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Unusual weather over northwest & west India during November, 2010

B. P. YADAV, MEDHA KHOLE* and NARESH KUMAR

India Meteorological Department, New Delhi, India

**India Meteorological Department, Pune, India*

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e mail: bp_yadav4@yahoo.co.in

सार – सामान्यतः नवम्बर का महीना धूप के दिनों व बिना बारिश वाला महीना कहलाता है और नवम्बर महीने के बीतने के साथ-साथ उत्तर पश्चिमी भारत के मैदानी भागों में सुबह की हल्की ठंडक लिए मौसम सुहावना रहता है किन्तु नवम्बर 2010 के दौरान उत्तर पश्चिमी और पश्चिम भारत में वर्षा की बौछारों के साथ लम्बे समय तक लगातार बादल छाए रहे जिसके कारण मौसम असामान्य रहा। इस असामान्य मौसम के लिए उत्तरदायी भौतिक प्रक्रियाओं का पता लगाने के लिए इस शोध पत्र में इस माह में बनी सिनाप्टिक स्थितियों का विस्तृत विश्लेषण किया गया है। इस अध्ययन से यह पता चला है कि अरब सागर में गहन निम्न अवदाब प्रणाली की उपस्थिति और निचले स्तरों में पश्चिमी हवाओं में मध्य क्षोभमंडलीय द्रोणियों के साथ–साथ पूर्वी हवाओं में उच्च आयामी द्रोणियों की परस्पर क्रियाओं के कारण नवम्बर माह में मौसम असामान्य रहा।

ABSTRACT. Generally, November is the dry month with sunny days and pleasant weather for plains of northwest & west India with a bit of early morning chill as the month progresses. But during November, 2010, there was unusual weather in the form of prolonged and persistent cloudy conditions with wet spell over northwest & west India. To find out the physical processes leading to this unusual weather, detailed analysis of synoptic conditions during the month has been carried out in this paper. This study reveals that the unusual weather that occurred in association with presence of an intense low pressure system in the Arabian Sea and interaction of high-amplitude troughs in easterlies in the lower levels with mid-tropospheric troughs in the westerlies.

Key words – Northwest & west India, Rainfall, Synoptic features, Temperature.

1. Introduction

The northwestern regions of India receive precipitation during December to March mainly in association with the passage of mid-latitude synoptic systems (Pisharoty and Desai, 1956; Mooley, 1957; Agnihotri and Singh, 1982). These systems are known as Western Disturbances (WDs). During these months, the mid-latitude disturbances move to their lowest latitudes and sometimes travel across the northern and central regions of India from west to east, disturbing the normal features of circulation patterns (Singh 1963, 1979; Dutta and Gupta, 1967; Bhaskara Rao and Morey, 1971; Singh and Kumar, 1977; Agnihotri and Singh, 1982). Sikka and Gadgil (1980) have studied the maximum cloud zone and ITCZ over Indian region during southwest monsoon. Yadav *et al.* (2010) have examined the influence of El Nino Southern Oscillation (ENSO) over precipitation over northwest India during winter, in recent decades. Climatologically, November is the driest month for plains of northwest & west India. It is known mainly for sunny days and pleasant weather with a bit of early morning chill as the month progresses. Frequency of dense fog, hail, thunder and rainy days in this month is negligible. However, in some years freak weather with rain/thundershowers even accompanied with hailstorm has been recorded. The weather during this season generally occurs from the intense low pressure systems forming over the Bay of Bengal, easterly waves affecting the southern peninsular region as well as from the precipitation systems leading to snow/rainfall over the extreme northwestern parts as a result of the passage of western disturbances. There are incidences in the past when rainfall due to the easterly wave activity is getting spread over to the central as well as western parts of the country under situations known in meteorological parlance as easterly-westerly interactions. Apart from these, high amplitude easterly troughs also sometimes cause a northward extension of rainfall during this period due to incursion of moisture from Bay of Bengal.

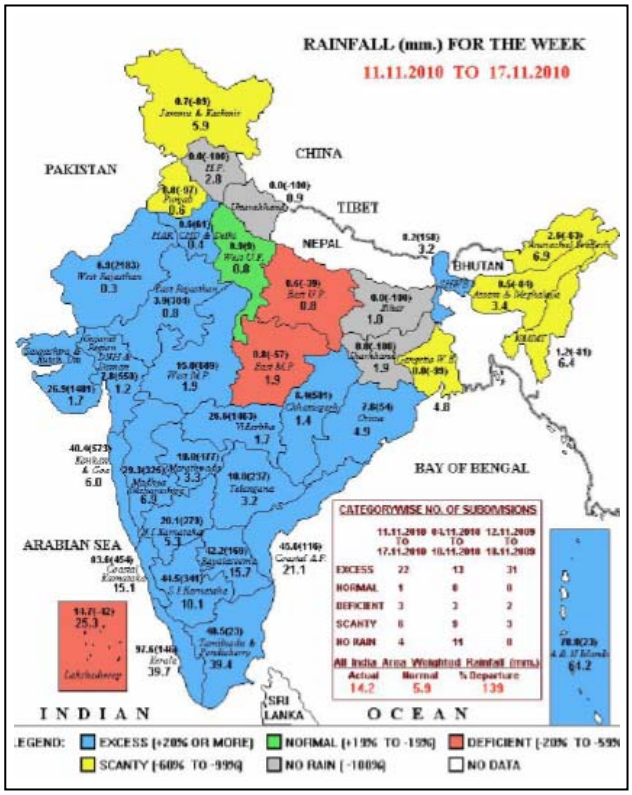


Fig. 1. Spatial distribution of weekly rainfall over India for the week ending on 17 November, 2010

