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Planetary wave coupling of the mesosphere-lower thermosphere-ionosphere (MLTI) region during deep solar minimum 2005-2008

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The present study investigates the role of planetary-scale waves in the mesosphere-lower thermosphere-ionosphere (MLTI) coupling during the deep solar minimum period of 2005-2008. In the absence of severe magnetic disturbances, it is expected that much of the observed variations in low latitude ionospheric current system, the equatorial electrojet (EEJ), in particular, is expected to be driven by global scale waves propagating from below. The availability of continuous wind data from MF radar at mesospheric heights and geomagnetic field variations, the latter providing a measure of the strength of the ionospheric current system provides a unique opportunity to investigate the role of planetary-scale waves in driving the variabilities in the ionospheric current system during this solar minimum epoch. The study presents interesting findings on the role of planetary waves, especially the 3.5-day ultra-fast Kelvin wave and the 6.5-day wave in the low latitude MLTI coupling.

Keywords: Mesosphere-lower thermosphere-ionosphere (MLTI) coupling, Equatorial electrojet (EEJ), Planetary wave, Ultra fast Kelvin waves (UFK)

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1 Introduction

Waves with periods ranging from few hours to few days exist in the atmosphere. These waves become more important in the mesosphere-lower thermosphere-ionosphere (MLTI) region, since their amplitudes are large and they drive the zonal mean circulation at these heights. Waves with periods ranging 2-20 days are generally referred to as planetary waves. Under steady state isothermal conditions and in the absence of dissipation, waves with periodicities near 2, 5, 10 and 16 days exist as freely propagating, normal modes or Rossby modes in the lower atmosphere and are confined below ~20 km[1-4]. These normal modes are westward propagating planetary waves for which the atmosphere shows resonant response. Meyer & Forbes[5] suggested that these normal modes cannot be sustained above the stratosphere since the background winds conditions are not favourable for their vertical propagation. Besides these normal modes, eastward propagating waves known as Kelvin waves (equatorially trapped) are also supported by the atmosphere. The most important member of this group of waves is the 3-4 day wave, commonly known as ultra fast Kelvin waves (UFK).

For a wave to reach up to MLTI heights, the background wind conditions have to be appropriate as they play a major role in filtering these waves. Thus, if the amplitudes are strong enough and when the background wind conditions are favourable, these waves can propagate upwards. In a realistic atmosphere, the period of oscillations may sometimes be Doppler shifted by the non-zero background winds and the periods observed at mesospheric and ionospheric heights may thus, be different from the original periods.

The quiet time electrodynamics of the MLTI region is believed to be driven by gravity waves, tides, and planetary waves propagating upward from their source regions in the lower atmosphere. Since the gas density decreases exponentially with height, the amplitudes of these waves increase with height in order to conserve the kinetic energy density. These waves often achieve greater amplitudes and take part in the dynamo action, thereby, modulating the ionospheric current system at dynamo heights (90-140 km).

The equatorial electrojet (EEJ) is an enhanced current system with intensity of the order of ~200 A m^{-1} flowing at about 105 km over the dip equator[6].

The understanding of EEJ is very essential when it is used as a diagnostic tool in any systematic study of ionospheric electrodynamics in the equatorial/low latitude region. For the past few decades, EEJ remained an area of active research, since the variabilities contributing to it even during quiet times are not understood well. One of the unresolved issues in this regard is the understanding of the short-term variabilities over period ranges starting from day-to-day to few tens of days. Tides, both solar and lunar, are suggested to be responsible for the day-to-day variation, and planetary waves and secondary waves resulting from nonlinear interaction of planetary waves and tides are believed to contribute to variabilities in the period range of few days to few tens of days.

The planetary wave-type oscillation (PWTO), observed in EEJ, is one of the least understood aspects of the short-term variabilities of EEJ discussed earlier. Previous studies have reported ambiguities in relating planetary wave signatures at mesospheric heights with the PWTOs observed in ionospheric parameters (Ref. 7 and references therein). It is believed that planetary waves with large amplitudes and fairly long vertical wavelengths propagating from below can influence EEJ by taking part in the dynamo action[8,9]. In such a case, this wave-like feature causes similar perturbation in geomagnetic field that can be recorded on the ground (Ref. 10 and references therein). Understanding the quiet-time variabilities of ionospheric parameters in terms of planetary waves and tides has been an unresolved issue due to the non-availability of large and simultaneous data sets for the MLTI region. For similar reasons, the role of *in situ* generated waves in causing ionospheric variabilities is still not clear. Knowledge of various physical processes contributing to the generation of these wave periods observed in EEJ would help in understanding and predicting the effects of space weather at low-latitudes.

The lower and middle atmospheric regions are connected to the upper atmosphere by neutral and electrodynamical forcing. Some of the waves detected in the MLTI region have their sources located in the lower atmosphere. The electrodynamical coupling of waves propagating from below has been discussed by many authors[10-13]. Despite good amount of work carried out in recent years, the quiet-time electrodynamical coupling of the atmosphere-ionosphere system remains enigmatic till date.

For addressing this issue, one can make use of simultaneous data on EEJ strength and MF radar winds available during 2005-2008, characterized by deep solar minimum, study the characteristics of various planetary waves and bring out some important features of the electrodynamical coupling in the MLTI region. It has been examined in particular, whether a planetary wave signature present in the MF radar wind data is associated with a similar signature in EEJ current system. If a planetary wave signature with similar period is noticed both in mesospheric winds and EEJ, it is presumed to be due to the propagation of the same planetary wave identified at mesospheric levels reaching up to ionospheric heights.

2 Data analysis

The hourly averages of MF radar winds and hourly values of magnetic data corresponding to 75° EMT are used. The strength of the EEJ at any instant is obtained by taking the difference in the horizontal component of Earth's magnetic field over Tirunelveli (8.7°N, 77.8°E, geomagnetic latitude 0.03°N) and Alibag (18.62°N, 72.87°E, geomagnetic latitude 10.36°N). The disturbance storm time index or Dst, expressed in nanotesla, is a proxy for measuring the geomagnetic activity or the severity of magnetic storms. Dst is computed from hourly averages of the horizontal component of the Earth's magnetic field from four near-equatorial (but outside the EEJ belt) geomagnetic observatories. Dst is widely used as an index of storm strength, since the strength of the surface magnetic field at low-latitudes is inversely proportional to the energy content of the ring current, which increases during geomagnetic storms.

Ionospheric variabilities are contributed by forcing from above as well as from below. Forcing from above is primarily of solar wind origin and related geomagnetic disturbances, whereas, forcing from below arises from global scale waves having their origin in the lower and middle atmosphere. The PWTOs observed in ionospheric parameters could be caused by either of the two. The Dst index helps in identifying the contributions of geomagnetic disturbances, if any. Absence of such signatures in Dst indicated by low Dst values (in absolute terms) signifies that the observed PWTOs are probably caused by forcing of waves from below. The study has been confined to variations in the range 2-10 days and at the same it may be noted that since periods greater than ~10 days could possibly be contaminated by solar rotational harmonics, care should be taken while interpreting any signature in EEJ in terms of planetary waves propagating from below at those time periods (>10 days).

