Overview of Global Dimming and Brightening – observations, causes, consequences, and hypotheses

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INTERNATIONAL WORKSHOP ON GLOBAL DIMMING AND BRIGHTENING – an international workshop of the Israel Science Foundation.
Ein Gedi, Israel, February 10-14, 2008

Global Dimming

Topics:

Is Dimming Real?

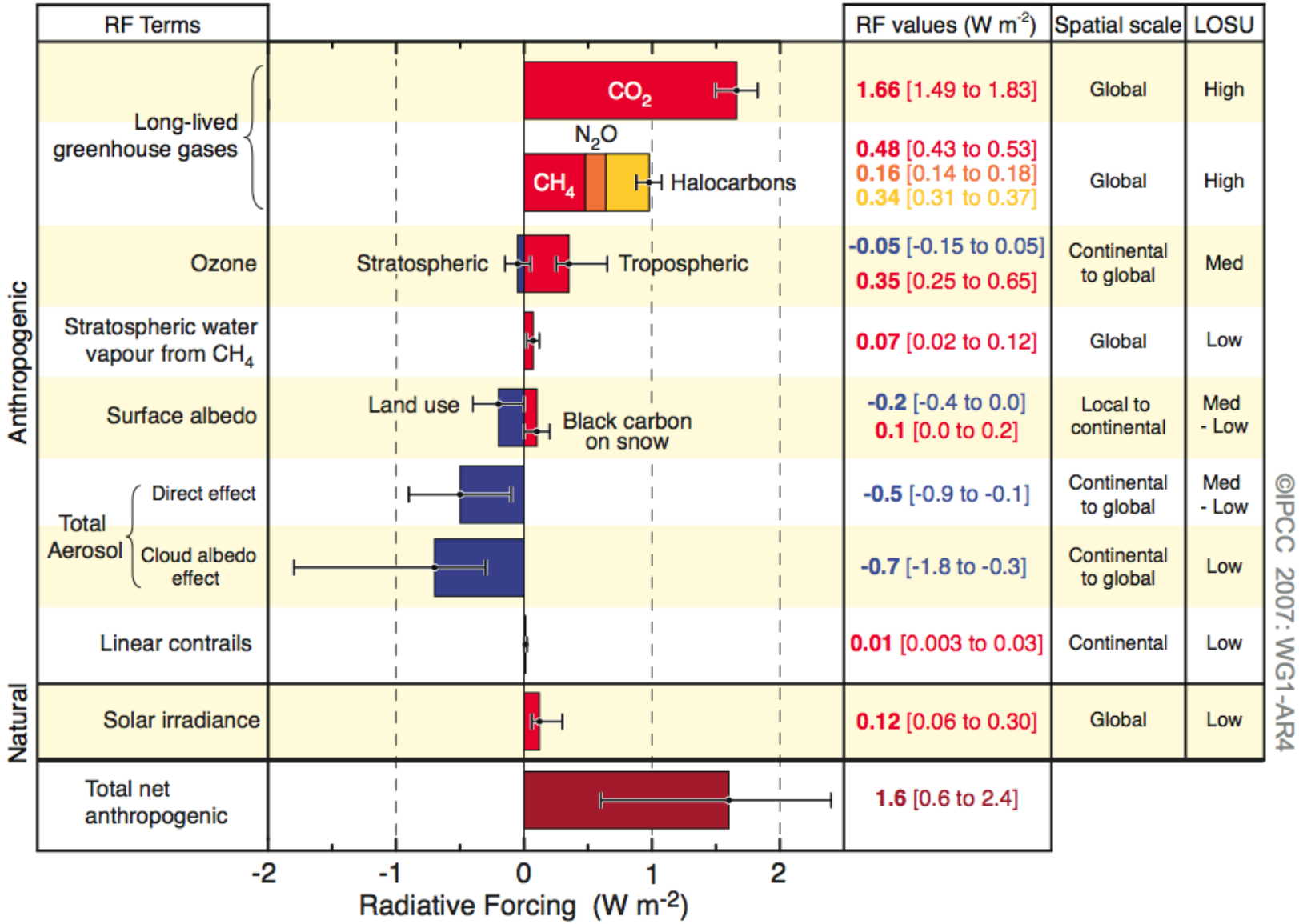
Is it Global or Regional ?

How Large is it?

What are the most likely factors causing the Dimming?

What are the Climatic Implications?

Radiative Forcing Components



Source: Updated: PLENARY, IPCC 2007

The Aerosol forcing is -1.2 (-0.5 to -2.5) Wm^{-2} (direct+Indirect Effect)

This is basically global scale dimming due to Aerosols

Thus according to IPCC the planet is dimmer now than
How it was during the pre-industrial period

Hence the Controversy is not about the reality of dimming;
but about its magnitude.

ELSEVIER

Agricultural and Forest Meteorology 107 (2001) 255–278

AGRICULTURAL AND FOREST METEOROLOGY

www.elsevier.com/locate/agrformet

Review

Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences

Gerald Stanhill*, Shabtai Cohen

Institute of Soil, Water and Environmental Sciences, ARO, Volcani Center, Bet Dagan 50250, Israel

Received 8 August 2000; received in revised form 26 November 2000; accepted 1 December 2000

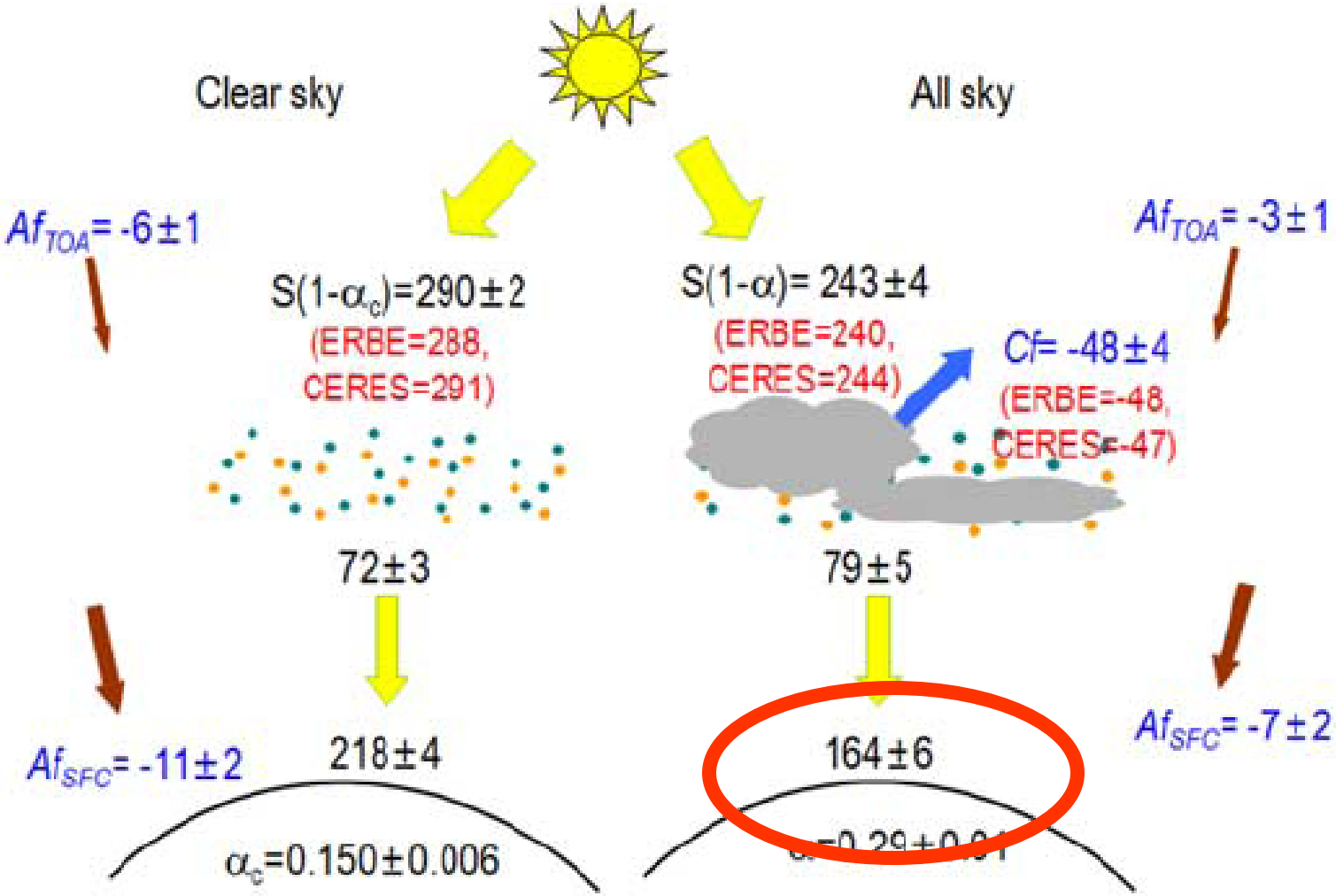
Abstract

A number of studies show that significant reductions in solar radiation reaching the Earth's surface have occurred during the past 50 years. This review analyzes the most accurate measurements, those made with thermopile pyranometers, and concludes that the reduction has globally averaged $0.51 \pm 0.05\ \mathrm{W\,m^{-2}}$ per year, equivalent to a reduction of 2.7% per decade, and now totals $20\ \mathrm{W\,m^{-2}}$, seven times the errors of measurement. Possible causes of the reductions are considered. Based on current knowledge, the most probable is that increases in man made aerosols and other air pollutants have changed the optical properties of the atmosphere, in particular those of clouds. The effects of the observed solar radiation reductions on plant processes and agricultural productivity are reviewed. While model studies indicate that reductions in productivity and transpiration will be proportional to those in radiation this conclusion is not supported by some of the experimental evidence. This suggests a lesser sensitivity, especially in high-radiation, arid climates, due to the shade tolerance of many crops and anticipated reductions in water stress. Finally the steps needed to strengthen the evidence for global dimming, elucidate its causes and determine its agricultural consequences are outlined.

Keywords: Global dimming; Solar radiation; Agricultural productivity; Arid climates; Shade tolerance

According to Stanhill and Cohen, the planet has dimmed by 20 Wm^{-2} since 1950;

Compared with the most current estimate of the solar radiation budget of the planet (shown next) this is about 12% of the absorbed solar radiation.



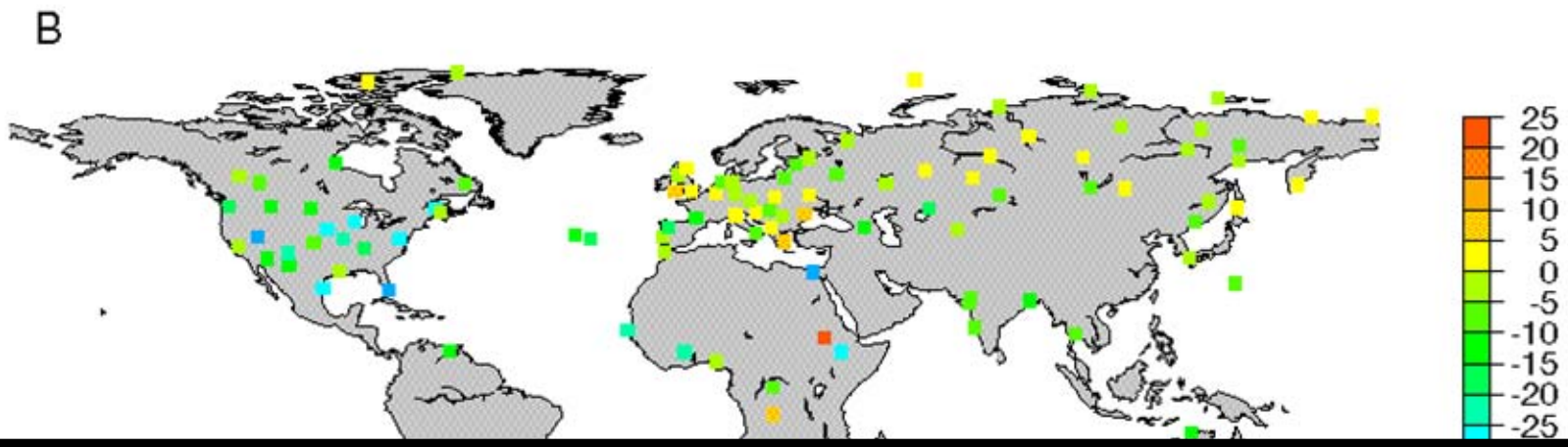
Solar radiation budget and radiative forcing due to aerosols and clouds

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, D02203, doi:10.1029/2007JD008434, 2008

Global Dimming

Changes of Decadal Mean Surface Solar Radiation:
1981 - 1990 minus 1961-1970 (Liepert, *GRL*, 2002)

$\Delta F = -7 W/m^2 \approx -4\%$

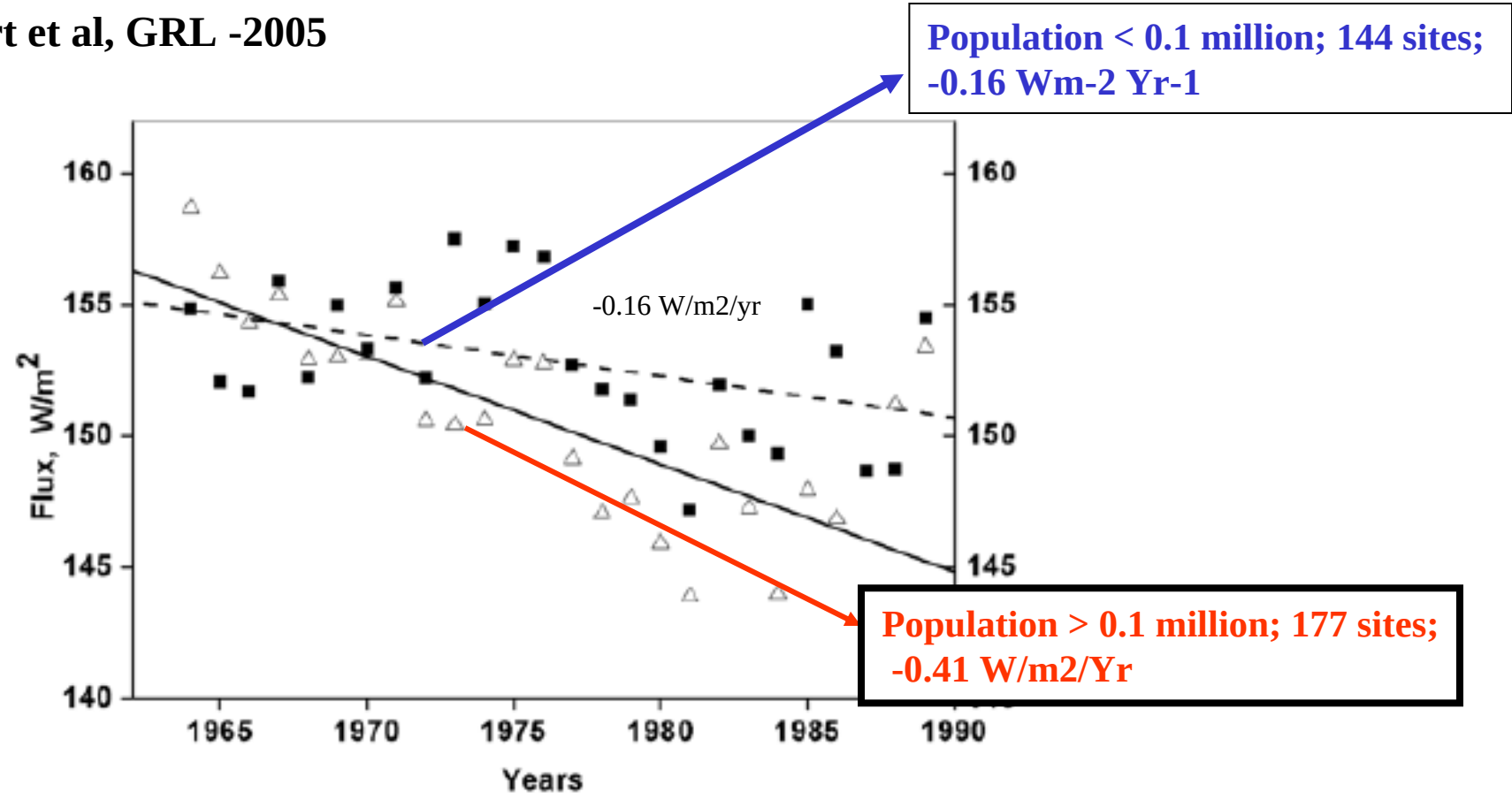


As per Liepert : the dimming is about –7 Wm^{-2} in 20 years; scaled to 50 years, It is equivalent to –17 Wm^{-2}..
Not very different from Stanhill and Cohen's estimates

Is Global Dimming Really just Local Dimming?

