FIRST COMPARATIVE SCINTILLATION STUDY USING ARCTIC AND ANTARCTIC GPS RECEIVER ARRAYS

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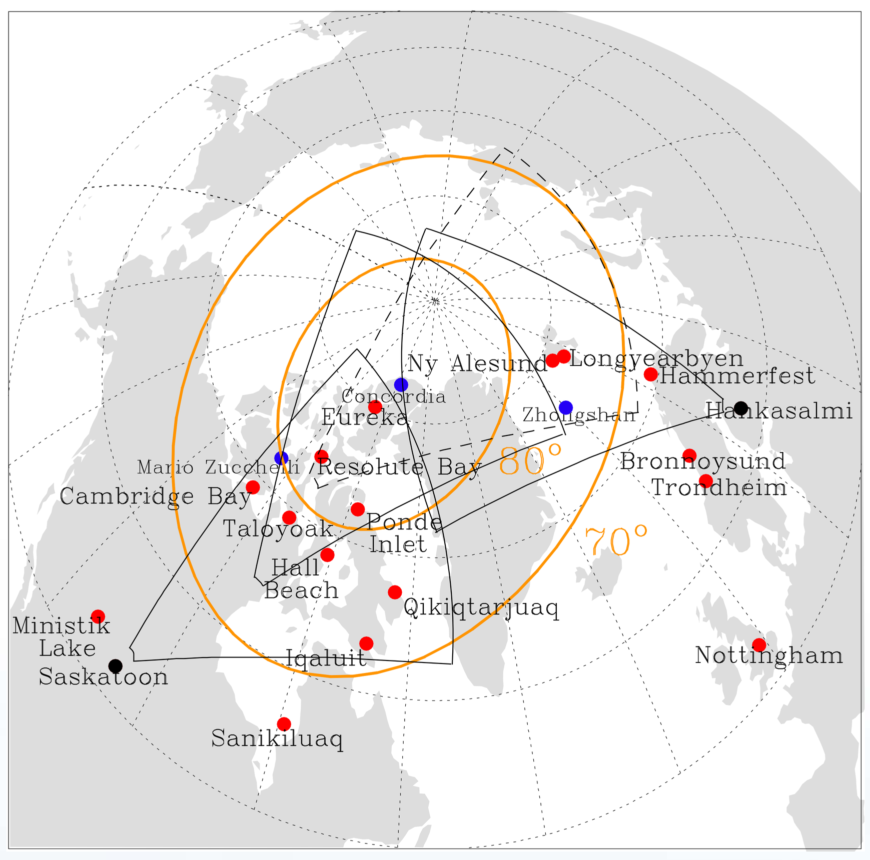
Abstract

Arrays of dual-frequency GPS receivers operating in the Arctic and Antarctic monitor scintillation and ionospheric total electron content at high latitudes. Even under solar minimum conditions, events of significant phase scintillation have been observed in both polar caps. Climatology studies in both hemispheres show that phase scintillation as a function of magnetic local time and geomagnetic latitude primarily occurs in the nightside auroral oval and ionospheric cusp, with the scintillation regions shifting in latitude in response to varying geomagnetic activity. Preliminary results from the first comparative scintillation study supported by ground-based instruments including HF radars, ionosondes and all-sky imagers are presented. In the future, in-situ measurements by the Enhanced Polar Outflow Probe (ePOP) will provide additional support to study the Arctic and Antarctic ionospheres.



The CHAIN and European GISTM arrays and fields of view of SuperDARN radars in Saskatoon, Rankin Inlet and Hankasalmi. Conjugate locations of selected Antarctic GPS receivers (blue dots) and McMurdo SuperDARN radar (dashed line) are superposed. Corrected geomagnetic (CGM) latitudes 70°N and 80°N 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, University of Bath and the University of Nottingham operate GISTM (GPS Ionospheric Scintillation and TEC Monitor) receivers in the northern Europe (Spogli et al., 2009) and Antarctica. The Canadian High-Arctic Ionospheric Network (CHAIN) is an array of GISTM receivers and ionosondes (Jayachandran et al., 2009) to study the high-latitude ionosphere 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.

