International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 3, September 2014)

New Algorithm for the Onset of Monsoon over Kadapa (14.28^0 N, 78.42^0 E)

S. B. Surendra Prasad[1], M. Venkatarami Reddy[2], U. V. Murali Krishna[3], R. Masthanaiah[4], K. Krishna Reddy[5]
[1,2,3,4,5]Semi-Arid-Zonal Atmospheric Research Centre (SARC), Department of Physics, Yogi Vemana University, Kadapa, Andhra Pradesh, India
[1,2]Department of Physics, Acharya Nagarjuna University, Guntur, Andhra Pradesh, India

***Abstract*- We developed new algorithm for onset of monsoon over Kadapa (14.28^0 N, 78.42^0 E) based on wind speed, wind direction from Mini Boundary layer Mast (MBLM), zonal wind speed at 1.5 km (850 hPa) using Global Position System (GPS) radiosonde observations and wind speed at 850 hPa from NCEP–NCAR reanalysis data. Based on this algorithm we define the onset of monsoon over Kadapa as: strengthening of the low level wind speed attaining 8 ms^{-1} with directional change from south-easterlies to south-westerlies defines the beginning of the monsoon over Kadapa. In addition to this the wind speed of MBLM at 15 m exceeds 5 ms^{-1} also defines the beginning of Monsoon over Kadapa.**

***Keywords*- Onset of Monsoon, MBLM, Wind Speed, Wind direction, Radiosonde**

I. INTRODUCTION

Monsoon is a seasonal phenomenon, in which reversal of wind direction from winter to summer. Indian Summer Monsoon is developed based on large thermal gradient between the Warm Asia continent of North and cooler Indian Ocean of south. Large amount of moisture bring from ocean surface by the strong southwesterly wind in the lower troposphere and these moisture is responsible for the heavy precipitation in the Indian subcontinent. During the onset of monsoon over India dramatic changes occur, a rapid increase in the daily precipitation rate, an increase in the vertically integrated moisture and an increase in kinetic energy, especially of the low-level flows [1]. The monsoon rains over the Indian subcontinent, is an important event in the socioeconomic life of the people of India, particularly in agricultural productions that affects living of over one billion people. But there is no precise definition for the onset of the monsoon and basically onset of monsoon noted by a change of wind direction and rainfall occurrence. Onset of monsoon defined by various methods

Fasullo and Webster [2] gave a definition about monsoon onset over India using vertically integrated moisture transport instead of rainfall. And large scale deep convection propagates from equatorial to continental regions [3, 4 and 5].

Increase in temperature over Tibetan Plateau in May-June is responsible for the reversal of land-sea thermal contrast which leads to climate driver of onset of monsoon [6]. Onset of monsoon index is based on reversal of the large-scale meridional temperature gradient in the upper troposphere, south of the Tibetan Plateau proposed by [7]. A band of deep convection (low OLR) in the east-west direction passing through southern tip of India, a maximum cloud zone was identified by Sikka and Gadgil [4]. Large scale changes occur in the circulation features in association with the onset phase of Indian [8, 9, 10, 11, 12 and 13] and combination of an increase in sea surface temperatures and dry intrusion in the 600–850-hPa layer over the ocean on the equatorial side of the continent plays an important role in determining the onset suggested by Kawamura et al. [14].

Increase in kinetic energy at 850 hPa during the process of onset of summer monsoon over Arabian Sea found by Krishnamurti et al. [15]. The advent of monsoon is different at various locations using operational analysis found by Rao et al. [16]. The intra seasonal oscillations and inter annual variability of Indian Summer Monsoon using NCEP/NCAR reanalysis for the period of 1956–1997 was studied by Goswami and Ajaya Mohan[17]. Three step method for defining monsoon onset objectively over Kerala (MOK) using NCEP/NCAR winds, OLR and integrated water vapor with a criteria of area mean wind reaching 6 ms^-1 at 600 hpa developed by Joseph et al. [13]. Strengthening of low-level wind over the south peninsular India has been noticed to be a good indicator of the onset of monsoon [18].