Band-pass filtering for the period range 2-10 days is applied to the data. Morlet wavelet transforms performed on the band-passed data are used to identify the presence of wave signatures in winds and EEJ. It has been chosen to show the response of the winds at 88 km owing to good radar data acceptance rates at this altitude compared to heights above and below. Further, there are constraints to choose heights below 90 km, because measurements at higher altitudes are possibly contaminated by electric fields and reliable winds need not be estimated at those heights[14]

Figures 1(a-d) present the time variation of hourly values of Dst index, EEJ strength, zonal and meridional winds from top to bottom for the years 2005-2008. From the Dst plots, it is noticed that the years 2006, 2007 and 2008 are very quiet compared to the year 2005. The Dst index for these years rarely drops below -60 nT except for two transient depressions during April 2006 and December 2006 when it reached -100 nT. The EEJ data are continuous except for one or two days in April 2007 and October 2008. The MF radar was not operated for four days during 2005. In 2006, there are three sets of dates on which the radar was not operated or the data quality is poor. The first window extends from third week of March to second week of April. The second window comprises of few days during second week of September and the third one starts from the end of September and continues up to middle of October. For 2008, the data quality is poor almost for all days in January and from middle of May to middle of June.

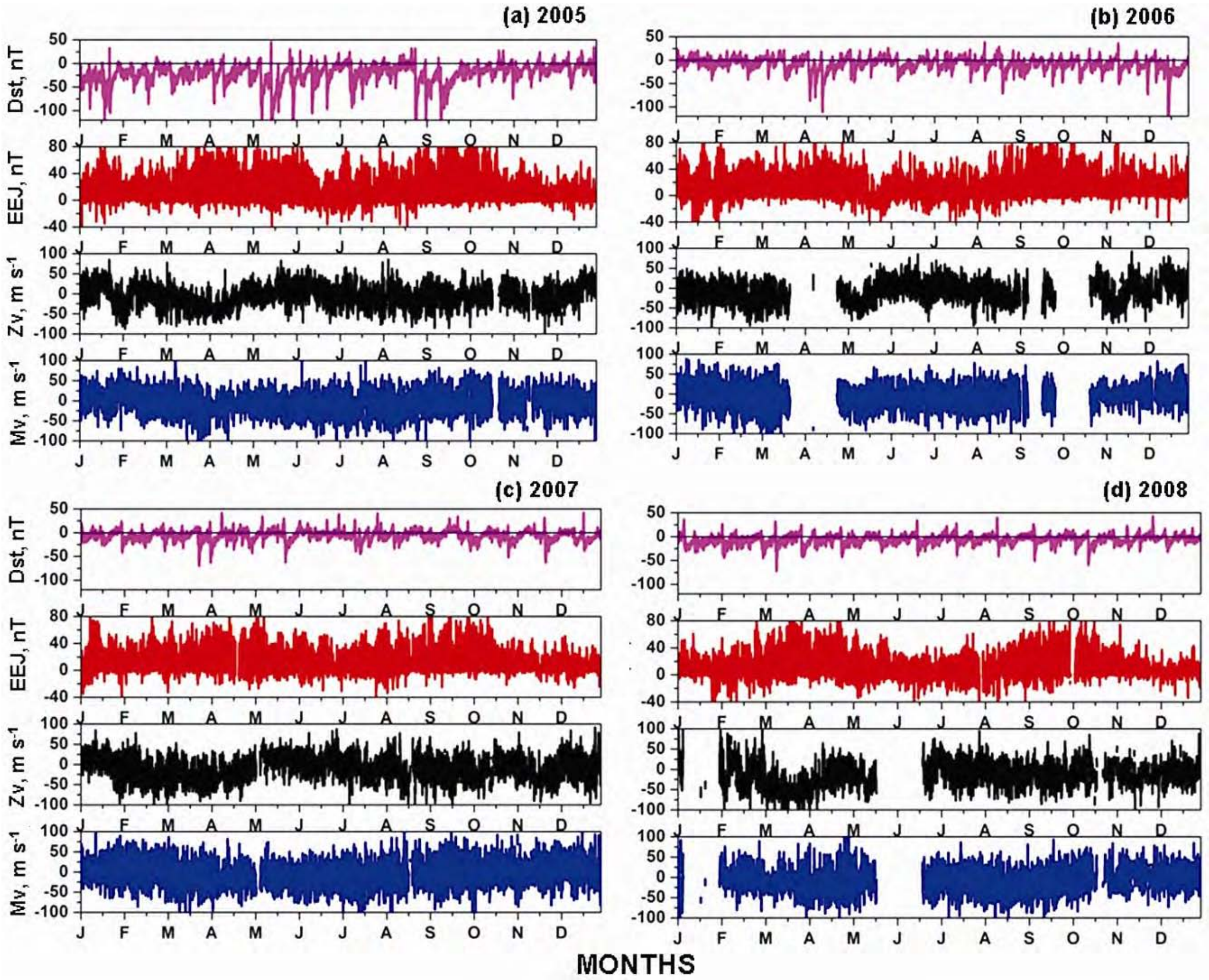

Fig. 1(a-d) — Time variation of hourly values of Dst index, EEJ strength, zonal and meridional winds (from top to bottom) for the years 2005-2008

3 Results

Wavelet spectra for each year from 2005 to 2008 are shown in Figs 2(a-h). Results for each year are shown as two six-month windows separately for clarity. The first window covers data from January to June and the second from July to December. Data are initially interpolated for gaps and continuous data gaps of more than 16 hours are replaced by blanks. The top panel shows the wavelet spectra for EEJ; and the middle and bottom panels depict the wavelet spectra in zonal and meridional winds, respectively. The previous results from the same site indicate the presence of quasi-two-day (QTD, 1.8-2.2 d), ultra-fast Kelvin (UFK) or ~3.5 d (3-4 d), ~6.5 day wave (5.6-8 d) and quasi 16 day (QSD) waves both in winds and EEJ[15,16]. Here in the present work, concentration has been mainly on the first three categories of waves. It is evident from Figs 2(a-h) that the wave activity is stronger in zonal wind compared to the meridional wind except for the QTD wave ranging 1.8-2.2 days. The horizontal white lines are drawn at 5.6 and 8 day periods for easy identification of the ~6.5 day wave.

For the comparative analysis, beginning is made with the QTD waves and their concurrent occurrence in winds and EEJ is observed during the solar minimum epoch of 2005-2008. During 2005 [Figs 2(a and b)], the moderate to strong QTD wave activity in meridional wind occurs intermittently throughout the year. In particular, strong bursts of QTD wave occur in meridional wind during the end of February, beginning of March, beginning of August, second week of September and mid November. Moderate activity is noticed during mid-May, June and July 2005. Simultaneous occurrence of PWTO at QTD periods in EEJ is noticed only during mid-June and July. As expected for this low-latitude site, the response to the QTD wave in the zonal component is weak. At certain times, the EEJ shows the presence of wave activity close to 3 days, in which case the period is slightly higher to be interpreted in terms of upward propagating QTD waves. During 2006 [Figs 2(c and d)], four strong wave bursts are noticed in meridional wind from the end of June to beginning of August, whereas the zonal wind shows weak wave activity from February to June. On the other hand, the electrojet shows enhanced wave activity during mid-January that is not accompanied by similar wave activity in winds. For the year 2007 [Figs 2(e and f)], meridional winds show the presence of enhanced QTD wave activity during end of January, middle of February, beginning of June, end of July and from last week of September to first week of October. The EEJ does not show the presence of PWTO during these times. Rather, the peaks observed in zonal wind and EEJ then are close to 3 days. During 2008 [Figs 2(g and h)], three bursts of wave activity are observed in meridional wind from July to September. EEJ shows weak activity in April that is not accompanied by similar activity in winds.

