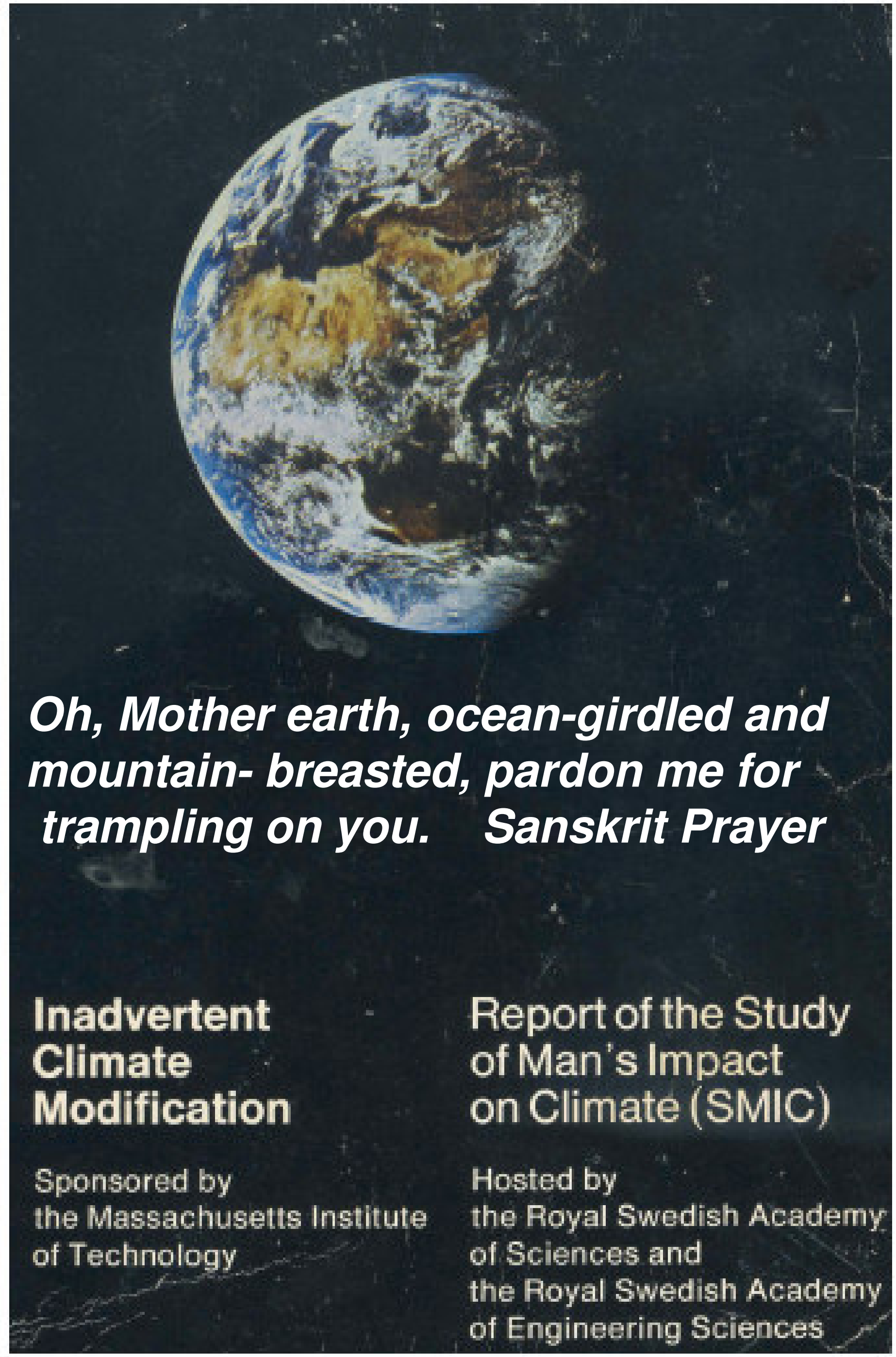
Black carbon & India

V. Ramanathan,
Scripps Institution of Oceanography
Environmental Ministry Meeting
Hotel Ashok, New Delhi, India, Oct 14, 20



Reprinted from
3 October 1975, Volume 190, pp. 50-52

SCIENCE

1975

Greenhouse Effect Due to Chlorofluorocarbons: Climatic Implications

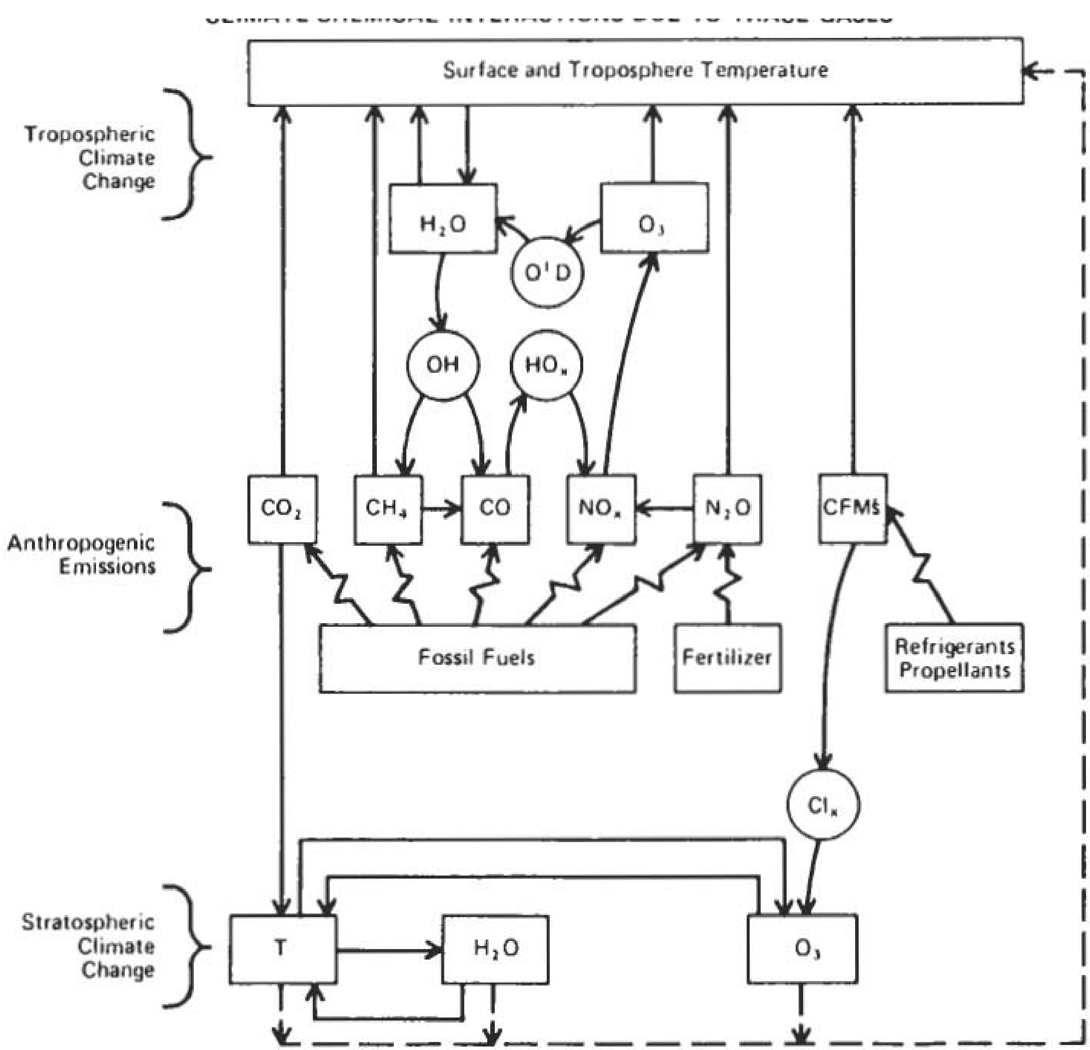
V. Ramanathan

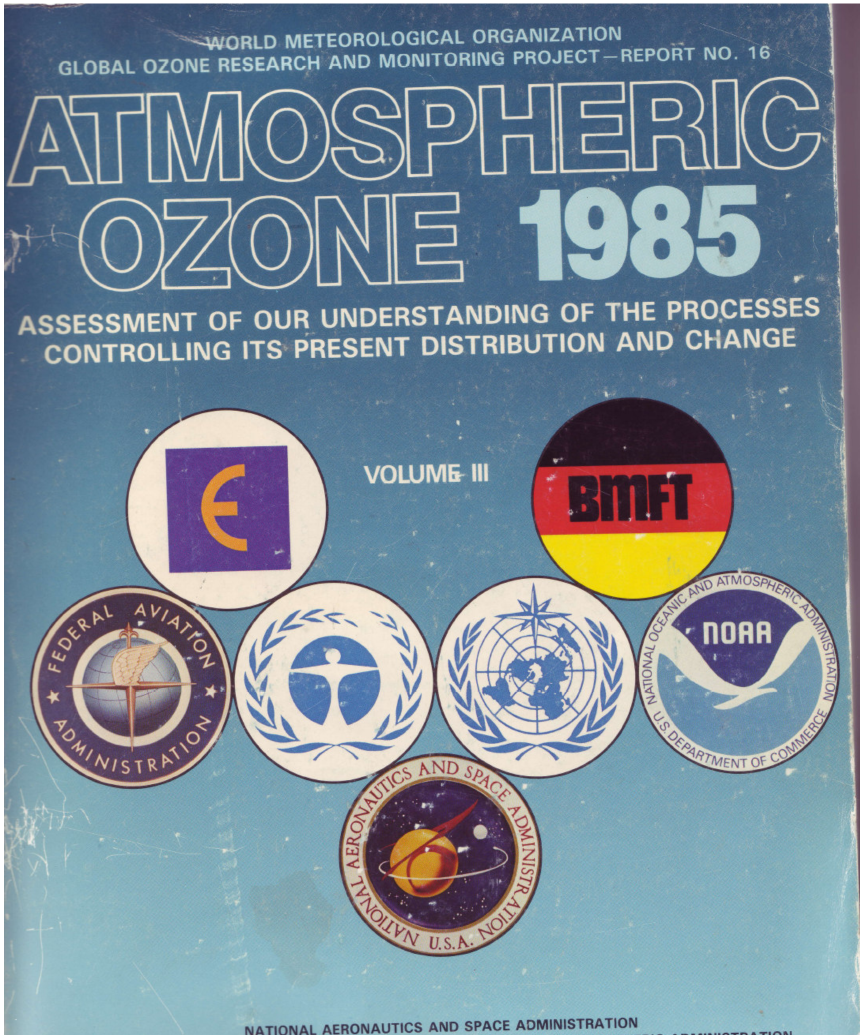
Abstract. ***The infrared bands of chlorofluorocarbons and chlorocarbons enhance the atmospheric greenhouse effect. This enhancement may lead to an appreciable increase in the global surface temperature if the atmospheric concentrations of these compounds reach values of the order of 2 parts per billion.***

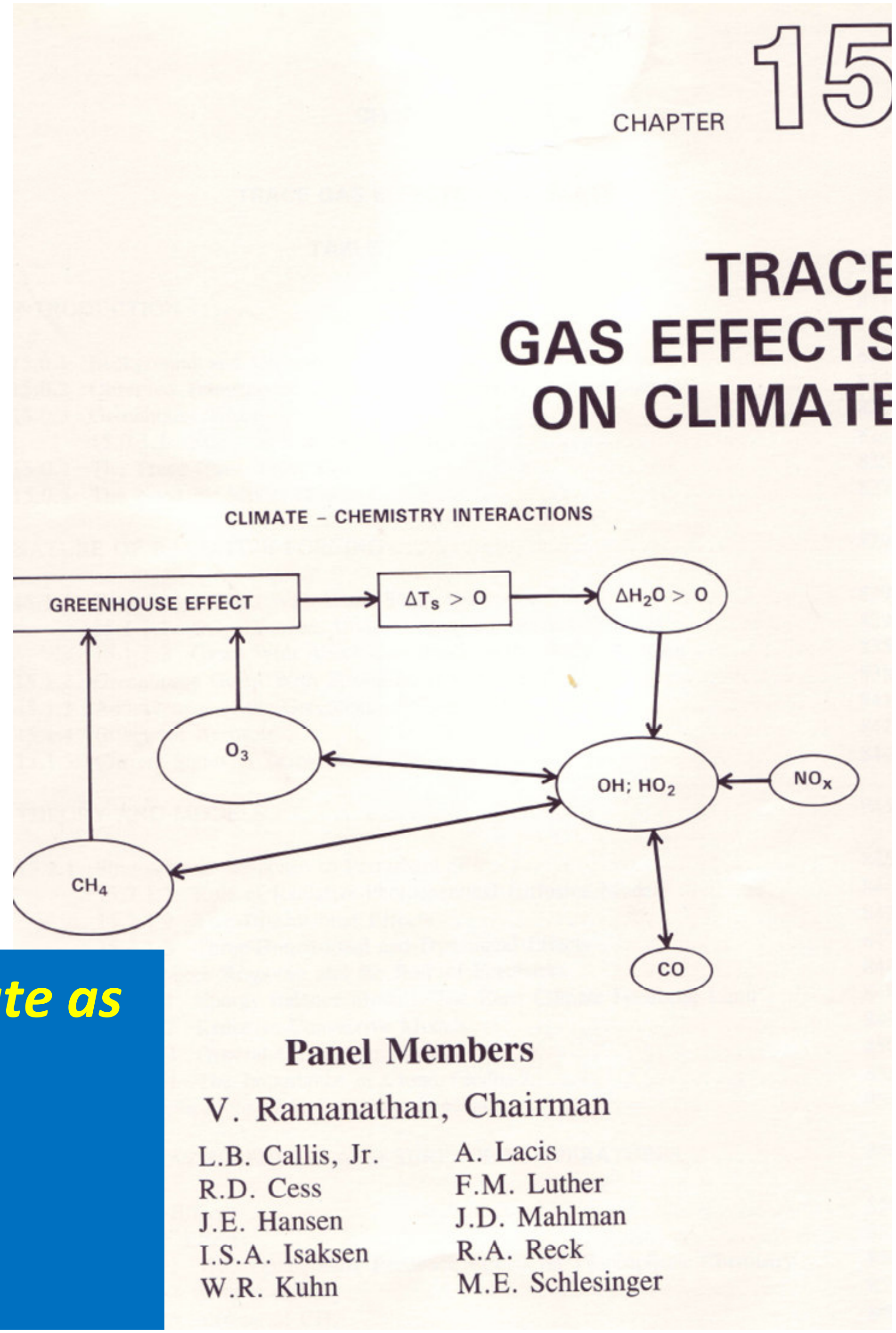
One molecule of CFC has the same greenhouse effect as the addition of more than 10000 molecules of Carbon Dioxide to the Atmosphere

Climate- Chemical Interactions due to Trace Gases

Ramanathan, V., 1980: in Interactions of Energy and Climate, (D. Reidel Publishing Co., 1980), pp. 269-280.






