Observations of simultaneous multi-constellation GNSS scintillation in nightside aurora over Svalbard

Christer van der Meeren[1] (christer.Meeren@uib.no), Kjellmar Oksavik[1,2], Dag Lorentzen[2]
[1]Birkeland Centre for Space Science, University of Bergen, Norway, [2]University Centre in Svalbard, Longyearbyen, Norway

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1. Abstract

Our objective is to understand how GNSS signals are compromised when polar cap patches enter the nightside auroral oval. We show the first direct observations that such events may cause severe scintillations in GPS, GLONASS, and Galileo signals. We present two such events in the nightside aurora over Svalbard on 3 November 2013.

The first event occurred around 2035 UT when a polar cap patch drifted into the oval at ~68 MLAT, coinciding with substorm onset and severe GNSS phase scintillations co-located with the poleward-expanding aurora.

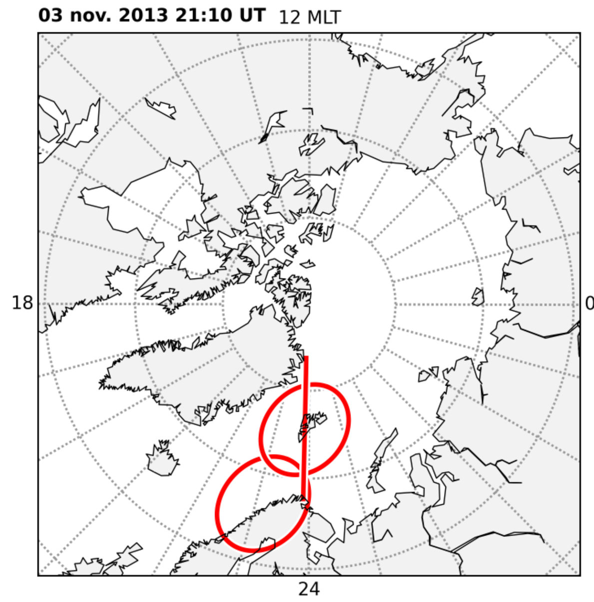
The second event occurred around 2105 UT when a new patch drifted into the auroral oval, coinciding with strong auroral intensification and severe phase scintillations in relation to the intense aurora.

GNSS performance is a major space weather concern under active geomagnetic conditions. Enhanced understanding of GNSS signal degradation is required to facilitate forecasting of GNSS performance in the highly dynamic polar cap.

2. Instrumentation

In 2013, a network of GNSS receivers (GPS, GLONASS, Galileo) was installed in the Svalbard region in Ny-Ålesund, Longyearbyen, Hopen, and Bjørnøya. We use raw 50 Hz data and reduced 60 s data from this network of receivers.

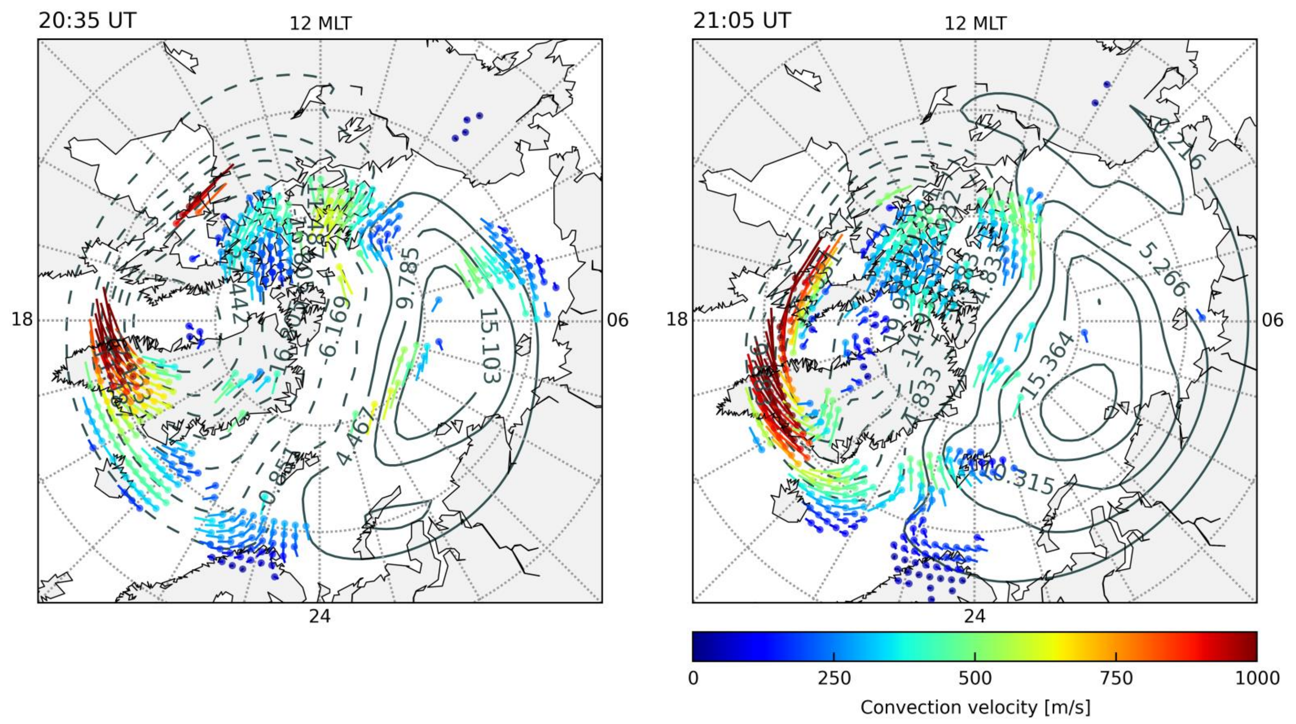
Additionally, we use all-sky imagers (ASI) in Longyearbyen, Ny-Ålesund, and Andøya, a meridian-scanning photometer (MSP) in Longyearbyen, SuperDARN convection data, and NASA OMNIweb solar wind data.



