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Weak formulation of the sensitivity equations for glacial isostatic adjustment

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Martinec (2000) developed a spectral-finite element approach for the forward modelling of the viscoelastic response of the Earth to a changing surface mass load. Here, we present a new method of assessing the sensitivity of GRACE gravity and GPS deformation-rate data to the Earth's mantle viscosity in relation to glacial-isostatic adjustment, which usually forms the first step of adjoint methods. Both the forward modelling and sensitivity methods are performed in the time domain, such that the boundary-value data are, respectively, a spatially and temporally varying surface mass load and the differences between the measured and predicted gravity and deformation rates.

The squares of the differences between measurement and prediction summed up over the time period of the satellite measurements determine the misfit function. The sensitivity of the gravity and deformation-rate data, that is the partial derivatives of the misfit function with respect to mantle viscosity parameters, is then determined by the product of the forward and sensitivity solutions, integrated over GRACE and GPS time series. Such exactly determined sensitivities are checked against the numerical differentiation of the misfit function, and a very good agreement is obtained. The attractiveness of this sensitivity method lies in the fact that the sensitivities are calculated for a half cost in terms of computation power in comparison to a numerical differentiation method. In addition, the method does not need to store the forward solution as, for instance, in the case of the adjoint sensitivity method.