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Analysis of Traveling Ionospheric Disturbances during Stratospheric Warming Events

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ABSTRACT

A sudden stratospheric warming (SSW) is an event where the polar vortex in the winter hemisphere slows down or reverses direction over the course of a few days. This is accompanied by a rise of 10's of degrees K in the stratospheric temperature. SSW's are the most dramatic meteorological events in the stratosphere. Recent work by Goncharenko and Zhang, [1] established the first connection between the SSWs and the ionosphere. Chau et al. [2] reported on the first observed major changes in the equatorial ionosphere following SSW events. Mechanisms by which these atmospheric regions "couple" is currently an active research area. Gravity waves, tides, planetary waves and their interaction with zonal winds all play a role.

This paper is a continuation of a study by Frissell et al. [3], and specifically focuses on their findings related to traveling ionospheric disturbances (TIDs) observed during SSW events. TIDs are a manifestation of atmospheric gravity waves, and it is thought that energy from the stratosphere can reach the thermosphere via horizontally and vertically propagating atmospheric gravity waves. This is modulated by a filtering process within the atmosphere where the zonal wind system selectively allows propagation of only a portion of the gravity wave spectrum. Once the atmospheric gravity waves reach the ionosphere, they can manifest themselves as traveling ionospheric disturbances (TIDs). As the stratospheric zonal wind flow rapidly changes during SSW events, variations in the properties of TIDs can be anticipated. Studying and quantifying the TIDs observed during SSW periods may help illuminate how energy is being exchanged between the different regions.

Although our primary interest is in the SSW findings reported by [3], it is useful to summarize their main results. Their paper presents a TID analysis of 3 years worth of Super-DARN data.

In their data processing, they select out TIDs that have horizontal sizes of 150 to 650 km and horizontal phase speeds of 75 to 325 ms^{-1}, or medium-scale (MS) TIDS. By quantifying the number of observed MSTIDs at the various mid-latitude and high-latitude SuperDARN sites, they were able to define an MSTID index. Using this index, they are able to observe an increase in MSTID activity during November 2012 to mid January 2013, followed by a decrease in MSTID activity from mid Jan 2013 to the end of April 2013. In addition, embedded in these larger categories are 2-4 week enhancements and depressions of MSTID activity. Of significance here, is that one large depression of MSTID activity is observed from 8 to 30 January. This corresponds to a time period of a major and long-lasting sudden stratospheric warming during moderate-to-high solar activity conditions [4]. Furthermore, their analysis shows that there is significant correlation between the MSTID index and what they refer to as the polar vortex index. Larger positive values of the polar vortex index indicate that the vortex is more coherent while larger negative numbers indicate a more disrupted polar vortex. They observed significant correlation between the MSTID index and the polar vortex index, suggesting that SSW phenomena somehow influence MSTID formation, or lack there of, in the ionosphere. It is also worth noting that they also observed no clear correlation with geomagnetic indices, AE or Sym-H.

For our study, we have used new GNSS processing capability developed by Vierinen et al., [5] to observe TID activity during the January 2013 time period. Figure 1 presents a sample of results for 16 January 2013. This is a time period that is associated with the January 2013 SSW, and has low geomagnetic activity throughout the day and medium solar flux. Large-scale, well-structured TIDs are clearly observable throughout the day, as illustrated in Figure 1, propagating in the southwest and southeast directions. These TIDs would not have been observed by [3] as they would have been filtered out. The morning and evening TIDs in Figure 1 are most likely related to the solar terminator, but their persistence and size are unusual. A lack of MSTIDS is observed during the daytime hours, similar to what is observed by [3]. Other SSW events have been processed to show similar results (e.g., January 2009). We examine this activity with regard to the strength and direction of the middle atmospheric wind flow.

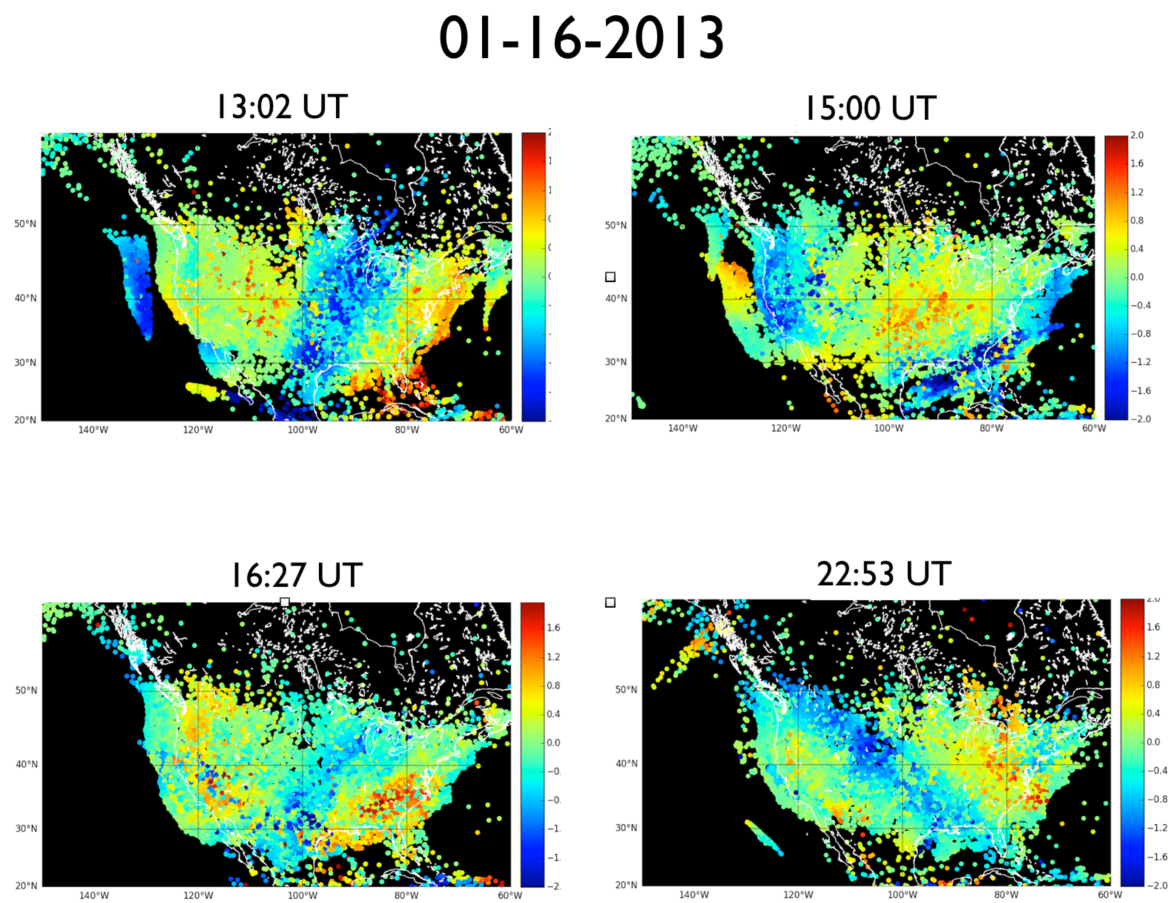

Figure 1. Observations of large scale TIDs over the US during the SSW of 16 January 2013.

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