Influence of the substorm precipitations and polar cap patches on the GPS signals at polar latitudes

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Introduction

The ionosphere as a medium for the radio waves propagation can have a negative influence on the quality of received signal.

Irregularities in the plasma density distribution can lead to fast fluctuations of amplitude and phase of the signal which is referred to as ionosphere scintillations.

The level of scintillations is characterized by the phase (σΦ) and amplitude (S4) scintillation indexes. It is a standard deviation of the signal.

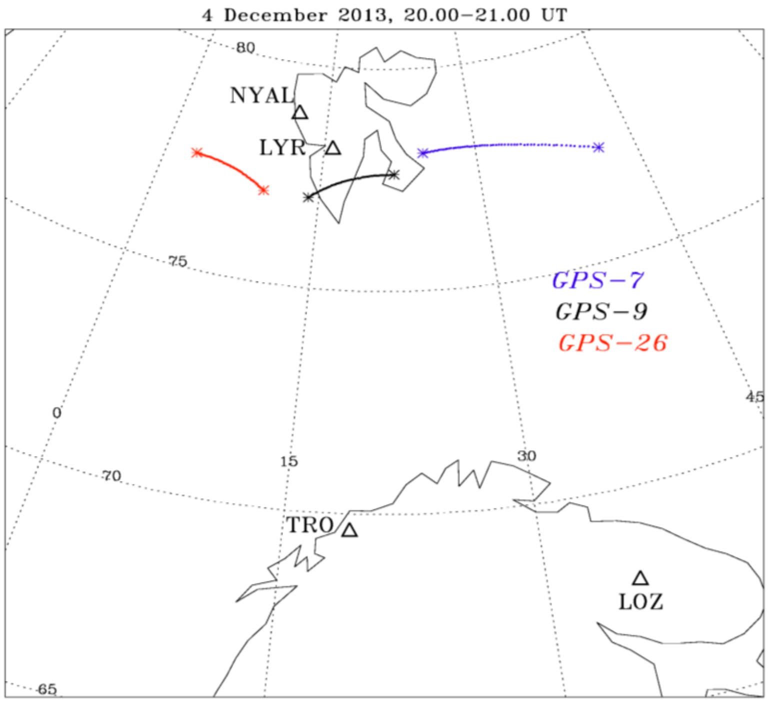
The most powerful disturbances in the polar ionosphere are particle precipitation and polar cap patches (PCP).

- *Y. Jin, Moen J., Miloch W. GPS scintillation effects associated with polar cap patches and substorm auroral activity: direct comparison // Journal of Space Weather and Space Climate,* ***4****, A23. 2014.*

It is found that PCP can produce GPS scintillations quite comparable with scintillations during the particle precipitation with appearance of strong green aurora.

What disturbances in the polar ionosphere (substorm particle precipitation or polar cap patches) have stronger impact on the scintillations of GPS signals?

Data used



- The Ny-Ålesund (NYA) GPS scintillation receiver of the University of Oslo.
- Svalbard EISCAT 42m radar.
- Optical observations of the aurora on Svalbard was used.
- IMAGE magnetometer data
- OMNI database

We have identified approximately 100 cases for years 2010-2017 when the data from the EISCAT 42m radar was available.

This report presents only some typical examples.

We considered the influence of 4 geophysical phenomena on the GPS scintillations:

- *morning-daytime precipitation*;
- *nighttime substorm precipitation*;
- *precipitation associated with the interplanetary shock arrival*;
- *polar cap patches*.

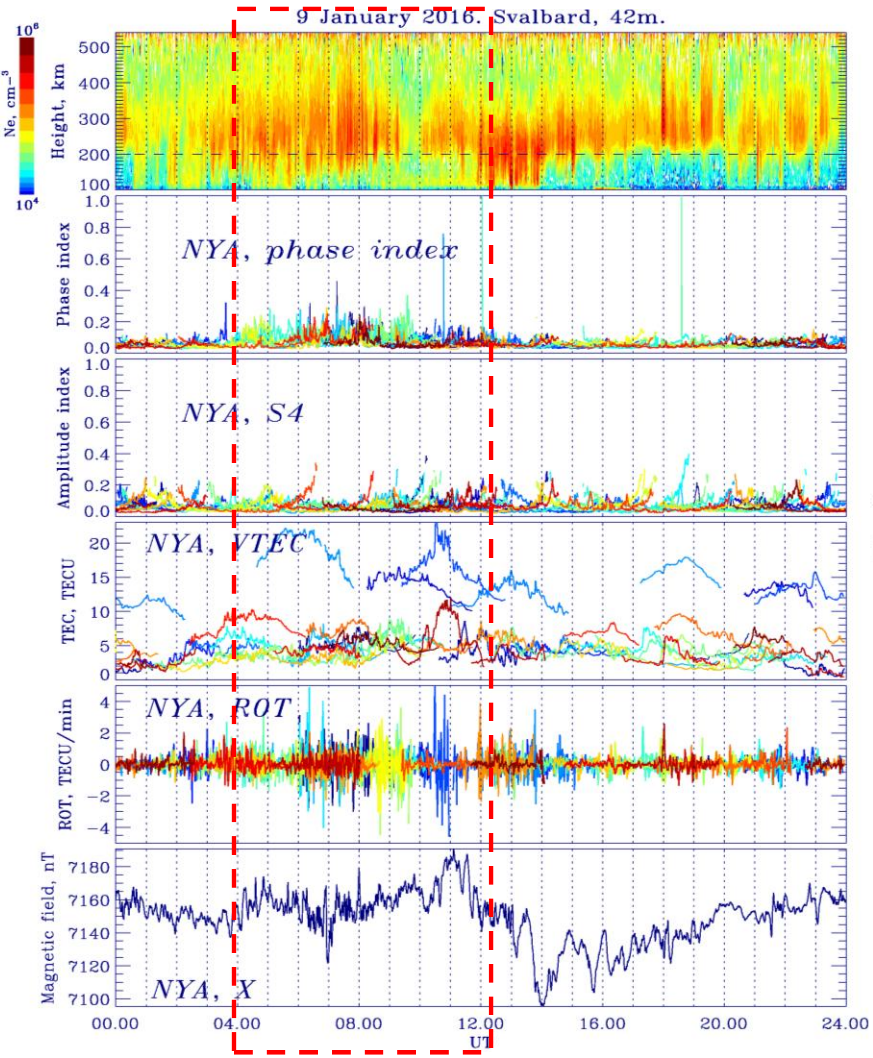
We focused mainly on the phase scintillation index because amplitude scintillation index (S4) practically has no large variations at high latitudes.

