Lecture 7.

How many types of indirect aerosol effects are known?

Outline:

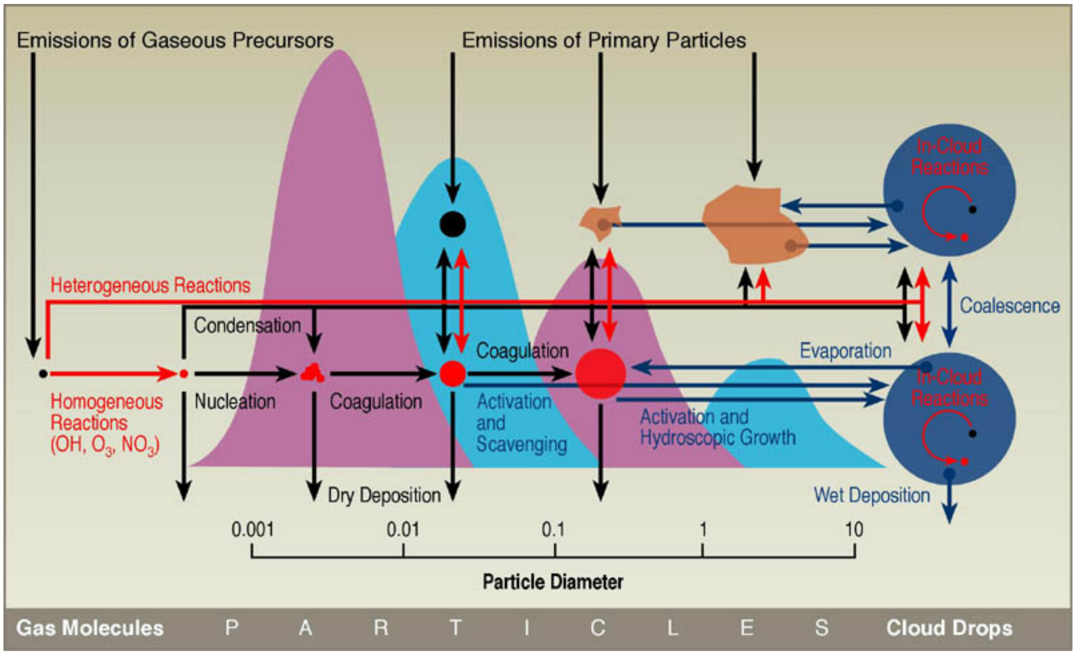
1. Background materials.

2. *Papers for class discussion*:

Lohmann, U., and J. Fletcher, Global indirect aerosol effects: A review, Atmos.Chem.Phys., 5, 715-737, 2005.

Background materials.

Main processes that cause the formation and transformation of aerosol particles: Aerosols can be emitted directly into the atmosphere or be formed there from the emissions of gaseous precursors. Particles grow by condensation of gases and by coagulation with other particles. Sizes of important atmospheric particles vary over several orders of magnitude. Reactions can occur on the surfaces of particles that can alter the composition of the particle or the surrounding atmosphere. Particles can also grow to become cloud droplets or ice crystals. Particle number and composition can influence the formation and characteristics of clouds. Particles scavenge a variety of gases from the atmosphere and are eventually removed from the atmosphere by wet or dry deposition to Earth's surface.



The above figure is from:

