Geophysical Research Abstracts
Vol. 16, EGU2014-15134, 2014
EGU General Assembly 2014

52 glaciers and one lake: how to reconstruct past regional glacier variability

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Sediment records from distal glacier-fed lakes have been used in numerous reconstructions of past glacier activity, where the basic assumption is that the amount of minerogenic material deposited in the lake is directly proportional to the amount of upstream glacier erosion. However, the minerogenic component of the sediments in a distal glacier-fed lake is commonly derived from several different sources, not only subglacial erosion. Furthermore, glacier reconstructions tend to focus on individual mountain glaciers, which due to local effects might not always reflect regional scale glacier variability. Presently, certain high-resolution analysis techniques allow for fast multi-proxy analyses of sediment cores, which improve the basis for inferring the provenance of lake sediments; however, the only way of actually testing such inferences is to identify the different sediment sources in the adjacent catchment and characterize them using the same proxy measurements as in the lake core. Multi-proxy sedimentary fingerprinting techniques are labor-intensive, however, and proxies such as bulk geochemistry may prove of little use in differentiating between source areas if the bedrock lithology is uniform across the catchment.

Here we present a simple method based on environmental magnetism that allow for tracking lake sediments to their sources in catchments where the bedrock lithology is uniform. Unlike ferro- and ferrimagnetic minerals, the magnetic susceptibility of paramagnetic minerals is inversely proportional to temperature. Thus, by measuring the bulk magnetic susceptibility (chi-Bulk) of a sediment sample both at room temperature (293K) and after freezing in liquid nitrogen (77K), the relative contribution from paramagnetic minerals to the total chi-Bulk can be inferred from the ratio of chi-Bulk77K over chi-Bulk293K. Theoretically, a ratio of 3.8 will indicate a purely paramagnetic sample, whereas progressively lower values reflect an increasing contribution from ferro- or ferrimagnetic minerals.

We found that in the catchment of Nerfloen, a distal lake draining a large (440 km2) catchment in western Norway that contains 52 separate glaciers, there was a systematic decrease in the chi-Bulk77K/chi-Bulk293K-ratio with increasing altitude and proximity to the glaciers. We have not studied the magnetic mineralogy of our samples in detail, but infer from our data that the relative amount of paramagnetic minerals increase as soil formation progresses, thereby creating the contrasting ratios between samples collected at different altitudes. In the lake core we observe rapid shifts between sedimentary regimes dominated by high- and low-altitude source areas, which can best be explained by regional-scale growth and decay of mountain glaciers in the lake catchment.