

Onset of northeast monsoon over South Peninsular India

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सार – दक्षिण प्रायद्वीपीय भारत में पूर्वोत्तर मॉनसून के आरम्भ की तिथियाँ, 850 hPa और 200 hPa पर पवन के आँकड़ों, बहिर्गामी दीर्घ तरंग विकिरण तथा डोमेन 40° पू. से 120° पू., 0° से 40° उ. के लिए माध्य समुद्र तल के दाब के आँकड़ों का उपयोग करके निर्धारित की जाती हैं। आँकड़ों के इन तीनों सेटों को एन.सी.ई.पी./एन.सी.ए.आर. पुनः विश्लेषण दैनिक आँकड़ा सेट से लिया जाता है। इसके अलावा भारत मौसम विज्ञान विभाग द्वारा भारत में दैनिक ग्रिड बिंदु (0.25° अक्षांश \times 0.25° देशांतर) वर्षा के आँकड़ों को वर्षा के पैटर्न के निर्धारण के लिए उपयोग किया जाता है। उपर्युक्त प्राचलों के लिए 21 वर्षों (1994 से 2014) के आँकड़े लिए गए हैं।

वर्षा के परिसंचरण के पैटर्न और वर्षा की सक्रियता की जाँच करने के लिए उपर्युक्त प्राचलों के पेंटाड वितरण को उपयोग में लाया और तैयार किया जाता है। अध्ययन के लिए 55^{th} पेंटाड (28 सितंबर - 2 अक्टूबर) से 65^{th} (17-21 नवंबर) पेंटाड को लिया गया है। दक्षिण प्रायद्वीपीय भारत पर उत्तर-पूर्व मॉनसून के निर्धारण में, निम्नलिखित बिंदुओं पर विचार किया जाता है: (i) 850 hPa स्तर पर उत्तर-पूर्वी हवाओं का बने रहना, (ii) दक्षिण प्रायद्वीपीय भारत में वर्षा की स्थिति, (iii) दक्षिण पूर्व अरब सागर, दक्षिण प्रायद्वीपीय भारत के दक्षिणी क्षेत्र और बंगाल की खाड़ी के पास से गुजरने वाले इथियोपिया क्षेत्र से मलेशिया क्षेत्र तक के निचले अक्षांशों में पूर्व-पश्चिम दिशा की ओर उन्मुख द्रोणी [इंटरट्रोपिकल कन्वर्जेंस जोन (ITCZ)] की उपस्थिति, (iv) दक्षिण-पश्चिम बंगाल की खाड़ी पर सतह स्तर पर निम्न दाब की उपस्थिति, (v) भारत के उत्तरी अक्षांशों में (सऊदी अरब/जॉर्डन क्षेत्र से उत्तरी अरब सागर, गुजरात और उड़ीसा होकर बंगाल की मुख्य खाड़ी तक विस्तारित) एक उच्च दबाव क्षेत्र का बने रहना (vi) 17.5° N, के आसपास 200 hPa पर उपोष्णकटिबंधीय रिज/कटक की उपस्थिति (vii) चीन के पूर्वी भागों में उत्तर-दक्षिण चोटी की उपस्थिति और (viii) दक्षिण प्रायद्वीपीय भारत में उत्तरी अक्षांशों की तुलना में अपेक्षाकृत कम बहिर्गामी दीर्घ तरंग विकिरण (ओ.एल.आर.) मानों की उपस्थिति।

यदि कोई भी पेंटाड उपर्युक्त बिंदुओं को पूरा करता है, तो पेंटाड की मध्य तिथि को दक्षिण प्रायद्वीपीय भारत पर उत्तर-पूर्व मॉनसून के आरम्भ की तिथि माना जाता है। यदि कोई भी पेंटाड बिंदु 2 को छोड़कर शेष सभी बिंदुओं के अनुकूल है, तो उत्तर-पूर्वी हवाओं की अवस्थिति को महत्व दिया जाएगा और पेंटाड की मध्य तिथि को मॉनसून के आरम्भ की तिथि के रूप में घोषित किया जाएगा। मानदंडों का पालन करके पूर्वोत्तर मॉनसून के आरम्भ की तिथियाँ नवीनतम 21 वर्षों के लिए निर्धारित की जाती हैं। इन तिथियों की तुलना भारत मौसम विज्ञान विभाग की तिथियों से की जाती है।

ABSTRACT. The onset dates of the northeast monsoon over South Peninsular India are determined using the wind data at 850 hPa and 200 hPa, OLR, mean sea level pressure data for the domain 40° E to 120° E, 0° to 40° N. These three data sets are sourced from NCEP/NCAR reanalysis daily data sets. Further the daily grid point (0.25° Lat. \times 0.25° Long.) rainfall data over India from Indian Meteorological Department is considered for delineation of rainfall pattern. The total length of the data of the above mentioned parameters is 21 years (1994 to 2014).

