

# Monsoon Rainfall over Gujarat State in Relation to Low Pressure Systems(A case Study)

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**Abstract**— During monsoon season, Gujarat, the north-western state of India, gets widespread and fairly widespread rains with heavy to extremely heavy rains in association with the synoptic systems. The synoptic systems, such as (i) low pressure area/ depression / deep depression forming over Bay of Bengal and moving west/west-north-westward along the monsoon trough, (ii) the persistence of cyclonic circulation extending up to mid tropospheric level off Gujarat coast, (iii) off-shore trough that extends from South Gujarat coast to Kerala coast, (iv) low pressure area/ depression/ deep depression forming over the Arabian Sea along/off Gujarat coast and (iv) western disturbances over Pakistan and neighbourhood. In the present study we estimated the contribution of rainfall over Gujarat state by the low pressure systems (LPS) during southwest monsoon season (June-September) by using rainfall data from year 2002 to 2011. It is observed that on an average 12 numbers of low pressure systems (LPS) form over Indian region during monsoon season. The rainfall over each of the four regions, viz., north Gujarat region, south Gujarat region, Saurashtra and Kutch of Gujarat state depends on the frequency of the formation, location and intensity of the low pressure systems. The characteristic intra-seasonal and inter-annual variation in the location, intensity and movement of the low pressure systems leading to intra-seasonal and inter-annual variation in monsoon rainfall over Gujarat state has been analyzed and discussed.

**Index Terms**—Gujarat, heavy rains, Very heavy rains, south west monsoon.

## 1 INTRODUCTION

India receives about 80% of total annual rain during the southwest summer monsoon season from June to September. The number of moderate rain days and low rain days averaged over whole of India have significantly decreased where as the number of heavy rain days is found to be increased though the trend is statistically not very significant (Dash et al. 2009). Heavy to very heavy rains during summer monsoon season lead to flood over different part of the country. Mohapatra (2005) observed that the heavy rainfall occurs over the south-eastern state Orissa because of the interaction of basic monsoon flow and the low pressure systems developing mostly over northwest Bay, Gangetic West Bengal and north Orissa with the monsoon trough. It is reported that the monsoon activity is significantly controlled by the monsoon trough (Rao 1976). While studying index of activity of the monsoon trough over India, Mooley and Shukla (1989a) have observed that a majority of days (about 56%) during the monsoon season, the seasonal monsoon trough is the only synoptic scale system contributing to rainfall over Indian region.

Mooley and Shukla (1989b) have found that LPS adds largely to the activity of the monsoon trough. Under favourable meteorological conditions, the low pressure areas are instrumental in enhancing the monsoon rainfall of the country (Dhar & Nangaragi 1999). Mohapatra (2008) have studied the synoptic situations leading to heavy rainfall events includes low pressure systems or cyclonic circulation in situ over the surroundings. The sub-divisions like West Bengal, Orissa, east and west Madhya Pradesh, Vidardha, Gujarat and east Rajasthan receive monsoon rainfall mostly due to the effect of LPS formed over Bay of Bengal (Yadav 2002). However, the complete study of monsoon rain in relation to low pressure systems have not done for the Gujarat state which is equally important for the daily prediction of heavy rains.

Gujarat state is located in the extreme western part of India. It is situated roughly between 20° 15' N and 24° 30' N. It has Sind (Pakistan) and Rajasthan to the north, Maharashtra to the south, Madhya Pradesh to the east, the Thar desert in the north-east. The mighty Arabian Sea envelops the state from the south and south-west. The state experiences a tropical dry climate. Based on meteorological parameters, the state is divided into two subdivisions such as (i) Saurashtra-Kutch, the sea coast land and (ii) Gujarat region, the northeast corner of the Indian west coast which is the mainland of the state. The bulk of the rainfall activity over this state occurs during the months of July and August under the influence of synoptic scale systems. In this paper, the subdivision wise monthly excess and deficient rainfall of Gujarat has been analysed. The contribution of heavy rainfall with respect to the location and duration of synoptic systems have been analyzed separately for North Gujarat region, South Gujarat region, Saurashtra

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and Kutch of the Gujarat state (Figure 1). The present study will be helpful in daily prediction of heavy rainfall and validation of numerical weather prediction models.

years (2002-2011). During low pressure systems and the upper air cyclonic circulations, the daily location and duration of these systems have been collected from Indian Daily Weather Report (IDWR - published by India Meteorological Department). We have analysed the contribution of heavy rainfall in the four regions of Gujarat state due to different synoptic systems.