There are several studies continued through the 1970s e.g., Reddy; Subbaramayya and Bhanukumar [19 and 20], the 1980s e.g., Kung and Shariff ; Deshpande et al. ; Joseph and Pillai [21, 22 and 23], the 1990s e.g., Rajeevan and Dube [24], and into the current decade e.g., Ghanekar et al. 2003[25].

But all the studies mentioned utilized either radiosonde data or reanalysis data. A strong low level westerly winds are main feature for the onset of monsoon and important parameter that is obtained from the Mini Boundary Layer Mast (MBLM) at three levels of wind information, an attempt is made to study the onset of monsoon over Kadapa.

II. Data And Methods

Mini Boundary Layer Mast (MBLM) has been established at Yogi Vemana University, Kadapa, semi-arid region with the objective to accurately represent surface layer parameters for varying land surface and terrain patterns under PRWONAM project. MBLM has 15 m high tower and it measures wind, temperature, relative humidity from the sensors mounted on MBLM at three levels, rain fall, surface pressure, surface radiative fluxes at the surface, soil moisture at six depths and soil temperatures at seven depths with high temporal resolution. The MBLM is a 15 m high, guyed, uniform triangular lattice structure designed to withstand wind speed of 60 m/s.

The booms on MBLM are fitted at 4 m, 8 m and 15 m heights above the ground. In addition, the rain gauge, the Incoming Short Wave (SW) and the outgoing Long Wave (LW) radiation sensors were installed on the ground. Subsurface sensors were installed for soil moisture and soil temperature measurements. Description of MBLM sensors is given in Table 1. In the present study daily averaged wind speed, wind direction at third level i.e. 15m and rainfall during 1st May 2010 to 31st July 2010 were utilized.

In addition to the MBLM data we utilized the Dr. Pisharoty GPS radiosonde data during 4th may 2010 to 17th June 2010 at 17:30 IST launched at Yogi Vemana University, Kadapa. Pisharoty GPS radiosonde gives the high vertical and high temporal resolution of temperature, relative humidity, pressure, wind speeds and wind direction. The temporal resolution of the data is 1 second and it corresponding to the 5 m vertical resolution. However, these data were equally gridded in to the 50 m vertical resolution in order to avoid the random motion of balloon generated fluctuation.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 3, September 2014)

Table. 1: Description of MBLM Sensors

Sl. No	Parameter	Make & Model No. of the Sensor	Accuracy	Sensor Installation height above the ground	Sensor basic output parameters and Sensor range
1	Wind Speed and Wind Direction	RM Young 05305	Wind Speed:±0.2 ms^{-1} Wind direction ± 30	4 m, 8 m, 15 m	Wind speed: 0-100 m/s Wind direction: 360^0 mechanical 355^0 electrical
2	Air temperature/ Relative Humidity	Rotoronics MP100H, HygroClip	Temperature: ±0.1^0c Relative Humidity ± 1%	4 m, 8 m, 15 m	Air temperature: -40^0c to +60^0c Relative Humidity 0 to 100%
3	Atmospheric Pressure	Komoline KDS-021/ISRO Pressure Sensor	Atmospheric Pressure: ±0.2hPa	1 m,	Atmospheric Pressure 600 to 1100 hPa
4	Long Wave Radiation	Kipp&Zonen CGR 3	Long wave Radiation ±10 W m^{-2}	2.5 m	Downward Atmospheric Long wave radiation:-250 to +250 W m^{-2} (Net Irradiance)
5	Short Wave Radiation	Kipp&Zonen CMP 3	Solar Radiation: ±10 W m^{-2}	2.5 m	Global Solar radiation: 0 to 200 W m^{-2}
6	Rain Gauge	RM Young 52203	0.5 mm upto 25mm/hr 1.5 mm up to 50mm/hr	1 m	Rain Catchment Area: 200 cm^2 Resolution :0.1 mm
7	Soil moisture profiler	Delta-T Devices Ltd. PR2/6 profiler with the Augering and extraction kit	±0.04 m^3/m^3	0 cm, -10cm,-20 cm, -40 cm, -60 cm,-100cm	Soil moisture at six level depths(m^3/m^3) Range : 0 to 1 m^3/m^3 Resolution : 0.01 m^3/m^3
8	Soil Temperature Probe	Komoline KDS-0	0.1^0C	+5 cm, 0 cm, -5 cm, -10 cm, -20 cm, -40 cm, 100 cm	Soil Temperature at seven levels (^{0}c) Range: -40 to 55 ^{0}c Resolution:0.01^0c