Pentad distributions of the above parameters for the domain considered are prepared for examining the circulation patterns and rainfall activity. The pentads taken for the study are from 55^{th} (28th September - 2nd October) pentad to 65^{th} (17-21 November) pentad. In the determination of the northeast monsoon over South Peninsular India, the following points are considered: (i) The persistence of the northeasterlies at 850 hPa level, (ii) Occurrence of the rainfall over the South Peninsular India, (iii) Presence of east-west oriented trough [Intertropical Convergence Zone (ITCZ)] in the lower latitudes from Ethiopia region to Malaysia region passing through South Arabian Sea, southern region of South Peninsular India and South Bay of Bengal, (iv) The presence of low pressure over the southwest Bay of Bengal at the surface, (v) Persistence of a high pressure zone in northern latitudes of India (extending from the Saudi Arabia/Jordan region to the Head Bay of Bengal running through North Arabian Sea, Gujarat and Orissa), (vi) Presence of subtropical

ridge at 200 hPa level around 17.5° N, (vii) Presence of north-south ridge over the eastern parts of China and (viii) Presence of relatively low OLR values over South Peninsular India when compared to the northern latitudes.

If any pentad satisfies the above points, the middle date of the pentad is considered as the date of onset of northeast monsoon over South Peninsular India. If any pentad satisfies all the points except point number 2, importance is given to the persistence of northeasterlies and the middle date of the pentad will be declared as the onset date. By following the criteria, the dates of onset of northeast monsoon are determined for the latest 21 years. These dates are compared with those of the India Meteorological Department.

Key words – Northeast monsoon, Onset date, Wind speed, OLR and Pressure.

1. Introduction

In July and August the monsoon trough extends from Ganganagar to the Head Bay of Bengal (Rao, 1976). In September, the trough moves southwards. In October it moves further southwards to about 15° N and is located south of Kanyakumari (formerly Comorin) by 1st November. The passage of the trough over southern peninsula from north to south is associated with reversal of low level winds from southwesterlies to northeasterlies. The subsequent increase in the rainfall over the southern peninsula is taken as the northeast monsoon onset. The normal date of the northeast monsoon onset is 20th October with a standard deviation of 7 to 8 days (Raj, 1992 and 2003). The presence of equatorial trough is located south of 9° N prior to or on the date of onset of northeast monsoon. Positive relative vorticity, frictional convergence resulting from land-sea contrast, thermodynamic instability and large amount of moisture flux transported towards coast besides convergence associated with equatorial trough appear to be the major mechanisms behind the cloud formation and the rainfall at the time of northeast monsoon onset (Raj *et al.*, 2007).

So far, considerable attention was not given to the northeast monsoon that extends from October through December over the south peninsular India. Northeast monsoon season plays a pivotal role in the occurrence of rainfall over the southern region of the Indian peninsula; especially the eastern half. With reference to the past events, the northeast monsoon outsets over Central Tamilnadu by October 20th subsequent to the retreat of the southwest monsoon upto 15° N latitude. Preceding the onset of northeast monsoon over Central Tamil Nadu, the lower level winds are observed to swap its directions from southwesterlies to northeasterlies along Central Tamilnadu and South coastal Andhra Pradesh. The comprehensive study of chaotic northeast monsoon character, incongruous relationship with southwest monsoon and pulsatory behavior with the southwest monsoon is necessary to determine the onset date of northeast monsoon. In the month of October, the ITCZ trough that is oriented over the northern parts of India in a NE-SW position at the surface and the lower troposphere begins a quick shift southwards (Khole and De, 2003). The lower level winds thus reverse its direction to northeasterlies and

the southwest monsoon retreats. De *et al.*, (1992) has identified that only two or three weeks of the post-monsoon season over South India experienced spells of rainfall above normal even during the years of normal and above normal rainfall. Raj, (1992) clarifies that the onset of northeast monsoon (NEM) over Indian southern peninsula emanates based on the synoptic features. The onset of NEM in India is calculated as the day on which Central Tamilnadu receives rain more than 5 mm and this is revealed in the later studies (Raj, 2011). The area average onset date verification and validation of NEM rainfall is analyzed by computing the deviation from the date of onset over coastal Tamil Nadu ascertained (Raj, 1992) for the years up to 1990 and that of IMD for years after 1990. Advancing of the trough zone of the equatorial wave can also be determined with the onset of monsoon. The erratic behavior of the lower troposphere in synchronization with the motion of frontal formation in the upper troposphere can be considered as Australian Monsoon is one more onset cause (Noel Davison *et al.*, 2007). The heat source region of the Asian winter monsoon is much nearer to the equator (Krishnamurti, 1971).

NEM is a diminutive monsoon which is restricted to the southern Indian peninsula. NEM is also an essential rainfall season for the parts of south peninsular India, albeit the southwest monsoon is the most crucial weather episode for the country providing virtually 75% of the normal annual rainfall of 115 cm (IMD, 2016). NEM is prominent over the belt of Central Tamilnadu. The clearly defined reversal of low level winds from southwesterlies to northeasterlies precedes the onset of NEM in Central Tamilnadu. This is a preliminary happening to the establishment of NEM over South peninsular India. Tamilnadu state is the major beneficiary of NEM, receiving 48% of its annual rainfall. Due to wide spatial variation of rainfall within the state and recipient of prodigious rainfall makes it the wettest state in India during NEM. The major weather phenomenon of southwest monsoon during June-September starts withdrawing from northwest India in the starting of September (Rao, 1976). The monsoon withdraws upto 15° N by 15th October over peninsular India. The withdrawal is integrated with the termination of rainfall and rise of maximum temperature in October. The

