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Impact of small-scale distribution of basal pressure for subglacial hydrology

Pierre-Marie Lefeuvre (1), Miriam Jackson (2), Gaute Lappegard (3), and Jon Ove Hagen (1)

(1) University of Oslo, Department of Geosciences, Norway (p.m.b.e.lefeuvre@geo.uio.no), (2) Norwegian Water Resources and Energy Directorate, Hydrology, Oslo, Norway, (3) Statkraft, Oslo, Norway

With the ongoing development of 2D subglacial hydrological models, new challenges to simulate the geometry of the drainage system arise notably as their resolution becomes finer. Indeed, the influence of small-scale ice mechanics and small-scale bed topography on subglacial water and ice flow is more likely to take over large-scale forcing. At the Svartisen Subglacial Laboratory (SSL - 200 m below the ice surface), we investigate the importance of basal normal pressure on constraining water flow path over different time scale and hypothesise its importance for water transfer from a channelized drainage system to a distributed one. Twenty years of field observations of normal basal pressure reveal short-lived pressure events, which are assumed to be related to the seasonal development of the hydrological system. We analyse their frequency and amplitude in relation to subglacial runoff measured close to a subglacial tunnel intake located 600-500m above the glacier snout.

These events are characterised by a drop in pressure of as much as 1 MPa in a matter of several hours and a sudden rise reaching more than twice the overburden pressure. The cause of this phenomenon seems to be the melting/migration of subglacial channels. Their occurrence is linked to periods of melt and rainfall, when the high capacity drainage system is pressurized above the ice overburden pressure. Then, as water pressure becomes lower than the ice flotation level, the centre part of channels is decoupled from the glacier bed. This decrease in contact area between the ice and the bed produces stresses greater than the mean ice overburden pressure around the channel sides. As a consequence, the flooded area surrounding the high capacity drainage system is sealed off by this large increase in pressure, creating local storage as mentioned in other studies. This water retention can be a highly significant feedback for ice dynamics creating large areas of high pressure that can be reactivated during speed-up events or a surge. In this study, we provide a long-term analysis of the occurrence of those events and infer their significance for maintaining areas of high water pressure over different time-scales (days, months and years) as well as for the basal drag. Finally, we discuss the importance of small-scale observations in the light of measurements showing very strong spatial disparities in normal pressure for two pairs of sensors located less than a meter apart.

Discharge measurements provide further insights into the overall behaviour of the subglacial system. Strong correlation with subglacial normal pressure demonstrates the existence of rare global events. In contrast, locally independent events are more frequent suggesting very variable water flow paths and a more distributed drainage system. These last observations suggest periods of water flow controlled mainly by small-scale pressure distribution and small-scale topography.

These results highlight the importance of the transition between high and low pressurised drainage system regarding local water storage and its possible impact on ice dynamics. As the resolution of models increases, new small-scale processes will have to be included.