

Signatures of meridional neutral wind variation in nighttime mid-latitude F region observed by HF Doppler

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The meridional neutral wind is a major driving force of nocturnal vertical plasma transport in the mid-latitude ionosphere. Although the zonal (east-west) electric field plays the major role in driving vertical plasma transport in the equatorial ionosphere, its contribution is supposed to be less significant in the midlatitude ionosphere. It has been understood theoretically that the nighttime offset of F-layer height from the equilibrium (so-called nighttime stationary layer) height is proportional to the vertical drift velocity, which in turn is almost proportional to north-south neutral wind in the mid latitudes. It is also known that the direction of meridional neutral wind shows diurnal and seasonal variations. These facts suggest that there must be signatures of neutral wind variation in the F-region height variations. However, no clear observational evidence is available to date.

We have been observing Doppler shift of ionospheric radio waves using the high-frequency Doppler (HFD) technique since 2003. In HFD observation, a positive frequency shift corresponds to downward motion of the layer that reflects the observed radio waves, and a negative shift corresponds to upward motion. We have examined 13-year archived data, which covers an entire solar cycle, and found clear seasonal pattern of frequency shift in each set of annual summary plot. The obvious causes of two of these patterns are sunrise and sunset, which rapidly enhances (at sunrise) or depletes (at sunset) the lower ionosphere. Other than these, there are two clear signature of sudden rise of 5 MHz layer in pre-midnight hours. There is also a signature of gradual sink of the layer in post-midnight hours. These signatures are supposed to be the indications of vertical plasma transport caused mainly by meridional neutral winds.

To examine the correspondence between neutral wind and the F-layer height we performed a model study using Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy (GAIA) database. We calculated the height profile of ionospheric plasma frequencies from major ion densities provided by GAIA. We also derived vertical plasma drift from neutral wind and electric field data. We have compared these data with HFD observations. The results show good correspondence between observation and model-derived parameters. This study suggests the possibility of using HFD technique to monitor the long-term trend in diurnal and seasonal variations in neutral wind direction.

Keywords: HF Doppler, F-region height, vertical plasma transport, meridional neutral wind, GAIA model, ionosphere