

The Science and Politics of Climate Change

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Indian Institute of Science



CLIMATE OF FEAR

Why We Shouldn't Worry about Global Warming

Thomas Gale Moore

**MICHAEL
CRICHTON**



STATE OF FEAR

**This Book claims that Global
warming is a hoax**

Michael Crichton's book
refers specifically

- absence of real world data
- lack of model testing and validation
- lack of independent assessments of models

With so much at stake, it is right that **climate science** is subjected to the most **intense scrutiny**.

Michael Le Page , **New Scientist**.

Socolow & Lam, Phil Trans Roy Soc., 2007

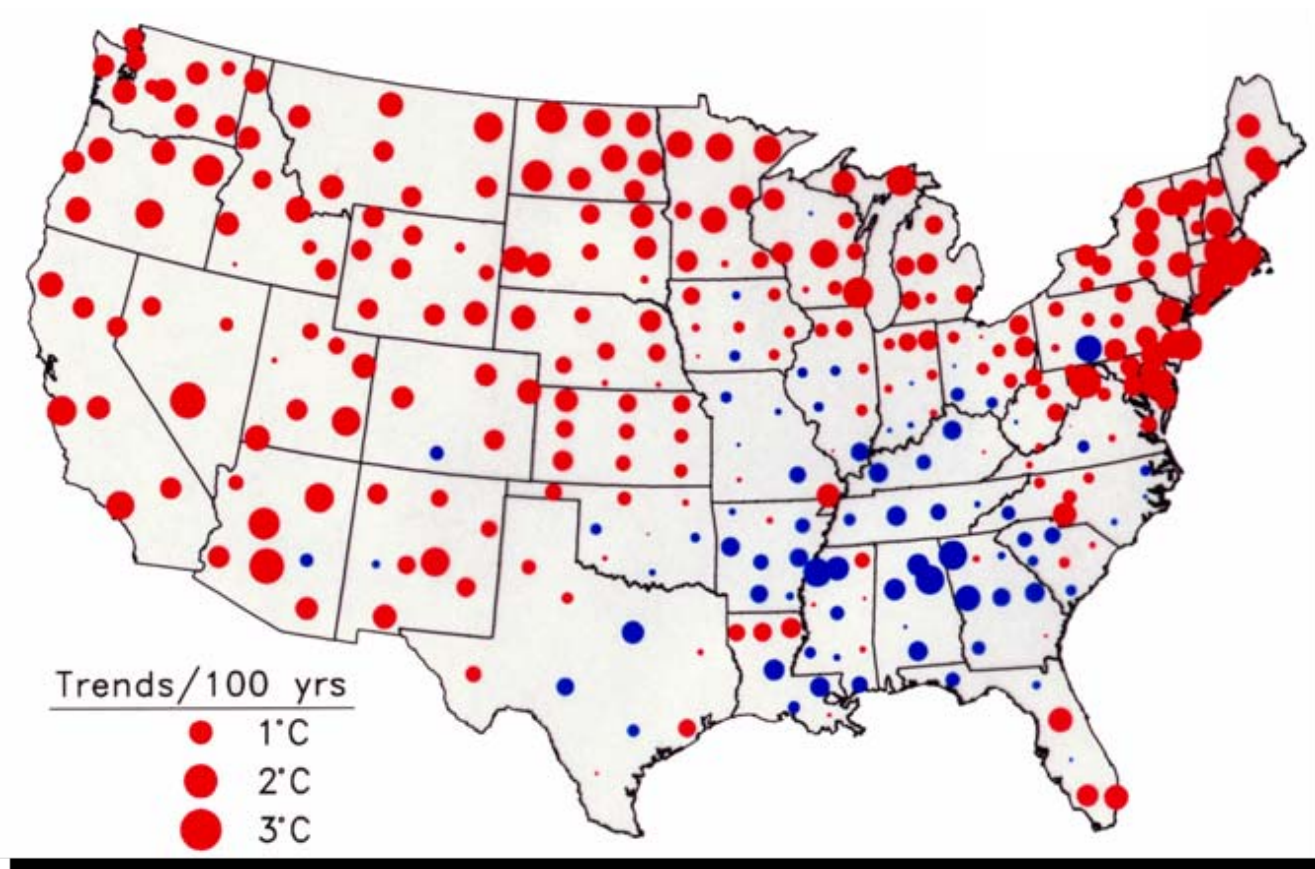
The climate problem is an **unprecedented challenge** to humanity. It is global in scope, its time-scale is centuries, and the **mitigation strategies** required are often fraught with risks as large as the problem itself.

How good is the scientific evidence for global warming ?

How sure are we that Global warming has been induced by human beings?

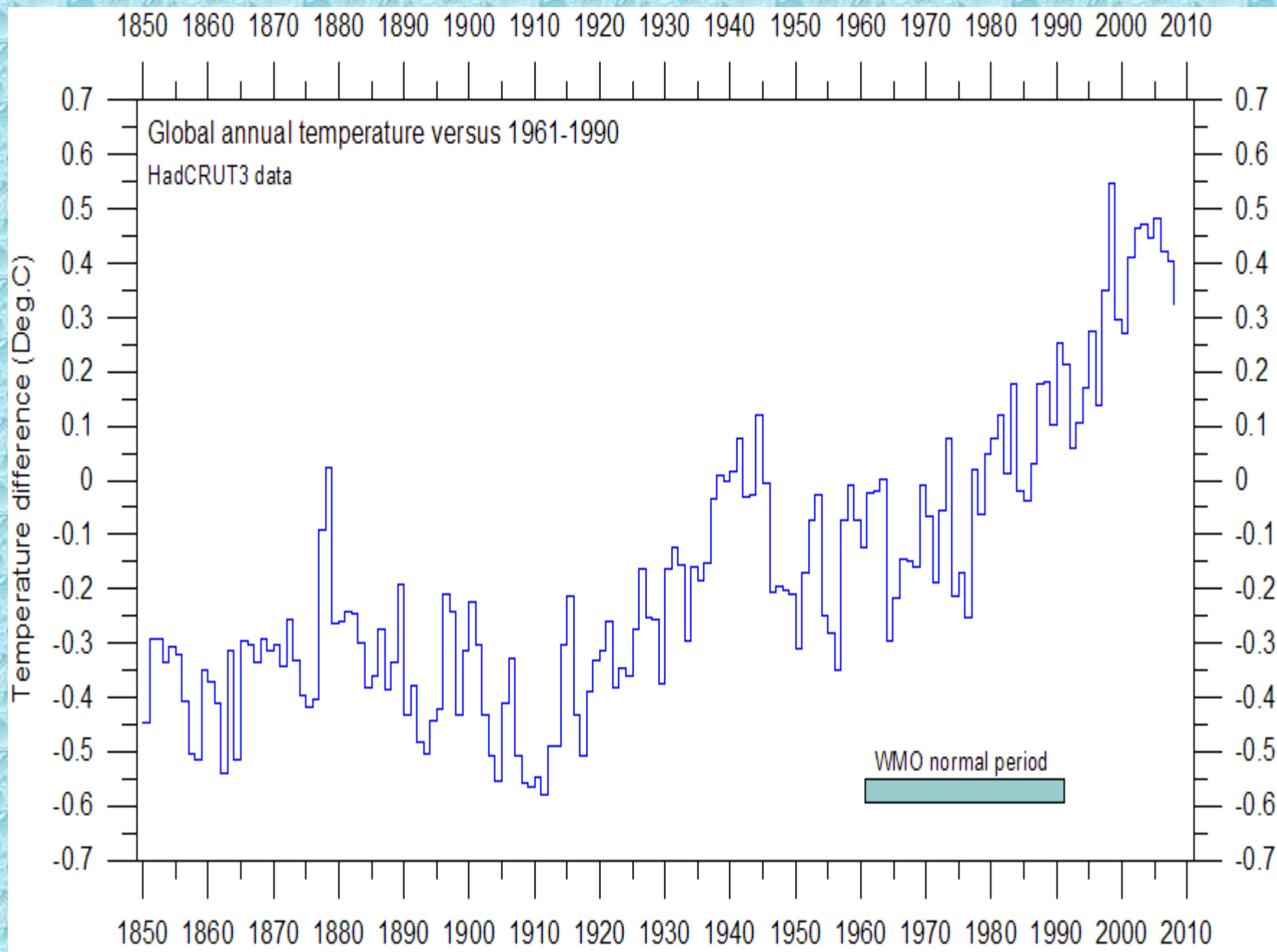
What is the impact of aerosols on climate change?

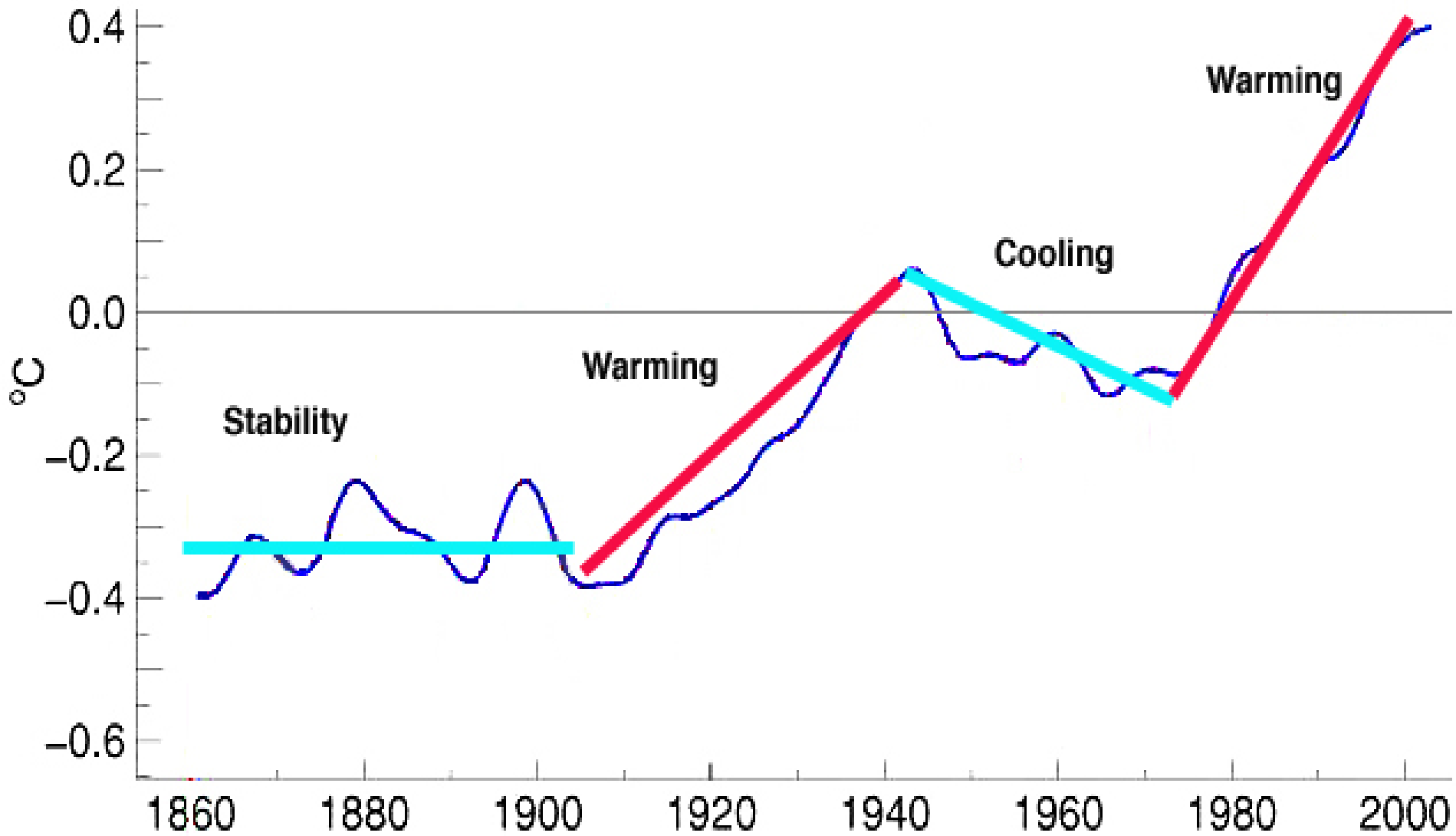
U.S. Temperature Trends: 1901 to 1998



Red circles = warming; Blue circles = cooling

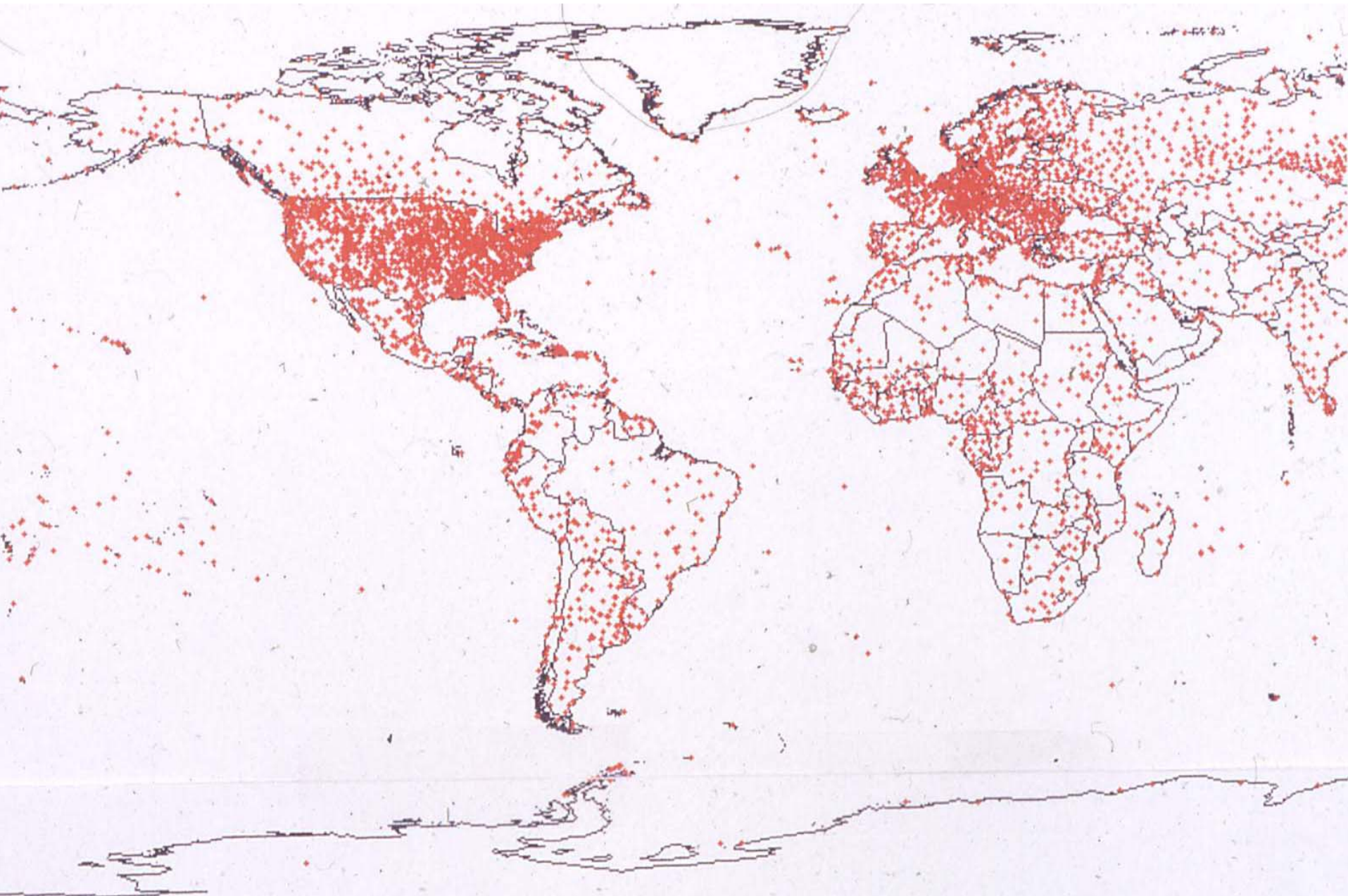
All stations/trends displayed regardless of statistical significance.

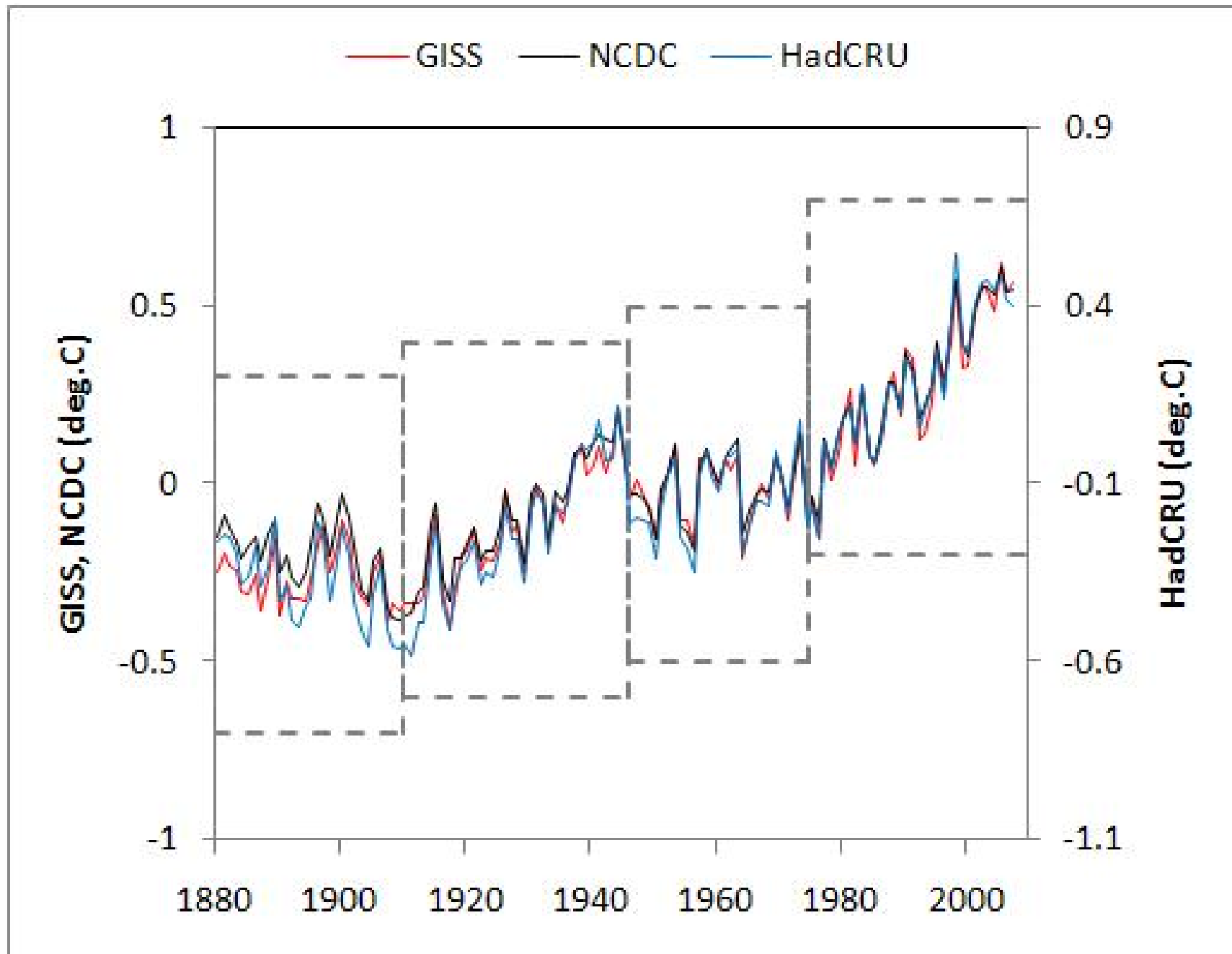




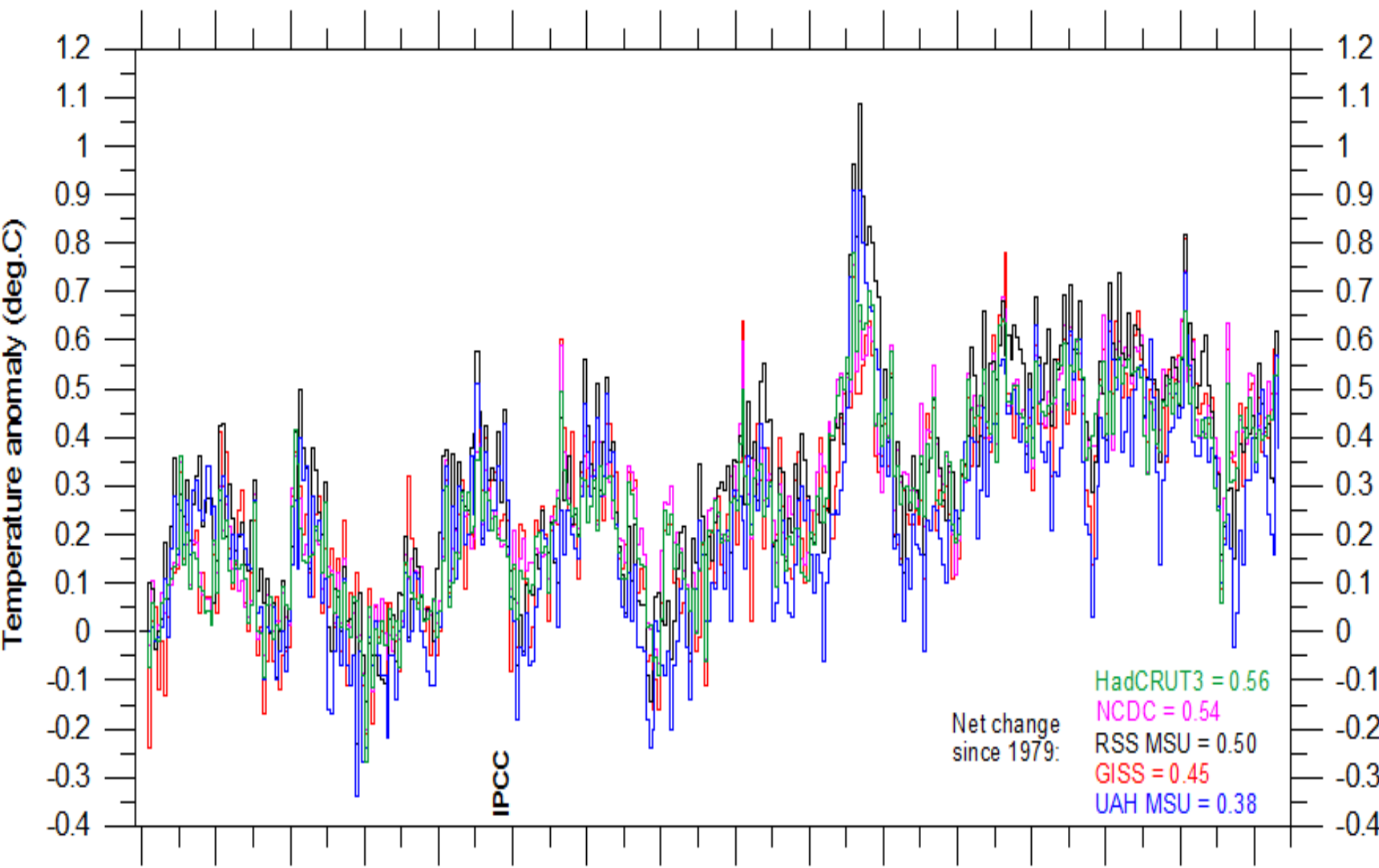
Before 1970, both natural and human factors could have played a role

**Surface weather stations: Note concentration in US and western Europe.
Vast areas of the world with no coverage. Ocean 70% of surface.**





1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009



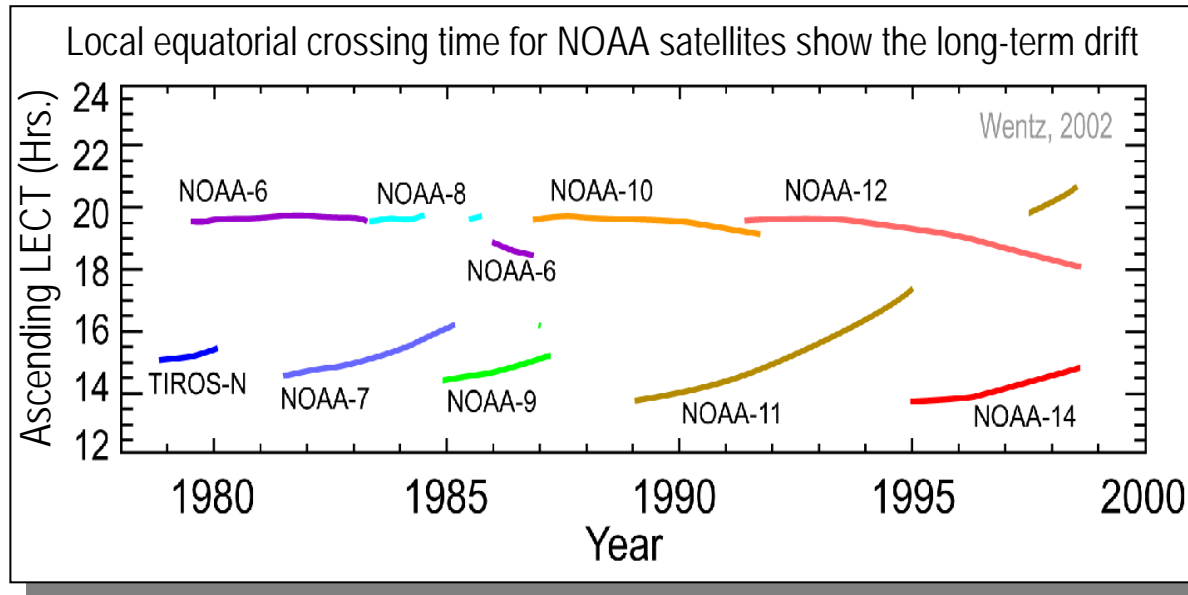
1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009

Satellite-Based Estimates of Temperature

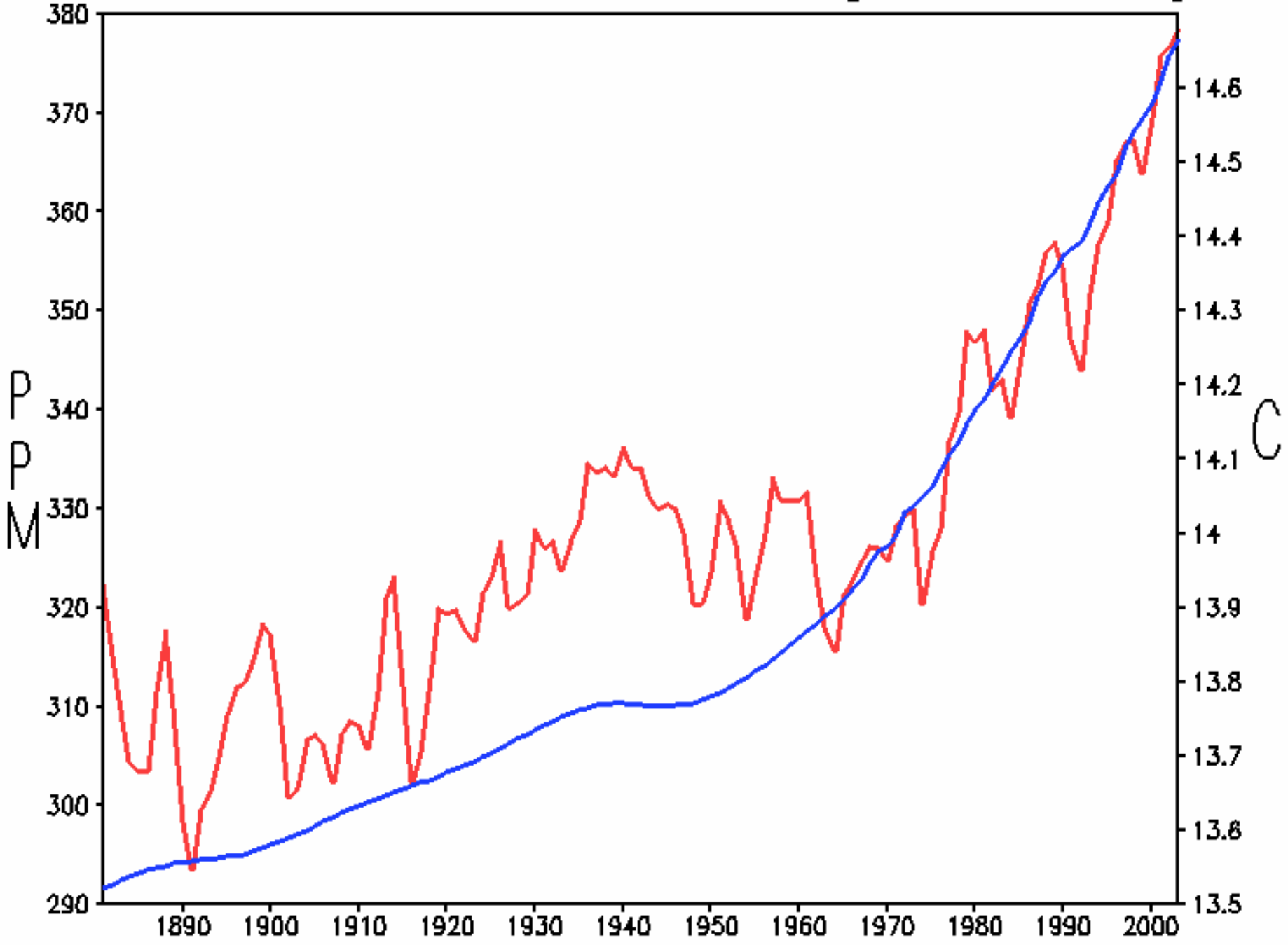
✓ Difficulties in piecing together a homogeneous temperature record

- 13 separate satellites 1979-2002 – all have varying degrees of overlap
- No on-board calibration
- Orbital drift and decay affects each satellite differently

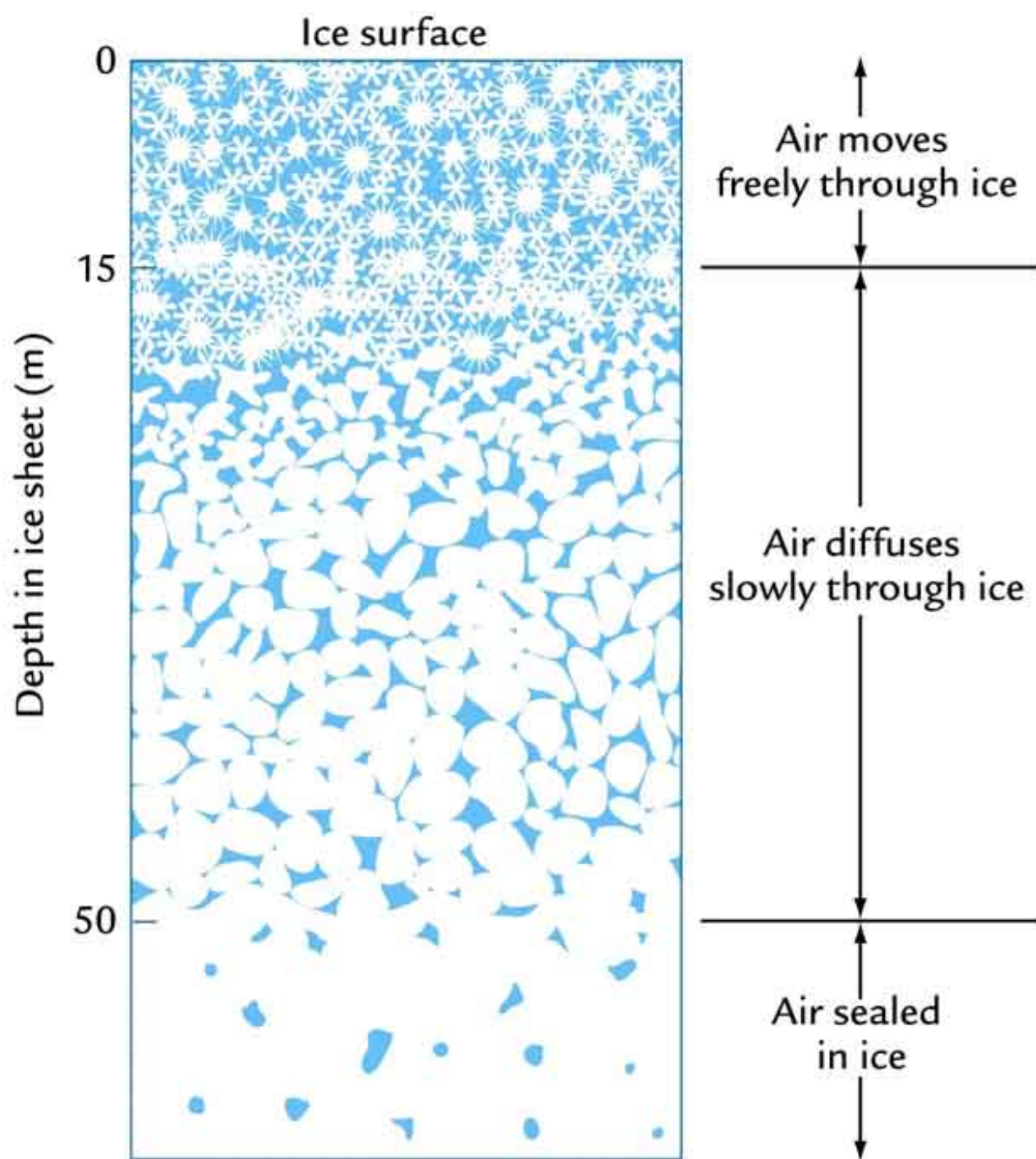
From Karl, NOAA, 2002



CO2 AND GLOBAL MEAN TEMPERATURE [1882 - 2004]