The figure shows ASI (Longyearbyen and Andøya) and MSP fields of view at 250 km. The Ny-Ålesund ASI field of view is similar to that of the Longyearbyen ASI.

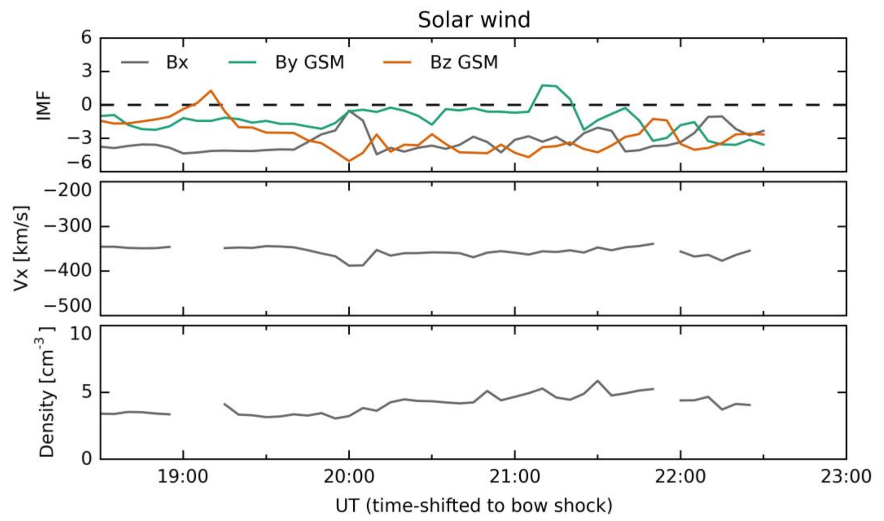
3. Overview: SuperDARN convection pattern

There is a stable two-cell convection pattern for the whole period. The two panels are at the time of the onset (event 1) and the intensification (event 2).