Alpert et al study

Alpert et al, GRL -2005



GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L17802, doi:10.1029/2005GL023320, 2005

Global dimming or local dimming?: Effect of urbanization on sunlight availability

Pinhas Alpert,[1] Pavel Kishcha,[1] Yoram J. Kaufman,[2] and Rotem Schwarzbard[1]

Received 22 April 2005; revised 4 July 2005; accepted 22 July 2005; published 2 September 2005.

GEOPHYSICAL RESEARCH LETTERS, VOL. 32, L17802, doi:10.1029/2005GL023320, 2005

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by the large urban sites. The global-scale analysis of year-to-year variations of solar radiation fluxes shows a decline of 0.41 $W/m^2/yr$ for highly populated sites compared to only 0.16 $W/m^2/yr$ for sparsely populated sites (<0.1 million). Since most of the globe has sparse population, this suggests that solar dimming is of local or regional nature. The

By Dimming, do we really mean only large dimming of the order of -0.4 W/m2/year?

Is -0.16 W/m2/Yr not dimming enough? Equals -4 W/m2 over 25 years!!

CO_2 forcing of the last 125 years is -1.6 Wm^{-2}!!

Is the Planet Brightening?

Inconsistency between the two Brightening Studies;

As shown Next

Pinker et al’s study shows brightening only over Oceans and no trend over land;

Whereas Wild et al show brightening over Land

Do Satellites Detect Trends in Surface Solar Radiation?

R. T. Pinker,[1] B. Zhang,[2] E. G. Dutton[3]

6 MAY 2005 VOL 308 SCIENCE www.sciencemag.org

Land+Ocean Average

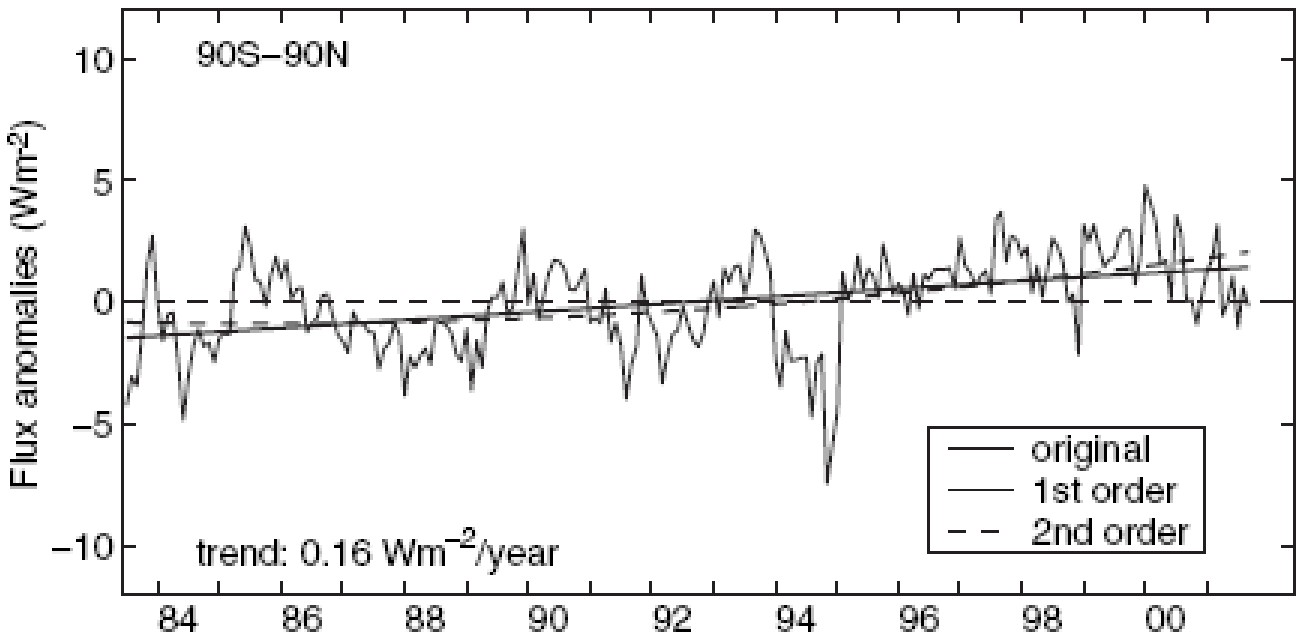


Fig. 1. Linear and second-order least-squares fits to the original satellite-derived time series of *S* (from 1983 to 2001) averaged over the globe, after removal of the mean annual cycle. The linear slope (solid line) of the surface solar radiation is positive at 0.16 W m^{-2} $year^{-1}$. The second-order polynomial (dashed line) indicates a small decrease from 1983 to 1992, with a reversal around 1992. Both the linear and the 2nd-order fits are significant at the 99% level of confidence.

Do Satellites Detect Trends in Surface Solar Radiation?

R. T. Pinker,[1] B. Zhang,[2] E. G. Dutton[3]

Land Only: Shows no trend

Oceans Only: All of the trend is Over the Ocean

A

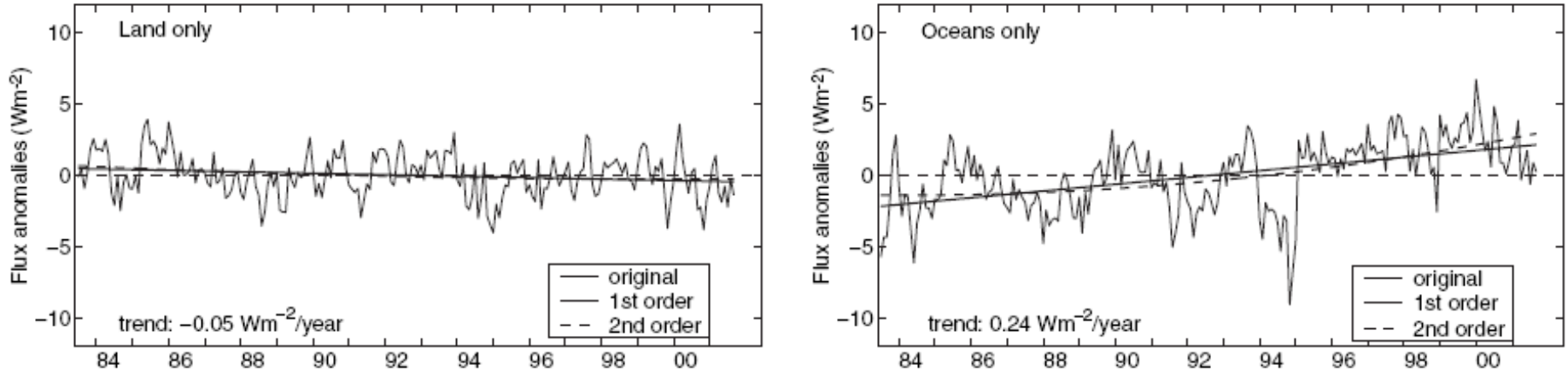
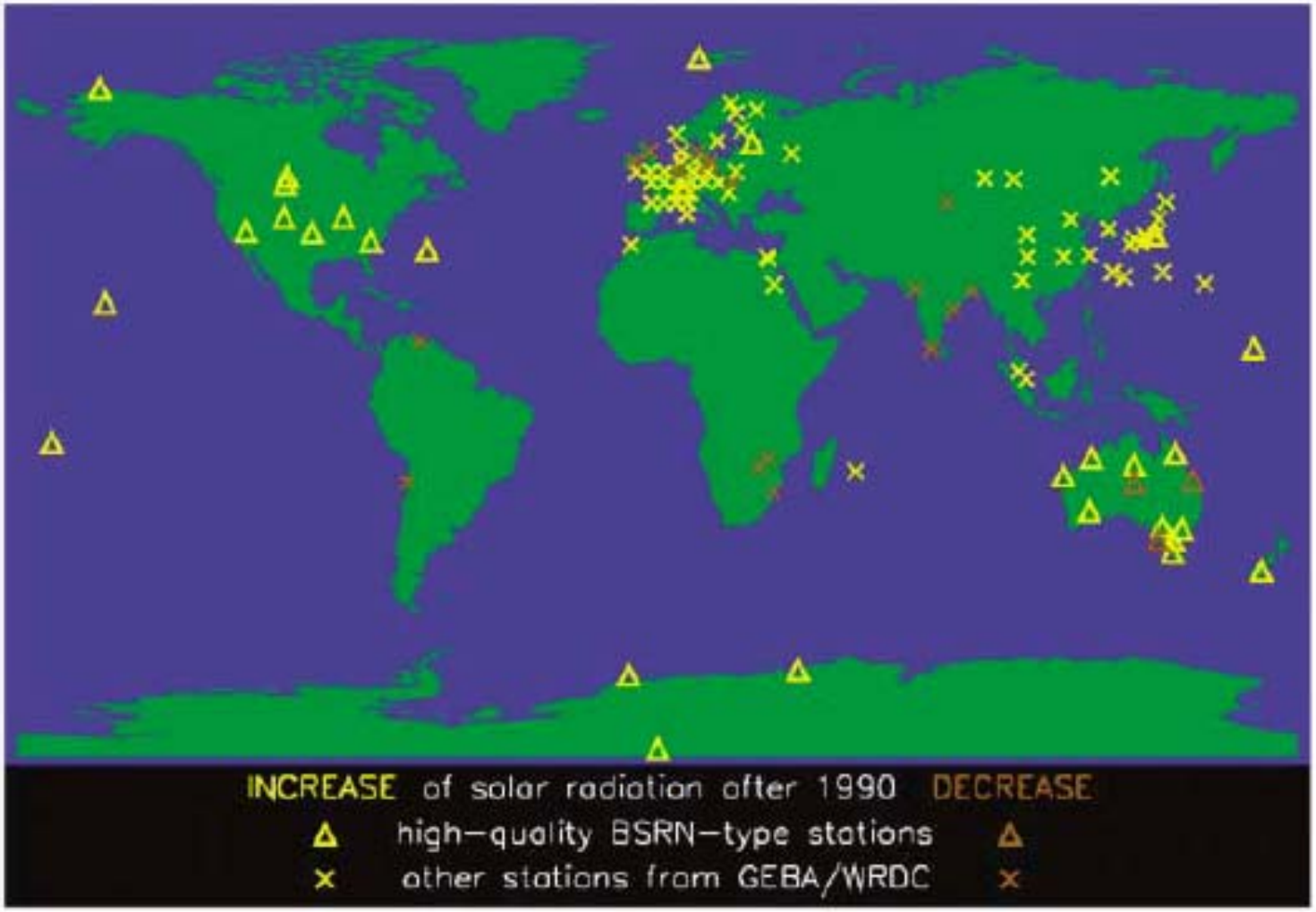


Fig. 5. Linear and second-order trends for (A) land areas only and (B) for oceans only.

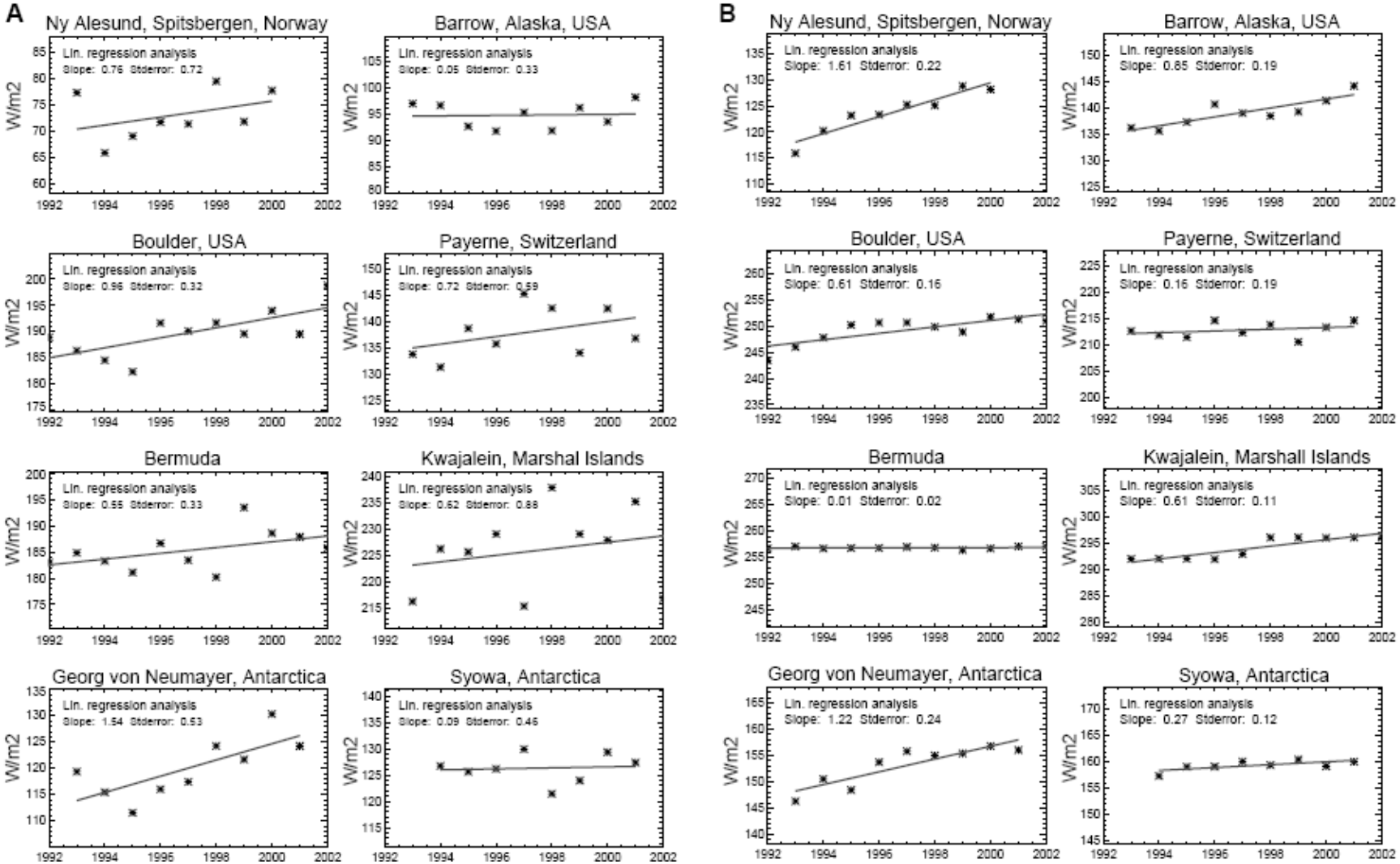
From Dimming to Brightening: Decadal Changes in Solar Radiation at Earth's Surface

www.sciencemag.org SCIENCE VOL 308 6 MAY 2005

Martin Wild,[1*] Hans Gilgen,[1] Andreas Roesch,[1] Atsumu Ohmura,[1] Charles N. Long,[2] Ellsworth G. Dutton,[3] Bruce Forgan,[4] Ain Kallis,[5] Viivi Russak,[6] Anatoly Tsvetkov[7]



