STUDIES ON WINDS AND MOMENTUM FLUXES USING UHF RADAR OBSERVATIONS OVER GADANKI (13.5^0 N, 79.2^0 E)

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ABSTRACT

Wind information obtained from UHF radar observations at Gadanki (13.5^0 N, 79.2^0 E) are utilized for the present study. These studies are related to ten clear air echo days in each month for the observation period of one year i.e. from April 1999 to March 2000. Diurnal, monthly and seasonal variations of horizontal winds and momentum fluxes are studied. Zonal winds are found to be westward in summer, post monsoon and winter seasons, eastward in monsoon season. Meridional winds are found to be northward in summer and southward in post monsoon and monsoon seasons. Zonal and meridional momentum fluxes show upward around noon time in summer and downward in winter seasons.

1. Introduction

These Doppler radar observations have provided detailed three-dimensional wind measurements which have enabled large advancement in the understanding of convective storms, Planetary Boundary Layer (PBL), frontal surfaces and other meteorological phenomena (Kropfli and Hildebrand, 1980).

Several inter comparisons were made between wind profiles of wind profiler and Doppler radar (Weber and Wuertz,1990; Luce et al., 2001; Krishna Reddy et al., 2000) found good agreement. Radar derived three dimensional wind measurements were made in the optically clear planetary boundary layer by Kropfli and Hildebrand, (1980) and concluded that wind fluctuations are in good agreement with anemometric data. Kallistratova et al., (2001) have compared turbulent momentum fluxes derived from Sodar and Sonic anemometer measurements and determined turbulent kinetic energy (TKE) from measurements of three wind components by Doppler radar, momentum flux from the density of turbulent kinetic energy. They showed a good comparison of the results. Peters and Kirtzel, (1994) have measured momentum flux in boundary layer and from radar measurements by Kropfli, (1986).

2 Data base

These studies are related to ten clear air echo days in each month for the observation period of one year. LAWP gives continuous measurement of wind over the entire diurnal cycle (24 hours). The available data in an hour is averaged to represent hourly data. So 24-hourly averages are available on all the days. Seasons are classified as summer (March, April and May), monsoon (June, July, August and September), post- monsoon (October, November and December) and winter (January and February). Diurnal variation of winds and momentum fluxes are represented choosing a typical day in each season. They are 19th April 1999 (summer), 11th July 1999 (Monsoon), 24th November 1999 (Post- monsoon) and 25th January 2000 (Winter). Results and discussion is presented in section 3. Diurnal variation of winds, momentum fluxes in different seasons are presented in section 3.1. Monthly variation of horizontal winds, momentum fluxes, are presented in section 3.2. Summary and results is presented in section 4.

3. Results and discussion

3.1 Diurnal variation of horizontal winds

Figure 1 (a) shows height- time contour of single day observations of zonal winds in different seasons in the altitude region of 0.6 km to 3.3 km. During summer, zonal winds are eastward (westerlies) up to an altitude of 1.0 km and prevail up to 1000 hours LT and then changed to westward (easterlies) over the entire altitude region and then increasing with height. During monsoon season below 2 km altitude, eastward winds of ~ 10 ms^{-1} are found starting from 0100 hours LT and grow towards the day until 1300 hours LT (noon-time). Strong westward winds are found from a lower altitude starting from 0000 hours LT to 1200 hours LT of that day, from then onwards there is a sudden decrease in the magnitude of wind to a value of ~5ms^{-1}. The dominant winds are found to be westward during summer, post- monsoon and winter, whereas eastward in monsoon season.

3.2 Diurnal variation of momentum flux

Vertical flux of horizontal momentum is calculated using the method given by Vincent and Reid, (1983). Figure 2(a) shows diurnal variation of vertical flux of zonal momentum observed on typical days in different seasons. During summer season, downward flux of westward momentum is showing a maximum negative value of ~ 7 m^2s^{-2} at around 1000 hours LT and at 1100 hours LT at an altitude of 0.6 km and 1.2 km. During monsoon season, at an altitude of 0.9 km, a maximum value of downward flux of westward momentum of ~ 22 m^2s^{-2} is observed at around 1200 hours LT and then decreasing. During post-monsoon, downward flux of westward momentum of 5 m^2s^{-2} at around 0300 hours LT and 2000 hours LT at an altitude of 0.6 km and 1.5 km is observed. During winter season, the downward flux of westward momentum of 6 m^2s^{-2} around 1400 hours LT at an altitude of 0.6 km is observed.

