

*Contribution of Black Carbon and Atmospheric
Brown Clouds to Climate Warming:
Impacts and Opportunities*

V. Ramanathan

Scripps Institution of Oceanography, UCSD

AMS Environmental Science Seminar Series

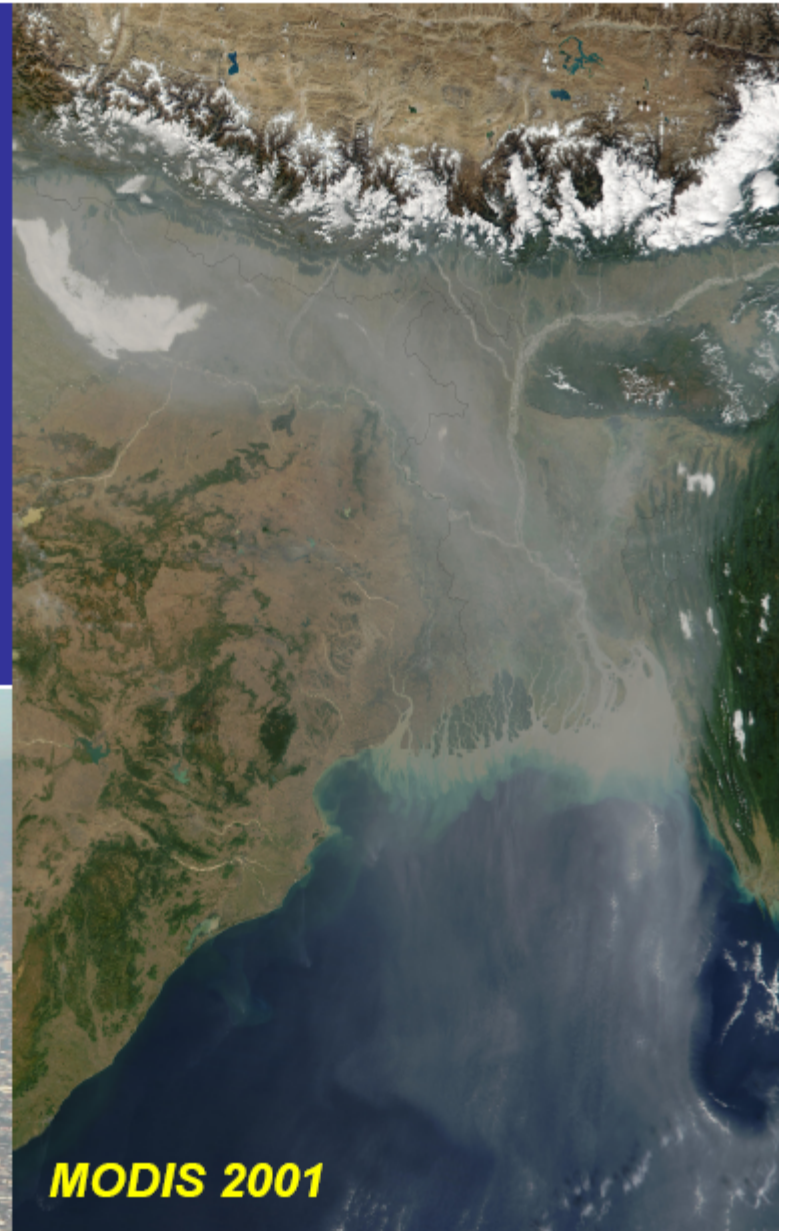
Russell Senate Office Building

May 16 2008



Los Angeles Smog, Dec 27, 2002

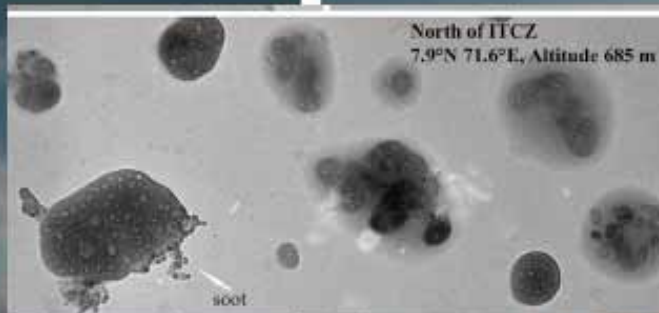
Ramanathan



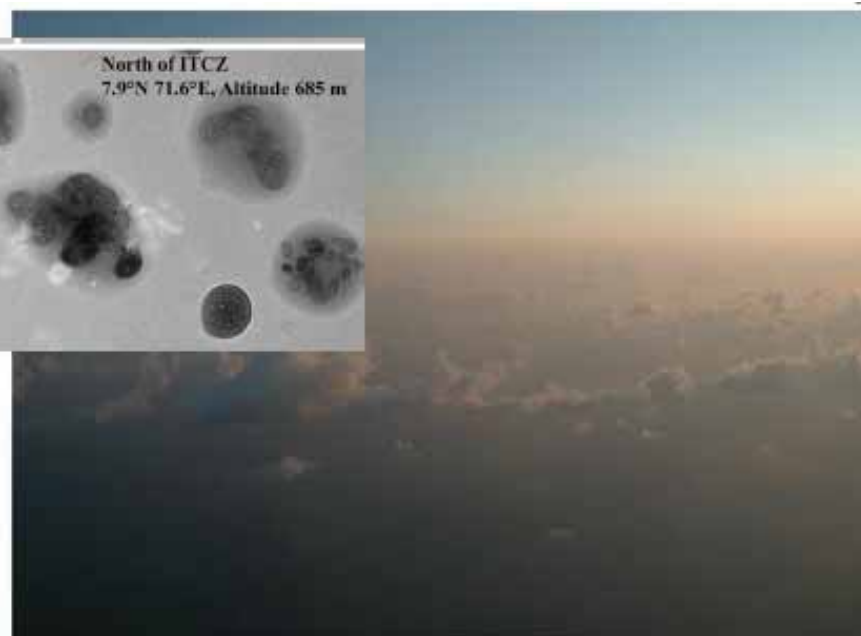
MODIS 2001

ABCs over S Asia

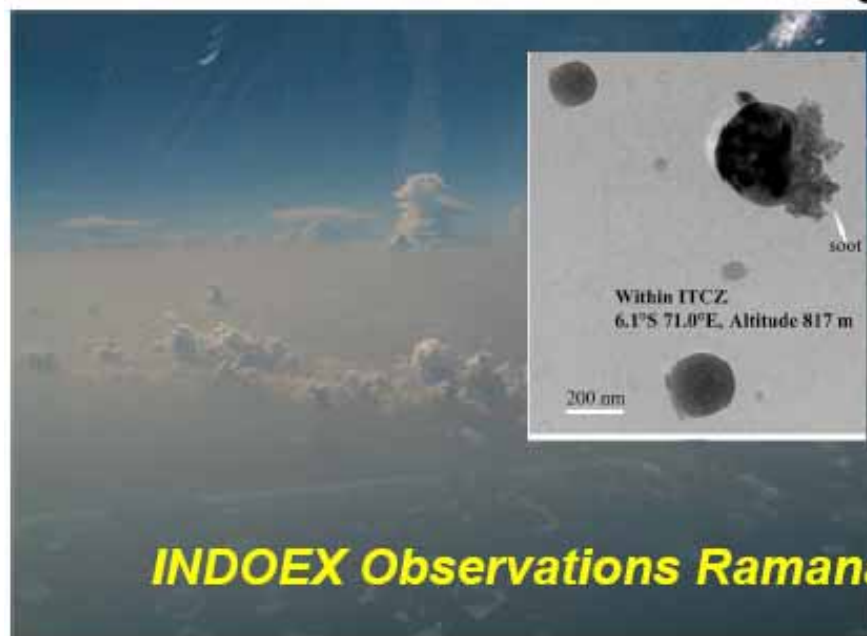
Satheesh
& Ramanathan, 2000



March 21, 1999: Arabian Sea; Thick haze (9.2°N, 73.5°E)

