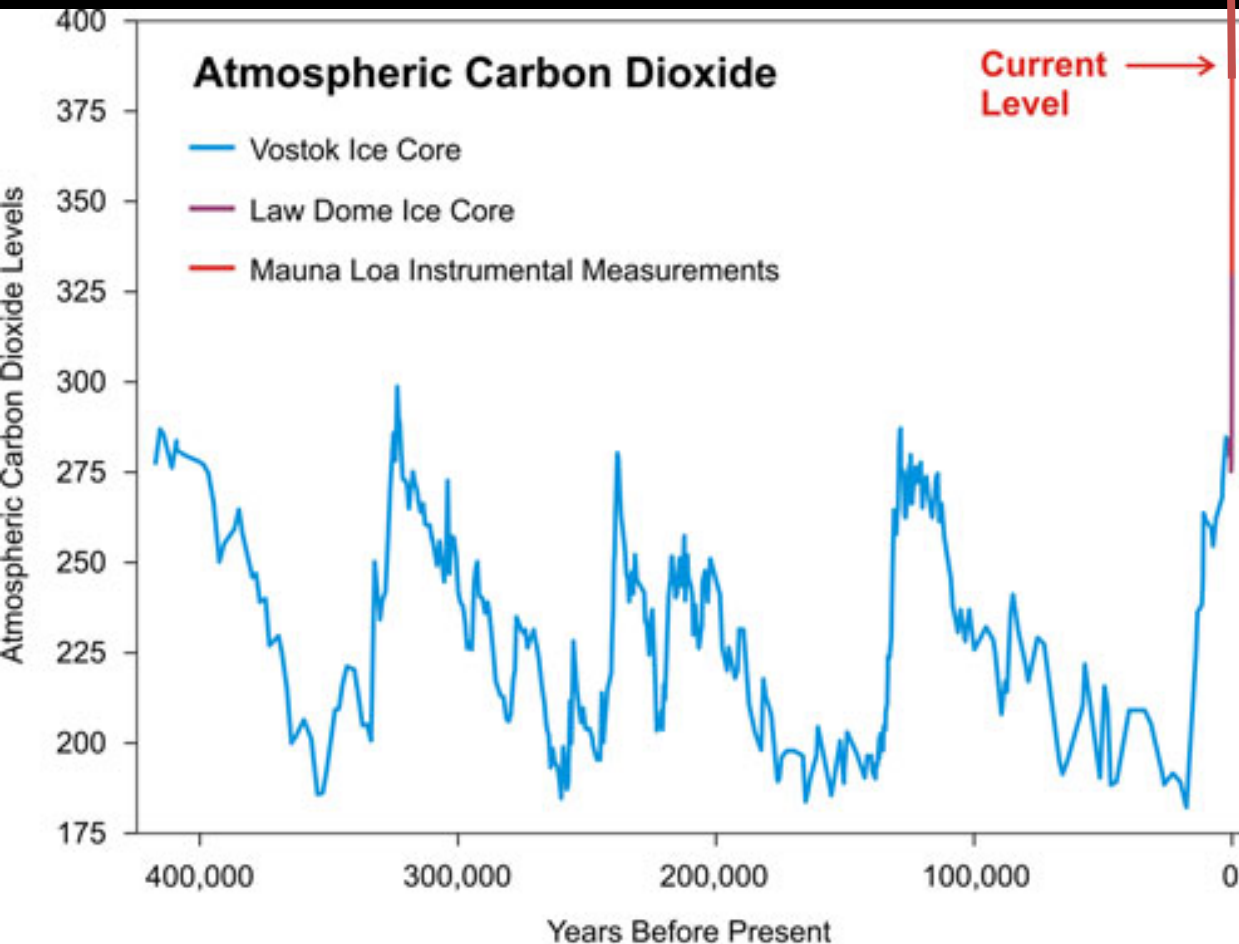
It's been 15 million years since CO<sub>2</sub> levels were this high



550 ppm, where we are headed

# Ice Cores Preserve the History of Atmospheric CO<sub>2</sub> and climate over the recent ice ages

CO<sub>2</sub> will double in your lifetime. It will triple in your kid's lifetimes.

