IDENTIFICATION OF THE CURRENT SYSTEMS ASSOCIATED WITH GEOMAGNETIC ACTIVITY

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A longstanding problem in geomagnetism is the identification and the separation of the currents systems that contribute to the total magnetic field. Several current systems can be identified, ranging from the inner Earth, up to the ionosphere and the magnetosphere; only few of them can be accessed by in situ measurements.

The separation of current systems from ground-based measurements is a source separation problem, whose solution is made difficult by to the complex spatio-temporal dynamics of the field. There are essentially two solutions to this problem : 1) use explicit models of the current distributions to separate concurrent processes; 2) invoke the differing statistical properties of the sources to separate them. Here we consider the second approach, based on the observation that sources such as the ring current and the auroral electrojets not only vary differently in time, but also generate fields with different spatial structures.

The robust separation of such spatio-temporal processes has recently become an active research topic (e.g. [1]), for which the classical tool is principal component analysis (or singular value decomposition). We have used in addition independent component analysis, which is more adequate for our purposes.

Both techniques have been applied to four years of 1-hour resolution geomagnetic data from 95 stations, distributed worldwide. The time resolution is sufficient to monitor global perturbations as caused by geomagnetic storms, but does not allow local substorm effects to be investigated. Two frames have been used to analyse the data: 1) a geodetic frame, which is appropriate for studying effects that occur at a fixed geographic location, such as core-induced fields; 2) a geomagnetic coordinate system, using magnetic local time and geomagnetic latitude. This frame is appropriate for studying current systems in the ionosphere and in the magnetosphere.

In both frames, the spatio-temporal analysis reveals that the salient features of the geomagnetic activity can be expressed as a linear superposition of a limited number of modes, that is, the vector magnetic field $\mathbf{B}(\mathbf{x}, t)$ can be decomposed into

$$\mathbf{B}(\mathbf{x}, t) = \sum_k A_k \; \mathbf{f}_k(\mathbf{x}) \; g_k(t)$$

where the spatial $\mathbf{f}_k(\mathbf{x})$ and the temporal $g_k(t)$ modes are orthonormal. A dozen modes suffice to capture over 98 % of the variance of the geomagnetic field. This means that the salient features of the geomagnetic activity are concentrated in a few dominant modes.

The dominant mode shows a slow drift; from its spatial structure we can immediately identify it as the declination of the magnetic field. The next mode is concentrated in the auroral oval, with an amplitude that is strongly dependent on the solar wind conditions. This mode matches almost exactly the pattern of the auroral electrojets, and is therefore interpreted as such. The next (weaker) modes decribe various effects such as the equatorward drift of the electojets during storm activity. The ring current system also clearly shows up in a single mode.

We conclude that most of the spatio-temporal modes that come out of the statistical analysis can be almost directly interpreted at the signature of specific current systems. This opens several perspectives such as: the search for temporal discontinuities (jerks) in the declination, the identification of latitude-dependent recovery times in the ring current signature, the separation of the auroral electrojet system into quiet and intermittent components, etc.

REFERENCE

[1] D. Vassiliadis et al., "Mapping inner magnetospheric convection and injections from and geosynchronous measurements", Proc. of the first SRAMP conference, Sapporo, Oct. 2000, paper S8-P01.