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Vertical Wave characteristics using OH(3-1) brightness and rotational temperature in the MLT region using Krassovsky's ratio method

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Abstract

This study explores the fundamental principles and significance of different spatial and temporal waves in the mesosphere and lower thermosphere (MLT) region. By examining airglow emissions, particularly those from hydroxyl (OH) molecules, we gain valuable insights into the complex processes and overall dynamics of the MLT region. This is primarily due to the ability of OH nightglow emissions to provide information about the ambient temperature. The PRL Airglow InfraRed Spectrograph (PAIRS) has been developed for continuous observation of the OH(3-1) band nightglow emissions emanating from a peak of 87 km altitude is being continuously operated from the Optical Aeronomy Observatory at PRL Ahmedabad (23ºN, 72.6ºE). This grating based spectrograph provides 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 which represent the ambient temperature. With a high data cadence of 100 seconds, PAIRS offers the opportunity to investigate the least explored high-frequency gravity waves in the MLT region. Key characteristics of vertically propagating waves are derived using simultaneous observations of OH(3-1) airglow brightness and corresponding rotational temperature.

This study presents derivation of brightness and temperature from PAIRS-measured OH(3-1) nightglow emissions for the year 2023 and comparison of PAIRS derived temperatures with SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) obtained temperatures of the region at the time of satellite overpasses over observing location. The simultaneous measurement of brightness and temperature have been used to derive vertical wave characteristics (period (τ), vertical wavelength (λ_z), and vertical phase speed (C_z)) in the MLT region using Krassovsky's ratio method. This method relies on observation of (1) coherent periodicities in brightness and temperature and (2) a negative phase difference between brightness and temperature perturbations. In 2023 we have a total of 304 observable nights out of which 226 nights showed coherent periodicities. The downward phase propagation is found in 103 nights showing vertical wave propagation originating from the lower atmosphere in to the MLT region which accounts for 34% nights. The vertical wavelength shows season dependent variations which goes with the present theoretical understanding.

These findings significantly contribute to understand the vertical coupling of the atmospheres due to upward propagating waves which are primarily generated in the troposphere and propagate vertically and horizontally away from the source region and their influence in the MLT region. Such work is possible due to continuous, reliable, and simultaneous measurement of airglow brightness and temperature using OH(3-1) band emissions in the short wave infrared region which is less affected by scattering and stray light compared to the observation made in the visible region. Therefore, this work provides observational evidence of the vertical coupling of the atmosphere and seasonal variations of the derived vertical wave characteristics which is important to compressively understand the forcing in the MLT region due to upward propagating waves. In this paper some of the exciting results pertaining to the vertical wave characteristics in the MLT region obtained from the PAIRS observation in 2023 would be presented.

KEYWORDS: Gravity waves, MLT dynamics, OH(3-1) Nightglow emission, Rotational temperature, Altitude separation in peak emission and peak perturbation in emission, Vertical wavelengths and Krassovsky's ratio method.