Temperature is one of the important factors which influences the global climate change and dynamics of the middle atmosphere especially in the stratosphere and the lower mesosphere region. It is a region that affects the weather systems in the lower atmosphere, as well as upper atmosphere. Stratospheric temperature changes are crucial for understanding its variability and trends, including predicting future changes. Due to lack of observational data, this part of the atmosphere provides a long list of challenging scientific problems, which includes variations in stratospheric ozone concentrations and its thermal structure. In the middle atmosphere, climatologies were first studied in 1964 and 1972 by Committee on Space Research (COSPAR) Reference Atmospheres using balloon and rocket datasets at a single-station. Later on a wide variety of observational techniques have been used to measure temperature in the stratosphere and their variations in time and space. These techniques include balloon soundings, rocket sonde measurements and LIDAR with a limited period of observations. As rocket data are available only at few locations around the globe, there is a difficulty for establishing climatology over a global scale, despite the good results from many of the ground-based and space-borne instruments. Recently, Global Positioning System (GPS) Radio occultation (RO) observations started offering several important and unique features complementary to other methods of observing Earth’s atmosphere. GPS based RO exploit signals received on board a Low Earth Orbiting (LEO) satellite for atmospheric limb sounding. The GPS signals are influenced by the atmospheric refractivity field resulting in a time delay and bending of the signal. The atmospheric excess phase is the basic observable that is measured with millimetric accuracy. This is the basis for high vertical resolution and precise refractivity and temperature profiles. The GPS-RO technique has the advantage of the global coverage, high accuracy, high vertical resolution (less than 1 km), long-term stability, self-calibration and capability to operate in all-weather conditions. It provides a powerful tool for atmospheric sounding, which requires no calibration, not affected by clouds, aerosols or precipitation, and provides an almost uniform global coverage with vertical profiles of atmospheric air density, temperature, and water vapor as well as ionospheric electron density. The GPSRO atmospheric temperatures are of good quality and provide unprecedentedly large number of the middle atmosphere up to the stratopause.
region (~50 km) that were not possible earlier as reliable temperature data were available only up to ~30 km. Using COSMIC GPSRO observations the climatology and comparison study of the stratosphere and lower mesosphere temperatures using different satellite and reanalysis data sets are studied.

Also, the characteristics of the planetary waves especially 2-day wave have been studied using COSMIC GPSRO measurements. Planetary waves are a part of the global scale oscillation, which plays a significant role in the middle atmosphere dynamics. Primary periods of the planetary waves contain quasi 2-day, 5-day, 10-day, and 16-day waves. Among these planetary waves, quasi 2-day wave (QTDW) is predominantly necessary due to its relevance in interactions with the mean flow and other planetary waves including solar tides. Apart from that, a case study was carried out to enhance the planetary waves in the upper stratosphere and lower mesosphere during 2009 Arctic major stratospheric warming. The Northern Hemisphere (NH) winter stratosphere is characterized by the occurrence of midwinter sudden warmings. Sudden Stratospheric Warmings (SSWs) events are now recognized as one of the clearest and strongest manifestations of the dynamical coupling of the troposphere-stratosphere system with effects seen up to the mesosphere and lower thermosphere (MLT) region. The cause for SSW is attributed to the propagation of atmospheric waves, mainly Planetary waves (PWs), gravity waves (GWs) and their breaking. It involves considerable changes of the background wind, temperature, planetary and gravity wave activity and redistributes ozone and other chemicals in high latitudes. Internal processes or possibly climate change effects could drive the occurrence of such type of winters. A novel method called Empirical Mode Decomposition (EMD) was used to extract the PWs from the temperature data.