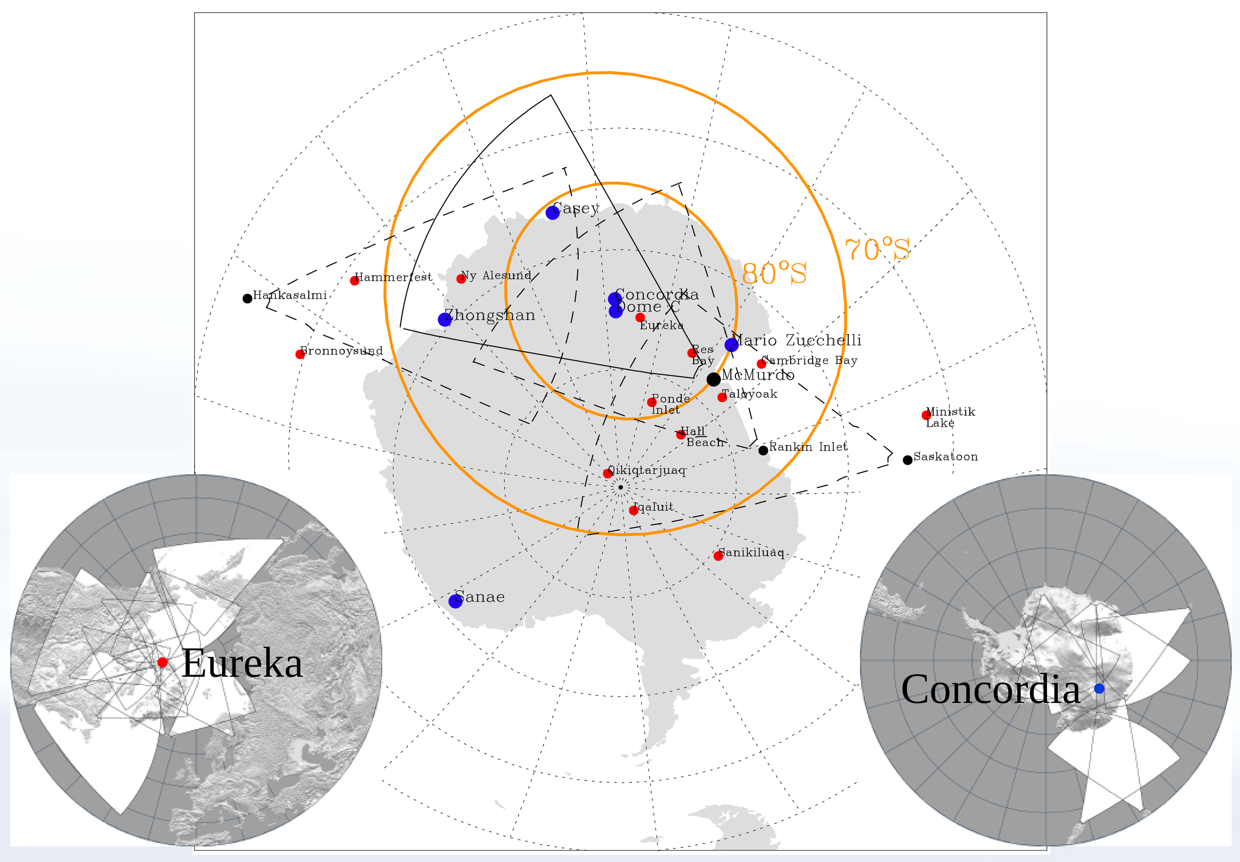
The Super Dual Auroral Radar Network (SuperDARN) is a network of coherent-backscatter HF radars with look areas covering a large fraction of the northern and southern high-latitude ionosphere. The radars transmit at frequencies 8-20 MHz along 16 successive azimuthal beams. The range bins are 45 km long in standard operations (75 range gates) 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. Line-of-sight (LoS) Doppler velocity, spectral width and backscatter power from field-aligned ionospheric (FAI) plasma irregularities are routinely measured.

The Northern Solar Terrestrial Array (NORSTAR) (Donovan et al., 2003) is an optical and radio facility designed to remotely sense auroral precipitation on a continental scale. NORSTAR consists of CCD-based All-Sky Imagers (ASIs), Meridian Scanning Photometers (MSPs), and riometers.

