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Rapid Late Holocene glacier fluctuations reconstructed from South Georgia lake sediments using novel analytical and numerical techniques

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The collapse of ice shelves, rapidly retreating glaciers and a dramatic recent temperature increase show that Southern Ocean climate is rapidly shifting. Also, instrumental and modelling data demonstrate transient interactions between oceanic and atmospheric forcings as well as climatic teleconnections with lower-latitude regions. Yet beyond the instrumental period, a lack of proxy climate timeseries impedes our understanding of Southern Ocean climate. Also, available records often lack the resolution and chronological control required to resolve rapid climate shifts like those observed at present. Alpine glaciers are found on most Southern Ocean islands and quickly respond to shifts in climate through changes in mass balance. Attendant changes in glacier size drive variations in the production of rock flour, the suspended product of glacial erosion. This climate response may be captured by downstream distal glacier-fed lakes, continuously recording glacier history. Sediment records from such lakes are considered prime sources for paleoclimate reconstructions. Here, we present the first reconstruction of Late Holocene glacier variability from the island of South Georgia. Using a toolbox of advanced physical, geochemical (XRF) and magnetic proxies, in combination with state-of-the-art numerical techniques, we fingerprinted a glacier signal from glacier-fed lake sediments. This lacustrine sediment signal was subsequently calibrated against mapped glacier extent with the help of geomorphological moraine evidence and remote sensing techniques. The outlined approach enabled us to robustly resolve variations of a complex glacier at sub-centennial timescales, while constraining the sedimentological imprint of other geomorphic catchment processes. From a paleoclimate perspective, our reconstruction reveals a dynamic Late Holocene climate, modulated by long-term shifts in regional circulation patterns. We also find evidence for rapid medieval glacier retreat as well as a synchronous bi-polar Little Ice Age (LIA). In conclusion, our work shows the potential of novel analytical and numerical tools to improve the robustness and resolution of lake sediment-based paleoclimate reconstructions beyond the current state-of-the-art.