CLIMATE AND CLIMATE CHANGE

CERTAINTIES AND UNCERTAINTIES

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http://www.ecd.bnl.gov/steve/schwartz.html

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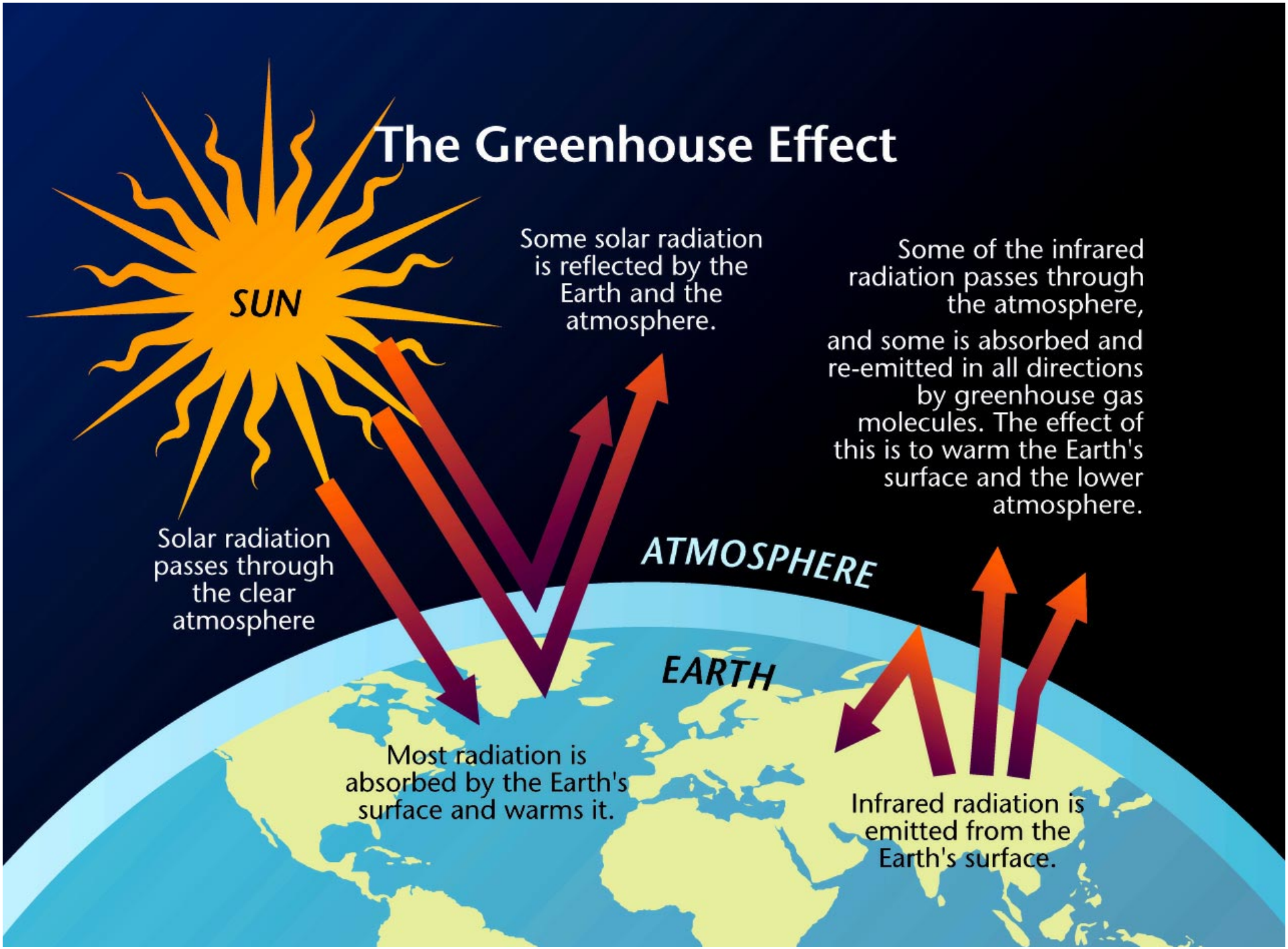
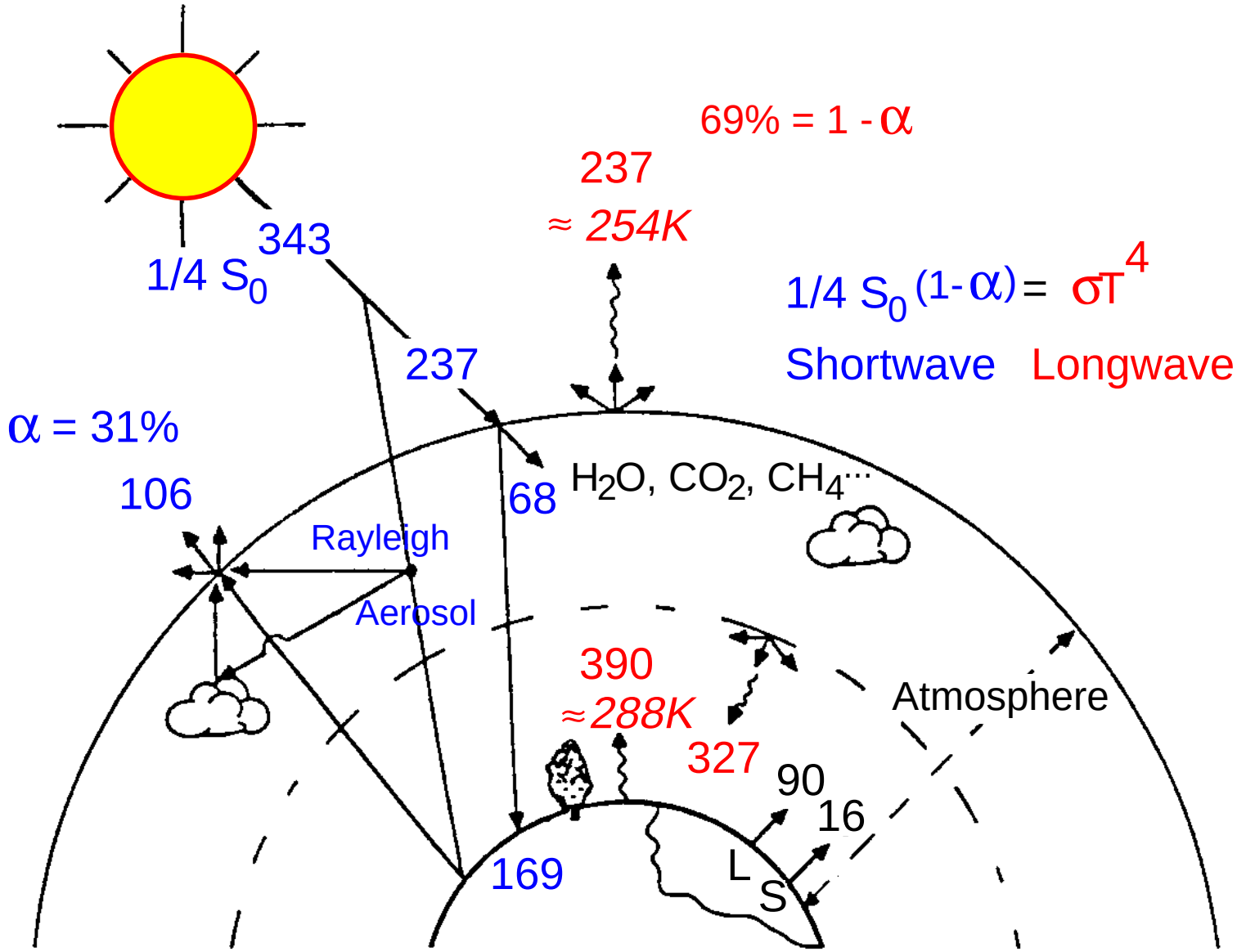
OUTLINE

- Overview of the Earth climate system
- Increased concentrations of “greenhouse gases”
- Radiative forcing of climate change
- Climate system response: Observations of temperature change on various time scales
- Climate system sensitivity: Models and Observations
- Sources of uncertainty: Aerosols
- Decision making in the face of uncertainty


