Ionospheric effects of recent stratospheric sudden warmings

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Abstract

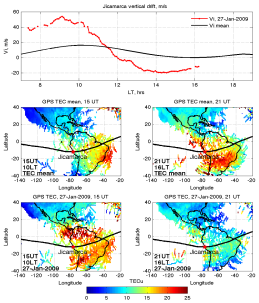
Recent studies have shown large variations in low-latitude ionospheric parameters occurring after stratospheric sudden warming events. We use observations of vertical ion drift from Jicamarca ISR and GPS total electron content data in the Western Hemisphere for winters of 2008-2009 and 2009-2010 to illustrate main features of ionospheric changes related to stratospheric sudden warmings. The common feature in all events is the increase in the electron density during the morning hours and the decrease in the afternoon, related to amplification of 12-hour signature in low-latitude vertical ion drifts. This feature persists for several days after the peak in stratospheric temperature. The observed phenomena is related to quasi-stationary planetary waves, which have a high amplitude level prior to the stratospheric warmings. Non-linear interaction of planetary waves with tides leading to increase in tidal amplitudes in the low latitude lower thermosphere and modulation of E-region electric field with subsequent mapping to the F-region is thought to be the primary mechanism responsible for the observed ionospheric response. We investigate the characteristics of ionospheric oscillations with planetary wave periods between 2 and 30 days and in a wide range of latitudes in context of variations in stratospheric parameters.

Summary and conclusions

1. Evidence of dramatic changes in daytime Jicamarca electric field data and daytime electron density during January 2009 and January-February 2010 stratospheric sudden warmings. We rule out solar or geomagnetic activity as possible drivers.
2. Strong tidal signature in both electric field and GPS TEC; the feature persists for several days after the peak warming.
3. January 2009 SSW event is associated with increase in TEC in the morning by 50-150%; suppression in the afternoon by ~50% [*Goncharenko et al., 2010*]; a weaker January 2010 SSW event produces ~50% depletions in the afternoon TEC.
4. TEC data at 75oW shows oscillations with periods 2-3, 5, 8, 10 and 16 days during both winters. Strong 2-day activity subsides during both SSW events.
5. Analysis of stratospheric parameters indicates that planetary wave activity in the stratosphere is limited to 40-80N and peaks 6-8 days prior to the peak in stratospheric temperature; high-latitude stratospheric warming is accompanied by stratospheric cooling at tropical latitudes and increase in total ozone at high latitudes and tropical latitudes.
6. Variations in total ozone could potentially contribute to the variability of the semidiurnal tide excited by ozone heating.

1. Winter 2008-2009

1.1. Ionospheric variations



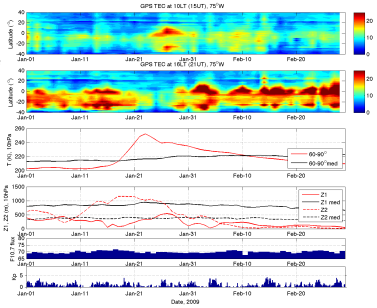


Figure 1. Observations of ionospheric behaviour during stratospheric warming. *Top*: Vertical drift observations by Jicamarca radar. *Middle*: mean TEC at 15 UT and 21 UT illustrate typical TEC without SSW. *Bottom*: TEC at 15 UT and 21 UT on Jan 27, 2009, during SSW.

Figure 2. Temporal variation in TEC at 10 LT and 16 LT. Maximum disturbances in TEC occur several days after the peak in SSW.

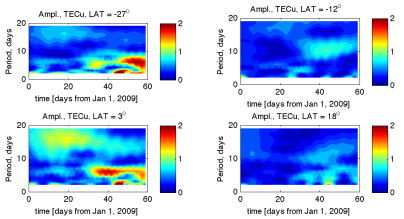


Figure 3. Amplitude of planetary wave-type oscillations in TEC as function of time and wave period for longitude 75W and several latitudes (27ºS, 12ºS, 3ºN, 18ºN – crests of EIA, magnetic equator, and latitude above northern crest). Strongest oscillations are found for the 2-day and 5-6 day periods, though 10 day and 16-day waves are also present.

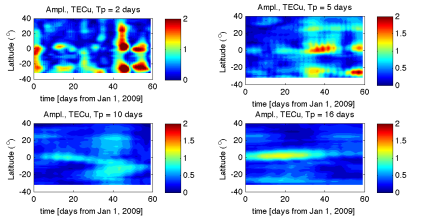


Figure 4. Amplitude of planetary wave-type oscillations in TEC as function of time and geographic latitude for selected wave periods. The 2-day wave activity is dominant and reaches 2-4 TECu in the EIA crests. Decrease in the 2-day wave is observed during the SSW event at different latitudes. Increase in 5-day waves is observed after day 30.

