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Assessing the significance of QG-flow modes computed using Principal Component Analysis

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Time-dependent geomagnetic field models fitting observatory measurements and recent satellite observations can be inverted to provide a view of the Earth's core flow on timescales smaller than about two centuries. The Quasi-Geostrophic assumption for the flows used in the inversion, inspired on the dynamics of rapid rotating fluids in spherical containers, has been gaining support during the past few years.

In this work, Principal Component Analysis (PCA) is used to extract the main modes characterizing the spatial (empirical orthogonal functions - EOF) and temporal (PC) variations of QG flows. For certain classes of stochastically forced mechanical systems, the computed EOFs match the mechanical free modes of the system and have a prompt physical interpretation.

The statistical significance of QG-flow modes and the corresponding eigenvalues is tested using Monte-Carlo methods. The standard procedure for calculating the EOF's stability in this case consists in a temporal subsampling of the original series, randomizing of the subsample (using e.g. bootstrapping procedure), calculating the subsample EOFs and comparing the subsample EOFs with EOFs of the whole original series. The comparison is conducted by calculation of congruence coefficients. This procedure is repeated a significant number of times to ensure the statistical significance of the resulting congruence coefficients. The same bootstrapping procedure can be also used to calculate the statistical significance of the eigenvalues, representing the amount of variability of the inverted QF-flows explained by each specific mode.

Inverted QG-flows can be prolongated inside the Earth's core. A proper spatial and temporal description of the most robust flow features on long timescales can be crucial if we want to assess the ability of QG columns to sustain the geodynamo.