For the present study we utilized wind speed and wind direction at 850 hpa which corresponding height around 1.5 km.

Also we utilized Automatic Weather Station deployed by Indian Space Research Organization (ISRO AWS) and Automatic Weather Station manufactured by the Devis Company (DEVIS AWS) for the comparison with the MBLM. ISRO AWS provides surface meteorological parameters like temperature, relative humidity, pressure and wind information etc., at 4 minute temporal resolution. Similar to ISRO AWS, DEVIS AWS also provides surface meteorological parameters with 1 minute temporal resolutions.

NCEP–NCAR reanalysis standard-level post processed daily zonal wind data available with 2.5^0 X 2.5^0 latitude–longitude grids during 1st May to 31st July 2010 were also utilized to the present study. For more details about the NCEP–NCAR reanalysis data are given in Kalnay et al. [26]. For comparison with GPS radiosonde and MBLM observations over Kadapa, a grid box covering 12.5^0–15^0N, 77.5^0–80^0E has been considered. And also to know the onset over the Arabian Sea we considered the grid over Arabian Sea.

In addition with MBLM, GPS radiosonde and NCEP-NCAR reanalysis data we utilized the daily mean outgoing Long wave radiation (OLR) data from National Oceanic and Atmospheric administration (NOAA).

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 3, September 2014)

The NOAA satellite gives the OLR data on $2.5^o \times 2.5^o$ latitude longitude grid over the globe. For the present study, we averaged the OLR data over Kadapa (12.5^0–15^0N, 77.5^0–80^0E) region.

Algorithm:

To know onset of monsoon we set up a new hybrid algorithm for inland region. For this we use the GPS radiosonde, NCEP/NCAR data and MBLM data. Based on previous study we perform the same operation using GPS radiosonde and NCEP/NCAR data.

