VHF radar and lidar observations of high frequency gravity waves from lower troposphere to mesosphere in the tropical region

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In the gravity wave spectrum, frequencies ranging from inertial frequency (low) of the geographical location to the Brunt-Vaisala (BV) frequency (high), it is the high frequency part that contributes to the significant vertical transport of momentum and energy flux up into the mesosphere and the low frequency part that plays a major role in the vertical transport of chemical constituents. Often the high frequency waves retard significantly or induce negative drag on the mesospheric flows and they can easily be incited by convective sources in the lower troposphere over equatorial regions. In the present work, we present the observational results on high frequency gravity waves that are generated in the lower troposphere and propagated deep into the mesosphere using very high frequency (VHF, 53 MHz) radar in the height region of 3.5-21 km and Nd-Yag lidar (532 nm) in the height region of $\sim$25-75 km over the Indian tropical station, Gadanki (13.5˚N, 79.2˚E). For this purpose, we identified a few days during which both the radar and lidar operated simultaneously but for day times in the case of lidar. The frequency spectral analyses carried out for both the radar and lidar data indicates that the high frequency part of the spectrum ($\sim$ 10-50 minutes) is present predominantly at almost all the heights from about 5 km. This would indicate that latent heating associated with low-level convective clouds is an important source of generation of the high frequency gravity waves that have the characteristics to propagate easily up to the mesosphere region. Apart from the frequency spectral analyses, vertical wavenumber spectra also calculated for all the heights. It is found that in the troposphere, the dominant vertical wavelength range is about 0.5 to 2 km and in the stratosphere it is about 2-5 km, indicating that short vertical wavelength gravity waves are filtered in the lower atmosphere and higher vertical wavelength gravity waves are propagated or otherwise the lower vertical wavelengths might have Doppler shifted to higher vertical wavelengths in the stratosphere. Another important observation is that the power spectral density ($\sim$10-50 minutes periodicity) in zonal wind enhances strongly above the tropopause in the vertical wavelength region of 0.5 –2 km. In the case of vertical winds, the spectrum shows enhanced power above about 19 km instead

of immediately above tropopause. In the stratosphere, particularly near stratopause, it seems that gravity waves in the lower vertical wavenumber spectrum ($\sim$2.5 to 5 km) are filtered out and again regenerate at higher heights by extracting energy from higher wavenumber spectrum. Detailed analyses are being carried out on the vertical propagation characteristics of gravity waves in the middle atmosphere using many such data sets.