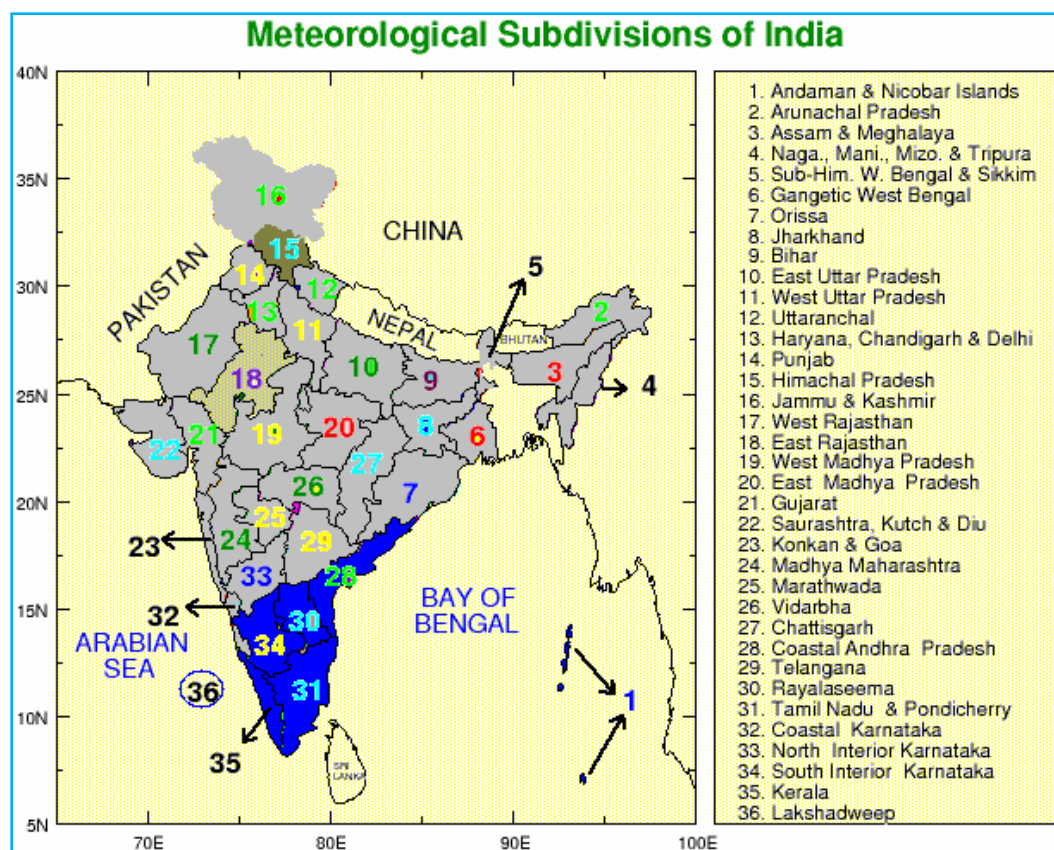


Fig. 1. Meteorological sub-divisions of India (The meteorological sub-divisions with numbers 28, 30, 31, 34 and 35 constitute the South Peninsular India)

significant increase in rainfall after the reversal of winds from southwesterlies to northeasterlies is said to be the onset of NEM. The onset date of NEM however show wide variations in individual years. There were no clearly defined and fixed criteria for proclaiming the onset of NEM (IMD, 1973). In the year 1987, the forecasting officers conference of IMD has been held where the set of criteria to recognize the onset of NEM over southern peninsula are defined (IMD, 1987). The onset criteria for the diagnostic study have been slightly modified to determine the onset of NEM over coastal Tamilnadu (Raj, 1992). The increase in rainfall activity over Andhra-Tamilnadu coast which takes place sometime around the middle of October is generally considered as the "setting in of Northeast Monsoon". Normal date of onset of the northeast monsoon is around 20th October with a deviation of about a week on either side (Geetha and Raj, 2015).

South Peninsular India (comprising of Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu, South Interior Karnataka and Kerala) experiences northeast monsoon rainfall effectively. The meteorological sub-

divisions of India are shown in Fig. 1. The onset of northeast monsoon is a peculiar phenomenon over the South Peninsular India. Sometimes it is very difficult to separate the northeast monsoon rains from that of southwest monsoon. In this paper an attempt is made to determine the date of onset of northeast monsoon over South Peninsular India by studying different meteorological parameters.

2. Data and method of analysis

In the present paper, the onset dates of the northeast monsoon over South Peninsular India are determined using the wind data at 850 hPa and 200 hPa, OLR, mean sea level pressure data for the domain 40° E to 120° E, 0° to 40° N. These three data sets are sourced from NCEP/NCAR reanalysis daily data sets. Further the daily grid point (0.25° Lat. × 0.25° Long.) rainfall data over India from Indian Meteorological Department is considered for delineation of rainfall pattern. The total period of the data of the above mentioned parameters is 21 years (1994 to 2014).