GPS phase scintillation in the polar cap and auroral oval in the Northern and Southern hemispheres

Climatology studies of GPS scintillation in the Northern hemisphere showed that at high latitudes phase scintillation primarily occurs in ionospheric regions defined by the process of solar wind coupling to the magnetosphere, namely, the auroral oval and the ionospheric footprint of the cusp. The strongest phase scintillation is associated with auroral arc brightenings particularly during auroral substorms or with a perturbed cusp ionosphere. The auroral scintillation tends to be intermittent, localized and of short duration while the dayside scintillation usually persists over a large area of the cusp/cleft region. In the polar cap, scintillation is caused by polar patches and possibly by sun-aligned arcs.

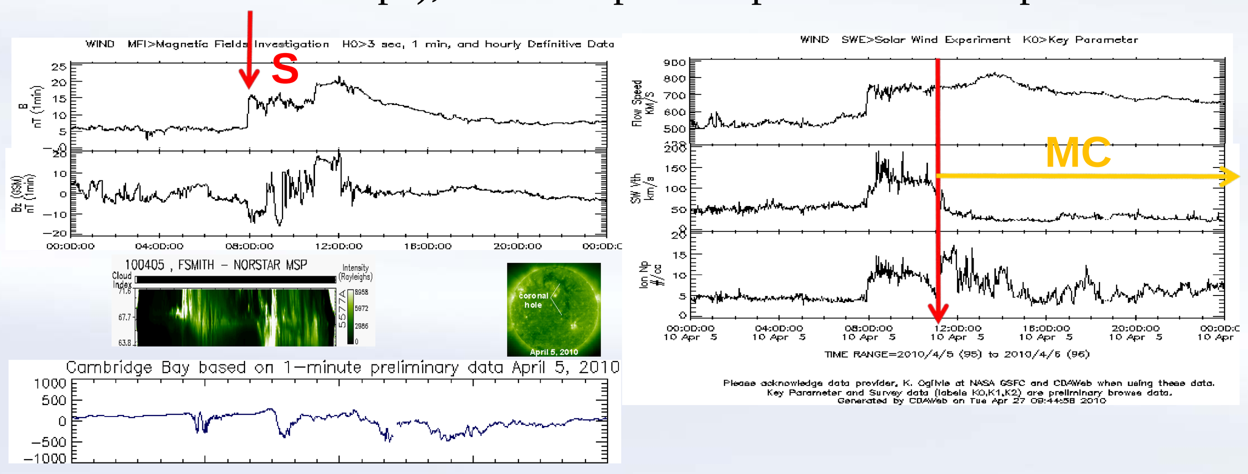
As with spatial and temporal conjugacy of aurorae some similarities in scintillation occurrence in the polar regions are to be expected in the auroral ovals. The polar caps, on the other hand, are regions of open field lines (connected to solar wind IMF) and thus, strictly speaking, not magnetically conjugate. However, conjugate processes in the auroral oval affect the polar ionosphere structure (polar cap patches) and under the northward IMF condition a more complex magnetic topology may result in conjugate polar cap aurorae. Comparative studies of polar ionospheres are now supported by new installations of GPS receivers, HF radars and other instruments.



