Climate Effects of Black Carbon Aerosols in China and India

Subari Menon, James Hansen, Larissa Nazarenko, Yunfeng Luo

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Presented by: Donifan Barahona

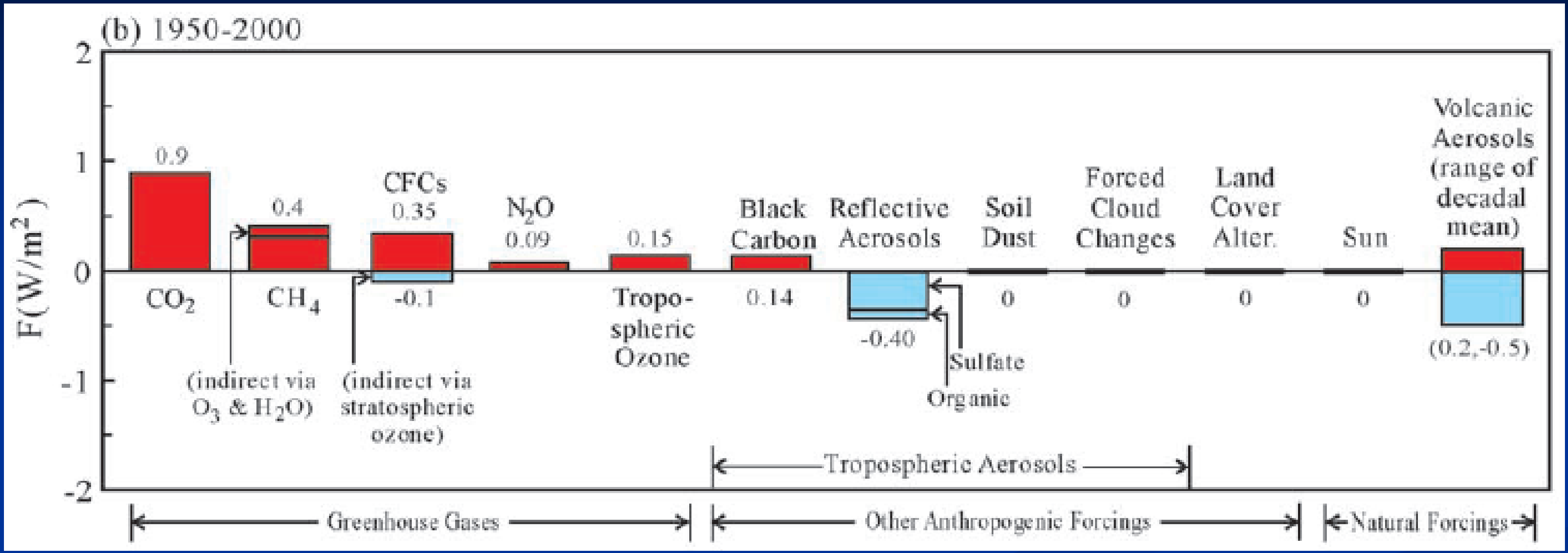
Black Carbon?

When BC is present it warms the air relative to the surface, and contributes to global warming

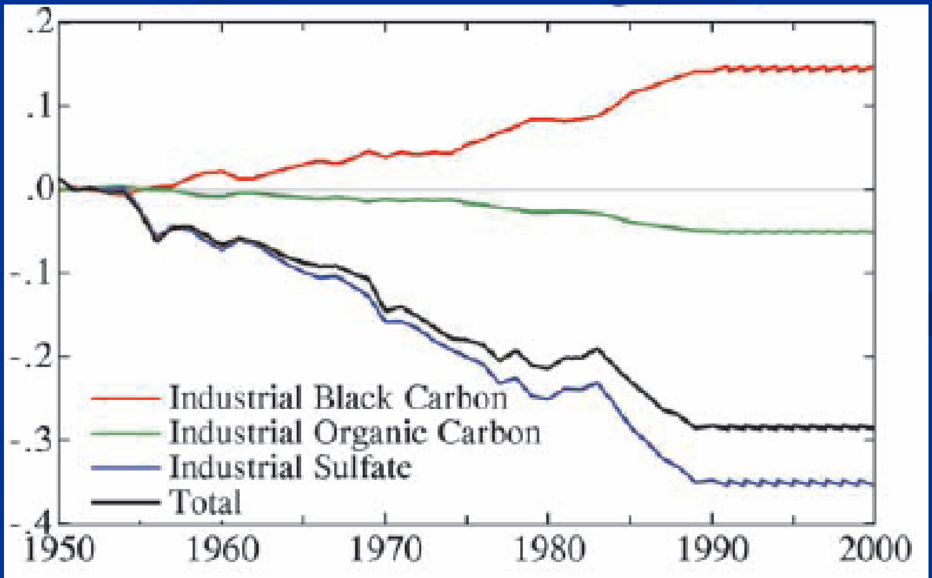
Aerosol	Optical Depth 1950/1990	Single Scattering Albedo 1950/1990
Tropospheric sulfate		
Natural	0.004	1.00
Biomass burning	0.0006	1.00
Anthropogenic	0.0072/0.0184	1.00
Black carbon		
Biomass burning	0.0013	0.48
Industrial	0.0004/0.0016	0.31
Organic carbon		
Natural	0.0009	0.98
Biomass burning	0.0096	0.93
Industrial	0.0016/0.0056	0.96
Soil dust	0.0324	0.89
Sea salt	0.0267	1
Stratospheric sulfate	0.0065/0.0110	1
Total	0.0912/0.1121	0.942/0.944