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

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

15 August 1980, Volume 209, Number 4458 SCIENCE

1980

Detecting Climate Change due to Increasing Carbon Dioxide

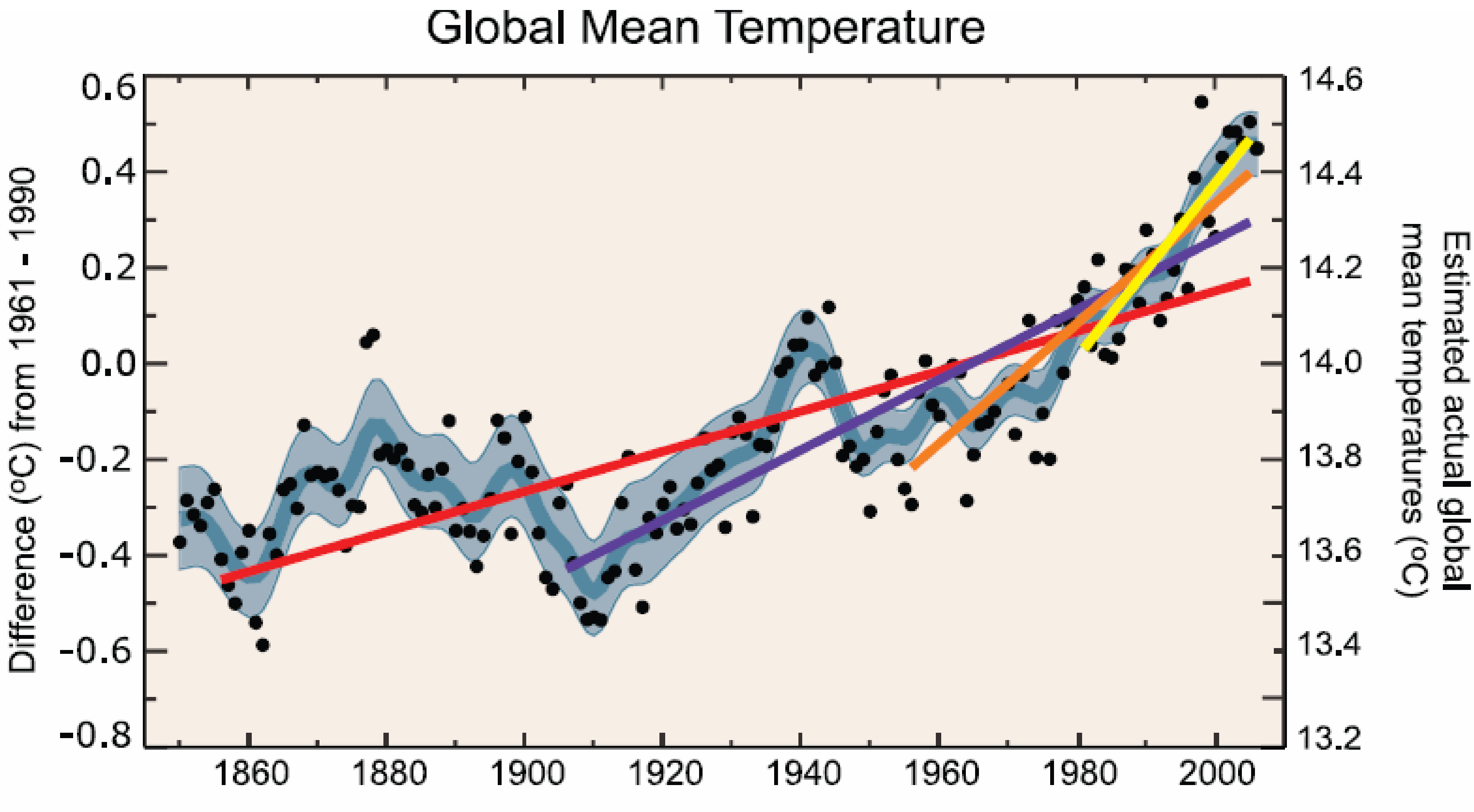
Roland A. Madden and V. Ramanathan

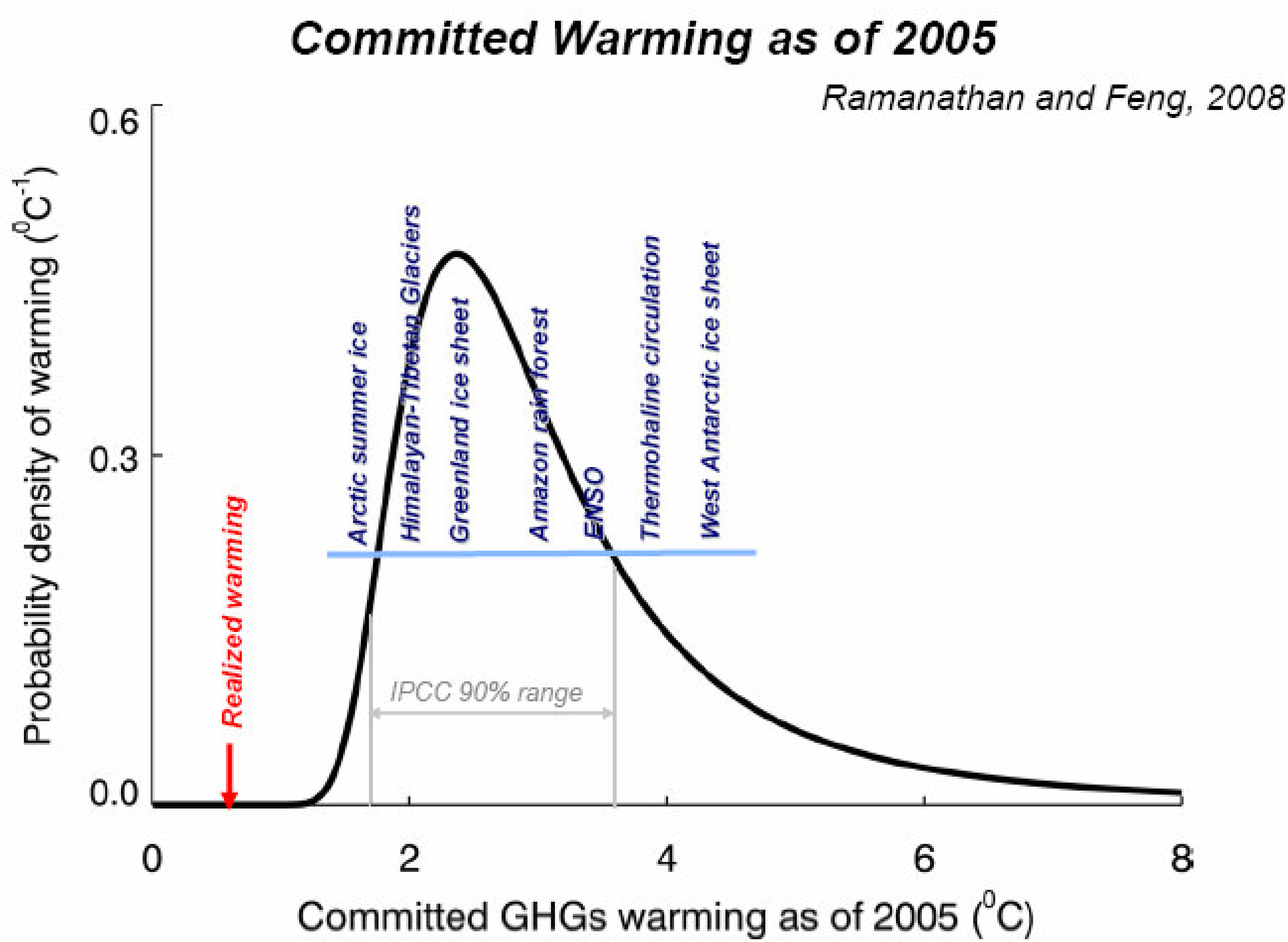
Summary. The observed interannual variability of temperature at 60°N has been investigated. The results indicate that the surface warming due to increased carbon dioxide which is predicted by three-dimensional climate models should be detectable now. It is not, possibly because the predicted warming 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.

The possible climatic effects of large increases in atmospheric CO_2 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 CO_2 increase. By

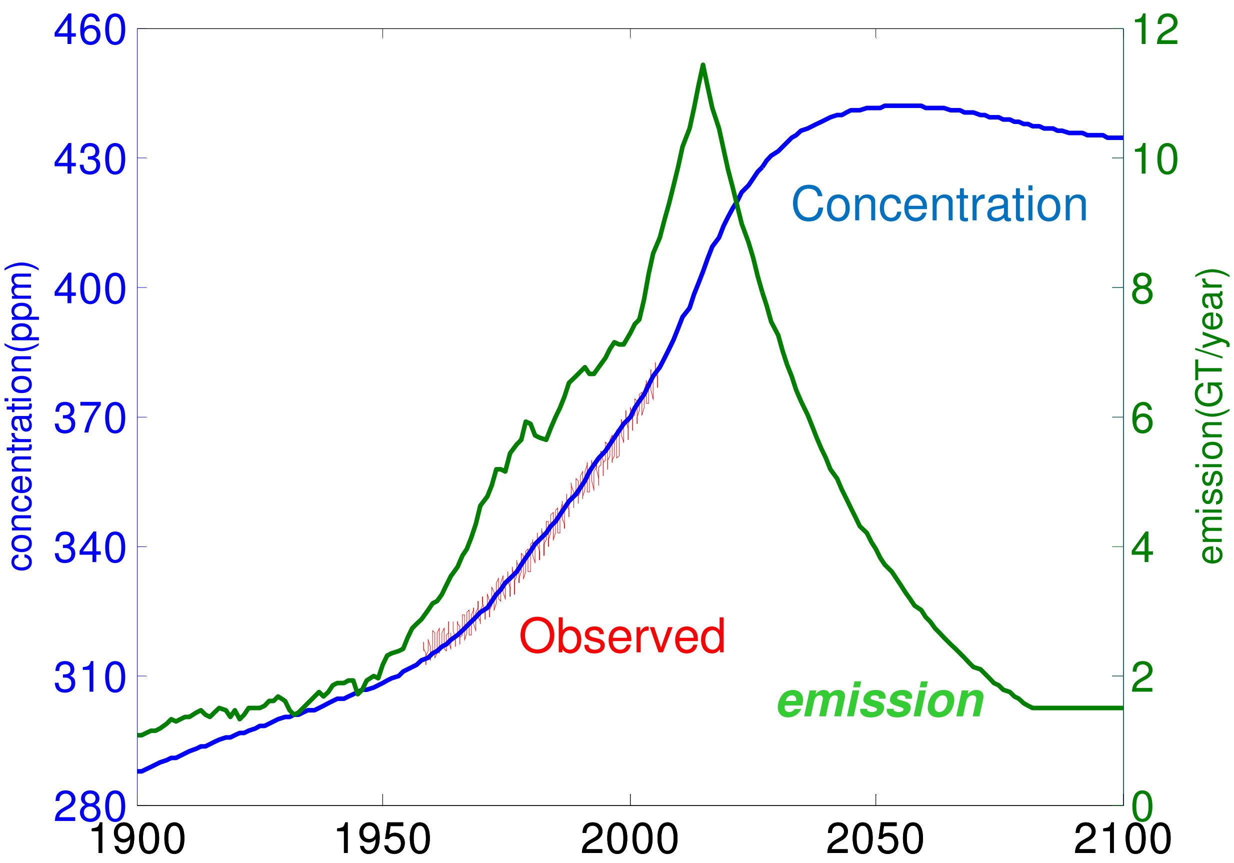
"Unequivocal" Warming of the Planet: IPCC, 2001 & 2007





Committed Warming as of 2005
Ramanathan and Feng, 2008
0.6
0.3
0.0
Probability density of warming ($^0C^{-1}$)
Realized warming
Arctic summer ice
Himalayan-Tibetan Glaciers
Greenland ice sheet
Amazon rain forest
ENSO
Thermohaline circulation
West Antarctic ice sheet
IPCC 90% range
0
2
4
6
8
Committed GHGs warming as of 2005 (^0C)

Impact of Proposed CO_2 Reductions in 2009 G8 Meeting
Ramanathan & Xu 2009



By 2050

440 ppm

1 Wm^{-2} Heating

0.8 C warming Commited

There may be a way out:

Reduce short lived warming *agents:*

Black Carbon (<2 weeks);
Ozone (< 2 months);
Methane (<15 years)
HFCs & HCFCs (<15 years)

Buy few decades time:

to develop transformational technologies for a massive thinning of the GHGs blanket

Non-CO_2 climate warmers

Contribution to 2005 forcing relative to CO_2 (1.66 Wm^{-2})

Greenhouse Gases

Ozone (troposphere)	**: 20%**
Methane	**: 30%**
Halocarbons	**: 20%**

Particles (Aerosols)

Black Carbon (soot/smoke)	**: 27% to 55%***
Total Non-CO_2	**: 97% to 125%**

All numbers except the red are IPCC values; Long lived N_2O not included

*** Ramanathan & Carmichael; 2008**

Global Black Carbon Emissions 2000

(8 Mtons/Yr)

Non-Residential (Fossil Fuels) **_2600 (33%)_**

Residential: Cooking and Heating **_2050 (25%)_**

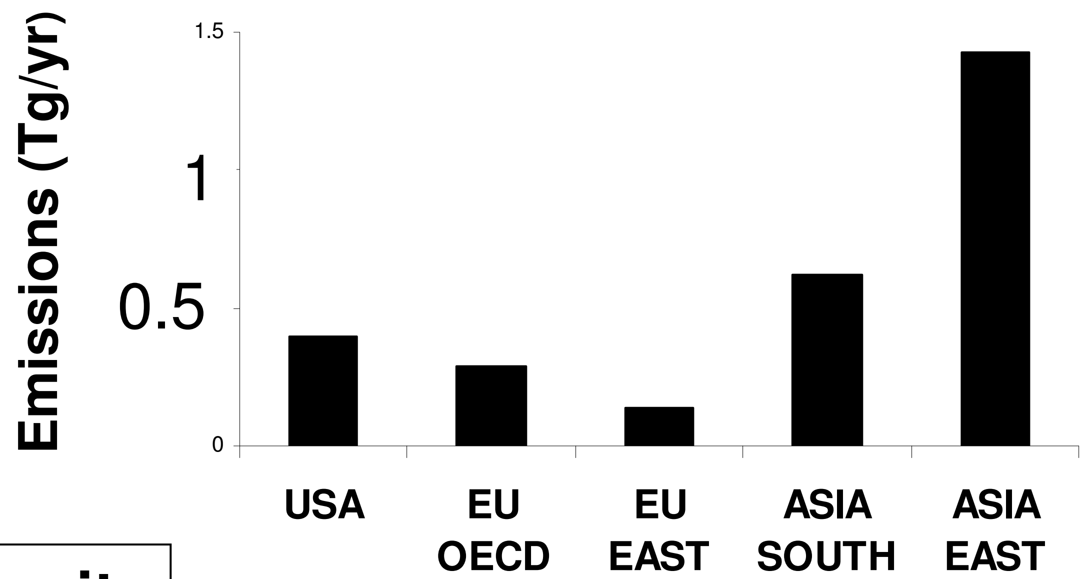
Bio-Fuels (1480); Coal & Diesel (565)

