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Estimating the Influence of Biological Ice Nuclei on Clouds with Regional Scale Simulations

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Cloud properties are largely influenced by the atmospheric formation of ice particles. Some primary biological aerosol particles (PBAP), e.g. certain bacteria, fungal spores or pollen, have been identified as effective ice nuclei (IN). The work presented here quantifies the IN concentrations originating from PBAP in order to estimate their influences on clouds with the regional scale atmospheric model COSMO-ART in a six day case study for Western Europe. The atmospheric particle distribution is calculated for three different PBAP (bacteria, fungal spores and birch pollen). The parameterizations for heterogeneous ice nucleation of PBAP are derived from AIDA cloud chamber experiments with *Pseudomonas syringae* bacteria and birch pollen (Schaupp, 2013) and from published data on *Cladosporium* spores (Iannone et al., 2011). A constant fraction of ice-active bacteria and fungal spores relative to the total bacteria and spore concentration had to be assumed.

At cloud altitude, average simulated PBAP number concentrations are $\sim$17 L^{-1} for bacteria and fungal spores and $\sim$0.03 L^{-1} for birch pollen, including large temporal and spatial variations of more than one order of magnitude. Thus, the average, “diagnostic” in-cloud PBAP IN concentrations, which only depend on the PBAP concentrations and temperature, without applying dynamics and cloud microphysics, lie at the lower end of the range of typically observed atmospheric IN concentrations . Average PBAP IN concentrations are between 10^{-6} L^{-1} and 10^{-4} L^{-1}. Locally but not very frequently, PBAP IN concentrations can be as high as 0.2 L^{-1} at -10°C.

Two simulations are compared to estimate the cloud impact of PBAP IN, both including mineral dust as an additional background IN with a constant concentration of 100 L^{-1}. One of the simulations includes additional PBAP IN which can alter the cloud properties compared to the reference simulation without PBAP IN. The difference in ice particle and cloud droplet concentration between both simulations is a result of the heterogeneous ice nucleation of PBAP. In the chosen case setup, two effects can be identified which are occurring at different altitudes. Additional PBAP IN directly enhance the ice crystal concentration at lower parts of a mixed-phase cloud. This increase comes with a decrease in liquid droplet concentration in this part of a cloud. Therefore, a second effect takes place, where less ice crystals are formed by dust-driven heterogeneous as well as homogeneous ice nucleation in upper parts of a cloud, probably due to a lack of liquid water reaching these altitudes. Overall, diagnostic PBAP IN concentrations are very low compared to typical IN concentration, but reach maxima at temperatures where typical IN are not very ice-active. PBAP IN can therefore influence clouds to some extent.

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Schaupp, C.: Untersuchungen zur Rolle von Bakterien und Pollen als Wolkenkondensations- und Eiskeime in troposphärischen Wolken, Ph.D. thesis, Institute of Environmental Physics, Heidelberg University, Heidelberg, Germany, 2013.