Enhanced ionospheric density variability and RTK positioning uncertainty at dayside subauroral latitudes

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Abstract

Enhanced density variability is known to occur related to auroral phenomena, mostly at dusk, on the night side and dawn, to polar cap patches, and to the post-sunset equatorial region. Surprisingly we found that the plasma density variability is statistically increased at subauroral latitudes, about 54-61 degrees, in the 1-2 hours around local noon. The Swedisch cadastral office (Lantmäteriet) offers satellite based positioning, called SWEPOS, which is using RTK (Real Time Kinematic) and reference stations covering the whole of Sweden. The SWEPOS uncertainty is about 1 cm. We found that this uncertainty statistically increases to a few centimeters in the hours around noon also down to the middle and southern parts of Sweden (Svealand and Götaland). We suggest that both phenomena are causally related.

Introduction

Satellite-based positioning is ubiquitously available, for example, with many mobile phones. For high accuracy, ∼1 cm, special systems are required. Real-Time Kinematic (RTK) is widespread and used by, among others, the Swedish cadastral office (Lantmäteriet) for the SWEPOS: Reference stations with known fixed positions record the carrier phase of the satellite signal and communicate to mobile RTK 'rovers' receiving signals of both GNSS and a reference station. With the phase information from one reference station ∼ 1 cm positioning accuracy is achieved.

