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Ice-stream response to ocean tides and the form of the basal sliding law

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The response of ice streams to ocean tides is investigated. Numerical modelling experiments are conduced using a two-dimensional flow-line model of coupled ice-stream and ice-shelf flow. The model includes all components of the equilibrium equations, and uses a non-linear viscoelastic constitutive equation for ice. Basal sliding is simulated with a Weertman type sliding law where basal sliding is proportional to some power of the basal shear stress. The response of ice-streams to tidal forcing is found to be profoundly affected by mechanical conditions at the bed. For a non-linear sliding law, a non-linear interaction between the two main semi-diurnal tidal constituents (M2 and S2) can give rise to a significant perturbation in ice-stream flow at the lunisolar synodic fortnightly (MSf) tidal period of 14.76 days. For a linear sliding law, in contrast, no such modulation in flow at the MSf frequency is found. For vertical ocean tides of the type observed on Filchner-Ronne Ice Shelf (FRIS), the amplitude of the horizontal modulation in ice-stream flow at the MSf frequency resulting from a non-linear interaction between the S2 and M2 tidal constitutes can be larger than the direct response at the S2 and the M2 frequencies. In comparison the non-linear interaction between K1 and O1 tidal components is weak. As a consequence, modelled ice-stream response to mixed oceanic tides of the type found on FRIS is stronger at the MSf period of 14.76 days than at both the semi-diurnal and diurnal frequencies, while at the same time almost absent at the similar Mf period of 13.66 days. The model results compare favourably with measurements of tidally induced flow variations on Rutford Ice Stream (RIS), West Antarctica. On RIS a strong tidal response is found at the MSf frequency with a smaller response at the semi-diurnal and diurnal frequencies, and almost no response at the Mf frequency. A non-linear viscous sliding law with a moderately large exponent ($m \approx 3$) appears to have the potential to fully explain these observations.