Characteristics of long-term variation in the amplitude of the geomagnetic solar quiet daily variation

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Geomagnetic solar quiet (Sq) daily variation is observed as a regular change in the X- (north-south) and Y- (east-west) components of the geomagnetic field at ground magnetometer stations from mid-latitudes to the equator on the dayside. The Sq variation is mainly produced by large-scale ionospheric currents flowing in the E- and lower F1-regions (90 –140 km) of the ionosphere. The Sq currents consist of two parts: one is the anti-clockwise current in the northern hemisphere, and the other is the clockwise current in the southern hemisphere. They are driven by the ionospheric electric field caused by the ionospheric dynamo action through interaction between charged and neutral particles in the E- and lower F1-regions of the ionosphere. Since the Sq currents concentrate in a height range of 90 -140 km, we can find several signals of long-term variation in the upper atmosphere from the analysis of long-term variation in the Sq field. In this study, we investigate characteristics of long-term variation in the monthly mean Sq variation in the X and Y components (Sq-X and Sq-Y) using long-term geomagnetic field data obtained at several mid- and equatorial stations from 1957 to 2016 with an aid of the Inter-university Upper atmosphere Global Observation NETwork (IUGONET) tools. Especially, we clarify local time and seasonal dependence of the sensitivity of Sq-X and Sq-Y to the solar activity. In the present analysis, we used long-term geomagnetic field data with 1-h time resolution obtained at MMB and GUA provided by the World Data Center for Geomagnetism, Kyoto University. In order to determine geomagnetic quiet days, we referred the geomagnetic activity index (Kp) with 3-h time resolution provided by the GeoForschungsZentrum (GFZ) Potsdam. In this study, we defined a geomagnetically quiet day as the day when the maximum value of the Kp index is less than 3. As a good indicator of solar activity, we selected the 10.7 cm solar radio flux (F10.7) data provided by the Natural Resources Canada. In this analysis, we used the monthly average of the adjusted daily F10.7 corresponding to geomagnetically quiet days. For identification of Sq-X and Sq-Y, we first determined the baseline of the X- and Y-components from the average value from 22 to 2 h (LT: local time) for each quiet day. Next, we calculated a deviation from the baseline of the X- and Y-components of the geomagnetic field for each quiet day, and computed the monthly mean value of the deviation for each local time. As a result, Sq-X and Sq-Y show a clear seasonal variation and solar activity dependence. The amplitude of the seasonal variation in Sq-X and Sq-Y tends to increase significantly as solar activity becomes high. The pattern of the seasonal variation of Sq-X and Sq-Y is quite different between two components observed in mid-latitudes and equator. The correlation analysis between the solar F10.7 index and Sq-X and Sq-Y shows almost the linear relationship, but the slope of the linear fitted line depends on both local time and month. This implies that the sensitivity of the Sq variation to the solar activity is different for different local times and seasons. The local time and seasonal variations of Sq-Y at GUA obtained from the linear fitted line for the minimum F10.7 suggest an effect of the magnetic field perturbations produced by inter-hemispheric field-aligned currents (FACs). From the sign of Sq-Y, it is inferred that the inter-hemispheric FACs flow from the summer to winter hemispheres in the dawn and dusk sectors and from the winter to summer hemispheres in the pre-noon to afternoon sectors. The direction of the inter-hemispheric FAC in the dusk sector is opposite to the prediction by Fukushima’s model. The result of the linear fitted line between the F10.7 index and Sq-Y at GUA shows that a solar activity dependence of the inter-hemispheric FACs is much smaller than that of Sq-X produced by the eastward equatorial electrojet.

Keywords: Geomagnetic solar quiet daily variation, Solar activity, Seasonal variation, Inter-hemispheric field-aligned currents, Equatorial region, Ionospheric dynamo

