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Effect of IMF-By on variations of ionospheric total electron content at mid-latitudes

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The primary factor that controls ionospheric total electron content (TEC) variation is solar UV/EUV radiations through direct and indirect processes. The direct effect is the ionization of the thermospheric neutral particles by EUV radiations with wavelengths (*lambda*) shorter than 102.5 nm. Virtually all photons of *lambda*<102.5 nm are absorbed by photoionization and the absorbed energy splits into the photo-electron channel and the chemical energy channel (ion-electron pair) with the ratio that depends on the wavelength. Indirect effects of solar irradiance on the ionosphere are through the modification of the thermosphere. The recombination of ion-electron pair and the dissociation process of molecular oxygen (O_2) by the Schumann-Runge continuum radiation (*lambda*= 130-175 nm) are the primary heat source of the thermosphere. Changes in temperature and composition of the neutral atmosphere, and the atmospheric circulation greatly affect the ionospheric electron density.

Because the relationship between the solar spectral irradiance and ionospheric TEC is highly complex, we applied an artificial neural network (ANN) technique that has a great capability of function approximation of complex systems to model solar irradiance effects on TEC. Three solar proxies, $F_{10.7}$, SOHO-SEM$_{26-34}$ EUV emission index, and MgII$_{c-w-r}$ were the input parameters to the ANN representing activities at various heights and regions of the solar atmosphere (Maruyama, JGR 2010). Although the trained ANN prediction model was confirmed to work well to predict TEC variations, there remained some errors as easily expected from the fact that another channel of energy flow from the sun to the earth's ionosphere in the form of solar wind was not considered in the model. Thus, in the next step, we have examined effects of magnetic disturbance, which is a manifestation of solar wind magnetosphere energy coupling. For this purpose, the K_p index and several solar wind magnetosphere coupling functions were chosen as an additional input parameter to the ANN-TEC model and we obtained a substantial improvement in the TEC prediction when the preprocessed K_p index was used.

Somewhat minor but interesting effects on TEC variations are expected to emerge when major effects of solar irradiance and magnetic disturbance have been removed. We analyzed the time series of residual error by using a wavelet transformation, which revealed an error characterized by a period of approximately 27-30 days in the summer. Possible origins of the error having such a period are (1) insufficient modeling of solar activity effect, (2) lunar tidal forcing, (3) coupling with planetary waves in the lower atmosphere, and (4) solar wind effect other than geomagnetic disturbances. Regarding the first and second possibilities, the time series of the error amplitude did not synchronize with the solar rotational modulation of the activity or the lunar age. The third possibility may not be probable because the penetration of planetary waves up to ionospheric heights is suppressed during the summer. We examined solar wind effects in detail.

A various solar wind parameters and their combinations were examined. The best result was obtained when the IMF-By component and the solar wind velocity were included in the input space of the ANN and the residual error showing the 27-30 day period during the summer was removed. Parallel use of the solar wind magnetosphere coupling function further improved the model. Possible explanation of the IMF-By effect is discussed in terms of changes in the thermospheric general circulation pattern.

Keywords: TEC, IMF-By, artificial neural network