WHY SOUTH AMERICA IS A GREAT PLACE TO DO SPACE PHYSICS: SPATIAL AND TEMPORAL EXTENT OF IONOSPHERIC ANOMALIES DURING SUDDEN STRATOSPHERIC WARMINGS

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Abstract

Recent studies have demonstrated large variations in the ionosphere during sudden stratospheric warmings (SSW), and a debate has started about the mechanisms driving this change and relative importance of solar and lunar tides in ionospheric variations (see review Chau et al., [2012]). Limited experimental evidence also suggests that largest ionospheric variations associated with SSW are observed in the American longitudinal sector [Goncharenko et al., 2013]. We analyze experimental data from several observational techniques (GPS receivers, digisondes, incoherent scatter radars) and conclude that South America is a prime location for observations of these effects. Further improvements in availability and quality of data at different atmospheric regions (troposphere, stratosphere, mesosphere and ionosphere) will help to understand contributions of different mechanisms responsible for these anomalies.

Method

We use observations by GPS TEC receivers along 75°W, several digisondes located at low and middle latitudes, and Arecibo and Millstone Hill incoherent scatter radars to investigate large-scale ionospheric disturbances for several SSW events. To separate ionospheric anomalies during SSW from regular ionospheric behavior, we develop empirical models 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 lon/lat bin (or digisonde location) as a function of solar activity, geomagnetic activity, day of year, and local time. Ionospheric anomalies are obtained as difference between observations and empirical model.

Results

Analysis of anomalies shows that they 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. SSW-associated variations are pronounced more strongly in NmF2 than in TEC. The largest variations in TEC in the daytime are observed both in the crests of equatorial ionization anomaly and at 40-60°S (geodetic). Variations in TEC and NmF2 are even discernable up to high latitudes (70°S) in the Southern Hemisphere and mid-latitudes (42°N) in the Northern Hemisphere.

In addition, we report a deep decrease in TEC that reaches ~70% of the background level and is observed between the local midnight and local sunrise (6-12UT). This decrease is observed for several consecutive nights in the range of latitudes from ~60°S to ~45°N, maximizes in the Southern Hemisphere (~40°S-10°N), and is accompanied by a spread-F development. Figure 1 presents a change in TEC (expressed as percentage of background level) observed on January 16, 2013, geomagnetically quiet day during major SSW. Both Arecibo and Millstone Hill radars observe a strong downward plasma motion and a significant decrease in ion temperature during deep depletions of electron density.

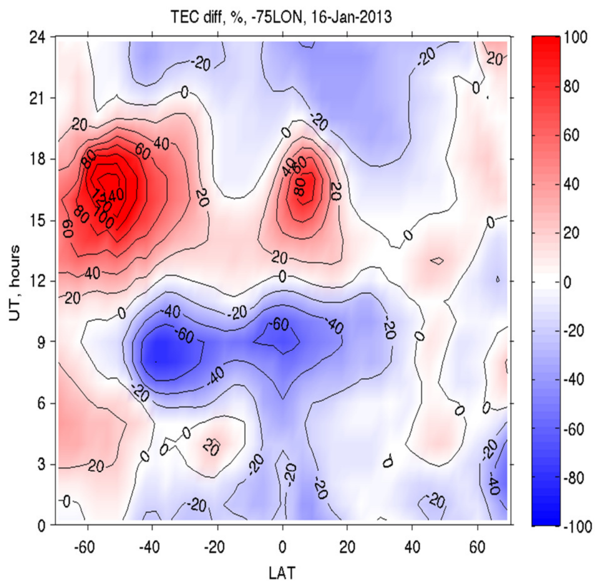

Figure 1. Change in TEC (expressed as percentage of the background level) observed on January 16, 2013, geomagnetically quiet day during major SSW.

Conclusion

We use multi-year observations from different techniques to investigate ionospheric effects of sudden stratospheric warmings and report several different ionospheric anomalies. These effects are observed during both daytime (12-24 UT) and nighttime (~0-12 UT) and in a large range of latitudes, from ~70°S to ~45°N. Ionospheric anomalies maximize in the latitudinal region ~60°S to ~20°N and can be studied best with additional measurements in South America. Explanation of this rich variety of ionospheric anomalies requires involvement of several drivers controlling ionospheric behavior, including solar and lunar tides, changes in the thermospheric dynamics at F-region altitudes, and changes in thermospheric composition. Connection of these drivers to stratospheric and mesospheric behavior during SSW opens an opportunity to explore several mechanisms responsible for altitudinal and interhemispheric coupling of different atmospheric regions, and presents an ongoing challenge for the observational and modeling research communities.

References

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