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**LIST OF ACRONYMS**

- AJK Azad Jammu & Kashmir
- CDPC Climate Data Processing Centre
- DCO District Coordination Officer
- FFC Federal Flood Commission
- FFD Flood Forecasting Division
- IFAS Integrated Flood Analysis System
- IRSA Indus River System Authority
- KPK Khyber Pakhtunkhwa
- MAF Million Acre Feet
- NCAR National Centre for Atmospheric Research
- NCEP National Centre for Environmental Prediction
- NDMA National Disaster Management Authority
- PCIW Pakistan Commissioner for Indus Water
- PDMA Provincial Disaster Management Authority
- PMD Pakistan Meteorological Department
- SDMA State Disaster Management Authority
- WAPDA Water And Power Development Authority
- XEN Executive Engineer
- BoB Bay of Bengal

## Preface

Pakistan has unique flood forecasting problems, which can be understood only if the meteorological causes of the floods are first understood. During summer, although monsoon is the dominating weather system, but the westerly waves also continue to affect the country. Intensification of the monsoon weather system and northwards recurving of the monsoon depressions is predominantly due to the westerly waves. Floods in Pakistan are mainly caused by the heavy monsoon rains during July to September.

Officially, the flood season in Pakistan is from 15<sup>th</sup> June to 15<sup>th</sup> October. Floods in Pakistan are categorized as I, II and III. Category I floods occur when seasonal low over Balochistan intensifies, Category II and III floods which are more catastrophic in nature, are associated with monsoon weather systems originating from the Bay of Bengal. They produce heavy rainfall in the catchment areas of rivers flowing in Pakistan. Category III floods are most catastrophic in nature. Under this situation monsoon low/depression under the influence of the westerly wave continues to move in the northerly direction finally ending up in Rawalpindi/Hazara divisions and adjoining areas.

The upper catchments of Rivers Jhelum, Chenab and Ravi come under its influence. These are the most threatening floods for Mangla reservoir. A rare but devastating flood situation also arises when the westerly wave is strong enough to drag the moisture into the Indus river catchment, causing heavy rainfall over Kohistan and Hazara Divisions. The most recent example is the 2010 flood in river Indus and its Tributaries. FFD Lahore besides conventional practice of forecasting is also using flood forecasting models. New flood model IFAS is going through rigorous evaluation and verification routines to customize it under local conditions.

FFD since its establishment is serving the nation by timely disseminating flood forecasts, warnings/alerts and creating awareness during each flood season. Issuance of Flood Report after the conclusion of flood season is a regular feature of the Flood Forecasting Division (FFD) Lahore, the Pakistan Meteorological Department (PMD). This report gives a comprehensive overview of all the events occurred during the flood season. Flood report for the year 2019 has been prepared under the kind directives of Director General, Pakistan Meteorological Department. It contains all details regarding flood forecasting, tracks of monsoon lows, rainfall amount during wet spells, flood peaks, monthly and seasonal isohyetal maps, normal isopercental maps, flood limits. The flood forecast evaluation report is also added at the end.

**Chief Meteorologist**  
**Flood Forecasting Division**  
**Lahore**

## 1 Executive summary

- The seasonal percentage departure map for precipitation during the present Monsoon Season-2019 indicates close to normal precipitation for whole of the country. Calculating on province wise the detail is given as below:  
Balochistan -4%, Kashmir -22%, Punjab -5%, Khyber Pakhtunkhwa -14% and Gilgit Baltistan -24% received below normal rainfall while Sindh received 46% above normal rainfall.
- Eight monsoon lows/Depressions originated during the present monsoon season-2019, three of these entered Pakistan, while five of them recurved Northeast wards in India.
- Nine rain-bearing spells occurred during the monsoon season 2019.
- No High Flood situation was observed in any major river except one instance of High Flood in River Chenab at Marala.
- The supply of hydro-meteorological data from WAPDA, Punjab, Sindh & Khyber Pakhtunkhwa irrigation departments remained satisfactory.
- During Flood Season 2019, No Discharge information shared from India up to 18<sup>th</sup> August-2019 through PCIW. However random information shared 18<sup>th</sup> to 21<sup>st</sup> August-2019.
- All the concerned federal and provincial authorities, the general public, along with print and electronic media were kept in touch with the prevailing weather/flood conditions through phone, fax & other electronic sources.
- The overall accuracy of forecast issued by FFD during the Monsoon Season 2019 was **90.5%**.

## 2 Tracks of Monsoon Lows during Monsoon Season 2019

During the monsoon season 2019 (15<sup>th</sup> June to 15<sup>th</sup> October) Eight Monsoon Lows/Depressions were developed in the Bay of Bengal.

**1<sup>st</sup> Monsoon low** was developed over Northwest Bay of Bengal on 1<sup>st</sup> July 2019. Moving Westwards it was relocated over North Madhya Pradesh on 06<sup>th</sup> July 2019, where it dissipated.

**2<sup>nd</sup> Monsoon low** was developed on the evening of 26<sup>th</sup> July 2019 over South Uttar Pradesh. It first moved Southwestwards and reached Southeast Rajasthan on 28<sup>th</sup> July 2019. Then it moved almost Westwards and reached Southeast Sindh on 30<sup>th</sup> July 2019 where it became insignificant.

**3<sup>rd</sup> Monsoon low** was developed over North Orissa on 30<sup>th</sup> July 2019. After moving west-northwest wards, it reached East Madhya Pradesh on 01<sup>st</sup> August-2019. Then it moved further North Northwest wards and dissipated over Northern Uttar Pradesh on 02<sup>nd</sup> August 2019.

**4<sup>th</sup> Monsoon low** was also developed over Northeast Bay of Bengal on 05<sup>th</sup> August 2019. It first moved westwards and centered over Northeast Orissa on 07<sup>th</sup> August-2019, then it moved sharply West-northwest wards and observed over West Madhya Pradesh on 09<sup>th</sup> August 2019. It further moved approximately westerly direction, entered Pakistan on 11<sup>th</sup> August-2019 and affected the South & Southeast Sindh significantly.

**5<sup>th</sup> Monsoon low** was developed over northwest Bay of Bengal on 12<sup>th</sup> August 2019. It moved westwards and located East Orissa on 13<sup>th</sup> August 2019, moved Northwards & then west-north westwards and centered over East Rajasthan on 16<sup>th</sup> August 2019. In the end moved Northwards and dissipated over North Haryana on 18<sup>th</sup> August-2019.

**6<sup>th</sup> Monsoon low** was developed over East Jharkhand on 19<sup>th</sup> August 2019. It moved West-northwest wards and located centered Uttar Pradesh on 21<sup>st</sup> August-2019 where it dissipated.

**7<sup>th</sup> Monsoon low** was developed over Northwest Bay of Bengal and adjoining Orissa on 24<sup>th</sup> August 2019. It first moved west-northwest wards and reached over Southeast Madhya Pradesh on 26<sup>th</sup> August-2019 then it moved further West-northwestwards and entered the country on 29<sup>th</sup> August 2019 near Northwest Sindh where it dissipated.

**8<sup>th</sup> & Final Monsoon low** was developed over North Bay of Bengal on 2<sup>nd</sup> September 2019. It first moved Southwestwards then westwards & then finally Northwestwards and reached Northeast Madhya Pradesh on 09<sup>th</sup> September-2019. It recurved Northeast

wards and dissipated over East Madhya Pradesh on 10<sup>th</sup> September-2019. The paths followed by each low/depression are shown in figure 1.

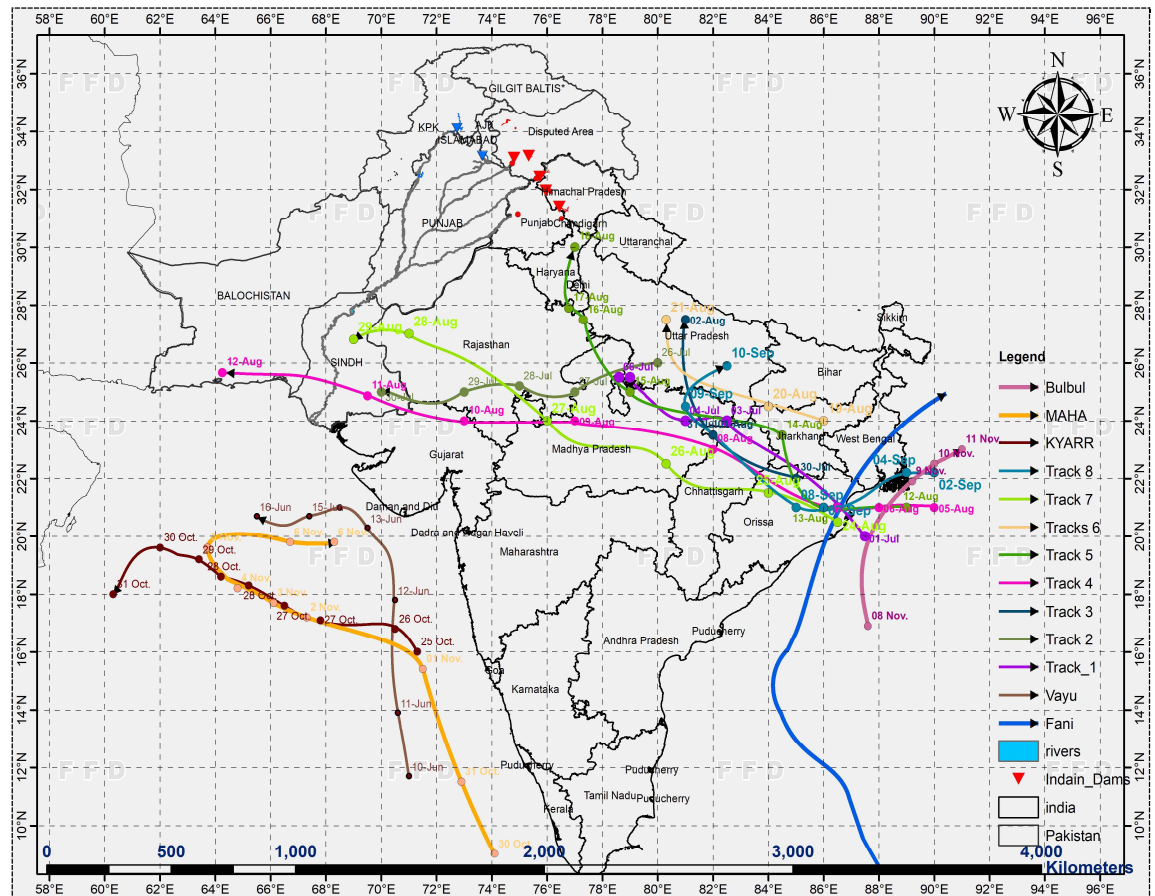


Figure 1: Tracks of rain-producing monsoon system in 2019.

## 2.1 Significant hydro-meteorological events during the month of June 2019

Only one significant rainfall spell was reported during the month of June 2019 over Pakistan. A cyclonic storm VOYU developed in the Arabian Sea on 10<sup>th</sup> June-2019. Tracks followed by VOYU is shown in the above Figure 1.

## 2.2 Meteorological events

No Monsoon low was developed over the Bay of Bengal during the month of June 2019. The rainfall mostly occurred across the country during the month of June 2019 was due to the accentuation of seasonal low over Balochistan and passing of a westerly wave to the north of the country.

## 2.3 1<sup>st</sup> wet spell of June 2019 (21<sup>st</sup> to 25<sup>th</sup> June 2019)

The first wet spell of June 2019 which remained active for five days was mainly due to the presence of a westerly trough accompanied by moist currents from the Arabian Sea as well as Bay of Bengal. Figures 2 represents 500 hPa and 850 hPa geopotential height

patterns along with 925 hPa wind flow during the spell. It indicates that most part of Pakistan is under the influence of the westerly wave. Southwesterly & Southeasterly winds at 925 hPa are also present ensuring enough moisture supply from the Arabian Sea.

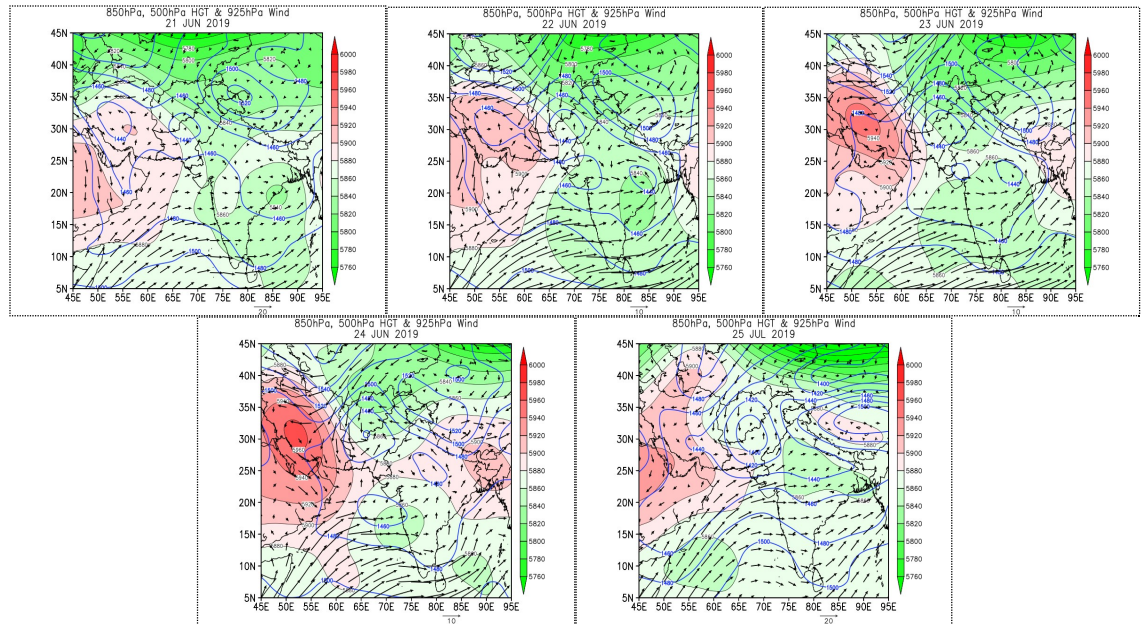


Figure 2: 500 & 850 hPa geopotential Height patterns and 925 hPa winds from 21<sup>st</sup> to 25<sup>th</sup> June 2019. Satellite/Radar images in figure 3 showing dense clouds over Punjab, Southeast Balochistan along with Kashmir during the spell of 21<sup>st</sup> to 25<sup>th</sup> June-2019.

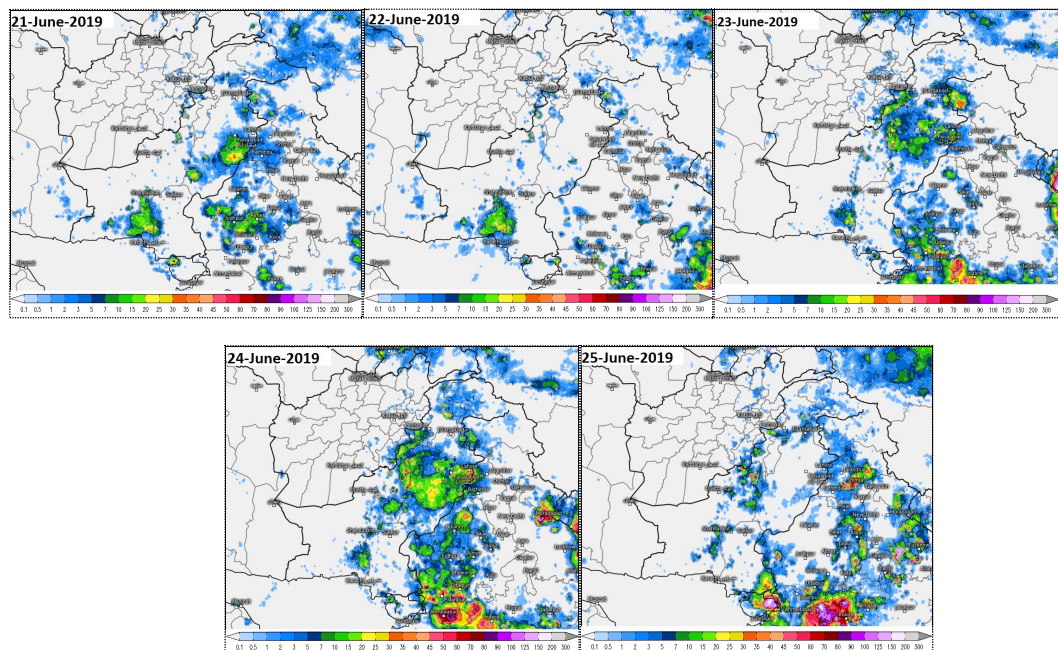


Figure 3: Satellites Images during the spell 21st to 25th June 2019.

Figure 4 shows the spatial distribution of significant rainfall during this spell. Maximum rainfall of more than 60 mm occurred over Lahore Division. Other maxima of more than 55 mm rainfall are located over Northeast Balochistan. Light rainfall also recorded over Southeast Sindh.

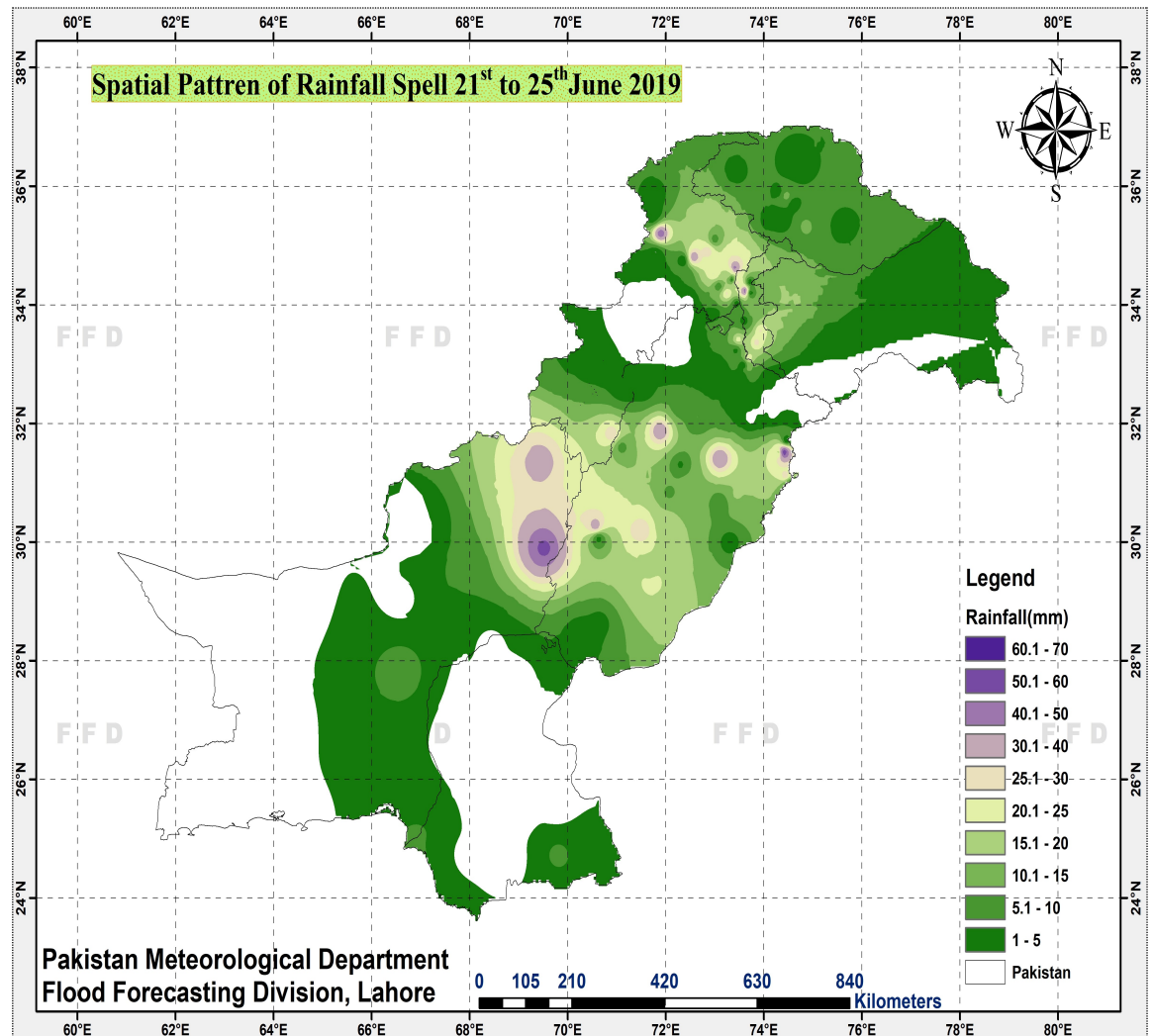


Figure 4: Spatial distribution of significant rainfall map of 21<sup>st</sup> to 25<sup>th</sup> June 2019.

#### 2.4 River position during June 2019

Flood peaks (thousands of Cusecs) recorded during June 2019 in different rivers at various points are given in Table 1.

Table 1: Maximum peaks recorded during June 2019.

Rivers	Stations	Peaks Inflows	Date	Flood level
Jhelum	Rasul	112.6	19/6/2019	Medium
Jhelum	Rasul	111.6	26/6/2019	Medium
Kabul	Nowshera	81.3	25/6/2019	Medium

### 2.5 Hydrographs during June 2019

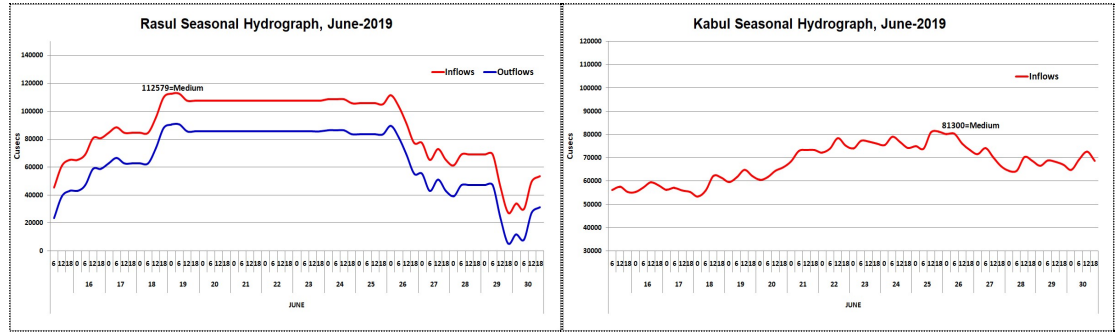


Figure 5: Hydrographs for the month of June 2019.