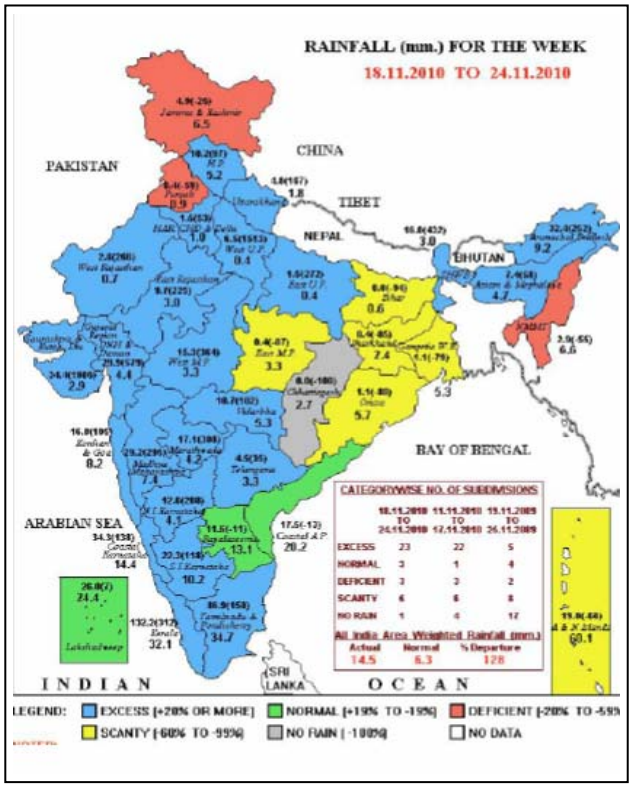


Fig. 2. Spatial distribution of weekly rainfall over India for the week ending on 24 November, 2010

2. Main features of weather over north-west India during November, 2010

During the post-monsoon season of 2010, northwest & western regions of India experienced unusual weather in terms of prolonged and persistent cloudy conditions accompanied with an unusual wet spell. While minimum temperatures remained above normal by 6 to 8 °C, the maximum temperatures were appreciably below normal for many days during second and third week of November 2010.

2.1. *Rainfall distribution*

The weekly rainfall (Figs. 1 and 2) for the week ending 17 and 24 November 2010 shows excess rainfall over many sub-divisions of northwest & western regions of the country.

2.2. *Anomalous rainfall pattern during November 2010*

Fig. 3 shows the actual, normal and departures of area weighted rainfall on day to day basis during 16-25 November. The rainfall over northwest & west India was either excess or normal of the corresponding climatological value.

3. Anomalous temperatures during November 2010

The moisture incursion, persistent clouding and occurrence of rainfall resulted in decrease in the maximum temperatures and increase in the minimum temperatures, over northwest & adjoining central India as given in Figs. 4(a&b). The setting-in of northerlies/ northwesterlies in the lower levels over the northern plains, which are generally responsible for advection of cold and dry continental air from the north, was also delayed.

4. Extreme weather events

4.1. *Temperatures*

Although, Gujarat state experienced almost similar weather situation during the month of November in the past 30 year period, *viz*., 1976, 1978, 1979, 1981 and 1982.

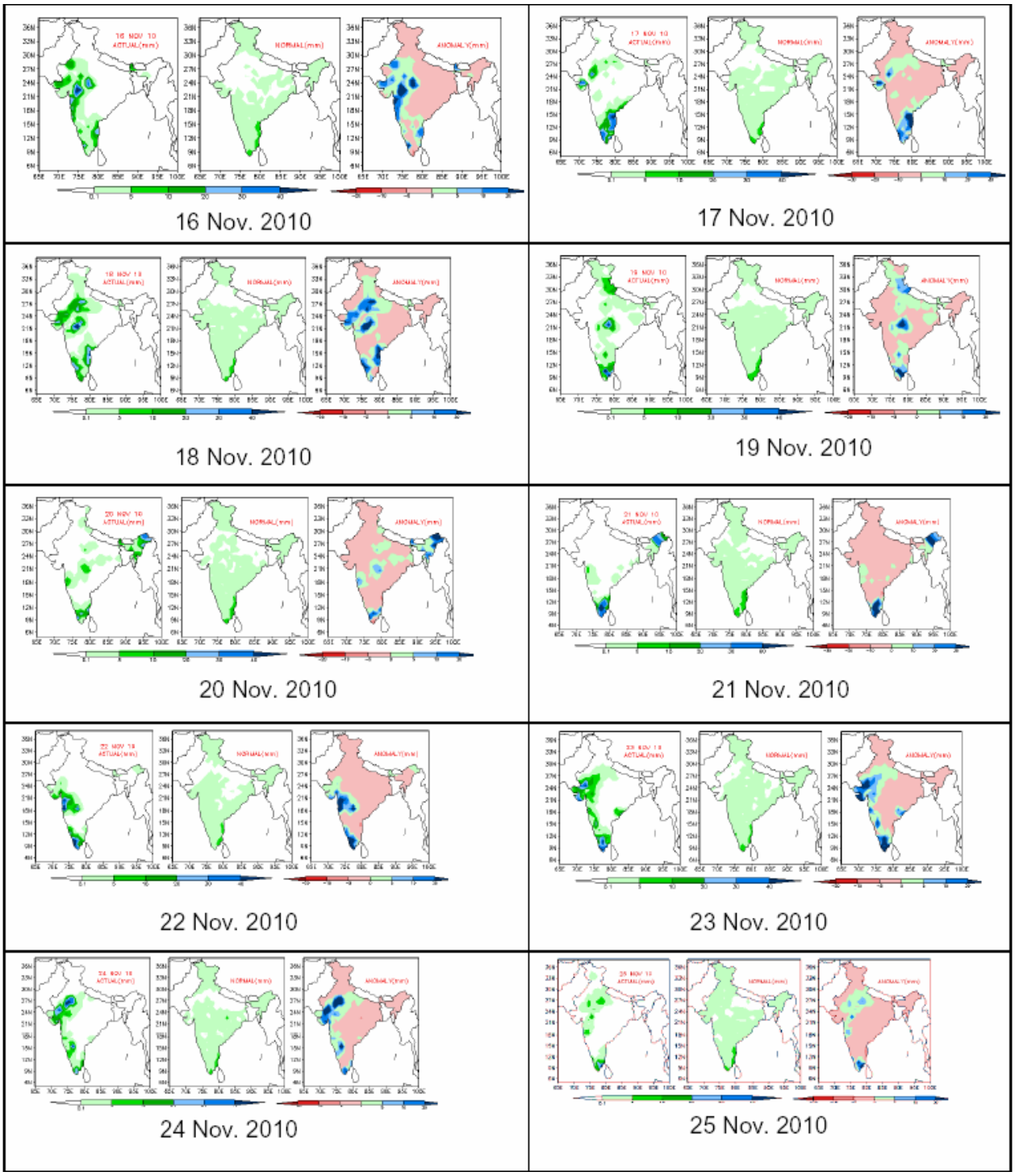
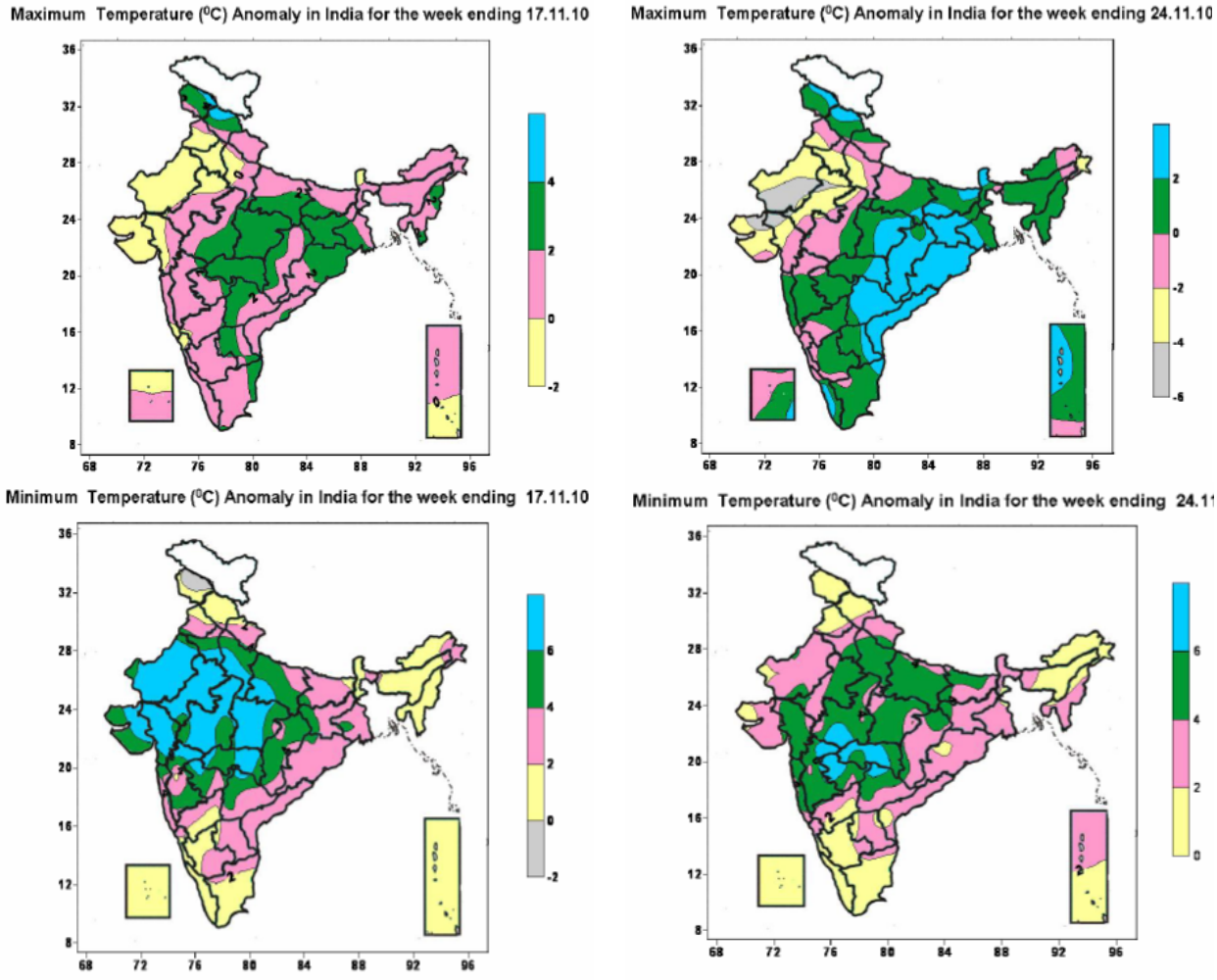


