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Abstract

Aerosols have a large effect on the radiative balance of the earth. One complexity that aerosols cause in the atmosphere is that not only can they directly absorb and reflect radiation, but they also indirectly influence the earth's radiative budget by acting as a cloud condensation nuclei (CCN). CCN are aerosols that become cloud droplets in a supersaturated parcel of air through the condensation of water vapor onto the aerosols. The size and chemical composition of an aerosol can determine if it will act as a CCN particle in a supersaturated parcel of air. For inorganic aerosols, the Köhler Theory sufficiently describes the level of supersaturation required for an aerosol to activate, or grow into a cloud droplet (Köhler 1936). Organic aerosols are estimated to represent 20-50% of atmospheric aerosols, so their quantities are not negligible (White 1990). Models that can sufficiently account for both inorganic and organic aerosols are necessary to accurately estimate the number of CCN available to form cloud droplets. Modeling organic aerosols using Köhler Theory is possible, however unpractical. Over 10,000 different organics are known to exist in atmospheric aerosols, so it is difficult to identify all organic species that are in an aerosol. Köhler Theory combines the Kelvin affect and Raoult's law. Two variables required for Raoult's law, Molecular weight or the aerosol and the Van't Hoff factor, are often inaccurately estimated due to the fact that it is impossible to measure all the organic species in an aerosol.

A modified form of Köhler Theory, referred to as κ- Köhler Theory, is a more accurate way of modeling the required supersaturation over a droplet to activate into a cloud droplet. In κ- Köhler Theory, Raoult's law is not used, so the Molecular weight of the aerosol and Van't Hoff factor are not needed. Instead the κ- Köhler Theory approach uses an activity coefficient and Kelvin equation. The activity coefficient is a function of the size of the aerosol, the volume of water on the aerosol and a hygroscopicity value (κ). The hygroscopicity ranges between 0 and 1.4, 0 representing a completely insoluble aerosol and 1.4 being a highly hygroscopic aerosol (Petters and Kreidenweis 2007). The hygroscopicity is estimated with the use of CCN or growth factor measurements and it is the only variable in the equation that is affect by the chemical composition of the aerosol. Technically the surface tension in the Kelvin equation is also affected by the chemical composition and it is often assumed to be the same as the liquid water surface tension. κ- Köhler Theory can indirectly account for a change in surface tension by using the liquid water surface tension when solving for κ (Petters and Kreidenweis 2007). When this is done, κ is effectively slightly higher, which reduces some of the error of using a higher surface tension in the Kelvin equation.

Comparisons of both approaches with aerosols of known organic composition have shown that Köhler Theory predicts higher critical supersaturations than κ- Köhler Theory. This is likely due to the assumption that the Van't Hoff constant is 1 for organics, rendering κ- Köhler Theory as a superior method. Finally, for practical purposes, the organic composition will not be known, which would cause even more error in the original Köhler Theory approach.

References

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