Statistical analysis of short-wave fadeout toward extreme event estimation for space weather hazardous map of Japan

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Solar flares trigger enhancements of ionospheric plasma density including D-region which causes absorption of radio waves especially at high-frequency (HF) ranges. This phenomena is called short wave fadeout (SWF) or Dellinger effect. This SWF interrupts trans-ionospheric radio communication system including ground-to-ground radio communications, satellite communication system, and disaster prevention radio system. SWF is one of important topics of space-weather hazardous-map for Japan society. In order to understand SWF statistical characteristics and behaviour, we analyse long-term (~20 years) ionosonde data observed by NICT and estimate extreme case based on the results.

We analyse manually scaled parameters with 15 min. resolution from ionosonde observation in Tokyo over 1997 to 2016. We use minimum reflection frequency, fmin, for detection of Dellinger effect. Since fmin varies with local time (LT) and season, we refer to dfmin, fmin subtracted by its 27-day running average at the same LT. SWF is detected by (i) dfmin>2.5 MHz, (ii) dfmin>3.5 MHz, and (iii) blackout criteria, occurred daytime associated with any flare(s) greater than C-class in this study. We refer to GOES flare list for the flare size.

As a result, SWF occurrence maximizes at local noon and decreases with the solar zenith angle. We confirm that the dfmin value and SWF duration increase with the flare size. We estimate the absorption strength and compare it with an empirical relationship derived from long-distance circuits by Maeda and Inuki [1972]. The absorption strength of ionosonde is almost ~1/3 of that of the long-distance circuits, which would be affected by elongation of ionospheric pass due to oblique propagation. From our analysis and extension of the empirical relationship, we estimate the duration of extreme events, i.e., once per 10-year, 100-year, and 1000-year occurrence events, to be 1-2.2 hour, 2.3-5 hour, and 4.6-11 hour, respectively. We also discuss probable longest duration of originating solar flare.

Keywords: short-wave fadeout, space weather hazardous map, ionosphere, solar flare