4. Overview: Solar wind and aurora

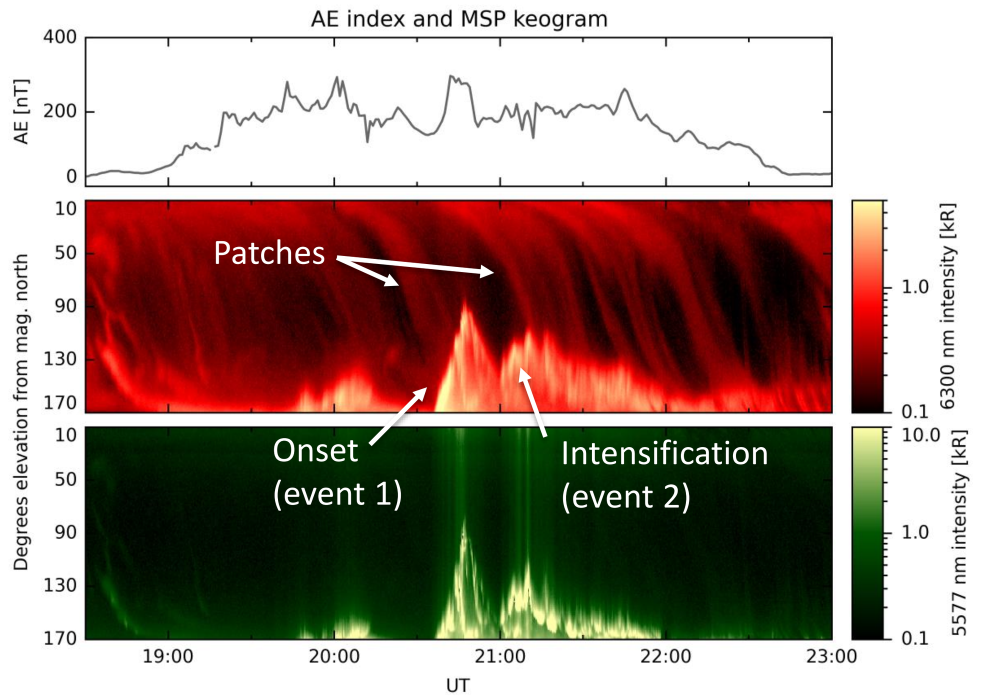
The period is characterized by stable, southward IMF, a substorm with onset/expansion at ~2045 UT, and patches drifting across the polar cap.



Bz negative with a brief northward excursion around 1910 UT

Stable solar wind speed

Stable solar wind density



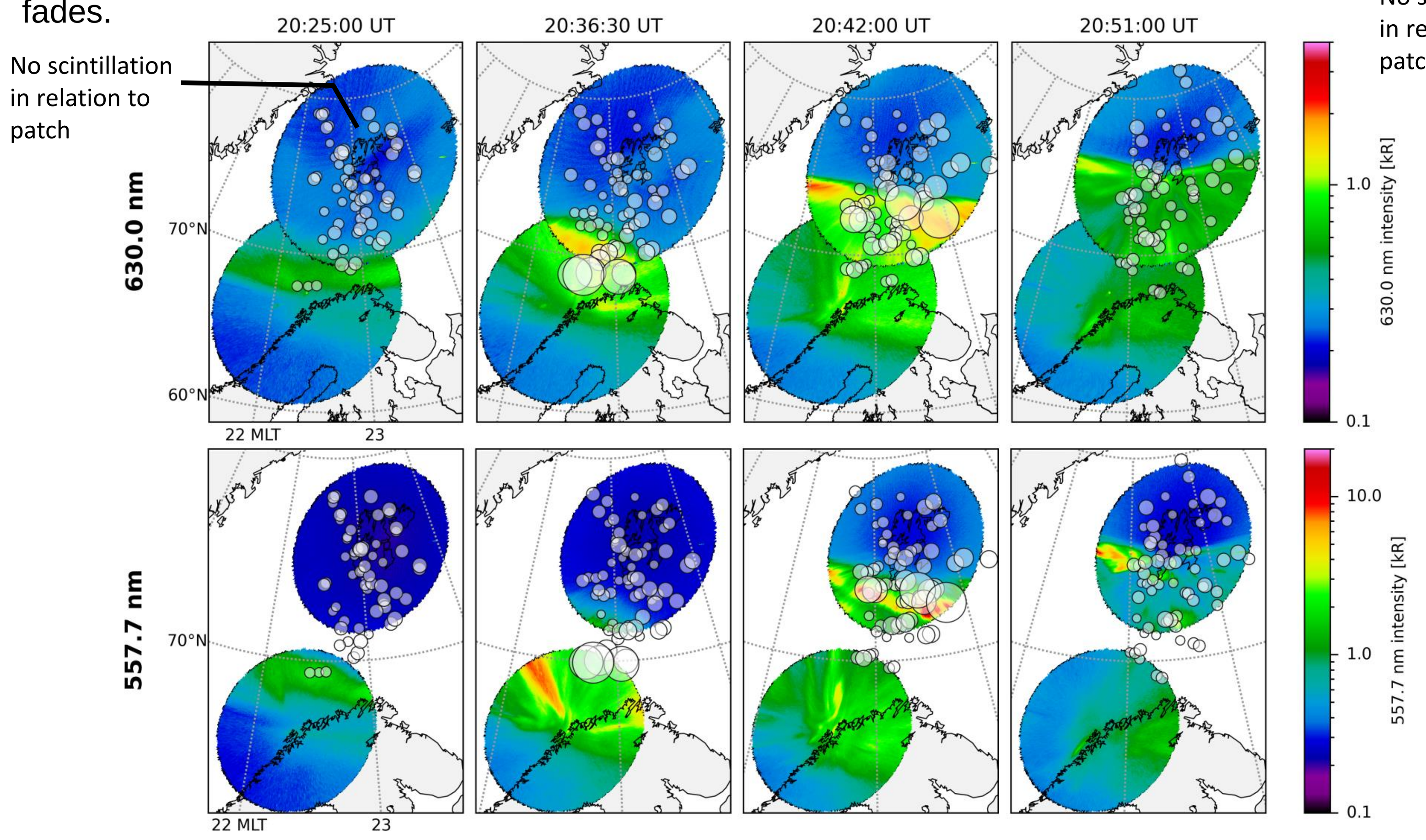
The AE index shows enhanced geomagnetic activity from 19 to 23 UT