Prominent 3.5-day (henceforth, simply 3.5-d) wave activity during 2005 [Figs 2(a and b)] occurs in EEJ in the beginning of February, first week of March, middle of May, beginning of June, end of July and middle of August. The enhanced PWTO in EEJ from May to August is accompanied by simultaneous enhancement of 3.5-d wave activity in zonal wind during these months, though the peaks do not possess one-to-one correspondence in their occurrence times. During 2006 [Figs 2(c and d)], the concurrent occurrence of 3.5-d wave activity both in EEJ and zonal wind is noticed from May to June. The peak during the middle of May is weak in zonal wind, whereas it is strong in EEJ. The second wave burst during June is prominent both in zonal wind and EEJ indicating enhanced wave activity during that time. During 2007 [Figs 2(e and f)], EEJ shows four wave bursts from February to April. None of these peaks are observed in MLT winds. The 3.5-d wave activity in EEJ during mid-June is present both in zonal wind and EEJ. During August 2007, 3.5-d wave activity is noticed in zonal wind and EEJ, presumably driven by the same equatorially trapped UFK wave. During the end of June 2008 [Figs 2(g and h)], a 3.5-d wave burst is noticed in both zonal wind and EEJ. The wave amplification noticed in EEJ from July to September could not be related to similar enhancement in winds on one-to-one basis. However, there are simultaneous enhancements of ~3.5 day wave activity during June-August that continues up to the end of September. Unlike QTD wave activity, the 3.5-d activity appears consistently close to summer solstice during the epoch of 2005-2008.

Focusing now on the PWTO at and around 6.5-day (henceforth, 6.5-d) period, during 2005 [Figs 2(a and b)], the 6.5-d wave signature is present in EEJ in the middle of February, whereas the zonal wind shows the presence of wave activity a few days later, during the beginning of March but peaking close to 8-day period. The EEJ shows the presence of a weak activity during April and a strong activity during May. The zonal wind reveals the presence of similar enhancement almost at the same time. Two peaks

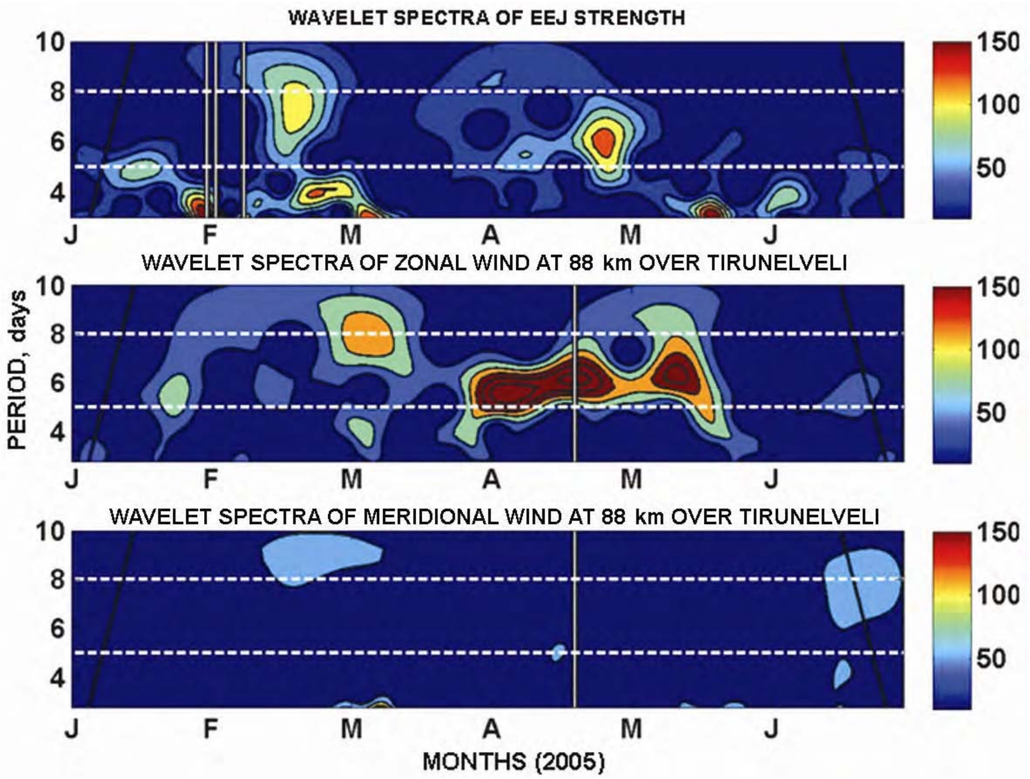

Fig. 2(a) — Wavelet power spectra of EEJ strength (top panel), zonal wind (middle panel) and meridional wind (bottom panel) from January-June 2005

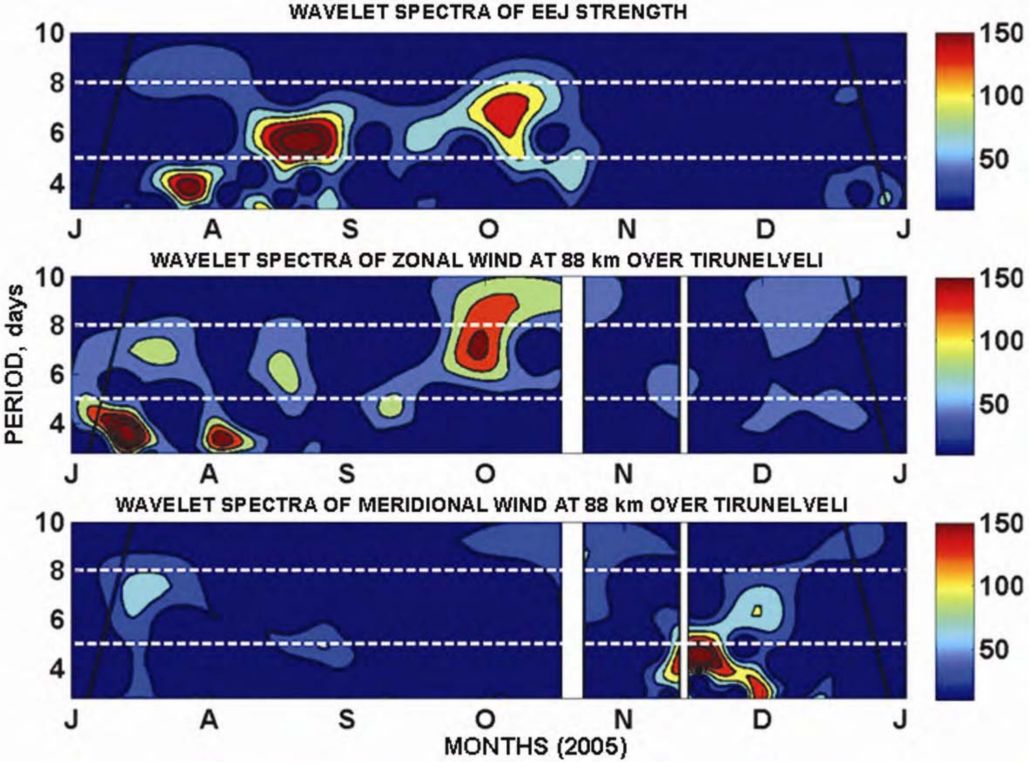

Fig. 2(b) — Wavelet power spectra of EEJ strength (top panel), zonal wind (middle panel) and meridional wind (bottom panel) from July-December 2005

