

Climate Change: A Quantitative Question

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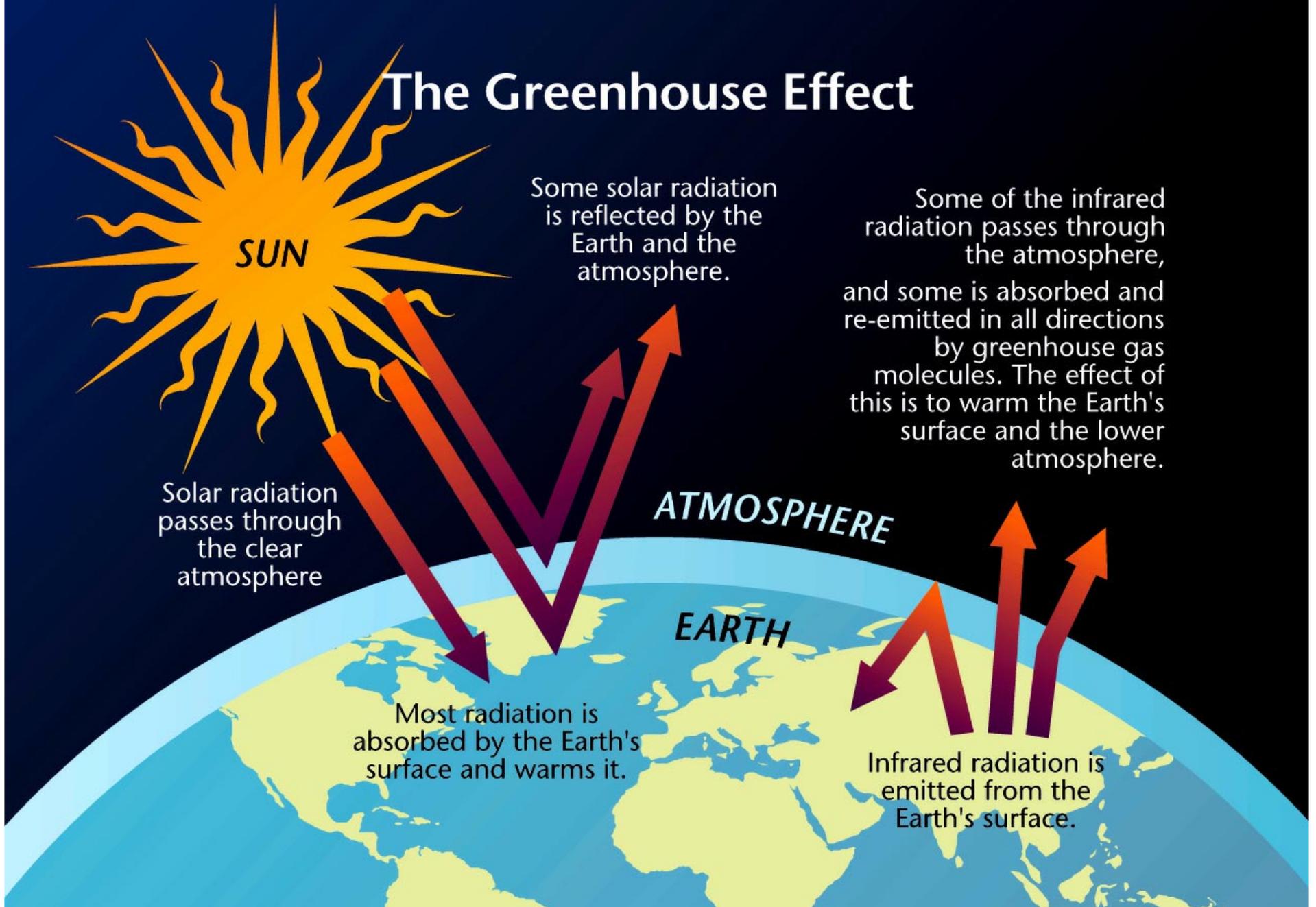
New York University
Graduate School of Journalism

Science, Health and Environmental
Reporting Program (SHERP)

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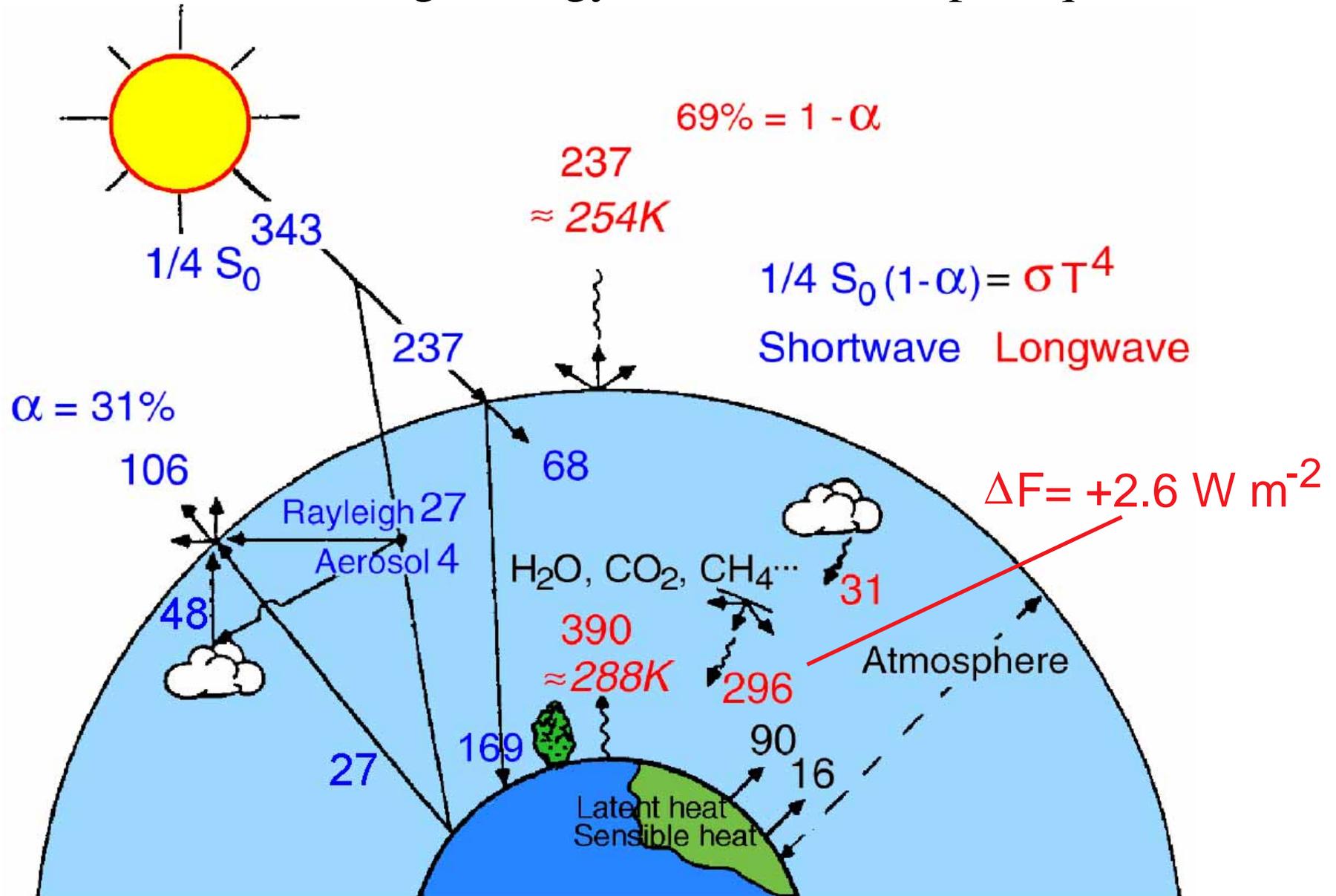
<http://www.ecd.bnl.gov/steve>