The presence of the particle precipitation into the ionosphere associated with the appearance of the aurora was determined as the density increase between 100-200 km altitudes according to the EISCAT radar data.

The presence of the polar cap patches was determined as a strong density increase above 200 km altitude.

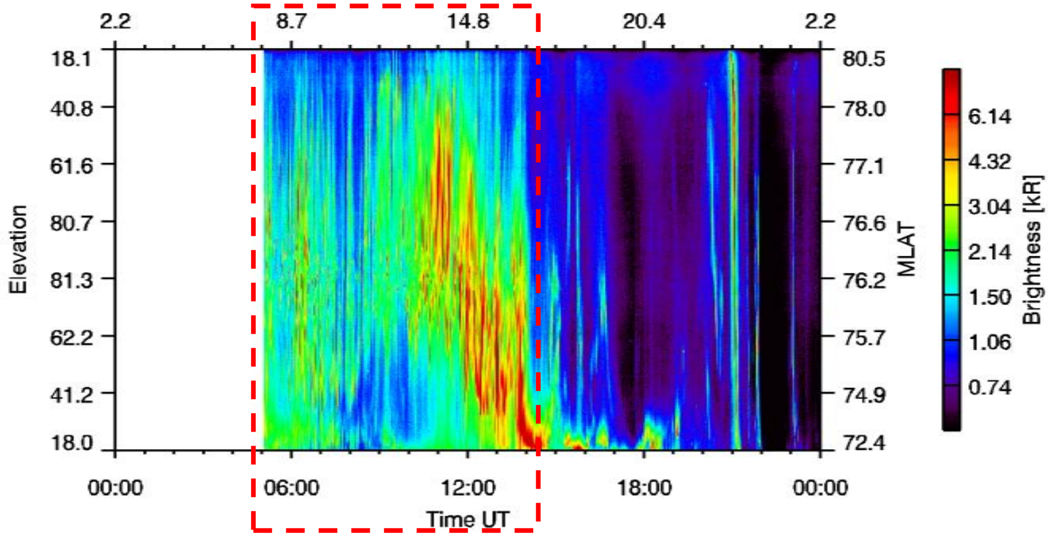
Its origin is caused by the reconnection on the dayside of the magnetosphere and penetration of plasma through the polar cap into the ionosphere.