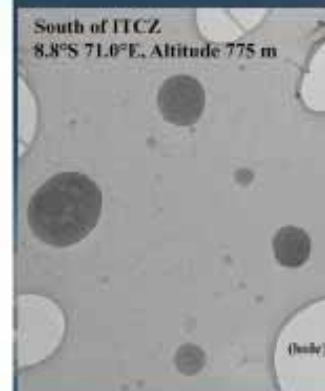
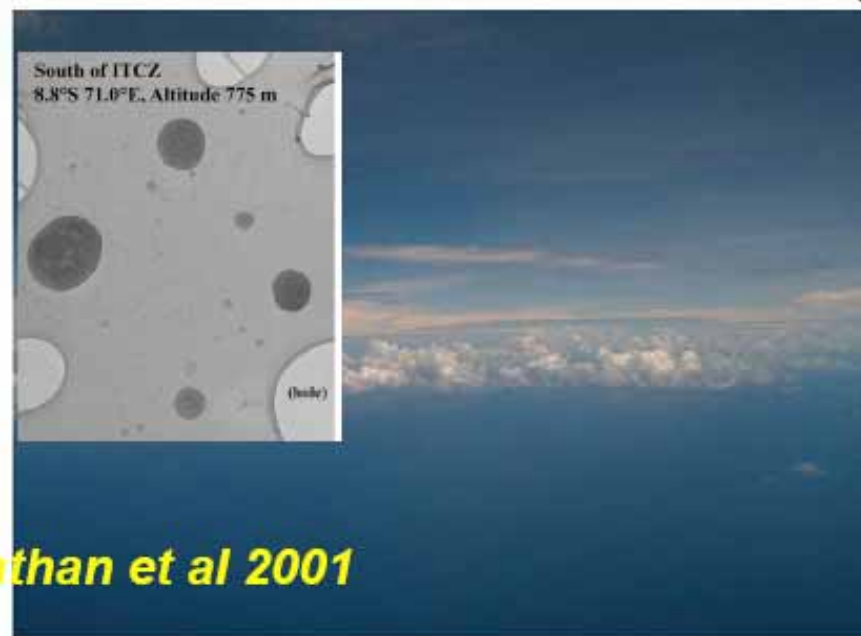


March 25, 1999: Clouds under thick haze (3.0°N, 74.5°E)



INDOEX Observations Ramanathan et al 2001

February 24, 1999: Just North of ITCZ;
Haze extends up to top of Cu (0.5°N, 73.3°E)



March 24, 1999: South of ITCZ;
Almost pristine clouds (7.5°S, 73.5°E)

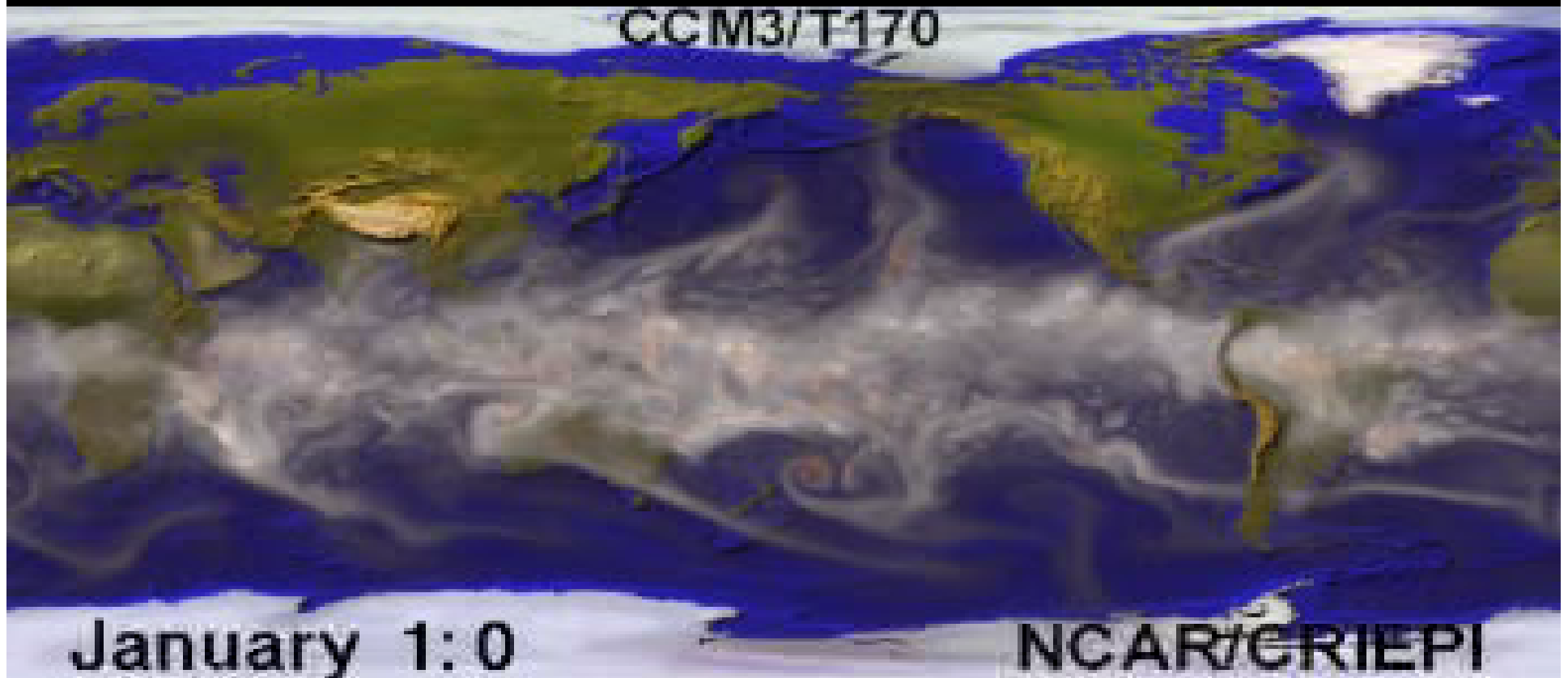


Sources of greenhouse Gases and Aerosols in Brown Clouds.

Ramanathan et al 2007

Global Atmosphere

Source: Washington, NCAR, 2005



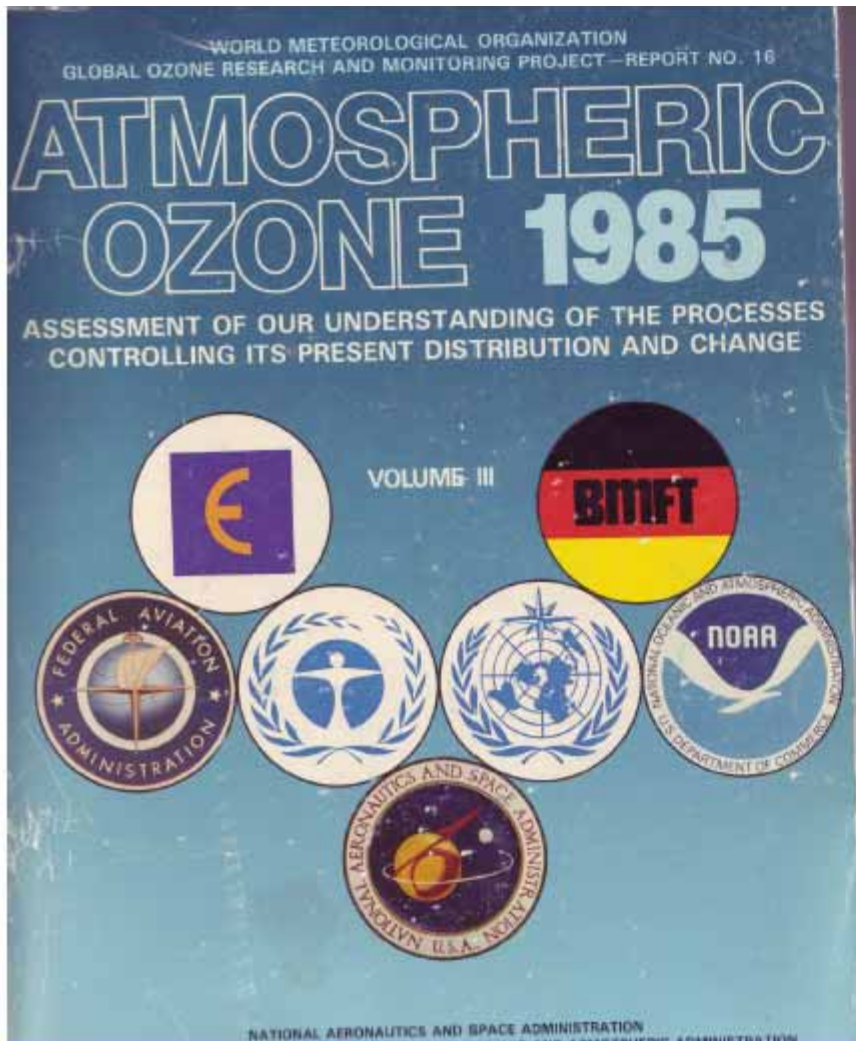
COMPONENTS OF EARTH RADIATION BUDGET

Solar
Incident
Energy

Solar
Reflected
Energy

Earth
Emitted
Energy

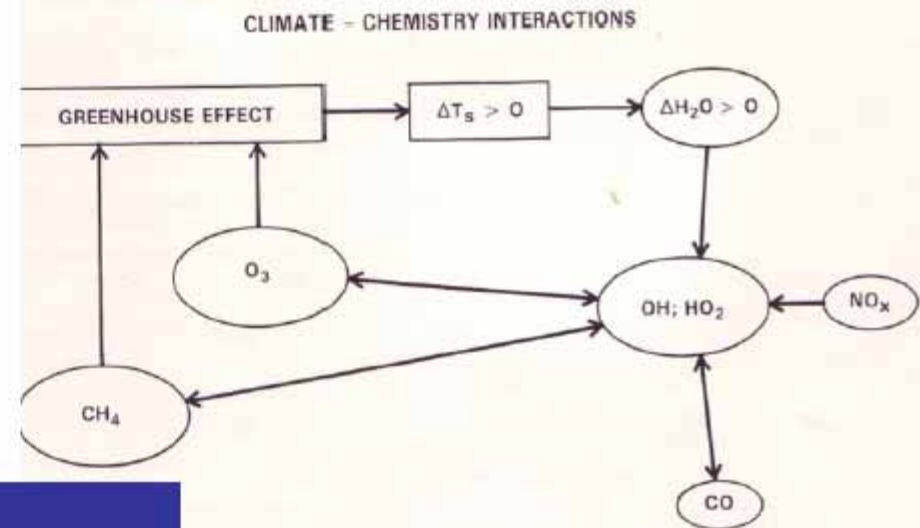
Ramanathan et al 2007; Original from NASA-Langley