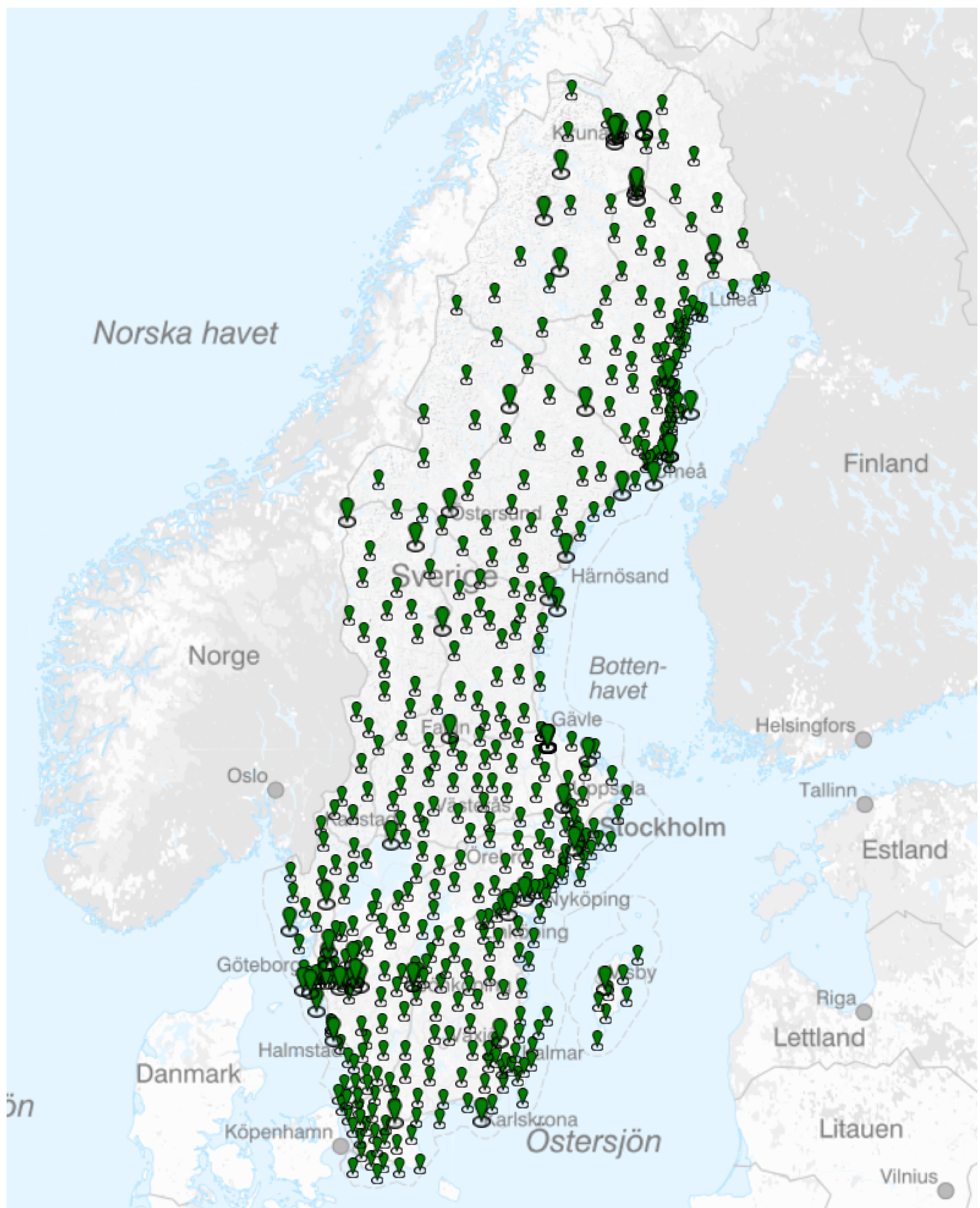

Figure 1: Map of the SWEPOS reference stations

Jonosfärmonitor

Some selected stations receive the phases from three (or more) references and so provide three independent estimates of the position and an estimate of its uncertainty. The main source of the uncertainty comes from the trans-ionospheric signal. Therefore the positioning uncertainty can indicate ionospheric effects, namely delay and disturbance, on the satellite signal. This is realized in Lantmäteriets 'Jonosfärmonitor' presenting a simple color-coded positioning uncertainty for four different regions of Sweden in real-time at a cadence of 30 seconds.

Ionospheric effects

While an effect of the ionosphere on the L-band (∼1–2 GHz) is well established, the actual causes could be

- unmitigated ionospheric delay (in spite of using two frequencies)
- signal disturbance from small-scale density variations

