Equatorial Counter Electrojets:- An Investigation using Ground Based Optical and Radio Probing Techniques

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Abstract

This study presents the behavior of the daytime zonal wind and OH temperature at upper mesospheric altitudes during the afternoon Equatorial Counter Electrojet (CEJ) events over a dip equatorial station, Trivandrum (8.5°N, 76.5°E, 0.5°N dip lat.) in India. The measurements were carried out using a unique Multiwavelength Dayglow Photometer (MWDPM), Meteor Wind Radar and the Proton Precession Magnetometers. It is observed that during the CEJ events: (i) zonal wind at 98 km exhibits an eastward acceleration and (ii) the mesopause undergoes a cooling, which in turn is proportional to the strength of the CEJ. The paper discusses these results in detail.

1. Introduction

The Mesosphere Lower Thermosphere (MLT) region over the dip equator replete with a number of unique electrodynamical processes. One such process is the Equatorial Electrojet (EEJ), which is an intense band of current flowing in the zonal direction with a latitudinal extent ±3° on either side of the dip equator in the height region centered at around~ 106 km (Forbes, 1981; Reddy, 1981; Stening, 1985). On certain days, the EEJ during the afternoon hours get weakened and reversed for a short duration. Then, it came back to its normal afternoon value before it disappears around sunset time (Gouin, 1962; Gouin and Mayaud, 1967). The event lasts for about 3 hours and the maximum negative value of ΔH usually occurs between 1500 and 1600 IST. This phenomenon is termed the 'Counter Equatorial Electrojet (CEJ)', as the EEJ reverses and flows westwards during this period.

Different causative mechanisms have been suggested for the occurrence of CEJ [1, 2, 3, 4]. While many of these studies investigate and attribute the occurrence of CEJ to the wind or additional current systems in the dynamo region. Recently, Vineeth et al., [5] has shown an association of CEJ with the mesopause energetics in the form of a localized cooling in mesopause during the CEJ events. It has been shown that, the temporal variation of the temperature within a day exhibited prominent changes in the form of significant lowering (10-20K) of the mesopause temperature on CEJ days in the afternoon hours between 12-16 IST (India Standard Time, which is ahead of GMT by 5.5 hours). Similarly, Somayajulu et al., [6] have reported a reversal in the upper mesospheric zonal wind from eastward to westward during the CEJ events. They found that the amplitude and phase of the tidal components were substantially different on the CEJ days. However, that study was based on a very limited data set. The installation of the SKiYMET meteor wind radar over Trivandrum during the year 2004, provided an opportunity to investigate about the behavior of neutral winds during the CEJ days. The SKiYMET radar uses a special transmitting scheme to avoid the echoes from the EEJ and therefore, the winds obtained are free from electrodynamical contamination from EEJ/CEJ [7]. In this context, the wind measurements from the SKiYMET radar are used for analyzing the wind variability during the CEJ events. The present study focuses on the behavior of the temperature and zonal wind at upper mesospheric altitudes during the CEJ events of varying strength. It has been found that the mesopause exhibits the cooling trend and zonal wind at 98 km shows an eastward excursion during almost all CEJ events.

The investigation of the day-to-day variation of mesospheric winds and temperatures, especially during daytime, is important for providing insight into the Mesosphere Lower Thermosphere (MLT) coupling processes. For instance, as is the case with the mesopause region, the ionospheric dynamo region is also controlled by the winds of lower atmospheric origin. The waves and tides generated in the stratosphere and troposphere play an important role in this context. Apart from chemistry, the waves and tides generated in the lower atmosphere while propagating upwards into the lower ionosphere through the mesopause influence its heat and momentum budget. The changes in heat and momentum manifest as modulations in the mesopause temperature and wind respectively.

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2. Dataset

The unique Multiwavelength Dayglow Photometer (MWDPM) can measure intensities of three different dayglow emissions (630.0, 731.6 and 740.2 nm) nearly simultaneously. As in the past, the daytime OH emission intensity measurements hence obtained were used to estimate the daytime mesopause temperature following the method of Meriwether [8]. The measurements at every 10 sec interval typically span ~ 8-10 hours during daytime between 0800 to 1800 hrs for the zenith sky everyday. The EEJ strength and the other parameters are estimated by subtracting the magnetic field measurements of an off-equatorial station (Alibag) from that of the equatorial station (Trivandrum). Since the place of the measurements is located right over the magnetic dip equator, the variation of the ground magnetic field essentially represents the horizontal component and is a measure of the EEJ. The zonal wind data is obtained from co-located SKiYMET (all SKy interferometric METeor) meteor wind radar.

