GPS IONOSPHERIC SCINTILLATION AND HF RADAR BACKSCATTER – A COMPARISON BETWEEN GISTM NETWORK AND SUPERDARN AT HIGH LATITUDES

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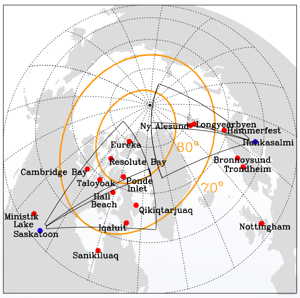
Abstract

The occurrence of GPS ionospheric scintillation at high latitudes is compared with the occurrence of HF radar backscatter from field-aligned irregularities as a function of magnetic local time and geomagnetic latitude. In the European sector, the scintillation was observed in 2003 and 2008 using GPS Ionospheric Scintillation and TEC Monitors (GISTM) included in a network extending from high to mid latitudes. In the North American sector, the GPS data have been collected with the Canadian High-Arctic Ionospheric Network (CHAIN) since 2008. Climatologies of phase scintillation in the auroral and polar ionospheres, that are being developed for both sectors, are compared with the HF radar backscatter occurrence observed by SuperDARN. It is found that both the HF radar backscatter and GPS scintillation predominantly occur in the night portion of the auroral oval and in the ionospheric footprint of the cusp. Data subsets for geomagnetically quiet and disturbed periods show the expected shift in latitude of the ionospheric regions both in the occurrence of phase scintillation and the HF radar backscatter from ionospheric irregularities.



The CHAIN and European GISTM arrays with the field of view and beam 8 of the SuperDARN radars in Saskatoon and Hankasalmi superposed. Corrected geomagnetic (CGM) latitudes 70° and 80° are shown.

Introduction

Ionospheric irregularities cause rapid fluctuations of radio wave amplitude and phase called scintillation. Scintillation may affect performance and operational capabilities of radio communication and navigation systems using satellite-to-ground links near the magnetic equator and at high latitudes.

To understand the effects at high latitudes the Istituto Nazionale di Geofisica e Vulcanologia (INGV) and the Institute of Engineering Surveying and Space Geodesy (IESSG) of the University of Nottingham operate GISTM (GPS Ionospheric Scintillation and TEC Monitor) receivers over the northern Europe (Spogli et al., 2009).

The Canadian High-Arctic Ionospheric Network (CHAIN) is a new array of GISTM receivers and ionosondes (Jayachandran et al., 2009) to study the ionospheric structure at high latitudes in the North-American sector. CHAIN is supported by radars, optical instruments and magnetometers, most of which are part of the Canadian GeoSpace Monitoring (CGSM) program.

GISTM consists of a NovAtel OEM4 dual frequency receiver with special firmware specifically configured to measure and log high rate (50Hz) power and phase of the GPS L1 signal. The receiver computes ionospheric TEC (total electron content) using both GPS L1 and L2 signals. GSV 4004B can also automatically compute and log the amplitude scintillation index, S4, which is the standard deviation of the received power normalized by its mean value, and the phase scintillation index σ_φ, the standard deviation of the detrended phase using a filter in the receiver with 0.1 Hz cutoff.

The Super Dual Auroral Radar Network (SuperDARN) is a network of coherent-backscatter HF radars with look areas covering a large fraction of the high-latitude ionosphere. The radars transmit at frequencies 8-20 MHz along 16 successive azimuthal beams, each of which is gated into 75 range bins. The bins are 45 km long in standard operations, and the dwell time for each beam is 7 s. A full 16-beam scan with successive beams separated by 3.24° covers ~52° in azimuth every 2 min. Several quantities including the line-of-sight (LoS) Doppler velocity, spectral width and backscatter power from field-aligned ionospheric (FAI) plasma irregularities are routinely measured.

Method

Maps of percentage occurrence of the phase scintillation index σ_φ are constructed by binning the data in magnetic local time (MLT) and Altitude Adjusted Corrected Geomagnetic Coordinates (Baker and Wing, 1989). The ionospheric pierce point (IPP) is assumed at 350 km altitude. The scintillation data are merged into bins of 1 hour MLT × 2.5˚ CGM latitude. Using elevation cutoff of 15˚, the percentage occurrence of phase scintillation above a given threshold is evaluated as:

$$N(\sigma_\varphi > \text{threshold}) \,/\, N_{tot}$$

where $N(\sigma_\varphi > \text{threshold})$ is the number of data points corresponding to a scintillation index above a given threshold (0.1 radians) and N_{tot} is the total number of data points in the bin. To remove the contribution of bins with poor statistics (indicated by blank or grey areas) we assume that the selected accuracy, defined as (Taylor, 1997):

$$R = 100 \times \sigma(N_{tot}) \,/\, N_{tot} = 100 \,/\, \sqrt{N_{tot}}$$

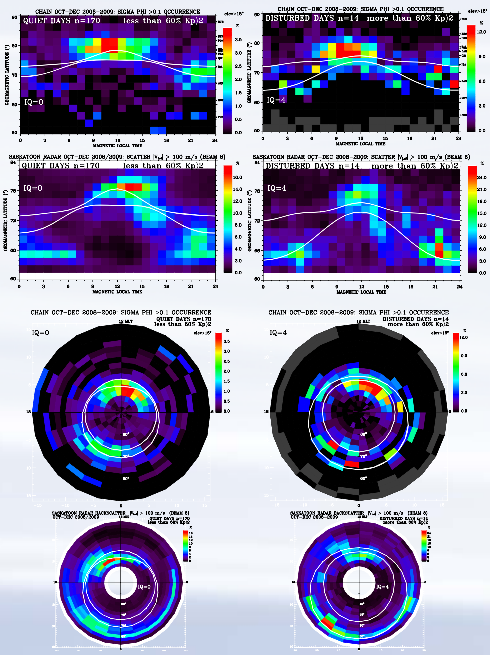
has to be lower than 5%, where $\sigma(N_{tot}) = \sqrt{N_{tot}}$ is the standard deviation of the number of data points in each bin.