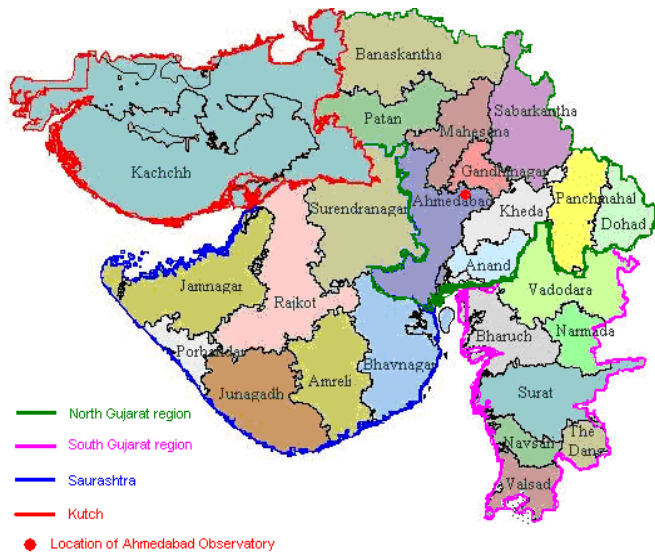


Fig. 1. The four regions (North Gujarat region, South Gujarat Region, Saurashtra and Kutch) considered for the present

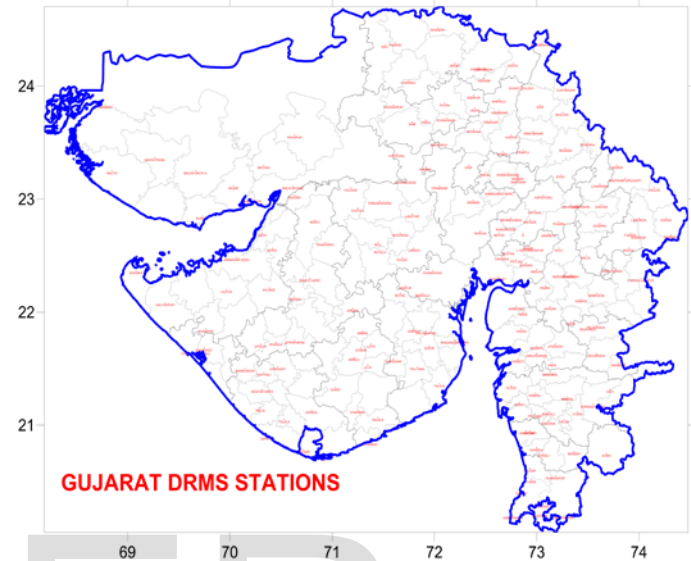


Fig. 2. Spatial distribution of 208 number of rain gauge stations from where rainfall data collected.

## 2 DATA AND METHODOLOGY

Different part of Gujarat state gets widespread (75-100% of the 208 raingauge stations of the state)/fairly wide spread (50 – 75% of the stations) rain with heavy ( $\geq 6.5$ ) to very heavy rains ( $\geq 12.5$  cm). The state receives occasional extremely heavy rains ( $\geq 24.5$  cm) when low pressure systems or cyclonic circulations lay over Gujarat region, South Rajasthan, west Madhya Pradesh, north-east (NE) Arabian Sea, mid-tropospheric circulation (MTC) over NE Arabian Sea or Off-Shore trough extends from Gujarat coast. As per criteria of India Meteorological Department (IMD), a low pressure system (LPS) is a low, if the wind speed associated with the system is less than 17 knots (kt), a depression if the wind speed is 17-27 kt, a deep depression if the wind speed is 28-33 kt, a cyclonic storm if the wind speed is more than or equal to 34 kt. Over the sea, wind strength is used as a criterion for classification of different intensities of LPS. In this study we have tried to find out region specific heavy rains with the location of the low pressure systems as any one of the above systems do not give wide spread rain to entire subdivisions of Gujarat region, Saurashtra-Kutch or Gujarat state as a whole. Therefore, the contribution of heavy to very heavy rains due to the low pressure systems over four regions of Gujarat state have been investigated. For this study, daily rainfall data from all the 208 stations (Figure 2) under district-wise rainfall monitoring scheme (DRMS) and IMD observatory have been collected for past 10

