Variability and Role of the D-region Ionosphere Based on VLF/LF Wave Observations

Hiroyo Ohya
Graduate School of Engineering
Chiba University
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522 Japan
Email: ohya@faculty.chiba-u.jp

The D-region ionosphere, defined as the region of 60-90 km height, is a link between the solid Earth and E-/F-region ionosphere, magnetosphere, and solar activities. The D-region also corresponds on upper region of global electric circuit, which is affected by meteorological phenomena such like thunderstorms, snowfall, and clouds in the stratosphere [1]. The D-region is an important region for various phenomena from above and below. However, for the D-region ionosphere observations, we cannot use usual observation tools such like ionozondes, GNSS-total electron content (TEC) data, and radars, because of high collision frequency for electrons with neutrals (10^5-10^8 s^{-1} at 60-90 km height, and 10^1-10^2 s^{-1} at 300 km height). Rocket measurements have high accuracy for measuring electron density in the D-region, although the location and time of rocket launches are limited. The D-region height is too high for balloon observations, and too low for usual tools of ionospheric observations. Traditionally, very low frequency (VLF, 3-30 kHz)/low frequency (LF, 30-300 kHz) waves that are radiated from lightning discharges and manmade transmitters have been used for studies of the D-region ionosphere. Routine observations of VLF/LF waves can be performed, which amplitude and phase respond sensitively to variations in electron density. Tweek atmospherics are originated from lightning discharges and propagate in the Earth-ionosphere waveguide for a long distance. The tweeks had been regarded as causative sferics of whistlers until 1990's, and have been used for studies of lightning and whistlers. From the large occurrence number of tweeks in nighttime (~100 tweeks/min.), we have used the tweeks for studies of the D-region ionosphere, such like geomagnetic storms, solar eclipse, and solar-cycle variations [2]. Daytime tweeks were newly found [3], and were used for studies of solar flares [4]. Manmade narrowband VLF/LF transmitter signals also have been used for the D-region studies, for example, solar flares, energetic electron precipitations, earthquakes, volcanic eruptions and so on [5]. Currently, this research field is experiencing rapid development by new constructions of some worldwide ground-based observation network such like AVON, OCTAVE, PWING, AARDDVARK and so on. In this presentation, we will show some D-region phenomena observed by VLF/LF waves and discuss future directions of the D-region studies.

References

1. H. Ohya, K. Nakamori, T. Takano, M. Kamogawa, T. Suzuki, and K. Morotomi, "Periodic oscillations of atmospheric electric field during snowfall in the Tokyo metropolitan area," *Sci. Rep.,* 11**,** 2280, 2021.
2. H. Ohya, K. Shiokawa, and Y. Miyoshi, "Long-term variations in tweek reflection height in the D and lower E regions of the ionosphere," *J. Geophys. Res.: Space Physics*, 116, A10322, 2011.
3. H. Ohya, K. Shiokawa, and Y. Miyoshi, "Daytime tweek atmospherics," *J. Geophys. Res.: Space Physics*, 120, pp. 654–665, 2015.
4. O. Santolík, and I. Kolmašová, "Unusual Electromagnetic Signatures of European North Atlantic Winter Thunderstorms," *Sci. Rep.,* 7**,** 13948, 2017.
5. H. Ohya, F. Tsuchiya, Y. Takishita, H. Shinagawa, K. Nozaki, and K. Shiokawa, "Periodic oscillations in the D region ionosphere after the 2011 Tohoku earthquake using LF standard radio waves," *J. Geophys. Res.: Space Physic*s, 123, pp. 5261–5270, 2018.