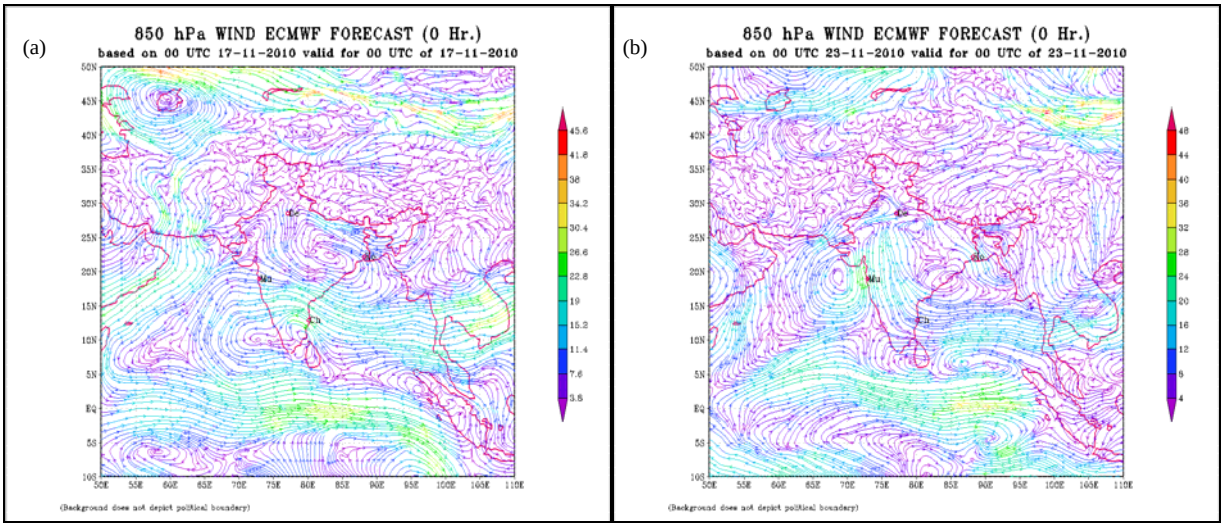
Fig. 3. Spatial distribution of daily rainfall over India

Anomaly of weekly maximum and minimum temperatures over India ending on 17 November 2010 and 24 November, 2010 are shown in Figs. 4(a&b). On 24 November, 2010, most of the observatories in Gujarat recorded very low maximum temperature due to rainfall activity. The cities of Ahmedabad, Rajkot, Bhuj, Deesa

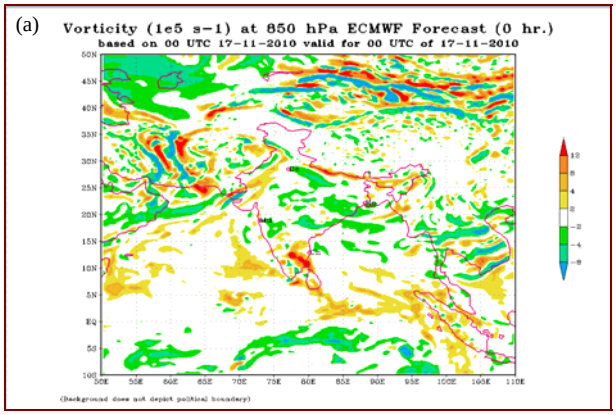
(a) week ending on 17th November 2010 (b) week ending on 24th November 2010

