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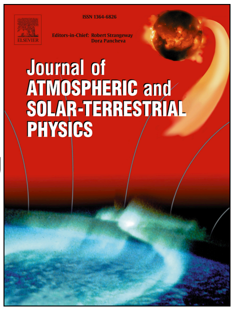


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# Data-adaptive harmonic analysis and modeling of solar wind-magnetosphere coupling

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**Abstract**

The solar wind-magnetosphere coupling is studied by new data-adaptive harmonic (DAH) decomposition approach for the spectral analysis and inverse modeling of multivariate time observations of complex nonlinear dynamical systems. DAH identifies frequency-based modes of interactions in the combined dataset of Auroral Electrojet (AE) index and solar wind forcing. The time evolution of these modes can be very efficiently simulated by using systems of stochastic differential equations (SDEs) that are stacked per frequency and formed by coupled Stuart-Landau oscillators. These systems of SDEs capture the modes' frequencies as well as their amplitude modulations, and yield, in turn, an accurate modeling of the AE index' statistical properties.

*Keywords:* stochastic modeling, solar wind, magnetosphere, auroral electrojet

## 1. Introduction

Empirical models have proven to be an important addition to understanding and predicting physical phenomena, largely due to the application of mathematical techniques which extract information of the variability of a system of which we do not fully understand the physical nature. In space physics, most historical empirical models have focused their attention on processes at or inside of geosynchronous orbit due, primarily, to the plethora of observations from geosynchronous, med-, and low-Earth orbit spacecraft, and recognition of harmful effects of relativistic energy radiation, such as deep-dielectric charging in spacecraft electrical components (Baker et al., 1987). The list of empirical models applied to model and understand the near-Earth space plasma is exhaustive. There are examples of the nearest-neighbor approaches for data-driven empirical magnetic field modeling (Sitnov et al., 2008), linear prediction (Baker and McPherron, 1990), statistical normalized mean (Kellerman and Shprits, 2012; Kellerman et al., 2013); neural networks (NN) (e.g. Koons and Gorney, 1991; Fukata et al., 2002; Ling et al., 2010; Zhelavskaya et al., 2016; Bortnik et al., 2016), and NARMAX (e.g Balikhin et al., 2011); while the Kalman filter data assimilation techniques may utilize linear (Kondrashov et al., 2007; Shprits et al., 2007; Daae et al., 2011; Shprits et al.,

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