Atmospheric Nucleation

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A key phenomenon associated with the atmospheric aerosol system is the formation and growth of new atmospheric aerosol particles. Atmospheric aerosol formation consists of a complicated set of processes including the production of nanometer-size clusters from gaseous vapours, the growth of these clusters to detectable sizes and the removal of growing clusters by coagulation with the pre-existing aerosol particle population. While atmospheric nucleation has been observed to take place almost everywhere, several gaps in our knowledge regarding this phenomenon still exist. These gaps range from the basic process-level understanding of atmospheric aerosol formation to its various impacts on atmospheric chemistry, climate, human health and environment.

In light of our current understanding, atmospheric aerosol formation is initiated by photochemical reactions in the gas phase, in particular the formation of sulphuric acid and other vapours of very low volatility, such as multifunctional organic compounds and iodine oxides. Pre-existing aerosol particles act as a sink for these vapours and nucleated clusters, thus inhibiting atmospheric aerosol formation. Aerosol formation also seems to be affected by several meteorological parameters and phenomena, including the intensity of solar radiation and atmospheric mixing processes, such as the evolution of a continental boundary layer or the mixing of stratospheric and tropospheric air near the tropopause. The recent result also indicates that the critical clusters in atmospheric conditions may be surprisingly small, and thus treatable by advanced quantum chemistry methods. On the other hand, it is very probable that the atmospheric nucleation is a two-step process which proceeds via an intermediate state (atmospheric clusters) as suggested by Kulmala et al. (2000) and verified by Kulmala et al. (2007).

The new aerosol particles formed by atmospheric nucleation events become climatically important only if they grow to sizes larger than about 50-100 nm in diameter. Particles of this size and larger can scatter sunlight back to space, and can also act as nuclei for cloud drop formation, thus having an indirect effect on the albedo of the Earth. Furthermore, the health effects of airborne particles are related not only to the toxicity of the particle material, but also to the particle size, since size determines whether or not the particles are able to penetrate to the lungs and further to the blood circulation. According to recent studies, nucleation can produce a significant fraction of the cloud condensation nuclei in both pristine (Pallas, Finland) and highly polluted (Po Valley, Italy; Laaksonen et al., 2005) environments.

Kulmala, M. et al., 2000, *Nature*, **404**, 66-69.
Kulmala, M. et al., 2007, *Science*, **318**, 89-92, 10.1126/science.1144124