Atmos. Chem. Lecture 22, 12/4/13: Chemistry and climate 2

Radiative forcing by aerosol

Chemistry and radiative forcing (aerosols)

Summary: Strat + Trop + Aerosol + Climate

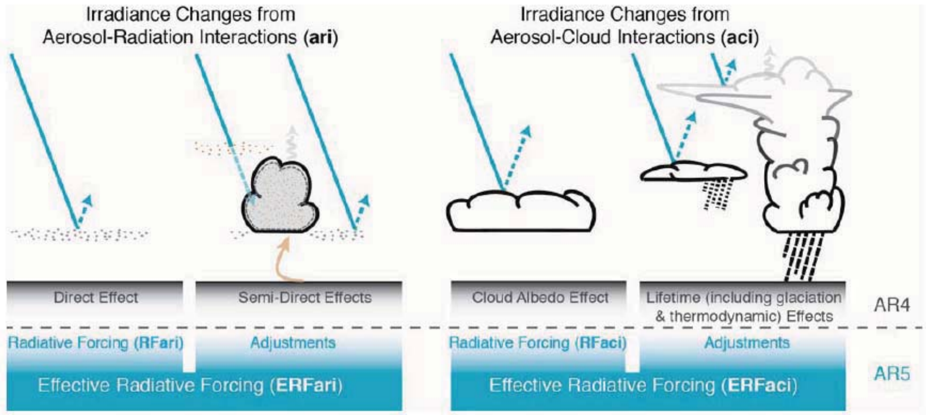
Final presentations Monday 12/9

Final projects due Wednesday 12/11

GHGs vs aerosols

S&P

Types of (effective) radiative forcing



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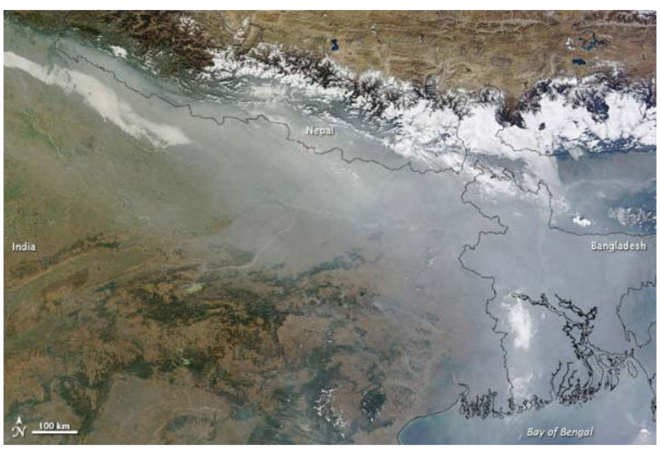
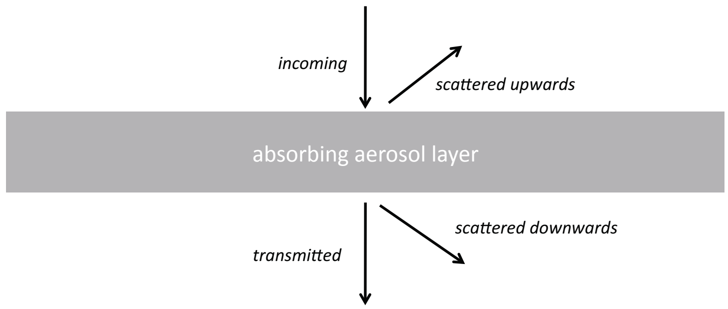
Aerosol-radiation interactions

Absorption, scattering of light (formerly known as "direct effects")



MODIS image (Terra satellite), Dec. 5, 2011

Aerosol-radiation interactions



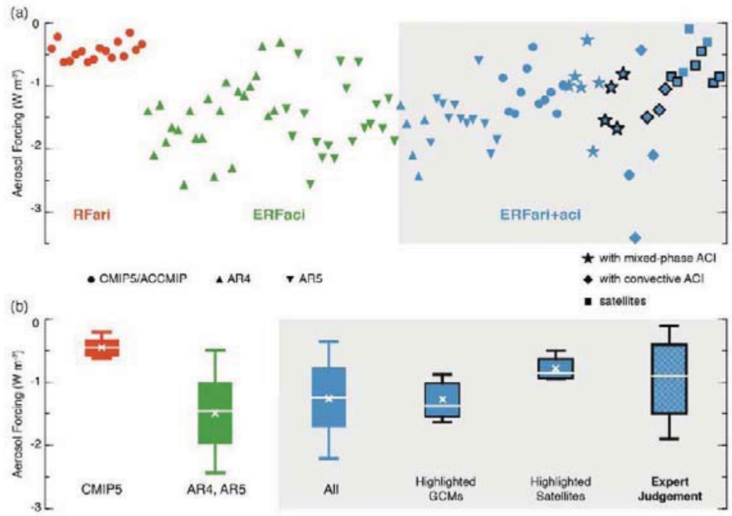
$$\Delta \bar{F} = -\tfrac{1}{2} F_0 T_a^2 (1 - A_c)\omega \bar{\beta} \bar{\tau} \left[(1 - R_s)^2 - \frac{2R_s}{\bar{\beta}} \left(\frac{1}{\omega} - 1 \right) \right]$$

Single-scattering albedo

Image removed due to copyright restrictions. See Figure 24.2 in Seinfeld, J. H., and S. H. Pandis. *Atmospheric Chemistry and Physics*, 2nd ed. Wiley 2006.

