Community structure of Earth's magnetic field measurements.

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Introduction

The Earth's magnetic field has dependence both in the time and spatial domains. Also, due to the underlying physical processes involved, the change of the magnetic field at a given point or at a given instant may induce variations at other points and/or subsequent times. We propose to study this complex dynamics of spatiotemporal correlations by means of tools derived from graph theory and complex networks, which have shown to be useful to describe the behavior of various systems of geophysical interest [1, 2, 3]. In particular, we intend to study the evolution of magnetic field measurements on the Earth's surface along the 23rd solar cycle. Based on records by 59 magnetometers during the 23rd solar cycle (taken from the World Data Center for Geomagnetism, Kyoto, http://wdc.kugi.kyoto-u.ac.jp/hyplt/index.html), we define a complex network where nodes are the magnetometers, and their connection is determined by the correlation between their respective magnetic field time series. Thus, the structure of the complex network is expected to be a representation of the spatiotemporal patterns of the Earth's magnetic field. Since the 59 stations are not uniformly distributed, we will also consider data from a simulation (taken from the Community coordinated modeling center, https://ccmc.gsfc.nasa.gov/modelweb/models/igrf_vitmo.php), where we can sample data on a uniform grid in spherical coordinates. In fact, we consider a network of 234 points with a separation of 12.5° in latitude and 20° in longitude. Thus, we expect to complement the conclusions taken from observed data.

Methodology

The network is defined by two similarity methods between time series, namely, the Pearson correlation [4, 5] and event synchronization [6]. Complex networks are built for each year from 1996 to 2008, covering the full 23rd solar cycle. Then, the community structure of each network is analyzed, and some of its basic features are analyzed along the cycle: the number of communities, their average coverage area and the value of their modularity.

We find that the community structure for both the real data and the simulation data do indeed have information about solar activity. For example, we observe that both the average coverage area and the value of the modularity of the communities decrease during the solar maximum, with both parameters producing a maximum at the beginning and at the end of the solar cycle. This suggests that the community structure of the network may reveal the changes in correlation length in the magnetic field structure as solar activity evolves. But we also show that results strongly depend on the choice of similarity methods, and the thresholds involved.

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