Morning-daytime precipitation



Different colors are different GPS satellites

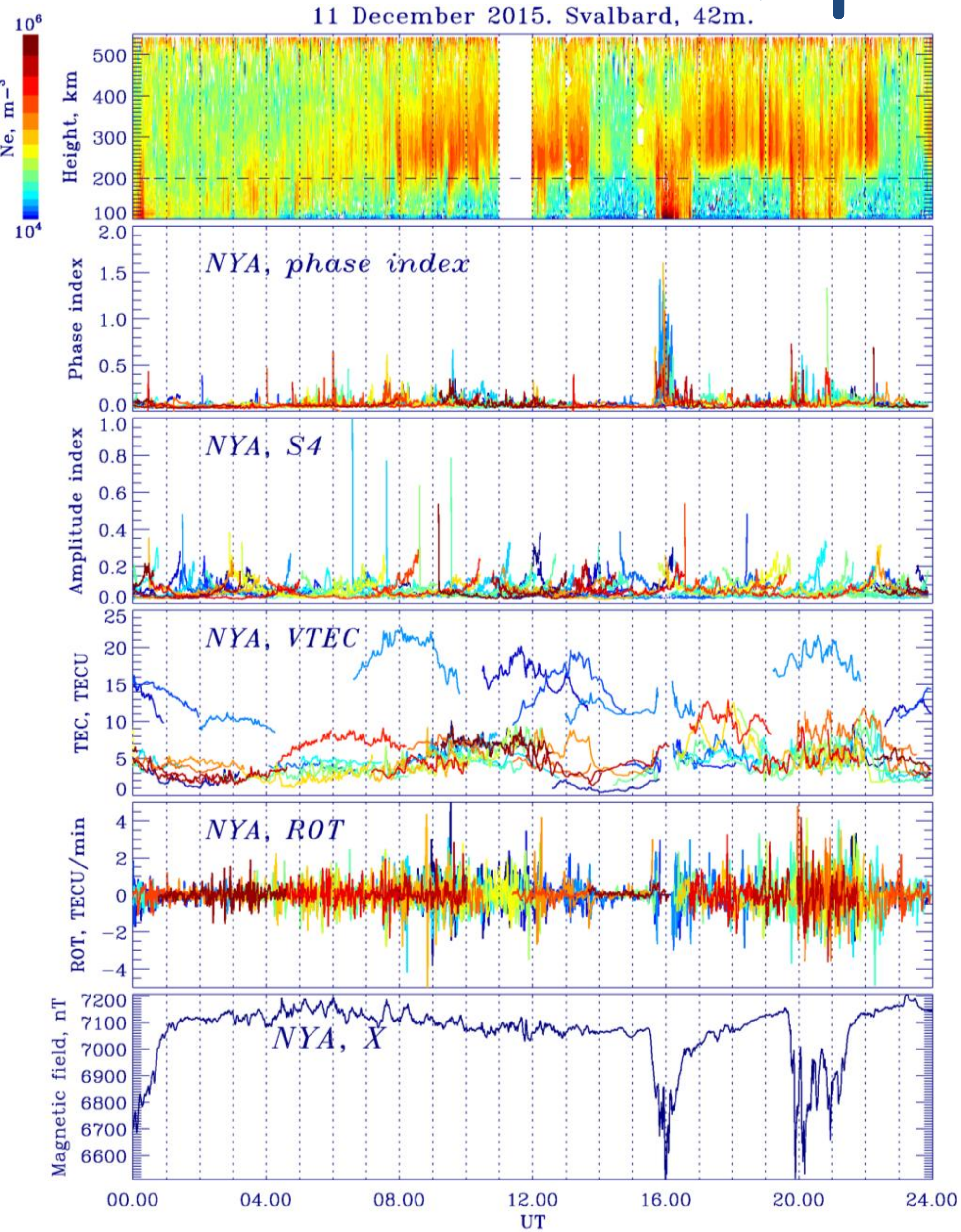
NYA, all-sky imager, 557.7 nm

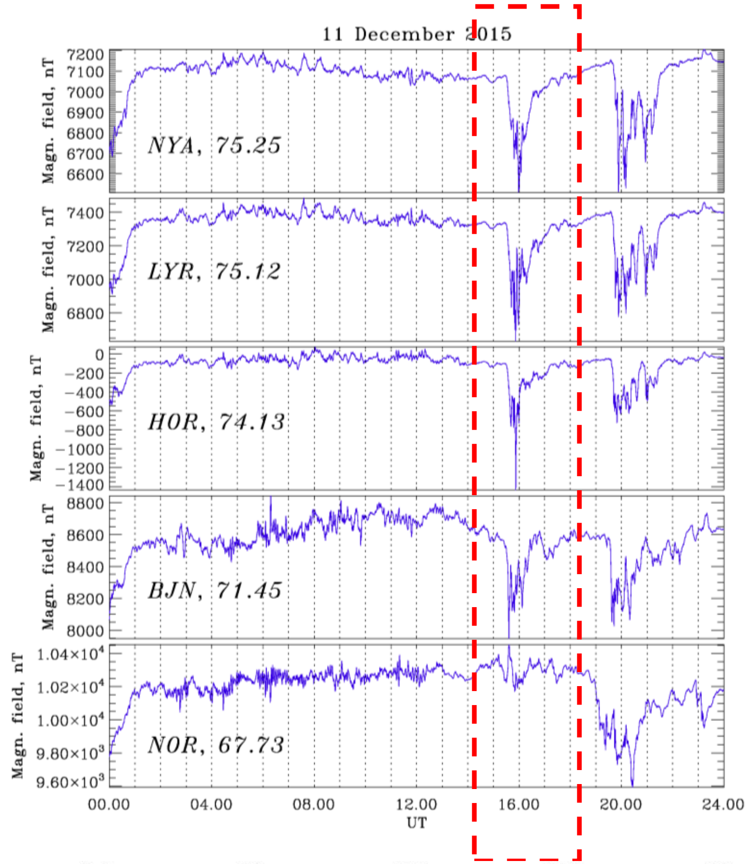


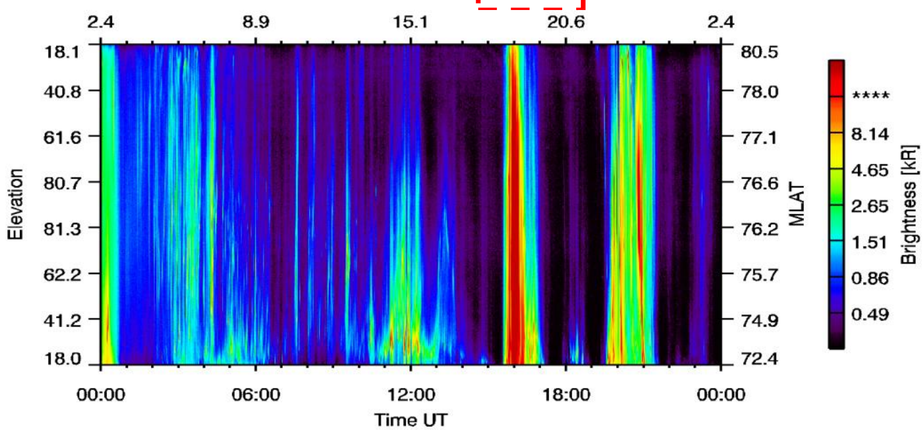
