Lecture 10.

How aerosols can affect clouds, precipitation and climate in Asia?

Outline:

1. Background materials.

2. *Papers for class discussion*:

Menon, S., J.E. Hansen, L. Nazarenko, and Y. Luo, Climate effects of black carbon aerosols in China and India. Science 297, 2250-2253, doi:10.1126/science.1075159, 2002.

Qian, Y., D. P. Kaiser, L. R. Leung, and M. Xu, More frequent cloud-free sky and less surface solar radiation in China from 1955 to 2000, Geophys. Res. Lett., 33, L01812, doi:10.1029/2005GL024586, 2006.

Background materials.

Impacts of atmospheric aerosols upon the climate system: Summary

Direct radiative impacts

IMPACT	IMPORTANCE
Top of the atmosphere (TOA) radiative forcing (solar plus IR)	affects energy balance of the Earth's climate system
Radiative forcing at the surface (solar plus IR)	affects surface temperature and surface-air exchange processes, ecosystem functioning
Radiative heating/cooling of atmospheric layers (solar plus IR)	affects temperature profile, cloud lifetime, and atmospheric dynamics thermodynamics
Actinic flux (UV)	affects photolysis rates and photochemistry

NOTE: The magnitude of the impact depends on the type of aerosols as well as atmospheric and surface conditions.

Further reading:

Yu et al., A review of measurement-based assessments of the aerosol direct radiative effect and forcing. Atmos. Chem. Phys., 6, 613-666, 2006.

Indirect radiative impacts (via clouds)

Lohmann and Feichter (2005) (see Lecture 7)

Table 1. Overview of the different aerosol indirect effects and range of the radiative budget perturbation at the top-of-the atmosphere (F_{TOA}) [$W m^{-2}$], at the surface (F_{SFC}) and the likely sign of the change in global mean surface precipitation (P) as estimated from Fig. 2 and from the literature cited in the text.

Effect	Cloud type	Description	F_{TOA}	F_{SFC}	P
Indirect aerosol effect for clouds with fixed water amounts (cloud albedo or Twomey effect)	All clouds	The more numerous smaller cloud particles reflect more solar radiation	−0.5 to −1.9	similar to F_{TOA}	n/a
Indirect aerosol effect with varying water amounts (cloud lifetime effect)	All clouds	Smaller cloud particles decrease the precipitation efficiency thereby prolonging cloud lifetime	−0.3 to −1.4	similar to F_{TOA}	decrease
Semi-direct effect	All clouds	Absorption of solar radiation by soot may cause evaporation of cloud particles	+0.1 to −0.5	larger than F_{TOA}	decrease
Thermodynamic effect	Mixed-phase clouds	Smaller cloud droplets delay the onset of freezing	?	?	increase or decrease
Glaciation indirect effect	Mixed-phase clouds	More ice nuclei increase the precipitation efficiency	?	?	increase
Riming indirect effect	Mixed-phase clouds	Smaller cloud droplets decrease the riming efficiency	?	?	decrease
Surface energy budget effect	All clouds	Increased aerosol and cloud optical thickness decrease the net surface solar radiation	n/a	−1.8 to −4	decrease

Impacts on the hydrological cycle (via clouds and precipitation and/or surface evaporation)

Aerosol particles can either promote or suppress precipitation – depends on aerosol type!

Current understanding:

- ✓ Smoke and pollution suppresses precipitation.

Further reading:

Rosenfeld D., Suppression of rain and snow by urban and industrial air pollution Science. 2000 Mar 10;287(5459):1793-6, 2000.

Andreae et al., Smoking rain clouds over the Amazon, Science 27 February 2004: Vol. 303. no. 5662, pp. 1337 – 1342, 2004.

- ✓ Dust particles either promote or suppress precipitation (unresolved problem!)

Further reading:

Rosenfeld et al., Desert dust suppressing precipitation: A possible desertification feedback loop, Proc Natl Acad Sci U S A. 2001 May 22;98(11):5975-80, 2001.

- All aerosols decrease solar radiation reaching the surface and hence lead to smaller evaporation rates which, in equilibrium, are balanced by lower precipitation rates

Further reading:

Ramanathan, V. et al, Aerosols, climate, and the hydrological cycle, Science *7 December 2001, Vol. 294. no. 5549, pp. 2119 – 2124, 2001.*

Ramanathan, V. et al. "Atmospheric Brown Clouds: Impacts on South Asian Climate and Hydrological Cycle." Proceedings of the National Academy of Sciences of the United States of America, Vol. 102, No. 15, pp. 5326-5333, 2005.

Indirect radiative impacts (via surface albedo)

Aerosol particles deposited on the surface alter its albedo (i.e., changes in surface reflectance):

Black carbon on ice/snow surface (e.g., Hansen and Nazarenko, 2004; see Lecture 8)

Dust on snow.

Indirect radiative impacts (via radiative active gases)

Aerosol particles affect the abundance and lifetime of atmospheric gases leading to changes in radiative forcing of these gases (e.g., aerosol-induced changes in O_3)

Emerging problems:

What are the roles of organic and biogenic aerosol types?

Further reading:

Fuzzi et al., Critical assessment of the current state of scientific knowledge, terminology, and research needs concerning the role of organic aerosols in the atmosphere, climate, and global change. Atmos. Chem. Phys.Discuss. 5, 11729-11780, 2005.