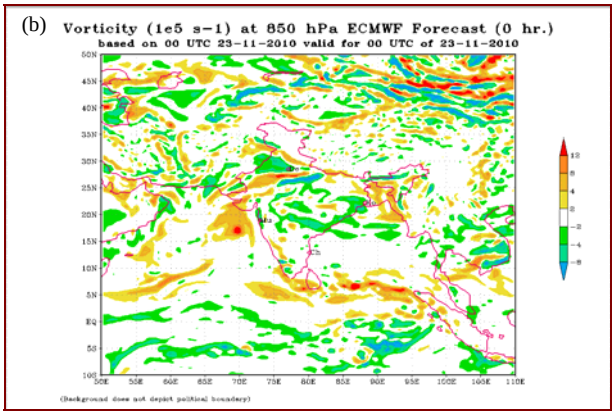


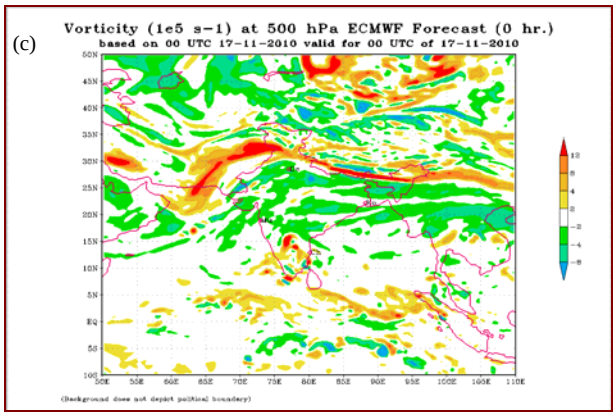
Figs. 4(a&b). Anomaly of weekly maximum and minimum temperatures over India. (a) week ending on 17th November, 2010 and (b) week ending on 24th November, 2010

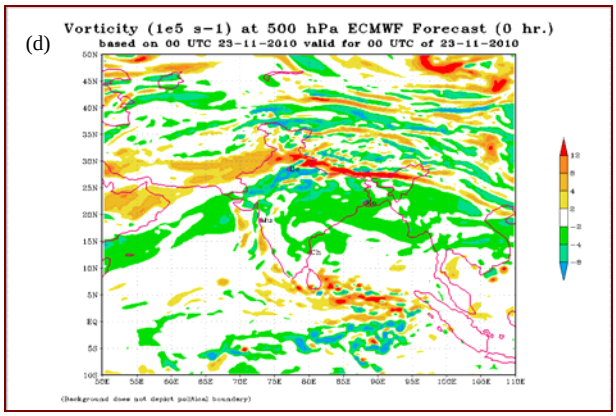


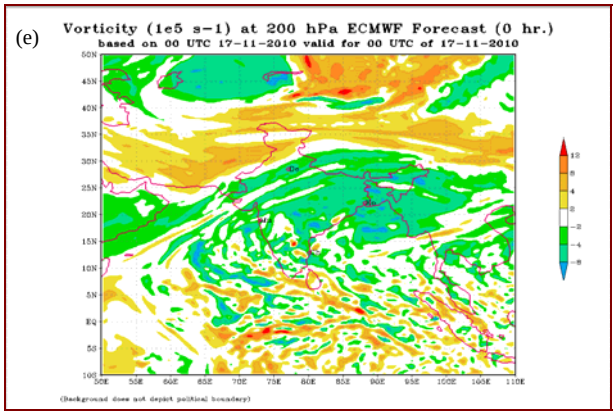
Figs. 5(a&b). (a) ECMWF 850 hPa wind analysis of 17 November, 2010, (b) ECMWF 850 hPa wind analysis of 23 November, 2010