S&P

Magnitudes, uncertainties of ERFs



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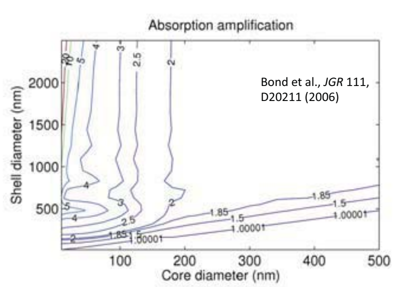
Mixing state of particles



Radiative Absorption Enhancements Due to the Mixing State of Atmospheric Black Carbon

"(Measured absorption enhancement) is less than predicted from observationally constrained theoretical calculations, suhhesying that many climate models overestimate warming by BC."

Cappa et al., *Science* 337:1078 (2012)

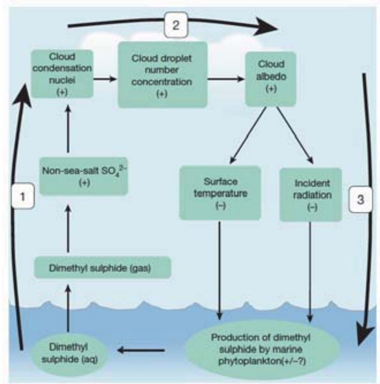
"CLAW hypothesis"

Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate

Robert J. Charlson*, James E. Lovelock†, Meinrat O. Andreae‡ & Stephen G. Warren*

Nature, 326:655 (1987)

The major source of cloud-condensation nuclei (CCN) over the oceans appears to be dimethylsulphide, which is produced by planktonic algae in sea water and oxidizes in the atmosphere to form a sulphate aerosol Because the reflectance (albedo) of clouds (and thus the Earth's radiation budget) is sensitive to CCN density, biological regulation of the climate is possible ..."



The case against climate regulation via oceanic phytoplankton sulphur emissions

Quinn and Bates, *Nature*, 480:51 (2011)

The evidence gained over the past 20 years of the significance of non- DMS sources of MBL CCN, the lack of observational evidence for a DMS-controlled marine biota–climate feedback, and the modelled low sensitivity between change and response in each step of the CLAW hypothesis feedback loop all indicate that it is time to retire the CLAW hypothesis."

Emissions-based forcing: including aerosol

Image removed due to copyright restrictions. See Fig. 1 in Schindell, D. T., et al. "Improved Attribution of Climate Forcing to Emissions." *Science* 326, no. 5953 (2009): 716-8.

Shindell et al., *Science* 326:716 (2009)
(mostly incorporated into AR5)

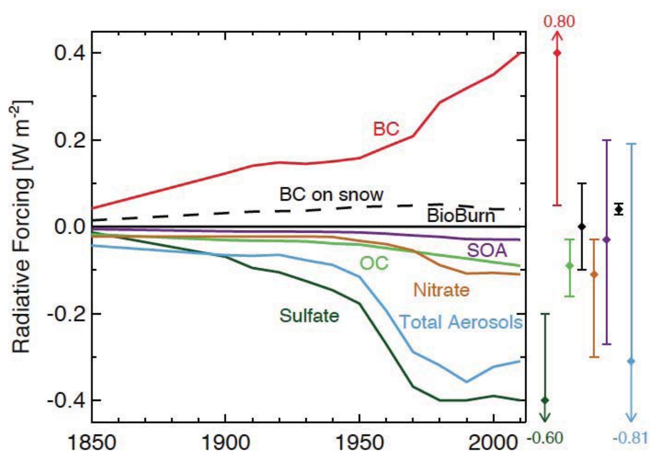
GWPs when aerosol is included

Image removed due to copyright restrictions. See Fig. 2 in Schindell, D. T., et al. "Improved Attribution of Climate Forcing to Emissions." *Science* 326, no. 5953 (2009): 716-8.