$\sigma_\Phi = 0.4 – 0.5$ rad

Amplitude scintillation index (S4) practically has no large variations

Substorm precipitation



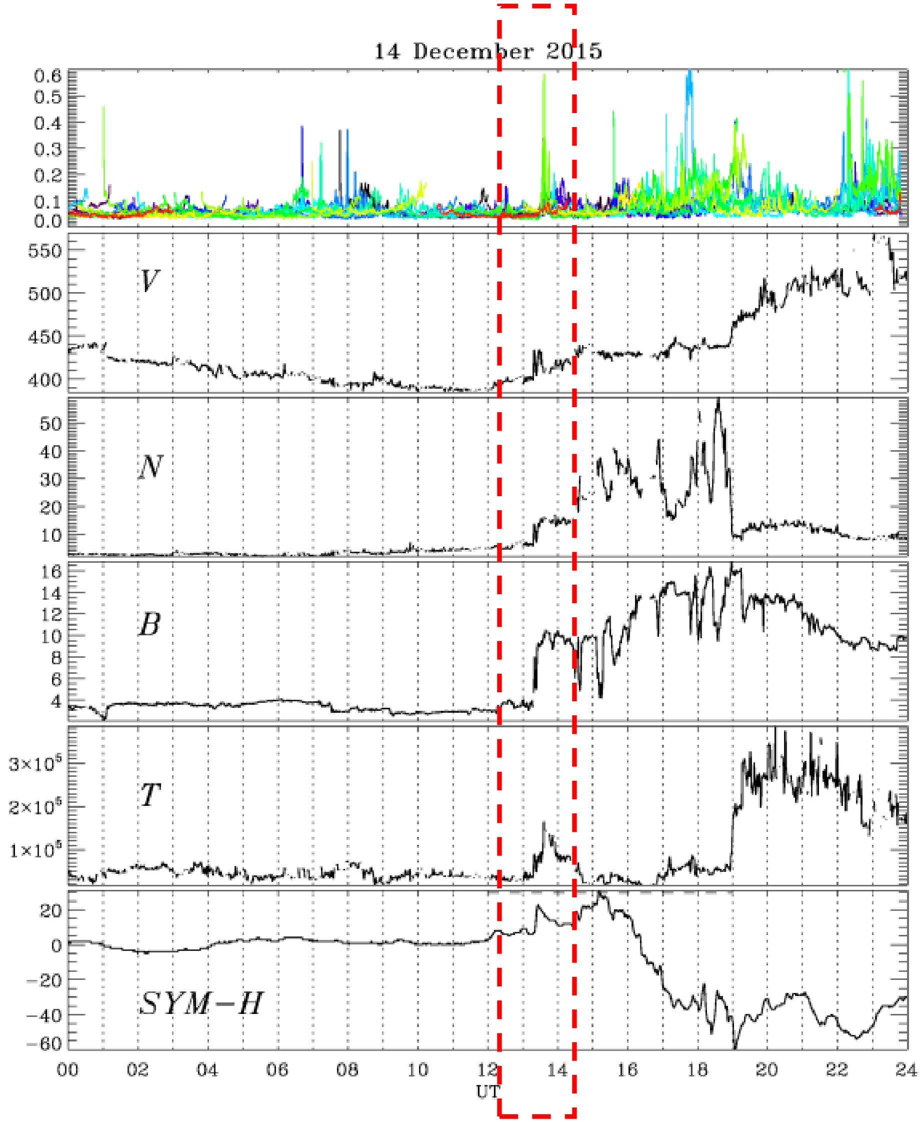




σ_{Φ} = 1.5-2. rad

ΔX = 1000 nT

