Chapter – IV

Intraseasonal oscillation (ISO)
in the MLT winds
Chapter IV

Intraseasonal oscillation (ISO) in the MLT winds

4.1 Introduction

We have seen long period motions such as AO, SAO in MLT mean winds in Chapter III. Besides such long period motions, mesospheric wind fields often exhibit Intraseasonal oscillations (ISO) in the time scale of 20-100 days. This is believed to be associated with the Madden and Julian Oscillation (MJO) of the tropical tropospheric circulation. The MJO also referred to as the 30-60 day or 40-50 day oscillation explains weather variations in the tropics. The MJO affects the entire tropical troposphere and is most evident in the Indian and western Pacific Oceans. The MJO involves variations in wind, sea surface temperature (SST), cloudiness and rainfall. It has also been identified in a parameter called ‘outgoing longwave radiation’ (OLR) [1]. Because most tropical rainfall is convective and convective cloud tops are very cold (emitting little longwave radiation), the MJO is most obvious in the variation of outgoing longwave radiation (OLR).

The MJO occurs when a large region of convective ascent moves eastward from the Indian Ocean into the western Pacific producing 30-60 day periodicities in regional convective activity as it passes. This disturbs the climatological Walker circulation, producing a planetary-scale response of similar period in the equatorial velocity field. This velocity response can be understood to first order as a coupled Kelvin-Rossby mode near the forcing region, which as one shift further eastward, is replaced by a wavenumber-1 Kelvin wave radiating away from this forcing zone. Rocket and radiosonde observations in the Indian sectors revealed important features of the ISO [2, 3]. The MJO activity is reported to attenuate rapidly above the tropopause but the Intraseasonal power appears to reintensify in the upper stratosphere. Higher
latitude rocket observations showed equal amounts of Intraseasonal variability in both wind components that has been consistent with the behaviour of Rossby waves. One school of thought proposed that these Rossby waves propagated into the tropical upper stratosphere from mid-latitudes whereas certain other workers suggested that the waves ‘leaked’ into the upper stratosphere from the tropical troposphere via vertical propagation. GCM simulations by Hayashi and Golder (1993) [4] showed penetration of equatorial Rossby-wave activity at Intraseasonal periods to near the top of their model (~75 km). Observations from Christmas Island in the Central Pacific, Pontianak in the Indonesia and Tirunelveli from the Indian sector, all reveal ISO in the MLT (80-100 km) region. It has been proposed that MJO associated, convectively generated, gravity wave and tidal modulation of momentum fluxes varying at ~45 day periods interact with SSAO to produce oscillations at ~60 days [5, 6].

The results to be presented here are divided into two sections i.e. section 4A and section 4B. In section 4A, we have presented intraseasonal oscillations in the MLT winds over Kolhapur. In section 4B, we have studied, compared and presented the intraseasonal oscillations in the zonal winds at 88 km over Kolhapur and Tirunelveli.
SECTION 4A: Intraseasonal oscillation (ISO) in the MLT winds over Kolhapur (16.8° N)

This section presents results on the identification of intraseasonal oscillations in MLT wind components over Kolhapur. Figure 4.1 shows time series of zonal and meridional wind velocities at 86 km for the period December 2007-March 2010. The top row of plots shows the raw daily-averaged data, while the row bellow it shows the same data after smoothing with a 20 day running average. The ~180-day oscillation due to MLT semi-annual oscillation is observed in both zonal and meridional wind. In addition to these oscillations, the smoothed time series of zonal and meridional winds show many wavy lines indicating the presence of Intraseasonal oscillations.

