**Investigating Earth's Oldest Ice by High-Throughput Elemental Mapping using LA-ICP-TOFMS**

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Polar glacier ice archives a unique combination of indicators reflecting past climatic conditions, preserved in chronological layers within ice cores. Current research focuses on explaining the Mid-Pleistocene Transition, during which the frequency of glacial-interglacial cycles fundamentally shifted. Ice core records of greenhouse gas concentrations, temperatures, and climate feedbacks offer the crucial evidence needed to decode this transition and improve our understanding of the climate system. The European consortium "Beyond EPICA: Oldest Ice" recently recovered a continuous Antarctic ice core extending back at least 1.2 million years, with initial high-resolution analyses now underway across Europe, including at the Alfred Wegener Institute (AWI) in Bremerhaven.

The retrieval of impurity-related climate information from the deepest and oldest ice sections is a three-fold challenge: first, because the highly thinned layers require high resolution analysis. More than 20k years are expected per meter. Second, the integrity of the records need to be carefully assessed, as various processes can disturb the original layer configuration. These processes include ice-impurity interaction by crystal growth, diffusion and geochemical reactions. Analyzing ice as a solid is of decisive advantage for studying these processes and identifying their imprint in high resolution signals. Third, the analysis needs to be conducted quasi-continuously over about 100m comprising the climate period of greater interest.

In view of this three-fold challenge, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) provides invaluable micro-chemical insights. The technique uses a focused laser to micro-sample solid surfaces and a mass spectrometer to identify trace elements. If the technique is used for two-dimensional chemical mapping we can carefully investigate ice-impurity interactions. To fully exploit LA-ICP-MS for analyzing the oldest ice, a synergistic hardware-software framework was developed at AWI that enables rapid, high-throughput mapping across large sample geometries.

In this seminar we discuss the basics of the ice core climate archive, with special focus on the geochemistry of deep ice. We highlight the unique potential of LA-ICP-MS ice core analysis, explaining the basics of the approach and how the potential can be expanded further by using a "time-of-flight" mass spectrometer. We conclude by highlighting state-of-the-art frontiers in this research, connected to ice core analysis but also other applications in environmental sciences, cultural heritage, and industrial applications.