International Beacon Satellite Symposium BSS-2016
Trieste, Italy

GPS phase scintillation during the geomagnetic storm of March 17, 2015: The relation to auroral electrojet currents

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ABSTRACT

The phase scintillation index is computed for L1 signal sampled at the rate of up to 100 Hz by specialized GNSS scintillation receivers of the Expanded Canadian High Arctic Ionospheric Network (ECHAIN) and the Norwegian Mapping Authority network supplemented by additional GNSS receivers operated by other institutions. To further extend the geographic coverage, the phase scintillation proxy index is obtained from geodetic-quality GPS data sampled at 1 Hz. In the context of solar wind coupling to the magnetosphere-ionosphere system, it has been demonstrated that GPS phase scintillation is primarily enhanced in the cusp, tongue of ionization (TOI) broken into patches drawn into the polar cap from the dayside storm-enhanced plasma density (SED) and in the auroral oval during energetic particle precipitation events, substorms and pseudo-breakups in particular. In this paper we examine the relation to auroral electrojet currents observed by arrays of ground-based magnetometers and energetic particle precipitation observed by the Defense Meteorological Satellite Program (DMSP) satellites. Equivalent ionospheric currents (EICs) are obtained from ground magnetometer data using the spherical elementary currents systems (SECS) technique [1] that has been applied over the entire North American ground magnetometer network [8].

Key words: Polar and auroral ionosphere, ionospheric irregularities, GPS scintillation, auroral electrojets, space weather

1. Introduction

Ionospheric irregularities cause rapid fluctuations of radio wave amplitude and phase that can degrade GPS positional accuracy and affect performance of radio communication and navigation systems [6]. The ionosphere becomes particularly disturbed during geomagnetic storms caused by impacts of coronal mass ejections compounded by high-speed plasma streams from coronal holes. Geomagnetic storm of March 17, 2015 was the largest in the current solar cycle. The high-latitude ionosphere dynamics is studied using arrays of ground-based instruments including Global Navigation Satellite System (GNSS) receivers, HF radars, ionosondes, riometers and magnetometers. A complementary paper will discuss response of a global 1-Hz GPS network to the storm as well the effects on GPS precise point positioning [3].

2. GNSS receivers

In the Canadian Arctic, the GPS phase and amplitude scintillation and total electron content (TEC) is monitored by the Canadian High Arctic Ionospheric Network (CHAIN) consisting of GNSS Ionospheric Scintillation and TEC Monitors (GISTMs) using NovAtel GSV4004B receivers and Septentrio PolaRxS multi-frequency receivers [5]. Geodetic quality GPS receivers sampling at 1-Hz rate complement the GISTMs by providing proxy scintillation indices [2]. These include, but are not limited to, GPS receivers provided by the International GNSS Service (IGS). In Europe, the Norwegian Mapping Authority (NMA) operates a dense nationwide network of 1-Hz geodetic receivers and Septentrio PolaRxS scintillation monitoring receivers. In the Svalbard region, the Birkeland Centre for Space Science operates four NovAtel GPStation-6 multifrequency receivers [7]. Additional GSV4004B and Septentrio PolaRxS receivers are operated by Nottingham Geospatial Institute. Technical University of Denmark, National Space Institute contributes high-rate GPS receivers of the Greenland GPS Network (GNET). GNET consists of 62 GPS stations (11 of these are operating at high-rate) that are distributed along the Greenland inland ice.

3. GPS phase scintillation and auroral electrojets

In a recent paper [4], the ionospheric irregularities in total electron content (TEC) were studied in relation to the auroral electrojet currents during the geomagnetic storm of March 17-18, 2015, showing that the most intense disturbances of GNSS signals that they characterized by the rate-of-TEC index (ROTI) occur on the poleward side of poleward-moving current regions over Scandinavia. We applied the SECS technique to obtain horizontal equivalent currents and the vertical current amplitudes from an array of ground magnetometers seeking a comparison with GPS phase scintillation occurrence. For the inversion technique we used ground magnetometer data from 77 stations in the North American sector. Fig. 1a shows the GPS phase scintillation occurrence as a function of AAGCM latitude and UT for GPS receiver stations located between 260 and 300°E geographic longitude overlaid with contours of J_y for the geographic meridian at 281°, with EICs transformed to geomagnetic coordinates using a geomagnetic model magnetic declination at each grid cell. To conform to the 15-min grid span used for scintillation occurrence map, the west-to-east J_y current component is averaged over 15 min (mean of 15 values using the 10-s EICs data decimated to one value per minute). In the auroral zone, the highest occurrence of GPS phase scintillation is generally collocated with strong EICs with a tendency to be observed near the poleward edge of the westward or eastward electrojet regions.