Pentad distributions of the above parameters for the domain considered are prepared for examining the circulation patterns and rainfall activity. The pentads taken for the study are from 55th (28th September - 2nd October) pentad to 65th (17th - 21st November) pentad. In the determination of the northeast monsoon over South Peninsular India, the following points are considered:

- (i) The persistence of the northeasterlies at 850 hPa level,
- (ii) Occurrence of the rainfall over the South Peninsular India,
- (iii) Presence of east-west oriented trough [Intertropical Convergence Zone (ITCZ)] in the lower latitudes from Ethiopia region to Malaysia region passing through south Arabian Sea, southern region of South Peninsular India and South Bay of Bengal,
- (iv) The presence of low pressure over the southwest Bay of Bengal in the surface level,
- (v) Persistence of a high pressure zone in northern latitudes of India (extending from the Saudi Arabia/Jordan region to the Head Bay of Bengal running through north Arabian Sea, Gujarat and Orissa),
- (vi) Presence of sub-tropical ridge at 200 hPa level around 17.5° N,
- (vii) Presence of north-south ridge over the eastern parts of China,
- (viii) Presence of relatively low OLR values over South Peninsular India when compared to the northern latitudes.

If any pentad satisfies the above points, the middle date of the pentad is considered as the date of onset of northeast monsoon over South Peninsular India. If any pentad satisfies all the points except point number 2, importance is given to the persistence of northeasterlies and the middle date of the pentad will be declared as the onset date. By following the criteria, the dates of onset of northeast monsoon are determined for the latest 21 years. These dates are compared with those of the India Meteorological Department.

3. Results and discussion

3.1. Onset of northeast monsoon in the year 2008

Wind pattern at 850 hPa : On the 57th pentad (October 8th to October 12th), at 850 hPa an anticyclonic circulation over Gujarat and adjoining area of India is well

marked and a ridge extends from Gujarat to the Head Bay of Bengal. A well marked east-west oriented trough is present along 4° N latitude over the Indian Ocean region [Fig. 2(a)].

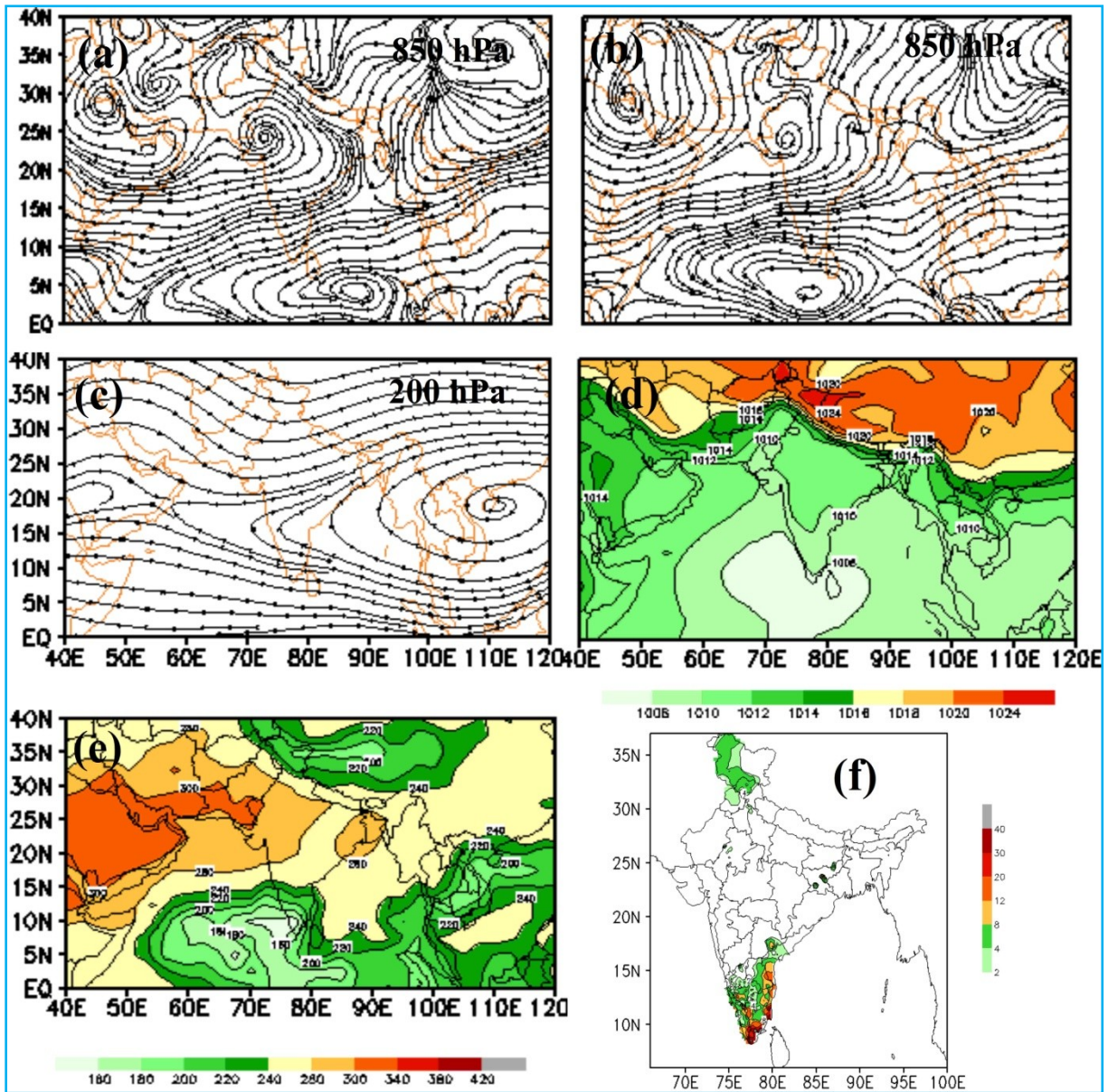
In the 58th pentad also, at 850 hPa a well marked anticyclone is present over Gujarat and a ridge extends from Iraq region to the Head Bay of Bengal [Fig. 2(b)]. A north-south ridge is present over the Bay of Bengal. An east-west trough is concentrated over the Indian Ocean in the latitude belt 4° - 6° N. The easterlies over southern peninsula are well defined and they are of continental origin. The onset of the northeasterlies over the South Peninsular India can be taken as the date of arrival of northeast monsoon. The middle date, 15th October, can be considered as the onset date of northeast monsoon over South Peninsular India.

