What Occam's razor teaches me about climate change

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April, 2009

What Occam's razor teaches me about climate change

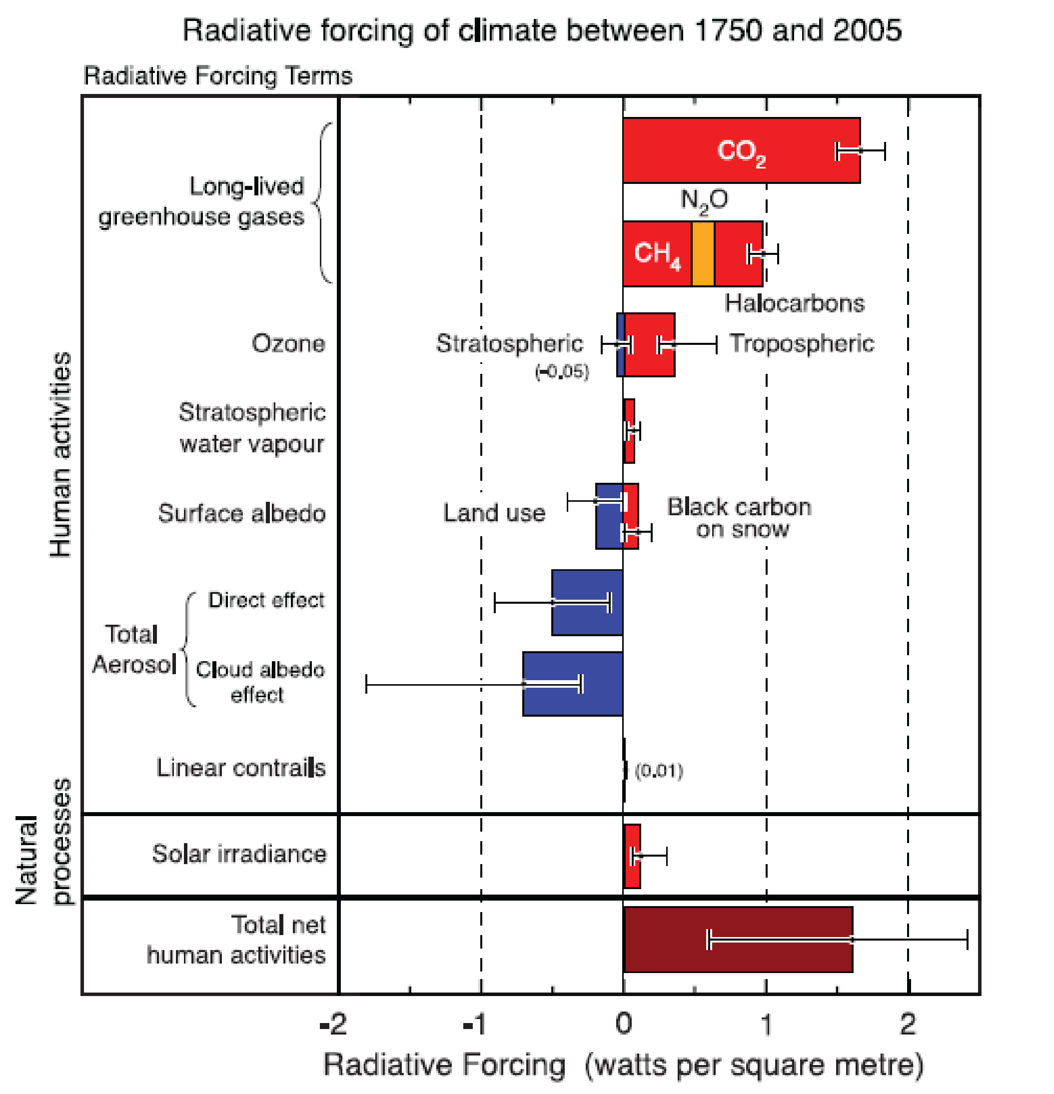
- “Law of succinctness”
- When multiple competing hypotheses are equal in other respects, choose the hypothesis that introduces the fewest assumptions

What Occam's razor teaches me about climate change

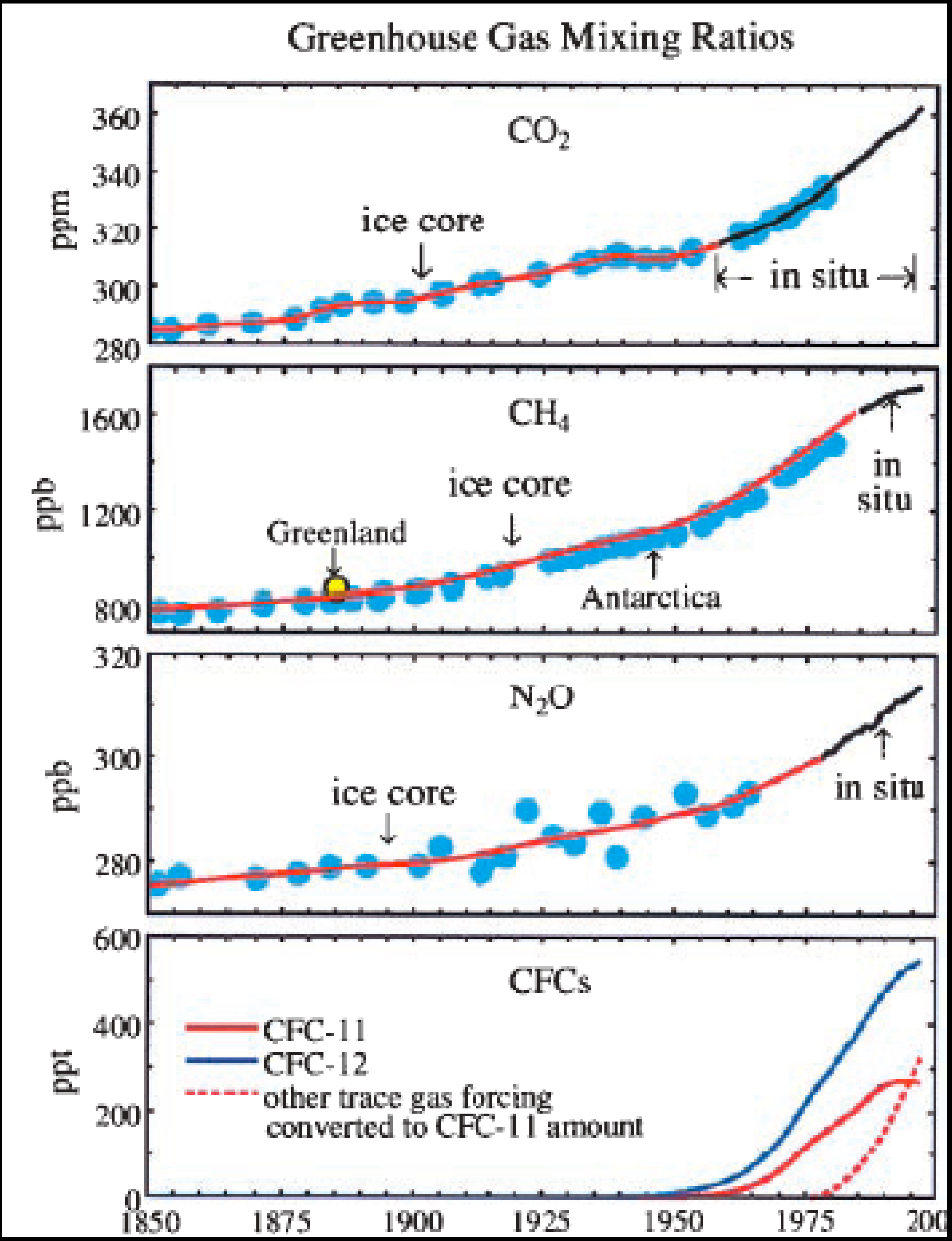
- The simplest model tends to be the right one
- CO_2 is a heat trapping gas
- If you put a heat trapping gas in the atmosphere you expect it to trap heat

