Equatorial Zonal Electric Fields during the 2002-2003 Sudden Stratospheric Warming Event

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INTRODUCTION

For nearly fifty years, the Jicamarca Radio Observatory (11.95°S, 76.87°W, 2°N dip latitude) near Lima, Peru, has measured ionospheric plasma drifts. Over the last ten years, measurements of plasma drift velocities have also been measured using radar observations of the equatorial 150 km altitude region (*Kudeki and Fawcett, 1993; Chau and Woodman, 2004*). Many studies have examined the day-to-day variability of ionospheric plasma drifts (e.g. *Fejer and Scherliess, 1997)*. Understanding this variability is essential to improve models of the ionosphere and thermosphere (*Chau et al., 2009*).

Strong evidence has recently been presented that during sudden stratospheric warming (SSW) events, the equatorial vertical **ExB** drifts develop distinct and unique semidiurnal patterns, namely an increase in upward drift velocities in the morning, and an increase in downward velocities in the afternoon (*Chau et al., 2009*). SSW events are defined by a sudden increase in stratospheric temperature and a decrease or reversal of zonal winds in high latitudes (e.g. *Liu and Roble, 2002*).

In this work, we examine the December 2002 – January 2003 SSW events using equatorial **ExB** plasma drift data from Jicamarca and electrojet measurements by the CHAMP satellite to study the relationship between SSW events and the equatorial thermosphere.

DATABASE

The data we used are from two primary sources. **ExB** drift velocities and magnetic field measurements were taken by the Jicamarca Radio Observatory incoherent scatter radar and magnetometer, respectively. The plasma drift velocities were derived from the motion of 150 km echoes in the time range between 0900 and 1600 solar local time and also from magnetometer observations. Data for 150 km echoes are available December 27, 2002 – January 6, 2003, so since measurements are sparse for the rest of January, magnetometer-derived velocities are used for that time.

The second source is the German satellite CHAMP. Launched July 15, 2000, one of its missions is to provide observations of the magnetic field to study long-term temporal variations. The satellite orbits once every 94 minutes in a near-polar orbit (*Lühr et al., 2004*). The satellite precesses in its orbit. The orbital plane takes four months to precess through all local times. As a result, daily measurements are taken around five minutes earlier than the previous day. This precession has been taken into account in the analysis.

Results

Figure 1 shows the three major SSW events, namely December 28-January 6, January 15-20, and January 24-29. None of these events show a reversal of zonal winds, so these are all classified as minor events. All three events are associated with low magnetic (Kp) activity.

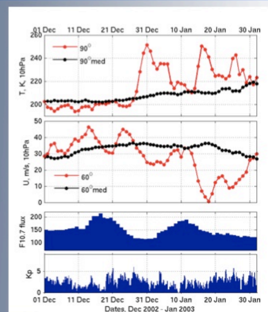

Figure 1. The first panel plots the 10 hPa temperature for December 2002 and January 2003 SSW events at 90°N latitude, in comparison with the mean. The three events peak on December 31, 2002, January 16, 2003, and January 26, 2003. The second panel plots the 10 hPa winds at 60°N latitude, in comparison with 60°N mean. The bottom panels shows the decimetric solar flux and the Kp indices. The Kp index is low for the SSW events.

Figure 2 shows that beginning on December 21, the two-day modulation begins to form in the afternoon, returning to normal values around December 30. The modulation is seen by noting the alternation between above-average and below-average measurements in the afternoon sector (after 1800 UT).

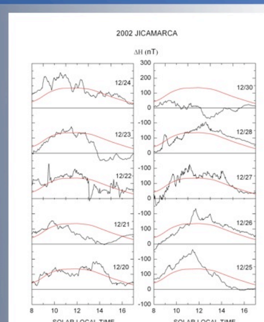

Figure 2. Magnetometer observations for December 20-30 and the quiet-time average (in red). This figure shows the two-day modulation in the afternoon sector (after 1800 UT) preceding the first SSW event. The modulation is most apparent December 21 through the end of the month.

Figure 3 displays the first event drift velocities. The quiet-time average is based on echoes measured before the SSW events, precisely December 9-13, 15-16, 2002. Figure 1 confirms this time period to be quiet. The drifts have a clear semidiurnal pattern, moving with a positive perturbation in the morning, and a negative perturbation in the afternoon.

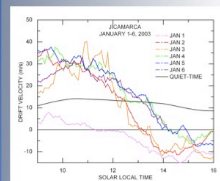

Figure 3. **ExB** drift velocities (positive upward) from 150 km echoes for the first January 2003 SSW event compared to the quiet-time average. This figure shows the semidiurnal pattern presented by *Chau et al. (2009)*.

Figure 4 shows the evolution of drift perturbations during both SSW events. Each exhibits a trend of increasing downward drifts throughout the day, followed by increasing morning upward and increasing afternoon downward drifts. The second event is displayed for January 19 through January 23, because the data up to and including January 18 and beginning again January 24 is disturbed, showing high variations due to magnetic activity.