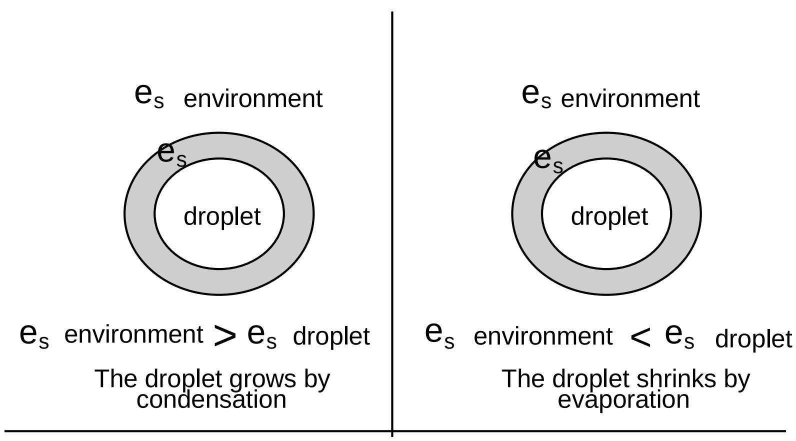
Heintzenberg, J., F. Raes, and S.E. Schwartz, 2003: Tropospheric aerosols. In: Atmospheric Chemistry in a Changing World: An Integration and Synthesis of a Decade of Tropospheric Chemistry Research [Brasseur, G.P., R.G. Prinn, and A.A.P. Pszenny (eds)]. Springer-Verlag, New York, NY, USA, pp. 125-156.

Cloud condensation nuclei (CCN) are particles on which water vapor condenses to form water droplets. The most effective are hygroscopic (water attracting), and water-soluble aerosols. If the CCN are water soluble, the resulting water droplet is not pure water, but a solution. The concentration of the solution (mass of CCN to volume of water in the droplet) depends upon the size of the CCN and the amount of vapor, which has condensed on to it (i.e., the volume of the droplet).

Warm rain formation:

Cloud drops initially growth by **condensation** (starting with CCN), then via **collision-coalescence**. Coalescence is not efficient when droplets < 14 μm.

- ✓ ***The amount of growth by condensation*** is governed by the difference in saturation vapor pressures (e_s) between the droplet and its surrounding environment.

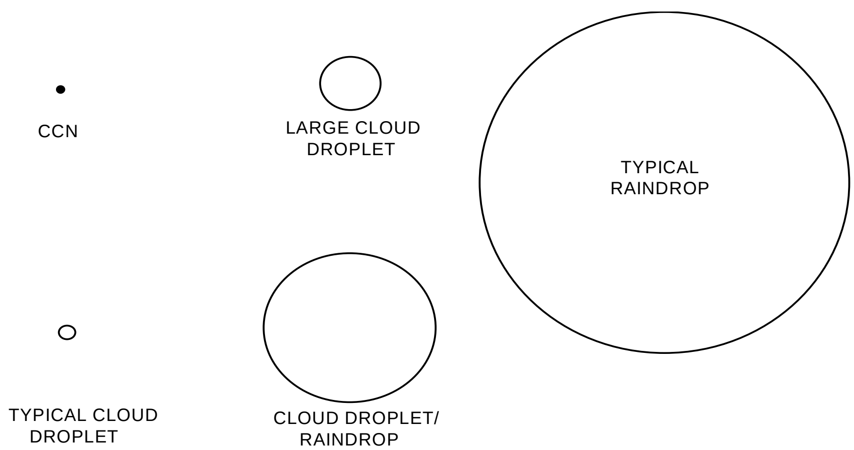


Each droplet will have a different e_s based upon its concentration (called *the solute effect*). Droplets consisting of higher concentrations of solution will have a lower e_s than more pure droplets.

Droplets that are smaller will have a higher e_s than a larger droplet which will have a flatter surface (called *the curvature effect*). Droplets that are larger will grow at the expense of the smaller droplet.