**The Non-CO₂ trace gases contribute as much as CO₂ to the increase in atmospheric Greenhouse effect:
Ramanathan et al, JGR, 1983**

CHAPTER 15

TRACE GAS EFFECTS ON CLIMATE



Panel Members

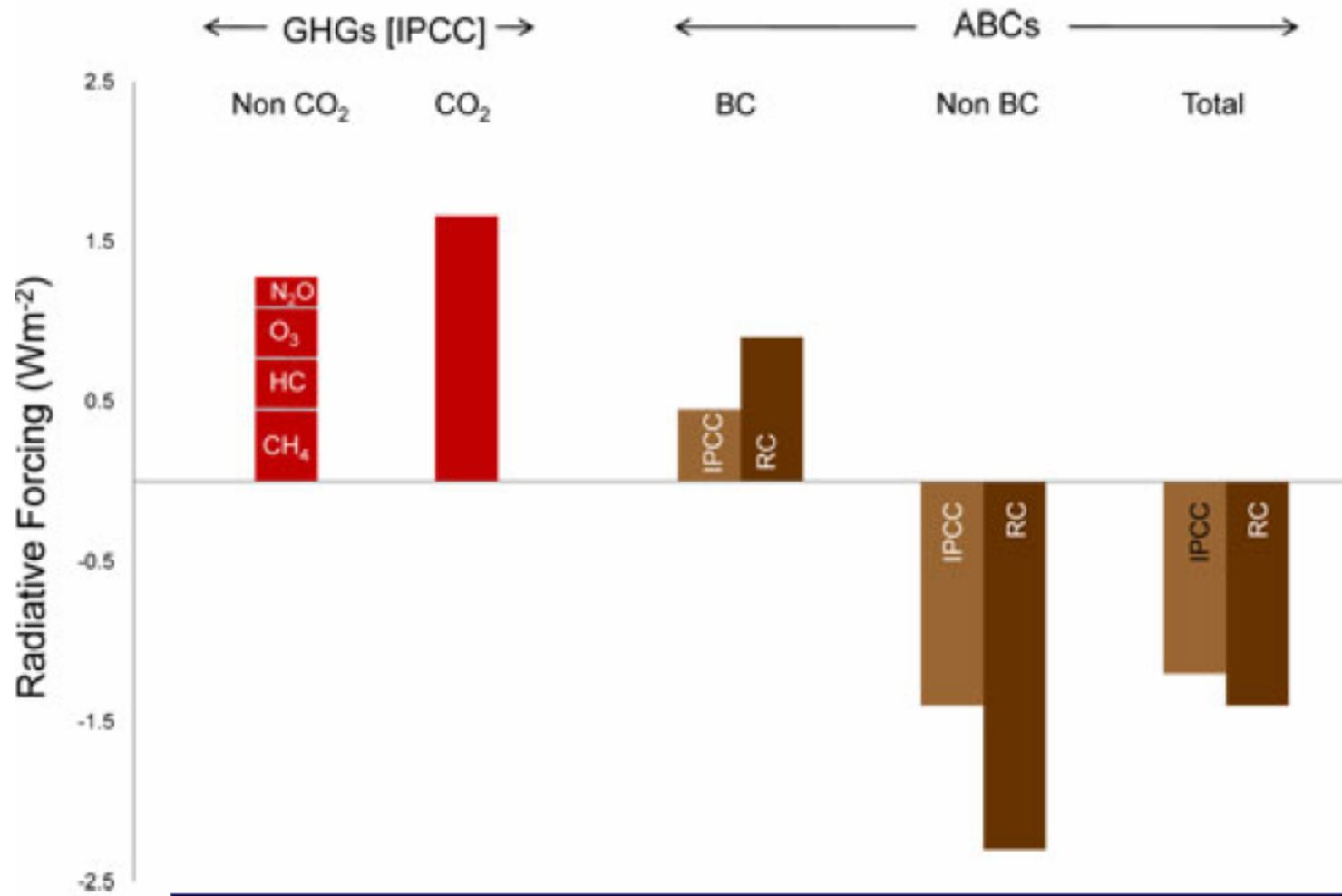
V. Ramanathan, Chairman

L.B. Callis, Jr.	A. Lacis
R.D. Cess	F.M. Luther
J.E. Hansen	J.D. Mahlman
I.S.A. Isaksen	R.A. Reck
W.R. Kuhn	M.E. Schlesinger

Global and regional climate changes due to black carbon

V. RAMANATHAN AND G. CARMICHAEL

nature geoscience | VOL 1 | APRIL 2008 | www.nature.com/naturegeoscienc



For high BC heating, also see: Jacobson, 2001; Hansen and Nazarenko, 2004; Chung and Seinfeld, 2005

Detecting Climate Change due to Increasing Carbon Dioxide

Roland A. Madden and V. Ramanathan

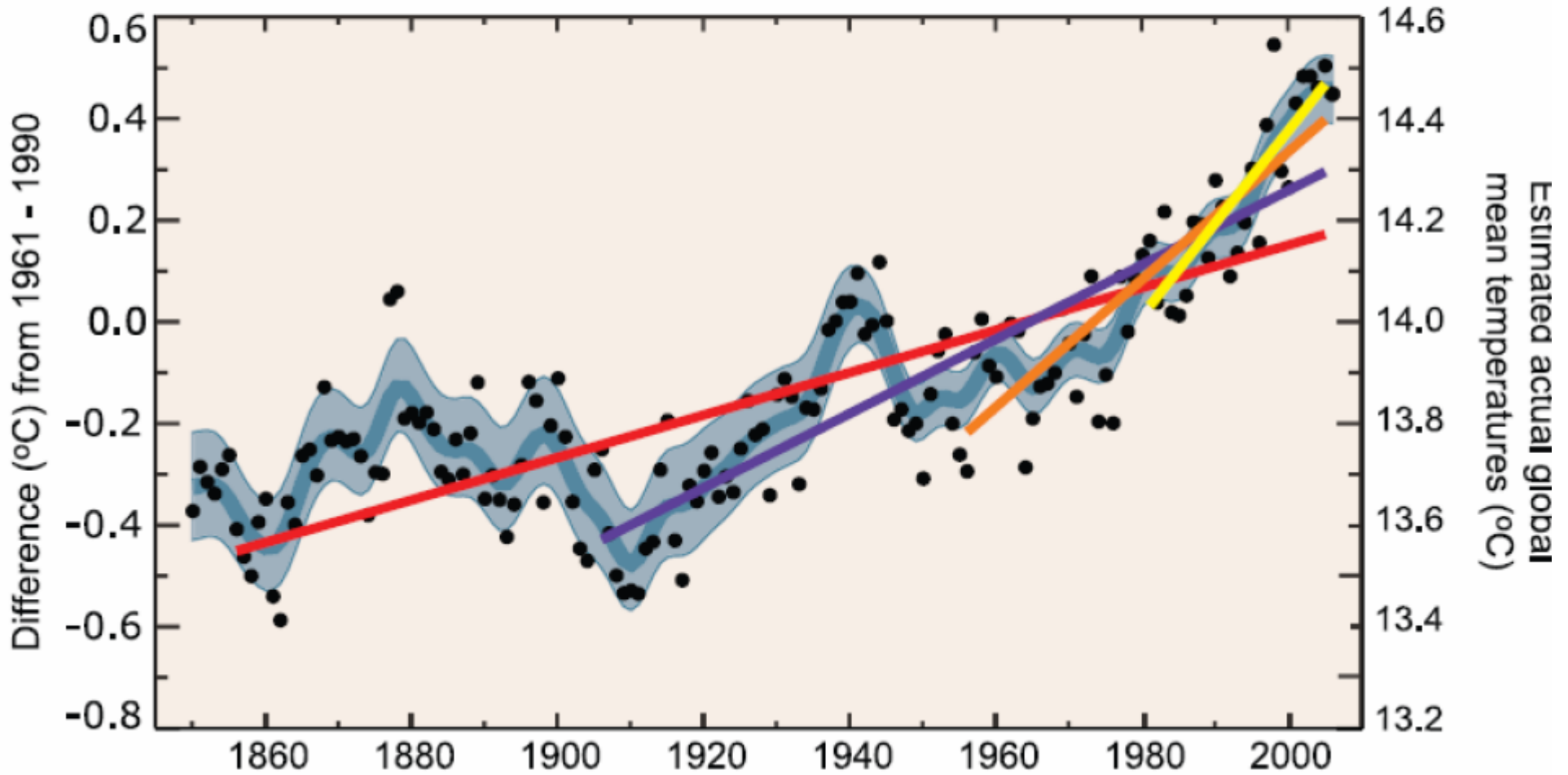
The possible climatic effects of large increases in atmospheric CO₂ due to burning of fossil fuels may constitute one of the important environmental problems of the coming decades. Research efforts are being made to reduce the large uncer-

