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Subglacial melting of glaciers by catchment streams is a missing link in temperate glacier mass balance

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The influence of snowmelt and rain water on subglacial hydrology and glacier mass balance of temperate valley glaciers is poorly understood. We present a thermo-hydraulic melt model to improve understanding of the potential influence that streams sourced from snowmelt and rain have on the subglacial hydrology and melting of the high-precipitation Franz Josef Glacier, New Zealand. The model simulates conduit expansion due to melting caused by heat advection and contraction to due ice deformation at an hourly time-step to obtain an annual melt rate along the length of individual subglacial conduits fed from terrestrial streams that enter the glacier from the ice-free sub-catchments surrounding it. These streams are fed by snowmelt and rainfall that enter the glacier well above 0°C (up to ∼10°C at low altitudes). Our model is calibrated using terrestrial stream temperature data and is validated with field measurements of surface and proglacial meltwater temperatures, as well as internal water flow velocities.

Modelled outputs based on the best available data from measurements and observations indicate that streams entering the Franz Josef Glacier contribute an estimated 7% to the total glacier melt. This is the equivalent of more than twice the surface rainfall heat flux, which shows that rain and snowmelt may melt significant quantities of ice within a glacier. Not accounting for this melting mechanism in glaciological models where streams enter glaciers may lead to: 1) an incorrect characterisation of the subglacial hydrological drainage system; and 2) a potentially serious bias error in mass balance estimations. The second implication is fundamentally important for model robustness given that glaciological models are increasingly being used to predict the effects of future climate change.