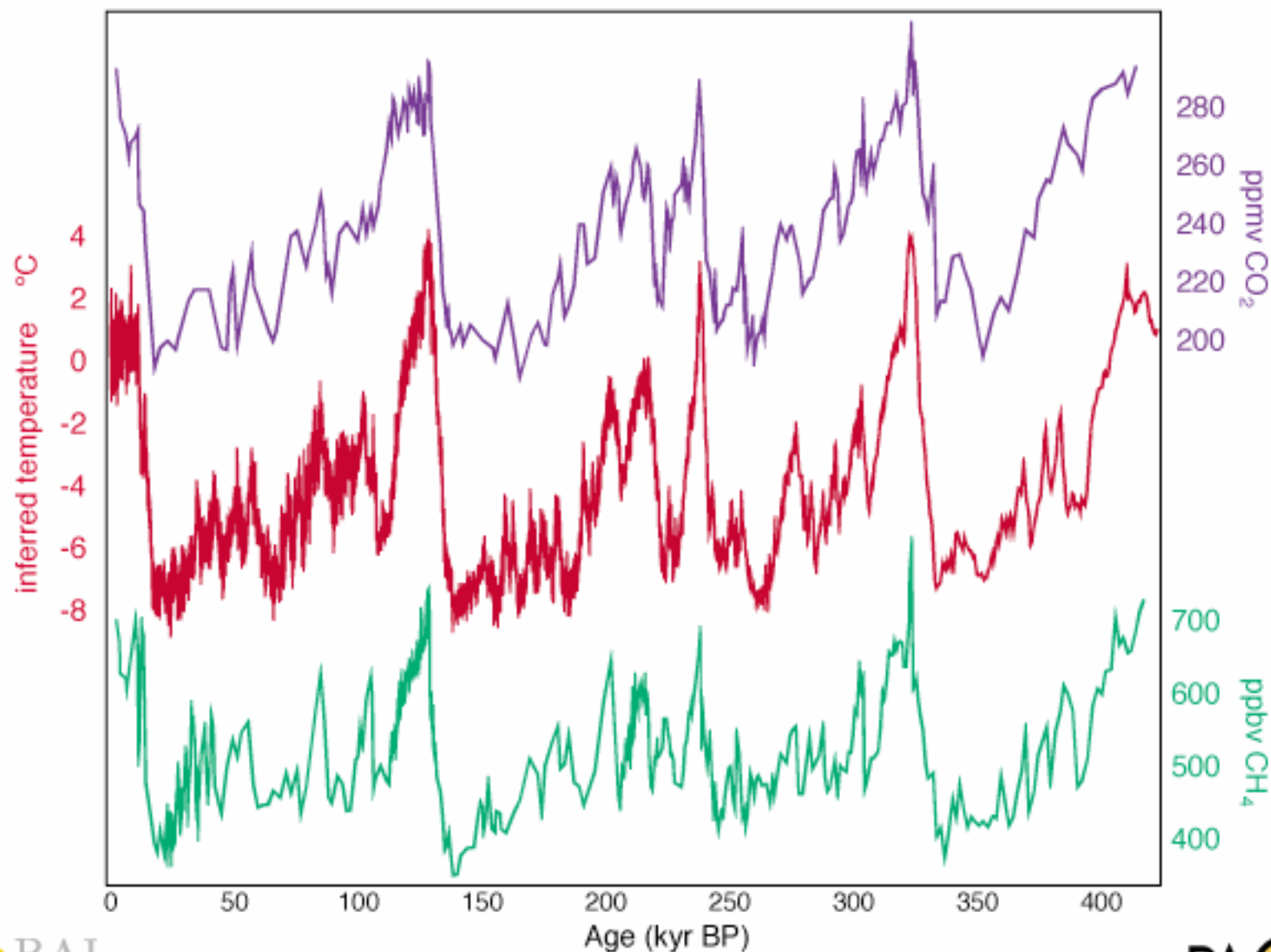




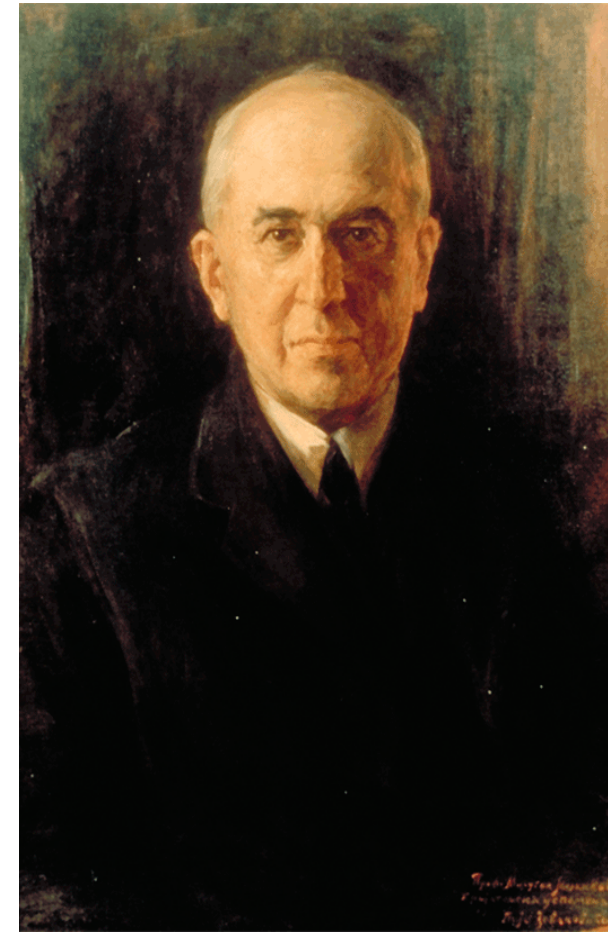
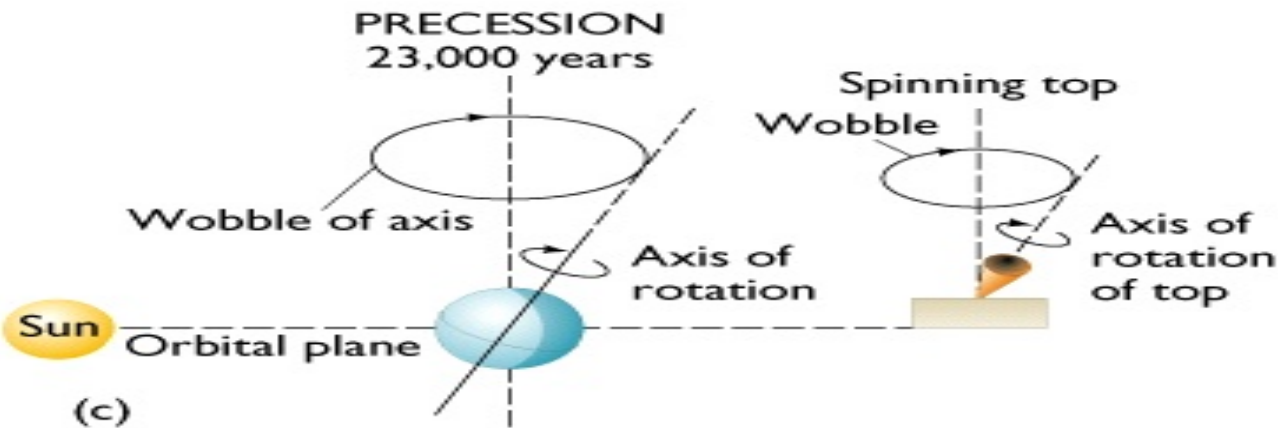
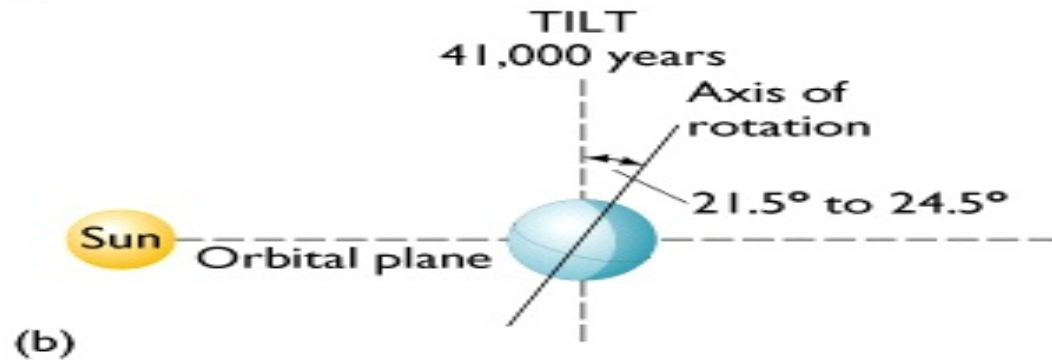
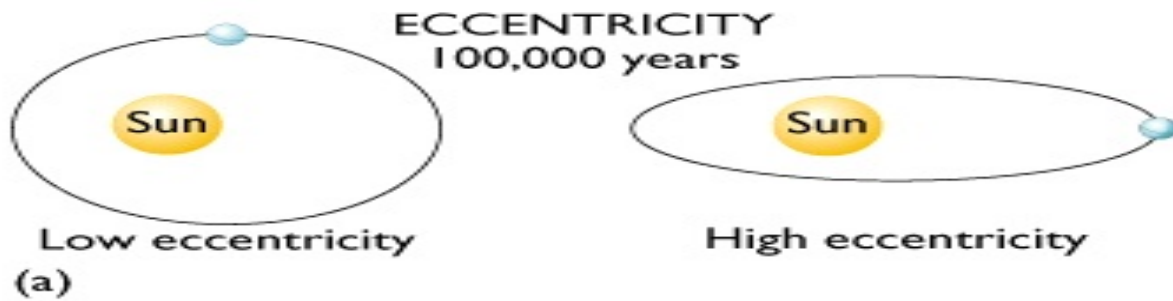


Permission from the British Antarctic Survey (BAS), Eric Wolff (BAS) and Keith Shine at the University of Reading.

4 glacial cycles recorded in the Vostok ice core



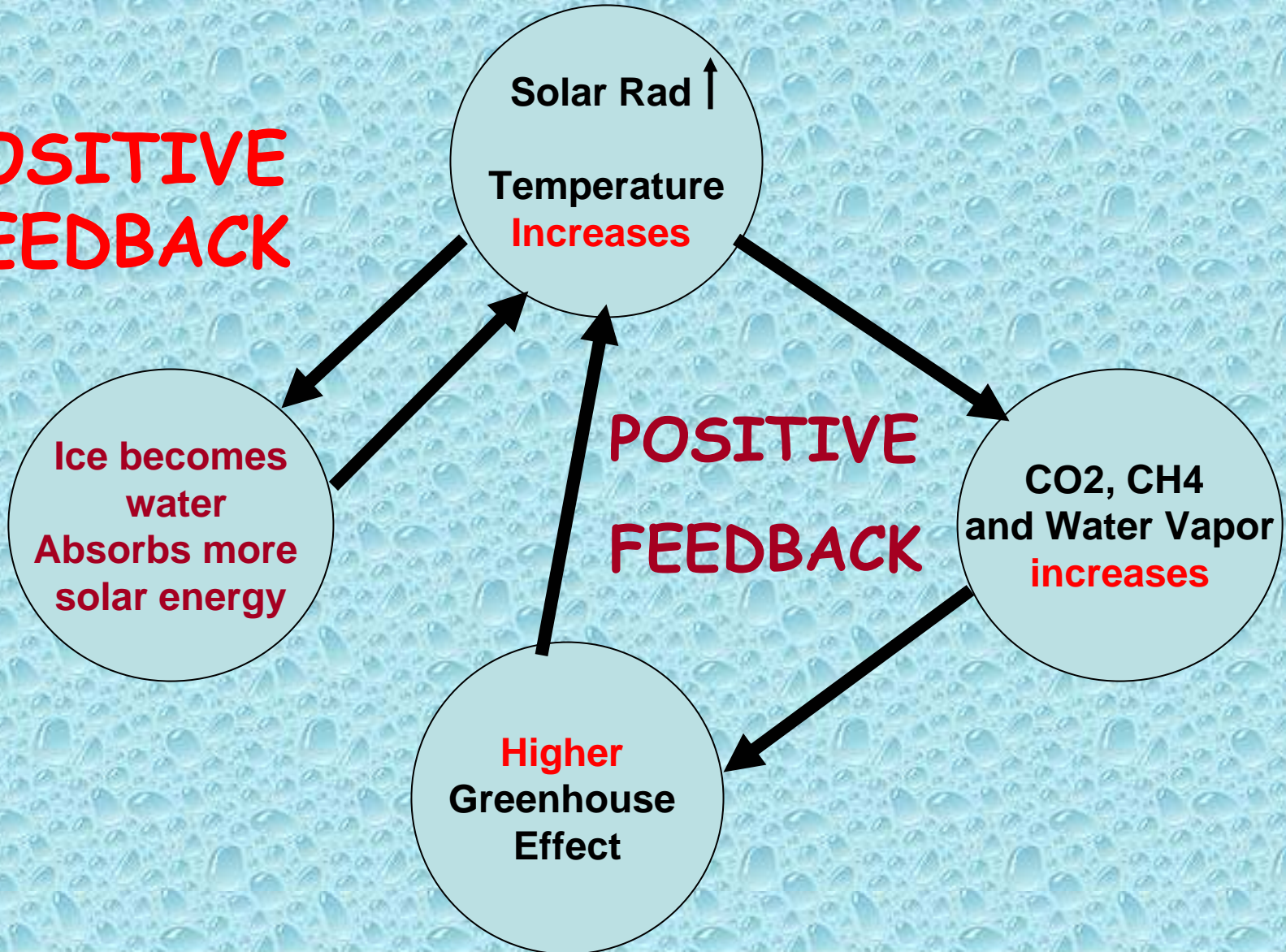
Milankovitch Hypothesis



The cooling and warming during the ice ages and interglacial periods, however, **was far greater** than would be expected from the tiny changes in solar energy reaching the Earth

The change in Solar radiation was amplified many times by positive feedbacks

**POSITIVE
FEEDBACK**



NON-LINEARITY & CHAOS

$$\frac{dX}{dt} = -\alpha_1 Y - \alpha_2 Z - \alpha_3 Y^2$$

$$\frac{dY}{dt} = -\beta_0 X + \beta_1 Y + \beta_2 Z - (X^2 + 0.004Y^2)Y + F_Y$$

$$\frac{dZ}{dt} = X - \gamma_2 Z$$

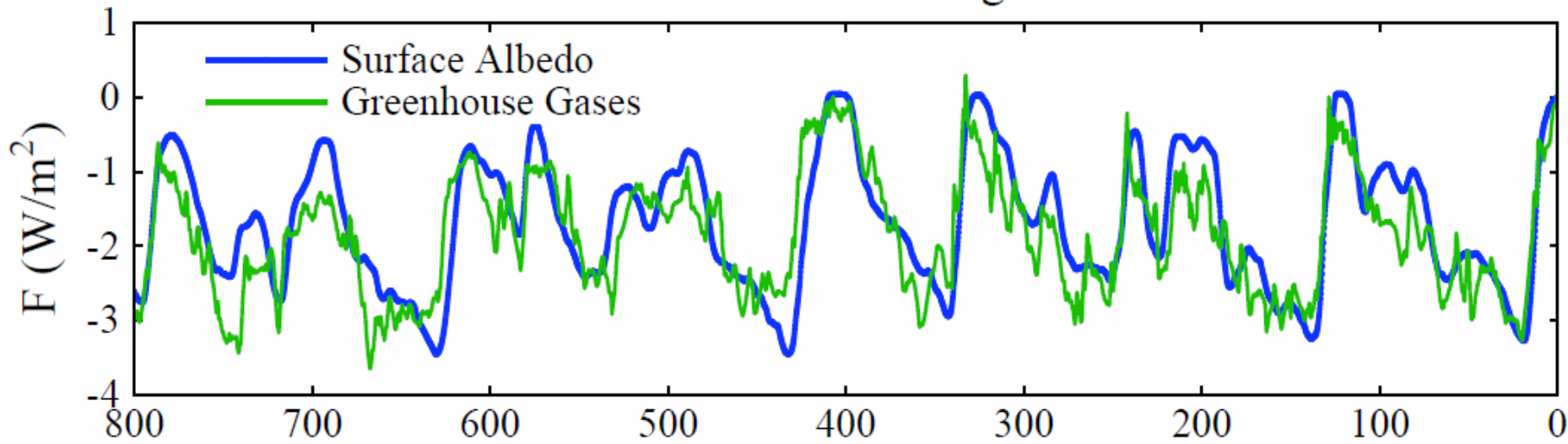
where in this particular case X , Y and Z are the ice mass, deep ocean temperature and atmospheric carbon dioxide.

where X is ice mass,

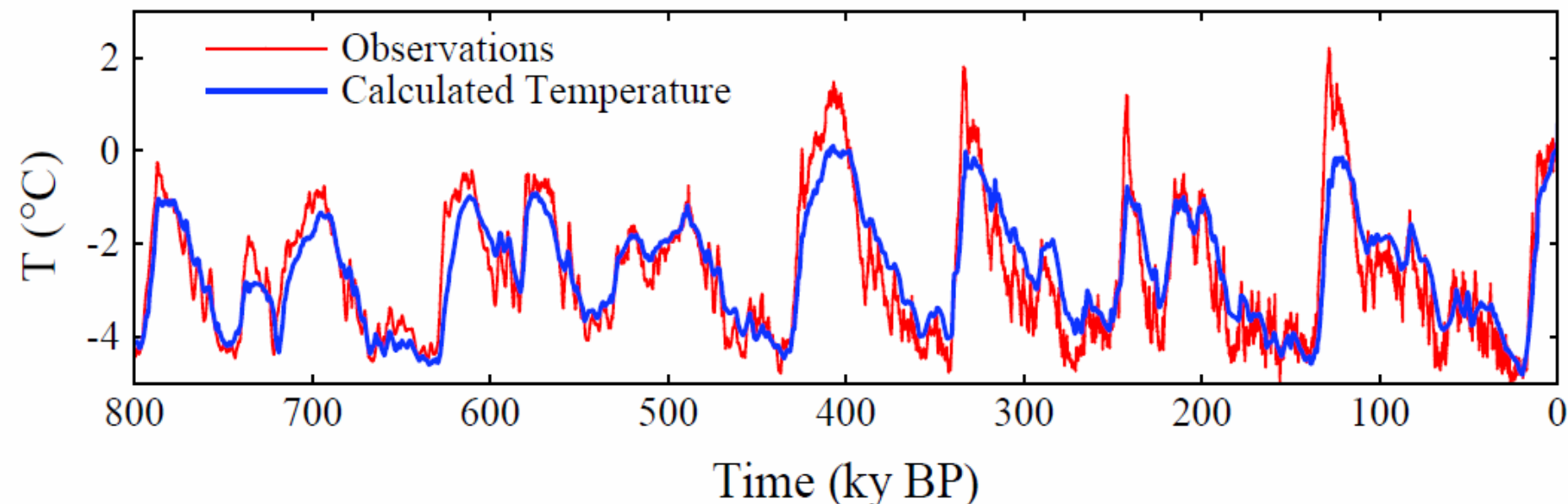
Y is ocean temperature

Z is CO_2

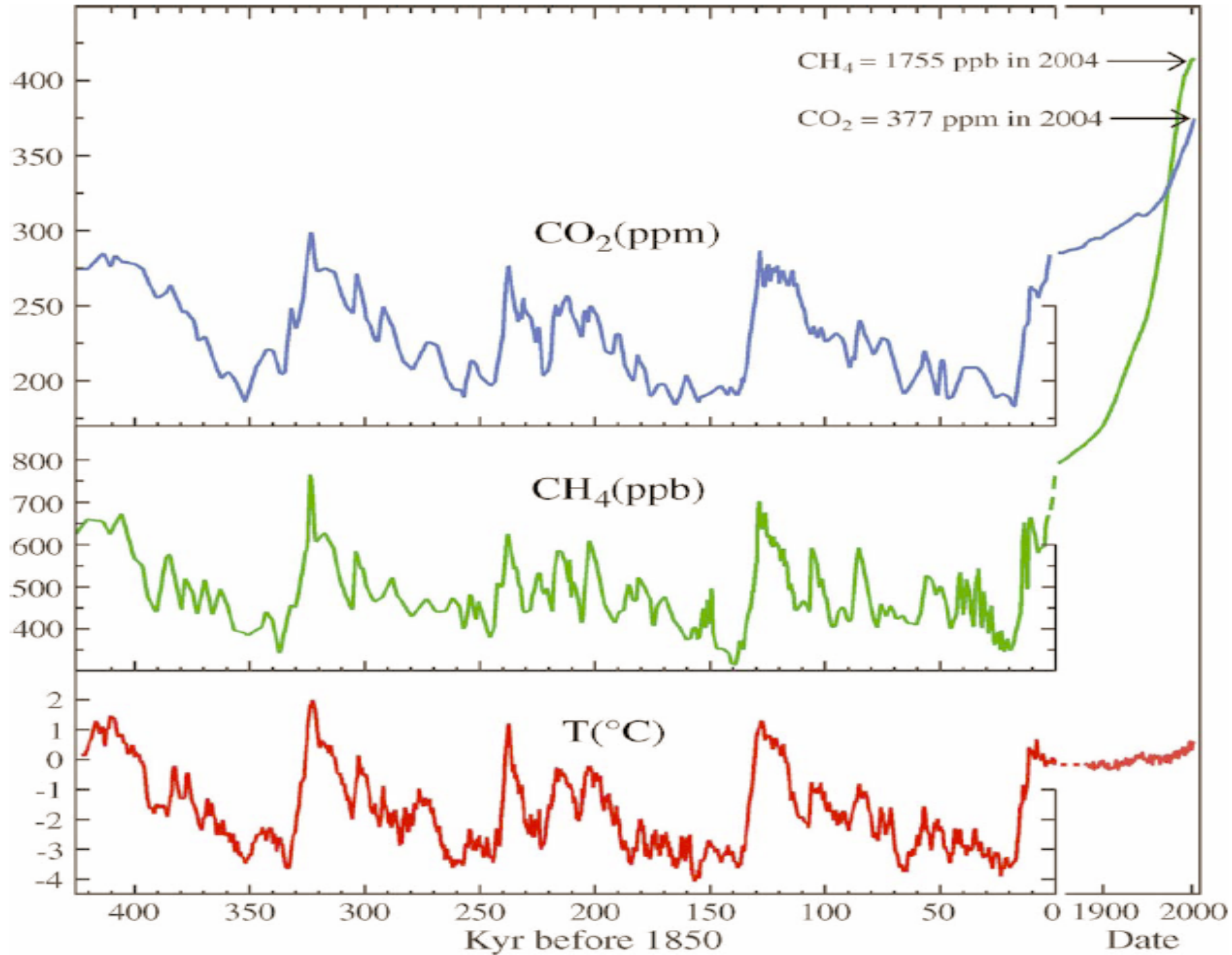
(b) Climate Forcing



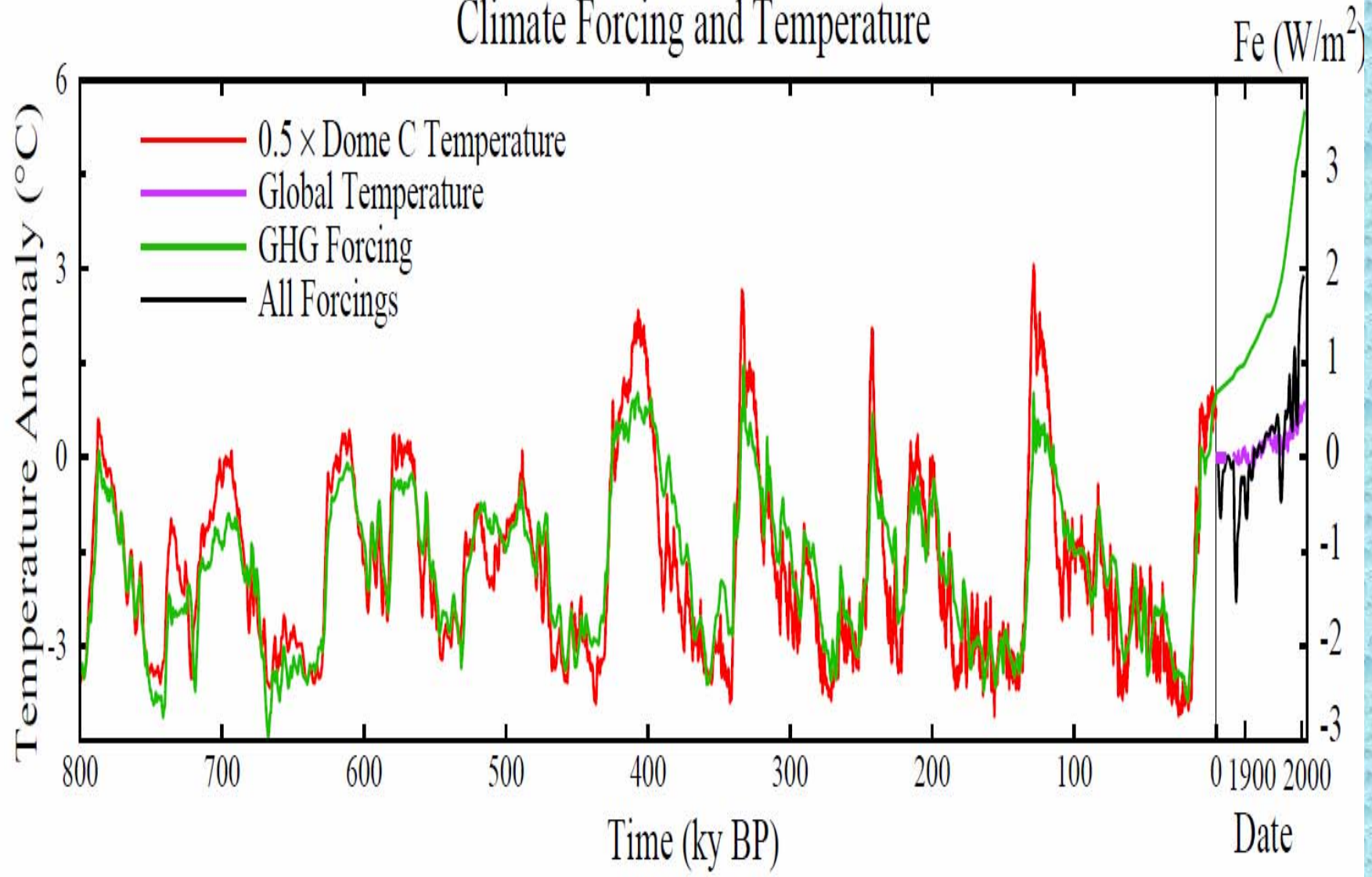
(c) Temperature Change



d



Climate Forcing and Temperature



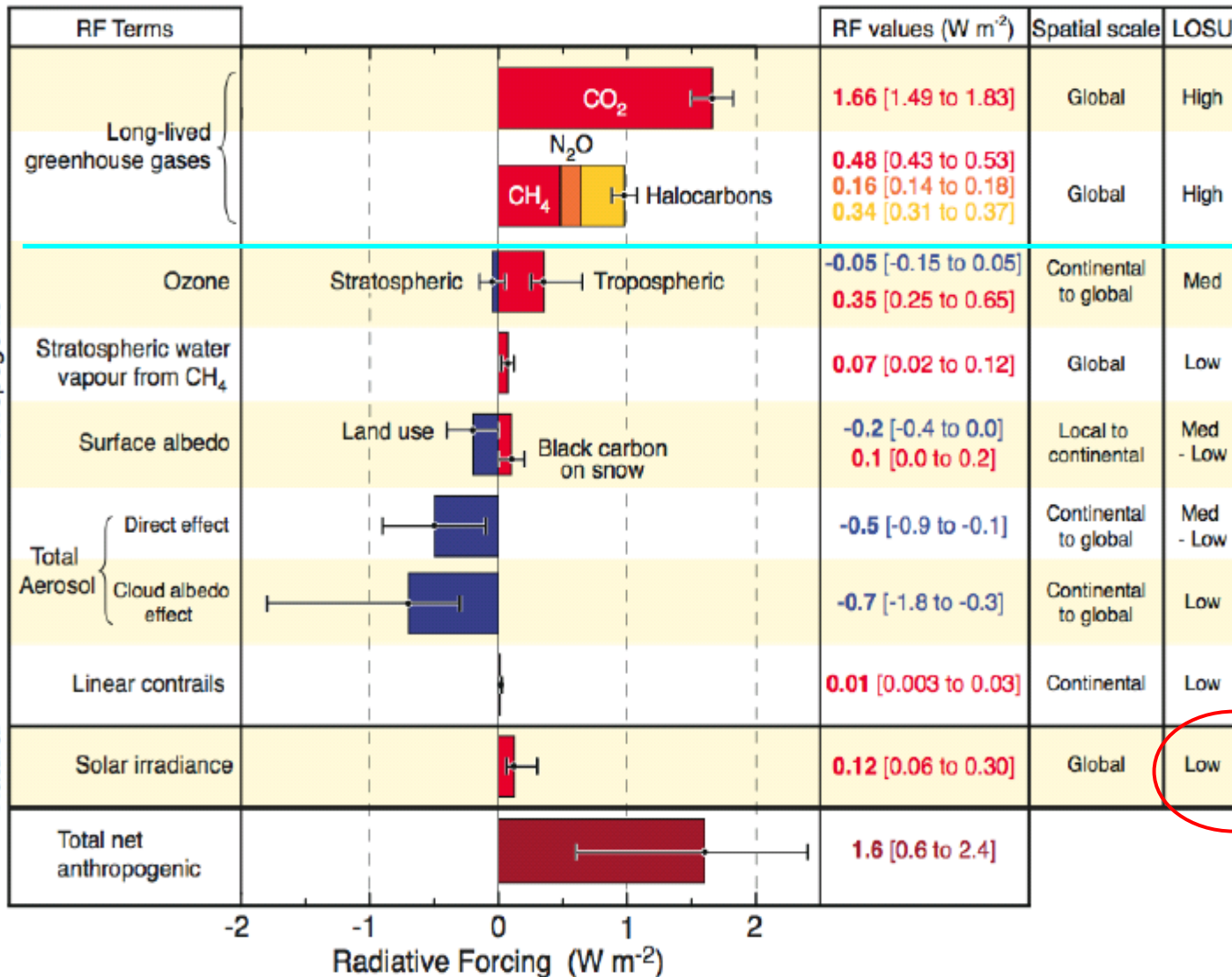
(Change relative to pre-industrial 1750) IPCC 2007