Hansen, J., et al., Climate forcings in Goddard Institute for Space Studies SI2000 simulations, *J. Geophys. Res.*, *107*(D18), 4347, 2002.

BC has a positive forcing

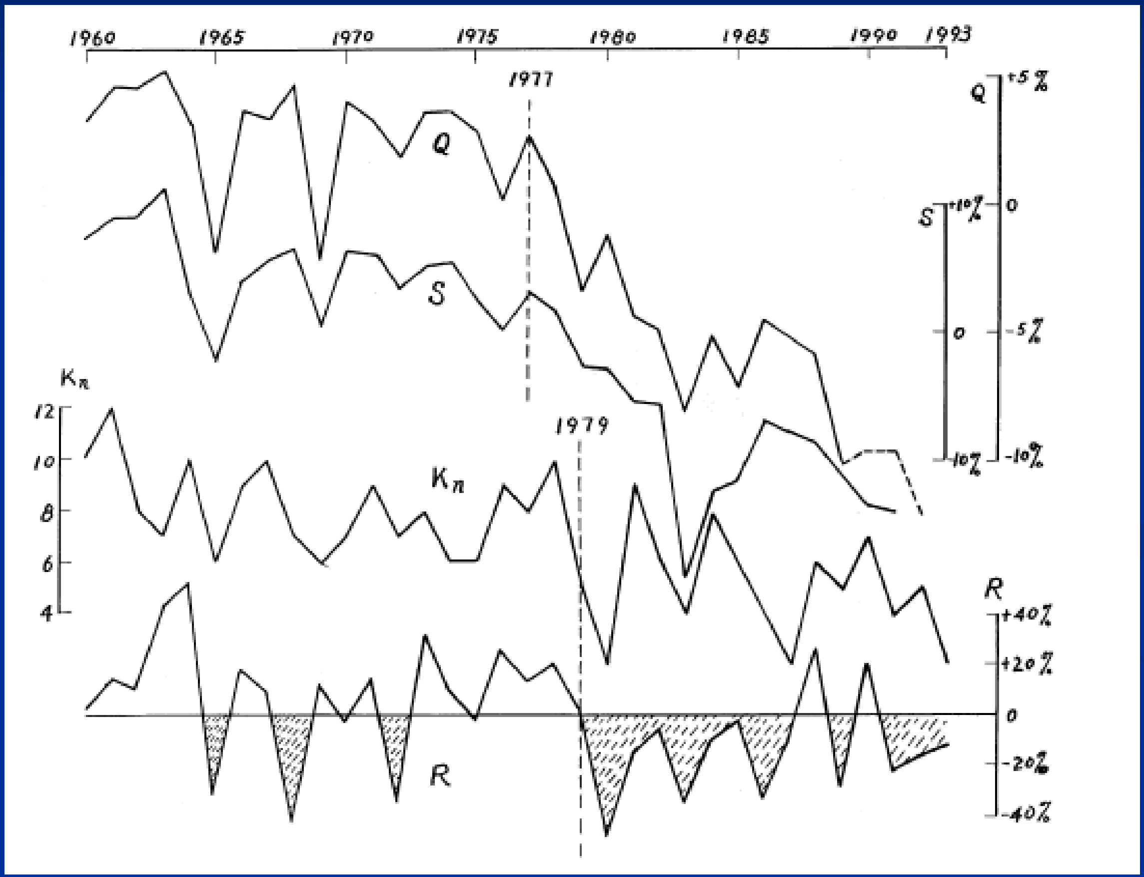


F (W/m2)



Hansen, J., et al., ibid.

