GPS Observation of the occultation of solar flares

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Solar flare is an explosive magnetic reconnection occurring near sunspots. Such a flare is associated with the sudden radiation of electromagnetic waves in various frequencies as well as high-energy plasma particles. Soft Xray (1-90A) and extreme ultraviolet (90-1030A, EUV) radiations cause rapid increases of the electron density in the Earth's ionosphere, which has been known as SITEC (sudden increase of TEC). The recent advent of dual frequency GPS networks has made measurements of TEC (total electron content) relatively easy and enabled studies of various kinds of ionospheric disturbances. Recent densification of continuous GPS stations is also making it easy to study ionospheric responses to solar flares from various points of view (e.g. Zhang and Xiao, JGR, vol. 108, 2003). In the present study, by analyzing the GEONET GPS L1 and L2 phase data, we first tried to detect signals associated with solar flares that occurred from April to July, 2004. As a result, not only the largest X-class flares, but also SITECs by M-class and C-class flares were also recognized as sudden increases of TEC with time constants of a few minutes. We also downloaded worldwide GPS data from International GPS Service (IGS) data centers, and studied the behaviors of TEC before and after the flares. For an X1.3 flare that occurred at the sunspot 649 on July 16, 2004, at around 11 o'clock in JST, we could see SITEC exceeding 1 TECU (=10e16 electrons/square meter) at Japanese GPS station. This was a typical impulsive flare, achieving the sudden increase of TEC within a few minutes. For this flare, following the method by Leonovich et al. (Ann. Geophys., vol.20, pp.1935-41, 2002), we investigated the SITEC values at GPS stations located near the day-night boundary. As we go into the night region, SITEC tend to reflect disturbances at the higher part of the ionosphere (i.e. the lower parts are in the shadow of the solid earth). In this study, we clarify the relationship between the distance from the night-day boundary and the amplitude of SITEC, and investigate quantitatively which part of the ionosphere contribute to the SITEC by solar flares.