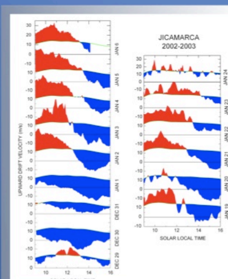

Figure 4. Departures of **ExB** drift velocities from the quiet-time average. Red signifies a positive departure, and blue a negative departure

Figure 5 displays the second event drift velocities. The derivation creates a morning bias, so morning velocities should be greater than what is shown (see figure 6). Even with the bias, however, a diurnal pattern similar to the first event is present.

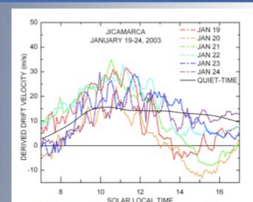

Figure 5. **ExB** drift velocities derived from magnetometer data for the second January 2003 SSW event compared to the quiet-time average.

Figure 6 is a plot of average plasma drift velocities for January 2-6, 2003, comparing the 150 km echoes to the velocities derived from magnetometer data. The derived values in the afternoon are relatively good approximations. Derivations in the morning sector, however, greatly underestimate the true value.

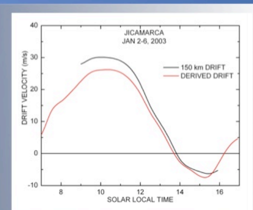

Figure 6. Averaged 150 km drift velocities and averaged drift velocities derived from magnetometer data for the first SSW event in January.

Figure 7 illustrates that during the two events (January 2-6, 19-24, 2003), the diurnal pattern displayed in figure 2 is again clear, with maximum upward drifts in the morning, and maximum downward drifts in the afternoon. There is also a clear temporal progression as the maximum upward drifts occur later in the day as the days progress. Also apparent is the occurrence of two-day modulations, or two-day waves.

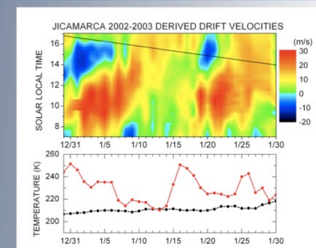

Figure 7. Derived drift velocities (positive upward) for January 2003 as a function of local time. The black line represents the time that the CHAMP satellite passed near Jicamarca's longitude. The lower panel plots the 10 hPa temperature and running average at 90°N. Note the relationship of the temperature peaks and upward drifts.

Figure 8 illustrates the electrojet current density as a function of longitude. The westward currents during both events are seen at all longitudes. In addition, there is a longitudinal progression of maximum and minimum values to more eastern longitudes. Delays in SSW event responses have been observed, and may be due to this longitudinal variation (e.g. figure 7 shows the second event peaks on January 16, but doesn't appear at Jicamarca until January 19). The density values along the Jicamarca longitude match with the drift velocities at the time of CHAMP measurement shown in figure 7.

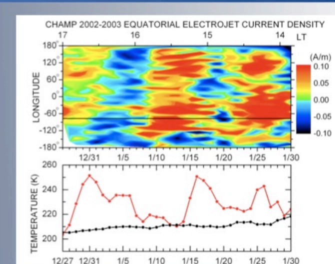

Figure 8. Equatorial electrojet densities measured by the CHAMP satellite. Eastward current densities are positive values, and westward are negative. The upper scale refers to the local time of the satellite measurement. The black line represents the longitude of the Jicamarca Observatory. The lower panel illustrates the 10 hPa temperature and running average at 90°N. Note the relationship of the temperature peaks and westward currents.

Conclusion

The December 2002-January 2003 SSW events show significant vertical plasma drifts and equatorial electrojet current perturbations. The perturbation patterns shown by Jicamarca and by the CHAMP satellite are in excellent agreement. These perturbations occurred at or near the same time as the peaks in the 10 hPa peak temperatures, but has a time delay greater than reported by *Chau et al. (2009)* for the January 2008 SSW event. This illustrates the complexity of the equatorial ionospheric response to sudden stratospheric warming.

References

Chau, J. L., B. G. Fejer, and L. P. Goncharenko (2009), Quiet variability of equatorial **E × B** drifts during a sudden stratospheric warming event, *Geophys. Res. Lett.*, *36*, L05101, doi:10.1029/2008GL036785.
Chau, J. L., and R. F. Woodman (2004), Daytime vertical and zonal velocities from 150-km echoes: Their relevance to *F*-region dynamics, *Geophys. Res. Lett.*, *31*, L17801, doi:10.1029/2004GL020800.
Fejer, B. G., and L. Scherliess (1997), Empirical models of storm time equatorial zonal electric fields, *J. Geophys. Res.*, *102*(A11), 24,047–24,056.
Liu, H.-L., and R. G. Roble (2002), A study of a self-generated stratospheric sudden warming and its mesospheric–lower thermospheric impacts using the coupled TIME-GCM/CCM3, *J. Geophys. Res.*, *107*(D23), 4695, doi: 10.1029/2001JD001533.
Lühr, H., S. Maus, and M. Rother (2004), Noon-time equatorial electrojet: Its spatial features as determined by the CHAMP satellite, *J. Geophys. Res.*, *109*, A01306, doi:10.1029/2002JA009656.
Kudeki, E., and C. D. Fawcett (1993), High resolution observations of 150 km echoes at Jicamarca, *Geophys. Res. Lett.*, *20*(18), 1987–1990.