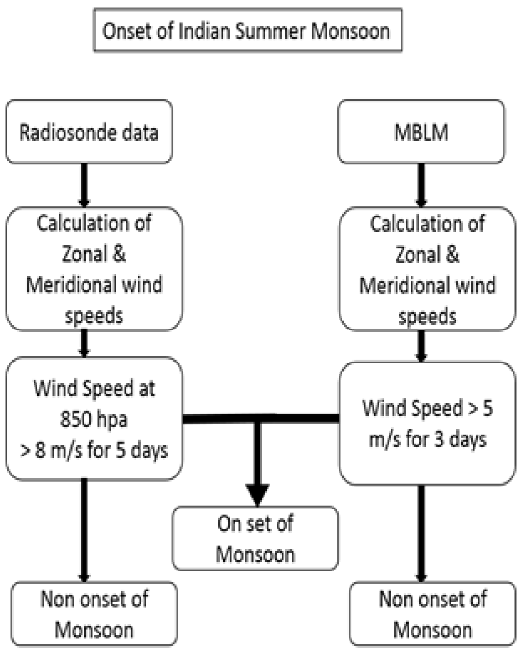

Fig. 1 Flow chart for the identification for the onset of monsoon over Kadapa

First calculate the zonal and meridional wind speed at 850 hpa from GPS radiosonde observations. From NCEP/NCAR data, we directly obtained the zonal wind speed. From the both observations, the zonal wind speed is exceeds 8 m/s and it persist the 5 continuous days. Then it said to be onset of monsoon. These are the existing methods from the earlier studies [18,11]. For the present study we include the MBLM observations to the earlier studies. Based on this study we proposed new algorithm for onset of monsoon over inland region, i.e. From MBLM winds information we calculate the zonal and meridional wind speeds. From this, the zonal wind speed is exceeds 5 m/s and it persist continuously for 3 days then it said to be onset of Indian summer monsoon. Based on this hybrid algorithm we know the date of onset of Indian summer monsoon.

III. Results And Discussions

Kadapa (14.47°N; 78.82°E) is located in semi-arid zone and often experiences drought and also it receives scant rainfall and its annual average rainfall is much below the National average. Fig. 2 shows the terrain map of India as well as population density. Kadapa is situated 150 m above the mean sea level and it surround by the hills about 1500 m with average height of 600 m (fig. 2 (b)) and its population density about 300 to 350 persons/ km^2 (fig. 2 (c)).

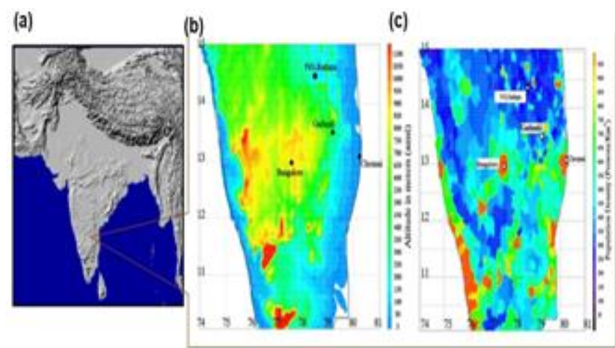

Fig. 2: (a) & (b) Terrain map of India, (c) Population density map of India

MBLM measures the meteorological parameters for every on second and the data is averaged for every 4-minutes and is stored in the data logger. This 4 minute average data is copied in to pen drive and it dumped in to the PC using MBLM software. Fig. 3 shows MBLM data availability from April 2010 to March 2012. A continuous data for 724 days is available during April 2010 to March 2012.

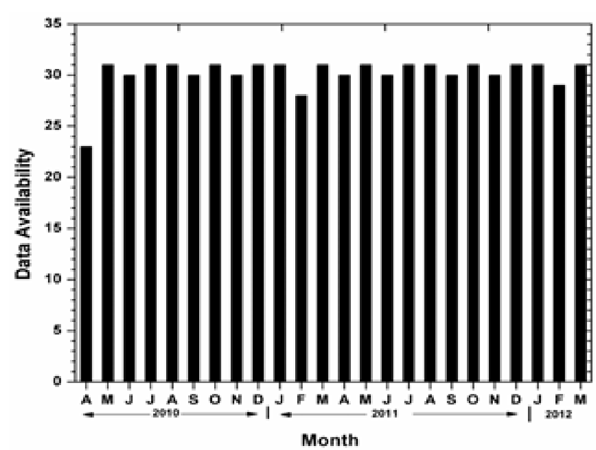

Fig. 3: 4-minute averaged data availability of MBLM from April 2010 to March 2012.