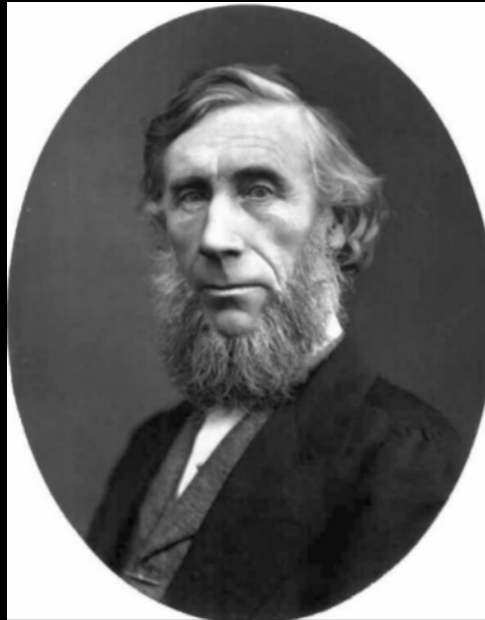


Data from Petit et al., 1999

# Early climate change history



Jean Fourier: 1768-1830  
World-class mathematician



John Tyndall 1820-1893  
Physics giant, polymath



Svante Arrhenius 1859-1927  
Nobel Prize in Chemistry

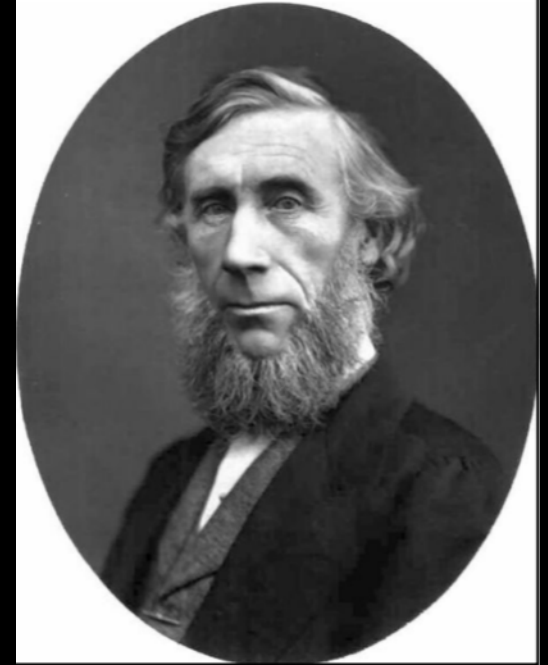
# Jean Fourier: 1768-1830

- Pioneered planetary energy balance studies
- Infrared radiation (“dark heat”) balances incoming solar radiation
- Without considering atmosphere, thinks earth should be much colder than it is
- Concludes earth acts as a ‘glass house’, trapping heat. Not sure what causes the effect



# John Tyndall 1820-1893

- Connected specific gases to the greenhouse effect
- Earth "held fast in the iron grip of frost" if not for greenhouse gases
- Greenhouse gases are "a local dam, by which the temperature at the earth's surface is deepened; the dam, however, finally overflows, and we give to space all that we receive from the sun."