LOSU =
level of
scientific
understand
ing

high

low

Radiative Forcing Components



©IPCC 2007: WG1-AR4

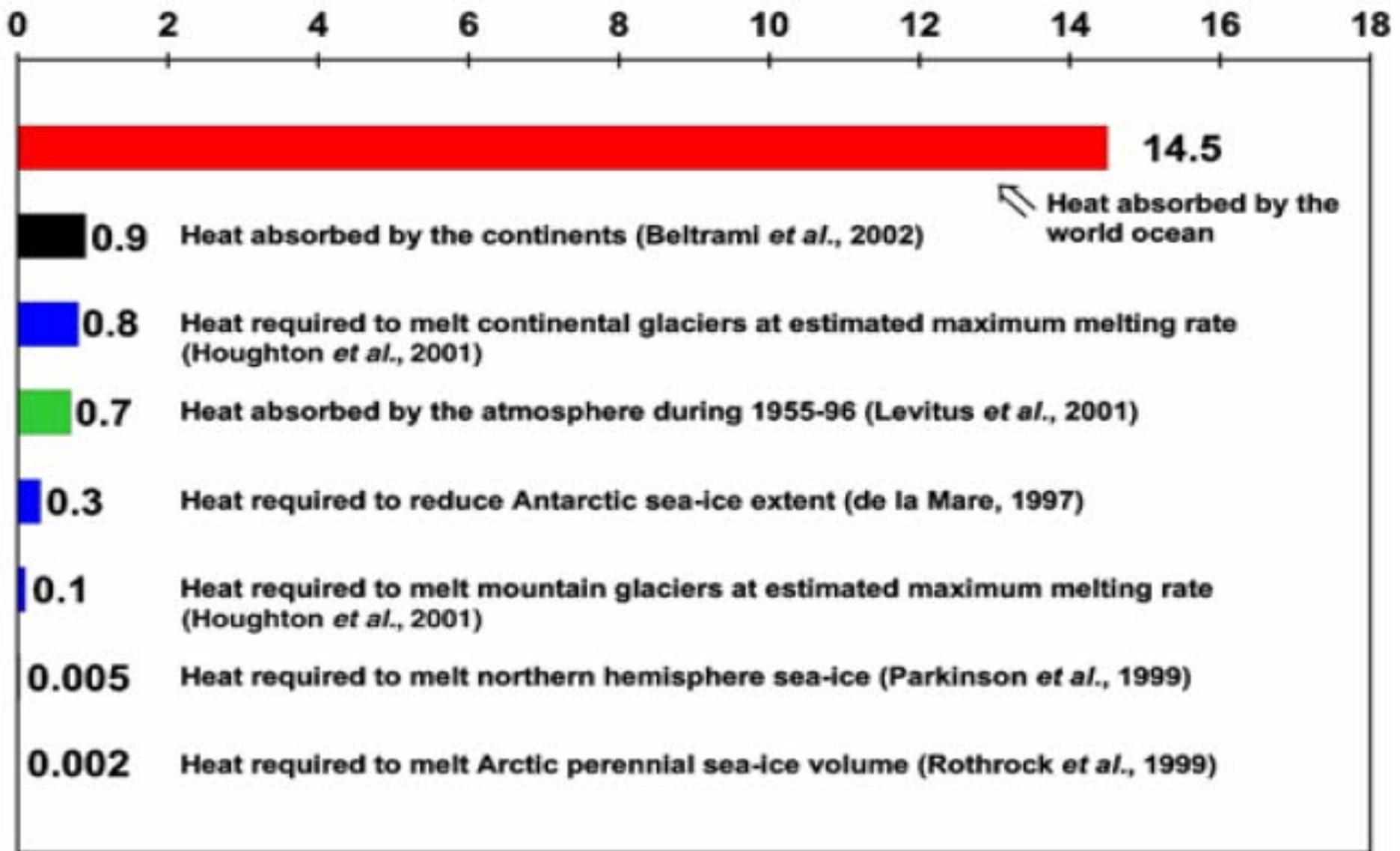
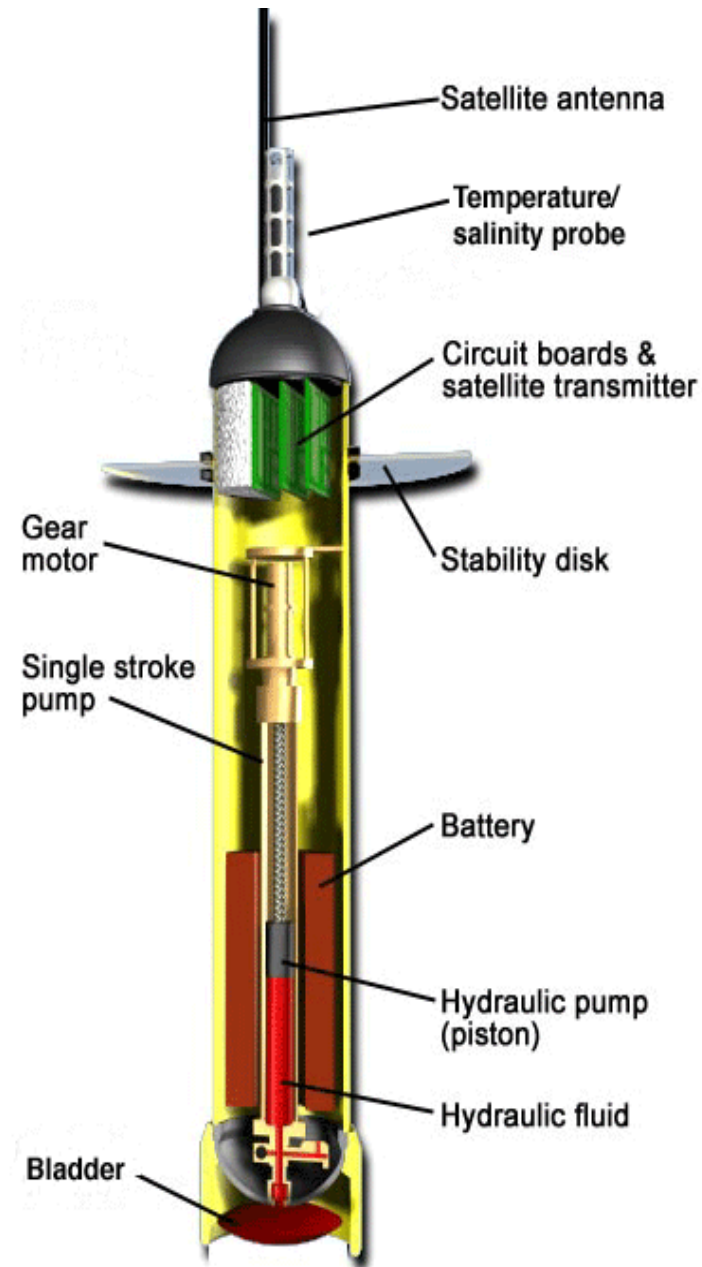
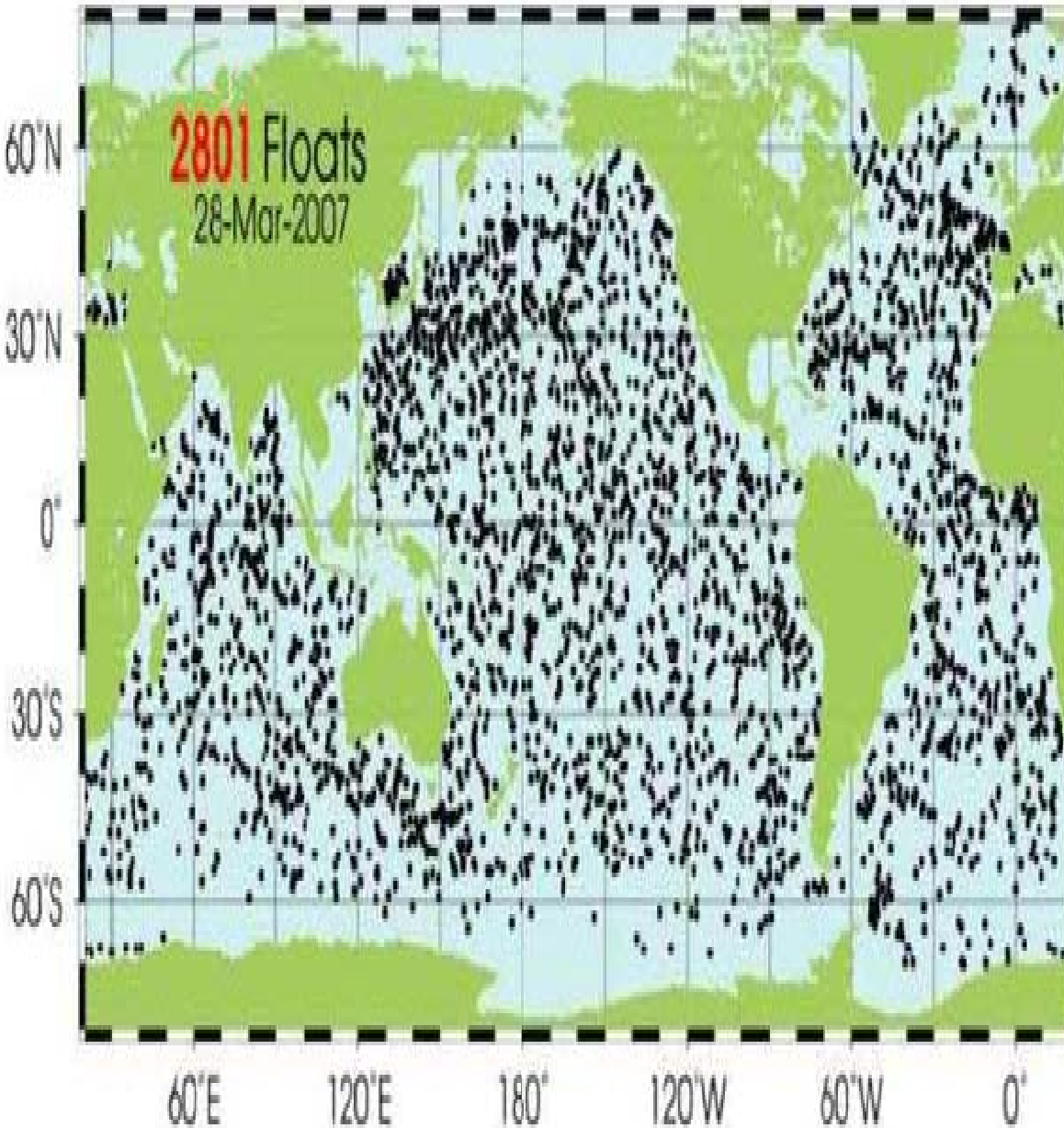
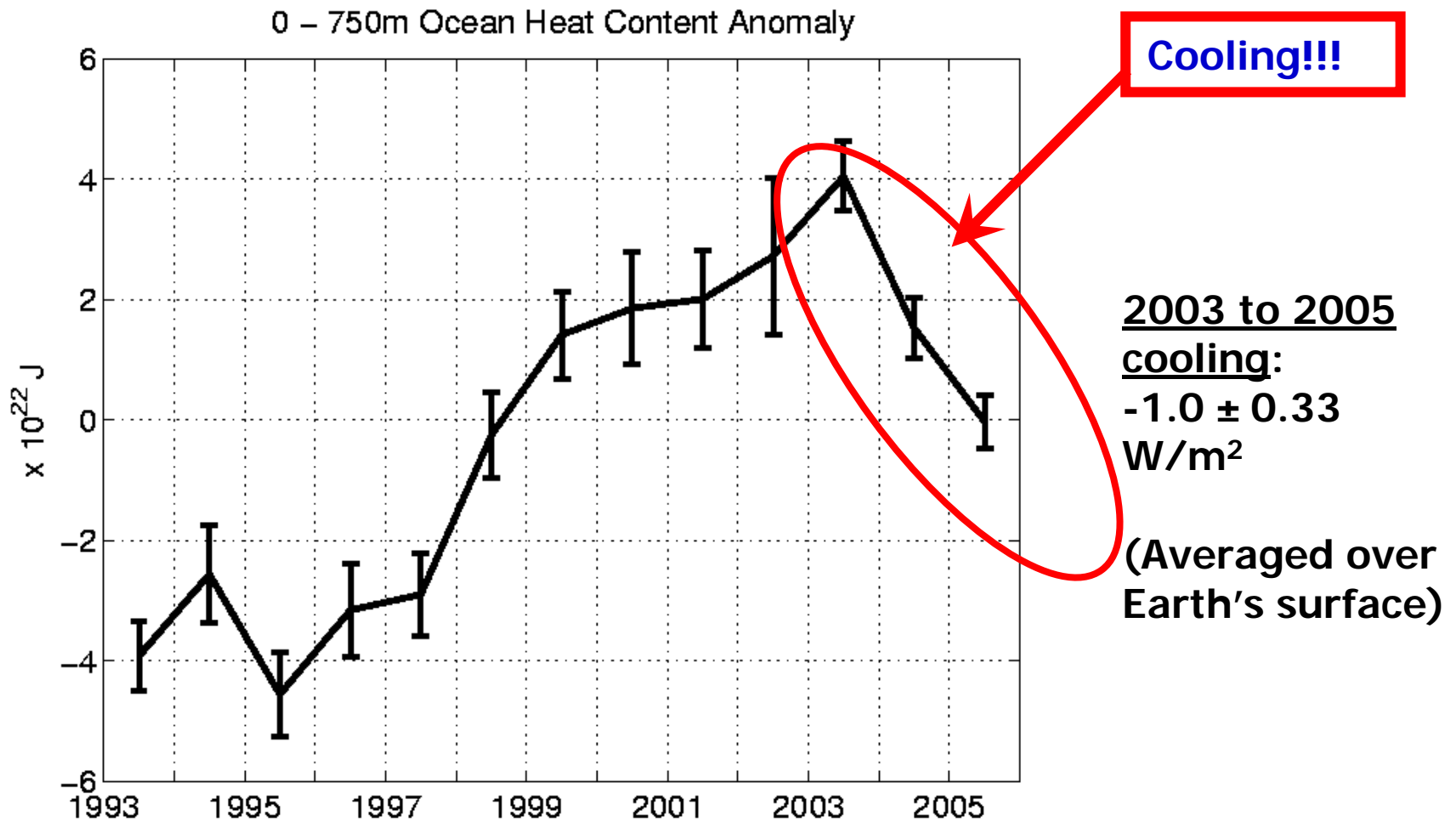


Figure 3. Estimates of Earth's heat balance components (10^{22} J) for the 1955–1998 period.

ARGO floats



Upper-Ocean “cooling”



from Lyman et al. (*GRL*, 2006)

Simulated and observed variability in ocean

temperature and heat content

by

Achuta Rao et al

Proceedings of National Academy of Sciences

Vol. 104,26 June 2007

We show that the 2003–2005 cooling is largely an artifact of a **systematic change in the observing system**, with the deployment of Argo floats **reducing a warm bias** in the original observing system.

Global mean **increase** in
Earth's **atmosphere** during
the past 100 yrs

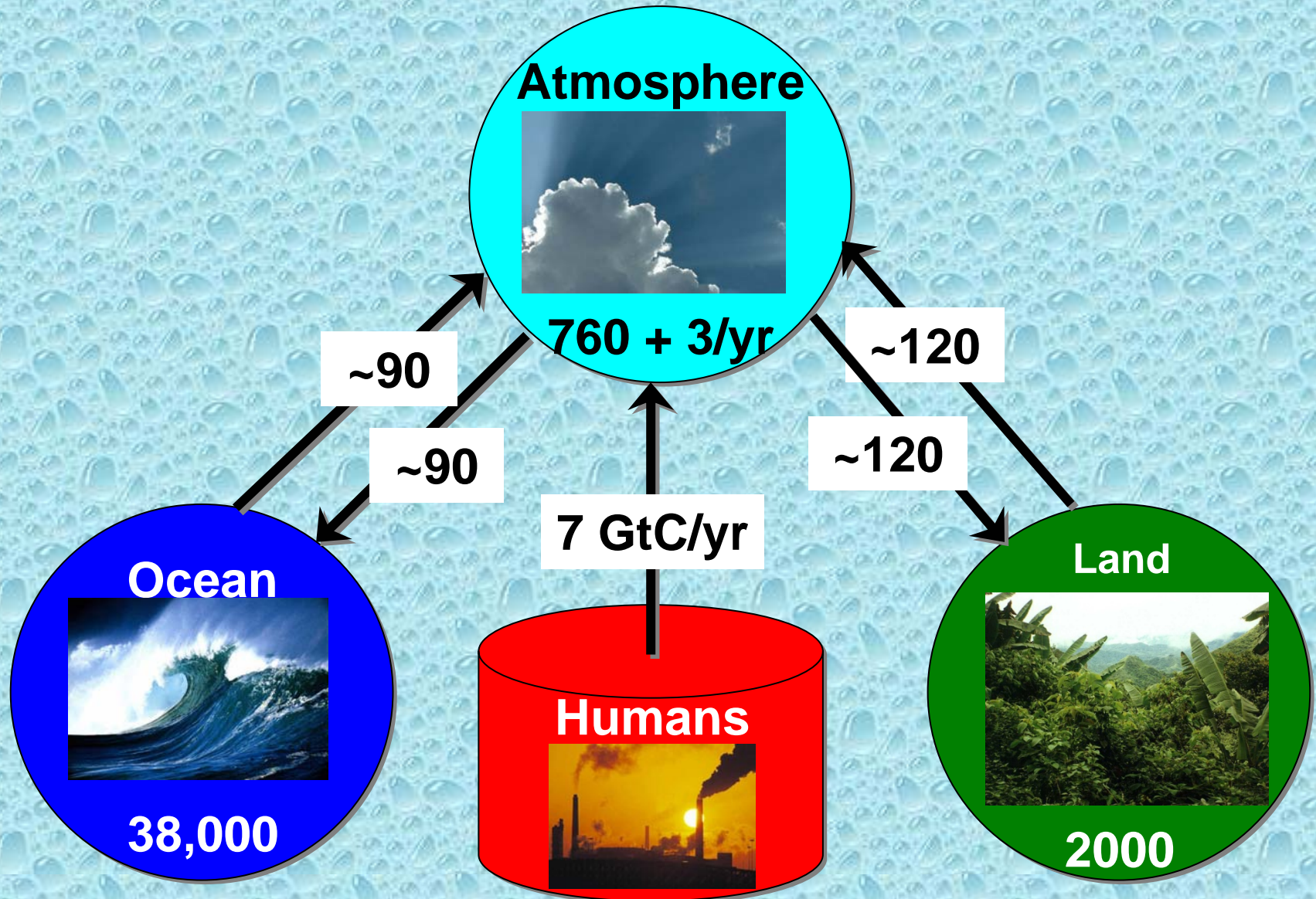
CO₂ increased by **37%**

CH₄ increased by **151%**

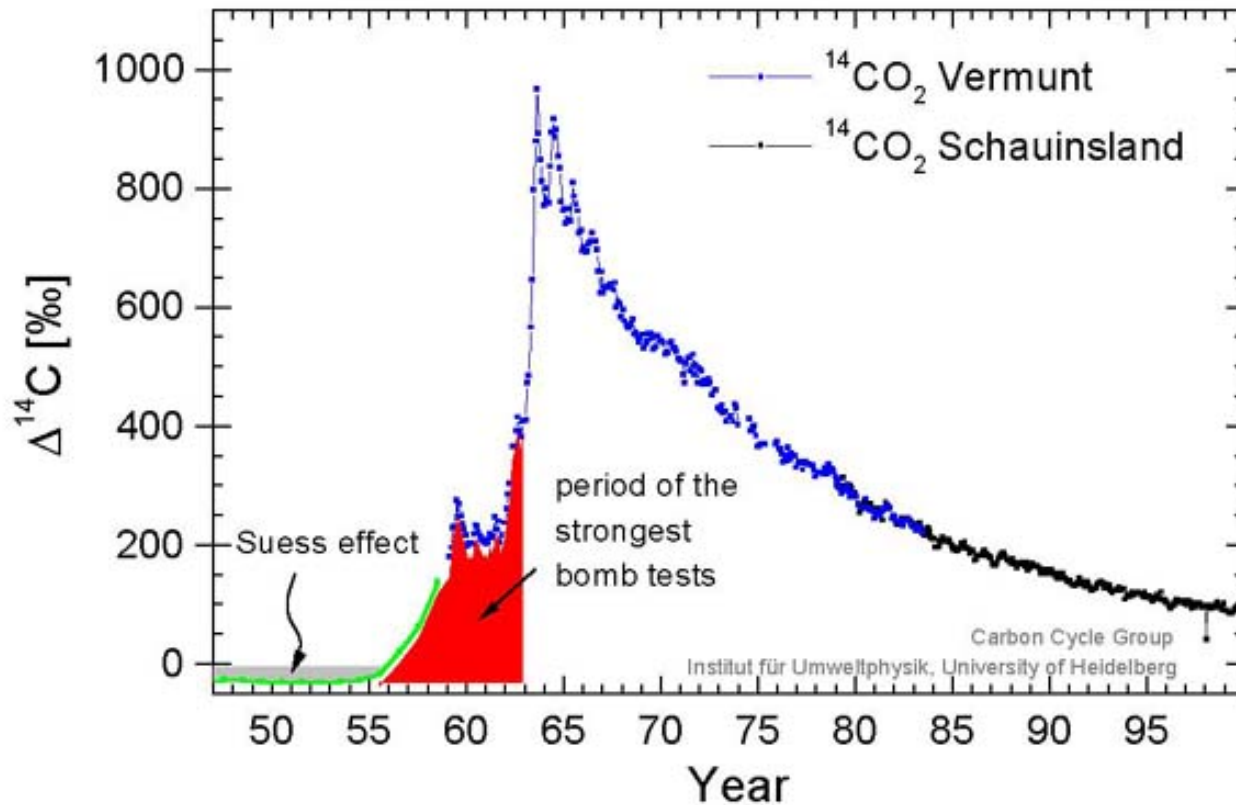
O₃(trop) increased by **31%**

N₂O increased by **31%**

The Global Carbon Cycle



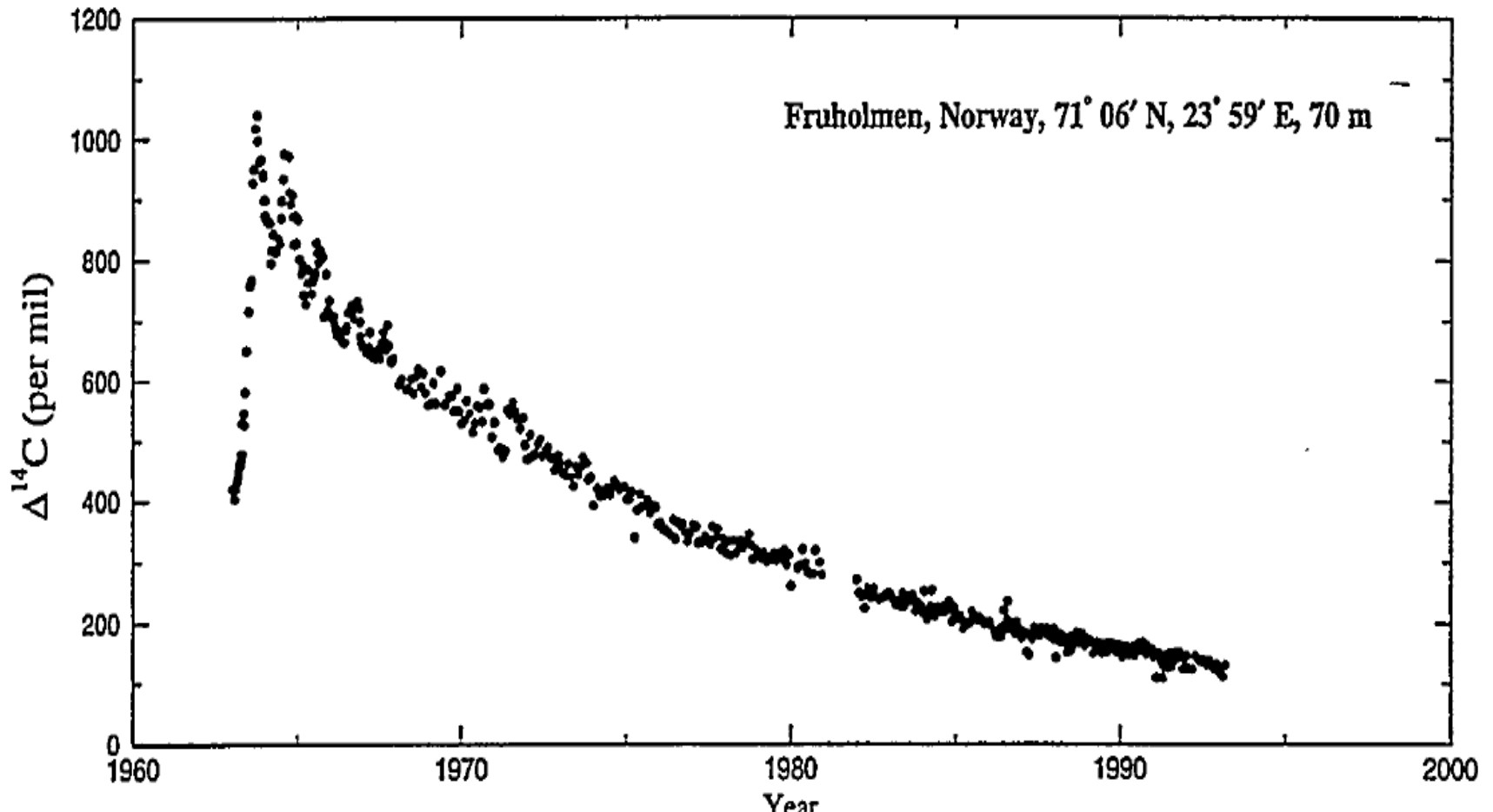
^{14}C in atmospheric CO_2



Development of ^{14}C in atmospheric CO_2 in the Northern Hemisphere in the last 50 years. Data before 1959 have been derived from tree rings (Stuiver and Quay, 1981). From 1959 to 1983 measurements were performed at the Alpine site [Vermunt](#) subsequent data from 1984 onwards are from the [Schauinsland station](#) in the Black Forest.

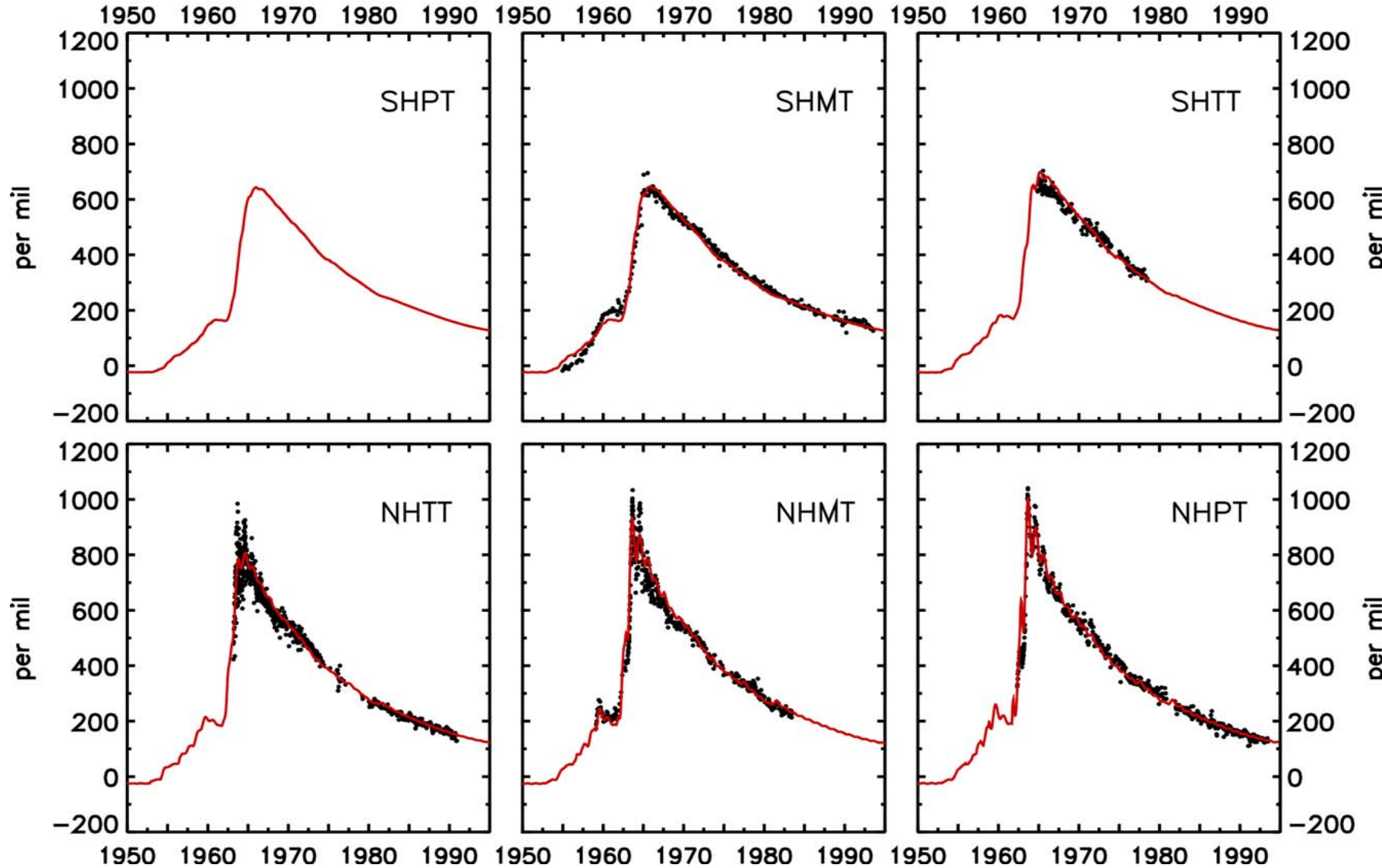
"Suess Effect"

The decline of C^{14} after the nuclear tests demonstrates that CO_2 entering the atmosphere through fossil fuel use

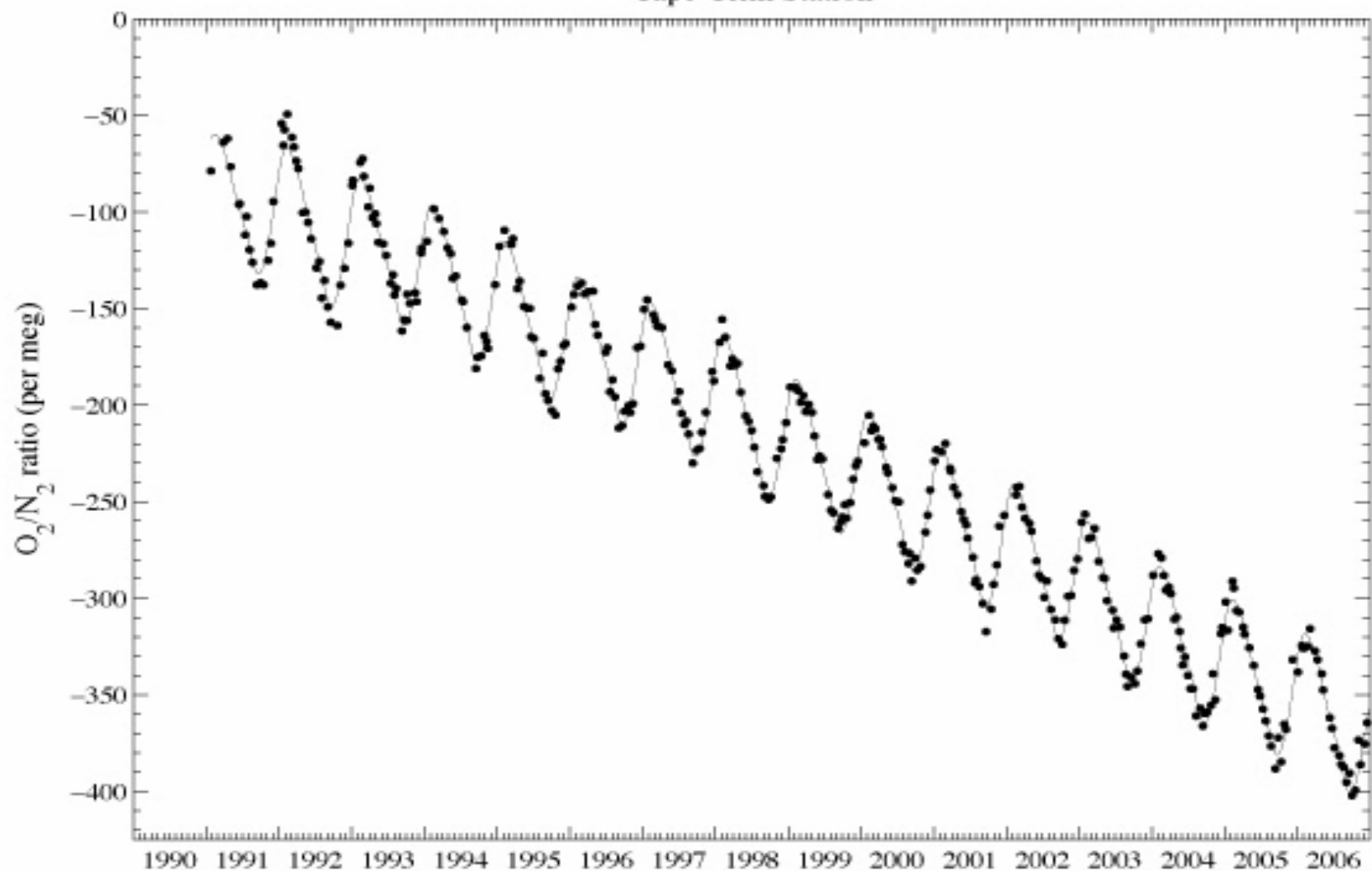


$\Delta^{14}\text{C}$ in the troposphere

Observation & models {from Naegler et al}



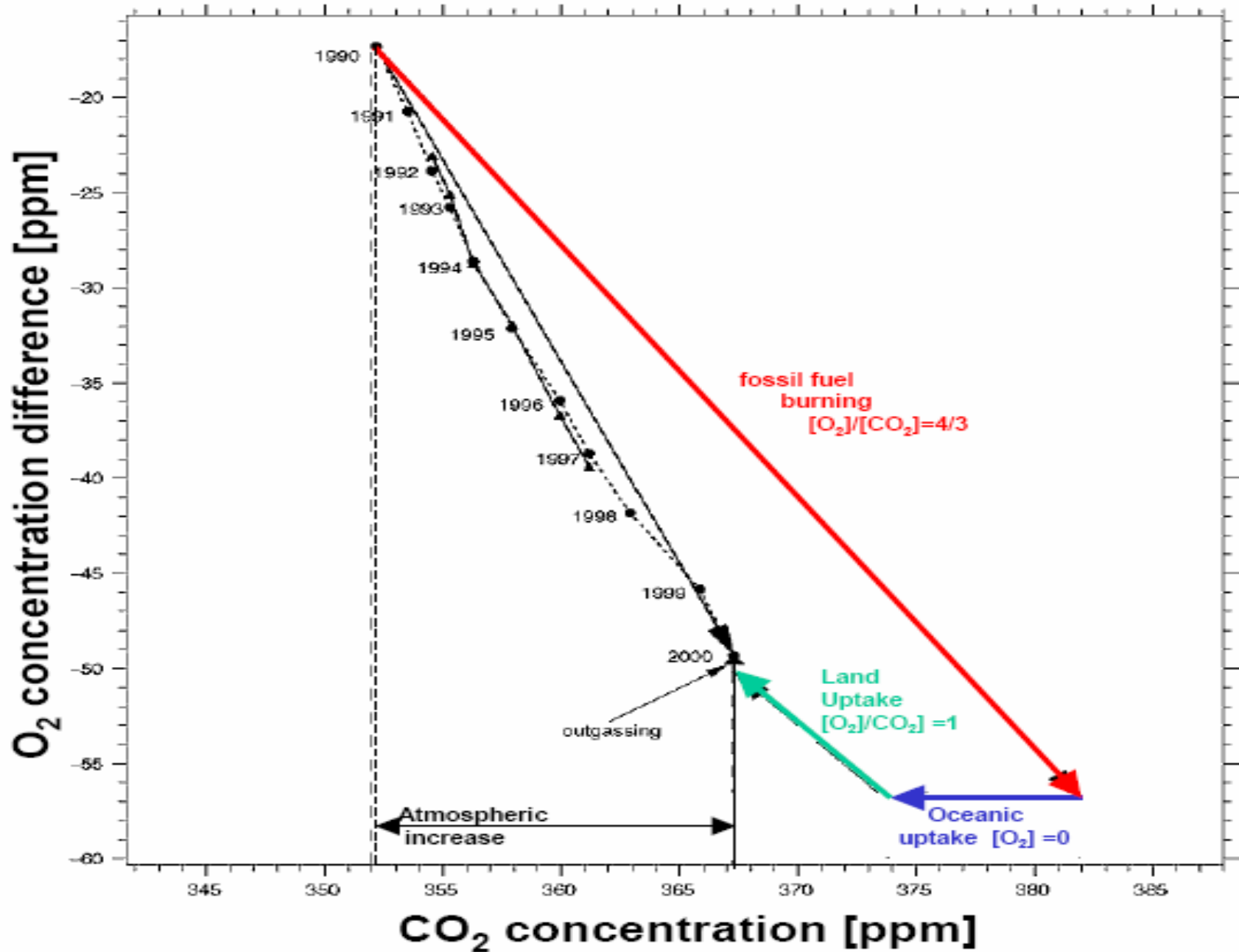
Cape Grim Station



Ralph Keeling's record of atmospheric oxygen, taken in places like Australia's Cape Grim, show a small but steady decline consistent with increased use of fossil fuels.