### 2.6 The spatial pattern of rainfall during the month of June 2019

Isohyetal map of June 2019 indicates that one maxima rainfall (more than 100 mm) lies over Astore in Gilgit Baltistan & at Muzaffarabad in Kashmir and other centers of rainfall of more than 90 mm lie over Kakul & Dir. Two rainfall centers of more than 70 mm are also observed over Barkhan in Northeast Balochistan and one over Lahore. The spatial distribution of significant rainfall map of June 2019 is shown in Figure 6.

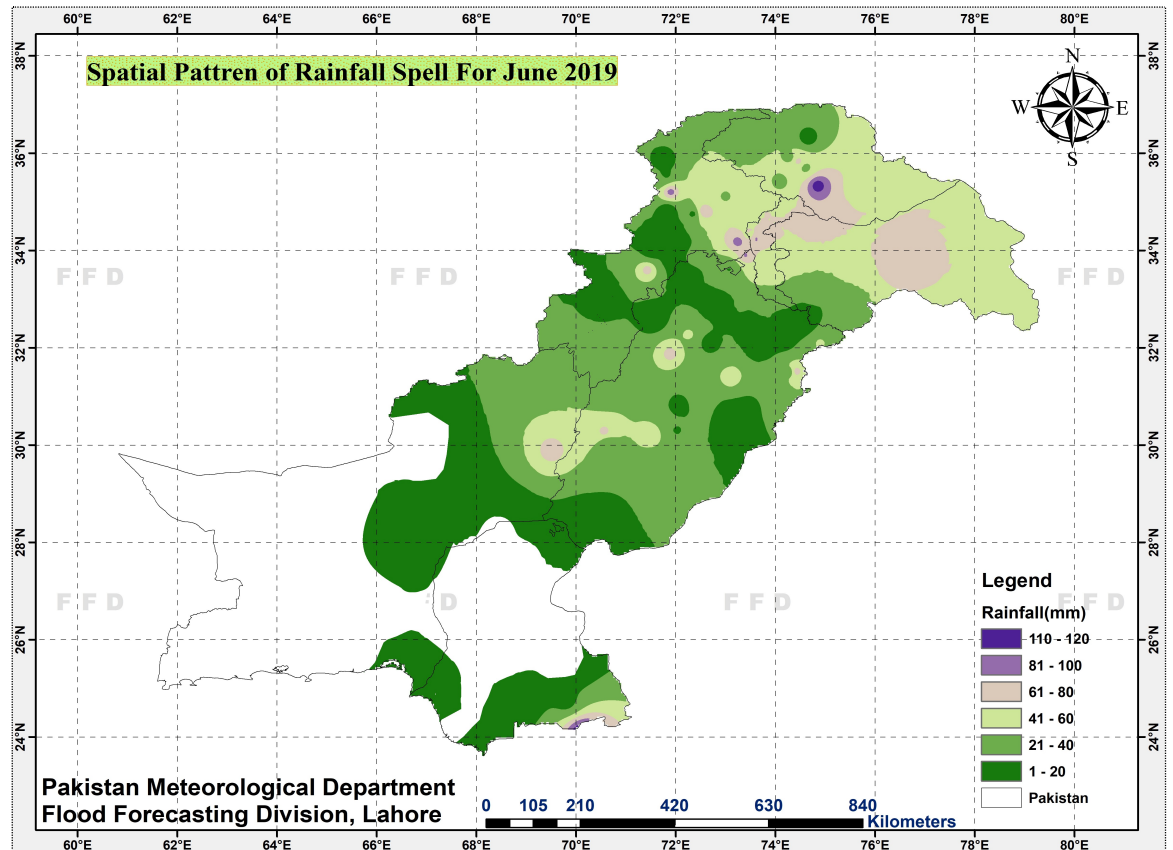


Figure 6: Spatial distribution rainfall map of June 2019.

### 2.7 Percentage Anomaly during the month of June 2019

Percentage Anomaly map for the month of June 2019 indicates that Gilgit Baltistan, Khyber Pakhtunkhwa, Northeast Balochistan & South Punjab received above normal Rainfall while most parts of Balochistan & Upper Sindh received below normal rainfall. Percentage Anomaly map of June 2019 is shown in Figure 7.

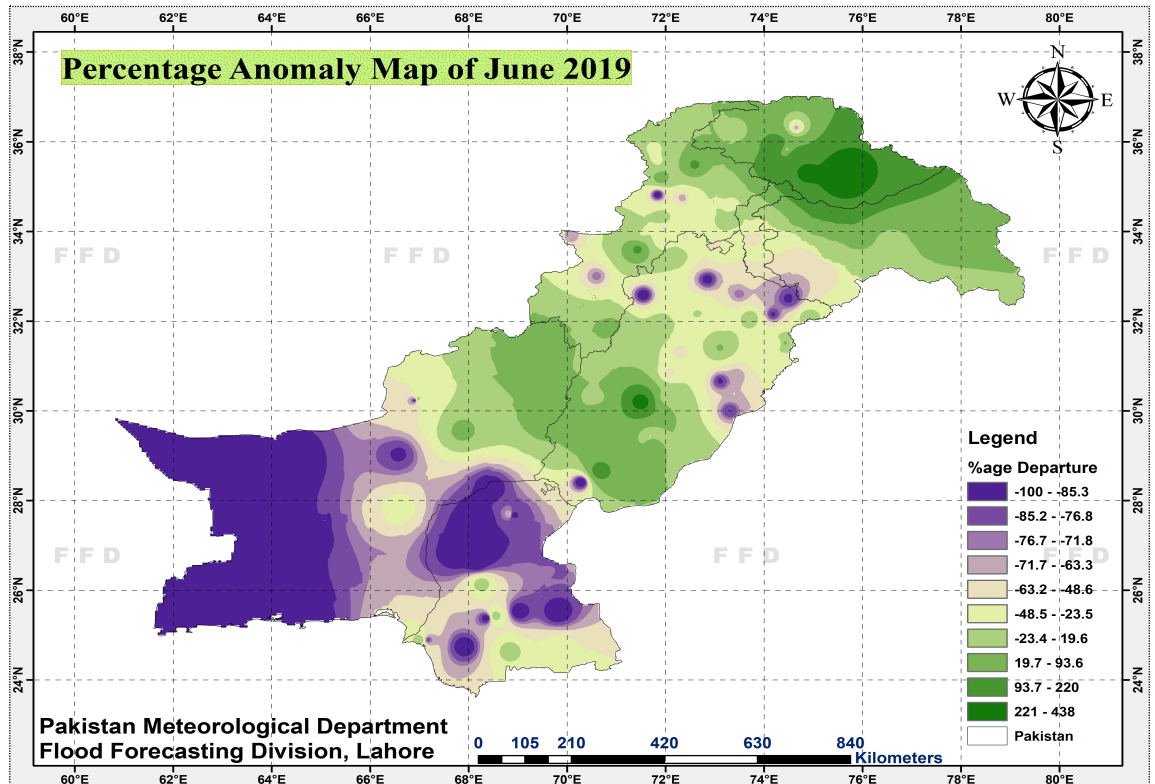


Figure 7: Percentage Anomaly rainfall map of June 2019.

### 2.8 Temporal Distribution during the month of June 2019

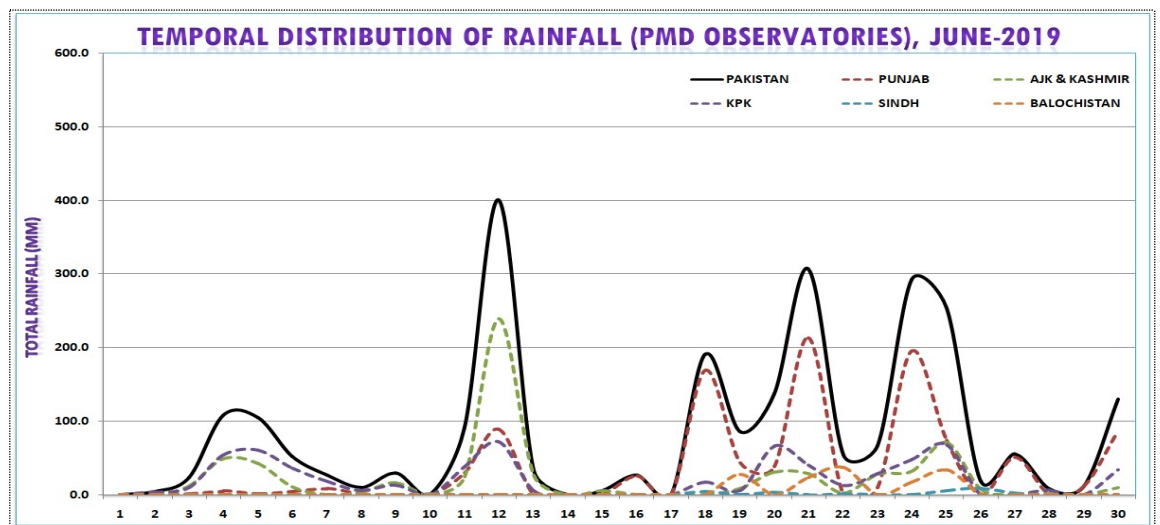


Figure 8: Temporal distribution of rainfall June 2019.

### 3 Significant hydro-meteorological events during the month of July 2019

Three significant rainfall spells occurred during the month of July 2019.

#### 3.1 Meteorological events

The first spell which occurred from 05<sup>th</sup> to 07<sup>th</sup> July 2019 was the result of penetration of moderate moist currents from Arabian Sea/Bay of Bengal, also due to the effect of westerly wave passing over northern parts of the country and the presence of well-marked seasonal low over Balochistan. The second spell of July was observed from 13<sup>th</sup> to 17<sup>th</sup> July 2019. It was caused by the interaction of deep westerly wave passing over northern parts of the country and the moist influx from Arabian Sea. The third & Final spell of the month of July was observed from 25<sup>th</sup> to 30<sup>th</sup> July 2019. It was also caused by moderate moist currents from Bay of Bengal and Arabian sea, presence of a westerly wave over the northern parts of the country and accentuated seasonal low over Balochistan.

#### 3.2 1<sup>st</sup> wet spell of July 2019 (05<sup>th</sup> to 07<sup>th</sup> July 2019)

The first wet spell of July 2019 which remained active for three days was mainly due to the presence of a westerly trough accompanied by moist currents from the Arabian Sea and Bay of Bengal. Figure 9 represents 500 hPa and 850 hPa Geopotential height patterns along with 925 hPa wind flow during this spell. It indicates that many parts of Pakistan are under the influence of westerly wave, Southwesterly & Southeasterly winds at 925 hPa are also present ensuring enough moisture supply from the both Arabian Sea & Bay of Bengal.

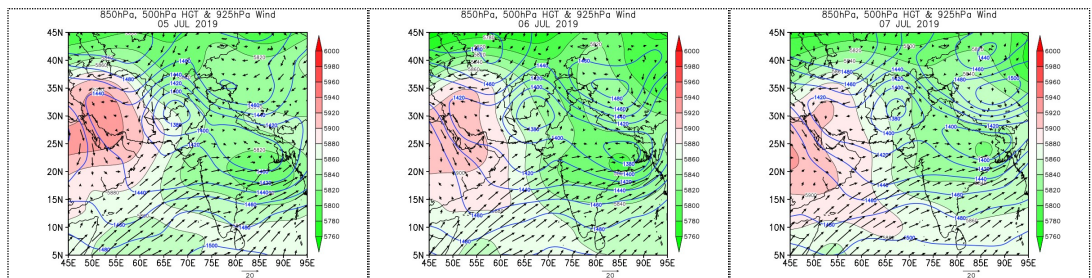


Figure 9: 500 & 850 hPa Geopotential Height patterns and 925 hPa winds from 05<sup>th</sup> to 07<sup>th</sup> July 2019.

Figure 10 is showing rainfall/clouds over Punjab, Lower Khyber Pakhtunkhwa & rare clouds over Kashmir during the spell.

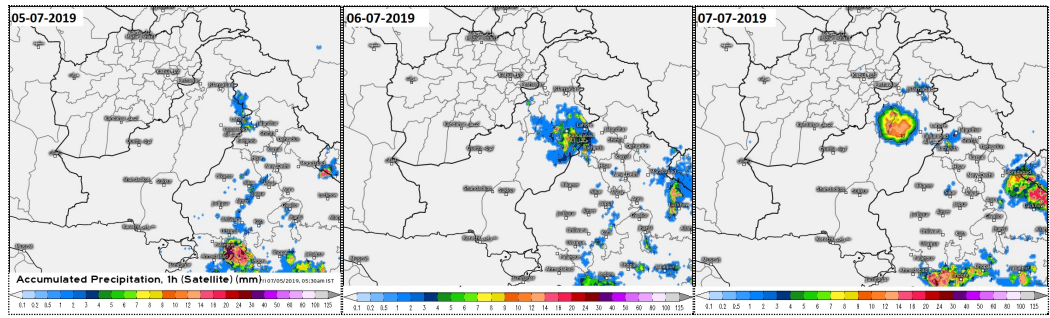


Figure 10: Satellites Images during the spell of 05<sup>th</sup> to 07<sup>th</sup> July 2019.

Figure 11 indicates the spatial distribution of significant rainfall during the event which shows that maximum rainfall of more than 75 mm occurred over Gujrat & Noorpur Thal (Sargodha Division). Moderate rainfall reported from most parts of Punjab. Light Rainfall is also reported from Khyber Pakhtunkhwa & Kashmir.

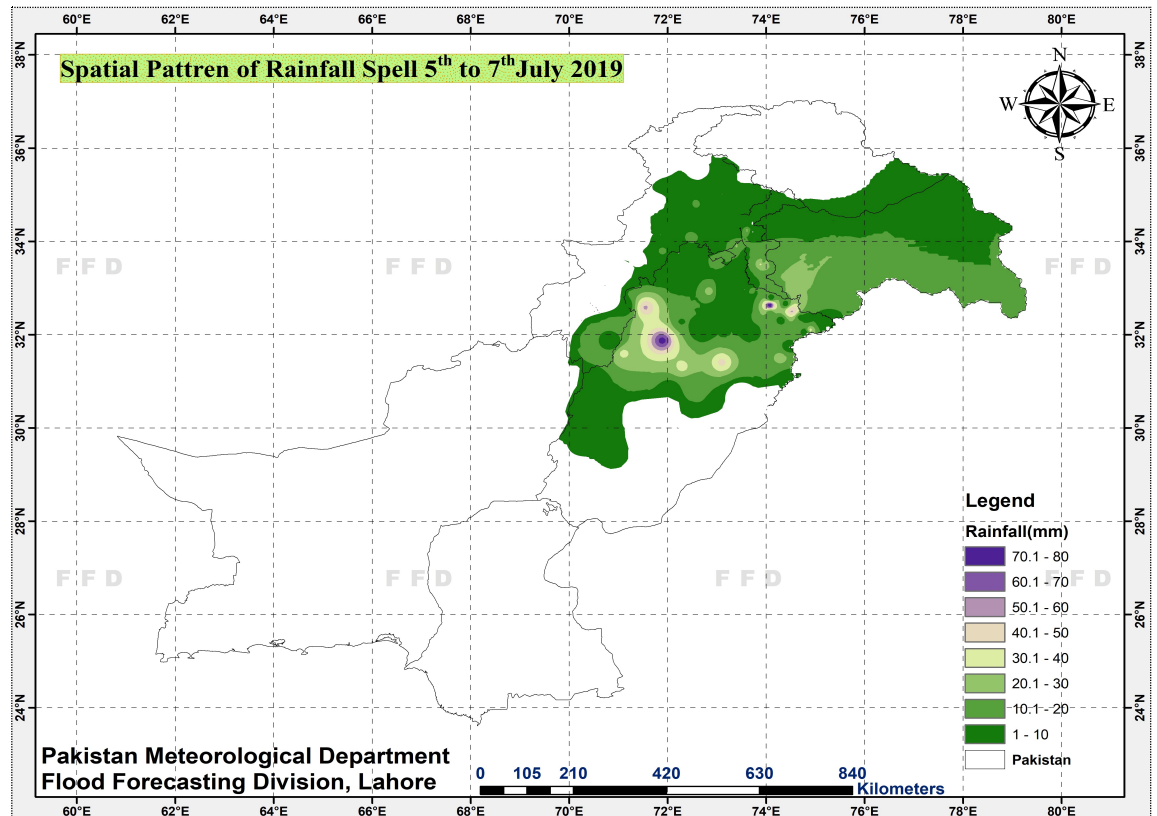


Figure 11: Spatial distribution of significant rainfall map of 05<sup>th</sup> -07<sup>th</sup> July 2019.

### 3.3 Rivers position due to first wet spell of July

No significant flood peak was observed during the period. However, one Low flood peak was observed in River Indus at Tarbela (Upstream).

### 3.4 2<sup>nd</sup> wet spell of July 2019 (13<sup>th</sup> to 17<sup>th</sup> July 2019)

The second wet spell of July 2019 which remained active for five days was mainly due to the presence of a deep westerly trough accompanied by moist currents from the Arabian Sea. Figure 12 represents 500 hPa and 850 hPa Geopotential height patterns along with 925 hPa wind flow during this spell. It indicates that many parts of Pakistan are under the influence of deep westerly waves, Southwesterly winds at 925 hPa are also present ensuring enough moisture supply from the Arabian Sea.

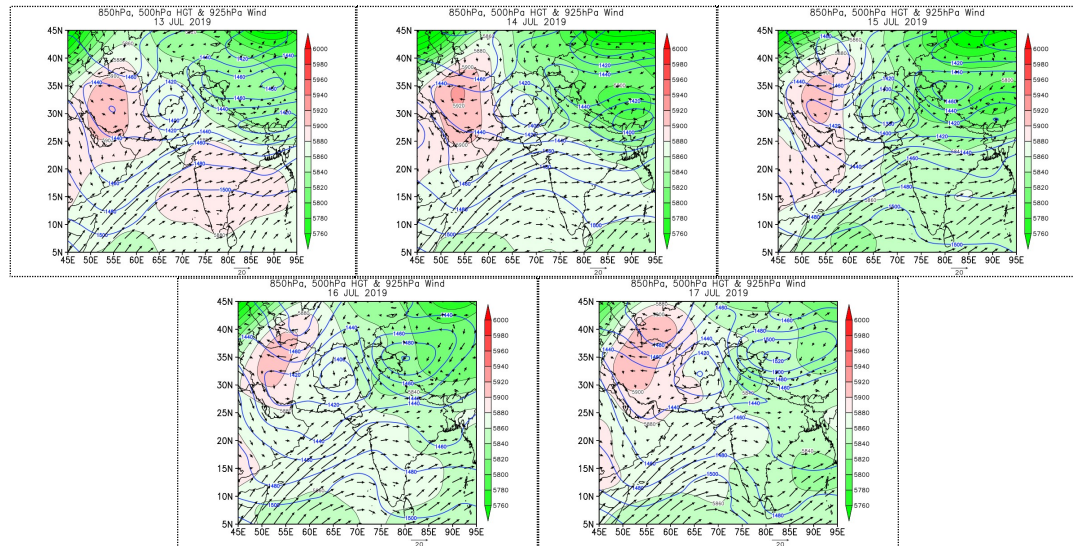


Figure 12: 500 & 850 hPa Geopotential height patterns and 925 hPa winds from 13<sup>th</sup> to 17<sup>th</sup> July 2019.

Figure 13 is showing rainfall/clouds over Central & northeast Punjab & Northeast Balochistan during the period.

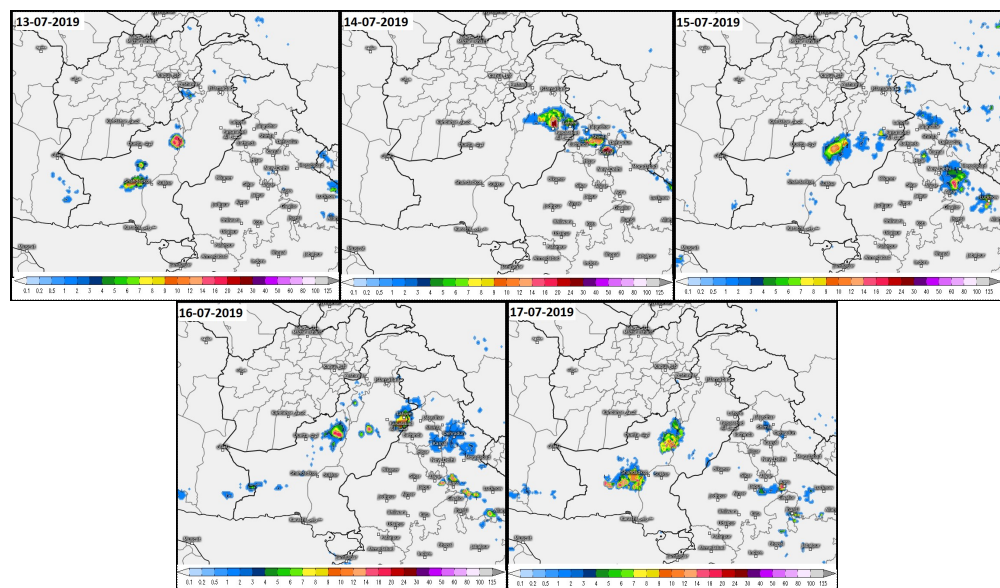


Figure 13: Satellites Images during the spell of 13<sup>th</sup> to 17<sup>th</sup> July 2019.