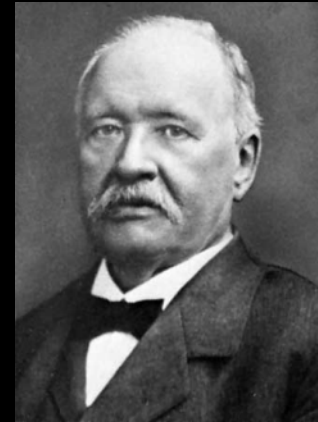
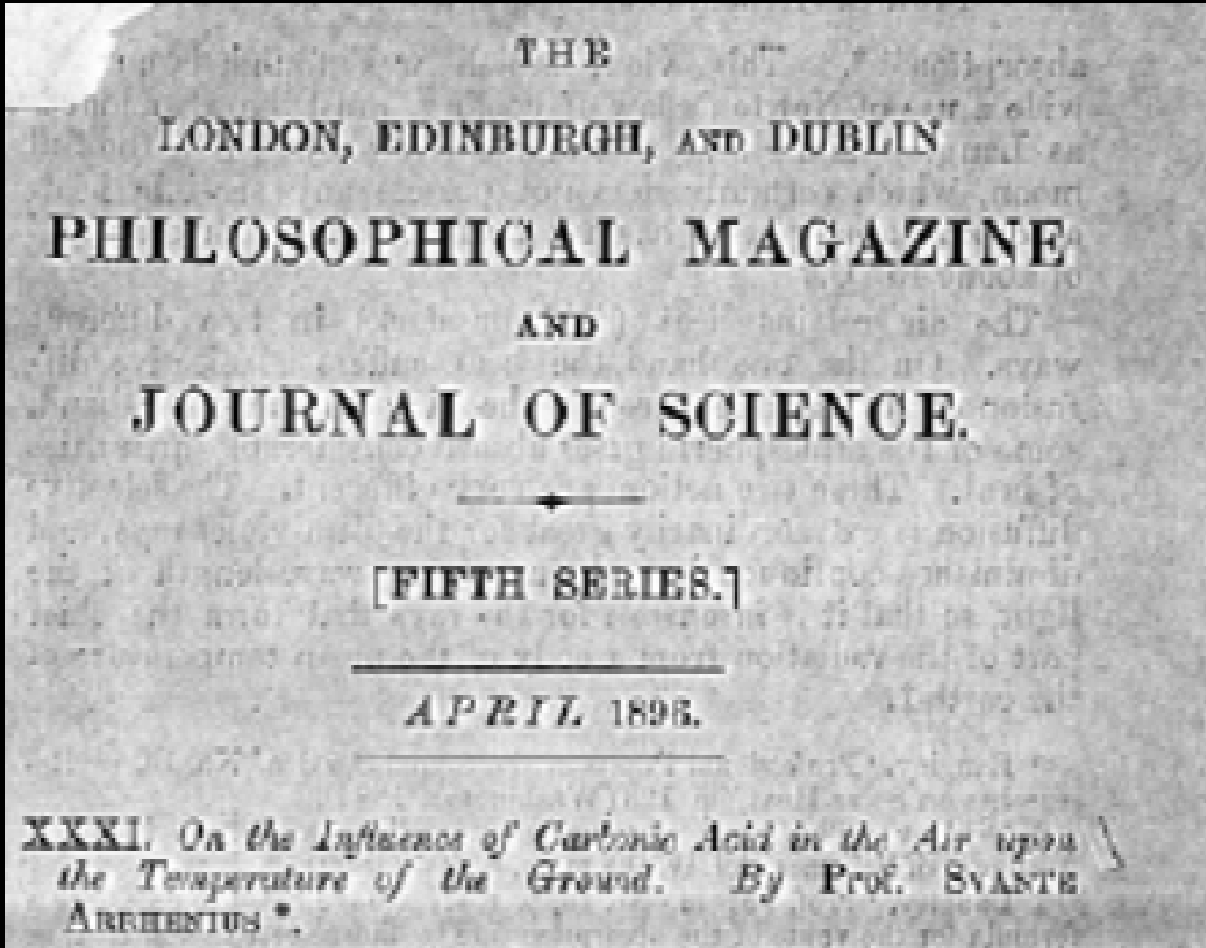
# Svante Arrhenius 1859-1927

- Fundamental work in chemical thermodynamics
- Built on Tyndall and made first estimate of temperature sensitivity to atmospheric CO<sub>2</sub> doubling



“By the influence of the increasing percentage of carbonic acid in the atmosphere, we may hope to enjoy ages with more equable and better climates, especially as regards the colder regions of the earth, ages when the earth will bring forth much more abundant crops than at present, for the benefit of rapidly propagating mankind.”

# Arrhenius to Revelle to Keeling to Hansen: Where will all this carbon go?



“On the Influence of  
Carbonic Acid in the Air  
upon the Temperature  
of the Ground,”  
by Svante Arrhenius  
(1896)

# Arrhenius: naïve assumption

- Added carbon will partition itself between the ocean and atmosphere in the same proportions that exists there now
- Atmosphere had something like 600 billion tons of C
- Ocean had had something like 38,000 billion tons of C
- I.e. 1.6% of any added CO<sub>2</sub> will stay in the atmosphere and the rest would be “sunk” into the oceans
- So Arrhenius didn't think this warming would ever happen, and neither did most scientists for another 60 years. Until...

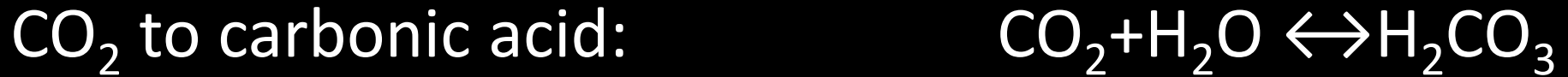


“Human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future.” Roger Revelle (Revelle & Suess, 1957)

Roger Revelle, seen here studying seawater chemistry, ca. 1936, and as a leading administrator as well as scientist, ca. 1958. <http://www.aip.org/history/climate/>