Wild et al: Most if not all the stations have only 8 years or less data…. Too short to make any climate change related statements



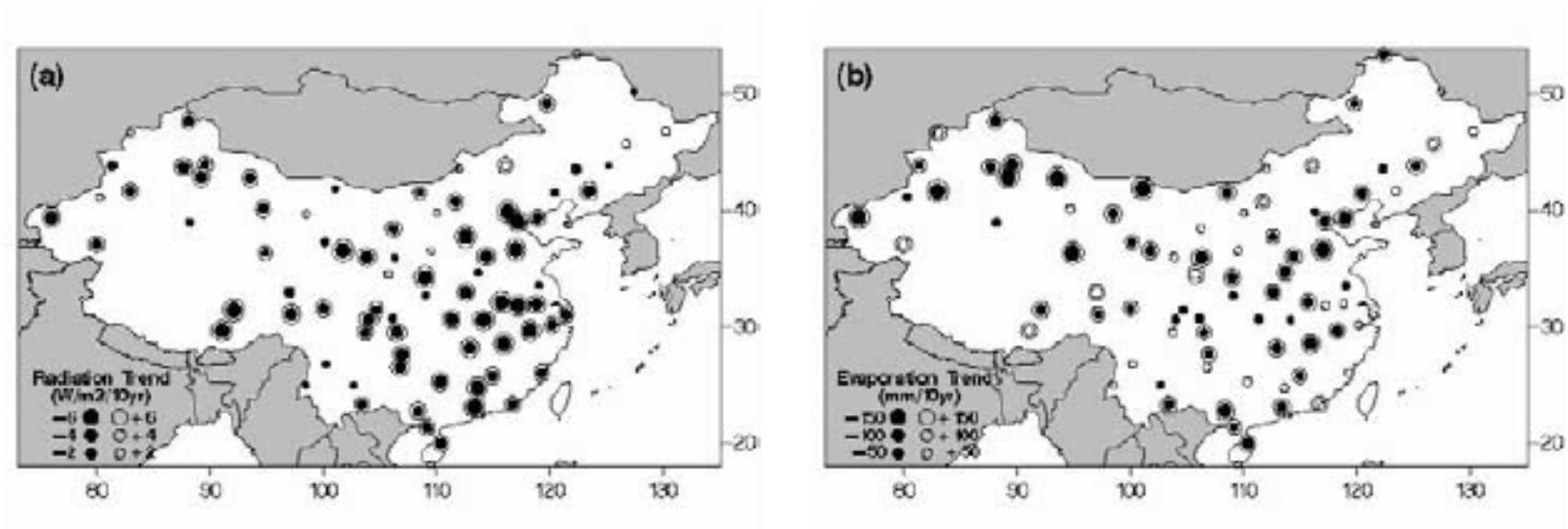
A perspective on the reality of dimming and brightening:

Let us look at China

More frequent cloud-free sky and less surface solar radiation in China from 1955 to 2000

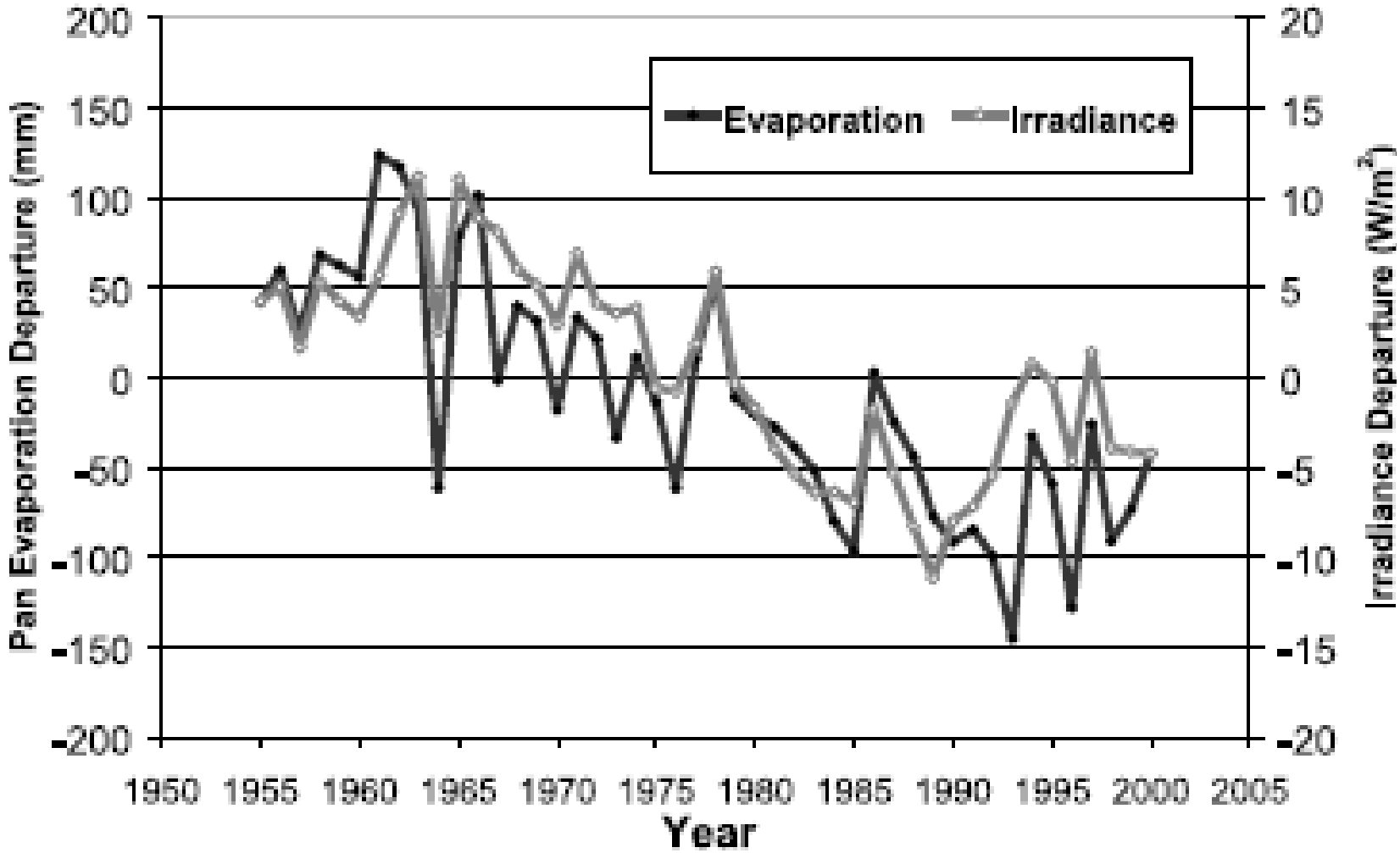
Yun Qian,[1] Dale P. Kaiser,[2] L. Ruby Leung,[1] and Ming Xu[3]

GEOPHYSICAL RESEARCH LETTERS, VOL. 33, L01812, doi:10.1029/2005GL024586, 2006



[1] Newly available data from extended weather stations and time period reveal that much of China has experienced significant decreases in cloud cover over the last half of the Twentieth century. This conclusion is supported by the

Qian et al study Continued.

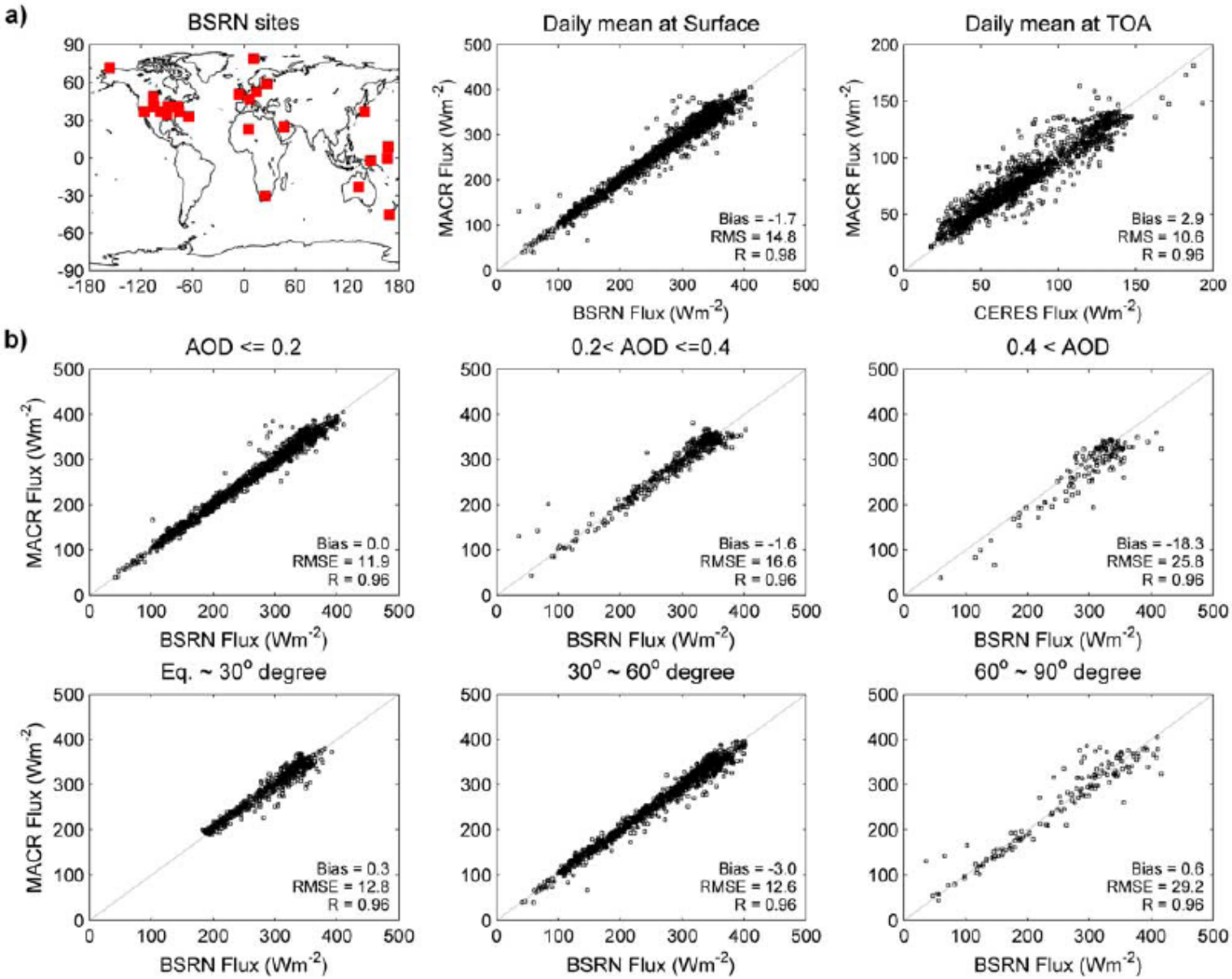


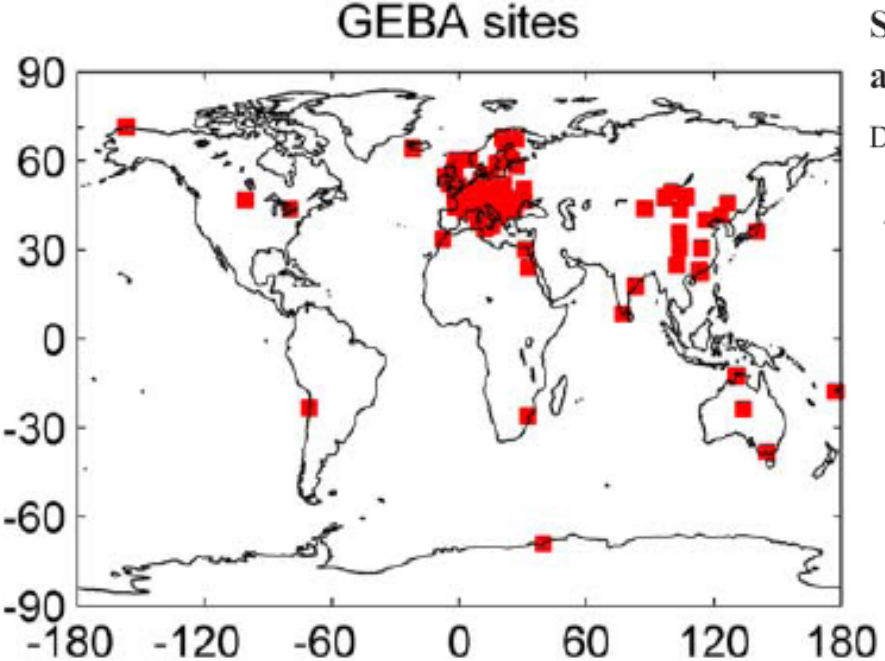
Decrease of 20 Wm^{-2} from 1955 to 1995, followed by 5 to 10 Wm^{-2} brightening; but it is still dimmer compared With the 1950s

How reliable are the GEBA data sets?

Next two figures which compare simulated fluxes With observed fluxes, over BSRN sites (next Figure) and GEBA sites suggest that GEBA Site data are reasonably reliable.

How good are the GEBA radiometers?