On 59th pentad also, the well marked anti-cyclone continues over northwestern parts of the country. A ridge continues from northwestern parts to the Head Bay of Bengal. The position of east-west trough in the southern latitudes is shifted to northern latitudes and concentrated along 9° to 10° N. One cyclonic cell is concentrated over the Arabian Sea at 10° N and 57° E and another is concentrated nearer to Tamil Nadu and Sri Lanka region (Here the figure is not included).

Wind pattern at 200 hPa : 15th October is considered as the onset date of northeast monsoon. The wind pattern at 200 hPa level for the corresponding pentad (58th) is given in [Fig. 2(c)]. Sub-tropical ridge is situated in between 16° N and 17.5° N over the study region comprising of India, Bay of Bengal and Arabian Sea. Westerlies are dominant over northern latitudes. North-south trough is present in the westerly belt in the northern latitudes along the meridian 75° E.

Sea level pressure : On the 58th pentad (pentad corresponding to the onset date), low pressure is concentrated over southeast Arabian Sea, south Bay of Bengal and adjoining eastern equatorial Indian Ocean and Indonesia & Malaysia region. The pressure over the northern latitudes is relatively high when compared to the lower latitudes. On this day, the monsoon onset takes place. The convective activity is present in the southern latitudes. It agrees with the onset date [Fig. 2(d)].

Out-going Long-wave Radiation (OLR) and Rainfall : On 58th pentad (pentad corresponding to the onset date), the OLR values over South Peninsular India and adjoining Arabian Sea are less (240-160 w/m²) [Fig. 2(e)]. OLR pattern also reflects the rainfall activity over South Peninsular India. The OLR values are high over Saudi Arabia and adjoining area. The OLR pattern clearly



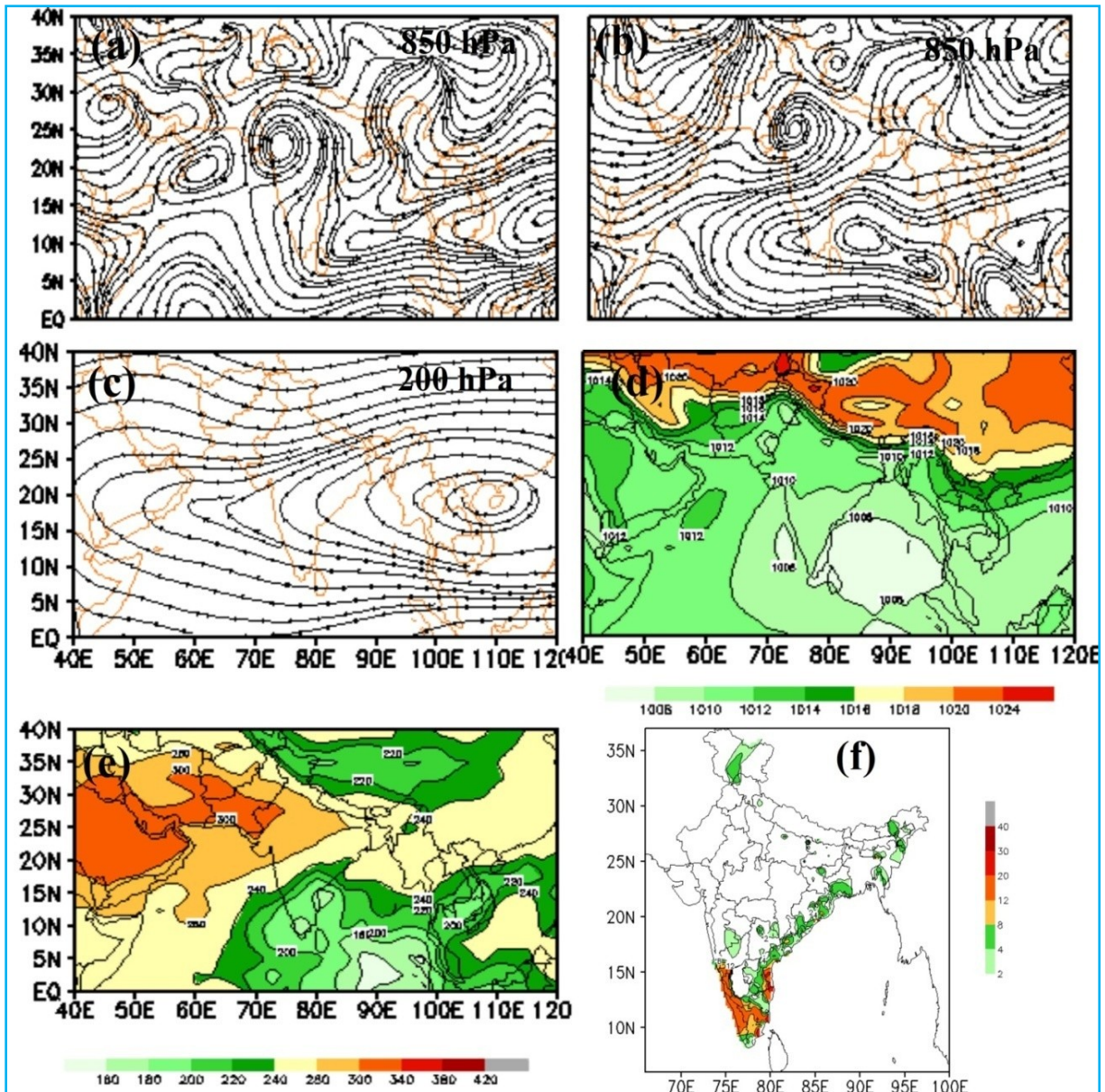
Figs. 2(a-f). Wind circulation in the lower troposphere (850 hPa) for the pentad (a) 57, (b) 58, (c) upper troposphere (200 hPa) for the pentad 58, (d) distributions of mean sea level pressure, (e) OLR and (f) grid point rainfall for the pentad 58 in the year 2008