Open Burning: **_............................ 3325 (42%)_**

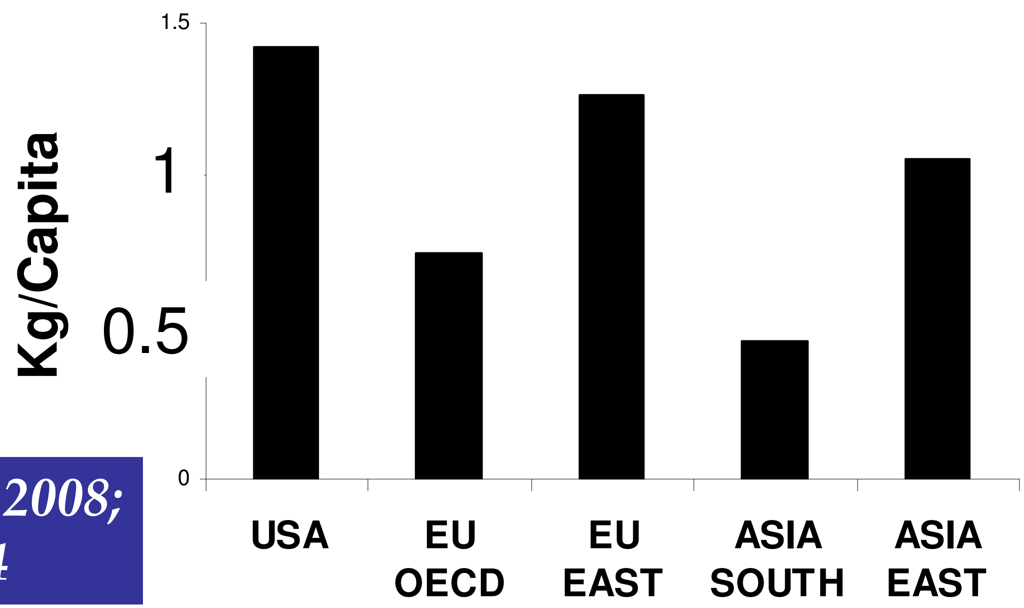
Forest Fires (1240)
Savanna Burning (1720)
Crop Residues (325)

Source: Bond et al, 2004; Uncertainty: about a factor of 2 or more

BC emission



BC Emission/Capita



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

Indian Ocean Experiment:

Europe/ India/ USA Collaboration

Lead Funding Agencies:

NSF; ISRO; MPI

Lead Institutions:

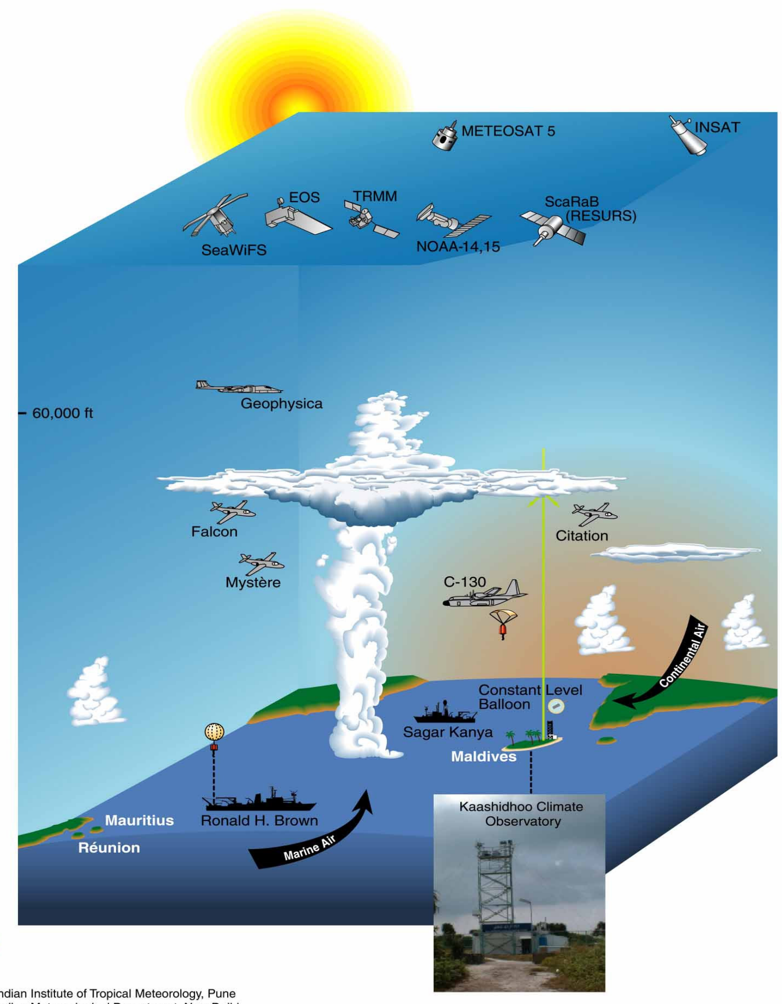
Scripps Inst. Of Oceanography; Univ of California at San Diego, USA

National Physical Laboratory, New Delhi, India

Max Planck Inst for Chemie, Mainz, Germany

Pis: Ramanathan, Crutzen & Mitra

The Indian Ocean Experiment (INDOEX), an international field experiment, has been collecting data since 1996, featuring an intensive field campaign conducted in Spring 1999. For details, see *http://www-indoex.ucsd.edu.*



INDOEX
INDIAN OCEAN EXPERIMENT

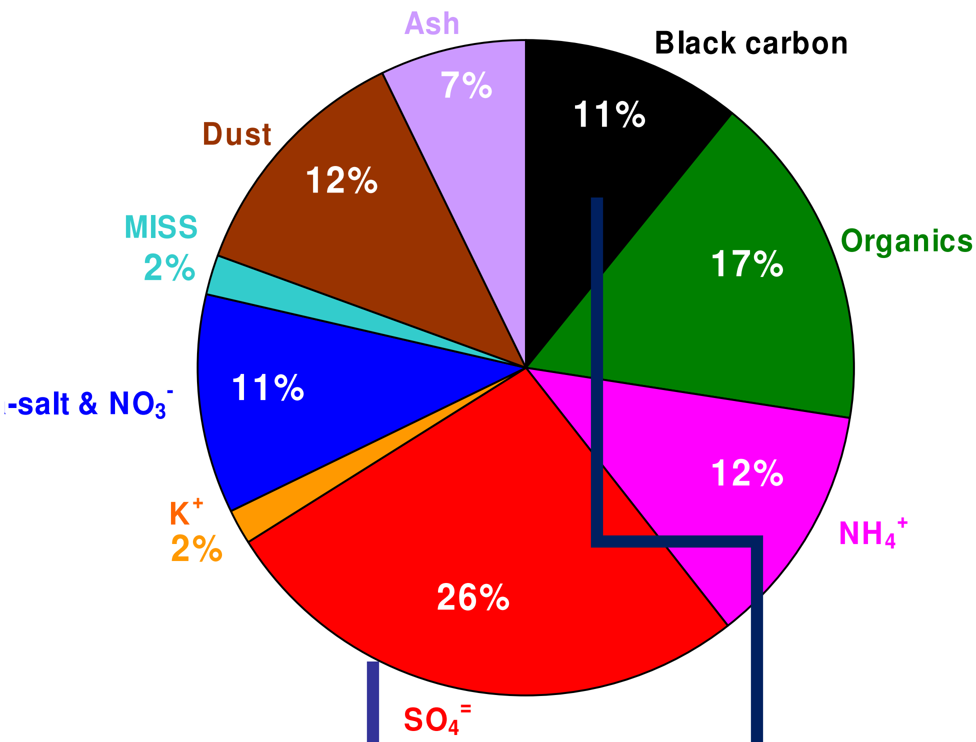
Participating Institutions

Austria
Universität Innsbruck
Canada
York University, Toronto
Europe
Airborne Platform for Earth Observation (Geophysica, Falcon)
European Organisation for the Exploitation of Meteorological Satellites (Meteosat-5)
France
Laboratoire d'Optique Atmosphérique
Laboratoire de Météorologie Dynamique du CNRS
Laboratoire de Météorologie Physique, Université Blaise Pascal
Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS
Laboratoire Interuniversitaire des Systèmes Atmosphériques
Service d'Aéronomie
Germany
Forschungszentrum Jülich
GKSS-Forschungszentrum Geesthacht
Institut für Troposphärenforschung
Max Planck Institut für Chemie
Max Planck Institut für Kernphysik
Max Planck Institut für Meteorologie
Meteorologisches Institut der Universität Hamburg
Universität Bremen
India
Antarctic Study Centre, Vasco-da-Gama
Indian Institute of Science, Bangalore
Indian Institute of Technology, New Delhi
Indian Institute of Tropical Meteorology, Pune
Indian Meteorological Department, New Delhi
Indian Space Research Organization, Bangalore
National Centre for Medium Range Weather Forecasting, New Delhi
National Institute of Oceanography, Goa
National Physical Laboratory, New Delhi
Physical Research Laboratory, Ahmedabad
Space Applications Centre, Ahmedabad
Space Physics Laboratory, Thiruvananthapuram
Israel
Tel-Aviv University
La Réunion
Université de La Réunion
Mauritius
Department of Meteorological Services, Mauritius
University of Mauritius, Reduit
Maldives
Department of Meteorology, Maldives
Ministry of Home Affairs, Housing and Environment
Netherlands
Koninklijk Nederlands Meteorologisch Instituut
Technische Universiteit Delft
Universiteit Utrecht
South Africa
University of Witwatersrand, Johannesburg
Sweden
Meteorologiska Institutionen, Stockholms Universitet
United Kingdom
Imperial College, London
United States
Center for Clouds, Chemistry and Climate
Arizona State University, Tempe
Atmospheric Research Laboratory
Colorado University, Boulder
Desert Research Institute
Florida State University, Tallahassee
NASA - Goddard Space Flight Center
National Center for Atmospheric Research
NOAA - Atlantic Oceanographic and Meteorological Laboratory
NOAA - Climate Monitoring and Diagnostics Lab
NOAA - Pacific Marine Environmental Laboratory
North Carolina State University, Raleigh
Oregon State University, Corvallis
Pennsylvania State University, University Park
Scripps Institution of Oceanography
SeaSpace Corporation
University Corporation for Atmospheric Research
University of Alaska, Fairbanks
University of California, Irvine
University of California, Riverside
University of California, San Diego
University of Hawaii, Manoa
University of Maryland, College Park
University of Miami
University of Washington, Seattle

Ramanathan et al, Nature, 2007.


Dec 27, 2002
A Brown Cloud in LA

ABCs: How do they influence climate ?



- The absorption of solar radiation by the surface and the atmosphere is the fundamental driver for the physical climate system , for atmospheric chemistry, and for all life on the planet.

- ABCs have altered this forcing significantly

Soot: Traps sunlight and heats the air

Sulfates: Reflect sunlight like mirrors and cool

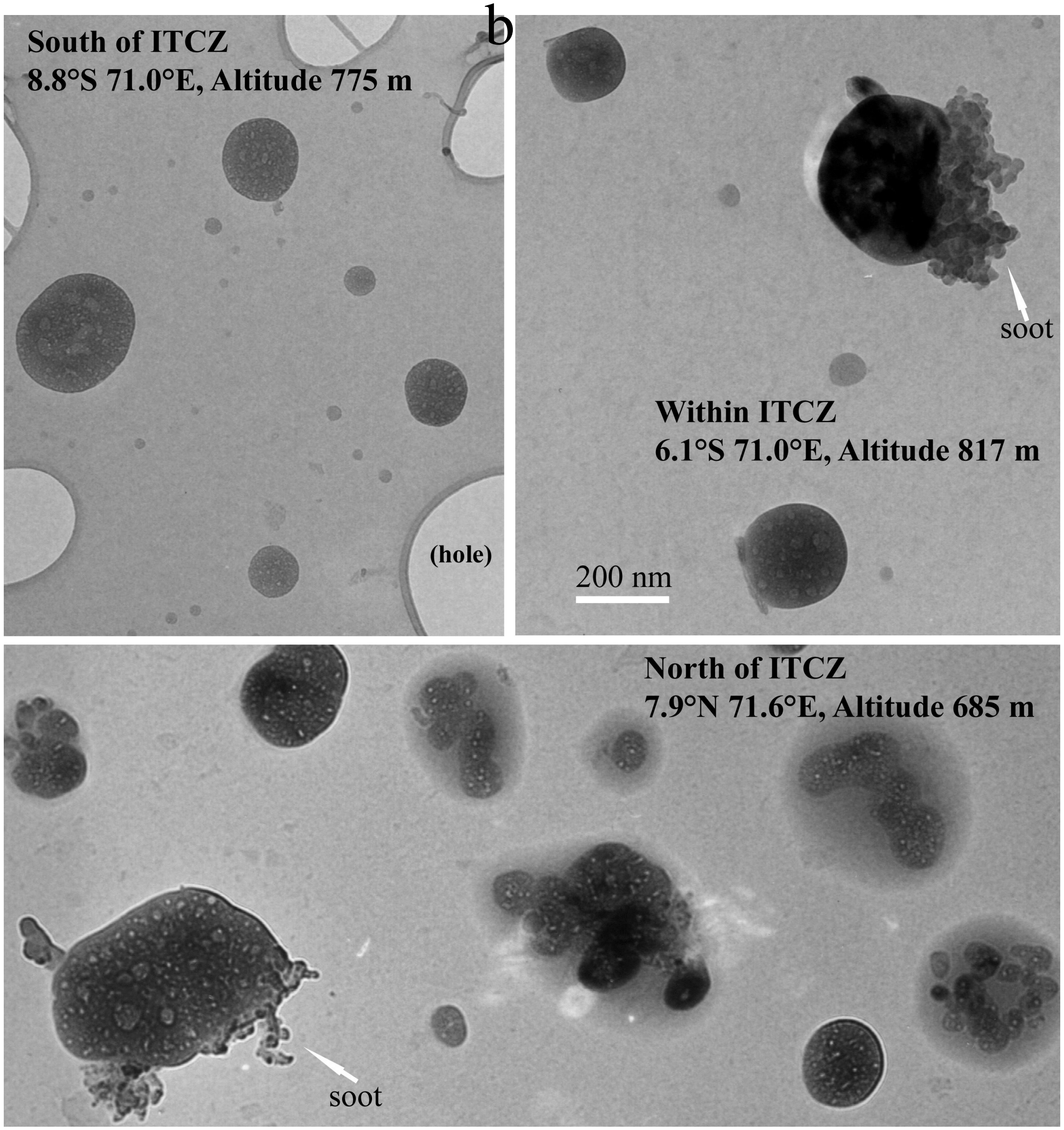
What does black carbon look like?