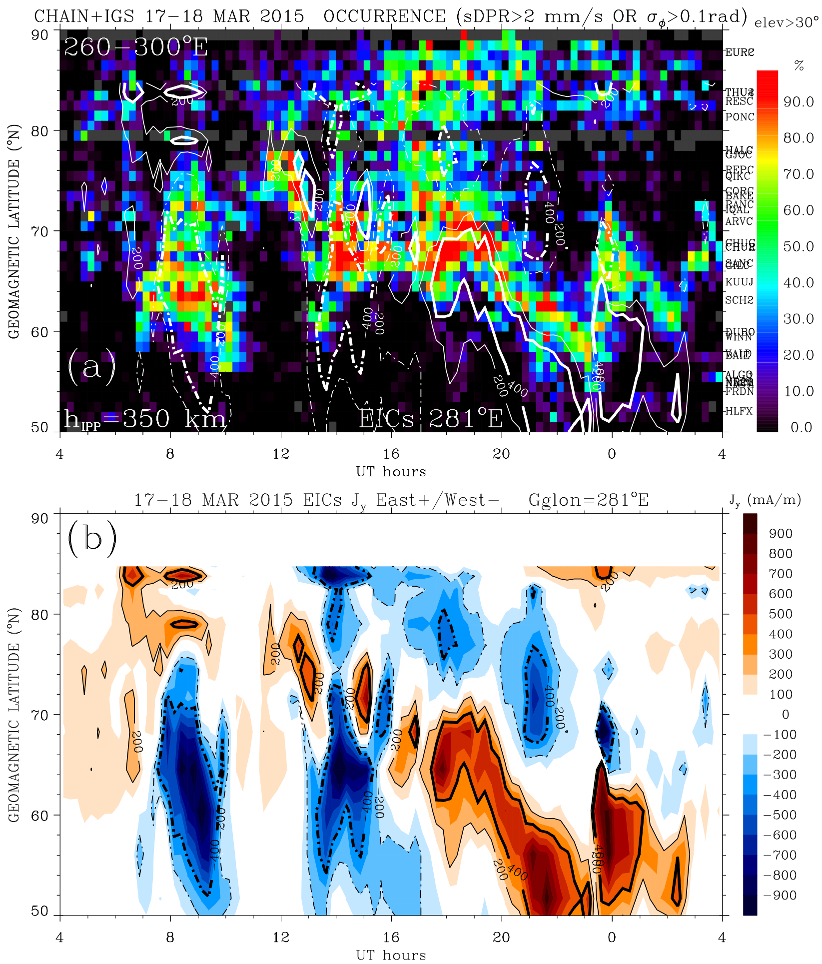

Figure 1. (a) The phase scintillation occurrence of $\sigma_\Phi > 0.1$ rad or proxy scintillation index sDPR > 2 mm/s as a function of AAGCM latitude and UT for ECHAIN combined with 1-Hz GPS receivers. The data are shown from 04:00 UT on March 17 to 03:59 UT on March 18, 2015. **(b)** Westward and eastward EICs.

References

[1] Amm, O., and A. Viljanen, (1999). Earth Planets Space, 51, 431–440.

[2] Ghoddousi-Fard R., P. Prikryl, and F. Lahaye (2013). Adv. Space Res., 52, 1397-1405, doi: 10.1016/j.asr.2013.06.035.

[3] Ghoddousi-Fard R., P. Prikryl, and F. Lahaye (2016). Geomagnetic storm of March 17, 2015: global RT-IGS GPS phase irregularities and effects in the Canadian auroral region. Submitted to International Beacon Satellite Symposium BSS-2016, Trieste, Italy.

[4] Jacobsen, K. S., and Y. L. Andalsvik, J. Space Weather Space Clim., **6**, A9, 2016.

[5] Jayachandran P. T., et al., Radio Sci. 44:RS0A03, doi:10.1029/2008RS004046.

[6] Kintner, P. M., Ledvina, B. M., and de Paula, E. R., (2009). Space Weather, 5, S09003, doi:10.1029/2006SW000260.

[7] van der Meeren, C., K. Oksavik, D. A. Lorentzen, M. T. Rietveld, and L. B. N. Clausen, J. Geophys. Res. Space Physics, 120, 10,607–10,621, doi:10.1002/2015JA021819, 2015.

[8] Weygand, J. M., et al., (2011). J. Geophys. Res., 116, A03305, doi:10.1029/2010JA016177.