The Greenhouse Effect



GLOBAL ENERGY BALANCE

Global and annual average energy fluxes in watts per square meter



Schwartz, 1996, modified from Ramanathan, 1987

ATMOSPHERIC RADIATION

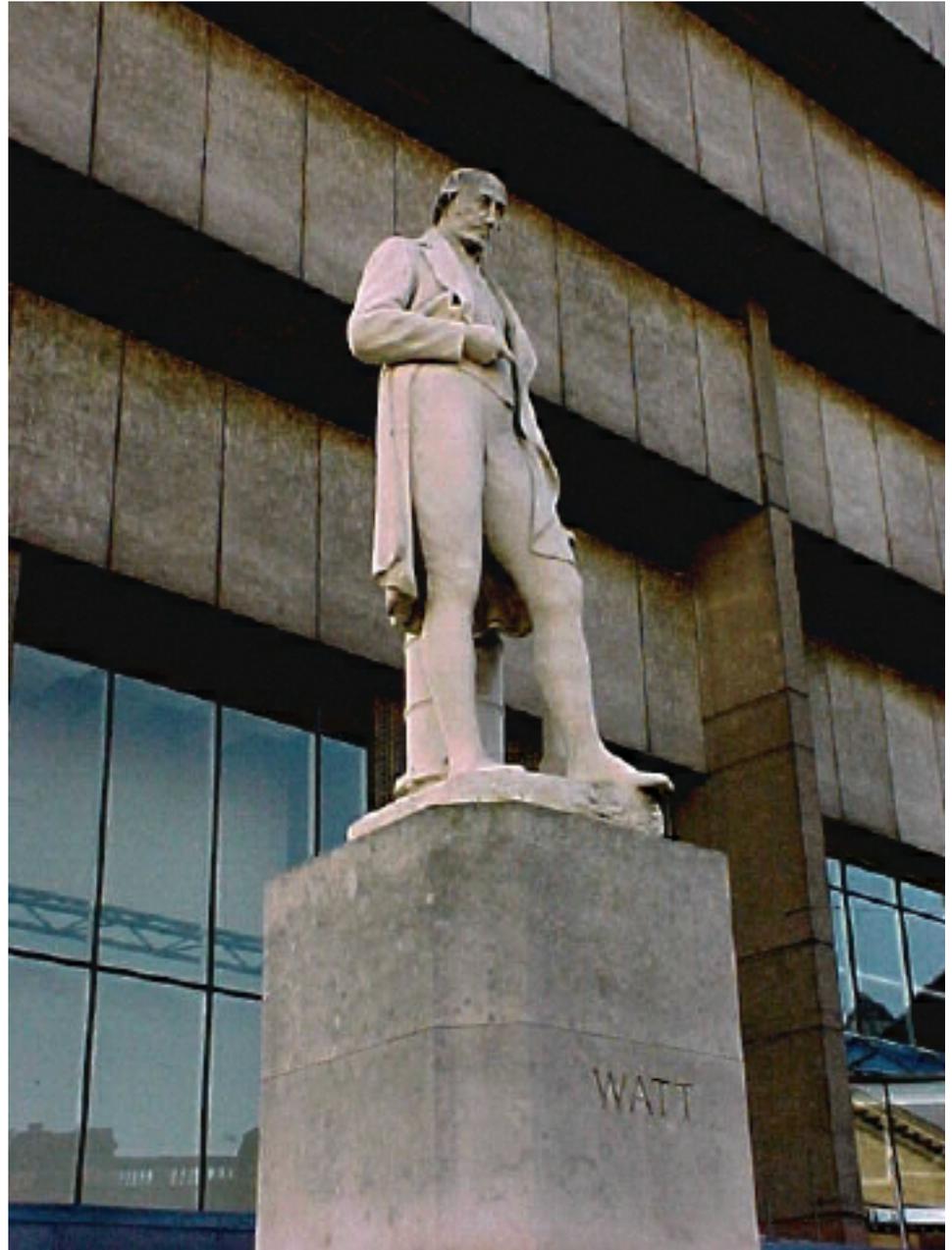
***Energy per area per
time***

Power per area

Unit:

Watt per square meter

$W m^{-2}$



STEFAN - BOLTZMANN RADIATION LAW

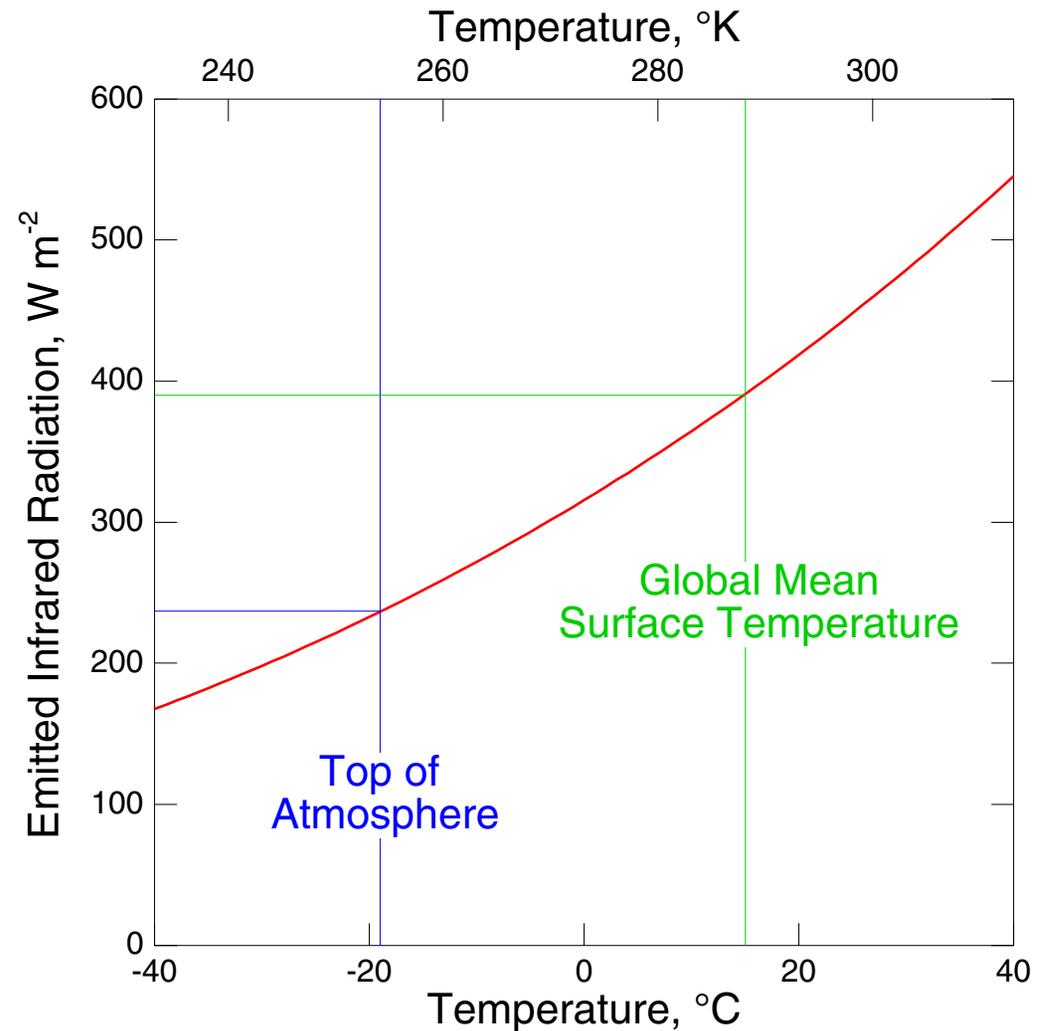
Emitted thermal radiative flux from a black body

$$F = \sigma T^4$$

F = Emitted flux, $W m^{-2}$

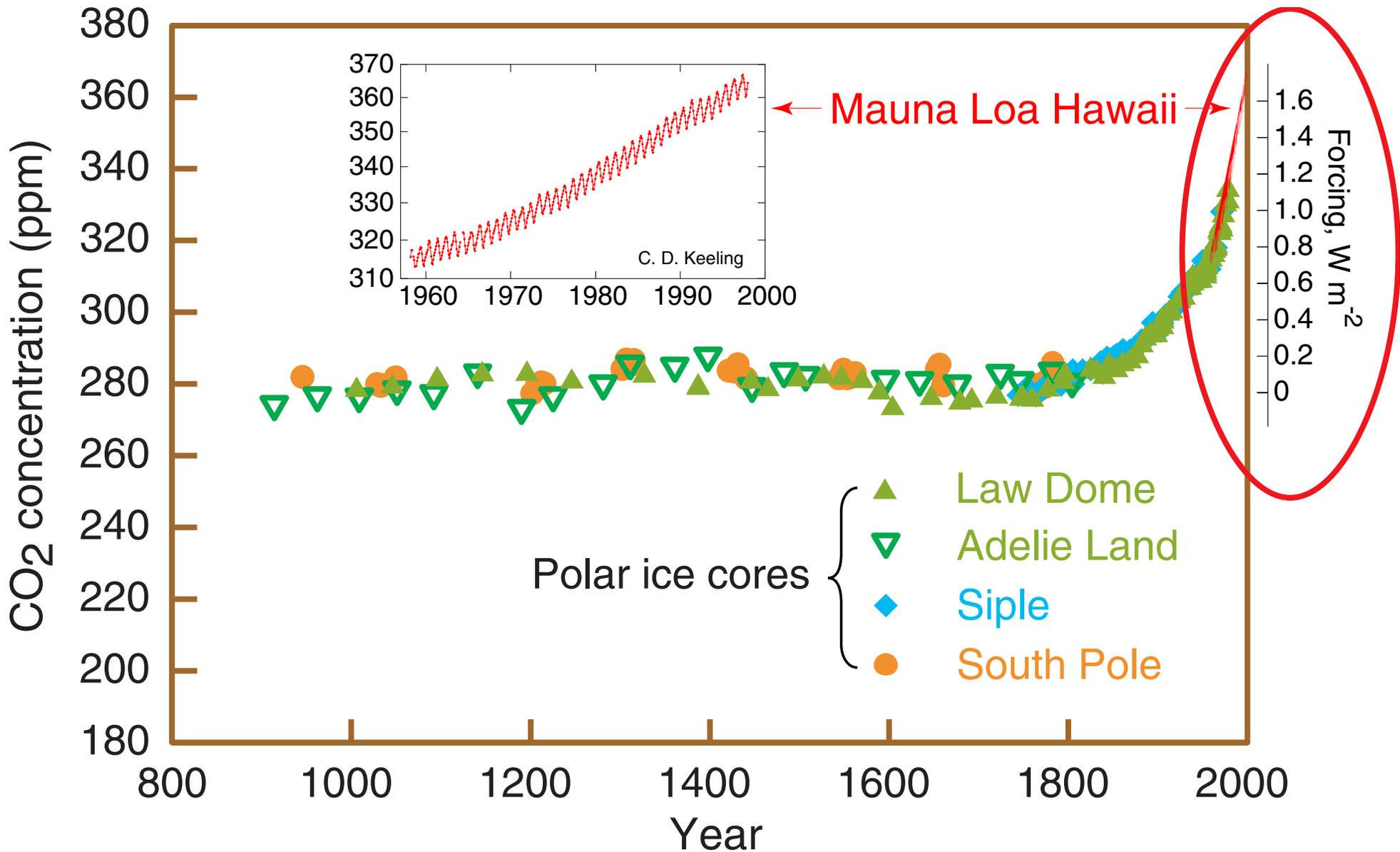
T = Absolute temperature, K

σ = Stefan-Boltzmann constant, $W m^{-2} K^{-4}$



Stefan-Boltzmann law “converts” temperature to radiative flux.