Ramanathan et al, 2001

Clean air;

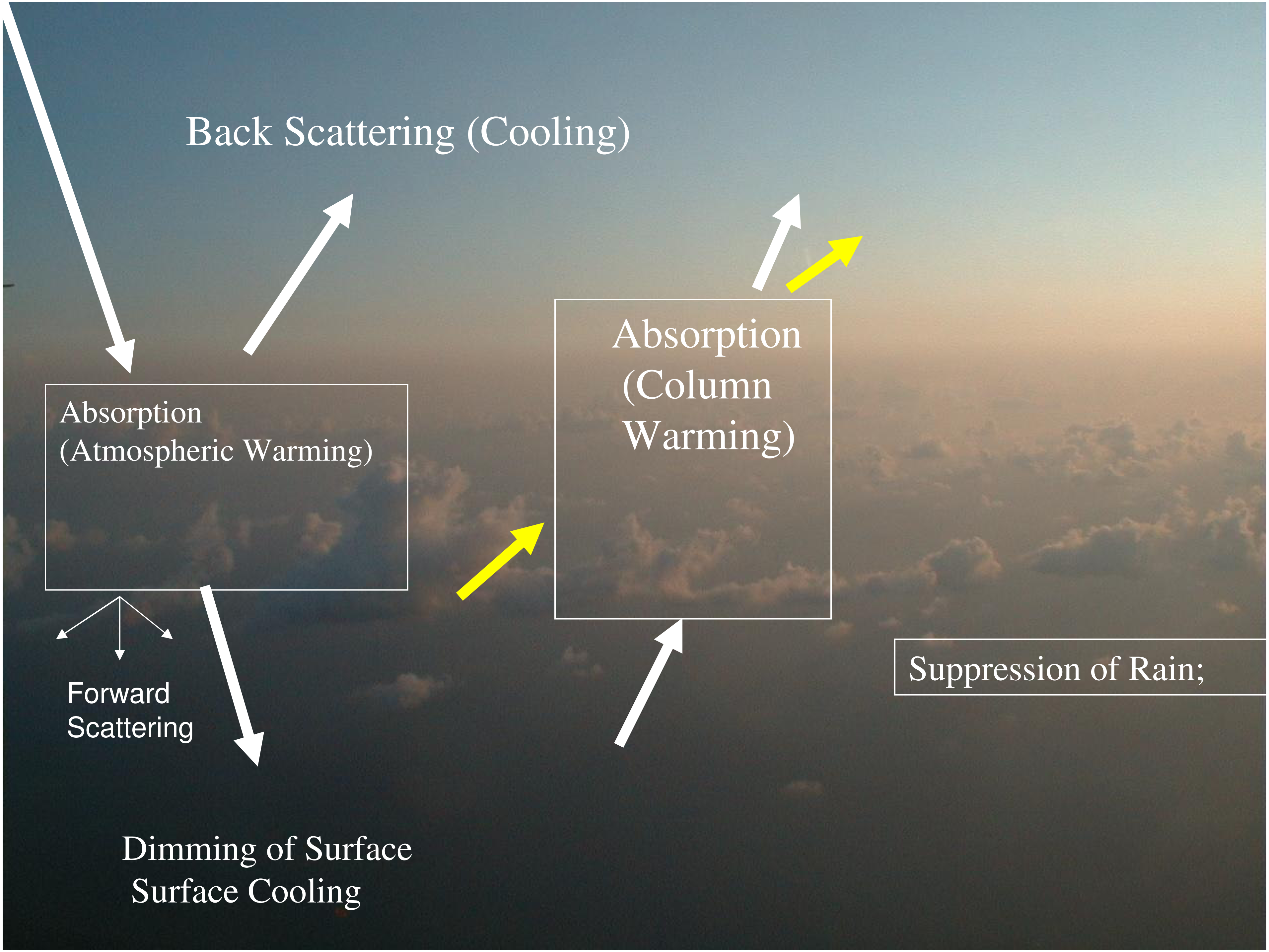
Southern Indian Ocean,

8S

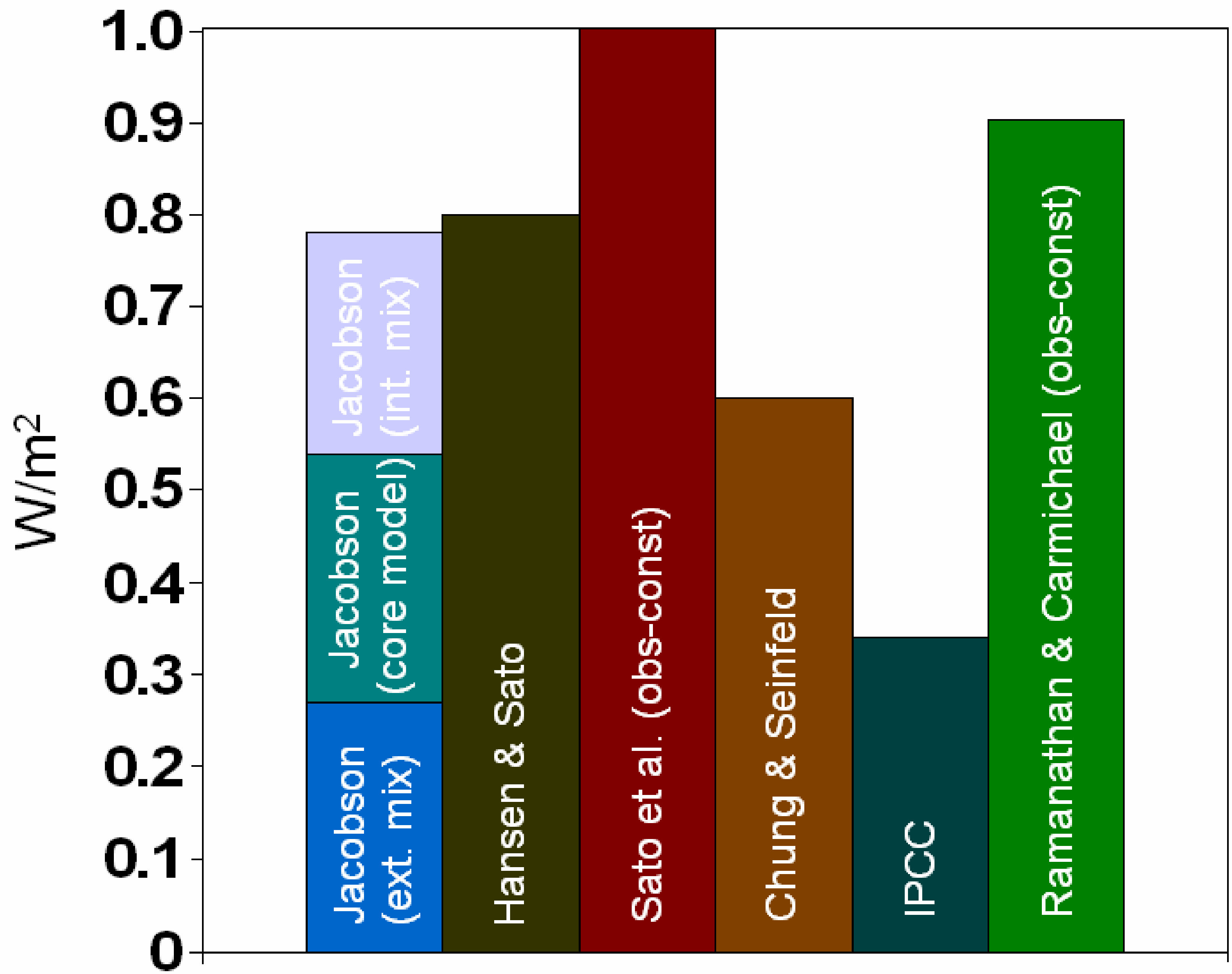


Southern Indian Ocean, 6S Polluted

Arabian Sea Polluted

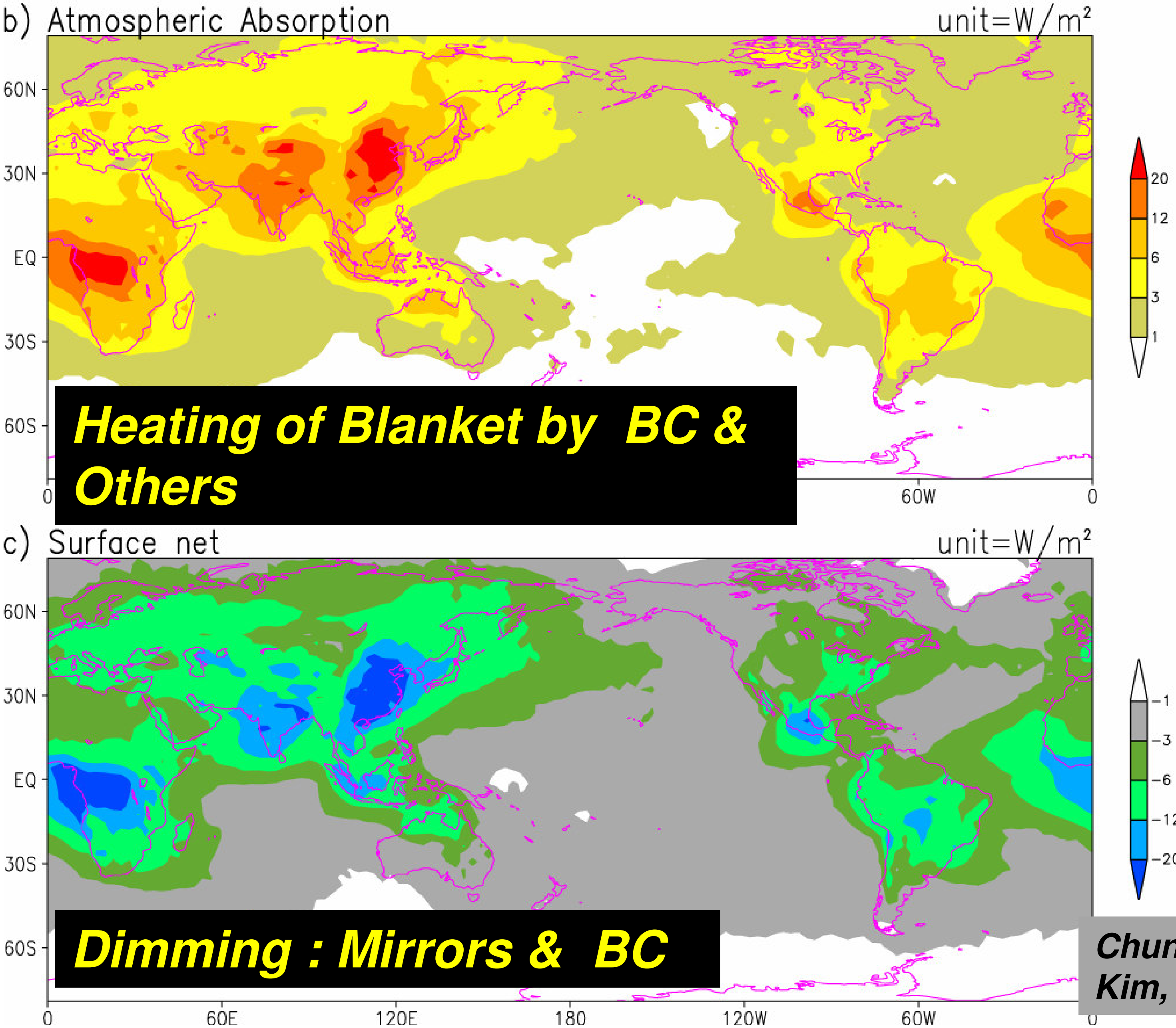

Back Scattering (Cooling)
Absorption
(Atmospheric Warming)
Absorption
(Column
Warming)
Forward
Scattering
Suppression of Rain;
Dimming of Surface
Surface Cooling

BC Global Radiative Forcing Estimates:



Masking of Global Warming: 2002

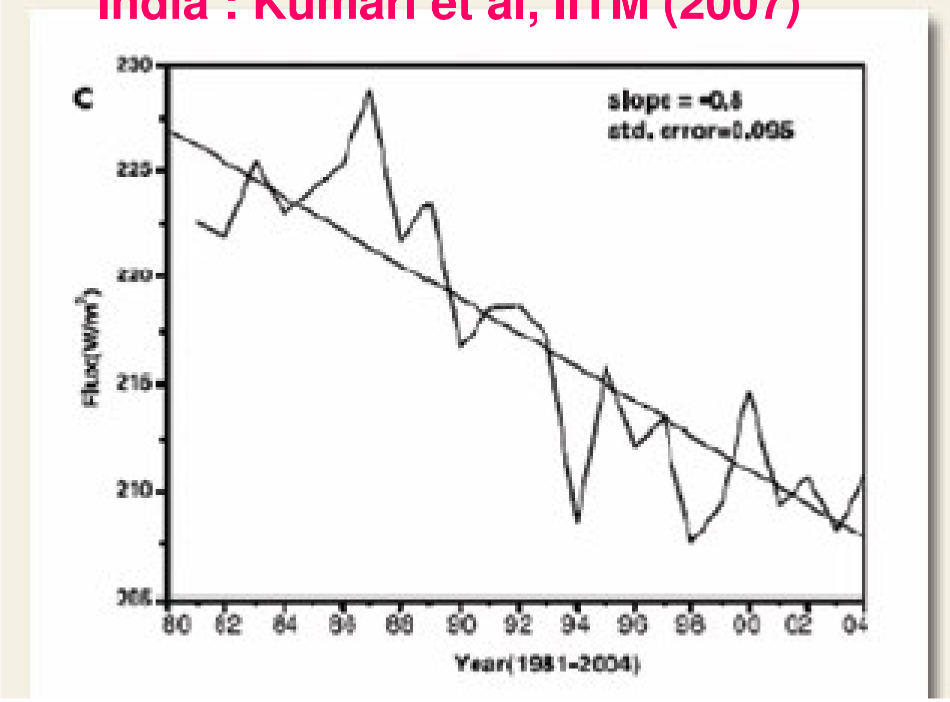
{A Synthesis of ground, aircraft and satellite observations}



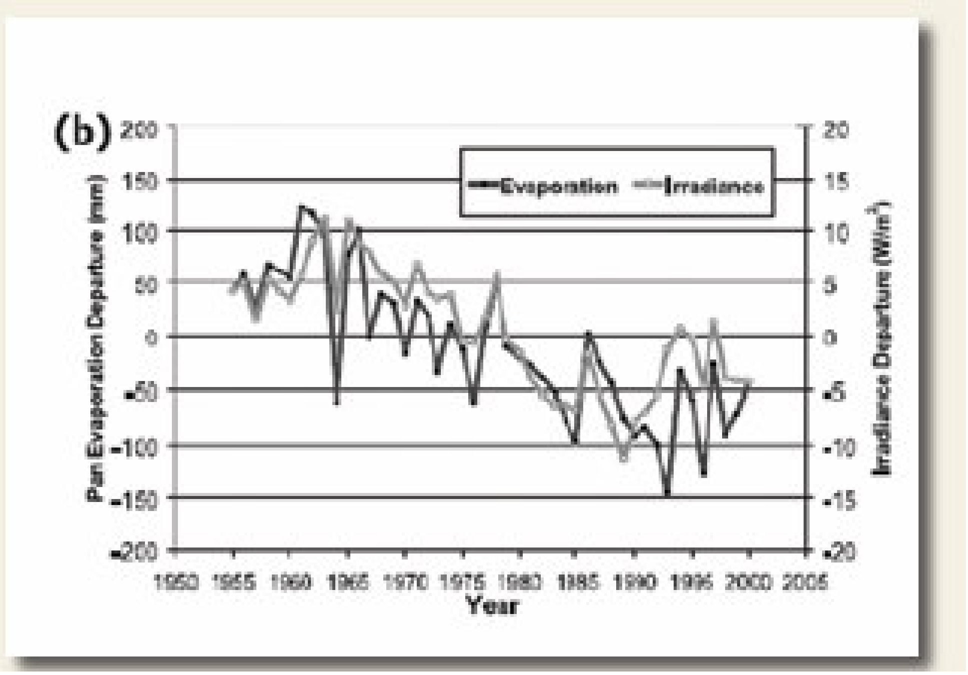
Chung, Ramanathan, Kim, Podgorny,2005

OBSERVED DIMMING TRENDS OVER INDIA ND CHINA

India : Kumari et al, IITM (2007)



China: FU et al (2006)



IABCs have led to large dimming over Asia; At least by 6% over China and India

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 114, D10109, doi:10.1029/2008JD010572, 2009

Changes in the characteristics of rain events in India

S. K. Dash,[1] Makarand A. Kulkarni,[1] U. C. Mohanty,[1] and K. Prasad[1]

Received 10 June 2008; revised 23 January 2009; accepted 23 February 2009; published 29 May 2009.

