The incoming solar radiation in the Earth’s atmosphere excites atoms of oxygen and nitrogen in the thermosphere. These excited atoms and molecules can either return to their ground state (un-excited) and emits a photon or collide with other atoms and molecules. These photochemical reactions release energy through chemiluminescence process which is known as airglow emissions. Most reported airglow emissions are associated with sodium (Na), hydroxyl radical (OH), molecular oxygen (O_2), and atomic oxygen (O). Emission of sodium occur at around 92 km altitudes, whereas emissions from OH, molecular oxygen, and atomic oxygen are most concentrated at an altitude of 87 km, 95 km, and 90–100 km, respectively.

Nightglow is very feeble occurring in the visible and infrared region of the spectrum. The illumination in the visible range, which arrives at the ground is as low as the illumination of a candle at a height of 91 meters (300 feet). It is about 1,000 times stronger in an infrared region. Observations from Earth’s surface and data from spacecraft and satellites indicate that most of the energy emitted during nightglow comes from recombination processes. In one such process, radiant energy is released when oxygen atoms recombine to form molecular oxygen, O_2, which had originally dissociated upon absorbing sunlight. In another process, free electrons and ions (notably ionized atomic oxygen) recombine and emit light.

Several intensive studies have been done to pinpoint the emission altitude of the OH Meinel emissions. These include Baker and Stair [1988] who used the composite results from many rocket observations to ascertain the height of the OH Meinel emissions. Their results found, this layer to be at 85 ± 2 km with a full width at half intensity of 6 km. With several rocket measurements it is now established that the unperturbed (6, 2) Meinel band of the hydroxyl radical is emitted from about 85 km altitude and the O_2 (0, 1) atmospheric band is emitted from about 94 km.

The middle atmosphere in 80 to 100 km height range is crucial as it couples the neutral dominated lower atmosphere to the ion dominated the upper atmosphere. The middle atmosphere is the place where much of the atmospheric waves deposit their momentum and energy and also significant photochemical reactions take place. Since this region is difficult to probe, because it is too low for satellite and too far for balloons and rocket flights, most of the studies rely on remote sensing techniques. At altitudes between
80 and 100 km, airglow instruments are the most suitable instrument. Further as the waves are generated in the lower atmosphere; Rayleigh Lidar can be utilized in the altitude range viz 30-80 km to complement the airglow measurements.

The present thesis attempts a detailed investigation on the basis of above stated facts. To understand the low-latitude middle atmospheric variability, a long-term database of high-resolution observations made by MLTP (2009-2014) along with co-located Rayleigh Lidar (1998-2013), and space borne measurements of SABER (2002-2014) have been used. The present thesis titled “Investigation of middle atmospheric variability over Indian low latitudes by optical means” consists of seven chapters. The chapter wise description of the present work is summarized as follows:

Chapter-1 gives necessary background information on the atmospheric structure and composition and atmospheric stability. A portion of the chapter is devoted to basic mathematics and physics that is required for understanding the gravity waves, and their sources, dispersion relations and propagation characteristics. Brief information about the classification of airglow and nightglow emission mechanisms is presented.

In Chapter-2, the brief description of MLTP is presented. The MLTP uses 7 narrow band interference filters, namely, 840 nm & 846 nm for OH, 866 nm & 868 nm for O₂, 857 nm for background, 557.7 nm (O¹S) and 630 nm (O¹D). These are fixed to the aluminum plate which rotates with the help of stepper motor controlled by the microcontroller 8051. The temperature of the filter chamber is maintained using thermoelectric temperature controlling unit which uses an array of Peltier elements. The received signal collected by the PMT are sent to counting unit and then to the data acquisition system. The data acquisition software has been developed using of programmable language visual basic.

Chapter-3 provides the technical details of supporting measurements employed in the present investigation, such as
1. Rayleigh Lidar collocated at Gadanki (13.5°N, 79.2°E),
2. Space-borne (satellite) remote sensing instruments, SABER, (Sounding of the Atmosphere using Broadband Emission Radiometry) and the data obtained from these two instruments are used in the present thesis.

In Chapter-4, first measurements of mesospheric short-period gravity wave signatures in temperature data deduced from OH and O₂ airglow emissions from Gadanki (13.8° N, 79.2° E) are presented. The mesospheric OH and O₂ temperature estimates, which represents ~ 85 and 94 km altitude regions, respectively, are found to be in good
agreement with the instantaneous overhead SABER measured temperature values onboard the TIMED satellite. The short period gravity waves dominant and propagates within 40–95 km altitude regions. It is found that waves with 0.4–0.6 hr periodicity are common throughout the altitude range of 40–95 km with significant amplitudes. With simultaneous Rayleigh Lidar (temperature) and mesospheric airglow (emission intensity and temperature) measurements, the amplitude growth and Krassovsky parameters to characterize the propagation and dissipation of the upward propagating waves are estimated.

In Chapter-5, the capability of a combination of simultaneous measurements made with Rayleigh Lidar and O$_2$ airglow monitoring to improve Lidar investigation to cover a higher altitude range is presented. Instantaneous O$_2$ airglow temperatures are fed instead of the model values at the peak altitude for a subsequent integration method of temperature retrieval using Rayleigh Lidar backscattered signals. Using this method, errors in the Lidar temperature estimates converge at higher altitudes indicating better altitude coverage compared with regular methods where model temperatures are used rather than real-time measurements. This improvement enables the measurement of short-term waves at upper mesospheric altitudes (~90 km). Using two case studies, it is shown that above 60 km the amplitude of a few short-term waves drastically increases while some of the short-term waves show either damping or saturation. It is claimed that by using such combined measurements, significant and cost-effective progress can be made in the understanding of short-term wave processes that are essential for coupling across different atmospheric regions.

In Chapter-6, long-term changes of middle atmospheric temperatures have been investigated using ground-based Rayleigh Lidar and space-borne TIMED/SABER measurements over low latitude station Gadanki, India (13.5° N, 79.2° E). The nightly mean Lidar temperatures are retrieved from 30 to 80 km altitudes, during the year 1998 - 2012 (i.e., 15 years). These are compared with the coincident SABER temperature data obtained in a grid encompassing latitudes 08°– 18° N and longitudes 74°–84° E during the year 2002 - 2012 (11 years). The comparison between the Lidar and SABER measurements reveals a good agreement with the deviation being ~1.5 K at 50 km and ~3 K at 70 km altitude. The temperature measurements are used to study the Semi-Annual Oscillations (SAO), Annual Oscillation (AO) and Quasi-Biennial Oscillations (QBO) and solar cycle influence. After removal of these oscillations, the residual trends reveal a
cooling of the mesospheric temperatures at a rate of \(~1\) K/decade. Results are compared with the values reported from other low and mid-latitude locations.

This chapter also summarizes two years of MLTP operation of mesospheric OH and O\(_2\) emission monitoring. The deduced mesospheric OH and O\(_2\) temperatures show considerable variability. Nightly temperature variations over Gadanki (13.5\(^\circ\)N, 79.2\(^\circ\)E) are dominated by the short period, wave features while tidal amplitudes are relatively small. These measurements are the first to report a long period seasonal variation at two upper mesospheric altitudes simultaneously over the Indian sector. The observations reveal the presence of a dominant semi-annual oscillation (~6 month periodicity) together with a shorter period (~2.5 month periodicity) oscillation in both OH and O\(_2\) data.

Chapter 7 provides overall summary and conclusions of the present study. The scope for further related studies in conjunction with the present thesis work is also discussed.