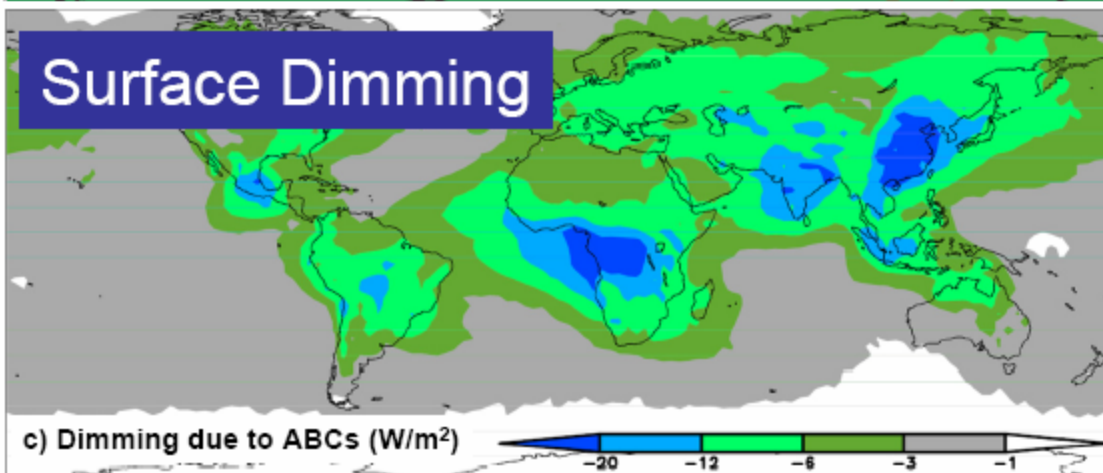
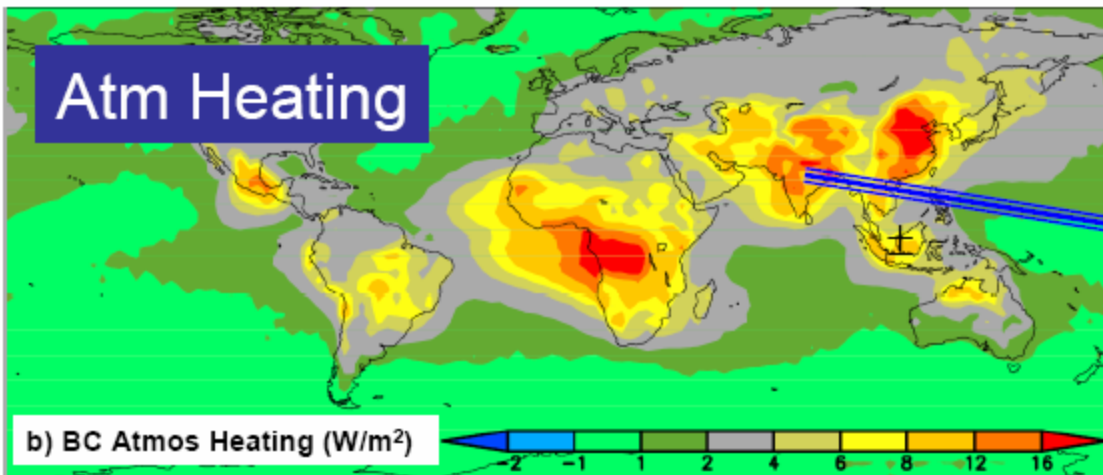
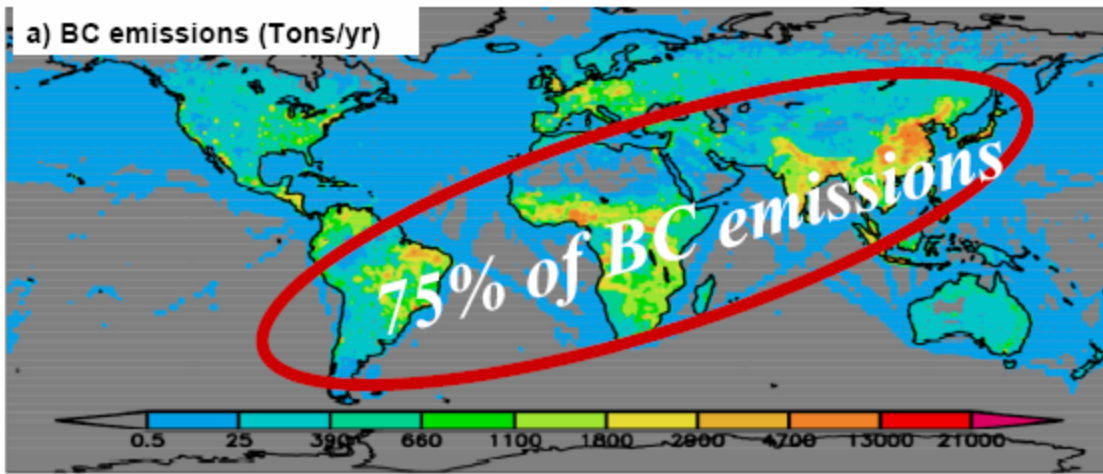
We first discuss a long time series of surface temperatures and the rationale on which our estimates of the inherent variability or noise are based. Next we present the model results for surface warming due to the CO₂ increase. By

Summary. The observed interannual variability of temperature at 60°N has been investigated. The results indicate that the surface warming due to increased carbon dioxide which is predicted by three-dimensional climate models should be detectable now. It is not, possibly because the predicted warming is being delayed more than a decade by ocean thermal inertia, or because there is a compensating cooling due to other factors. Further consideration of the uncertainties in model predictions and of the likely delays introduced by ocean thermal inertia extends the range of time for the detection of warming, if it occurs, to the year 2000. The effects of increasing carbon dioxide should be looked for in several variables simultaneously in order to minimize the ambiguities that could result from unrecognized compensating cooling.