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

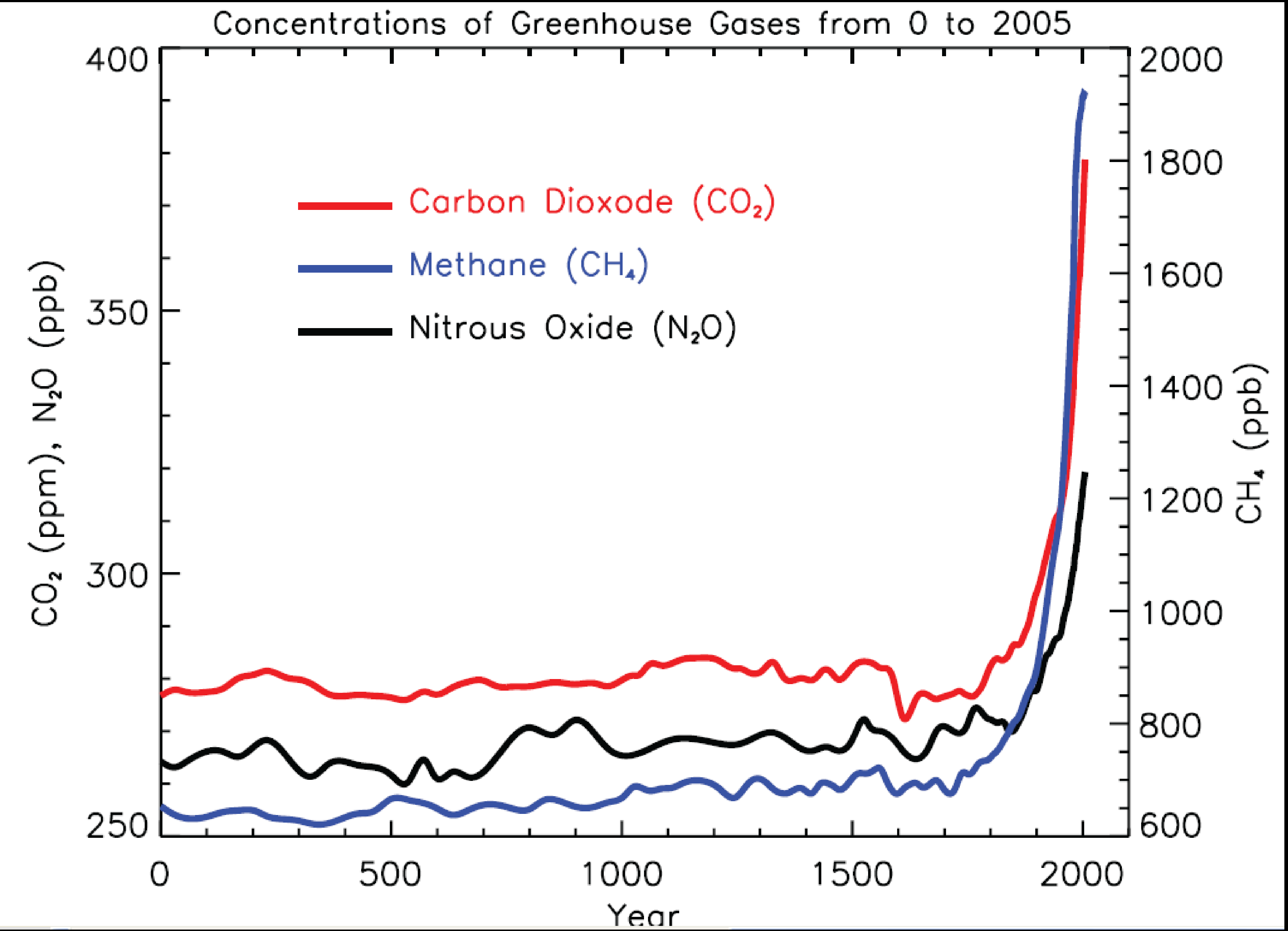
It is physics and physics is easy



IPCC AR4

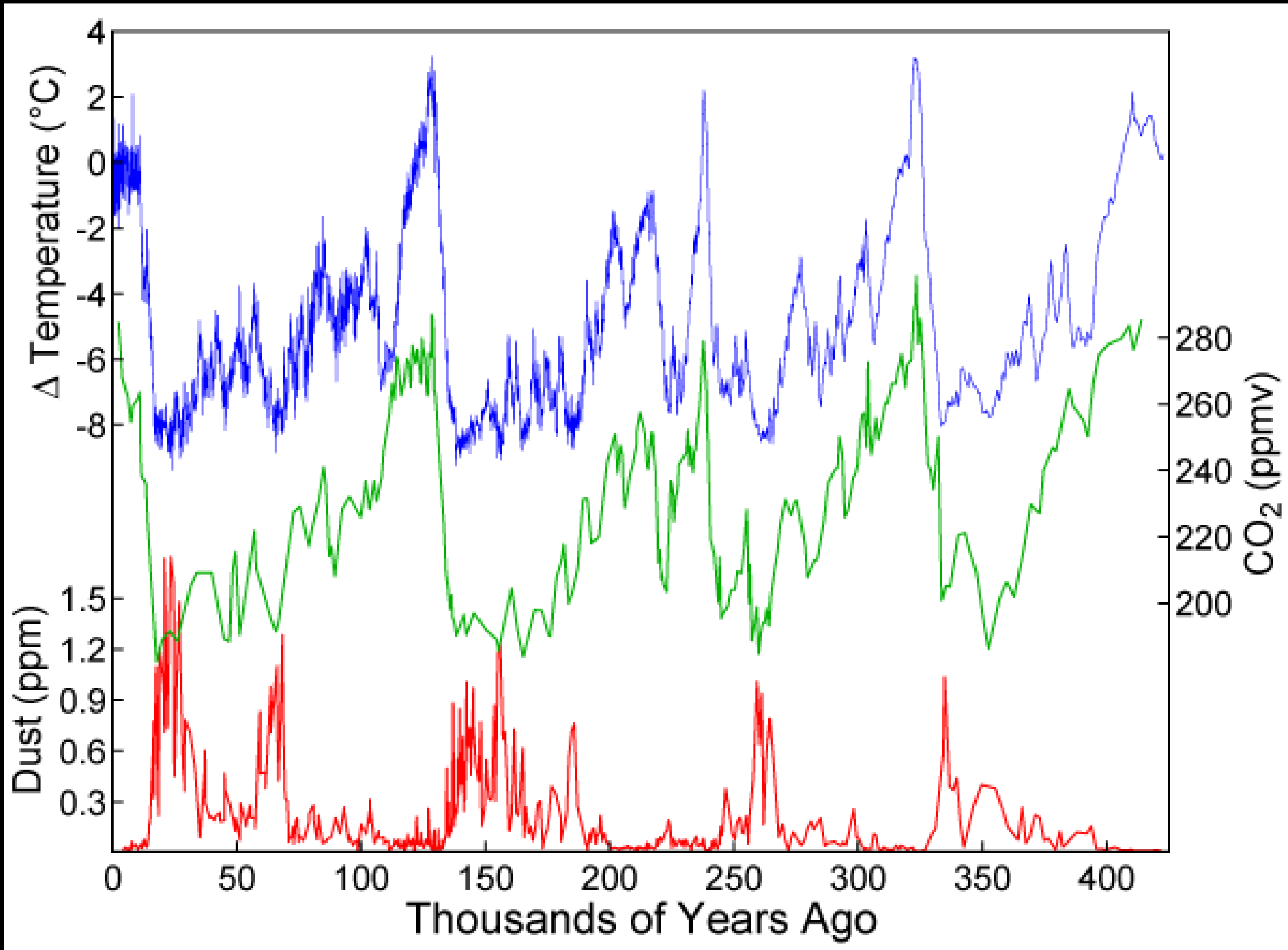


Greenhouse Gas Mixing Ratios
CO2
ppm
ice core
in situ
CH4
ppb
ice core
Greenland
Antarctica
in situ
N2O
ppb
ice core
in situ
CFCs
ppt
CFC-11
CFC-12
other trace gas forcing
converted to CFC-11 amount
1850
1875
1900
1925
1950
1975
2000