IJRDET
International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 3, September 2014)

To Validate The MBLM Data, 4- Minute Averaged Temperature, Relative Humidity, Pressure And Wind Speed Observed By The MBLM Are Compared With 4-Minute Averaged Temperature, Relative Humidity, Pressure And Wind Speed Respectively Observed By The ISRO AWS And DEVIS AWS. Fig. 4 (A), (C), (E) And (G) Show The Correlation Of Temperature, Relative Humidity, Pressure And Wind Speed Observed By MBLM And DEVIS AWS. A Fairly Good Correlation Is Observed Between Temperatures, Relative Humidities And Pressures But Somewhat Less Correlation Is Observed Between The Wind Speeds Observed By The MBLM And DEVIS AWS. Fig. 4 (B), (D), (F) And (H) Shows The Correlation Of Temperature, Relative Humidity, Pressure And Wind Speed Observed By MBLM And ISRO AWS. And We Found The Similar Results, MBLM Measurements Of Temperature, Relative Humidity And Pressure Correlate Well With The ISRO AWS. Here Also The MBLM Wind Speed Shows A Slightly Less Correlation With ISRO AWS Wind Speed. This Is Because Of MBLM Is Deployed In Open Area Which Is At About 500 M Away From The DEVIS AWS And ISRO AWS. DEVIS AWS And ISRO AWS Are Deployed Inside The Campus Which Surrounded By The Buildings Which May Obstruct The Wind Measurements. For This We Compare The Wind Measurements Of DEVIS AWS And ISRO AWS (Figure Not Shown). A Good Correlation Is Observed Between The Two Measurements.

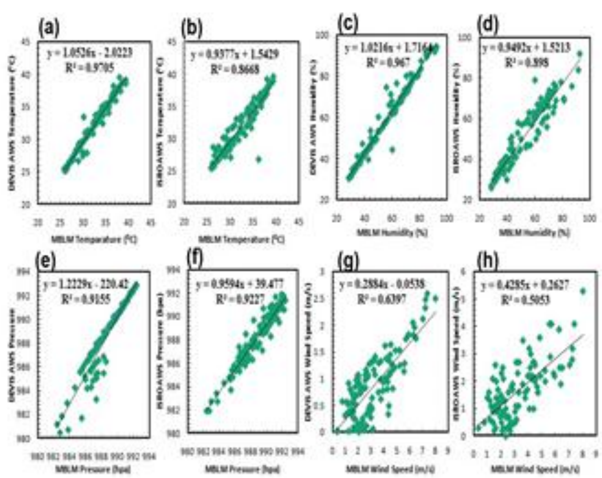

Fig. 4: Scatter plots of (a) & (b) temperature, (c) & (d) relative humidity, (e) & (f) Pressure and (g) & (h) wind speed between MBLM, DEVIS AWS and ISRO AWS.

The heat gradient between Indian subcontinent and the ocean surrounding is responsible for the producing of a circulation in the lower troposphere, as a result it cross the equatorial flow blowing into Arabian Sea and developing into low level south westerlies . Strengthening of these westerlies over peninsular India is the important feature at the time of onset [11]. Based on the Indian Meteorological Department reports and earlier studies shows that, the onset of the Indian summer monsoon is around the last week of May over the southern tip of peninsular India i.e. Kerala coast of Arabian Sea.

Before we know about the date of onset of monsoon over Kadapa, it is important to know the onset of monsoon over Arabian Sea and it gives the basis for looking into the subsequent advancement across the country.

