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Vector-valued spherical Slepian functions for lithospheric-field analysis

A. Plattner (1) and F. J. Simons (2)

(1) Princeton University, Geosciences, Princeton, United States (plattner@princeton.edu), (2) Princeton University, Geosciences, Princeton, United States (fjsimons@gmail.com)

One of the mission objectives of Swarm is to resolve and model the lithospheric magnetic field with maximal resolution and accuracy, even in the presence of contaminating signals from secondary sources. In addition, and more generally, lithospheric-field data analysis will have to successfully merge information from the global to the regional scale. In the past decade or so, a variety of global-to-regional modeling techniques have come of age that have, however, been met with mixed feelings by the geomagnetics community. In particular, the theory of scalar Slepian functions has been developed for applications mostly in geodesy, but support from within geomagnetism has been tepid. In the Proceedings of the First Swarm International Science Meeting, now six years ago, it was written with reference to Slepian localization analysis that *these methods are theoretically powerful but still need to find their way from the applied mathematician's desk to the geophysicist practitioners'*. In the intervening six years "these methods" have done just that, and thereby enjoyed much use in a variety of fields: but the root cause of their slow adoption for lithospheric-field analysis had not been remediated. To this date, only the theory of scalar Slepian functions on the sphere has been completely worked out. In this contribution we report on the development, at last, of a complete vectorial spherical Slepian basis, suited for applications specifically of geomagnetic data analysis, representation, and model inversion. We have designed a basis of vector functions on the sphere that are simultaneously bandlimited to a chosen maximum spherical harmonic degree, while optimally focused on an arbitrarily shaped region of interest. The construction of these bases of vector functions is achieved by solving Slepian's spatiospectral optimization problem in the vector case, as has been done before for scalar functions on the sphere. Scalar Slepian functions have proven to be very useful in fields as wide as geodesy, geomagnetism, gravimetry, geodynamics, biomedical science, planetary science and cosmology. We expect the same benefits from our newly designed vector Slepian bases for example in the inversion for crustal magnetization. In this presentation, we discuss our construction in detail, including a treatment of numerical efficiency for a variety of specific scenarios, and discuss the first examples of fully vectorial-field representation and approximation tailored to problems in lithospheric-field analysis.