Image 2 of 9

CLOSE X



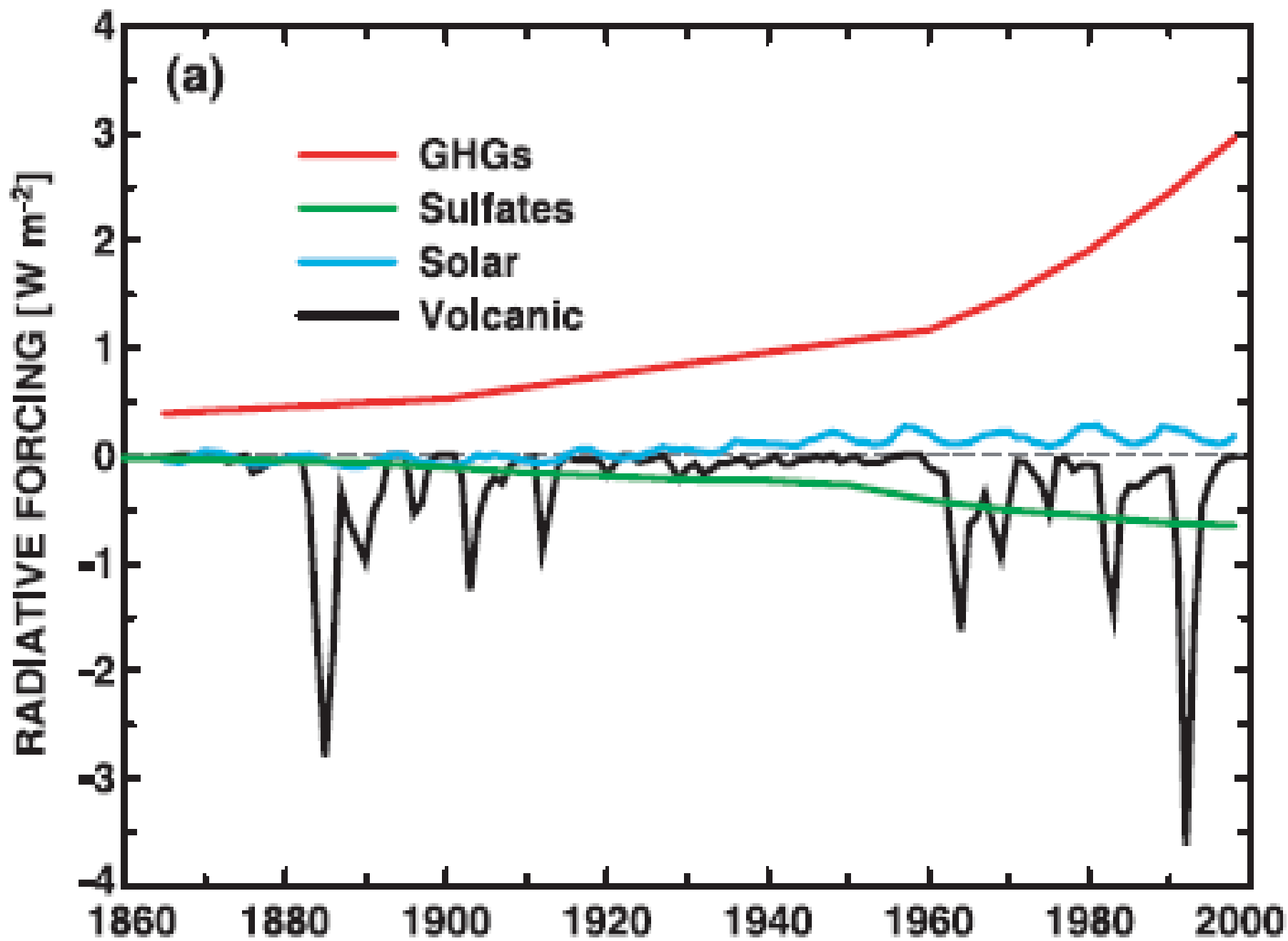
Climate Change

Natural

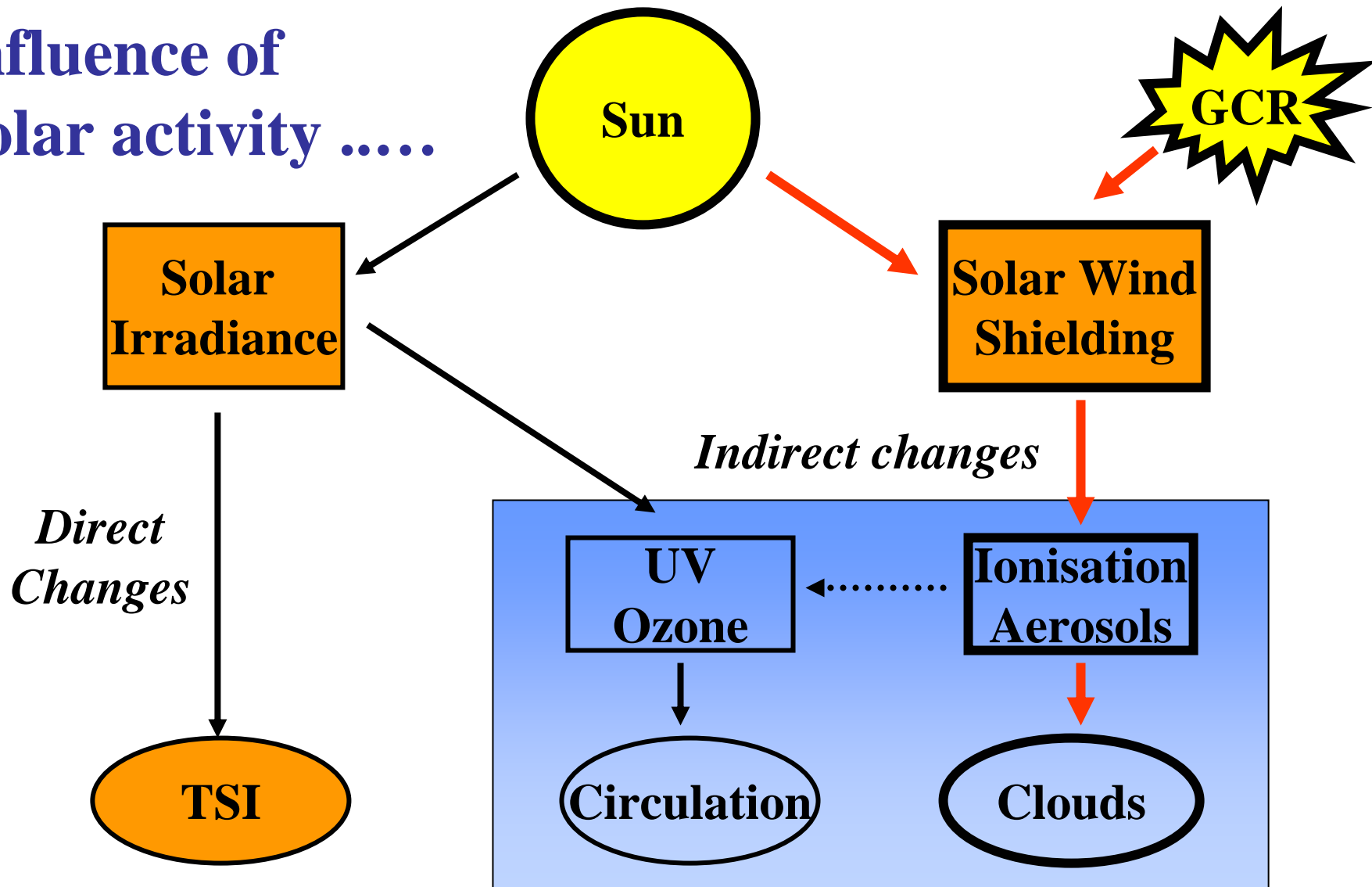
Vs.

Anthropogenic

Is the **global warming**
in the 20th century
due to the **increase**
in **radiation** emitted
by the **sun**?



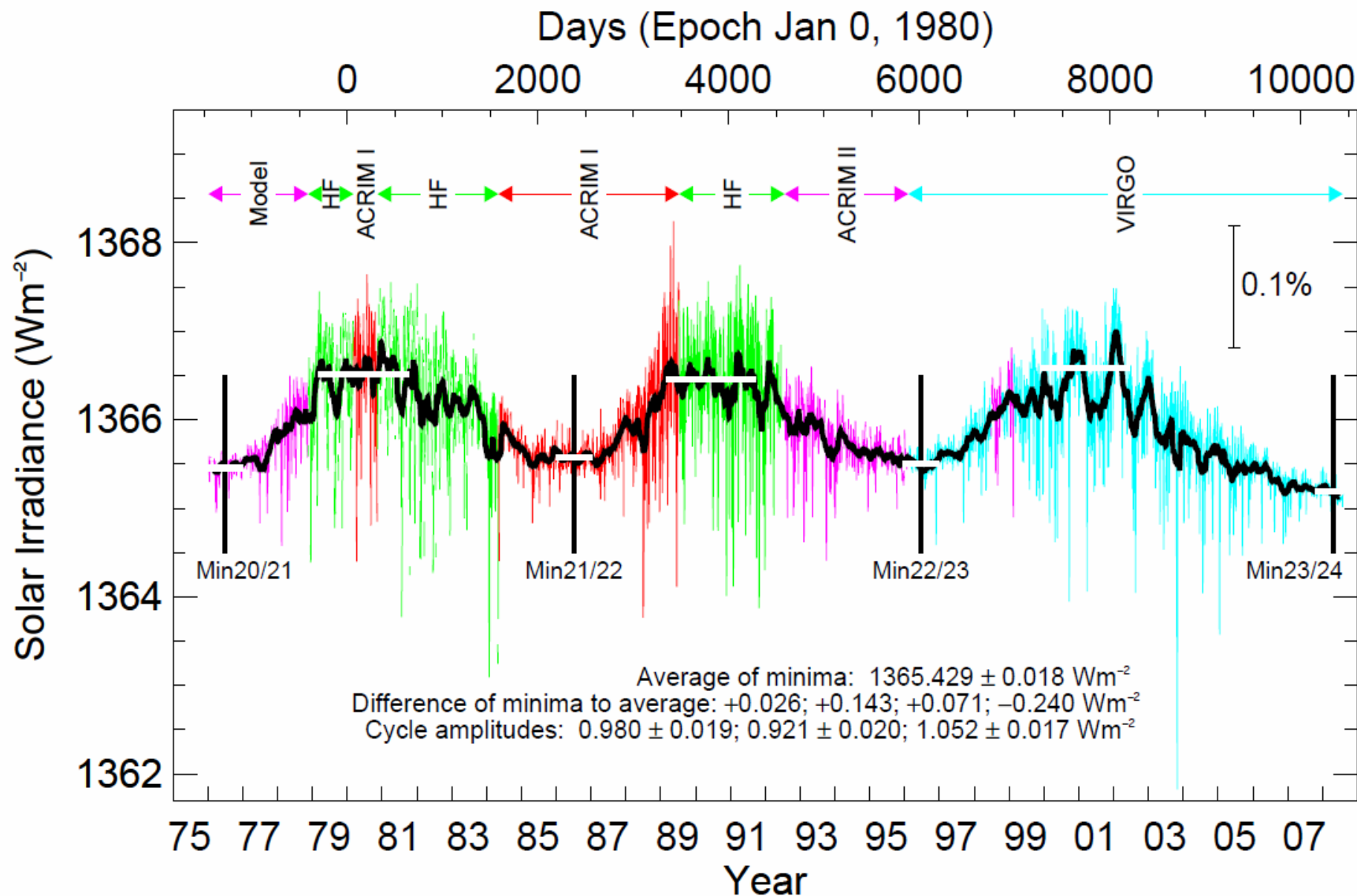
Influence of Solar activity

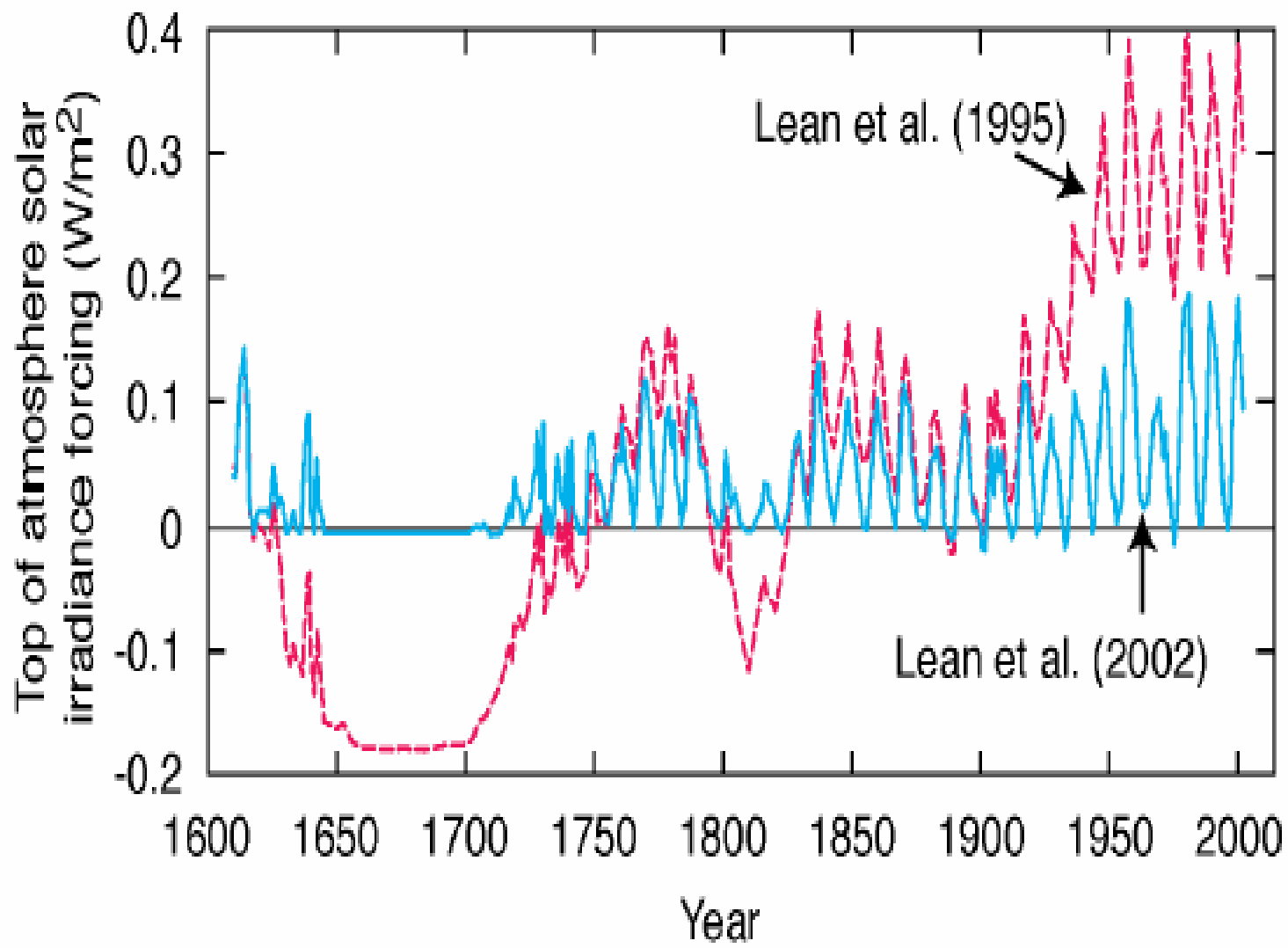


CCN are fairly insensitive to the nucleation rate for a simple reason: during the time taken for nuclei to grow to CCN sizes, coagulation depletes particle concentrations

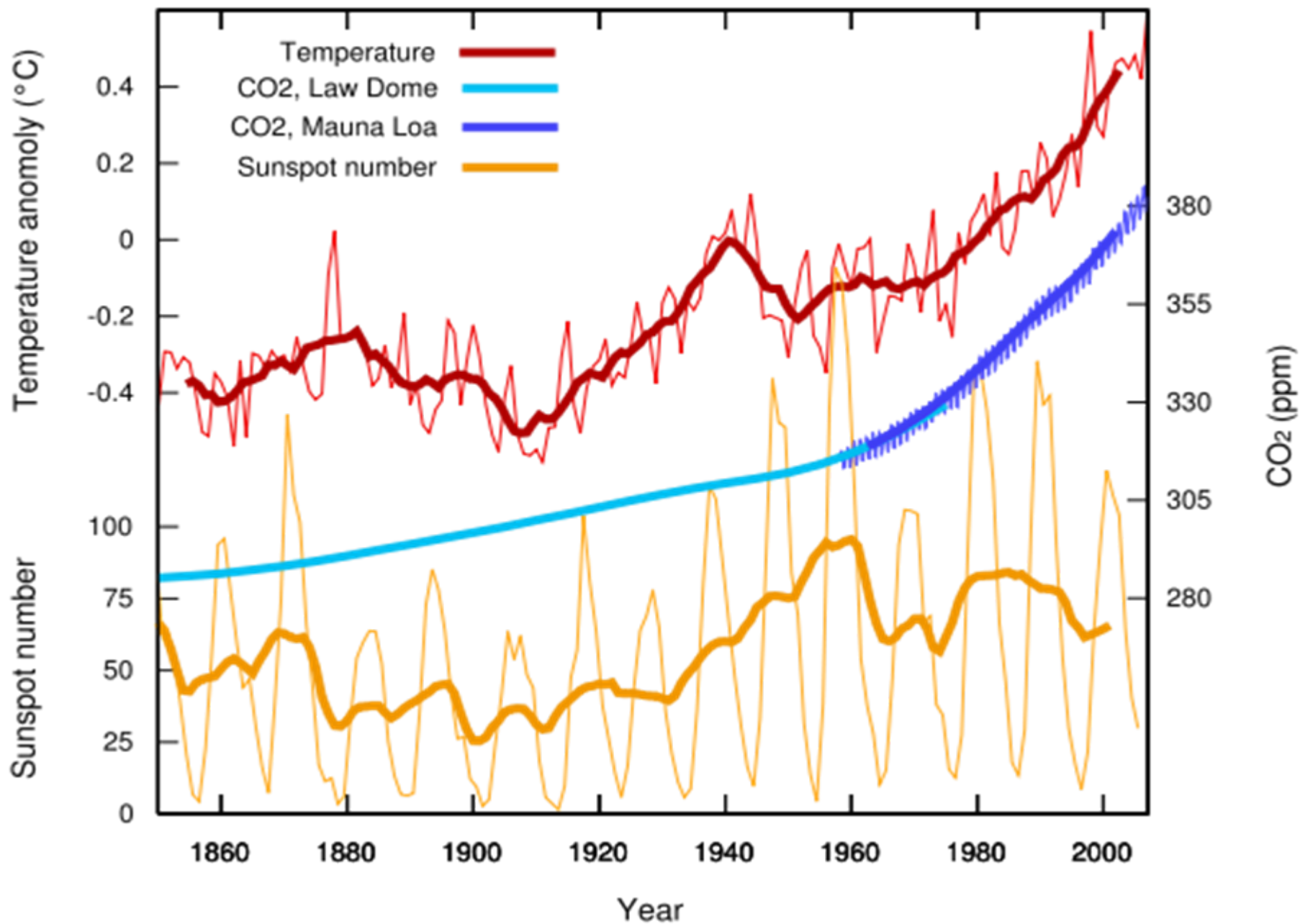
Frohlich C, Lean J. 1998;

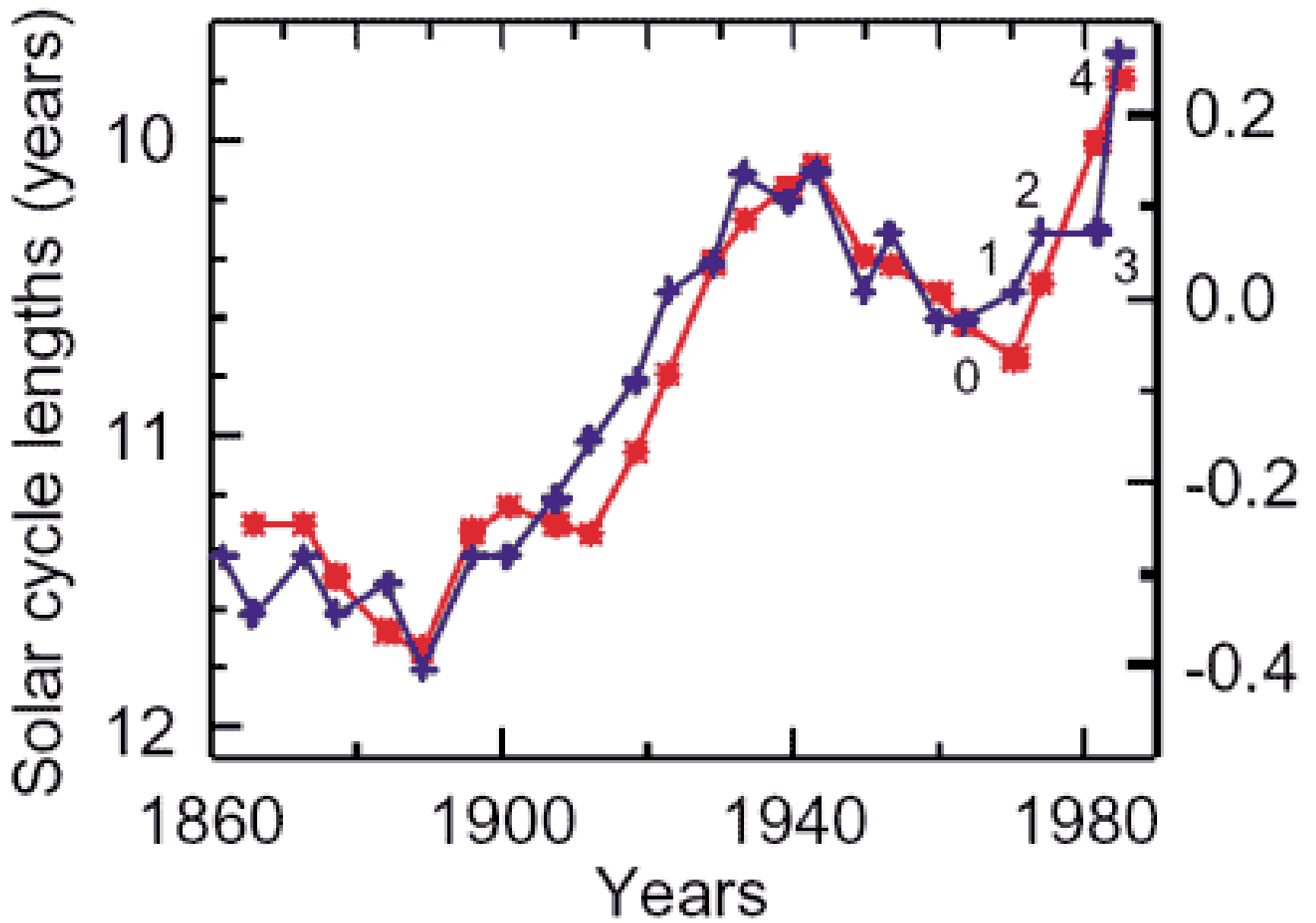
(<http://www.pmodwrc.ch/pmod.psi/composite/SolarConstant>)





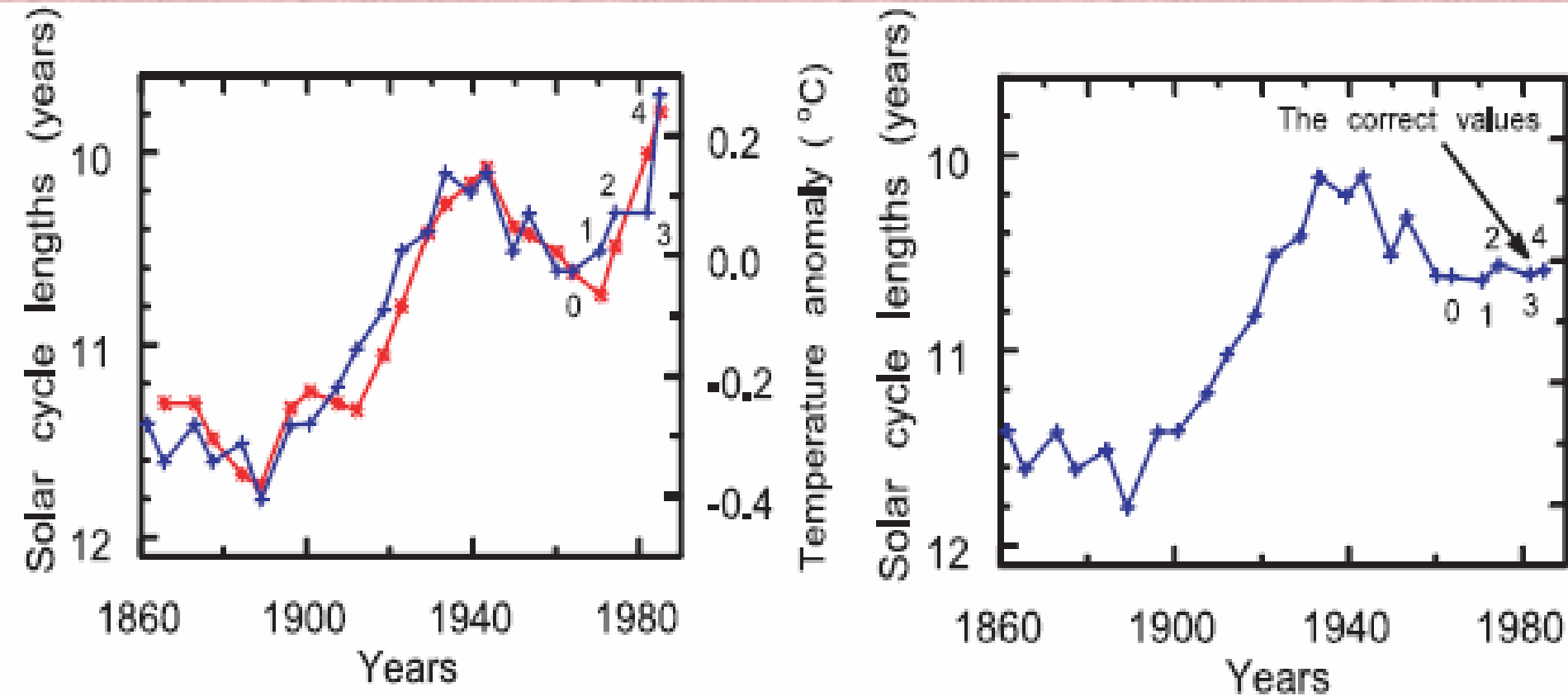
Temperature, CO₂, and Sunspots





Pattern of Strange Errors Plagues Solar Activity and Terrestrial Climate Data

Damon & Laut, EOS, 2004



E. Friis-Christensen & K. Lassen Science, 1991

J.Kirkby, Surveys in Geophysics 28, 333–375,2007

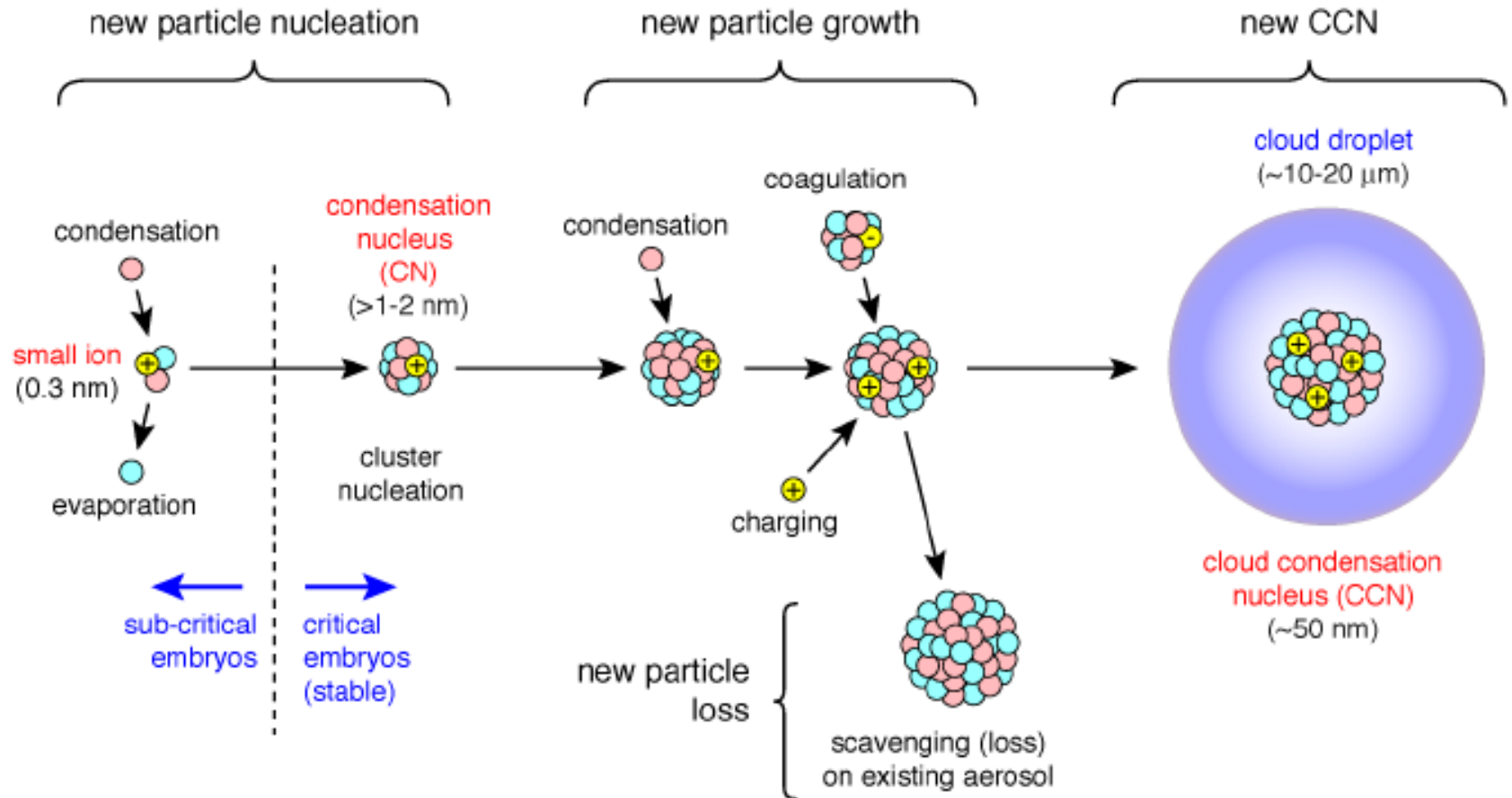
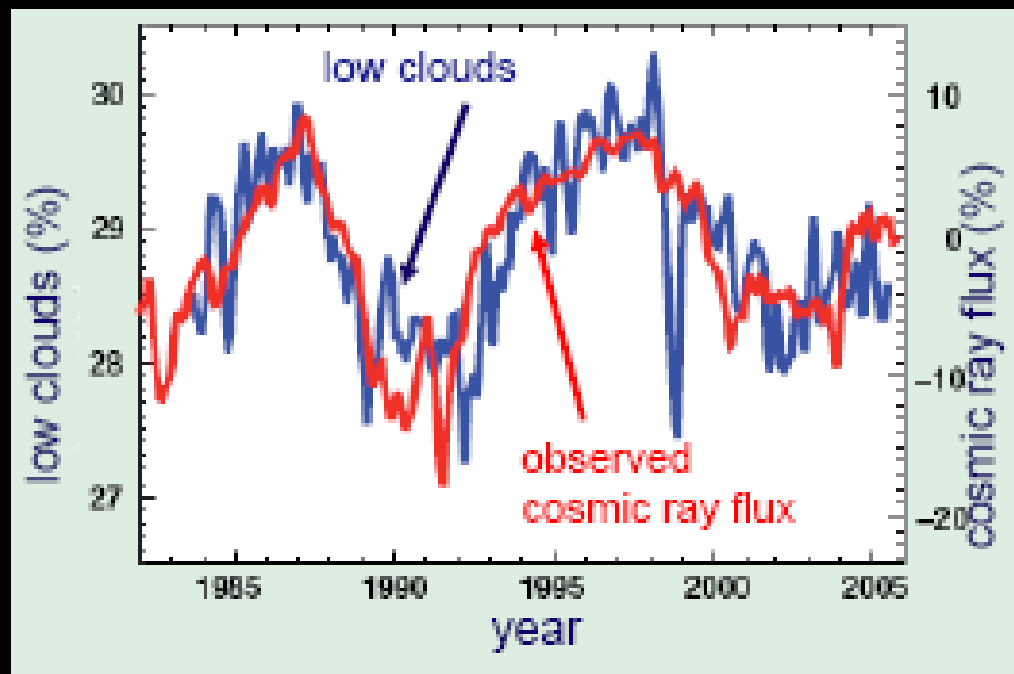


Fig. 12: Ion-induced nucleation of new particles from trace condensable vapours and water in the atmosphere.

Correlation between sunspot cycle, galactic cosmic rays and global cloudiness

Solar flux rise → GCR influx drop → cloud cover drops → surface warms



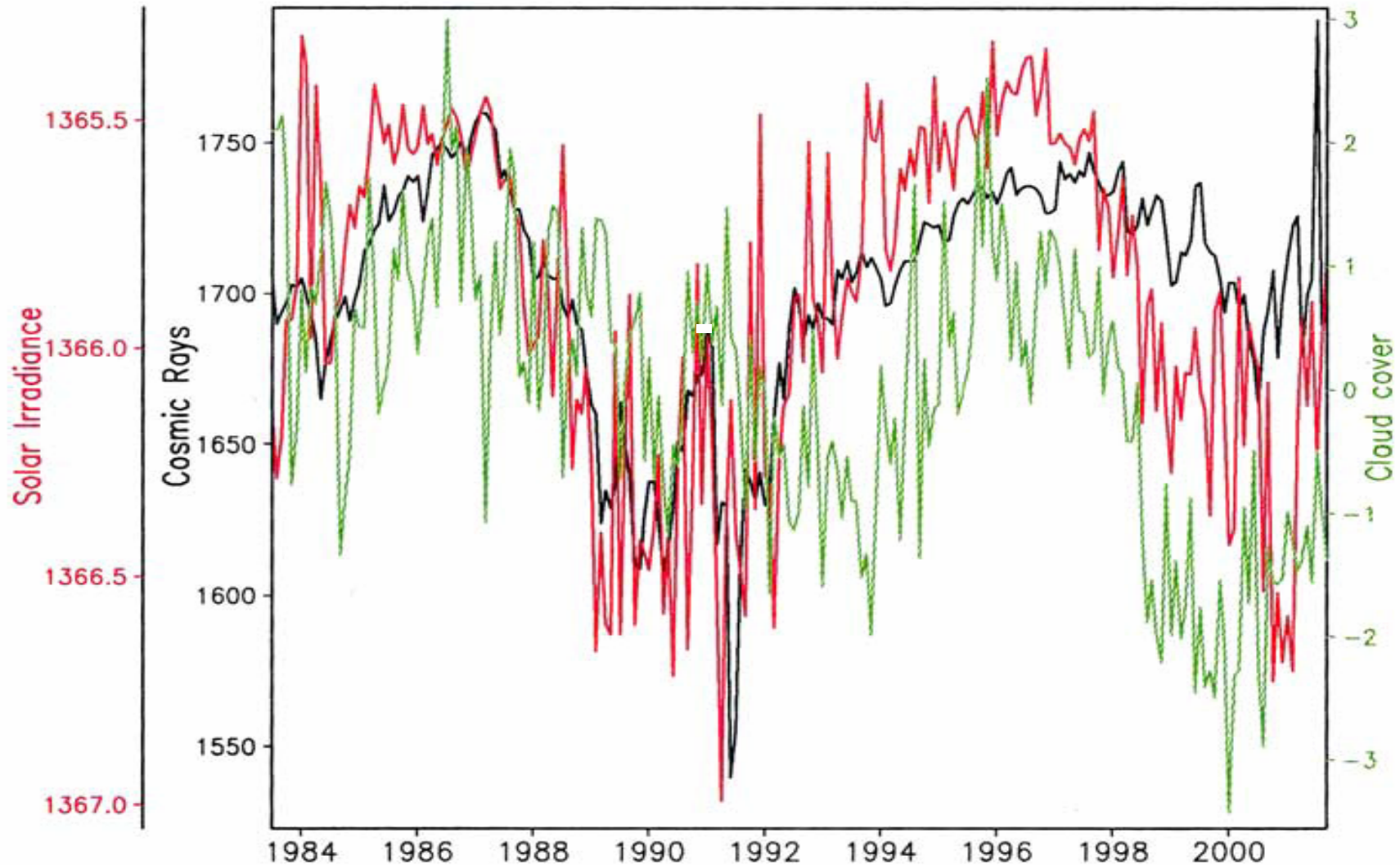
Svensmark 2007 A & G, v. 43, p. 119-124.

15% variation in cosmic ray penetration between solar max. and min. causes 1.7% variation in low cloud formation.