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

GLOBAL ENERGY BALANCE

Global and annual average energy fluxes in watts per square meter



Schwartz, 1996, modified from Ramanathan, 1987

WATT PER SQUARE METER

STEFAN-BOLTZMANN RADIATION LAW

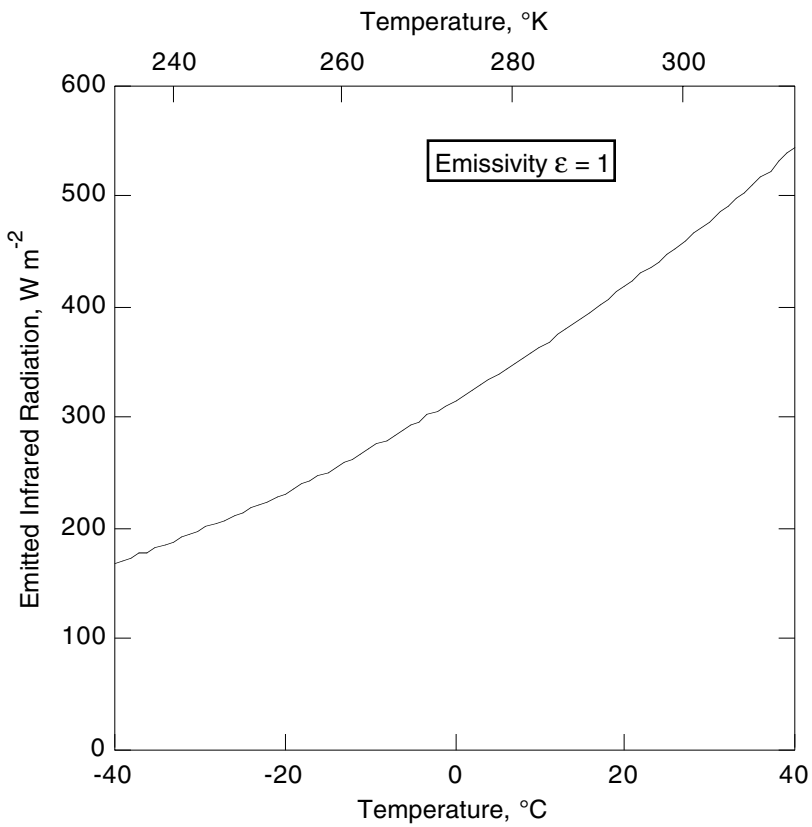
$$F = \varepsilon \sigma T^4$$

F = Emitted Flux (W m^{-2})

ε = Emissivity (approximately 1)

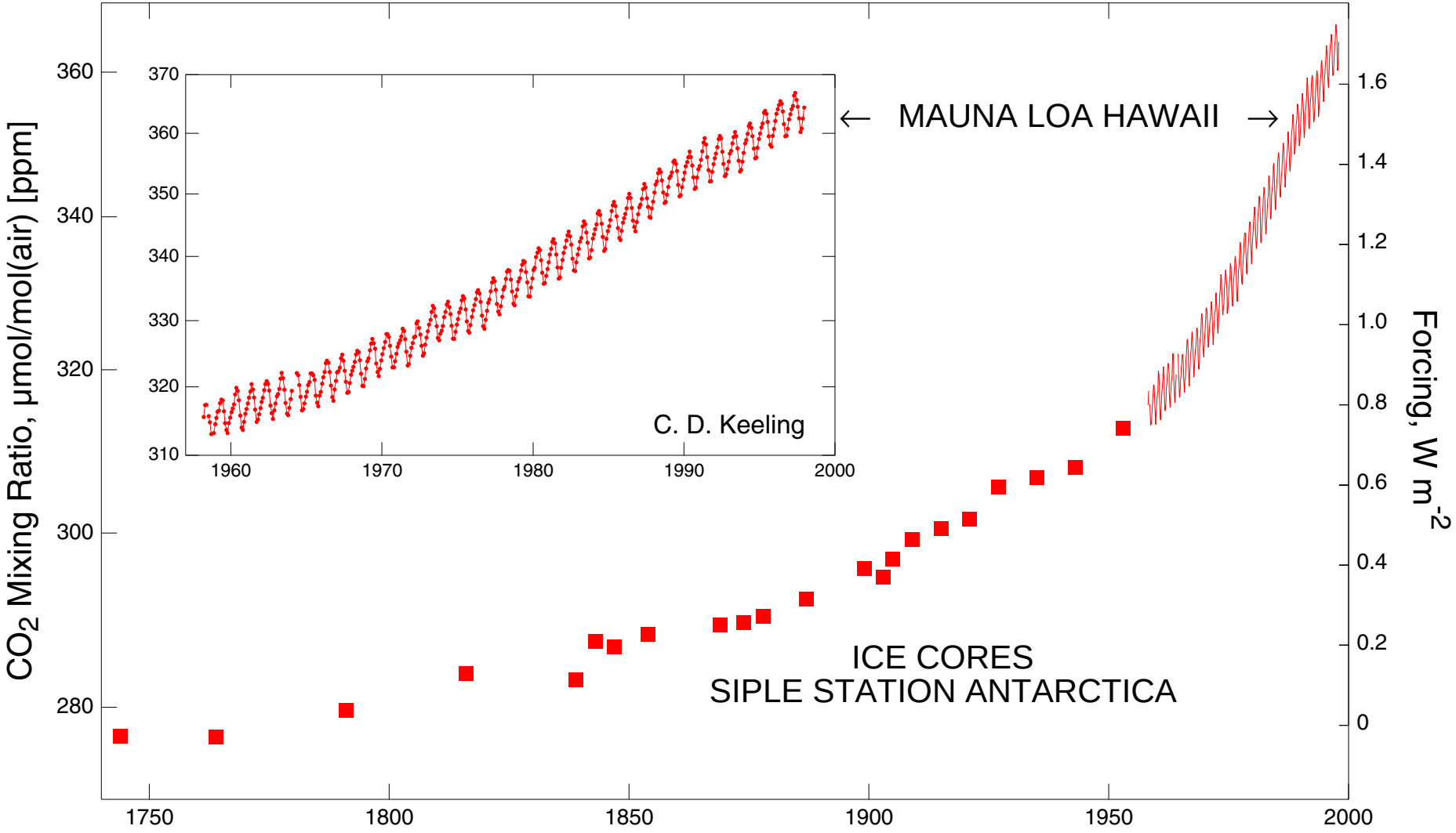
σ = Stefan-Boltzmann constant (5.67×10^{-8} W m^{-2} K^{-4})

T = Absolute temperature (K)

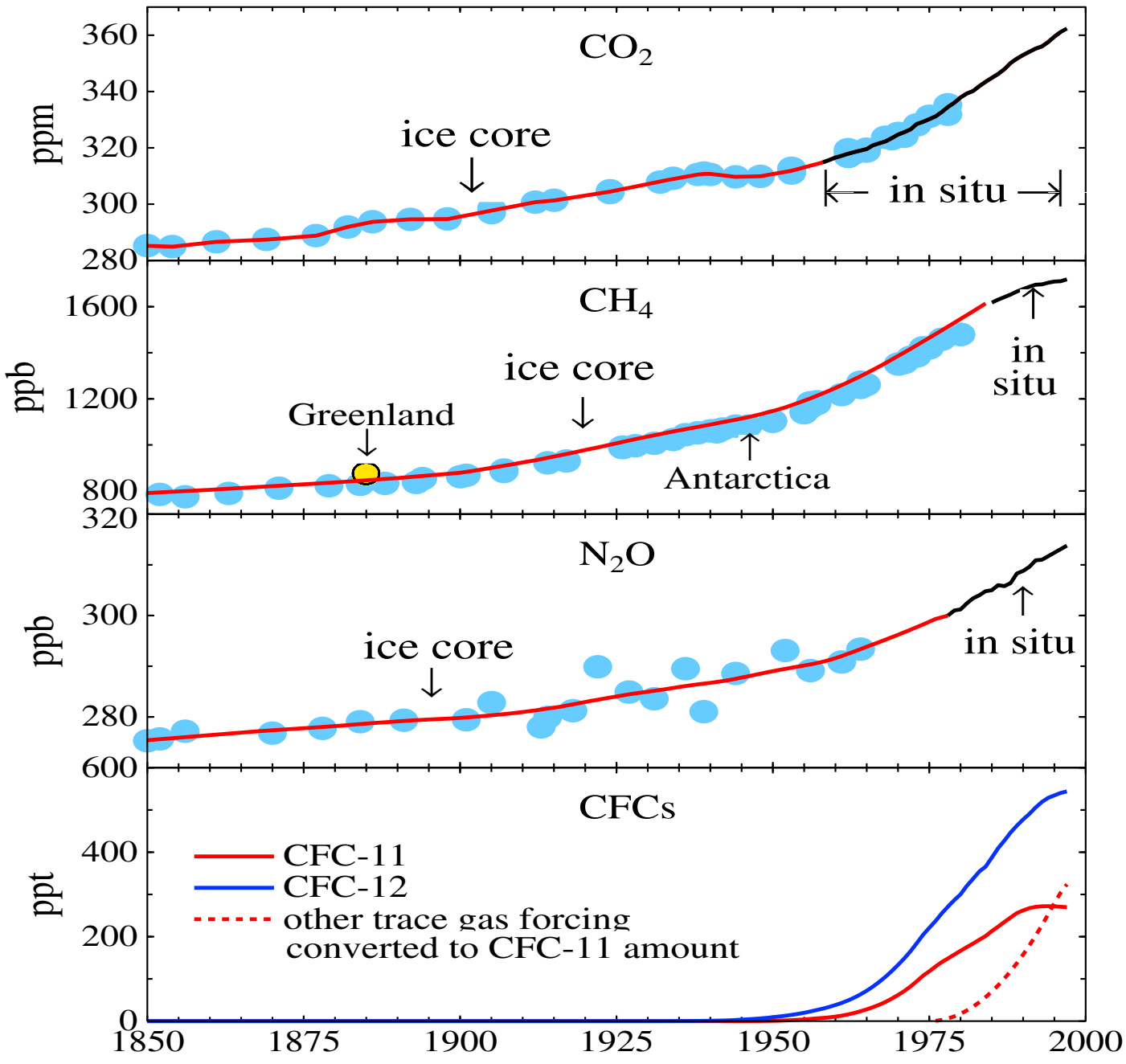


For T = 288 K (15 °C or 59 °F) F = 390 W m^{-2}.