ATMOSPHERIC CARBON DIOXIDE IS INCREASING



Global carbon dioxide concentration and infrared radiative forcing over the last thousand years

RADIATIVE FORCING

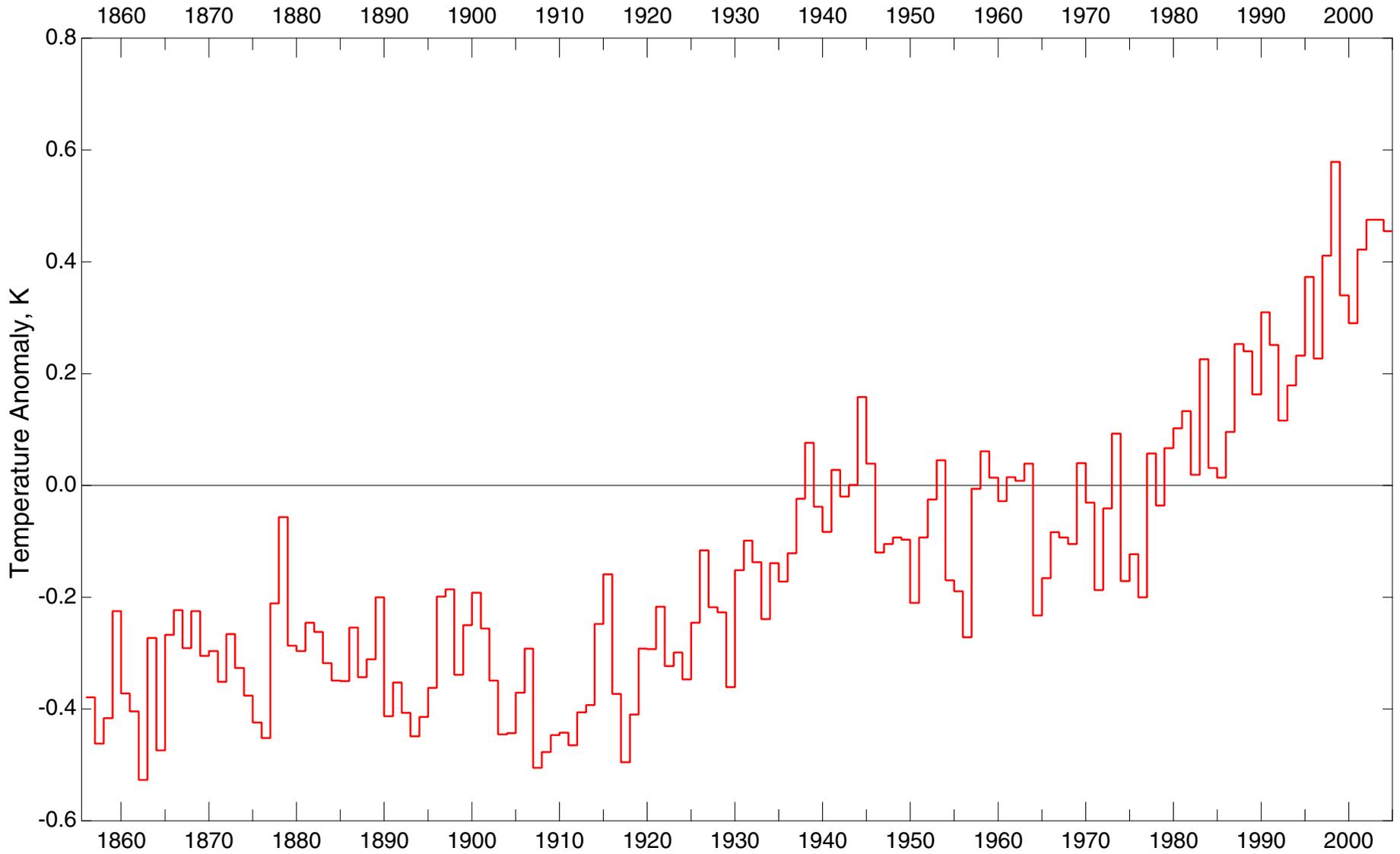
A *change* in a radiative flux term in Earth's radiation budget, ΔF , W m^{-2} .

Working hypothesis:

On a global basis radiative forcings are additive and fungible.

- This hypothesis is fundamental to the radiative forcing concept.
- This hypothesis underlies much of the assessment of climate change over the industrial period.

CHANGE IN GLOBAL MEAN SURFACE TEMPERATURE 1855-2004



Climate Research Unit, University of East Anglia, UK

CLIMATE RESPONSE

The *change* in global and annual mean temperature, ΔT , K, resulting from a given radiative forcing.

Working hypothesis:

The change in global mean temperature is proportional to the forcing, but independent of its nature and spatial distribution.

$$\Delta T = S \Delta F$$

CLIMATE SENSITIVITY

The *change* in global and annual mean temperature per unit forcing, S , $\text{K}/(\text{W m}^{-2})$,

$$S = \Delta T / \Delta F.$$

Climate sensitivity is not known and is the objective of much current research on climate change.

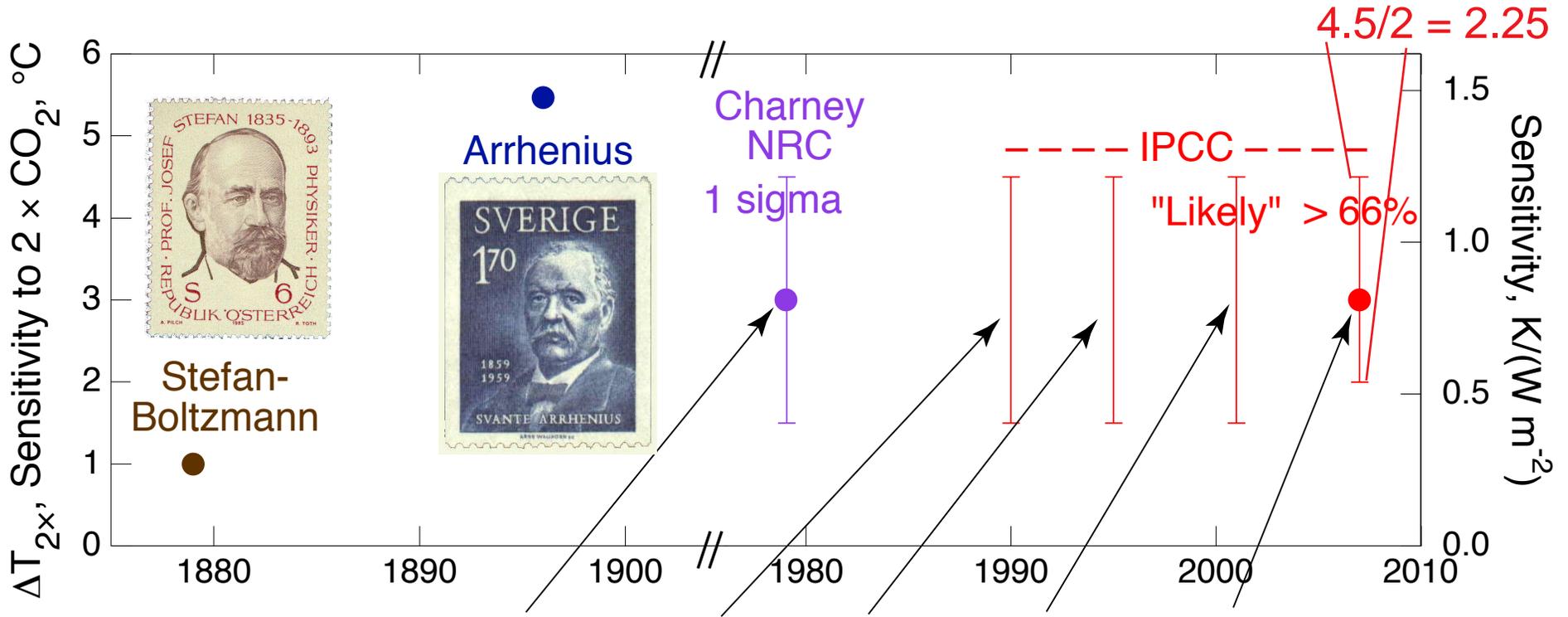
Climate sensitivity is often expressed as the temperature for doubled CO_2 concentration $\Delta T_{2\times}$.