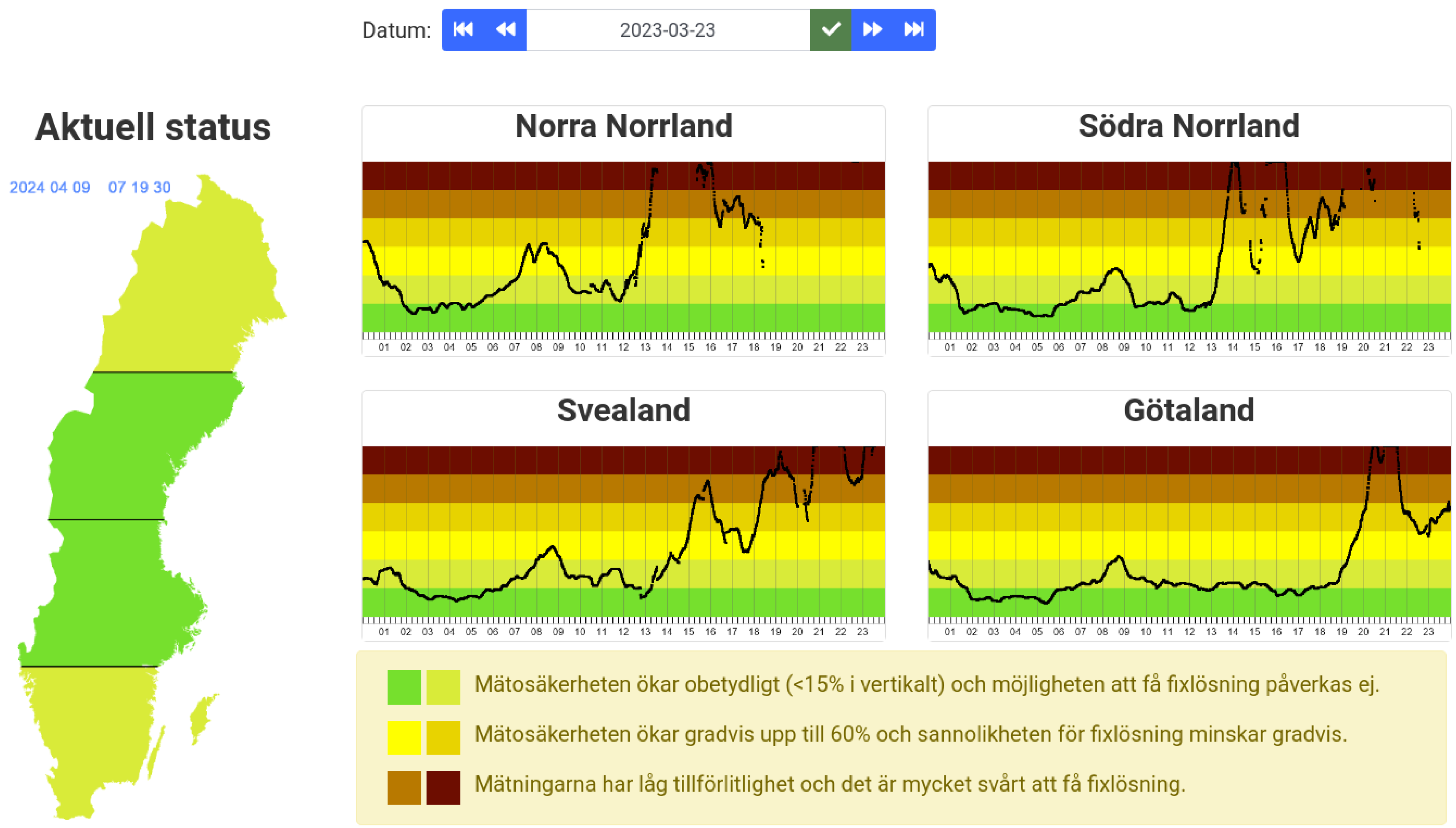

Figure 2: The monitor (https://swepos.lantmateriet.se/services/iono.aspx) shows red warnings during a major geomagnetic storm in 2023 even in the southern parts of Sweden.

Swarm over Sweden

The polar orbiting Swarm satellites pass over a region of the size of Sweden 1-2 times/day/satellite on each of the ascending and descending legs (for a better coverage in time a satellite constellation akin StarLink would be needed).

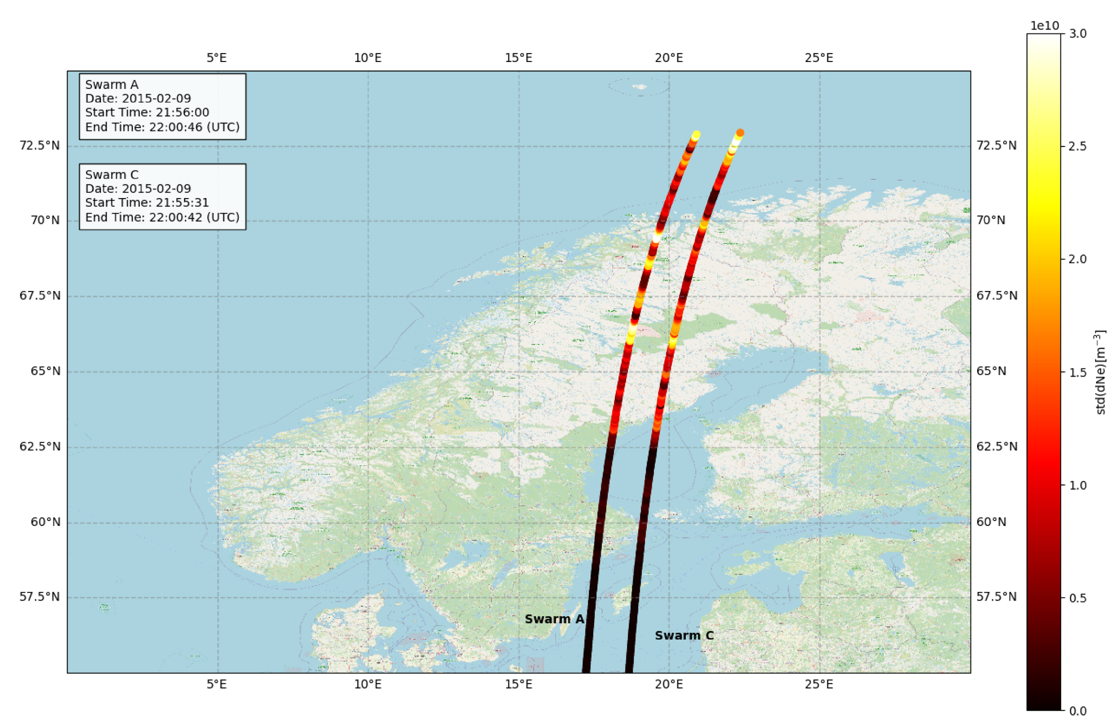

Figure 3: Trajectory of the Swarm A and C satellites on 2015-02-15 with color-coded running standard deviation of the plasma density N_e

