

## Ionospheric disturbances associated with typhoons and a tornado observed by HF doppler sounding

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It is reported that ionospheric disturbances are excited in association with natural hazards, such as earthquakes, volcanic eruptions, because the atmospheric waves generated by these natural hazards propagate upward to the ionosphere. Although the extreme weather events, such as typhoons and tornados, also excite the strong atmospheric waves, the ionospheric disturbances associated with these extreme events are not fully examined. In this study, therefore, we have examined ionospheric disturbances associated with typhoons and a tornado using HF doppler sounding system (HFD) and wind data observed by AMeDAS data provided by Japan Meteorological Agency.

We have examined the ionospheric disturbance associated with a tornado occurred on May 5, 2012 which is the largest event in Japan. The fluctuations of Doppler shifts were observed and the spectral intensities at the frequencies of 5-20 mHz were enhanced. However, the ionospheric fluctuations continued after the disappearance of the tornado. The enhancement of the doppler shift had a good correlation with a wind speed below the ground of the reflection point.

The ionospheric disturbances associated with typhoons were also correlated with the wind speed on the ground. Examining typhoons that come closer to Japan in 2013-2017, it is found that spectral intensities of the disturbances of HFD data at the frequencies from 5 mHz to 45 mHz were enhanced. The frequencies of the atmospheric disturbances observed on the ground were also the same as those of HFD disturbances. The spectral intensities of HFD and atmospheric disturbances are proportional to each other and the correlation coefficient between them is larger for higher-frequency disturbance. From these results, the ground weather condition, especially wind data, is very important to examine the mechanism of the ionospheric disturbances associated with these extreme weather events.

Keywords: ionospheric disturbance, typhoon, tornade, infrasound wave, neutral wind