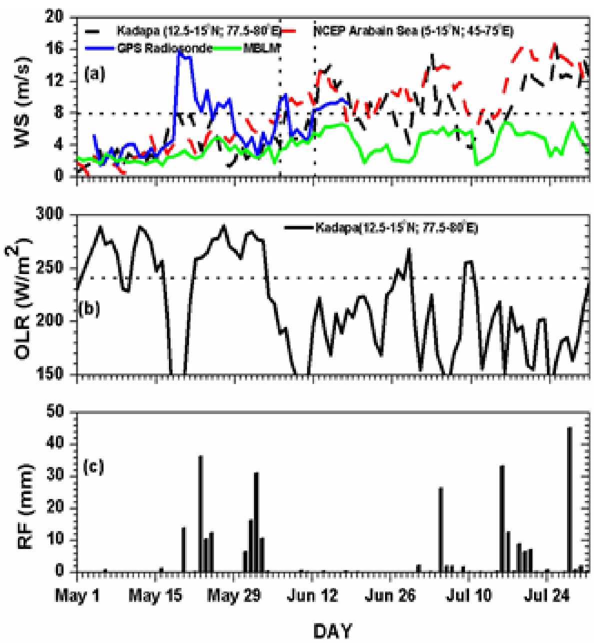

Fig. 5: (a) Daily wind speed at 850 hPa over Arabian Sea (5–15^{0}N; 45–75^{0}E) (red dashed line) and Kadapa (12.5^0 N –15.0^{0}N, 77.5^0 E –80.0^{0}E) (black dashed line) during April–July 1999 using NCEP reanalysis data. Daily wind speed observed at 850 hPa by GPS radiosonde (blue line) and daily averaged MBLM wind speed observed at 15 m is also plotted for comparison. The vertical lines shown at 06 June 2010 and 12 June 1999 on the x-axis indicate the onset days over Arabian Sea and Kadapa, respectively. (b) Time series of OLR and (c) daily accumulated rainfall.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 3, September 2014)

From the earlier study Taniguchi and Koike [18], the zonal wind speed is exceed 8 m/s, it persist continuously for 5 days and also wind direction is changed to southwest direction then it said to be an onset of southwest monsoon. In this connection we show the time series of daily wind speed at 850 hpa over Kadapa (12.5^0 N –15.0^{0}N, 77.5^0 E –80.0^{0}E) and Arabian Sea (5.0^{0}N–15.0^{0}N, 45.0^{0}E–75.0^{0}E) in Fig. 4(a) obtained from the NCEP/NCAR daily mean zonal wind speed. Along with the NCEP/NCAR daily mean zonal wind speed we correlate the wind speeds obtained from the both GPS radiosonde and MBLM. From this figure we can notice that the wind speed exceeding the value of 8m/s on 6 June 2010 and it is continuous for several days and this is said to be onset of monsoon over Arabian Sea as shown in red dashed line. And the similar phenomena were observed on 12 June 2010 over Kadapa with exceeding of wind speed 8 m/s and it is continued for seven days as shown in black dashed line. From the GPS radiosonde observations, wind speed is exceeding the 8 m/s on 18 May 2010 and it is continuous for seven days (Blue colour line). May be this is due to cyclone induced effect, not the onset of monsoon. Again wind speed exceeds the 8m/s on 12 June 2010 and it is continuous up to 17 June 2010. So, 12 June 2010 is the onset of Monsoon over Kadapa and its surrounding regions. From the MBLM observations the wind speed (green colour) is follow the NCEP/NCAR wind speed pattern, but magnitude is less than NCEP/NCAR wind speed. From the MBLM observation the wind speed is exceeds the 5 m/s one 12 June 2010 and it is continuous for five days (Fig 5a). The same phenomenon can observed from the GPS radiosonde observations.

The strength of monsoon can be understood using OLR, which can be resembled for tropical deep convection. Figure 5b shows the daily average of OLR over Kadapa region (12.5^0 N –15.0^{0}N, 77.5^0 E –80.0^{0}E). The values of rainfall with 0.7–0.8 are associated with OLR values around 220 W/m^2 [18], hence OLR less than 220 W/m^2 is considered as convective activity. From figure the deep convection started over Kadapa around 5 June 2010, and it is continued up to 26 June 2010. Daily accumulated rainfall also shown in the Fig. 5c. Even though, onset of monsoon over Kadapa region on 12 June 2010, the accumulated rainfall is very less from 12 June 2010 to 30 June 2010. However, the significant rainfall can be observed from 1 July 2010 to 31 July 2010(fig. 5c). From figure 5 one can notice that, the active phase of monsoon over Kadapa from 15 July 2010 to 24July 2010.