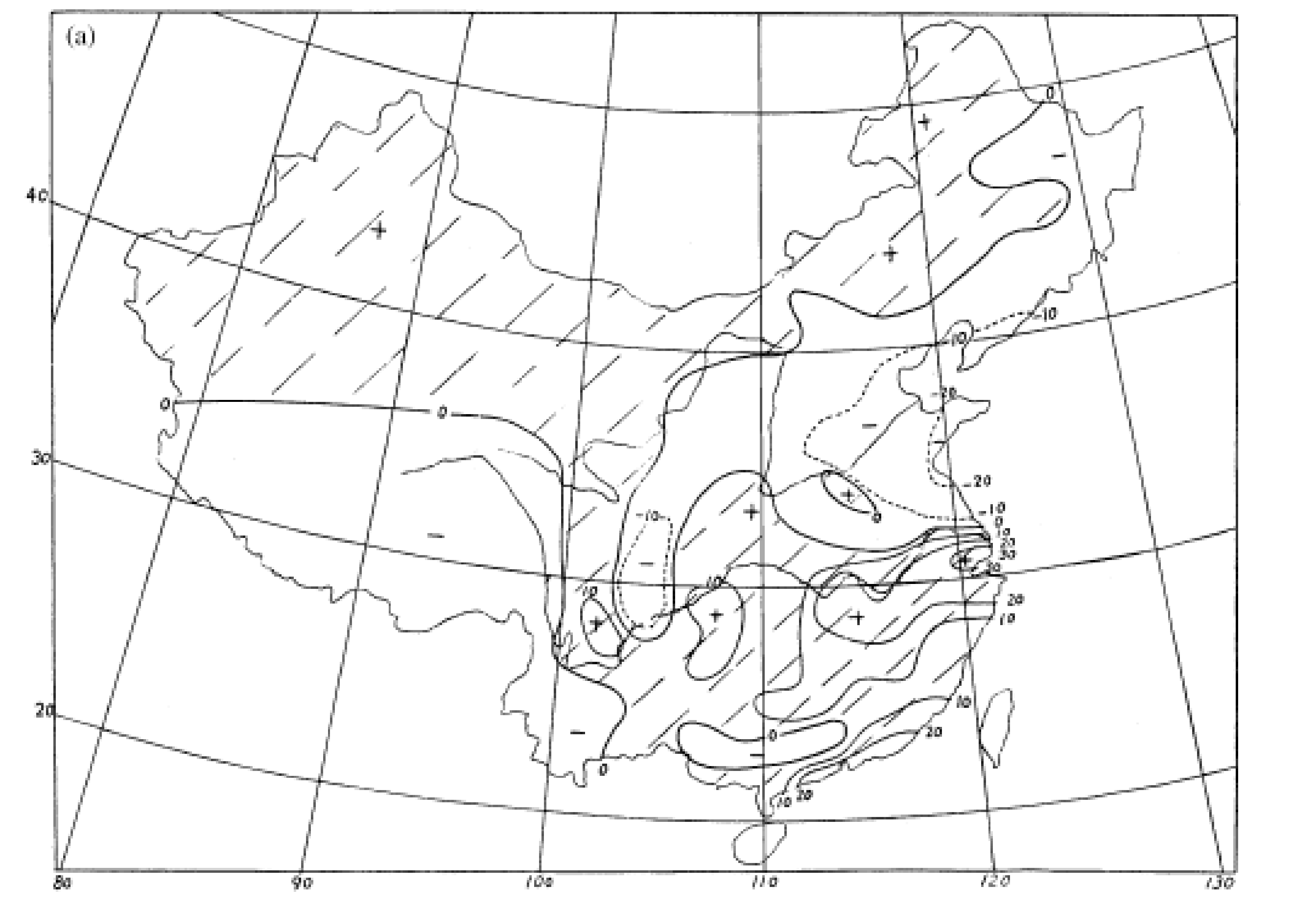
Climate Change in Northern China



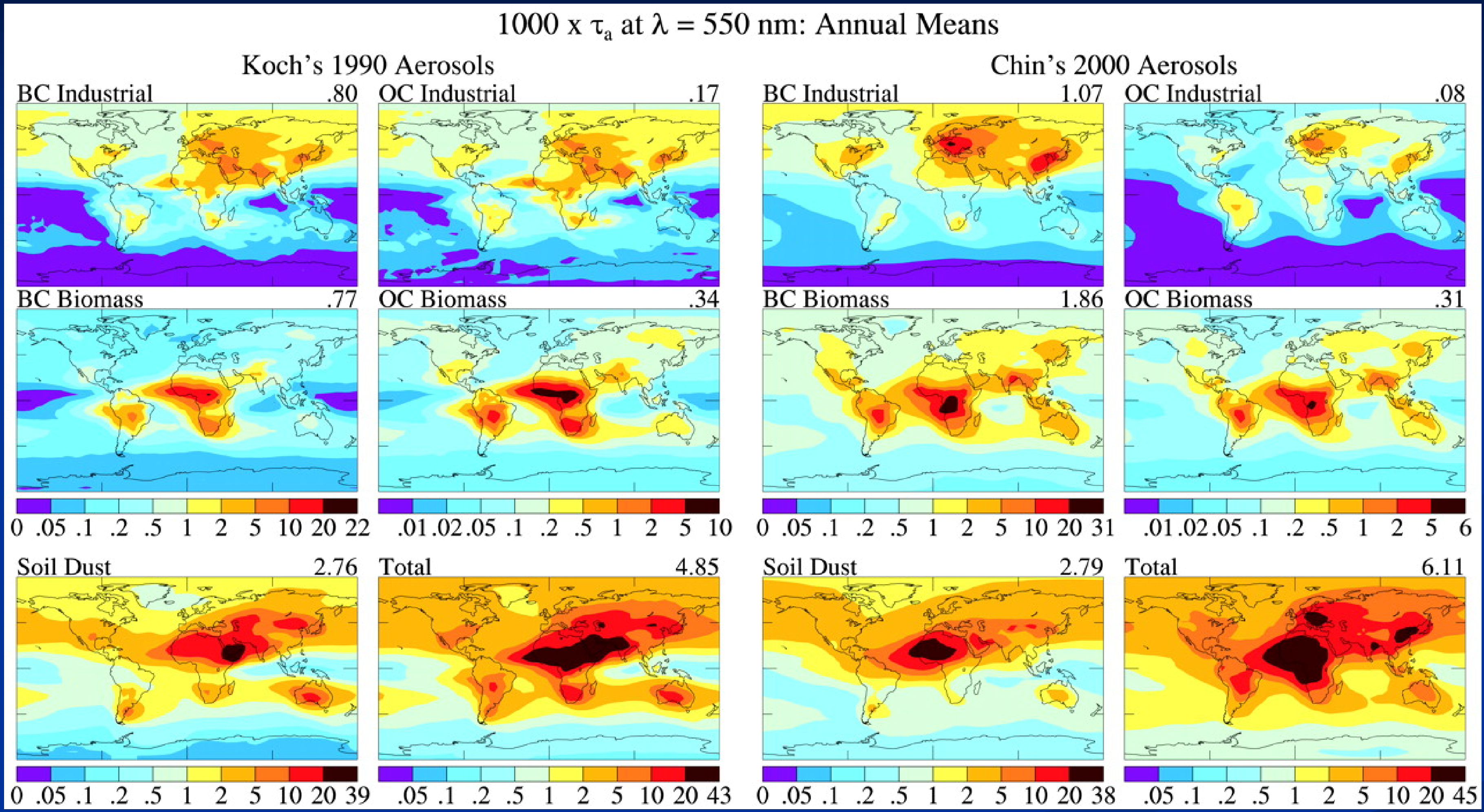
80% of China's energy comes from coal burning, with a 5 times-fold increase in the last 40 years.

Clear sky global solar radiation (Q) and clear sky direct solar radiation (S) of 9 stations in China, Pentad number (Kn). R: the average rainfall (R) anomaly percent of north China during JA. Q. Xu, Atm. Env. (2001) 5029–5040

Changes in Precipitation Patterns Over China



The mid-summer (JA) rainfall trend distribution (unit: mm/10 yr) of China for the years 1960–1999. Q. Xu, Atm. Env. (2001) 5029–5040