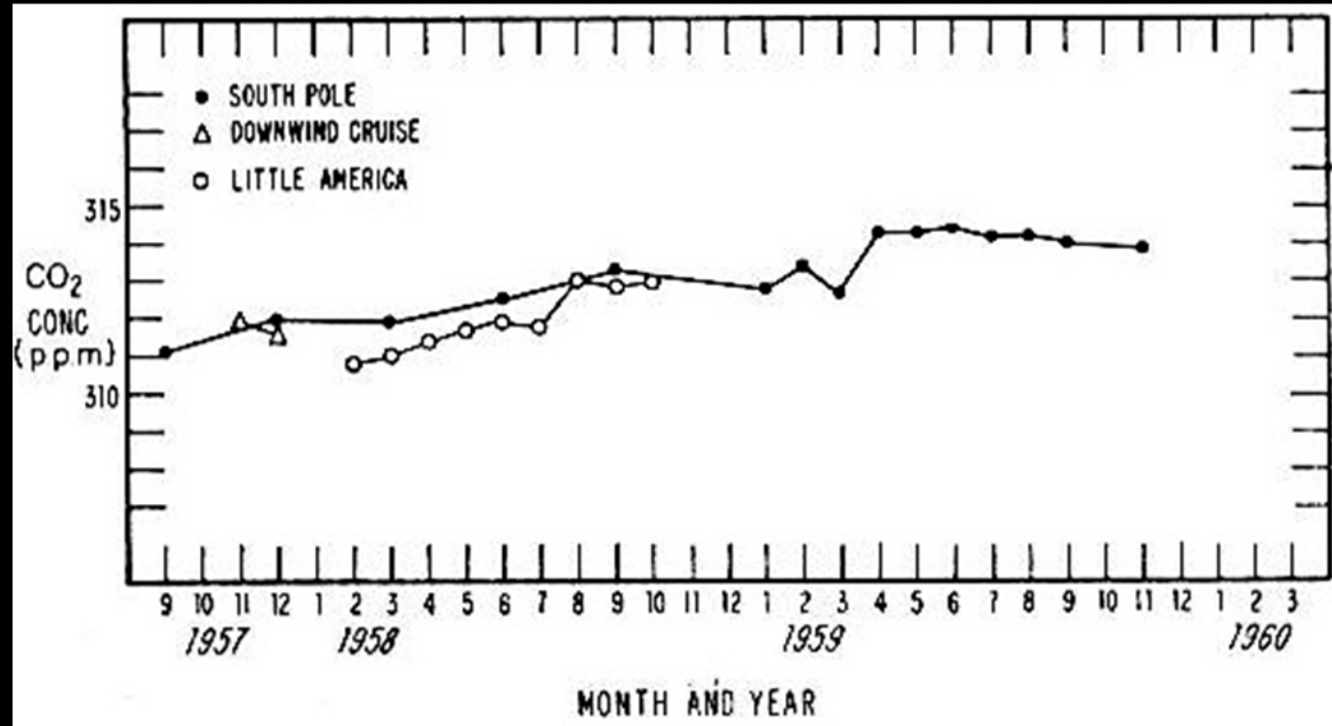


# Dissolution of CO<sub>2</sub> in Seawater



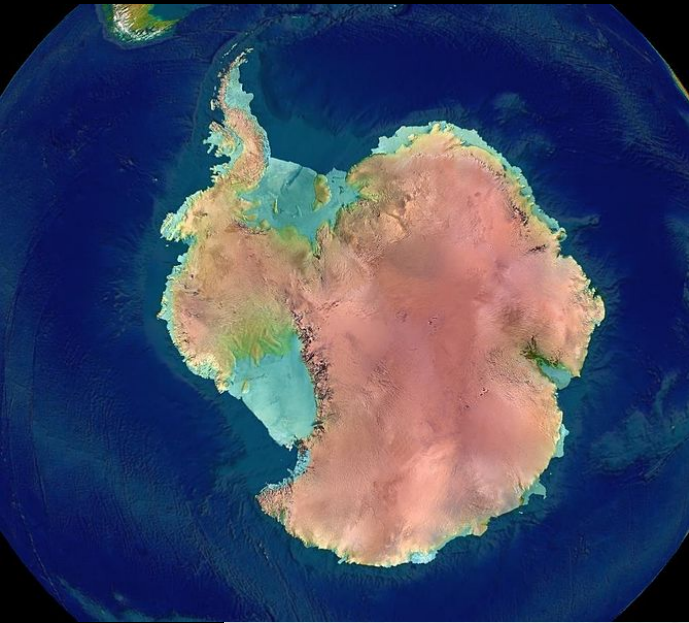
The ability to dissolve CO<sub>2</sub> depends on the relative concentrations of carbonate ions (HCO<sub>3</sub><sup>-</sup> & CO<sub>3</sub><sup>-2</sup>) which are controlled by ocean pH. The net results is that the factor oceans can absorb CO<sub>2</sub> is reduced by a factor of ~10. This is called the “Revelle factor”.