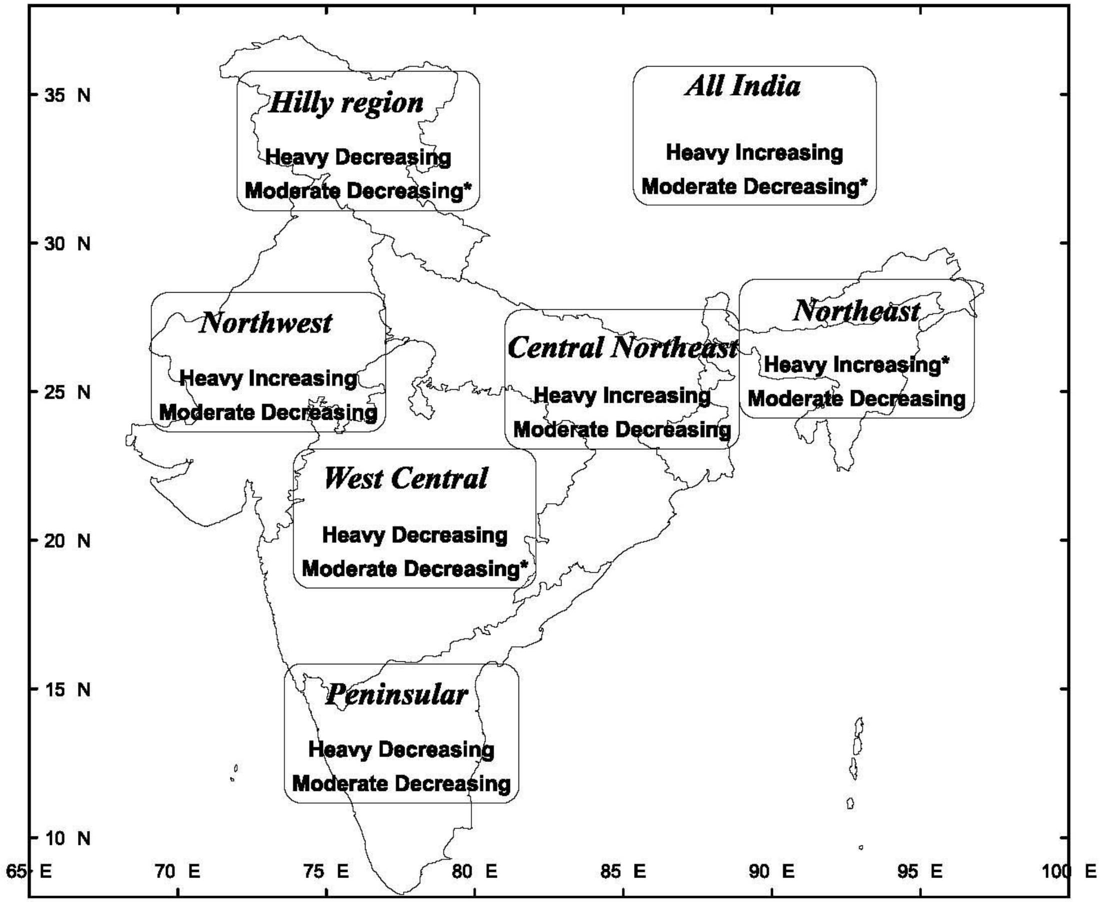


Figure 3. Summary of the trends in heavy and moderate rain days occurring during the summer monsoon season in different regions. Asterisks denote a significant trend at the 5% level.

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[‖]

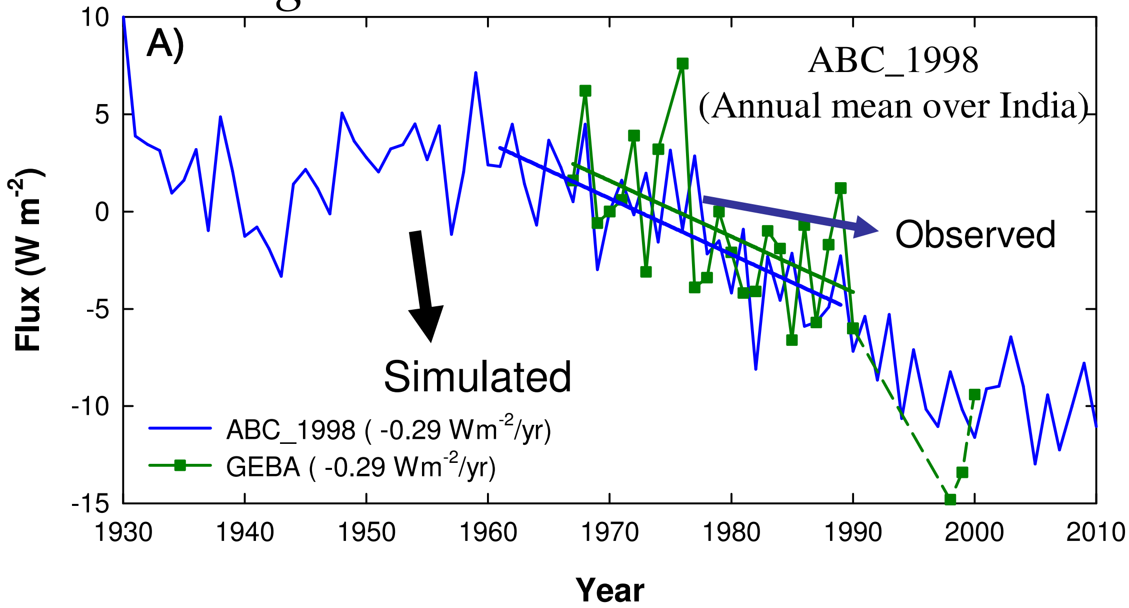
[*]Scripps Institution of Oceanography, University of California at San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0221; [‡]National Center for Atmospheric Research, Boulder, CO 80307; [§]University of Washington, Box 351640, Seattle, WA 98195-1640; [¶]40 Mausam Vihar, New Delhi, 110 051, India; and [‖]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.

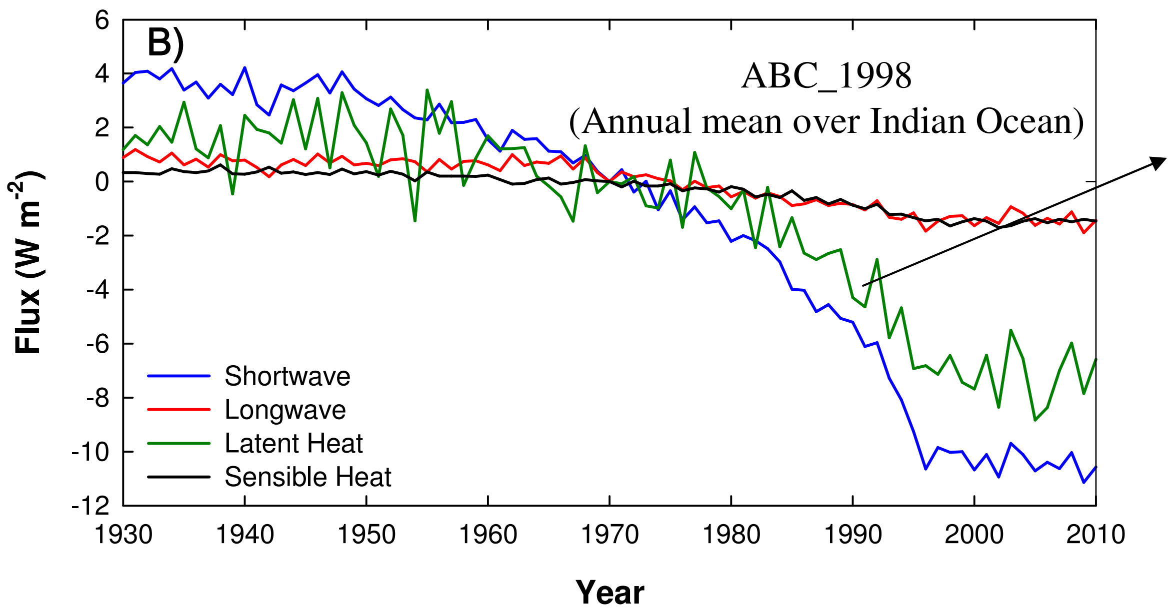
Contributed by V. Ramanathan, January 25, 2005

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

South Asian Dimming



Solar Radiation at the Surface: Simulated And Observed
(12 stations)

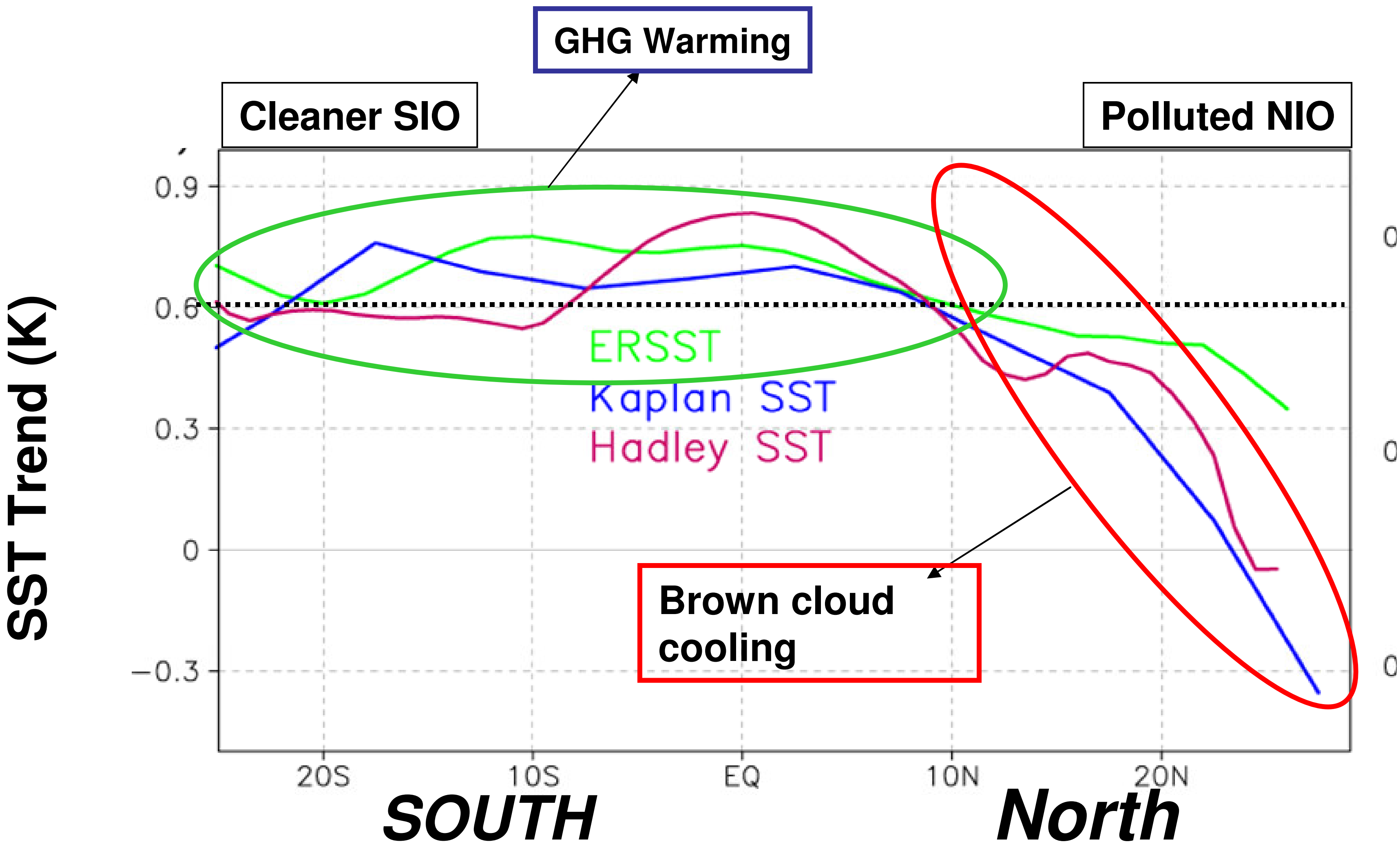


The Dimming Led to a Decrease in Evaporation From Indian Ocean

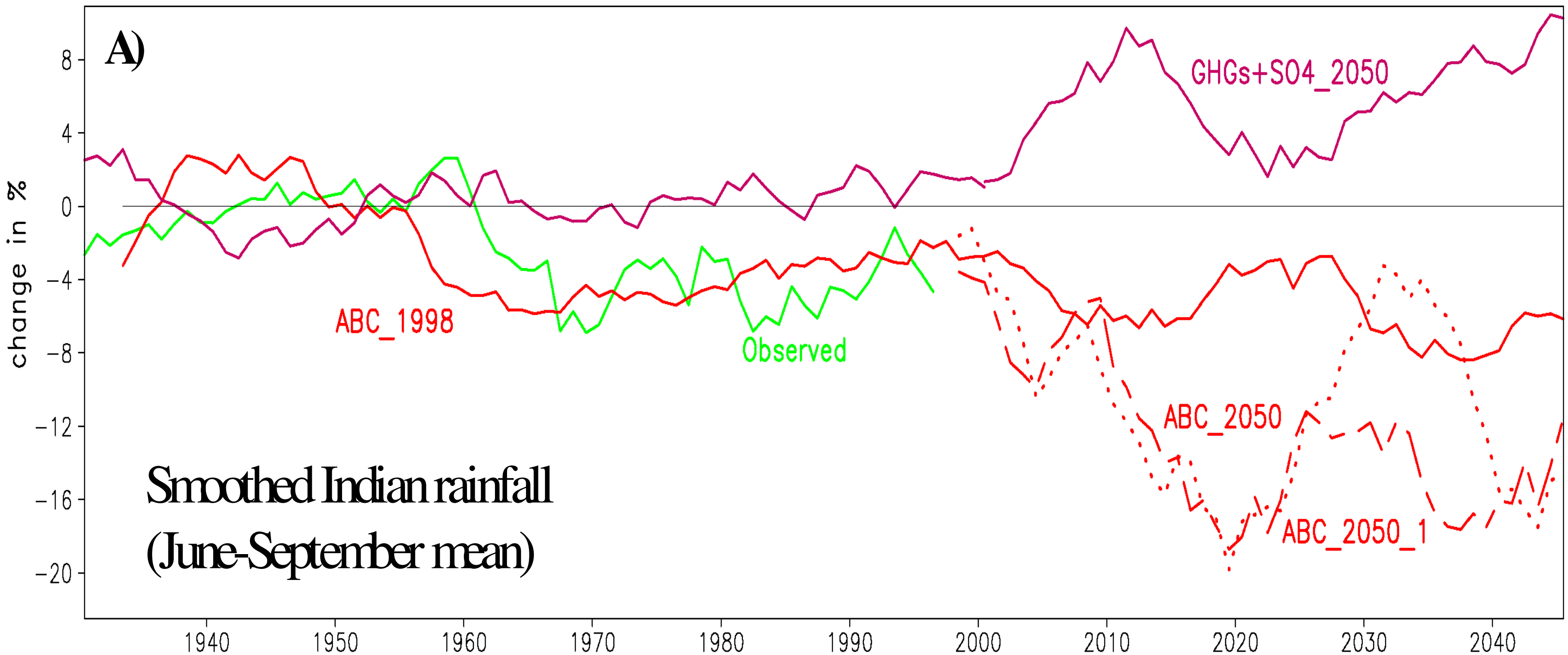
Source: Ramanathan et al, Proceedings of National Academy of Sciences, March 2005