3. Observation

In order to investigate the behavior of temperature and wind field of the upper mesosphere region, three fully developed afternoon CEJs of strengths -45, -30 and –25 nT, which occurred during the months of March 25 and May, 19 & May 20, 2005 have been analyzed. For better representation, the EEJ induced magnetic field on ground (ΔH_{TRV}-ΔH_{ABG}), mesopause temperature and zonal wind at 98 km altitude are plotted together. For comparison, the variability of these three parameters for a nearby normal electrojet day are also shown in each panel.

Figures 1a and 1b depict the time variation of magnetic field, temperature and, zonal wind at 98 km for the CEJ day of March 25 and a normal day March 27, 2005 respectively. It is clear from the figure that the mesopause exhibited a cooling of ~25 K during the CEJ when the magnetic field exhibited the reversal. It is very interested to note that, all the small period temperature fluctuations appear to be correlated with the same in magnetic field on this day. The zonal wind at 98 km was in westward direction till 11:00 IST and after that it shows a clear-cut eastward acceleration during the time of the field reversal.

Figure 2 shows the time variation of temperature, magnetic field and zonal wind during the CEJ events of May 19 and May 20, 2005. As is evident from the figure these parameters also follow the variabilities seen on March 25. On May 19, a strong CEJ day the temperature dropped almost 20 K during the afternoon hours almost simultaneously with the magnetic field. The zonal wind at 98 km shows westward acceleration till 12:00 IST, turning eastward to become westward again at ~16:00 IST. On May 20, the magnetic field reversal occurred between 14:00 and 16:00 IST and the temperature exhibits cooling. Like March 25, this day is also a disturbed day with Ap value 22. The zonal wind at 98 km shows strong westward acceleration till 12:00 hrs turning eastward afterwards. On the control day, i.e May 18 the temperature does not show any prominent cooling. Further, the zonal wind remains westward through out the day. The wind becomes more westward in the morning hours till 12:00 hrs to be followed by an eastward acceleration. In general, the variations seen in temperature, magnetic field and wind during the CEJ events seem to be correlated. The eastward acceleration in the zonal wind at 98 km, are associated with lowering of mesopause temperature and the reversal of the equatorial electrojet current.

4. Discussion

Many mechanisms have been suggested for the generation of CEJ. The occurrence of CEJs are proposed to be due to (i) the local interaction of height-varying winds [9, 10 and references therein) (ii) the gravity wave associated vertical winds [11] (iii) appropriate phase combination of global scale tidal wind modes [6, 12, 13] (iv) contributions of the global wind and current systems [3, 4] (v) the prevailing phase of Stratospheric Quasi Biennial Oscillation [14] and (vi) the circulation changes associated with polar stratopshric sudden warming [3, 15] etc. However, the relative contributions of the aforesaid mechanisms are yet to be understood. In the present paper the role of vertical coupling processes in producing the CEJs is attempted.

In order to modify the mesosphere energetics and the E region electric field, the dynamical field, especially the tides in MLT region should get modified. The reversal of the zonal wind at 98 km altitudes clearly indicates this aspect. Earlier studies have shown that the gravity-wave drag could modify the amplitude and phase of the tides [16]. It has also been shown that the vertical eddy diffusion significantly damps the amplitude of the diurnal tide

[17]. This corroborates with the vertical wind hypothesis of Raghavarao and Anandarao [10]. The modified tidal components could very well alter the currents systems in the dip equatorial E region. Over the MLT region, the gravity-wave produces a strong eastward drag. This acts to reduce the tidally induced westward flow to a weak eastward flow of around 20 m s^{-1} above 90 km. The eastward reversal of the zonal wind at 98 km very well supports the aforesaid mechanism. Apart from these it has been shown that the tidal variabilities can alter the temperature as high as 20 K [17]. In fact, in a study by Vineeth et al., [5] have shown that such a vertical wind could explain the lowering in mesopause and the occurrence of the CEJ. The mechanism suggested was the decreased exothermic heating due the blockage of the downward diffusion of the atomic oxygen [O] from the lower thermosphere. In other words, the gravity waves associated vertical wind would oppose the downward diffusion of the [O]. This would cause a reduction in the O_3 concentration and OH emission rates in the mesopause region, which would in turn manifest as a lowering in the temperature. At the same time, the vertically upward wind in the ionospheric dynamo region would either weaken or reverse the vertical polarization field [10]. The study presents a classical example of vertical coupling process prevailing in the dip equatorial MLT region.