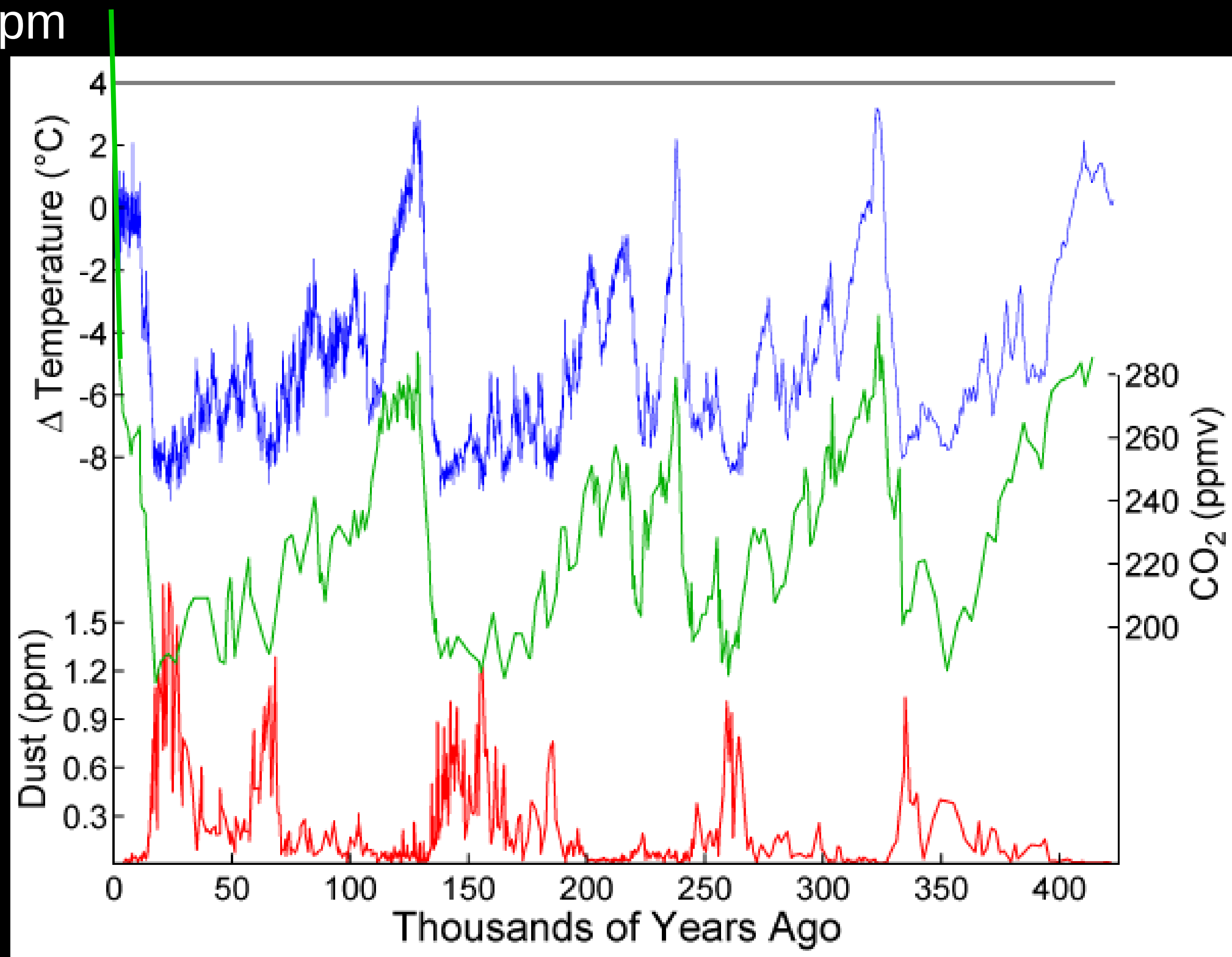
Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO₂)
Methane (CH₄)
Nitrous Oxide (N₂O)
CO₂ (ppm), N₂O (ppb)
CH₄ (ppb)
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000
Year

Ice Cores Preserve the History of Atmospheric CO_2 and climate over the recent ice ages



Ice Cores Preserve the History of Atmospheric CO_2 and climate over the recent ice ages

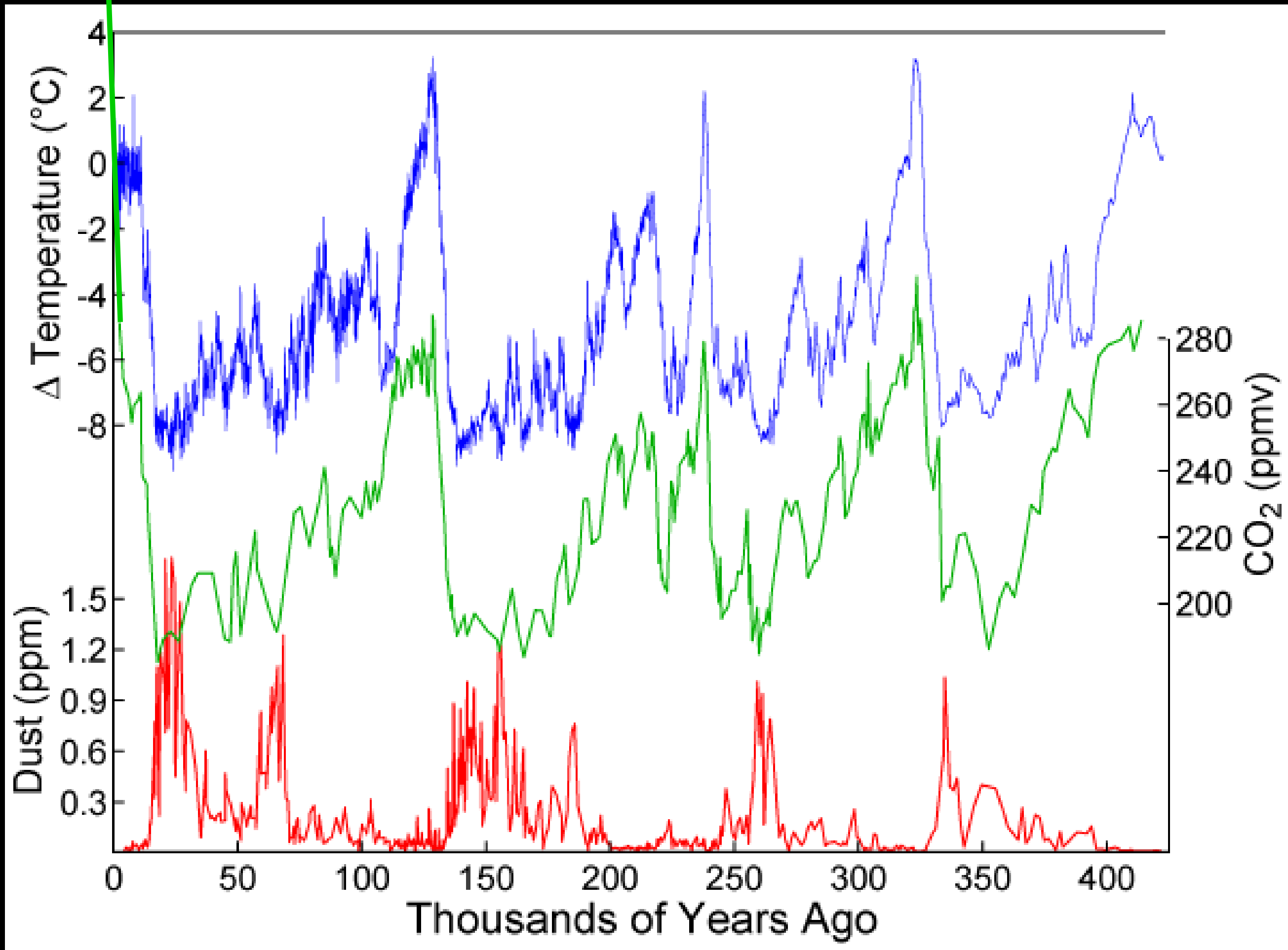
Human change 385 ppm



550 ppm, 1000ppm?

