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Instantaneous fractal dimensions and stability properties of geomagnetic indices based on recurrence networks and extreme value theory

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An accurate understanding of dynamical similarities and dissimilarities in geomagnetic variability between quiet and disturbed periods has the potential to vastly improve Space Weather diagnosis. During the last years, several approaches rooted in dynamical system theory have demonstrated their great potentials for characterizing the instantaneous level of complexity in geomagnetic activity and solar wind variations, and for revealing indications of intermittent large-scale coupling and generalized synchronization phenomena in the Earth's electromagnetic environment. In this work, we focus on two complementary approaches based on the concept of recurrences in phase space, both of which quantify subtle geometric properties of the phase space trajectory instead of taking an explicit temporal variability perspective. We first quantify the local (instantaneous) and global fractal dimensions and associated local stability properties of a suite of low (SYM-H, ASY-H) and high latitude (AE, AL, AU) geomagnetic indices and discuss similarities and dissimilarities of the obtained patterns for one year of observations during a solar activity maximum. Subsequently, we proceed with studying bivariate extensions of both approaches, and demonstrate their capability of tracing different levels of interdependency between low and high latitude geomagnetic variability during periods of magnetospheric quiescence and along with perturbations associated with geomagnetic storms and magnetospheric substorms, respectively. Ultimately, we investigate the effect of time scale on the level of dynamical organization of fluctuations by studying iterative reconstructions of the index values based on intrinsic mode functions obtained from univariate and multivariate versions of empirical mode decomposition. Our results open new perspectives on the nonlinear dynamics and (likely intermittent) mutual entanglement of different parts of the geospace electromagnetic environment, including the equatorial and westward auroral electrojets, in dependence of the overall state of the geospace system affected by temporary variations of the solar wind forcing. In addition, they contribute to a better understanding of the potentials and limitations of two contemporary approaches of nonlinear time series analysis in the field of space physics.