# Keeling's test of Revelle's hypothesis

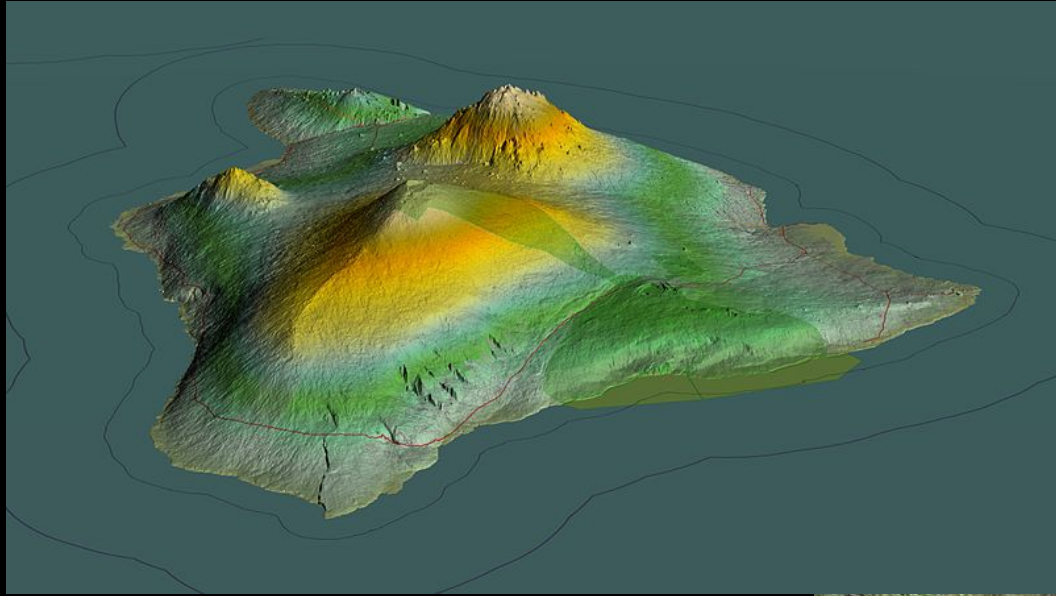


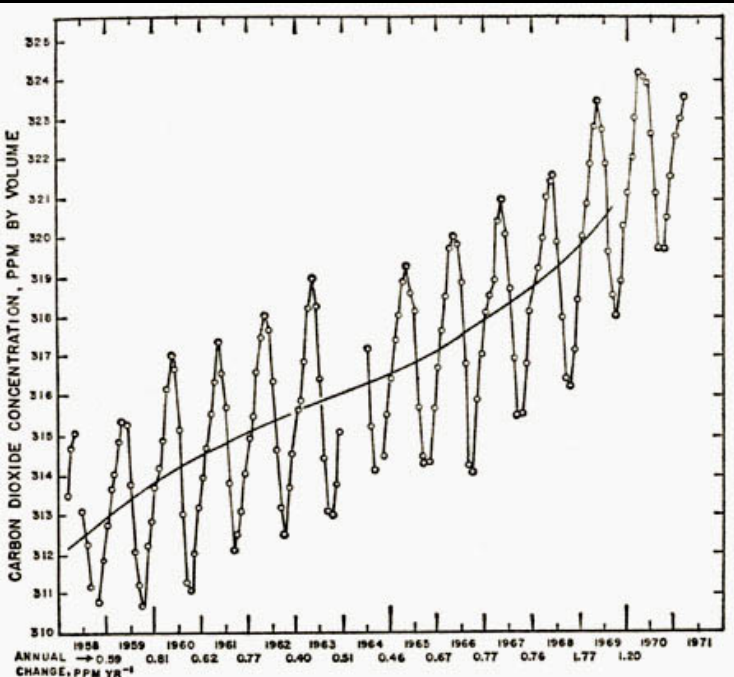
Above: 1961  
Right: in  
1990s

"Keeling's a peculiar guy," Revelle later remarked. "He wants to measure CO<sub>2</sub> in his belly... And he wants to measure it with the greatest precision and the greatest accuracy he possibly can."