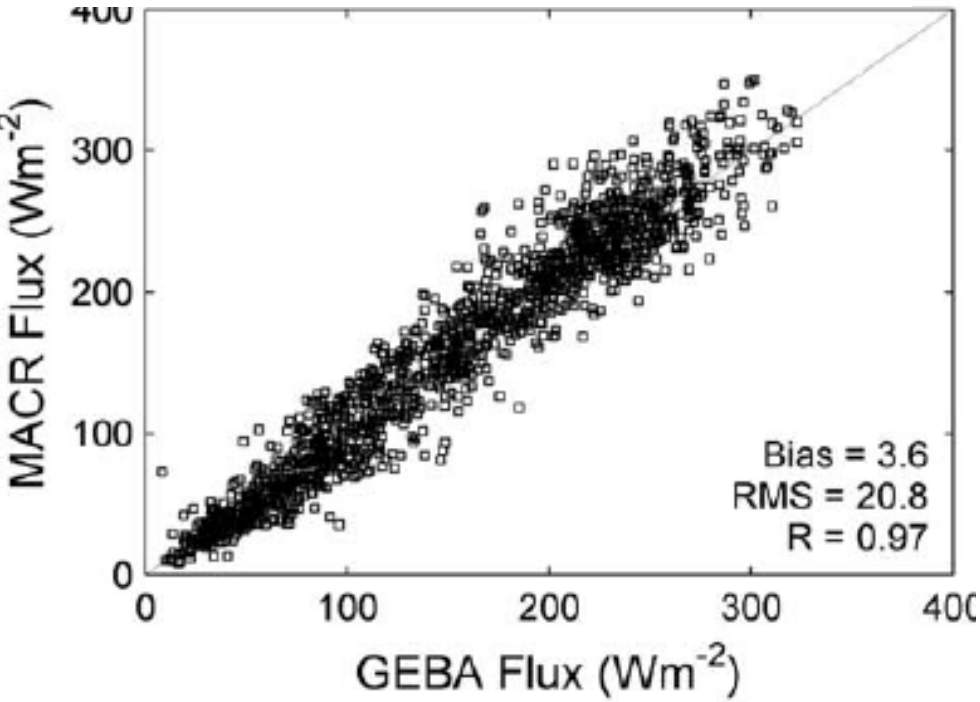


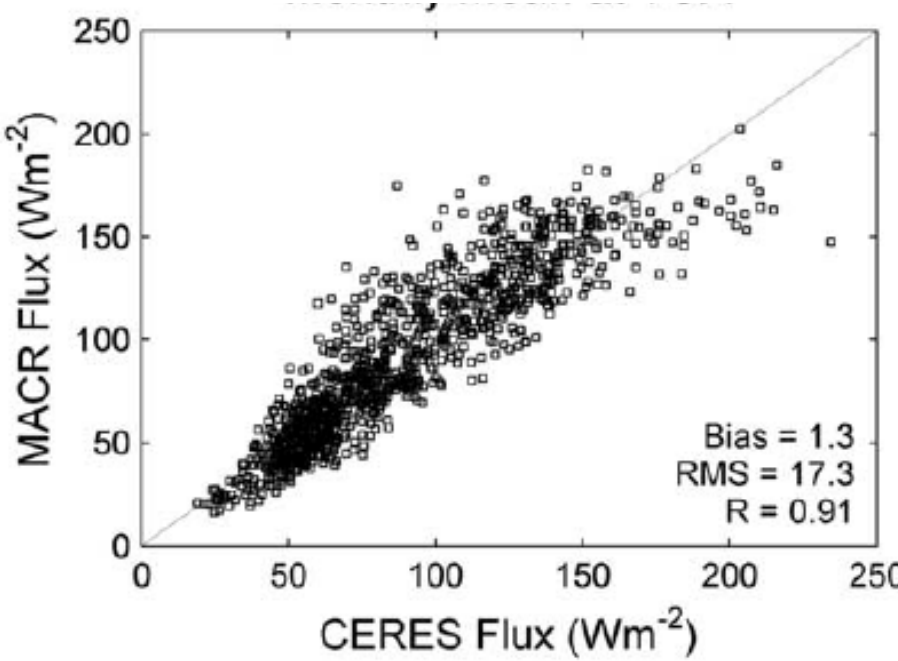
Solar radiation budget and radiative forcing due to aerosols and clouds

Dohyeong Kim[1,2] and V. Ramanathan[1]

JOURNAL OF GEOPHYSICAL RESEARCH, 2008

Monthly mean fluxes at TOA and at Surface; All Sky





What is the role of Air Pollution in the Diimming?

Atmospheric Brown Clouds

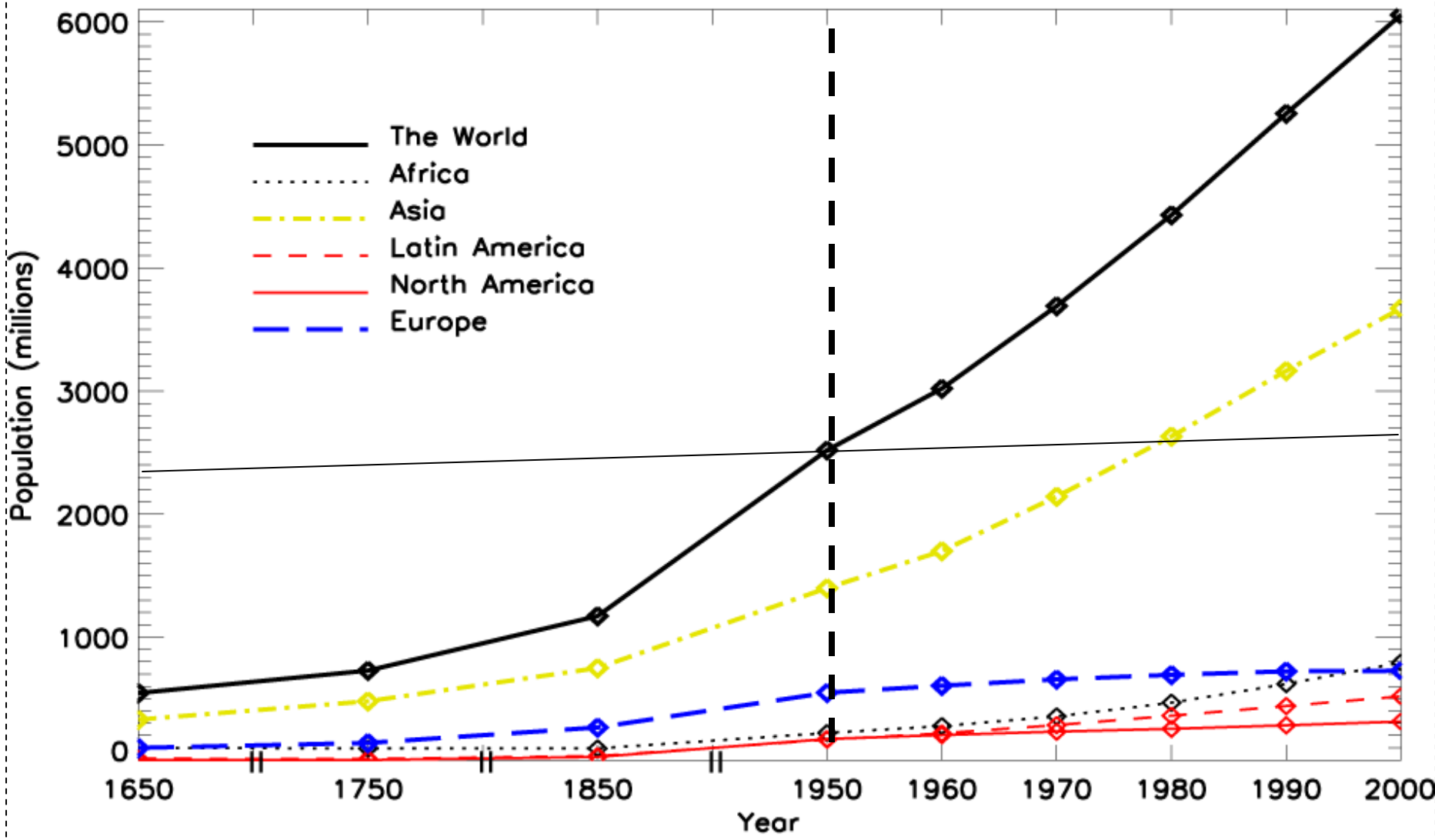
When did the dimming begin?

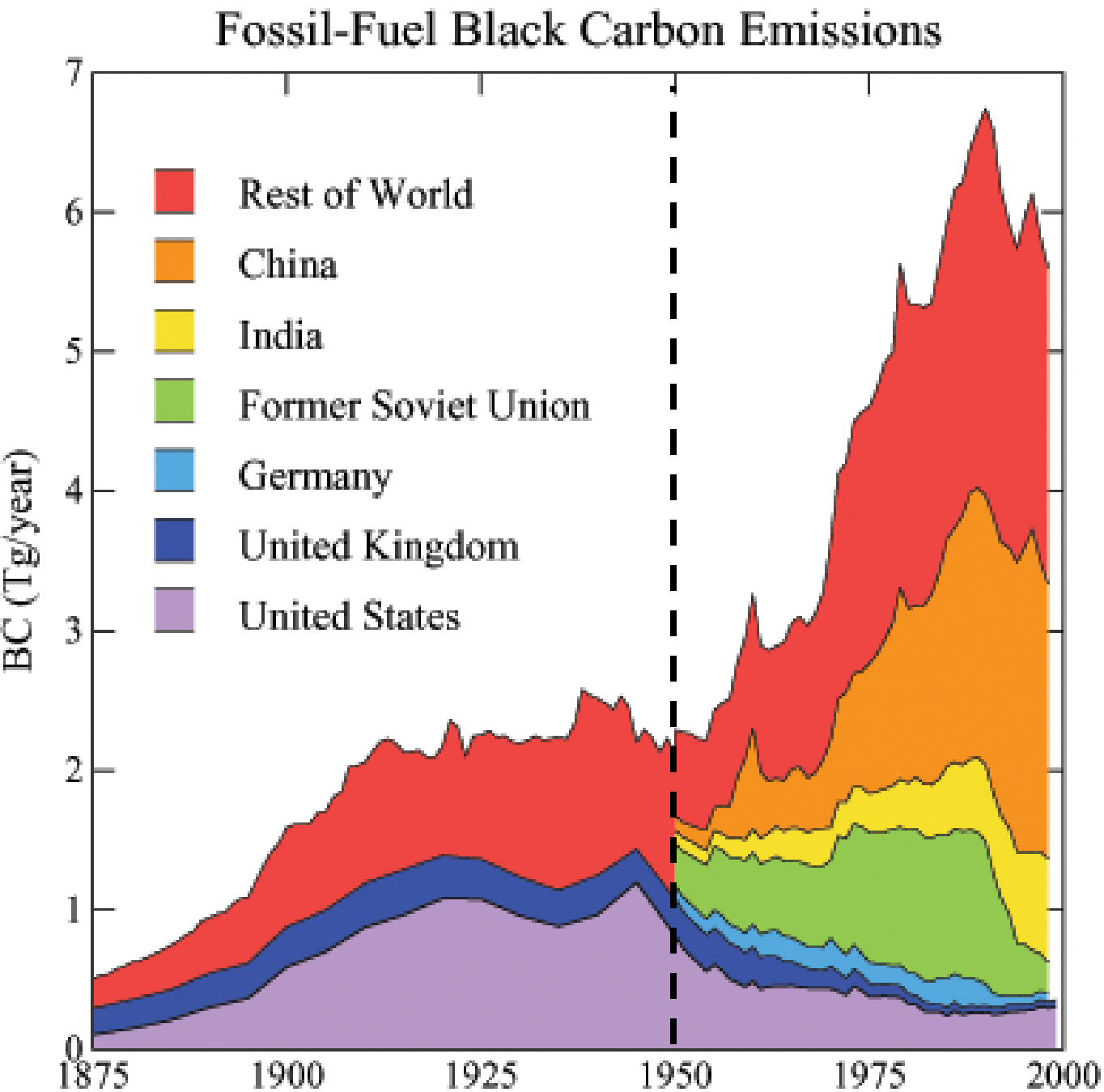
What happened after the early 1950s??

i) Population explosion began after 1950

ii) The emission of BC, SO2 and other aerosols Inreased explosively after 1950

World Population Growth:





Ref: T. Novakov, V. Ramanathan, J. E. Hansen, T. W. Kirchstetter, M. Sato, J.E. Sinton, J. A. Sathaye Geophys. Res. Lett, Dec. 2002

How Clean is the atmosphere over the western hemisphere ?

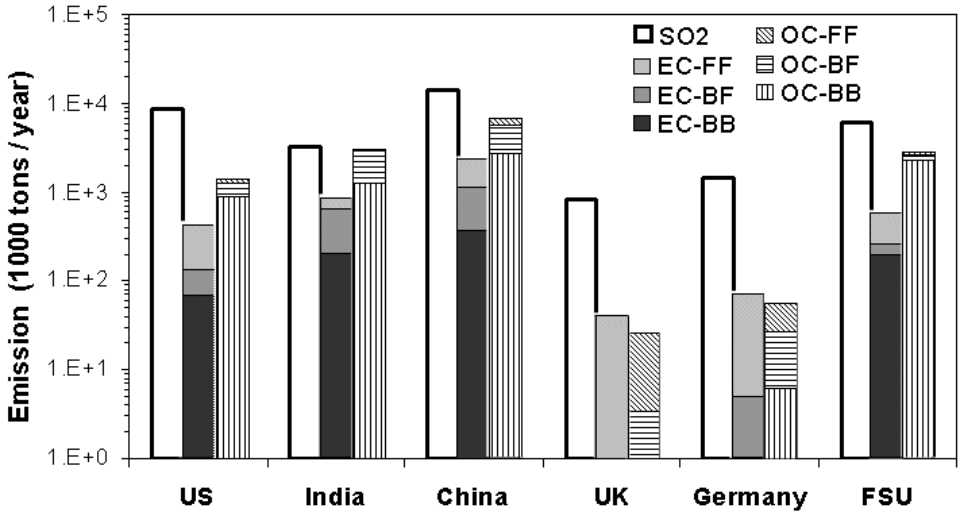
Or over Developed Nations?

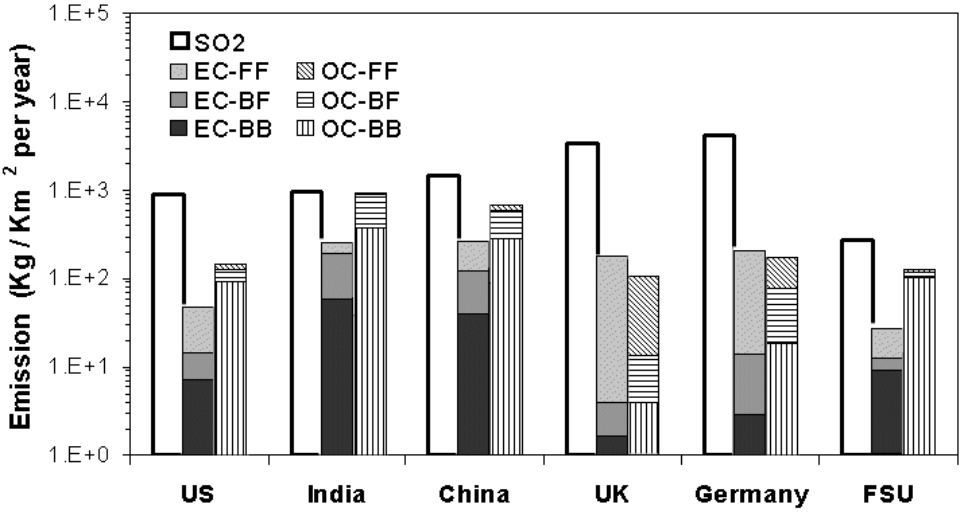
Wild et al claimed Europe and US have recovered Completely from the dimming.

