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Ice stream reorganization and ice sheet mass balance following the reactivation of Kamb Ice Stream, West Antarctica

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Ice streams in Antarctica account for most of the ice volume discharged to the ocean, and their flow variability greatly influences the mass balance of the ice sheet. Today, the Siple Coast region of West Antarctica is the only one to experience a positive mass balance (∼36Gt/yr), as a consequence of the stagnation of Kamb Ice Stream about 170 years ago and the ongoing slowdown of Whillans Ice Stream. However, this positive trend could be temporary; past studies have shown that both ice streams experienced significant flow variability over the past millennia, with stagnation typically followed by reactivation on centennial timescales, occurring in response to internal processes. The impact this variability may have on the future mass balance of the WAIS remains unknown. Here, we explore the future flow variability of the Siple Coast ice streams by using a three-dimensional higher-order ice sheet model (CISM), coupled to a physically-based basal processes model and a model of regional hydrology. To obtain realistic initial flow conditions, we assimilate available velocity data for this region from 1997. We perform forward simulations over a 200 year period, during which the basal properties evolve according to the distribution of meltwater beneath the ice and its drainage/flow through a subglacial till layer. First, we assume that the bed evolves according to ice-till interactions with only local exchange of water between the ice and till. Next, we include a model of the regional basal water system capable of transporting water over long distances, so that meltwater is routed laterally along the bed before interacting with the till layer. We also explore the effect of geothermal heat flux uncertainties.

We find that ice discharge to the grounding line is larger and more sustained in time when the regional water system is included in the simulations. Still, in all experiments, the main future perturbation to the current state of flow follows from the reactivation of Kamb Ice Stream tributaries. As a consequence, ice in the tributaries reaches the Whillans Ice Stream catchment, maintaining active flow in its main trunk for the next century. At the same time, the relict Siple Ice Stream reactivates, which significantly decreases the mass balance for this region. Because the modelled state of the bed is the coldest for the trunk of Kamb Ice Stream, this region reactivates last (during the second century of the experiment). Our modelled patterns of ice stream flow variability are similar to those in the past, as inferred from observations (e.g., Catania et al., J.Glac., 2012). We discuss the mechanisms for migrating ice flow regimes and the implication for the future mass balance of the Siple Coast region.