$$\Delta T_{2\times} = S \Delta F_{2\times}$$

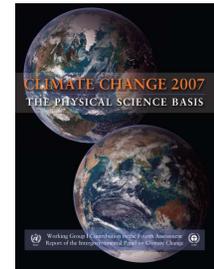
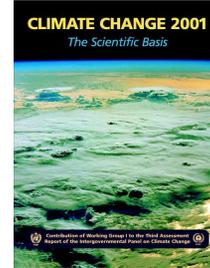
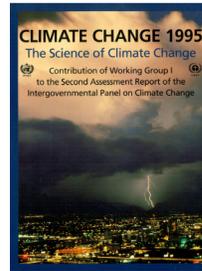
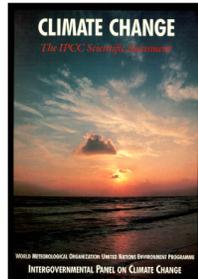
$$\Delta F_{2\times} \approx 3.7 \text{ W m}^{-2}$$

CLIMATE SENSITIVITY ESTIMATES THROUGH THE AGES

Estimates of central value and uncertainty range from major national and international assessments



**Carbon Dioxide and Climate:
A Scientific Assessment**
NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1979



Despite extensive research, climate sensitivity remains *highly uncertain*.

IMPLICATIONS OF UNCERTAINTY IN CLIMATE SENSITIVITY

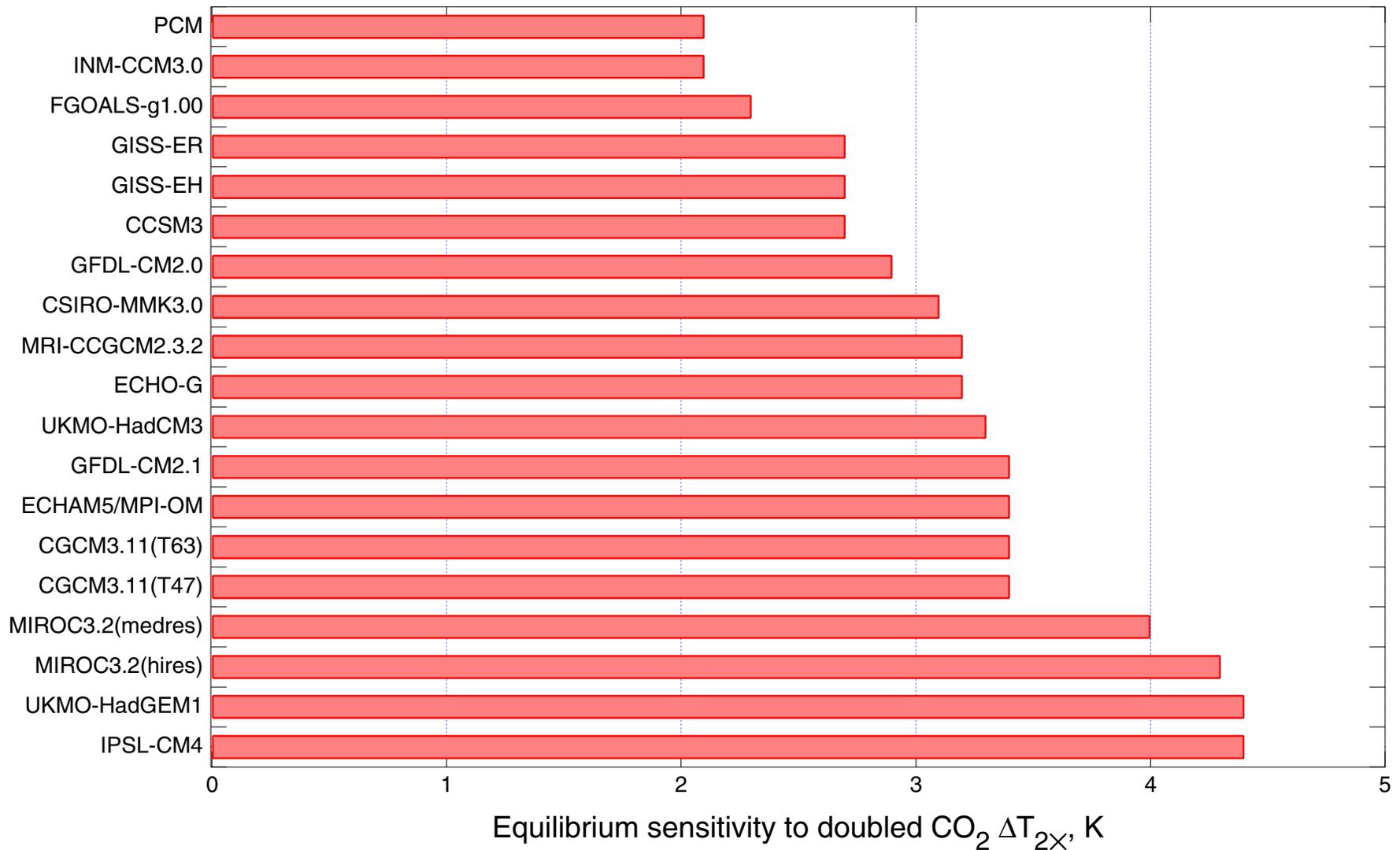
Uncertainty in climate sensitivity translates directly into . . .

- Uncertainty in the amount of *incremental atmospheric CO₂* that would result in a given increase in global mean surface temperature.
- Uncertainty in the amount of *fossil fuel carbon* that can be combusted consonant with a given climate effect.

At present this uncertainty is at least a factor of 2.

EQUILIBRIUM SENSITIVITIES IN CURRENT CLIMATE MODELS

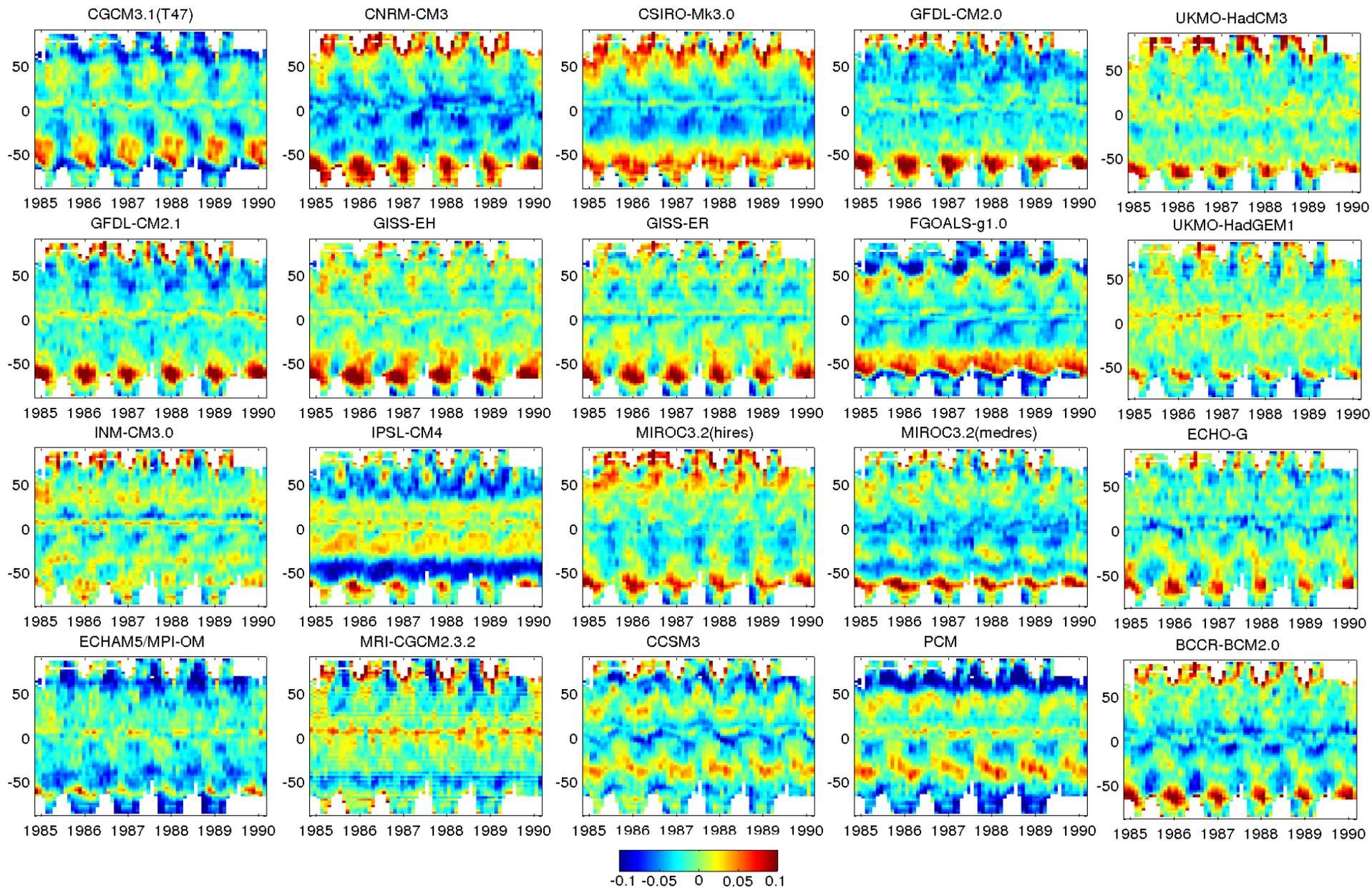
20 Models employed in IPCC AR4 simulations



Sensitivity varies by more than a factor of 2.