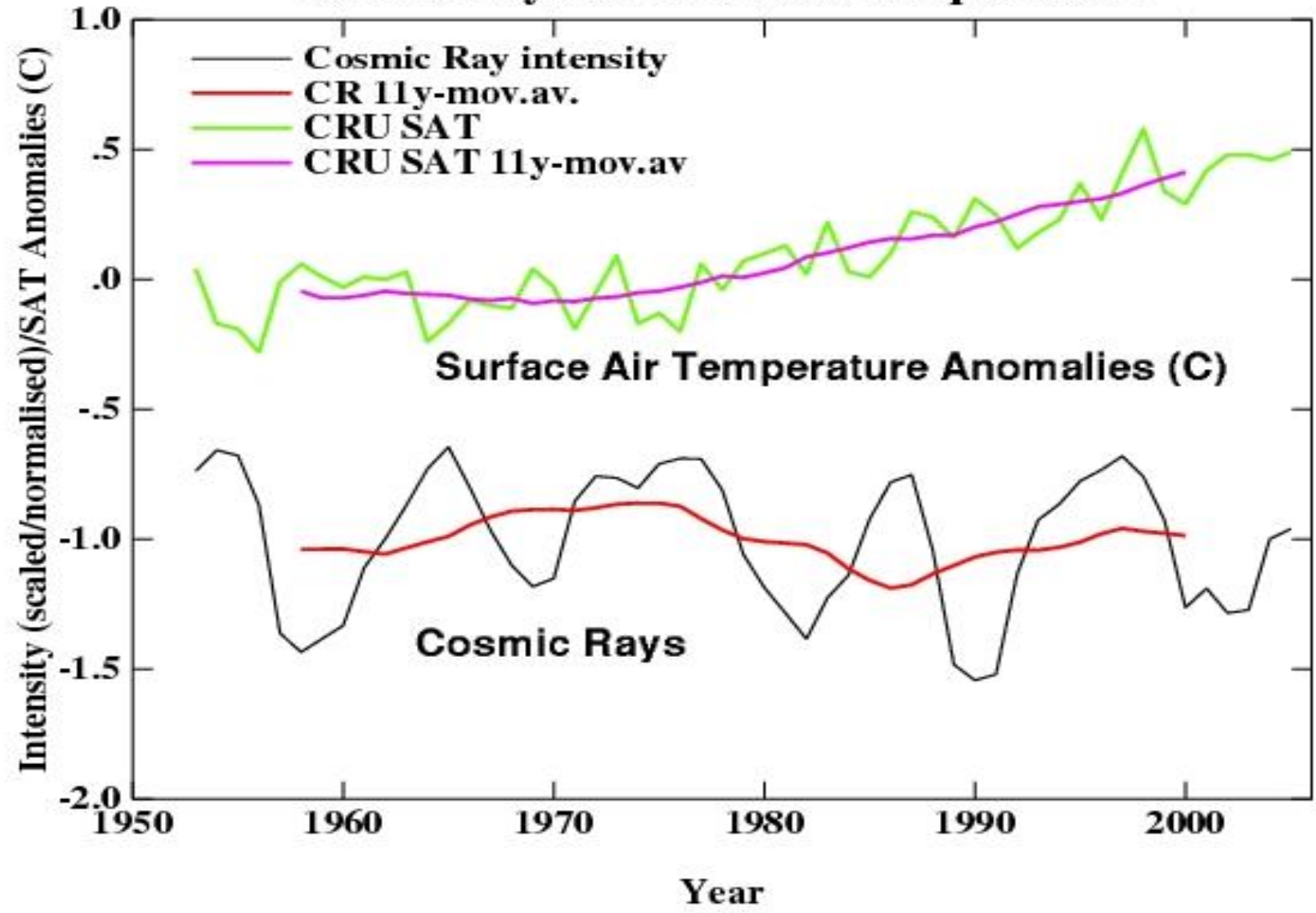
1.7% variation in low cloud formation causes 1.3 W/m^2 in surface warming which is >85% of IPCC estimate for effect of all CO_2 since beginning of industrial revolution = 1.4 W/m^2 .

Kristjansson et al , Advances in Space Research ,2004

One may conclude that neither the coupling between solar irradiance and low clouds suggested by Kristjansson et al.(2002) nor the coupling between cosmic rays and low clouds suggested by Marsh and Svensmark (2000) would have any impact on the global warming over the period 1950-2000.



Cosmic Rays and Surface Temperatures



from www.realclimate.org

Krivova & Solanki,

Advances in Space Research, 2004

We have shown that even in the extreme case that solar

variability caused all the global climate change prior to 1970 it

cannot have been responsible

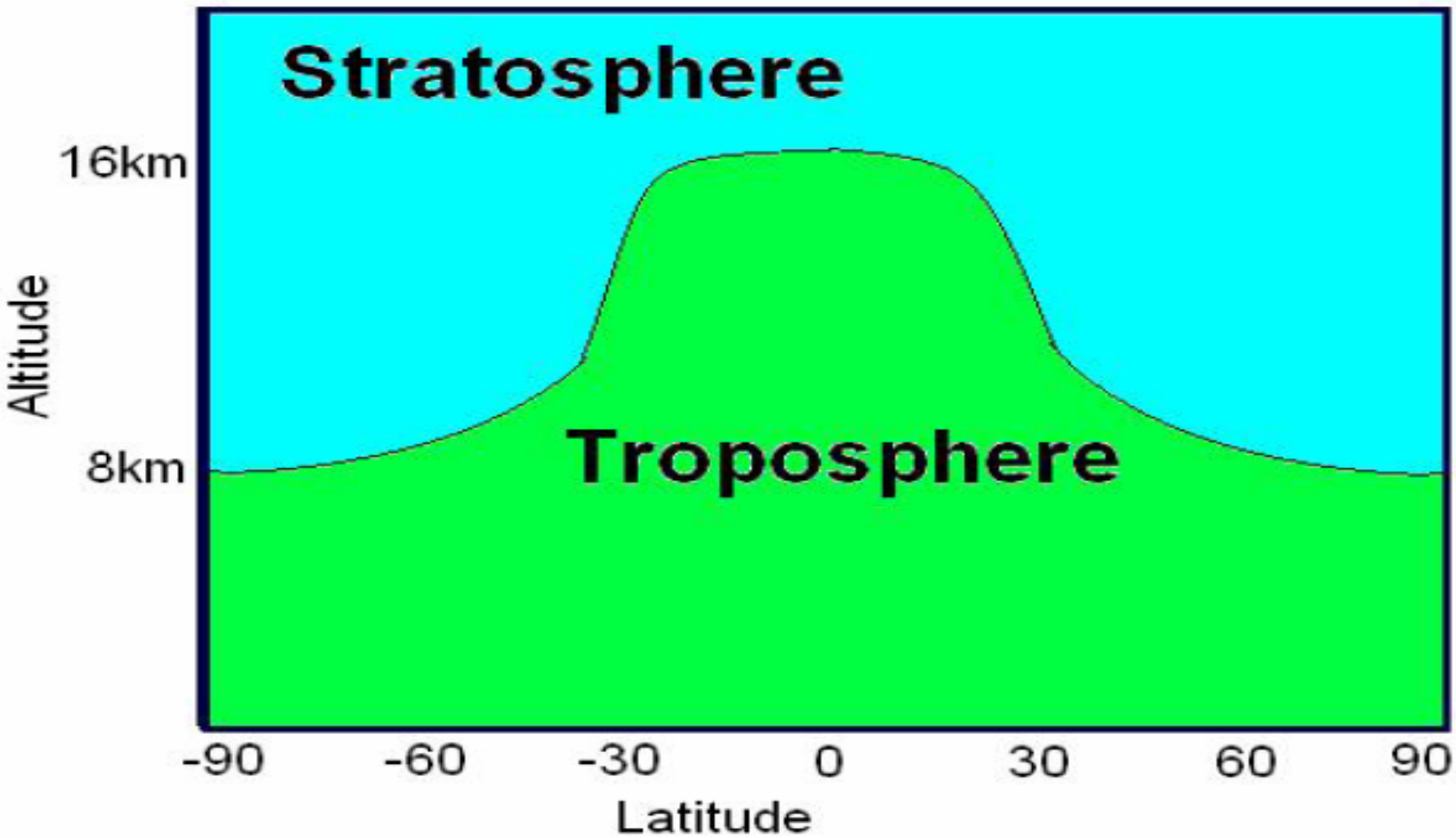
for more than 30% of the strong

global temperature rise since

1970

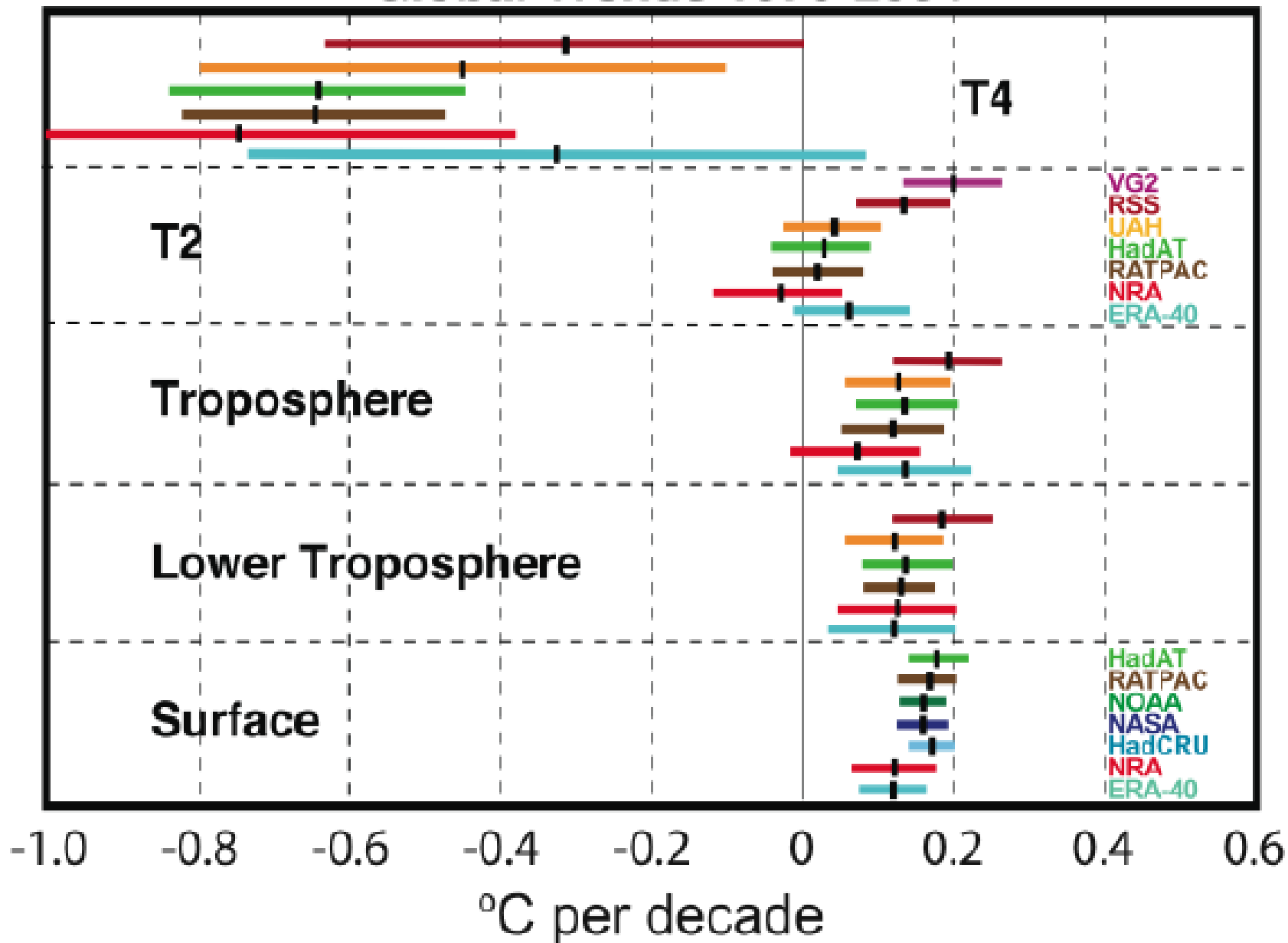
CLOUD (Cosmics Leaving Outdoor Droplets) experiment is being set up at CERN to investigate GCR-cloud microphysics under controlled conditions in the laboratory

The experiment involves a 4 m diameter aerosol chamber and a 0.5 m cloud chamber which are exposed to a CERN particle beam, providing an adjustable source of “cosmic rays” that closely simulates GCRs at any altitude or latitude.

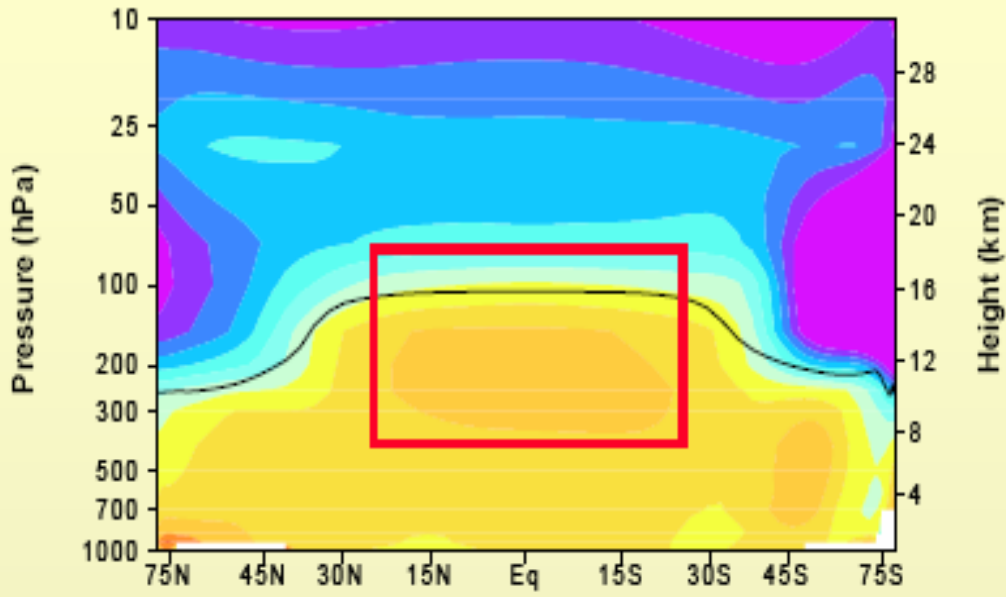


INCREASE IN CO₂ CAUSES WARMING OF THE TROPOSPHERE AND COOLING OF THE STRATOSPHERE

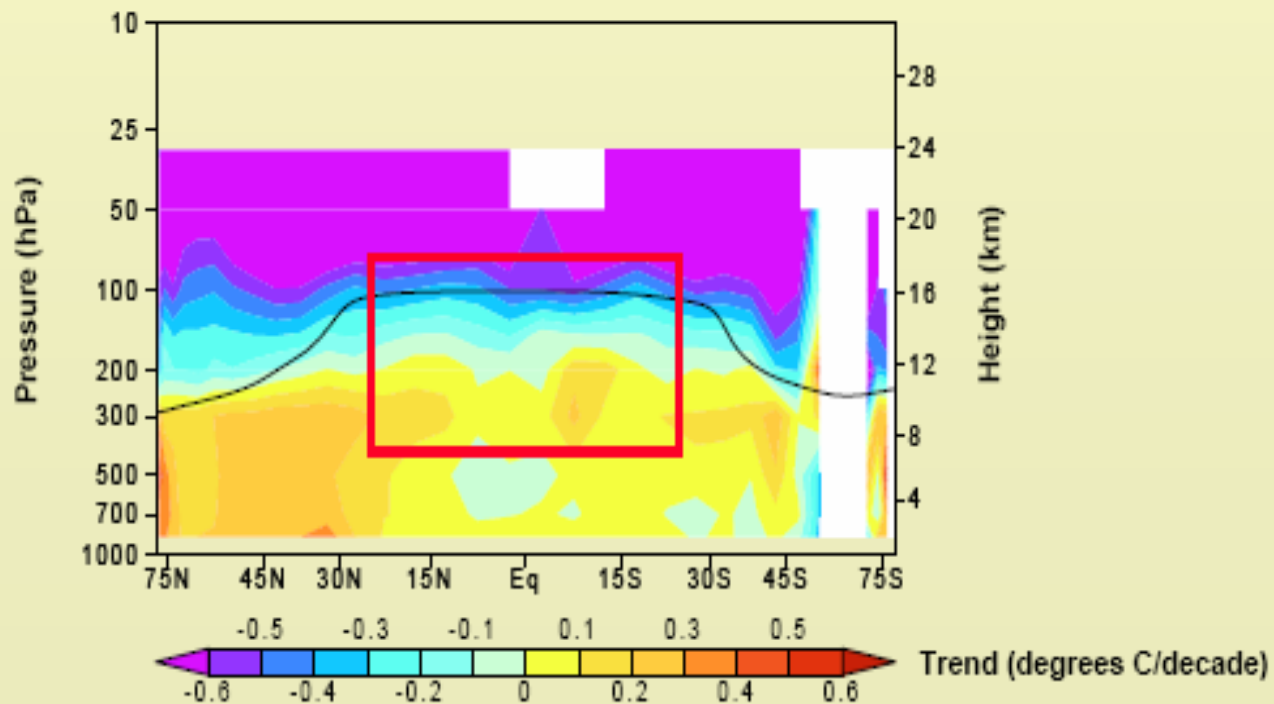
Global Trends 1979-2004



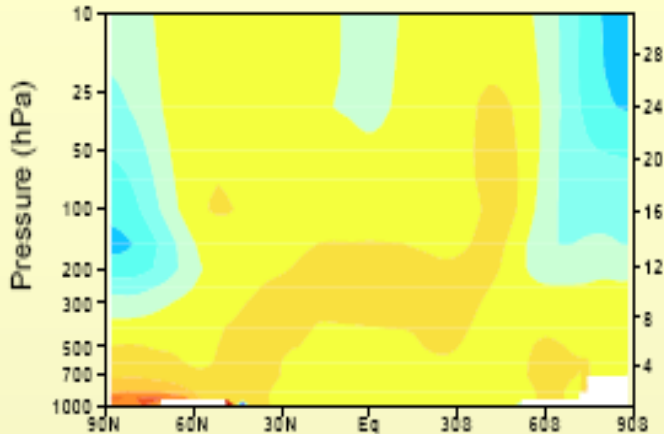
Climate model results



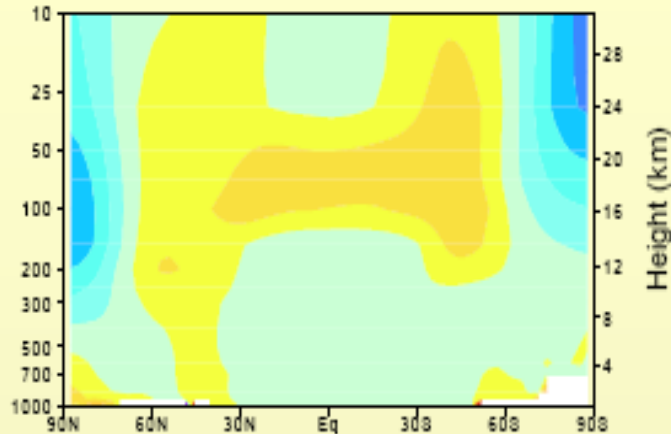
Weather balloon data



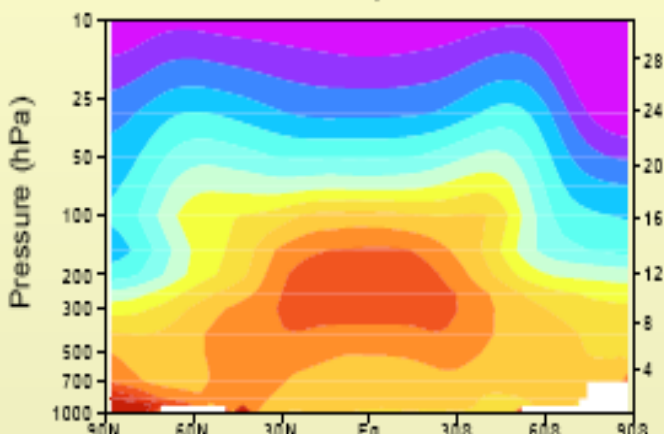
1. Solar



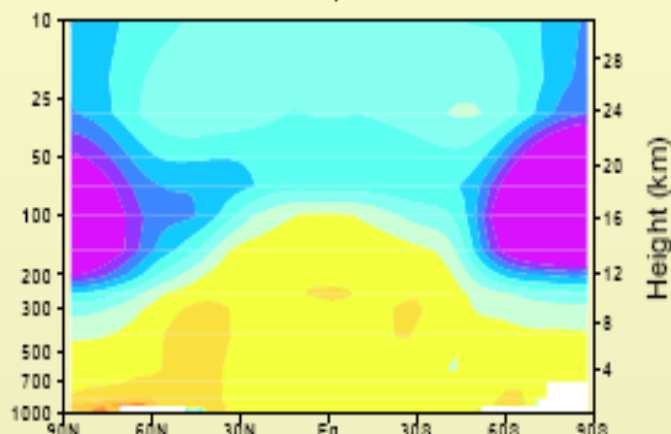
2. Volcanoes



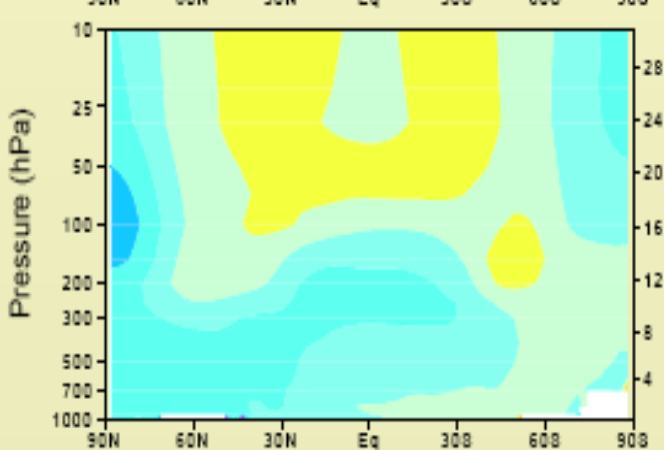
3. Well-mixed greenhouse gases



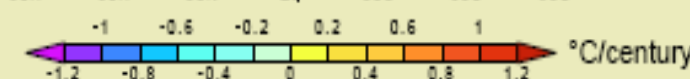
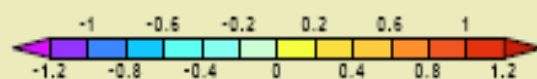
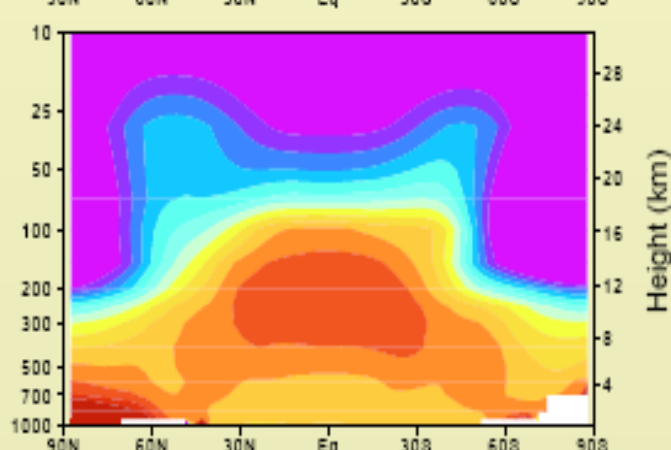
4. Ozone



5. Sulfate aerosol particles



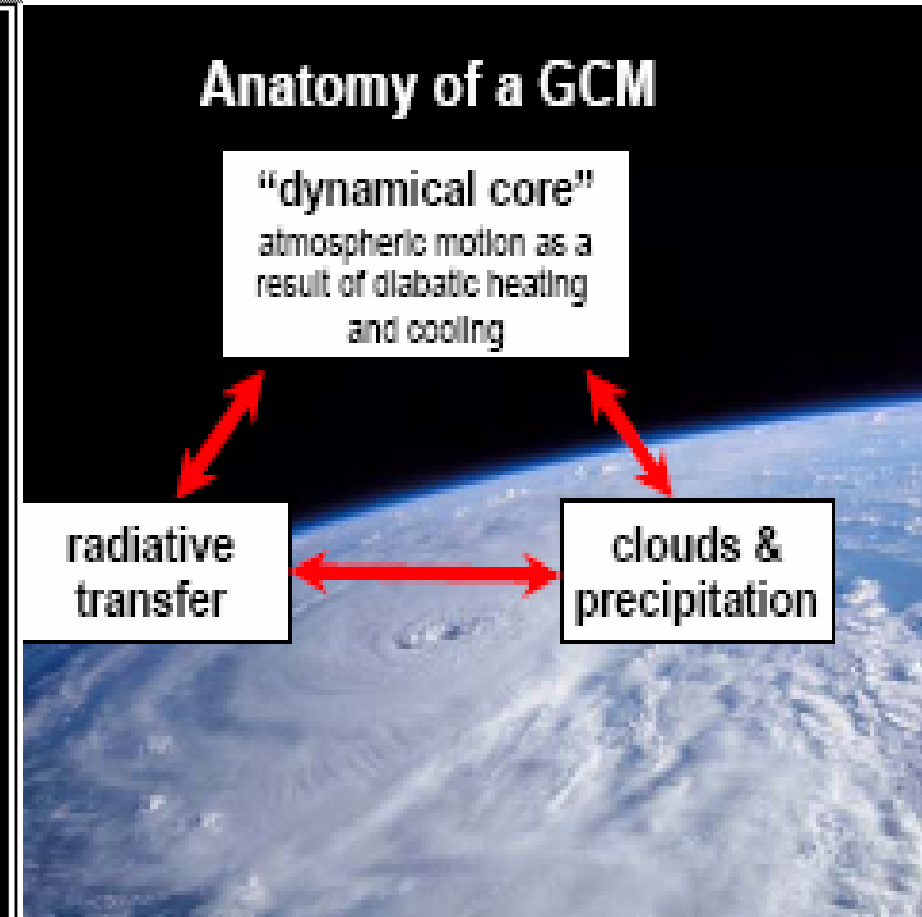
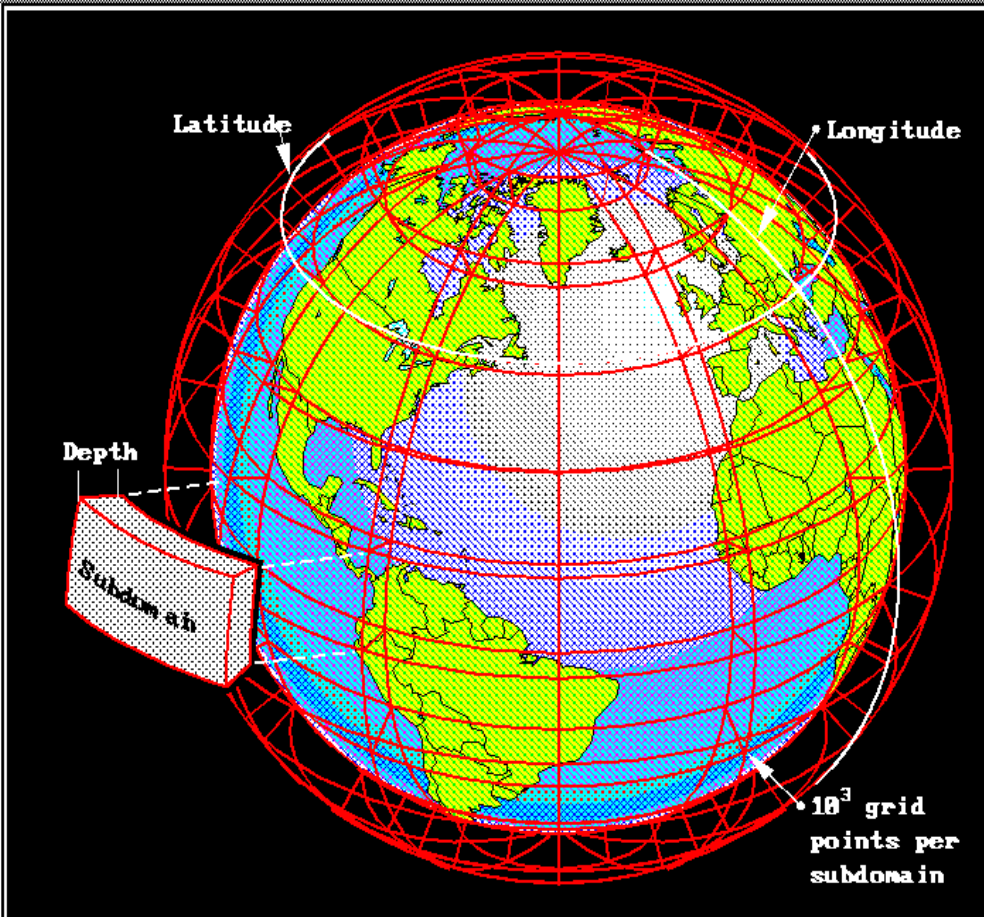
6. 1st five factors combined



We Need Climate Models

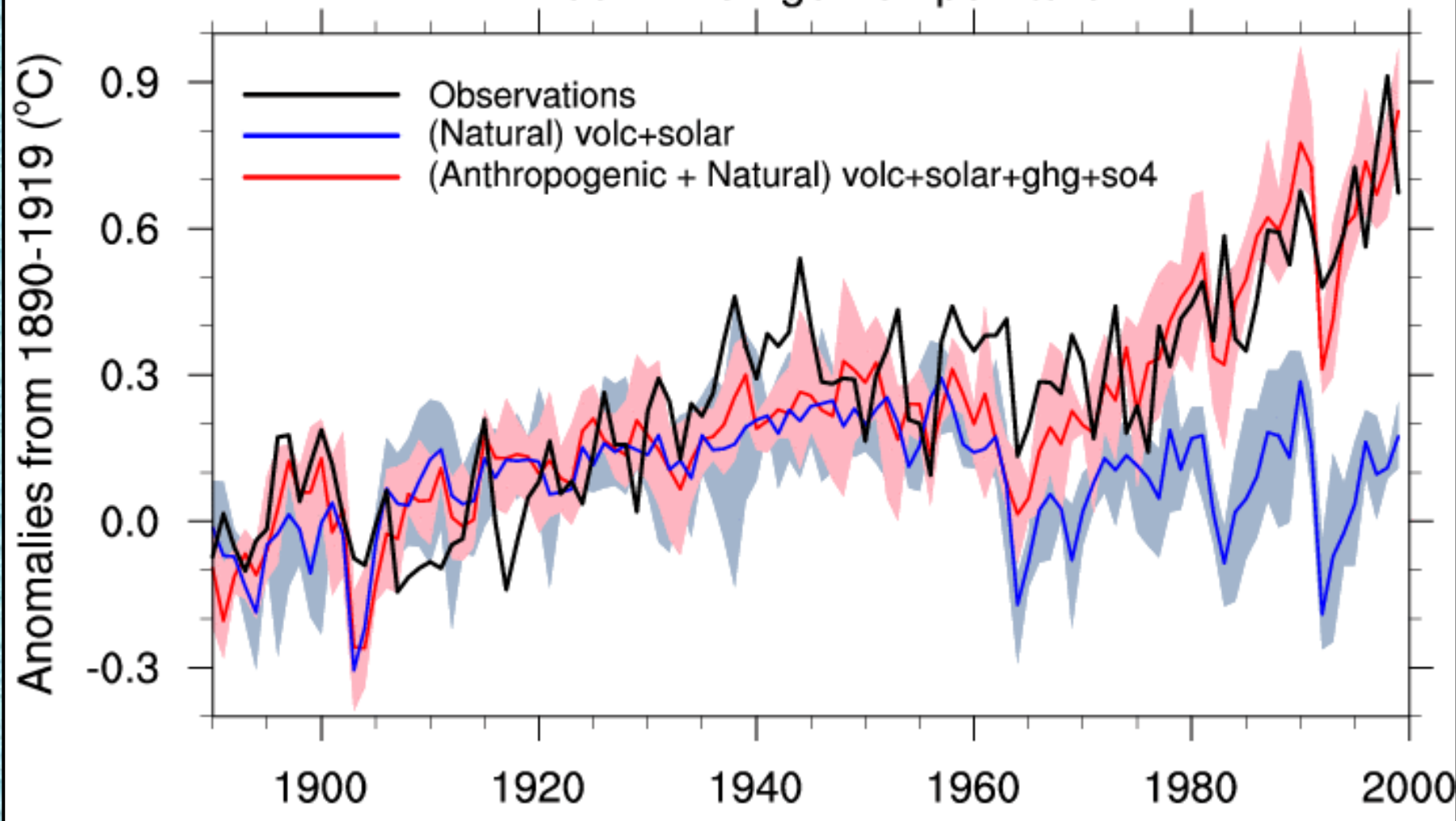
- To discriminate between natural and anthropogenic causes
- To Predict future climate change

GENERAL CIRCULATION MODELS(GCM) INCORPORATE ALL KNOWN LAWS OF PHYSICS AND EXPLOIT THE NUMBER CRUNCHING POWER OF MODERN COMPUTERS



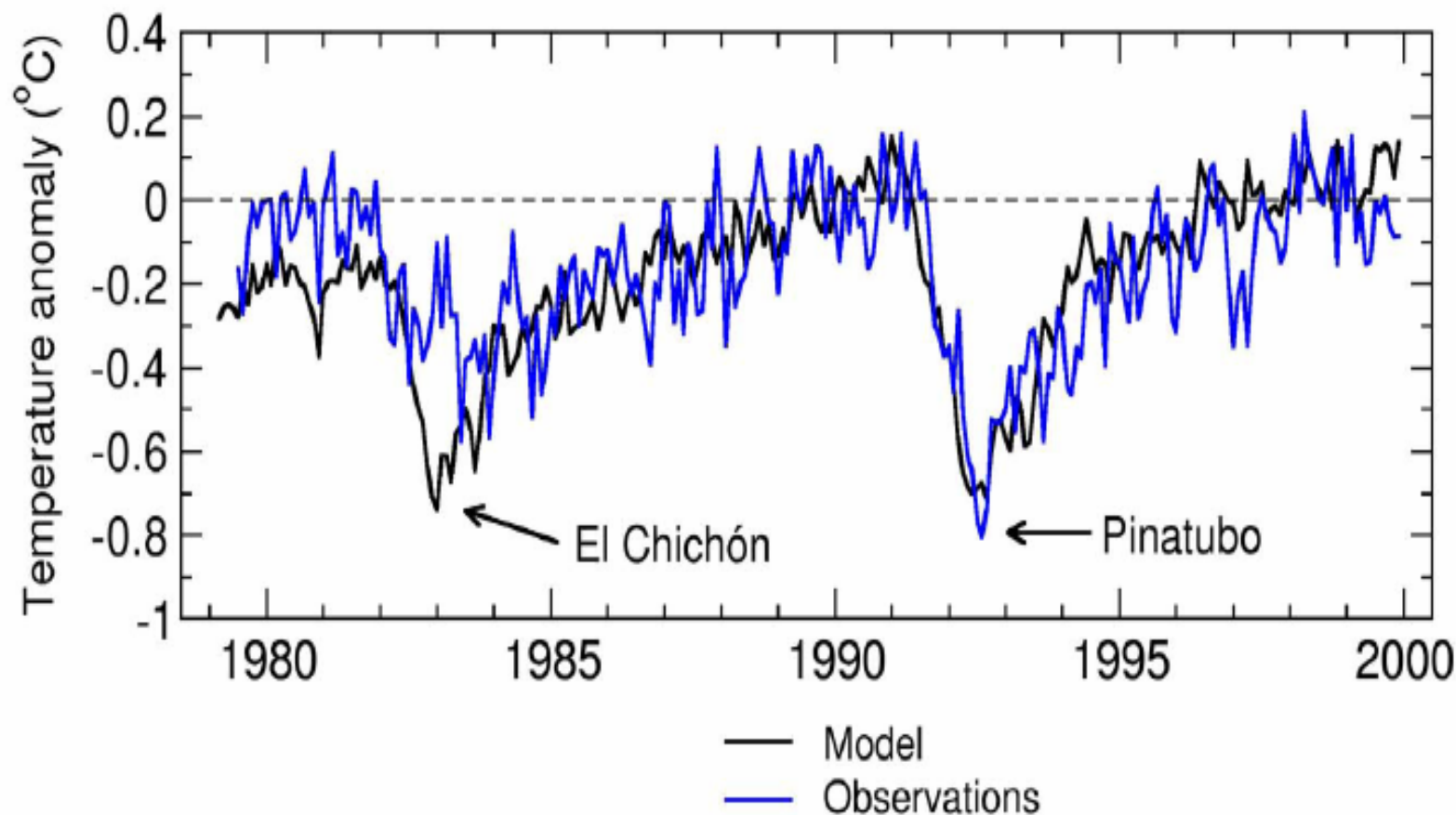
PCM Ensembles

Global Average Temperature



Source: Jerry Meehl, National Center for Atmospheric Research

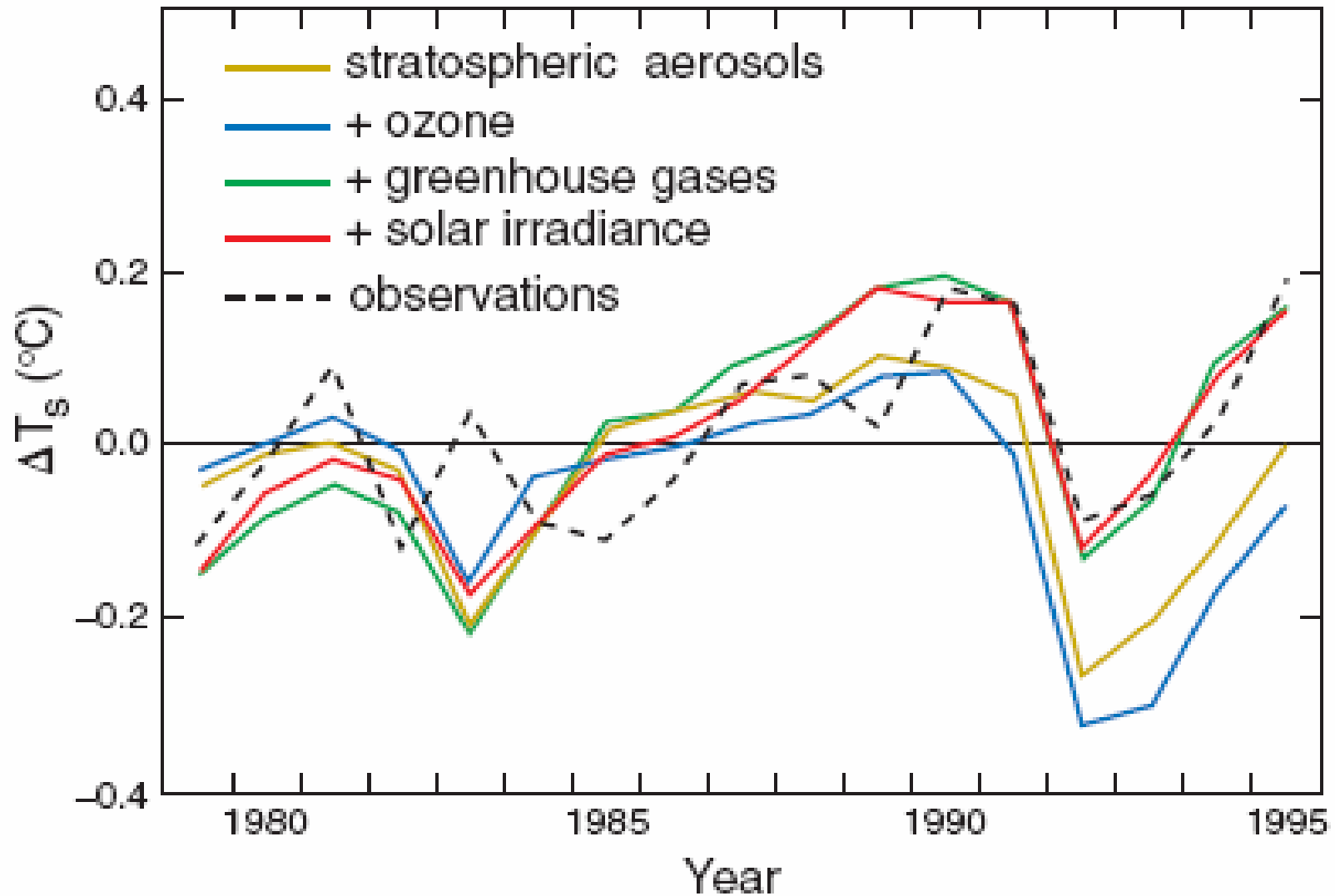
Another test: Do coupled models capture the atmospheric temperature changes after major volcanic eruptions?



