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Prediction and parameterization of CCN concentrations

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From studies in central Germany, Dusek et al. (2006) conclude that "Size matters more than chemistry in determining cloud nucleating properties". The findings are based on sensitivity studies, where the variation in the measured CCN concentration was related to the variation in measured critical supersaturation for activation (S_{crit}) (as a proxy for variations in chemical composition), and the variation in the measured aerosol number size distribution. The results show that the variation in the observed CCN concentration is more correlated to variations in aerosol number size distributions than to variations in chemical composition.

These results can also be verified by theoretical considerations. The fundamental reason is that S_{crit} depends to a first approximation on the total number of soluble molecules/ions in the particle. This number depends only linearly on the soluble mass fraction, but to the third power on particle diameter, making particle size the dominant factor in controlling S_{crit}. Also theoretical model studies suggest that the influence of particle chemical composition on cloud droplet number is moderate (e.g. Junge and McLaren, 1971). We therefore assume that although the findings in Dusek et al. (2006) are limited to a continental site in Europe, we expect the primary role of particle size in CCN activation, to apply more generally.

The secondary role of particle composition has great advantages for estimating CCN concentrations from observations, and for their parameterization in cloud and climate modelling. This, since it's easier to measure or model aerosol number size distributions than aerosol chemical composition. Based on the findings, we propose a method to predict and parameterize CCN concentrations and CCN number size distributions,

based on observed typical relations between activation diameters (Dp_{crit}) and S_{crit}, representative of key regions and aerosol types (air mass types), and observed or modeled aerosol number size distributions. At many locations, the variation in the $Dp_{crit} - S_{crit}$ - relation is relatively moderate, and an average can be used. Also results from locations of similar type, e.g. various continental sites, show a similar relation. We have for example observed a similar relation in central Germany as in the continental Amazon region. However, at locations were the aerosol varies drastically, it might be necessary to choose activation diameters based not only on location, but also on air mass type. A data-base of such critical activation diameters should be established.

By assuming that all particles larger than S_{crit} serve as CCN, the CCN number size distribution can directly be obtained The CCN concentration can be calculated by integration, and a CCN spectrum ($N_{CCN}(S)$) can be determined. Examples from continental and marine locations will be presented. The method can be further developed for predictions and parameterisations of cloud droplet number concentrations, if the updraught velocity also is taken into account.

References:

Dusek, U. et al.: Science, 312, 1375, 2006

Junge and McLaren: J. Atmos. Sci., 28, 382, 1971