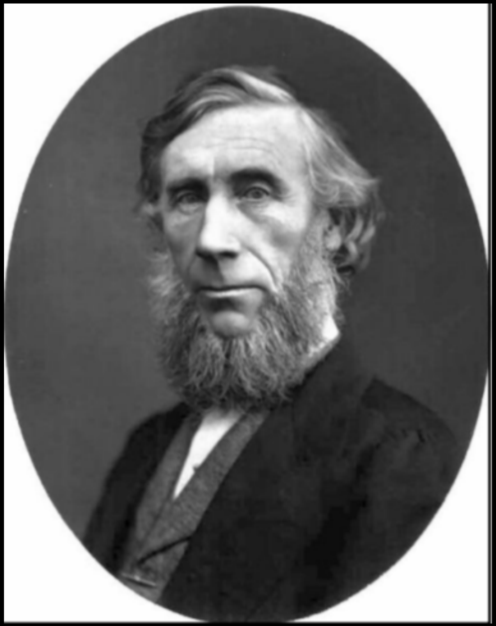
Ice Cores Preserve the History of Atmospheric CO_2 and climate over the recent ice ages

Human change 385 ppm



Early climate change history

Jean Fourier: 1768-1830
World-class mathematician



John Tyndall 1820-1893
Physics giant, polymath

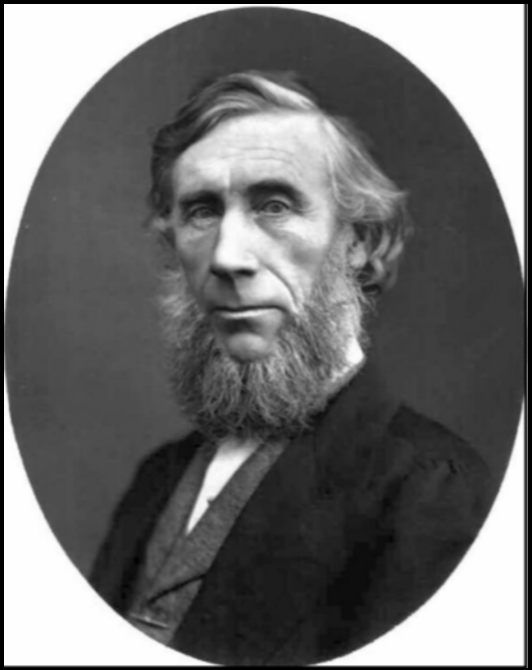
Svante Arrhenius 1859-1927
Nobel Prize in Chemistry

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

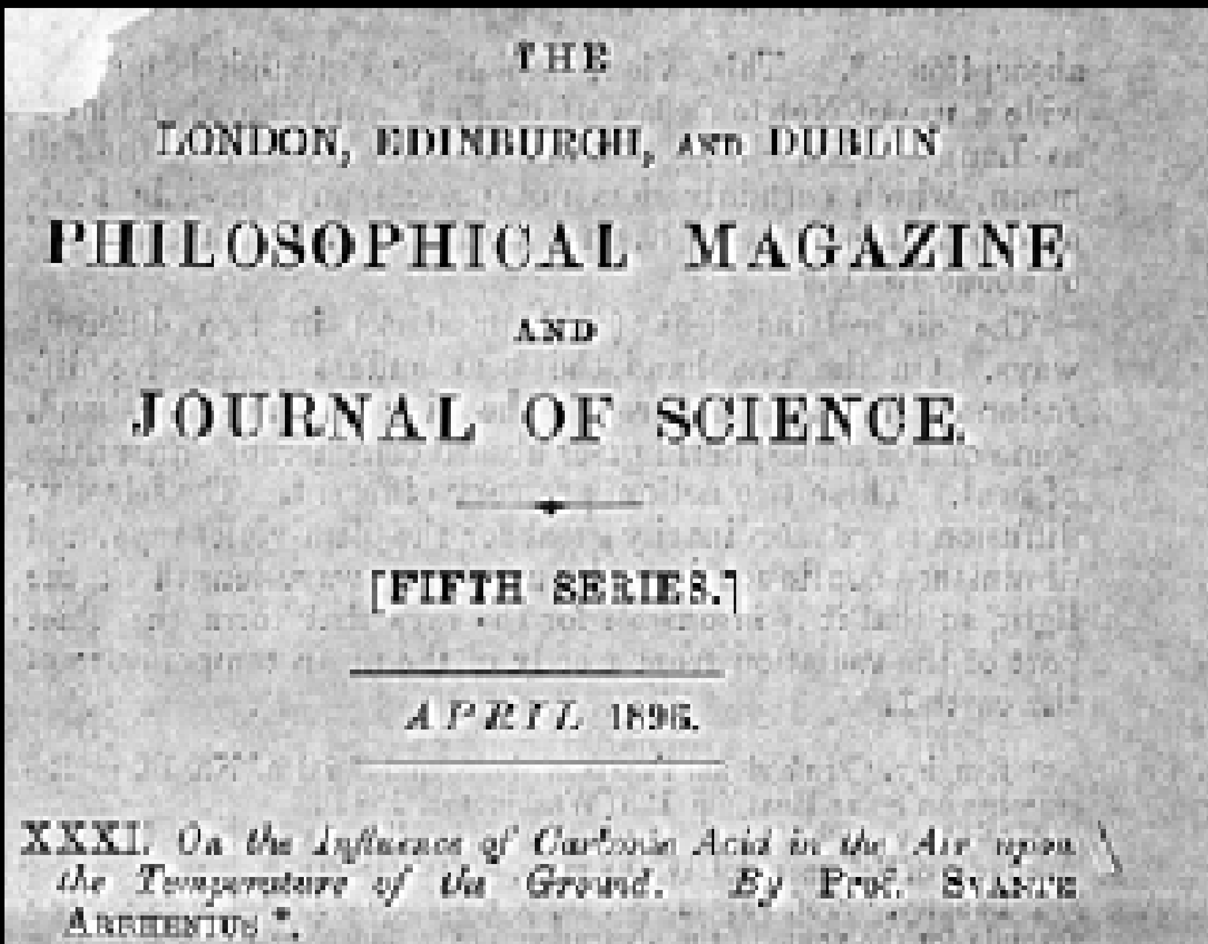
- Greenhouse gases are “a local dam, by which the temperature at the earth's surface is deepened; the dam, however, finally overflows, and we give to space all that we receive from the sun.”

Svante Arrhenius 1859-1927

- Fundamental work in chemical thermodynamics
- Built on Tyndall and made first estimate of temperature sensitivity to atmospheric CO_2 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?



THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

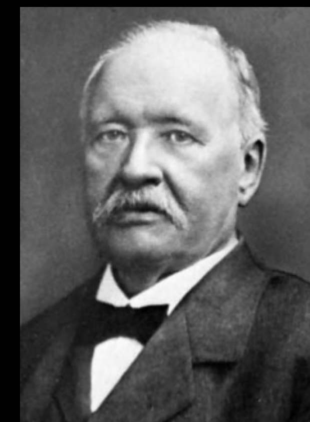
AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.



"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 Pg of C
- Ocean had had something like 38,000 Pg of C
- I.e. 1.6% of any added CO_2 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 adminstrator as well as scientist, ca. 1958. http://www.aip.org/history/climate/

Dissolution of CO_2 in Seawater

CO_2 to carbonic acid: $CO_2 + H_2O \leftrightarrow H_2CO_3$

Carbonic acid to bicarbonate: $H_2CO_3 \leftrightarrow H^+ + HCO_3^-$

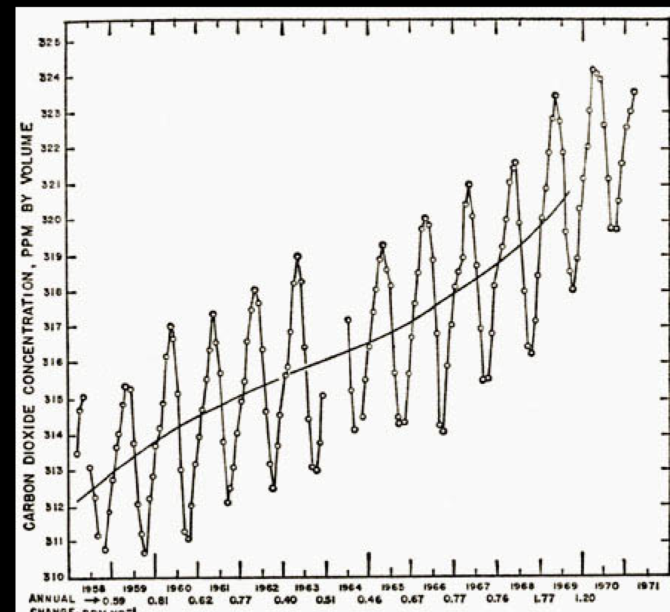
Bicarbonate to carbonate: $H_2CO_3^- \leftrightarrow H^+ + CO_3^{-2}$

Net: $CO_2 + H_2O + CO_3^{-2} \rightarrow H_2CO_3$

The ability to dissolve CO_2 depends on the relative concentrations of carbonate ions (HCO_3^-&CO_3^{-2}) which are controlled by ocean pH. The net results is that the factor oceans can absorb CO_2 is reduced by a factor of ~10. This is called the “Revelle factor”.

