

Long-term trends of the ionospheric F2 layer over Japan

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Long-term trends of the ionospheric parameters through analyses of long and continuous time series of ionosonde data have been widely discussed during the last decade. This interest is due to possible anthropogenic impact on the Earth's atmosphere. Especially, it has been expected that the ionospheric trends may serve as an indicator of such changes in the upper atmosphere, because some models predict that an increasing content of atmospheric greenhouse gases leads to the global cooling in the upper atmosphere and subsequently to the shrinking of the upper atmosphere and ionosphere. In addition to such atmospheric greenhouse effect, our previous study found that the foF2 and hmF2 long-term trends at Kokubunji (35.42N, 139.29E) for the period 1959-2003 are sensitive also to the long-term changes in geomagnetic activity. In this paper, we reveal long-term trends of the F2-layer parameters using the long-term (more than 30 years) data at different ionosonde stations in Japan, and assess the validity for influence of geomagnetic activity on the long-term trends. In the long-term data at Wakkanai (45.23N, 141.41E) for the period 1960-2003, we find that the monthly median values of the measured foF2 and hmF2 are well correlated with the monthly mean values of the solar activity (F10.7 index); for both F2-layer parameters the correlation coefficient (r) exceeds 0.80. In contrast, monthly geomagnetic activity (A_p index) provides no significant influences on monthly values of both F2-layer parameters (0.11 or less). In order to extract the long-term trend component, the solar-dependent components in the F2-layer parameters are removed by using multiple regression analysis. The linear trends in the foF2 and hmF2 anomaly data for 1960-2003 are -0.00970 MHz/year and -0.434 km/year, respectively. The negative linear trends are in qualitative agreement with the hypothesis which includes greenhouse effect on the ionosphere. Furthermore, we applied a running mean filter of width 11 years to the foF2 and hmF2 anomaly values, in order to obtain the variable long-term trends. The estimated F2-layer parameter trends undergoes periods of negative and positive changes. The foF2 long-term changes have negative correlation ($r = -0.62$) with the 11-year running mean values of A_p index, whereas the hmF2 changes have a weak positive correlation ($r = 0.33$). The negative correlation between foF2 and geomagnetic activity shows similarity with the tendency obtained from the F2-layer parameter trends at Kokubunji ($r = -0.59$), which supports the influence of long-term changes in geomagnetic activity (namely, ionospheric storm effects) on the foF2 long-term changes. However, the relatively weak relationship between long-term changes of hmF2 and geomagnetic activity has still been no quite clear. In this study, also the latitudinal variation of F2-layer long-term trends over Japan will be discussed including features of the long-term trends at Yamagawa (31.12N, 130.37E) and Okinawa (26.17N, 128.09E).