ZONAL MONTHLY MEAN ALBEDO

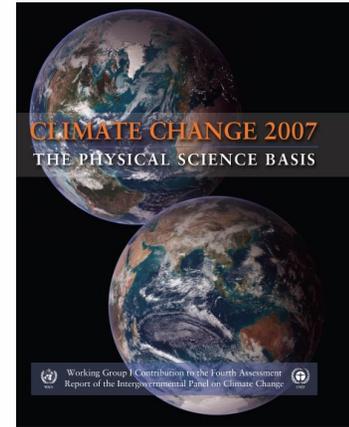
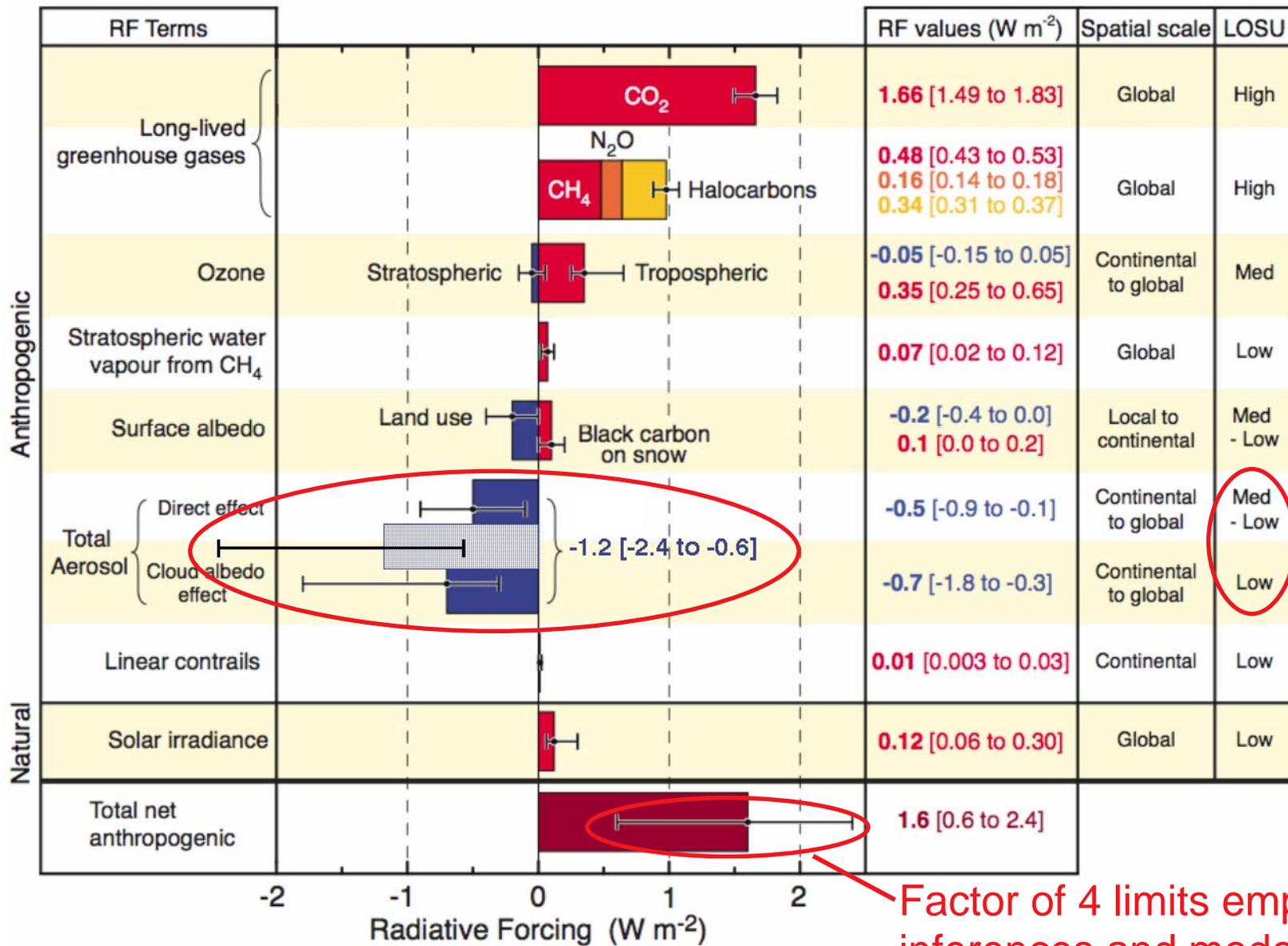
20 GCMs – Difference vs. ERBE Satellite



Modified from Bender et al., Tellus, 2006

GLOBAL-MEAN RADIATIVE FORCINGS (RF)

Pre-industrial to present (Intergovernmental Panel on Climate Change, 2007)



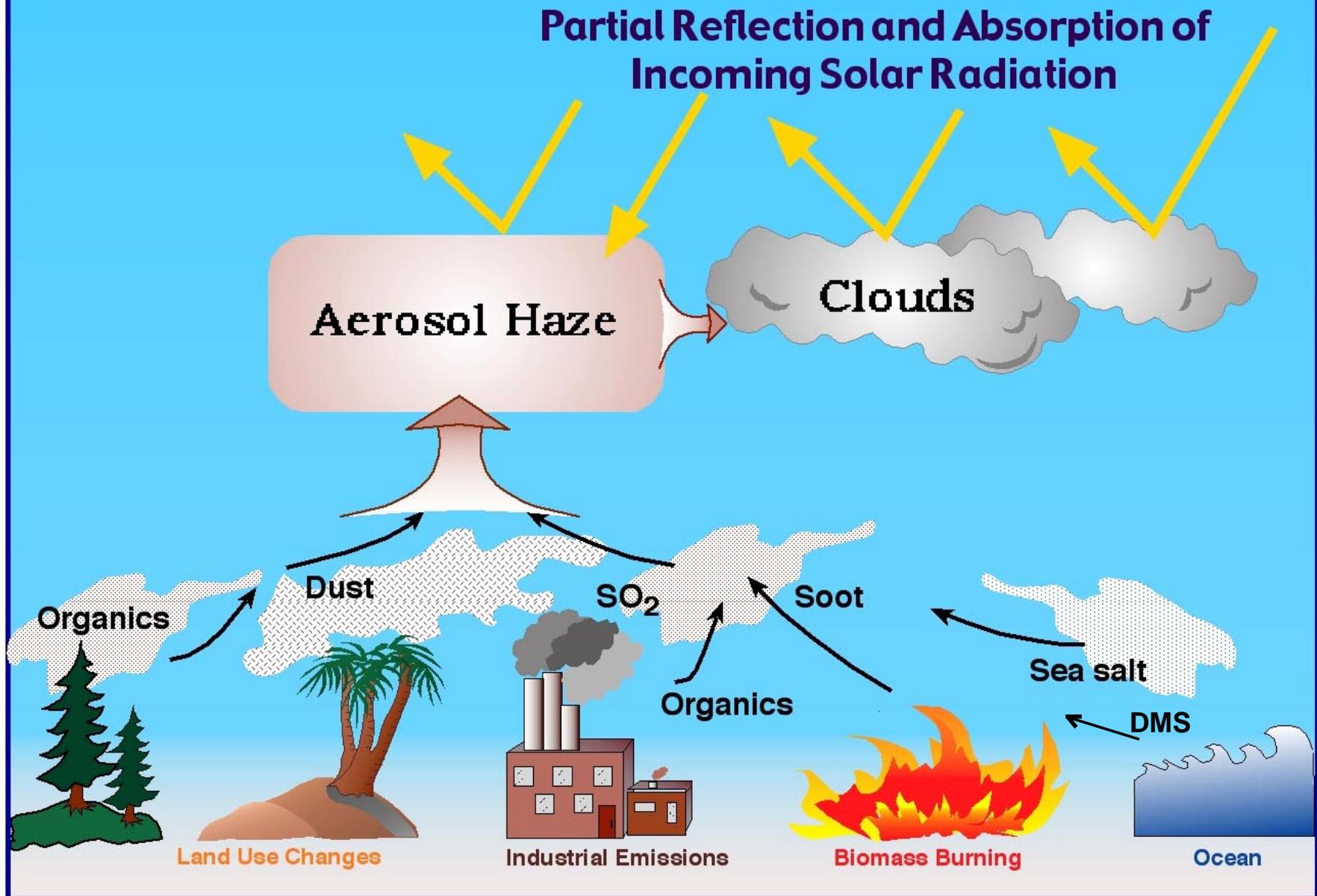
©IPCC 2007: WG1-AR4

Factor of 4 limits empirical inferences and model evaluation.