Observed Trend in Indian Ocean Surface Temperatures 1951 to 2002

Chung & Ramanathan J Clim, 2006

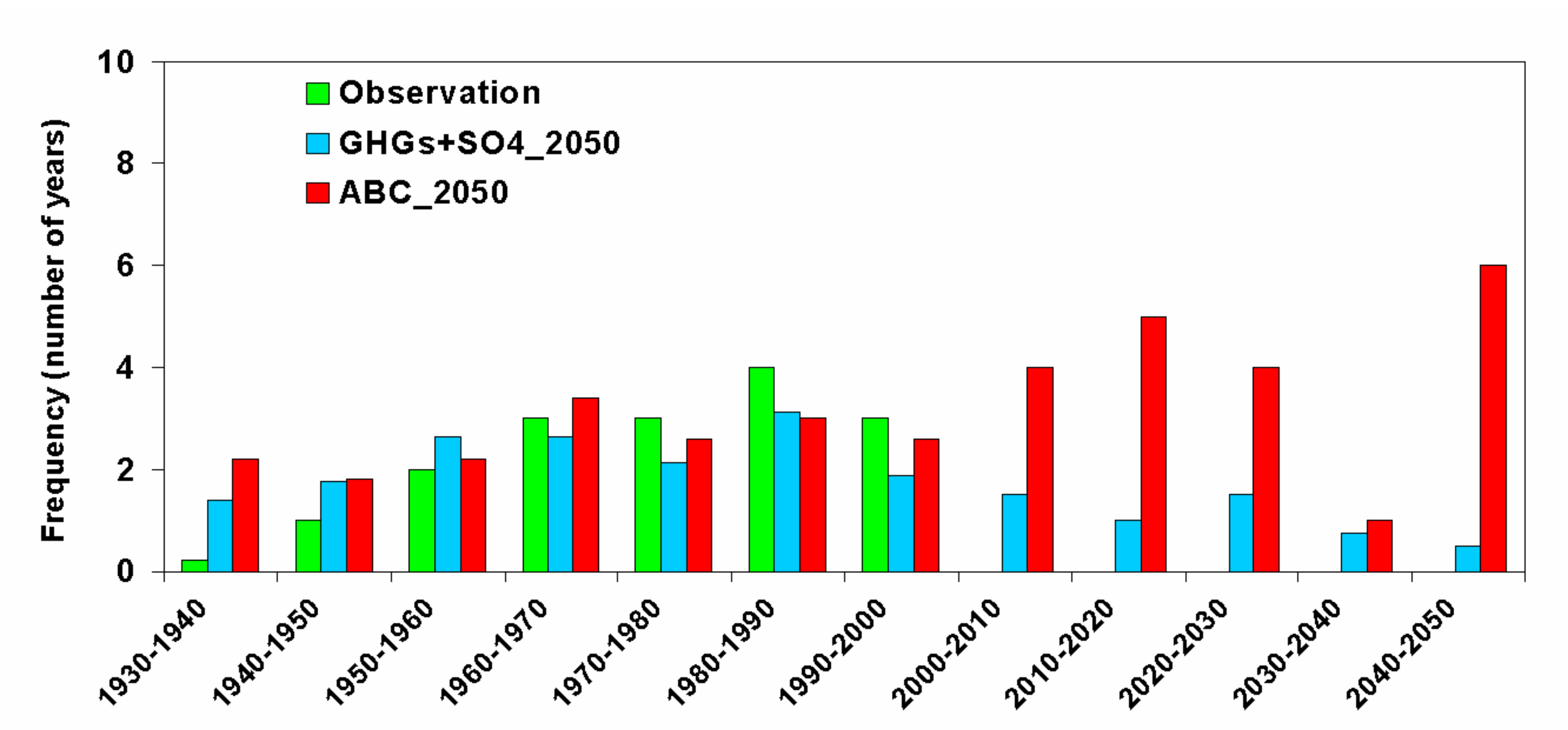


Changes in Summer Monsoon Rainfall averaged over India



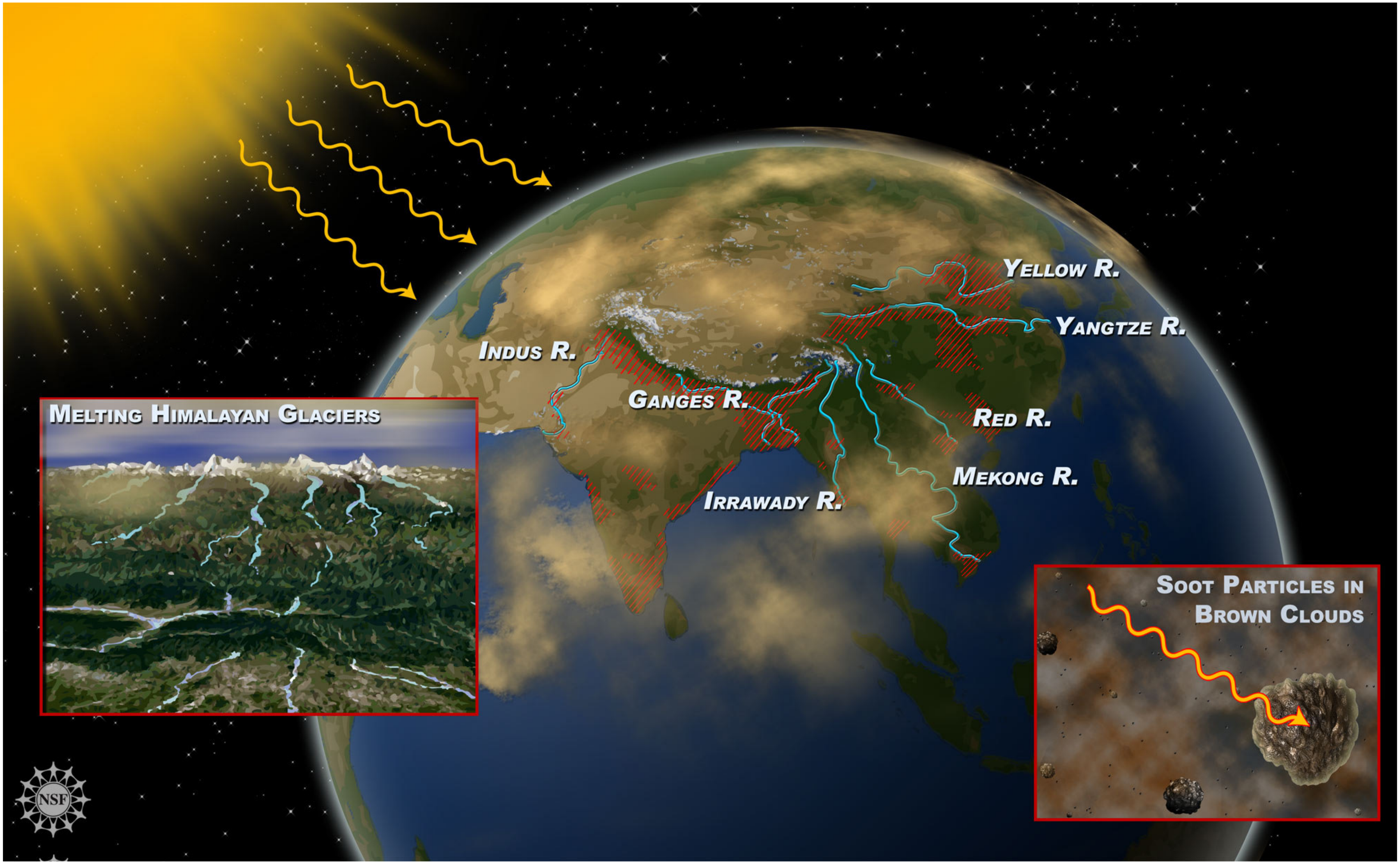
Ramanathan et al 2005

Model Prediction: ABCs induced dimming is likely to increase Frequency of droughts during 2000 to 2030

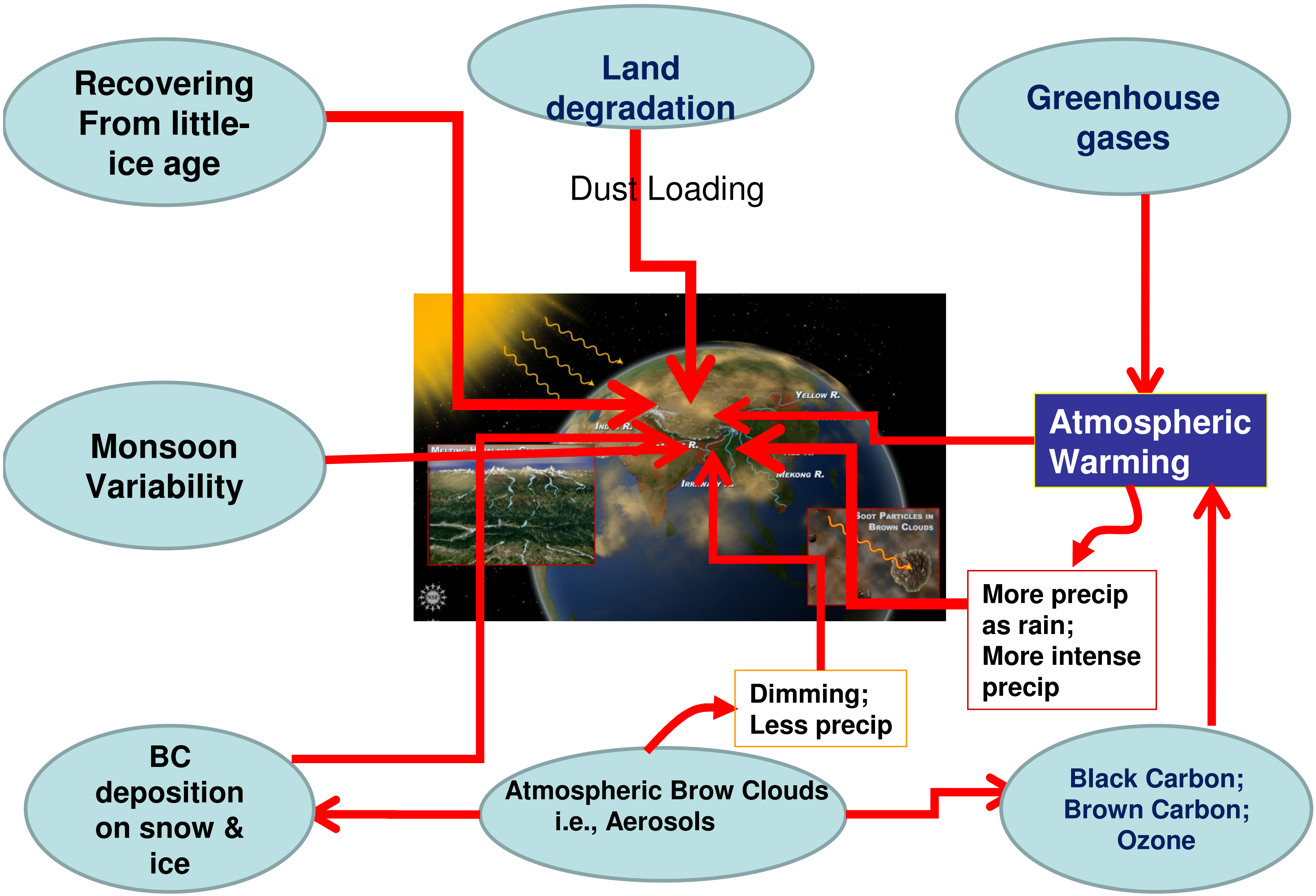


Ramanathan et al, 2005

Hindu Kush-Himalayan-Tibetan Glaciers: Water Fountain of Asia



Multiple Stressors on Glaciers and snowpacks



Contents lists available at ScienceDirect

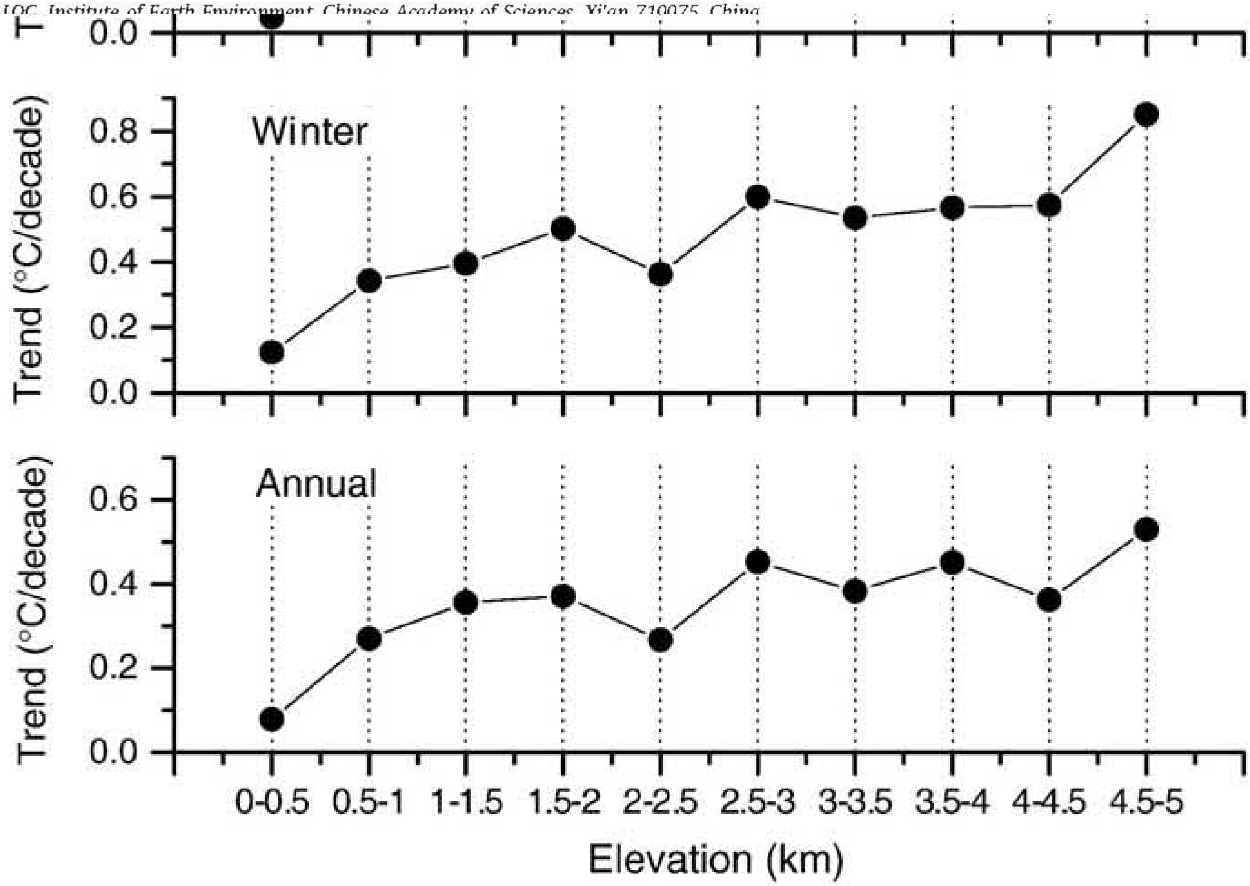
Global and Planetary Change

journal homepage: www.elsevier.com/locate/gloplacha

Elevation dependency of recent and future minimum surface air temperature trends in the Tibetan Plateau and its surroundings