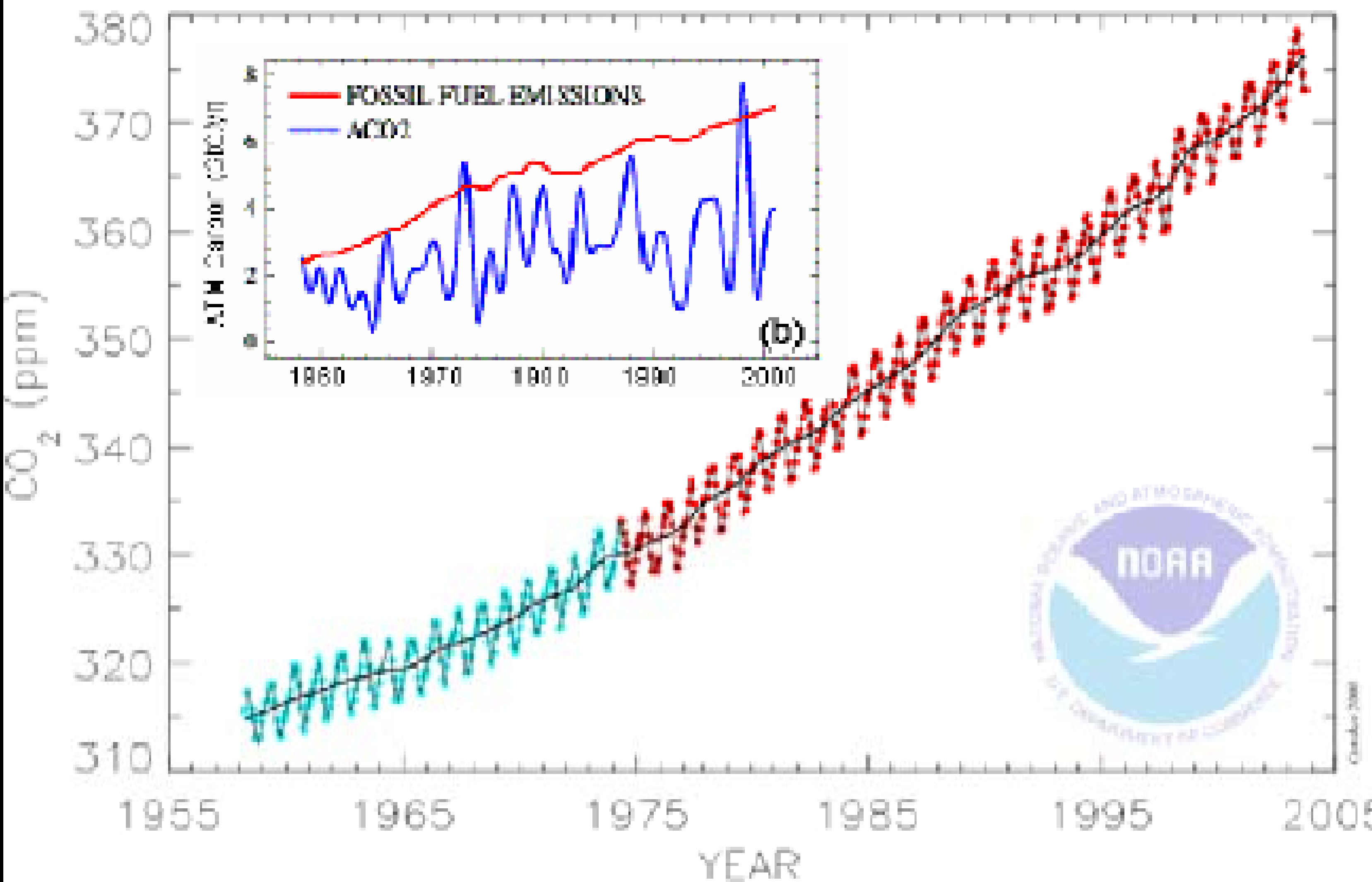
Keeling's test of Revelle's hypothesis

Above: 1961
Right: in 1990s



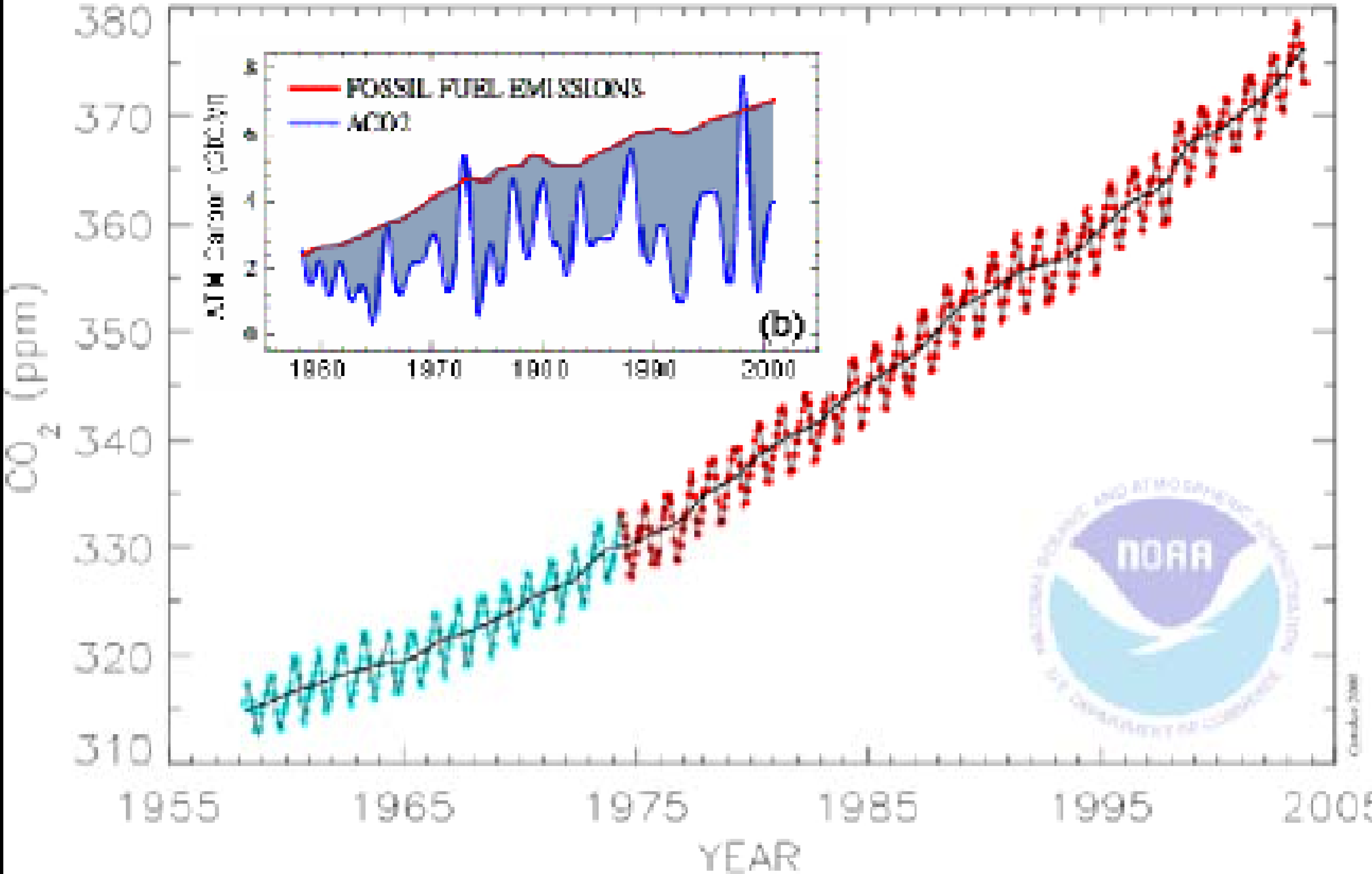
"Keeling's a peculiar guy," Revelle later remarked. "He wants to measure CO2 in his belly... And he wants to measure it with the greatest precision and the greatest accuracy he possibly can."