“Unequivocal” Warming of the Planet: IPCC, 2007

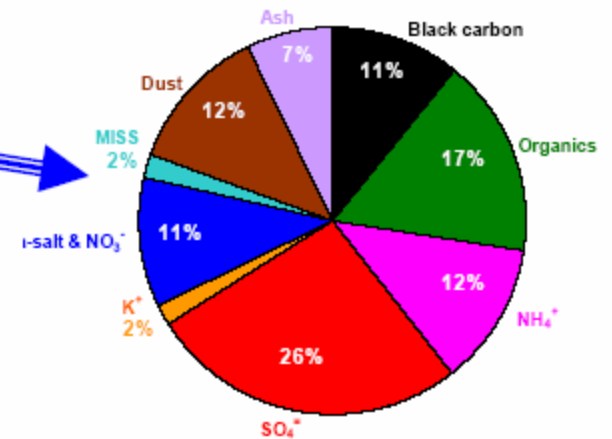
Global Mean Temperature





ABCs: Emission & Global Forcing

Ramanathan and Carmichael, Nature_Geoscience 2008



Ramanathan et al, 2001

2 August 2007 | www.nature.com/nature | \$10

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

nature



**TRAUMATIC
BRAIN INJURY**
Consciousness
raising therapy

**VERTEBRATE
ORIGINS**
Gone fishing

**EATING IN THE
GREENHOUSE**
Are high-CO₂
crops bad for you?



THE HEAT IS ON

Atmospheric brown
clouds enhance
climate warming



NATUREJOBS
Atmospheric science



*Warming Trends in Asia
amplified by brown cloud
solar absorption*

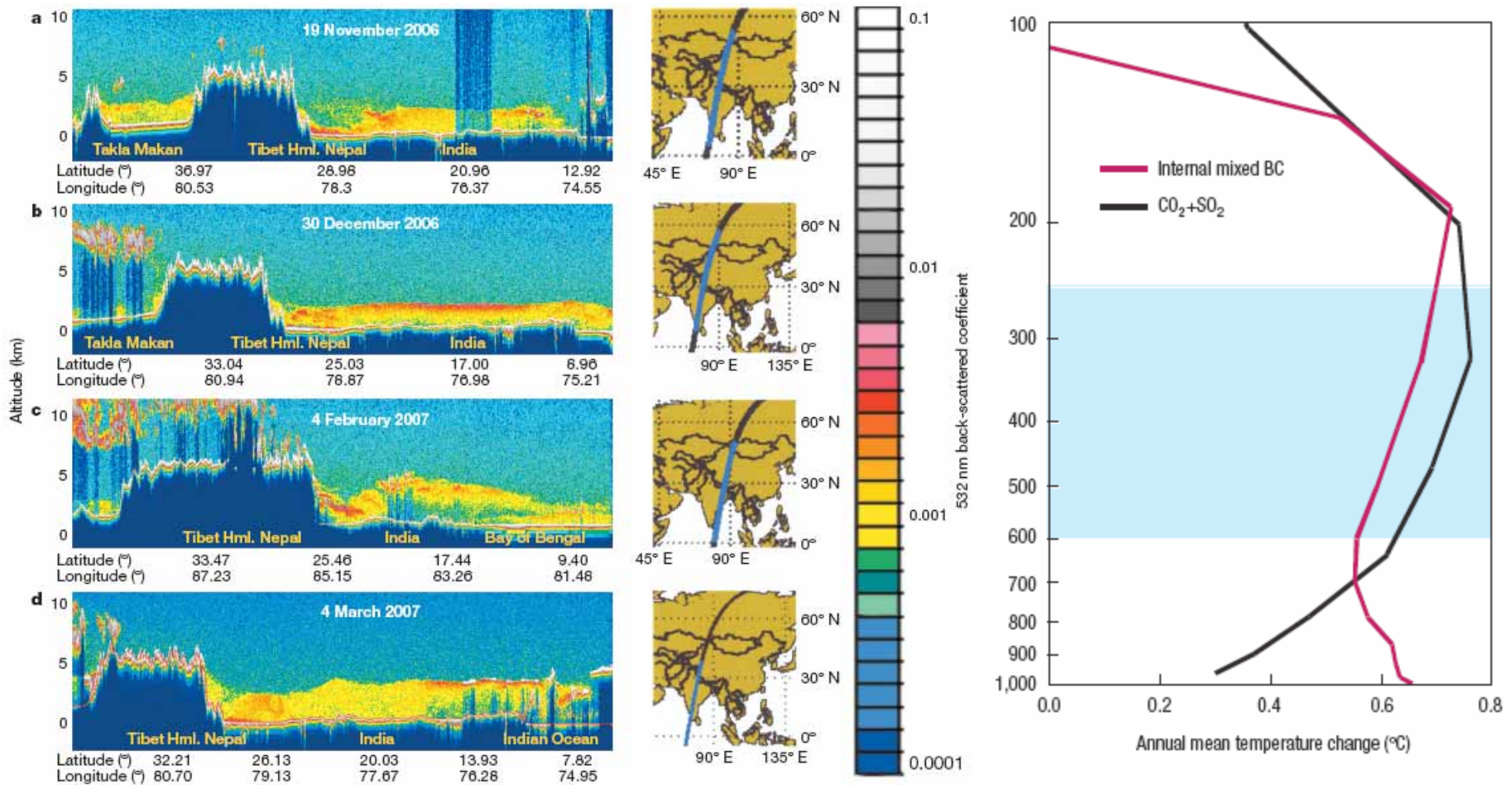
*Ramanathan et al, Nature, 448,
575-578, 2007.*



Warming trends in Asia amplified by brown cloud solar absorption

Nature Aug 2007

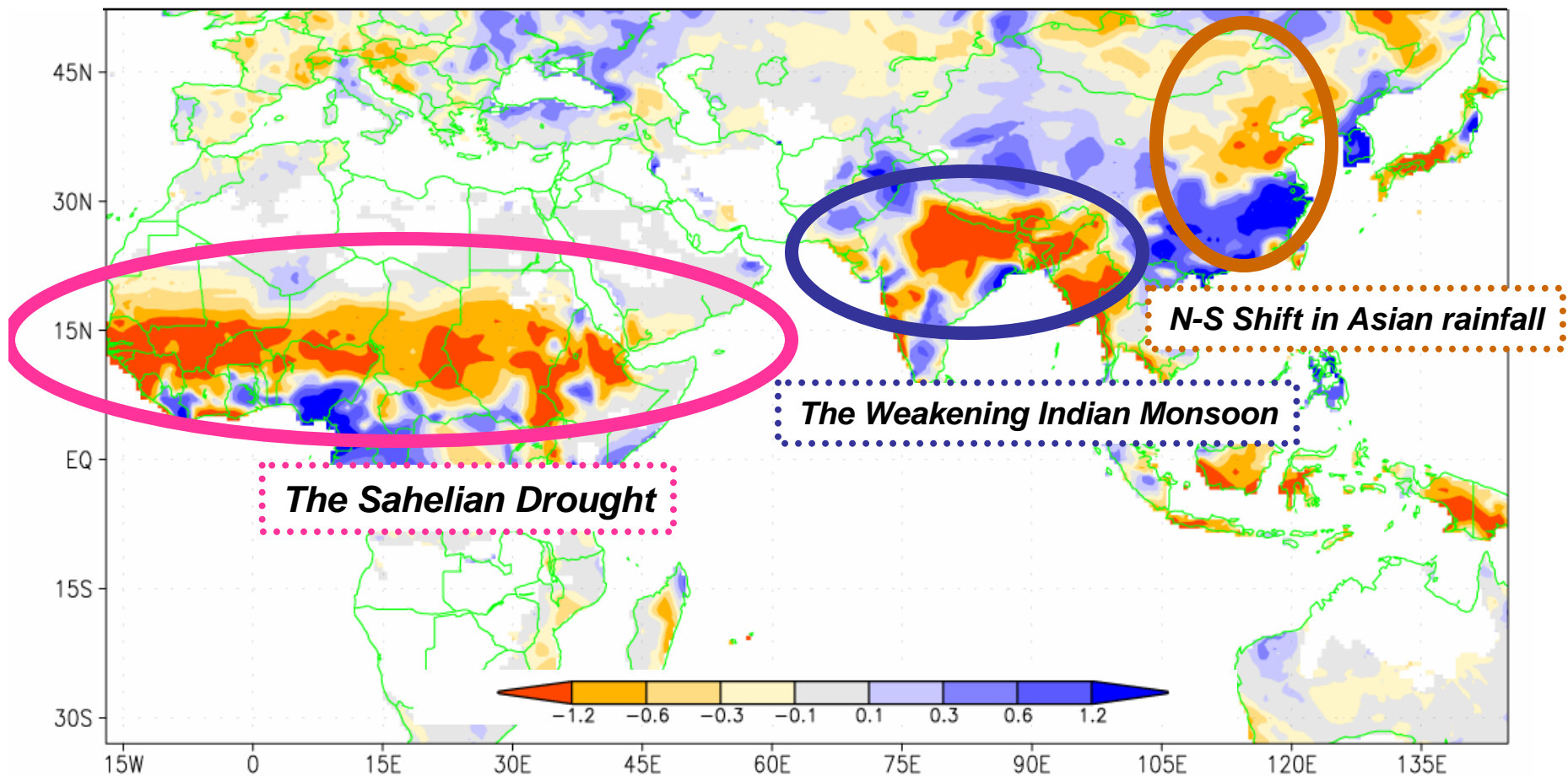
Veerabhadran Ramanathan¹, Muvva V. Ramana¹, Gregory Roberts¹, Dohyeong Kim¹, Craig Corrigan¹, Chul Chung¹ & David Winker²