HF radar backscatter from drifting decameter irregularities

The scintillation is caused by ionospheric irregularities of scale sizes from hundreds of meters to a few kilometers. However, these larger irregularities may coexist with small-scale field-aligned irregularities produced by plasma instabilities including the gradient-drift instability. Also, the phase scintillation is expected to be closely linked to the magnitude of relative motion of the irregularity and its variability. HF radar backscatter from decameter-size irregularities drifting with **E** × **B** velocity is routinely observed with SuperDARN. The occurrence of ionospheric backscatter with LoS velocity exceeding 100 m/s observed with beam 8 of the Hankasalmi or Saskatoon radars is mapped as a function of MLT and CGM latitude, averaged in bins of 1 hour MLT × 1.5˚ CGM latitude, similarly to scintillation data.

Phase scintillation and HF radar backscatter occurrence: CHAIN and Saskatoon SuperDARN radar

October-December 2008/2009

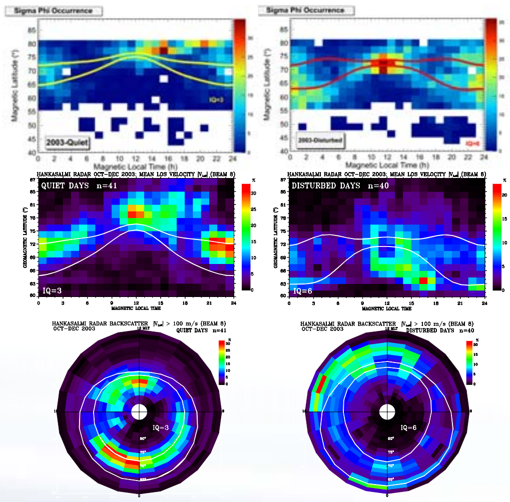


Percentage occurrence of phase scintillation and of the Saskatoon radar backscatter with absolute value of LoS velocity exceeding 100 m/s. The data are divided into subsets of quiet (left) and moderately disturbed days (right). The positions of the Feldstein auroral oval (Feldstein, 1963; Holzworth and Meng, 1975) for two levels of auroral activity (IQ) are superposed.

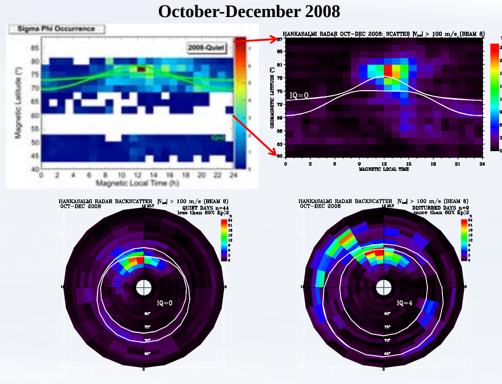
Phase scintillation and HF radar backscatter occurrence: European GISTM network and Hankasalmi SuperDARN radar

Percentage occurrence of phase scintillation and of the Hankasalmi radar backscatter with absolute value of LoS velocity exceeding 100 m/s are compared. The data are divided into subsets of quiet and disturbed days. A day for 2003 period is assumed to be quiet if every Kp index is strictly less than 5 and if 50% of values in that day is less than or equal to 4. Using the same criterion for the 2008 period, almost all days except one were quiet. Thus the 2008 radar backscatter data are divided into quiet and moderately disturbed days using much less stringent threshold (Kp=2). The positions of the Feldstein auroral oval (Feldstein, 1963; Holzworth and Meng, 1975) for two levels of auroral activity (IQ) are superposed.

October-December 2003



October-December 2008



Summary

The occurrence of GPS phase scintillation observed by the CHAIN and European GISTM arrays at high latitudes are compared with the occurrence of HF radar backscatter from **E** × **B** drifting field-aligned irregularities observed by SuperDARN. The amplitude scintillation (S4 index) has remained very low during the current deep solar minimum. The phase scintillation occurrence as a function of magnetic local time and geomagnetic latitude is co-located primarily with the nighttime auroral oval and the ionospheric cusp. Subset climatologies for geomagnetically quiet and disturbed periods show expected shifts in latitude of the ionospheric regions both in the occurrence of phase scintillation and the HF radar backscatter from ionospheric irregularities.

References

Baker, K. B. and Wing, S., *J. Geophys. Res.*, 94, 9139–9143, 1989.
Feldstein, Y. I., *Geomagn. Aeron.*, 3, 183–192, 1963.
Holzworth, R. H. and Meng, C.-I., *Geophys. Res. Lett.*, 2, 377–380, 1975.
Jayachandran, P. T., et al., *Radio Sci.*, 44, RS0A03, doi:10.1029/2008RS004046, 2009.
Spogli et al., *Ann. Geophys.*, 27, 3429-3437, 2009.
Taylor, J. R.: An introduction to Error Analysis: The Study of Uncertainties in Physical Measurement, 2nd ed., University Science Books, USA, 1997.

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