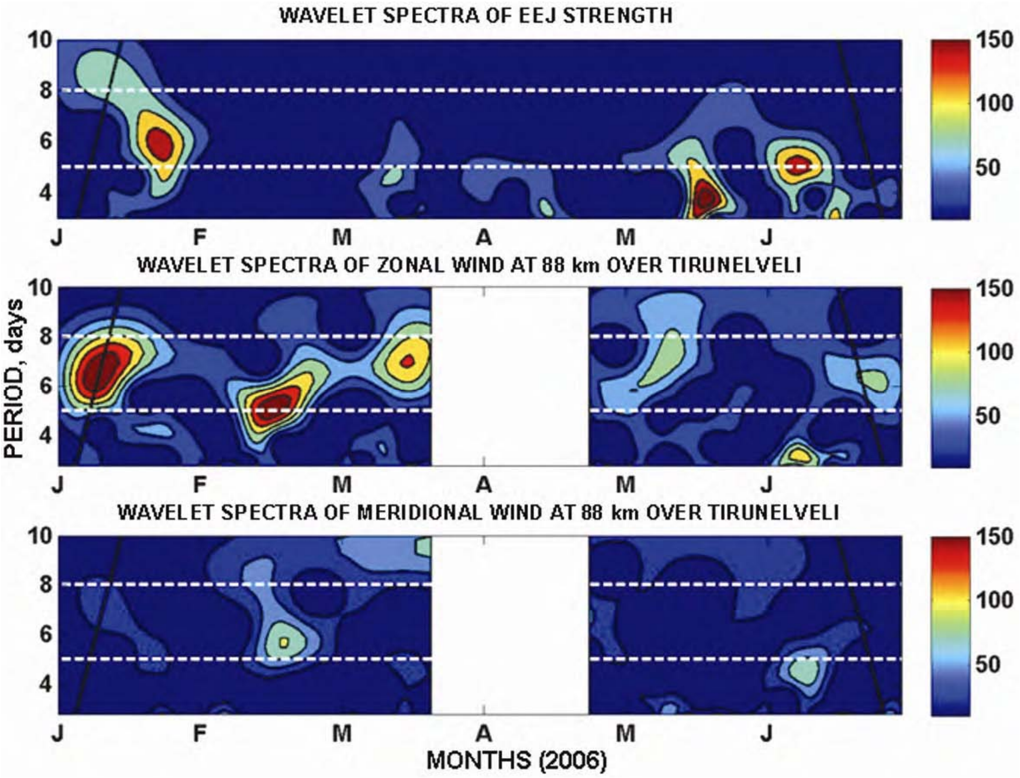

Fig. 2(c) — Wavelet power spectra of EEJ strength (top panel), zonal wind (middle panel) and meridional wind (bottom panel) from January-June 2006

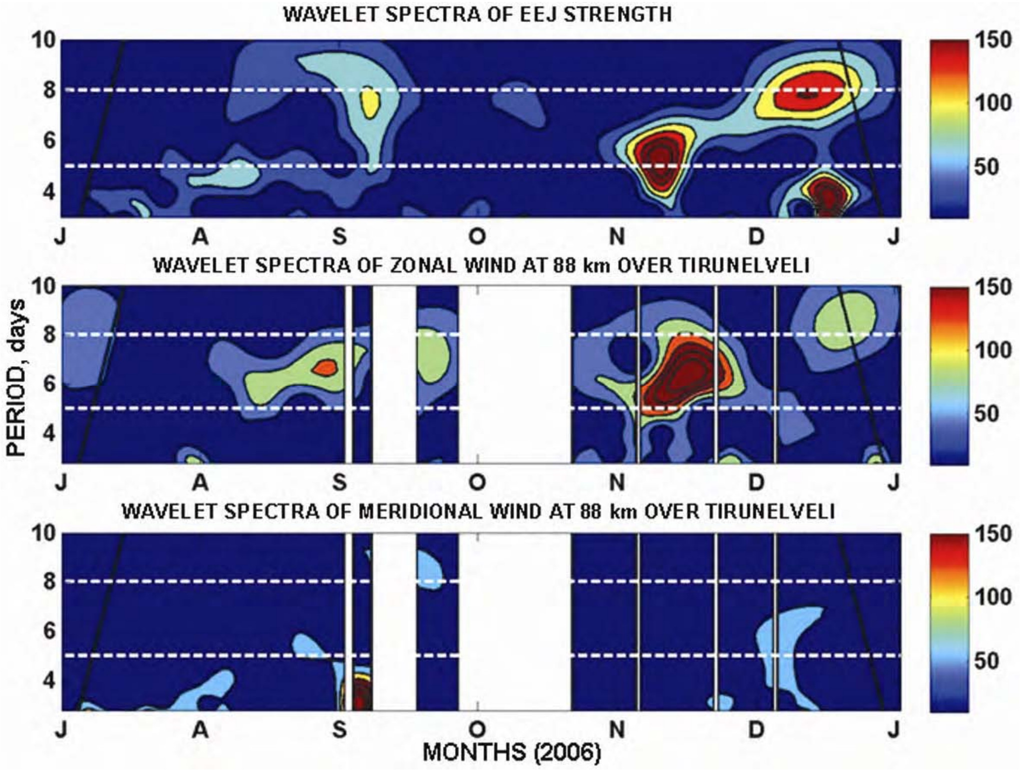

Fig. 2(d) — Wavelet power spectra of EEJ strength (top panel), zonal wind (middle panel) and meridional wind (bottom panel) from July-December 2006