Figure 2(b) shows vertical fluxes of meridional momentum in different seasons at four altitude regions. During summer season, vertical fluxes are low at early hours of the day and then increase negatively with a maximum downward flux of southward momentum of 10 $m^2 s^{-2}$ at around 1100 hours LT at an altitude region of 0.6 km and then decreasing towards the night time. Above this altitude a slightly low value of 9$m^2 s^{-2}$ is observed around 1200 hours LT at an altitude of 0.9 km. During monsoon season, vertical fluxes are increasing up to 0.9 km with a maximum downward flux of southward moment um of 13m^2s^{-2} at around 1800 hours LT. During the post- monsoon season fluxes are very much low, slight downward flux of southward momentum of ~1.5 m^2s^{-2} is observed around 1200 hours LT at an altitude of 0.9 km. During winter season, at 0.6 km altitude region, a variation of 7 m^2s^{-2} to 9 m^2s^{-2} in between local time of 0200 hours LT to 1300 hours LT is observed.

3.3 Monthly variation of horizontal winds

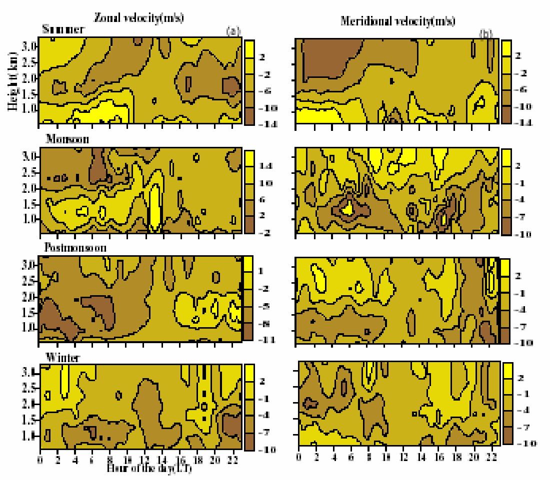
Figures 3 (a) and 3 (b) show height-time contour diagram of monthly averaged clear air days of zonal and meridional winds for a period of one year (April 1999 to March 2000). From the figure it is clear that zonal winds are eastward with a maximum of ~10 ms^{-1} in the months of May to September. After September there is a change in the direction from eastward to westward with a maximum of 5 ms^{-1} in the months of October to January. From figure 3 (b) meridional winds are northward up to an altitude of 1.5 km in the month of June. Above this altitude there is a slight change in the direction from northward to southward. Southward winds are observed over the entire altitude region from the months of July to January with a maximum of 6 ms^{-1} in the months of post-monsoon season.

3.4 Monthly variation of momentum flux

Figures 4 (a) and 4 (b) show monthly variation of vertical flux of zonal and meridional momentum averaged over ten days from the afternoon hours (1200-1400LT) in a month for a period of one year. From the month of April, flux is decreasing with time and show maximum downward flux of westward momentum of value ~2.0 m^2s^{-2} at an altitude of 0.6 km in the month of July. From July it increases to August with altitude. From the month of August it increases with altitude, but in the downward direction. Maximum downward flux of westward momentum is observed in the month of July and upward flux of eastward momentum of 0.5m^2s^{-2} in the month of April. Figure 4(b) shows maximum downward flux of southward momentum of ~1.0 m^2s^{-2} in the months of July, August and November.

4. Summary and conclusions

Diurnal and seasonal variation of horizontal winds, momentum fluxes are studied in different seasons using typical clear air days. Seasonal variations are studied using ten day clear air day averages in each month for a period of one year. Zonal winds are found to be westward in summer, post- monsoon and winter and eastward in monsoon season. Meridional winds are found to be northward in summer and southward in post- monsoon and winter seasons. Diurnal variation of vertical flux of zonal and meridional momentum indicates maximum downward fluxes in monsoon season. From the monthly mean values, zonal winds show eastward in pre- monsoon and monsoon seasons and westward in post-monsoon and winter seasons. Momentum fluxes around noon time indicate upward fluxes in summer and downward fluxes in winter seasons.