5. References

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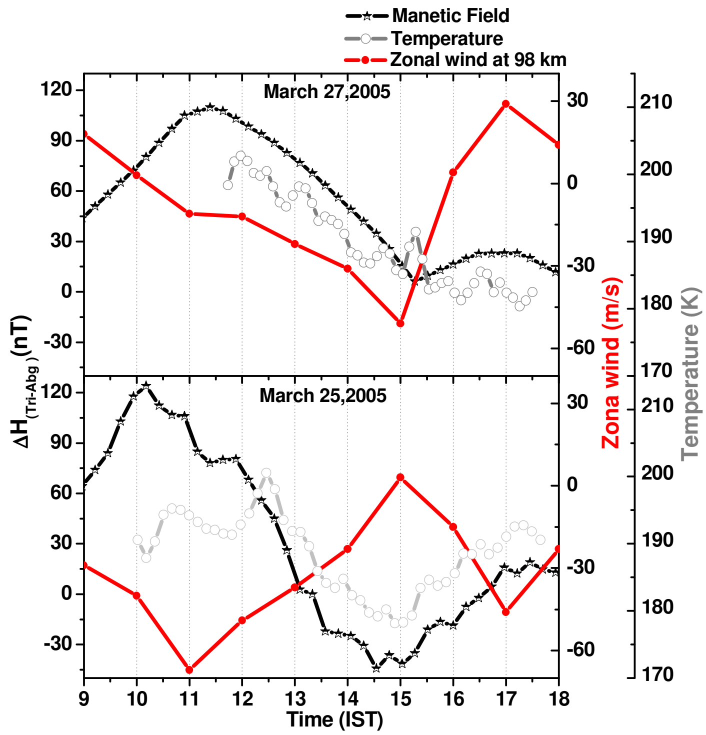

Figure 1:- *Time variation of EEJ strength (ΔH_{TRV} - ΔH_{ABG}), mesopause temperature and zonal wind at 98 km for March, 25 and 27, 2005.*

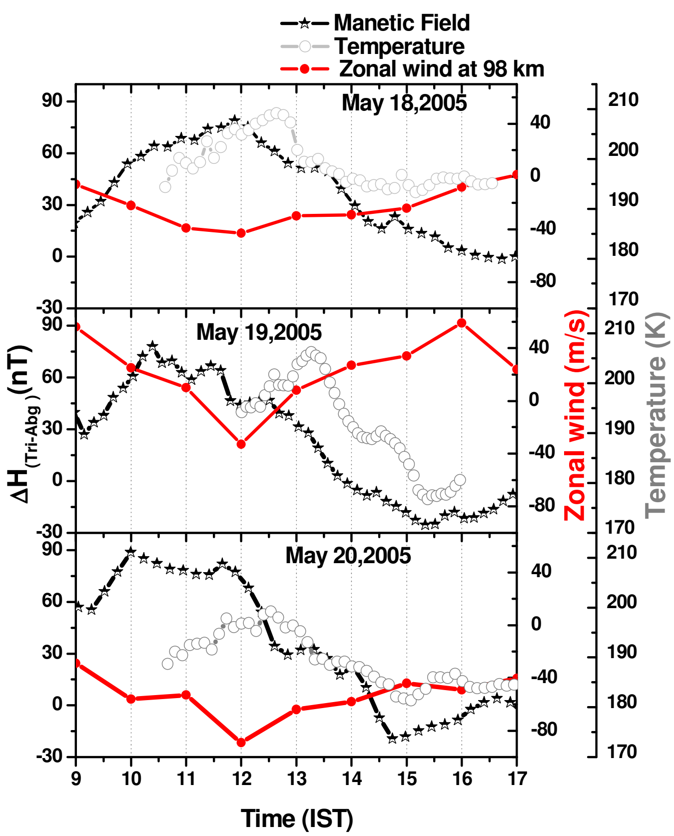

Figure 2: *Same as Figure 1 but for May 18, 19, and 20, 2005.*