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## Wind Profilers - Weather Forecast

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### Abstract

Wind profilers are an important source of meteorological data for numerical weather prediction. Wind profilers are Doppler radars that most often operate in the VHF (30-300 MHz) or UHF (300-1000 MHz) frequency bands. A wind profiler is a type of weather observing equipment that uses radar or sound waves (SODAR) to detect the wind speed and direction at various elevations above the ground. Readings are made at each kilometer above sea level, up to the extent of the troposphere.

In meteorology, wind profilers play an increasingly important role. They can provide upper-wind measurements with an accuracy comparable to radiosonde data, but with a significantly higher temporal resolution. Height coverage and vertical resolution depend on the operating frequency, which, depending on the application, is usually chosen to be around 50, 400 or 1000 MHz. Information from nearby profilers can help the individual meteorologist to optimize local short-term weather forecasts.

Wind profiler Observations at Pune (18°32N, 73°51E) reveal the potential in identifying the various phases associated with monsoon such as onset, active and weak and/or break phases, and withdrawal rather solely. For this, all three wind vectors (zonal, meridional and vertical), wind speed and wind direction for years 2004 and 2005 has been examined. The monsoon winds are westerly i.e., dominance of zonal wind, average wind speeds are around 15 m/sec with westerly in direction. Daily average zonal wind speed shows above 20 m/sec with westerly wind direction around 270°, identified as active monsoon spell. During break monsoon spell it has noticed wind speeds are meager with change in wind direction from existing westerly to easterly. This criterion has been checked with IMD reported monsoon active and break spells for the years 2004 and 2005 and found good correlation as well. It is also interesting to see the change in seasonal wind from prevailing easterlies during pre-monsoon season to westerlies around the middle of May and is similar but opposite change is noticed around at the end of monsoon season near the end of September.

**Keywords:** Wind Profilers, Weather Forecast, Indian Summer Monsoon, Low-Level Jet (LLJ), Doppler radar.

### 1. Introduction

An important atmospheric phenomenon that occurs over the Indian sub-continent is the monsoon, as they account for the majority of the annual rainfall. The Indian economy is basically agro based one and thus the vigor of monsoon plays a vital role on economy and consequently on pulse of lives. The word 'monsoon' is an Arabic word, means 'season' which is used to connote a seasonal rain and wind reversal with consistency and regularity over Indian sub-continent and surroundings. According to *Ramage* [1971], monsoon is defined as; prevailing wind directions during January and July should be enhanced by 40% and wind direction shift should be at least by 120° between January and July. This 'monsoon region' includes practically the whole of the African continent, south Asia and north Australia. Monsoon is a synoptic phenomenon, which needs proper understanding for predicting the variability of the Indian monsoon rainfall. The monsoon is strongly coupled to the warm oceans surrounding the subcontinent. There are monsoon related phenomena whose associations are very much prominent in deciding the vigor of monsoon. Two such phenomena are Low-Level Jet (LLJ) and Tropical Easterly Jet (TEJ). TEJ is a strong cross-

equatorial, synoptic-scale boreal summer monsoon induced atmospheric jet streams at 150 hPa over tropical India [*Mokashi*, 1974]. According to the definition of World Meteorological Organization (WMO), Jet stream is a strong narrow wind current concentrated along a quasi-horizontal axis, characterized by strong vertical and lateral wind shears. The wind speed must be greater than 30 m s<sup>-1</sup>. The jet stream commonly has length, width and depth of about 1000 km, 100 km and a few kilometers respectively. Jet stream exhibits vertical wind shears of nearly 2 - 5 m s<sup>-1</sup> km<sup>-1</sup> and lateral wind shear of about 2.5 m s<sup>-1</sup> per 100 km. This jet stream corresponds to a height of ~16 km, which often occurs at tropical latitudes. The other jet stream (LLJ) occurs at 850hPa. LLJ is another strong cross-equatorial, synoptic-scale boreal-summer SW monsoon induced atmospheric jet stream [*Joseph and Raman*, 1966; *Findlater*, 1966, 1967; *Desai et al.*, 1976]. The wind speed associated with this, however, is not as high as that observed with TEJ. Often, the wind speeds are less than 30 m s<sup>-1</sup>, occasionally exceeding this value. According to the WMO definition, which was basically meant for TEJ, may not be often valid for LLJ. In spite of this fact, a low level (850hPa), wind system having strong wind that

occurs in the lowest few kilometers of the atmosphere with wind shear and the vertical profile of wind speed should show increase and then decrease with height [Stensrud, 1996] has been named as LLJ. This jet stream is often observed during June-August and strongest being in July, in the southern part of India Joseph and Raman, [1966]. The LLJ observed over Indian peninsula is an Afro-Asian cross-equatorial phenomenon. The LLJ features over peninsular India were first examined by Joseph and Raman [1966] followed by Desai *et al.* [1976], which confirms the existence of a westerly LLJ stream over peninsular India with strong vertical and horizontal wind shears. Wind analysis by Findlater [1971] has shown that there is cross-equatorial strong wind flow from South Africa to Indian Ocean and southern India via Somalia and then LLJ month-to-month propagation was also observed. Almost all those observations, however, were based on radiosonde/rawinsonde observations taken twice a day. Such temporal resolution is not sufficient enough to explore the diurnal features of LLJ. So these low temporal resolution radiosonde observations cannot allow us in exploring the diurnal features of LLJ.