Figure 4.2 shows the average amplitude spectra of daily averaged velocity time series computed FFT technique for zonal (top panel) and meridional winds (bottom panel) for the altitude region 84-98 for 1-256 days and 409-664 days. The bottom axis shows periods of intraseasonal scales. The corresponding spectral amplitude is given on the left axis. It may be noted that the meridional spectral scaling (2.5 m/s) is smaller than the zonal scaling (5 m/s), as it is evident that intraseasonal oscillations are stronger in zonal wind than in meridional wind. This shows that these oscillations behave like Kelvin wave in the MLT region, whereas earlier observations from India showed that they behaved like Rossby waves in the stratospause region [7, 3]. The mixed behaviour of these oscillations is similar to the Madden-Julian Oscillation (MJO) which exhibits the mixed Kelvin-Rossby wave structure over the eastern hemisphere, but over the western hemisphere, it only shows a Kelvin wave structure. It is observed that there is rich spectrum within the 20-100 day period range which has been called as ‘intraseasonal oscillations’ (ISO). Significant peaks are observed in the period range 50-70-days, 30-50-days and 20-30-days. The peaks observed in the intraseasonal band (20-100 days) of meridional wind spectra show height coherency, only for the oscillation at about 25 day. Ekermann et al. (1997) [6]
using the longer time series (1994 days), identified small but distinct peaks in the meridional velocity spectrum at \( \sim 60 \)-days and \( \sim 35 \)-days. Though peak near 35-days is observed in our observations, the peak near 60-days is not observed. The 40-day oscillation is present in both zonal and meridional components. It may be noted similar intraseasonal oscillations with periods in the range 40-50 days and 20-30 days have been extensively studied in meteorological parameters like pressure and wind in the equatorial troposphere.
Figure 4.1 Time series of daily mean zonal and meridional winds (top panels) and 20-point smoothed (bottom panels) daily mean winds for December 2007-March 2010.
Figure 4.2 Average amplitude spectra of daily averaged zonal (top panel) and meridional winds (bottom panel) for 1-256 and 409-664 days and for the altitudes 84-98 km.
Meteorologists use a variety of data and analysis techniques to monitor, study and predict tropical MJO and their evolution. Of primary importance is information derived from NOAA’s polar-orbiting and geostationary satellites. Satellite-derived data are used to indicate regions of strong tropical convective activity and regions in which the convective activity departs substantially from the long-term mean. These departures from normal are a fundamental diagnostic tool that is used directly to monitor and predict the MJO as it propagates around the global tropics. Outgoing longwave radiation (OLR) is one such satellite-derived measure of tropical convection and rainfall and can be used to infer the presence of MJO in lower tropical atmosphere. The daily values of OLR provided by the NOAA satellite are downloaded from the web site http://ingrid.ldgo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.GLOBAL/.daily/.olr/ [8] for the latitude of 17.5°N and 75°E, which nearly corresponds to the geographical location of Kolhapur.
Figure 4.3 shows variation of 10-point smoothed OLR data with time and it clearly reveals the annual oscillation with maximum value in winter and spring equinox and minimum values in summer and fall equinox. High values of OLR are associated with high radiative temperatures of matter on or near earth’s surface and lack of intense convective clouds in the free atmosphere. On the other hand, low values of OLR are associated with low radiative temperatures of cold cloud tops. To identify whether similar Intraseasonal oscillations occur in the lower atmosphere, the daily values of OLR are subjected into spectrum analysis. Figure 4.4(top panel) shows the amplitude spectrum of OLR data. The spectra of zonal and meridional winds at 86 km (Figure 4.4 (bottom panel)) are also plotted for comparison. The spectrum of OLR data (Figure 4.4 (top panel)) shows dominant peaks in the period range ~50-70-days, ~30-50-days and ~20-30-days. The amplitude of the peak near 60-days is slightly larger than that of other two dominant peaks. It may be noted that the spectrum of zonal wind at 86 km (Figure 4.4 (bottom panel)) also peaks corresponding to these period range.

