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Aerosol hygroscopicity distribution concept and its applications in the cloud parcel modeling of CCN activation in the megacity air of Beijing

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This paper for the first time proposed a concept of hygroscopicity distribution (HD) for the analysis and modeling of aerosol particle hygroscopicity and cloud condensation nucleus (CCN) activity. The HD concept reflects the heterogeneous properties of aerosols in the same size bin and corrects the misunderstanding in the traditional way of reading a size-resolved CCN spectrum. Then results from the hygroscopicity (by a CCN counter and a hygroscopicity tandem differential mobility analyzer, HTDMA) and volatility measurements (by a volatility tandem differential mobility analyzer, VTDMA) in the megacity Beijing were presented which confirmed the aerosol heterogeneous properties (in the same size bin) and HD in the atmosphere. The HD for polluted megacity air in Beijing exhibits a lognormally distributed mode with hygroscopicity κ values around 0.2-0.4, and a significant particle fraction (ca. 10-20%) with κ values <0.1, which could be attributed to externally mixed soot particles.

The activation of cloud condensation nuclei (CCN) determines the initial number of cloud droplets, and thus influences the evolution of the cloud and formation of precipitation. Characterizing the CCN activation process by parcel model studies with detailed cloud microphysics and dynamics provides useful information for parameterizing the activation process in meso-scale and global-scale models. Here we investigated the aerosols activation process with an improved cloud parcel model capable of including observed HD (two hygroscopic modes as describe above). The number of droplets formed at the cloud base was examined for a wide range of updraft velocities and aerosol particle number concentrations. The simulation results based on the HD was then used to evaluate the uncertainties of aerosol- and updraft-limited regimes determined by simulations with a single hygroscopicity parameter κ and the uncertainties of using single κ in the parameterizations of aerosol activation process for the global models.

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