indicates the presence of ridge from Iraq and surrounding region to the head Bay of Bengal passing through Gujarat region. On this pentad, major part of South India experiences rainfall; particularly it is high over southern parts of east coast of Tamil Nadu [Fig. 2(f)].

3.2. Onset of northeast monsoon in the year 2005

Wind pattern at 850 hPa : On 56th pentad, an anticyclone over northwestern parts of India is pronounced. The cyclonic circulation present over

northern Arabian Sea continues. The anticyclonic circulation over western equatorial Indian Ocean is shifted further to the east and centered at 2° N, 60° E. There is an east-west trough extending from southern Bay of Bengal to South China Sea. The northeast - southwest oriented trough extends from south Bay of Bengal to equatorial Indian Ocean passing through Sri Lanka. A northwest-southeast oriented trough extends from Northern Arabian Sea off Oman coast to the south central Bay of Bengal. A well marked anticyclone is formed with centre at 108° E, 35° N [Fig. 3(a)].

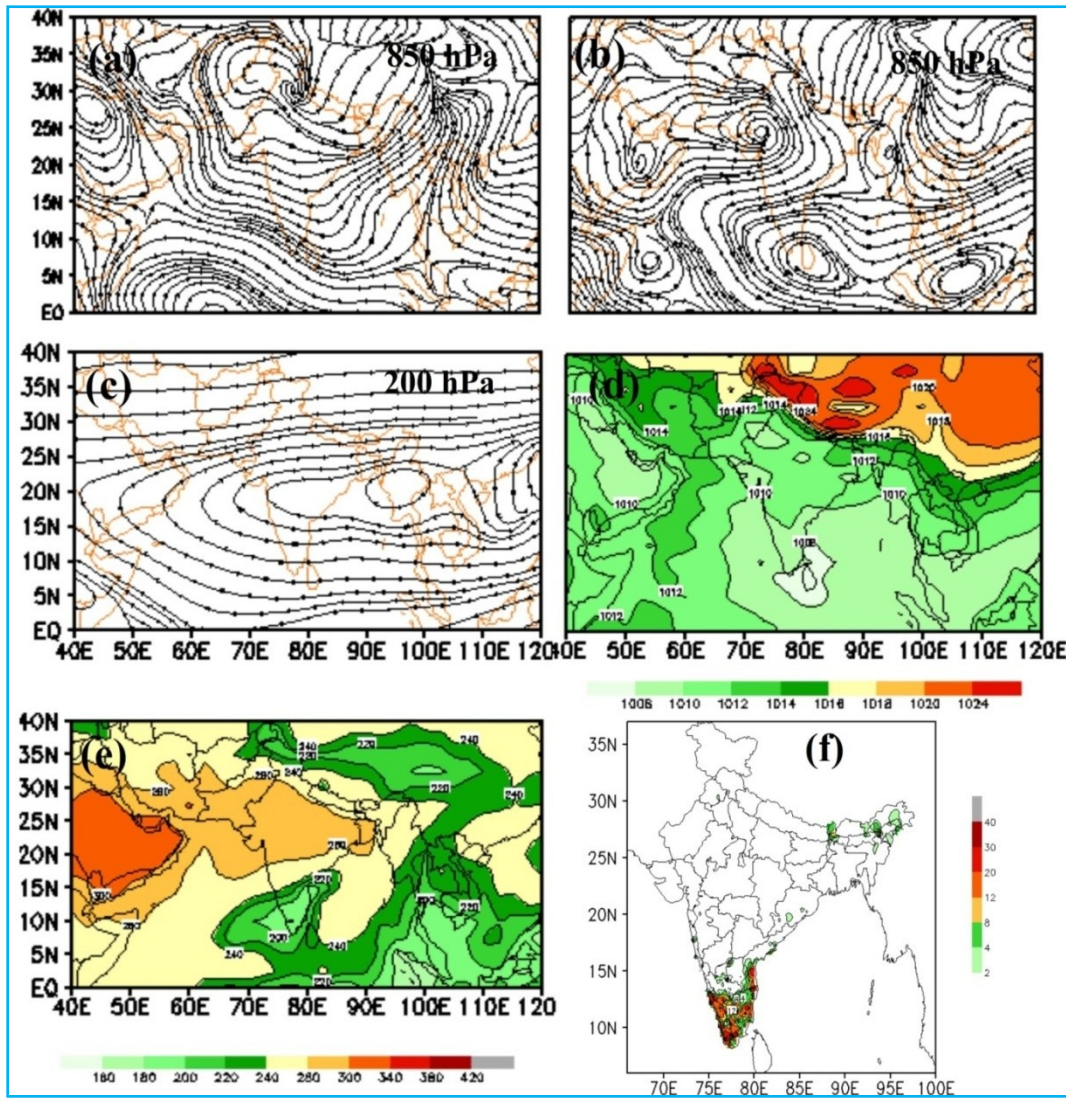


Figs. 3(a-f). Wind circulation in the lower troposphere (850 hPa) for the pentad (a) 56, (b) 57, (c) upper troposphere (200 hPa) for the pentad 57, (d) distributions of mean sea level pressure, (e) OLR and (f) grid point rainfall for the pentad 57 in the year 2005

On 57th pentad, an anticyclone is present over Gujarat. An easterly wind enters into Andhra Pradesh and Tamil Nadu. An east-west trough, which lies in between 8° N and 11° N, extends from Ethiopia region to Malaysia region passing through Southern Arabian Sea and Southern Bay of Bengal. Particularly, the part of the trough over southern Bay of Bengal is pronounced. The middle date of the pentad (10th October) can be considered as the onset date of northeast monsoon [Fig. 3(b)].

On pentad 58th, a cyclonic circulation is pronounced over the Arabian Sea and centered at 70° E and 12° N. An east-west trough connects Somalia, Arabian Sea, South Peninsular India and Indonesia region. An anticyclone over northern latitude is also prominent with the centre at 106° E and 36° N (here the figure is not included).

200 hPa wind pattern : On 57th pentad (10th October), the subtropical ridge is situated at 17.5° N. Westerlies are dominant in the northern latitudes.



Figs. 4(a-f). Wind circulation in the lower troposphere (850 hPa) for the pentad (a) 56, (b) 57, (c) upper troposphere (200 hPa) for the pentad 57, (d) distributions of mean sea level pressure, (e) OLR and (f) grid point rainfall for the pentad 57 in the year 1996

