

New analytical solutions describing the effects of small-amplitude perturbations in boundary data on flow in the shallow-ice-stream approximation are presented. These solutions are valid for a non-linear Weertman-type sliding law and for Newtonian ice rheology. Comparison is made with corresponding solutions of the shallow-ice-sheet approximation, and with solutions of the full Stokes equations. The shallow-ice-stream approximation is commonly used to describe large-scale ice stream flow over a weak bed, while the shallow-ice-sheet approximation forms the basis of most current large-scale ice sheet models. It is found that the shallow-ice-stream approximation overestimates the effects of bed topography perturbations on surface profile for wavelengths less than about 5 to 10 ice thicknesses, the exact number depending on values of surface slope and slip ratio. For high slip ratios, the shallow-ice-stream approximation gives a very simple description of the relationship between bed and surface topography, with the corresponding transfer amplitudes being close to unity for any given wavelength. The shallow-ice-stream estimates for the timescales that govern the transient response of ice streams to external perturbations are considerably more accurate than those based on the shallow-ice-sheet approximation. In particular, in contrast to the shallow-ice-sheet approximation, the shallow-ice-stream approximation correctly reproduces the short-wavelength limit of the kinematic phase speed given by solving a linearised version of the full Stokes system. In accordance with the full Stokes solutions, the shallow-ice-sheet approximation predicts surface fields to react weakly to spatial variations in basal slipperiness with wavelengths less than about 10 to 20 ice thicknesses.