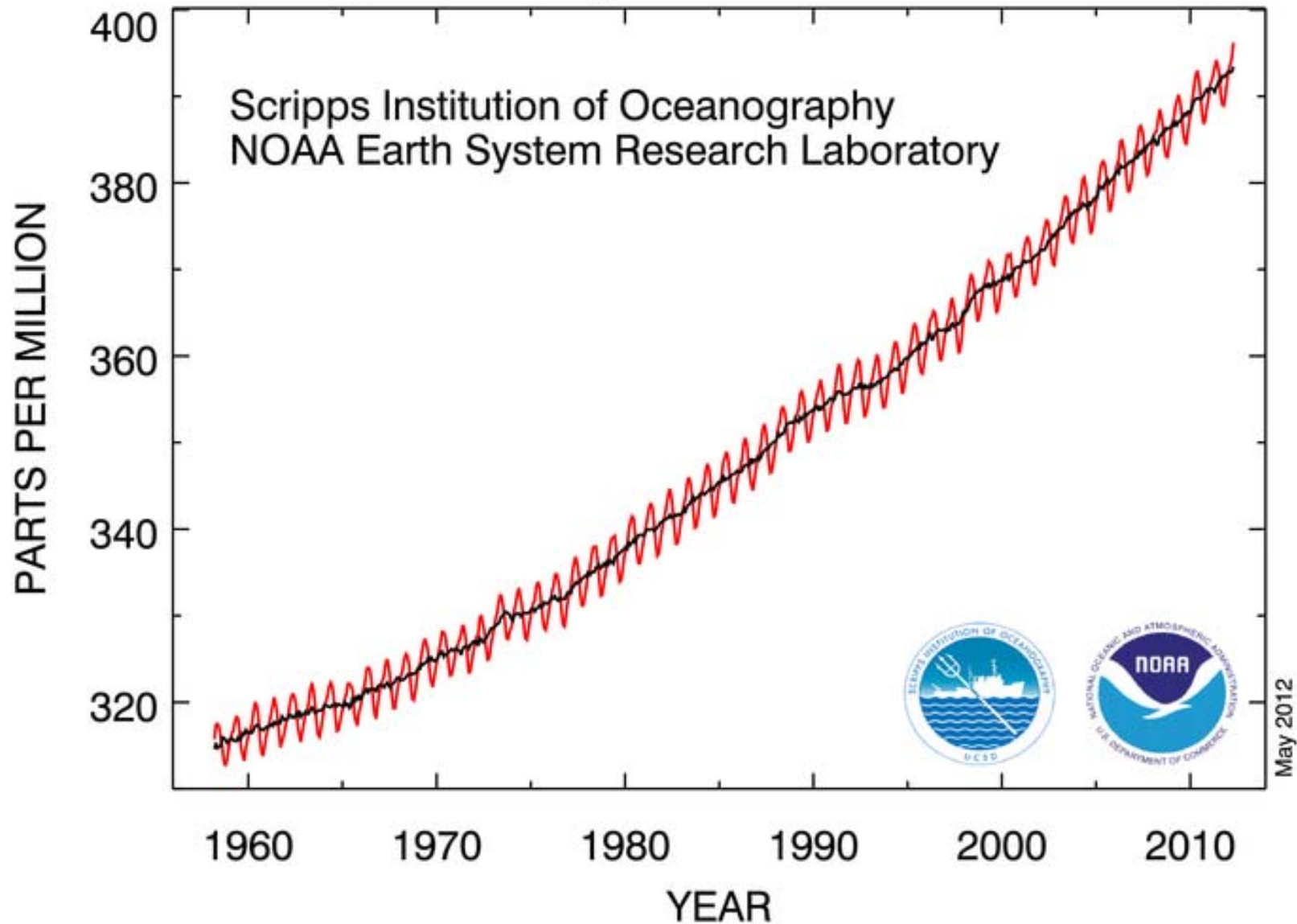




From *Inadvertent Climate Modification. Report of Conference, Study of Man's Impact on Climate (SMIC), Stockholm*, edited by Carroll L. Wilson and William H. Matthews, p. 234, copyright MIT Press, 1971.



# Atmospheric CO<sub>2</sub> at Mauna Loa Observatory



- 1824: Fourier realized that the Earth's atmosphere kept the planet warmer than the sun alone could.
- 1859: Tyndall established that the major greenhouse gases in Earth's atmosphere were water vapor and carbon dioxide.
- 1896: Arrhenius calculated temperatures from human-induced changes to the atmosphere
- 1955: Suess detected the isotope signature of fossil-fuel CO<sub>2</sub> in the atmosphere.
- 1957: Revelle & Suess showed that the new CO<sub>2</sub> was primarily from fossil-fuel burning
- 1960: Keeling showed that CO<sub>2</sub> was rising very quickly
- 1988: Hansen and others showed that, despite occasional bouts of cooling, the world temperature trend had been up overall for over a century
- 1990: IPCC issues first report (fourth report issued in 2007, fifth in 2014)

# The basic science of the physical causes of the greenhouse effect is very well understood

It is physics...

...and physics is easy

Physics is easy...

