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Error Estimates for Raymond Effect Dating Using Adjoint Sensitivities

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Raymond Effect Dating is a tool for determining the age of the last disturbance of an ice-rise. It works by timing the rate of creation of folds (Raymond Arches) under an ice-divide, which evolve underneath a divide; the rate is determined by the ice rheology, accumulation rate and thinning rate. The size and elevation of the fold give the age. In general, the thinning rate and formation time are inferred parameters from observed fold architecture; sometimes rheology is included as an inversion parameter. Solutions are non-unique.

So far error estimation of the formation age and other inversion parameteres has been restricted to sensitivity studies. We carry out a more formal study, quantifying the error in the inversion parameter both in relation to the data errors, and to errors in assumed parameters such as the rheological index.

Scaling analysis shows that velocity fields scale with ice thickness and thence with vertical velocity. We can therefore decouple the flow problem, a non-linear Stokes flow problem, from the evolution problem, deriving a simple first-order 1D equation for the evolution of arch amplitude with depth.

We carry out an adjoint study of the evolution of Raymond bumps, using the Lagrange multiplier to examine sensitivity of the solution to data errors. Errors scale with the advection time-scale, but are also dependent on the progress of the creation of Raymond Arches. We quantify the errors, with particular attention to the sensitivity of the error estimates to observation depth.