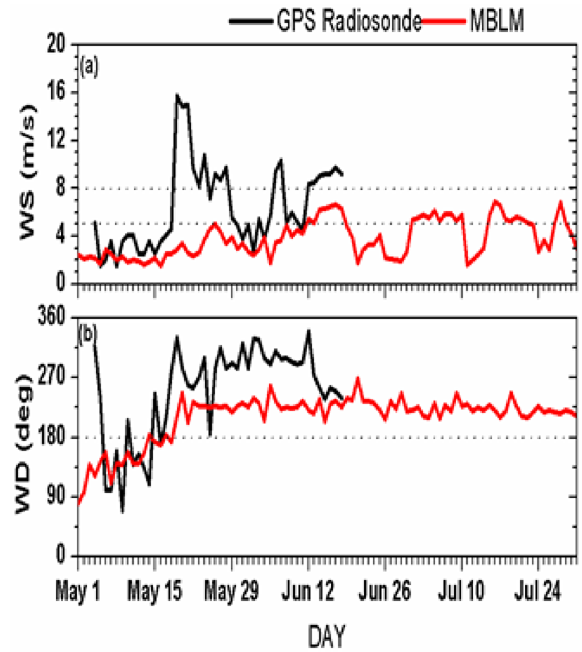

Fig. 6: (a) Time series of wind speeds and (b) time series wind directions of GPS radiosonde (black line) and MBLM (red line).

We compare the MBLM wind speed and wind direction at level 3 (15 m) with GPS radiosonde wind speed and wind direction at 850 hpa for the understanding of the onset of monsoon, shown in Figure 6. Both wind speeds are following the same trend but magnitude is of the MBLM wind speed is less (Fig. 6a). From Fig 5b the wind direction is change from North East direction to South West on 18 May 2010 on both MBLM and GPS radiosonde observations and it is continued for the longer period.

IV. Conclusions

In this study, a systematic change in low level wind speed, wind direction and rainfall are studied and the onset/arrival of monsoon over Kadapa was investigated using MBLM, NCEP – NCAR reanalysis data and GPS Radiosonde. Enhancement of the low level south westerly winds attaining 8 ms^{-1} at 1.5 km (850 hPa) and wind speed at 15 m from MBLM data exceeds 5 ms^{-1} with persistency during the next few days indicates the beginning of monsoon season over Kadapa.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 3, Issue 3, September 2014)

Acknowledgments:

We acknowledge to Indian Space Research Organization (ISRO) for sponsoring Semi arid zonal Atmospheric Research Centre (SARC) to carryout research. Mr. S.B. Surendra Prasad and Mr. M. Venkatarami Reddy greatly acknowledges Indian Space Research Organization (ISRO), Govt. of India for providing the financial support through research fellowships to carry out this research work

REFERENCES

[1] Krishnamurti, T. N., 1985, Summer Monsoon Experiment—A review. Mon. Wea. Rev., 113, 1590–1626.

[2] Fasullo, J., and Webster, P. J., 2003, a hydrological definition of Indian monsoon onset and withdrawal. J. Climate, 16, 3200–3211.

[3] Rao, Y. P., 1976, South West Monsoon.India Meteorological Department, 376 pp.

[4] Sikka, D. R., and Gadgil, S., 1980, On the maximum cloud zone and the ITCZ over Indian longitudes during the southwest monsoon. Mon. Wea. Rev., 108, 1840–1853.

[5] Webster, P. J., Magana, V. O., Palmer, T. N., Shukla, J., Tomas, R. A., Yanai, M. and Yasunari, T., 1998, Monsoons: Processes, Predictability, and the prospects for prediction, J. Geophys. Res., V103, pp14451-14510.

[6] Li, C., and Yanai, M., 1996, The onset and interannual variability of the Asian summer monsoon in relation to land–sea thermal contrast. J. Climate, 9, 358–375.

[7] Goswami, B. N., Wu, G., and Yasunari, T., 2006, The annual cycle, intraseasonal oscillations, and roadblock to seasonal predictability of the Asian summer monsoon. J. Climate, 19, 5078–5099.