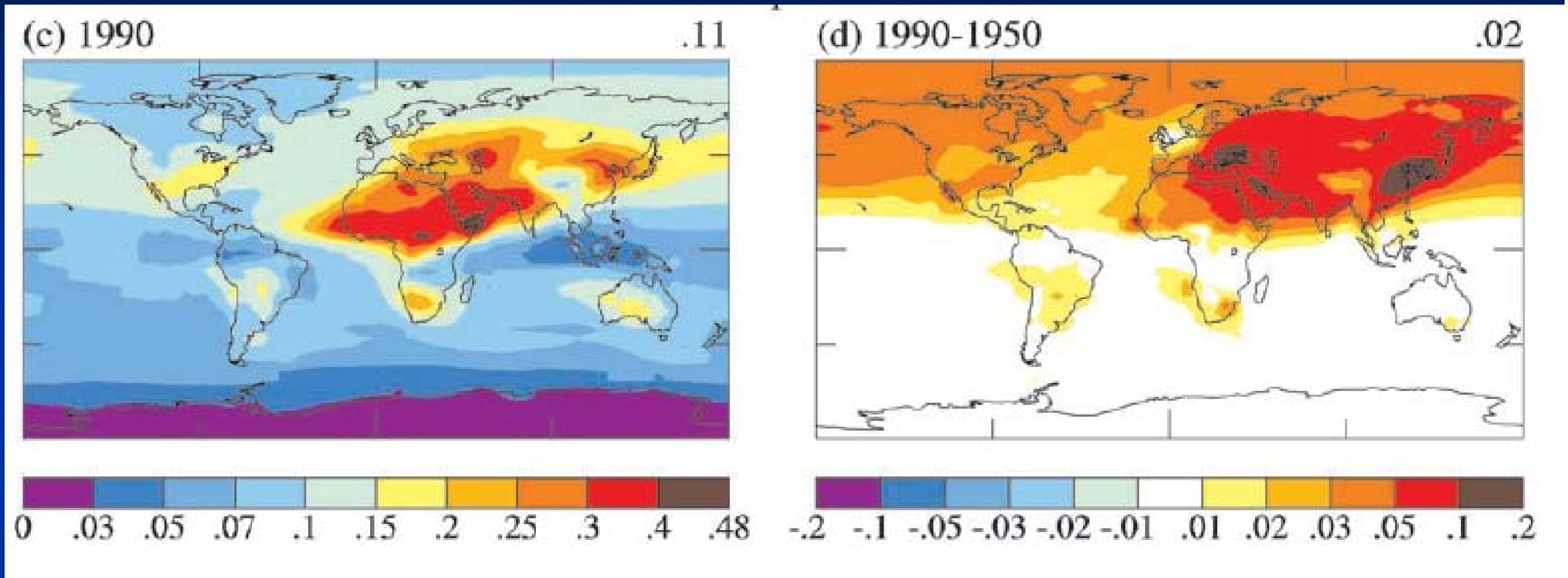


Sato, Makiko et al. (2003) Proc. Natl. Acad. Sci. USA 100, 6319-6324

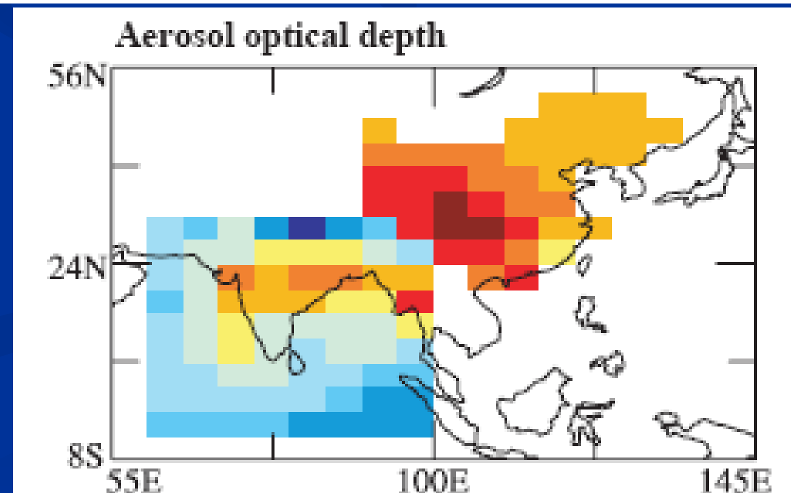
Hypothesis

Human-made absorbing aerosols in remote industrial regions may alter the regional atmospheric circulation in China and contribute to climate change through a direct radiative effect