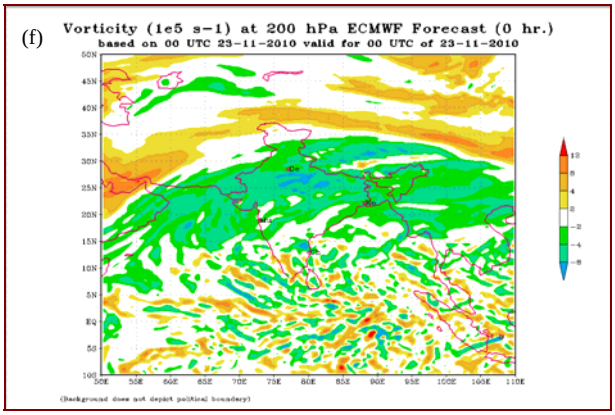




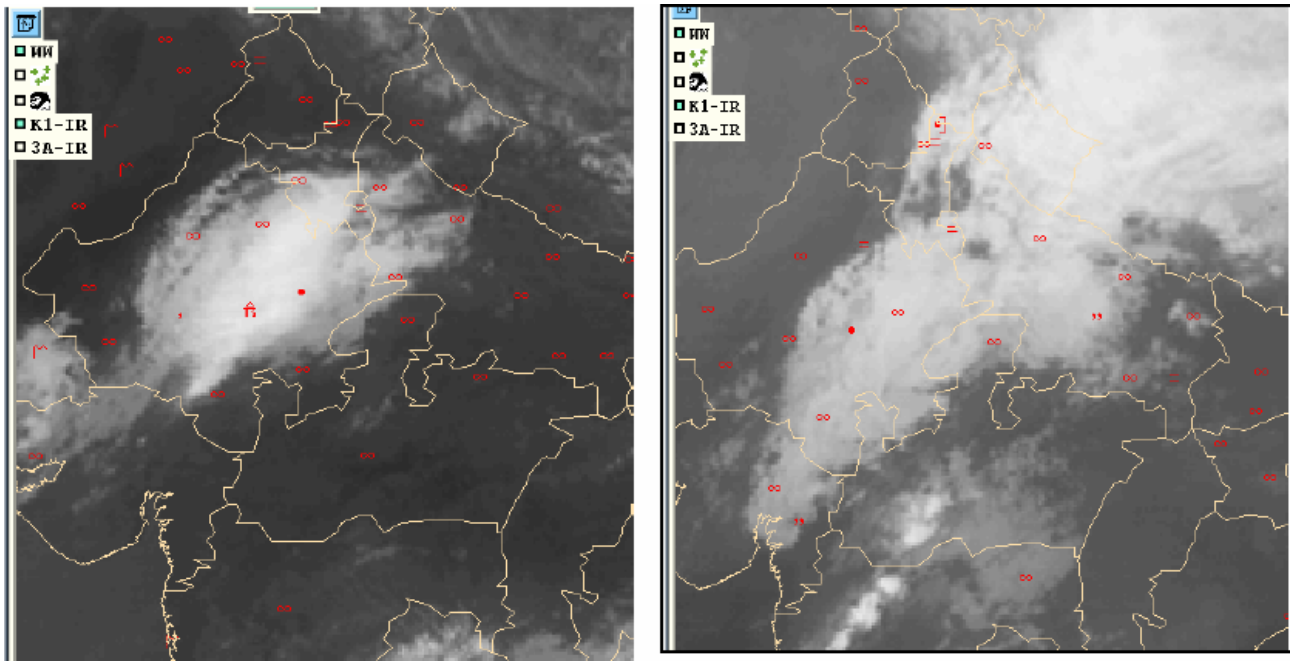








Figs. 6(a-f). ECMWF vorticity for 17 November, 2010 and 23 November, 2010 at 850, 500 and 200 hPa levels



Weather at 0600 UTC and 1800 UTC on 17th November, 2010

Description of Weather Symbol used	Symbol
Haze	∞
Visibility reduced by smoke	≈
Mist	=
Fog (sky visible)	≡
Fog (sky obscured)	≡
Drizzle (during past hour)	,]
Drizzle (slight)	,
Drizzle (continuous)	,,
Rain (during past hour)	•]
Rain, (slight)	•
Rain, (continuous)	••
Rain, (intermittent moderate)	• •
Thunder without precipitation	K
Thunderstorm with rain/ snow	•K
Thunderstorm, slight or moderate, with hail	▲K

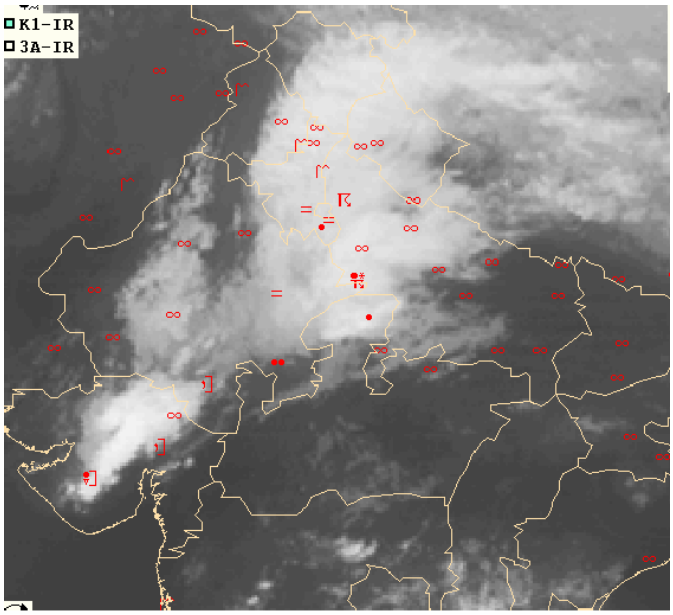


Fig. 7. Weather at 1200 UTC on 17 November, 2010

(as shown Table 1 below) recorded lowest maximum temperature in the last 40 years:

TABLE 1

Maximum temperature (°C) recorded at some station

Stations	Maximum temperature
Ahmedabad	21.3
Bhuj	19.6
Rajkot	19.5
Deesa	19.0

4.2. *Rainfall*

In Rajasthan, there was all time highest rainfall (Month's total and 24 hr. rainfall) recorded at many stations during November 2010, as given in the Table 2 below:

TABLE 2

Highest rainfall (mm) recorded at some stations

Stations	Highest total R/F of the month		Highest R/F in 24 hours	
	Previous all time Record	Nov 2010	Previous all time Record	Nov 2010 (Date)
Jaipur	56.9	77.4	41.4	47.2 (24)
Ajmer	47.2	107.0	42.4	46.0 (24)
Churu	15.5	15.3	14.4	14.4 (15)
Barmer	67.6	70.3	37.4	54.1 (12)

5. Causative factors for the unusual weather over northwest & western India

The type of unusual weather reported above usually occurs in association with presence of an intense low pressure system in the Arabian Sea (either formed *in situ* over the region or in the form of emergence of remnant of low pressure system over the Bay of Bengal, across peninsular India) and interaction of high-amplitude troughs in easterlies in the lower levels with mid-tropospheric troughs in the westerlies. The two spells (17 and 23 November) of rainfall activity were associated with more or less similar synoptic conditions. A striking features of rainfall (as shown in Fig. 3) is the northeastward extension of precipitation belt from Gujarat/Maharashtra to east Rajasthan/west U. P. This is apparently the shear zone between the two anticyclones where moisture is being trapped and lifted.

(*i*) The trough in mid-tropospheric westerlies during first spell was north of 25° N, whereas during second spell, it extended southward up to 20° N.

(*ii*) During first spell the movement of the trough in westerlies was faster than during second spell.

(*iii*) Also during the second spell, there were two anti-cyclones where moisture is being trapped and lifted as shown in Figs. 5(a&b).

(*iv*) There was widespread thunderstorm activity during the first spell whereas there was no thunderstorm activity during second spell. Vertical profile of temperature and RH data suggest that the atmosphere was conditionally unstable during the first spell whereas it was stratified during second spell.