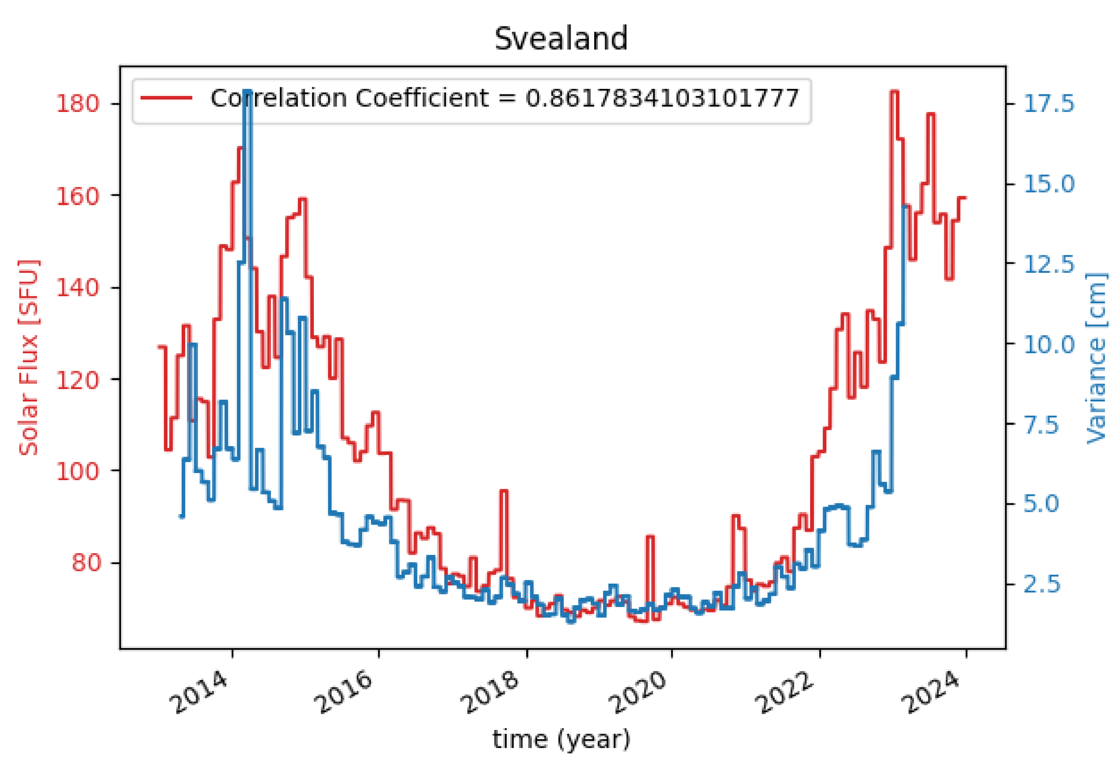

Figure 4: The SWEPOS Δx in mm and solar F10.7

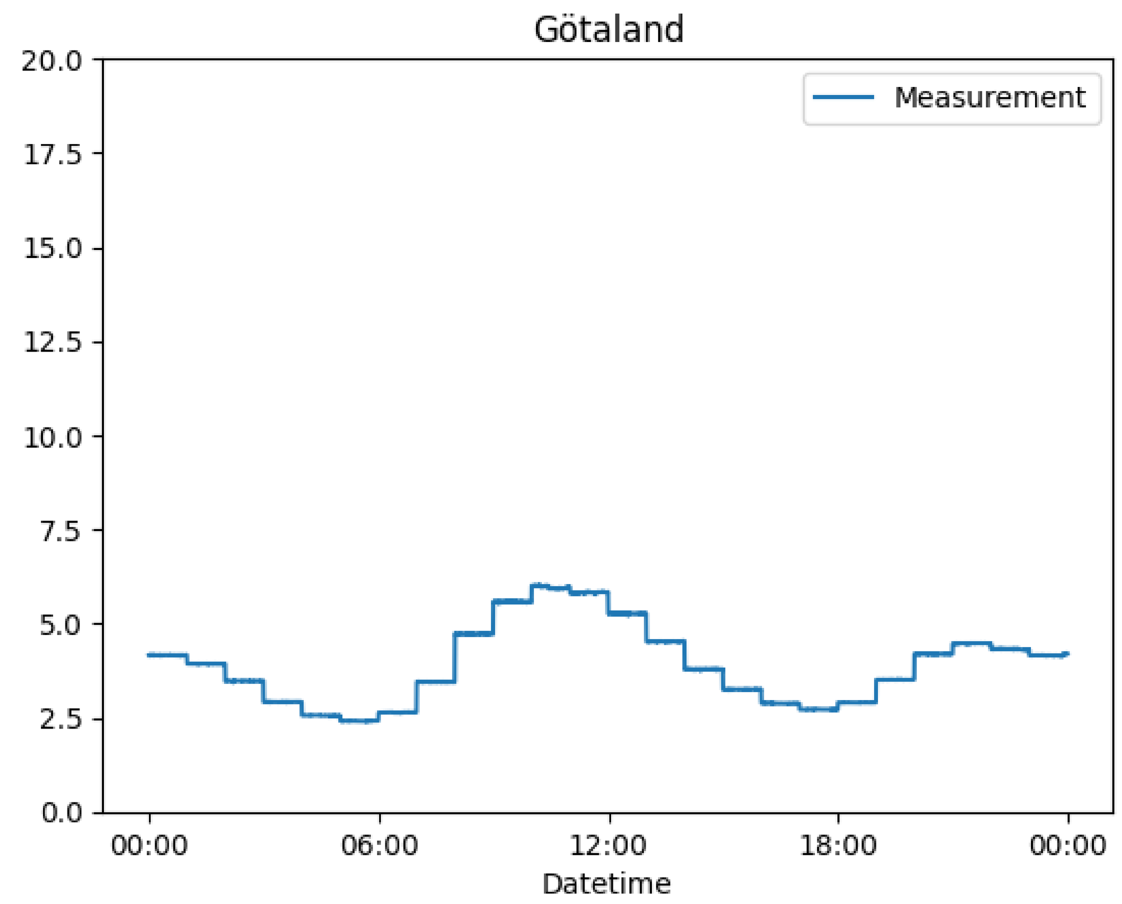

Figure 5: In the southern parts of Sweden the positioning uncertainty increases around noon

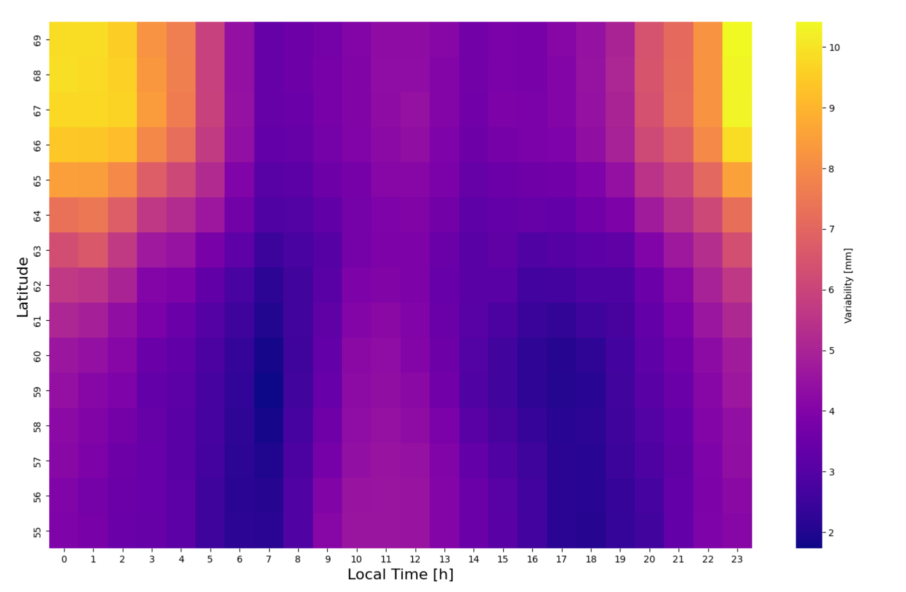

Figure 6: Heatmap of the Δx over latitude and LT

The noon time increase of Δx in the south Sweden is small compared to the high latitude disturbances in the night, but significant and clearly present.

Conclusions

- high latitude night-side effects of the ionosphere on GNSS signals correlate with increased variations of the plasma density as seen by Swarm;
- preliminary results indicate that an increase of the positioning uncertainty in the southern regions around noon is perhaps an unmitigated ionospheric delay when the density is high.