Atmospheric aerosol (continued)

Topics:
- Aerosol and condensation nuclei (continued)
- Influence of aerosol on atmospheric phenomena

Aerosol and condensation nuclei

The next figure is an activity spectrum from a field project set around the Azores in Summer of 1992. The y-axis label is a bit strange; I think what is meant is \( \frac{dN}{d \log Sc} \) with units of \([\text{cm}^{-3} \text{(log}(\% \text{ Sc}))^{-1}]\) such that when you integrate over the spectrum you get \([\text{cm}^{-3}]\). The top rows indicate the number of nuclei observed at respective supersaturation values. The figure also reports the value of \(k\) for three supersaturation intervals.
Figure 4.7 from Wallace and Hobbs is a nice schematic summary of aerosol spectra, along with sources, sinks, and residence timescales for various aerosol sizes.

![Figure 4.7 Schematic curves of aerosol surface area distributions for urban polluted air, continental air, and marine air. Shown below the curves are the principal sources and sinks of atmospheric aerosol and estimates of their mean lifetimes in the troposphere. [Adapted from Atmos. Environ. 9, 763 (1975).]](image)

**Influence of aerosol on atmospheric phenomena**

[This discussion follows Section 4.1.4 in Wallace and Hobbs.] The next figure shows the relationship between aerosol size categories and the role they play in atmospheric processes.

![Figure 4.8 Approximate size ranges of aerosol of importance in various atmospheric phenomena.](image)
We have already covered how aerosol act to begin cloud physics processes through heterogeneous nucleation (including Köhler curves, droplet solution effects, etc.) This includes not only developing embryonic droplets with characteristics enabling them to grow by vapor deposition, but also stable haze particles. Aerosol particles also exert an influence on atmospheric electrical properties, radiative transfer, and chemistry.

Aerosol that are electrically charged are called ions. Their concentration \([\text{cm}^{-3}]\) and type determine the fair weather conductivity and electric field. Ions in the lower troposphere arise from cosmic rays and ionization from radioactive isotopes in the earth. Ions are classified as small or large based on a quantity called electrical mobility, which is the ion velocity in an electrical field of 1 V m\(^{-1}\). Small ions of near molecular size have electrical mobilities of \(\sim 1 \times 10^{-4} \text{ m s}^{-1}\). Large ions, which coincide approximately with the size range of Aitken nuclei (10\(^{-3}\) μm to 0.01 μm) have much lower mobilities in the range of \(3 \times 10^{-8} \text{ m s}^{-1}\) to \(8 \times 10^{-7} \text{ m s}^{-1}\). Number of concentrations of small ions are 40-1500 cm\(^{-3}\) at sea level. Concentrations of large ions range from \(\sim 200 \text{ cm}^{-3}\) over the ocean to as much as 800,000 cm\(^{-3}\) in urban regions. Electrical conductivity is proportional to ion mobility and concentration, and is atmospheric conduction is largely carried out by the small ions. In urban regions, large ions and other uncharged aerosol tend to capture ions in the small range, which significantly reduces conductivity. In order to maintain current density, Ohm’s law says that electric field has to increase. This is why the fair weather electric field is typically at its highest values over cities and at the times of day when the aerosol concentration is greatest (e.g. rush hour).

Many aerosol are chemically active. Trace gases can be absorbed by certain solid particles and then react. Liquid aerosol can absorb soluble gases, which can then react in solution. Of course, the aqueous chemistry involving ammonia and sulfates that we mentioned before is vitally important in cloud physics. Aerosol chemistry is important in understanding pollution, too. For example, when sulfur dioxide and aerosol accumulate, the sulfur dioxide can be converted into sulfates, which can then become aqueous sulfuric acid.

Aerosol characteristics and concentrations have a profound impact on scattering and absorption of radiation. [We will discuss this more rigorously in depth in the “Optics” section of the course.] Scattering of visible light is dominated by large aerosol (0.2-2.0 μm
in diameter). These aerosol can be activated at subsaturated conditions, forming haze (very small liquid droplets) that scatters short-wave radiation and reduces visibility. For example, as the RH increases from 60 to 80%, the amount of light that sea-salt particles remove from a beam increases by a factor of three. Aerosol both absorb and scatter incoming solar radiation, and an increase in concentration might conceivably alter the radiation balance of the earth, i.e. either raise or lower temperatures.