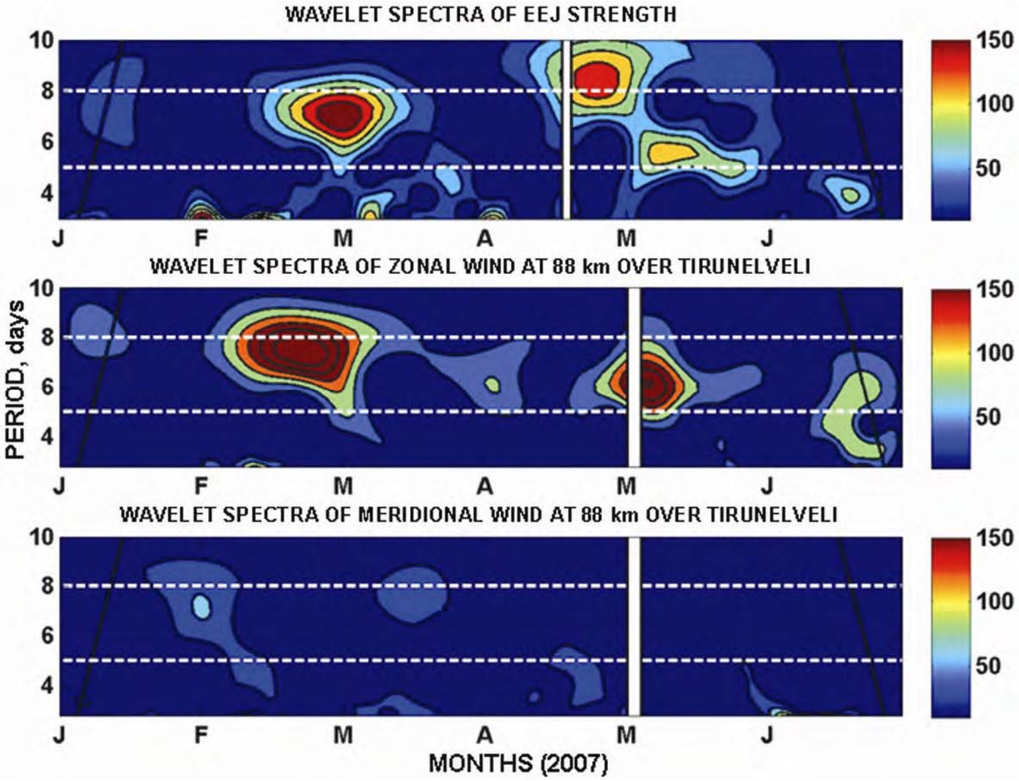

Fig. 2(e) — Wavelet power spectra of EEJ strength (top panel), zonal wind (middle panel) and meridional wind (bottom panel) from January-June 2007

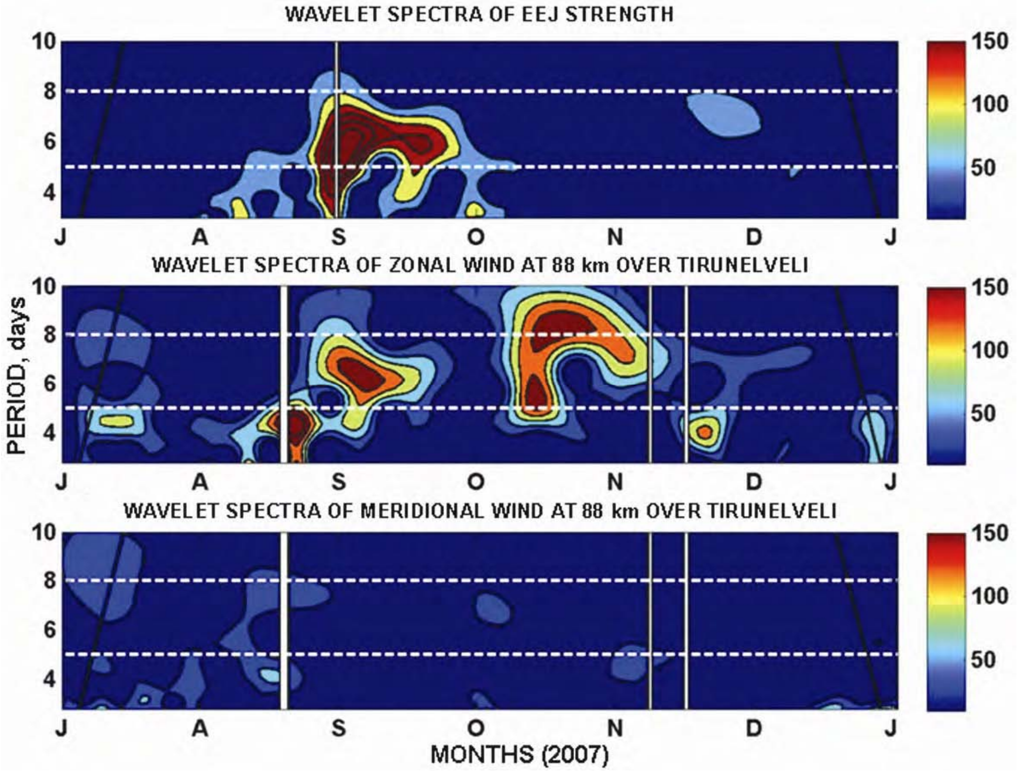

Fig. 2(f) — Wavelet power spectra of EEJ strength (top panel), zonal wind (middle panel) and meridional wind (bottom panel) from July-December 2007

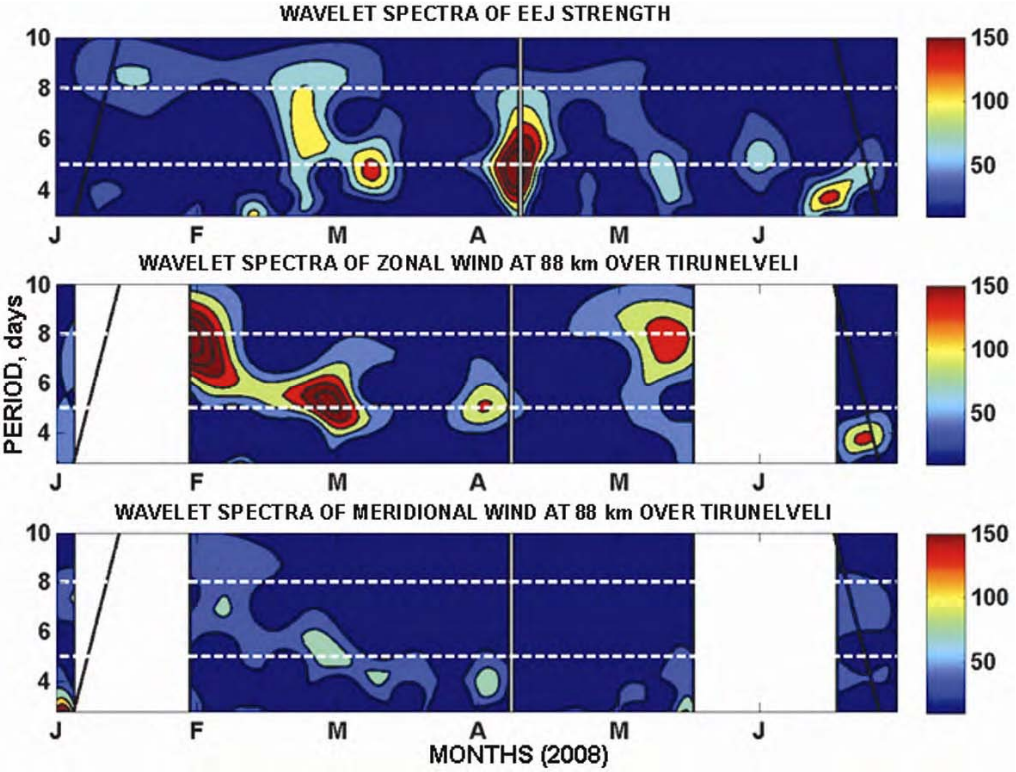

Fig. 2(g) — Wavelet power spectra of EEJ strength (top panel), zonal wind (middle panel) and meridional wind (bottom panel) from January-June 2008

