Observations of night time Sporadic-E layer by HF Doppler sounder network: association with Medium-Scale Traveling Ionospheric Disturbance (MSTID)

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Sporadic-E (Es) is a thin layer in the E-region ionosphere (~100 km) composed of dense metallic ions and electrons. Es is known to appear in the mid-latitude region during summer months. Extremely high electron density within Es sometimes reflects radio waves in VHF frequency range, especially above 100 MHz. Such a Es-related reflection of radio waves causes anomalous long- distance propagation of waves leading to radio interferences of commercial/navigation signals. Thus, Es is one of the important ionospheric phenomena which should be studied in the framework of space weather applications. Recent theoretical studies and numerical simulations have suggested that Es plays an important role in generating wave-like structures at F-region altitudes in summer nighttime, which are known as Medium-Scale Traveling Ionospheric Disturbances (MSTIDs). However, there have been only a few studies investigating the simultaneous observations Es and MSTIDs appearing in the E and F regions, respectively. Such a situation is primarily due to the lack of instruments that can directly observe Es in summer night time. To overcome this limitation, we employed data from HF Doppler (HFD) sounder network in Japan to detect Es in summer night time and tried to evaluate the E-F coupling, i.e., Es in the E-region and MSTIDs in the F-region. The HFD system is composed of a transmitting station in Chofu, Tokyo (35.7˚N, 139.5˚E) and receiving stations at ~10 places in Japan. Based on such multi-point observations, we can derive the dynamical characteristics of Es layer, for example, its moving speed and direction.
In this paper, we show an Es event on August 22, 2014 (00:00 to 02:00 JST). This Es event was analyzed in detail by Ejiri et al. (2019) who used a Lidar system to detect Es above Tokyo. The HFD system also detected the same Es feature near the Tokyo area. We made use of Es reflection data from the HFD receivers in Sugito, Saitama (36.0˚N, 139.7˚E), Fujisawa, Kanagawa (35.3˚N, 139.5˚E) and Sugadaira, Nagano (36.4˚N, 138.3˚E). By using this triangle observation, we succeeded in deriving the horizontal speed and direction of the motion of Es. In addition, we estimated the phase velocity of MSTIDs seen in the maps of Total Electron Content (TEC) from GPS receivers of GEONET. The Es layer propagated with a horizontal speed of 68.9 m/s in the azimuthal direction of - 113.0˚ from the geographic pole (approximately SWW). The phase speed of the simultaneously observed MSTIDs was estimated to be 68.1 m/s and the propagation direction was -110.1˚. This striking correspondence of the dynamical characteristics of Es and MSTIDs implies that the E-F coupling is actually working in the generation process of summer night time MSTIDs and MSTIDs are moving in tandem with Es.

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