Based on the amplitude spectra of zonal and meridional winds (Figure 4.2 and Figure 4.4 (bottom panel)), three principal oscillations with periods in the range of 20-30 days, 30-50 days and 50-70 days can be conveniently isolated. They will, hereafter be called as 25-d, 40-d and 60-d oscillations respectively. Figures 4.5, 4.6 and 4.7 show the comparision of the time variation of 20-day averaged daily mean zonal wind with that of 25-d, 40-d and 60-d oscillations in zonal wind respectively. From the figures, it can be inferred that the bursts of 25-d oscillation do not generally occur at similar times except during spring equinox period. The 25-d oscillation shows bursts of activity in September-November months. Enhanced 25-d oscillations are observed during fall equinox of both the years, 2008 and 2009, whereas relatively small amplitudes are observed during other months of both the years. It may be recalled that the year 2008 is characterized by enhanced westward zonal winds in the mesopause region. These enhance westward winds coincide with the enhanced amplitudes of 25-d oscillation in year 2008, spring months.
Figure 4.4 Average amplitude spectra of OLR data (top panel) for 1-768 days and zonal and meridional winds (bottom panel) for 1-256 and 409-664 days at 86 km.
Figure 4.5 Comparison of 20-day averaged daily mean wind and 20-30-d oscillations in zonal wind.
Figure 4.6 Comparison of 20-day averaged daily mean wind and 30-50-d oscillations in zonal wind.
Figure 4.7 Comparison of 20-day averaged daily mean wind and 50-70-d oscillations in zonal wind.
Chapter IV

The 40-d oscillations in zonal wind do not occur at same time. The 40-d oscillation also shows moderate activity during February, May-June, 2008, but the amplitude of the oscillation decreases, as height increases. During October-November, 2009, oscillations occur at all heights. The 60-d oscillation in zonal wind occur at nearly same time for the altitudes 92-96 km throughout the entire period considered for the analysis.

Summary and conclusions

The present analysis suggests that the intraseasonal oscillations (ISO) in the period range 20-100 days are mainly observed in zonal and weakly observed in meridional winds in the MLT region. Three main period bands of oscillations are identified at around 25-days, 40-days and 60-days. Oscillations in these three period bands are also observed in OLR, which can be used to infer the presence of intraseasonal oscillations (generally called as MJO) in tropical troposphere, as it is a measure of tropical convection and rainfall.
Chapter IV

References

Chapter IV

SECTION 4B: Intraseasonal oscillation (ISO) in the MLT
zonal wind over Kolhapur and Tirunelveli

4B.1 Introduction

The equatorial/low latitude region is the source of many unique atmospheric processes that couple the entire atmosphere vertically from bottom to top and horizontally from equator to pole. The circulation of the equatorial middle atmosphere is known to be dominated by a semi-annual oscillation (SAO) and a quasi-biennial oscillation (QBO). The winds are dominated by the QBO at heights below 35 km, while above 35 km, by the SAO [1-3]. The SAO has maximum amplitudes near the stratopause (~ 50 km) and mesopause (~ 85 km), with minimum near 65 km, and the stratospheric SAO (SSAO) is in antiphase with the mesospheric SAO (MSAO) [4-6]. The SAO and QBO are centered at or near the equator, and their cycles start first at upper levels and then descend steadily with time. Descending wind regimes are usually a characteristic of a circulation driven primarily by waves propagating from below. It has been suggested that upward coupling of energy and momentum by waves generated in regions of intense tropospheric convection is expected to be important for determining the state of the equatorial middle atmosphere. Convectively generated waves such as Kelvin, Rossby-gravity and gravity waves play a crucial role in driving the QBO in the lower stratosphere and the SSAO[7-10], whereas Kelvin waves and gravity waves are considered to be important for driving the MSAO [4,11].

Zonal winds in the equatorial mesosphere and lower thermosphere (MLT) region are characterized by long-term variations such as the annual oscillation (AO) and the semi-annual oscillation (SAO) [12]. In addition, the SAO
amplitudes show biennial variations [13]. Wind oscillations caused by the Ultra-
Fast Kelvin waves (UFK) with 3-4 day period and quasi 2-, 5-, and 16-day wind oscilla-
tions have also been investigated [14-20]. Besides these oscillations, the MLT zonal winds also undergo variations with a period between the seasonal cycle and planetary-scale wave periods (periods ranging from 20 to 100 days), which have been termed as the intraseasonal oscillation (ISO), first reported by Eckermann and Vincent [21] from Christmas Island (2°N, 150°W). Eckermann et al. [22] further investigated the ISO using long-term (1990-1995) observations by medium-frequency (MF) radar made at Christmas Island. Periodicities of about 25, 40, 60 days were observed not only in the zonal wind, but also in the amplitude variations of gravity waves and diurnal tidal amplitudes.

