Nighttime enhancement of the D-/E-region electron density at mid-latitude in summer observed with MF radar

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Sporadic E (Es) layers are ionization enhancements in the E-region at altitudes between 90 and 120 km. It is known that occurrence rate of intense mid-latitude Es layers in May-August is much higher than that in the other months. As for nighttime local time (LT) variations, the occurrence rate is highest just after sunset, and decreases with time. Then the Es layers hardly occur from 0200 LT to sunrise.

On the other hand, it is known that characteristic frequency-time dispersion near the first-order mode cut-off frequency of tweek atmospherics is not almost seen at summer night. That is, the tweek signal is seen as a simple pulse without the frequency-time dispersion near the cut-off frequency. This is similar to daytime observational condition. The daytime D-region electron density is 10^3 - 10^4 cm^{-3}, while for the nighttime it is 10^2 - 10^3 cm^{-3}. The nighttime mean apparent height of tweeks is about 89 km altitudes, where the height is located around a boundary between the D- and the E-region.

As the similar summer night anomaly in the D-/E-region ionosphere, we report that high blue/red ratio events of elves are likely to occur in the summer hemisphere while the low blue/red ratio events in the winter hemisphere. We consider that the color variations of elves may depend on the background electron density in the D-/E-region ionosphere at summer night.

We take notice the summer night anomaly in the mid-latitude D-/E-region ionosphere, and investigate electron density variations at summer night based on Differential Absorption Experiment (DAE) data for one year (2003) with MF radar over Yamagawa, Japan (31.20 N, 130.62 E).

As a result, monthly mean electron density at midnight (0000 LT) remarkably increases up to 2.4 times of annual mean value at 86 - 92 km altitudes in May-August (Figure). The y-axis shows a ratio of monthly mean electron density to annual mean value. In figure, monthly mean *foEs-fbEs* parameter at midnight (0000 LT) measured by ionosonde at Yamagawa is also drawn. The ratios increase gradually from March and have maximum values in May - August, while it shows sudden decreases in September. The *foEs-fbEs* shows similar tendency of clear enhancements in summer season, although the increase lasts until October. The decreases of the ratios in September are very sharp, while the decreases of the *foEs-fbEs* are more gradual than the MF radar data.

As for nighttime LT variations of the D-/E-region electron density in summer, we find that electron density enhancements move down in height range of 90 - 100 km from 2000 LT to 0000 LT. After 0100 LT, the electron density enhancements are not seen. The downward vertical velocity is about 0.3 - 0.6 km/h.

It has been considered that formation and vertical motion of so-called Es layers are predominantly caused by atmospheric tide at mid-latitudes. So we calculate ion trajectories that form inside convergent nodes of vertical wind shears in the tidal wind which move downward with the vertical phase velocities of the diurnal and semidiurnal tides. As a result, the trajectories of the semidiurnal tides show a good agreement with *h'Es* parameter variations, while the trajectories of diurnal tide are almost coincident both with the *h'Es* points around 1200 LT and with the peak heights of electron density in the D-/E-region in 2000 - 0000 LT.

Although these enhancements of electron density measured by MF radar apparently seem a bottom part of Es layers, the peak of the enhancements is very smaller (10^2 cm^{-3}) than normal Es layers (10^5 - 10^6 cm^{-3}). Also, the D-/E-region enhancements are similar to Tidal Ion Layers (TILs) (80 - 150 km) observed by Incoherent Scatter Radar over Arecibo. In this paper, we will discuss the mechanism of the D-/E-region enhancements of electron density.