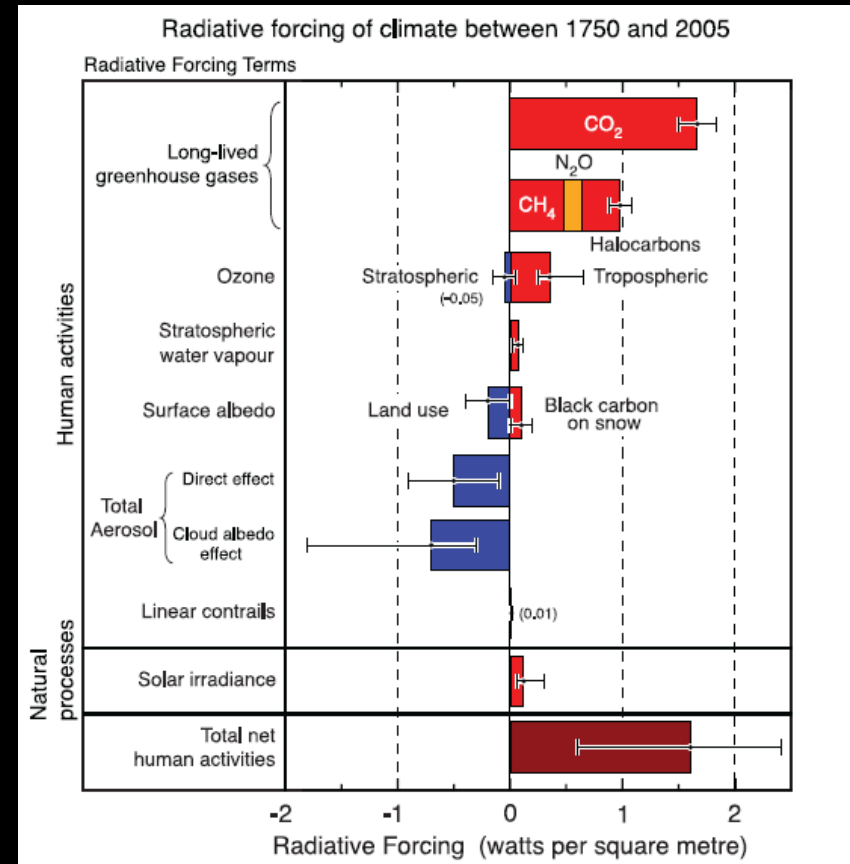
...compared to chemistry

Chemistry is easy...

...compared to biology

Biology is easy...

...compared to understanding human societies





Adopted by Council December 2003  
Revised and Reaffirmed December 2007

# AAAS Board Statement on Climate Change

Approved by the Board of Directors  
American Association for the Advancement of Science  
9 December 2006

The scientific evidence is clear: global climate change caused by human activities is occurring now, and it is a growing threat to society. Accumulating data from across the globe reveal a wide array of effects: rapidly melting glaciers, destabilization of major ice sheets, increases in extreme weather, rising sea level, shifts in species ranges, and more. The pace of change and the evidence of harm have increased markedly over the last five

ring, with a mounting toll on vulnerable ecosystems and societies. These events are early warning signs of even more devastating damage to come, some of which will be irreversible.

Delaying action to address climate change will increase the environmental and societal consequences as well as the costs. The longer we wait to tackle climate change, the harder and more

The growing torrent of information presents a clear message: we are already experiencing global climate change. It is time to muster the political will for concerted action. Stronger leadership at all levels is needed. The time is now. We must rise to the challenge. We owe this to future generations.

The conclusions in this statement

The Earth's climate is now clearly out of balance and is warming. Many components of the climate system—including the temperatures of the atmosphere, land and ocean, the extent of sea ice and mountain glaciers, the sea level, the distribution of precipitation, and the length of seasons—are now changing at rates and in patterns that are not natural and are best explained by the increased atmospheric abundances of greenhouse gases and aerosols generated by human activity during the 20th century. Global average surface temperatures increased on average by about 0.6°C over the period 1956–2006. As of 2006, eleven of the previous twelve years were warmer than any others since 1850. The observed rapid retreat of Arctic sea ice is expected to continue and lead to the disappearance of summertime ice within this century. Evidence from most oceans and all continents except Antarctica shows warming attributable to human activities. Recent changes in many physical and biological systems are linked with this regional climate change. A sustained research effort, involving many AGU members and summarized in the 2007 assessments of the Intergovernmental Panel on Climate Change, continues to improve our scientific understanding of the climate.