At 74° E, north-south trough is present over Northern India [Fig. 3(c)].

Pressure : On 57th pentad (10th October), the mean sea level pressure distribution shows a low pressure area over the southwest Bay of Bengal. This is a good indication for the presence of north-easterlies over the east coast of South Peninsular India [Fig. 3(d)].

OLR and Rainfall : On this pentad, the OLR values are high over northwestern parts of India and also over Iraq and surrounding area [Fig. 3(e)]. Low values are concentrated over the eastern equatorial Indian Ocean region and also over South Peninsular India &

surrounding region. Rainfall activity particularly over South Peninsular India & neighbouring region is more. All these features are connected with the onset of northeast monsoon [Fig. 3(f)].

3.3. Onset of northeast monsoon in the year 1996

Wind pattern at 850 hPa : On 56th pentad of 1996, the cross equatorial flow is strong. A broad belt of westerlies covers the entire India. A trough in the westerlies is seen from the west-central Bay of Bengal to Indonesia region [Fig. 4(a)]. An anticyclone is present over Jordan region. But on 57th pentad, the northeasterlies enter into the South Peninsular India. An east-west trough

TABLE 1
Onset dates over South Peninsular India

Year	Present study (A)	IMD (B)	Error in days (A-B)
1994	20 th October	18 th October	2
1995	25 th October	23 rd October	2
1996	10 th October	11 th October	-1
1997	10 th October	13 th October	-3
1998	25 th October	28 th October	-3
1999	25 th October	21 st October	4
2000	4 th November	2 nd November	2
2001	20 th October	16 th October	4
2002	25 th October	25 th October	0
2003	15 th October	19 th October	-4
2004	20 th October	18 th October	2
2005	10 th October	12 th October	-2
2006	15 th October	19 th October	-4
2007	20 th October	22 nd October	-2
2008	15 th October	14 th October	1
2009	27 th October	29 th October	-2
2010	27 th October	29 th October	-2
2011	25 th October	25 th October	0
2012	17 th October	19 th October	-2
2013	25 nd October	22 nd October	3
2014	20 th October	18 th October	2
Mean	19th October	19st October	Zero

is present [Fig. 4(b)]. It runs from west central Arabian Sea to Malaysia region passing through southern tip of India and Sri Lanka. An east-west ridge is present over the northern latitudes running through Saudi Arabia, Gujarat, Orissa and Bay of Bengal. An anticyclone is present over the northeastern parts of China. Under these circulation characteristic features, the onset date can be considered as 10th October.

