Tomographic studies of 3-D structures of daytime mid-latitude sporadic-E patches from a dense GNSS array

*Kosuke Heki[1], Ihsan Naufal Muafiry[1], Jun Maeda[2]

1. Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University, 2. Library, Hokkaido University

A dense array of continuously operating Global Navigation Satellite System (GNSS) receivers is useful for drawing 2-dimensional maps of sporadic-E (Es) patches. From changes in the ionospheric total electron content (TEC) observed with Japanese GEONET, Maeda and Heki (2014) revealed that Es irregularities often show frontal structure extending predominantly in east-west. We further performed systematic studies of the morphology and dynamics of Es patches analyzing ~70 cases of daytime mid-latitude Es (Maeda and Heki, 2015). In our recent paper (Maeda et al., 2016), we used Interferometric Synthetic Aperture Radar (InSAR) to draw a high resolution of map of an Es irregularity in Southwest Japan. In the GNSS-TEC method, however, we often assume that the irregularities lie at height of ~100 km, and draw 2-D maps using the penetration point of the line-of-sight (LOS) vectors with the thin layer of prescribed height.

Here we try to infer 3-D structure of the Es patches using the 3-D tomography technique of the ionosphere. We set up 2000-3000 small blocks, with dimensions of a few tens of kilometers, covering the altitudes ranging from the D region to the F region, above a certain district of 300 km x 500 km in Japan. We also make a data set composed of slant TEC anomalies with thousands of LOS connecting ground GNSS stations and satellites (we use both GPS and GLONASS) that penetrate these blocks. Finally, we invert for the electron density anomalies of individual blocks, applying a certain continuity constraint. Before an actual tomography with the real data, we performed checkerboard test using synthesized data, and confirmed the resolution of the inversion.

The attached figure shows the map view at the height of 100 km and longitudinal and latitudinal profiles for the northward drifting frontal-shape Es patches that appeared around 4 UT on 22 May, 2010, shown in Figure 1d of Maeda and Heki (2015). We could confirm that the positive electron density anomalies extend east-west at the E region height. One interesting feature is that positive anomalies extend upward and southward. We also studied a case of the southward drifting Es patches that appeared on the Kanto District at around 8 UT on 21 May, 2010 first studied by Maeda and Heki (2014). In that case, we found the Es patch extend upward and northward. The extension direction might be controlled by the drift directions of the Es patches.

References

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Figure caption: Results of 3-D tomography of the Es irregularity patch that appeared around 4:00 UT (13:00 LT) on May 22, 2010 above the Kyushu, Southwest Japan, see Fig.1d of Maeda and Heki (2015).

Frontal shape Es patches extend east-west, and migrate northward. We show the map view at altitude 100 km (a), longitudinal profile (longitude: 130.5E) (b), and latitudinal profile (latitude: 32N) (c). Blocks in red indicate positive electron density anomaly and correspond to the Es patch. In (b), we can see upward continuation of the Es extending southward, reaching the height of 200 km at the southernmost part of the studied region.

Keywords: sporadic-E, GNSS, TEC, 3-D tomography