Figure 14 indicates the spatial distribution of significant rainfall during the event which shows that maximum rainfall of more than 230 mm occurred over northeast Punjab in the Lahore Division. More than 100 mm rainfall was also observed over Gujranwala Division at Hafizabad & over Kashmir at Domel.

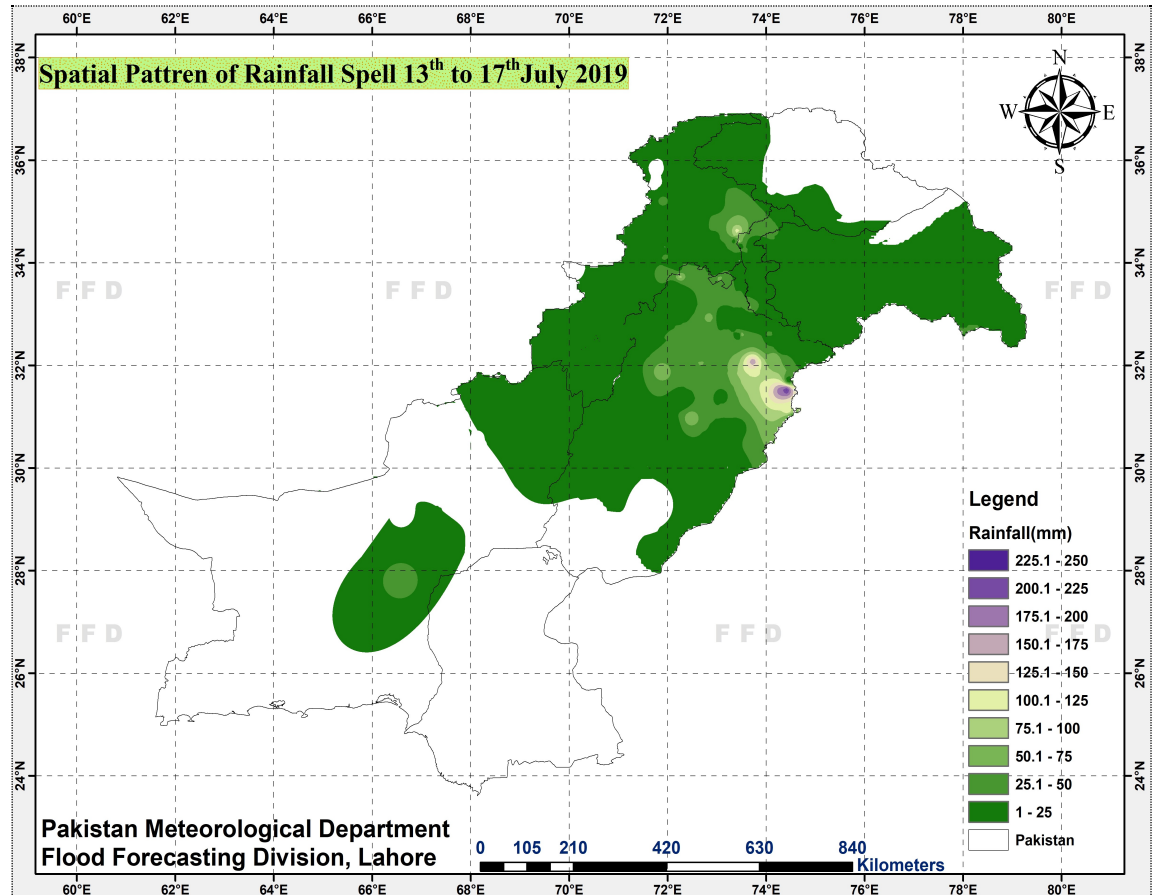


Figure 14: Spatial distribution of significant rainfall map of 13<sup>th</sup> -17<sup>th</sup> July 2019.

### 3.5 Rivers position due to second wet spell of July

No significant flood peak was observed during the period. However, two Low flood peaks in River Indus one at Tarbela & second at Taunsa were recorded.

### 3.6 3<sup>rd</sup> wet spell of July 2019 (26<sup>th</sup> to 31<sup>st</sup> July 2019)

The third spell of July 2019 which was 4<sup>th</sup> of the flood season 2019, lasted for six days. It was mainly due to the passing of a westerly wave, accentuation of seasonal low and incursion of moist currents from Arabian Sea and Bay of Bengal as shown in Figure 15 an overall southwesterly trend of 925 hPa winds caused rainfall in north & northeast Punjab and Kashmir.

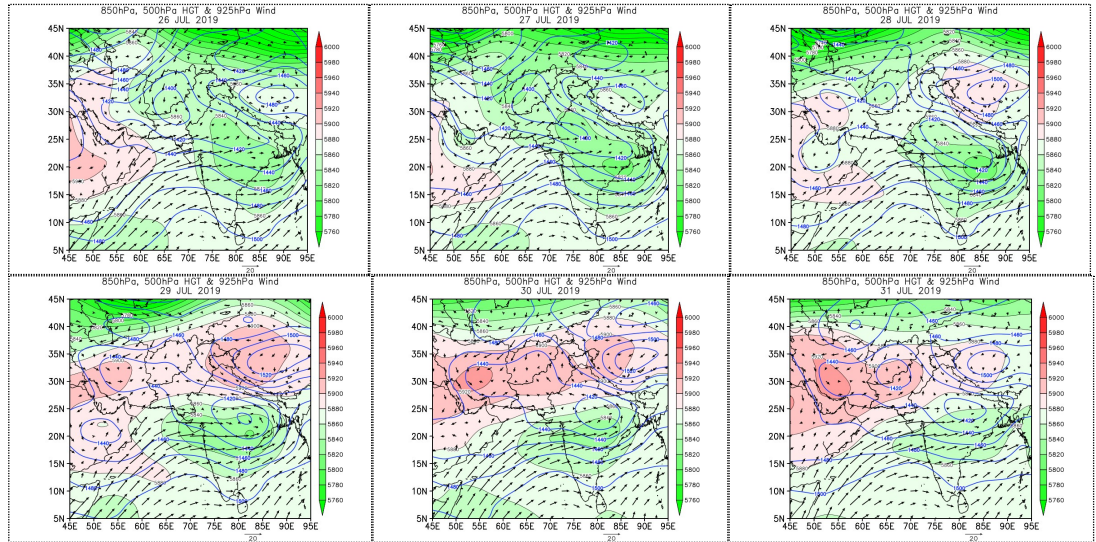


Figure 15: 500 & 850 hPa Geopotential Height patterns and 925 hPa winds from 26<sup>th</sup> to 31<sup>st</sup> July 2019.

Figure 16 is showing clouds over Southern Sindh & Eastern Balochistan and Kashmir. Scattered clouds were also observed over South Punjab & Coastal Balochistan during the spell.

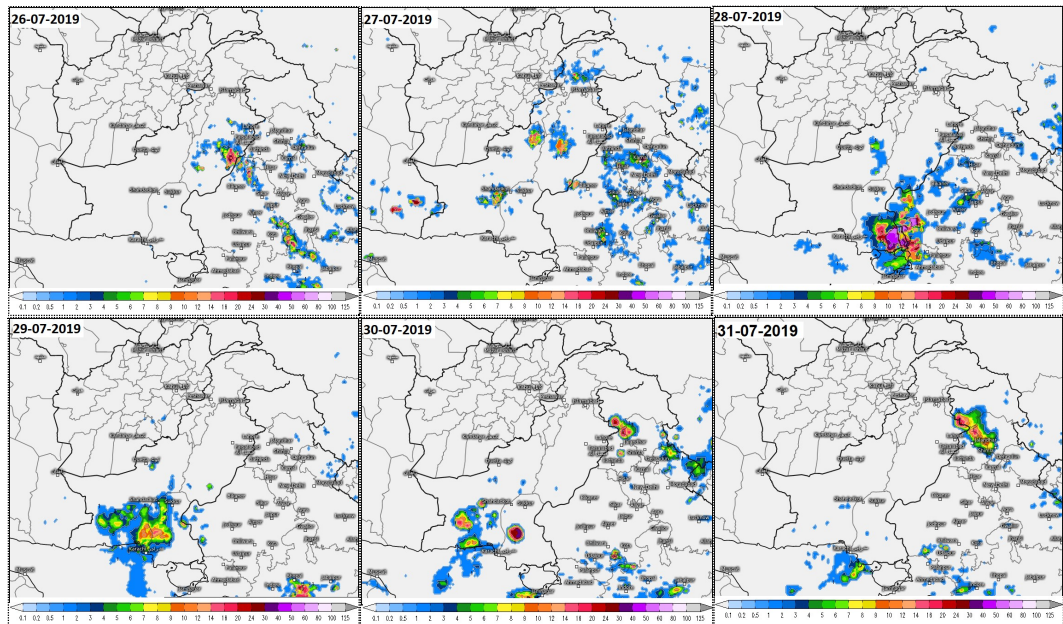


Figure 16: Satellites Images during the spell of 26<sup>th</sup> to 31<sup>st</sup> July 2019.

Figure 17 indicates the spatial distribution of significant rainfall during the event which shows that maximum rainfall of more than 270 mm occurred over northeast Punjab around Sialkot.

Another maxima of rainfall more than 190 mm was observed over South Sindh at Thatta. Moderate rainfall more than 140 mm was observed over Khyber Pakhtunkhwa at Kakul & Malam Jabba.

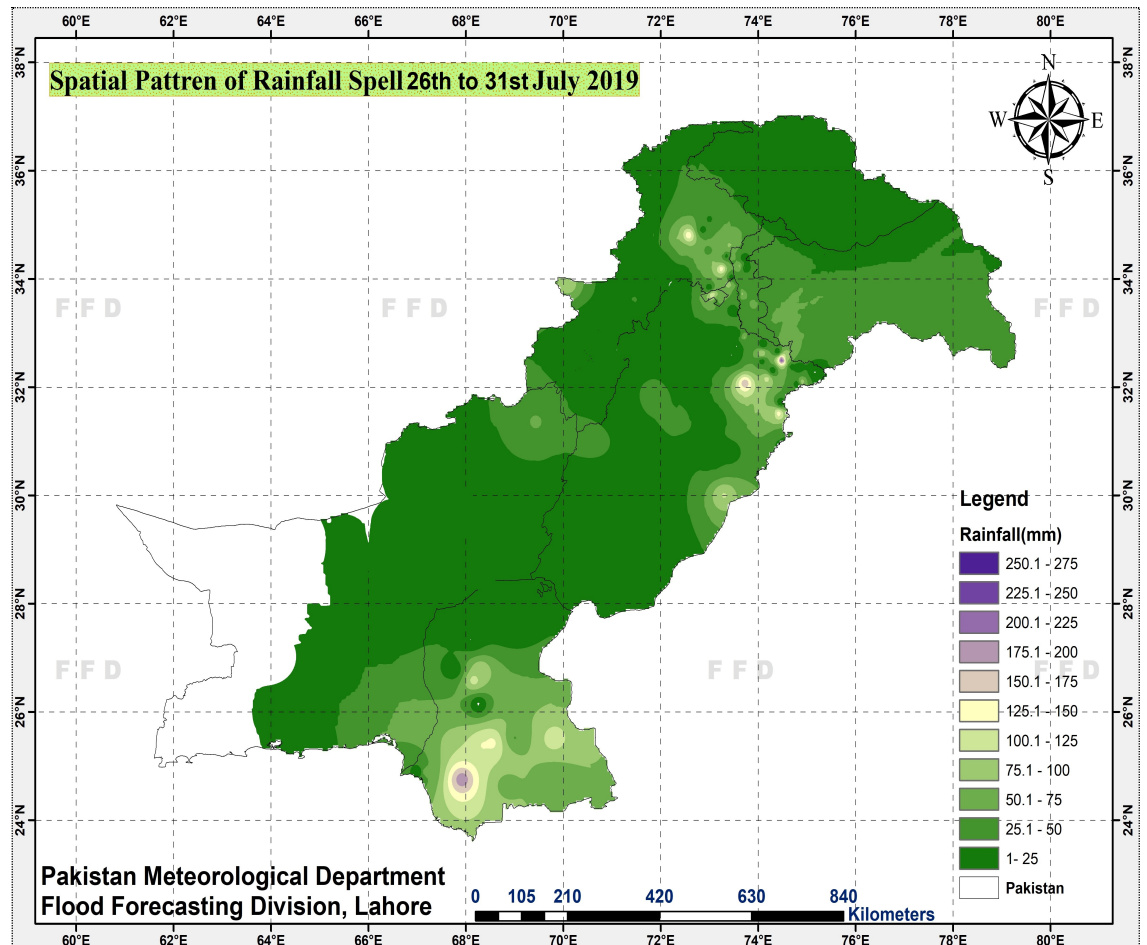


Figure 17: Spatial distribution of significant rainfall map of 26<sup>th</sup> to 31<sup>st</sup> July 2019.

### 3.7 River position due to the third wet spell of July

River Chenab at Marala attained a High flood peak. River Chenab at Khanki & River Kabul at Nowshera attained Medium flood level. Low-level Flood peaks were recorded at River Indus at Tarbela, Kalabagh, Chashma & Taunsa, River Jhelum at Mangla and River Chenab at Qadirabad.

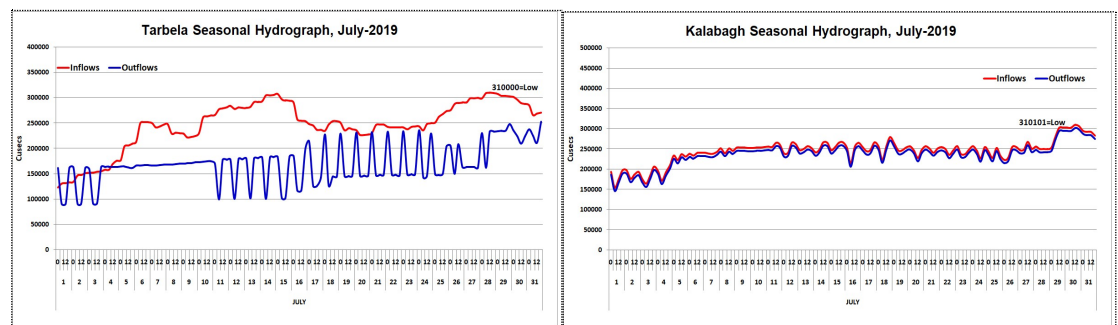
### 3.8 River position during July 2019

Flood peaks (thousands of cusecs ) recorded during July 2019 in different rivers at various points are shown in table 2.

**Table 2: Maximum peaks recorded during July 2019.**

Rivers	Stations	Peaks Inflows	Date	Flood level
Indus	Tarbela	252.0	6/7/2019	Low
Indus	Tarbela	284.0	12/7/2019	Low
Indus	Tarbela	308.0	15/7/2019	Low
Indus	Tarbela	254.0	18/7/2019	Low
Indus	Tarbela	310.0	28/7/2019	Low
Indus	Kalabagh	279.9	18/7/2019	Low
Indus	Kalabagh	310.1	30/7/2019	Low
Indus	Chashma	260.2	9/7/2019	Low
Indus	Chashma	261.4	24/7/2019	Low
Indus	Chashma	284.1	28/7/2019	Low
Indus	Chashma	323.8	31/7/2019	Low
Indus	Taunsa	263.9	13/7/2019	Low
Indus	Taunsa	272.9	18/7/2019	Low
Indus	Taunsa	270.4	26/7/2019	Low
Indus	Taunsa	288.5	31/7/2019	Low
Indus	Guddu	242.4	19/7/2019	Low
Indus	Sukkur	201.8	31/7/2019	Low
Jhelum	Mangla	87.0	9/7/2019	Low
Jhelum	Mangla	75.0	10/7/2019	Low
Jhelum	Mangla	75.0	25/7/2019	Low
Chenab	Marala	151.9	25/7/2019	Medium
Chenab	Marala	136.9	29/7/2019	Low
Chenab	Marala	237.0	31/7/2019	High
Chenab	Khanki	100.3	26/7/2019	Low
Chenab	Khanki	113.5	29/7/2019	Low
Chenab	Khanki	169.4	31/7/2019	Medium
Chenab	Qadirabad	122.1	31/7/2019	Low
Kabul	Nowshera	105.0	29/7/2019	Medium

### 3.9 Hydrographs during July 2019



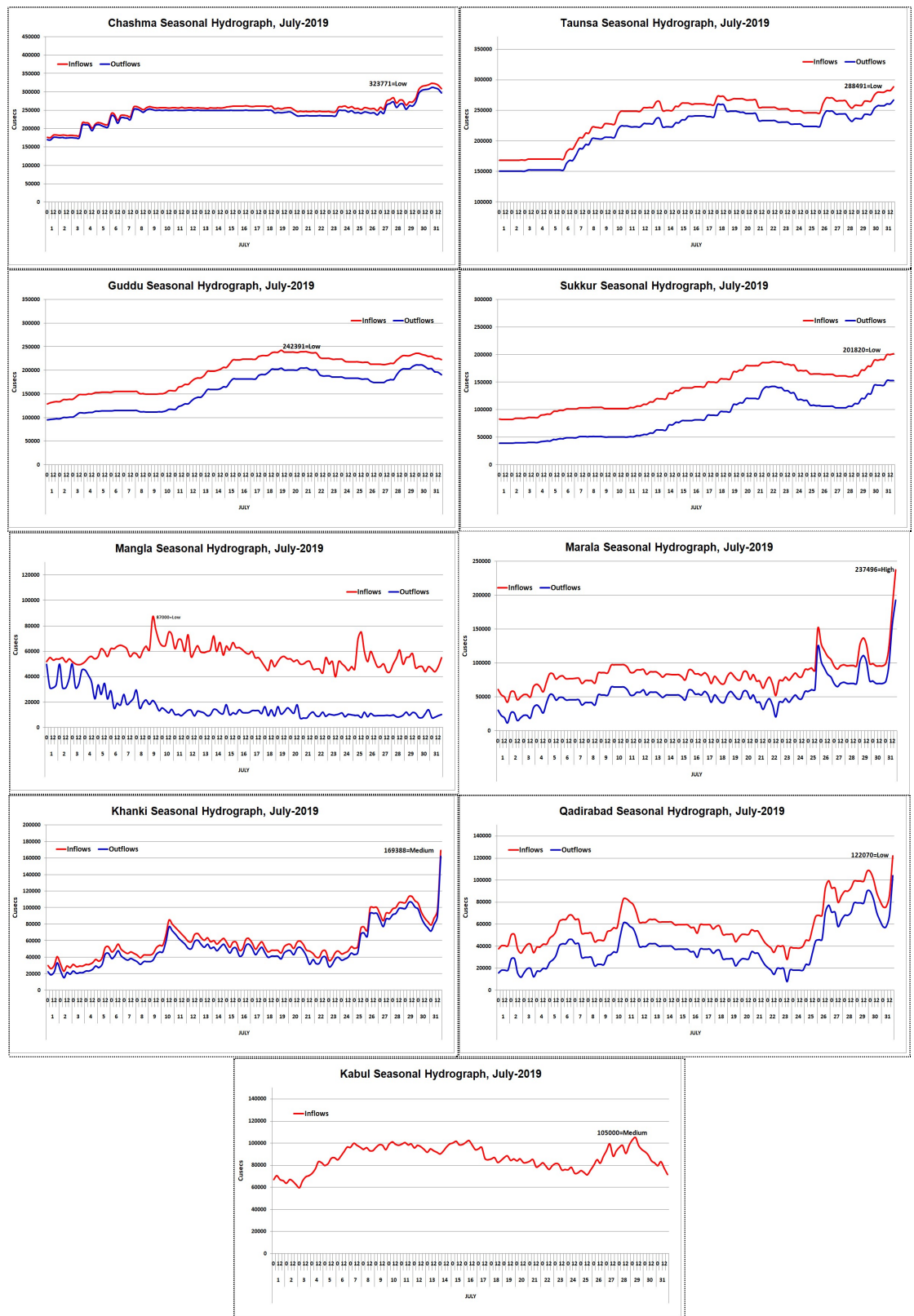


Figure 18: Hydrographs for the month of July 2019.

### 3.10 The spatial pattern of rainfall during the month of July 2019

Isohyetal map of July 2019 indicates that one maxima rainfall more than 450 mm lies over Sialkot in Northeast Punjab and other centers of rainfall of more than 350 mm lie over Kakul in Khyber Pakhtunkhwa. More than 300 mm are also observed over Azad Kashmir. Southeast Sindh over Thatta received more than 190 mm while more than 150 mm rainfall recorded over Tandojam & Shaheed Bainazerabad. The spatial distribution of significant rainfall map of July 2019 is shown in Figure 19.