Intra-seasonal oscillation (ISO) is an important component of atmospheric variability in both the lower and upper atmosphere [23-25]. In the equatorial troposphere, intraseasonal variability is a dominant feature of convective anomalies. Intraseasonal variabilities in the zonal wind velocity and tropical rainfall are observed and are mostly confined in the region between the Indian Ocean and the western and central Pacific [26, 27]. The Madden-Julian oscillation (MJO) of this kind is characterized by large-scale convective anomalies that develop over the tropical Indian Ocean and propagate slowly eastward over the maritime continent to the western Pacific [28], slowly decay over central Pacific and vanish over the eastern Pacific. In the tropics, ISO is associated largely with the Madden-Julian Oscillation (MJO) which has characteristic time period of about 30-60 days. The MJO [26, 29] has been studied extensively because of its role in influencing air/temperature, wind, convection, rainfall, outgoing long wave radiation (OLR) and several other aspects of the weather and climate system [27, 30-33]. Large-scale pressure and circulation anomalies develop with the convective anomalies and can be interpreted as a moist equatorial Kelvin–Rossby wave response in the tropics [34, 35].

The MJO can be considered as a mixed Kelvin and Rossby wave near the source region and an eastward propagating Kelvin wave radiating away from the
source region [29]. The MJO attenuates rapidly above the tropopause [26]. The studies of rocket and radiosonde data from tropical Indian stations showed that the wind variabilities in the intraseasonal time period are diminished above tropopause and reintensified at the upper stratospheric heights [36-38]. Nagpal and Raghavarao [36] and Nagpalet al. [39] argued that the Rossby waves of time period in the intraseasonal time scale could propagate into the tropical atmosphere from mid-latitudes, whereas Kumar and Jain [38] suggested that the Rossby waves associated with the MJO might leak into the upper stratosphere from tropical troposphere via vertical propagation. Ziemke and Stanford [40] observed strong ISO activity at in daily global geopotential height data from British Meteorological Office analyses in a longitude zone near India which they associated with tropical Rossby waves that refracted to mid latitudes then back to tropical latitudes near the stratopause.

Eckermann and Vincent (1994) observed an intraseasonal variation of zonal winds in the MLT region at Christmas Island. Eckermann et al. [22] further reported that the ISO periods observed in the zonal winds of the MLT region are similar to the MJO periods and suggested that the intraseasonal cycles in the tropospheric convection associated with the MJO cannot propagate directly into the MLT region because of their slow phase velocity but modulate the intensity of the upward propagating gravity waves and non migrating diurnal tides and that these induce intraseasonal variations in the MLT region zonal winds through wave induced driving of the mean flow (when they either dissipate or break).

Using Upper Atmospheric Research Satellite-High Resolution Doppler Imager (UARS/HRDI) data, Lieberman [41] studied the ISO in the zonally averaged zonal winds in the altitude range 65-100 km. The maximum amplitudes of the ISO were observed at 95 km and 75 km height, with a local minimum at around 80 km. The ISO was found to be present between ± 20° latitude from the equator and these ISO features moved downward in time and exhibited equatorial symmetry with the maximum at the equator.
Isoda et al. [42] compared observations from the three equatorial radar sites, Jakarta (6ºS, 107ºE), Pontianak (0ºN, 109ºE), and Christmas Island in order to investigate possible differences in the zonal wind ISO as a function of latitude and longitude. Their results suggest that the generation of nonmigrating tides is modulated at the ISO period in the lower atmosphere, and these modulated nonmigrating tides propagate to the MLT region. Then the breaking/dissipating tides modulate the zonal mean wind in this region. Their correlative analysis suggests that though the ISO in the diurnal tide correlates well with the ISO in zonal wind, the ISO in the gravity waves does not. However, this study did not rule out the role of gravity waves in causing the ISO in zonal wind.

In 2006, Miyoshi and Fujiwara studied the excitation mechanism of the ISO of the zonal mean zonal wind in the equatorial MLT using a general circulation model. Their results showed that the wave-mean flow interaction involving ultra-fast Kelvin waves [17] and diurnal tides (both migrating and non-migrating) is important for driving the ISO.

