Journal of Atmospheric and Solar-Terrestrial Physics 110-111 (2014) 37–49

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Interannual variability of the nonmigrating semidiurnal tide at high latitudes and stationary planetary wave in the opposite hemispheres

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ARTICLE INFO

Article history:
Received 1 July 2013
Received in revised form
3 January 2014
Accepted 7 January 2014
Available online 23 January 2014

Keywords:
Nonmigrating semidiurnal tide
Stationary planetary wave
Interannual variation
Nonlinear interaction

ABSTRACT

The westward propagating zonal wavenumber 1 nonmigrating semidiurnal tide (SW1) enhanced at high latitudes during summer in the mesosphere and lower thermosphere (MLT) is believed to originate from the nonlinear interaction between the migrating semidiurnal tide (SW2) and the stationary planetary wave zonal wavenumber 1 (SPW1) in the opposite winter hemispheres. This paper presents correlations of the SW1 over the Antarctic and Arctic and the SPW1 in the opposite hemispheres. The SW1 is determined from horizontal wind measurements by the TIMED Doppler Interferometer (TIDI) and the SPW1 is from temperature measurements by the Sounding the Atmosphere using Broadband Emission Radiometry (SABER), both aboard the NASA's Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. We focus on the SW1 over the Antarctic and the SPW1 in the northern hemisphere during an interval from mid-September to mid-November, and the SW1 over the Arctic and the SPW1 in the southern hemisphere during an interval from mid-March to mid-May. Large interannual variations of the SW1 and SPW1 are exhibited in both northern and southern hemispheres. For amplitudes of the SW1 at 90 km and 82.5°S, positive correlations are exhibited with SPW1 amplitudes at ~55 km in the equatorial region, and ~25 km and 55°N. Although zonal SW1 amplitude at 95 km and 86.5°N is positively correlated with SPW1 amplitudes at ~30°S above 35 km, meridional SW1 amplitude is negatively correlated with SPW1 amplitudes equatorward of 30°S. We also present results of a correlation analysis for SW3 amplitudes during an interval from mid-January to mid-March over the Antarctic and from mid-July to mid-September over the Arctic with SPW1 amplitudes.

1. Introduction

Atmospheric tides in the mesosphere and lower thermosphere (MLT) are primarily generated from solar thermal absorption in the troposphere and lower stratosphere and grow in amplitude as they propagate to higher altitudes (Chapman and Lindzen, 1970; Forbes, 1995; Kato, 1980; Lindzen, 1990). These tides are waves propagating along a latitude circle with a zonal wavenumber s. Propagation of the migrating tides coincides with the apparent motion of the sun, such as westward propagating $s=1$ for the diurnal tide (DW1) and $s=2$ for the semidiurnal tide (SW2), whereas nonmigrating tides propagate westward, eastward, or are standing (Lindzen, 1979). Nonmigrating tides can be generated by a nonlinear interaction of tides with planetary and gravity waves (Grieger et al., 2004; Mayr et al., 2005; Yamashita et al., 2002), latent heat source in the troposphere (Hagan and Forbes, 2002, 2003; Oberheide et al., 2002; Yoshikawa and Miyahara, 2005; Zhang et al., 2010), and atmospheric heating by longitudinal inhomogeneity of topography (Tsuda and Kato, 1984).

Nonlinear interactions between tides and planetary waves (PWs) result in fluctuations of tide amplitudes. Merzlyakov et al. (2001, 2005) analyzed day-to-day variations of northern midlatitude MLT winds and concluded that variations of semidiurnal tide amplitudes could be explained by the interactions with the 3-day PW with $s\sim3$, 5–6-day PWs with $s=1$, and zonal mean winds. Mitchell et al. (1996) and Beard et al. (1997) found that a short-term variability in semidiurnal tide amplitudes was coincident with a PW activity. Pancheva et al. (2000a, b) also found amplitude variations by a significant nonlinear interaction between tides and PWs with periods of 2–20 days.

The nonlinear interactions are also expected to result in generations of the secondary waves (Hagan et al., 2009; Mayr et al., 1999, 2011) and observed from ground-based measurements (Kamalabadi et al., 1997; Pancheva, 2000; Teitelbaum and Vial, 1991). A 16-h period wave during summer, for example, was found to result from the nonlinear interaction between the semidiurnal tide and the 2-day PW (Manson and Meek, 1986; Rüster, 1994). The terdiurnal tide has also been studied, as a result of the interaction between the diurnal and semidiurnal tides, at low (Venkateswara Rao et al.,

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http://dx.doi.org/10.1016/j.jastp.2014.01.003

2011), middle (Cevolani and Kingsley, 1992) and high latitudes (Beldon et al., 2006; Younger et al., 2002).

The nonlinear interaction for nonmigrating tides was studied by Lieberman et al. (2004) from correlations of day-to-day variabilities between the nonmigrating diurnal tide westward propagating s=2 (DW2) and PW s=1 (PW1) in geopotential height observed by Limb Infrared Monitor of the Stratosphere (LIMS) aboard the Nimbus 7. They found a large correlation at low latitudes as an evidence for the DW2 by the interaction between the DW1 and PW1.