During recent millennia of relatively stable climate, civilization became established and populations have grown rapidly. In the next 50 years, even the lower limit of impending climate change—an additional global mean warming of 1°C above the last decade—is far beyond the range of climate variability experienced during the past thousand years and poses global problems in planning for and adapting to it. Warming greater than 2°C above 19th century levels is projected to be disruptive, reducing global agricultural productivity, causing widespread loss of biodiversity, and—if sustained over centuries—melting much of the Greenland ice sheet with ensuing rise in sea level of several meters. If this 2°C warming is to be avoided, then our net annual emissions of CO<sub>2</sub> must be reduced by more than 50 percent within this century. With such projections, there are many sources of scientific uncertainty, but none are known that could make the impact of climate change inconsequential. Given the uncertainty in climate projections, there can be surprises that may cause more dramatic disruptions than anticipated from the most probable model projections.

With climate change, as with ozone depletion, the human footprint on Earth is apparent. The cause of disruptive climate change, unlike ozone depletion, is tied to energy use and runs through modern society. Solutions will necessarily involve all aspects of society. Mitigation strategies and adaptation responses will call for collaborations across science, technology, industry, and government. Members of the AGU, as part of the scientific community, collectively have special responsibilities: to pursue research needed to understand it; to educate the public on the causes, risks, and hazards; and to communicate clearly and objectively with those who can implement policies to shape future climate.

#### Permissions:

Members everywhere are encouraged to help inform the policy making process in their home locales with thoughtful presentation of scientific viewpoints. Council adoption of position statements is one way that the Union can assist in this process. Any member may use an AGU policy statement in discussions with local or national policy makers as an official statement of the Union. If you use excerpts from a statement, then you should not attribute those as a Union position. Societies anywhere may use an AGU position statement with or without attribution as a basis for developing their own statements.



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80301-9140 USA

## Global Climate Change

#### Contributors:

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Mickey Glantz, Lynn Soreghan

#### Position Statement

The Geological Society of America (GSA) supports the scientific conclusions that Earth's climate is changing; the climate changes are due in part to human activities; and the probable consequences of the climate changes will be significant and blind to geopolitical boundaries. Furthermore, the potential implications of global climate change and the time scale over which such changes will likely occur require active, effective, long-term planning. GSA also supports statements on the global climate change issue made by the joint national academies of science (June, 2005), American Geophysical Union (December, 2003), and American Chemical Society (2004). GSA strongly encourages that the following efforts be undertaken internationally: (1) adequately research climate change at all time scales, (2) develop thoughtful, science-based policy appropriate for the multifaceted issues of global climate change, (3) organize global planning to recognize, prepare for, and adapt to the causes and consequences of global climate change, and (4) organize and develop comprehensive, long-term strategies for sustainable energy, particularly focused on minimizing impacts on global climate.

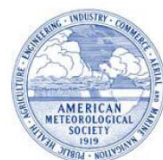
#### Background

The geologic record provides a direct measure of the frequency, range, and duration of significant global climate changes throughout Earth's history. Natural phenomena and processes have caused significant alterations of Earth's climate. Of significance to the issue of modern global

## GSA Position Statement

Adopted in October 2006

Please let us know how you used this GSA  
Position Statement. Click on the questionnaire  
link at [www.geosociety.org/aboutus/position.htm](http://www.geosociety.org/aboutus/position.htm).



## Climate Change

An Information Statement of the American Meteorological Society

(Adopted by AMS Council on 1 February 2007) *Bull. Amer. Met. Soc.*, **88**

The following is an Information Statement intended to provide a trustworthy, objective, and scientifically up-to-date explanation of scientific issues of concern to the public at large.

#### Background

This statement is consistent with the vast weight of current scientific understanding as expressed in assessments and reports from the Intergovernmental Panel on Climate Change, the U. S. National Academy of Sciences, and the U. S. Climate Change Science Program. All these reports recognize the uncertainties in climate projections, and identify the scientific work needed to reduce those uncertainties. Although the statement has been drafted in the context of concerns in the United States, the underlying issues are inherently global in nature.

This summary of the current state of scientific understanding is based on the peer-reviewed

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[www.geosociety.org](http://www.geosociety.org)



# Joint science academies' statement: Global response to climate change

## Climate change is real

There will always be uncertainty in understanding a system as complex as the world's climate. However there is now strong evidence that significant global warming is

potentially cost-effective technological options that could contribute to stabilising greenhouse gas concentrations. These are at various stages of research and development. However barriers to their broad deployment still need to be overcome.

- Academia Brasileira de Ciências Brazil
- Royal Society of Canada, Canada
- Chinese Academy of Sciences, China
- Académie des Sciences, France
- Deutsche Akademie der Naturforscher Leopoldina, Germany
- Indian National Science Academy, India
- Accademia Nazionale dei Lincei, Italy
- Science Council of Japan, Japan
- Russian Academy of Sciences, Russia
- Royal Society, United Kingdom
- National Academy of Sciences, United States of America

How science works