Kumar et al. [43] reported ISO activity in zonal winds over Tirunelveli for the observational period, February 2004 to May 2005. They observed similar ISO activities in the time scale of 50-70 days that peaked at the same time in OLR at 75ºE, averaged over 5-10ºN latitude, as well as in MLT zonal winds, whereas shorter period ISO (20 - 40 days) in the MLT zonal wind coincided with that in the tropospheric water vapor. However, to confirm the relation between the ISO in lower tropospheric convective activity and the ISO in mesospheric zonal wind long-term data obtained from a longitudinally distributed network of radars is required.

Sridharan et al. [44] studied the long term variability of ISO in MLT zonal winds and its relation to MJO in the troposphere, using long term data (1993 to 2006) obtained from the MF radar at Tirunelveli. They observed biennial variability in the ISO of both MLT zonal winds and tropospheric convective activity. Their observations could establish that larger ISO amplitudes coincided with strong westward winds.
Chapter IV

Rao R. K. et. al.,[45] studied the longitudinal variability in ISO in the tropical MLT region using observations from four radar sites, Cariri (7.4°S, 36.5°W), Ascension Island (7.9°S, 14.4°W), Tirunelveli (8.7°N, 77.8°E) and Pamuengpeuk (7.7°S, 107.7°E). Their study revealed the longitudinal dependence of the ISO at MLT heights and observed greater ISO amplitudes over regions where the MJO was strong.

The present work is confined to Indian region only. In this work, to study the latitudinal nature of the ISO of the zonal winds in the equatorial MLT region and its relation to the intraseasonal variability of convective activity associated with the MJO in the troposphere, we have used simultaneous data obtained from the network of radars situated at the low latitude sites, Kolhapur (KOL) (16.8°N, 74.2°E) and Tirunelveli (TIR) (8.7°N, 77.8°E) during the period from January 2008 to December 2009.

4B.2 Data

In the present study we have utilized the data obtained from the MF radars operated at Kolhapur and Tirunelveli. The radar system at Kolhapur is very similar to the one installed at Tirunelveli (8.7° N, 77.8° E), India. Both the MF radars are operating at 1.98 MHz frequency The MF radars measure winds using the spaced antenna technique in the 68-98 height range during day time and from 70 km during night time. The MF spaced antenna technique provide reliable winds for synoptic studies of neutral air motions in the height range 84-94 km at time scales of greater than 12 h. The data acceptance rate is relatively high at heights above 84 km with largest acceptance rate around 88 km. Winds are recorded every 2 minutes at 2 km height intervals [46]. The wind data with two minutes time interval are averaged to compute hourly mean winds. The daily mean values were calculated by averaging hourly data for those days having number of data points more than 18 points. The days during which number of hourly data points less than 18 were not considered.
The outgoing long-wave radiation (OLR) data (obtained from the National Oceanic and Atmospheric Administration- National Centers for Environmental Prediction (NOAA-NCEP)) has been used as a proxy for deep tropical convection [47], to study the nature of the ISO activity in the lower tropospheric convection. The OLR data are indicators of cloud top heights. Very high and cold clouds (low OLR) at tropical latitudes are presumed to be associated with deep convection.

4B.3 Behavior of the ISO in zonal wind at 88 km height

The time series of daily mean zonal winds determined from the observations made by both the radars at a height of 88 km for the period of January 2008 – December 2009 are shown in Figure 4.8.

The quality of data is very poor during the observation periods, with day numbers in the range 324-387 at KOL and days 139-167 and days 427-587 at TIR and we have shown gaps for those particular periods. The data acceptance rate is relatively high at heights above 84 km, with largest acceptance rate at around 88 km for both the MF radars at KOL and TIR. In this work, we have chosen to consider the daily mean zonal winds at 88 km for studying the ISO.
Figure 4.8  Time series of daily mean zonal winds at 88 km altitude over Kolhapur (KOL) (top plot) and Tirunelveli (TIR) (bottom plot) for the observational period 01 January 2008 – 31 December 2009.