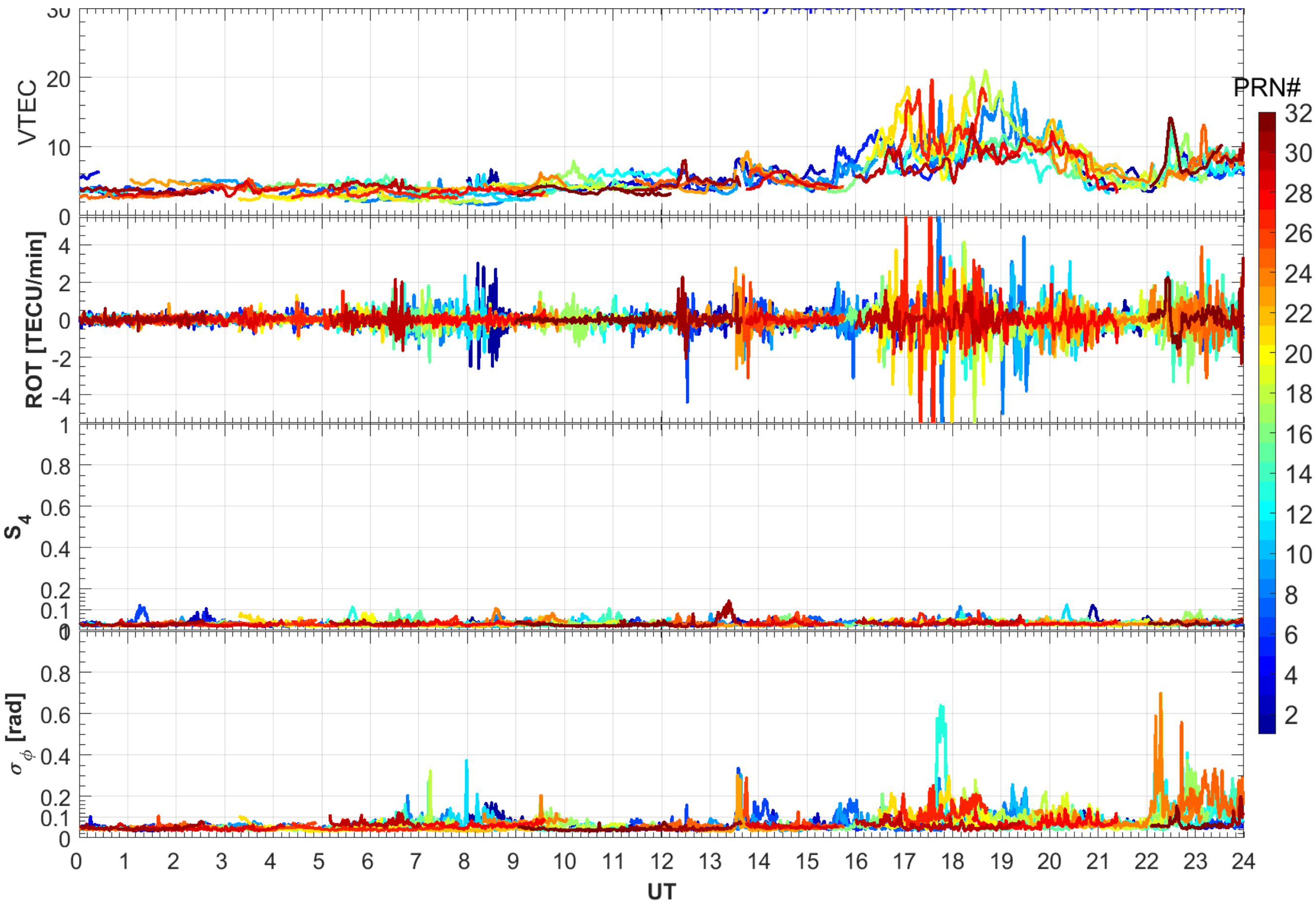
Interplanetary shock



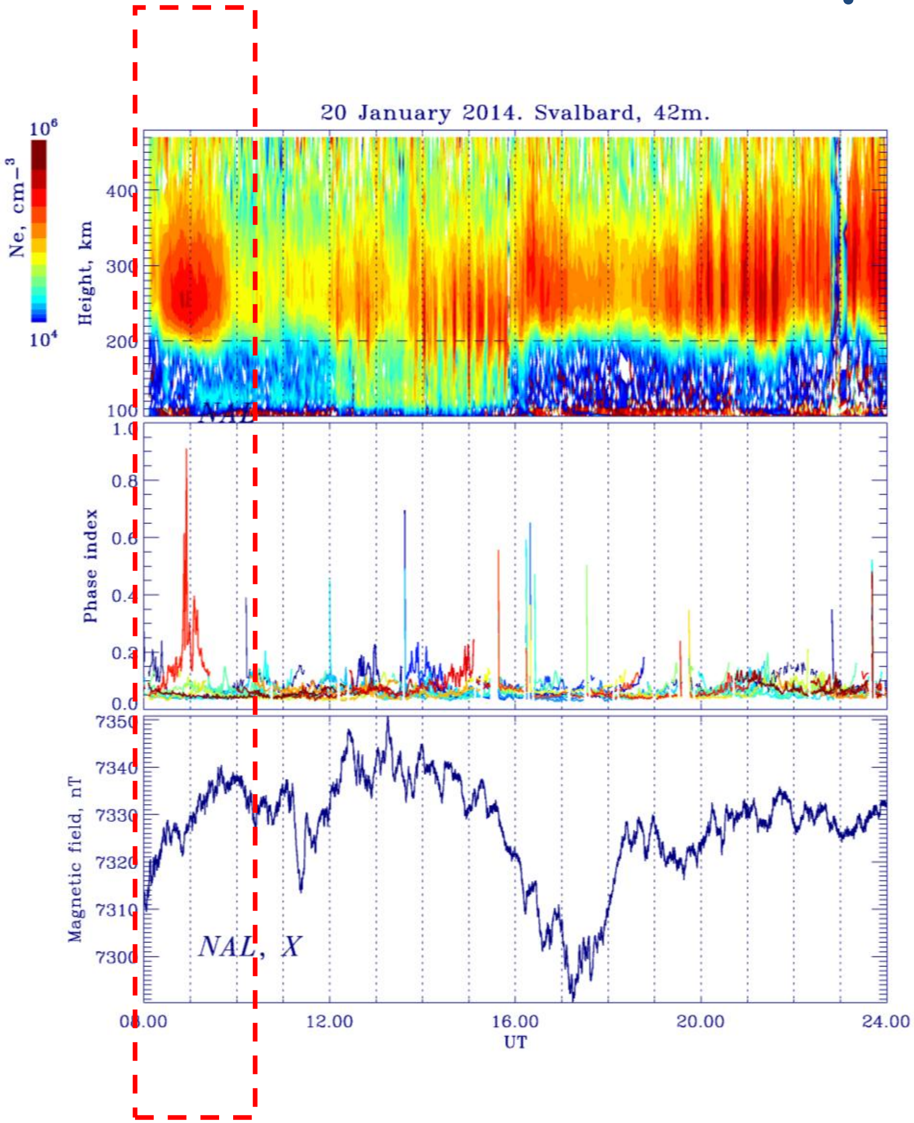
The arrival of interplanetary shock wave to the Earth's magnetosphere are associated with the particle precipitation in wide spectrum range

