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ORIGINAL ARTICLE

Multifractality due to long-range correlation in the L-band ionospheric scintillation S_4 index time series

H.J. Tanna · K.N. Pathak

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Abstract The earth's ionosphere is well recognized as a dynamical system and non-linearly coupled with the magnetosphere above and natural atmosphere below. The shape and time variability of the ionosphere indeed shows chaos, pattern formation, random behaviour and self-organization. The present paper studies the propriety of Multifractal Detrended Fluctuation Analysis (MF-DFA) technique for the ionospheric scintillation index time series. MF-DFA is used to identify the scaling behaviour of the ionospheric scintillation time-series data of two different nature. The obtained results show the robustness and the relevancy of the MF-DFA technique for the ionospheric scintillation index time series. The comparison of the MF-DFA results of original data to those of shuffled and surrogate series shows that the multifractal nature of considered time-series is almost due to long-range correlations. Subsequently, the Hurst exponents derived from two parallel methods namely Rescaled range analysis (R/S) and Auto Correlation Function (ACF) are also suggesting the presence of long range correlation. The presented results in this work may be of assistance for future modeling and simulation studies.

Keywords Ionospheric scintillation time series · Persistency · Multifractality

H.J. Tanna (✉) · K.N. Pathak
Department of Applied Physics, S. V. National Institute of Technology, Ichchhanath, Surat 395007, Gujarat, India
e-mail: hemalitanna8@gmail.com

H.J. Tanna
e-mail: t.hemali@ashd.svnit.ac.in

1 Introduction

The history of ionospheric research, starting with the pioneering experiments by Appleton and Barnett (1925) and Breit and Tuve (1926), is long and rich in physics and chemistry (Rishbeth et al. 1996). The Earth's ionosphere is composed of energy and neutral atoms/molecules for ionization process and is well recognized as a complex nonlinear system. Being governed by classical equations, the real ionosphere is a dynamical system of non-linearly coupled fields to the magnetosphere above and neutral atmosphere below and strongly affected by neutral winds, atmospheric tides, motion due to electric and magnetic fields etc. Indeed, the space and time variability of the real ionosphere shows chaos, pattern formation, random behaviour and self-organization (Materassi et al. 2003). One of the most dramatic manifestations of the "irregularity" of the ionosphere is the fluctuation of radio signals crossing it. The rapid fluctuation of amplitude and phase of the radio signal passing through the ionospheric region, embedded with plasma density irregularities refers to as the ionospheric scintillation.

The irregularities that can cause scintillation of radio waves are being studied using data from digisonde, scanning photometers/imager (optical techniques) and VHF monitors among others (Oladipo and Schüler 2013). Ionospheric scintillations mainly occur near the magnetic equator region essentially at night, shortly after local sunset and are associated with the presence of spread-F irregularities in the path of radio waves. However, there is a recent agreement that day-time ionospheric scintillations are sometimes associated with E region irregularities (Zou and Wang 2009; Zou 2011). The existence of ionospheric scintillation degrades the performance of satellite based communication system, resulting in signal fading below the fad margin of the receiver, and leading to the signal loss and cycle slips

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