Chemistry in Ice and Snow: From the Atmosphere to the Molecular Scale

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The cryosphere and ice clouds strongly interact with the atmosphere and play an active role in Earth's geochemical cycles and in the climate system. For example, snow and ice play a major role in driving the near-surface atmospheric chemistry in Polar Regions. In addition they serve to accumulate and 'amplify' organic pollutants and mercury. Ice and snow further affect the transport of greenhouse gases.The specific consequences of these processes are potential negative health effects. Such outcomes have been well documented for the Arctic population and for consumers of Arctic fish in Europe and also discussed for populations in vicinity of alpine glaciers. Further, a powerful impact not only on the local climate in the Arctic and Antarctica, but also on the larger scale in Europe and globally is recognised.

That those large-scale effects within the Earth system can be assigned to chemical activity in ice and snow on a microscopic level, is one crucial result of the most recent research. However, we are far from a detailed understanding of this emerging field. I will start with highlighting results from laboratory studies that investigated how the structure and composition of ice and snow impacts its reactivity. Examples include

- The transport of trace gases through the porous surface snow cover
- The photo-reactivity in surface snow

Results of these studies are briefly discussed focusing on our ability to parameterise and model processes in snow and ice. Differences and similarities of chemistry in snow to chemistry in liquid water will be shown.

A fundamental understating of above processes can be gained by directly observing how the water molecule network at ice surfaces interacts with atmospheric trace gases upon adsorption. Near ambient pressure XPS and NEXAFS have been successfully used to obtain micro-chemical information of contaminants on ice under environmental conditions. Examples include acetic acid, bromide, acetone, nitrate and chloride. The molecular interaction of water molecules with chemical traces in the topmost, disordered layer on ice is of significant debate. Based on ellipsometry measurements a feedback mechanism was described were adsorption of the acidic trace gas HCl induces disorder along the whole ice surface which in turn leads to an enormous increase in the uptake of this trace gas to the ice. Recent results from surface sensitive near edge X-ray absorption fine structure spectroscopy of nitrate and acetic acid on ice surfaces indicate a more complex picture where changes to the hydrogen-bonding network may be most pronounced to the vicinity of the ionic impurity. Results of these surface sensitive studies will be the main focus of this talk, highlighting the differences between ice surfaces and liquid films.