GLOBAL CARBON DIOXIDE OVER THE INDUSTRIAL PERIOD

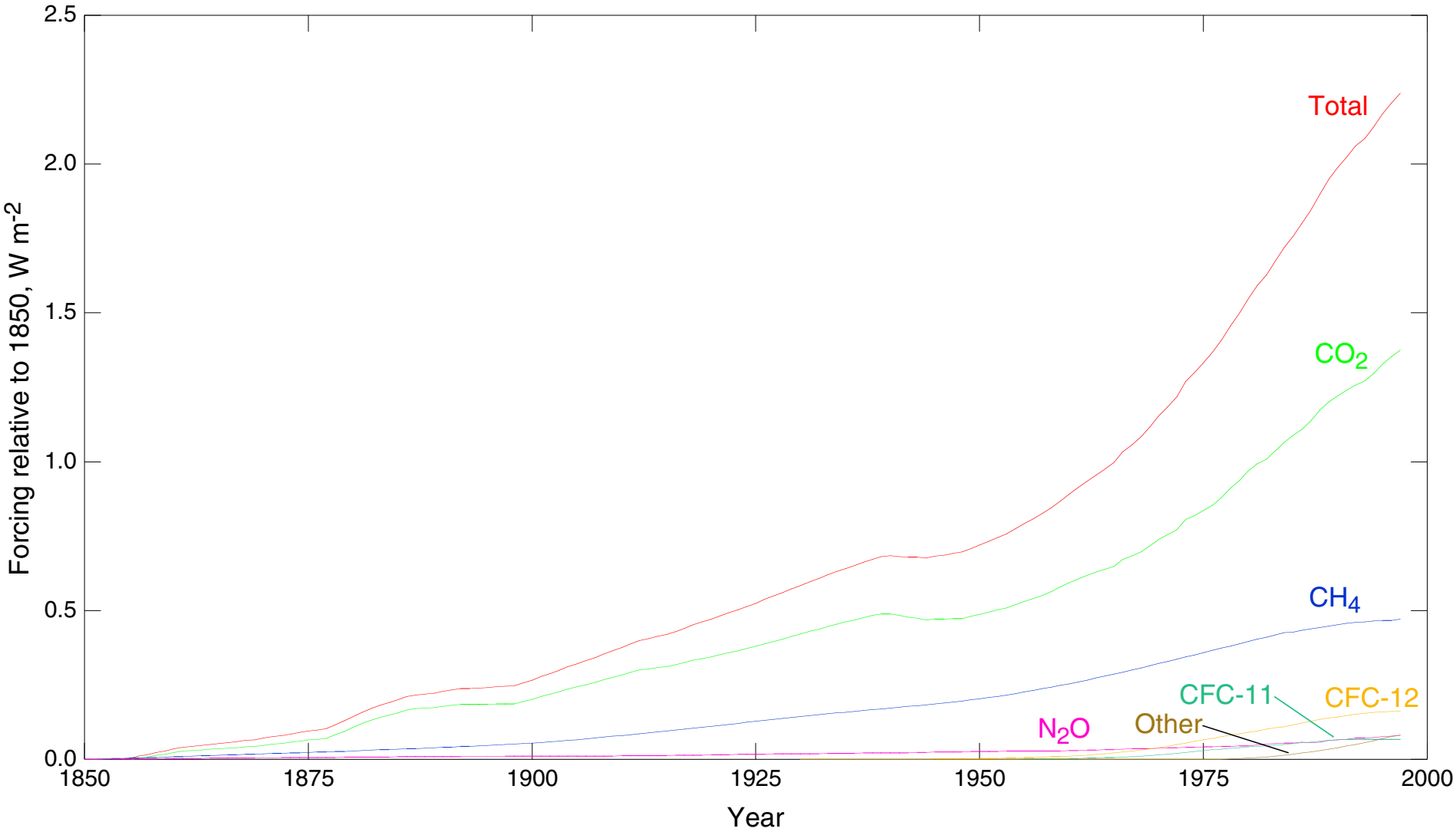


GREENHOUSE GAS MIXING RATIOS OVER THE INDUSTRIAL PERIOD



Hansen *et al.*, PNAS. 1998

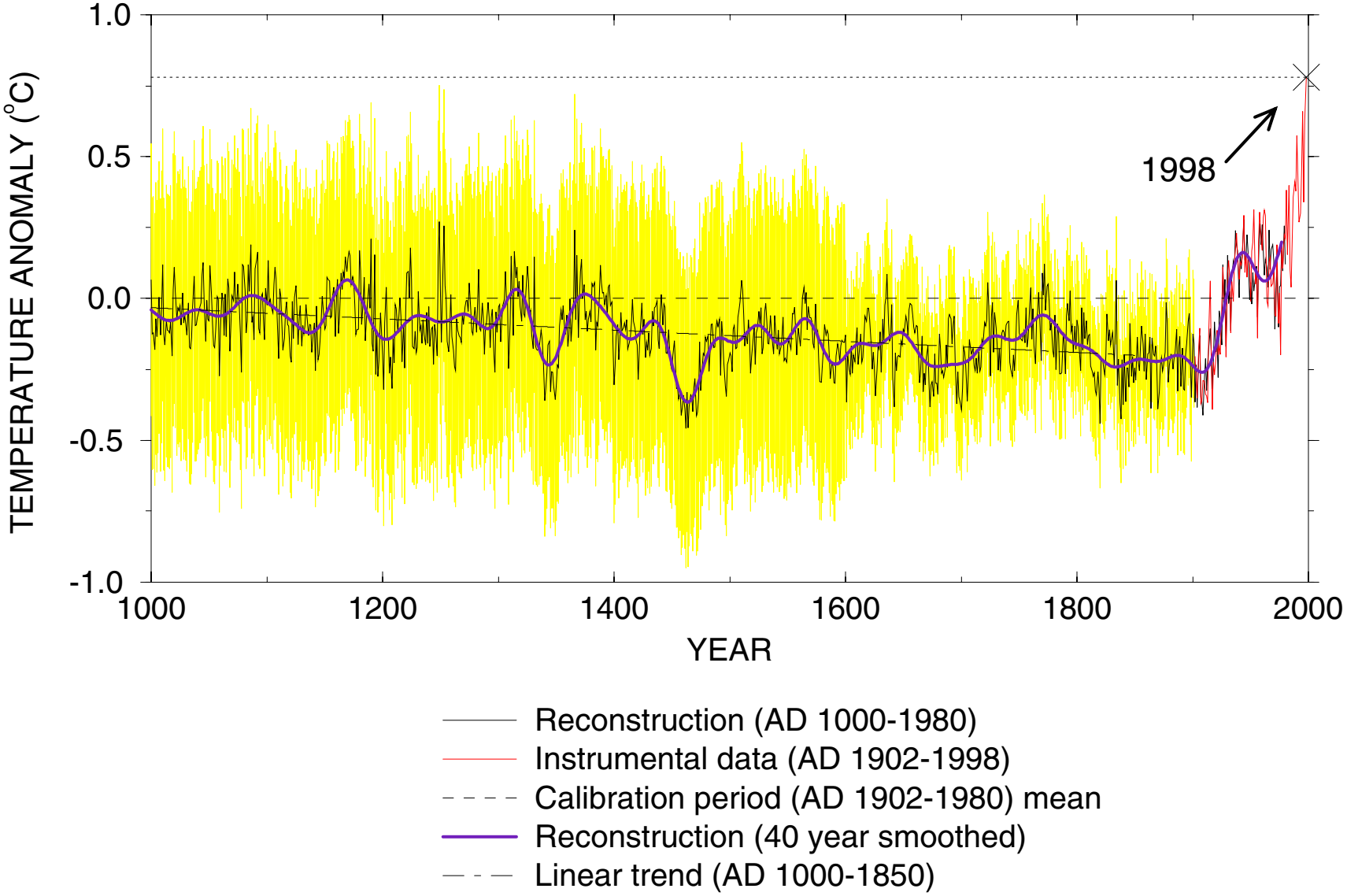
GREENHOUSE GAS FORCINGS OVER THE INDUSTRIAL PERIOD



Data: GISS

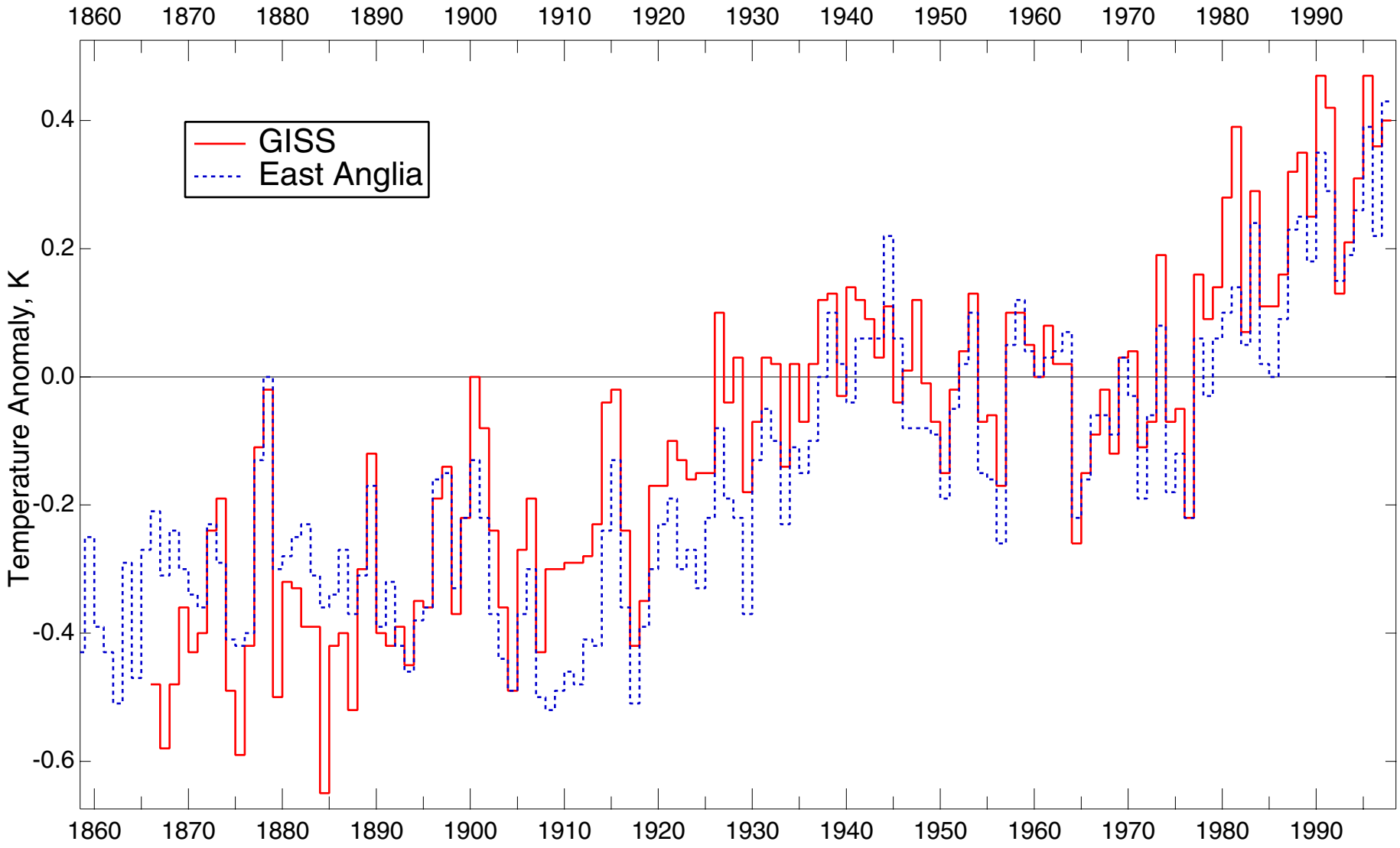
NORTHERN HEMISPHERE TEMPERATURE TREND (1000-1998)

From tree-ring, coral, and ice-core proxy records
As calibrated by instrumental measurements