Aerosols optical depth

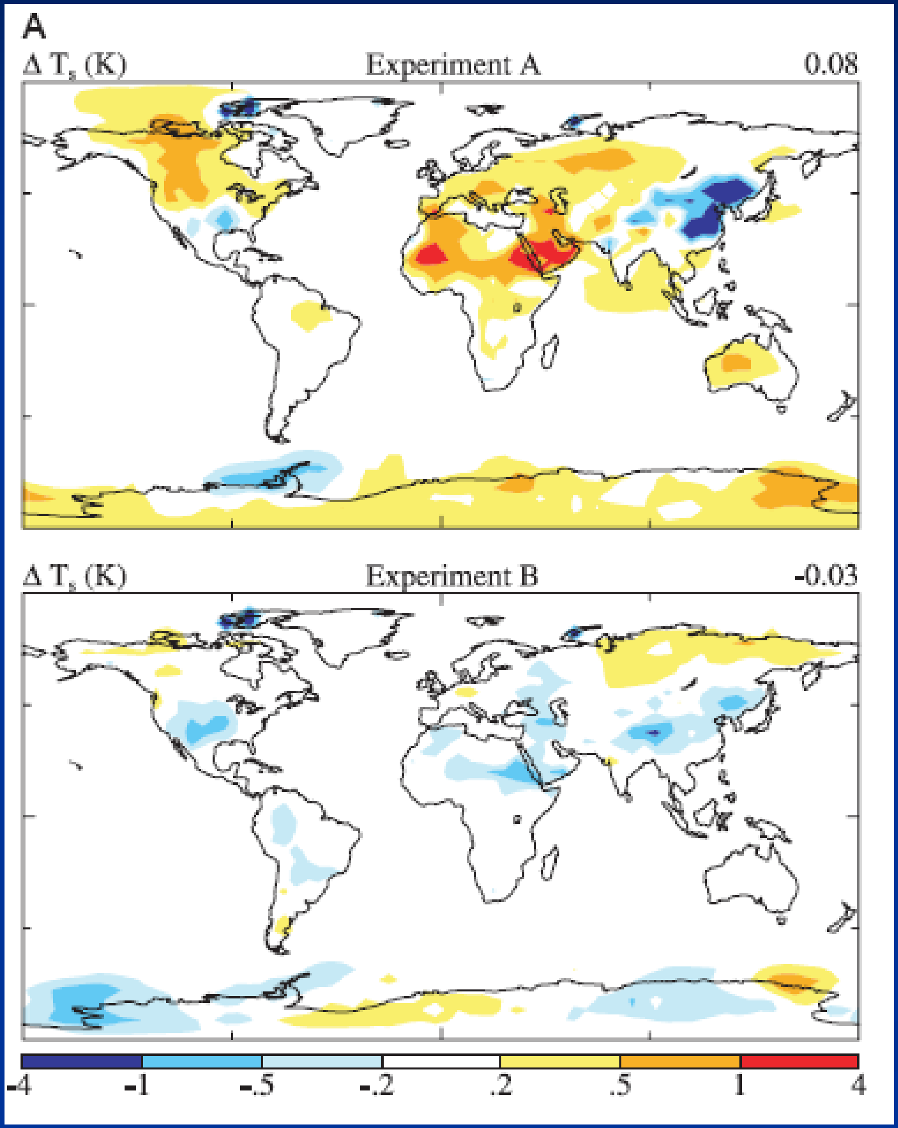


Exp.	BC	SSA
A	Yes	0.85
B	No	1.0



Hansen, J., et al., ibid.