An enhancement of the nonmigrating semidiurnal tide westward propagating s=1 (SW1) in the summer over the Antarctic (Forbes, 1995; Hernandez et al., 1993; Lau et al., 2006; Hibbins et al., 2010; Murphy et al., 2006, 2003) and Arctic (Manson et al., 2009) is expected from the nonlinear interaction between the SW2 and quasi-stationary planetary wave $s=1$ (SPW1) in the stratosphere of the opposite hemispheres (Angelats i Coll and Forbes, 2002; Aso, 2007; Suvorova and Pogoreltsev, 2011). Smith et al. (2007) proposed the nonlinear interaction as a plausible mechanism of the SW1 from variability of the semidiurnal tide observed by a meteor radar at Esrange (68°N, 21°E), Sweden, and SPW1 in geopotential height and temperature of the southern hemisphere from the Sounding the Atmosphere using Broadband Emission Radiometry (SABER) aboard the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. Baumgaertner et al. (2005, 2006) compared seasonal variations of the semidiurnal tide from radar measurements at Scott Base (78°S, 167°E) and Halley (76°S, 26°W) with the SPW1 in geopotential height from the NCEP/NCAR reanalysis and the United Kingdom Met Office (UKMO). Murphy et al. (2009) also examined correlations between the nonmigrating semidiurnal tides above Antarctica and UKMO SPW1 in the northern hemisphere. Furthermore, correlation studies with the UKMO indicated that the SPW1 in the northern winter hemisphere is stronger than in the southern hemisphere (Xu et al., 2009). This supported that the summer Antarctic SW1 is stronger than the Arctic (Iimura et al., 2010).

This paper presents correlations between SW1 amplitudes at high latitudes in the MLT determined from TIMED Doppler Interferometer (TIDI) horizontal wind measurements and stratospheric SPW1 amplitudes in the opposite hemispheres from SABER temperature measurements. From previous studies of the high latitude SW1 by TIDI (Iimura et al., 2009, 2010), the SW1 is enhanced during a yaw interval of the TIMED from mid-September to mid-November in both zonal and meridional winds over the Antarctic while the SW1 is enhanced during an interval from mid-March to mid-May over the Arctic. Therefore, we focus on interannual variations of the SW1 and SPW1 in these yaw intervals. Section 2 diagnoses structures of the nonmigrating tides from TIDI wind and SABER temperature measurements, as well as describing an analysis method. Section 3 presents interannual variations of TIDI SW1 amplitudes at high latitudes and SABER SPW1 amplitudes in the opposite hemispheres, and correlation analyses between them. In Section 3, we also present correlations between SW3 amplitudes over the Antarctic and SPW1 amplitudes during an interval from mid-January to mid-March, and SW3 amplitudes over the Arctic and SPW1 amplitudes from mid-July to mid-September. Discussion and summary are described in Sections 4 and 5.

2. Analysis method and instrumental diagnostics

2.1. Analysis method

TIDI measures horizontal line-of-sight (LOS) winds from 70 to 120 km every 2.5 km, viewing O_2(0–0) p9 emissions at a wavelength of 763.78 nm (Killeen et al., 1999, 2006; Niciejewski et al.,

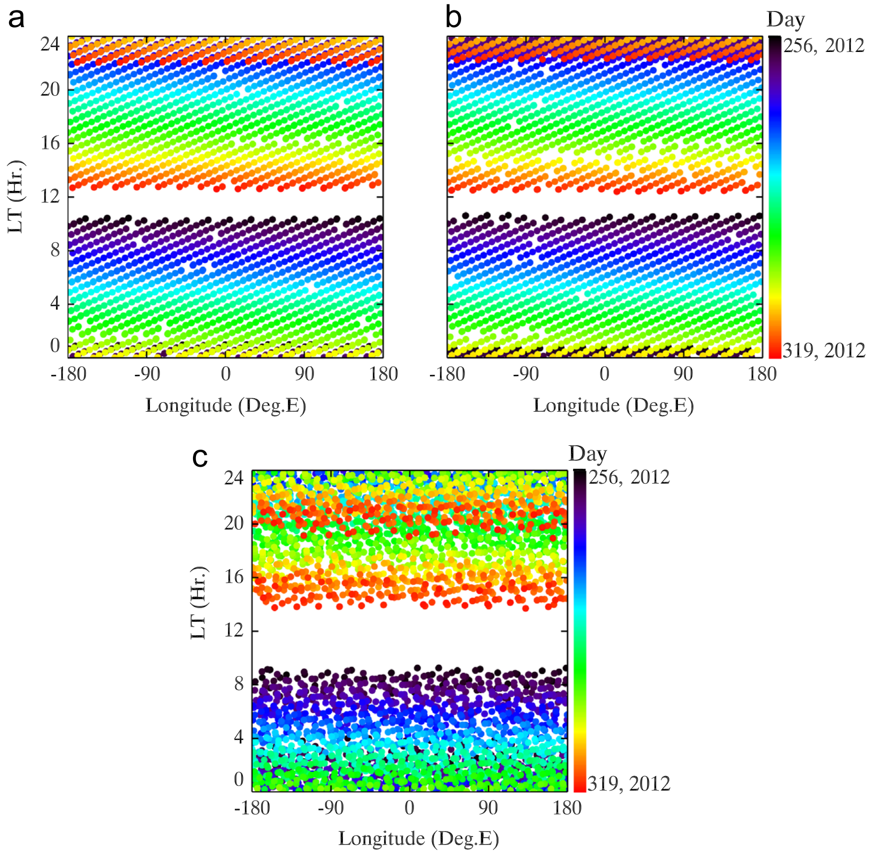

Fig. 1. Longitude and local time distribution of SABER measurements at 90 km at 15°N (top left), 50°N (top right), and 80°N (bottom) during a yaw interval from day 256 to 319, 2012.