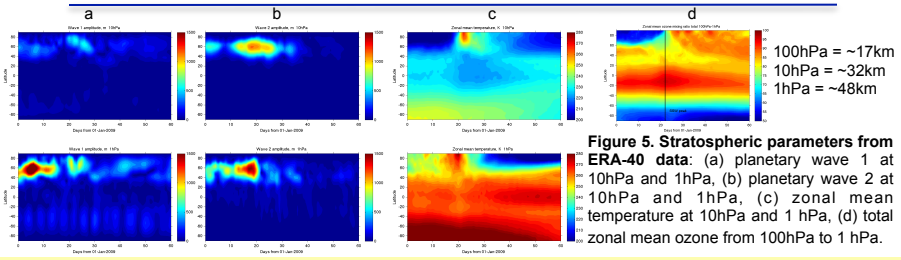
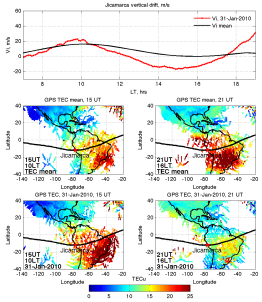


Figure 5. Stratospheric parameters from ERA-40 data: (a) planetary wave 1 at 10hPa and 1hPa, (b) planetary wave 2 at 10hPa and 1hPa, (c) zonal mean temperature at 10hPa and 1 hPa, (d) total zonal mean ozone from 100hPa to 1 hPa.

Reference: Goncharenko et al, (2010), Unexpected connections between the stratosphere and ionosphere, *GRL*.

2. Winter 2009-2010

2.1. Ionospheric variations



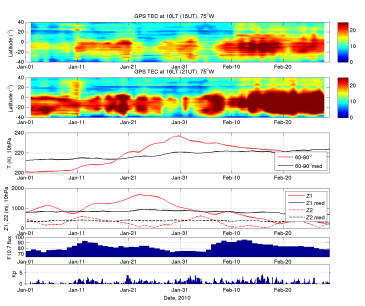


Figure 6. Observations of ionospheric behaviour during stratospheric warming. *Top*: Vertical drift observations by Jicamarca radar. *Middle*: mean TEC at 15 UT and 21 UT illustrate typical TEC without SSW. *Bottom*: TEC at 15 UT and 21 UT on Jan 31, 2010, during SSW.

Figure 7. Temporal variation in TEC at 10 LT and 16 LT. Maximum disturbances in TEC occur several days after the first peak in SSW. Increased solar and geomagnetic activity complicates interpretation.

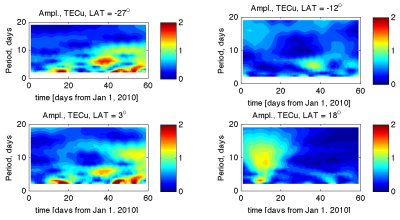


Figure 8. Amplitude of planetary wave-type oscillations in TEC as function of time and wave period for several latitudes (27ºS, 12ºS, 3ºN, 18ºN – crests of EIA, magnetic equator, and latitude above northern crest). Strongest oscillations are found for the 2-day and 5-6 day periods, though 8-10 day and 16-day waves are also present.

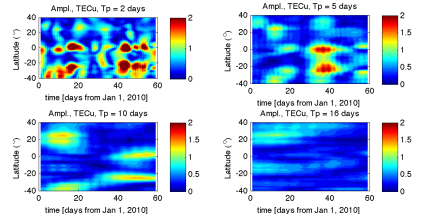


Figure 9. Amplitude of planetary wave-type oscillations in TEC as function of time and geographic latitude for selected wave periods (2-day, 5-day, 10-day, 16-day). The 2-day wave activity is dominant and reaches 4 TECu in the EIA crests. Decrease in the 2-day wave is observed during the SSW event, similarly to SSW 2009 case. Complex patterns are observed for other wave periods.

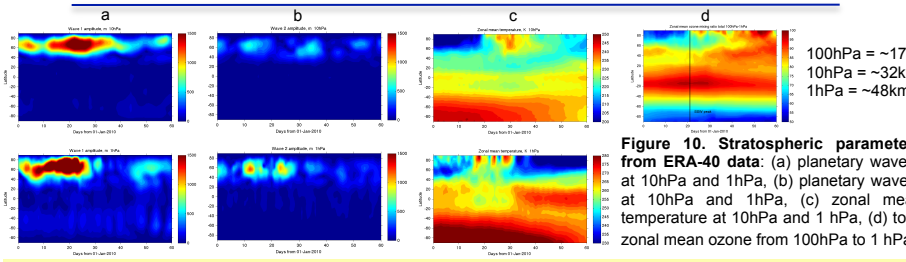


Figure 10. Stratospheric parameters from ERA-40 data: (a) planetary wave 1 at 10hPa and 1hPa, (b) planetary wave 2 at 10hPa and 1hPa, (c) zonal mean temperature at 10hPa and 1 hPa, (d) total zonal mean ozone from 100hPa to 1 hPa.

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