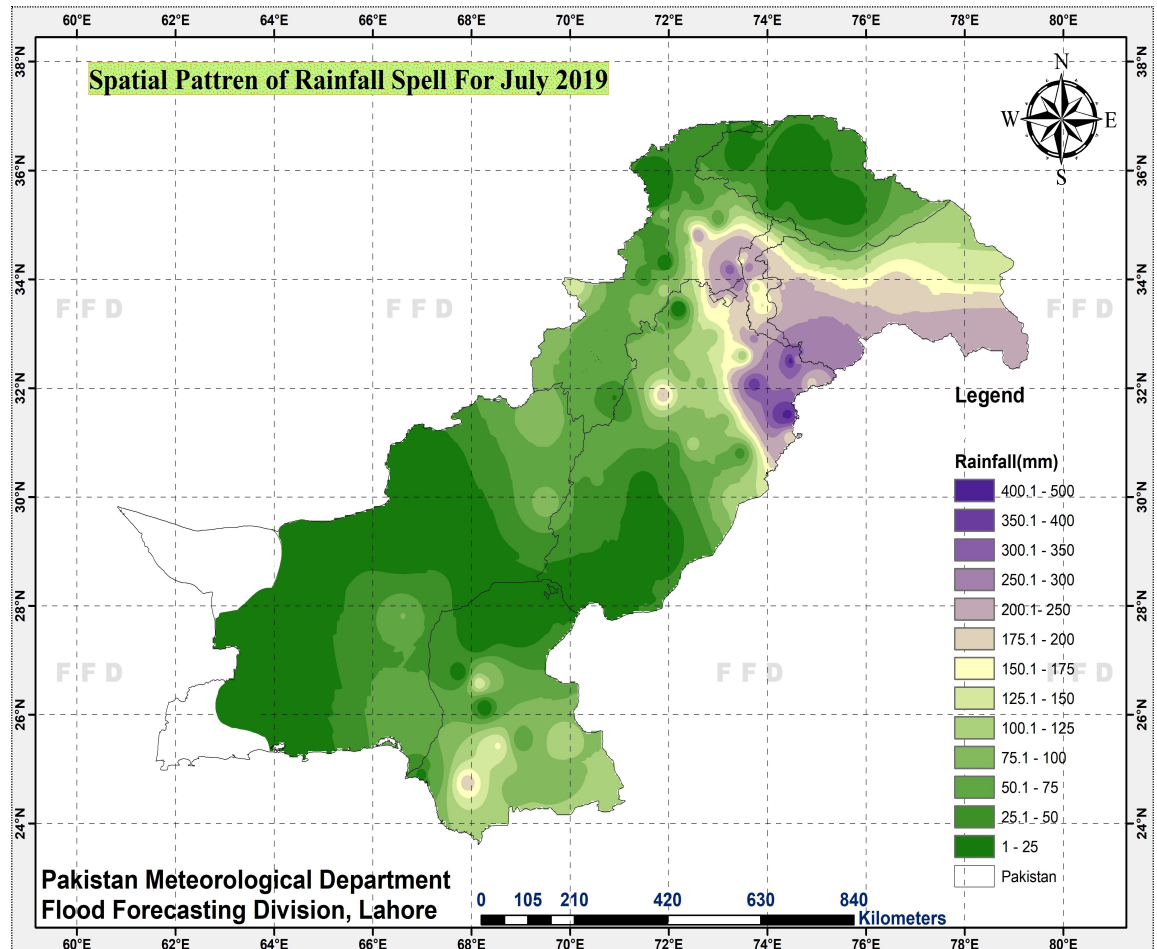


Figure 19: Spatial distribution rainfall map of July 2019.

### 3.11 Percentage Anomaly during the month of July 2019

Percentage Anomaly map for the month of July 2019 indicates that Southeast Sindh, Northeast Punjab received above normal Rainfall while most parts of Khyber Pakhtunkhwa, Balochistan, Kashmir, South Punjab & Upper Sindh received below normal rainfall. Percentage Anomaly map of July 2019 is shown in Figure 20.

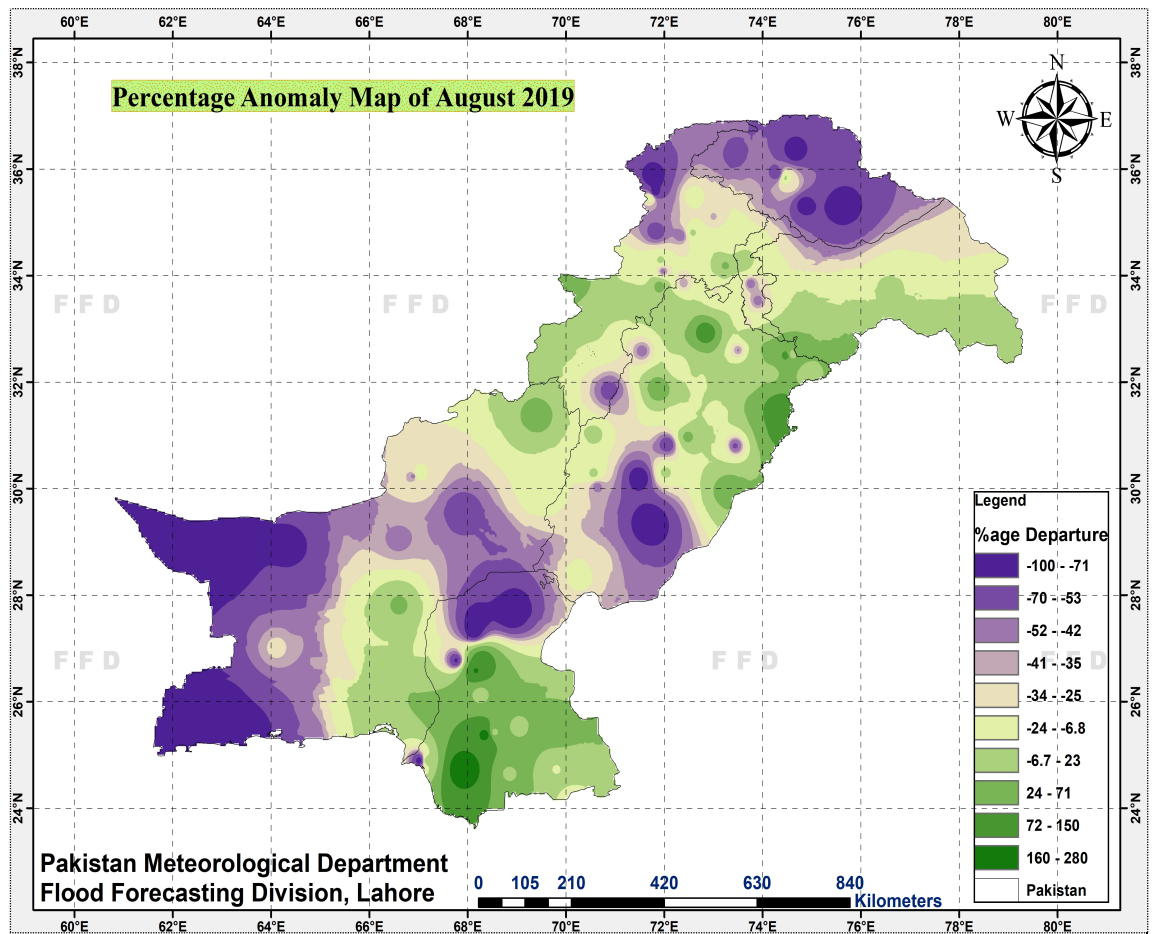


Figure 20: Percentage Anomaly rainfall map of July 2019.

### 3.12 Temporal Distribution during the month of July 2019

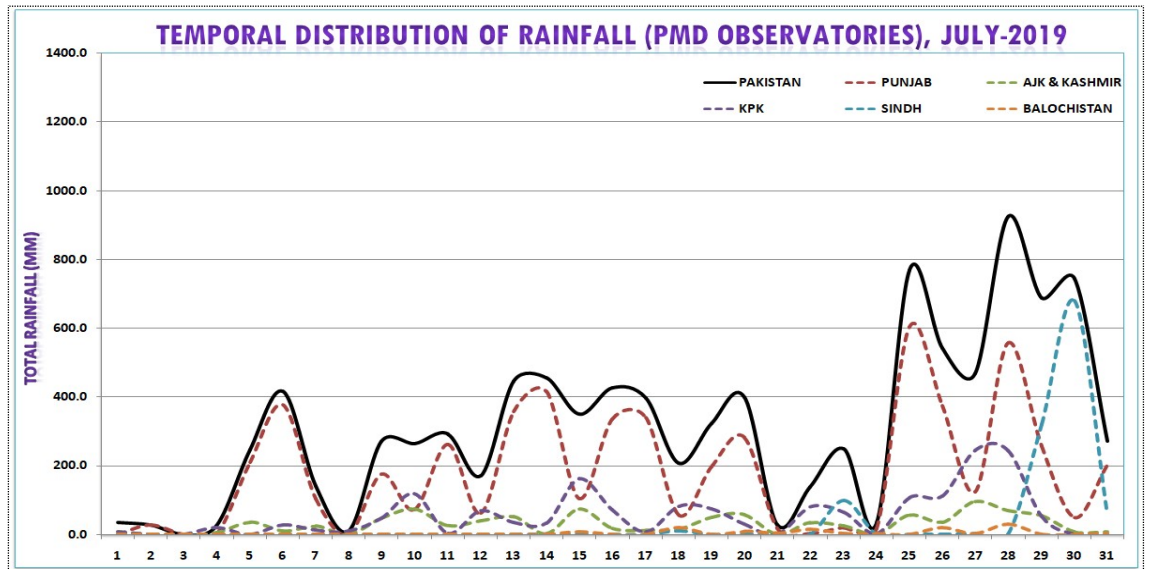


Figure 21: Temporal distribution of rainfall July 2019.

## 4 Significant hydro-meteorological events during the month of August 2019

Three rainy spells occurred during the month of August 2019..

### 4.1 Meteorological events

The first spell continued from 01<sup>st</sup> to 03<sup>rd</sup> August 2019. This spell was caused by the presence of seasonal low over northeast Balochistan, westerly wave over north of the country and moderate moist currents from the Arabian Sea as well as from Bay of Bengal. The second wet spell of August was observed from 07<sup>th</sup> to 11<sup>th</sup> August 2019. This spell was caused by the interaction of westerly wave over northern parts of the country and Well marked Monsoon Low over Southeastern parts of Sindh along with strong moist currents from the Arabian Sea and Bay of Bengal up to 7000 feet. The third & final short wet spell of August was observed from 30<sup>th</sup> to 31<sup>st</sup> August 2019. This spell was caused by the trough of westerly wave over northern parts of the country and weak Monsoon Low over Eastern parts of Sindh along with moderate moist currents from the Arabian Sea and Bay of Bengal.

### 4.2 1<sup>st</sup> wet spell of August (01<sup>st</sup> to 03<sup>rd</sup> August 2019)

The rainfall during the first spell of August occurred from 01<sup>st</sup> to 03<sup>rd</sup> August 2019. Light to Moderate rainfall was observed during this spell over the upper catchments of river Indus and Jhelum along with north and northeast Punjab. Atmospheric conditions during this wet spell are shown in figure 22.

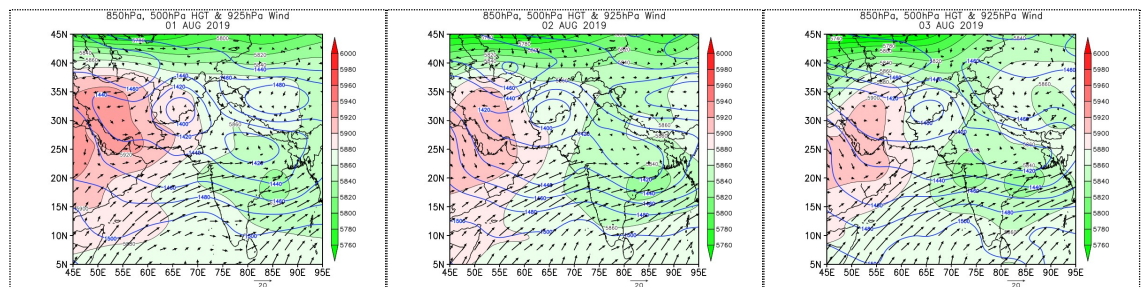


Figure 22: 500 & 850 hPa geopotential height patterns and 925 hPa winds on 01<sup>st</sup> to 03<sup>rd</sup> August 2019.

Satellite images in figure 23 are showing dense clouds over Punjab, Lower Khyber Pakhtunkhwa & Kashmir. Light clouds are also present over South Sindh & East Balochistan.

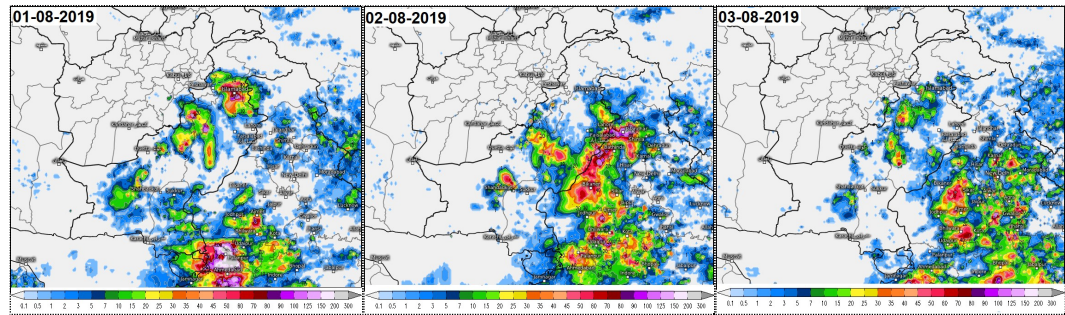


Figure 23: Satellites Images during the spell of 01<sup>st</sup> to 03<sup>rd</sup> August 2019.

Figure 24, Isohyetal map of 01<sup>st</sup> to 03<sup>rd</sup> August 2019 indicates that one maxima of rainfall more than 90 mm lies over North Punjab around Islamabad and adjoining Kashmir. Another maximum of rainfall of more than 80 mm lies over northeast Punjab over Gujranwala Division. Lesser maxima of more than 50 mm were also observed over Bhakkar in Sargodha Division along with more than 40 mm also observed over Kalat.

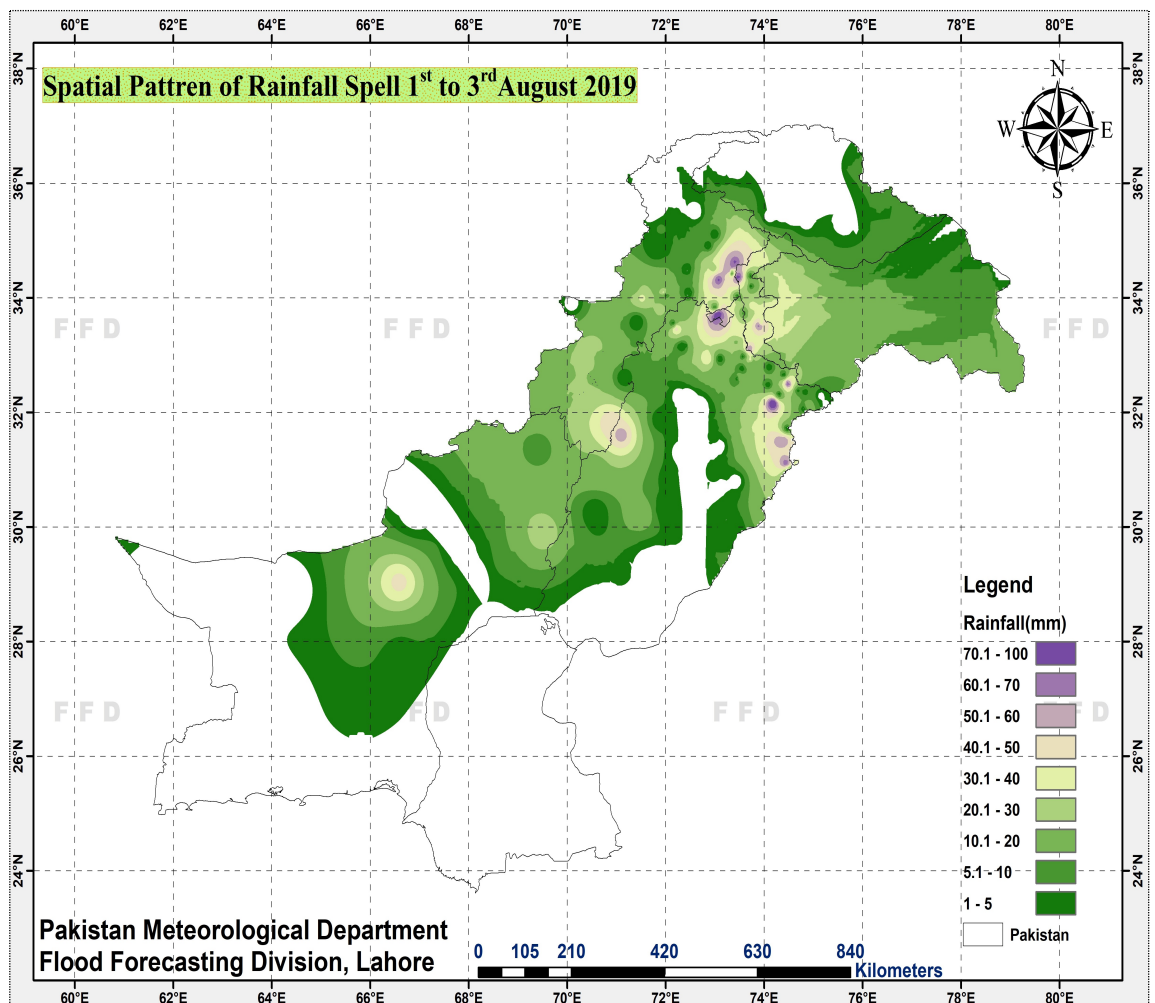


Figure 24: Spatial distribution of significant rainfall map of 01<sup>st</sup> to 03<sup>rd</sup> August 2019.

### 4.3 Rivers position during the first spell of August-2019

Due to moderate rainfall in the upper catchments of Rivers Indus, Jhelum & Chenab Medium level floods were recorded in River Indus at Chashma & River Jhelum at Mangla and River Chenab at Khanki & Qadirabad. The low-level flood was also observed in River Indus at Tarbela & Kalabagh.

### 4.4 2<sup>nd</sup> wet spell of August (07<sup>th</sup> to 11<sup>th</sup> August 2019)

Rainfall of moderate-intensity was recorded over South Sindh, Northeast Punjab and Upper Catchments of River Indus. Figure 25 represents the atmospheric conditions during this wet spell. This spell was caused by the interaction of westerly wave over northern parts of the country and Well marked Monsoon Low over Southeastern parts of Sindh along with strong moist currents from the Arabian Sea and Bay of Bengal and the influx of southwesterly & Easterly currents at 925 hPa.

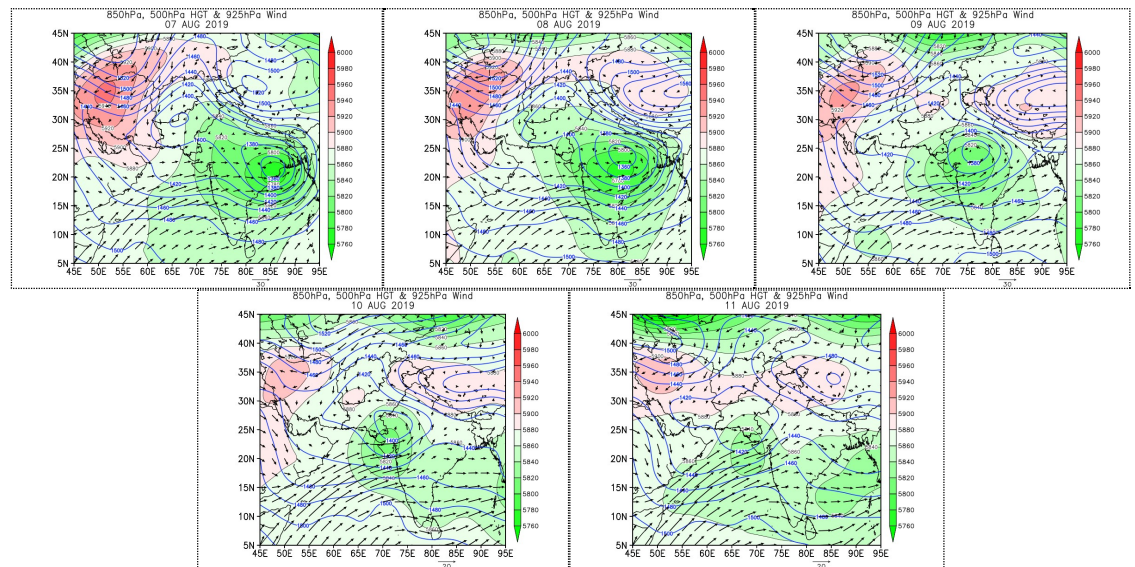
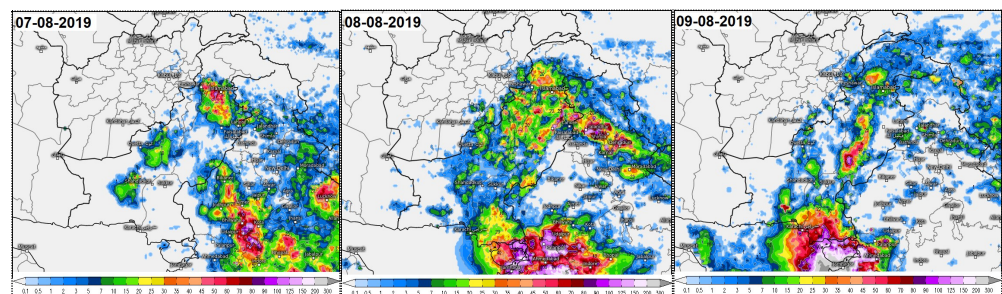


Figure 25: 500 & 850 hPa Geopotential height patterns and 925 hPa winds from 07<sup>th</sup> to 11<sup>th</sup> August 2019.

Satellite/Radar images in figure 26 showing dense clouds over Lower Sindh and Coastal & Eastern Balochistan. Scattered Clouds of moderate-intensity also visible over parts of Punjab, Northeast Balochistan, Kashmir & Khyber Pakhtunkhwa.



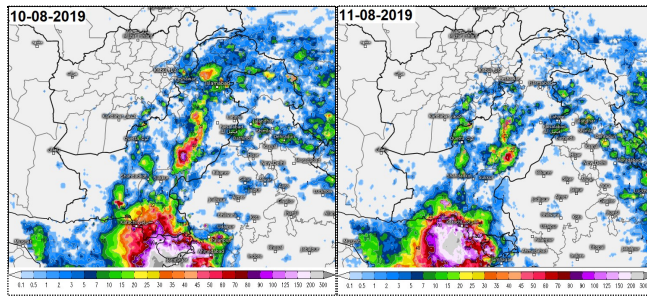


Figure 26: Radar & Satellites Images during the spell of 07<sup>th</sup> to 11<sup>th</sup> August 2019.

Figure 27 shows the spatial distribution of significant rainfall of more than 170 mm recorded over North Punjab around Islamabad and Upper Catchments of River Indus over Malam Jabba. More than 150 mm rainfall recorded over South Sindh near Thatta.

