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Interactions between meltwater drainage, bed erosion and ice dynamics beneath terrestrial ice streams: insights from a new experimental modelling approach.

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The interactions between subglacial drainage, bed erosion and basal sliding govern past and modern ice stream activities, thus controlling the evolution of ice sheet dynamics and mass balance. If both palaeoglaciological and numerical modelling studies have provided a tantalizing glimpse on subglacial processes occurring at ice stream beds, we here present a new analog modelling approach. This approach has been underestimated in glacial sciences while having the potential to circumvent the challenge of numerically modelling interactions between ice stream dynamics, subglacial drainage and bed processes.

The subglacial bed and the ice are respectively simulated with a layer of fine sand and a layer of silicon putty. Meltwater production is simulated with a punctual injection of water within the experimental subglacial bed. The formation of subglacial drainage landforms was monitored through time, and their shapes were analyzed from digital elevation models obtained by stereo-photogrammetry. The ice dynamics was also monitored using the temporal displacement of markers placed at three different levels of the silicon putty. This initial experimental setup, developed over the past three years, has shown promising results. We managed to address the temporal relationships between (1) meltwater pocket storage/drainage (2) meltwater subglacial drainage types, (3) temporal evolution of subglacial meltwater drainage efficiency, (4) tunnel valley formation and (5) ice stream dynamics. Experimental results highlight that distributed subglacial drainage such as transient water pocket migration can trigger ice flow acceleration similar to an ice stream. The subsequent distributed-channelized transition occurring when the water pocket reaches the ice margin initiate tunnel valleys formation. Thereafter, ice stream dynamics is mainly controlled by the ability of tunnel valleys to drain all meltwater leading to modifications of ice streams directions, geometries and velocities. Ultimately, when the tunnel valleys system become efficient, ice streams can enter a stagnation phase. These experimental results reconcile several natural observations in modern ice sheets and provide some temporal constraints on the spatial coexistence of tunnel valleys and palaeo-ice streams.

Recently, significant modifications have been carried out on the initial experimental setup; we tripled its size, we added 12 meltwater injection points to simulate more complex meltwater storage and drainage patterns and we developed a new analog subglacial bed. Indeed, an analog subglacial till (scaled to natural till) has been developed in the lab using permeability and mechanical tests. We also show you some of the preliminary results of this updated setup together with the new array of landforms related to ice-bed interactions under fast-flowing ice we are able to reproduce experimentally.