There is significant evidence of SSW events over high latitudes, and mid-latitudes but SSWs are very rarely seen in the low-latitudes. Recent studies on the 2006 SSW event offer an opportunity to examine the performance of assimilation systems in which the troposphere, stratosphere, and mesosphere were strongly coupled. Hence, the evaluation of the impact of warming on the tropopause, stratopause and mesopause characteristics over different latitudes and to find out any wave activity during the warmings obtained from satellite and reanalysis data sets is more important.
The objectives of the present study are to

(1) Bring out the global climatology and comparison study of the stratosphere and lower mesosphere temperatures using different satellite and reanalysis data sets.

(2) Study the 2-day wave characteristics over the middle and high latitudes in both hemispheres using COSMIC GPSRO measurements.

(3) Investigate the planetary waves in the upper stratosphere and lower mesosphere during 2009 arctic major stratospheric warming.

(4) Study the stratosphere sudden warmings in the last decade using satellite measurements and reanalysis data sets.

The thesis is organized as follows:

Chapter-1 presents an introduction to the global temperature morphology and planetary wave (PW) characteristics using different satellite measurements. Review of the work done is also presented where ever necessary. Finally, the motivation and objectives of the present study are outlined.

Chapter-2 describes the experimental techniques used for the present study. A brief description of GPS (CHAMP+COSMIC) RO technique and its processing for the retrieval of the temperature data is presented. Details of other supporting datasets like, Microwave Limb Sounder (MLS), SABER onboard TIMED satellite observations, and the details of reanalysis datasets viz., ERA-Interim, JRA-25, NASA’s Global model Assimilation Office (GMAO) atmospheric global reanalysis project: Modern Era Retrospective-Analysis for Research and Applications (MERRA), GEOS-5 Data Assimilation System, UK Meteorological Office (UKMO) are provided in this chapter. A relatively new promising and highly adaptive Empirical Mode Decomposition (EMD) technique is introduced in this chapter to investigate the PWs in the upper stratosphere and lower mesosphere region. This technique decomposes any complicated signal into so-called intrinsic mode functions (IMFs) and leads to a clean representation of the signal by a few well behaved signal components which this method separates time series into intrinsic oscillations using the local temporal and structural characteristics of the data.
Chapter-3 reports the ability of using stratospheric temperatures from GPS RO (CHAMP+COSMIC) and the measurements are compared with several reference data sets, including assimilation analyses of ERA-Interim, JRA-25, GEOS5 and MetO, satellite observations of AIRS_AQUA, AURA_MLS, SABER, HIRDLS. The latitude-height temperature structures by GPS (CHAMP+COSMIC) with reanalysis data sets and satellite measurements for the northern summer and winter seasons shows very good similarities in most of the latitude regions. The mean values and standard deviations of different latitude bands at different height levels for summer and winter seasons are summarized. Although the good agreement was found between GPS RO and several reference data sets, there are some differences in the upper stratosphere and lower mesosphere, especially at polar regions. These differences are could be due to the effect of spatial-temporal mismatch between the measurements GPS RO temperature analysis algorithms, the difference in sampling data between space-based and reanalysis data sets, as well as the larger uncertainties at, the higher heights, are the major possible reasons for the differences observed. The different vertical resolutions of the temperature measurements may also have their contributions to the differences calculated by interpolating the data onto a common grid. The annual and semi-annual oscillations are studied at equatorial region (5ºS – 5ºN) over height based on satellite and model observations. It was found that the measured AO and SAO amplitudes by satellite and model data sets be in reasonably good agreement with previous results.

Chapter-4 examines the global Quasi Two-Day Wave (QTDW) structure in mid and high latitudes in the upper stratosphere and the lower mesosphere region using high-resolution temperature data collected by the COSMIC/FORMOSAT-3 satellite mission during the period of November 2006 to December 2010. The COSMIC GPSRO temperature data reveal the regular presence of a westward propagating QTDW and also studied the seasonal, latitudinal and inter-annual variation with zonal wave number 3 in both hemispheres in the altitude between 20 and 60 km. Maximum wave amplitudes are observed during winter in the middle to high latitudes in both hemispheres. For the analysis purpose, we utilized the Lomb-Scargle Periodogram (LSP) spectral analysis method was used to determine wave spectral amplitudes and confidence levels, as well as the phase information. For spectral analysis purpose, 4-day groupings of temperature data in each time series were used, and the intervals were
shifted by one-day. The observed QTDW periods are similar seasonal behavior with the earlier reports, but some differences are apparent in high latitudes (50-60°, 60-70°) in both the hemispheres. The vertical phase structure shows phase and the vertical wavelengths are smaller than theoretical values. However, the phase values show little variation with height when the amplitude is large. The amplitudes of the wave are more in winter in both the hemispheres and comparatively NH amplitudes are larger than SH in higher latitudes.

