THE ADJOINT SENSITIVITY METHOD OF GLOBAL ELECTROMAGNETIC INDUCTION FOR CHAMP MAGNETIC DATA

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Martinec and McCreadie (2004) developed a time-domain spectral-finite element approach for the forward modelling of electromagnetic induction vector data as measured by the CHAMP satellite. Here, we present a new method of computing the sensitivity of the CHAMP electromagnetic induction data on the Earth's mantle electrical conductivity, which we term the adjoint sensitivity method. The forward and adjoint initial boundary-value problems, both solved in the time domain, are identical, except for the specification of prescribed boundary conditions. The respective boundary-value data at the satellite's altitude are the X magnetic component measured by the CHAMP vector magnetometer along satellite tracks for the forward method and the difference between the measured and predicted Z magnetic component for the adjoint method.
The squares of these differences summed up over all CHAMP tracks determine the misfit. The sensitivity of the CHAMP data, that is the partial derivatives of the misfit function with respect to mantle conductivity parameters, are then determined by the scalar product of the forward and adjoint solutions, multiplied by the gradient of the conductivity and integrated over all CHAMP tracks. Such exactly determined sensitivities are checked against numerical differentiation of the misfit, and very good agreement is obtained. The attractiveness of the adjoint method lies in the fact that the adjoint sensitivities are calculated for little cost, regardless of the number of conductivity parameters. However, since the adjoint solution proceeds backwards in time, the forward solution must be stored at each time step, leading to memory requirements that are linear with respect to the number of steps undertaken.
Having determined the sensitivities, we apply the conjugate gradient method to infer 1-D and 2-D conductivity structures of the Earth based on the CHAMP residual time serie(after the subtraction of static field and secular variations as described by the CHAOS model) for the year 2001. We show that this time series is capable of resolving both 1-D and 2-D structures in the upper mantle and the upper part of the lower mantle, while it not sufficiently longto reliably resolve the conductivity structure in the lower part of the lower mantle.

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