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# The changes in the ionosphere during the recent deep solar minimum

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The solar activity is low and extremely extended in 2007-2009, with a highest record of spotless days in 2008 since the finding of the ionosphere. It is a critical issue that whether or not this deep solar minimum brought serious influences on the Earth's space environment.

To explore what happened in the ionosphere during the deep minimum, we analyzed the historical records of ionospheric parameters (the F2 layer critical frequency foF2, E-layer critical frequency foE and F-layer virtual height h'F) observed by global ionosondes. A comparative study is performed to evaluate the difference in the ionosphere between recent deep minimum (2008-2009) and past solar minima. The analysis indicates that the moving 1-year mean foF2 at most ionosonde stations went to the lowest during cycle 23/24 minimum. The solar cycle differences in foF2 minima display local time dependence, being more negative during the daytime than at night. In contrast, a complex picture presents in global h'F and foE. Evident reduction exists prevailingly in moving 1-year mean h'F at most stations, while no huge differences are detected at several stations. A compelling feature is the increase in foE at some stations, which requires independent data for further validation.

In addition, the ionograms recorded by a DPS ionosonde at Jicamarca (12.0o S, 283.2o E) are also collected and manually scaled these data to retrieve F-layer parameters and electron density profiles. Compared to 1996-1997, the seasonal median values of foF2 were identified to be remarkably reduced during the deep solar minimum. It is the first time to find that lower values prevail at most times in 2008-2009 in the F2-layer peak height (hmF2) and Chapman scale height (Hm). In contrast, the bottomside profile thickness (B0) in 2008-2009 shows higher values than that in 1996-1997 at some daytime intervals, although it is also smaller during the rest times. Furthermore, the ionogram-retrieved electron density profiles demonstrate that the ionosphere in 2008-2009 is contracted strongly at altitudes above hmF2 and more perceptible in the afternoon hours. The decrease in Ne is strongest in September equinox and weakest in June solstice.

Quantitative analysis indicates that record-low foF2 can be explained principally in terms of the decline 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 at such low solar activity levels. The reduction in solar EUV input from solar minimum to minimum mainly contributes to the ionospheric responses, but the involved ionospheric processes are competed and variable in different time scales and played roles in the complicated variations in different seasons and altitudes.

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