Major Rainfall Shifts during the last 50 Years

Chung and Ramanathan 2006

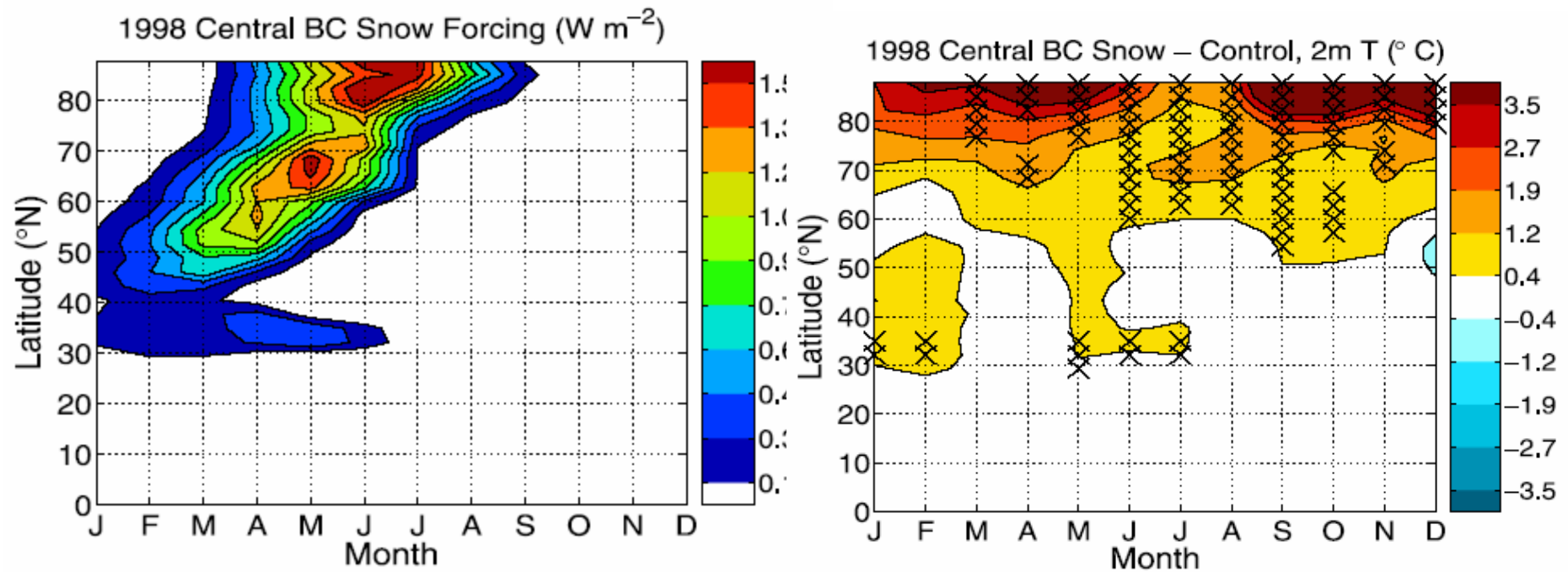
Observed Trends in Summer Rainfall: 1950 to 2002



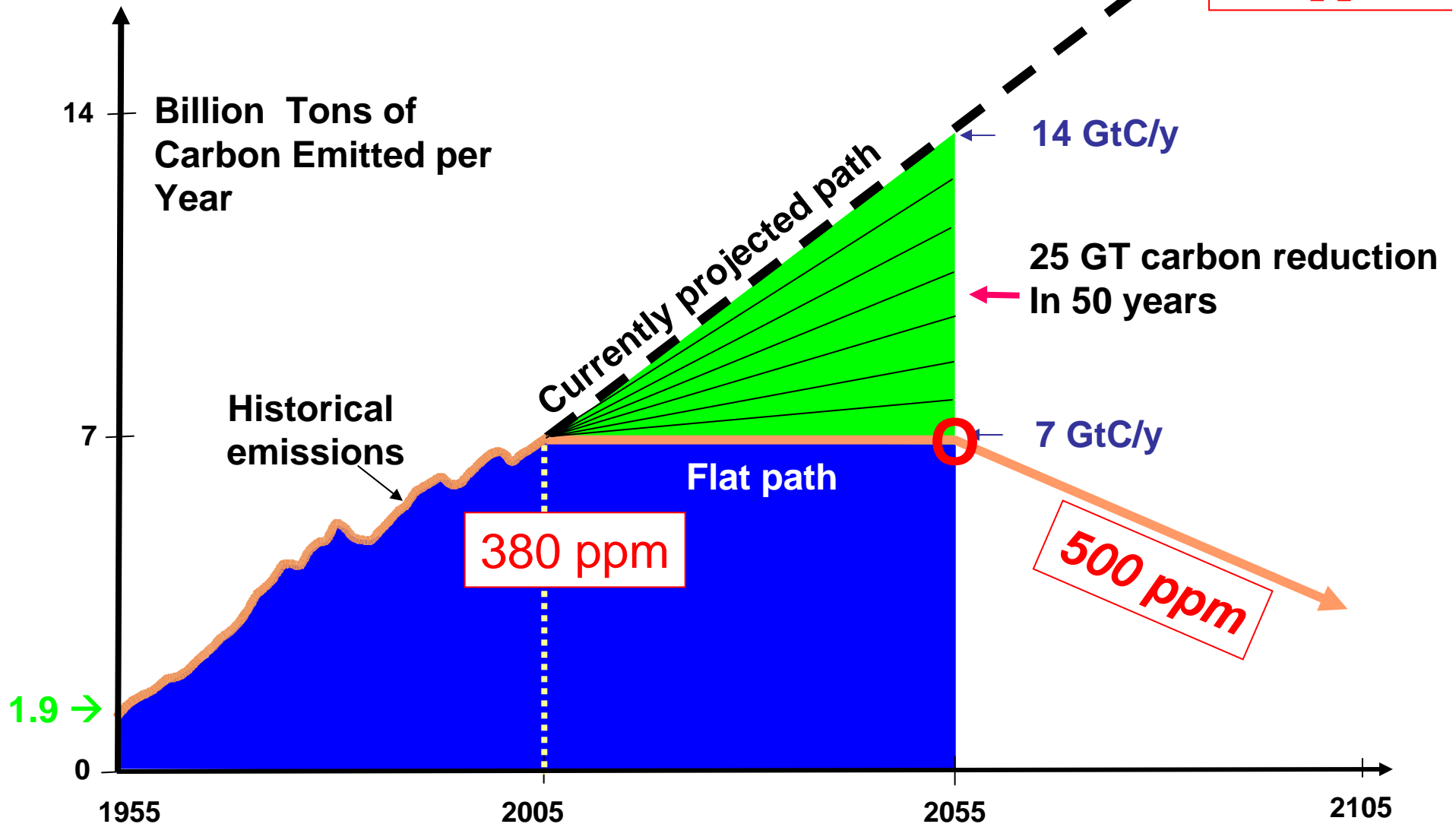
Black Carbon deposition on Snow is a major source for arctic sea ice retreat

Present-day climate forcing and response from black carbon in snow

Mark G. Flanner,¹ Charles S. Zender,¹ James T. Randerson,¹ and Philip J. Rasch²



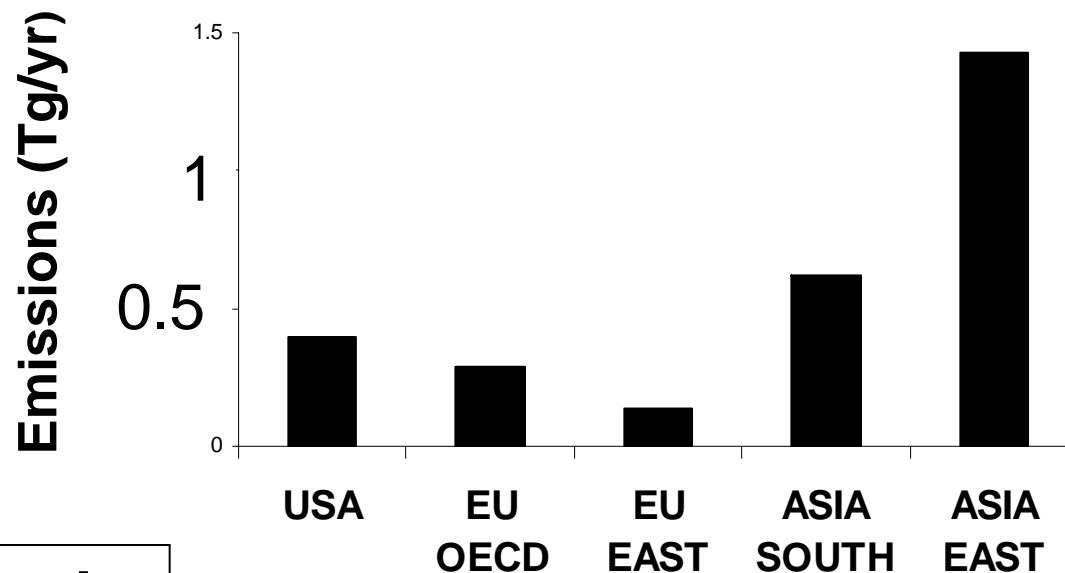
Wedge Approach { Pacala and Socolow, 2005}