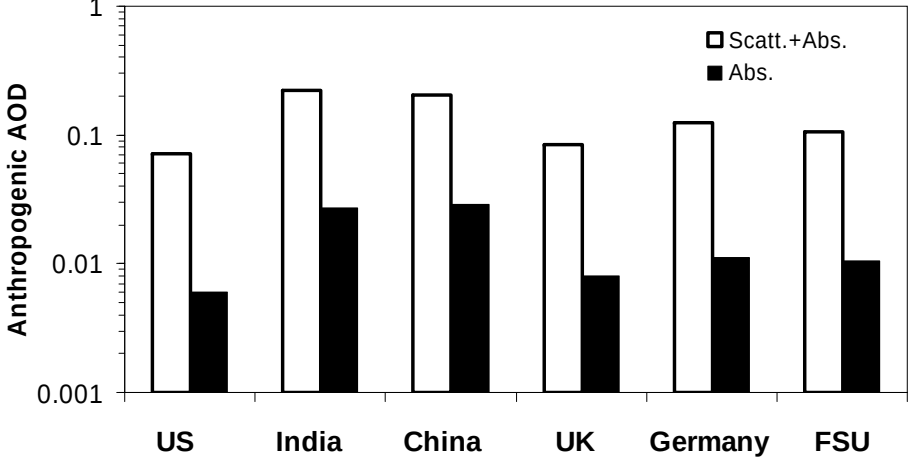
This does not mean the aerosol pollution vanished; Next two figures BC and SO2 emissions, and AODs from various developed and developing nations

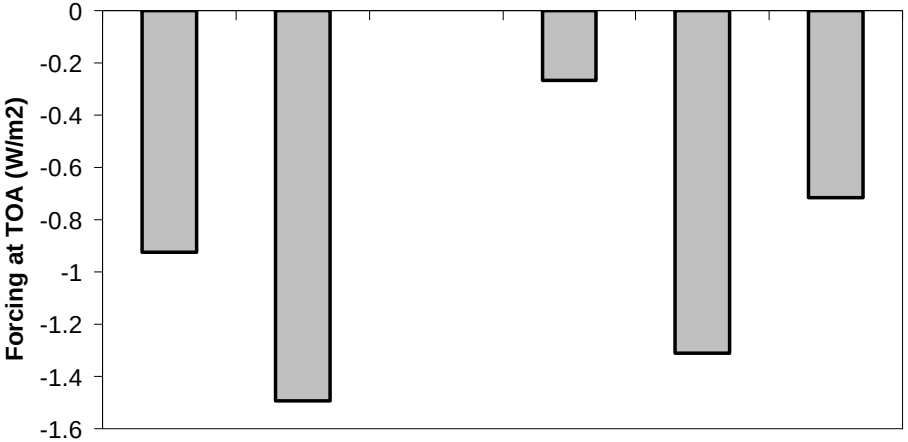
Source: Ramanathan et al, 2007

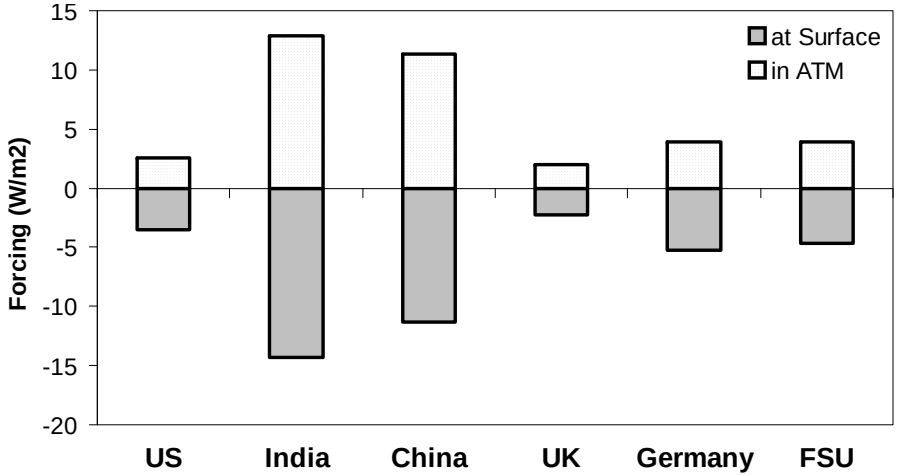
Ramanathan et al, JGR, 2007











Is there Direct Evidence for the Dimming

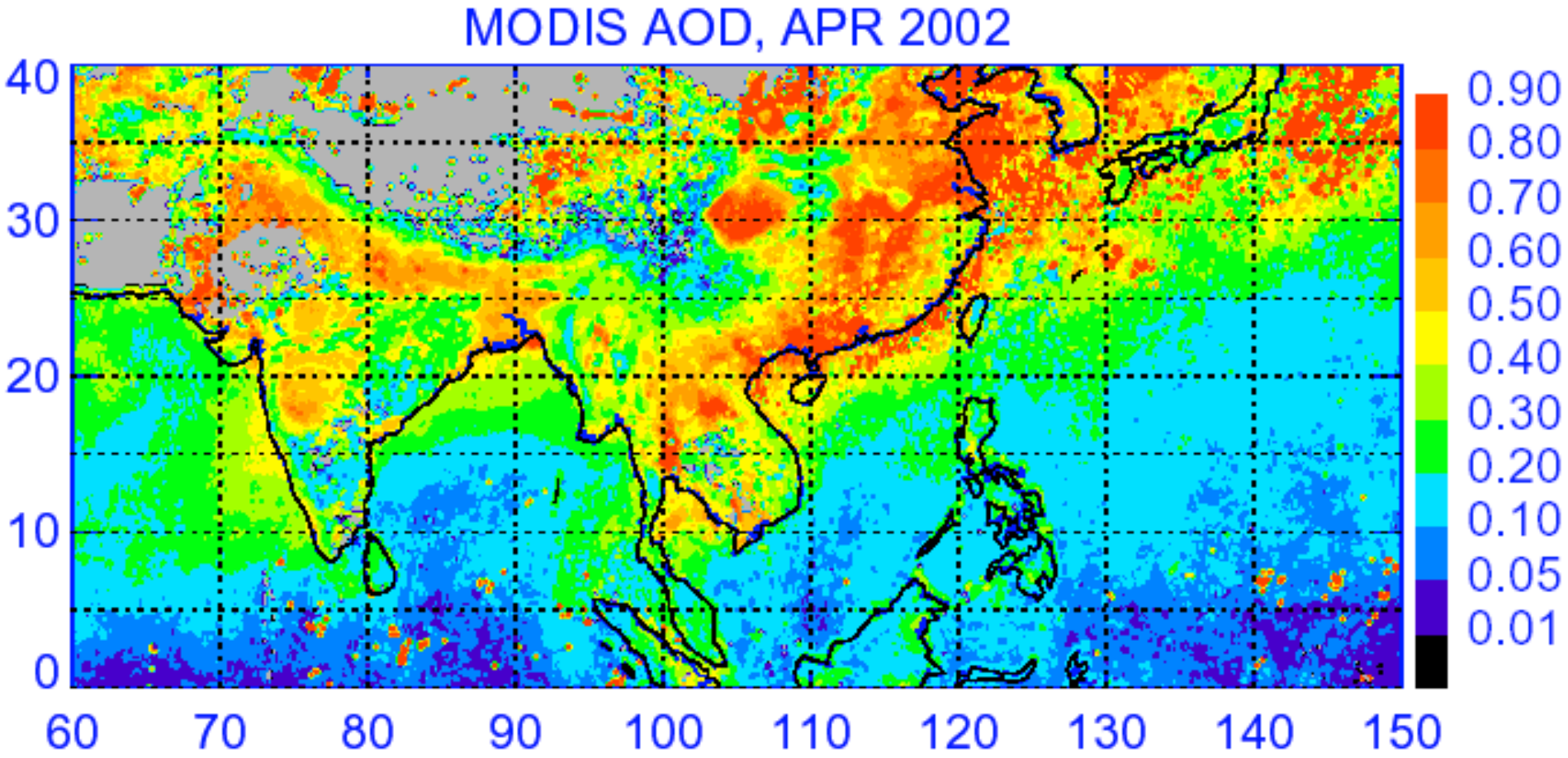
- The Indian Ocean Experiment Provided Direct Chemical, Microphysical and Radaiometric Evidence that absorbing aerosols can lead to 5 to 10% reduction in seasonal averaged solar radiation at the surface over a large area, as large as the entire Arabian sea, Bay of Bengal and the S. Asian Region an area as large as USA;

Satheesh and Ramanathan, 2000;
Ramanathan et al, 2001;
over 100 papers and two special volumes in JGR

The Role of Air Pollution and Aerosols: Atmospheric Brown Clouds

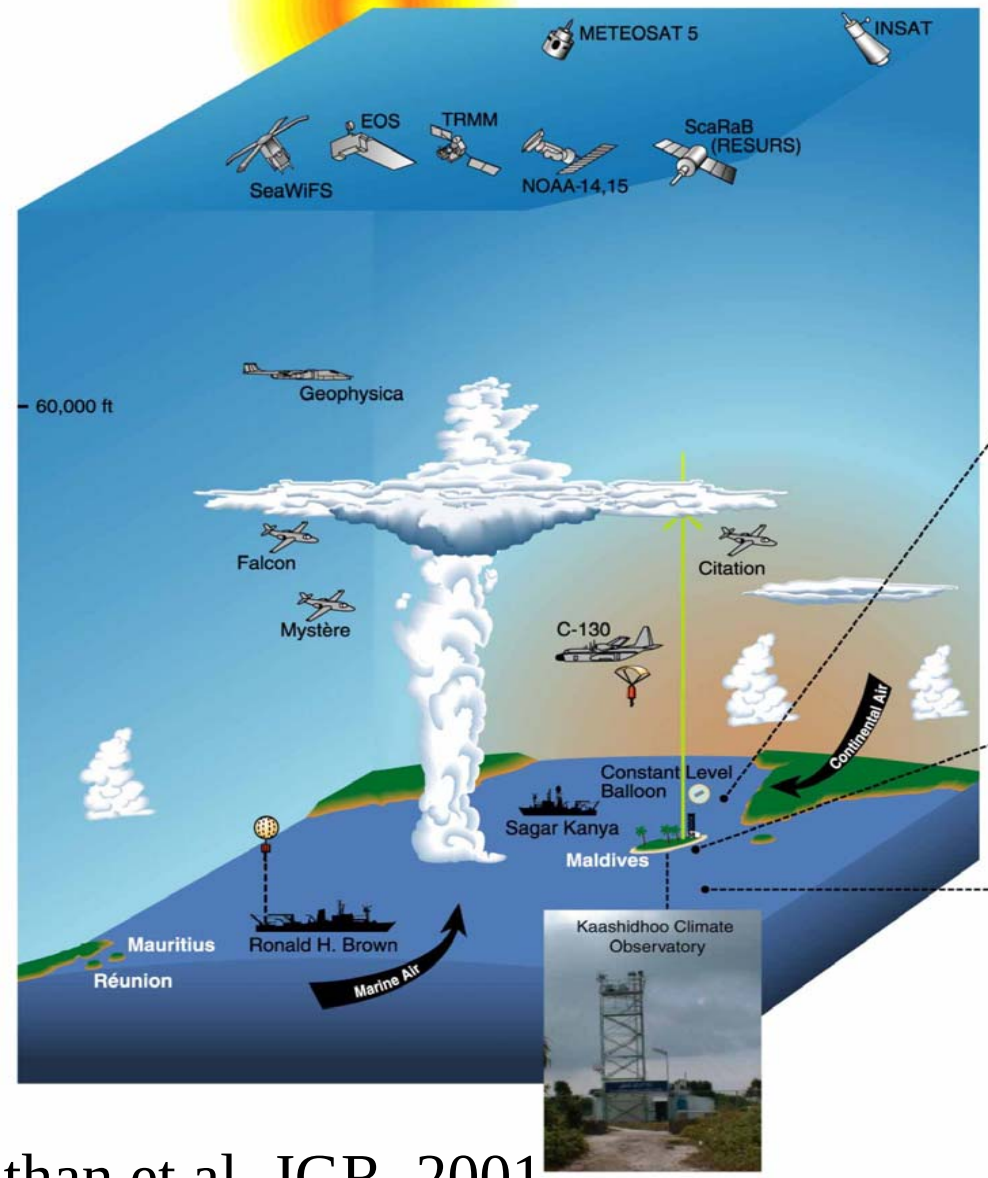
***Long Range Transport of Brown Clouds: Aerosol Optical Depth from TERRA-MODIS*:**

Ramana and Ramanathan 2003



Indian Ocean Experiment

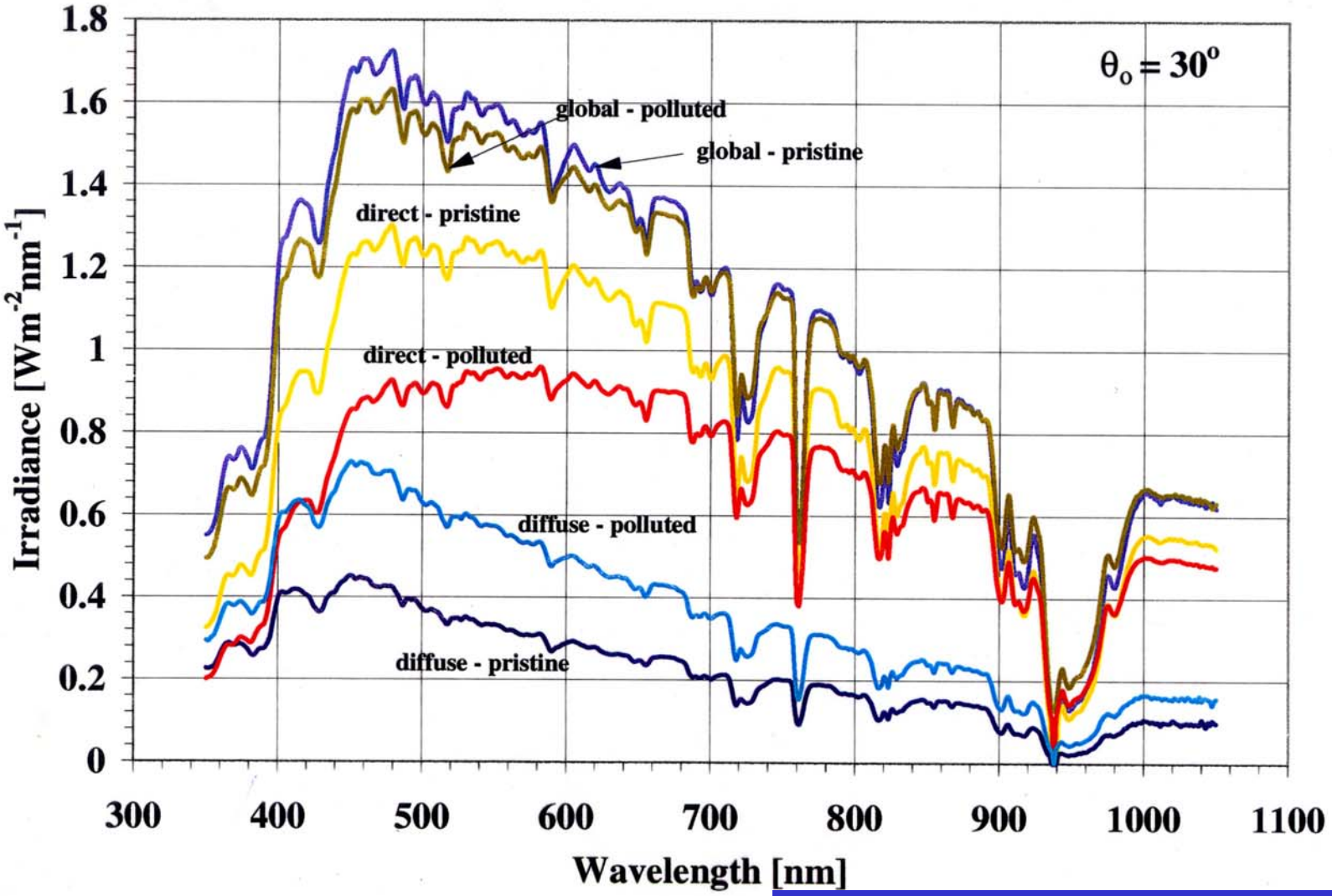
Why Brown Cloud?



