Geophysical Research Abstracts
Vol. 16, EGU2014-10881-2, 2014
EGU General Assembly 2014

Ice nucleation by cellulose and its potential impact on clouds and climate

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Biological aerosol particles have recently been accentuated by their efficient ice nucleating activity as well as potential impact on clouds and global climate. Despite their potential importance, little is known about the abundance of biological particles in the atmosphere and their role compared to non-biological material and, consequently, their potential role in the cloud-hydrology and climate system is also poorly constrained. However, field observations show that the concentration of airborne cellulose, which is one of the most important derivatives of glucose and atmospherically relevant biopolymers, is consistently prevalent (>10 ng per cubic meter) throughout the whole year even at remote- and elevated locations. Here we use a novel cloud simulation chamber in Tsukuba, Japan to demonstrate that airborne cellulose of biological origin can act as efficient ice nucleating particles in super-cooled clouds of the lower and middle troposphere. In specific, we measured the surface-based ice nucleation activity of microcrystalline cellulose particles immersed in cloud droplets, which may add crucial importance to further quantify the role of biological particles as ice nuclei in the troposphere. Our results suggest that the concentration of ice nucleating cellulose to become significant (>0.1 per liter) below about -17 ˚C and nearly comparable to other known ice nucleating clay mineral particles (e.g., illite rich clay mineral – INUIT comparisons are also presented). An important and unique characteristic of microcrystalline cellulose compared to other particles of biological origin is its high molecular packing density, enhancing resistance to hydrolysis degradation. More in-depth microphysical understandings as well as quantitative observations of ice nucleating cellulose particles in the atmosphere are necessary to allow better estimates of their effects on clouds and the global climate.

Acknowledgement: We acknowledge support by German Research Society (DfG) and Ice Nucleation research UnIT (FOR 1525 INUIT).