Mann et al., GRL, 1999

GLOBAL TEMPERATURE TREND OVER THE INDUSTRIAL PERIOD



BILLIARD BALL TEMPERATURE SENSITIVITY

Climate Sensitivity Evaluated according to the Stefan-Boltzmann Radiation Law

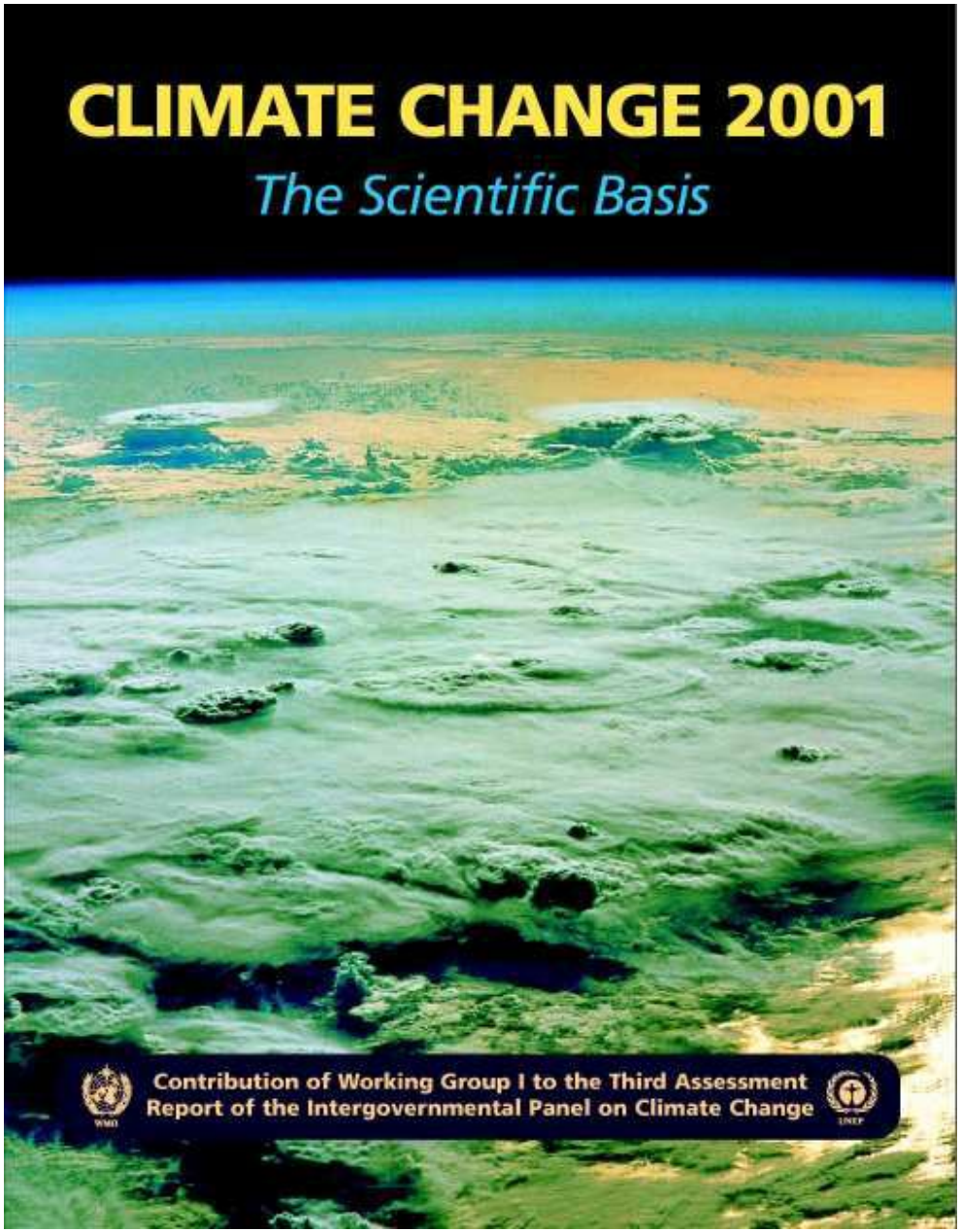
$$F = \varepsilon\sigma T^4$$

$$\frac{dF}{dT} = 4\varepsilon\sigma T^3$$

$$\text{Sensitivity } \lambda = \frac{dT}{dF} = (4\varepsilon\sigma T^3)^{-1}$$

For T = 288 K (15 °C or 59 °F) λ = 0.18 K / (W m^{-2}).