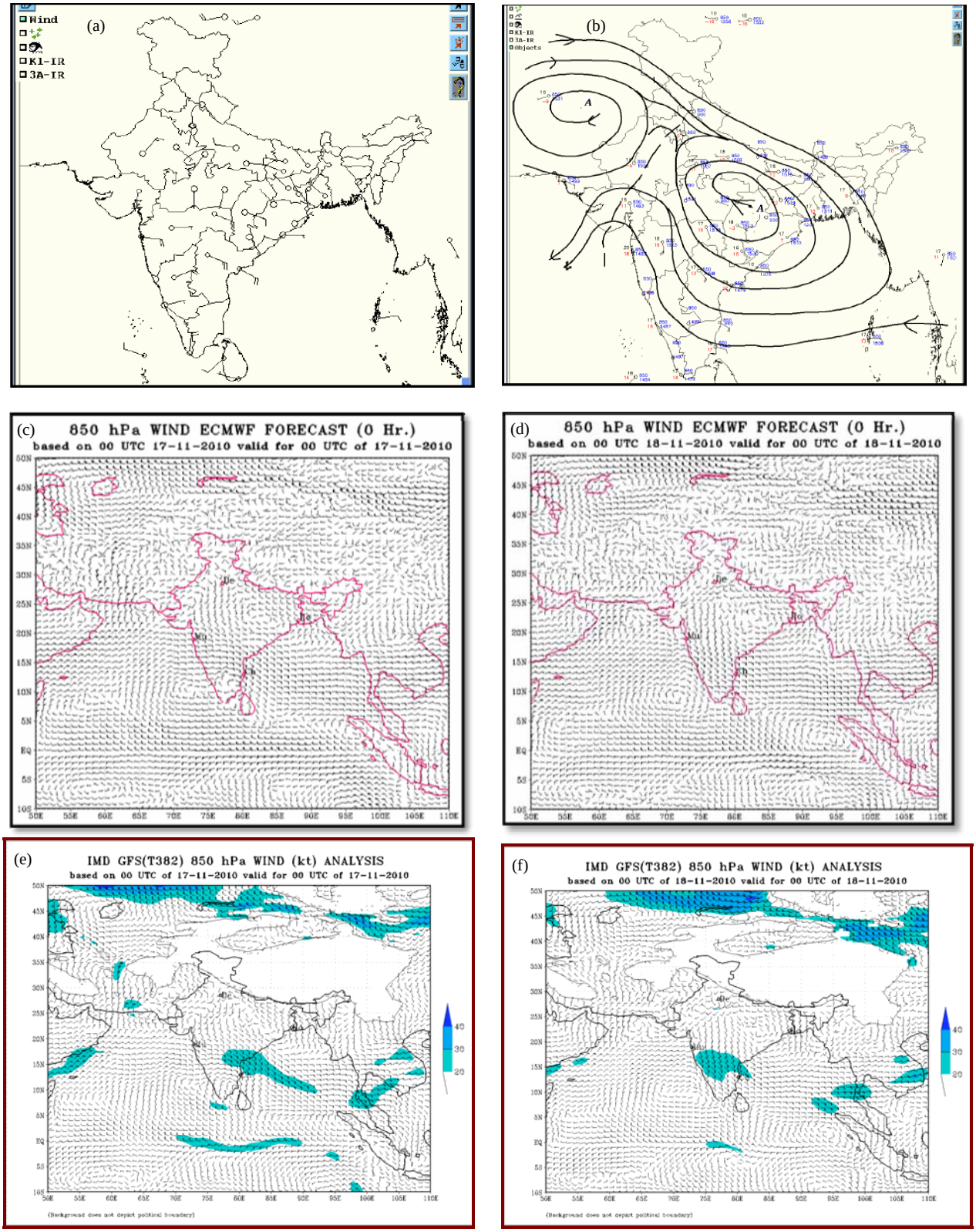
The details are as discussed below:

(a) *Enhanced activity of Easterly Waves with high-amplitude troughs therein*

On many occasions during second and third weeks of November 2010, the easterly waves have exhibited amplification, with trough in lower level easterly winds extending up to latitude of 20° N, over the regions of north Maharashtra, Gujarat and Rajasthan [Figs. 5(a&b)]. Prevalence of higher than normal Sea Surface Temperatures over north Arabian Sea may be among the causative factors for such amplification of the easterly waves. Due to these high-amplitude troughs in easterlies, there has been enhanced moisture incursion over peninsular and western India, due to south-easterly winds coming from Bay of Bengal.

(b) *Favourable interaction between systems in tropical easterlies and mid-latitude westerlies*

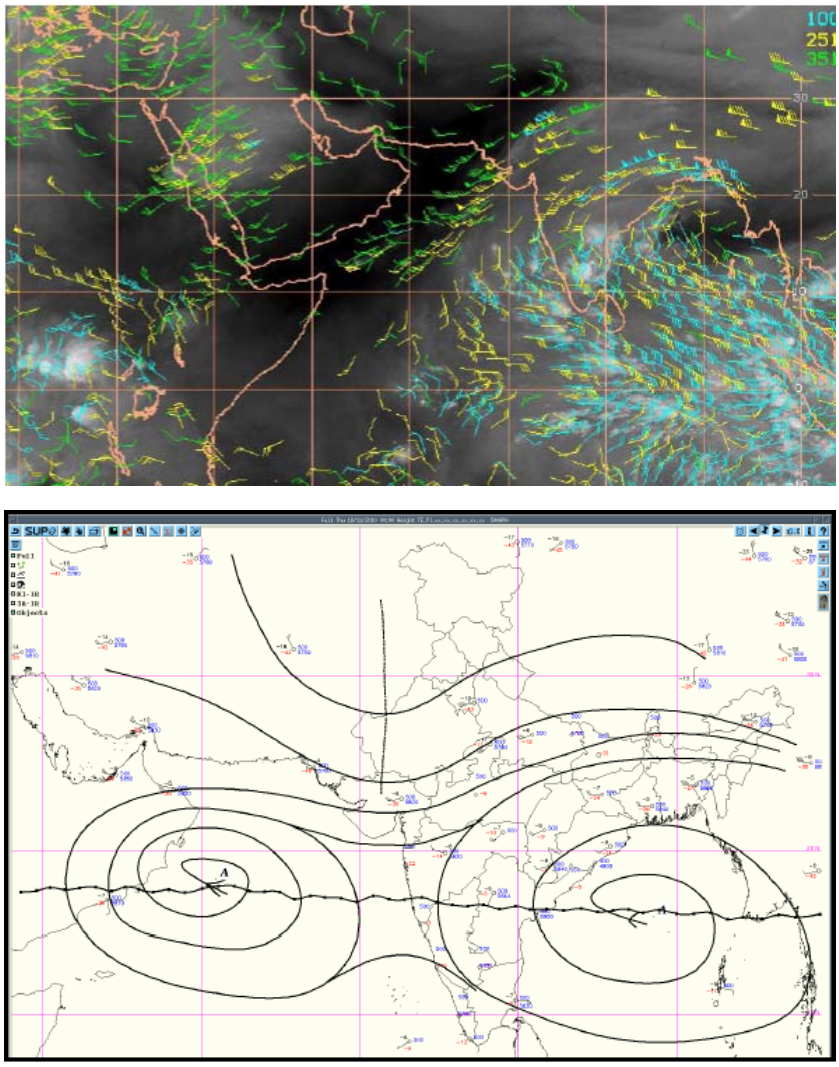
The favourable interaction between trough in the lower level easterlies along the west coast of India and the trough in mid-latitude westerlies caused a further enhancement in the rainfall activity. This synoptic feature led to the northward extension of northeast monsoon activity towards west Madhya Pradesh as well as east Rajasthan. Also from Figs. 6 (a&b), it can be seen that there was positive vortices at 850 hPa over Gujarat and Rajasthan and west Madhya Pradesh. Also strong vorticity can be seen at 500 and 200 hPa [Figs. 6 (c&f)] over northern parts of the country, which is mainly due to western disturbance over the region. Postive vorticity at 850 hPa at above mentioned region may be due interaction of tropical easterlies and mid-latitude westerlies. This favourable interaction resulted into spells of above normal rainfall activity over northwest & western India [Fig. 7].