[8] Ananthakrishnan, R., Pathan, J. M., and Aralikatti, S. S., 1983, The Onset phase of the southwest monsoon, Current Science., V52, pp155-164.

[9] Pearce, R. P., and Mohanty, U.C.,1984, Onsets of the Asian Summer Monsoon 1979-82, J. Atmos. Sci., V41, pp1620-1639.

[10] Ananthakrishnan, R. and Soman, M.K., 1988, The onset of southwest monsoon over Kerala for the period 1870-1990, Int. J. Climatol., V9, pp283-296.

[11] Soman, M. K. and Krishna Kumar, K., 1993, Space-time evolution of meteorological features associated with the onset of the Indian summer monsoon, Mon. Wea. Rev., V121, pp1177-1194.

[12] Joseph, P.V., Eishcheid, J. K. and Pyle, R. J., 1994, Interannual variability of the onset of the Indian Summer Monsoon and its Association with atmospheric features, El Nino and sea surface temperature anomalies, J. Climate, V7, p81-105.

[13] Joseph P.V., Sooraj, K. P., and Rajan. C. K., 2006, The Summer Monsoon onset over Process over South Asia and an Objective method for the Date of Monsoon Onset over Kerala, International Journal of Climatology, V26, pp1871-1893.

[14] Kawamura, R., Fukuta, Y., and Ueda, H., 2002, A mechanism of the onset of the Australian summer monsoon, Geophys. Res. Lett., 107, doi:10.1029/2001JD001070.

[15] Krishnamurti, T. N., Ardanuy, P., Ramanathan, Y., and Pasch, R., 1981, On the onset vortex of the summer monsoon, Mon. Weather Rev., 109, 344– 363.

[16] Rao, P. L. S., Mohanty, U. C., and Ramesh, K. J., 2005, The evolution and retreat features of the summer monsoon over India, Meteorol. Appl., 12, 241– 255.

[17] Goswami, B. N., and Ajaya Mohan, R. S., 2001, Intra seasonal oscillations and inter annual variability of the Indian summer monsoon, J. Clim., 14, 1180–1198.

[18] Taniguchi, K., and Koike, T., 2006, Comparison of definitions of Indian summer monsoon onset: Better representation of rapid transitions of atmospheric conditions. Geophys. Res. Lett., 33, L02709, doi:10.1029/2005GL024526.

[19] Reddy, S. J., 1977, Forecasting the onset of southwest monsoon over Kerala. Indian J. Meteor. Geophys., 28, 113–114.

[20] Subbaramayya, I., and Bhanukumar, O. S. R. U., 1978, The onset and northern limit of southwest monsoon. Meteor. Mag., 107, 37–47.

[21] Kung, E. C., and Shariff, T. A., 1982, Long-range forecasting of the Indian summer monsoon onset and rainfall with upper air parameters and sea surface temperature. J. Meteor. Soc. India, 60, 672–681.

[22] Deshpande, V. R., Kripalani, R. H. and D. K. Paul, 1986, some facts about monsoon onset dates over Kerala and Bombay. Mausam, 37, 467–470.

[23] Joseph, P. V., and Pillai, P. V., 1988, 40-day mode of equatorial trough for long range forecasting of Indian summer monsoon onset. Curr. Sci., 57, 951–954.

[24] Rajeevan, M., and Dube, D. P., 1995, Long range prediction of monsoon onset over Kerala. Mausam, 46, 287–290.

[25] Ghanekar, S. P., Puranik, P. V., and Bhide, U. V., 2003, Forecasting the onset of monsoon over Kerala using the peak in pre monsoon convective activity over south peninsular India. Mausam, 54, 645–652.

[26] Kalnay, E., et al. (1996), The NCEP/NCAR 40-year reanalysis project, Bull. Am. Meteorol. Soc., 77, 437–472.