Adjoint sensitivity method for the downward continuation of the Earth's geomagnetic field through an electrically conducting mantle

J.M. Hagedoorn & Z. Martinec

Dublin Institue for Advanced Studies, School of Cosmic Physics, Geophysics Section, 5 Merrion Square, Dublin 2, Ireland (janh@cp.dias.ie)

Recent models of the Earth's geomagnetic field at the core-mantle boundary (CMB) are based on satellite measurements and/or observatory data, which are mostly harmonically downward continued to the CMB. One aim of the upcoming satellite mission Swarm is to determine the three-dimensional distribution of electric conductivity of the Earth's mantle. On this background, we developed an adjoint sensitivity downward continuation approach that is capable to consider three-dimensional electric conductivity distributions.

Martinec (Geophys. J. Int., 136, 1999) developed a time-domain spectral-finite element approach for the forward modelling of vector electromagnetic induction data as measured on ground-based magnetic observatory or by satellites. We design a new method to compute the sensitivity of the magnetic induction data to a magnetic field prescribed at the core-mantle boundary, 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 are the measured X magnetic component for the forward method and the difference between the measured and predicted Z magnetic component for the adjoint method. The squares of the differences in Z magnetic component summed up over the time of observation and all spatial positions of observations determine the misfit. Then the sensitivities of observed data, i.e. the partial derivatives of the misfit with respect to the parameters characterizing the magnetic field at the core-mantle boundary, are obtained by the surface integral over the core-mantle boundary of the product of the adjoint solution multiplied by the time-dependent functions describing the time variability of magnetic field at the core-mantle boundary, and integrated over the time of observation. The time variability of boundary data is represented in terms of locally supported B-splines. The adjoint sensitivity gradients are then used in a conjugate gradient approach to determine the B-spline coefficients of the magnetic field at the CMB.

The first application is presented here along some case studies of the influence of large scale highly conducting structures like plumes or patches of post-perovskite in the D'' on the geomagnetic field at the CMB and its time behaviour. This method allowing to consider a three-dimensional conductivity structure of the Earth's mantle is an alternative to the perturbation method *(e.g. Stewart et al., Phys. Earth Planet. Inter. 92; 1995)* or the nonharmonic downward continuation, developed by *Ballani et al. (Geophys. J. Int. 149, 2002)*, which are both restricted to radial varying profiles of electric conductivity.