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Observation of high latitude ionospheric disturbances and distortion of L-band radar satellite images

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ABSTRACT

We present studies of high latitude ionospheric disturbances by using space borne and ground radars as well as Global Navigation Satellite Systems (GNSS) measurements. During an evening of geomagnetic disturbances, enhancement of ionospheric electron densities associated with auroral activity were detected by European Incoherent Scatter (EISCAT) radar near Tromsø, Norway. Simultaneous acquisitions of Synthetic Aperture Radar (SAR) satellite images over northern Scandinavia show distortions of SAR ground images where streak-like structures are present in azimuth shift domain. EISCAT UHF radar was programmed to track GNSS and ALOS2 satellites in order to compare high resolution electron density measurements and Total Electron Content (TEC) and estimate of Faraday rotation from L-band SAR radio signals. It is indicated that the streaks in SAR images may be associated with electron density enhancement up to 200 km altitude due to auroral activity.

Key words: Ionosphere, TEC, SAR, Aurora, GNSS

Interactions between charged particles and propagating radio waves along the trans-ionospheric link are known as a main error source for L-band satellite signals including GNSS. This ionospheric propagation effects include signal delays, advances in phase and rapid variations of amplitude and phase known as scintillation. On the other hand, global networks of GNSS receiver stations have been used as a tool to probe ionospheric activities and space weather applications. TEC is integrarated electron density along the ray path and serves a measure of estimating signal delay and phase advances due to refraction effects. Small scale spatial and temporal variation embeded in bakcground TEC are known to influence L band radio signals.

In the field of remote sensing, high sensitivity L –band SAR satellites such as ALOS/ALOS2 have been important tools for many earth observation applications including ground deformation and forest research. The propagation effect in L-band SAR can be seen in distortion of the image products. Distortion of space borne SAR images with streak-like structures by small scale plasma density fluctuations have been reported both in equatorial region (Shimada et al. 2008) and polar regions (Gray et al. 2000). In equatorial regions, extended analysis have been with simulation (Carrano et al. 2012) and statistical studies (Meyer et al. 2015).

Governed by physical processes such as particle precipitations and plasma convection, the polar ionosphere show dynamic structures, especially during active space weather conditions. *Gray et al.* reported the azimuth-streak from Antarctic and Canadian observation and discussed its possible ionospheric origin. The analyzsis was based on geomgentic distrubance data several hundreds kilometer away from the corresponding SAR image swath. The aruged mechanisum is that the rapid changes of electrons in transionospheric link between SAR and illuminated foot point may lead to shifts in azimuth direction.

In this paper, we present simultaneous observation of polar ionospheric disturbances with SAR satellite images, incoherent scatter radar and GNSS measurementws. After the launch in 2014, ALOS2 has shown a number of images that exhibit ionospheric effects over Northern Scandinavia. The distortions of the image are usually appeared as steak-like structures, more or less elongated with mapped geomagnetic field lines. Fig.1(a) is an example of the relative shift in azimuth direction between approaching and departing look directions. The acquisition time is 21:58 UT, 13th October 2015. The footpoint of the image is approximately 100km east of the EISCAT facility (69.58°N/ 19.21°E). The white line indicates the magnetic field direction projected at 200 km altitude. It is seen that the streak like disturbances are nearly oriented with projected magnetic field lines. The values in azimuth shift are scaled from 10 m (blue) to 10 m (red). The EISAT UHF radar was programmed to track GNSS satellites from 20:00 UT with 60 seconds antenna update and then after 21:56 with 10 seconds antenna update to track ALOS2. Fig.1(b) shows enhanced electron density extended up to 200 km. The electron temperature enhancement around 300 km altitude can also be observed. The UHF observation confirms presence of plasma irregularities between the foot point and the SAR satellite.

We aim to explore ionospheric mapping possibility with SAR by using simultaneous observation of GNSS and incoherent scatter radars especially on electron density variations. This study may lead to validation of SAR as a new tool that could help better understand ionospheric effect on satellite signals and contribute to space weather research.

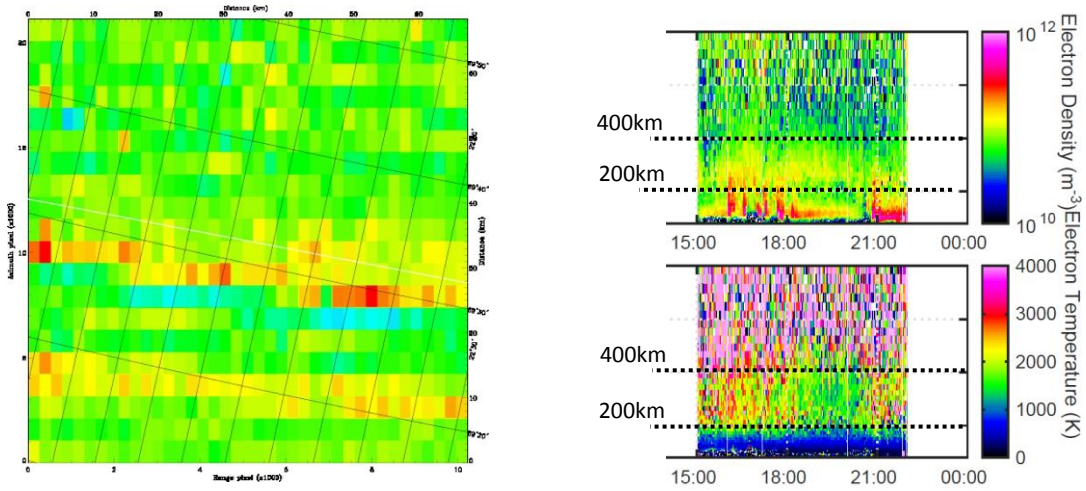

Figure 1. (a) SAR azimuth shift image recorded at 21:58 UT, 13.10.2015. The value is scaled from -10 m (blue) to 10 m (red). The white line indicates the projected magnetic field direction. The foot point is approximately 100 km east of EISCAT site. (b) EISCAT UHF radar observation on 13.10.2015. The black dashed lines indicate altitudes.

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