Mauna Loa Monthly Mean Carbon Dioxide



Atmospheric carbon dioxide monthly mean mixing ratios. Data prior to May 1974 are from the Scripps Institution of Oceanography (SIO, blue), data since May 1974 are from the National Oceanic and Atmospheric Administration (NOAA, red). A long-term trend curve is fitted to the monthly mean values. Principal investigators: Dr. Pieter Tans, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, and Dr. Charles D. Keeling, SIO, La Jolla, California, (616) 534-6001, cdkeeling@ucsd.edu.

Mauna Loa Monthly Mean Carbon Dioxide



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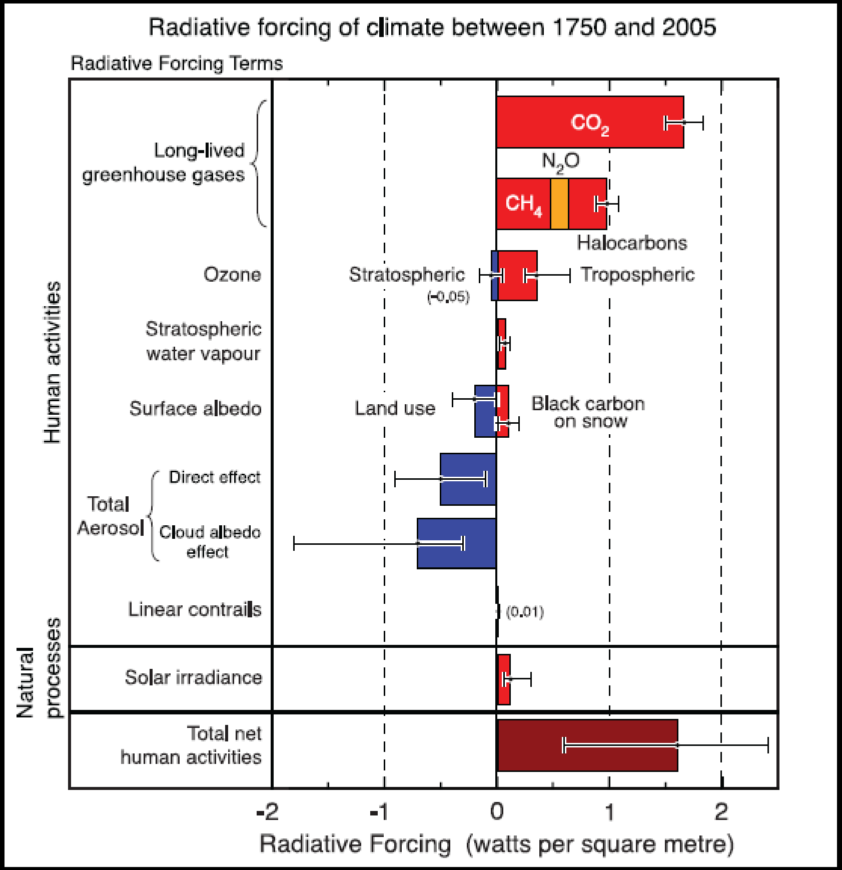

It is physics…

…and physics is easy

Physics is easy…

…compared to chemistry

Chemistry is easy…

…compared to biology

Biology is easy…

…compared to understanding human societies!

Embargoed: Not for release until 12:30 p.m. Pacific Standard Time
Sunday, 18 February 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 years, 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

Human Impacts on Climate

AGU

Adopted by Council December 2003
Revised and Reaffirmed December 2007

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_2 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.

THE GEOLOGICAL SOCIETY OF AMERICA

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.

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Global Climate Change

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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

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

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 occurring[1]. The evidence comes from direct measurements of rising surface air temperatures and subsurface ocean temperatures and from phenomena such as increases in

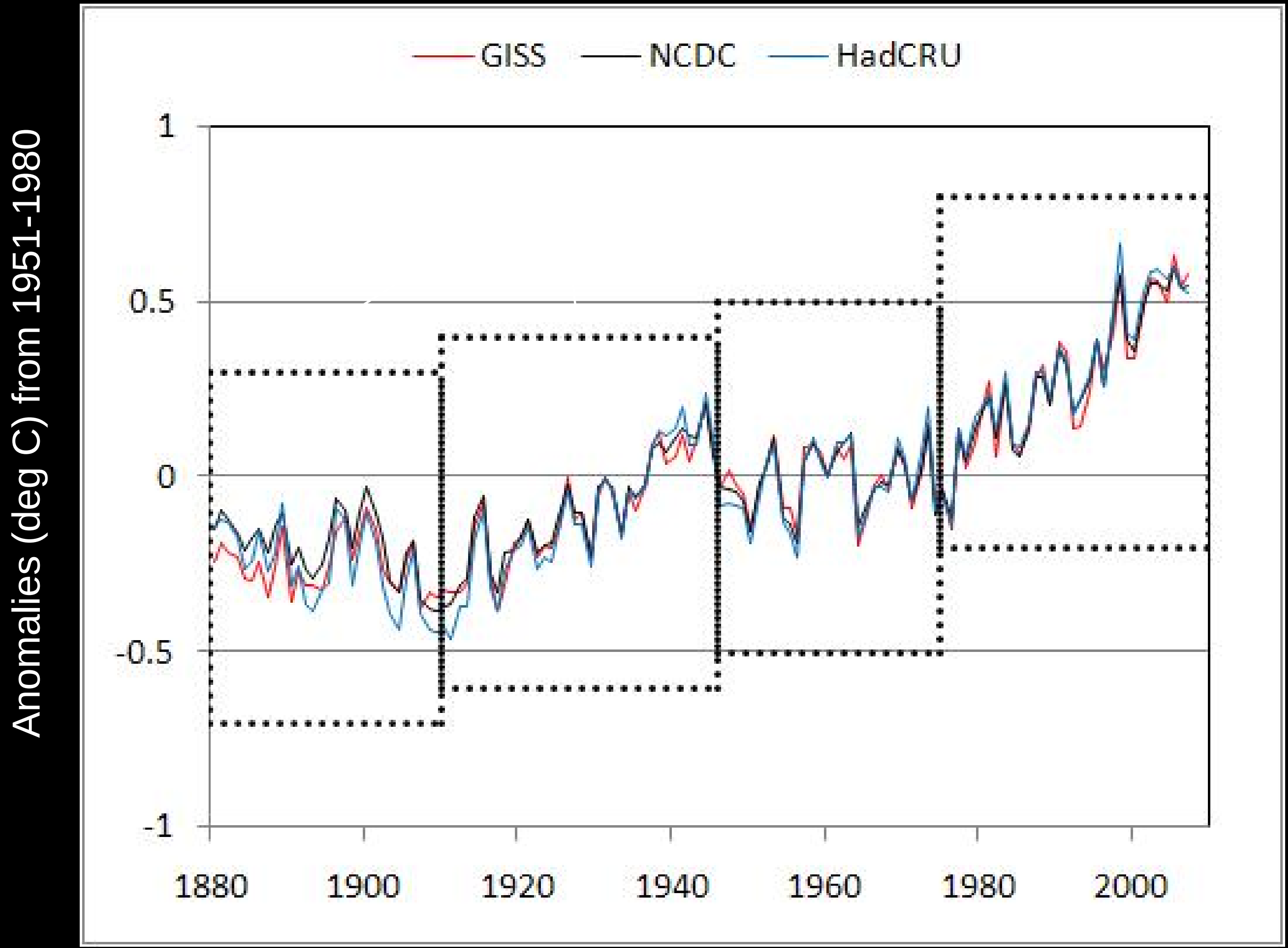
potentially cost-effective technological options that could contribute to stabilising greenhouse gas concentrations. These are at various stages of research and development. However barriers to their broad deployment still need to be overcome.

