5 SUMMARY AND SCOPE OF FUTURE WORKS

5.1 Introduction

The thesis discusses electrodynamic phenomena that are specific to the geomagnetic equator or the low latitude region in the Indian longitude sector during geomagnetically quiet times. Even though the focus is on the electrodynamic processes, the study is carried out in the background of various dynamical phenomenons as dynamics play a very crucial role in the electrodynamics of the ionosphere. Therefore the thesis can be considered to be a discussion on the dynamic – electrodynamic coupling of the ionosphere. The present chapter provides the summary and conclusions of the thesis along with future possibilities of works.

5.2 Summary

The first chapter of the thesis introduced all major dynamic and electrodynamic phenomena occurring in the low latitude ionosphere during geomagnetically quiet times; that are relevant to the study. In the first chapter the basic thermal structure and chemical structure of the atmosphere is introduced and is connected to the formation of the ionospheric layers like D, E and F regions. The chapter then introduced certain dynamical phenomena such as waves and tides in the atmosphere. An important dynamical parameter in the high latitude stratosphere called the sudden stratospheric warming, that has tremendous influence on the low latitude ionosphere, is introduced in the subsequent section. Then the chapter discusses important features of the geomagnetic field, the field components, its main origin and the contributions from ionosphere. The interaction of the ionospheric plasma with the geomagnetic field is then discussed in the light of ionospheric conductivity and electric fields generated through dynamo action. Such effects and their role in generating electric currents like solar quiet (Sq) current and the equatorial electrojet (EEJ) and F region drifts and the equatorial ionization anomaly are discussed subsequently. The chapter finally discussed about two important indices of geomagnetic activity – the Kp and the Ap indices that are used to decide whether a day is geomagnetically quiet or disturbed. Then the chapter briefly discussed the outline and the scope of the thesis.

The second chapter is dedicated to discussions on the instruments that provided the much needed data used in the present study. The chapter also discussed the methods and techniques adopted for various analyses in the study. The chapter first introduces three important ground based data sources; the Medium Frequency radar, the geomagnetic data and the Canadian Advanced Digital Ionosonde (CADI). Though geomagnetic data is the most used data for the present thesis, the detailed description of various available magnetometers, the selection of sites, construction of observatories and many other details are beyond the scope of this work as they themselves need to be written as separate books. The chapter then introduces other important data sources that are mainly a compilation of ground based and space and air borne measurements. The total electron content data, reanalysis data on winds and temperatures are introduced. The chapter then discusses about the method of calculation of lunar position and phase. For this purpose, the coordinate system used is also explained in detail. The chapter finally discusses the method of estimation of the amplitudes and phases of the lunar semidiurnal tides using regression analysis methods.

The third chapter discusses long term variability of counter eletrojet including inter annual and seasonal variability. It also discusses the lunar influences on the CEJ occurrences. Firstly, the classification of CEJ events is done based on the hour of peak CEJ value on the day. CEJ days are considered morning CEJ events (MCEJ) if the peak CEJ occur during the local hours 0500 – 0900 and afternoon CEJ events (ACEJ) if the peak CEJ occur during the local hours 1400 – 1900. Those that peak in between are not considered for the present study. It is found that at the highest number of CEJ events peak at 0600 - 0700 and 1600 hours.

The solar cycle dependent variability is described in the subsequent section where the occurrence of both afternoon and morning events are studied in detail. It is found that the occurrence rates of ACEJ events anti – correlates with the solar cycle. The highest occurrence rate was during the low solar minimum periods 1995 – 1996 and 2008 - 2009 and the lowest occurrence rate during high solar activity year 2001. The occurrence rate of MCEJ events are found to correlate with sunspot number. The highest occurrence rate was during the year 2001 whereas the lowest rates were during 1996 and 2008. The occurrence rate in year 2009, a year of extended solar minimum, was slightly unexpected in which there was an increase in the occurrence rate for MCEJ and a decrease in the rate for ACEJ events.

