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Refining LA-ICP-MS techniques for the exploration of ultra-thin layers in Alpine and Polar ice

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Laser ablation inductively coupled plasma mass spectrometry, (LA)-ICP-MS, offers minimally destructive ice core impurity analysis at unsurpassed sub-mm depth resolution. As such it is uniquely suited for exploring the closely spaced layers of ice cores collected in low accumulation sites or in regions of compressed and thinned ice. Here we present an updated characterization of the LA system developed at the University of Maine Climate Change Institute's Keck Laser Ice Facility, as determined through 1) experimentation with sticks of frozen distilled water and 2) exploitation of the exceptionally thin layers within a new ice core drilled at the Alpine glacier saddle Colle Gnifetti (4450m asl, Monte Rosa, Swiss-Italian Alps) and the variety of high-density chemical data collected from it.

Colle Gnifetti (CG) is characterized by low net accumulation rates and strong vertical shear, which causes its annual layers to rapidly thin below the cm-resolution of conventional ice core analysis techniques. To best utilize its unique archive, LA measurements of Ca and Na were directly compared to those from continuous flow analysis. Through this comparison, we demonstrate that LA captures low frequency trends similar to traditional melting techniques while also emphasizing the benefits of its increased resolution. The resolution was itself verified through experimental determination of peak decay times, where peaks were created by spiking frozen distilled water at known interval with high concentration riverine water standards. Using ion chromatography and liquid-based ICP-MS measurements of discrete meltwater samples from CG we were also able to explore high-resolution profiles of S as measured by LA. The ability to resolve S at sub-mm resolution (a capability not yet demonstrated for LA analysis of ice cores) may allow more accurate determination of the character and timing of volcanic eruptions. We illustrate this finding using an exemplary S-anomaly, potentially of volcanic origin, archived in the CG ice core.

Considering more broadly our findings from the CG ice and the refined characterization of our LA system, this technique promises to be of great benefit to the analysis of ultra-thin ice core layers. This may be especially relevant for members of the ice core community pursuing million year old ice kilometers below the surface. As such we also provide examples of LA analysis of deep polar ice from Greenland (GISP2) and shallow, yet ancient (up to 1 Mya), ice from the Allan Hills Blue Ice Area, Antarctica, which demonstrate how the insight gained from our study could be applied by the polar ice coring community.