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Frequency response of ice-streams

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Changes in the forcing near the grounding lines of ice-streams are of paramount importance when predicting inland ice dynamics and ice-sheet contribution to sea level rise. In this study, the frequency response of an idealised ice-stream to periodic forcing in the strain-rate at the downstream end is examined for both basally and laterally resisted conditions. A one-dimensional, linearised membrane stress approximation (MSA) for a stream on an inclined plane is solved to yield the spatial wavenumber and propagation length of the resulting upstream perturbations in velocity and thickness as functions of the ice-stream configuration, rheology and forcing period. Upstream propagation for a range of periodic sinusoidal forcings is assessed for 29 Antarctic ice-streams. Studies of wavenumber variations with frequency reveal two distinct behavioural branches. At low frequencies, a slow forcing branch occurs where velocity, slope and thickness vary in phase hundreds of kilometres inland and significant volume change can occur within a cycle. At high frequencies, a fast branch is found on which velocity adjusts rapidly to the forcing, whereas ice thickness responds slowly and varies very little, becoming out of phase with velocity. Consequently there is little volume change within a period. We find that even forcings with decadal or shorter timescales can be transmitted many tens of kilometres upstream with the MSA, but such forcings decay away on very short length scales if the shallow ice approximation (SIA) is used. The inability of the SIA to capture the dynamics on these timescales highlights the need for higher order models in these situations. Solutions are constructed for streams that change from lateral to basal resistance, allowing better representation of real ice-streams. By summing arbitrary frequency solutions a periodic square wave function in the frontal stress is explored, possibly simulating the resulting dynamics of sudden ice-shelf collapse. We also investigate conditions under which changes in thickness or velocity due to frontal forcing can be misattributed to spatial anomalies in basal slipperiness.