Figs. 8(a-f). (a) 850 hPa wind on 17 November, 2010, (b) 850 hPa wind on 18 November, 2010, (c) ECMWF 850 hPa wind analysis of 17 November, 2010, (d) ECMWF 850 hPa wind analysis of 18 November, 2010 (e) GFS 850 hPa wind analysis of 17 November, 2010 and (f) GFS 850 hPa wind analysis of 18 November, 2010

(a)

(b)



Figs. 9(a&b). (a) Water vapour derived winds at 0300 UTC on 17 November, 2010 and (b) 500 hPa wind on 18 November, 2010

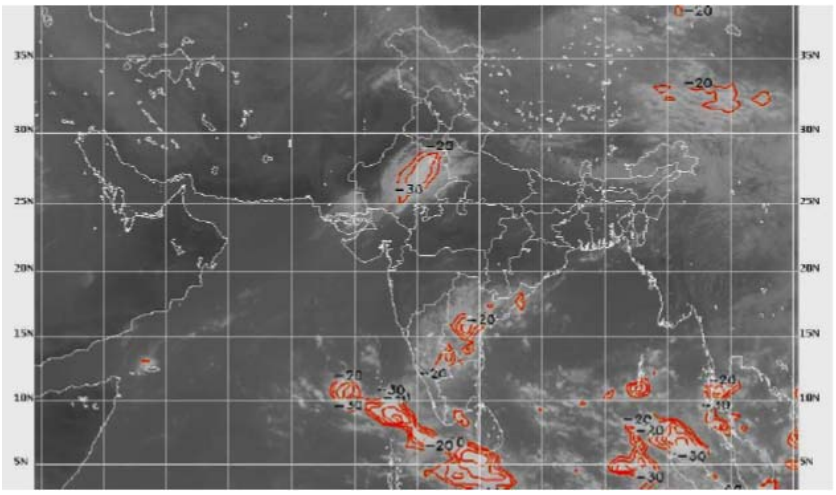


Fig. 10. Cloud Top Temperature (CTT) at 0600 UTC on 17 November, 2010

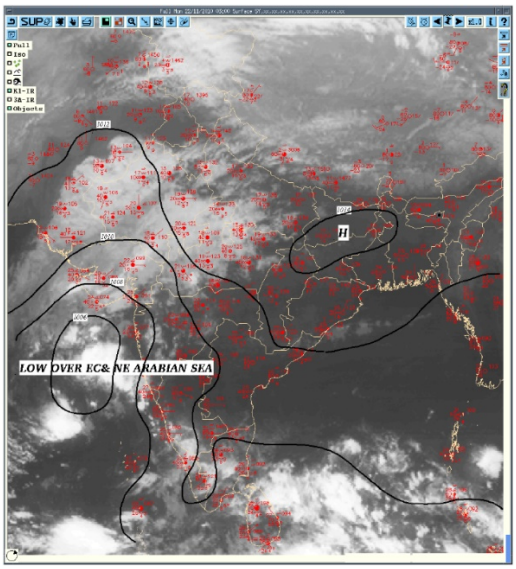


Fig. 11 (a). 0300 UTC MSLP and IR image on 22 November, 2010

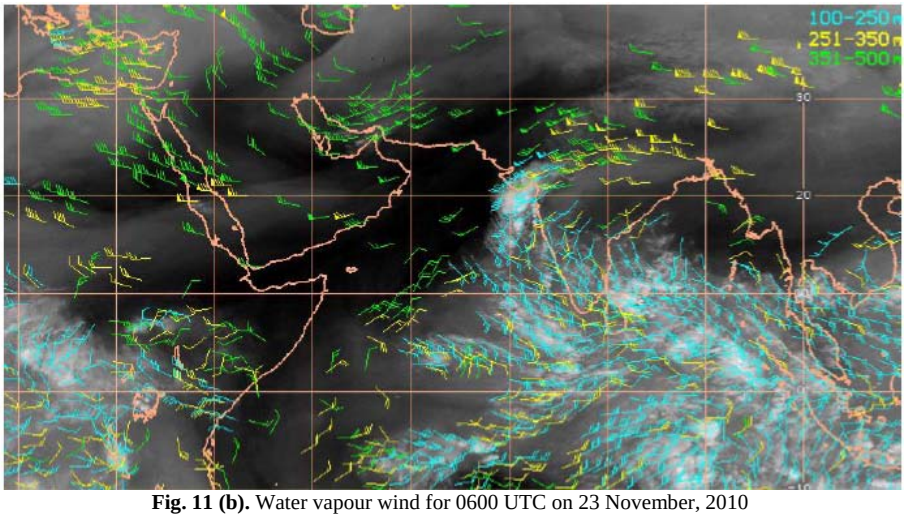


Fig. 11 (b). Water vapour wind for 0600 UTC on 23 November, 2010

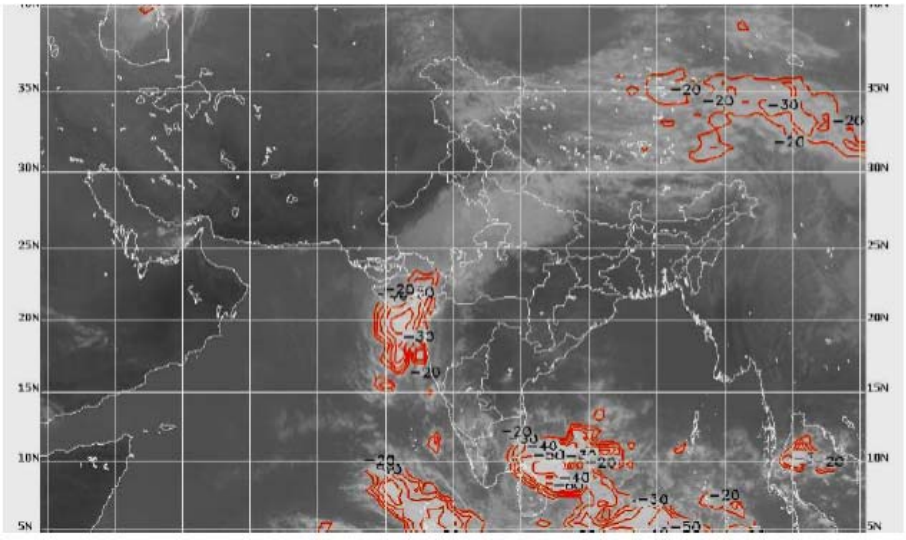


Fig. 11 (c). Cloud Top Temperature (CTT) at 0600 UTC on 23 November, 2010

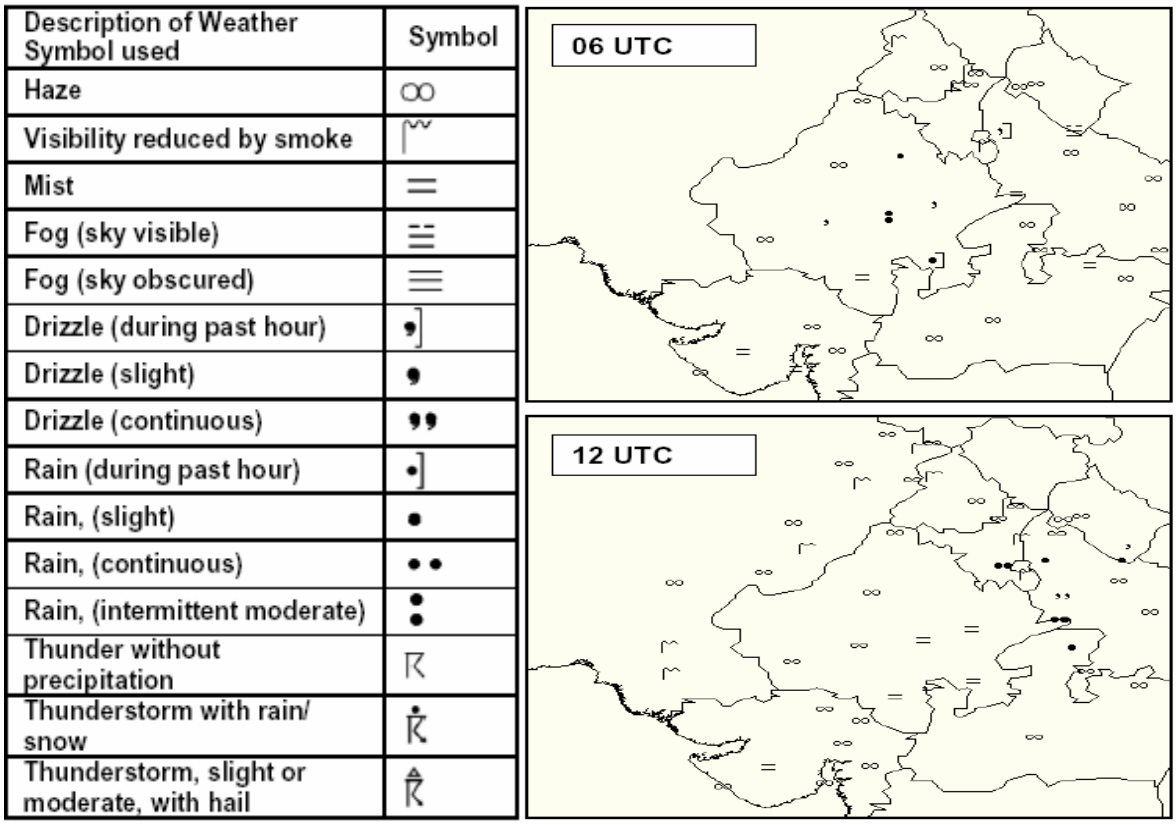


Fig. 11 (d). Weather of 23 November, 2010

The trough in lower level easterlies extended from southeast Arabian Sea and adjoining Lakshadweep area up to north Maharashtra, Gujarat, Rajasthan on many days. On some occasions, it extended up to as north as Haryana as shown in synoptic as well as ECMWF & GFS model analysis [Figs. 8 (a-f)].

This trough, with presence of a trough in mid and upper tropospheric westerlies located to the west of the trough in easterlies, made the dynamical conditions in the atmosphere highly favourable for enhanced convective activity over western India [Figs. 9 (a&b) and Fig. 10]. This interaction caused lower level convergence and upper level divergence (ahead of the eastward moving trough in mid-latitude westerlies). Also, the lower level winds from the south easterly direction, from over Bay of Bengal (to the east of the high