$\sigma_{\Phi} = 0.6$ rad

4 December 2015. Shock.

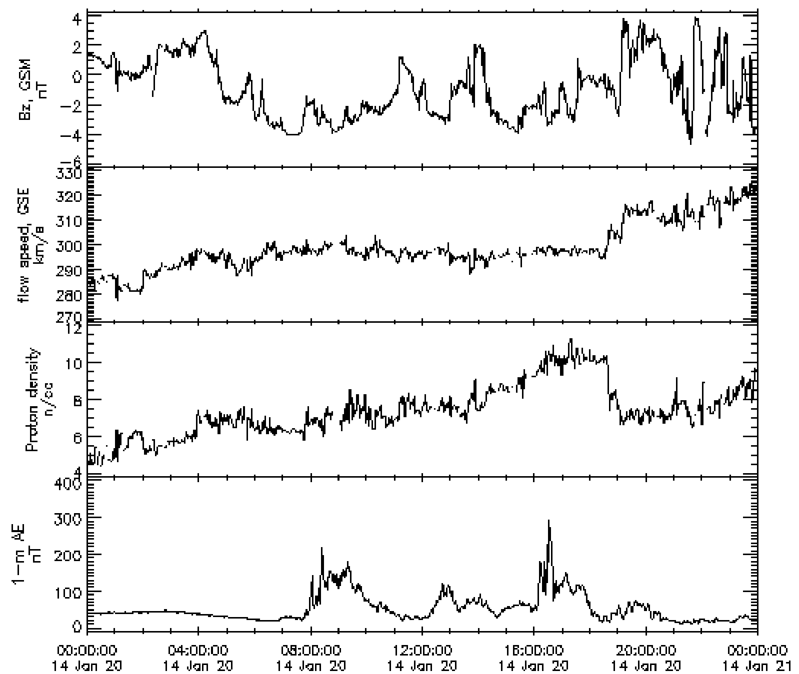


Polar cap patches (PCP)