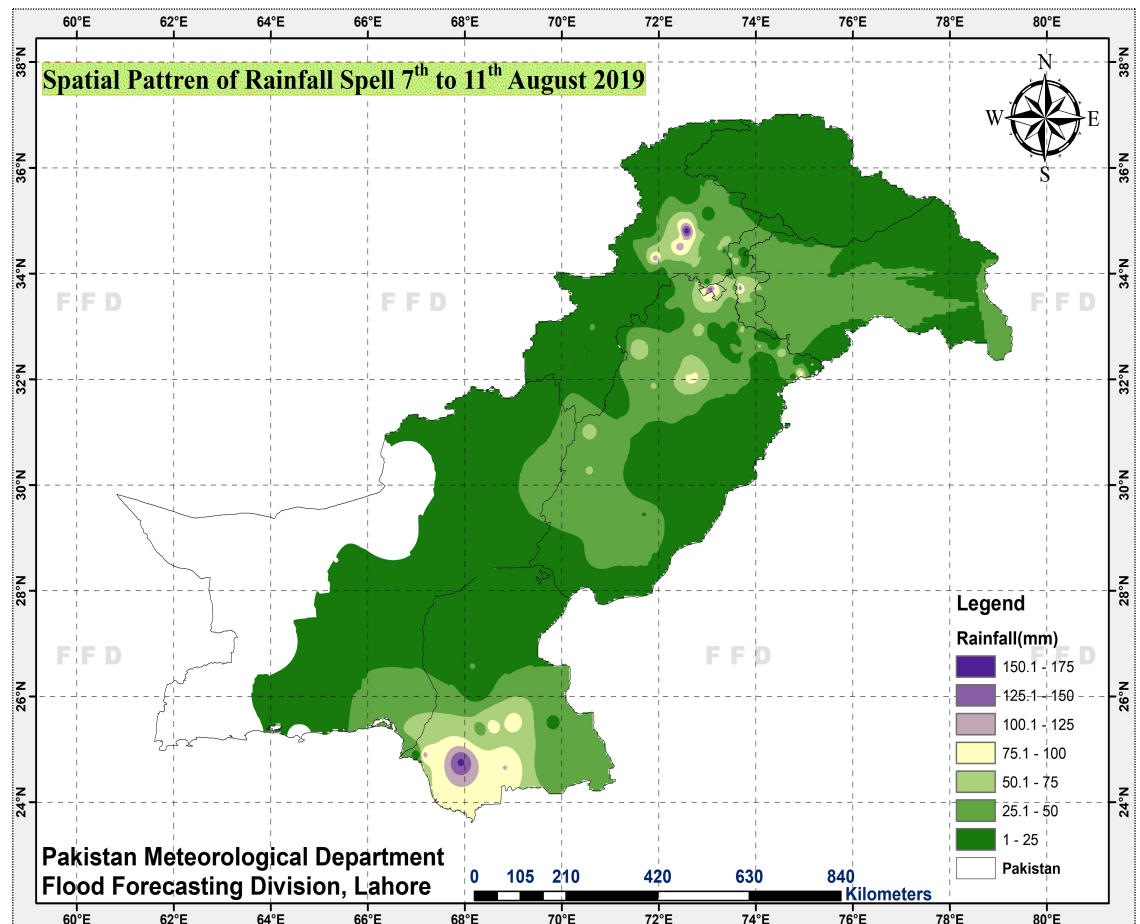


Figure 27: Spatial distribution of significant rainfall map of 07<sup>th</sup> to 11<sup>th</sup> August 2019.

#### 4.5 Rivers position during the second spell of August-2019

Due to moderate rainfall, Medium level flood was recorded at upstream in River Indus at Guddu, River Chenab at Marala & River Kabul at Nowshera. Low flood level was

observed in River Indus at Tarbela, Kalabagh & Chashma, River Jhelum at Mangla and River Chenab at Khanki and Qadirabad.

#### 4.6 3<sup>rd</sup> wet spell of August (30<sup>th</sup> to 31<sup>st</sup> August 2019)

Rainfall of light to moderate intensity was recorded over north-northeast Punjab. Light rainfall was observed over Southeast Sindh & Kashmir. Figure 28 represents the atmospheric conditions during this wet spell. This wet spell was caused by a westerly trough affecting the upper parts of the country and the influx of southwesterly currents at 925 hPa.

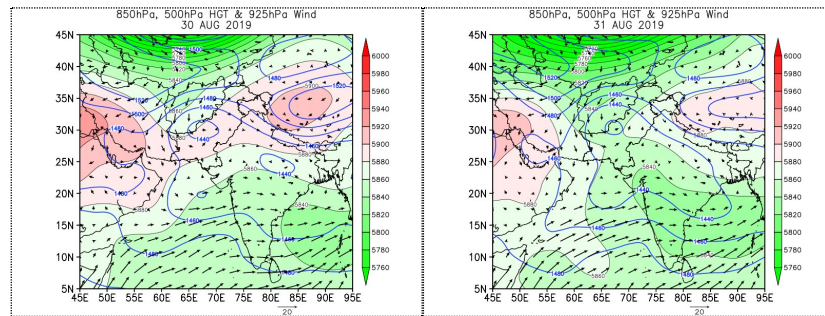


Figure 28: 500 & 850 hPa Geopotential height patterns and 925 hPa winds from 30<sup>th</sup> to 31<sup>st</sup> August 2019.

The satellite image in figure 29 is showing clouds cover over North & Northeast Punjab and Sindh. Scattered clouds are also visible over Coastal & Eastern Balochistan.

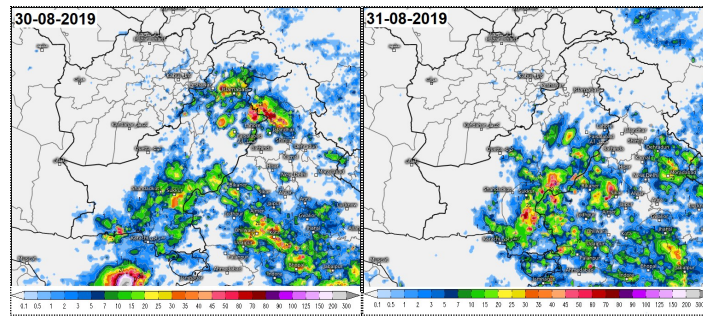


Figure 29: Radar & Satellites Images during the spell of 30<sup>th</sup> to 31<sup>st</sup> August 2019.

Figure 30 shows the spatial distribution of significant rainfall of more than 100 mm recorded over Northeast Punjab around Sialkot and rainfall of more than 70 mm was also recorded over North Punjab around Attock. More than 20 mm rainfall recorded over South Sindh.

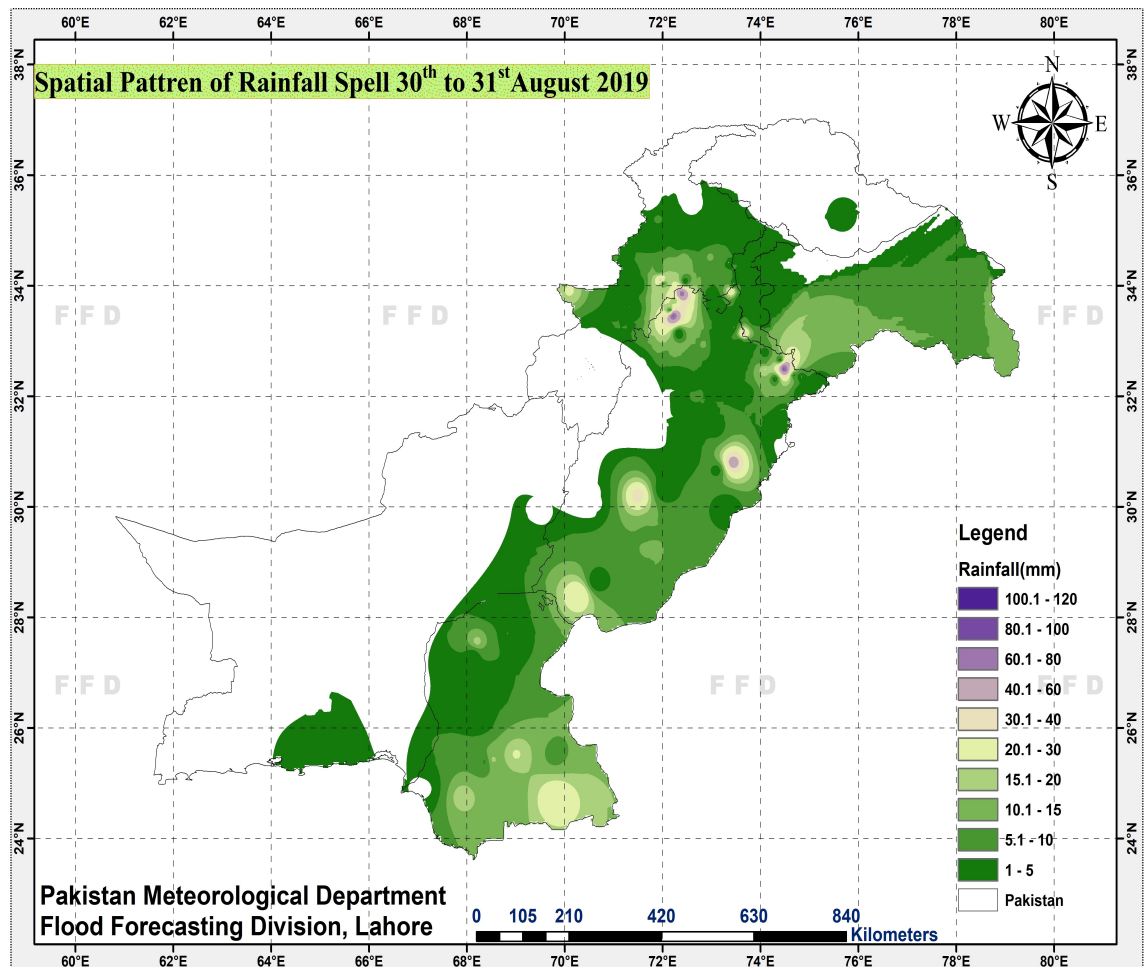


Figure 30: Spatial distribution of significant rainfall map of 30<sup>th</sup> to 31<sup>st</sup> August 2019.

#### 4.7 Rivers position during the third spell of August-2019

No significant flood situation was recorded during the spell except one low flood peak was registered in River Sutlej at Islam.

#### 4.8 Spatial distribution of rainfall during the month of August 2019

The precipitation during the month of August is shown in figure 31 which indicates that monsoon activity remained active over North Punjab and South Sindh. One center of maximum rainfall exceeding 450 mm is located at Islamabad. While another maxima of 350 mm is located around Sialkot in Northeast Punjab. Another maxima of slightly above 250 mm is also observed in South Sindh over Thatta.

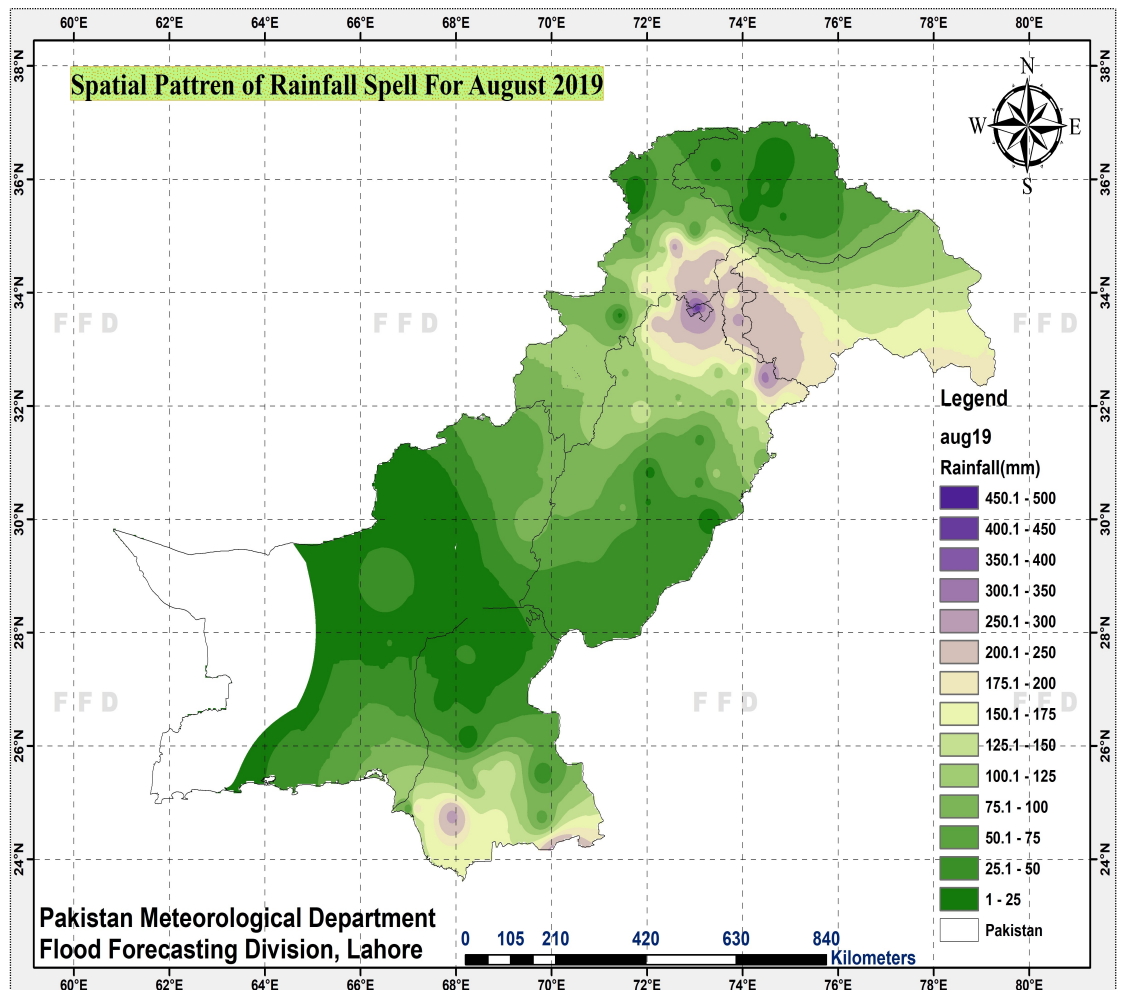


Figure 31: Spatial distribution of significant rainfall map of August 2019.

#### 4.9 Percentage Anomaly during the month of August 2019

Percentage Anomaly map for the month of August 2019 indicates that South & Southeast Sindh & South Balochistan received above normal Rainfall while most parts of Khyber Pakhtunkhwa, Kashmir, South Punjab & Upper Sindh received below normal rainfall. Percentage Anomaly map of August 2019 is shown in Figure 32.

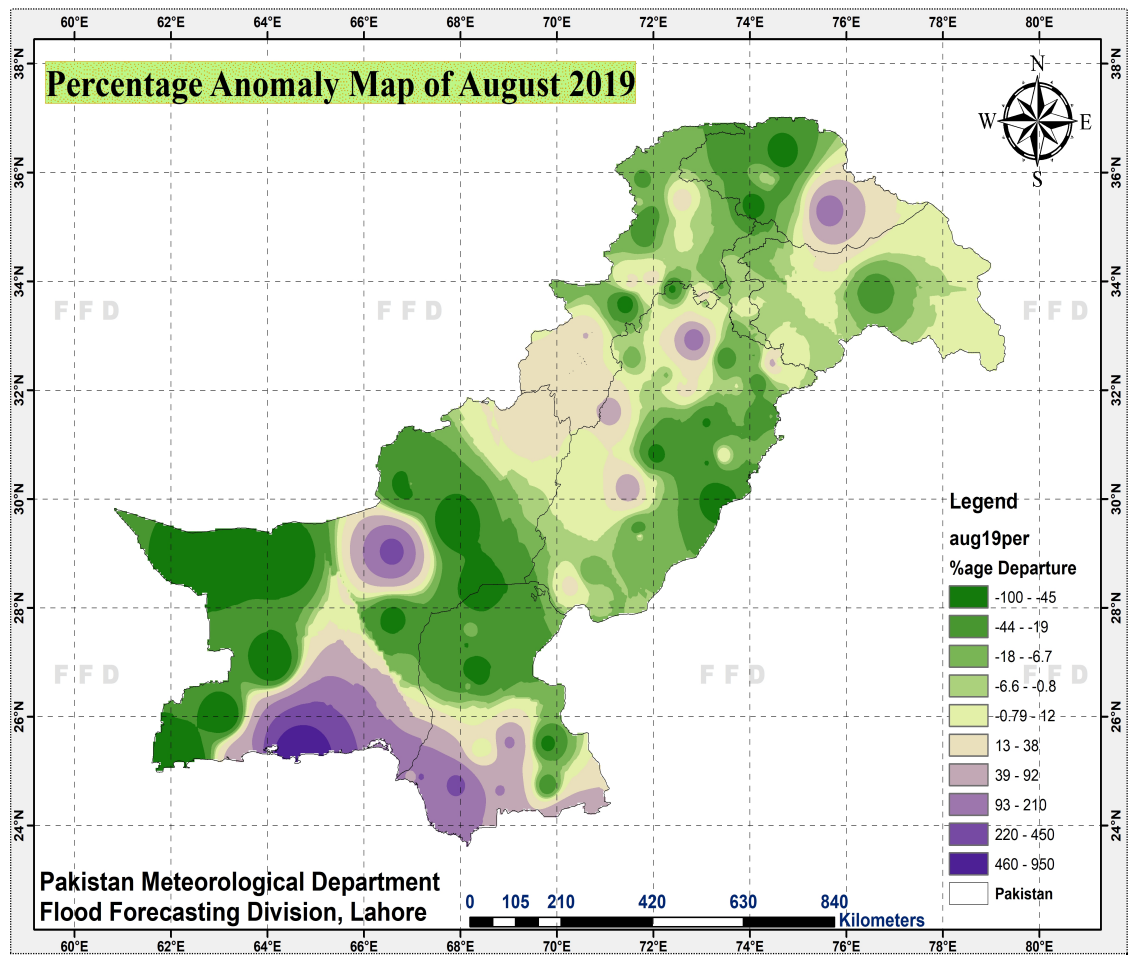


Figure 32: Percentage Anomaly rainfall map of August 2019.

#### 4.10 Temporal Distribution during the month of August 2019

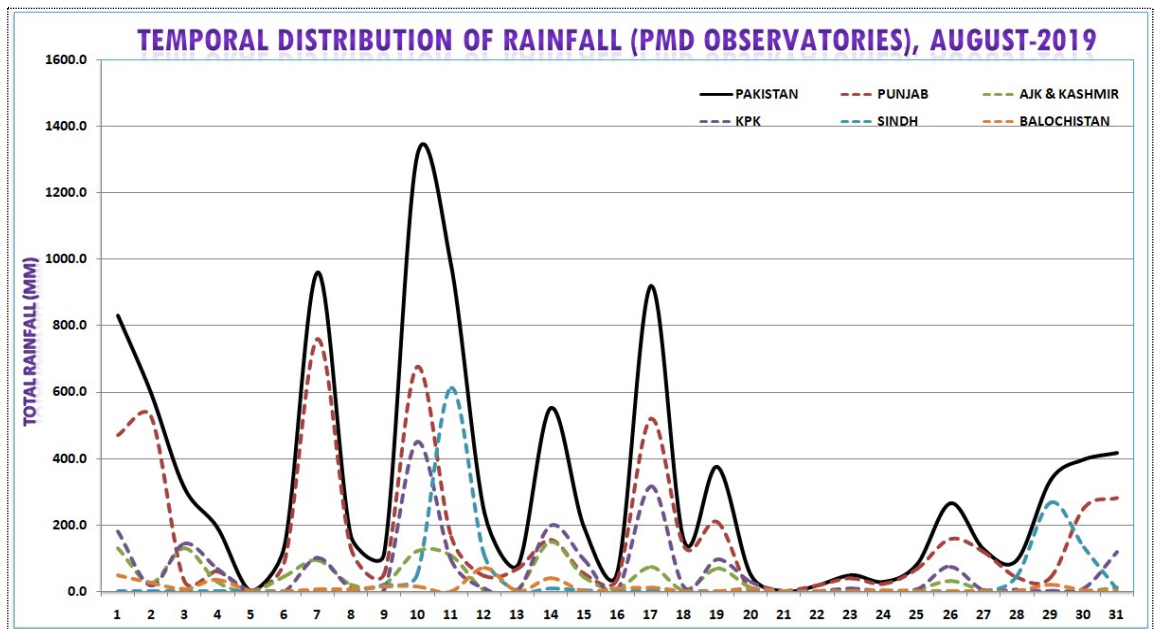


Figure 33: Temporal distribution of rainfall during August 2019.