Shindell et al., *Science* 326:716 (2009)

Although our calculations are more complete than previous studies, additional processes should be included as they become better understood. These include mixing between aerosol types, formation of secondary organic aerosols, which are sensitive to both organic aerosol emissions and oxidant levels, and interactions between pollutants and ecosystems. The latter includes suppression of CO_2 uptake by increased surface ozone concentrations, aerosols enhancing the ratio of diffuse to direct radiation reaching the biosphere leading to increased CO_2 uptake (at least for some plant types when aerosol loading is not so large as to dramatically reduce total surface irradiance), and the effects of nitrogen and sulfur deposition on ecosystems."

Changes to aerosol forcings



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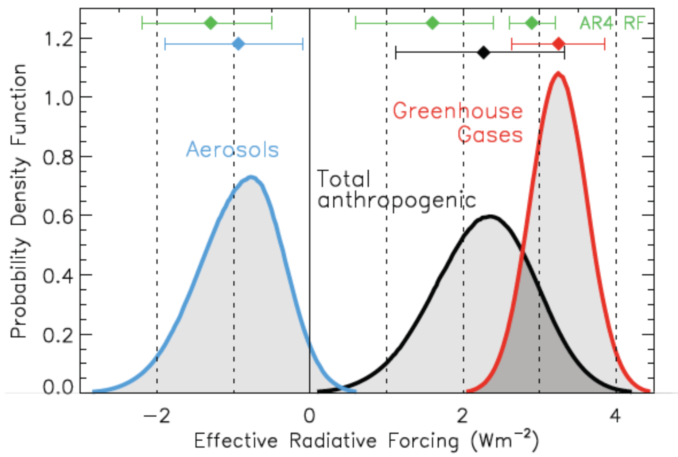
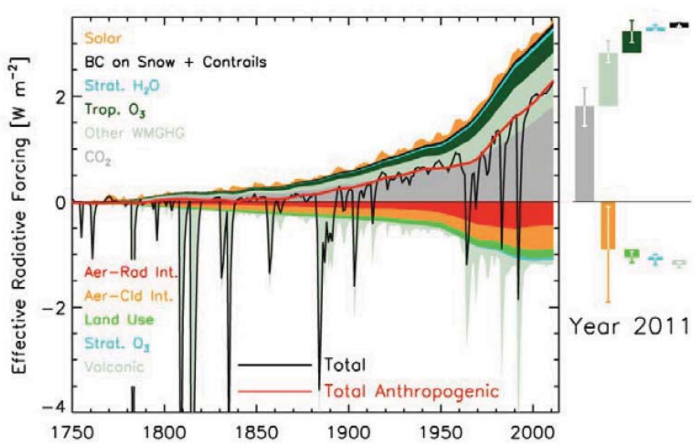
Uncertainties: GHGs vs particles



IPCC AR5, 2013

Forcings since 1750



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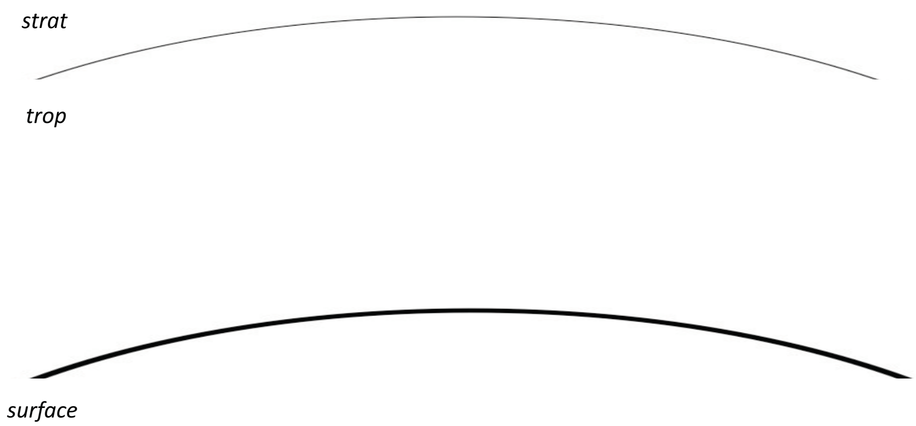
Summary



[Note: Additional material is discussed here during lecture.]

Other atmospheric chemistry classes at MIT

1.841: Atmospheric Composition in the Changing Earth System (Heald, S-even)
12.814: Aerosol and Cloud Microphysics and Chemistry (Cziczo, S)
12.806J: Atmospheric Physics and Chemistry (Prinn, S)
12.835: Experimental Atmospheric Chemistry (Cziczo/Ono/Prinn, F)
12.848J: Global Climate Change: Economics, Science, and Policy (Prinn, S)
12.885 Environmental Science and Society (Solomon, F)
16.715: Transportation and the Environment (Barrett, S)
ESD.110J: Global Environmental Science and Politics (Selin, F-odd)
ESD.120J: Sustainability Science and Engineering (Selin, F-even)
ESD.864J: Modeling and Assessment for Policy (Selin, S)

1.84J / 10.817J / 12.807J Atmospheric Chemistry
Fall 2013