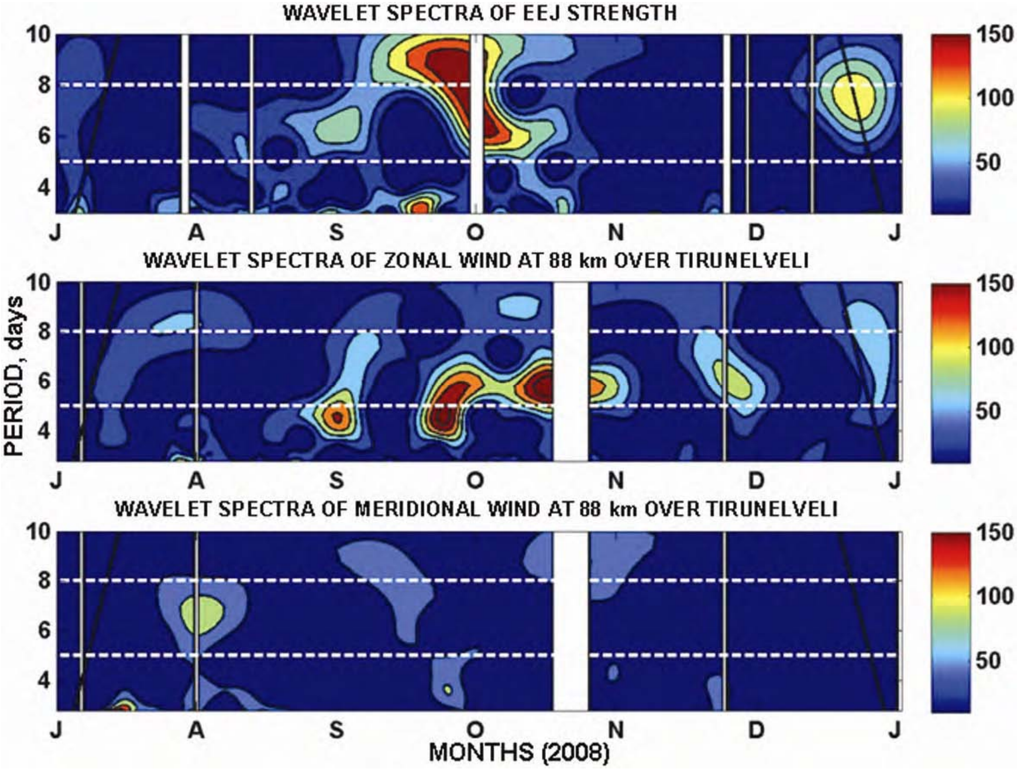

Fig. 2(h) — Wavelet power spectra of EEJ strength (top panel), zonal wind (middle panel) and meridional wind (bottom panel) from July-December 2008 in EEJ during August and October 2005 are accompanied by similar peaks in zonal winds. The peak occurring both in zonal and meridional wind during the middle of July is not noticed in EEJ. In 2006 [Figs 2(c and d)], the peak activity in EEJ occurs during the end of January, in case of winds a peak occurs during early January that lies close to the cone of influence. The wave peaks in zonal and meridional winds during February and March are not seen in EEJ. The wave activity occurring during September is noticed both in zonal wind and EEJ. The peak noticed during the month of November occurs simultaneously in winds and EEJ but the wave period is slightly lower in EEJ compared to winds. The year 2007 [Figs 2(e and f)], shows two wave bursts at 6.5-d period. The wave activity concurrently occurs in zonal wind and EEJ at the end of February and beginning of May. The meridional wind, as expected for the 6.5d wave at low latitudes, did not show any wave signature. Further, the peak noticed in EEJ during September is accompanied by similar peak in zonal wind. The presence of 6.5-d wave signature occurring in zonal wind in the middle of October is also seen in EEJ. During the equinoctial months of 2008, the 6.5-d wave co-exists in the wavelet spectra of both EEJ and winds.

From Figs 2(a-h), it is inferred that the 3.5-d and 6.5-d waves appear frequently in the wavelet spectra of zonal winds and EEJ. It is interesting to note that the simultaneous appearances of these waves both in zonal wind and EEJ have preferential periods of occurrence in any given year during this solar epoch. The 6.5-d wave appears in both the parameters during equinoxes except during 2006 spring equinox when the wave is very weak. The 3.5-d wave appears in winds and EEJ close to summer solstice. However, the presence of this wave is not well defined during winter solstice.

The presence of 3.5-d and 6.5-d waves simultaneously in winds and EEJ taking place only during certain months in the wavelet spectra encouraged to examine the time variation of wave variance, which represents the energy contained in the wave band, in a systematic manner. This helps to ascertain whether the wave activity in winds and EEJ occurred concurrently only during certain months of a year. Figure 3 shows the time variation of wave variance for 3.5-d wave for the years 2005 to

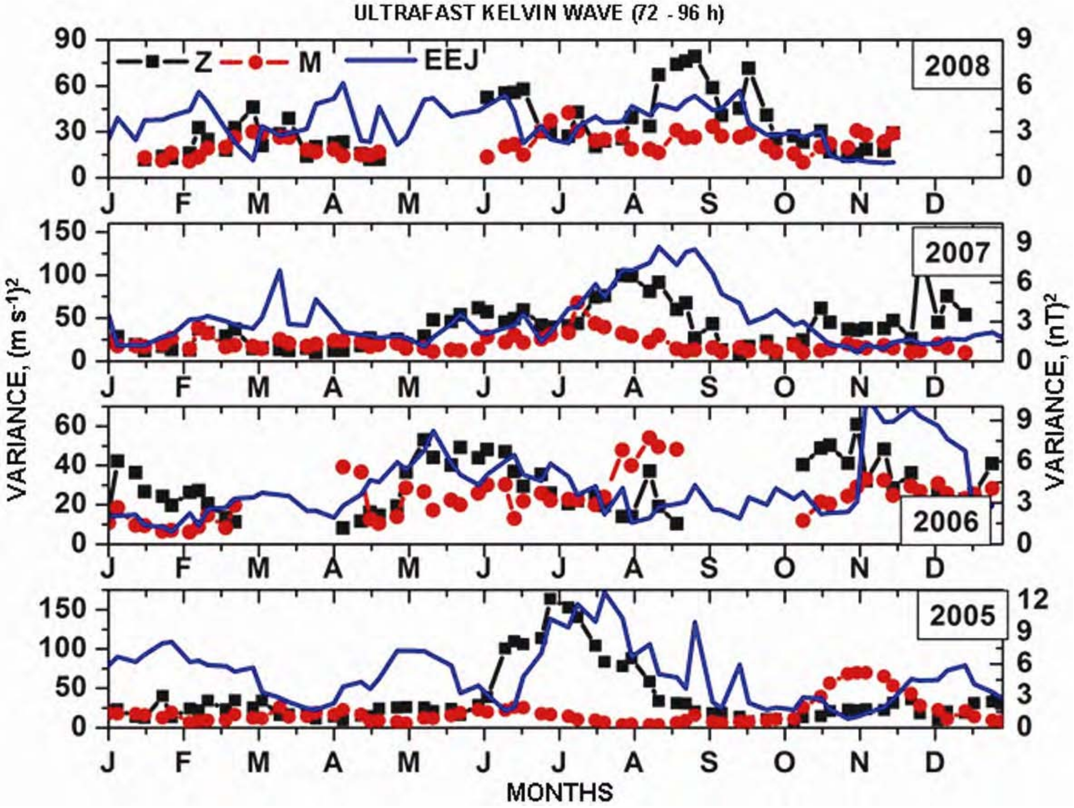

Fig. 3 — Time variation of 3.5-day wave variance for the years 2005 - 2008 (from bottom to top) (curves in blue, black and red depicts variations in EEJ strength, zonal wind and meridional wind, respectively)

2008 running from bottom to top. It is noted that in general the wave amplification both in wind and EEJ occurs close to summer solstice. Amplification of this wave is noticed during winter months also but it is not that consistent compared to the amplification noticed during summer solstice.