THE “BIBLE” OF CLIMATE CHANGE RESEARCH



Cambridge University Press, 2001

CLIMATE CHANGE SENSITIVITY
Summary of Current Models
Units: K / (W m^{-2})

Number of Models	Mean	Standard Deviation	Range
15	0.87	0.23	0.5 - 1.25

Climate Change 2001, Cambridge University Press, 2001

EMPIRICAL TEMPERATURE SENSITIVITY

Greenhouse forcing over the industrial period is 2.5 W m^{-2}

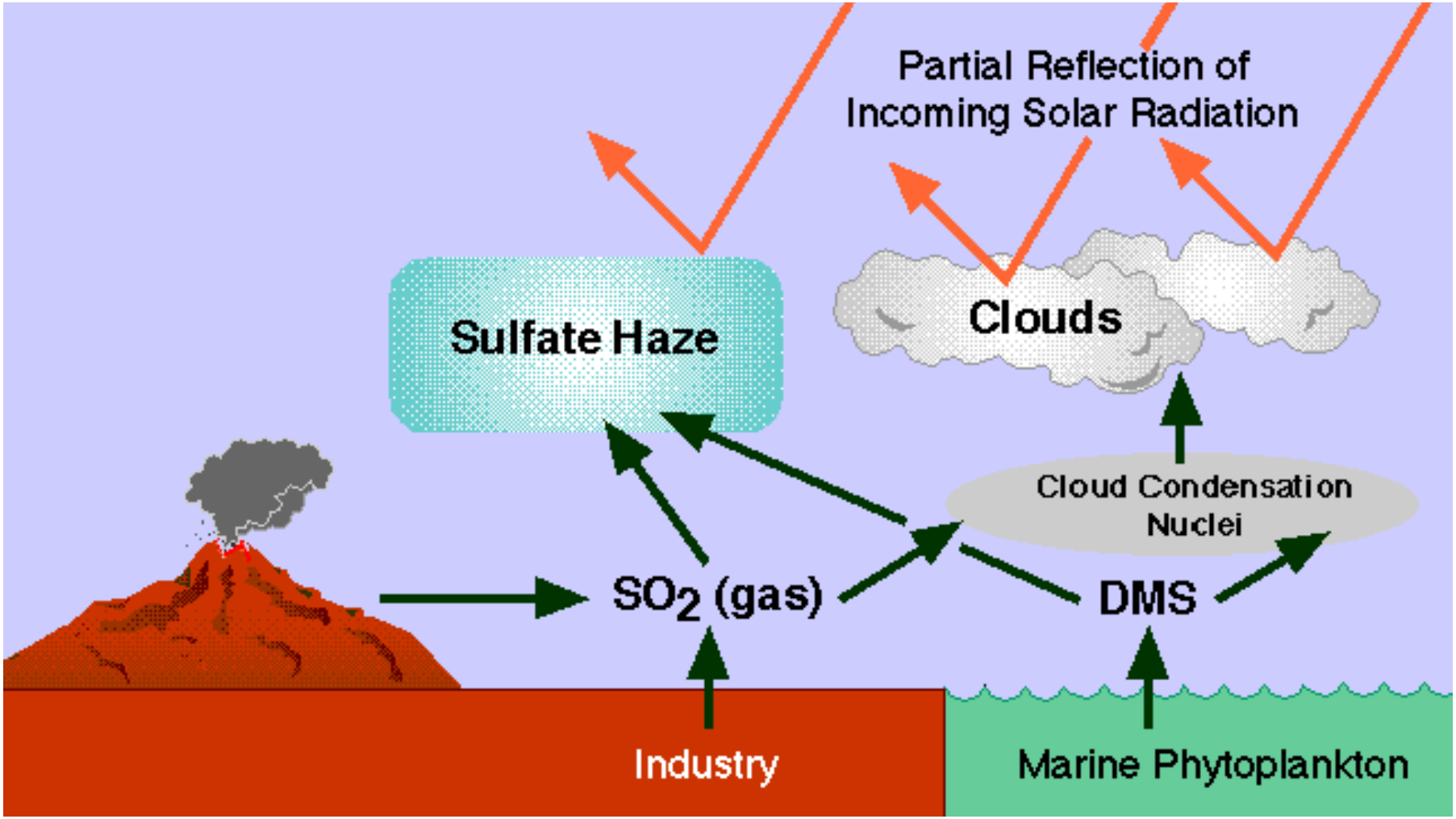
Temperature increase over the industrial period is 0.6 K.

Empirical Sensitivity: $\lambda = \frac{dT}{dF} = \frac{0.6 \text{ K}}{2.5 \text{ W m}^{-2}} = 0.24 \text{ K / (W m}^{-2})$

This value is much lower than model predictions.

WHY?