Along with this, the spatial distributions of rainfall over Gujarat during heavy rainfall days have also been analysed. The percentage departure of rainfall from long period average for different monsoon months and the season as a whole (June-September) for the period (2002-2011) have been collected for the two subdivisions Gujarat region (South Gujarat and north Gujarat) and Saurashtra-Kutch from India Meteorological Department.

## 3 RESULTS AND DISCUSSION

### 3.1 Excess and Deficient Rainfall Years

The seasonal rainfall over a sub-division is normal if the rainfall departure from the long period average is within -19% to

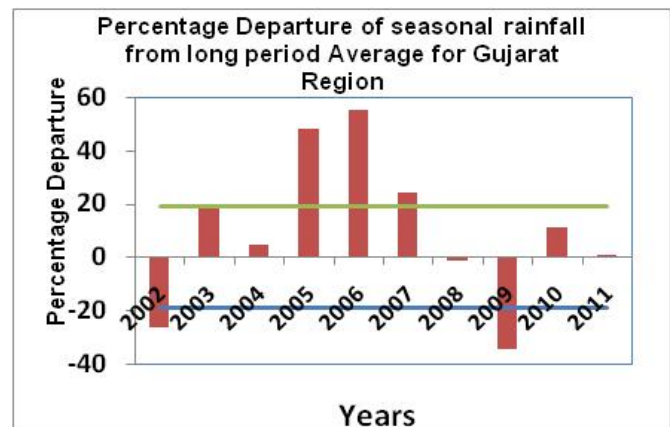


Fig. 3. Time series of the percentage departure of seasonal rainfall of Gujarat region during 2002-2011.

+19%, excess ( $\geq 20\%$ ) and deficient ( $\leq -20\%$ ). It is observed that the seasonal rainfall over Gujarat region was excess in consecutive 3 years (2005, 2006 and 2007), normal during 5 years (2003, 2004, 2008, 2010, 2011) and deficient during 2 years (2002 and 2009). The seasonal rainfall departure from the long term average rainfall over Gujarat state from 2002 to 2011 is shown in Figure 3. However, the seasonal rainfall was excess since 2003 to 2011 (7 years) except 2004 and 2008 which were normal (2 years), and deficient in 2002 over Saurashtra-Kutch as shown in Figure 4.

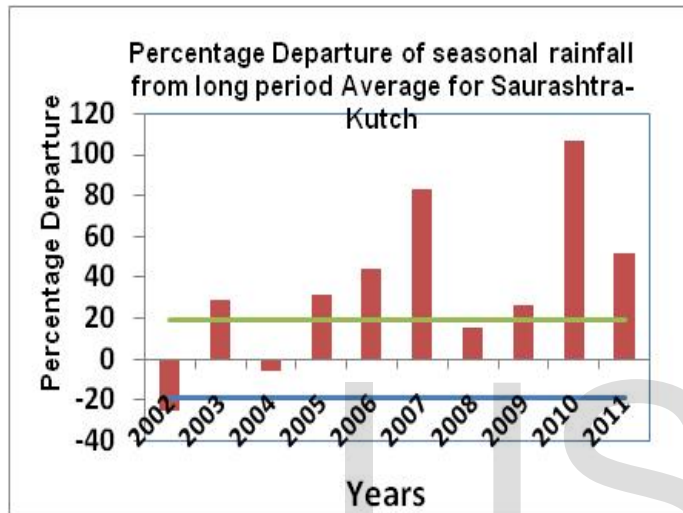


Fig. 4. Time series of the percentage departure of seasonal rainfall of Saurashtra-Kutch during 2002-2011.