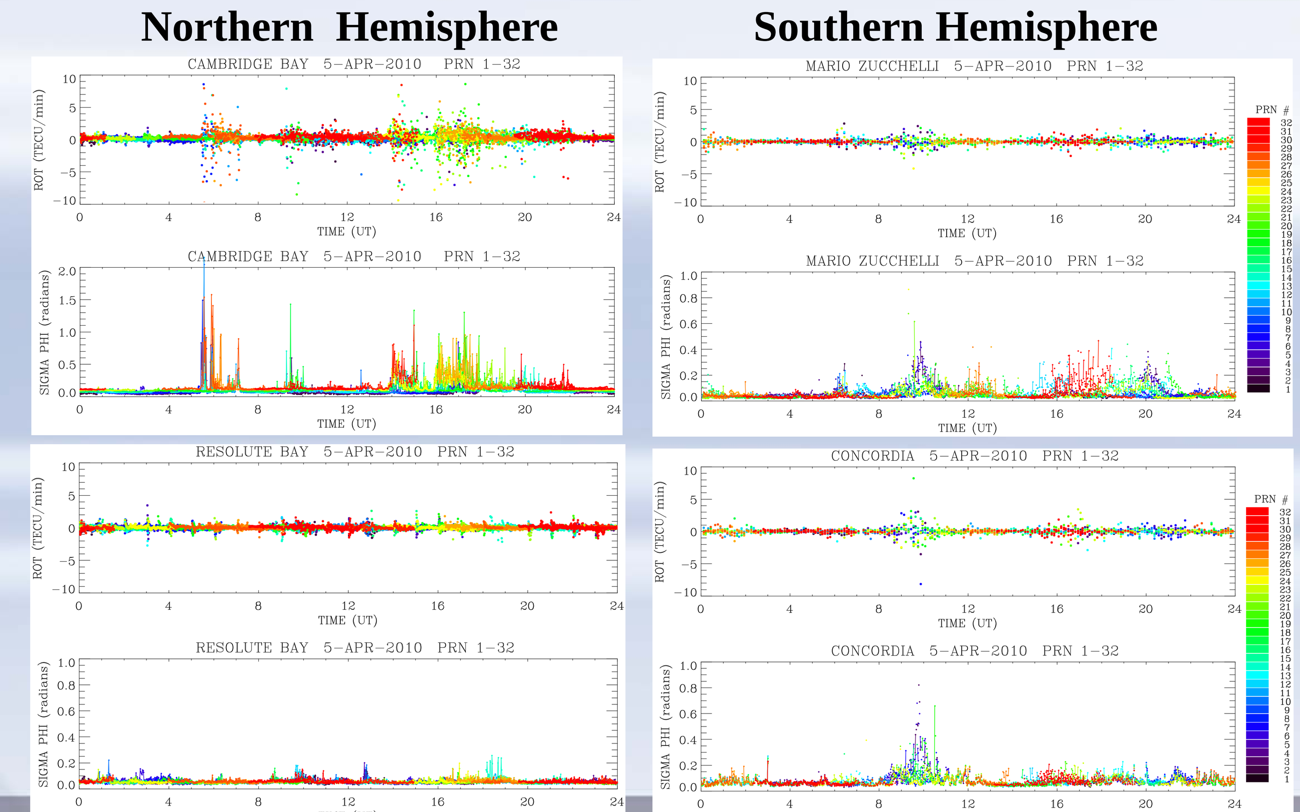
GPS scintillation receivers in Antarctica (blue dots) and the field of view of a new SuperDARN radar in McMurdo. Conjugate locations of northen GISTM arrays (red dots) and Saskatoon, Rankin Inlet and Hankasalmi SuperDARN radar (dashed line) are superposed. Corrected geomagnetic (CGM) latitudes 70°S and 80°S are shown. Insets show other SuperDARN radars.

Case #1: April 5, 2010

A magnetic cloud accompanied by upstream shocks and pressure pulses produced a gust of dense (> 10 proton per cm^3) solar wind exceeding 700 km/s that sparked the strongest geomagnetic storm of the year (maximum Kp-index of 8-). The dynamic pressure ranged 5-17 nPa and the IMF Bz oscillated between large negative and positive values before it turned northward and changed more smoothly inside of the cloud. Phase scintillation was observed in auroral oval (associated with auroral breakups), cleft and polar cap in both hemispheres.



