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Research Paper

Climatology of ionospheric amplitude scintillation on GNSS signals at south American sector during solar cycle 24

Eduardo Perez Macho [a,*], Emília Correia [a,b], Luca Spogli [c,d], Marcio Tadeu de Assis Honorato Muella [e]

[a] Escola de Engenharia, CRAAM, Universidade Presbiteriana Mackenzie, 01302-907, São Paulo, Brazil
[b] Instituto Nacional de Pesquisas Espaciais (INPE), 12227-010, São José dos Campos, Brazil
[c] Istituto Nazionale di Geofisica e Vulcanologia (INGV), 00143, Rome, Italy
[d] SpacEarth Technology, 00143, Rome, Italy
[e] Universidade do Vale do Paraíba (UNIVAP), 12244-390, São José dos Campos, Brazil

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ABSTRACT

Scintillations are caused by ionospheric irregularities and can affect the propagation of trans-ionospheric radio signals. One way to understand and predict the impact of such irregularities on Global Navigation Satellite System (GNSS) signals is through the spatial/temporal characterization of the scintillation's climatology during different phases of a solar cycle covering different latitudes and longitudes. This characterization is performed using amplitude scintillation index S_4, during the full solar cycle 24, in the South American (SA) sector. The investigation considers the diurnal, daily, and seasonal variation of S_4 index for climatological purpose, and the goal of this study is to investigate the scintillations covering a large spatial scale during the full solar cycle 24. The characterization shows a latitudinal asymmetry, whereas at the south, the scintillations were more frequent and their peak was more distant from the magnetic equator, which can be attributed by the South Atlantic Magnetic Anomaly (SAMA), and/or by the transequatorial meridional neutral winds. It also shows a longitudinal asymmetry, where the scintillations at the eastern sector occurred between November and February, while at the western sector, they occurred during the months of October, November, February and March, which can be attributed to the difference between the magnetic and geographic equators. The occurrence of scintillations during two distinct geomagnetic storms with similar storm time in the SA sector is also presented.

1. Introduction

Radio signals that propagate through the ionosphere are subject to scintillations, which are rapid changes in their amplitude and/or phase caused by ionospheric electron density irregularities. The ionospheric scintillations can affect the Global Navigation Satellite Systems (GNSS) signals, the High Frequency (HF) communication, and the satellites-controlled systems (Yeh and Liu, 1982; Kintner et al., 2009). If a strong amplitude scintillation occurs, the carrier to noise ratio of a GNSS signal fluctuates rapidly and may drop more than 20–25 dB (Seo et al., 2009; Akala et al., 2012), reaching a level in which the receiver is unable to track it, causing navigation unavailability or reducing its accuracy (Conker et al., 2003; Spogli et al., 2013a; Moraes et al., 2014; Vani et al., 2019). Phase scintillations may cause the phase-locked loop to lock onto a wrong phase, degrading the quality of the tracked signal or causing a loss of lock, which in turn causes cycle slips (Sreeja et al., 2011). Amplitude scintillations are triggered by diffraction effects, and are ruled out by the Fresnel's filtering mechanism (e.g., Ghobadi et al., 2020 and references therein). According to this, irregularities having scale size below the Fresnel's scale for L-band signals (order of few hundreds of meters for L-band signals) when crossed by the plane-wave, act as new wave sources, resulting in an interference at the receiver level (Wernik et al., 2003). Among the phenomena that can trigger the formation of such small-scale ionospheric irregularities are those associated with the growth and decay processes of equatorial plasma bubbles (EPBs), and also with particles' precipitation (Burke et al., 2004). The EPBs are large-scale ionospheric structures characterized by depleted electron density with respect to the ambient ionosphere, which are usually developed after the local sunset at the magnetic equator. The EPBs propagate towards high latitudes along the magnetic field lines,

* Corresponding author.
E-mail address: eduardopmacho@gmail.com (E.P. Macho).

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