LOSU denotes level of scientific understanding.

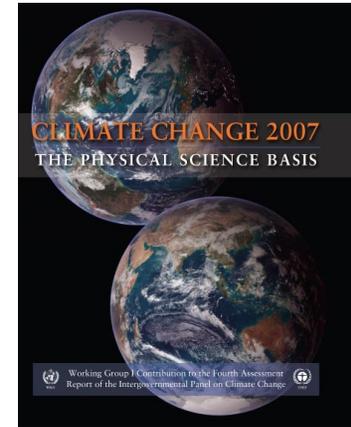
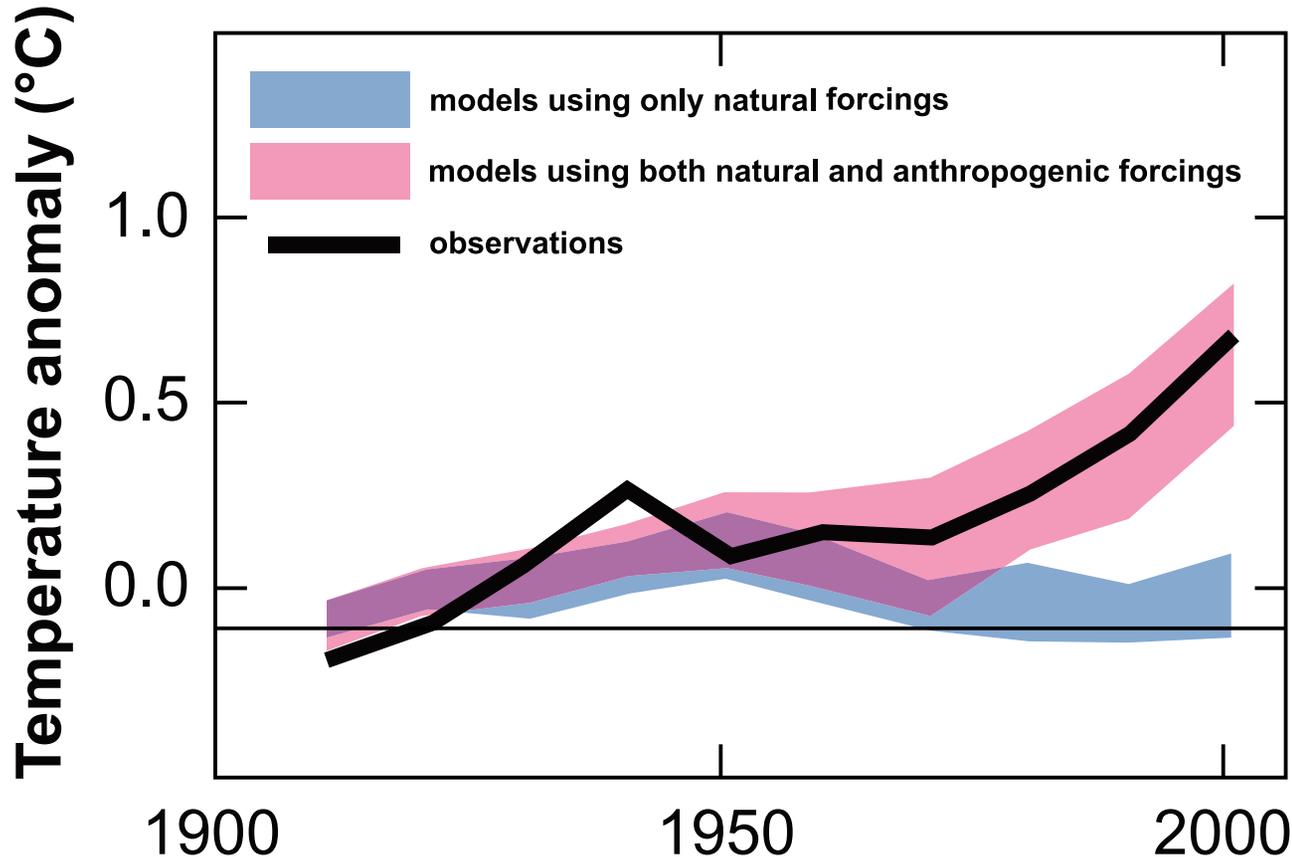
Uncertainty range: 5 - 95%.

Radiative Forcing by Tropospheric Aerosol



TOO ROSY A PICTURE?

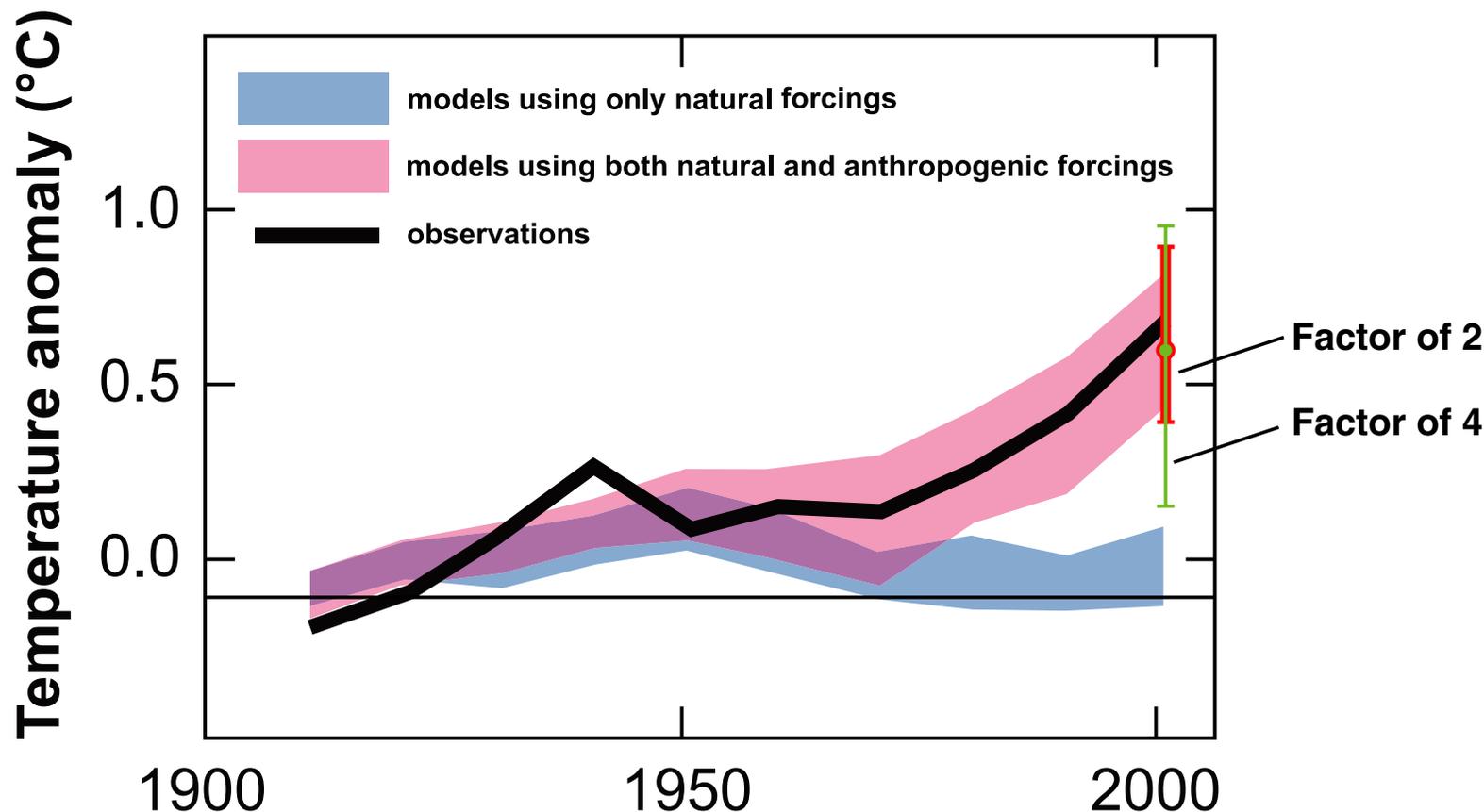
Ensemble of 58 model runs with 14 global climate models



- “ Simulations that incorporate anthropogenic forcings, including increasing greenhouse gas concentrations and the effects of aerosols, and that also incorporate natural external forcings provide a *consistent explanation of the observed temperature record*.
- “ These simulations used models with *different climate sensitivities, rates of ocean heat uptake and magnitudes and types of forcings*.

TOO ROSY A PICTURE?

Ensemble of 58 model runs with 14 global climate models



Schwartz, Charlson & Rodhe, Nature Reports – Climate Change, 2007

Uncertainty in modeled temperature increase – less than a factor of 2, red – is *well less than uncertainty in forcing* – a factor of 4, green.