Figure 4 shows the time variation of 6.5-d wave variance for the years 2005 to 2008 running from bottom to top. The wave variance clearly shows the presence of two peaks both in winds and EEJ every year during/close to equinox indicating the presence of a semi-annual type variation (henceforth, referred as SAO). This is perhaps for the first time the PWTO at 6.5-d period exhibiting an SAO signature in EEJ is reported.

The preferential amplification of waves during certain months/seasons either indicates the seasonal dependence of wave activity on the excitation mechanism itself or the influence of background wind in controlling the underlying coupling processes. Because background wind conditions play an important role in upward wave coupling, it is necessary to examine these winds at MLT heights. Figure 5 represents the monthly mean background wind estimated for those months for which MF radar data are available for at least one-third of the respective month.

Comparison of Figs (4 and 5) suggests that the MLTI coupling of 6.5-d wave occurs when the background wind is westward. It is expected that waves with phase speeds comparable to and in the same direction as the background winds get damped and are not expected to propagate upwards. However, the present observations suggest that the 6.5-d waves observed in EEJ is either generated independently at dynamo heights or such waves have greater phase speeds enabling them to propagate upwards and reach dynamo heights. Such an inference corroborates with a previous report[17]. Comparison of Figs (3 and 5) indicates that the 3.5-d wave coupling in the MLTI region occurs when the background wind undergoes transition from eastward to westward or vice versa. It is known that the 3.5-d waves are ultra-fast Kelvin waves having eastward phase speeds. Conditions are favourable for these waves to leak through the mesosphere when the background phase speeds are small or negligible compared to the wave phase speed.

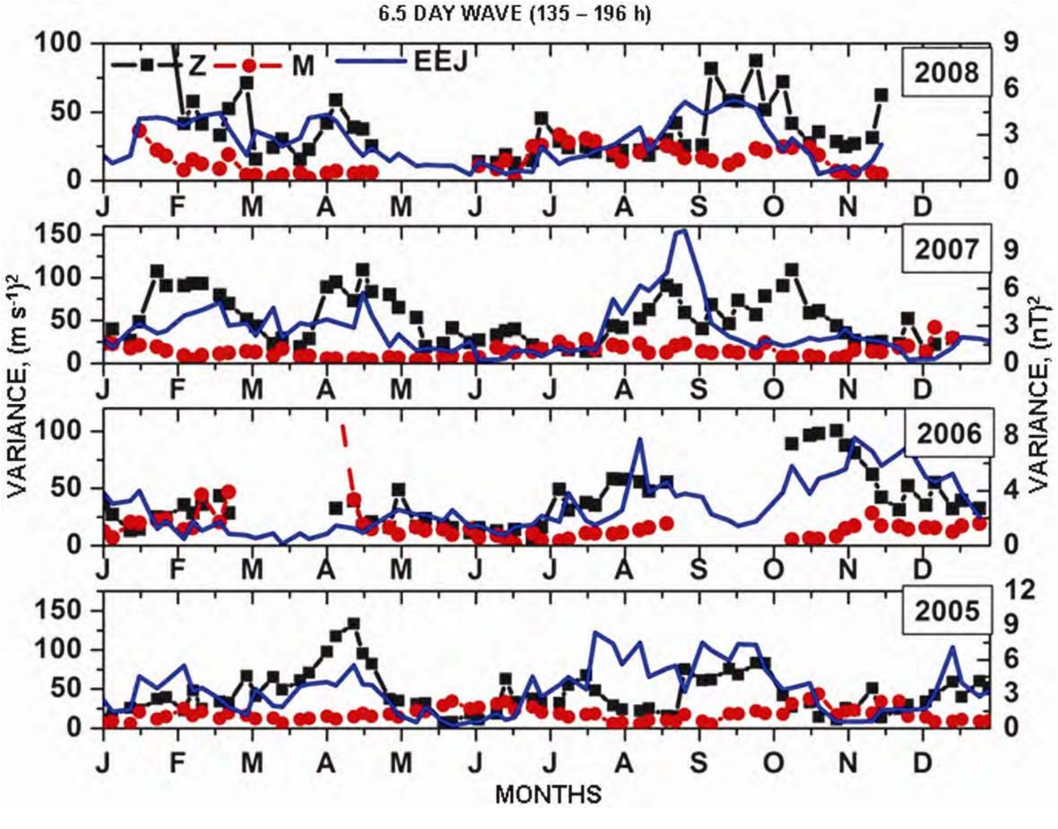

Fig. 4 — Time variation of 6.5-day wave variance for the years 2005 - 2008 (from bottom to top) (curves in blue, black and red depicts variations in EEJ strength, zonal wind and meridional wind, respectively)

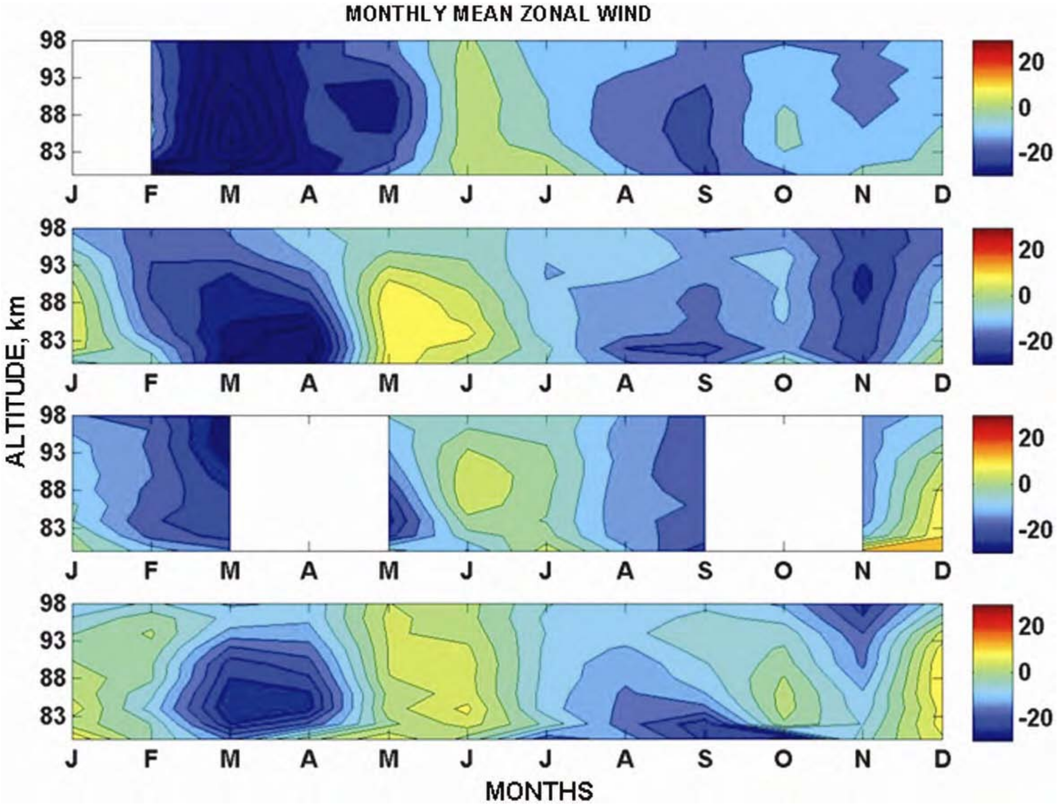

Fig. 5—Monthly mean zonal wind for 2005-2008 (from bottom to top)

4 Discussions

Even though planetary waves are observed in various parameters in the equatorial MLTI region, the understanding on the role of planetary waves and tides in various physical phenomena has so far been limited by the non-availability of large and simultaneous global data sets. Dynamical coupling of atmosphere-ionosphere system by waves from below has been one of the important topics of research till date due to their myriad effects on ionospheric current systems and density distribution with longitude. Planetary wave signatures have been studied in detail in the ionosphere and mesosphere individually. However, the vertical coupling of these regions is not very clear compared to the current knowledge about the individual regions. Systematic analysis using large dataset with simultaneous mesospheric and ionospheric observations needs to be carried out to handle this issue.

