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Long time scale oscillations in OH(3-1) intensities and its temperatures using ground and satellite based measurements

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Abstract

This study explores the long time scale oscillations in the mesosphere and lower thermosphere (MLT) region. In this work we have used ground-based measurement of OH(3-1) band emissions which emanate from 87 km altitude, satellite based observations, and horizontal winds obtained from horizontal wind model. In order to investigate the MLT dynamics over long time scales, we have used daily mean values of OH brightness and its corresponding temperatures, satellite derived volume emission rates (VER), kinetic temperatures, and horizontal winds.

The lower vibrational bands of OH* radicals are in local thermodynamic equilibrium (LTE), allowing the OH(3-1) band emission to accurately derive the ambient temperature from $P_1(2), P_1(3),$ and $P_1(4)$ rotational lines of the OH(3-1) Meinel band. The PRL Airglow InfraRed Spectrograph (PAIRS) operated from the Optical Aeronomy Observatory in Thaltej campus, PRL, Ahmedabad observe the OH(3-1) nightglow emissions in a continuous mode of operation. This instrument captures OH(3-1) band nightglow emissions in the 1.5–1.6 µm spectral region with a resolution of 0.001 µm at 1.532 µm. This resolution is sufficient for deriving rotational temperatures. Long-term observations using PAIRS are conducted from January 2023 to May 2024 which provides OH(3-1) nightglow brightness and temperatures simultaneously. During these observational period of 17 months, 430 clear nights were identified out of 517 observable nights, each having more than 4 hours of continuous observation. In order to explain our findings, we have used complimentary data from SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) on-board NASA's TIMED (Thermosphere Ionosphere Mesosphere Energetics Dynamics) satellite which provide OH 1.6 µm VER and temperature in the MLT region. The horizontal winds were obtained using HWM-14 model.

PAIRS derived brightness and temperature is subjected to Lomb-Scargle periodogram analysis which showed presence of a strong annual oscillation (AO) in brightness and temperatures and semi-annual oscillation in the brightness. It is interesting to note a similar behaviour in the SABER obtained nightly mean brightness and temperatures derived during satellite overpasses at Ahmedabad which provide a total of 209 data points. The Lomb-Scargle periodogram analysis of SABER data shows AO in VER and temperatures and SAO in VER. In the MLT region, solar radiation in the EUV/UV range affects the densities of atomic oxygen [O], atomic hydrogen [H], and ozone (O_3). These elements are essential for the exothermic reactions that produce OH airglow. Hence, it is expected that OH(3-1) nightglow intensity and temperature will be influenced by solar F10.7 flux. Further investigation showed presence of SAO in the F10.7 cm flux. The HWM-14 obtained horizontal wind provides AO and SAO which is also present in the zonal and meridional components. These oscillations underscore the complex interactions between atmospheric waves and provide insight of mesospheric behaviour on seasonal and annual timescales. The findings in this work enhance our understanding of long time scale oscillations present in the MLT and underlying processes for such oscillations.

KEYWORDS: OH(3-1) Nightglow emission, Rotational temperature, AO, SAO, MLT dynamics.