Ramanathan et al, JGR, 2001

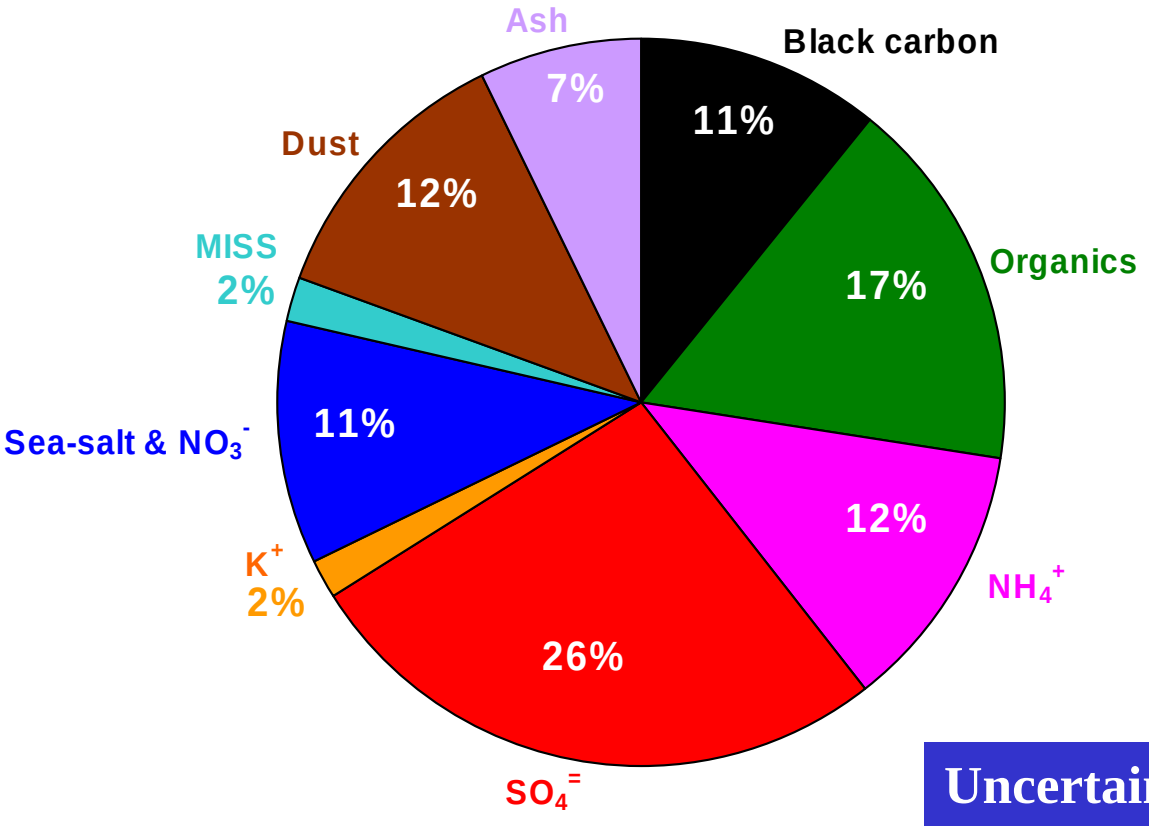
Direct Evidence for dimming

Irradiance inside and outside brown clouds in Arabian Sea



Ref: Meywerk and Ramanathan, 1999; 2004

Contribution to Aerosol Optical Depth

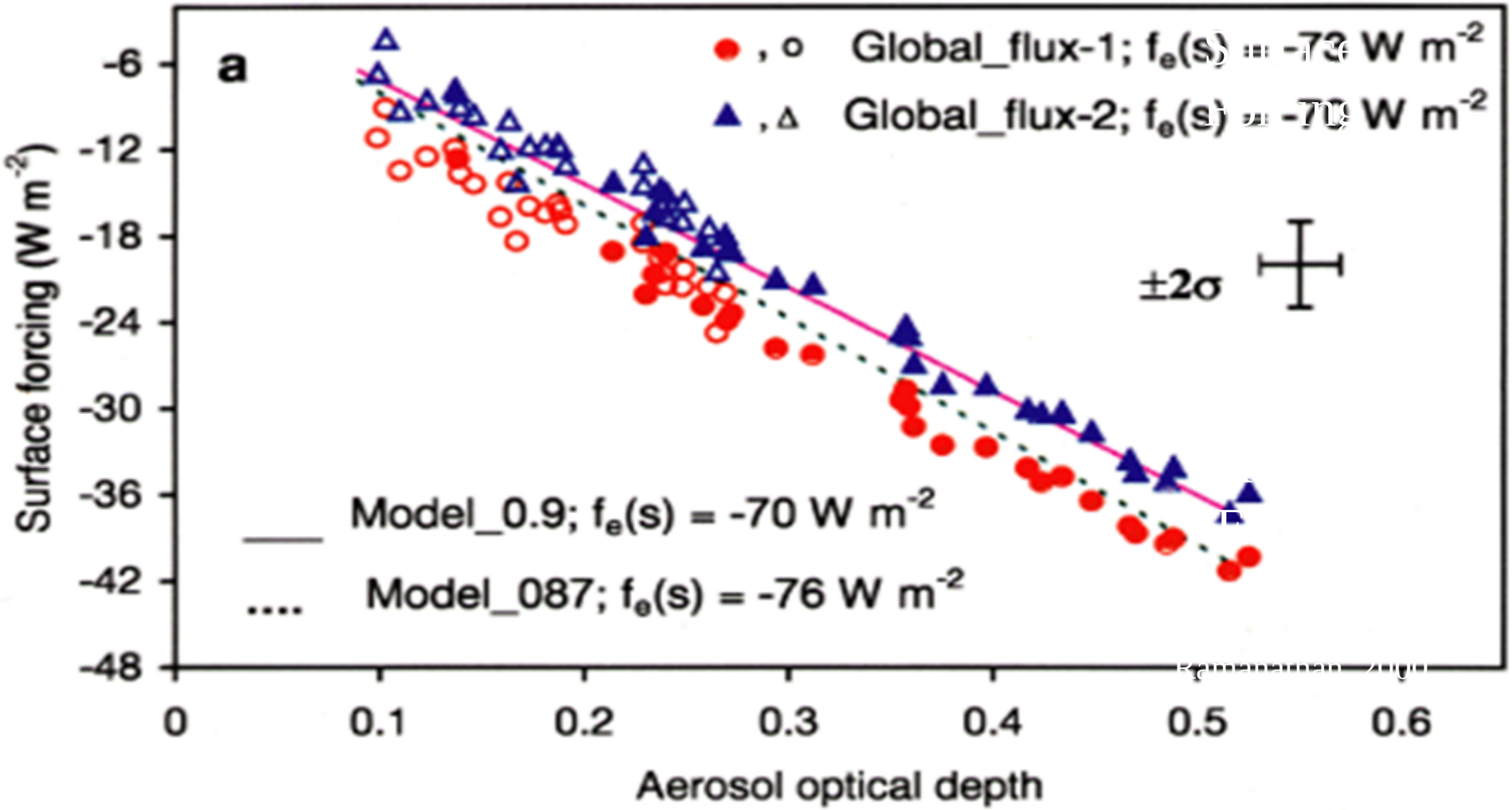


Uncertainty < +- 4%

Ramanathan et al, 2001

Direct observations: Clear-sky Forcing Efficiency

Satheesh and Ramanathan, Nature 2000



Simulations with coupled Ocean_Atmosphere models
With historical emissions of BC and SO2 reveal that the observed dimming
Over India can be accounted for mostly by Aerosol increases

Ref: Ramanathan et al, 2005

5326–5333 | PNAS | April 12, 2005 | vol. 102 | no. 15

Proceedings of the National Academy of Sciences, April 2005

Atmospheric brown clouds: Impacts on South Asian climate and hydrological cycle

V. Ramanathan*†, C. Chung*, D. Kim*, T. Bettge‡, L. Buja‡, J. T. Kiehl‡, W. M. Washington‡, Q. Fu§, D. R. Sikka¶, and M. Wild‖

*Scripps Institution of Oceanography, University of California at San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0221; ‡National Center for Atmospheric Research, Boulder, CO 80307; §University of Washington, Box 351640, Seattle, WA 98195-1640; ¶40 Mausam Vihar, New Delhi, 110 051, India; and ‖Swiss Federal Institute of Technology, Winterhurerstrasse, 190 CH-8057 Zurich, Switzerland

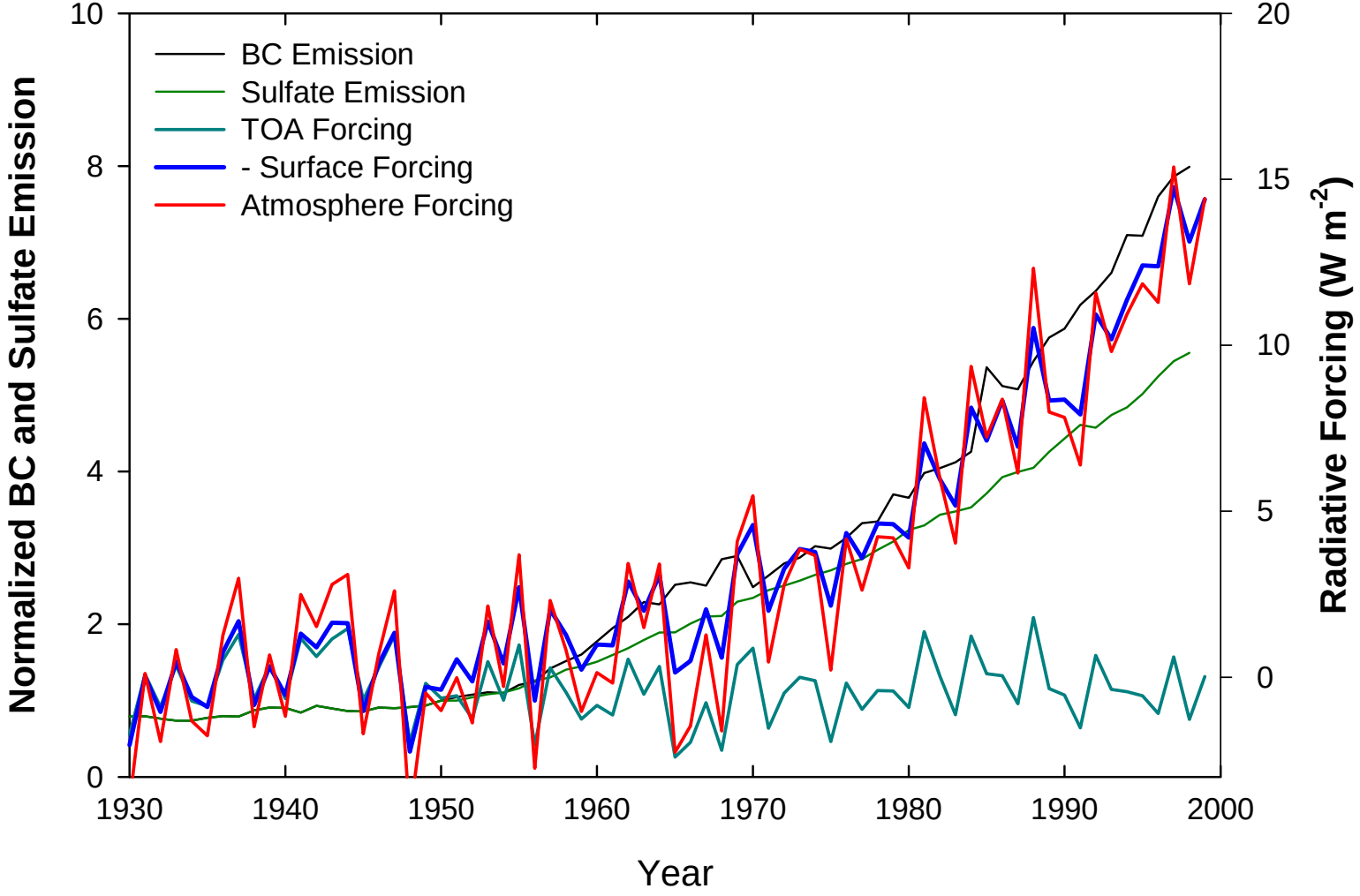
This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected on April 30, 2002.