GISS GCM (Ch8 IPCC AR4)

(b)

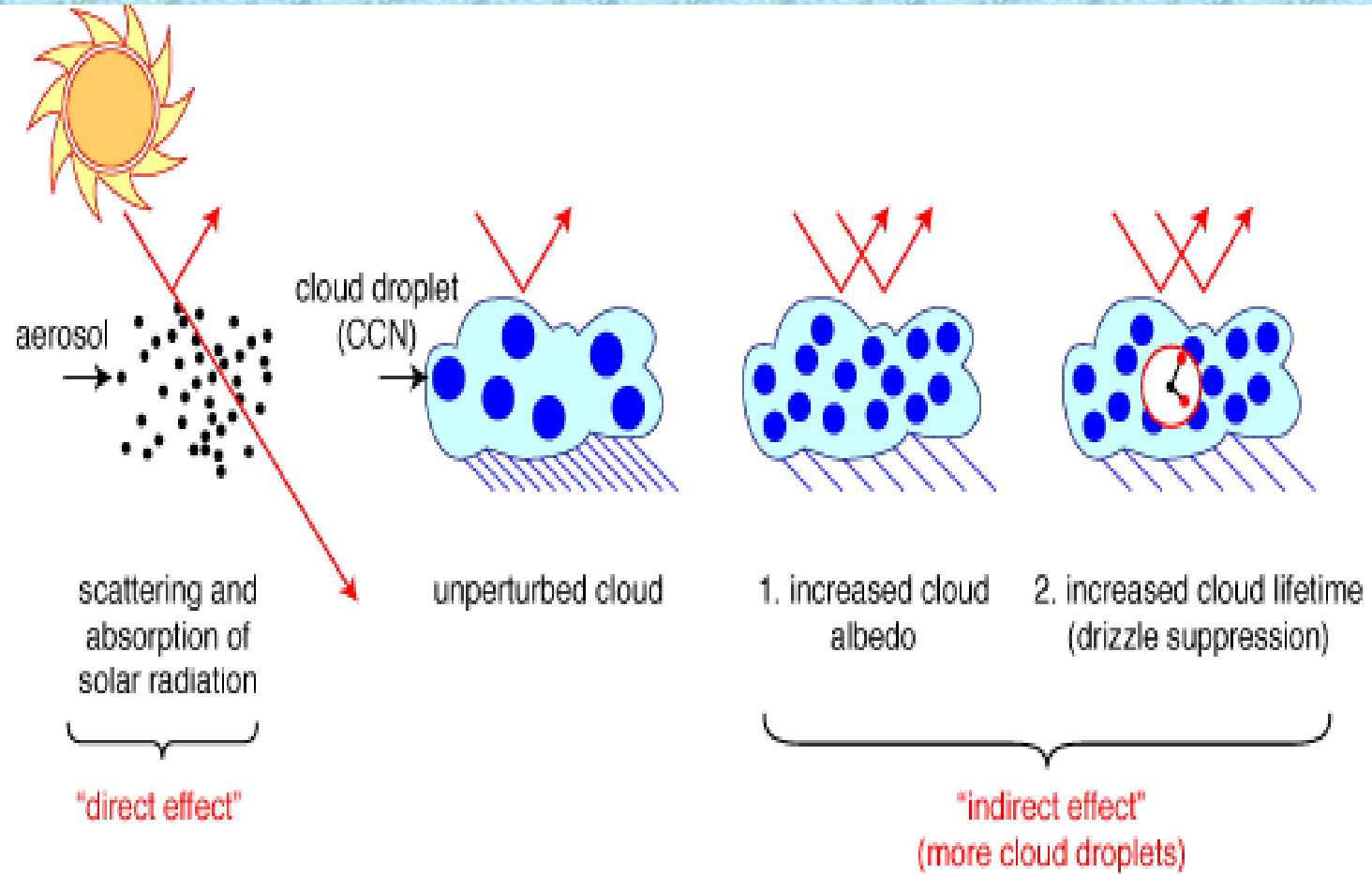
Surface temperature



Aerosols and Climate

- Impact of aerosols on climate is complex
- Most aerosols cool the earth (sulphate)
- Some aerosols heat the atmosphere but cool the surface (soot)
- In contrast to CO_2 , aerosols are not uniformly mixed in the atmosphere
- Life time of aerosols is around one week while that CO_2 is of the order of 100 years

J.Kirkby, Surveys in Geophysics 28, 333–375,2007





INDOEX

INDIAN OCEAN EXPERIMENT

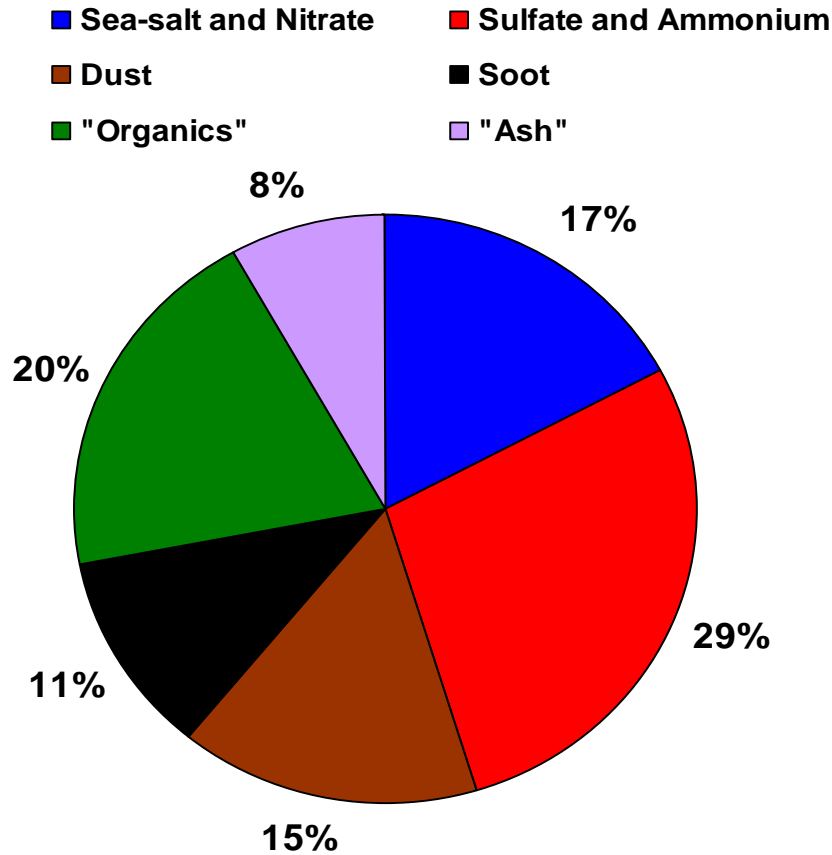
INDIAN OCEAN EXPERIMENT

An International Field Experiment in the Indian Ocean



Feb-Mar, 1998
Jan-Mar, 1999

Aerosol Optical Depth (500 nm)



“Kyoto also failed to address two major pollutants that have an impact on warming, black soot and tropospheric ozone...”

--President George W. Bush, June 11, 2001

Ramanathan, et al., Indian Ocean Experiment:
An integrated analysis of the climate forcing
and effects of the great Indo-Asian haze,
J. Geophys. Res., 106(D22), 2001.

“Climate Effects of Black Carbon Aerosols in
China and India”
Menon et al *Science*, 297, 2002

Atmospheric brown clouds: Impacts on South
Asian climate
Ramanathan et al , *PNAS*, April 2005

Reducing Black Carbon May Be the **Fastest Strategy** for Slowing Climate Change

IGSD/INECE Climate Briefing Note June 2009

A drastic reduction of black-carbon emissions could provide **near-immediate relief**

Grieshop et al., Nature Geoscience, August 2009

Climate trade-off between **black carbon** and **carbon dioxide** emissions by Boucher & Reddy, Energy Policy, 36. 2008



WILL K. STEYER
CORRECTIONAL SERVICES

Petition to the World Heritage Committee:

January 29, 2009

by

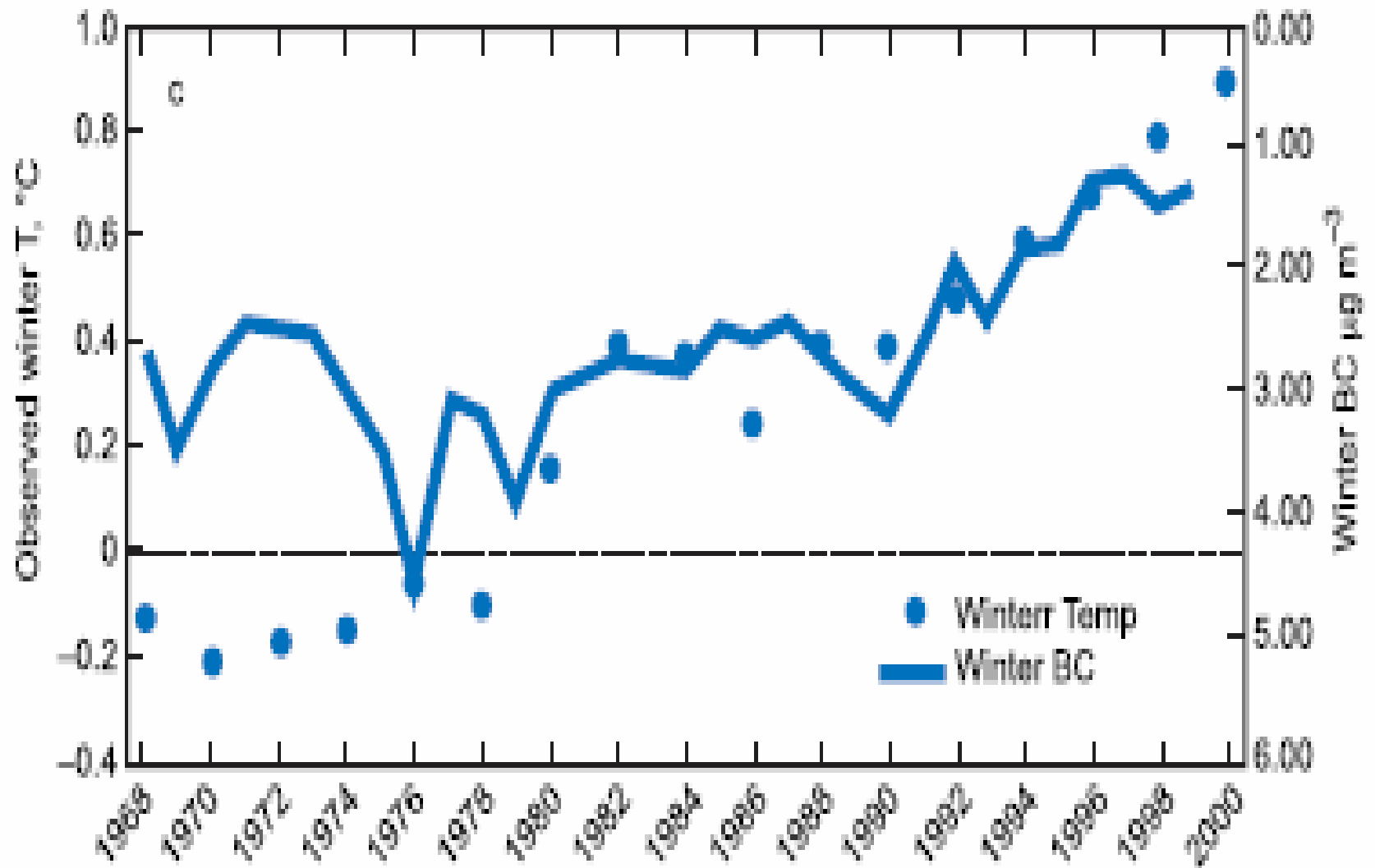
**Earthjustice, USA & Australian Climate
Justice Program**

**The Role of Black Carbon in
Endangering **World Heritage
Sites** Threatened by Glacial
Melt and Sea Level Rise**



Over the last **25** years, **Gangotri** glacier has retreated more than **850** meters





Clean the Air, Heat the Planet?

Arneth et al., **SCIENCE**, 30 October 2009

Air pollution control could help to mitigate climate change, buying time until greenhouse gas reductions take effect,

The jury is out on whether air pollution control will accelerate or mitigate climate change

Studies available to date *mostly suggest that **air pollution control will accelerate** warming in the coming decades.*

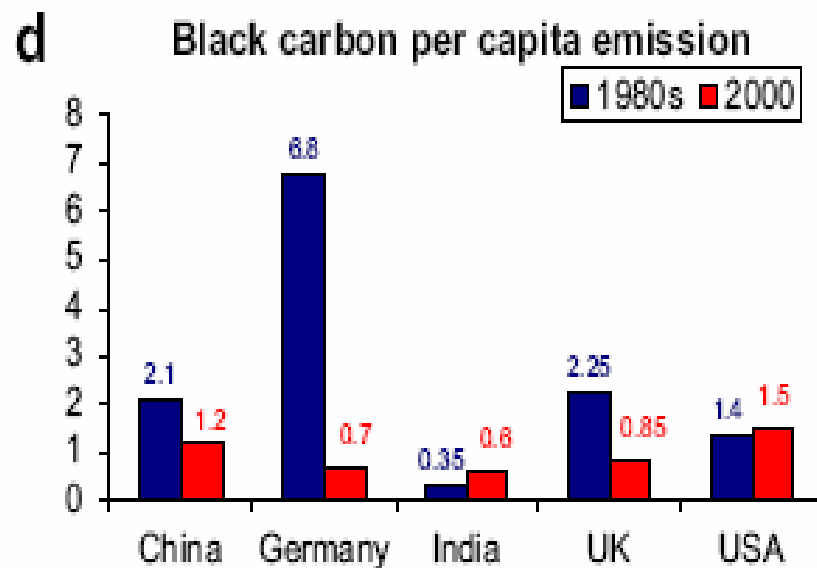
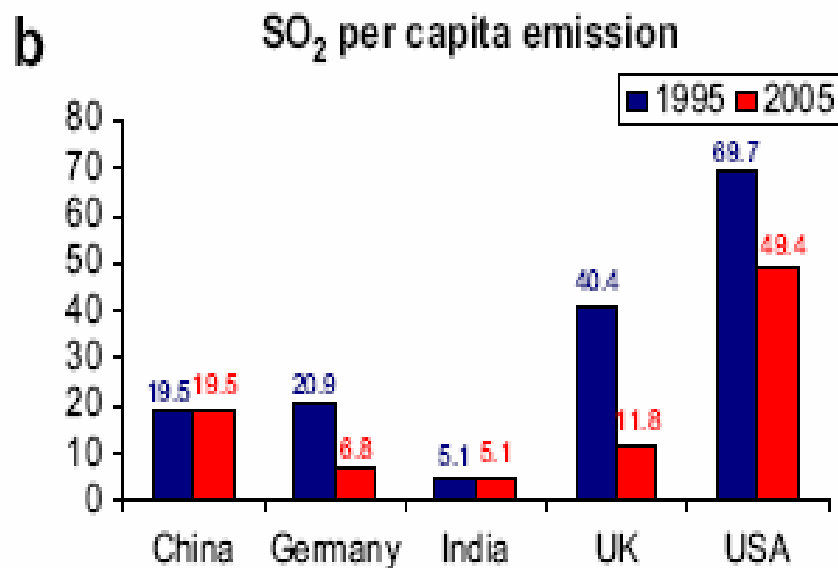
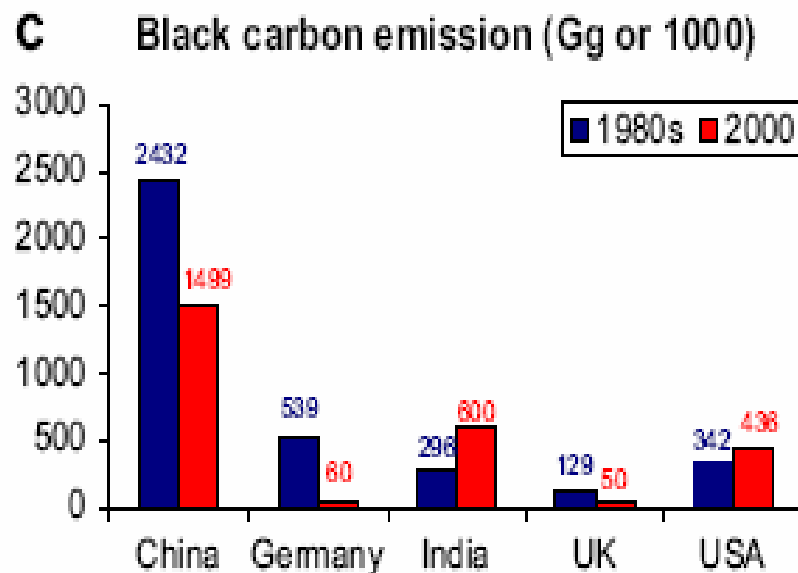
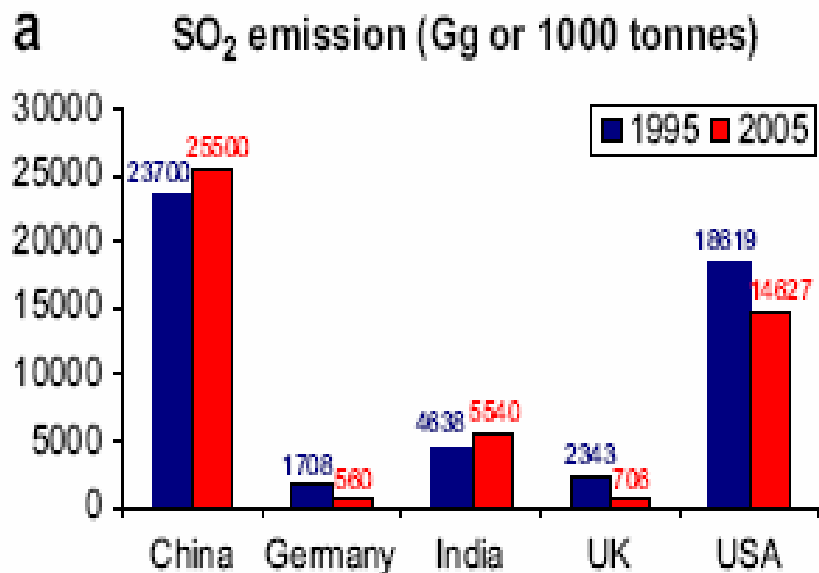
Conclusions

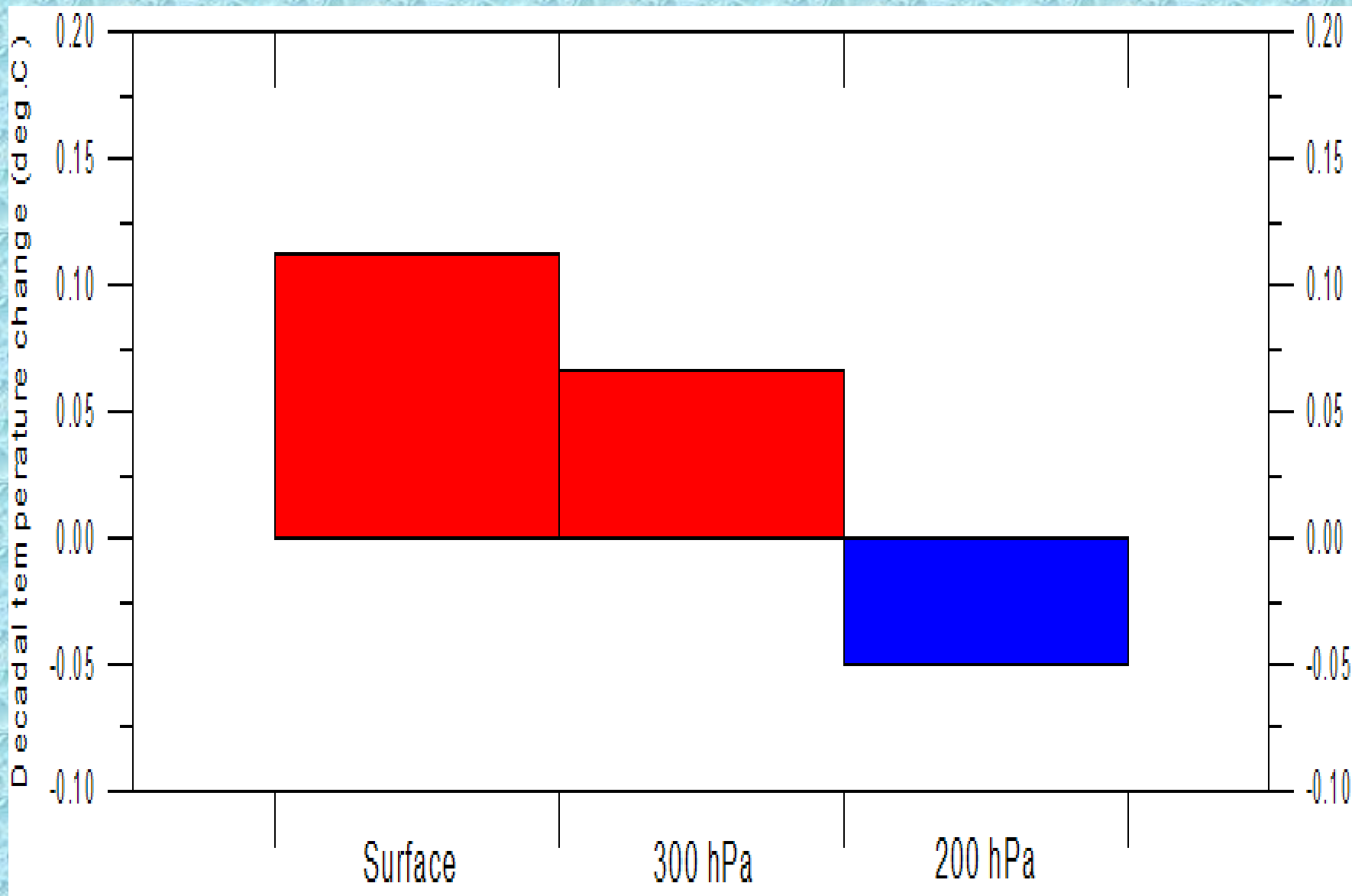
- The global warming in the 20th century was mainly account of increase in greenhouse gases
- The impact of variations in solar radiation and cosmic rays not clearly understood
- The impact of aerosols can cause cooling as well as heating
- **We need to act** although we do not have a **clinching evidence** about the **adverse impact** of global warming

Thank You

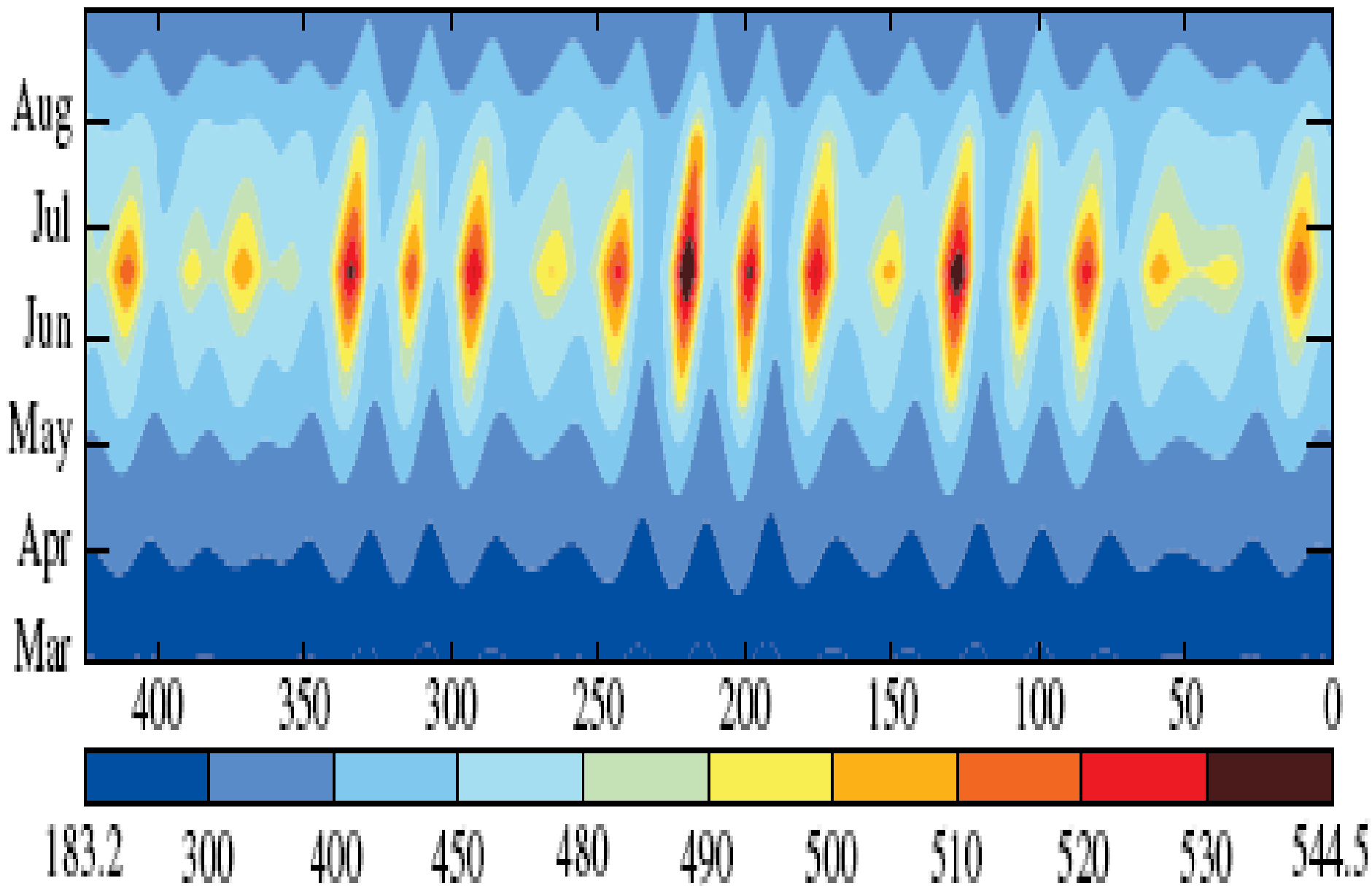
**I am ready for a barrage of
questions!**

V. Ramanathan, Y. Feng ,Atmospheric Environment 43 2009

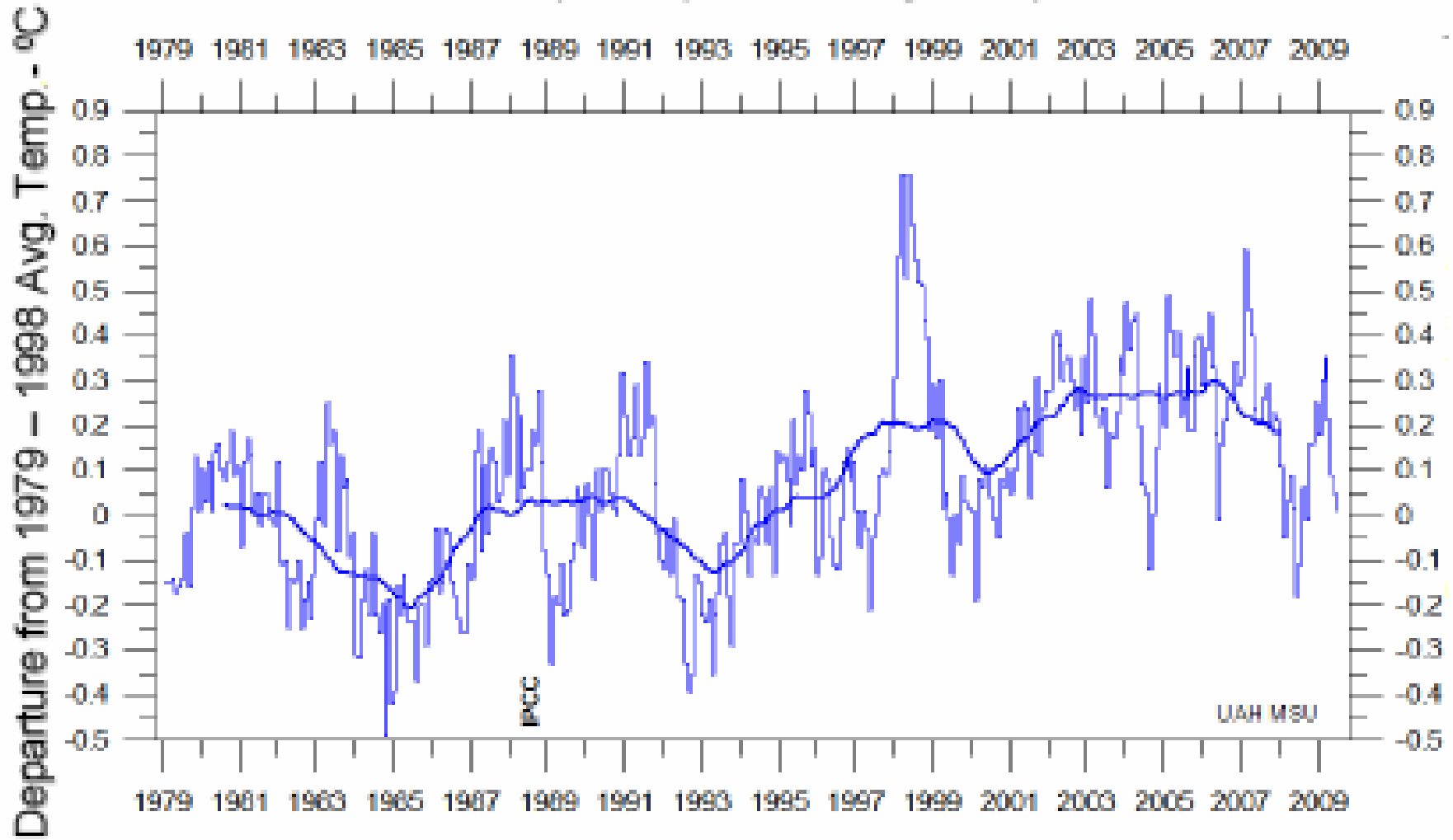




Solar Radiation (W/m^2) at $60^\circ N$ during the last 400,000 years



UAH Globally Averaged Satellite-based Temperature of the Lower Atmosphere (1979 – early 2009)



University of Alabama, Huntsville, (UAH)
Microwave Sounding Unit (MSU)

Climate Surprises ?

