We can ask ourselves, why we should consider aerosols in a course on global change. As we've learned in a previous lecture, infrared-observing species known as greenhouse gases-- namely carbon dioxide, methane, and nitrous oxide-- trap terrestrial heat, thereby warming the planet.

Aerosols predominately scatter solar radiation. That is to say, they do not allow solar radiation to reach the earth's surface and thereby warm the planet. Aerosols do this directly-- that is, the particles themselves scatter solar radiation-- as well as indirectly-- they are the condensation nuclei on which clouds form, and those cloud droplets or ice crystals then scatter solar radiation.

Anthropogenic aerosols in clouds can therefore be thought of as raising the planet's albedo. It is very important to note that aerosols in clouds formed anthropogenically do not cancel the greenhouse effect. That is to say, although they scatter solar radiation trying to reach the earth's surface, they do not fully offset the warming due to the greenhouse gases. The result, the net of human activities, is still a positive term. More energy is still trapped than would otherwise have been trapped without human activities.

This can also be visualized in terms of measurements, not the global climate model data shown in the last figure. Here we see the cumulative radiative forcing-- that is to say, the extra energy in the Earth system-- since the year 1950, due to the greenhouse gases, CO2, methane, nitrous oxide, and halo carbons, as well as slight changes in solar activity and changes in stratospheric and tropospheric ozone.

In the right-hand panel, we can see the response of the Earth system. There's been some heating of the ocean and warming the planet that corresponds to more outgoing radiation detected by satellites above the atmosphere. Some energy has also been eliminated by the presence of volcanic aerosols high in the atmosphere. This is the part of this figure called strat, or stratospheric aerosol.

Important to this part of the lecture is the unresolved portion of the figure. Some of the energy that is known to have been put into the Earth system is unaccounted for. This is energy that was scattered back into space without making it into the Earth system due to the presence of anthropogenic aerosols and their effect on clouds. It is often suggested that aerosols offset greenhouse gas warming, and one possible solution is to intentionally add more aerosol to the atmosphere.

It has to be taken into account, however, that aerosol has serious side effects, such as an increase in mortality. One striking example is the so-called "Great Smog" that occurred in London in 1952. The Great Smog was due to a combination of meteorology-- there was a temperature inversion, which trapped particles near the surface-- as well as cold temperatures, which led to an increased combustion of coal and other biomass-burning sources. During The Great Smog, particles reached 14,000 micrograms per cubic meter.

To put this into perspective, this is almost 300 times the current US standard for average particle concentration, and more than 90 times the peak allowable concentration. Visibility during The Great Smog was less than one meter, and 4,000 deaths were recorded within two weeks. Over 10,000 deaths were estimated in total.

Aerosols in clouds cause us to modify the simple one-layer atmospheric model that we constructed earlier in this class, where the atmosphere acts only to absorb outgoing terrestrial radiation, re-radiating some of it back to the planet surface, thereby increasing the surface temperature. First, we need to account for some scattering of solar radiation in the atmosphere. This scattering is due to the presence of aerosols and clouds, and it therefore reduces the intensity of sunlight reaching the surface of the planet.

An accurate picture of the radiative balance of our atmosphere is thus rather complicated. Specifically, incoming solar radiation can be absorbed by a cloudless atmosphere. Some species actually absorb solar radiation before it reaches the surface. It can also be reflected back into space by particles and clouds. Terrestrial radiation, which we assumed took place in a discrete, single layer above the surface of the planet, actually can both be absorbed by the atmosphere, the greenhouse gases, as well as a minor amount by clouds and aerosol particles.

This figure provides current estimates for the amount of absorption and scattering by the different atmospheric components.