Xiaodong Liu [a,b], Zhigang Cheng [a], Libin Yan [a], Zhi-Yong Yin [c,*]

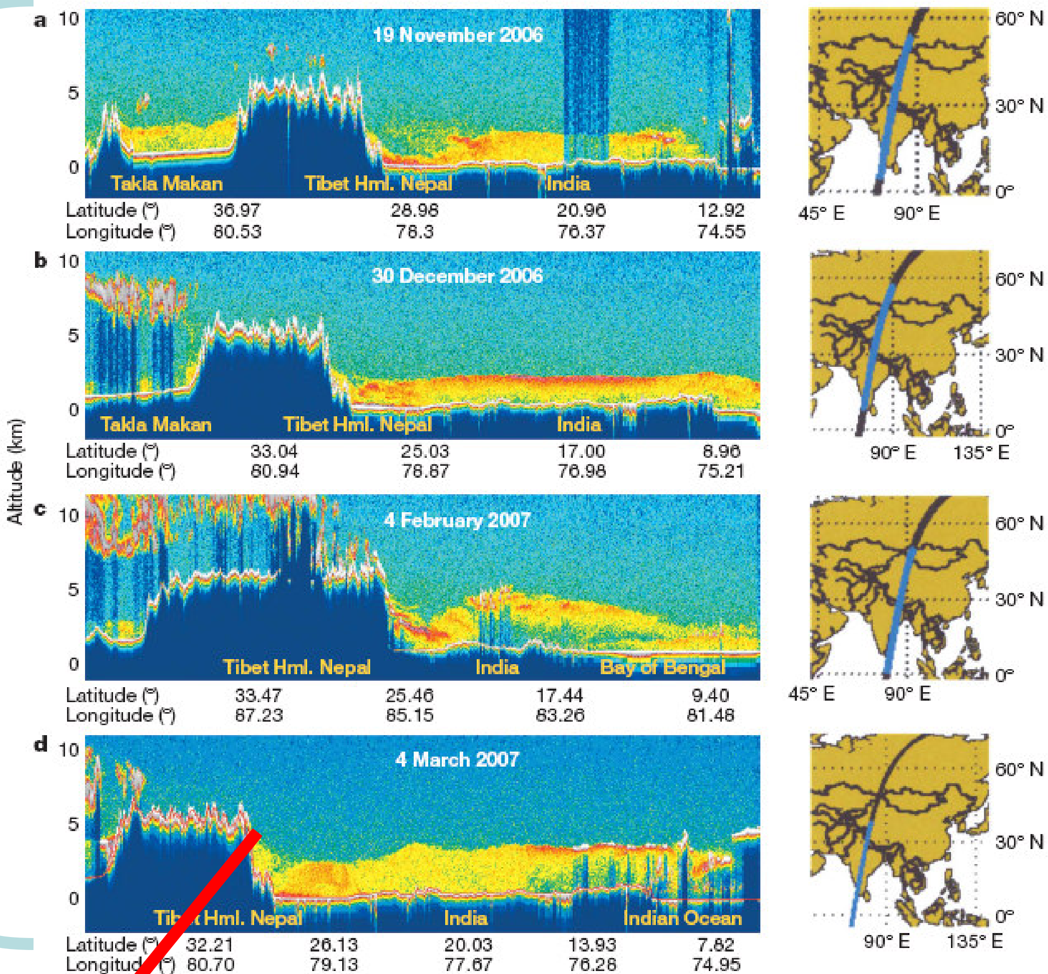
[a] SKLLOC, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710075, China

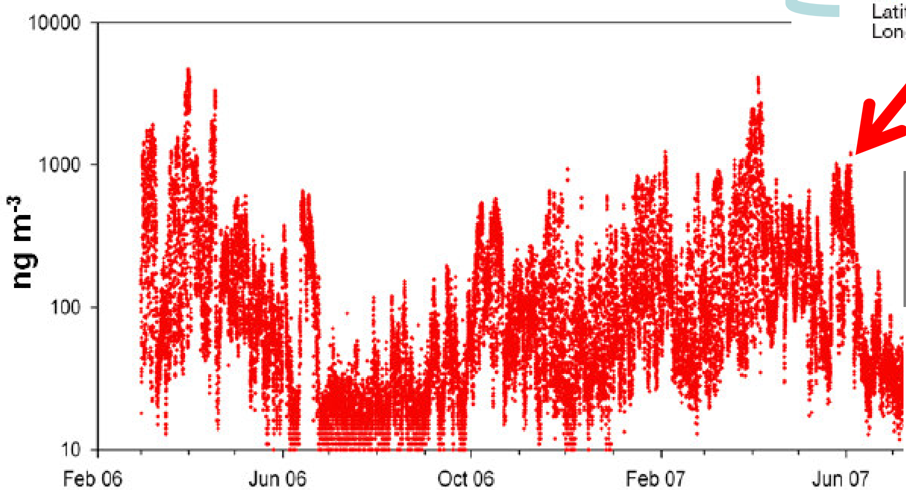


1961 to 2006 Trend

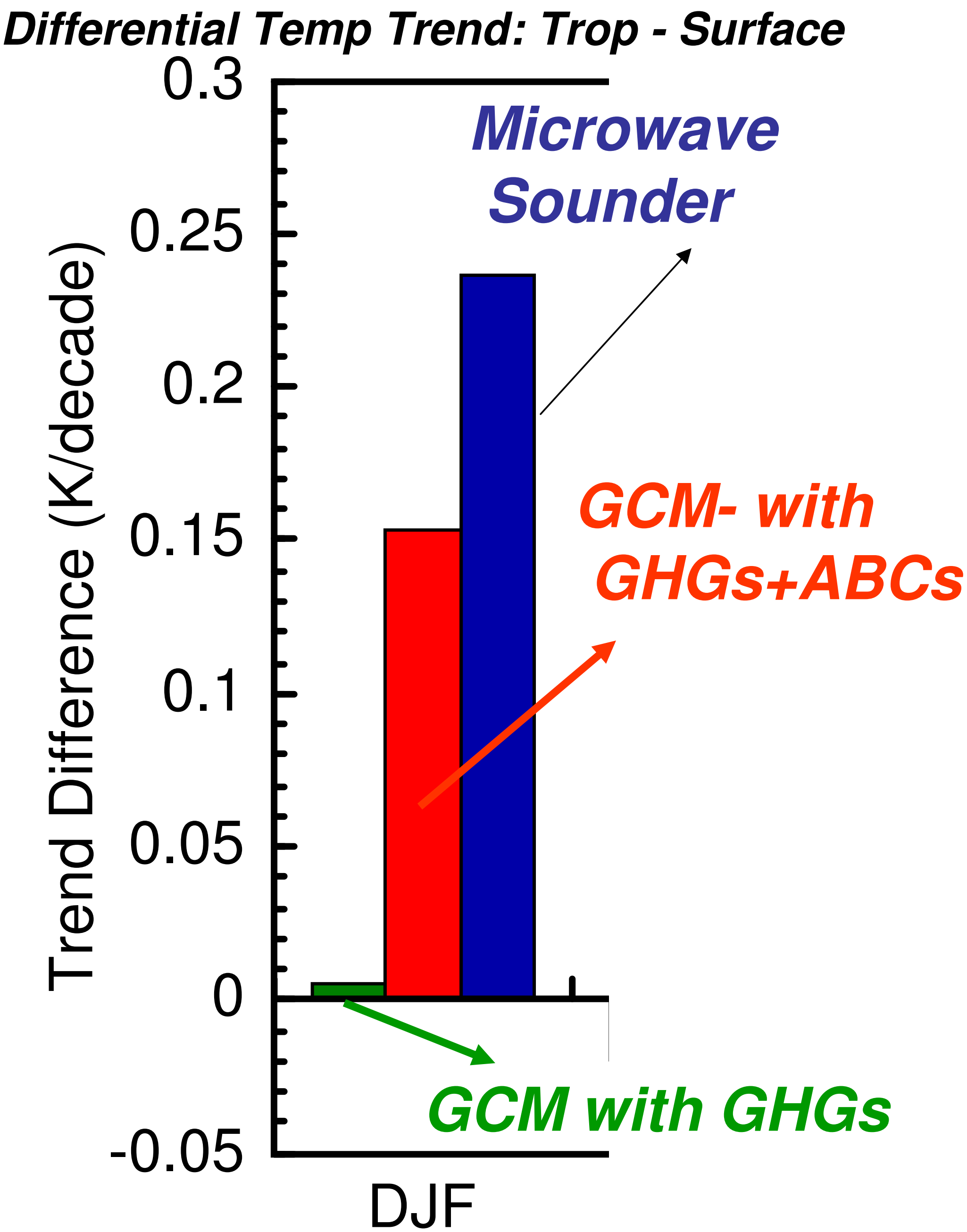
ABCs surround the Himalayas

NASA, CALYPSO LIDAR
Ramanathan et al, 2007

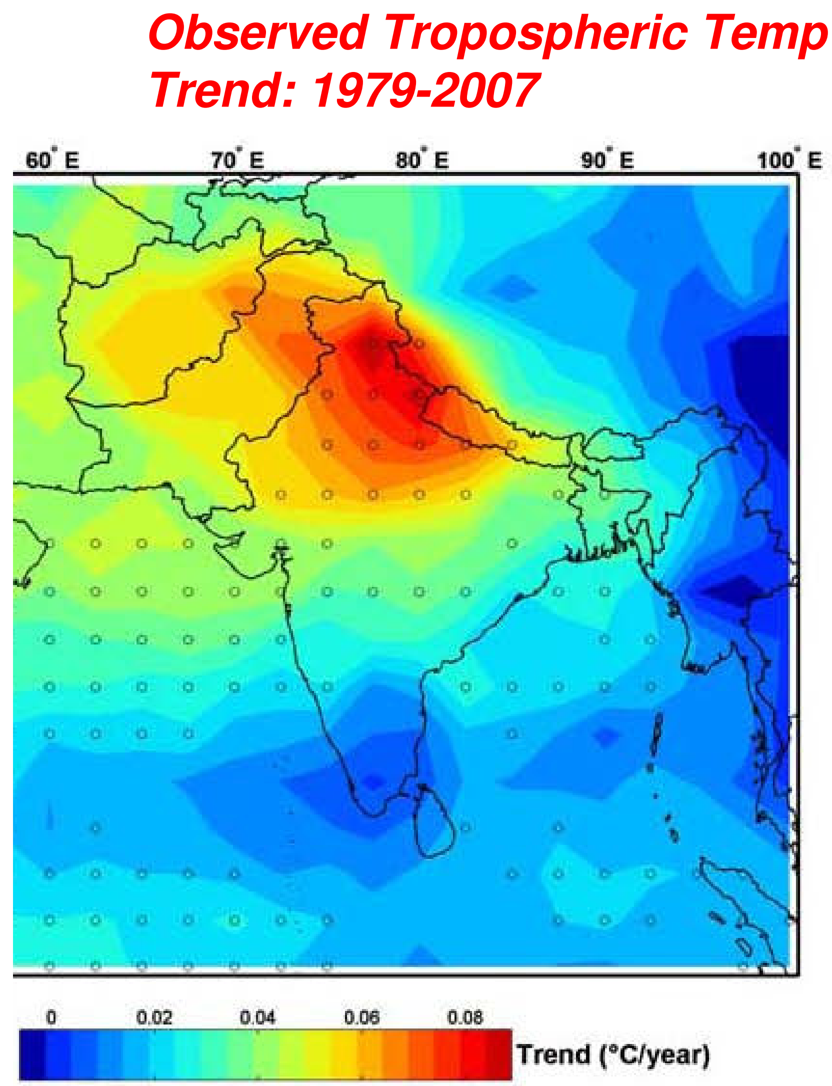




ABC-Pyramid Station; Base Camp
Mt Everest; Fuzzi et al 08



Ramanathan et al 2005



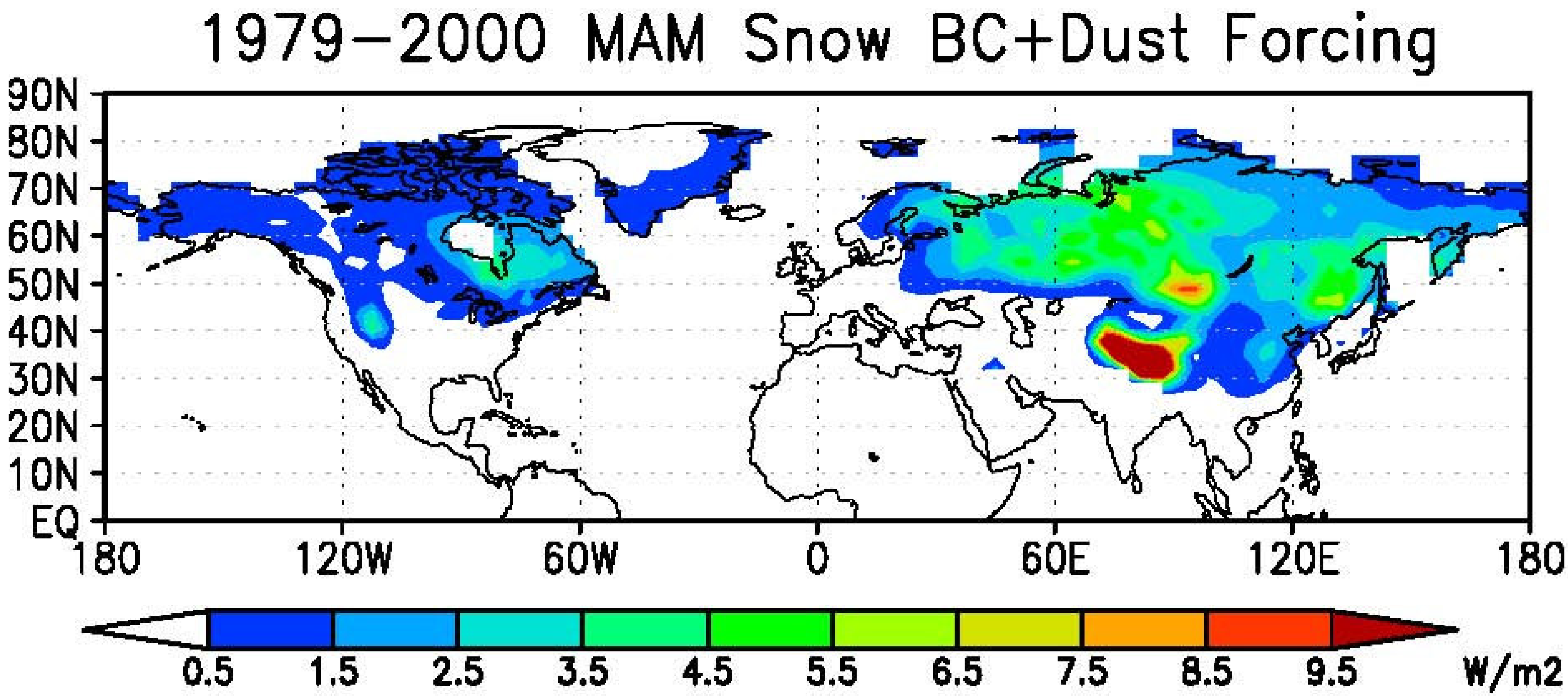
Gautam et al, GRL, 2009

Atmos. Chem. Phys. Discuss., 8, 19819–19859, 2008
www.atmos-chem-phys-discuss.net/8/19819/2008/