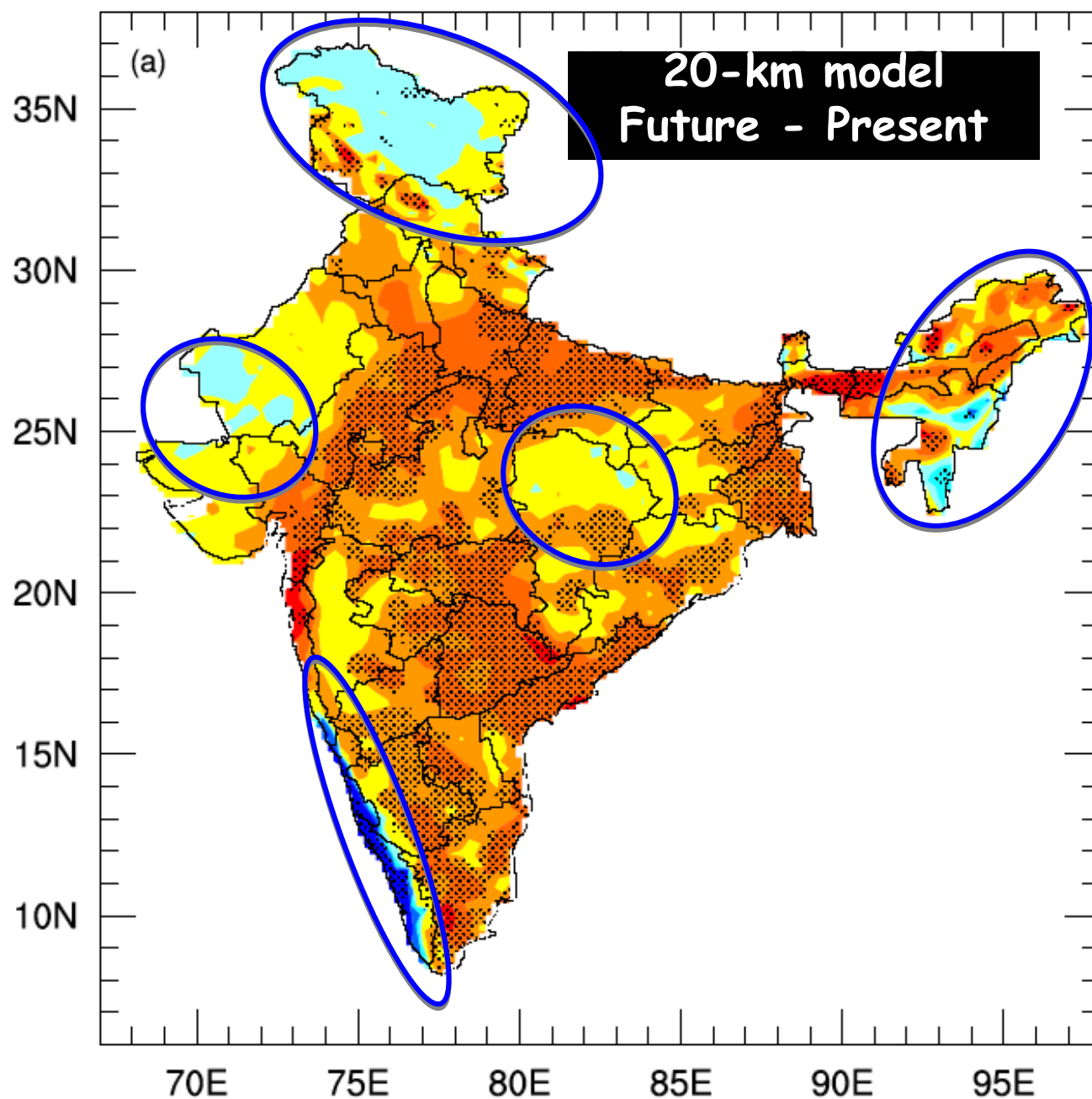
- Rapid melting of Greenland
- Break-off of the West Antarctic Ice Sheet

Climate is what
you **expect** but
weather is what
you **get**

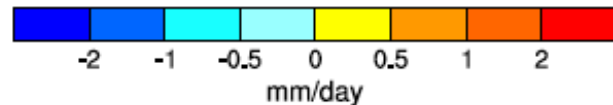
Mark Twain

The Himalayan Dilemma: Reconciling Development and Conservation by Ives and Messerli 1989

“The impacts of climate change are **superimposed** on a variety of other environmental and social stresses, many already recognized as **severe**”

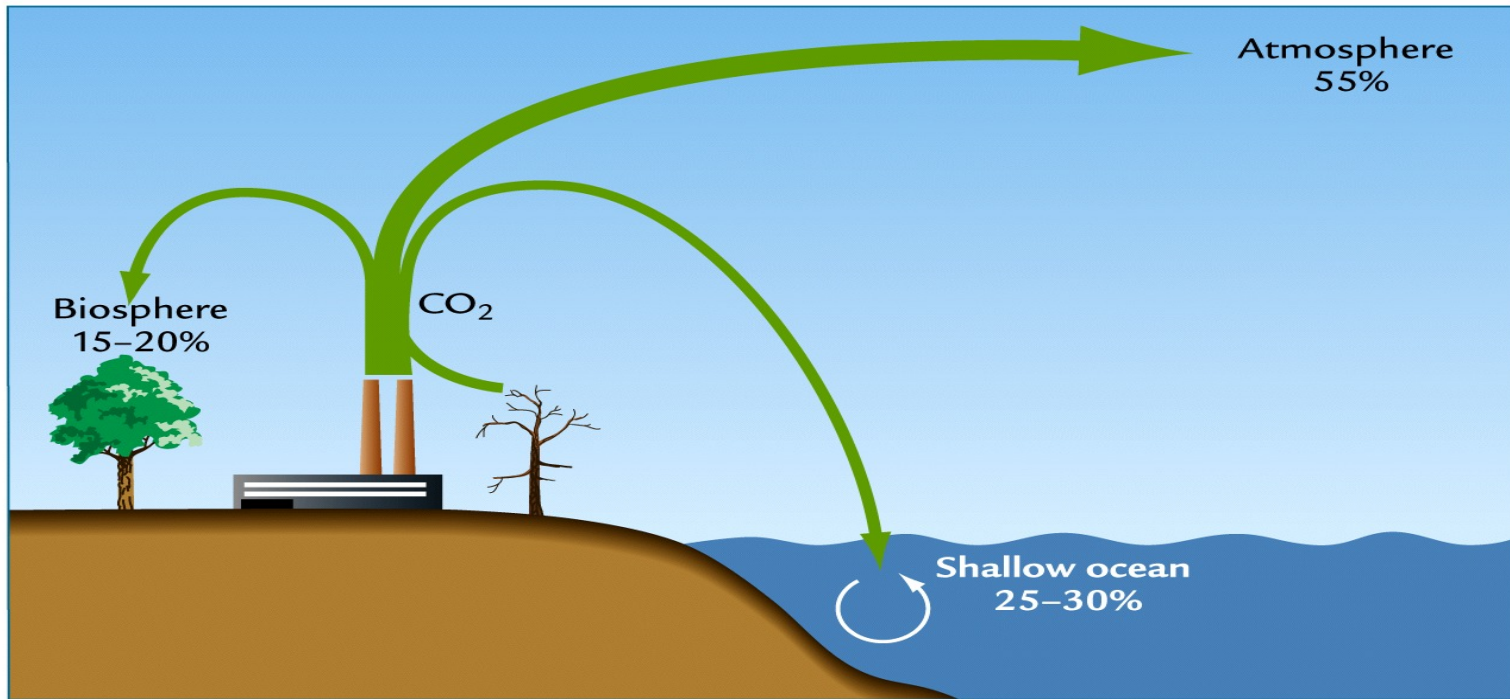


Note the change over
the southwestern coasts



Rajendran & Kitoh, 2005

Where does the anthropogenic CO_2 go?

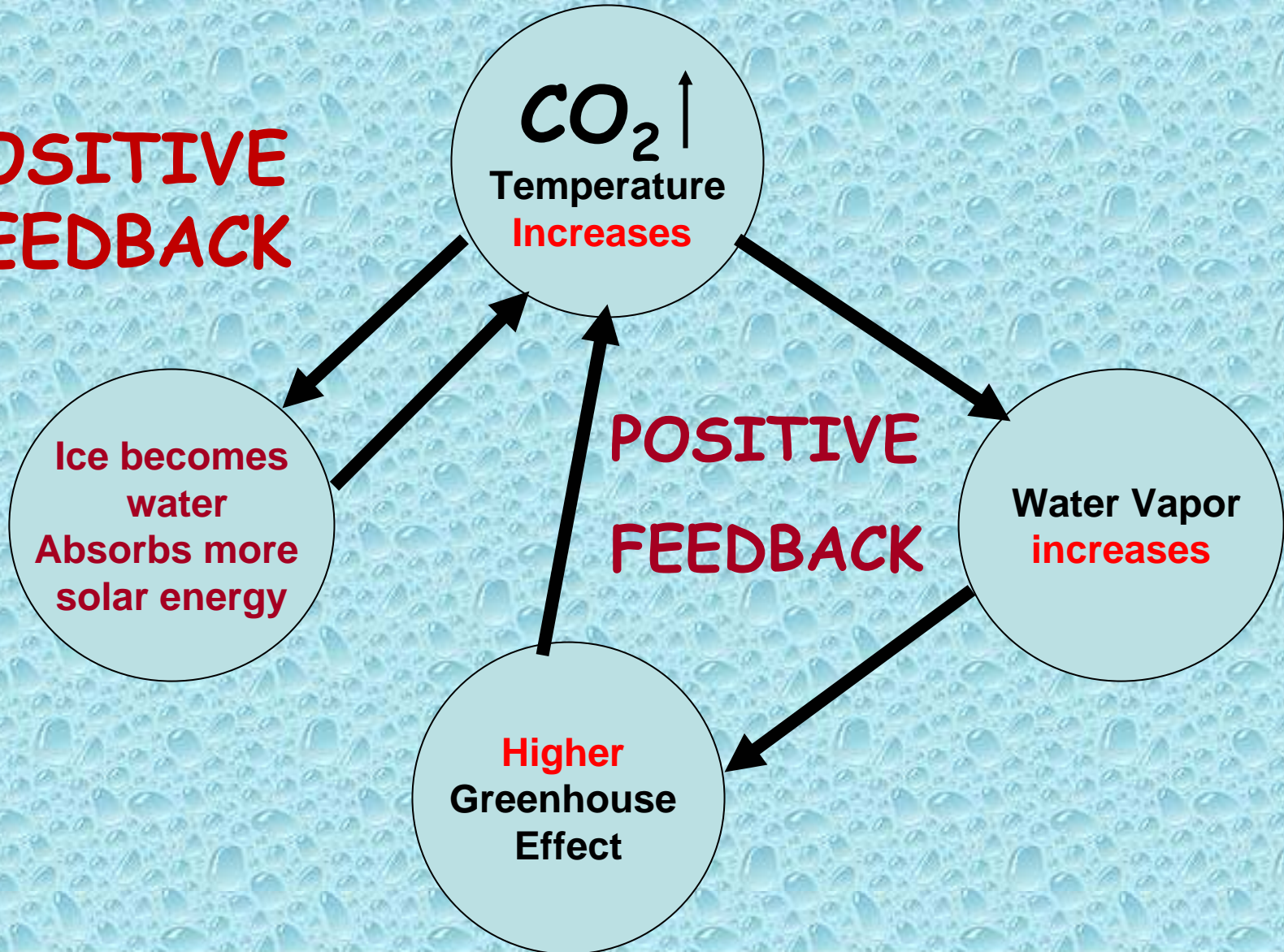


Ruddiman, 2001

- **Atmosphere - 55%**
- **Ocean - 25 % to 30%**
- **Biosphere - 15% to 20%**

The increase in CO_2 will amplified many times by positive feedbacks

**POSITIVE
FEEDBACK**



**POSITIVE
FEEDBACK**

**Ice becomes
water
Absorbs more
solar energy**

**Water Vapor
increases**

**Higher
Greenhouse
Effect**

Global Mean Reference Height Temperature (K)

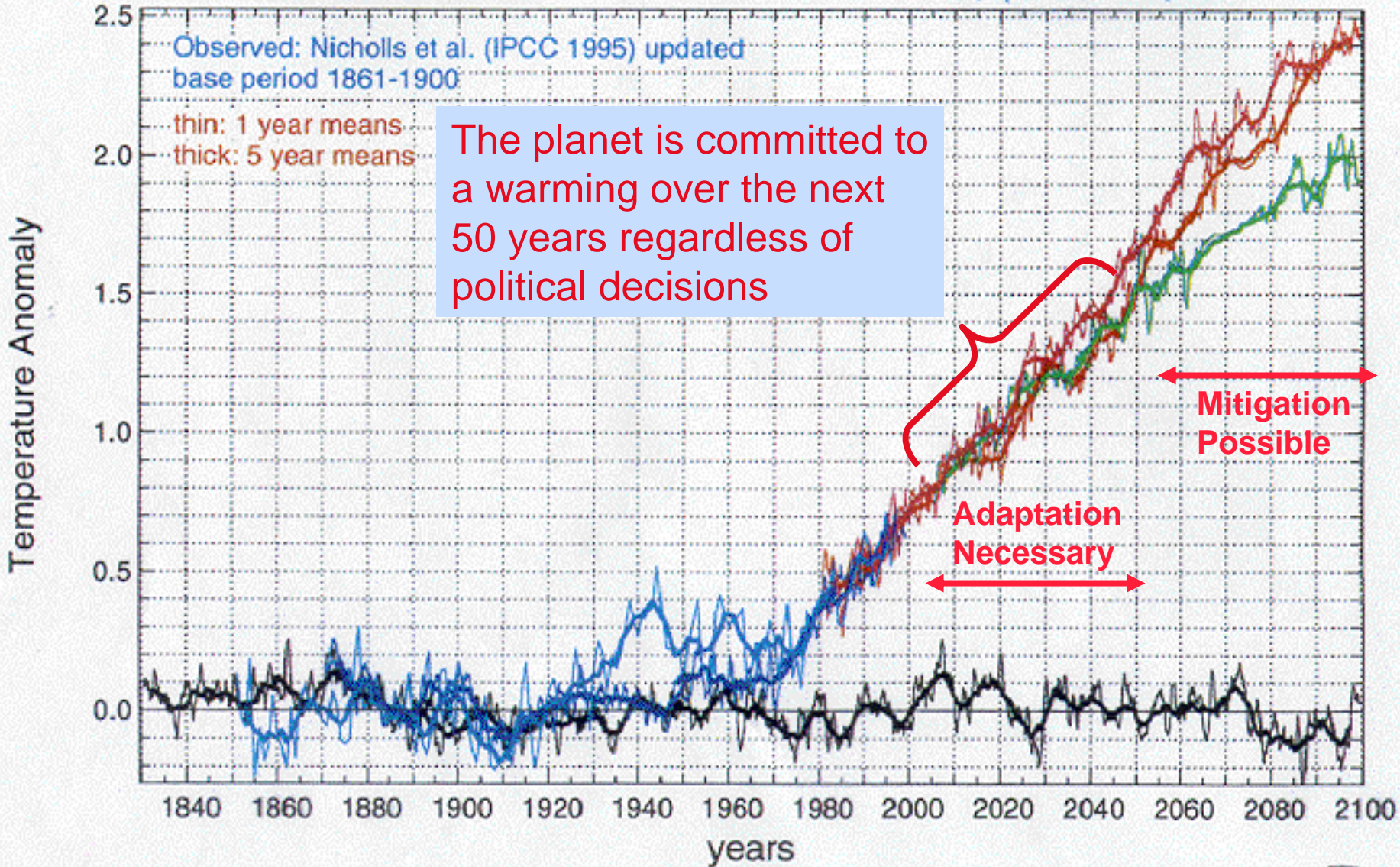
b030.04: IPCC SRES scenario A1

s020.02: BAU scenario, interactive SO4

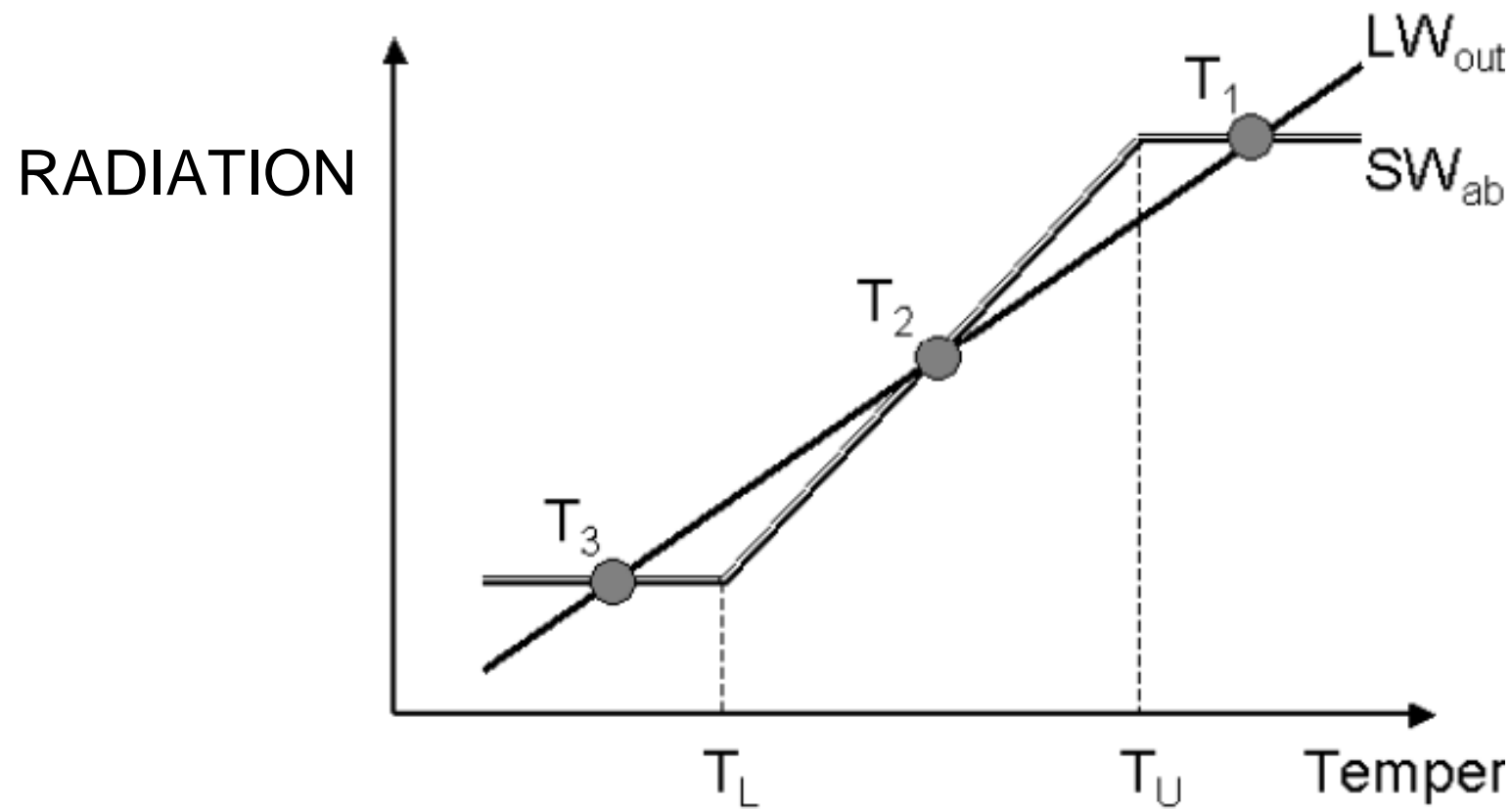
b018.16l: Control: constant 1870

s020.04: 550 ppmv scenario, interactive SO4

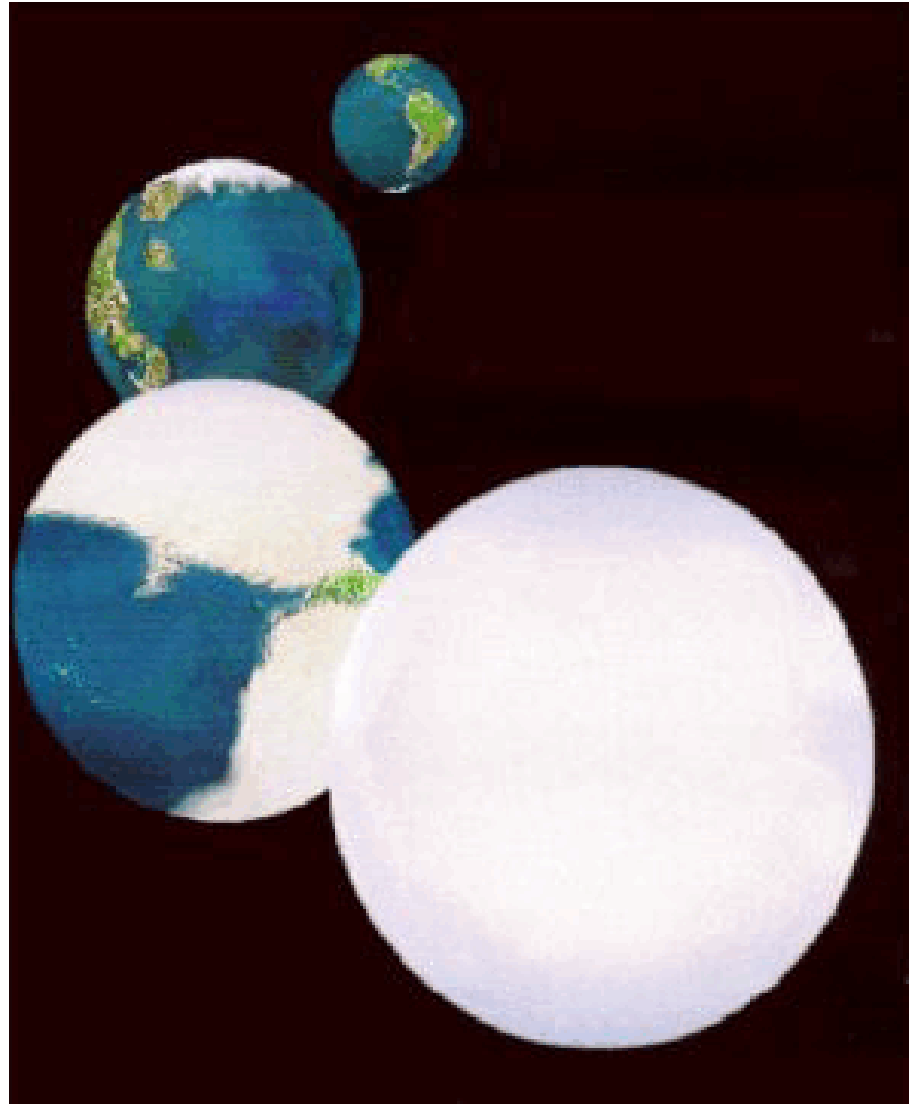
b018.15: 20th cen, specified SO4, GHG



MULTIPLE EQUILIBIRUM

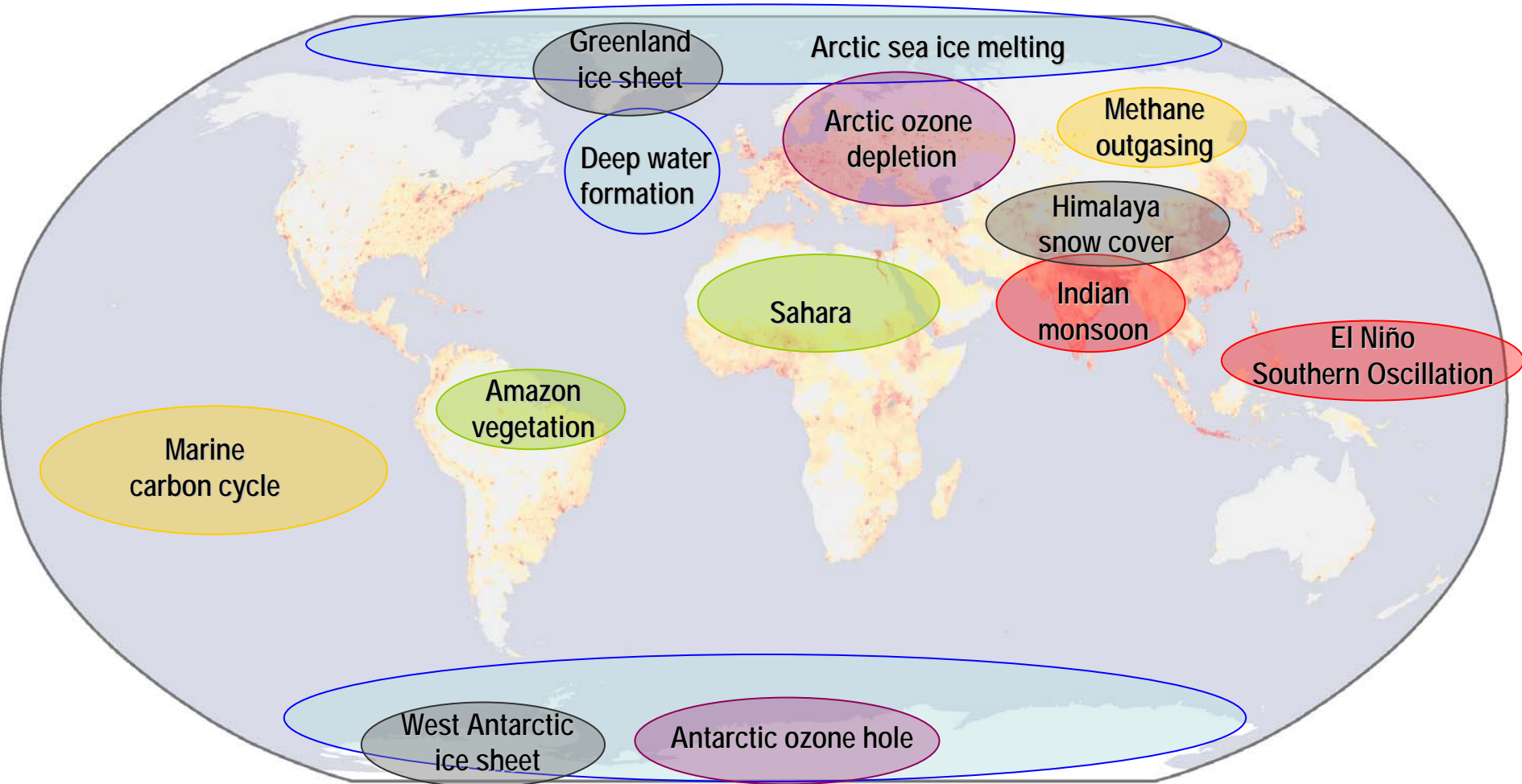


Oscillation between ice-free and ice-covered earth

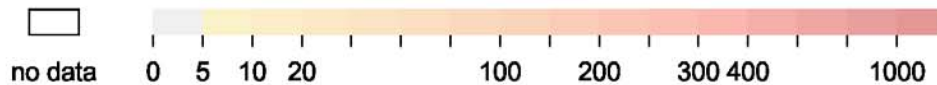


Tipping elements

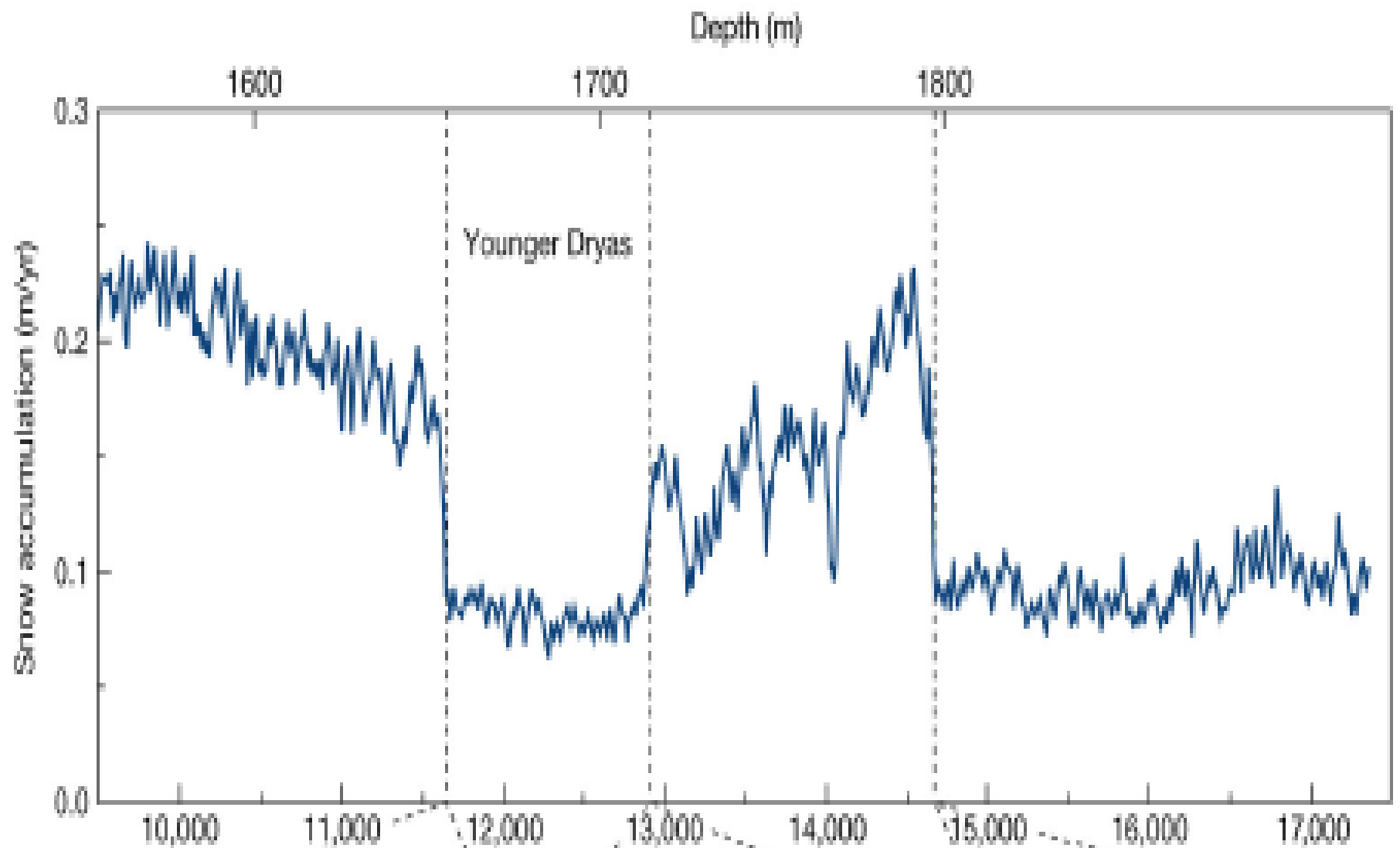
Processes, particularly sensitive to climate change

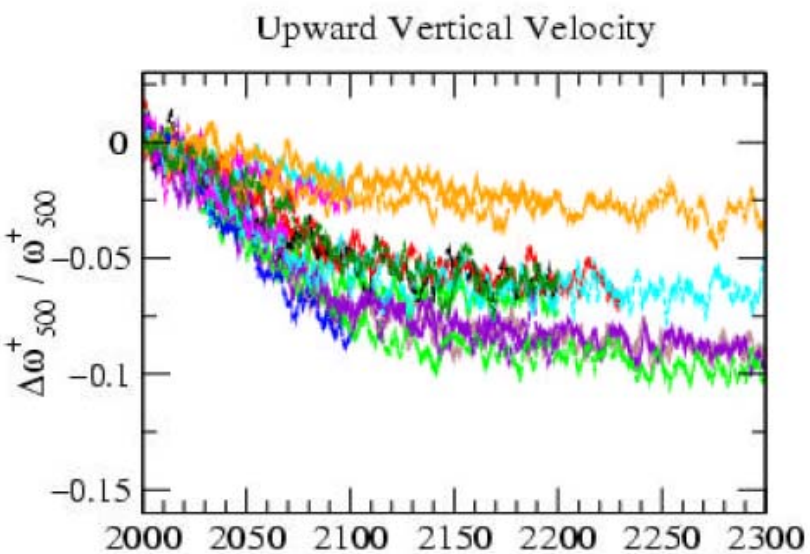
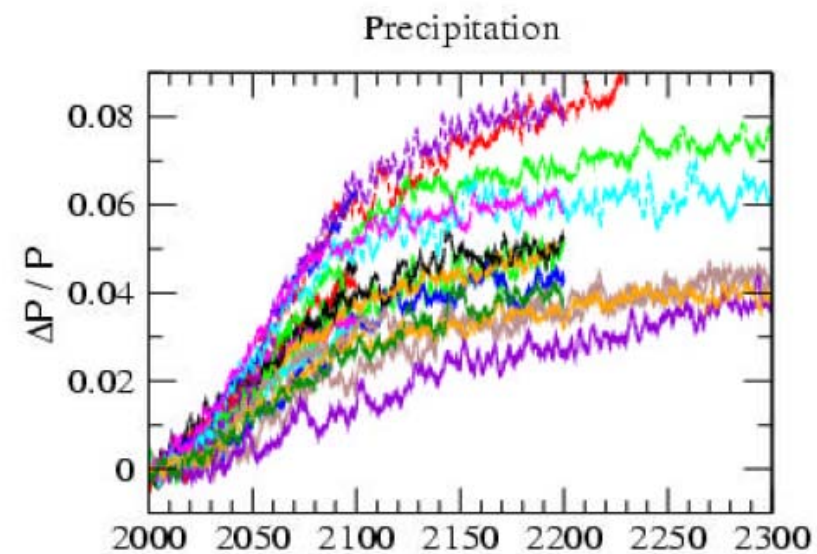
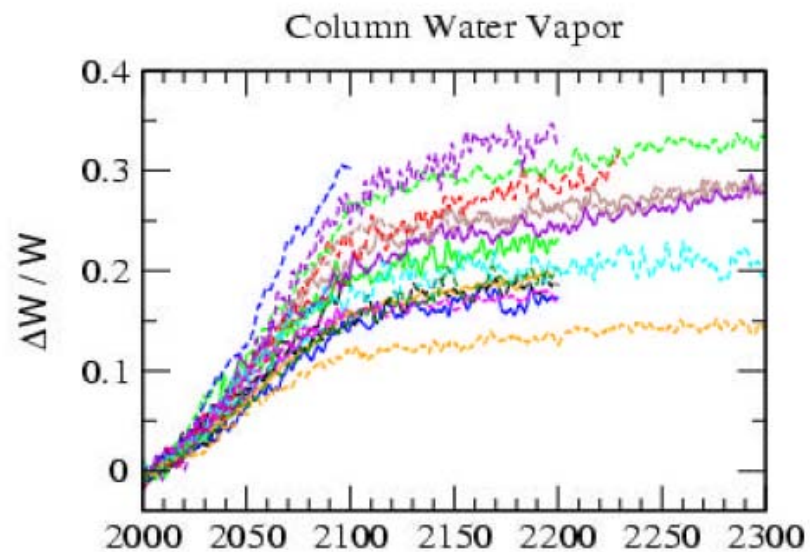
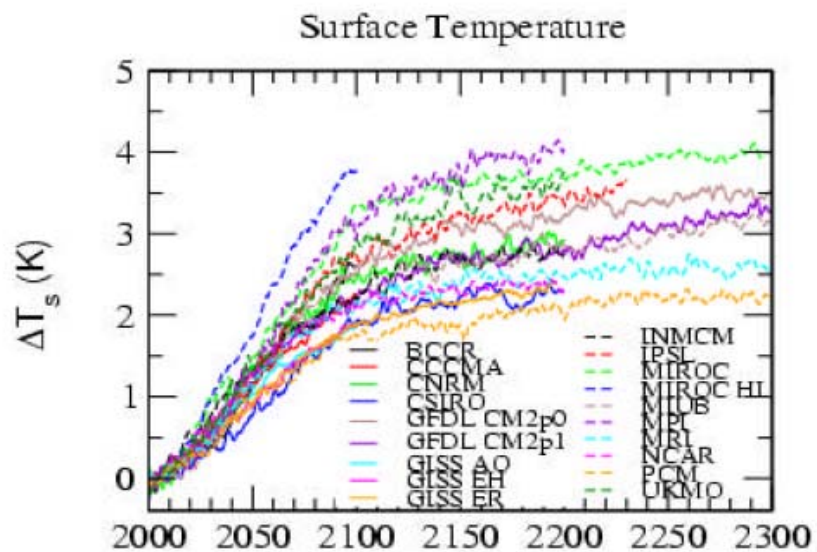


population density [persons per km²]