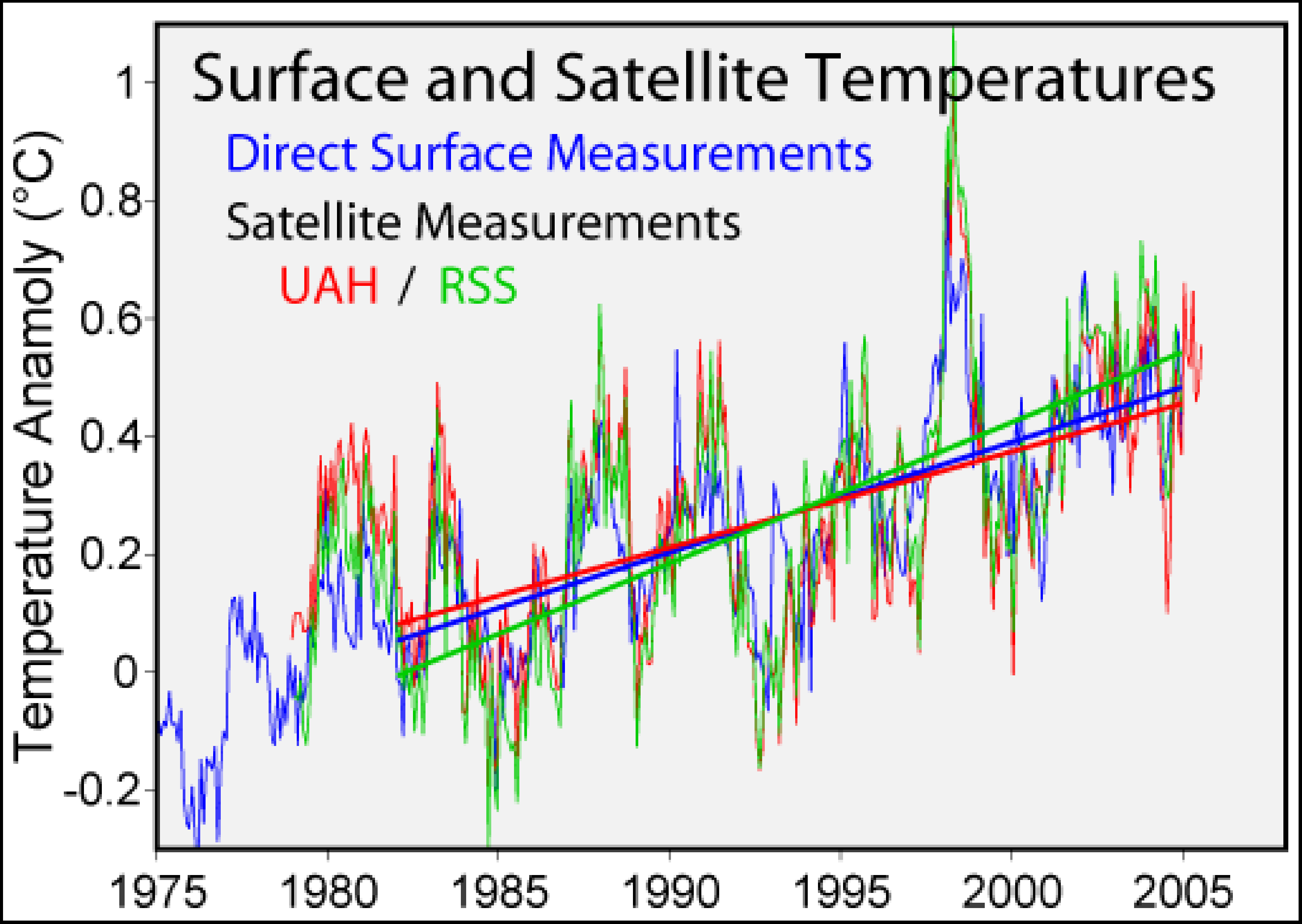
Carbon dioxide can remain in the atmosphere for many