Atmospheric Chemistry and Physics Discussions

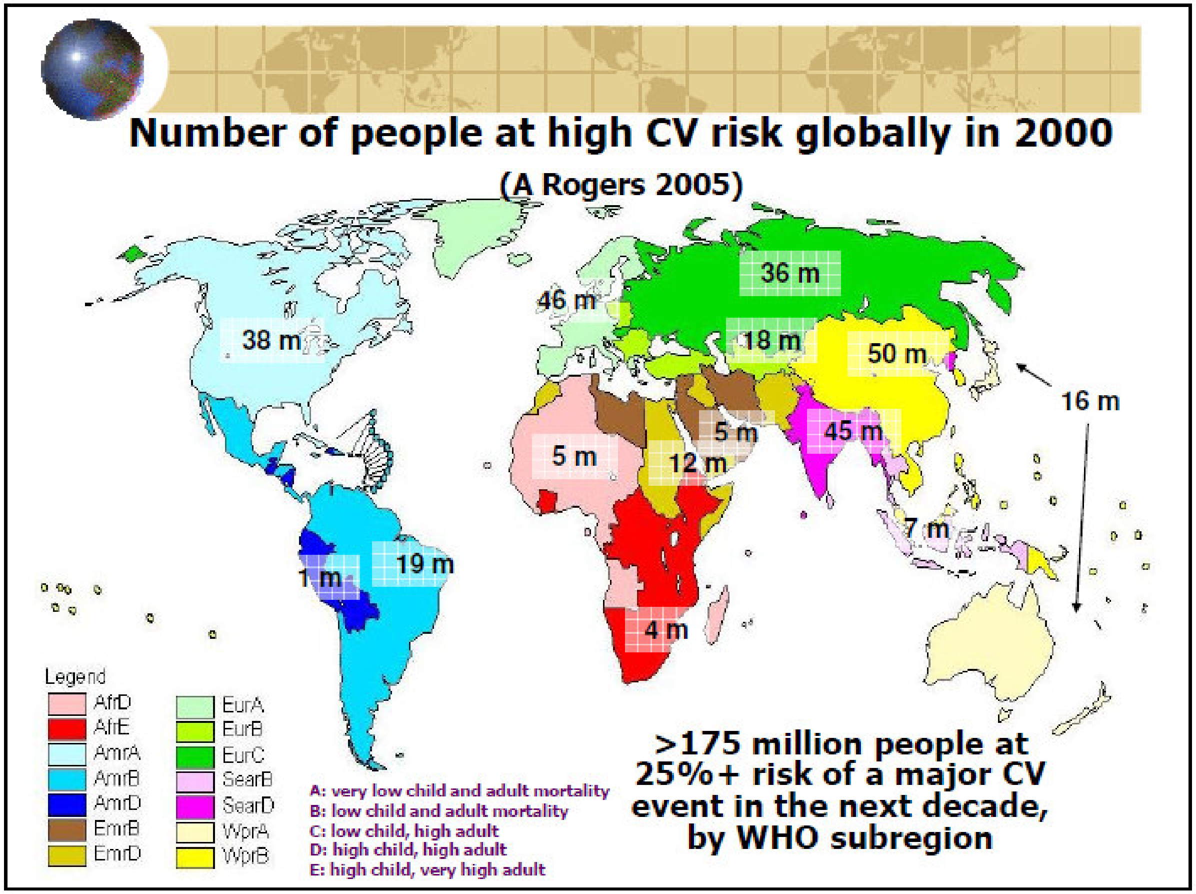
Springtime warming and reduced snow cover from carbonaceous particles

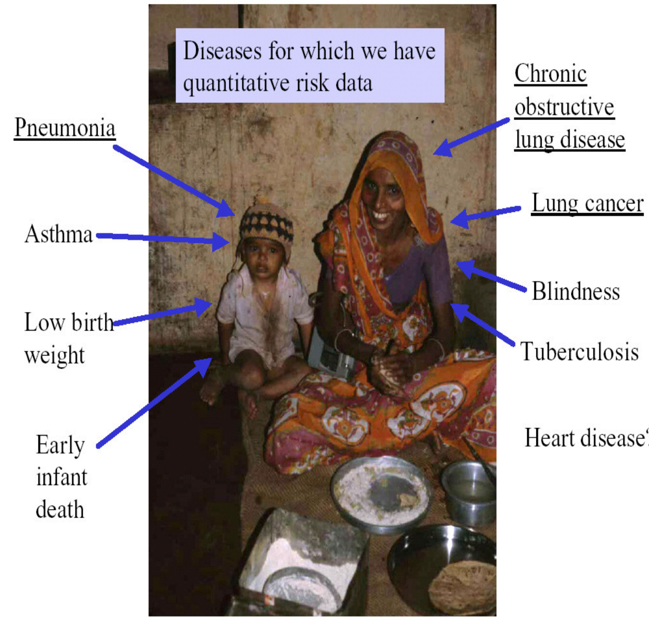
M. G. Flanner[1], C. S. Zender[2], P. G. Hess[1,3], N. M. Mahowald[1,3], T. H. Painter[4],
V. Ramanathan[5], and P. J. Rasch[1]



Health Burdon Of ABCs Is Enormous

No region is immune!





~800,000 excess deaths per year (in USA >50,000 deaths; $100B/yr)

Strong Motivator For Change!

Smoke and BC have Major Impacts on Health; Water Security and Food Security

- **Greatest advantage for Policy Actions**
  1. *Short Lived in the air (about a week or less)*
  2. *Immediate response to mitigation laws*
  3. *Response felt locally by improved air quality*
  4. *Will reduce fatalities due to indoor and outdoor air pollution*

Suggested Approach

Mitigation Technology is Available

1)Start with Fossil Fuel BC: Major reductions

Diesel Particle Filters are in Market
$250 Euros for diesel passenger car
More than 99% reduction in BC

2)Initiate mitigation of Biofuel Cooking

But Science is needed to refine numbers

Env Sci & Technology, 2008

Policy Analysis

Climate Impacts of Air Quality Policy: Switching to a Natural Gas-Fueled Public Transportation System in New Delhi

CONOR C. O. REYNOLDS† AND MILIND KANDLIKAR*,†,‡

New Delhi's Pioneering Efforts

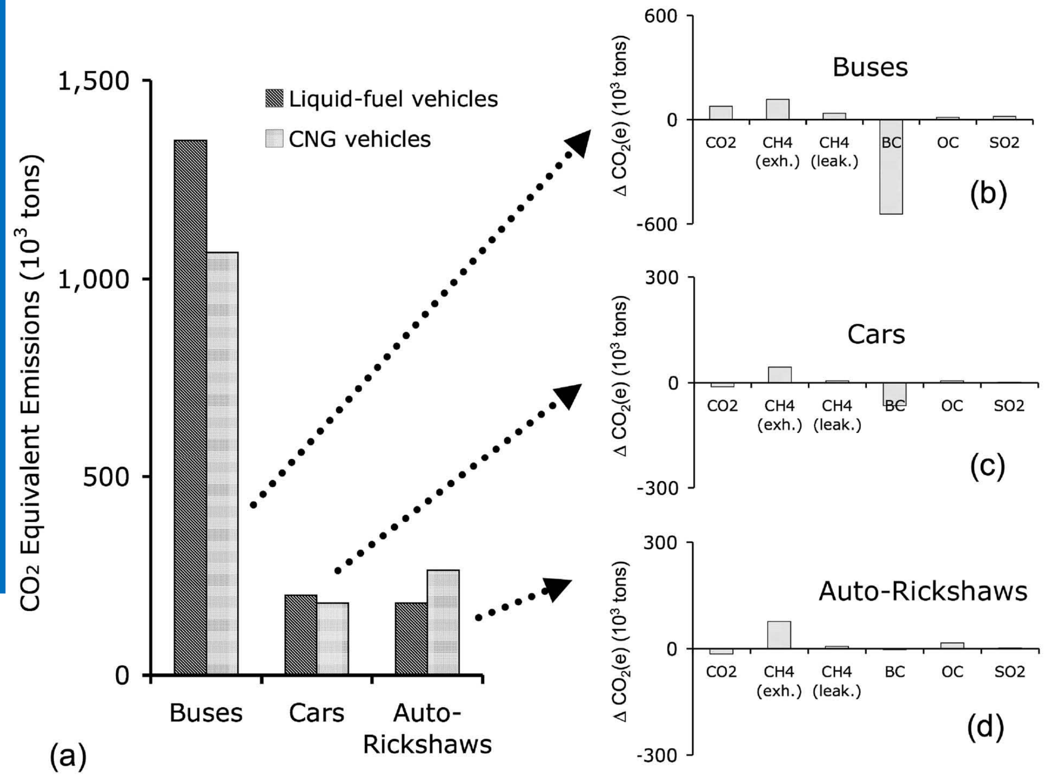
Switching to LPG resulted in:

Increase in CO2
Increase in Methane

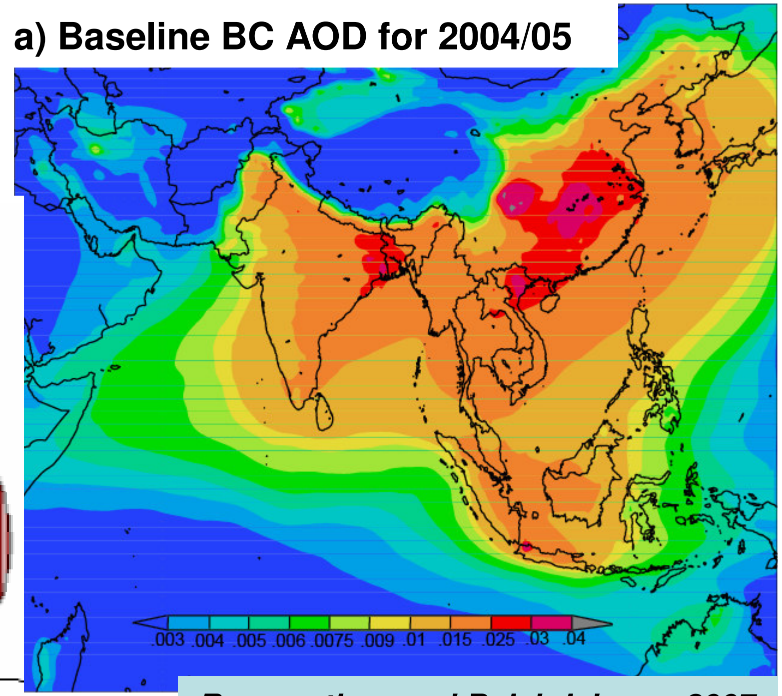
But, when black carbon reductions from Buses were accounted for,

There was on overall reduction in CO2 of

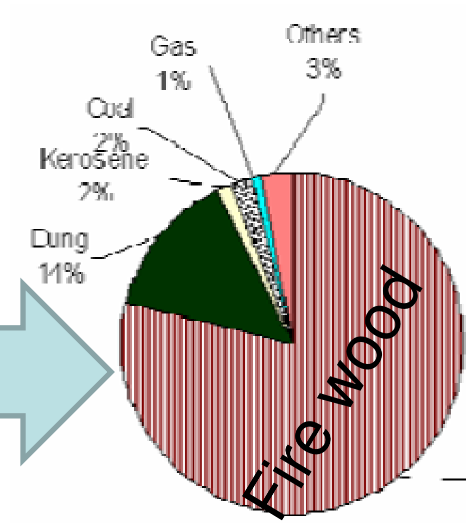
300,000 tons of CO_2 Eq.



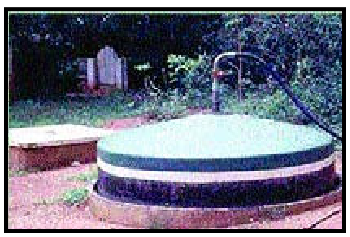
a) Baseline BC AOD for 2004/05



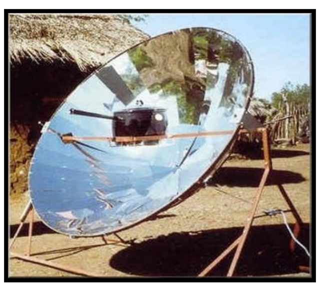
Rural Cooking



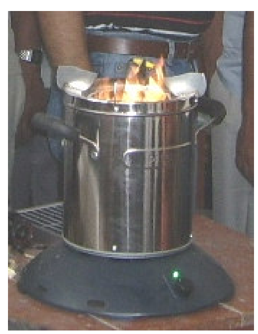
Ramanathan and Balakrishnan, 2007
Ramanathan and Carmichael, 2008



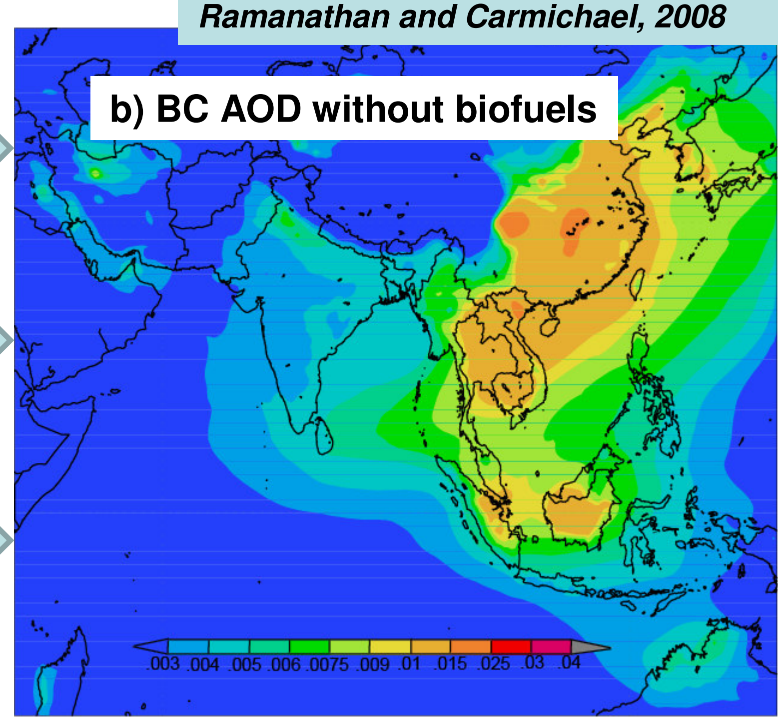
Biogas plants converts organic waste into gas



Parabolic solar cooker



b) BC AOD without biofuels



project surya

Fighting Climate Change Now

<u>Lead Institutions</u>

TERI, Delhi

Sri Ramchandra Univ, Chennai

JNU, Delhi

UCLA

UCSD