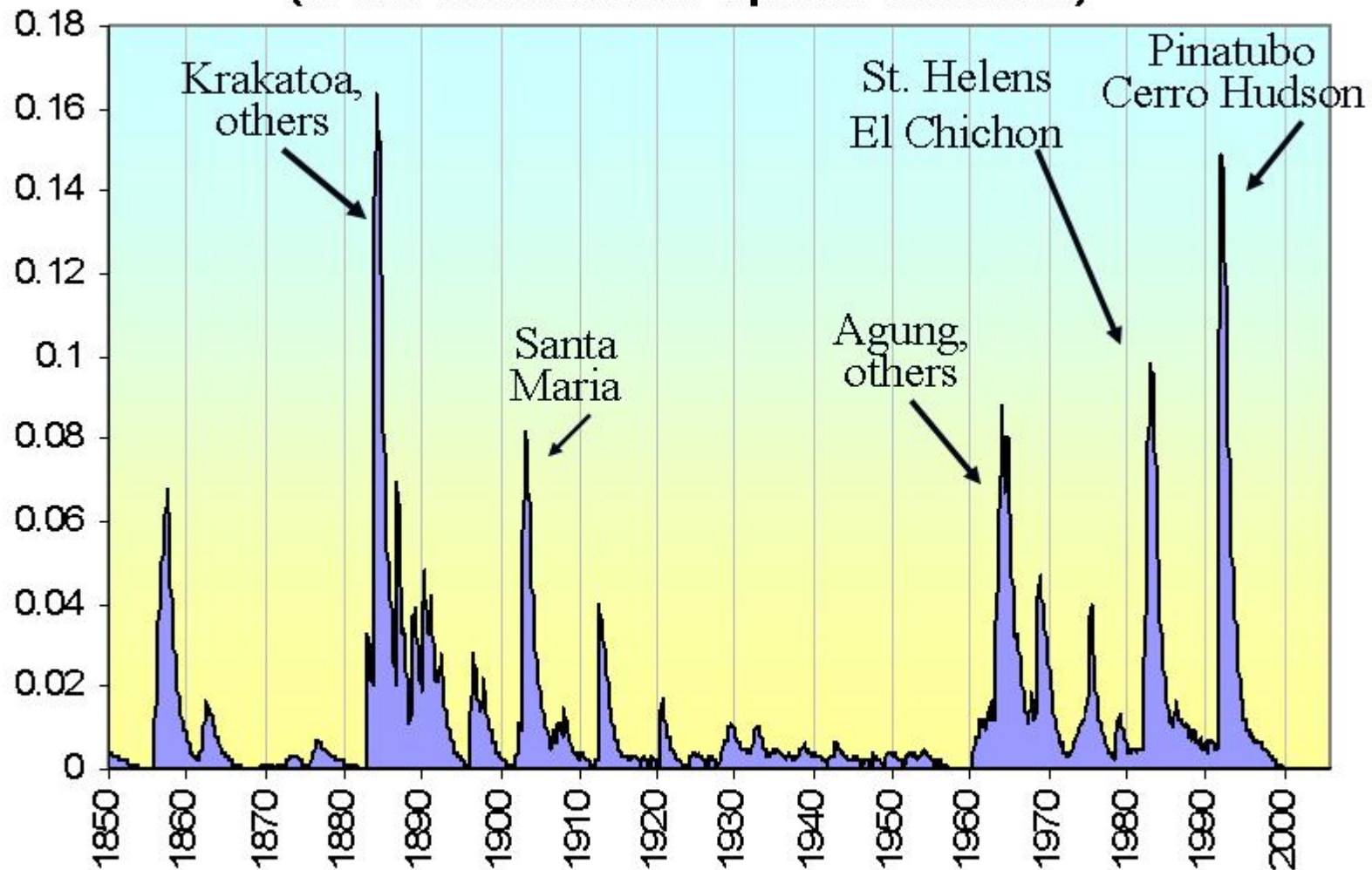


Abrupt Climate Change



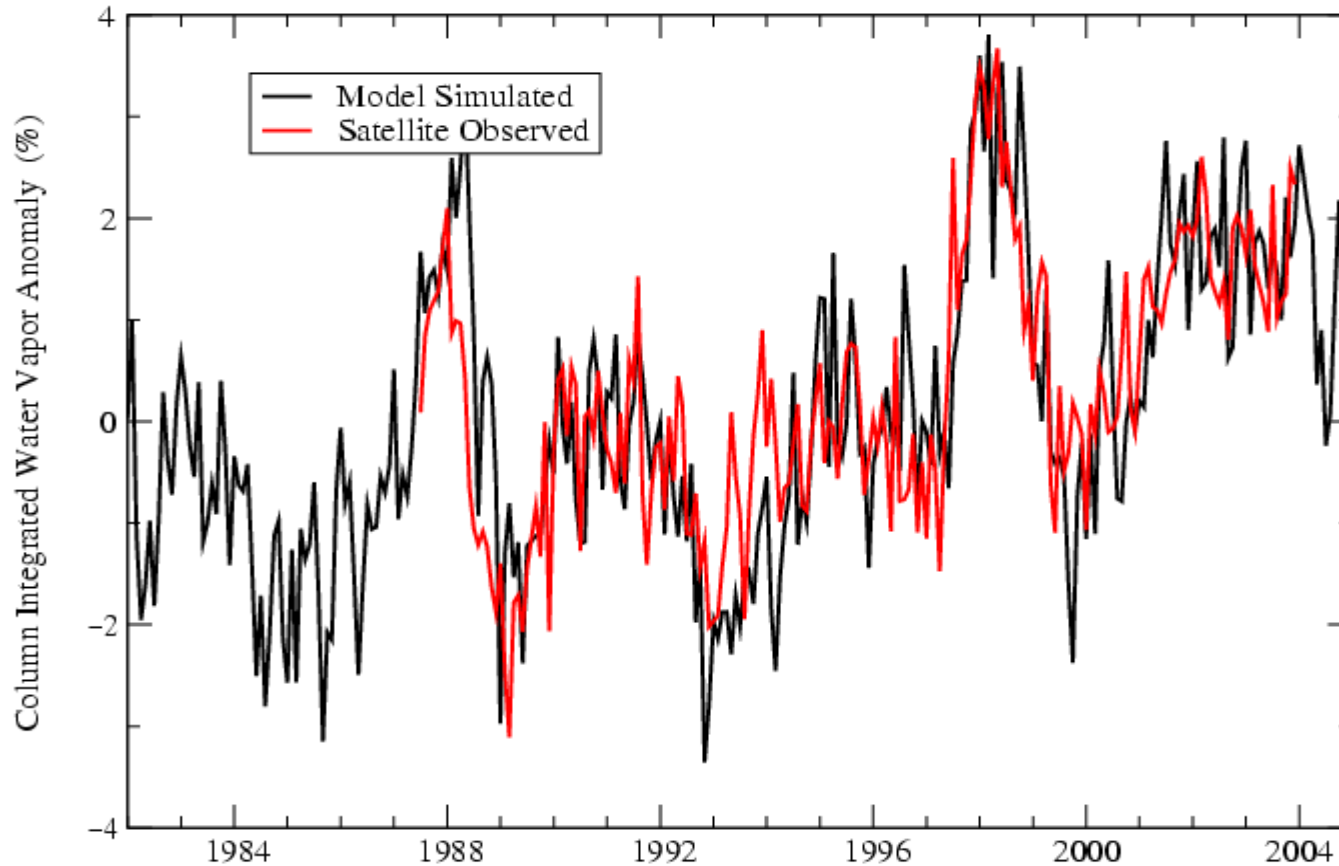


Stratospheric Volcanic Aerosol (NASS GISS Aerosol Optical Thickness)



Volcanic aerosols in the high atmosphere block solar radiation and increase cloud cover leading to widespread cooling, especially significant in summer

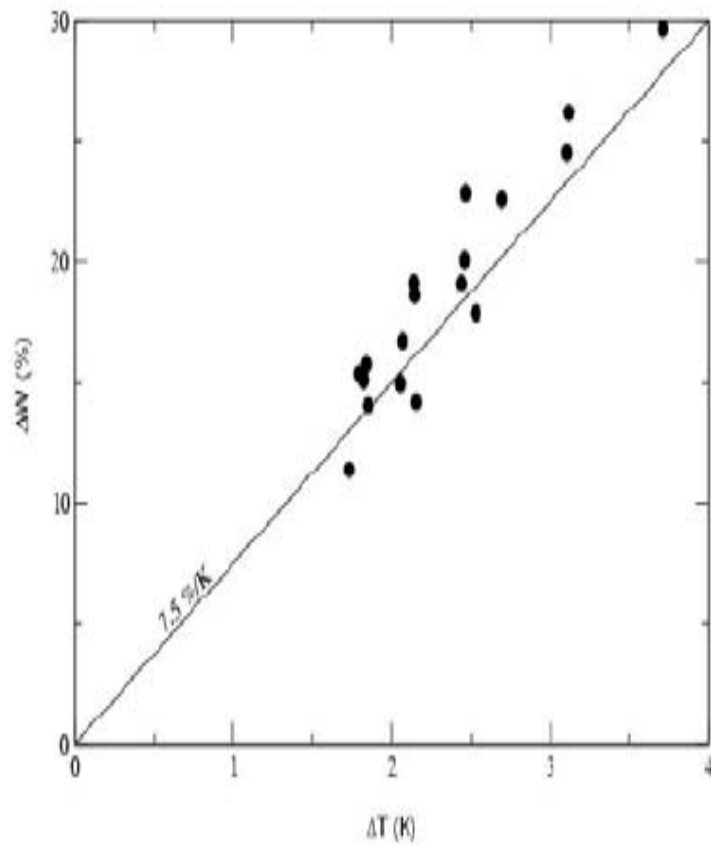
Total Column Water Vapor Anomalies (1987-2004)



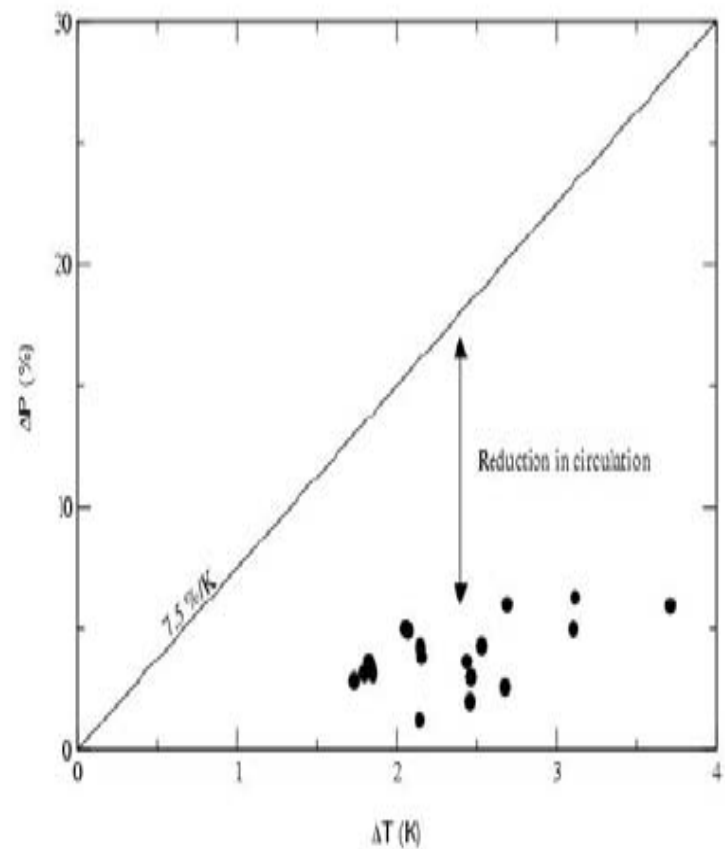
We have high confidence in the model projections of increased water vapor.

Vecchi and Soden, Journal of Climate, 2007

(a) Water vapor vs. Temperature



(b) Precipitation vs. Temperature



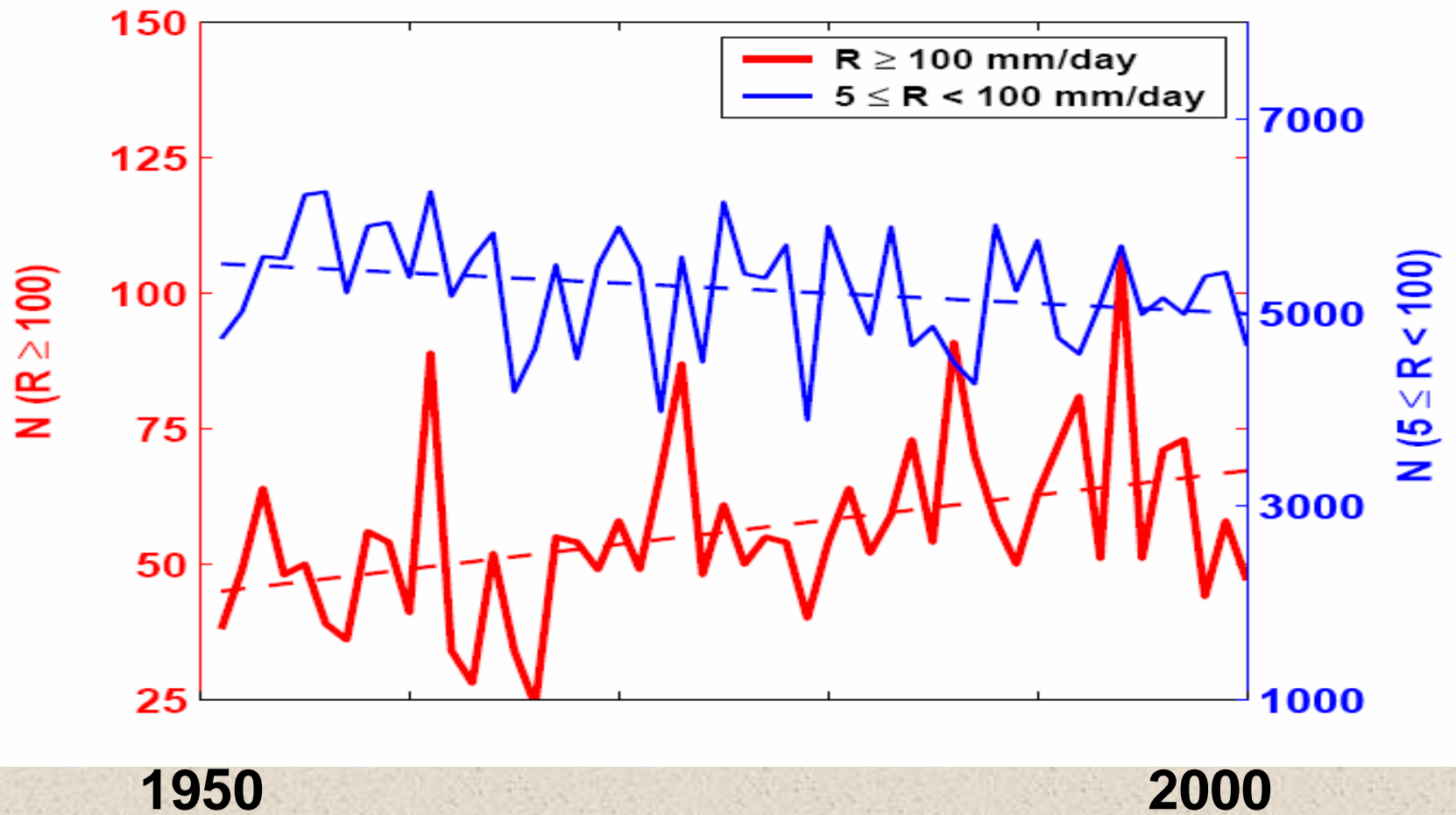
IPCC-1990 “The **unequivocal detection** of the enhanced greenhouse effect from observations is **not likely for a decade or more.**”

IPCC1995 “The **balance of evidence** suggests a discernible human influence on global climate.”

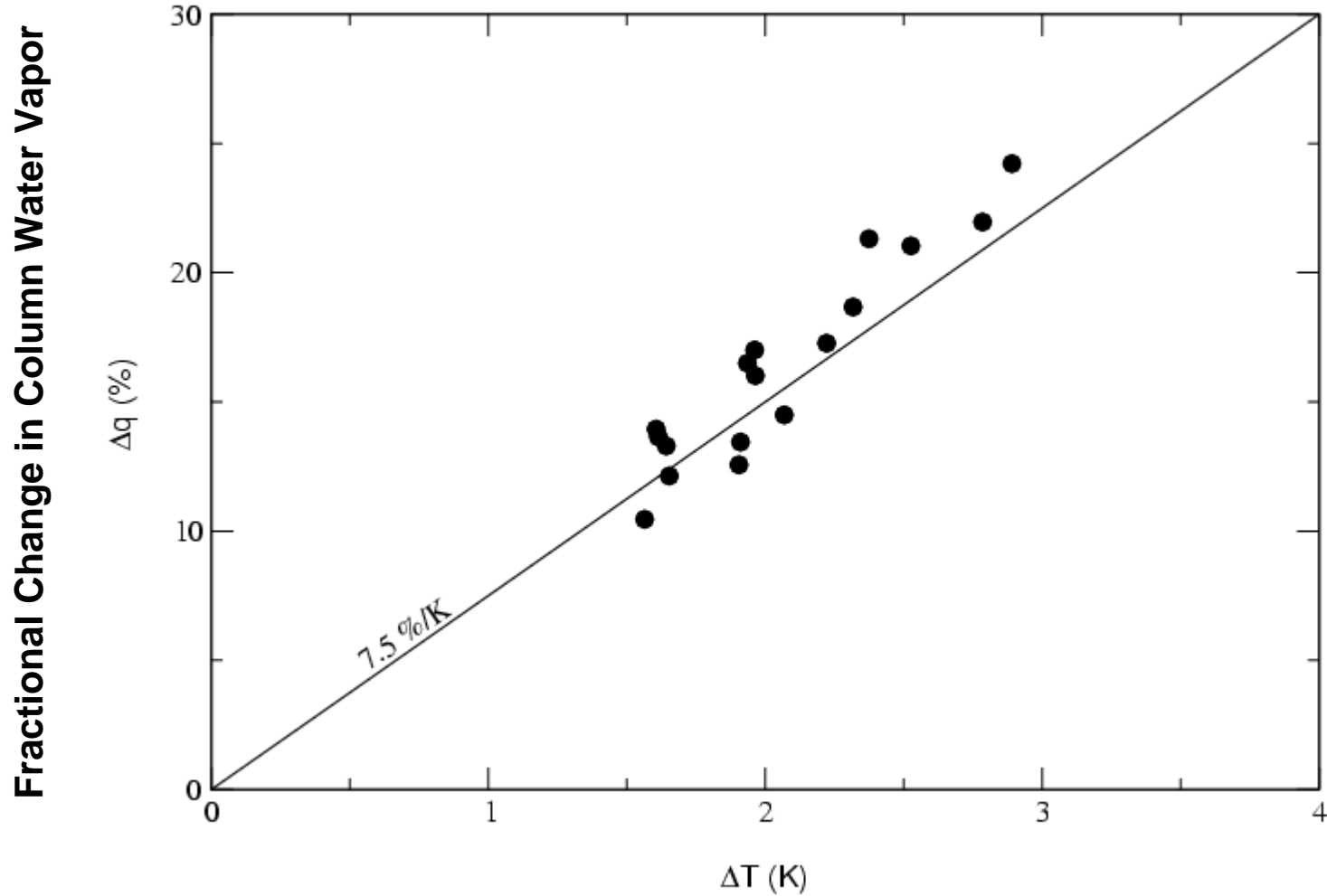
IPCC 2000 “Most of the observed warming over the last 50 years is **likely** to have been due to the increase in greenhouse gas concentrations.”

IPCC 2007 “Most of the observed increase in global temperatures since the mid-20th century is **very likely** due to the observed increase in anthropogenic greenhouse gas concentrations.”

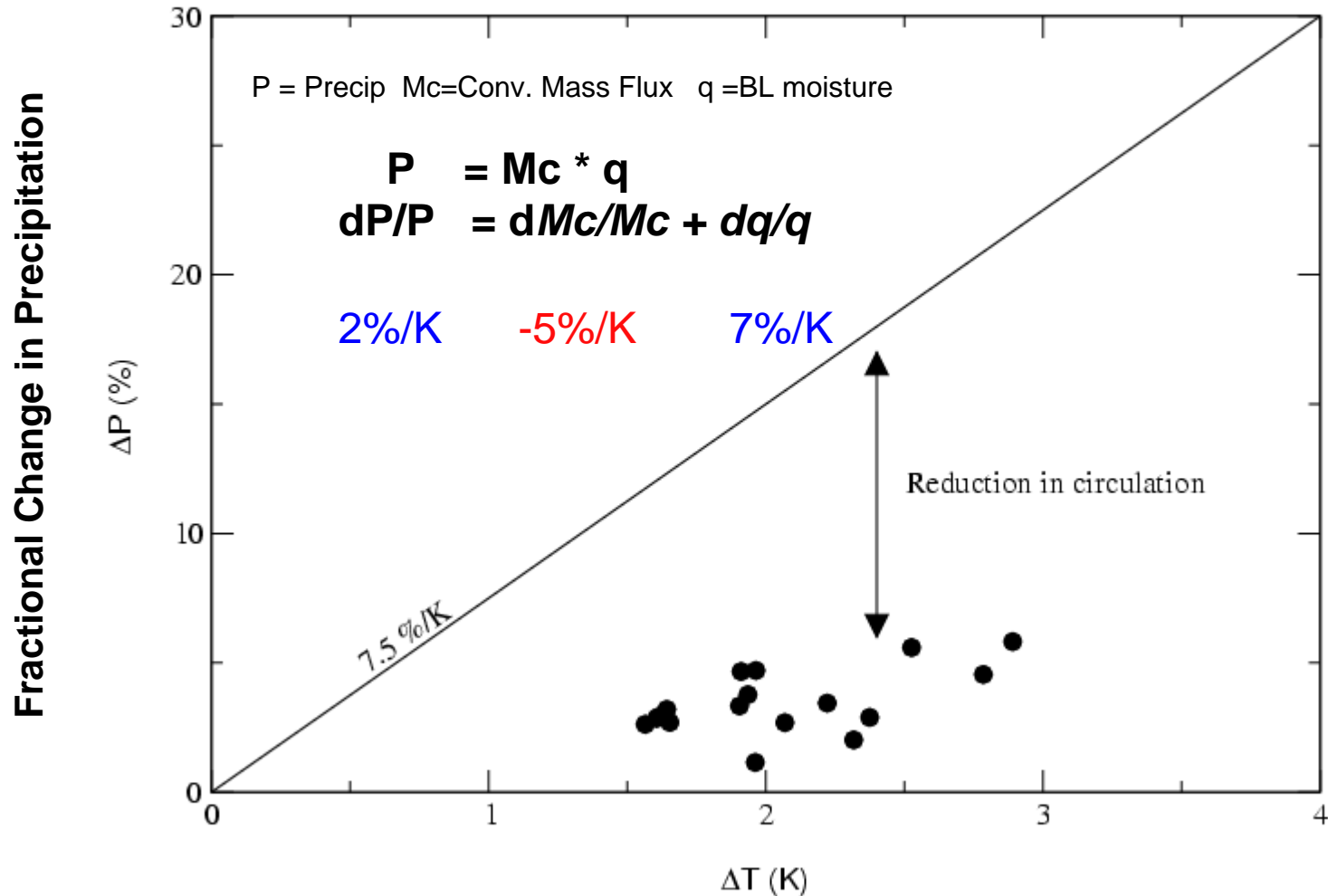
Trends in “Extreme” and “Moderate” Events



Change in Global Water Vapor at 2100

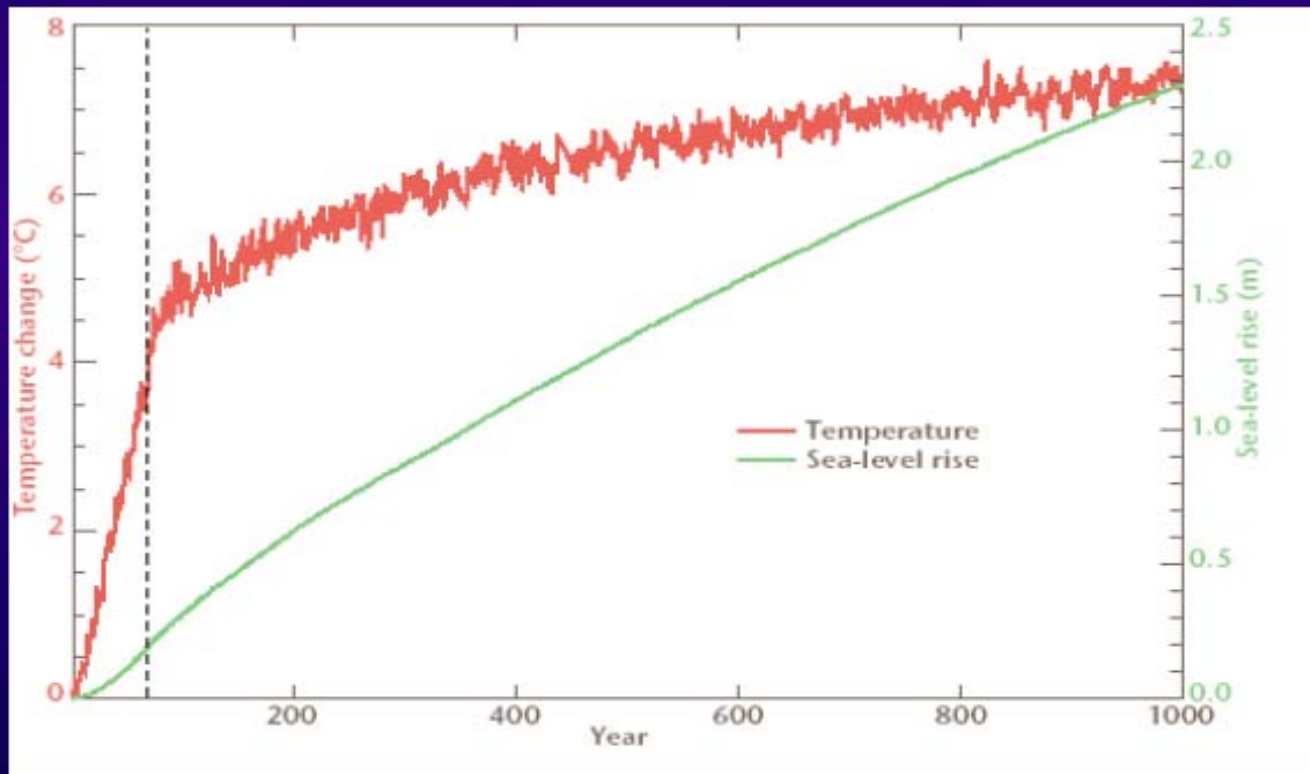


Change in Global Precipitation at 2100



The heart of the Kyoto and post-Kyoto discussion:

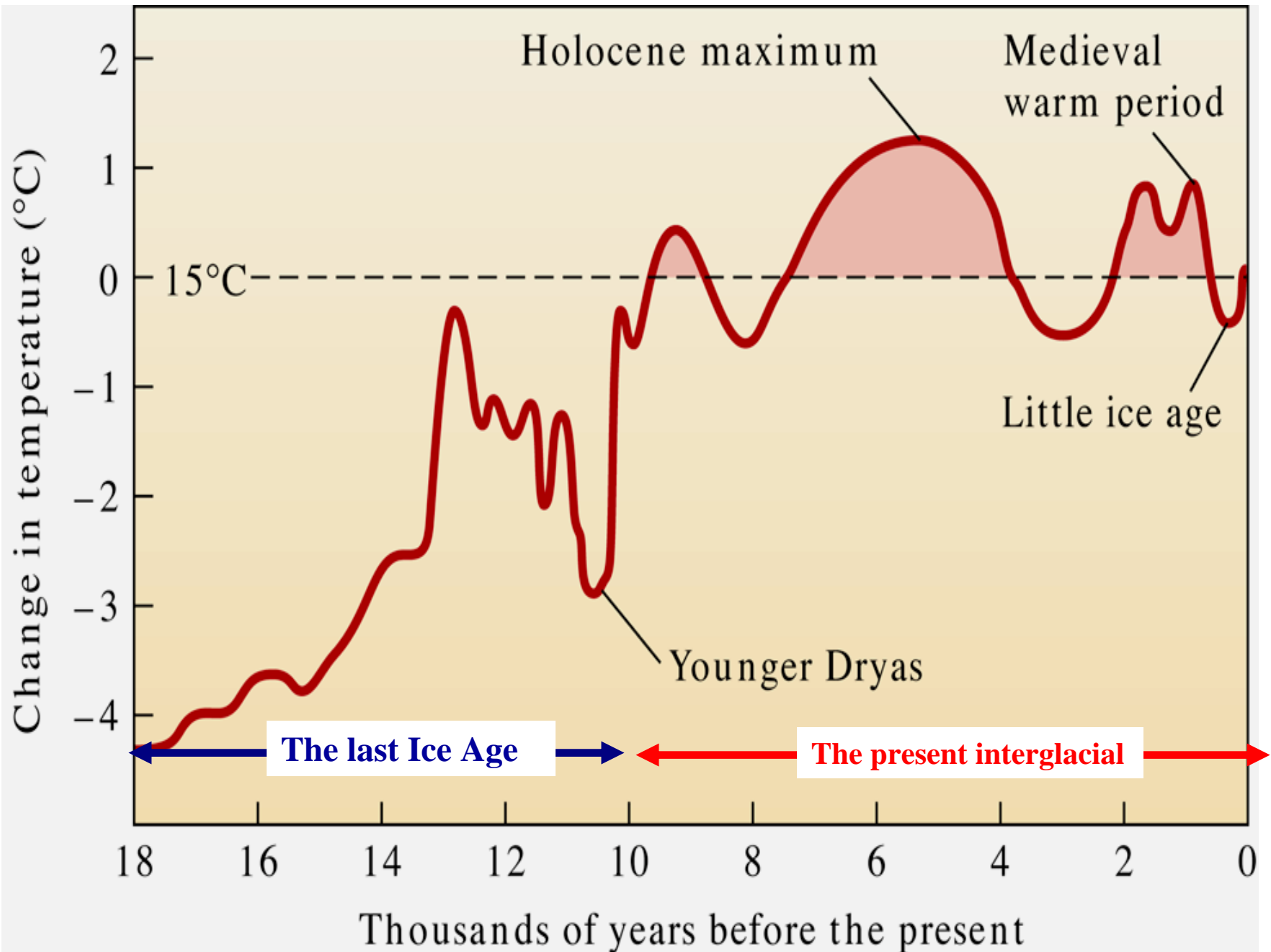
Achieve CO₂ stabilization at levels that do not pose serious threats to the earth's climate



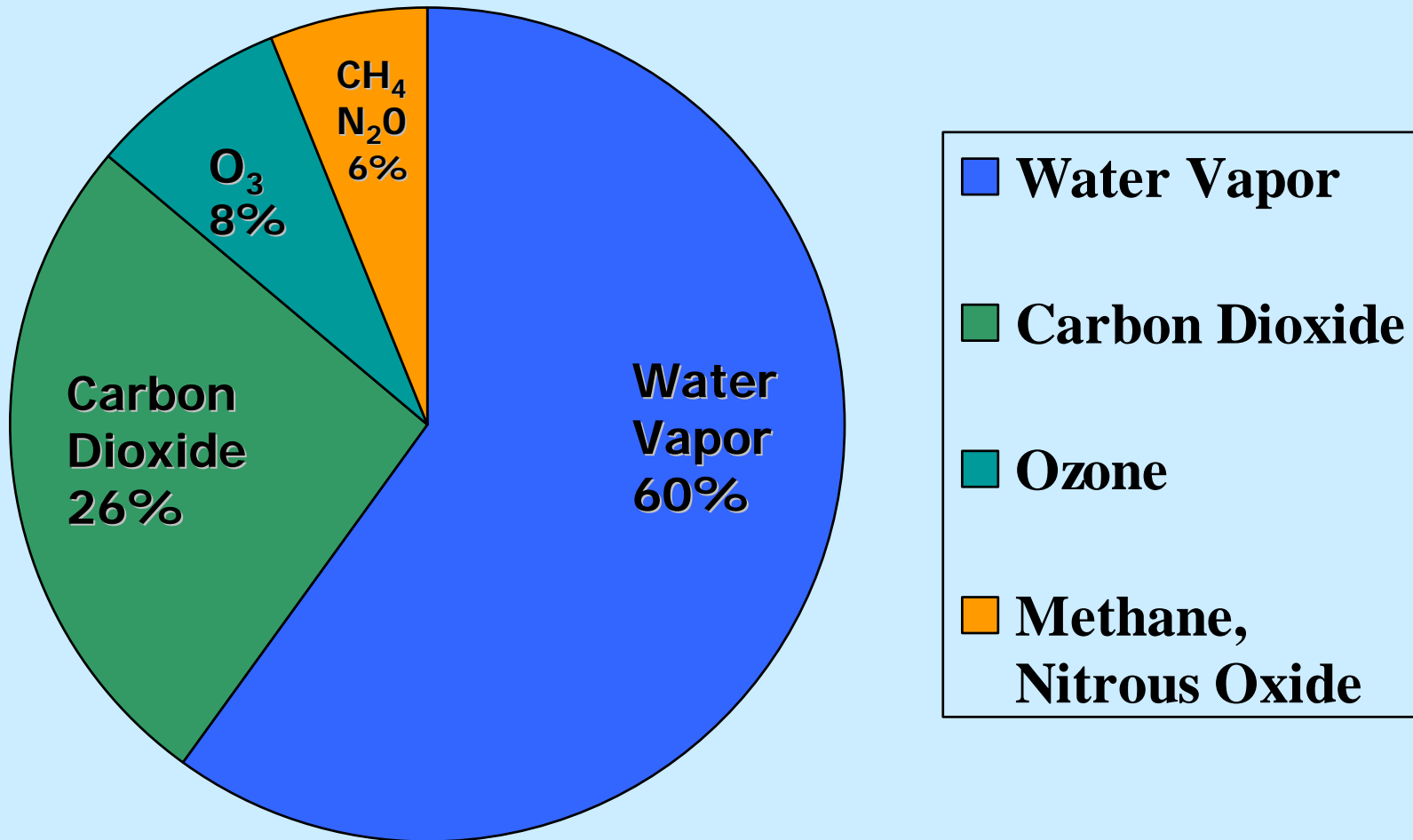
From Giorgi , ICTP, Trieste



Natural climate change over the last 18,000 yrs



The Natural Greenhouse Effect: clear sky



Clouds also have a greenhouse effect

Kiehl and Trenberth 1997