The mean departure of rainfall from the long period average during excess rainfall period, deficient rainfall period and normal period for the Gujarat region and Saurashtra-Kutch are shown in Table-1 and Table-2, respectively.

TABLE 1

Mean rainfall departure over Gujarat region during excess rainfall months, deficient rainfall months and normal months based on that data(2002-2011).

Gujarat Region			
Period	Mean percentage departure		
	Excess period	Deficient period	Normal period
June	135.8667	-59.58	2.7
July	47.43333	-47.7667	-0.875
August	70.1	-52.7	-5.56667
September	64.7	-46.625	-1.56667

It is observed that most of the places of north Gujarat region receive heavy (more than 64.5 mm) to very heavy rains (above 124.5 mm) and extremely heavy falls (above 244.5 mm) at isolated places if the low pressure system lies over Gujarat region, Rajasthan or west Madhya Pradesh in association with mid-latitude westerlies. As an example, Figure 3 shows the rain fall over north Gujarat regions on 26 July 2010 due to the interaction of mid latitude westerlies with the upper air cyclonic circulation over Gujarat region.

TABLE 2

Mean rainfall departure over Saurashtra-Kutch during excess rainfall months, deficient rainfall months and normal months based on that data(2002-2011).

Saurashtra-Kutch			
Period	Mean percentage departure		
	Excess period	Deficient period	Normal period
June	79.575	-46.1	-10.55
July	95.975	-50.425	6.1
August	108.9167	-33.3333	3
September	179.22	-71.4	4.7

The mean departure of rainfall from long period average during excess, deficient and normal period for Gujarat region and saurashtra-Kutch are show in the Table-1 and Table-2. The mean percentage departure of rainfall during during normal period in June for Gujarat region is above average where as it is significantly below average rainfall over Saurashtra-Kutch. It may be due to the LPS forms over Bay of Begal and moves nort-westnorth ward and either loose it's intensity after giving rainfall upto Gujarat region or takes turn towards north and not able to give good rain to Saurashtra-Kutch. During September, the departure is low over Gujarat region where as it is quite high over Saurashtra-Kutch. It may be due to most of the system forms in lower latitude which move west ward and give good rain to saurashtra-Kutch.

### 3.2 Examples of Heavy Rains with Respect to the Location of the LPS.

It is observed that most of the places of north Gujarat region receives heavy (more than 64.5 mm) to very heavy rains (above 124.5) and also the isolated extremely heavy falls (above 244.5) if the systems lies over Gujarat region or Rajasthan or west Madhya Pradesh in association with mid latitude westerlies. Most part of North Gujarat region receives heavy rains and few places receive very heavy to extremely heavy rains as shown in Figure-5 and was due to Upper air

Cyclonic circulation lay over Gujarat region with interaction of mid latitude westerlies. It is also observed that most of the places of South Gujarat region receive heavy rains due to the mid tropospheric circulation (MTC) over north-east Arabian Sea, LPS over southeast Madhya Pradesh or active off-shore trough over Gujarat coast.

**Spatial distribution of Rainfall (mm) over Gujarat State on 26th July 2010**

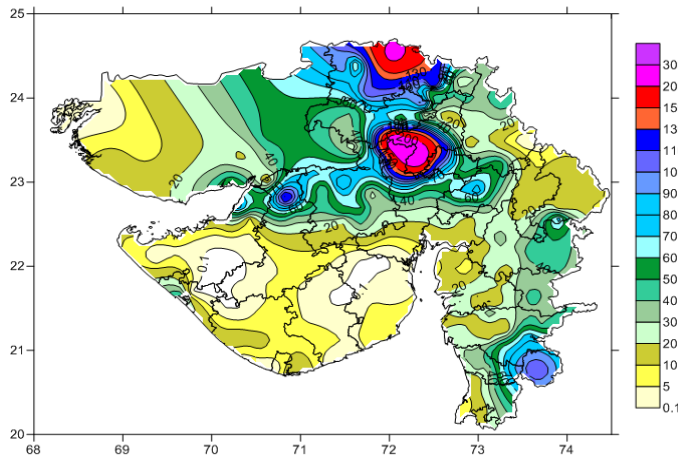


Fig. 5. Spatial distribution of rainfall over Gujarat state on 26<sup>th</sup> July 2010.