On the 58th pentad also, the northeasterlies with more zonal component are present over South Peninsular India and the east-west trough is running through 50° E, 1° N, southern tip of India, 85° E, 10° N and Malaysia region & surrounding area (Here the figure is not included).

Wind pattern at 200 hPa : The 200 hPa wind pattern on 57th pentad shows dominant westerlies over the northern latitudes. The strength of the westerlies is high over the northeastern parts of the study region. An east-

west ridge (subtropical ridge) is present over the study region in between 17.5° N on the western parts and 20° N on the eastern parts of the study region [Fig. 4(c)].

Sea level pressure : Regarding the mean sea level pressure pattern for 57th pentad, low pressure exists over the southern tip of India and Sri Lanka region and also over Malaysia & surrounding area [Fig. 4(d)].

OLR and rainfall : On the 57th pentad, the OLR is high over Saudi Arabia, Jordan and Gujarat & surrounding area [Fig. 4(e)]. The high extends from Jordan region to the head Bay of Bengal. The OLR values are lowest over the Malaysia region and surrounding area and also over the South Peninsular India. Correspondingly the rainfall activity is more over the entire South Peninsular India and peripheries [Fig. 4(f)].

3.4. Comparison of onset dates of the northeast monsoon

The dates of onset of northeast monsoon determined as above are presented along with the dates of India Meteorological Department (Table 1). The differences between the two dates lie in between -4 and +4. The mean date according to the present study and the India Meteorological Department is the same *i.e.*, 19th October.

4. Conclusions

In this paper, an attempt is made on the determination of dates of onset of northeast monsoon over South Peninsular India for a period of 21 years (1994-2014). For this study the circulation patterns in the lower troposphere (850 hPa) and in the upper troposphere (200 hPa), the OLR distribution, mean sea level pressure patterns and rainfall patterns are examined on the pentad basis. The domain considered for the study is 0 to 40° N, 40° E to 120° E. The analysis has been made for the all the pentads starting from the 55th pentad (September 28th - October 2nd) to 65th pentad (17-21 November). In the analysis, features like northeasterly belt over South Peninsular India, cessation of the cross equatorial flow from the Southern Hemisphere into the Northern Hemisphere, low pressure activity over the southern latitudes, high pressure cells over northern latitudes, subtropical ridge position in upper troposphere, low OLR values over southern latitudes and high OLR values over the northern latitudes are examined.

The following features are commonly associated with the onset of northeast monsoon over the South Peninsular India. A broad belt of north-easterlies are established over South Peninsular India in the lower troposphere. They are of continental origin and persistent

over South Peninsular India and surrounding area. An east-west trough, *i.e.*, Intertropical Convergence Zone is more prominent over southern latitudes of the study area covering the Somalia, southern Arabian Sea, southern latitudes of South Peninsular India, Malaysia-Indonesia region and South China Sea. In the northern latitudes, an east-west ridge is perceptible. This ridge passes through the Jordan, Saudi Arabia, UAE, Gujarat and Head Bay of Bengal. In all the occasions, this type of ridge persists with slight north-south shifts in the locations. A cyclonic cell, which is part of the east-west trough in the lower latitudes, exists in most occasions over the southwest Bay of Bengal. In most of the occasions, the onset of northeast monsoon is associated with the presence of anticyclonic cell over the northeastern parts of China and a ridge which extends from this cell to the Myanmar region.

In the upper troposphere (200 hPa level), the winds are more zonal. In the northern latitudes of the study region, the westerlies are present with pronounced strength. The strength is high over the northeastern parts of the study region. In many occasions, the wind speed over this region exceeds 50 knots and a feeble trough, which is part of long waves in the upper troposphere, is present in westerlies belt in between 65° E to 85° E. In many occasions of the onset of the northeast monsoon over South Peninsular India, the subtropical ridge is present around 17.5° N. The subtropical ridge passes through Saudi Arabia, Arabian Sea, India, Bay of Bengal, Myanmar, Vietnam and South China Sea.

The onset of the northeast monsoon over South Peninsular India is associated with the presence of low pressure in the southern latitudes of the study domain. In many occasions, the pressure is low over the Malaysia-Indonesia and also over the South Peninsular India and adjacent oceanic area.

The OLR distributions at the time of the onset of northeast monsoon reveal that the high values exist over the region extending from the Jordan to the Head Bay of Bengal passing through Saudi Arabia, northern Arabian Sea, Gujarat and Head Bay of Bengal. Over the southern latitudes, the OLR values are less including South Peninsular India. The OLR values are much less over the Indonesia, Malaysia and South China Sea region. The grid-point rainfall data over India reveals that in many occasions of the onset of the northeast monsoon over South Peninsular India, the major part of the South Peninsular India (comprising the Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu, South Interior Karnataka and Kerala) experiences good amounts rainfall.

This paper conclusively discloses the dates of onset of northeast monsoon, while some of the authors of the

systematical studies may at times be conclusive only regarding the southwest monsoon. This key research on northeast monsoon comes out with a clearer answer regarding the northeast monsoon onset dates. In this study, low level circulation, ITCZ, rainfall distribution, pressure distributions, subtropical ridge position in the upper troposphere are analyzed systematically with proper care in determining the onset dates. The present study would make a notable contribution to the agriculturists of South Peninsular India for crop sowing.

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