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UHF wind profiler observations of monsoon low-level jet (MLLJ) and its association with rainfall over a tropical Indian station

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RESUMEN

Los datos de alta resolución de perfiles horizontales de viento (zonal y meridional) en la troposfera baja, derivados del perfilador de viento de muy alta frecuencia de Pune, una estación tropical de la India (18º 32' N, 73º 51' E, 559 masl), correspondientes a un periodo de tres años (junio de 2003 a mayo de 2006), se utilizaron para estudiar la variabilidad estacional e intraestacional de los vientos. Los vientos muestran una evolución estacional sistemática con comportamientos opuestos en cuanto a su fase en los regímenes de altitud superiores e inferiores a 4-5 km de altura. En la región baja, durante los meses del monzón del suroeste (junio a septiembre) los vientos soplan predominantemente desde el oeste, con un rango máximo de 1.5 a 3 km, el cual indica la presencia de la corriente monzónica en chorro de baja altitud (MLLJ, por sus siglas en inglés). Poco después de concluido septiembre, los vientos en este rango de altura cambian de dirección y soplan desde el oeste, lo cual se prolonga a los meses de invierno (diciembre a febrero). Por arriba de los 4 km de altura, los vientos del oeste se observan en la temporada posterior al monzón (octubre a noviembre) y en el invierno. El MLLJ cobra fuerza en los años con temporadas monzónicas normales o intensas. En una escala diaria, durante los meses del monzón del suroeste el viento muestra considerable variabilidad intraestacional, y las temporadas de MLLJ intensos parecen asociarse con la ocurrencia de fuertes aguaceros en la región.

ABSTRACT

High resolution data of horizontal winds profiles (zonal and meridional) in the lower troposphere, derived from a UHF wind profiler at a tropical Indian station, Pune (18º 32' N, 73º 51' E, 559 masl) during a 3-yr period (June 2003-May 2006) has been utilized to study seasonal and intra-seasonal variability of winds. Winds display a systematic seasonal evolution with behavior opposite in phase in the two altitude regimes below and above a height of 4-5 km. In the lower region, during the southwest monsoon months (June to September) winds are predominantly westerly with a peak in the 1.5-3.0 km range indicating the occurrence of the monsoon low-level jet (MLLJ). Soon after September, winds in this height region change from westerly to easterly and these easterlies continue in winter months (December to February). Above a height of 4 km, westerlies are observed during post-monsoon (October to November) and winter periods. The MLLJ is observed to be strong during normal/good monsoon years. On a day-to-day scale during southwest monsoon months, winds exhibit considerable intra-seasonal variability and periods of strong MLLJ seem to be associated with occurrence of spells of rainfall over the region.

Keywords: Tropospheric winds, wind profiler, southwest monsoon, monsoon low-level jet.

1. Introduction

Wind plays a vital role in atmospheric energetics and it transports heat, mass, moisture and pollutants from one place to another. These transport processes, in turn, affect the local weather including cloud and precipitation processes. Hence, detailed observations of winds with high spatial and temporal resolutions are necessary to understand the processes and their interaction with the environment. The ability to understand atmospheric phenomena increases as the ability to observe them with finer resolution in time and space improves. Wind profilers are a powerful tool to obtain vertical profiles of three components of wind velocities at high spatial and temporal resolution, and are widely used not only for atmospheric research but also for operational weather prediction. In clear air, the technique involves backscattering of the UHF/VHF radar signal from turbulent variations in the refractive index and measuring the Doppler shift of the return. Three or more beam directions (non-coplanar) can be used to get a complete wind velocity vector. This technique has been described in a number of reviews including those by Gage and Balsley (1978), Balsley and Gage (1980), Rottger (1980) and Larsen and Rottger (1982). UHF/VHF Wind profiler radars have proven to be excellent tools to study atmospheric winds, associated vertical shears of horizontal winds and various atmospheric turbulence parameters. Several studies are confined to mid and high latitudes (e.g., VanZandt *et al*., 1978; Smith *et al*., 1983; Nastrom *et al*., 1986) and some observational studies are available at low latitudes (e.g., Sato and Woodman, 1982; Tsuda *et al*., 1985; Jain *et al*., 1995; Rao *et al*., 1997).

There are many components of the monsoon system that have significant influence on monsoon variability over the Indian sub-continent. One of them is the strong cross equatorial wind flow in the lower troposphere, which is known as the monsoon low-level jet (MLLJ). It is recognized as one of the important synoptic components of Indian summer monsoon, with a cross equatorial current from the southern Indian Ocean to the central Arabian Sea (Krishnamurti *et al*., 1976), and provides large moisture supply over land regions (Ordóñez *et al.,* 2012). The MLLJ arises mainly because of thermal gradient between the Asian landmass and surrounding oceans. Initially it is southerly in direction over the south Indian Ocean, but as it crosses the equator and as a result of the Coriolis force, it turns southwesterly as it reaches the Indian subcontinent (Hoskins and Rodwell, 1995). The dynamics involved in the sustaining mechanism of this MLLJ is described in detail by Rodwell and Hoskins (1995). Goswami *et al.* (1998) have shown the MLLJ is interlinked with active and break phases of the Indian summer monsoon, as its strength and position controls the moisture transport over Indian land mass, and Joseph and Sijikumar (2004) analyzed the intra-seasonal variability of the MLLJ. Using wind profile data from radiosonde/radio-wind network over India, Joseph and Raman (1966) have provided observational evidence of this westerly low-level jet stream over peninsular India during the southwest monsoon period (June-September). More recently, Kalapureddy *et al*. (2007) have utilized high-resolution wind observations from lower atmospheric wind profiler (LAWP) data over a tropical Indian station, Gadanki (13.5º N, 79.2º E) to characterize the diurnal and seasonal features of MLLJ, whose core was observed to be at a height of 1.8 ± 0.6 km with a mean jet intensity of about 20 ms^{-1}. From UHF wind profiler measurements over Pune, India wind speeds in excess of 15-20 ms^{-1} have been frequently observed during the active southwest monsoon phase in July, with a peak wind speed occurring around 2-3 km (Joshi *et al*., 2006). Thus the strong low-level westerlies over the current observing station in India (Pune) are representative of the large-scale monsoon low-level jet (MLLJ).

High resolution UHF wind profiler observations made over a 3-yr period (June 2003-May 2006) over a tropical Indian station at Pune (18º 32’ N, 73º 51’ E, 559 masl) are used in this work to study the seasonal variation of horizontal winds, the structure of MLLJ and its association with rainfall over the region. A brief description of the wind profiler radar system and data set used here is given initially followed by presentation and discussion of the results.

2. Wind profiler system and data

The 404 MHz wind profiler was in continuous operation at Pune for nearly four years since June 2003. The wind data collected during this period has been quality checked and archived for the scientific users’ community by the India Meteorological Department (IMD), Pune. The system consists of a dual polarized coaxial collinear antenna array, with both arrays aligned along true N-S and E-W directions. The arrays produce three beams, two of them tilted; one along the east, another along the south and the third beam directed to the zenith. The profiler measures the radial velocities along these three beams by analyzing the observed Doppler shifted signals with the Doppler beam swinging technique. Such a configuration enables simultaneous measurement of all three components (zonal, meridional and vertical) of