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Variabilities of mesospheric tides during sudden stratospheric warming events of 2006 and 2009 and their relationship with ozone and water vapour

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ABSTRACT

The present study demonstrates how the relationship between the high latitude northern hemispheric major sudden stratospheric warming (SSW) events of 2006 and 2009 and low-latitude mesospheric tidal variability in zonal winds observed by the MF radar at Tirunelveli (8.7°0N, 77.8°E) exists. It is found that the ozone mixing ratio increases at low latitudes during the SSW and it could probably be due to the SSW induced reversal of meridional circulation towards southward, which may aid the transport of ozone from high to low latitudes, but prevent the same from low to high latitudes. As semi-diurnal tide is produced due to solar insolation absorption of ozone and the increase in the ozone mixing ratio could be a reason for the increase in the semi-diurnal tidal amplitude. The variabilities of diurnal tide appear to be governed mostly by variation of specific humidity at 300 hPa over equator and intraseasonal variability dominates the variabilities in both the parameters.

1. Introduction

One of the most prominent phenomena observed in the winter stratosphere is the development of sudden stratospheric warming (SSW; see McIntyre (1982), for a tutorial review). These large disturbances are the consequence of the interactions between vertically propagating planetary waves and the zonal winds (Matsuno, 1971; Holton, 1976). These planetary waves produce a significant poleward and downward transport of lower-latitude ozone. Manney et al. (1994a) noted decrease of ozone in the Arctic lower stratosphere during February and early March 1993, when a major SSW event occurred and the decrease was attributed to chemical loss in the presence of nitrous oxide and methane, though dynamical effects were not altogether neglected. Understanding variabilities of ozone in particular during the SSW events is important to understand the variabilities of tides, as the forcing of the semi-diurnal tide, in particular, is mainly due to the absorption of ultraviolet radiation by ozone in the stratosphere and mesosphere. The stratospheric warming effects on tidal propagation at high latitudes have been reported in the past in a few studies (Bhattacharya et al., 2004; Hoffmann et al., 2007; Jacobi et al., 1999). Recently, Sridharan et al. (2009) noted enhancement in semi-diurnal tidal amplitude and suppression of diurnal tide in zonal winds at 88 km over Tirunelveli, a low-latitude site. As it is not clear how the low-latitude tidal variabilities are related to the occurrence of SSW events, Sridharan et al. (2009) suggested that the low-latitude mesospheric tidal variabilities during major SSW events could be ascribed to the non-linear interaction between tides and planetary waves, variability of ozone in the stratosphere and/or convective activity associated with latent heat release in the equatorial troposphere and subsequent to meridional circulation associated with the SSW events. Recently, Pedatella and Forbes (2010) demonstrated close relation between the planetary wave activity at high latitude northern hemisphere and non-migrating semi-diurnal tide in the low-latitude ionosphere. In the present paper, the ozone variabilities at high and low latitudes are reported during major warming events of 2006 and 2009 and their relationship with the variabilities of mesospheric tidal amplitudes at 90 km is presented.

2. Observations and data analysis

2.1. MF radar at Tirunelveli

The MF radar (1.98 MHz) at Tirunelveli (8.7°N, 77.8°E) has been giving nearly continuous wind information in the upper mesospheric region (78–98 km) since November 1992 (Rajaram and Gurubaran, 1998). The wind measurements, sampled for every 2 min, are averaged for each hour and used for further analysis. Though the winds are measured every 2 km, the data acceptance rate, based on several data rejection criteria (Briggs, 1984), is higher only above 84 km. Moreover, the wind measurements by the radar above 92 km appear to be contaminated by electric field

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and the radar tends to measure electron drift motion rather than neutral winds at these heights (Gurubaran and Rajaram, 2000). Hence, for the present study, the tidal amplitudes are computed for zonal winds at 90 km using a least squares harmonic fit over a five-day composite window of hourly wind values, which is successively forwarded every day to obtain the daily variation. The five-day window is chosen so that it will average out all incoherent wind variations due mostly to gravity waves.

2.2. ERA-interim data

In this paper, we use a few ERA-Interim parameters, namely, zonal winds, temperature and specific humidity, available for the 37 pressure levels from the surface to 1 hPa at the ECMWF (European Center for Medium Range Weather Forecasting) website (http://www.ecmwf.int/research/era/do/get/index). These data were prepared by ECMWF using their variational data assimilation system. The ERA-interim data set consists of results from analysis conducted at six-hour intervals available for a 1.5° latitude–longitude grid.