As an example, Figure-6 shows the heavy to very heavy rain fall received over south Gujarat region on 22 July 2010 when the MTC was over north-east Arabian Sea. It is also observed that several places of Gujarat state received heavy to very heavy rains and some parts of south Gujarat and Saurashtra received extremely heavy rainfall during the interaction of mid latitude westerlies with the MTC. If the LPS lay over south Rajasthan then Saurashtra also gets heavy rain.

**Spatial distribution of Rainfall (mm) over Gujarat State on 22nd July 2010**

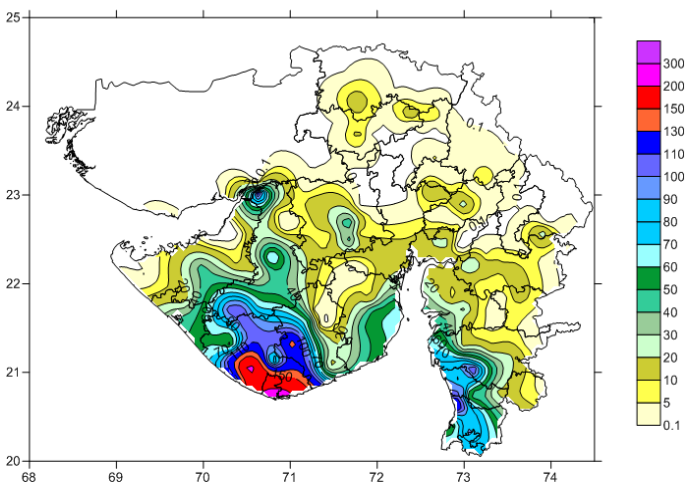


Fig. 6. Spatial distribution of rainfall over Gujarat state on 22<sup>th</sup> July 2010.

Kutch receives heavy to very heavy rains when an upper air circulation lies over Gujarat state or over south Rajasthan. Figure 7 shows such an example of heavy to very heavy rains over Kutch on 27 July 2010 due to well marked low pressure area over South Rajasthan and adjoining Gujarat state.

**Spatial distribution of Rainfall (mm) over Gujarat State on 27th July 2010**

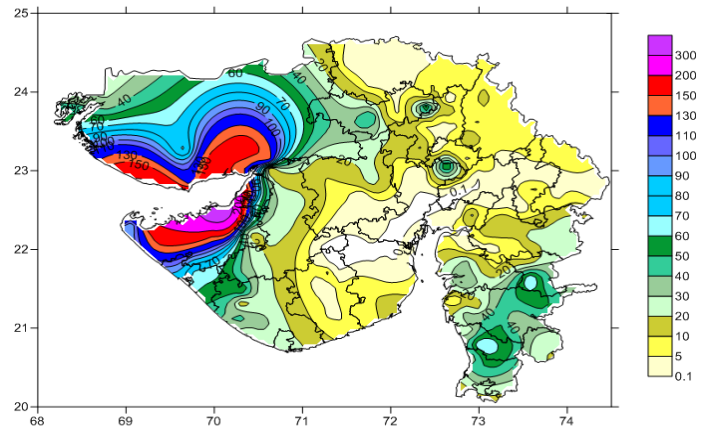


Fig. 7. Spatial distribution of rainfall over Gujarat state on 27<sup>th</sup> July 2010.

#### 4 CONCLUSION

- Interaction of mid latitude westerlies with the synoptic systems plays a major role for contributing heavy rains over North Gujarat region.
- Active off shore trough and MTC are responsible for contributing heavy rains to South Gujarat region and Saurashtra.
- Most part of Kutch receives heavy to very heavy rains when there is upper air circulation over Gujarat state or over south Rajasthan.

#### ACKNOWLEDGEMENT

The authors are thankful to Director General of Meteorology, IMD, Additional Director General of Meteorology, (NDC), Pune, Deputy Director General of Meteorology, Regional Meteorological Centre, Mumbai, Director (I/C), Meteorological Centre, Ahmedabad for their encouragement and support for this study.

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