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Linking two thousand years of European historical records with environmental change recorded in a high Alpine ice core

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Its extraordinary network of historical and archaeological records makes Europe exceptionally promising for investigating environmental change and human response over the last two thousand years. Among natural proxy archives, ice core records offer a wide range of environmental reconstructions including natural and human source histories of the chemistry of the atmosphere. To link these robust environmental records with historical evidence of past civilizations remains a great challenge, however. In central Europe the unique target for a comparison for environmental change recorded in ice cores and human activity is the small firn saddle of Colle Gnifetti (4550 m above sea level on the Italian-Swiss border). Its exceptionally low net accumulation make Colle Gnifetti (CG) the only feasible site in the Alps for retrieving a long-term ice core record beyond the last century. However, at CG rapid annual layer thinning eventually limits conventional cm-resolution analysis to multi-annual signals and hampers dating by annual layer counting beyond a few hundred years. Thereby, a crucial gap is introduced to the sub-seasonal time scale of events typically recorded in written archives.

In our ongoing project we pioneer correlating the CG environmental ice core archive with a unique compilation of European historical records provided through the Harvard Initiative for the Science of the Human Past and the Digital Atlas of Roman and Medieval Civilization. For this purpose, state-of-the-art glacio-chemical analysis was performed on a newly recovered CG ice core, including continuous flow analysis chemistry and stable isotopes. A crucial contribution comes from the application of LA-ICP-MS (laser ablation ion coupled plasma mass spectrometry) to meter long sections of frozen ice samples, developed and operated by the University of Maine's Climate Change Institute, offering glacio-chemical records up to 100 μm in resolution. The new methods significantly improves sampling resolution and allows detection of annual layers even in highly compressed old sections of CG ice cores: A breakthrough not only for extending the ice core dating over the last two millennia but also for bridging the gap in time scales to historical records.

Here we present first results from our ongoing efforts in bringing together ice core time series with historical evidence, focusing on the time period from 1 to 1400 C.E. Based on a thorough consideration of the glaciological constraints at CG we explore various ice core proxy signals for their significance to correlate with events recorded in human writing, such as dust storms, volcanic events, climate-induced crop failures and starvation as well as metal production levels. Distinct dust layers are frequently found in CG ice cores, representative for meteorological conditions that transported sand from the Sahara to Europe. At the same time, Saharan dust events were also frequently recorded by ancient and medieval observers as "blood rain". Ultimately we work towards using past extreme climate events from medieval Europe recorded as written evidence to constrain the ice core age scale and, vice versa, to investigate the response of human societies to environmental change recorded in the CG glacier archive.