amplitude trough in easterlies) was responsible for large scale incursion of moisture. The humidity levels at 850 hPa and 700 hPa over these regions were more than 90% persistently for many days. A similar synoptic situation amounting to favourable interaction between system in lower level easterlies and mid and upper tropospheric westerlies giving rise to enhanced convective activity over northwestern and western regions of India is depicted through Figs. 11 (a-d).

On 22nd November, 2010, a low pressure area formed over northeast Arabian Sea, in a high amplitude easterly wave [Fig. 11 (a)]. The low level convergence associated with this system, coupled with upper level divergence ahead of the trough in mid-latitude westerlies and moisture incursion from Bay of Bengal [Fig. 11 (b)] resulted into development of convective clouds with Cloud Top Temperatures reaching up to -30 °C [Fig. 11 (c)]. This gave rise to weather over northwestern and western regions of India, in the form of drizzle, rain, haze, mist, etc. [Fig. 11 (d)].

5. Summary

During the post-monsoon season of the year 2010, northwestern and western regions of India experienced unusual weather in terms of prolonged and persistent cloudy conditions with wet spell. This type of unusual weather occurred in association with presence of an intense low pressure system in the Arabian Sea and interaction of high-amplitude troughs in easterlies in the lower levels with mid-tropospheric troughs in the westerlies. The prolonged wet spell over this region lasting for almost two weeks over northwest and west

India stands out as an example of a rare phenomenon of interaction between tropical easterlies and mid-latitude westerlies, especially in the month of November.

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