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Homogeneous Nucleation from an Asymptotic Point of View

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Spontaneous freezing of pre-existing liquid solution droplets in the upper troposphere is one possible way to form ice crystals and therefore cirrus clouds. The process of homogeneous ice nucleation can be modelled with a stochastic ansatz: The probability for a solution droplet within a given volume and time frame to freeze may be expressed using the so-called homogeneous nucleation rate. An expression of this nucleation rate was derived by Koop et al. (2000) using the water activity. If the solution droplets are in equilibrium with the environment, the water activity essentially boils down to the relative humidity, so the nucleation rate is basically a function of the environmental conditions, as long as the chemical composition of the solution droplets is comparable.

We used the nucleation rate to describe a single nucleation event with a minimum set of ordinary differential equations. Within a numerical model, one could solve those equations with a small timestep to generate a parameterization for homogeneous nucleation. In order to avoid a subtimestepping, we analysed the governing equations with the help of an asymptotic expansion. Using the reduced asymptotic equations in leading order, we derive their exact solutions. This allows to evaluate the leading order asymptotic expansion in order to calculate the nucleated number of particles. This ansatz will allow us to formulate an adaptive parameterization for models on variable grids.