The mesospheric semiannual oscillation (MSAO) is clearly evident over both the sites, with westward flow during the equinoxes and eastward flow during the solstices. Also wind variabilities in intraseasonal time scale can be seen clearly. In order to examine the dominant periods of time variations of the zonal winds in the intraseasonal time scale, a spectral analysis of zonal winds at 88 km was performed whose results are shown in Figure 4.9 (a-c). From the whole data set, three data segments have been chosen corresponding to different time intervals in which data from both the stations are available, namely, days 1-128 (1 January 2008 - 07 May 2008) (128 data points), days 190-317 (09 July 2008 – 13 November 2008) (128 data points) and days 590-717 (13 August 2009
Chapter IV

– 18 December 2009) (128 data points), and a Fast Fourier transform (FFT) is applied to the each data segment to check the presence dominant periodicities in different time intervals. The 95% confidence levels for both the stations are shown. To test the statistical significance of the spectral amplitude (Rk), we have used a method in which the probability ‘p’ that the ratio $R_k^2/\sum R_k^2$ exceeds a parameter ‘g’ is given by $p = \{m (1 - g)^{m-1} + \text{higher order terms}\}$ (here, $\sum R_k^2 = 2/N \sum (X_i - X\text{ mean})^2$), the summation on the left hand side runs from $k = 1$ to m and that on the right hand side runs from $i = 1$, N, the number of points; $m = N/2$. The error introduced in neglecting the higher order terms is only 0.1% for $p = 0.05$ (95% confidence level). Therefore, the parameter g (for $p = 0.05$) can be calculated from the relationship, $p = m (1 - g)^{m-1}$. The parameter $g_k$ is given by $g_k = R_k^2/(2/N \sum (X_i - X\text{ mean})^2)$. If $g_k > g_p = 0.05$ (for 95% confidence level), the amplitude is 95% significant.

Since our main interest is to study intraseasonal oscillations, we now concentrate on the oscillations in the period range 20-100 days. During the time interval 1-128 days (Fig. 4.9 (a)), dominant peaks around day number 32 and 42 are observed over both the stations KOL and TIR. A peak around 67 day is also observed over TIR. The 32 and 42 day oscillations are relatively strong over TIR and compared to KOL during this interval. During the interval 190-317 days (Fig. 4.9 (b)), oscillations with the time period around 37 and 67 days are observed over both the stations and are dominant over KOL compared to TIR. A weak oscillation of time period around 21 is also observed over TIR. During the interval 590-717 days (Fig. 4.9 (c)), again a dominant peak is observed around 37 days and a peak around 21 days is also evident over both the stations. In addition to this, a peak around 67 days is observed over TIR. The 37 and 67 day oscillations are strong over TIR and 21 day oscillation is relatively strong over KOL during this interval. From Fig. 4.9 (a-c), it can be noticed that that the ISO activity with time period around 67 days is observed during all the time intervals i.e. 1-128 days and 190-317 days and 590-717 days, where as a 37 days and 21 days activity is dominant during the intervals 190-317 days and 590-717 days and oscillation with 42 and 32 are observed during the interval 1-128 days.
Figure 4.9 Amplitude spectra of the daily zonal winds at 88 km over two sites Kolhapur (KOL) and Tirunelveli (TIR) for the three time intervals (a) 1-128 days (b) 190-317 days and (c) 590-717 days. The horizontal lines represent the 95% confidence levels.
Figure 4.10  Band pass (20-100 days) filtered daily zonal winds at 88km observed at Kolhapur (KOL) and Tirunelveli (TIR) for the observational period 01 January 2008 – 31 December 2009.

By applying a filter with band-pass of 20-100 days, fluctuations in the period range 20-100 days in the daily mean zonal winds at 88 km height were extracted and are shown in Fig. 4.10. As can be seen in Fig. 4.10, during the observational period days 1-128 (January 2008 to May 2008), the ISO activity in the 60-70 day period band is dominant over TIR and 30-40 day oscillation are dominant at both the stations. The observation period days 190-317 (June 2008
to February 2009) is dominated by both 30-40 day and weak 60-70 day ISO activity at both sites and for the period 590-717 (August 2009 to December 2009), 60-70 day activity is dominant at TIR. Also, 20-30 days and 30-40 days activities are dominant over both the stations. The results from this exercise reveal the similarity of 20-30 day and 30-40 day ISO variations over both the sites during the observational period days 190-317 and days 590-717 whereas 60-70 day ISO activity is not similar during the observational period days 1-128 and 590-717. The ISO activity at MLT heights is relatively more prominent over TIR as compared to other station KOL during most of the time in all time periods except few occasions.
Figure 4.11  Time-height sections of the ISO of the zonal winds (m/s) over Kolhapur (KOL) and Tirunelveli (TIR) for the observational period 01 January 2008 – 31 December 2009.
Figure 4.11 shows the height-time contours of the ISO amplitudes (20-100 day filtered zonal winds) of the zonal winds over KOL and TIR. The height-time contours in the Fig. 4.11 are tilted slightly downward with increasing time indicating the downward phase progression of the ISO with time. Earlier studies on ISO [41, 42] in zonal winds at MLT region also revealed the downward phase progression of the ISO in the MLT region.