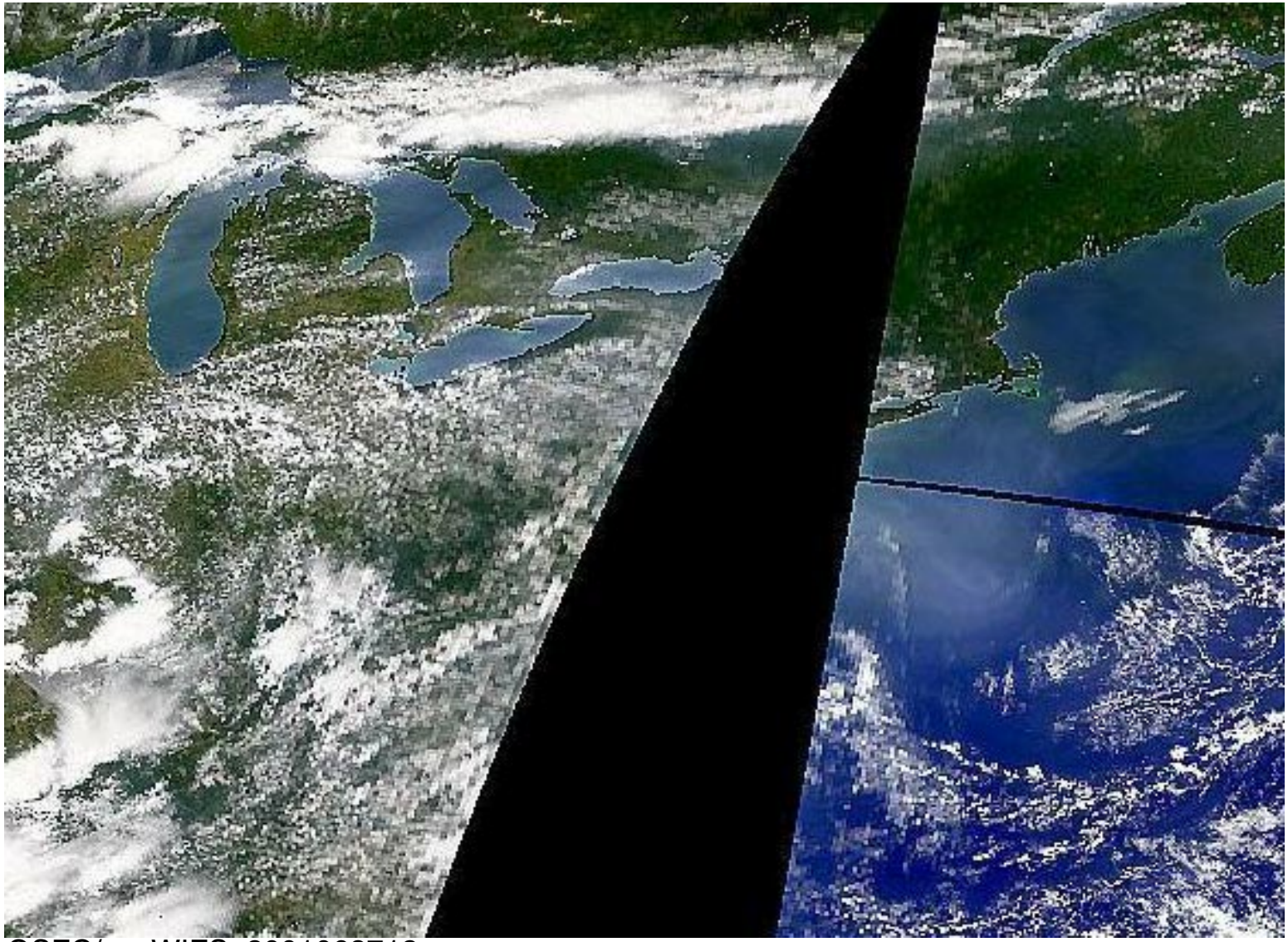
CLIMATE FORCING BY SULFATE AEROSOL



HUDSON RIVER 1998 - 11 - 09

BIOMASS BURNING AND WIDESPREAD AEROSOL, Western Arkansas, 2000-12-01

SEAWIFS IMAGE OF NORTH AMERICAN AEROSOL

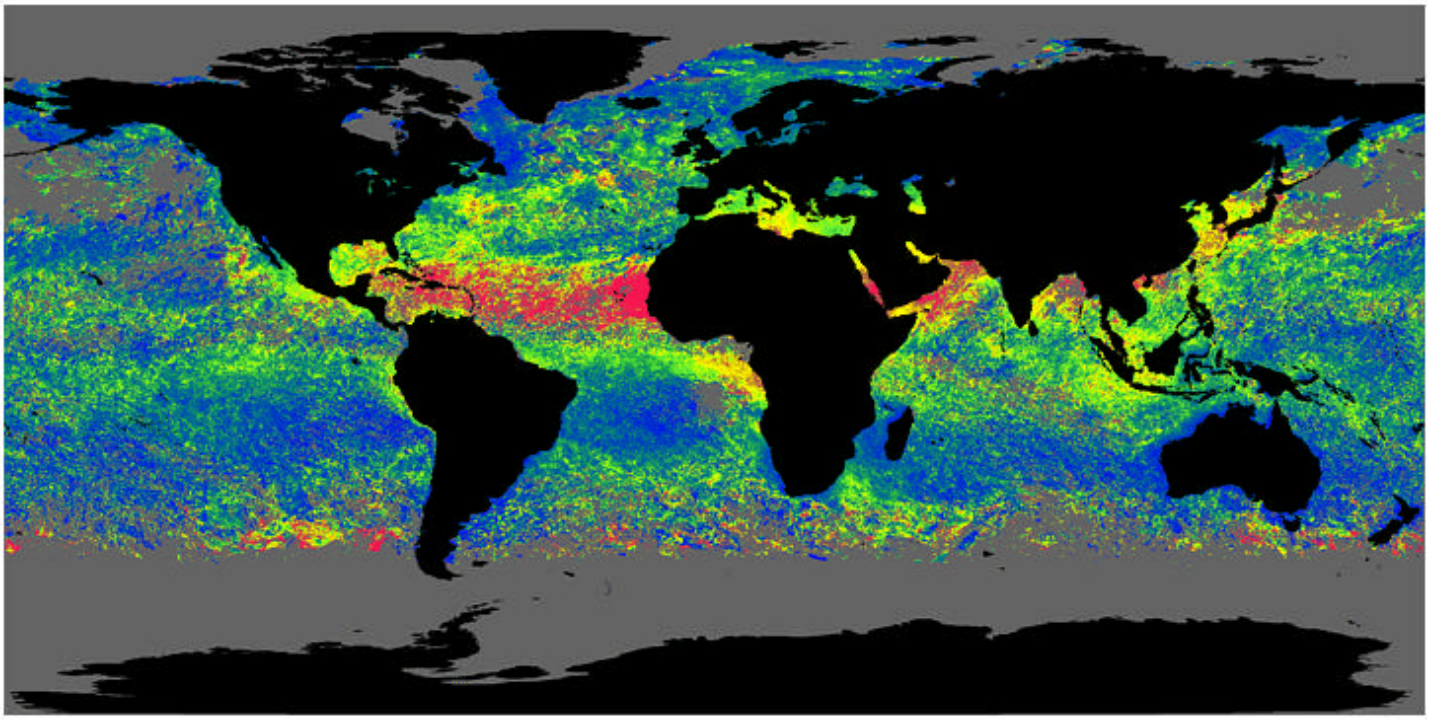


GSFC/seaWIFS_2001062712

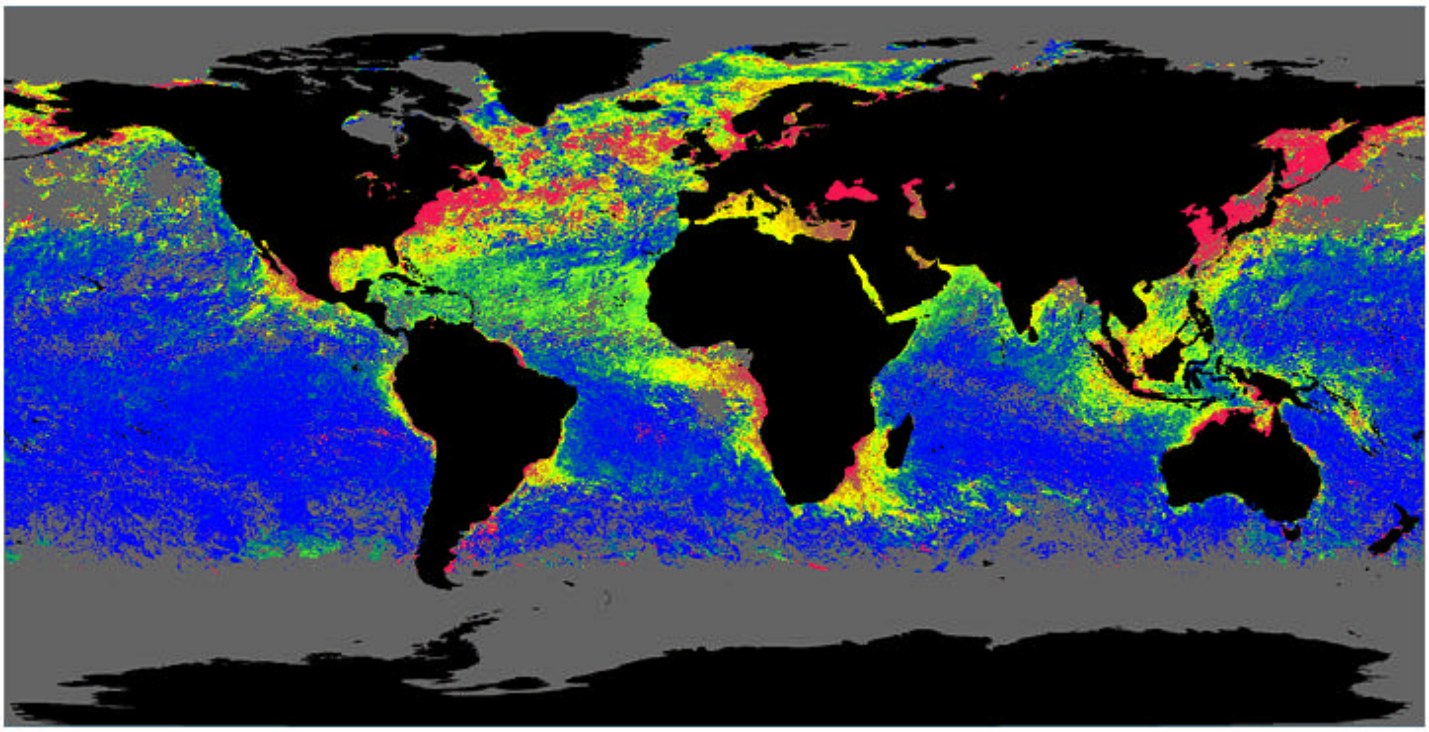
Provided by the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE

http://www.nrlmry.navy.mil/aerosol/satellite/seawifs/conus/200106/2001062712_conus.jpg

