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A conservation-based moving mesh approach together with data assimilation for solving the shallow ice equation

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We present a new moving mesh approach to simulating ice sheets and glaciers computationally and show how assimilation of measured data can be used within the moving framework to improve the prediction of ice sheet movement.

The techniques we describe are well suited to tracking moving phenomena accurately, and here we focus on tracking the moving terminus. We use the shallow ice approximation to analyse the behaviour of the model velocity, i.e. the velocity induced by ice movement alone. In particular we discuss a mechanism whereby the local profile affects the diffusion component of the model velocity at the terminus, causing the ice diffusion to wait until a certain profile is reached before affecting movement of the boundary. We then introduce a solution procedure based on conservation of mass fractions (CMF) to define a deformation velocity that generates movement of the support of the ice. The ice thickness is subsequently recovered using the conservation principle. For comparison we use the set of standard variables from the EISMINT test scenario to compare our moving mesh method with the fixed grid methods used in the EISMINT tests, showing that our results are considerably closer to the "true" model solutions.

We then describe techniques for assimilating measured observations of the ice sheet into the moving mesh model to obtain improved estimates of the current states of the system (height profile and terminus position). We develop a procedure for treating the mesh point positions, together with the ice thickness, as unknown state variables within the assimilation system. The correlations between the unknown mesh positions and the ice thickness is approximated by a simple correlation function that provides state dependent covariances. We demonstrate the success of the technique for noisy, very infrequent, partial measurements of ice thickness, both with and without noisy measurements of the terminus position.