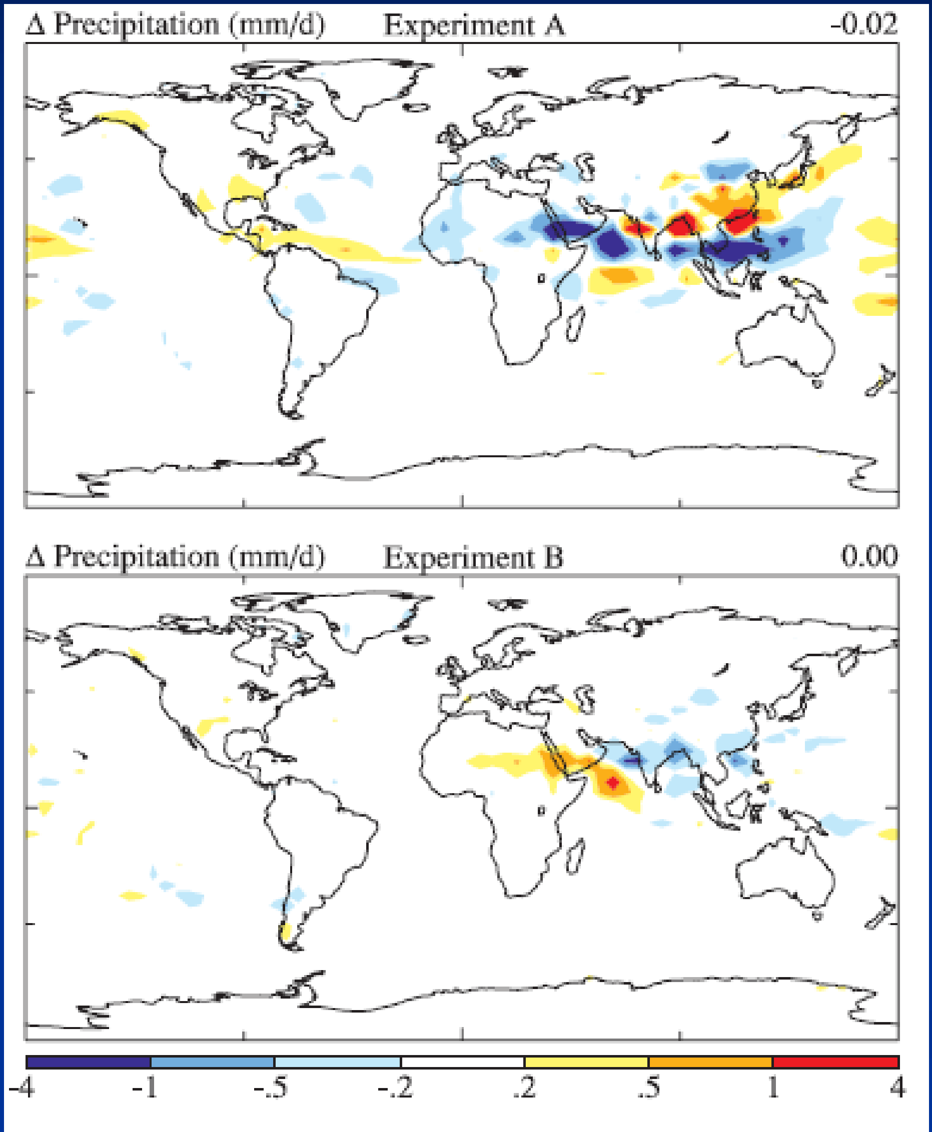
Surface Air Temperature Changes



The aerosols with SSA 0.85 yield cooling in China by 0.5 to 1 K, but warming in most of the world, due to BC heating of the troposphere

Exp.	BC	SSA
A	Yes	0.85
B	No	1.0

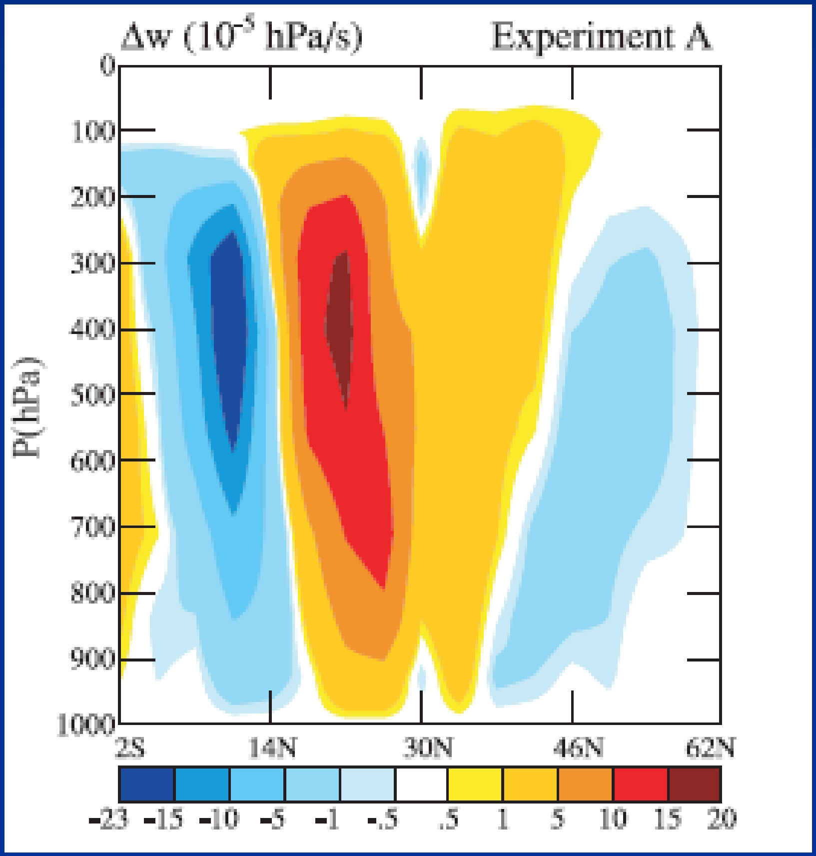
Precipitation Changes



The aerosols with SSA 0.85 yield increased precipitation in southern China and over India and Myanmar where $\Delta\tau_{aer}$ was largest

