Geophysical Research Abstracts
Vol. 17, EGU2015-9104, 2015
EGU General Assembly 2015

Spatially-resolved chemical analysis of frozen ice cores by cryo-cell-UV-laser-ablation-ICPMS

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High-latitude ice cores have become the master records of late Pleistocene climate variability. Especially the high-resolution data from Greenland of the past ∼125 ka reveal a remarkably changeable glacial climate, and these rapid climate oscillations have been shown to take place within a few years only [1, 2]. The requirement for an improvement in spatial resolution in ice core analysis arises from 1) the continuous thinning of annual layers in deep parts of ice cores to below what is routinely resolvable by continuous flow analysis and 2) the concomitant recrystallization of ice that potentially affects the location of impurities and thus the identification of annual layers.
We developed a new technique to analyze elemental concentrations at ppb-levels in frozen ice cores at ∼100 um (0.1 mm) resolution, which focuses on seasalt and dust tracers (e.g. Na, Mg, Ca, Al, Fe). It utilizes a custom-built, peltier-cooled cryo-sample holder fully compatible with the two-volume Laurin LA-cell of our RESOlution M-50 excimer (193 nm ArF) LA system, which is coupled to an Agilent 7500cs ICPMS, operated in reaction cell gas mode with H2 to eliminate 40Ar and 40Ar16O to access 40Ca and 56Fe [3]. Using 3 x 5 cm strips of ice cores per sample holder, this setup allows elemental concentrations to be acquired using both depth-profiling along (chains of) spots and/or as continuous lateral profiles, following surface cleaning with a major-element-free ceramic blade. Ice crystal boundaries can be observed with transmitted or reflected light illumination.
We focus on NGRIP samples from Greenland Stadial 22 (GS22; ∼84-88 ka; ∼2695-2720 m) with its corresponding transitions. Owing to analysis in frozen ice, we can easily identify - relative to ice crystal boundaries - the location of cation impurities in both clear ice and so-called cloudy bands that are enriched in impurities. We find a remarkable difference in the location of impurities between these different ice domains [4]. Lower concentration clear ice shows strong impurity-enrichment along grain boundaries and junctions (similar to S concentrations in [5]), whereas cloudy bands do not display significant differences in elemental concentrations between grain interiors and boundaries, at overall higher concentrations. These results together with those of 2D and even 3D mapping of impurities as well as profiles across the two warm/cold transitions will be presented.