Red aurora shows drifting airglow patches and auroral onset and intensification when the patches enter the auroral oval

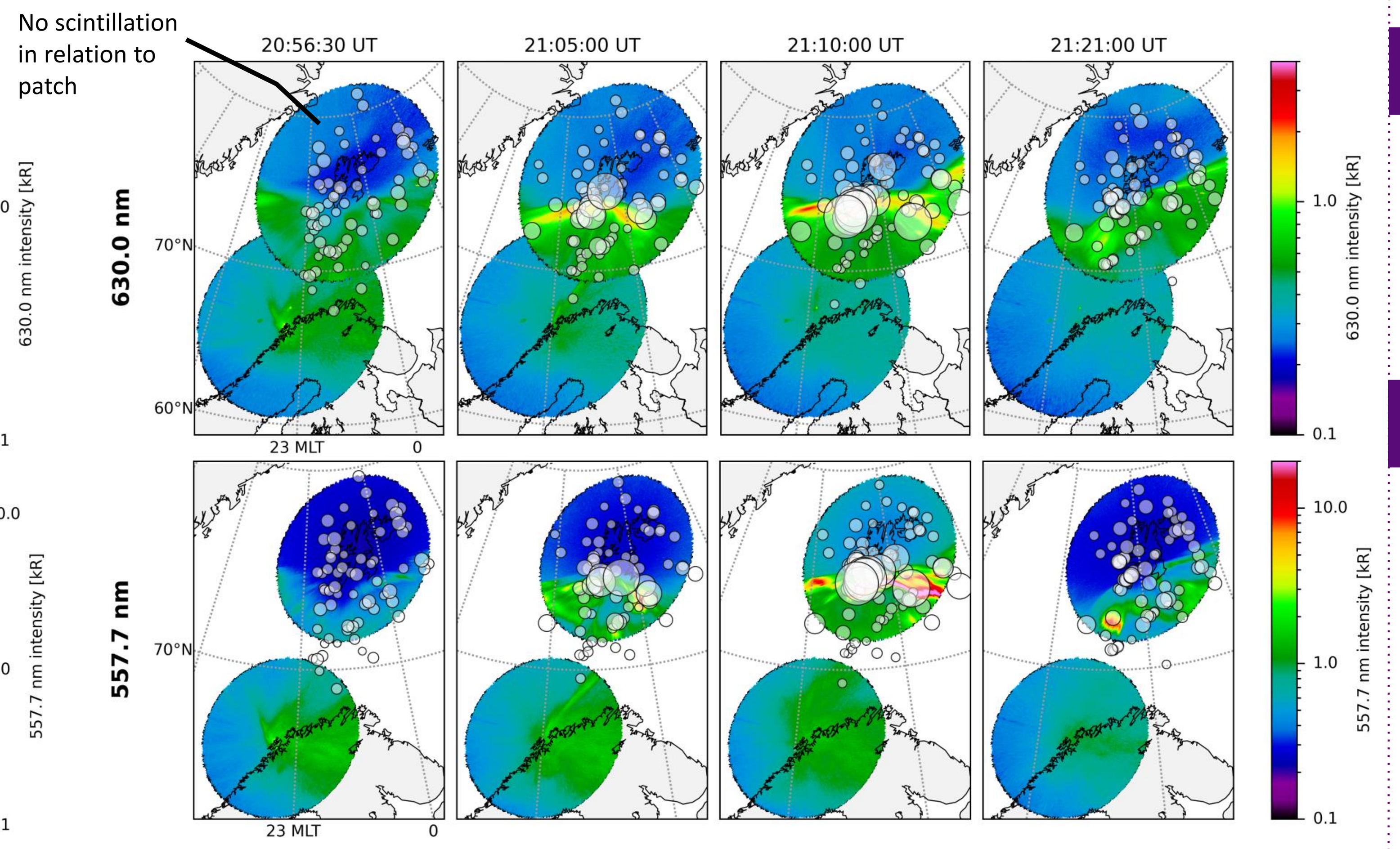
Green aurora shows intense aurora with onset at ~2045 UT and intensification at ~2105 UT (peak ~35 kR)

