Non-gaussian diffusion and long-time correlations in the magnetosphere-ionosphere system

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The magnetosphere-ionosphere (MI) system hosts different concentrations of cold plasma. The magnetosphere interaction with the solar wind, the Earth's rotation, and the interactions of protons, ions, and electrons with the electromagnetic fields drive the behavior of plasma dynamics [1]. Since the interactions of the magnetosphere with the solar wind are chaotic [2], this produces substantial random alterations in the plasma densities, temperatures, and velocities of the particles immersed in it, thus inducing random fluctuations in the electrical currents present in these regions. These random fluctuations in the MI system could wreak havoc on many technologies, such as satellite communications and power grids. We study the statistical properties of the temporal displacements of the magnitude of the horizontal Earth's magnetic field H over three solar cycles. The probability distribution function (PDF) of these temporary displacements allows us to characterize the dynamics of the MI system during the different solar cycles (Figure 1) [3]. All the PDFs for different solar cycles have the same form: at short times, they show a stretched Gaussian shape, and at long times, non-Gaussian tails (nGTs) are observed. nGTs are associated with "long-time tail correlations" that generate a system with non-Markovian dynamics. Likewise, at long times, there is a persistent peak associated with trajectories of random walks that never leave their local paths and with processes of the Fickian, yet non-Gaussian diffusion type [4]. Moreover, we calculate a robust statistical observable, the magnetic mean squared displacement (MMSD), using data from several geomagnetic stations in the northern and southern geomagnetic latitudes. We propose a physical model to describe the MMSD system using the Generalized Langevin Equation (GLE), provided with a smoothly decaying kernel memory $\gamma(t)$ [3], and Alfvén's ideas for space plasmas in terms of electrical circuits [5]. We describe electrical currents in the MI system by an ensemble of serial electric circuits (RCL) fed by one random voltage source. Finally, we successfully compare calculated MMSD with our model (Figure 2), finding the following key results: (i) the MI system exhibits long-time tail correlations, and (ii) these correlations are explained by a memory kernel that arises from a two power-law.

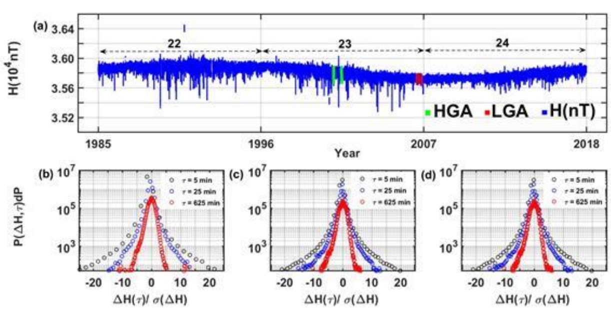

Figure 1

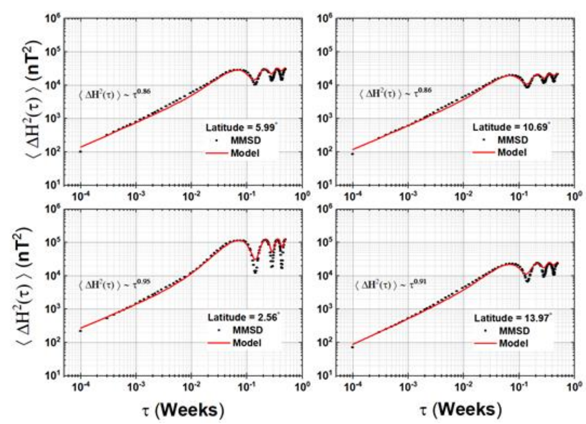

Figure 2

References

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