Simultaneous observations of plasma bubbles with an HF Doppler sounding system in Taiwan and an all-sky imager in Ishigaki Island

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Plasma bubbles are regions of electron density depletion in the equatorial ionosphere appearing at altitudes above 200 km. Plasma bubbles, that develop to higher altitudes near the magnetic equator, are observed at low latitude regions 10-20 degrees away from the magnetic equator. Plasma bubbles are known to cause disruptions of global navigation satellite systems and/or degradations of their positioning accuracy. For this reason, plasma bubbles are still being actively investigated by using various observation methods. Chum et al. (2016) conducted a statistical study of Doppler spectrograms obtained from HF Doppler sounding systems at low-latitudes, and suggested that plasma bubbles can be detected as oblique spreading traces in the Doppler spectrograms. However, it has not yet been confirmed if the oblique spreading traces are really the manifestations of plasma bubbles in the HF Doppler observations.

In this study, we examined an interval of simultaneous observations of plasma bubbles with an HF Doppler sounding in Taiwan and an all-sky imager in Ishigaki Island, Japan, which occurred on February 14, 2015. By comparing the radio and optical data, we aimed at demonstrating that the oblique spread structures in the Doppler spectrogram are indeed caused by plasma bubbles. In addition, from the intercomparison of the radio and optical data, we also intended to show the relationship between the size of the oblique spread structures in the Doppler spectrograms and the actual spatial extent of plasma bubbles seen in the optical data. The comparison also enabled us to evaluate the accuracy of methods for estimating the propagation velocity of the plasma bubbles using the HF Doppler observations.

During the simultaneous observations, the arrival of the airglow signatures of plasma bubbles at the reflection point of the HF Doppler system well coincided with the start time of the oblique spread structures in the Doppler spectrogram. This strongly implies that the oblique spread structures in the Doppler spectrogram was surely associated with the passage of plasma bubbles. We also found that there is a strong relationship between the size of the oblique spread structures in the Doppler spectrograms and the spatial extent of the airglow signatures of plasma bubbles, which will allow us to monitor the scale size of plasma bubbles by using the HF Doppler sounding system in Taiwan before arriving in the longitudes of Japan. By comparing the radio and optical observations, it was found that, when we determine the propagation velocity of the plasma bubbles from the Doppler spectrogram, the time-delay method using multiple HF Doppler stations is more accurate than the tilt method using single station data. This finding would be useful when estimating the time-lag between the observation of plasma bubbles in Taiwan and their subsequent arrival in the longitudes of Japan. The knowledge obtained from the current simultaneous observations is of particular importance for the detection, monitoring and prediction of plasma bubbles in Japan.

