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A spatio-temporally detailed and regular description of the external field over the last solar cycle using EOFs

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Using the Empirical Orthogonal Function (EOF) method, we demonstrate that an irregular network of ground-based vector magnetic data can provide a spatio-temporally detailed and regular description of the external magnetic field without a priori assumptions of the source current geometry. The EOF method analyses the spatio-temporal co-variance of the data to decompose it into dynamically distinct modes (each mode is a pair of spatial and temporal basis vectors). A small number of these modes can cumulatively represent most of the variance of the original data. After binning the observatory data we use the modes to provide a self-consistent infill mechanism for empty bins. Since the basis vectors are defined by the data, the infill solutions only converge upon reinforcement of the natural patterns present in the data, hence the completion of the data coverage is self-consistent. This is in contrast to other commonly-used decomposition methods such as Fourier and spherical harmonic expansions.

We discuss the application of the iteratively-infilled EOF method to vector data from the SuperMAG archive spanning 1997—2008 (a full solar cycle). Using a comparison of the temporal behaviour of the modes alongside independent measures of solar-terrestrial coupling, we demonstrate that the leading three modes describe the well-known Disturbance-Polar currents types 2 and 1 (DP2, DP1) and the system of cusp currents (DPY). These three modes account for the majority of the variance of the data – other modes describe the spatial motions of these current systems. We demonstrate that the use of ground-based data provides an important complement to the coverage of polar data available from satellites, such as AMPERE. Lastly we discuss situations in which the EOF analysis will perform better or worse than other methods, and assess the types of signal that the analysis responds to most strongly.