5. Co-location of scintillation and intense aurora

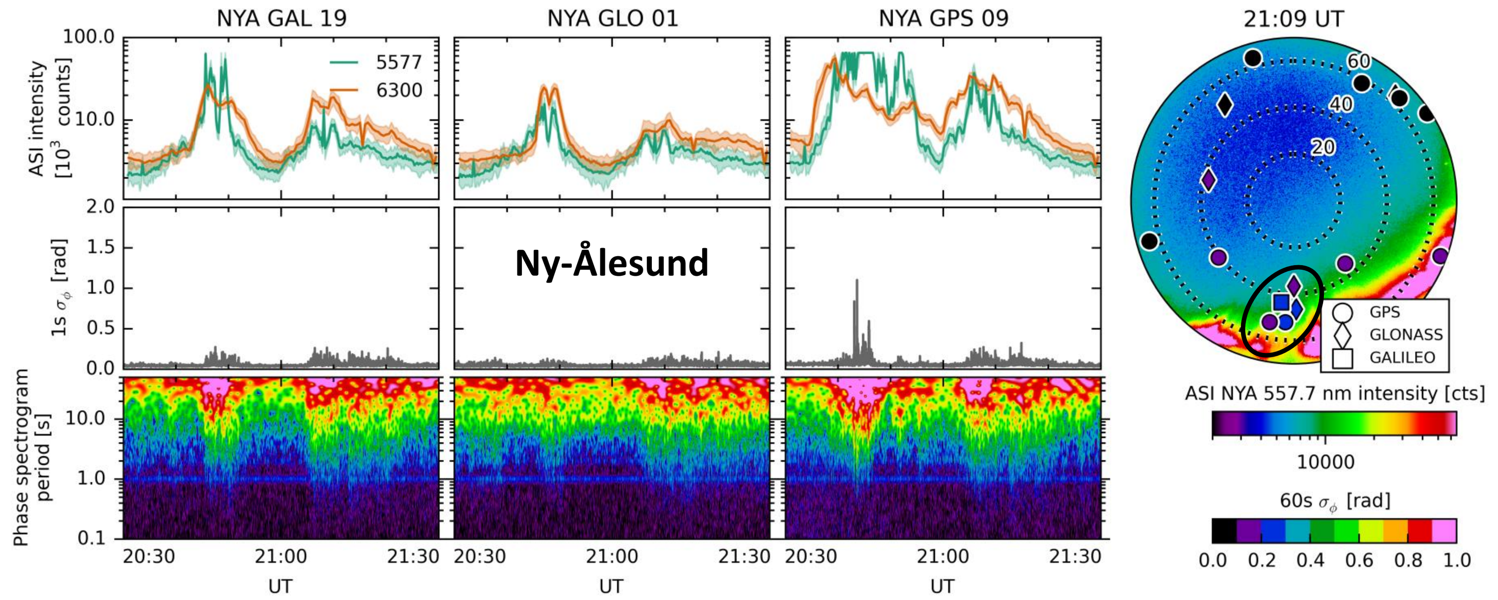
Event 1: Onset at 2035 UT. A patch hits the auroral oval, coinciding with substorm onset from a stable arc at ~68 MLAT. Strong phase scintillations start immediately and follow the poleward edge of the aurora as it expands poleward. Scintillations stop when the aurora fades.