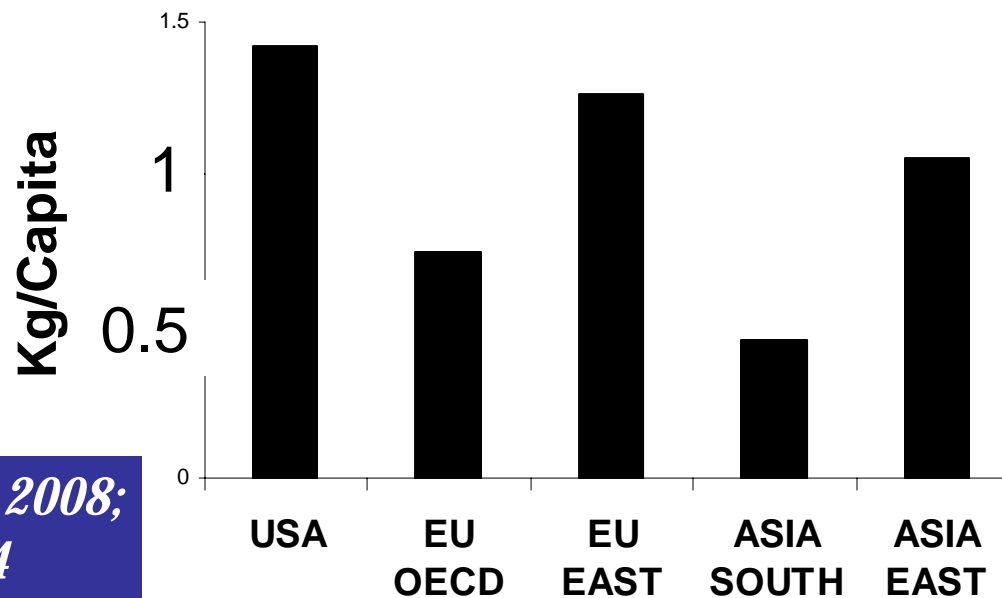
10-20% reduction in black carbon emissions would accomplish the task of 1 wedge.. Buy the planet some time



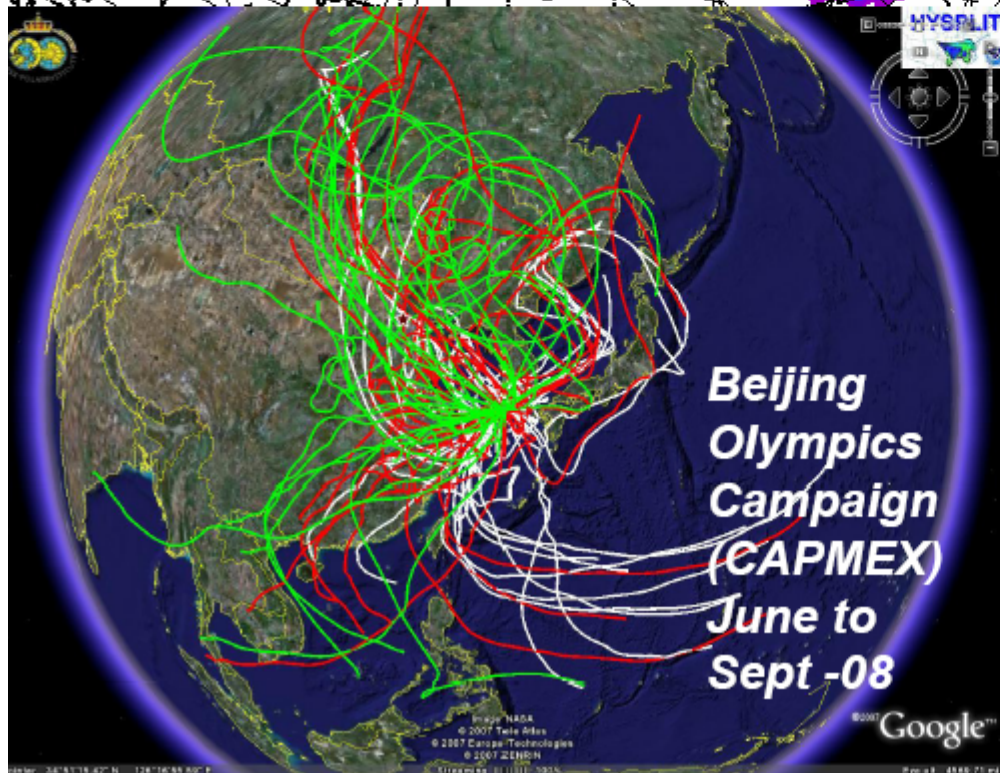
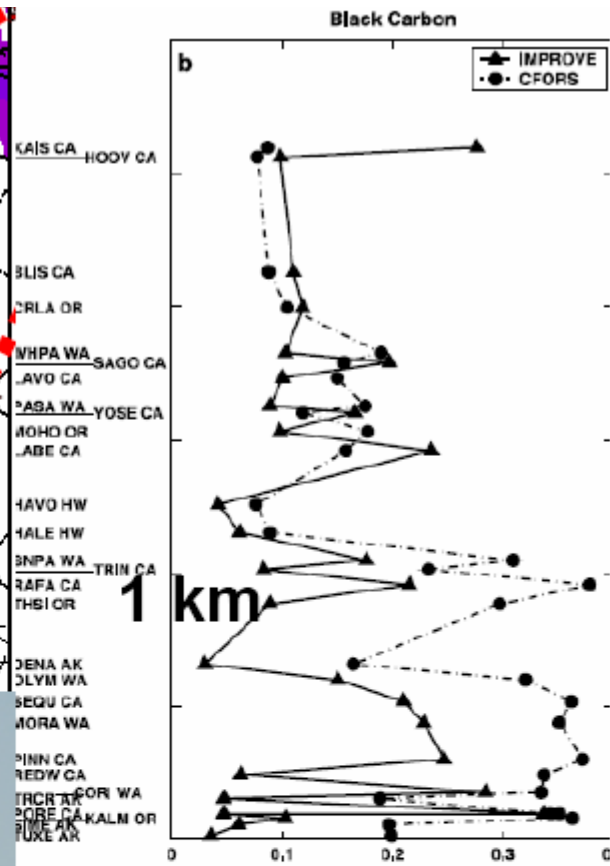
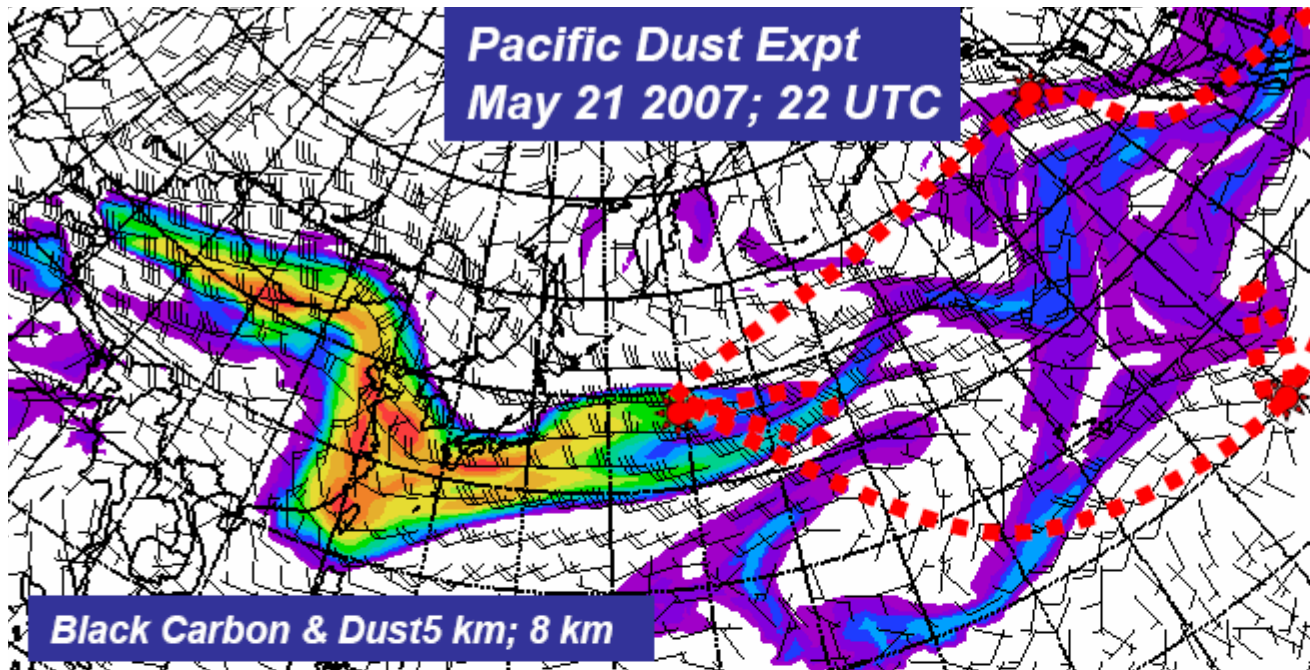
BC emission



