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Determining a comprehensive water balance for a proglacial area in Svalbard

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The aim of this contribution is to determine, for the first time, a comprehensive water balance for the proglacial area of a Svalbard glacier, quantifying water fluxes to and from the proglacial zone at the surface, in the sub-surface and exchanged with the atmosphere, for a full annual cycle. Proglacial areas are expanding globally as a consequence of sustained glacier retreat, and can be characterized as highly dynamic fluvial environments. Given the intractability of most proglacial areas, and the complex experimental design necessary for monitoring multiple hydrological fluxes over sustained periods, it is unsurprising that still very few comprehensive water balance studies are available for glacierized catchments.

The proglacial area studied is that of Finsterwalderbeen, a 30 km^2 glacier occupying a 44 km^2 catchment at 77˚ N in the Norwegian Arctic archipelago of Svalbard. Surface water fluxes were determined by instrumented monitoring of surface runoff at proximal and distal ends of the proglacial area (respectively, where meltwaters issue from the glacier and where they debouch to a fjord) over the period 24/06/99–18/08/99, the majority of the short melt season at this high latitude. Fluxes prior to and following the period of monitoring are estimated from a temperature-index melt model, validated by ablation monitoring, and are small compared to those of the monitoring period.

Sub-surface water fluxes were determined by instrumented monitoring of hydraulic head in a well transect sunk into the permafrost active layer. The saturated hydraulic conductivity, K_{sat}, of the active layer was determined by falling-head slug tests, and was found to be 4x10^{-5}–4x10^{-4} m s^{-1}. Fluxes prior to and following the period of

monitoring were estimated from the very strong relationship between air temperature and active layer depth, assuming constant specific discharge.

Atmospheric water fluxes were determined by instrumented monitoring by Automatic Weather Station and by survey of the snow cover. Evaporation was modeled using the general combination model for non-saturated surfaces, which depends on available energy, relative evaporation, air drying power and the psychrometric constant.

The annual proglacial water balance of the Finsterwalderbeen proglacial area can therefore be summarized. The highest flux values (7.4x10^7 m^{-3}) are associated with glacial runoff, but these are essentially a throughput as the discharges at the proximal and distal ends of the proglacial area are not significantly different. The flux from direct precipitation onto the proglacial area is an order of magnitude smaller than the glacial runoff (1.1x10^6 m^3), and the evaporation flux is an order-of-magnitude smaller still (6.1x10^5 m^3). The net flux from the active layer is only 4.9x10^4 m^3. Assuming an annual net proglacial flux of zero, the implied storage change is –1.0x10^5 m^3,which is less than 2% of the uncertainty in total catchment runoff (7.1x10^7 $m^{-3}\pm$11%).