4B.4 ISO in the lower tropospheric convective activity

Figure 4.12 depicts the time-longitude behavior of OLR averaged over 5°N-20°N. OLR values less than 190 W/m² represent deep convective activity. The deep and broad convective clusters are present mainly over the 70°E-180°E longitude sector and relatively weak convective activity is observed around 20°E and 270°E regions and the remaining regions are convectively quiescent. The contours over the 70°E-180°E longitude sector tilt slightly towards the right or towards the left during certain times with increasing or decreasing longitude indicating an eastward or a westward motion of the convective clusters.

It can be noticed clearly in Fig. 4.12 that there is a variation in the convective activity on the intraseasonal time scale over the 70°E-180°E longitude region that is evident without any filtering of OLR data. The convective clusters with nearly 60-70 day variability can be observed during the observation periods 1-180 days, 300-480 days and 600-730 days (the convective centers are separated by specified number of days) and 30-50 day variability can be observed during the observational period 180-320 days. Convective clusters with 20-35 day variability are also observed during the period 480-640.
Figure 4.12  Time-longitude cross sections of the OLR (W/m$^2$) averaged over 5°N-20°N for the observational period 01 January 2008 – 31 December 2009.

In order to know the exact dominant periods of time variations of the OLR in the intraseasonal time scale, the daily OLR data were averaged over the 70°E-80°E and 5°N-20°N region and spectral analysis was performed on the
averaged OLR data in the same three time intervals (days 1-128, days 190-317 and days 590-717) for which a spectral analysis was earlier performed on the daily mean zonal wind (Fig. 4.9 (a-c)) and results are shown in Fig. 4.13 (a-c). The 95% confidence levels are also indicated in each of the panels. A dominant peak at 42 days is observed during the time interval days 1-128. A strong ISO activity with 42 days period is observed during the period 190-317 days. It can be noted that during both the time intervals i.e. days 1-128 and days 190-317, a weak oscillation around 32 days is observed. During the remaining time interval 590-717 days, peaks around the period 42 day and 21 day are observed. From this exercise, we can infer that the convective activity and its ISO variability over 5°N-20°N region are quite pronounced. The deep convective activity over the 70°E-80°E and 5°N-20°N region undergoes strong intraseasonal variations with different time periods (42 days, 32 days and 21 days, for example) in different time intervals. Now, we shall proceed to examine the influence of latitudinal variability in convective activity on the latitudinal nature of the ISO in MLT zonal winds by comparing the ISO in convective activity at the latitudes corresponding to respective radar locations with the ISO in zonal winds at 88km.
Figure 4.13 Amplitude spectra of the daily OLR averaged over 70°E-80°E and 5°N-20°N region for the three time intervals (a) 1-128 days (b) 190-317 days and (c) 590-717 days. The horizontal lines represent the 95% confidence levels.
4B.5 Comparison of ISO in zonal winds at 88 km height with ISO in lower tropospheric convective activity