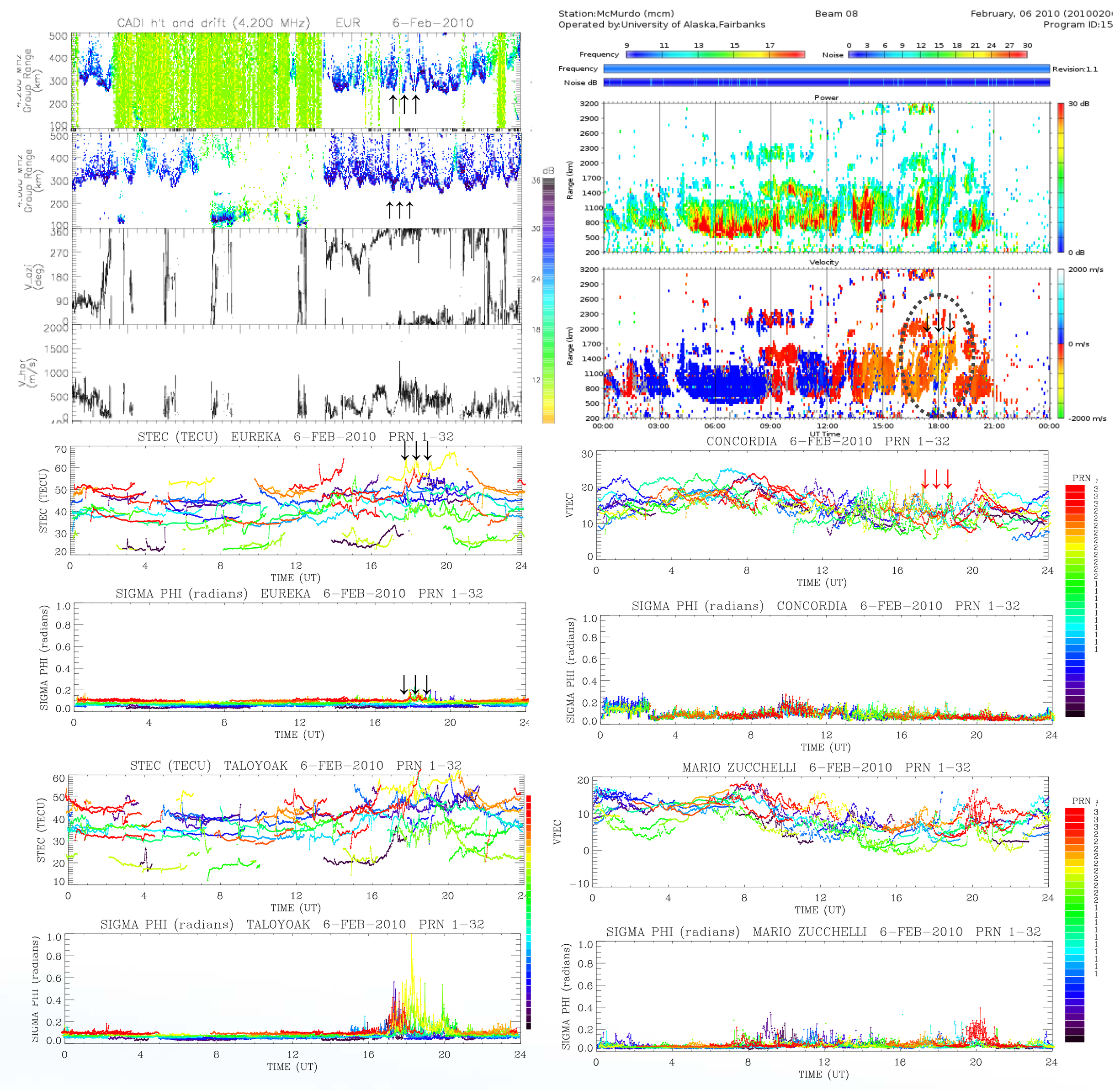
Northern Hemisphere | **Southern Hemisphere**