Contributed by V. Ramanathan, January 25, 2005

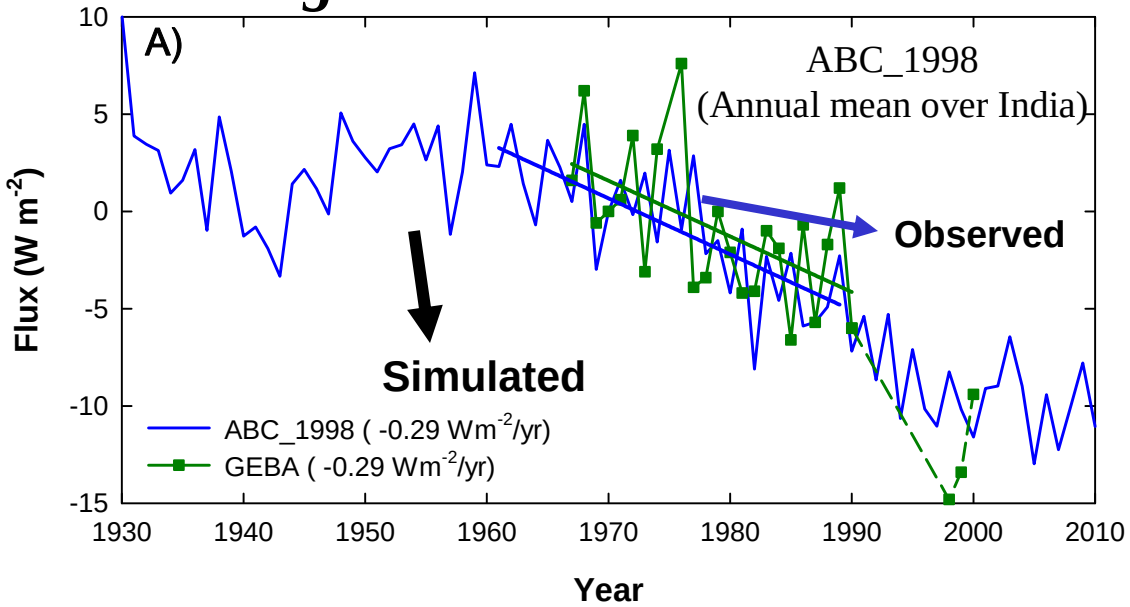
A Fully Coupled Ocean-Atmosphere Model Study from 1870 to 2025; Five Ensemble Runs:
The NCAR Parallel Climate Model;
GHG gas and volcanic forcing from 1870;
ABC forcing from INDOEX and past emissions histories

Time series of radiative forcing (W m^{-2}), and normalized BC/Sulfate emissions at 1950

[Regional average over land and ocean
: Lat (Eq. to 30N), Lon (60E to 100E)]

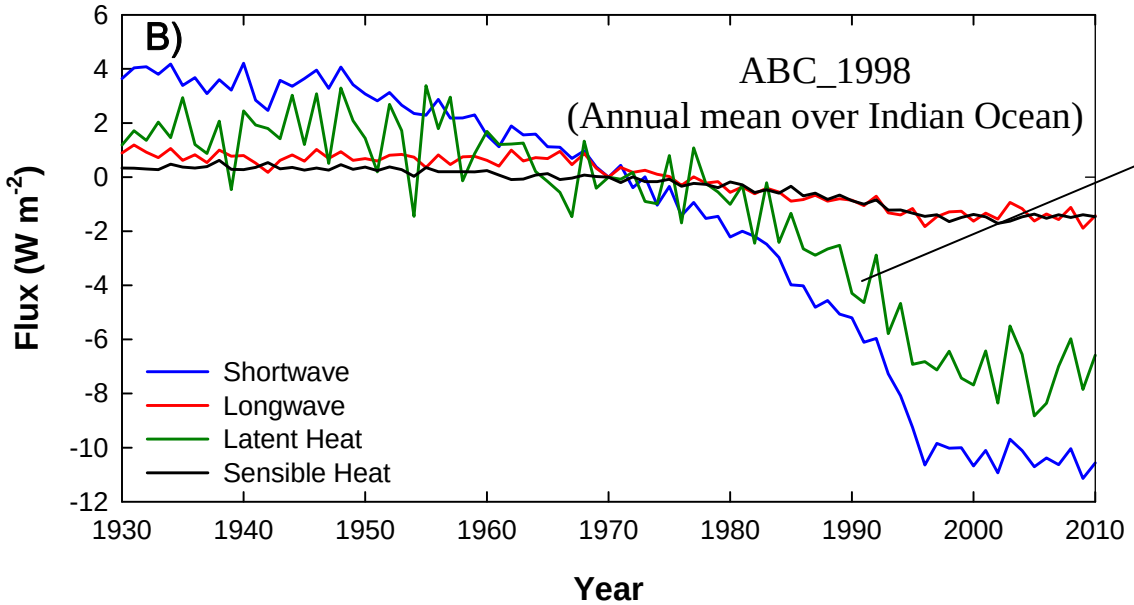


South Asian Dimming



Solar Radiation at the Surface: Simulated And Observed

(12 stations)

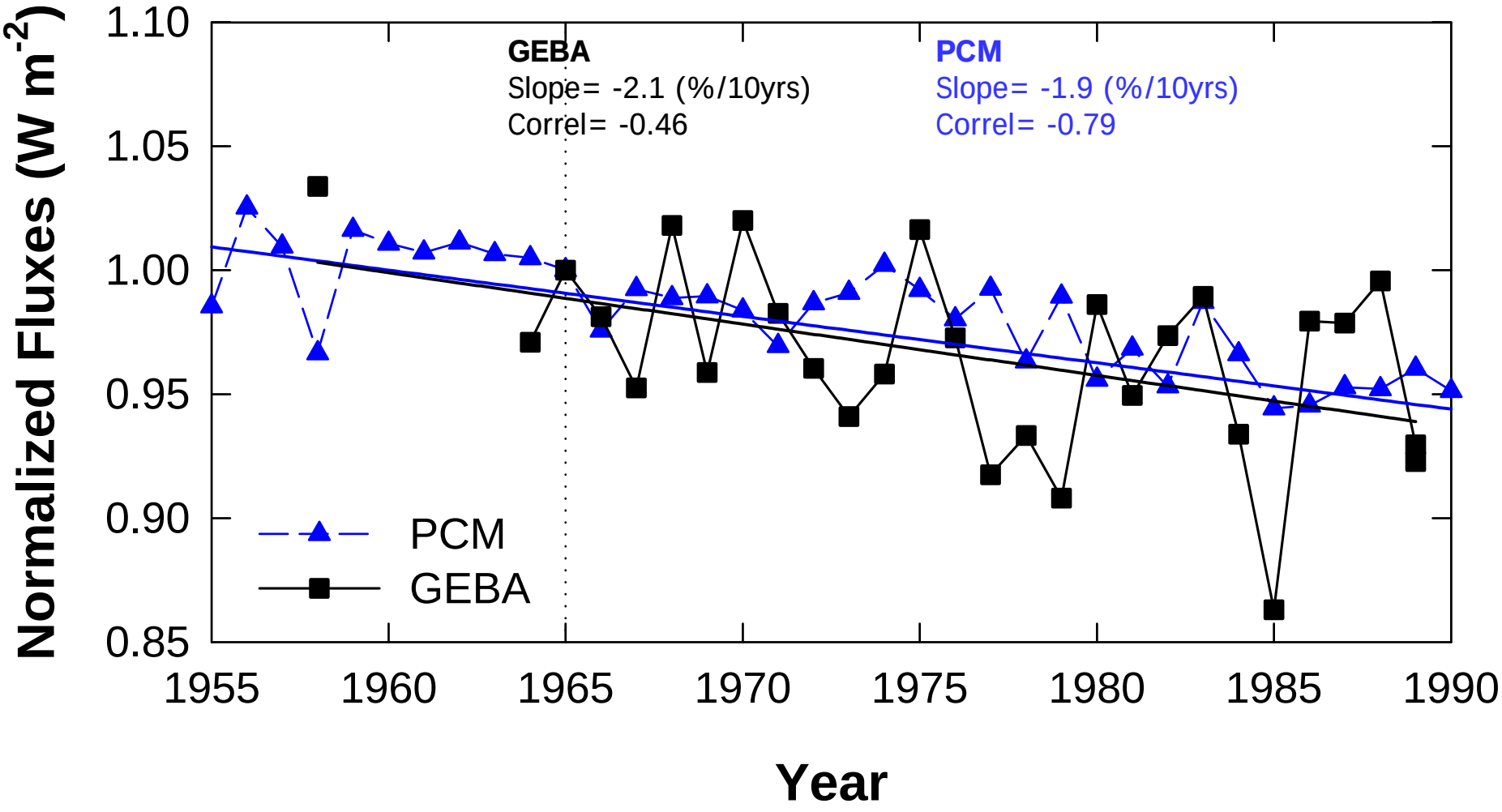


The Dimming Led to a Decrease in Evaporation From Indian Ocean

Source: Ramanathan et al, Proceedings of National Academy of Sciences, March 2005

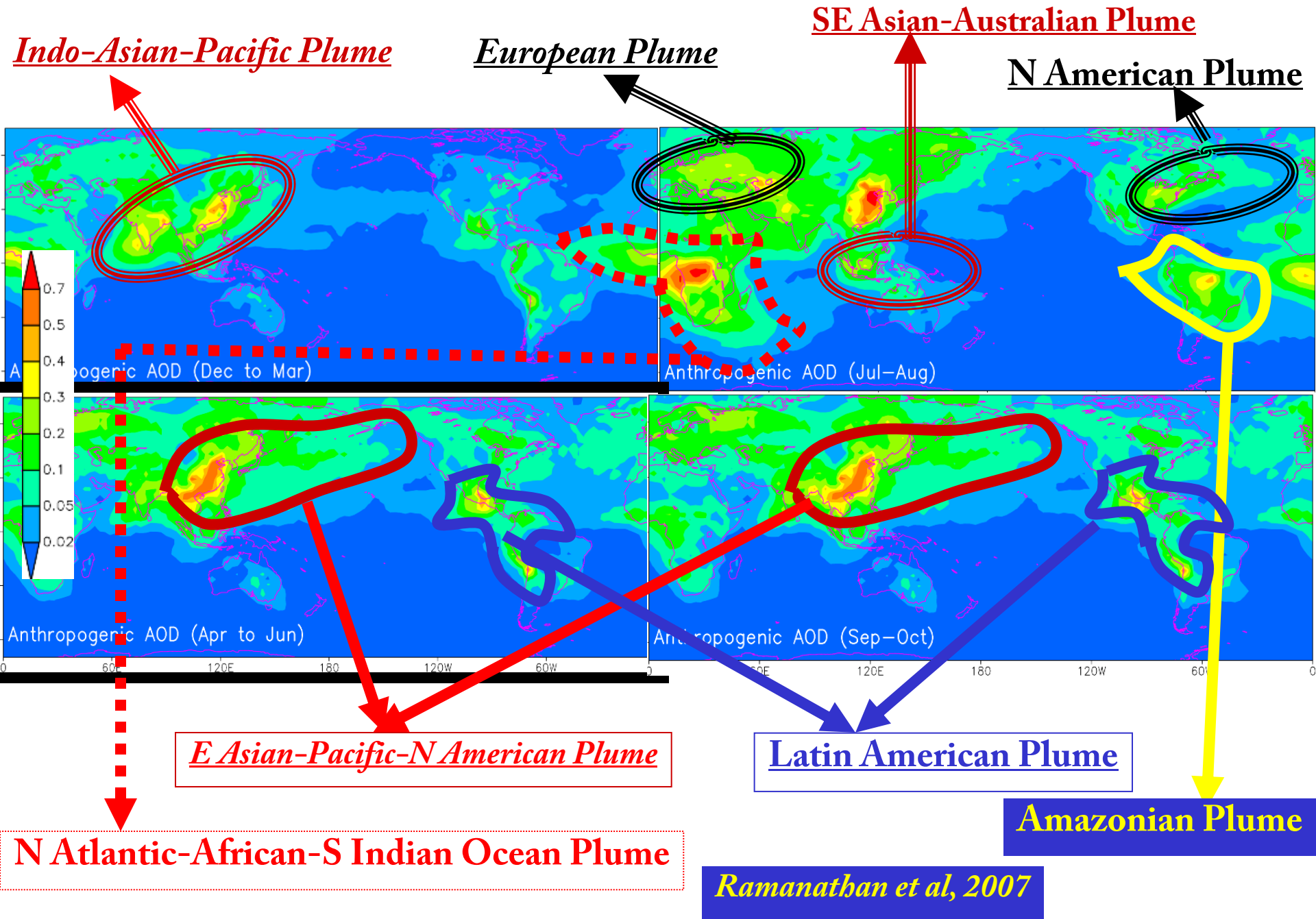
GEBA and PCM Estimated Trends in Surface Solar Radiation: March.

All values were Normalized with 1965 Values; For West Coast Only



How local or regional or global is the dimming ?

Anthropogenic Aerosol Optical Depths: Regional Hot spots



Ramanathan et al, 2007

Model-Observations Integrated Estimates of Global Dimming Due to ABCs: Chung et al, 2005

Model: Monte Carlo Aerosol Radiation Model

Satellite Observations:

MODIS for Aerosol Optical Depth

AERONET: Ground " Truth "

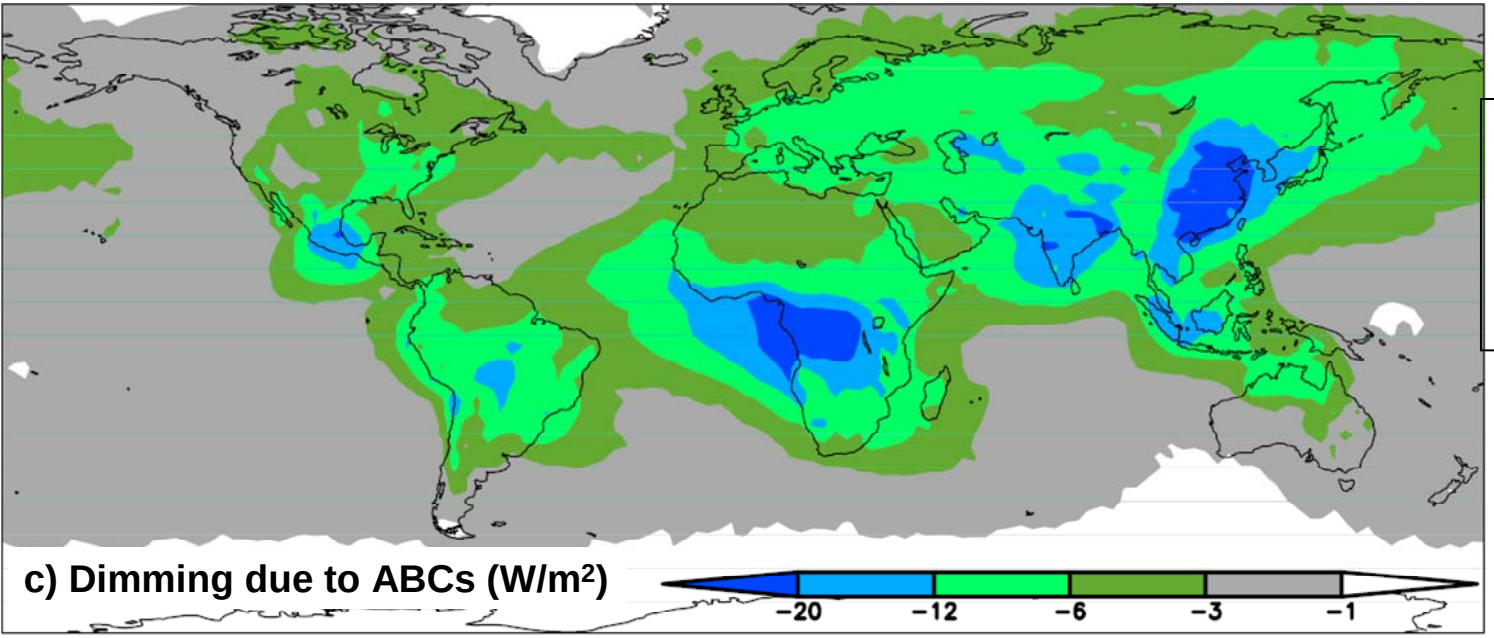
GOCART : Aerosol Assimilation Model for Determining Anthropogenic Fraction