MONTHLY AVERAGE AEROSOL JUNE 1997



Optical Thickness at 865 nm

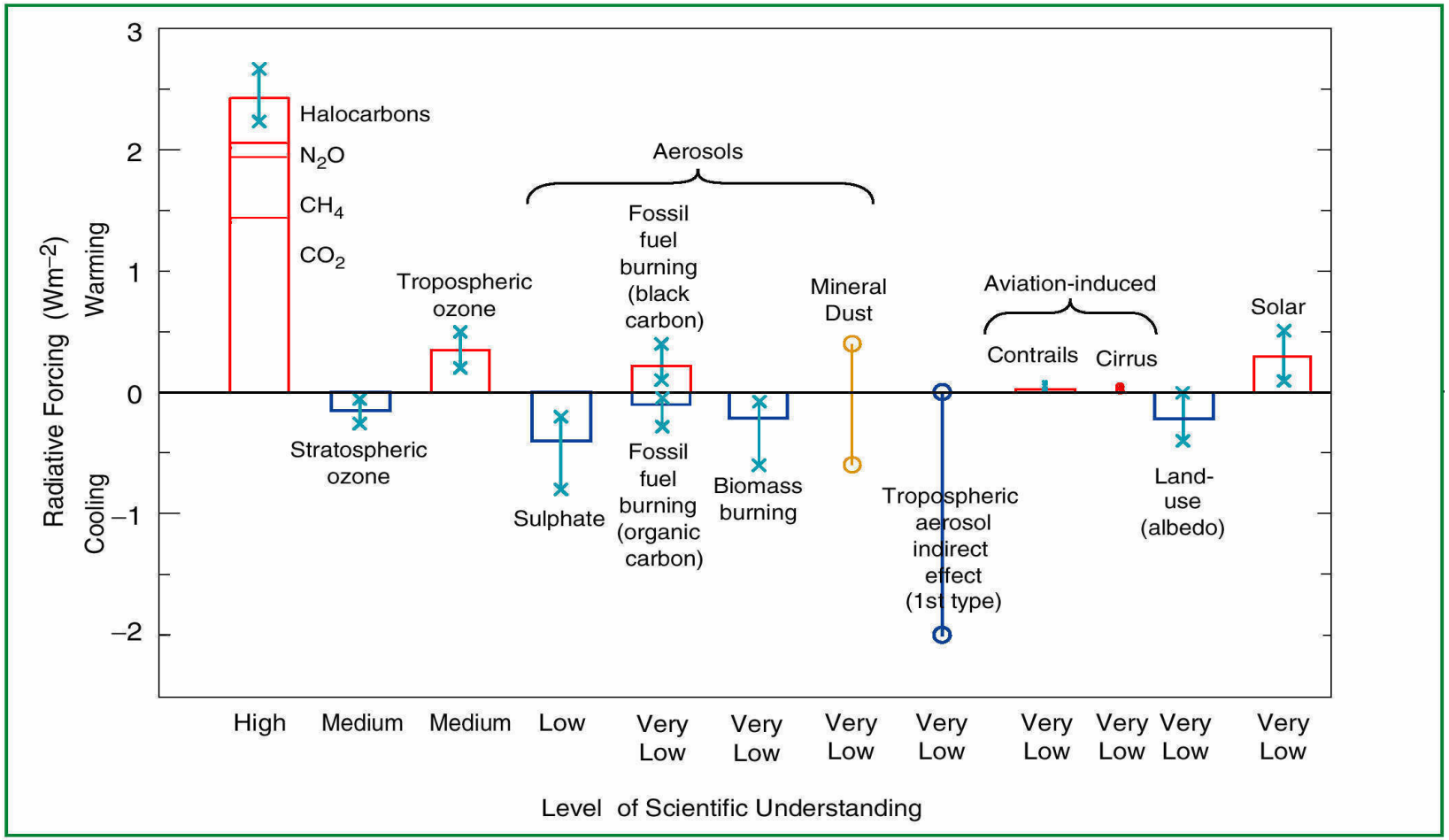


Ångström Exponent

Polder/Adeos CNES/NASDA LOA/LSCE

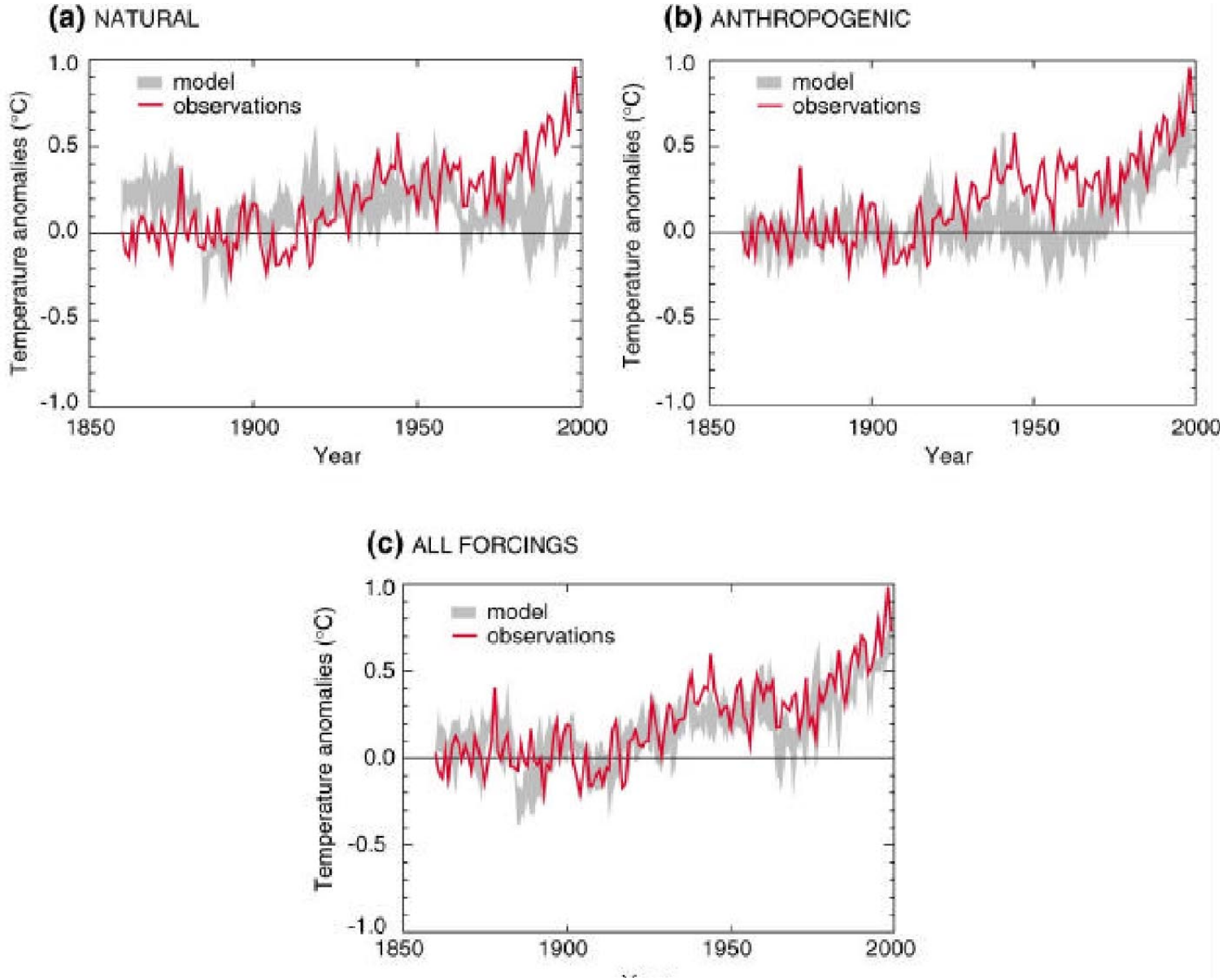
Global-and-Annual-Mean Radiative Forcing

[1750-present]



IPCC, 2001

IPCC-2001 COMPARISONS OF MEASURED AND MODELED SURFACE TEMPERATURE TRENDS



IPCC-2001 STATEMENT ON CONFIDENCE IN ABILITY OF MODELS TO PROJECT FUTURE CLIMATE

- ***Simulations that include estimates of natural and anthropogenic forcing reproduce the observed large-scale changes in surface temperature over the 20th century*** (Figure 4). However, contributions from some additional processes and forcings may not have been included in the models. Nevertheless, ***the large-scale consistency between models and observations*** can be used to provide an independent check on projected warming rates over the next few decades under a given emissions scenario.

IPCC-2001 STATEMENTS ON DETECTION AND ATTRIBUTION OF CLIMATE CHANGE

- ***Detection and attribution studies comparing model simulated changes with the observed record can now take into account uncertainty in the magnitude of modelled response to external forcing***, in particular that due to uncertainty in climate sensitivity.
- Most of these studies find that, over the last 50 years, the estimated rate and magnitude of warming due to increasing concentrations of greenhouse gases alone are comparable with, or larger than, the observed warming. ***Furthermore, most model estimates that take into account both greenhouse gases and sulphate aerosols are consistent with observations over this period.***

IPCC-2001 STATEMENTS ON DETECTION AND ATTRIBUTION OF CLIMATE CHANGE (cont'd)

- The best agreement between model simulations and observations over the last 140 years has been found when all the above anthropogenic and natural forcing factors are combined, as shown in Figure 4 (c). These results show that ***the forcings included are sufficient to explain the observed changes,*** but do not exclude the possibility that other forcings may also have contributed.