Some of the recent works, e.g. Pancheva *et al.*[17], have successfully tracked the planetary waves from the stratosphere all the way to the mesosphere and beyond. Pancheva[11] succeeded in tracking a 2-d wave from mesospheric heights up to ionospheric F-region and studied the characteristics of the wave at various levels using data from various stations around the globe. Despite the understanding based on previous reports, the contribution of waves propagating from below affecting the E-region ionospheric current system and the F-region behaviour during quiet times still remains an area of active research.

Forbes[18] performed numerical simulations based on previous reports, deviating from classical theory of atmospheric waves, to verify the vertical propagation of ultra-fast Kelvin waves up to the dynamo region. It was shown that the UFK wave is capable of achieving amplitudes of the order 10-25 K in temperature and 10-40 m s^{-1} in zonal wind in the 100-150 km height regime. His results emphasized the importance of these waves in the dynamo action causing short-term variability in several ionospheric parameters. Recently, Abdu *et al.*[19] presented evidence for the presence of 6.5-d day waves in the MLTI region and Takahashi *et al.*[20] observed common wave periods in mesospheric winds and h’F data with periods in the range 3-6 days. As shown in later observations, the variability in EEJ can modulate the pre-reversal enhancement in electric fields at those periods that would in turn affect F-region processes like equatorial ionization anomaly and formation of plasma bubbles, thereby causing significant day-to-day variability at F-region heights. The results based on four years of continuous data from the equatorial station, Tirunelveli, are important in this context of understanding the low-latitude MLTI coupling.

The oscillations in 3-4 day waves observed in the present work are identified as UFK, also referred as trapped equatorial Kelvin waves, that are often found to dominate the MLT region (Refs 4,21-24 and references therein). The 3-4 day wave variance is greater in the zonal wind compared to meridional wind suggesting that the waves observed in 3-4 day band are indeed UFK waves. Recently, Ramkumar *et al.*[25] presented simultaneous observations of UFK both in EEJ and winds from the same site and reported that the wave activity in EEJ was strong during spring equinox and summer solstice, mostly accompanied by a similar variation in winds. The present results are in agreement with their results. It has been also found in few cases (Fig. 5, second panel from the top) that the simultaneous amplification in planetary wave activity in winds and PWTO in EEJ occurs even during winter solstice. It is interesting to note that the simultaneous amplification in winds and EEJ in 3-4 day band occurs when the background wind changes from westward to eastward or vice versa, facilitating the waves to reach up to ionospheric heights. Ramkumar *et al.*[25] posed an interesting question as 'What actually causes the vertical coupling between ionosphere and atmosphere through upward propagating planetary waves to be operative only during some (and not all) of the episodes?' One of the keys to this question lies in identifying the state of the background wind in the MLT region. If the background winds support wave propagation, as in this case, a PWTO is expected in EEJ with the same period as planetary wave. On the other hand, it is also noticed that PWTOs are observed only in EEJ without any concurrent oscillation in MLT winds. This could be either due to waves generated *in situ* or non-linear interaction of two or more waves generating secondary waves at dynamo heights that would appear only in EEJ. Further investigation is required to analyze these possibilities.

The oscillation in the band 5.5-8 days could easily be identified as the well studied 6.5-d wave. The presence of 6.5-d wave was already reported from this site[26,27] using wind data. Several mechanisms have been proposed to explain the generation of the 6.5-d wave. Earlier, it was regarded as a manifestation of the (1,-2) Rossby planetary wave, commonly referred to as the 5-day wave[28] that would Doppler shift to longer periods by interaction with background winds. Later, it was believed to be produced by baroclinic instability of the mid-latitude mesosphere[5]. Another school of thought considers these waves as resulting from direct forcing or nonlinear interaction of 4 and 10-day waves in the lower atmosphere[29] and 7-day wave and stationary planetary wave (SPW) with wave number m=1 (Ref. 30). From the previous reports using MF radar winds, it is evident that the 6.5-d wave is an equinoctial phenomenon and shows semi-annual variability. The present observation corroborates with the previous observation and similar semi-annual variability of PWTO of 6.5 day wave period is found in EEJ also. As expected for the 6.5-day wave at low latitudes, the amplitude in meridional wind is less than that in zonal wind. Simultaneous presence of this wave in winds and EEJ is observed during the westward phase of the background mean wind.

The present work aims at understanding the coupling of various atmospheric layers by individual planetary waves. The former works choose a particular window covering few months and discuss on similar signatures in winds and EEJ, wherein all planetary wave periods from 2-20 days are considered. The present work, on the other hand, differs from previous works, as it chooses a particular planetary wave and examines various aspects like preferential period for coupling, state of the background wind and the role of background wind in favouring upward propagation and hence, MLTI coupling by the specific planetary wave.

Previous reports, e.g. Ramkumar *et al.*[25], used five years (1994–1998) of similar wind and magnetic data to demonstrate that the northern spring equinox month of April is favourable for the existence of planetary-scale oscillations in EEJ strength. Previous reports did not bring out the regular occurrence of the 6.5-day coupling during spring and fall equinoxes, every year. The concurrence of SAO signature in mesospheric winds and EEJ for all four years, reported herein, indicates that the 6.5-day wave coupling of MLTI region is a regular equinoctial phenomenon that contributes to the variations in equatorial and low latitude ionospheric current systems. Presuming that the background wind conditions are favourable at heights greater than

98 km, there is a reasonable evidence to believe that the PWTOs observed in EEJ could be caused by the passage of the same planetary waves observed at mesospheric heights.

5 Conclusions

The present study is an attempt made towards delineating the role of planetary waves in equatorial MLTI region using four years of data during a period that was characterized by a deep solar minimum. The following are some important aspects worth highlighting: concurrent occurrence of 3.5-d oscillations in zonal winds and EEJ is noticed around summer solstice when the background wind changes direction, though the signatures are not consistent during winter solstice. Similar behaviour for the 6.5-d waves is noticed around equinoctial months when the background wind is westward. The 6.5-d wave variability in EEJ also exhibits an SAO type signature akin to mesospheric winds that is being reported for the first time. This work reaffirms earlier suggestions that planetary wave coupling in the low latitude MLTI region occurs around a preferential period. It also adds support to the assumption that planetary waves propagating from below do contribute substantially to the short term variations in EEJ.

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