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Effect of mantle electrical conductivity on the geomagnetic secular variation

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The electrical conductivity of the Earth's mantle has been a subject of much debate in the last few years. Induction studies agree mainly in the first 1000 km of the mantle, however in the lower mantle the conductivity is still very uncertain. Experimental studies of mineral physics simulating the conditions of the deep mantle have been performed and results disagree by 3 orders of magnitude depending, for example, on the considered geotherm, composition, etc. As a complement to mineralogical and induction studies, geomagnetic jerks can also contribute towards a better understanding of mantle conductivity.

Geomagnetic jerks involve abrupt temporal changes in the secular variation of Earth's magnetic field and are believed to be due to motions in the fluid core. The secular variation around the time of a jerk was modeled by two straight-line segments, where their intersection defines the jerk occurrence time and the difference between the two slopes defines the jerk amplitude. We detected global jerks occurring at 1969, 1978, and 1991 that show different time arrivals at the surface, with differential time delays of the order of 2 years. One way to explain this intriguing temporal pattern is to consider the Earth's mantle as a conductor, consequently the secular variation observed at the Earth's surface will correspond to a filtered version of the original time variations generated in the core.

In this work, we used Velímský & Martinec (2005) approach to solve exactly the diffusion equation for 1D mantle models to calculate the Impulse Response Functions (IRFs). The 1-D mantle conductivity model of Kuvshinov & Olsen (2006) was adopted up to 700 km depth and below that two simulations were performed. In both simulations the lower mantle was modeled as 1900 km thick and the D" 300 km thick. The difference between the simulations is that in the first the D" presents no variations of electrical conductivity, while in the second simulation it is subdivided in a layer of 200 km and 100 km thick. The electrical conductivity was varied from 27000 S/m to 0.05 S/m.

The output model secular variation was treated in the same way as the data: by calculating annual means and fitting of two straight-line segments by the least-squares method. We calculated differential time delays for data and synthetics in order to find possible electrical conductivity models for the lower mantle that explain jerk differential delays. These models were used to illustrate the effect that an electrical conducting mantle would cause in the secular variation.