The chapter then discusses seasonal variability of CEJ events which has many interesting features. The high occurrence rate of CEJ events in summer solstice is captured in the ACEJ events. A clear pattern of equinoctial maxima in addition to an exceptional maximum in the month of January is observed. The most striking seasonal variability is the low occurrence rate of the MCEJ events and high occurrence rate of ACEJ events in the summer. The seasonal variability of the hours at which MCEJ events attain their peak value exhibits peculiar features. Though the peak occurrence rate is at 0600 – 0700 hours on all months, there is substantial variability in the occurrence rates at other morning hours. During equinoctial months, the occurrence rate substantially narrows down into the hours 0600 – 0700 where as during other months; there is a better distribution of peak hours. The summer months April, May and June show high occurrence rates at 1600 - 1700 local hours for ACEJ events. During July – August, the preference shifts to a later local hour 1700. In September, the maximum occurrence hour again shifts back to 1600 hours. During October – December, the peak hour shifts to earlier hours 1400 but it is not very significant as their magnitudes are much less than summer and nearby equinoctial months. In January month, the peak hour again shifts to 1500 – 1600 hours and in February to 1500 hours. In March month the peak again reaches 1600 hours. The shift of peak occurrence rate maxima shows an annual pattern that maximizes at later hours around summer and earlier hours around winter months. This could be attributed to the shorter lengths of winter day times and longer lengths of summer day times.

The present chapter discuss occurrence of CEJ events in the light of lunar influences. The lunar age or alternatively, lunar phase has a significant effect on the occurrence of CEJ events. There is a high occurrence rate of both MCEJ and ACEJ of all intensities during and around full moon and new moon phases. The next section discussed about the relationship of occurrence rate with respect to the solar and the lunar hours. There is a strong correlation for the MCEJ events, peaking at 0700 solar LT, with the lunar hours 240 – 0100 and 1200 – 1300; the hours at which the Moon reach overhead the station, Tirunelveli, or at its anti – pode respectively, that is, the hours at which the lunar M2 tidal amplitude is maximum. The ACEJ events also show a high occurrence rate at 1200 lunar hours. A secondary high occurrence rate is seen at 0400 and 1400 local lunar hours for ACEJ events peaking at 1600 solar local hours. For other hours, the correlation is not remarkable as these cases. The facts that the most probable CEJ events (solar hours 0600 and 0700 for MCEJ and 1600 for ACEJ) are strongly most probable during lunar hours 2400 – 0100 and 1200 – 1300 clearly indicates the possibility of lunar influences on the occurrence of a huge number of CEJ events that match certain lunar conditions. The calculations of lunar semi – diurnal tides in mesosphere – lower thermosphere (MLT) winds over Tirunelveli during the same period have been calculated and compared. It was shown that the tidal activities in zonal (east – west) as well as meridional (north south) winds exhibit similar seasonal behaviour. The calculated maximum amplitudes is about 5 m/s during the March equinox, and about 3 m/s during September. The minimum amplitudes were observed during summer months. This seasonal structure matches well with the results presented in the chapter for morning CEJ events. But the variability does not account for the January peak observed in MCEJ seasonal variability.

The fourth chapter is another finding of the present thesis that presents the observation of an unusual low latitude electrodynamic effect in the Indian equatorial region. The chapter first introduces some characteristics of the noon time CEJ (NCEJ) events observed at Tirunelveli over the years from 1993 to 2012. The response of F2 layer height to the equatorial electrojet and counter electrojet through the zonal electric field at the equator is discussed in the following section. Then the case of oppositely flowing currents in two closely spaced low latitude stations, one at the equator and the other at the fringe of the equator, is explained. Cases that are similar to the events but for which ionosonde observations are not available are discussed in the subsequent section. The possible existence of opposite zonal electric fields is proposed as a conclusion. To substantiate the proposal, the equatorial ionization anomaly observed in total electron content data is used.

5.3 Scope of future works

The most important future works resulting from the present thesis consists of four broad parts. Firstly, the CEJ events (both ACEJ and MCEJ) need to be studied for various longitudinal sectors and their long term variability and has to be compared with lunar positions and phases. This is important while delineating the effects of localized effects such as gravity waves and non migrating tides on the occurrence of CEJ events. Secondly, the noon time CEJ (NCEJ) events are to be studied thoroughly in the light of ionospheric F1 and F2 variability as well as the EIA. Thirdly there are several occasions of possible opposite fields prevailing in the equatorial ionosphere during quiet times as discussed in the fourth chapter. Such cases need careful and case by case analysis. The role of various effects such as photo chemistry, conductivities and electric fields, tides and lunar effects are all players in this study. Fourth important future work that can be carried out is the comparison between long term tendencies of tides and waves in the middle atmosphere and their relationship with counter electrojet events using ground based as well as satellite measurements of winds and electric currents.