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What can adjoint modelling tell about the response of the Greenland Ice Sheet to changes in basal sliding?

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Studying the future behaviour of the Greenland Ice Sheet is important considering the ice sheet has a sea-level equivalent of 7 metres and the rate of mass loss from it is increasing (Velicogna, 2009). Examining the modelled response of the Greenland Ice Sheet to changes in forcing parameters can give insight into how it will behave in the future. The response of the ice sheet to specific changes in forcing parameters is referred to as the sensitivity.

Being able to obtain model sensitivities in as little computation time as possible would be useful for examining the future response of the Greenland Ice Sheet. Adjoint models allow sensitivities to be obtained more efficiently than the conventional way, when considering spatially varying parameters. Conventionally, such sensitivities are obtained by perturbing a parameter at every grid point in turn and calculating the sensitivity at every grid point. Adjoint sensitivities, though, are calculated in a single step. This reduces the computational cost when obtaining sensitivities over large model domains. The adjoint method also has the advantage that it gives the exact value of the model sensitivity, rather than a finite difference approximation to it.

We present the adjoint of a finite difference, shallow ice, thermomechanical ice sheet model with basal sliding, applied to the Greenland Ice Sheet. This adjoint model is obtained using the OpenAD automatic differentiation tool (Utke, 2006), which is open source. The adjoint model is validated by comparing adjoint and forward model sensitivities over 100 years. This work builds on the work of Heimbach (2009).

We use the adjoint model to examine the sensitivity of the model to changes in basal sliding. About half the mass loss from the Greenland Ice Sheet occurs from surface runoff and half from dynamic mass loss (Broeke, 2009). Melt-water from Greenland Ice Sheet supra-glacial lakes can percolate to the bed through moulins. The melt-water that reaches the bed can then act as a lubricant and increase basal sliding (Zwally2002). We investigate whether the volume of the Greenland ice sheet is sensitive to changes in basal sliding in areas of fast draining supra-glacial lakes. It is seen that the overall volume is more sensitive to changes in basal sliding coefficient areas in areas with fast draining supra-glacial lakes than in areas without these.

References

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