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Worldwide impacts of sudden stratospheric warmings on the ionosphere and thermosphere

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Recent studies have demonstrated large variations in the low-latitude ionosphere during strong, persistent meteorological disturbances known as sudden stratospheric warmings. Several possible lower/upper atmosphere coupling mechanisms were identified, including changes in the dynamics of the background neutral atmosphere, modification of solar and lunar tides, and subsequent variations in electric field. We extend these studies using observations by GNSS TEC receivers, by several ionosondes located at low, middle, and high latitudes, and by Jicamarca, Arecibo and Millstone Hill incoherent scatter radars to investigate large-scale ionospheric disturbances for several SSW events. To separate ionospheric anomalies associated with SSW from regular ionospheric behavior, we develop an empirical model of ionospheric parameters (TEC, NmF2) using available long-term data records (10-40 years of data depending on the instrument). The models describe variations in parameters for each longitude/latitude bin (or ionosonde location) as a function of solar activity, geomagnetic activity, day of year, and local time. Ionospheric anomalies are obtained as the difference between the observations and the empirical model.

Ionospheric anomalies are observed for both major and minor SSW events, reaching 50-100% variation from expected seasonal behavior for major SSW events and 30-60% variation for minor SSW events. The largest variations in the daytime TEC and NmF2 are observed both in the crests of equatorial ionization anomaly and at 40-60S (geodetic). Recent expansion of GNSS TEC receiver network to high latitudes in the southern hemisphere indicates that SSW anomalies are communicated across the globe and associated with ionospheric disturbances even over Antarctica.

Observational studies focused on SSW events present an important opportunity to better understand processes governing the behavior of the Earth's ionosphere and thermosphere. We use examples of observations from different latitudes and longitudes to illustrate how additional information helps to constrain global circulation models and to characterize the relative importance of different coupling mechanisms.