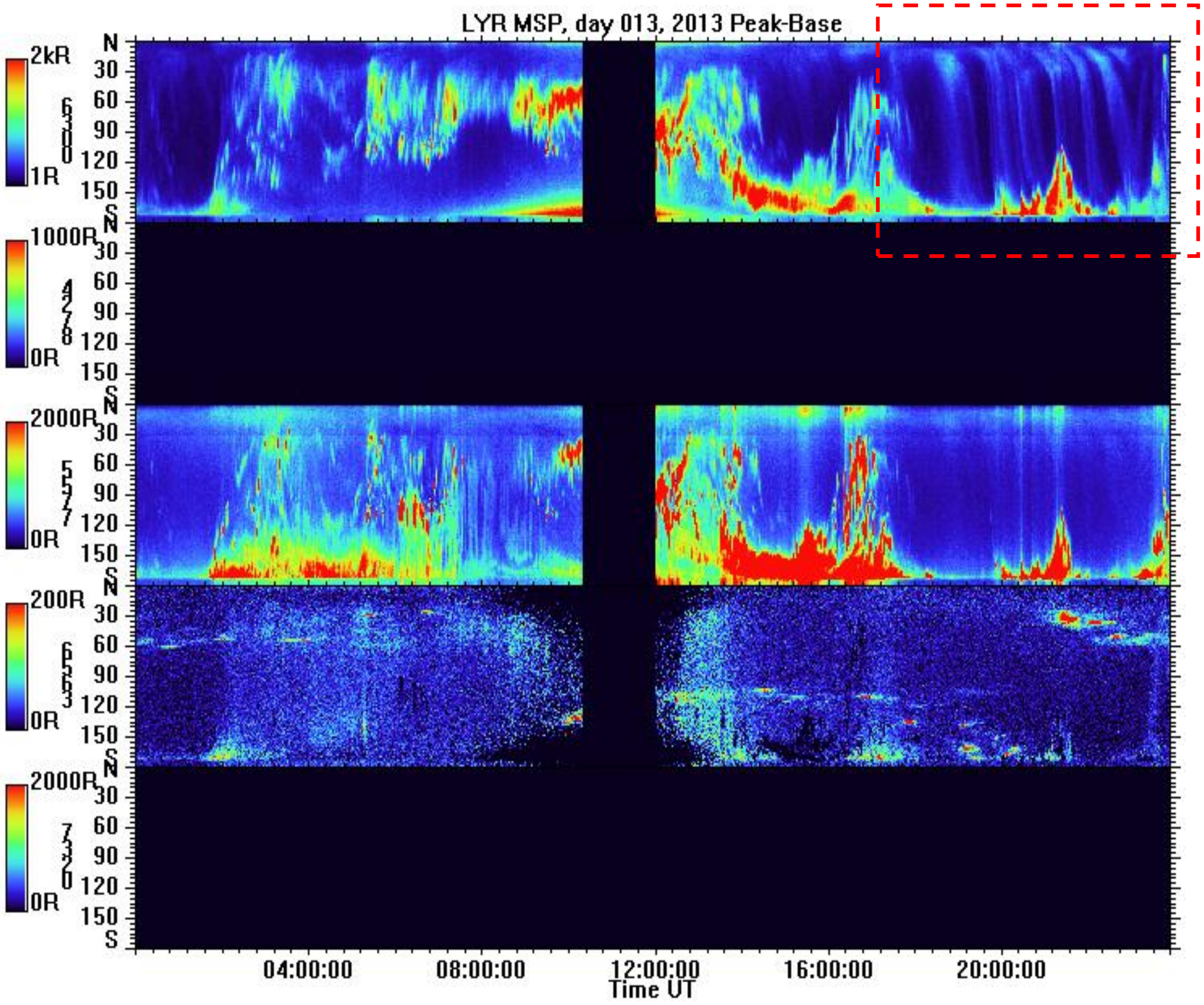


The PCP is observed at 08-10 UT as a density increase above 200 km according to the EISCAT 42m data.

$\sigma_\Phi = 0.9$ rad

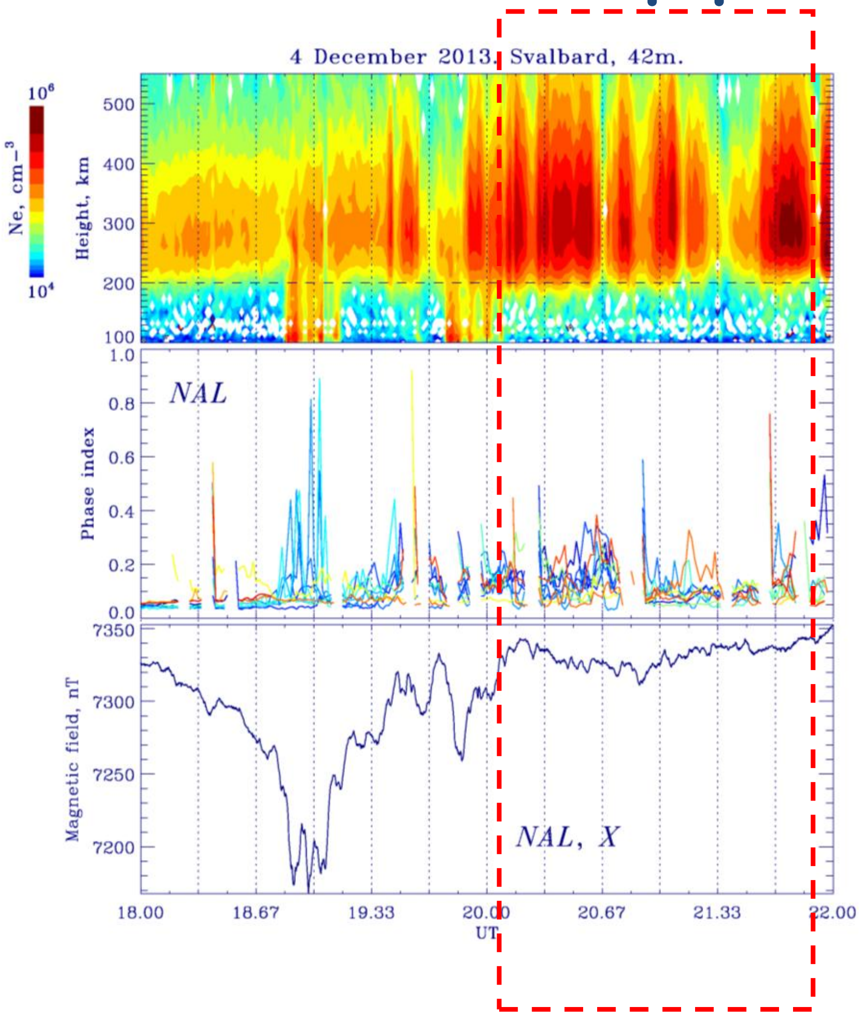


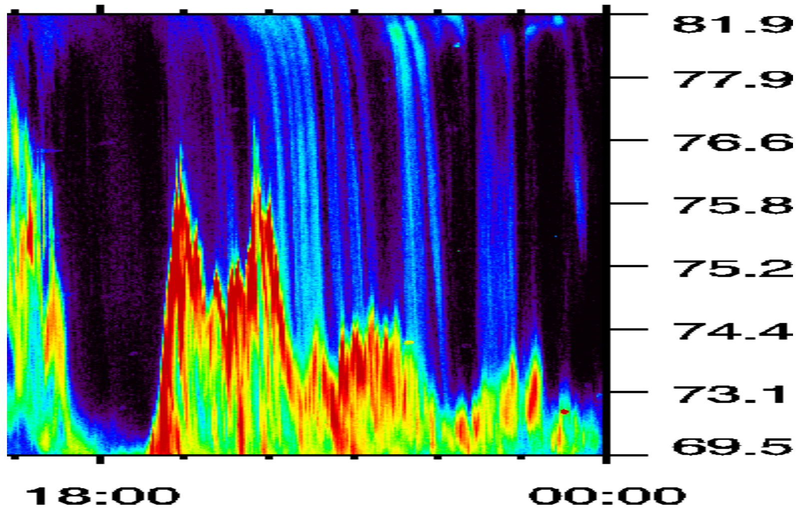
The Bz-component of IMF was negative during the appearance of PCP



The PCP are identified as a density increase above approximately 200 km. It is well known that the appearance of these structures is accompanied by the increase of the airglow intensity in 630.0 nm spectrum lines.