Chapter-5 The Northern Hemispheric winter is disturbed by large scale variability mainly caused by PWs, which interact with the mean flow and thus result in Sudden Stratospheric Warming (SSW). According to the World Meteorological organization (WMO), a major SSW is defined by the reversal of the zonal mean wind at 10 hPa (~30 km), 60° latitude and a positive temperature gradient at 10 hPa, from 60° and 90° latitude. A SSW event is triggered by the interaction of PWs with the zonal mean flow that causes disruption of the winds, temperature, and the mean meridional circulation in both the stratosphere and mesosphere. The AURA-MLS daily mean temperatures and zonal wind from NASA-MERRA reanalysis for latitudes between 60°N and 80°N be used to investigate the planetary wave (PW) characteristics in the stratosphere and lower mesosphere during SSW November 2008 to March 2009. This SSW is one of the major warmings, which occurred with a reversal of zonal wind on 24 January 2009. This SSW is more pronounced in the NH high latitudes, expanding to the middle latitudes ~50 ° N. For the present analysis purpose, Lomb-Scargle Periodogram (LSP), Empirical Mode Decomposition (EMD) and wavelet analysis are used for extracting the PWs during SSW period. A novel method called empirical mode decomposition (EMD) is used to extract the PWs from the temperature data. The EMD is an interesting approach to decomposing signals into locally periodic components, the intrinsic mode functions (IMFs), and will easily identify the embedded structures, even those with small amplitudes. The spectral analysis reveals prevailing Pw periods of ~6-day, ~8-day, ~15-day, and ~21–23-day in IMFs 1, 2, 3, and 4, respectively. Clear upward propagation of these waves (20–30 days) is observed, suggesting that sources for these oscillations are in the troposphere. This study emphasizes the use of such techniques to extract the signals even with the small amplitudes.
Chapter 6 presents the Sudden Stratospheric Warming (SSW) events observed by the satellite measurements (GPS RO, SABER, and MLS) and different reanalysis products (ERA-Interim reanalysis and GEOS-5) from the past decade (2001/02-2012/13). There were 9 SSWs out of the 12 winters. First, warming events between satellite and reanalysis (ERA-Interim) products are compared. In general, there is a good agreement in all the major features noticed between satellite and reanalysis datasets, suggesting that the reanalysis datasets can be used in the absence of observations. The impact of warming on the tropopause, stratopause, and mesopause characteristics over different latitudes have been evaluated. Tropopause altitudes are found to decrease by ~1 km during few warming years when compared to non-warming years; however, this pattern is restricted to high latitudes. A significant increase in the stratopause altitude is observed, which reaches almost ~75 km while warming years compared to ~50 km during non-warming years. Again the effect of warming on stratopause altitude is noticed only up to 50°N. Interestingly, large reductions in the mesopause altitudes (by 3-4 km) are observed while warming years, which propagates to the tropical altitudes in some of the warming winters. Thus warming effect on the tropopause and stratopause noticed at polar latitudes may not felt directly on the tropical latitudes. The gravity wave activity during these warming obtained from satellite and reanalysis data sets are also shown. Interestingly, delayed effect of warming by few days on the tropopause and stratopause, the early effect on the mesopause and gravity wave potential energy ($E_g$) is observed.

Chapter 7 represents the summary and important conclusions drawn from the entire study. Future scope of the study on this topic is also presented.