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Hygroscopic Seeding and the CCN-Albedo Hypothesis

Twomey (1974) first postulated that increases pollution results in greater CCN concentrations and numbers of cloud droplets, which, in turn, increase the reflectance of clouds. Twomey et al. (1984) argued that enhanced cloud albedo has a magnitude comparable to that of greenhouse warming and acts to cool the atmosphere, in opposition to greenhouse warming.

Subsequently Albrecht (1989) proposed that higher droplet concentrations in polluted air will reduce the rate of drizzle formation, resulting in wetter, more reflective clouds. Furthermore, Ackerman et al. (1993; 1994) proposed that heavily drizzling straticumulus clouds can reduce cloud top cooling to such an extent that a stratus-topped boundary layer can collapse. Pollution-caused increases in CCN can thereby suppress the drizzle process leading to the formation of a stratus-topped boundary layer in some boundary layer regimes that may not otherwise be sustainable. Cotton and Pielke (1995) noted, however, the susceptability of the drizzle process in marine stratocumulus clouds to anthropogenic emissions of CCN may depend on the presence or absence of large and ultra-giant aerosol particles in the subcloud layer. In other words the drizzle formation process is not solely regulated by the concentrations of CCN and cloud liquid water contents but possibly also by the details of the spectrum of the hygroscopic aerosol population. This concept has been reinforced by the hygroscopic seeding simulations by Cooper et al. (1997). Their model calculations suggest that high concentrations of hygroscopic particles in the 0.1 to 1.0 size range can accelerate the drizzle formation process. An implication is that even though pollution may increase the total concentration of CCN particles, if the concentration of particles greater than 0.1 is likewise increased, the drizzle formation process may not be suppressed, but instead could be actually enhanced. This could counter the tendency of clouds in polluted air from being more reflective. Again, we emphasize that knowledge of the total size-distribution of hygroscopic aerosol is needed to assess the potential impacts of polution on global climate!