2.3. SABER ozone and temperature observations

The present study also utilizes version 1.07 of processed level 2 ozone volume mixing ratio (VMR) and temperature data from the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on the Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics (TIMED) satellite available in the website http://saber.gats-inc.com/. The SABER uses CO_2 emission from two 15 μm channels for temperature profiles (Remsberg et al., 2008) and two independent techniques, 1.27 μm emission from molecular oxygen and the strong 9.6 μm emission from ozone itself, for determining ozone profiles in the mesosphere and lower thermosphere (Smith et al., 2009). The emission from ozone itself in the strong 9.6 μm band provides a method for observing ozone both day and night as the origin of this emission is thermal in nature. For the present study, ozone measurements at 9.6 μm are used. The ozone values are averaged for the latitudes 5°S–5°N, 5°N–15°N, 15°N–25°N and so on to represent, respectively, the latitudes 0°, 10°N, 20°N and so on. It may be noted that at mesospheric heights, ozone undergoes a significant diurnal variation. However, as daytime ozone data have many gaps, in order to maintain uniformity, zonal mean and night-time averaged ozone and also temperature are presented in this paper. There are gaps in the temperature and ozone data beyond 50°N poleward, at times, when the TIMED satellite yawed around and pointed SABER instrument towards southern hemisphere. The sampled local solar times of ozone and temperature by TIMED–SABER are given for both cases (2005–06 and 2008–09) in Fig. 1 for all latitudes. It may be noted that the sampled time is not same and there is a gradual change from one night to next night. It may affect the results only at upper mesospheric altitudes, where there is a change in the ozone mixing

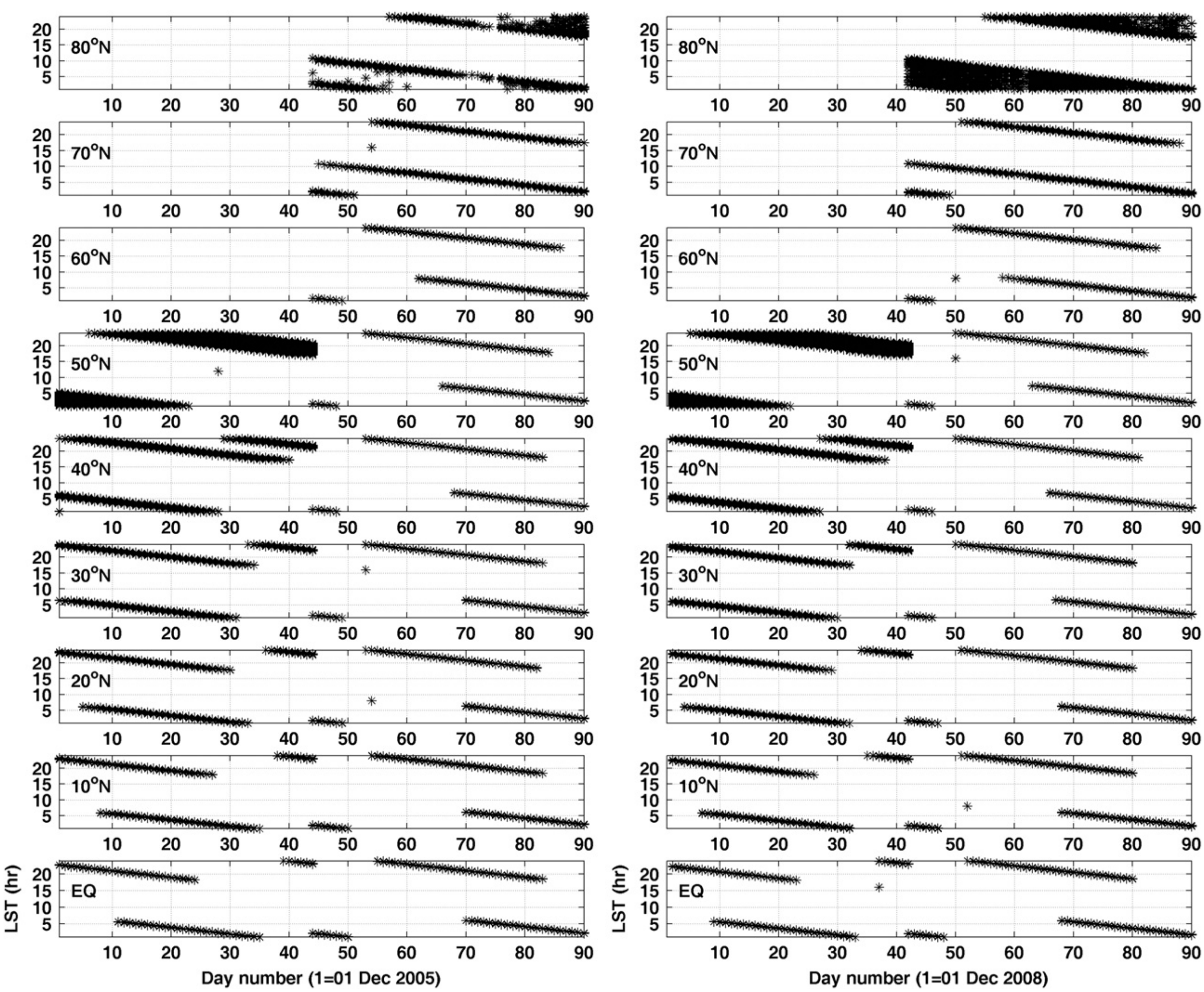

Fig. 1. Sampled local solar time of TIMED-SABER instrument during night-time for a time interval of 1–90 days starting from 01 December 2005 (left panels) and from 01 December 2008 (right panels).