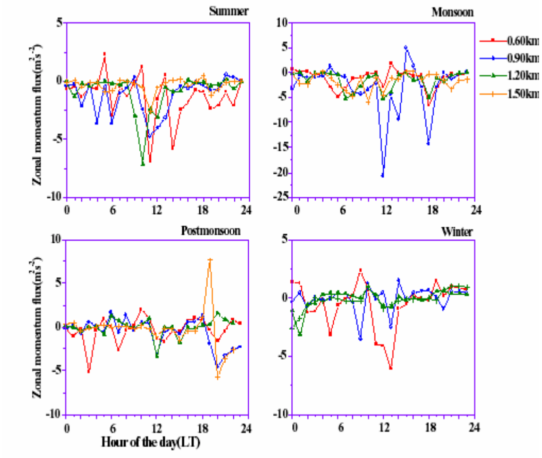
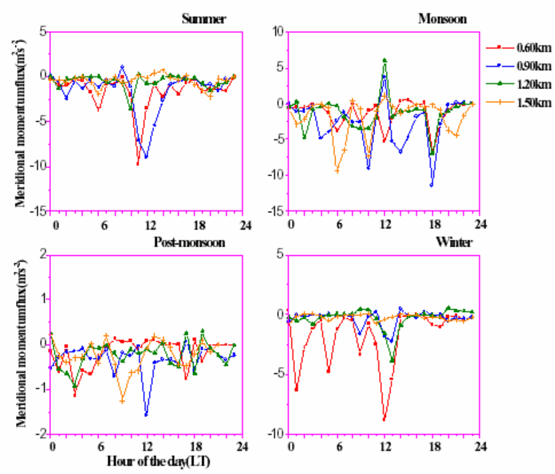


Figure 1. Diurnal variation of height time contour of a) zonal and b) meridional winds observed on typical days: 19mApril 1999 (Summer), 11July 1999 (monsoon) 24 November 1999 (postmonsoon)and 25 January 2000 (winter) in different seasons.

Figure 2(a) Diurnal variation of zonal momentum flux observed on typical days:19 April99 (summer)
11 July99(monsoon),24 November99(post-monsoon) and 25 January 2000(winter)in different seasons)



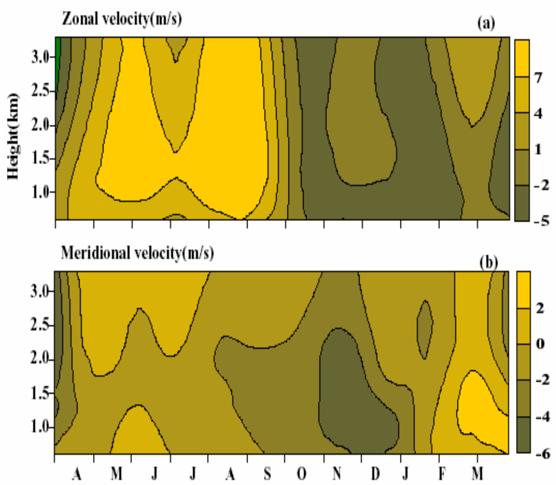


Figure 2 (b) Diurnal variation of meridional momentum flux observed on typical days:19 April99 (summer)
11 July99(monsoon),24 November99(post-monsoon) and 25 January 2000(winter)indifferent seasons)

Figure 3. Monthly variation of a) zonal and b) meridional velocities from April 1999 to March 2000 in the altitude range of 0.6 -3.3 km.

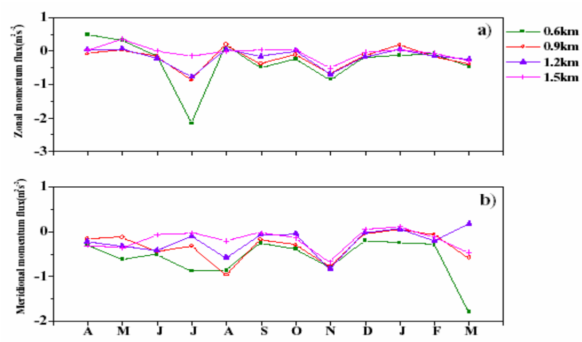


Figure 4. Monthly variation of a) zonal momentum flux and b)meridional momentum flux averaged over 1200-1400 LT of ten clear air days in a month of year (April 1999-March 2000)