The Emperor's New Clothes

A Fairy Tale
by
Hans Christian
Andersen

Illustrated by
Monika
Zimmgruber

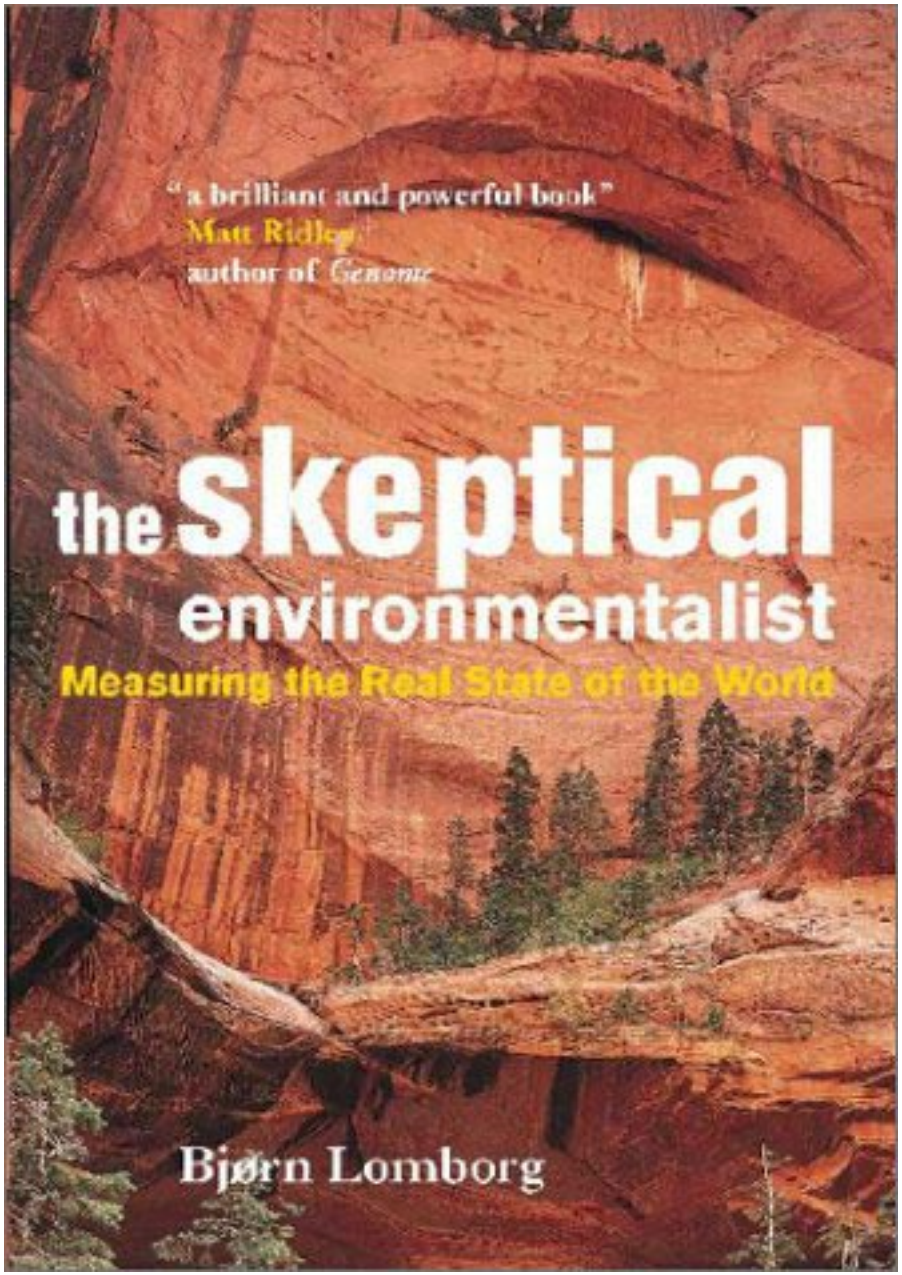
REMARKS BY THE PRESIDENT ON GLOBAL CLIMATE CHANGE

June 11, 2001

“Our useful efforts to reduce sulfur emissions may have actually increased warming, because ***sulfate particles*** reflect sunlight, bouncing it back into space.”

“Kyoto also failed to address two major pollutants that have an impact on warming: ***black soot*** and tropospheric ozone. Both are proven health hazards. Reducing both would not only address climate change, but also dramatically improve people's health.”

RECOMMENDED READING



No need to worry about the future

Environmentally, we are told, 'things are getting better'.

The Skeptical Environmentalist: Measuring the Real State of the World
by Bjørn Lomborg
Cambridge University Press: 2001, 515 pp. £47.50, £17.95

Stuart Pimm and Jeff Harvey

The subtitle gives the book away. It rehashes books such as Ronald Bailey's *The True State of the Planet* (Free Press, 1995). As Bjørn Lomborg tells us, the book's origin was a class he taught in 1997. The original Danish version appeared a mere year later — remarkably fast, given the delays of academic publishing. It shows, too. This survey of global environmental problems — food, forests, energy, water, pollution, biodiversity, global warming — reads like a compilation of term papers from one of those classes from hell where one has to fail all the students. It is a mass of poorly digested material, deeply flawed in its selection of examples and analysis.

— for example, the claim that the evidence for pollution at New York's Love Canal was "jaded". At other times it seems fictional. "Scientific luminaries such as Harvard biologist E. O. Wilson and Stanford biologist Paul Ehrlich are the enthusiastic supporters of an ambitious plan … to move the entire population of the US. … people would live in small enclosed city islands." The reference is directly attributable neither to Wilson nor to Ehrlich. "Is it true?" we asked them. Ehrlich: "I know of no such plan. If there were one, I wouldn't support it." Wilson concurred.

Lomborg's great optimism about humanity's future shows up in the way he presents statistics. In the hell-hole that is so much of sub-Saharan Africa, "starving people" constituted "38 percent in 1970 … [but only] "33 percent … in 1996. [The percentage is] expected to fall even further to 30 percent in 2010." The absolute numbers of starving are curiously missing from these paragraphs. Roughly, the region's population malnourished in the region — as well as those whom fate will spare through their death from the myriad consequences of poverty (including AIDS) — are surely inconsistent with the first-listed "global trend" in a chapter entitled "Things are getting better".

Often, Lomborg misses the critical literature in exactly the same ways as did Simon. For example, consider the chapter on biodiversity. It starts out with the by-now standard denigration of consensus estimates on extinction rates and omits relevant papers in even obvious places — including the paper demonstrating that Simon's estimates are three to four orders of magnitude below everyone else's.

The text employs the strategy of those who, for example, argue that gay men aren't dying of AIDS, that Jews weren't singled out by the Nazis for extermination, and so on. "Name those who have died!" demands a hypothetical critic, who then scorns the discrepancy between those few we know by

FROM THE *NATURE* REVIEW

- “This survey of global environmental problems — food, forests, energy, water, pollution, biodiversity, global warming — reads like a compilation of term papers from one of those classes from hell where one has to fail all the students. It is a mass of poorly digested material, deeply flawed in its selection of examples and analysis.”
- “Like bad term papers, Lomborg’s text relies heavily on secondary sources. Out of around 2,000 references, about 5% come from news sources and 30% from web downloads — readily accessible, therefore, but frequently not peer reviewed. A mere 1% are original papers in *Nature*...”
- “The text employs the strategy of those who, for example, argue that gay men aren’t dying of AIDS, that Jews weren’t singled out by the Nazis for extermination, and so on. “Name those who have died!” demands a hypothetical critic, who then scorns the discrepancy between those few we know by name and the unnamed millions we infer.”

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FROM THE BOOK

“ This chapter accepts the reality of man-made global warming but questions the way in which future scenarios have been arrived at and finds that forecasts of climate change of 6 degrees by the end of the century are not plausible.

“ I shall argue that the limitations of computer modeling, the unrealistic nature of the basic assumptions made about future technological change and political value judgments have distorted the scenarios being presented to the public.

“ I shall further argue that an economic analysis of the costs and benefits of an immediate reduction in CO_2 emissions clearly shows that the world was a whole would benefit more from investing in tackling problems of poverty in the developing world and in research and development of renewable energy than in policies focused on climate change. ”

Lomborg, *Skeptical Environmentalist*, 2001, p. 259

MORE FROM THE BOOK

“ Temperatures have increased 0.6 ˚C over the past century and it is unlikely that this is not in part due to an anthropogenic greenhouse effect...

“ The central climate sensitivity of 1.5 - 4.5 ˚C has not changed over the past 25 years, indicating a fundamental lack of model adequacy, because we still do not know whether we live in a world where doubling the CO_2 concentrations will mean a rather small (1.5 ˚C) or a dramatic (4.5 ˚C) temperature increase.

“ All the IPCC predictions are based on GCMs, but there are still crucial problems with the representation of aerosols, water vapor feedback, and clouds. ”

Lomborg, *Skeptical Environmentalist*, 2001, p. 317

SOME CONCLUDING OBSERVATIONS

- Greenhouse gases persist in the atmosphere for decades to centuries. (Aerosols last about a week.)
- Actions we take today will affect future generations.
- The sensitivity of the climate system remains highly uncertain.
- Decisions must be made in an uncertain world. (Lack of controls on emissions is also a decision).
- How do we make decisions in the face of uncertainty?