Case #2: February 6, 2010

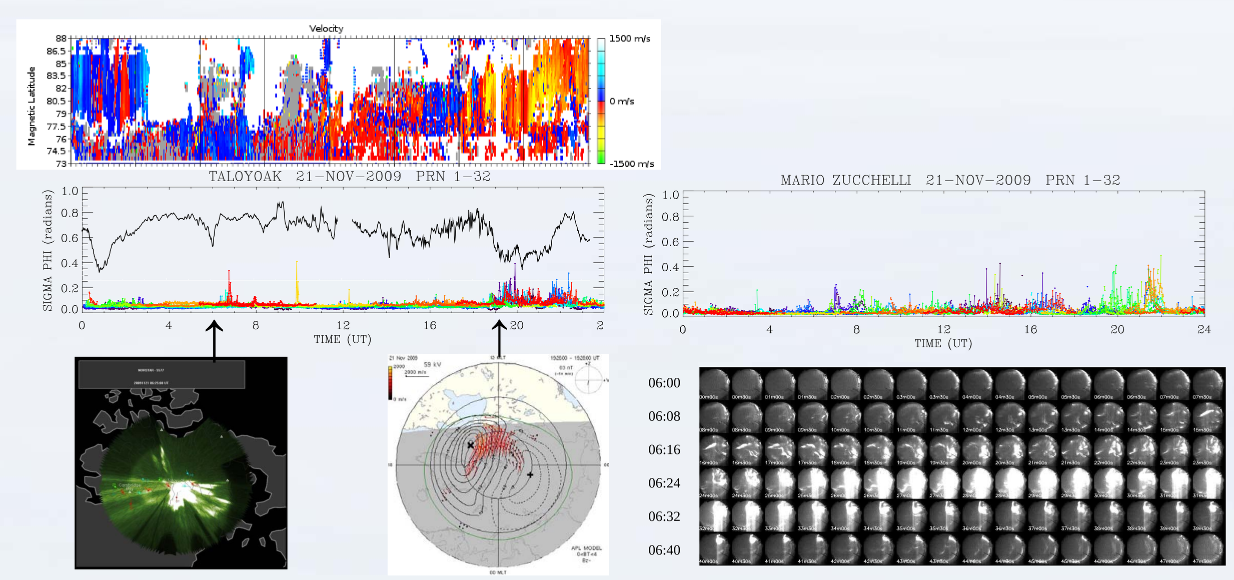
This moderately strong scintillation event occurred in the cusp and polar cap during relatively low-speed solar wind (<400 km/s) but after the solar wind density increased from 5 to 13 protons cm^{-3} for about 2 hours and then rapidly dropped back to 5 cm^{-3} followed by large amplitude Alfvénic fluctuations. The solar wind Alfvén wave coupling to dayside magnetopause modulated ionospheric convection in both cusps and produced a series of patches. The patches were observed moving poleward in both polar caps where scintillation was observed.

Northern Hemisphere | **Southern Hemisphere**

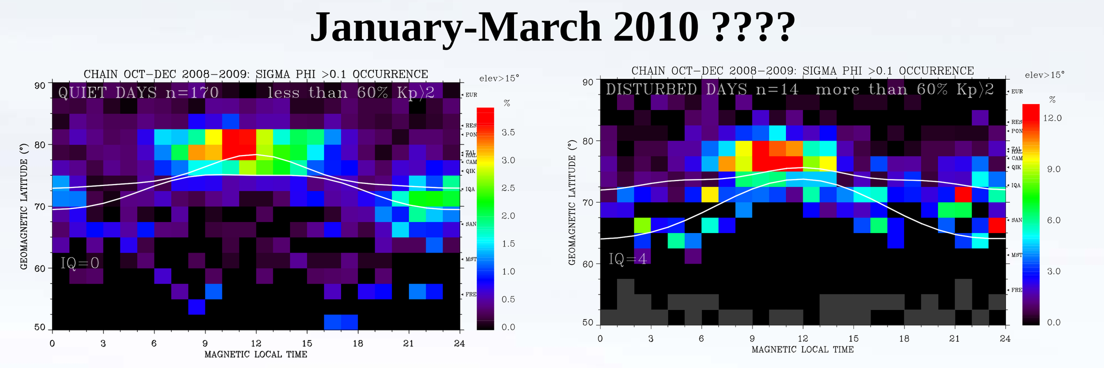


Case #3: November 21, 2009

High-speed solar wind from a coronal hole caused enhanced geomagnetic and ionospheric activity on November 21, 2009 resulting in rapid TEC variations and phase scintillation in the auroral oval and poleward of it on the dayside in the cusp/cleft region. The scintillation was associated with auroral arc brightenings and substorms in the nightside auroral oval and with enhanced dayside convection including flow channel events in the ionospheric footprint of the cusp.



Climatology of phase scintillation occurrence
January-March 2010 ????



Percentage occurrence of phase scintillation exceeding 0.1 radians in the northern and southern high latitudes. The position of the Feldstein auroral oval (Feldstein, 1963; Holzworth and Meng, 1975) for quiet conditions is superposed.

Summary

The occurrence of GPS phase scintillation in northern and southern high latitudes observed by CHAIN and Antarctic GISTM arrays is compared for three days of enhanced activity. The comparative scintillation study that is supported by ground-based instruments including HF radars, ionosondes and all-sky imagers indicates similarities but also differences between the northern and southern auroral ovals, cusps and polar caps. The phase scintillation as a function of magnetic local time and geomagnetic latitude primarily occurs in the nighttime auroral oval and the ionospheric cusp.

References

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