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Aerosol nucleation and its impacts on particle distributions and cloud condensation nuclei: the current best understanding and the most critical knowledge gaps

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Nucleation of aerosol particles from atmospheric vapors, also referred to as new-particle for-mation, is a frequently occurring phenomenon in the atmosphere. Although primary particles emitted to the atmosphere directly as particulate matter, such as dust or sea salt, often dominate the aerosol mass, secondary particles originating from gas-to-particle conversion make a substan-tial contribution to the particle number. Particle formation processes affect the chemical properties of aerosol populations and modify the ambient particle size distribution: the larger the fraction of particles formed through nucleation, generally the smaller the average size and the larger the surface-to-volume ratio of the particles. This affects aerosol impacts on clouds and climate, as they are strongly dependent on particle size and composition. Understanding and accurately de-scribing the sources, sinks and atmospheric processing of these secondary particles is thus a pre-requisite for predicting aerosol-climate interactions, and for assessing the sensitivity of the climate system to changes in aerosol production due to e.g. human actions.

Predictions of secondary particle numbers and effects are, however, highly sensitive to assump-tions on the formation mechanisms in different environments, and on the growth dynamics of the very smallest particles. While the initial nucleation of nanoparticles of a couple of nanometers in diameter sets the upper limit for the number of new particles, the early growth in the nanometer size range largely determines the fraction of particles surviving to larger sizes instead of being lost by scavenging processes. The precursor vapors have both anthropogenic and natural sources: according to the current understanding, particle formation is in many locations initiated by sulfu-ric acid and bases such as ammonia, with organic compounds largely driving the further growth. Specifically, highly oxidized organic species are likely to play a critical role in particle survival to larger sizes.

This presentation gives an overview of the physics and chemistry of aerosol nucleation, summa-rizing the current understanding and the most important knowledge gaps. The discussion will fo-cus on (1) the mechanisms controlling the initial nucleation of small nanoparticles and their growth in the ultrafine size range to climatically relevant sizes, and (2) the predicted effects of new-particle formation on cloud condensation nuclei concentrations.