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The unusual ionosphere under prolonged solar minimum

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A critical question in ionospheric physics is the state of the ionosphere and relevant processes under extremely low solar activity. The solar activity in 2007-2009 is prolonged extremely low, which offers us a unique opportunity to explore this question. In this study, we collected global ionosonde measurements of the F2 layer critical frequency (foF2), E-layer critical frequency (foE) and F-layer virtual height (h'F), and total electron density (TEC) maps produced at Jet Propulsion Laboratory (JPL), which were retrieved from dual-frequency Global Positioning System (GPS) receivers, to investigate the nature of the ionosphere during solar minimum of cycle 23/24, particularly the difference in the ionosphere between solar minima of cycle 23/24 and the preceding cycles. The analysis indicates that the moving 1-year mean foF2 over most available ionosonde stations and global-average TEC went to the lowest during cycle 23/24 minimum. The solar cycle differences in foF2 minima display local time dependence, being larger during the day than at night. Furthermore, cycle difference in daytime foF2 minima is about -0.5 MHz, even reaches to around -1.2 MHz. In contrast, a complex picture presents in global h'F and foE. Evident drop exists in moving 1-year mean h'F at many stations, while no evident differences are found at few stations too. A surprising feature is the increase in foE at some stations, although this feature is not consistent globally; however, the opposite behaviors of foE require independent data for further validation. Further quantitative analysis indicates that record-low foF2 and low TEC can be explained principally in terms of the decrease in solar extreme ultraviolet (EUV) irradiance recorded by SOHO/SEM, which suggests low solar EUV being the prevailing contributor to the unusual low electron density in the ionosphere during cycle 23/24 minimum. It also verifies that a quadratic fitting still reasonably captures the solar variability of foF2 and global-average TEC at such low solar activity levels.
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