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Forcing and timing of Holocene glacier advances in the hyperhumid southernmost Andes (50-53°S): an evaluation based on continuous glacial clay and paleoclimate records as well as modelling

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The Southern Patagonian Icefield (PIF) constitutes the largest continental ice-sheet outside the polar regions. Its Holocene glacier fluctuations and their forcing mechanism are still poorly explored, especially on the western hyperhumid side of the Andes. Glacier fluctuations have been previously constrained by 14C and/or cosmogenic ages of moraines on the eastern side of the PIF providing single advance ages but no constraints on advance and retreat dynamic. To the west of the PIF moraines are often subaquatic which complicates their mapping and dating. Furthermore, younger and more extended Neoglacial advances could have obliterated the remnants of earlier less extended advances.

We present four sediments cores from the Andean fjord zone between 50 to 53°S which cover the time span of the Holocene and document variations in the glacial clay transport (clay mineralogy and related geochemical composition based on high resolution XRF records) along fjord pathways of glacial clay plumes. Additional subaquatic and terrestrial mapping of moraine extents as well as dating of glacier advances by stalagmites within the Neoglacial moraine belt document that the timing and length of these advances is correlated with an increased glacial clay signature in the sediment cores. Based on our records we distinguish two limited early Holocene advances (A0 at ∼10 kyrs and A1 from 8.5 to 7.9 kyrs BP) and four Neoglacial advances from 5.4 to 4.9 kyrs BP (A2), from 4.1 to 3.7 (A3), from 2.34 to 2.1 (A4), from 1.15 to 0.85 (A5), and from 0.65 to 0.05 Kyr BP (A6). Stalagmite dating, well-dated lake sediment records and moraine mapping indicate that A4 was the most extended Holocene advance, again consistent with the most pronounced glacial clay signature in the sediment records.

Tree-ring based temperature reconstructions, alkenone-derived open marine and fjord SST records as well as precipitation records from a stalagmite (53°S) and lake sediments are considered as the paleoclimatic background to evaluate and model the driving mechanism of the glacier fluctuations. Based on a regional glacier mass balance model that was developed at the 200 km2 large Gran Campo Nevado Ice Cap (52°30'S) and its surrounding glaciers, we used the average alkenone SST's (extrapolated to air temperatures) during the advance periods to calculate the required precipitation for a reasonable positive glacier mass balance. The results indicate that the advances A0, A1, A3, A4 and A5, which occurred during relatively warm Holocene periods required extraordinary high accumulation of 9500 to 14000 mm/year, which is consistent with very high precipitation documented for these phases in the paleoclimate records. Only for A2 and A6 (with ∼1.5°C lower paleotemperatures) our models require significantly lower precipitation/accumulation of ∼6000 mm/year, again consistent with lower precipitation in the considered records. This indicates a predominant accumulation-driven forcing in this hyperhumid oceanic setting, contrasting to a general ablation-control of Holocene advances and retreat phases in many regions world-wide and especially during recent global warming. Our results indicate that increasing westerly strength during further future warming may cause accumulation-driven glacier advances on the western side of the southernmost Andes (south of 50°S).