The meteorological conditions over Indian sub-continent have been defined by India Meteorological Department (IMD). According to it, the seasons over India are divided into winter (January and February), pre-monsoon/summer (March, April, and May), monsoon/South-West (SW) monsoon (June, July, August, and September), and post-monsoon/North-East (NE) monsoon (October, November, and December). The SW and NE monsoon are also known as summer-monsoon and winter-monsoon respectively. The normal onset of the SW monsoon is around the first week of June, and withdrawal during the middle of September. After onset of SW monsoon, it takes around a week time to observe it at the observational site. Post-monsoon season is a period of rains in the southern part of India, and is called locally the NE monsoon, because of the northeasterly winds that prevail in this period.

Onset of the summer monsoon has been defined by various methods. Using rain gauge data, Ananthakrishnan and Soman [1988] defined the onset of ISM based on Kerala rainfall during which the rainfall amounts increase to over 15 mm per day. Fasullo and Webster [2003] defined the ISM onset and withdrawal by vertically integrated moisture transport over the Arabian Sea. Flatau *et al.* [2001] defined double onset or bogus onset of ISM based on a conceptual model. Prasad and Hayashi [2005] studied onset in terms of Zonal asymmetric temperature anomaly between 850 hPa and 200 hPa with NCEP/NCAR reanalysis data. Taniguchi and Koike [2006]

defined onset based on wind speed exceeding  $8 \text{ ms}^{-1}$  at 850 hPa using NCEP/NCAR reanalysis data. Jagannadha Rao and Roja Raman [2007] studied the onset of Indian summer monsoon over Gadanki. Several investigators found interesting features during evolution of numerous parameters related to the monsoon activity. Wind profiler's Observations reveals the potential of wind profiling radars in identifying the various phases associated with monsoon (onset, active, weak, break and withdrawal) rather solely. In the present study UHF wind profiler (UWP) enables us to observe monsoon progress using the wind and other radar parameters.

## 2. Experimental Technique

In India the only 400 MHz wind profiler system now available was developed by Society for Applied Microwave Electronics Engineering & Research (SAMEER) in 2001 under sponsorship of Department of Science and Technology, Government of India. The system is situated at Pashan campus of India Meteorology Department (IMD) in Pune and is being regularly operated as an R & D unit since June 2003. The Pune UWP configured has a typical height coverage up to 6-10 km (depending on the weather conditions) with a resolution of 300 m for wind and 2-3 km for temperature measurement. The system consists of a dual polarized coaxial collinear antenna array made out of low loss dielectric RF coaxial cable of 7/8" size, operating at 404.37 MHz with a peak power aperture product of  $3.6 \times 10^4 \text{ W-m}^2$  [Pant *et al.*, 2005]. The two polarized arrays are aligned along true N-S and E-W directions respectively the receiver is a heterodyne type and consists of a blanking switch, Low Noise Amplifier (LNA), RF amplifier chain, Mixer and band pass filters. Local Oscillator (LO) signals required for the receiver operation are derived from exciter subsystem. During first stage the LO frequency (404.37-IF) is mixed to get IF (Intermediate frequency) output which is filtered and amplified using IF amplifier. In second stage a quadrature mixer is used to recover the base band in I and Q channels. This is subsequently passed through a low pass filter and Video amplifier and then fed to two independent ADC channels. Output of ADC goes to processor where time domain processing takes place. Coded signal is first decoded in the processor and then subjected to coherent integrations. The pre-processed data is then given to FFT processor and the host computer for further frequency domain analysis. More details of the hardware are described by [Chande *et al.* 2000]. Fig. 1(a) shows the Antenna array and Fig. 1(b) receiver-transmitter assembly of the wind profiler.



