Multi-GNSS observation of LSTID in Japan and its link with auroral activities

*橋本 繭未[1]、日置 幸介[1]
*Mayumi Hashimoto[1], Kosuke Heki[1]

1. 北海道大学
1. Hokkaido University

Interaction between southward magnetic field in solar winds and the Earth’ s magnetosphere causes geomagnetic activities and auroral substorms. The auroral activity is associated with strong electric currents (auroral jet) within the auroral oval. This disturbs the geomagnetic field at high latitude region and is reflected in changes in the AE (Auroral Electrojet) index. At this time, atmospheric gravity waves, generated as a result of the heating of the atmosphere by electric currents, propagate toward the middle and low latitudinal regions and make Large-Scale Traveling Ionospheric Disturbances (LSTID). In this study, we observed ionospheric disturbance in Japan located in middle and low latitudes as the changes in TEC (Total Electron Content). Here we study the relationship between LSTID observed with multiple-GNSS (Global Navigation Satellite System), GPS, GLONASS, Galileo, and QZSS, and short-term changes in the high time resolution AE index time series.

In this study, we used the AE index one minute values from Kyoto University, World Data Center for Geomagnetism (wdc.kugi.kyoto-u.ac.jp). As the GNSS observation point, we used Tsukuba (tskb), one of the IGS observation points in Japan with inter-frequency bias values available. To examine the relationship, we first identified the day when the AE index exceeded 2,000 nT between 2011 and 2017. Then, we converted the RINEX data files of tskb on these days to TEC, removed satellite and receiver biases, and converted them to vertical TEC (VTEC). We compared the AE index and VTEC for 22 cases, and the occurrences of LSTID were confirmed in 5 of them. In these cases, LSTIDs were observed 1 or 2 hours after the peak of the AE index. We estimated the propagation velocity in two ways, i.e. by calculating the time lag between the AE peak and LSTID arrivals in Japan and the distance between the auroral oval and Japan, and by comparing the times of TEC peaks within Japan. Both approaches showed the velocity of ~0.7 km/sec.

Since 2018 summer, the Japanese GNSS network started to track multiple GNSS including the Japanese Quasi-zenith Satellite System (QZSS) and to open the raw data on-line by RINEX 3.02 format. discuss the relationship LSTID and AE index. QZSS includes three satellites with quasi-zenith orbits (PRN01, 02, 03) and one satellite with geostationary orbit (PRN07). Generally speaking, GNSS-TEC data changes by the three reasons, (1) temporal change in ionosphere, (2) spatial change in ionosphere, and (3) apparent change by changes in satellite elevation angle. However, QZSS-TEC includes only (1), and useful in studying ionospheric disturbances without bothering about (2) and (3).

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