Characteristics of long-term variations in the ionospheric electric field estimated with geomagnetic solar quiet daily variation

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Geomagnetic solar quiet (Sq) variation observed on the ground is produced by the large-scale ionospheric currents flowing in the E-region of the ionosphere. The Sq currents are driven by the ionospheric electric fields consisting of polarization electric field and dynamo field (VxB), where V and B indicates the neutral wind and background magnetic field, respectively. The neutral wind is driven by atmospheric tidal waves in the mesosphere and lower thermosphere (MLT) (60-150 km), which are caused by atmospheric heating due to solar extreme ultraviolet (EUV) radiation and an effect of atmospheric gravity waves. Therefore, to investigate the long-term variation in the ionospheric electric field estimated with the Sq variation is important to find the signals of long-term variation in the MLT and ionosphere. In this study, in order to clarify the seasonal and solar activity dependence of the ionospheric electric fields estimated with the Sq variation from 1958 to 2015, we analyze 1-hour geomagnetic field data obtained from 83 geomagnetic observatories from the middle-latitude to equatorial regions with an aid of the IUGONET data analysis tool. These geomagnetic field data were provided by WDC for Geomagnetism, Kyoto University. In this analysis, we first selected geomagnetic field data for the solar quiet days, which is defined as a day through which the Kp index is less than 4. Next, we identified the Sq variation as a deviation from the value at midnight in both the X and Y components of the geomagnetic field data. Finally, we obtained the monthly-mean ionospheric electric fields by solving Ohm’s equation with the two-dimensional height-integrated ionospheric conductivity and geomagnetic Sq variation. As a result, the ionospheric zonal and meridional electric fields show a clear seasonal variation and 11-year solar activity dependence at all of the investigated geomagnetic stations. The power spectra of the zonal electric field show three dominant peaks in period at 6, 12 and 132 months. Moreover, the 4-month periodic component is also found in the middle-latitude region. The intensity of the zonal electric field is positively correlated with the F10.7 index near the equatorial region ($|q| < 20$ degrees, q: magnetic latitude) with no time lag, while they show a negative correlation in the middle-latitude region ($|q| > 20$ degrees). Such a latitudinal difference is seen in all the geographical longitudes. As a cause of the negative correlation in the middle latitudes, we infer that the neutral wind originating from solar tidal waves in the lower thermosphere weakens during a high solar activity due to the enhancement of ion drag effect.

Keywords: Geomagnetic solar quiet daily variation, Ionospheric electric field, Seasonal variation, Solar activity, Long-term vairation, IUGONET