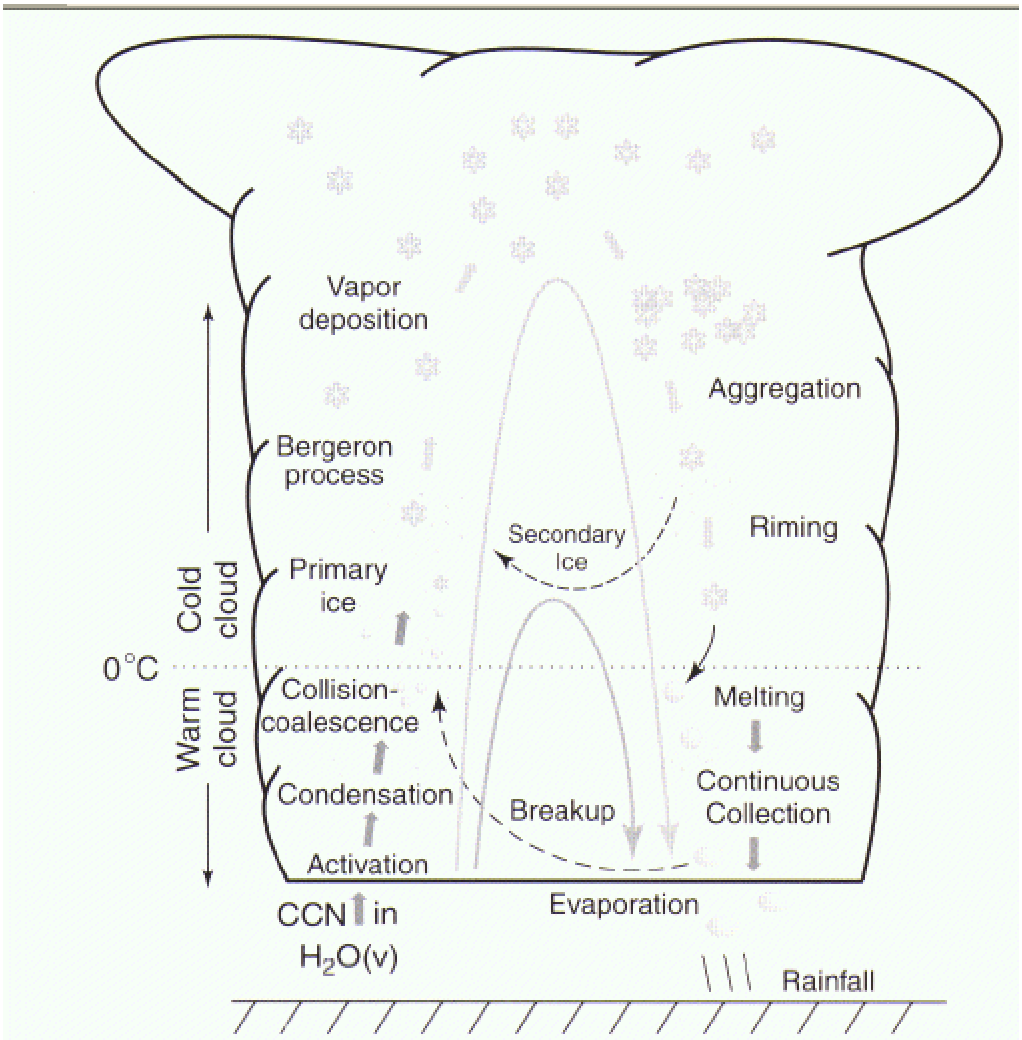
✓ ***Collision and Coalescence.*** Once droplets grow large enough to fall they can collide with other droplets, and merge to form even larger droplets. Coalescence means the droplets, which collide with each other, will stick together. This is the most efficient method of droplet growth (much more efficient than condensation)
Factors affecting efficiency of the collision-coalescence process:
1) Residence time in the cloud**.** The longer the droplet remains in the cloud the greater chance it has to interact with other droplets. Thick clouds provide a greater distance for the droplet to fall. Updrafts within the cloud can bring droplets to upper portions of the cloud.
2) Variable droplet fall velocities. If droplets are falling at different rates, the faster ones will catch up and collide with the slower ones. Larger droplets fall at a faster rate than smaller ones. A wide spectrum of sizes is indicative of variable fall velocities.

Schematic illustration of differences in sizes



A good recent review paper:
McFiggans et al., The effect of physical and chemical aerosol properties on warm cloud droplet activation, Atmos. Chem. Phys. Disc., 5, 8507-8646, 2005.

Microphysical processes operating during the formation of precipitation in a deep convective cloud



There are several good review articles in Encyclopedia of Atmospheric Sciences . Holton J., Pyle J., and J. Curry (Eds.), Academic Press, London, 2003.