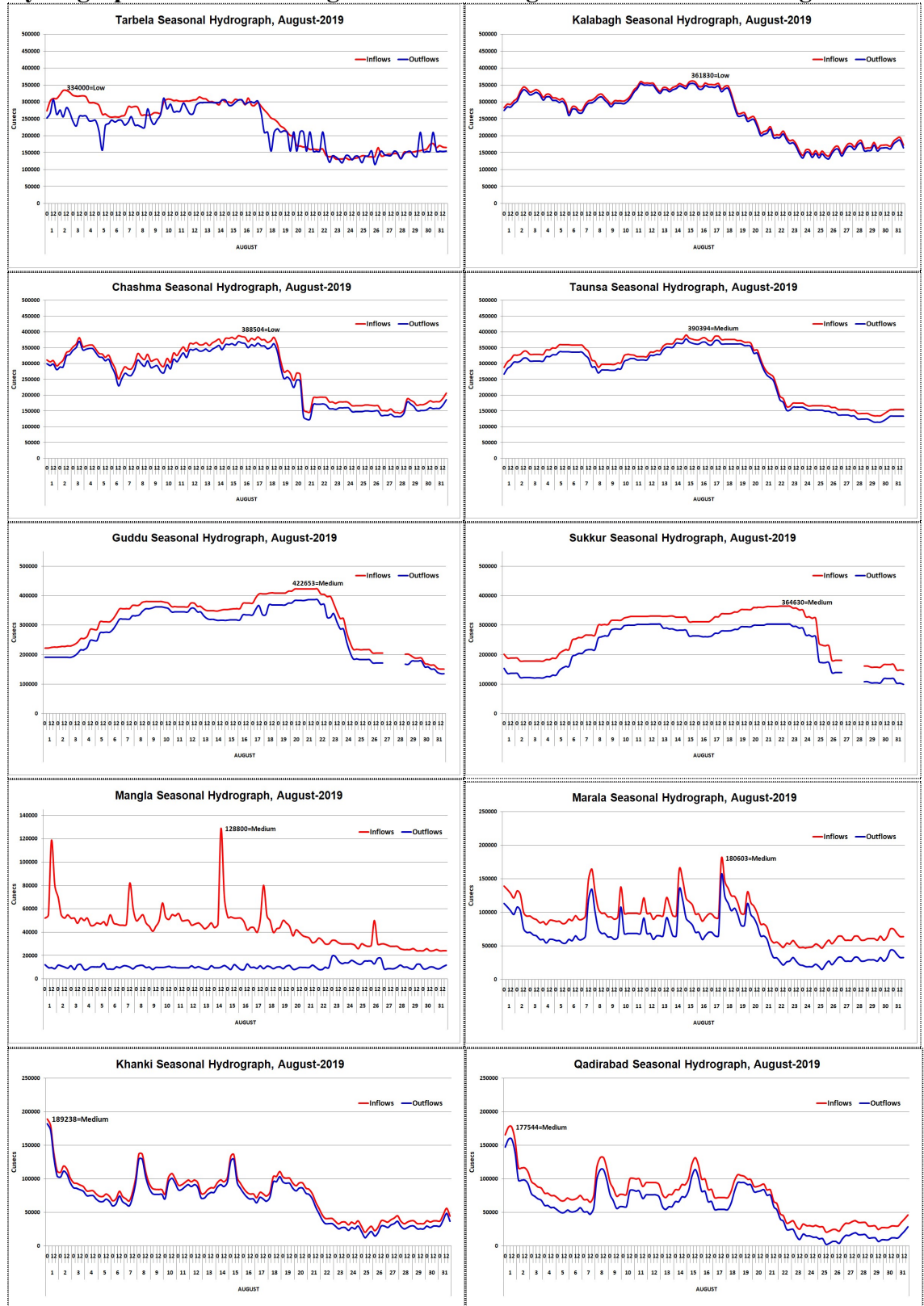
#### 4.11 Rivers position during the month of August-2019

Flood peaks recorded during August 2019 are shown in table 3.

Table 3: Maximum peaks recorded during August 2019.

Rivers	Stations	Peaks Inflows	Date	Flood level
Indus	Tarbela	334	2/8/2019	Low
Indus	Tarbela	287	7/8/2019	Low
Indus	Tarbela	308.3	10/8/2019	Low
Indus	Tarbela	315	12/8/2019	Low
Indus	Tarbela	311	16/8/2019	Low
Indus	Kalabagh	344.2	2/8/2019	Low
Indus	Kalabagh	321.1	8/8/2019	Low
Indus	Kalabagh	359.9	11/8/2019	Low
Indus	Kalabagh	361.8	15/8/2019	Low
Indus	Chashma	381.7	3/8/2019	Medium
Indus	Chashma	331.8	8/8/2019	Low
Indus	Chashma	388.5	15/8/2019	Medium
Indus	Taunsa	359.3	5/8/2019	Medium
Indus	Taunsa	390.4	15/8/2019	Medium
Indus	Guddu	380.5	8/8/2019	Medium
Indus	Guddu	408.8	18/8/2019	Medium
Indus	Guddu	422.7	20/8/2019	Medium
Indus	Sukkur	330.9	12/8/2019	Low
Indus	Sukkur	364.6	22/8/2019	Medium
Jhelum	Mangla	118.5	1/8/2019	Medium
Jhelum	Mangla	82	7/8/2019	Low
Jhelum	Mangla	128.8	14/8/2019	Medium
Jhelum	Mangla	80	17/8/2019	Low
Chenab	Marala	164.7	7/8/2019	Medium
Chenab	Marala	137.9	10/8/2019	Low
Chenab	Marala	121.8	11/8/2019	Low
Chenab	Marala	121.8	13/8/2019	Low
Chenab	Marala	164.6	14/8/2019	Medium
Chenab	Marala	180.6	17/8/2019	Medium
Chenab	Marala	130.6	19/8/2019	Low
Chenab	Khanki	189.2	1/8/2019	Medium
Chenab	Khanki	136.7	8/8/2019	Low
Chenab	Khanki	136.3	15/8/2019	Low
Chenab	Khanki	111.1	18/8/2019	Low
Chenab	Qadirabad	177.5	1/8/2019	Medium
Chenab	Qadirabad	131.6	8/8/2019	Low
Chenab	Qadirabad	131.9	15/8/2019	Low
Sutlej	GS Wala	60.3	22/8/2019	Low
Sutlej	GS Wala	58.9	24/8/2019	Low
Sutlej	Sulemanki	58.2	23/8/2019	Low
Sutlej	Sulemanki	66.5	24/8/2019	Low
Sutlej	Sulemanki	57.9	26/8/2019	Low
Sutlej	Islam	54.1	31/8/2019	Low
Ravi	Jassar	51	18/8/2019	Low
Kabul	Nowshera	85.6	11/8/2019	Medium

4.12 Hydrographs observed during the month of August 2019 are shown in figure 37



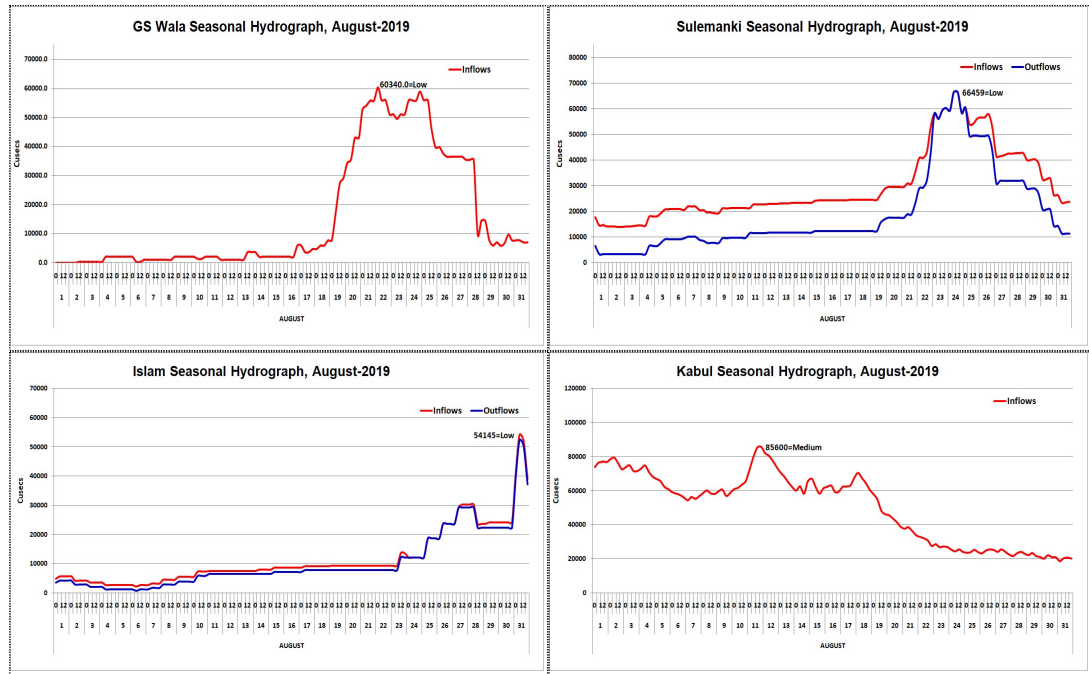


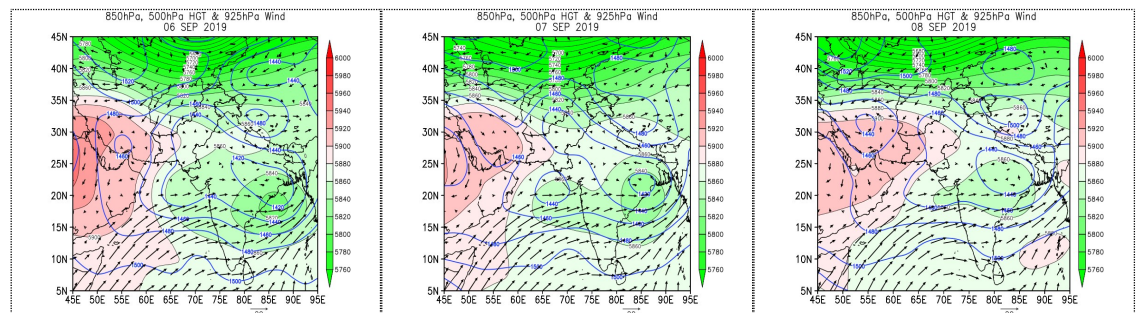
Figure 34: Hydrographs for the month of August-2019.

## 5 Significant hydro-meteorological events during the month of September 2019

During the month of September, one monsoon low was developed over Bay of Bengal and two wet spells were recorded during the month.

### 5.1 1<sup>st</sup> wet spell of September (06<sup>th</sup> to 08<sup>th</sup> September 2019)

This spell occurred from 06<sup>th</sup> to 08<sup>th</sup> September 2019. During this event light to moderate rainfall was reported from Mandi Bahauddin, Jhelum, Islamabad, and Southeast Sindh. This situation was created by the presence of a westerly wave over north of Pakistan, interacting with the sufficient moisture available as shown in Figure 35.

Figure 35: 500 & 850 hPa geopotential height patterns and 925 hPa winds on 06<sup>th</sup> to 08<sup>th</sup> September 2019.

The satellite image in figure 36 shows moderate clouds over North Punjab, Southeast Sindh and Kashmir.

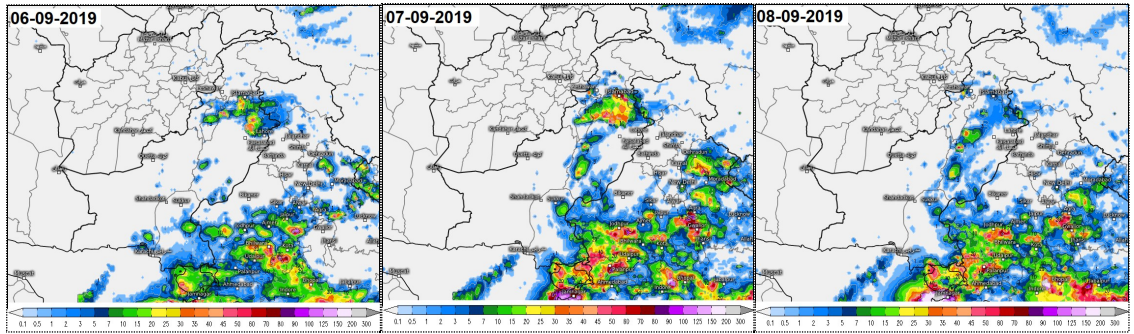


Figure 36: Satellites Images during the spell of September 06<sup>th</sup> to 08<sup>th</sup> September 2019.

Figure 37 shows the spatial distribution of significant rainfall round about 100 mm recorded over Mandi Bahauddin & other maxima centre of rainfall more than 40 mm observed around Jhelum & Islamabad along with light rainfall over Bakkhar in Sargodha Division, Bahawalpur Division and Southeast Sindh around Mithi.

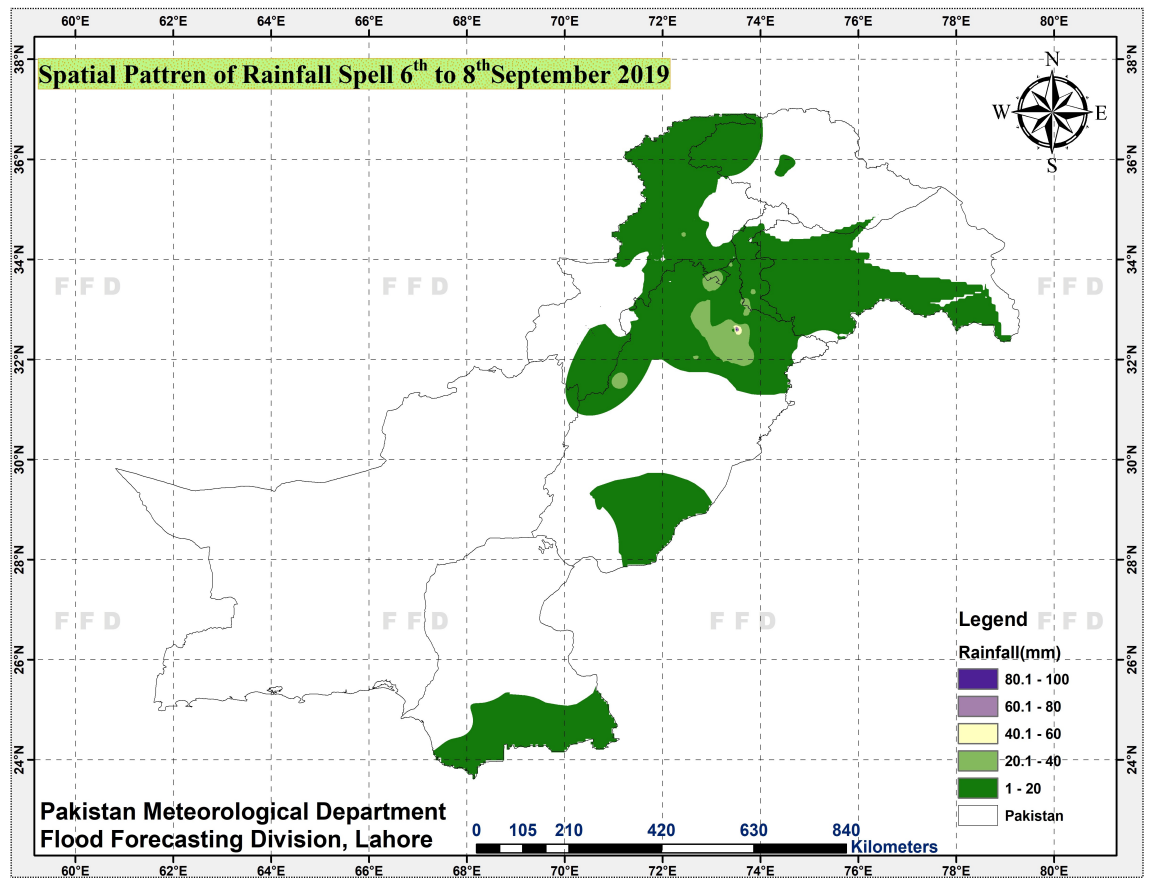


Figure 37: Spatial distribution of significant rainfall map of 06<sup>th</sup> to 08<sup>th</sup> September 2019.

## 5.2 Rivers position during the first spell of September-2019

Due to light to moderate rainfall, the low level flood was observed in River Ravi at Balloki.

### 5.3 2<sup>nd</sup> wet spell of September (27<sup>th</sup> to 30<sup>th</sup> September 2019)

The second rainy spell occurred from 27<sup>th</sup> to 30<sup>th</sup> September 2019. During this event light to moderate rainfall was reported from Islamabad, Narowal in Gujranwala Division and Muzaffarabad in Kashmir. This situation occurred by the interaction of a westerly wave over the north of Pakistan with the sufficient moisture available as shown in Figure 38.

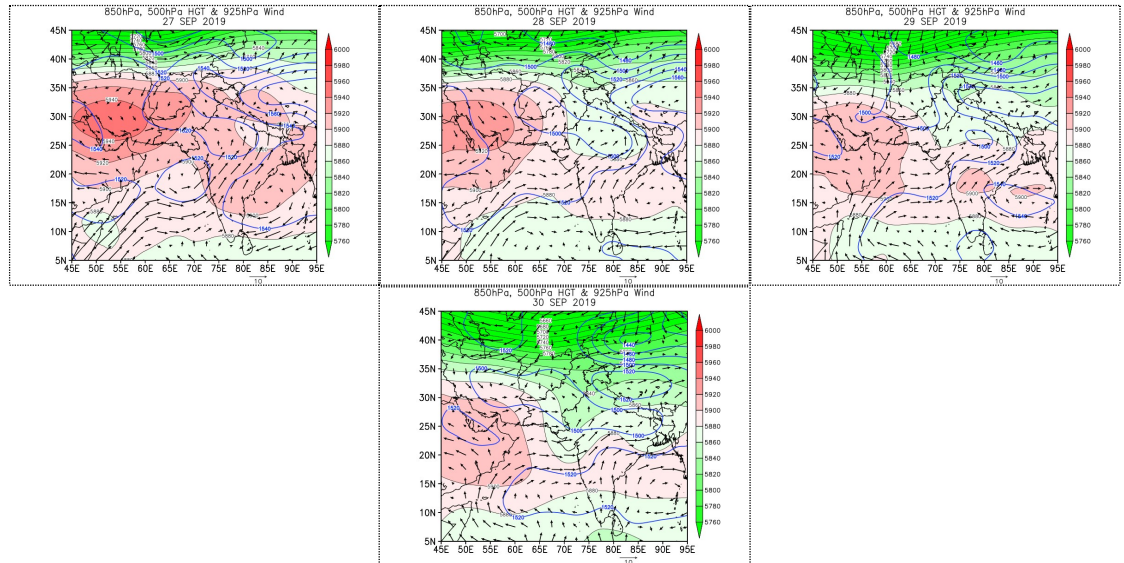


Figure 38: 500 & 850 hPa geopotential height patterns and 925 hPa winds on 27<sup>th</sup> to 30<sup>th</sup> September 2019.

Satellite images in figure 39 show moderate clouds over Punjab, Kashmir & Southeast Sindh.

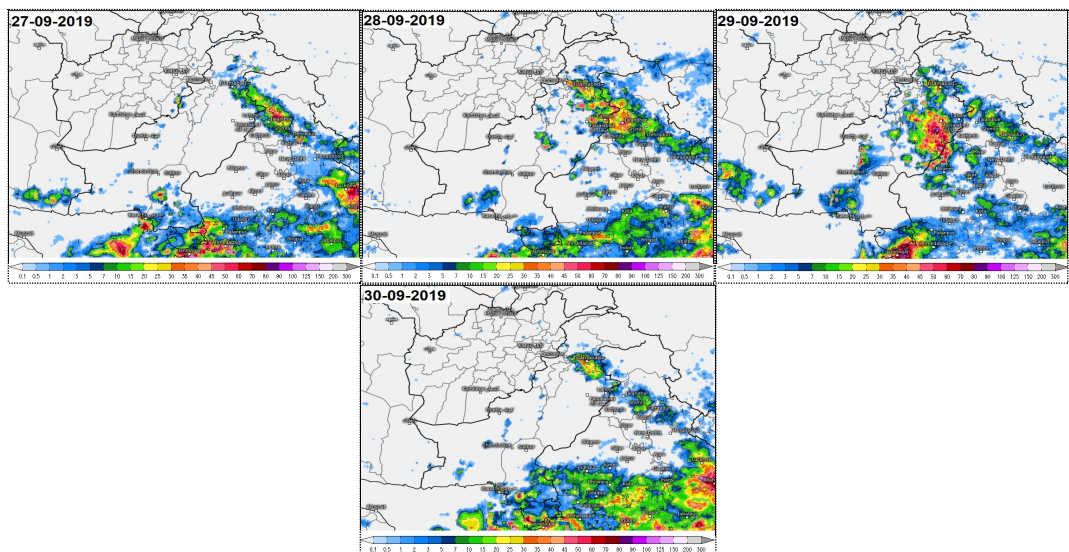


Figure 39: Satellites Images during the spell of September 27<sup>th</sup> to 30<sup>th</sup> September 2019.

Figure 40 shows the spatial distribution of significant rainfall of more than 100 mm recorded over Islamabad & Northeast Punjab. Another two maximum of more than 60 mm rainfall was observed over Muzaffarabad & Lahore Division.

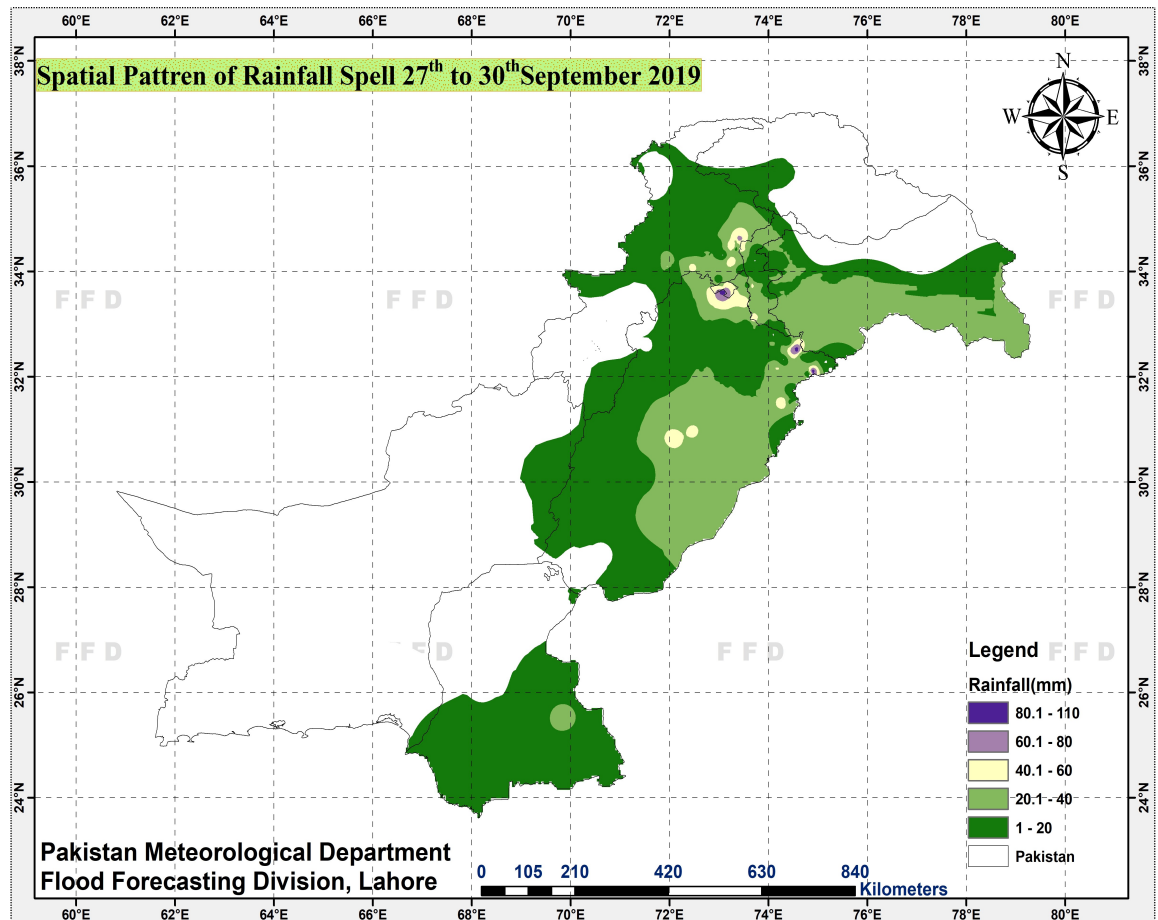


Figure 40: Spatial distribution of significant rainfall map of 27<sup>th</sup> to 30<sup>th</sup> September 2019.