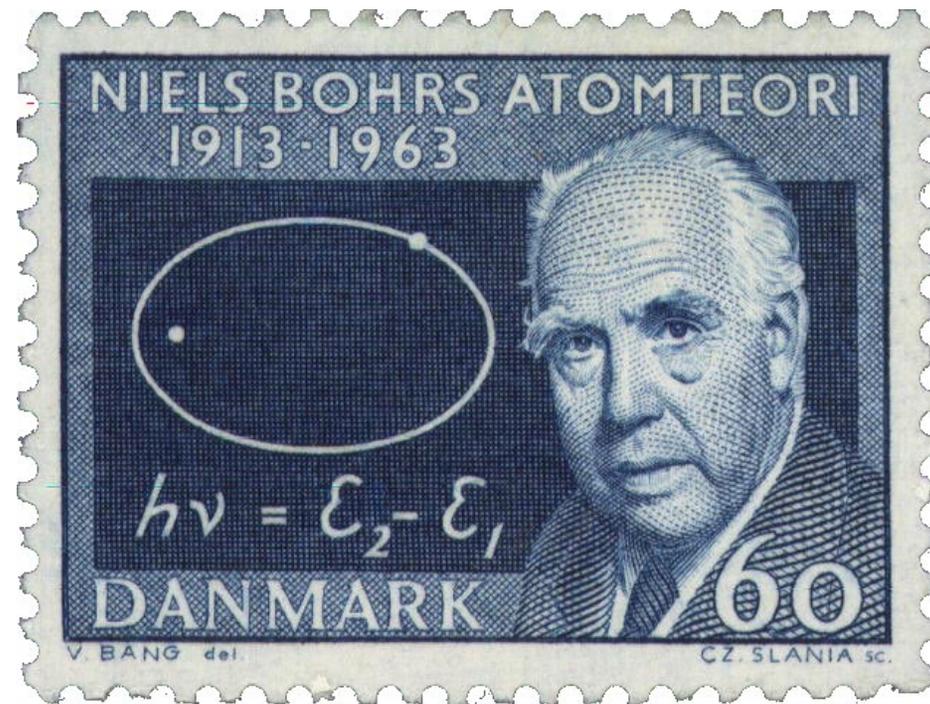
The models *did not span the full range of the uncertainty* and/or . . .

The forcings used in the model runs were *anticorrelated with the sensitivities of the models*.

*Looking to the
Future . . .*

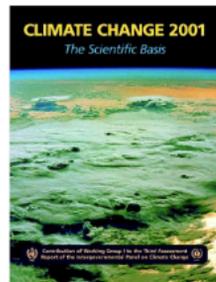
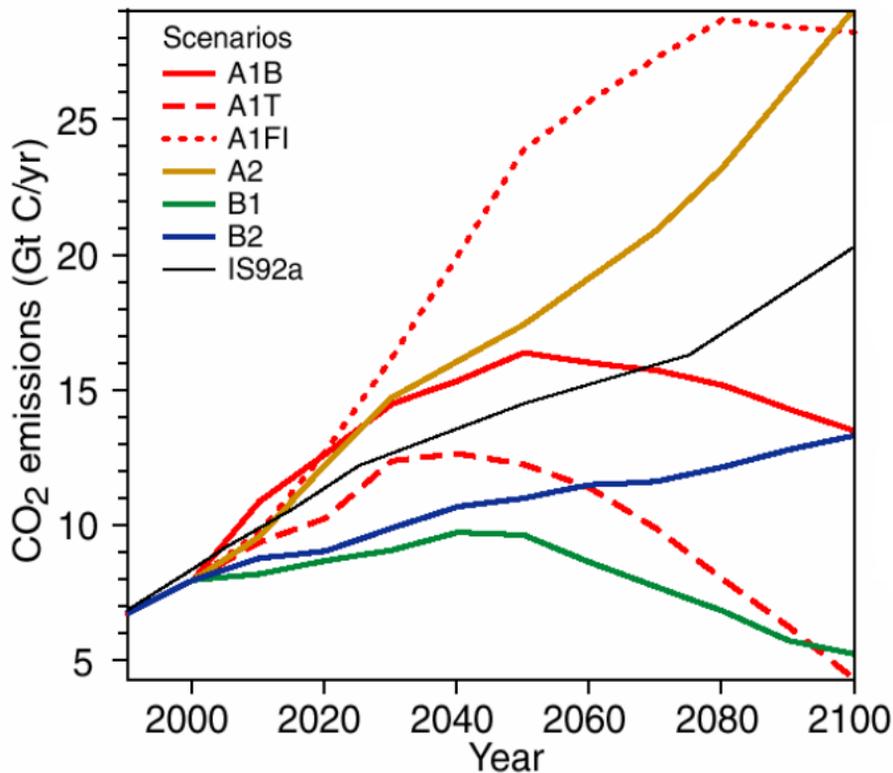


*Prediction is difficult,
especially about the future.*

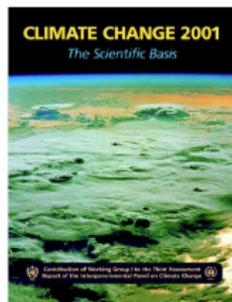
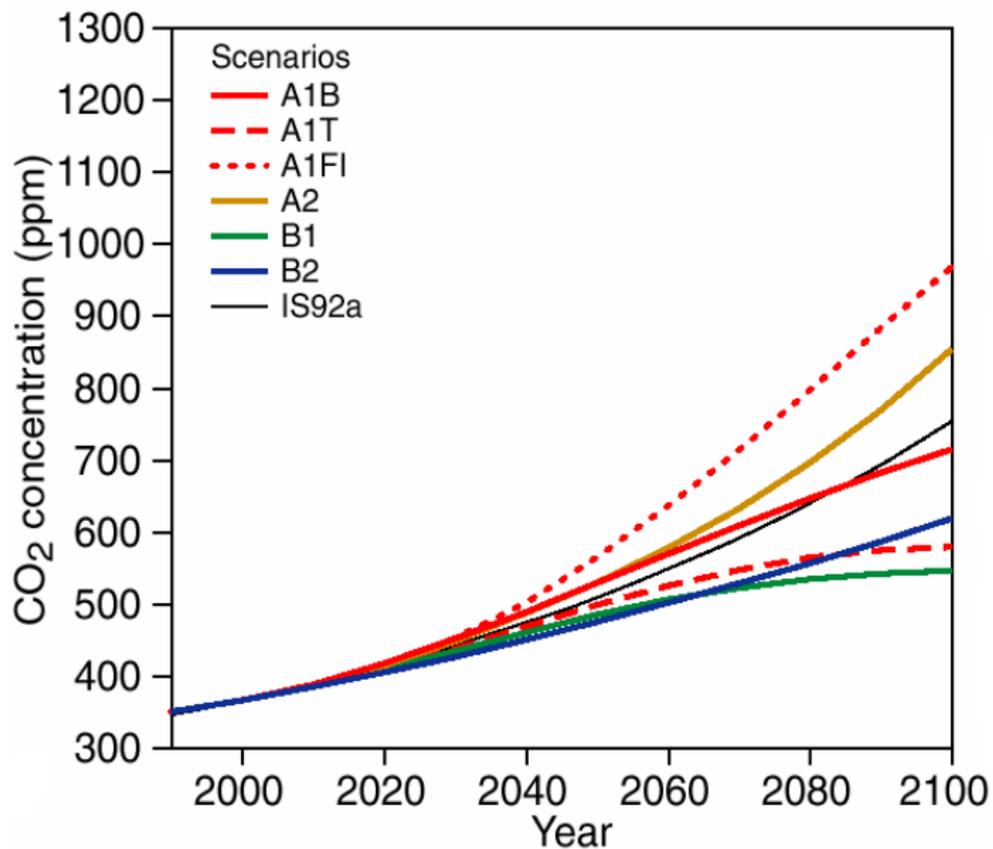


