ABSTRACT

The Earth's upper atmosphere is influenced by the incoming solar radiation from above and upward propagating atmospheric waves from lower atmosphere. The present thesis deals with the understanding of these two influences on the Earth's upper atmosphere. While Earth's upper atmosphere have been studied in the past using all sort of available techniques, there still exist large gap in our understanding of mesosphere lower thermosphere (MLT) region. MLT region is the part of the upper atmosphere where most of the atmospheric waves deposit their energy and momentum affecting overall structure and composition of the middle atmosphere. Therefore, quantitative understanding of the various processes that influence MLT region becomes essential. In this work, the main atmospheric parameters that have been used to understand the various coupling processes in the MLT region are nightglow emission intensities and mesospheric temperatures. Nightglow is a very weak emission occurring in the Earth's upper atmosphere in the infrared, visible, and ultraviolet wavelength regions. These nightglow emissions comes mainly from the recombination processes e.g., when two oxygen atoms recombine to form molecular oxygen. Therefore, intensity of these nightglow emissions depends upon the number densities of the reactants. Hence, by measuring the variations in nightglow emission intensities provides information on the densities of the reactants that is mainly affected by the atmospheric waves and/or solar influences. Measurements of these parameters are carried out mostly by ground- and space-based remote sensing techniques and less frequently using in-situ rocket-based measurements.

In this work, the main focus was to characterize various coupling processes in the MLT region, wave dynamical couplings under varying geophysical conditions, effect of the solar influences in the MLT region, lower- and upper-atmosphere coupling during cyclones, and latitudinal couplings during sudden stratospheric warming (SSW) events. These investigations were carried out

mainly by using ground-based long-term data obtained from couple of in house built instruments namely, Near InfraRed Imaging Spectrograph (NIRIS) and CCD-based Multi-Wavelength Airglow Photometer (CMAP). NIRIS provides nightglow emission intensities and temperatures corresponding to 87 and 94 km altitudes using OH(6-2) Meinel and O_2(0-1) atmospheric band emissions, CMAP provides nightglow emission intensities using sodium doublet line (589.0 and 589.6 nm), OI green line (557.7 nm), and OI red line (630.0 nm) which emanate from 92, 100, and 250 km altitudes, respectively. In addition to these nightglow emission intensities and temperatures, mesospheric temperatures obtained from multiple satellite-based observations, data of F10.7 cm radio flux and SSN number, stratospheric zonal winds and temperatures from reanalysis dataset, OLR data from Kalpna-1 satellite etc. have been used. In the present doctoral thesis entitled "**Investigations of Interactions in The Earth's Upper Atmosphere Using Optical and Radio Wave Techniques**" an attempt has been made for a detailed investigations on the basis of the above stated broad topics. The work carried out in this thesis is presented in six chapters.

In this thesis work, development of a new spectrograph, NIRIS, which is capable of simultaneous measurements of OH(6-2) Meinel and O_2(0-1) atmospheric band nightglow emission intensities have been described. In this spectrographic technique, rotational line ratios are obtained to derive temperatures corresponding to the emission altitudes of 87 and 94 km. In addition to NIRIS, development of a new nightglow photometer, CMAP, to measure the nightglow emission intensities at multiple wavelength is also described. These two instruments have been commissioned for continuous operation from optical aeronomy observatory, Gurushikhar, Mount Abu (24.6^{o}N, 72.8^{o}E).

Large- and small-timescale variations in the mesosphere have been investigated using three (2013-2015) years of O_2(0-1) and OH(6-2) bands nightglow emission intensities and corresponding rotational temperatures as tracers of mesospheric dynamics. The solar activity show different small- and large-time periods along with well known 27 days and 11 years periods. Both O_2 and OH intensities show variations similar to those of number of sunspots and F10.7 cm radio flux indicating a strong solar influence on mesospheric dynamics. In addition, both mesospheric airglow intensities also showed periodicities which are of atmospheric origin. Statistical study were performed using the periodicities derived from the nocturnal variations in all the four parameters (O_2 and OH intensities and their respective temperatures) in order to understand mesospheric gravity wave behaviour over long term.

Vertical coupling of atmospheres during cyclone Nilofar have been studied, wherein, we have observed a common periodicity of around 4-hours in mesospheric nightglow intensities at three emissions (O_2(0-1), OH(6-2) bands, and Na(589.3 nm)) from Gurushikhar, Mount Abu on the night of 26 October 2014. A convective activity due to the cyclone Nilofar, which had developed in the Arabian Sea during 25–31 October 2014, was found to be the source as this too showed a gravity wave period coherent with that of the mesospheric emissions on the 26^{th}. The periodicities at the source region were obtained using Outgoing Longwave Radiation (OLR) fluxes (derived from Kalpana-1 satellite) which were used as a tracer of tropospheric activity. We have derived all the GW parameters (wave period, τ, horizontal phase speed, c_h, horizontal wavelength, λ_h, vertical phase speed, c_z, vertical wavelength, λ_z, and vertical propagation angle, θ_v) which were obtained experimentally from ground-based optical data that exist during cyclone Nilofar. These results thus provide not only unambiguous evidence on the vertical coupling of atmospheres engendered by the tropical cyclone Nilofar, but also the characteristics of waves that exist during such cyclonic events.

Significant enhancements observed in the NIRIS derived mesospheric rotational temperatures at 87 and 94 km altitudes during the major sudden stratospheric warming (SSW) event of January 2013 provided motivation for the further investigation on the global scale. To investigate the relationship of these enhancements in the context of SSW occurrences, a detailed study

was carried out for eleven SSW events that occurred during 2004–2013 using SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) data. In addition to SABER, Optical Spectrograph and InfraRed Imaging System (OSIRIS) and Solar Occultation For Ice Experiment (SOFIE) mesospheric temperatures were also used which showed similar latitudinal behaviour as obtained by SABER. The longitudinal mean mesospheric temperatures at different latitudes of northern and southern hemispheres have been derived. It is found that, during SSW events the well-known mesospheric cooling over the northern hemispheric high-latitudes turns to heating over mid-latitudes and then reverts to cooling closer to equatorial regions. This trend continues into the southern hemisphere as well. These variations in the mesospheric temperatures at different latitudes have been characterized based on northern hemispheric stratospheric temperature enhancements at high-latitudes during SSW periods. In comparison with the CIRA-86 derived temperatures the SABER temperatures show an increase/decrease in southern/northern hemisphere. Such a characterization in mesospheric temperatures with respect to latitudes reveals an hitherto unknown intriguing nature of the latitudinal coupling in the mesosphere that gets set up during the SSW events.

Keywords: Nightglow emissions, Mesospheric temperatures, OH(6-2) and O_2(0-1) rotational temperatures, Mesosphere Lower Thermospheric (MLT) dynamics, Gravity wave characteristics, Tropical cyclone generated gravity waves, Atmospheric coupling, Low-latitude MLT dynamics, Stratospheric mesospheric coupling, Inter-hemispheric mesospheric couplings, Sudden Stratospheric Warming (SSW), Mesospheric inversion layers, Mesospheric temperature inversions, Optical techniques, Near Infrared Imaging spectrograph (NIRIS), CCD-based Multi-Wavelength Airglow Photometer (CMAP).