In Fig. 4.14 and 4.15, the OLR at 17.5°N latitude (over longitude sector 60°E-140°E) is compared with the ISO in zonal wind at 88 km over KOL (16.8°N, 74.2°E) and the OLR at 7.5°N latitude (over longitude sector 60°E-140°E) is compared with the ISO in zonal wind at 88 km over TIR (8.7°N, 77.8°E) respectively. The convective activity at 17.5°N latitude is strong only during the time intervals 150-300 days and 450-650 days and is weak during remaining periods where as convective activity is strong with dominant ISO activity at 7.5°N latitude during the entire observational period. The convective activity over 7.5°N latitude and the zonal wind at 88 km over TIR undergo similar variations on ISO time scales. During the observational periods days 1-128 and days 590-717, when convective clusters with 60-70 day variability are observed over the 7.5°N latitude region, the zonal winds over TIR also show strong 60-70 day variability whereas ISO in zonal winds over KOL do not exhibit 60-70 day variability. During the remaining observational periods, 20-30 and 30-40 day ISO variations in MLT zonal winds over both the stations are similar with the ISO in convective activity. It seems that the zonal winds over TIR, as compared with those over KOL, are influenced more by the 60-70 day convective activity. One important thing to be noticed is that the ISO in MLT zonal winds over KOL is similar to ISO in MLT zonal winds over TIR during the observational periods 150-300 days and 590-660 days during which the convective activity at 17.5°N latitude region is strong and show also similar ISO activity. From this, it can be understood that the ISO in MLT zonal winds over both the stations are in similar phase when the convective activity and its ISO are strong over both the locations. The earlier results [42, 45] on longitudinal variability of ISO in MLT zonal winds showed that ISO in convective activity induce similar (same phase) ISO variations in MLT zonal winds in the
longitudinal direction though the amplitudes of the ISO are different. In the present case, the ISO in zonal winds do not exhibit coherency in the latitudinal direction during certain time intervals. The following could be a plausible explanation for this latitudinal behavior of ISO in the MLT zonal winds. A spectrum of atmospheric waves is generated in the tropical troposphere owing to deep convection. The intraseasonal cycles in the tropospheric convection associated with the MJO modulate the intensity of the upward propagating gravity waves, nonmigrating diurnal tides and planetary (equatorial) waves, and these generate intraseasonal variations in the MLT region zonal winds through wave induced driving of the mean flow [22, 24, 42, 44]. Even though the MJO related convective signals are dominant only over the Indian ocean and western and central Pacific, the waves (especially nonmigrating diurnal tides, planetary and equatorial waves) generated by this deep convective activity are of planetary scale and they could propagate zonally and vertically and could show their effect on the zonal mean circulation globally. But, the equatorial waves decay rapidly away from the equator and could not propagate in the latitudinal direction. That means the spectrum of waves that could cause for driving the ISO in MLT zonal winds are stronger close to the equator. So, we may expect a stronger ISO in MLT zonal winds at the locations close to the equator. The measurement sites are not many enough in latitudinal direction to make better assessment of the distribution of ISO and the distribution of waves participating in driving the ISO.
Figure 4.14  Bottom panel shows OLR at 17.5°N latitude (over 60°E-140°E longitude) and top panel shows the ISO in zonal wind at 88 km over Kolhapur (KOL).
Figure 4.15  Bottom panel shows OLR at 7.5°N latitude (over 60°E-140°E longitude) and top panel shows ISO in zonal wind at 88 km over Tirunelveli (TIR).
Chapter IV

4B.6 Summary and conclusions

The present work is focused on studying the latitudinal behavior of intraseasonal oscillations of the zonal wind in the low latitude MLT region, and its relation to the lower tropospheric convective activity, using data on zonal winds obtained by two low latitude MF radars at KOL (16.8°N, 74.2°E) and TIR (8.7°N, 77.8°E). The zonal winds at 88 km over both the sites i.e. KOL and TIR exhibit similar ISO in different time period bands (around at 20-30 day, 30-40 day) but 60-70 day ISO activity is stronger over TIR as compared to KOL. The convective activity over 7.5°N latitude region and the zonal winds over TIR exhibit similar ISO variations whereas convective activity over 17.5°N latitude region is weak and do not show any similarity with the ISO in zonal winds over KOL during some periods. The reason for this could be the confinement of the convectively generated equatorial waves in the region close to the equator.

Our observations strengthen the earlier inferences [22, 42] that ISO in convective activity associated with MJO induce similar ISO in MLT zonal winds through wave driven forcing. The latitudinal dependency of the ISO at MLT heights revealed stronger ISO activity in the regions where convective activity is strong.
References