#### 5.4 Rivers position during the second spell of September-2019

No Significant flood peak was observed during the spell in any major rivers.

#### 5.5 Rivers position during the month of September-2019

Flood peaks recorded during September 2019 are shown in Table 4

Table 4: Maximum peaks recorded during September 2019

Rivers	Stations	Peaks Inflows	Date	Flood level
Ravi	Balloki	52.1	2/9/2019	Low
Ravi	Balloki	50.2	7/9/2019	Low

## 5.6 Hydrographs recorded during the month of September 2019 are as below

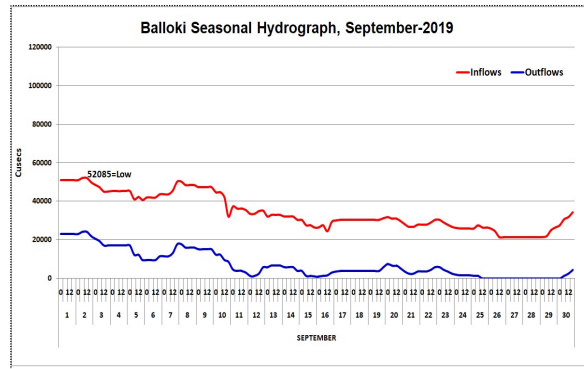


Figure 41: Hydrographs for the month of September-2019.

## 5.7 Spatial distribution of rainfall during the month of September 2019

The precipitation during the month of August is shown in figure 42, it indicates monsoon activity remained over North & Northeast Punjab and Kashmir along with Southeast Sindh. One center of maximum rainfall exceeding 225 mm is located at Indian Gujarat while more than 120 mm recorded at Mithi in Southeast Sindh. More than 210 mm of rainfall was also observed at Islamabad. While maxima of above 100 mm are located around Kashmir & Northeast Punjab. West Balochistan remained dry during the month.

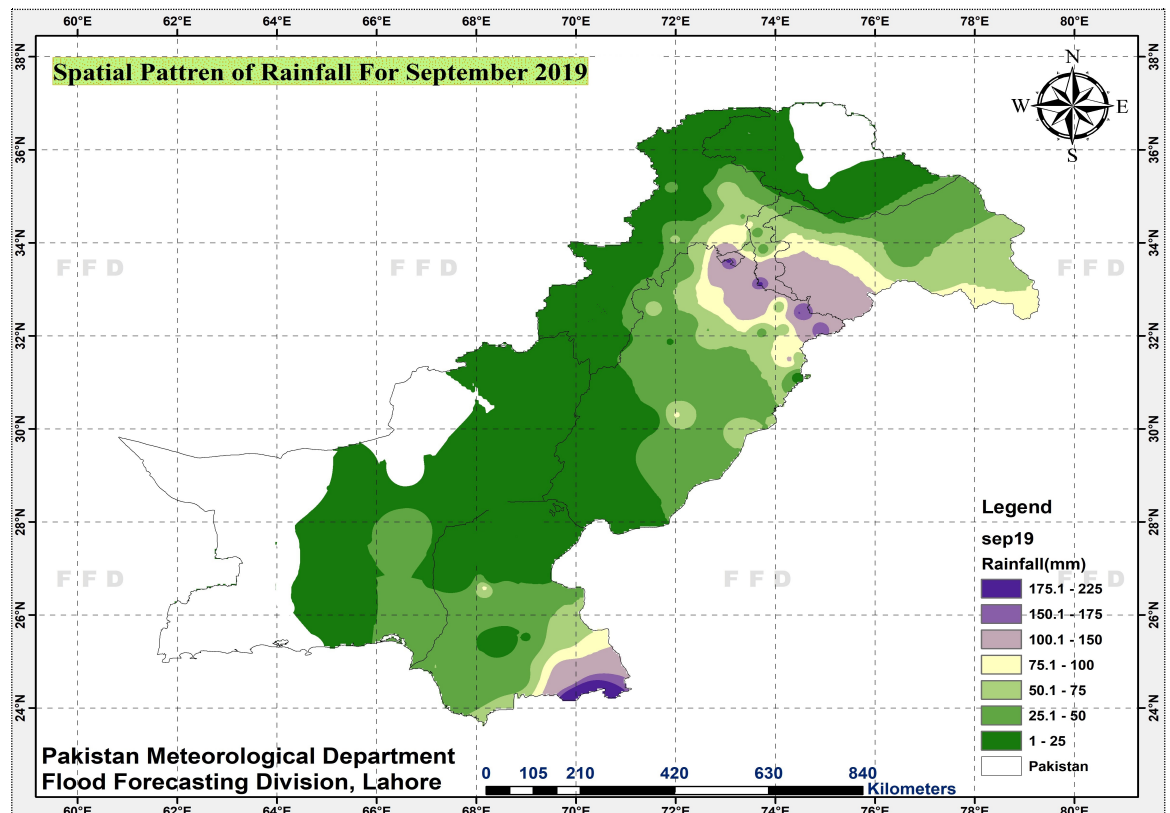


Figure 42: Spatial distribution of significant rainfall map of September 2019.

### 5.8 Percentage Anomaly during the month of September 2019

Percentage Anomaly map for the month of September 2019 indicates that Sindh & East Balochistan received above normal Rainfall. Normal rainfall received in Punjab & Kashmir while most parts of Khyber Pakhtunkhwa, Gilgit Baltistan, Northeast Balochistan received below normal rainfall. Percentage Anomaly map of August 2019 is shown in Figure 43.

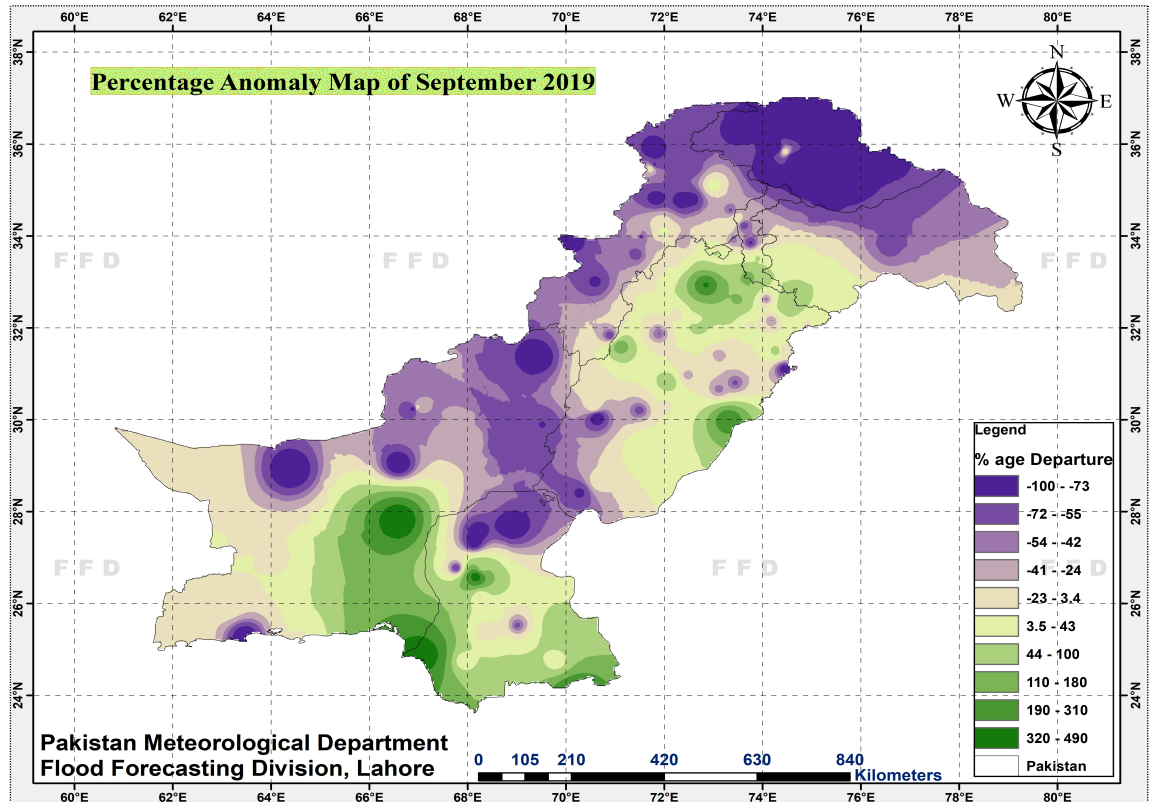


Figure 43: Percentage Anomaly rainfall map of September 2019.

### 5.9 Temporal Distribution during the month of September 2019

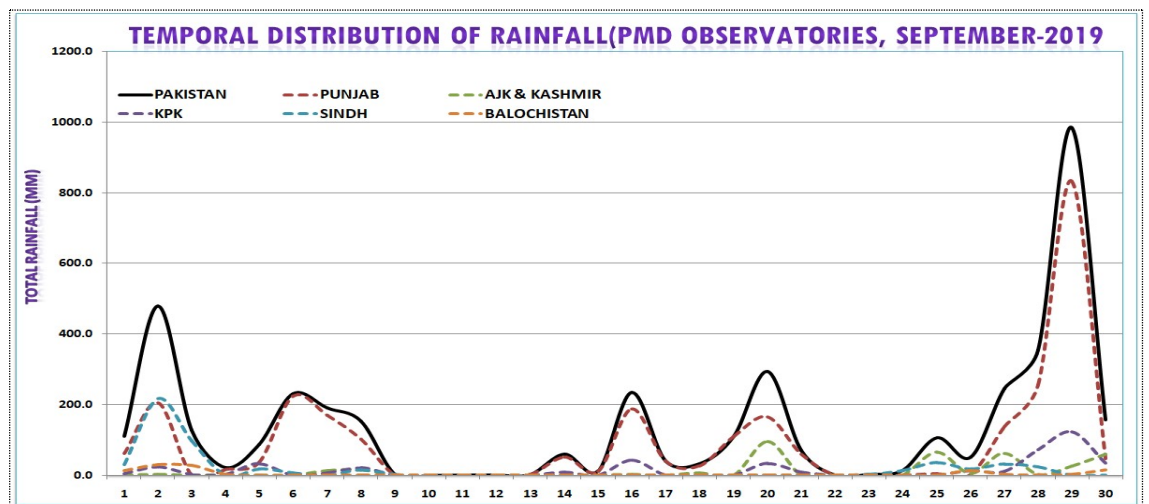


Figure 44: Temporal distribution of rainfall during September 2019.

## 6 Seasonal rainfall pattern July to September 2019

Seasonal rainfall distribution during the season is shown in figure 45. Region of maximum precipitation (more than 1000 mm) is located over Sialkot in Northeast Punjab. Another center of extreme rainfall of more than 800 mm is located over Islamabad. South Sindh received around 500 mm while West Balochistan remained almost dry during the season.

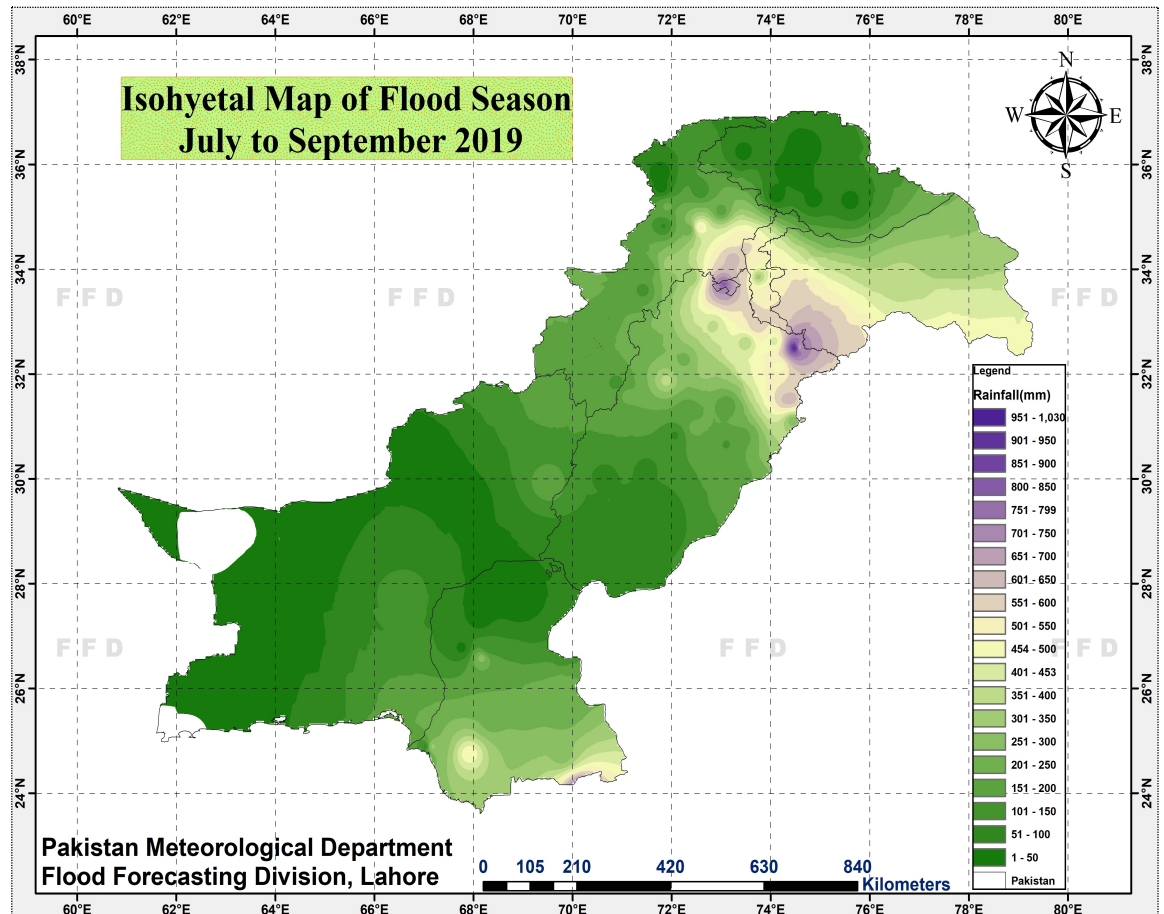


Figure 45: Spatial distribution of significant rainfall map of July-September 2019.

### 6.1 Percentage Anomaly during the Season July-September 2019

Percentage Anomaly map for the months of July-September 2019 indicates that South Sindh, Coastal Balochistan, Northeast Punjab, Sargodha Division received above normal Rainfall while most parts of Khyber Pakhtunkhwa, West & Northeast Balochistan, Gilgit Baltistan & Kashmir received below normal rainfall. Percentage Anomaly map of July-September 2019 is shown in Figure 46.

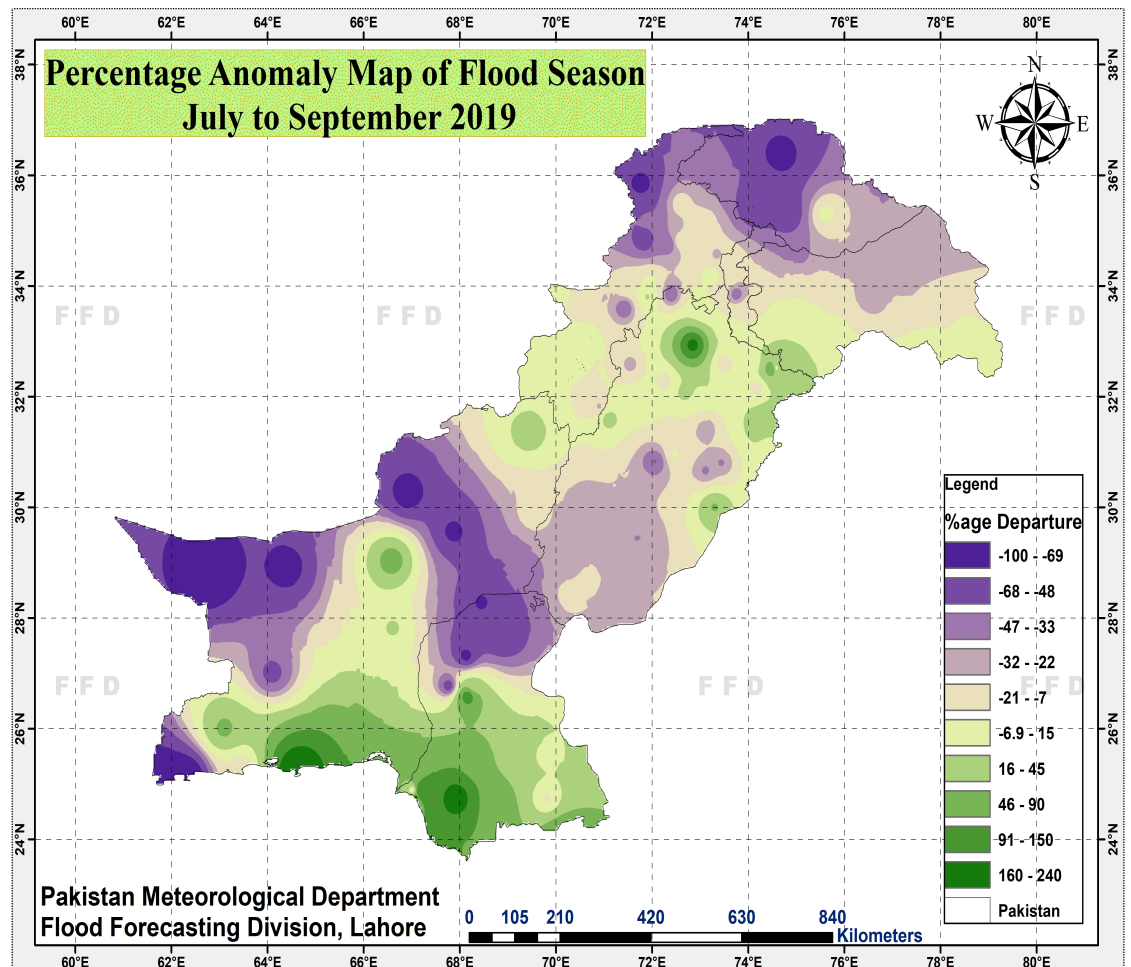


Figure 46: Percentage Anomaly rainfall map for Season July-September 2019.

## 7 Seasonal area weighted precipitation from July-September 2019

The seasonal percentage departure precipitation map obtained from Climate Data Processing Centre (CDPC) of Pakistan Meteorological Department for monsoon season 2019 indicates that close to normal (0 %) rainfall was recorded during monsoon (JAS) 2019 season over the country. On regional scale, the seasonal rainfall was above normal over Sindh province, largely deficient over Gilgit Baltistan (-24%), Kashmir (-22%), Khyber Pakhtunkhwa (-14%) and slightly below normal over Punjab (-5%) & Balochistan (-4%). In July 2019, close to normal (-8%) rainfall was observed over the country.

On provincial scale, In the month of July 2019 below normal rainfall was recorded over Kashmir, Balochistan, Khyber Pakhtunkhwa and close to normal over Punjab whereas above normal over Sindh.

In, August 2019, close to normal (+3%) rainfall was recorded over country and above normal rainfall was observed over GB & Sindh; blow normal over Kashmir & Punjab and close to normal over Balochistan & Khyber Pakhtunkhwa.

In September 2019, slightly above normal (+15%) rainfall was recorded over country. On provincial scale, above-normal rainfall was observed over Sindh, Punjab & normal over Kashmir, Balochistan & Khyber Pakhtunkhwa map as shown in figures 47.

