QZSS geostationary satellite for ionospheric TEC observations

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Most Global Navigation Satellite System (GNSS) satellites employ orbital periods with a half sidereal day. This makes the satellites move rapidly in the sky when observed from ground receivers. This is important in relative positioning by observing carrier phases and in estimating zenith tropospheric delays. However, measurement of ionospheric total electron content (TEC) could be done instantaneously by comparing phases of the two carrier waves, and the changes in the satellite azimuth and elevation becomes a nuisance. The change in STEC (slant TEC) comes from (1) temporal change and (2) spatial changes of ionosphere, and (3) apparent U-shaped changes coming from the elevation changes. We can mitigate (3) by using VTEC, i.e. removing the inter-frequency biases and multiplying the bias-free STEC with cosine of the line-of-sight penetration angle. Nevertheless, discrimination of (1) and (2) is difficult and becomes possible only by processing the whole data sets of dense networks. The Japanese Quasi-zenith Satellite System (QZSS) is currently composed of four satellites, 3 satellites with quasi-zenith orbits (PRN01, 02, 03) and 1 satellite with geostationary orbit (PRN07). The latter enables continuous observation of certain points in ionosphere fixed to the Earth, i.e. the changes in TEC come entirely from temporal changes.

The Japanese GEONET network GNSS receivers continuously track GPS, GLONASS, Galileo, and QZSS, and their raw data are available on line as the RINEX (Receiver independent exchange format) Ver.3.02 files. I made a software system to read them and convert the phase data to TEC time series. With TEC observations from the geostationary satellite, we could study temporal changes in ionosphere without being bothered by spatial variations. This implies certain benefits in studying ionospheric disturbances, such as LSTID (Large-Scale TID), MSTID (Medium-scale TID) (Otsuka et al., 2011), Es (sporadic-E) (Maeda & Heki, 2015), artificial ionospheric electron depletion due to launches of satellites and ballistic missiles (Hashimoto & Heki, 2018), and preseismic ionospheric anomalies (Heki, 2019). In contrast, geostationary satellites are not suitable for studying coseismic ionospheric disturbances by acoustic waves (Cahyadi & Heki, 2015) and those by volcanic eruptions (Nakashima et al., 2015). This is because stronger signals always appear in poleward line-of-sights from ground stations located at the equatorward side of the epicenters/volcanoes (Heki, 2019).

References

Cahyadi, M. N., and K. Heki (2015), Coseismic ionospheric disturbance of the large strike-slip earthquakes in North Sumatra in 2012: Mw dependence of the disturbance amplitudes, Geophys. J. Int., 200(1), 116-129.

Hashimoto, M. and K. Heki (2018), Estimation of thrust powers of missiles/rockets by GNSS-TEC observations, J. Geod. Soc. Japan, in press.

Heki, K. (2019), Ionospheric disturbances related to Earthquakes, in “Advances in Ionospheric Research: Current Understanding and Challenges”, Wiley/AGU Book, in press.

Nakashima, Y., K. Heki, A. Takeo, M. N. Cahyadi, A. Aditiya, & K. Yoshizawa (2016), Atmospheric resonant oscillations by the 2014 eruption of the Kelud volcano, Indonesia, observed with the ionospheric Total Electron Contents and seismic signal, Earth Planet. Sci. Lett., 434, 112-116.

Maeda, J. & K. Heki (2015), Morphology and dynamics of daytime mid-latitude sporadic-E plasma patches revealed by GPS total electron content observations in Japan, Earth Planets Space, 67, 89, doi:10.1186/s40623-015-0257-4.

Otsuka, Y., N. Kotake, K. Shiokawa, T. Ogawa, T. Tsugawa, & A. Saito (2011), Statistical study of mediumscale traveling ionospheric disturbances observed with a GPS receiver network in Japan, in Aeronomy of the Earth's Atmosphere and Ionosphere, edited by M. A. Abdu and D. Pancheva, IAGA Special Sopron Book Series 2, doi:10.1007/978-94-007-0326-1_21, Springer.

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