Size Matters: From Aerosol Particles to Cloud Droplets

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Clouds play a central role in the Earth's climate system and water cycle. A cloud's behavior depends to a great extent on the number and size of the droplets it is made of. Since each of these droplets requires a seed aerosol particle to grow upon (called cloud condensation nucleus, CCN), it is essential to understand what properties of an aerosol particle allow it to grow into a cloud drop.

Basic physical chemistry shows that, to a first approximation, this depends on the number of soluble molecules it contains, which is a function of its size and composition. Given the very diverse origin of atmospheric particles (e.g., sea salt, dust, smoke, and industrial emissions), the complexity of their composition has long been seen as a major obstacle to modeling and predicting aerosol effects on cloud properties and climate.

To separate the effects of size and composition, the researchers of the Max Planck Institute for Chemistry and the University of Mainz divided ambient aerosols into narrow size classes and then determined their chemical composition and ability to grow into cloud drops.

They made the measurements in summer 2004, on top of the Kleiner Feldberg in the Taunus Mountains of Germany. During the 3-week measurement period, diverse air masses were encountered at the mountaintop station: aged continental air that had accumulated industrial and traffic pollution, marine air masses that had moved in rapidly from the North Atlantic, and fresh pollution from the densely populated and industrialized Rhine-Main area.

The aerosol composition was dominated by organic material in all air mass types, followed by ammonium, sulfate and nitrate. Interestingly, in spite of the different histories of the air, the soluble fraction of the particles did not appear to vary all that much.

The measurements showed that, at least for the types of aerosol encountered at our continental site in Europe, particles size plays a much greater role than composition in regulating cloud droplet nucleation. The fundamental reason is that CCN ability depends to first approximation on the total number of soluble molecules in the particle. This number depends only linearly on the soluble mass fraction (i.e., composition), but to the third power on size.

The fact that, at least for the kinds of aerosols found in regions like Europe, particle composition plays only a secondary role in cloud drop growth has great practical advantages. It makes it much easier to estimate CCN concentrations by relatively simple measurements, and simplifies their representation in cloud and climate models. With the knowledge of typical size-resolved CCN efficiencies for key regions and aerosol types, CCN concentrations can be estimated from observed or modeled size distributions. Establishing a data base of such size-resolved CCN efficiencies should be the focus of field studies in different locations. In models, more effort should be spent on accurately predicting particle size distributions, rather than detailed chemical composition.

The findings of the Mainz researchers also provide a basis for the estimation of CCN abundances over larger time and space scales by remote sensing, as aerosol size distributions can be obtained much more easily by remote sensing than particle compositions.

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