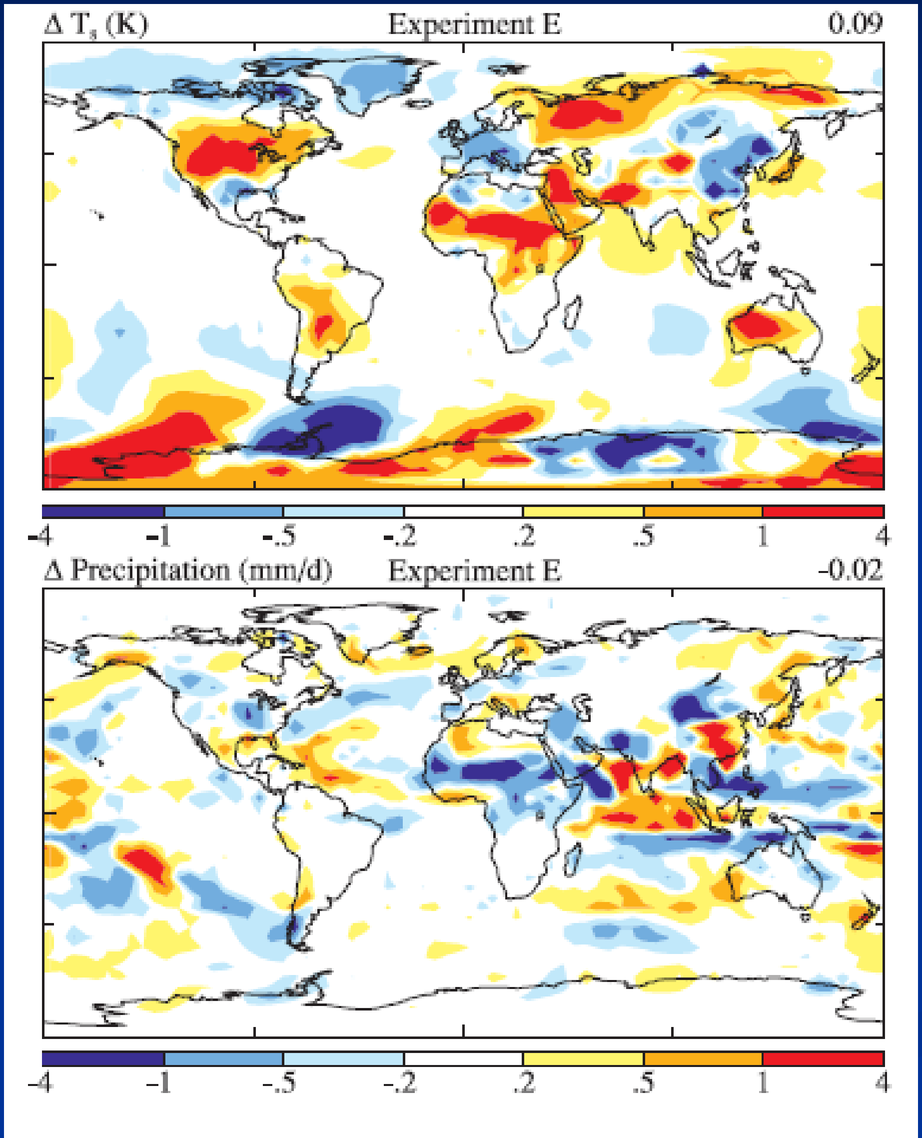
Exp.	BC	SSA
A	Yes	0.85
B	No	1.0

Vertical Velocity Change for Experiment A



The effect of aerosols derives from heating of the air and changes in the vertical temperature profile,
evaporation,
latent heat fluxes, atmospheric stability,
and in the strength of convection. Changes in convection,
in turn, can modify the large-scale circulation

Fixed Cloud Cover



The simulated increase of cloud cover over China in experiment A is contrary to observations from 1951–1994, however cloud cover may not interfere with the conclusions

Conclusions

- Absorbing aerosols can affect regional climate. Precipitation trends in China over the past several decades, with increased rainfall in the south and drought in the north, may be related to increased BC aerosols.
- The increase of dark carbon-rich aerosols in India could contribute to a tendency toward increased droughts in northern areas, such as Afghanistan, as well as to climate changes in India.

More Work is Needed

- Direct and semi-direct effects are included in the simulations. There must be an indirect effect associated with BC.
- Feedback mechanisms can be quite complicated.