(a)



(b)

Fig 1: Photograph of the (a) Antenna Array (b) Transmitter, Duplexer and Receiver assembly of Wind Profiler at IMD, Pune

### 3. Results and Discussion

**Table 1:** UWP data details

Sl. No.	Season	Month & Year	No. of Data available days	Data gap dates		
1.	MONSOON	June 2004	27	23,24 and 25		
		July 2004		7,8,10,11,13,15,16,19,23,		
		August 2004	29	24,25,26,27,28,29,30,31		
		September 2004		1 and 2		
		June 2005	31	5,6,7,8,27,28,29 and 30		
		July 2005		Nil		
		August 2005	30	Nil		
		September 2005		Nil		
2.	POST-MONSOON	October 2004	25	2,3,4,12,18 and 19		
		November 2004				
		December 2004				
		October 2005				
		November 2005				
		December 2005				
		January 2005			31	2
		February 2005				Nil
January 2006	Nil					
February 2006	Nil					
3.	WINTER	January 2005	26	Nil		
		February 2005		Nil		
		January 2006		8 and 9		
		February 2006		Nil		
		May 2004		20	Nil	
March 2005	Nil					
April 2005	Nil					
May 2005	Nil					
March 2006	18,26 and 27					
April 2006	6,14,15,16 and 19					
May 2006	Nil					
		Total no. of days	695	50		

The UWP observation on all three wind components in the height region, 1.05-6.45 km, has been used for the period May 2004 to May 2006. This data has processed to ensure its quality and continuity. Moreover, only clear air observations are chosen for the present study. The details of data can be found in table 1. The figure 2. shows the Height Time Intensity (HTI) maps on observed dynamical parameters, zonal, meridional and vertical wind, wind speed and direction. Nearly every 6 minutes interval height profiles in each hour are averaged and hourly profiles of all dynamical parameters for all clear air period are used. It can be seen strong zonal wind (U) of magnitude around 15 m/s observed during monsoon, June-September.

These strong positive zonal winds indicate they are originating from west of the observation site. During the rest of the seasons zonal winds magnitudes are weak i.e.,  $\pm 5$  m/s. These low level strong zonal winds in the height region of 2-4 km and its magnitude falls either side of the height region named as Low Level Jet (LLJ) [Findlater J, 1969]. It is also

observed that during monsoon season itself, there are strong and weak spells in observed zonal winds, zonal wind magnitudes respectively around 15 m/s and  $\pm 5$  m/s. These strong positive zonal winds indicate they are originating from west of the observation site. During the rest of the seasons zonal winds magnitudes are weak i.e.,  $\pm 5$  m/s. These low level strong zonal winds in the height region of 2-4 km and its magnitude falls either side of the height region named as Low Level Jet (LLJ) [Findlater J, 1969].

It is also observed that during monsoon season itself, there are strong and weak spells in observed zonal winds, zonal wind magnitudes respectively around 15 m/s and  $\pm 5$  m/s. In general, the meridional wind (V) is noticed to be meager and southerly (positive). During winter and pre-monsoon southerlies are observed in the lower levels, below 2 km. whereas, during monsoon, meridional winds are scanty whenever zonal winds are strong. The vertical wind (W) shows strong updrafts (positive) in the lower level, below 2 km, indicating convective activity associated with atmospheric boundary layer (ABL). This convective activity is observed to be strong and frequent during around monsoon season. The wind speed (WS) has arrived from zonal and meridional wind. During monsoon, WS essentially shows the same features as zonal wind do. It indicates the dominance of zonal wind over meridional wind during monsoon. Few couple of strong WS spells observed during June and July 2004 and July and August 2005 have been observed to be correlated with active monsoon spells. The weak spells in between are indication of break monsoon spells.

The wind direction (WD) shows clear westerlies/north westerlies during monsoon and rest of the seasons it is easterly. It is observed that winds are easterlies during break monsoon. In order to identify the active and break monsoon spells solely from UWP, zonal winds and wind direction has examined. It is well aware that monsoon winds are westerly, i.e., dominance of zonal wind, around 15 m/s, with wind direction around  $270^\circ$  [Joseph and Sijikumar, 2004]. Hence, daily mean zonal wind and wind direction during monsoon has plotted for the years 2004 and 2005 in figure 3.

Daily average zonal wind speed shows above 20 m/s with wind direction around  $270^\circ$ , westerly, identified as active monsoon spell. Whereas during break monsoon spell is identified when zonal wind speed less than 5 m/s and wind direction around  $90^\circ$ , easterly.

This criterion has been checked with IMD reported monsoon breaks for the years 2004 and 2005 [Thapliyal et al., 2005; 2006] and found good correlation as well. Hence, the UWP can identify active and break monsoon spells, which are presented in table 2.

**Table 2:** Details of monsoon periods for the years 2004 and 2005

S. No.	Monsoon	2004		2005	
		UWP	IMD	UWP	IMD
1		---	18 July	---	30 June
2	Active	7 August	---	2 July & 26 July	---
3	Break	24-26 July	19-27 July	14 August 23 August	11-12 August 24-27 August
4	Withdrawal	---	22 September	---	22 September

### 4. Conclusions

- UWP observations during two monsoon years able to identify the various monsoon phases such as onset,

active/break phases and withdrawal of Indian Summer Monsoon over observational site.

- Identified active and break spells shows significant difference in wind magnitude and direction.
- Correlating all these findings with OLR and Radar reflectivity/SNR is under investigation.

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