– Niels Bohr

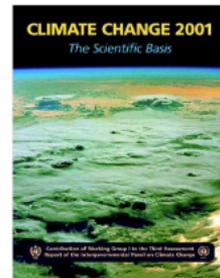
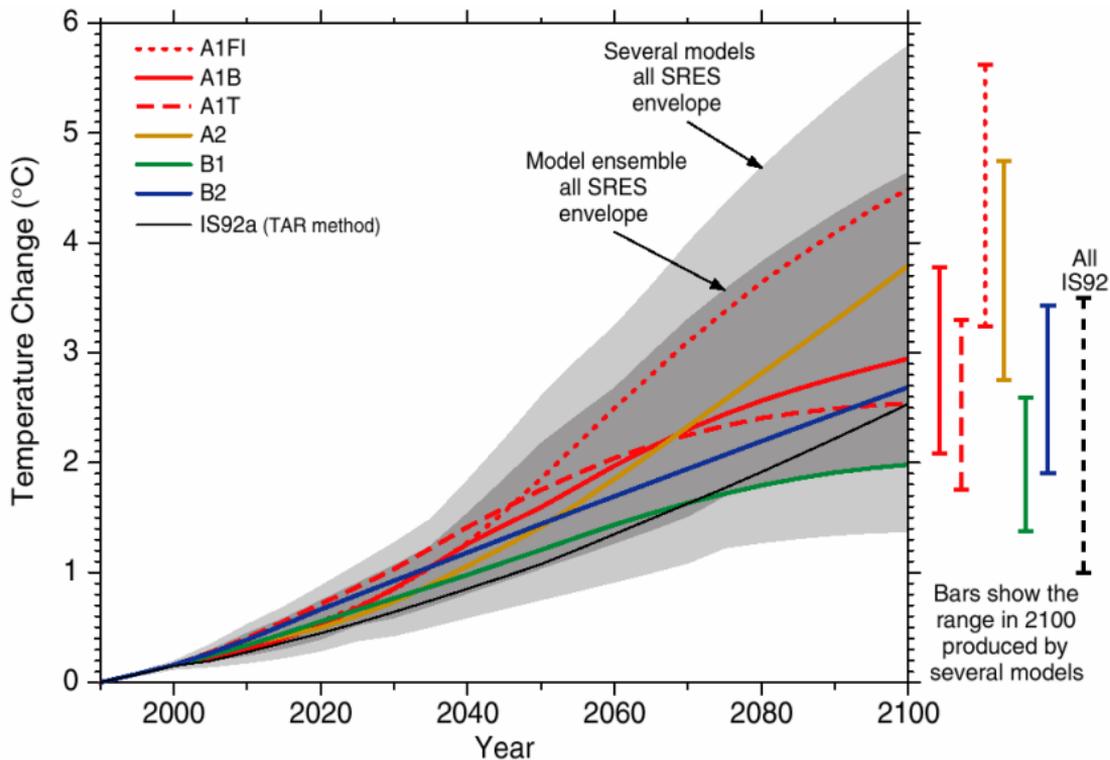
PROJECTIONS OF FUTURE CO₂ EMISSIONS



PROJECTIONS OF FUTURE CO₂ CONCENTRATIONS



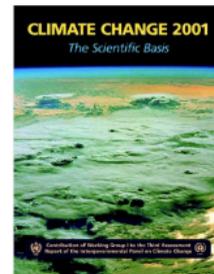
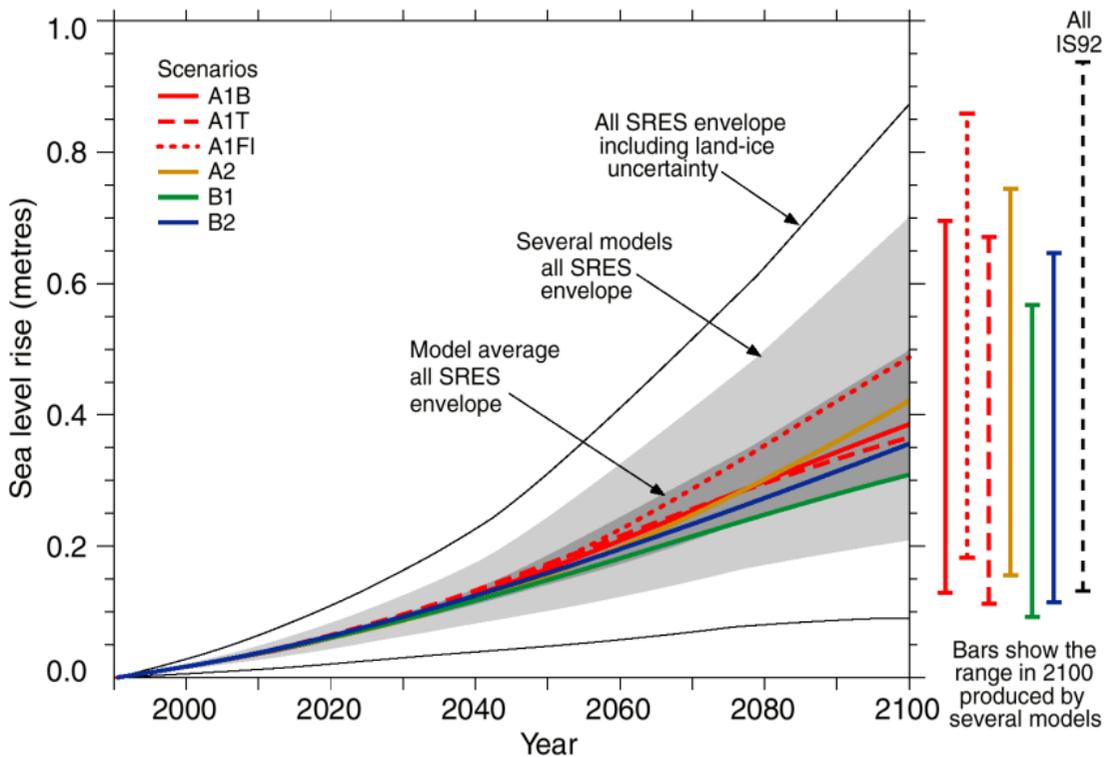
PROJECTIONS OF FUTURE TEMPERATURE CHANGE



Bars show the range in 2100 produced by several models

PROJECTIONS OF FUTURE SEA LEVEL RISE

Thermosteric (density change) only



Heat capacity, time constant, and sensitivity of Earth's climate system

Stephen E. Schwartz¹

Received 3 April 2007; revised 14 June 2007; accepted 10 July 2007; published 2 November 2007.

[1] The equilibrium sensitivity of Earth's climate is determined as the quotient of the relaxation time constant of the system and the pertinent global heat capacity. The heat capacity of the global ocean, obtained from regression of ocean heat content versus global mean surface temperature, GMST, is $14 \pm 6 \text{ W a m}^{-2} \text{ K}^{-1}$, equivalent to 110 m of ocean water; other sinks raise the effective planetary heat capacity to $17 \pm 7 \text{ W a m}^{-2} \text{ K}^{-1}$ (all uncertainties are 1-sigma estimates). The time constant pertinent to changes in GMST is determined from autocorrelation of that quantity over 1880–2004 to be $5 \pm 1 \text{ a}$. The resultant equilibrium climate sensitivity, $0.30 \pm 0.14 \text{ K}/(\text{W m}^{-2})$, corresponds to an equilibrium temperature increase for doubled CO_2 of $1.1 \pm 0.5 \text{ K}$. The short time constant implies that GMST is in near equilibrium with applied forcings and hence that net climate forcing over the twentieth century can be obtained from the observed temperature increase over this period, $0.57 \pm 0.08 \text{ K}$, as $1.9 \pm 0.9 \text{ W m}^{-2}$. For this forcing considered the sum of radiative forcing by incremental greenhouse gases, $2.2 \pm 0.3 \text{ W m}^{-2}$, and other forcings, other forcing agents, mainly incremental tropospheric aerosols, are inferred to have exerted only a slight forcing over the twentieth century of $-0.3 \pm 1.0 \text{ W m}^{-2}$.



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The Inhofe EPW Press Blog

New Peer-Reviewed Scientific Studies Chill Global Warming Fears

August 20, 2007

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New Peer-Reviewed Scientific Studies Chill Global Warming Fears

Posted By Marc Morano – [Marc Morano@EPW.Senate.Gov](mailto:Marc_Morano@EPW.Senate.Gov) – 4:44 PM ET

Washington DC – An abundance of new peer-reviewed studies, analyses, and data error discoveries in the last several months has prompted scientists to declare that fear of catastrophic man-made global warming “bites the dust” and the scientific underpinnings for alarm may be “falling apart.” The latest study to cast doubt on climate fears finds that even a doubling of atmospheric carbon dioxide would not have the previously predicted dire impacts on global temperatures. This new study is not unique, as a host of recent peer-reviewed studies have cast a chill on global warming fears.

“Anthropogenic (man-made) global warming bites the dust,” declared astronomer Dr. Ian Wilson after reviewing the new study which has been accepted for publication in the Journal of Geophysical Research. Another scientist said the peer-reviewed study overturned “in one fell swoop” the climate fears promoted by the UN and former Vice President Al Gore. The study entitled “Heat Capacity, Time Constant, and Sensitivity of Earth’s Climate System,” was authored by Brookhaven National Lab scientist Stephen Schwartz. ([LINK](#))



Clicking on image should download and play movie; otherwise download from <http://www.ecd.bnl.gov/steve/pop/specreport-20070821-co2.mov>

Reply to comments by G. Foster et al., R. Knutti et al., and N. Scafetta on “Heat capacity, time constant, and sensitivity of Earth’s climate system”

Stephen E. Schwartz¹

[1] Reanalysis of the autocorrelation of global mean surface temperature prompted by the several comments, taking into account a subannual autocorrelation of about 0.4 year and bias in the autocorrelation resulting from the short duration of the time series has resulted in an upward revision of the climate system time constant determined by *Schwartz* [2007] by roughly 70%, to 8.5 ± 2.5 years (all uncertainties are 1-sigma estimates). This results in a like upward revision of the climate sensitivity determined in that paper, to 0.51 ± 0.26 K/(W m⁻²), corresponding to an equilibrium temperature increase for doubled CO₂ of 1.9 ± 1.0 K, somewhat lower than the central estimate of the sensitivity given in the 2007 assessment report of the Intergovernmental Panel on Climate Change, but consistent within the uncertainties of both estimates. The conclusion