Polar cap patches (PCP) and substorm

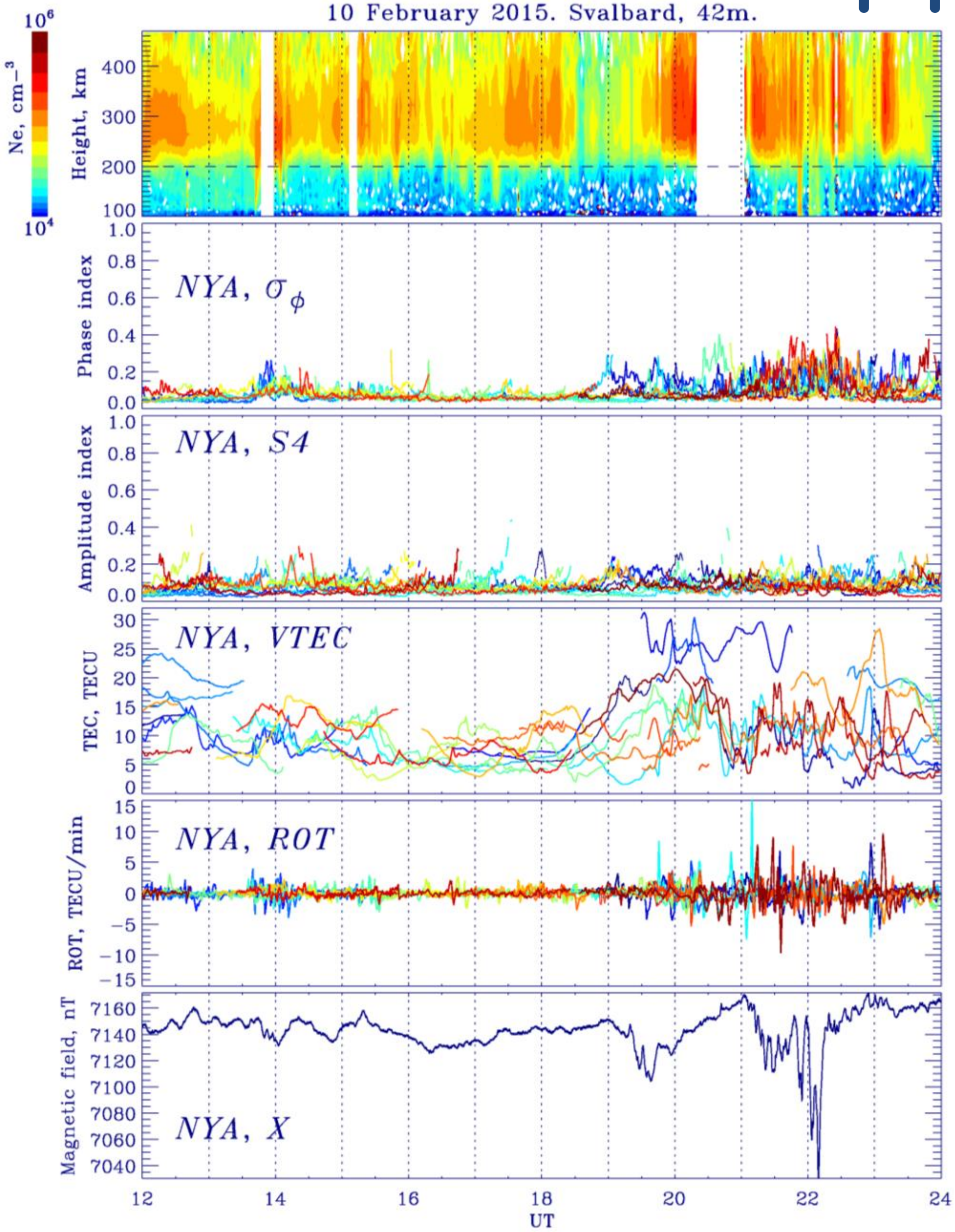




The PCP is also identified in the aurora intensity variations as forms propagating from the polar to low latitudes in 630.0 nm (red line) emission

$\sigma_\Phi = 0.8$ rad

Polar cap patches (PCP)



Polar cap patches leads to the prolonged variations of phase index with smaller values (less than 1). At the same time polar cap patches can lead to strong ROT variations (10-15 TECU/min) in comparison with the substorms disturbances. So our observations suggest that the substorms and PCPs, being different types of the high-latitude disturbances, lead to the development of different types and scales of ionospheric irregularities.

Conclusion

We find that all considered geophysical phenomena (morning-dayside precipitation, nighttime substorm precipitation, shock induced precipitation, polar cap patch) give rise to increased scintillation levels.

But the particle precipitation during substorm lead to the strongest scintillations (the phase scintillation index reaches values even close to 3 rad) of the GPS signals in the polar ionosphere. Thus, the substorm precipitation has the strongest impact on the scintillation of GPS radio signals in the polar ionosphere.

Polar cap patches leads to the prolonged variations of phase index with smaller values (less than 1). Polar cap patches can lead to strong ROT variations in comparison with the substorms disturbances. So our observations suggest that the substorms and PCPs, being different types of the high-latitude disturbances, lead to the development of different types and scales of ionospheric irregularities.

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