- Academia Brasiliera 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

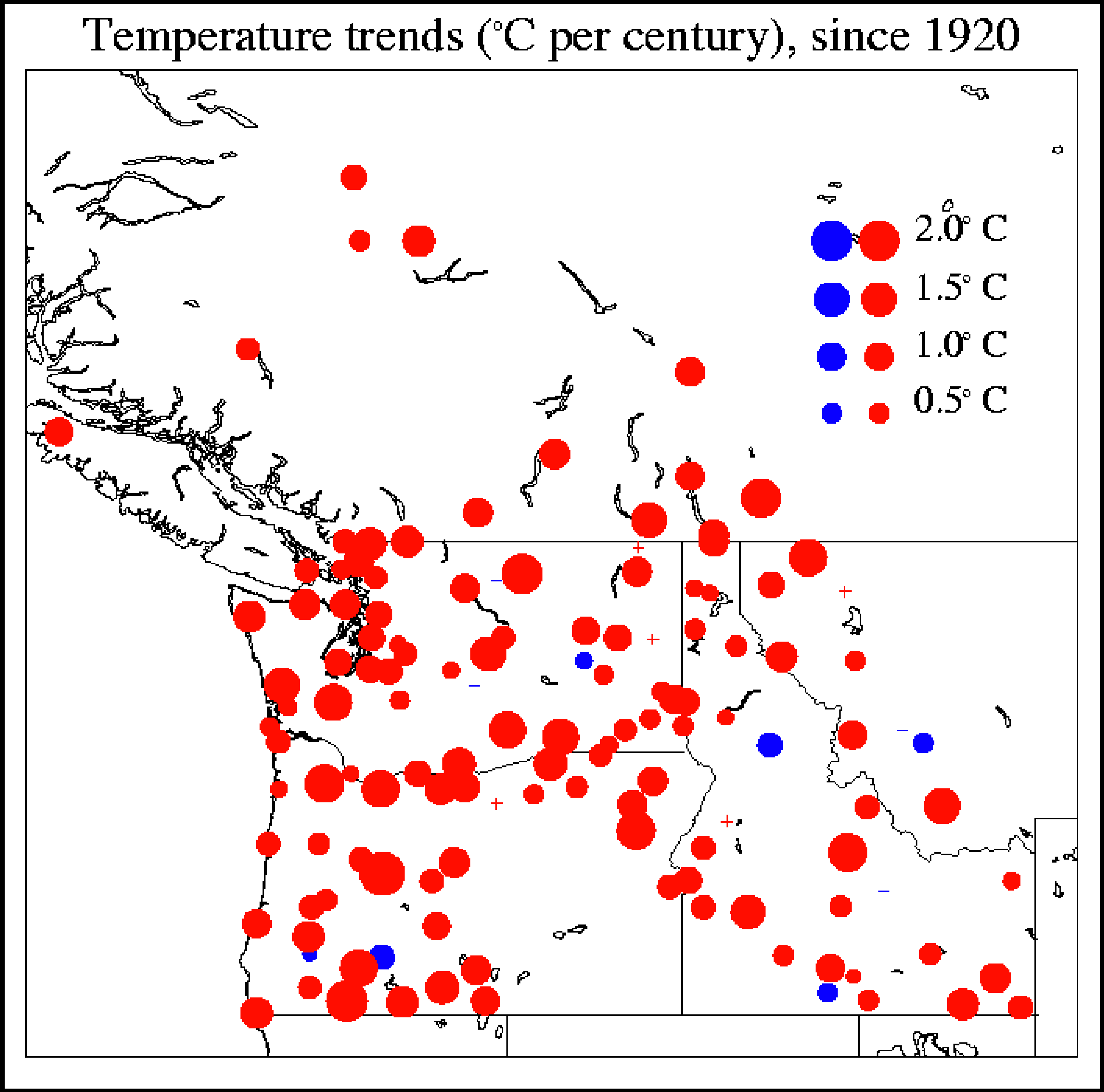
Thermometer records



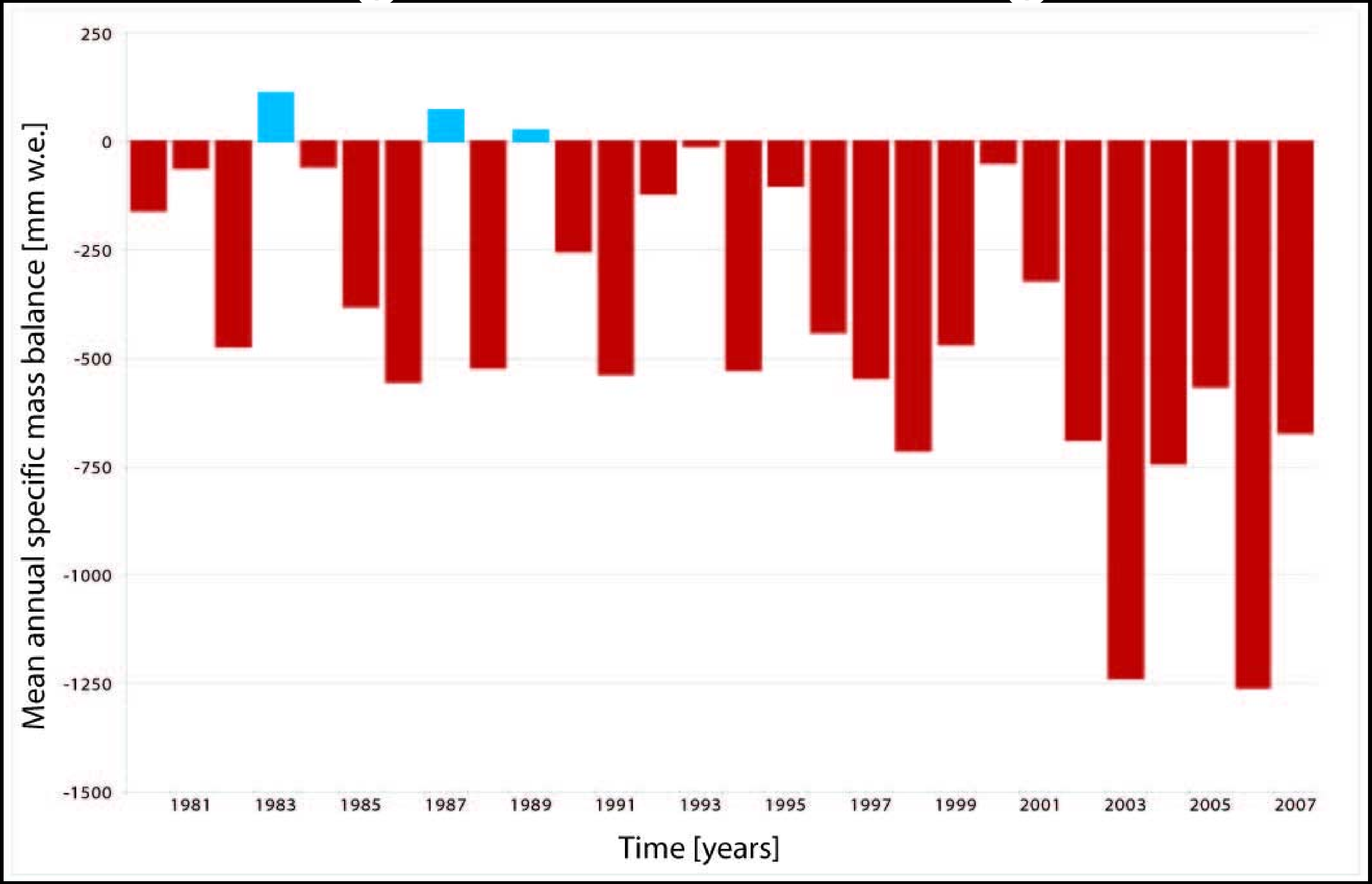


Surface and Satellite Temperatures
Direct Surface Measurements
Satellite Measurements
UAH / RSS
Temperature Anamoly (°C)
1
0.8
0.6
0.4
0.2
0
-0.2
1975
1980
1985
1990
1995
2000
2005

Temperature trends (°F per century) since 1920



World glacier monitoring service



Annual

http://www.geo.unizh.ch/wgms/

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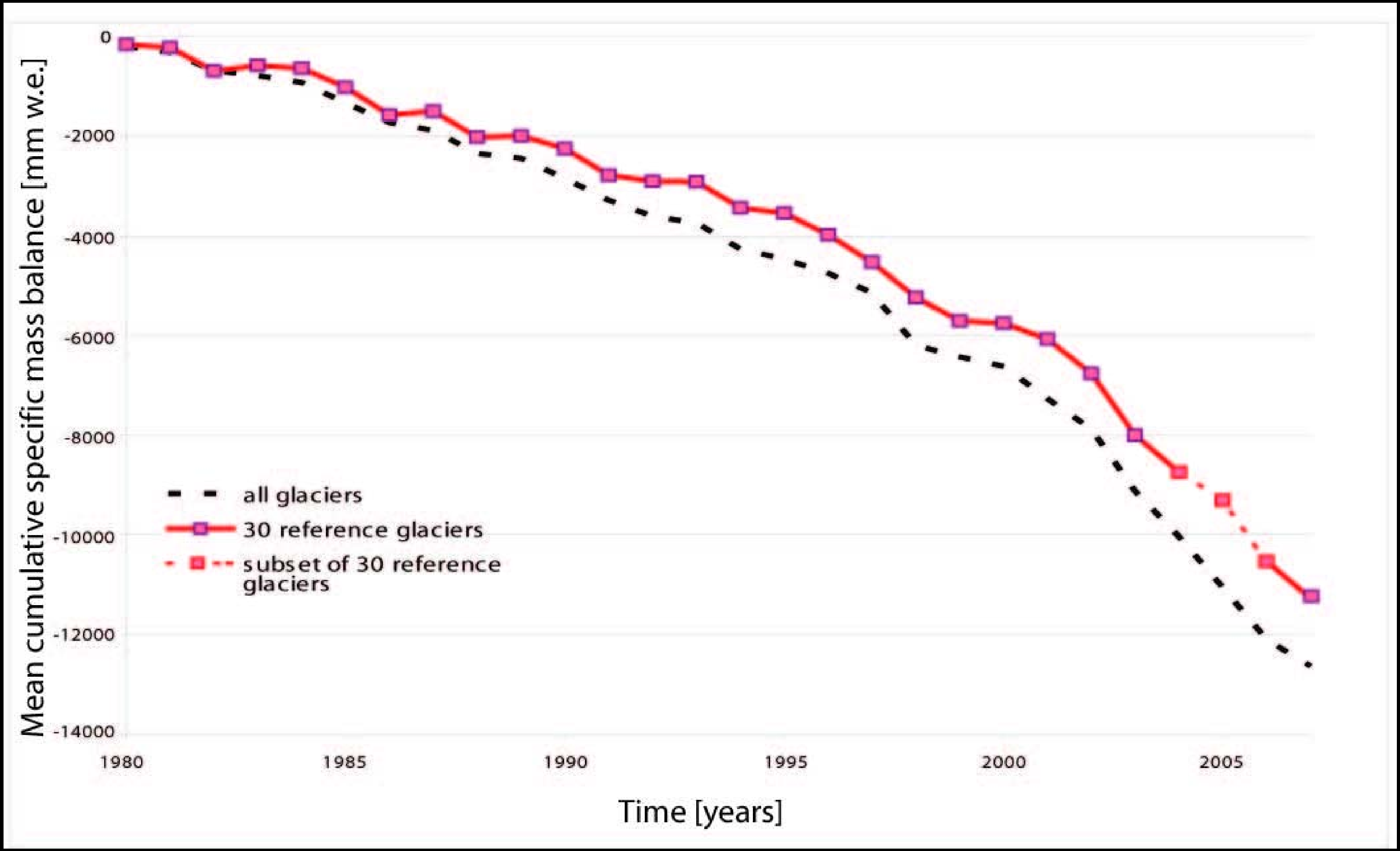

Cumulative

http://www.geo.unizh.ch/wgms/