BC Emission/Capita



*Ref: Ramanathan and Feng, 2008;
Data source: Bond et al 2004*



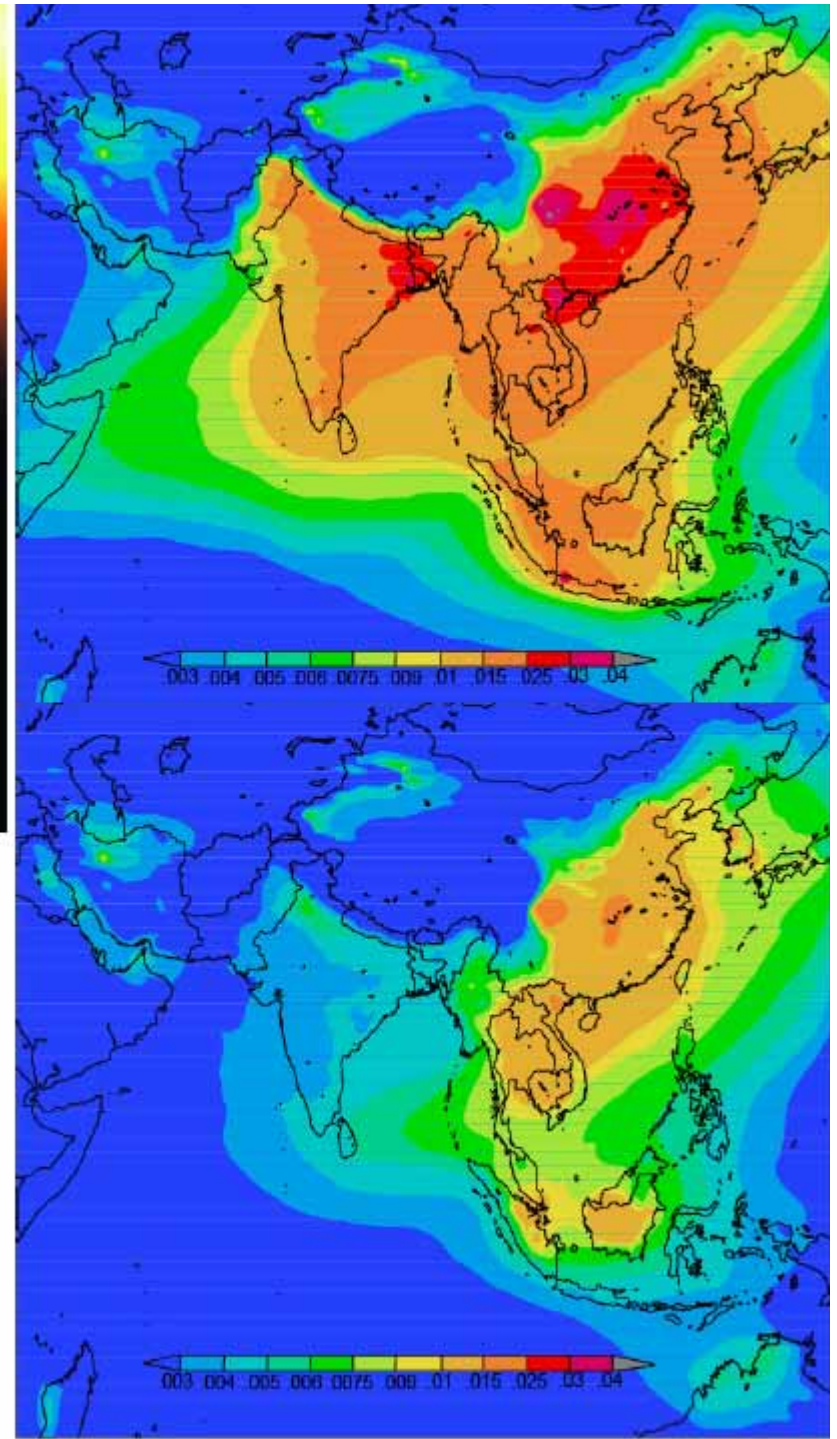
Source:
 Hadley et al, 2006;
 Stith and Ramanathan, 2006;
 Ramanathan and Corrigan, CAPPs proposal
 Ramanathan &

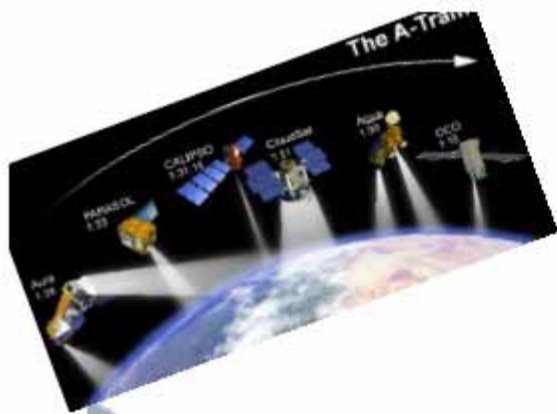
PROJECT SURYA सूर्य

Reduction of Air Pollution and Global Warming by
Cooking with Renewable Sources



Ramanathan & Balakrishnan, 2007





Surya Observing System



ABC Observatories



**Indoor cheap sensors:
2000 sensors**

**Traveling
Laboratory**



Physicians

Ramanathan and Balakrishnan, 2007

Basically a win-win proposal

Summary: Principal Advantages of BC

Short Lifetime (order of days)

We know how to reduce it.



- **A 10%-20% reduction in global BC emissions would be a wedge = 25 GT of carbon as CO₂**

2) Regionally (Polar and Asian)

- * **reduces melting of snow packs and glaciers in Himalayas**
- * **reduces retreat of arctic sea ice**
- * **Mitigates slow down of monsoon**
- * **saves about 500000 premature deaths (just in India) from smoke inhalation**
- * **Rural development & poverty alleviation(women have more time for other gainful employment)**
- * **steering 1 billion rural Asians towards green technology**

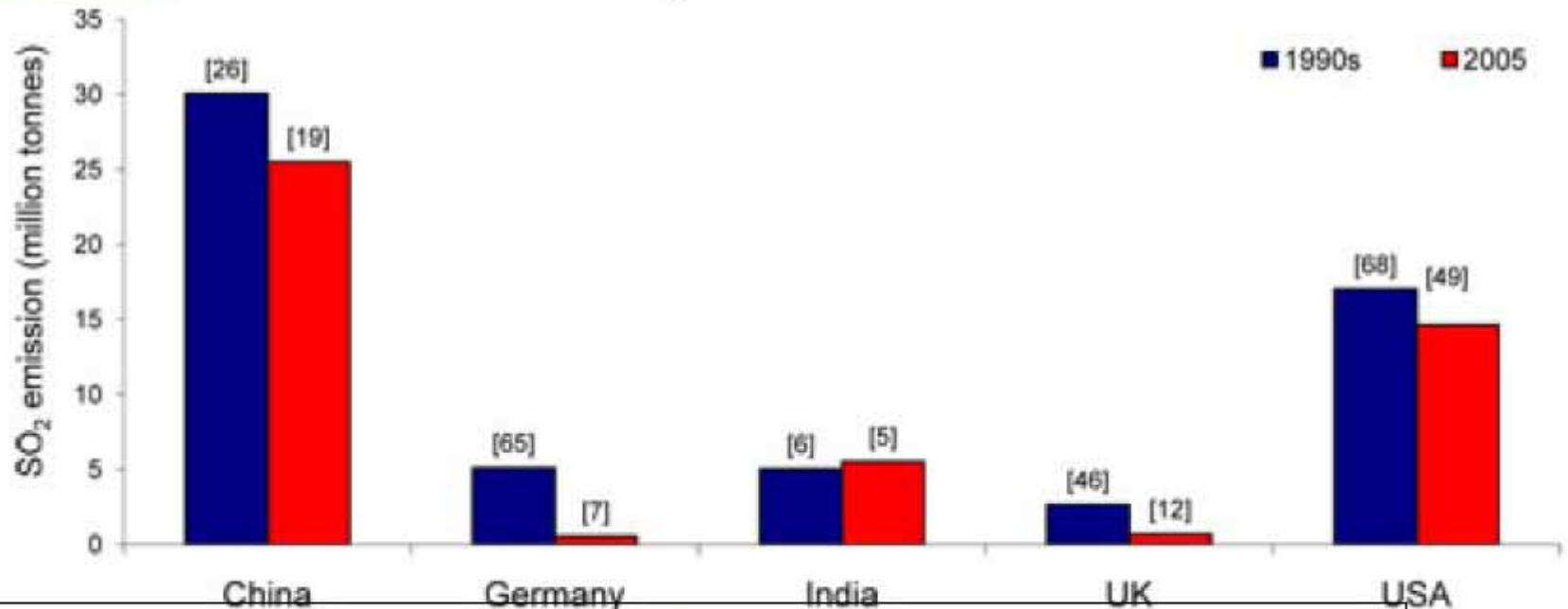
****** *BC reduction is not a substitute for CO₂ reduction* ******



How should We Unmask the ABC Effect ?

.....With great care. Same care we give for decommissioning thermonuclear devices

SO₂ Emissions



Research Funded by NSF; NOAA; California Energy Commission; Vetlesen Fndn

Major Environmental Problems: Intersecting Issues

*Research Funded
by
NSF;
NOAA;
California Energy
Commission;
Vetlesen Fndn*

*Air
Pollution*

*Haze ; Smog;
Aerosols; Acid
rain*

*Ozone
Depletion*

*Greenhouse
gases & Global
Warming*

Ramanathan 2008