ISCCP: Cloud Data

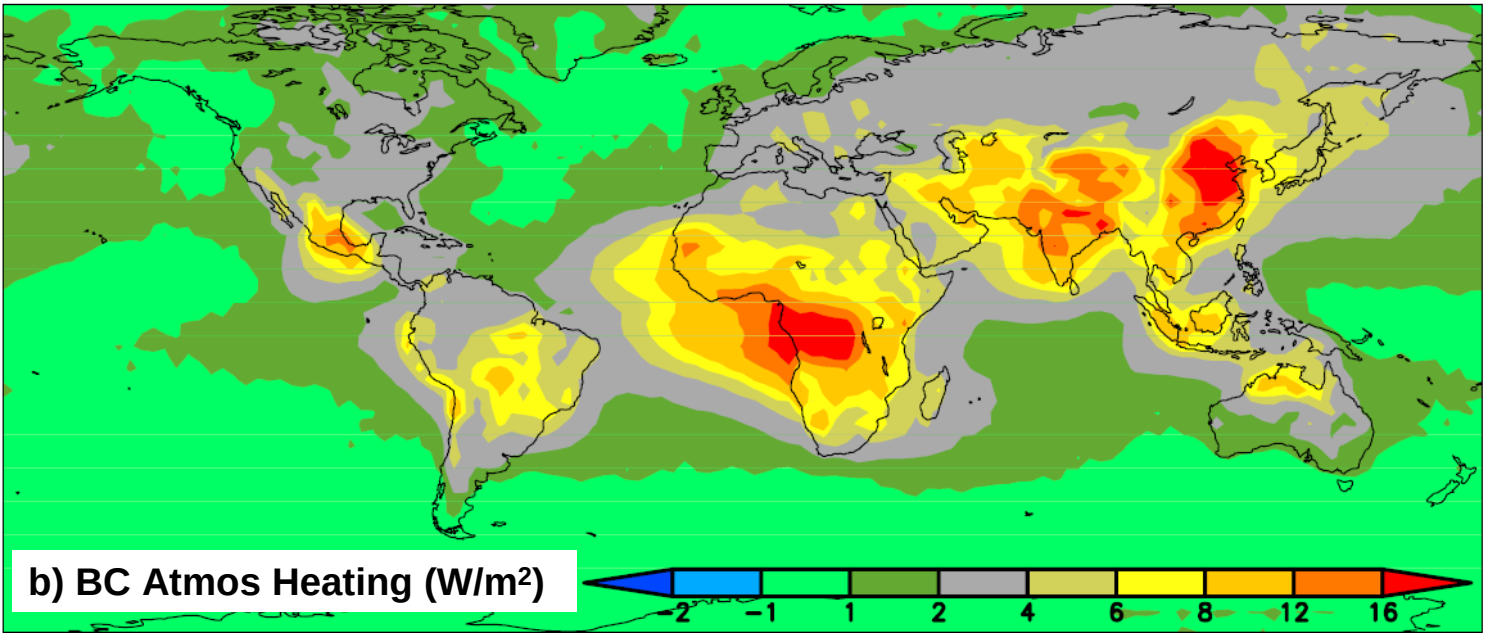
Field Observations : INDOEX; CIFEX; APMEX

Period: 2001 to 2003

Ramanathan et al, 2007; Chung et al, 2005



*Surface Forcing (W/m**2): Dimming*



*Atm Forcing (W/m**2): Solar Heating*

Note: Surface forcing is same as dimming

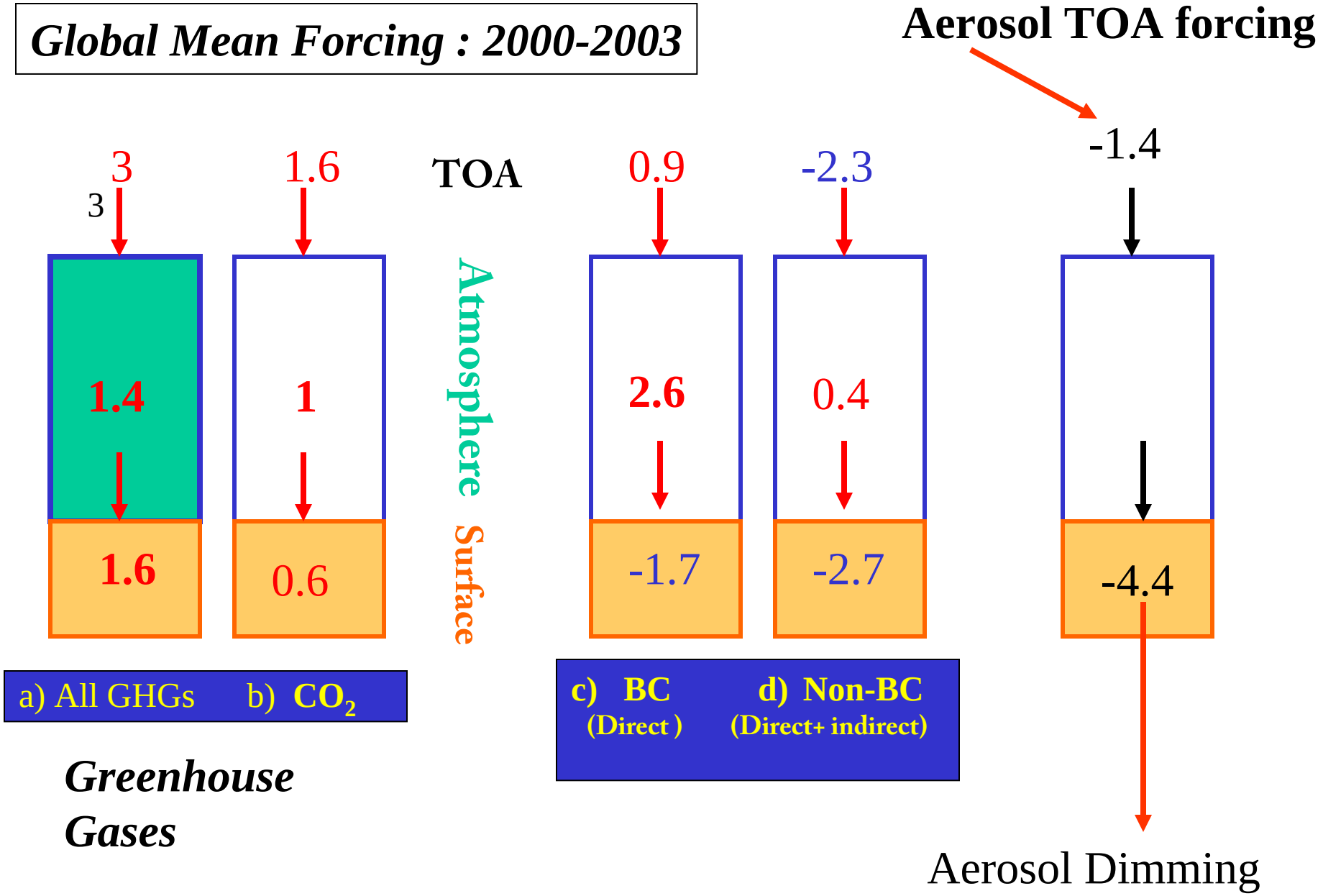
1) Over large land regions the Aerosol forcing at the surface exceeds -20 Wm^{-2}

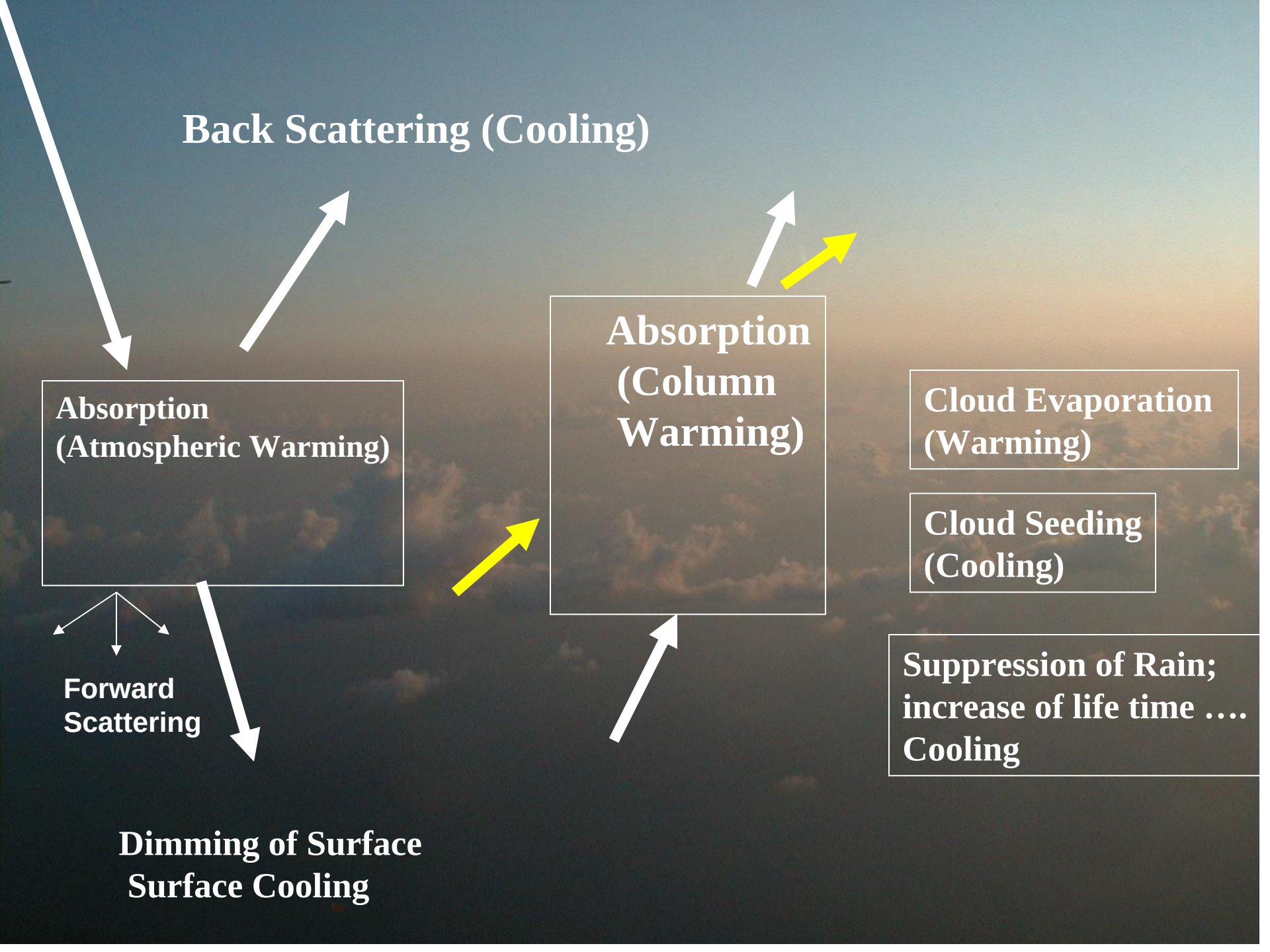
2) When global averaged the dimming is only -4.4 Wm^{-2} (see next fig); It is still significant, however

3) Note that the TOA forcing is a factor of 3 less than the surface forcing; For BC even the sign of the forcing at TOA is different;
Key Lesson: It is misleading, if not erroneous, to compare the dimming With TOA forcing by greenhouse gases;
Reason is: The dimming is largely compensated by aerosol heating Of the atmosphere by solar absorption

4) Note that: if the changes are due to clouds, then the dimming is nearly The same as TOA forcing

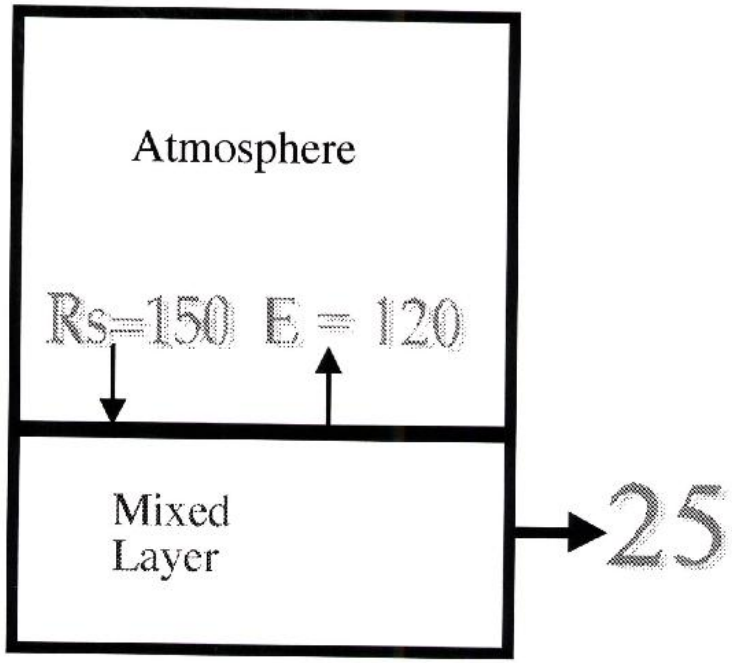
Global Mean Forcing : 2000-2003




Back Scattering (Cooling)
Absorption (Atmospheric Warming)
Forward Scattering
Dimming of Surface
Surface Cooling
Absorption (Column Warming)
Cloud Evaporation (Warming)
Cloud Seeding (Cooling)
Suppression of Rain; increase of life time …. Cooling

The main impact of dimming is on the hydrological cycle.
Dimming should lead to decrease in evaporationa nd precipitation

Annual Mean Surface Heat Budget ($W.m^{-2}$)
20 N to 20 S



Other Major Dimming Factors

Anthropogenic:

Increase in Cloudiness and Cloud OD:
Aerosol-Indirect Effects
Jet Contrails : 2% decade over the US
Increase in Dust Concentration
Cloud Increase: Sea Ice Melting and exposing Open Ocean
Cloudiness Changes due to Land Use Changes

Natural Variations:
Change in Cloudiness Due to AO, PDO, ElNino

Dust Loading due to Desertification

1) The Dimming Observations are mostly land based observations and are mainly from 1950s to 1990s; nevertheless, they seem to indicate a global scale phenomenon; but the magnitude inferred from land observations may exaggerate global means.

2) Atmospheric Brown Clouds with absorbing Aerosols are found in most regions of the planet;

3) The ABC induces dimming is about -5 Wm^{-2} for the 2000-2003 period; But its trend (change with time from 1950 to now) needs to be determined

4) The ABC related dimming is balanced mostly by a corresponding increase in atmospheric solar heating

5) Its main effect is stabilization of the column and a decrease in global average precipitation; and a cooling of the land during the dry season

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- ABC: UNEP& Colleagues from China/ Germany/Japan/ S. Korea/ India/Sweden
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