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First observation of upper mesospheric semi annual oscillations using ground based airglow measurements from Indian low latitudes

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Abstract

We summarize two years of Mesosphere Lower Thermosphere Photometer (MLTP) operation of mesospheric OH and O_2 emission monitoring. The deduced mesospheric OH and O_2 temperatures show large variability. Nightly temperature variations over Gadanki (13.5°N, 79.2°E) are dominated by the short period wave features, while tidal amplitudes are relatively small. Our measurements are the first to report a long period seasonal variation at two upper mesospheric altitudes simultaneously over the Indian sector. Our observations reveal the presence of a dominant semi-annual oscillation (~6 months periodicity) together with a shorter period (~2.5 months periodicity) oscillation in both OH and O_2 data.

Keywords: Mesosphere; Temperature; Wave; Tides; Seasonal variation; Semiannual oscillation

1. Introduction

It is understood that nocturnal variability in mesospheric temperature and wind fields are characterized by processes associated with gravity waves and tides (Hines, 1960). Similarly, the longer period seasonal variability of middle atmospheric temperature and wind fields is characterized by semi-annual, annual and quasi-biennial oscillations, which essentially are an outcome of myriad processes involving wave–wave and wave–wind interaction (e.g. Hamilton, 1982; Sassi and Garcia, 1997). Among these processes, the semi-annual oscillation is one of the most dominating features in the equatorial middle atmospheric seasonal variability. The semi-annual oscillation, first observed in temperature and zonal wind data (Reed and Rogers, 1962; Reed, 1966), has been an important aspect of study to date. It is understood that the semi-annual oscillation peaks at around the stratopause and its amplitude reduces to a minimum around 65 km (e.g. Hirota, 1980). Above 65 km, the amplitude of the semi-annual oscillation becomes large, reaching a secondary maximum around the mesopause (e.g. Garcia et al., 1997). It is also understood that semi annual oscillation in zonal winds at mesopause altitudes has comparable amplitude to that of the stratopause but with about 180° phase difference (e.g. Hamilton, 1982). Although in recent years, space borne methods have been widely utilized to study the seasonal variability in mesospheric temperatures (e.g. Garcia et al., 1997; Shepherd et al., 2006), ground based measurements provide a complimentary picture having a desired temporal accuracy to account for short period variability. Although there are several reports, using ground based radar wind measurements, of semiannual wave periods in seasonal oscillations at mesospheric altitudes (e.g. Iimura et al., 2010; Kishore Kumar et al., 2008), studies of the semiannual oscillation in mesospheric temperatures are rare over tropical latitudes. The measurement tools utilized to investigate the semiannual oscillation

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in temperature data are either lidar (e.g. Friedman and Chu, 2007; Kishore Kumar et al., 2010) or airglow monitoring of OH (peak emission altitude ~85 km) and O_2 (peak emission altitude ~94 km) species during nighttime (e.g. Takahashi et al., 1995; Taylor et al., 2005).

In particular, over the Indian sector, observations of semi annual oscillations at upper mesospheric altitudes are rare. Although a few studies are available on the presence of semi annual oscillations in mesospheric winds (e.g. Kishore Kumar et al., 2008 and references cited therein), reports on temperatures are limited to lidar investigations, which too are confined to the lower mesosphere (~70 km) (Sivakumar et al., 2001). The only study that reports semi-annual oscillations at upper mesospheric altitudes using ground-based instruments is by Vineeth et al. (2011), which uses daytime OH emission measurements. In this regard, present investigations from Gadanki (13.5°N, 79.2°E), are novel in reporting a semiannual wave periodicity simultaneously observed in mesospheric temperatures at OH and O_2 layers representing ~85 and 94 km altitude regions.

2. Instrument

2.1. Ground based mesospheric OH and O_2 temperature measurements

The Mesosphere Lower Thermosphere Photometer (MLTP) is high precision, photomultiplier tube based, narrow field (full field of view 4°) photometer with F/2 optics. The MLTP measures OH, O_2, $O(^1S)$, $O(^1D)$ and background (at 858 nm) emissions near simultaneously with a time resolution of ~3 min. The interference filters have full width at half maxima (FWHM) of ~0.4 nm. For the present study we utilize the measured band intensities for OH (6–1) and O_2 (0–1) band emissions. The mesospheric OH and O_2 temperatures are computed from the measurements using the ratio method as described by Meriwether (1984). The details and validation of initial results of MLTP measurements are discussed elsewhere (Taori et al., 2011a,b,c). Of importance to note is that mesospheric OH and O_2 airglow emission typically represent 85 ± 5 and 94 ± 5 km altitude regions respectively.

2.2. Space borne mesospheric temperature measurements

To compare the MLTP observed mesospheric OH and O_2 temperatures, we utilize the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) measurements onboard the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite. The temperature values are retrieved from SABER measurements of the atmospheric 15 μm CO_2 limb emission. We use the SABER 1.07 data retrievable from http://www.saber.gats-inc.com/. The SABER measurements have good temperature precision of the order of ±1.4 K in lower stratosphere, ±1 K in middle stratosphere and ±2 K in upper stratosphere and lower mesosphere (e.g., Remsberg, 2008)

For a comparison with ground based measurements, we average the SABER observed temperature profiles for a grid of 10-20°N and 70-90°E during 1800 h IST – 0500 h IST (i.e. nighttime profiles only) for the nights when MLTP observations were made. Further, for an appropriate comparison with ground based OH and O_2 layers temperature measurements, the SABER data were averaged for ±5 km with centroid altitude being 85 and 94 km respectively and a mean monthly value were obtained for those nights. Although, a Gaussian averaging around the centroid emission may provide best comparable value, owing to the fact that layer may vary by 1–3 km within a given night; we opted for box averaging in the present investigation.

3. Observations

Since the MLTP operations started from Gadanki (13.5°N, 79.2°E) in April 2009, routine measurements on the above wavelengths have been carried out during clear, moonless night sky conditions. Because Gadanki is a tropical station in the Indian sector and in the vicinity of the Indian Ocean, cloud-free clear dark nights are very rare. In general, every month about 5 nights of good quality data with measurements over 5 h have been made. However, during monsoon seasons, viz., June, July, August, fewer nights were available. Fig. 1 shows the histogram of composite data obtained from April 2009 to March 2011. One may note that February–March is the best season for the optical observations, during which a maximum of 95 h of monthly observations (with each night representing >5 h of observation duration) could be made while during the monsoon seasons (June, July, August) only 7–16 h of observations were possible to study the seasonal variability. In this report we utilize ~485 h of observations to exhibit the behavior of upper mesospheric temperatures.

In our data we generally note that short period oscillatory features with periodicity less than three hours are prominent in the nocturnal OH and O_2 temperature data (Taori et al., 2011a,b,c). Plotted in Fig. 2(a)[3] are the OH and O_2 temperature measurements of MLTP observations carried out on 22–23 September 2010. The blue filled circles with dashed connecting lines show the mean temperature deviations of OH data while the red open diamonds with connecting lines represent the O_2 data. Large temperature variations with comparable amplitudes in both OH and O_2 data are evident. On this night, amplitudes of short period waves are more than 8 K compared to the tide-like wave exhibiting amplitudes of ~5.5 K (see Fig. 4 for details).

On occasions when such short period features are absent, a tide-like wave feature with periodicity more than

[3] For interpretation of color in Fig. 2, the reader is referred to the web version of this article.