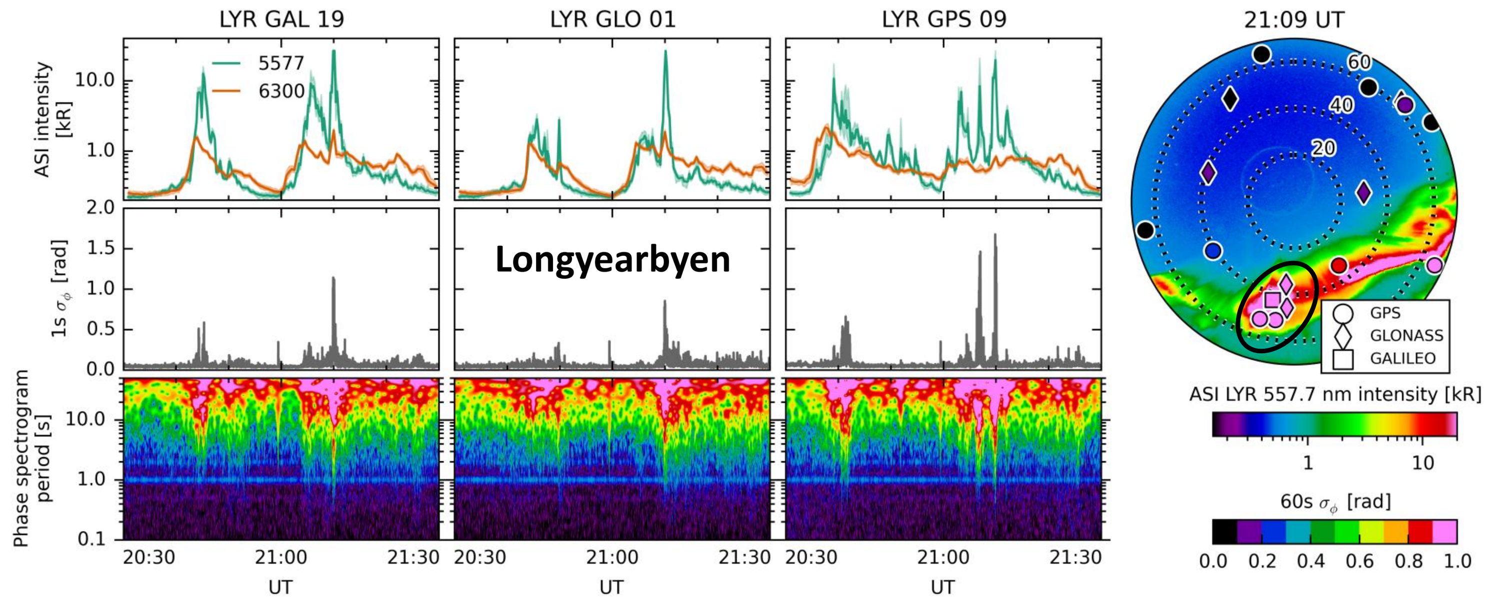


Event 2: Intensification at 2105 UT. A patch hits the auroral oval and the aurora intensifies, reaching peak intensity of ~35 kR (557.7nm). Again, there are strong scintillations.



6. GNSS phase variations and scintillations in relation to line-of-sight auroral intensity





The aurora is at its most intense at 2110 UT. In Longyearbyen (bottom figure), a cluster of five satellites from all three constellations (encircled in the ASI images) experience severe phase scintillations of $\sigma_\phi > 1$ in the intense aurora. In Ny-Ålesund, this scintillation is not seen since the aurora is at a lower elevation here and do not intersect the GNSS line of sight. This indicates that the scintillations are caused by the aurora, not the drifting polar cap patch. There is no scintillation in data from satellites further north in either receiver.

Ny-Ålesund (top figure):
For event 1, only the southernmost satellite (GPS 09) experience severe scintillation. There are phase variations at large scale sizes, but little or no scintillation. There is no significant scintillation in event 2 (the ASI image is from event 2).

Longyearbyen (bottom figure):
Both events show severe scintillation and enhanced phase variations at a variety of scales (1–60s).

7. Summary and conclusions

Patches entering the nightside auroral oval are known to be associated with auroral intensifications and substorm onset [3, 4]. Both patches and aurora may cause scintillation independently of each other [1, 2]. One might therefore expect – as observed – particularly severe scintillations when patches enter the nightside auroral oval.

The patches showed no sign of scintillation prior to entering the auroral oval. Severe scintillations occurred when the patches entered the auroral oval. The scintillation was co-located with the intense poleward edge of the auroral oval. There were no scintillations after the intense aurora had faded, when the patch is anticipated to exist as an auroral blob inside the oval.

The hot-spot of severe scintillation is so localized that two observers 100 km apart might report highly different space weather impacts in terms of scintillation. In Longyearbyen scintillation was severe, affecting 7 of 16 spacecraft, while in Ny-Ålesund there was no scintillation. This shows the need for a dense network of receivers to monitor scintillation events.

Acknowledgments

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