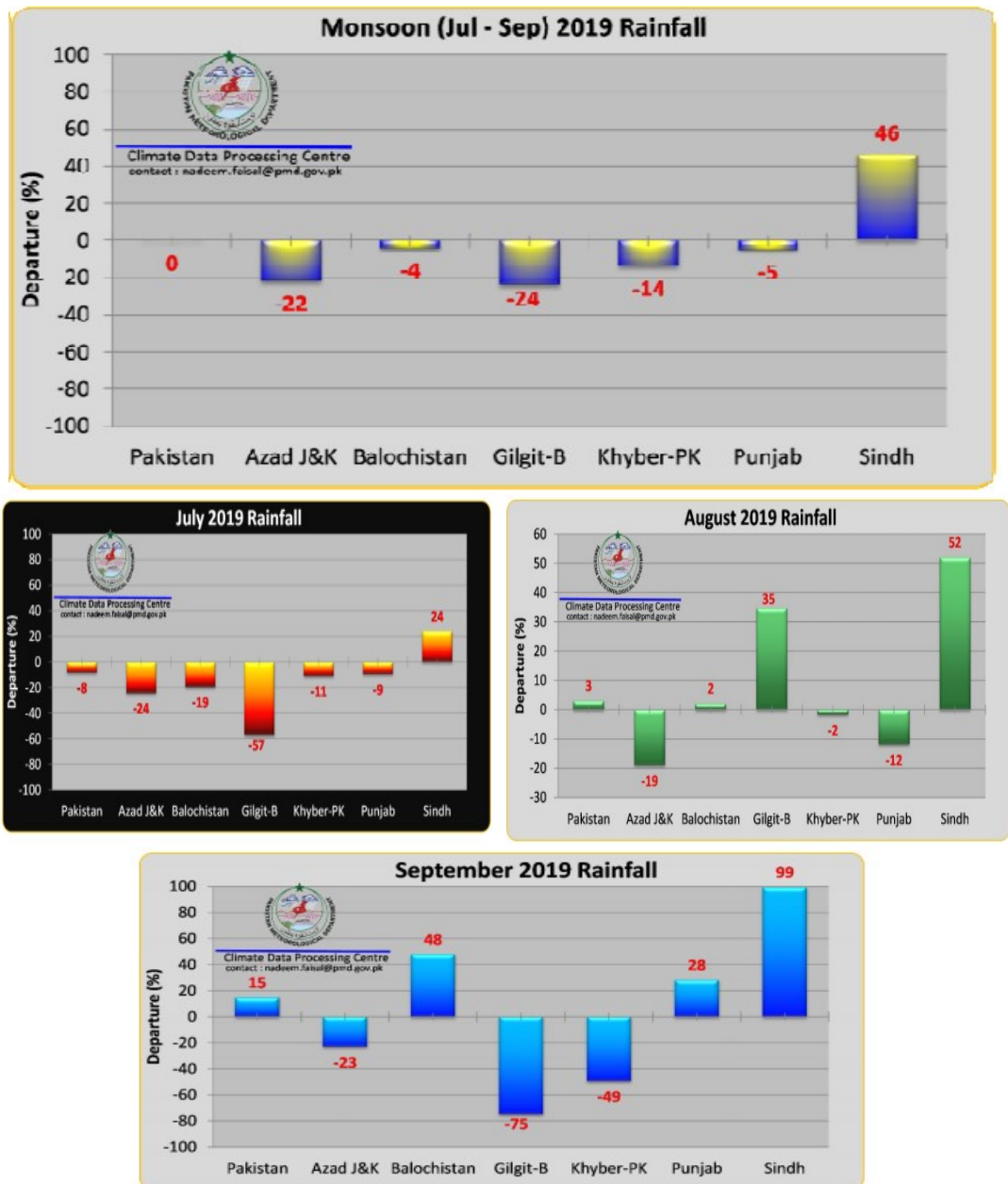


Figure 47: Monsoon July-Aug-Sept (JAS) 2019 rainfall.

Source: CDPC Karachi

## 8 Kharif season forecast

The water availability (MAF) forecast for Kharif season was issued on 01<sup>st</sup> April 2019 for Tarbela at River Indus & for Mangla at River Jhelum. A comparison of forecasted and observed volume (MAF) is shown in fig 48.

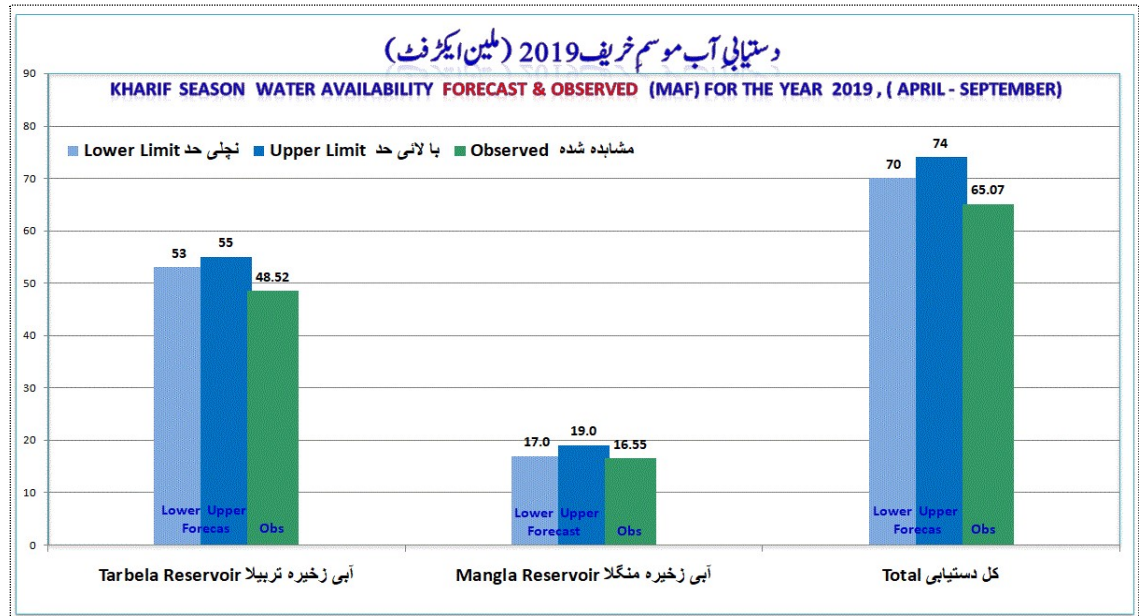


Figure 48: Kharif Season forecast & Observed MAF (April-September 2019).

## 9 Facilities Provided By FFD Lahore during the Flood Season

- Flood Forecasting Division Lahore provides semi-furnished accommodation facilities to the Police Tele Communication officers & officials in the office premises.
- Flood Forecasting Division Lahore has provided space & facilities to the Environmental Protection Department (EPD), Punjab to install their instruments to monitor air quality of Lahore.
- Sports facilities were also provided to the flood relating agencies working in FFD during the flood season.
- Flood Forecasting Division Lahore also provided facilities to media for live coverage regarding Flood/Weather events.

## 10 Flood forecast evaluation report

The Flood Forecast evaluation report for 2019 for all categories of floods is given in table 5.

Table 5: Flood forecast evaluation table

FLOOD SEASON-2019, FORECAST ACCURACY						
Rivers	Stations	Forecast	Observed	Date	Level	% Accuracy
Indus	Tarbela	260-300	252	6/7/2019	Low	97
Indus	Tarbela	270-300	284	12/7/2019	Low	100
Indus	Tarbela	290-300	308	15/7/2019	Low	97
Indus	Tarbela	240-260	254	18/7/2019	Low	100
Indus	Tarbela	300-320	310	28/7/2019	Low	100
Indus	Tarbela	310-350	334	2/8/2019	Low	100
Indus	Tarbela	290-330	287	7/8/2019	Low	99
Indus	Tarbela	260-290	308.3	10/8/2019	Low	94
Indus	Tarbela	310-340	315	12/8/2019	Low	100
Indus	Tarbela	300-350	311	16/8/2019	Low	100
Indus	Kalabagh	230-270	279.9	18/7/2019	Low	96
Indus	Kalabagh	300-310	310.1	30/7/2019	Low	100
Indus	Kalabagh	330-375	344.2	2/8/2019	Low	100
Indus	Kalabagh	300-310	321.1	8/8/2019	Low	97
Indus	Kalabagh	340-360	359.9	11/8/2019	Low	100
Indus	Kalabagh	360-375	361.8	15/8/2019	Low	100
Indus	Chashma	250-260	260.2	9/7/2019	Low	100
Indus	Chashma	230-250	261.4	24/7/2019	Low	96
Indus	Chashma	250-270	284.1	28/7/2019	Low	95
Indus	Chashma	300-320	323.8	31/7/2019	Low	99
Indus	Chashma	330-380	381.7	3/8/2019	Medium	99
Indus	Chashma	300-340	331.8	8/8/2019	Low	100
Indus	Chashma	370-385	388.5	15/8/2019	Medium	99
Indus	Taunsa	250-260	263.9	13/7/2019	Low	99
Indus	Taunsa	250-265	272.9	18/7/2019	Low	97
Indus	Taunsa	250-280	270.4	26/7/2019	Low	100
Indus	Taunsa	280-310	288.5	31/7/2019	Low	100
Indus	Taunsa	345-375	359.3	5/8/2019	Medium	100
Indus	Taunsa	360-390	390.4	15/8/2019	Medium	100
Indus	Guddu	230-240	242.4	19/7/2019	Low	99
Indus	Guddu	370-380	380.5	8/8/2019	Medium	100
Indus	Guddu	395-415	408.8	18/8/2019	Medium	100
Indus	Guddu	400-410	422.7	20/8/2019	Medium	97
Indus	Sukkur	200-210	201.8	31/7/2019	Low	100
Indus	Sukkur	330-360	330.9	12/8/2019	Low	100
Indus	Sukkur	350-365	364.6	22/8/2019	Medium	100
Jhelum	Mangla	55-75	87	9/7/2019	Low	84
Jhelum	Mangla	60-90	75	10/7/2019	Low	100
Jhelum	Mangla	80 R 160	75	25/7/2019	Low	94

Jhelum	Mangla	100-180	118.5	1/8/2019	Medium	100
Jhelum	Mangla	60-110	82	7/8/2019	Low	100
Jhelum	Mangla	60-110	128.8	14/8/2019	Medium	83
Jhelum	Mangla	40-70	80	17/8/2019	Low	86
Jhelum	Rasul	100-120	112.6	19/6/2019	Medium	100
Jhelum	Rasul	100-105	111.6	26/6/2019	Medium	94
Chenab	Marala	100 R 250	151.9	25/7/2019	Medium	100
Chenab	Marala	90-130	136.9	29/7/2019	Low	95
Chenab	Marala	130 R 220	219	31/7/2019	High	100
Chenab	Marala	130-210	164.7	7/8/2019	Medium	100
Chenab	Marala	90-130	137.9	10/8/2019	Low	95
Chenab	Marala	80-110	121.8	11/8/2019	Low	90
Chenab	Marala	100-150	121.8	13/8/2019	Low	100
Chenab	Marala	100 R 170	164.6	14/8/2019	Medium	100
Chenab	Marala	100-170	180.6	17/8/2019	Medium	95
Chenab	Marala	100-150	130.6	19/8/2019	Low	100
Chenab	Khanki	60 R 240	100.3	26/7/2019	Low	100
Chenab	Khanki	90-130	113.5	29/7/2019	Low	100
Chenab	Khanki	90 R 210	169.4	31/7/2019	Medium	100
Chenab	Khanki	70-150	136.7	8/8/2019	Low	100
Chenab	Khanki	100 R 150	136.3	15/8/2019	Low	100
Chenab	Khanki	100-150	111.1	18/8/2019	Low	100
Chenab	Qadirabad	80 R 200	122.1	31/7/2019	Low	100
Chenab	Qadirabad	70-100	131.6	8/8/2019	Low	70
Chenab	Qadirabad	90-130	131.9	15/8/2019	Low	99
Sutlej	GS Wala	55-90	60.3	22/8/2019	Low	100
Sutlej	GS Wala	50-60	58.9	24/8/2019	Low	100
Sutlej	Sulemanki	40-50	58.2	23/8/2019	Low	84
Sutlej	Sulemanki	55-70	66.5	24/8/2019	Low	100
Sutlej	Sulemanki	45.57	57.9	26/8/2019	Low	100
Sutlej	Islam	45.55	54.1	31/8/2019	Low	100
Ravi	Jassar	10-35	51	18/8/2019	Low	70
Ravi	Balloki	40-50	52.1	2/9/2019	Low	96
Ravi	Balloki	40-45	50.2	7/9/2019	Low	90
Kabul	Nowshera	65-75	81.3	25/6/2019	Medium	92
Kabul	Nowshera	100-175	105	29/7/2019	Medium	100
Kabul	Nowshera	70-90	85.6	11/8/2019	Medium	100

The overall accuracy of the forecast issued by FFD, Lahore during the flood season 2019 has been calculated which shows a good **90.5%** against all odds.

## 11 Flow chart of daily routine work at FFD Lahore

The website (<http://ffd.pmd.gov.pk/cp/ffd.php>) is maintained by FFD Lahore and is updated regularly. This is a source of real-time information to all the stakeholders, concerned authorities, organizations and individuals.

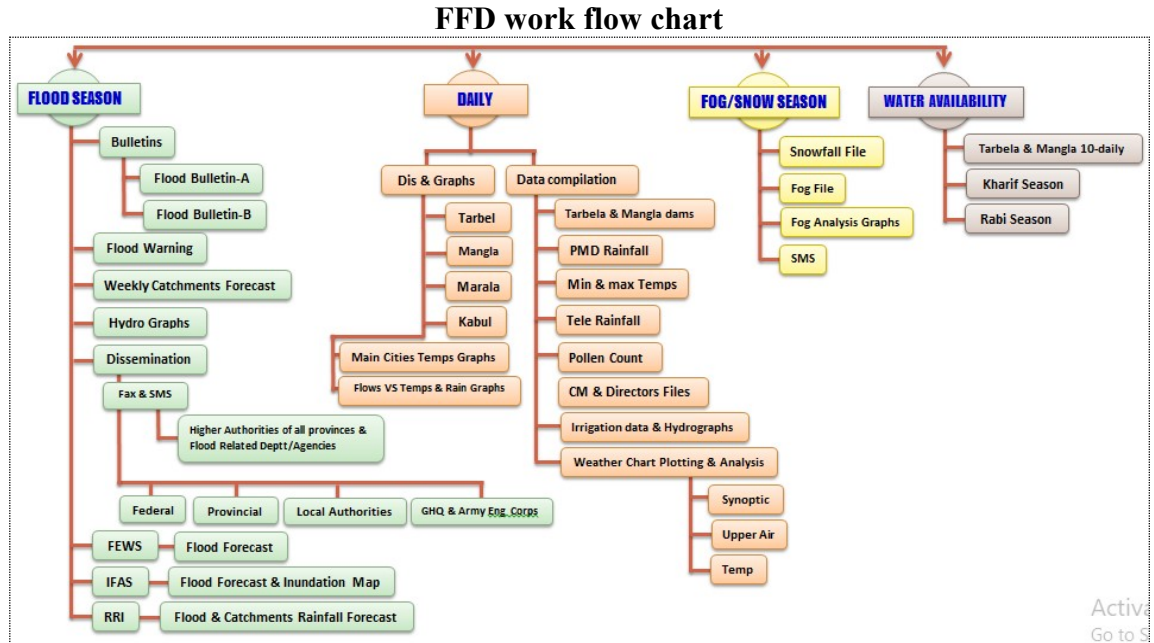


Figure 49: FFD Lahore work flow chart.

Sr#	Work	Time Interval
1	Flood Bulletins A & B	Updated daily
2	Weekly Catchment Forecast	Updated daily
3	Flood Warning	When required
4	Inundation Map	When required
5	FEWS Model Forecast	Twice a day & when required
6	IFAS Model Forecast	Updated daily & when required
7	RRI Model Forecast	Updated daily & when required
8	Hydrographs	Hourly & six-hourly basis
9	Discharge file (Tarbela & Mangla Dams)	Updated daily
10	Discharges Graphs (Tarbela, Mangla, Marala & Kabul)	Updated daily
11	Flows VS Temps & Rain Graphs	Updated daily
12	PMD Rainfall data	Updated daily
13	Temperatures data	Updated daily
14	Main Cities Temperature Graphs	Updated daily
15	WAPDA Telemetric Rainfall	Updated daily
16	MAF Forecast (Tarbela & Mangla Dams)	10-day basis
17	Kharif MAF Forecast (Tarbela & Mangla Dams)	Six monthly basis
18	Rabi MAF Forecast (Tarbela & Mangla Dams)	Six monthly basis
19	Pollen Count for Lahore City	Updated daily
20	Fax	Daily & when required
21	SMS	Hourly & six hourly basis & when required

## 12 Flood Forecast Dissemination

Dissemination of flood forecasts and warnings is an important part of flood mitigation. Flood information is communicated on daily basis by using different modes of communication i.e phone, fax and cellular networks. Electronic versions of daily flood forecasts are also available to different agencies and organizations. This is also made a part of FFD web page. To ensure that flood forecast is disseminated to the right person at the right time, contact numbers are also collected and verified during pre-flood season.

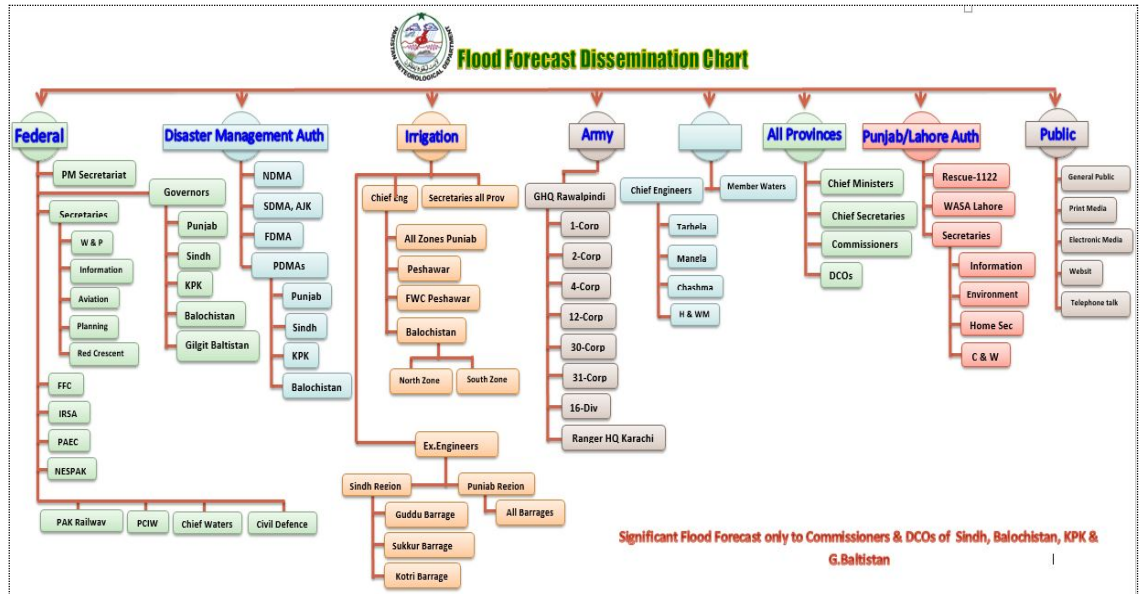










Figure 50: Flood report dissemination chart.

## 13 Internship at Flood Forecasting Division Lahore

FFD Lahore offers an Internship program for the young students of different Universities & Colleges providing a hands-on opportunity to work in the field of Meteorology, Hydrology, Seismology, GIS and Weather Radar. They can learn how theory applies in the practical field and also provides a valuable experience which makes them a strong candidate in practical life. The chart of internee students during 2019 is shown in table 6. More detail for internees can be followed on this link:

Table 6: List of internees

University/College		Students
	Punjab University Lahore	40
	Lahore College for Women University, Lahore	44
	Kinnaird College for Women, Lahore	07
	University of Agricultural, Faisalabad	01
	University of Engineering & Technology Lahore	01
	Govt College University Lahore	06
	Postgraduate College for Women, Samanabad Lahore	02
	Balochistan University of Information technology, Engineering & Management Sciences, Quetta	02

#### 14 Monsoon Season 2019 Damages/Losses

No of Deaths, Injured Persons and Houses Damaged during the Flood 2019 are shown in table 7.

Table 7: Flood forecast evaluation table

Provinces	Deaths				Injured			
	M	F	C	T	M	F	C	T
ICT	-	1	1	2	-	-	-	-
Punjab	18	5	7	30	43	-	-	43
KP	25	16	37	78	42	12	15	69
Sindh	34	7	22	63*	9	4	4	17*
Balochistan	5	1	6	12	4	-	6	10
GB	6	1	1	8	8	2	2	12
AJ&K	19	16	7	42	14	4	-	18
<b>TOTAL</b>	<b>107</b>	<b>47</b>	<b>81</b>	<b>235</b>	<b>120</b>	<b>22</b>	<b>27</b>	<b>169</b>

Source: FFC Islamabad

**15 Flood limits (in Lacs of cusecs):**

Table 8: Flood limits

River	Site	Design Capacity	Low	Med	High	V.high	Ex.high
Kabul	Nowshera	-	0.45	0.80	1.4	2.0	4.0
	Warsak	15.0	0.30	0.45	1.0	2.0	4.0
Indus	Tarbela	15.0	2.5	3.75	5.0	6.5	8.0
	Attock	-	2.5	3.75	5.0	6.5	8.0
	Kalabagh	9.5	2.5	3.75	5.0	6.5	8.0
	Chashma	9.5	2.5	3.75	5.0	6.5	8.0
	Taunsa	10.0	2.5	3.75	5.0	6.5	8.0
	Guddu	12.0	2.0	3.5	5.0	7.0	9.0
	Sukkur	9.0	2.0	3.5	5.0	7.0	9.0
	Kotri	8.5	2.0	3.0	4.5	6.5	8.0
Jhelum	Kohala	-	1.0	1.5	2.0	3.0	4.0
	Mangla	10.6	0.75	1.1	1.5	2.25	3.0
	Rasul	8.5	0.75	1.1	1.5	2.25	3.0
Chenab	Marala	11.0	1.0	1.5	2.0	4.0	6.0
	Khanki	8.0	1.0	1.5	2.0	4.0	6.0
	Qadirabad	8.07	1.0	1.5	2.0	4.0	6.0
	Trimmu	6.45	1.5	2.0	3.0	4.5	6.0
	Panjnad	7.0	1.5	2.0	3.0	4.5	6.0
Ravi	Jassar	2.75	0.5	0.75	1.0	1.5	2.0
	Ravi syphon	4.5	0.4	0.65	0.9	1.35	1.8
	Shahdra	2.5	0.4	0.65	0.9	1.35	1.8
	Balloki	2.25	0.4	0.65	0.9	1.35	1.8
	Sidhnai	1.5	0.3	0.46	0.6	0.9	1.3
Sutlej	Sulemanki	3.25	0.5	0.8	1.2	1.75	2.25
	Islam	3.0	0.5	0.8	1.2	1.75	2.25

### 16 Time Lag

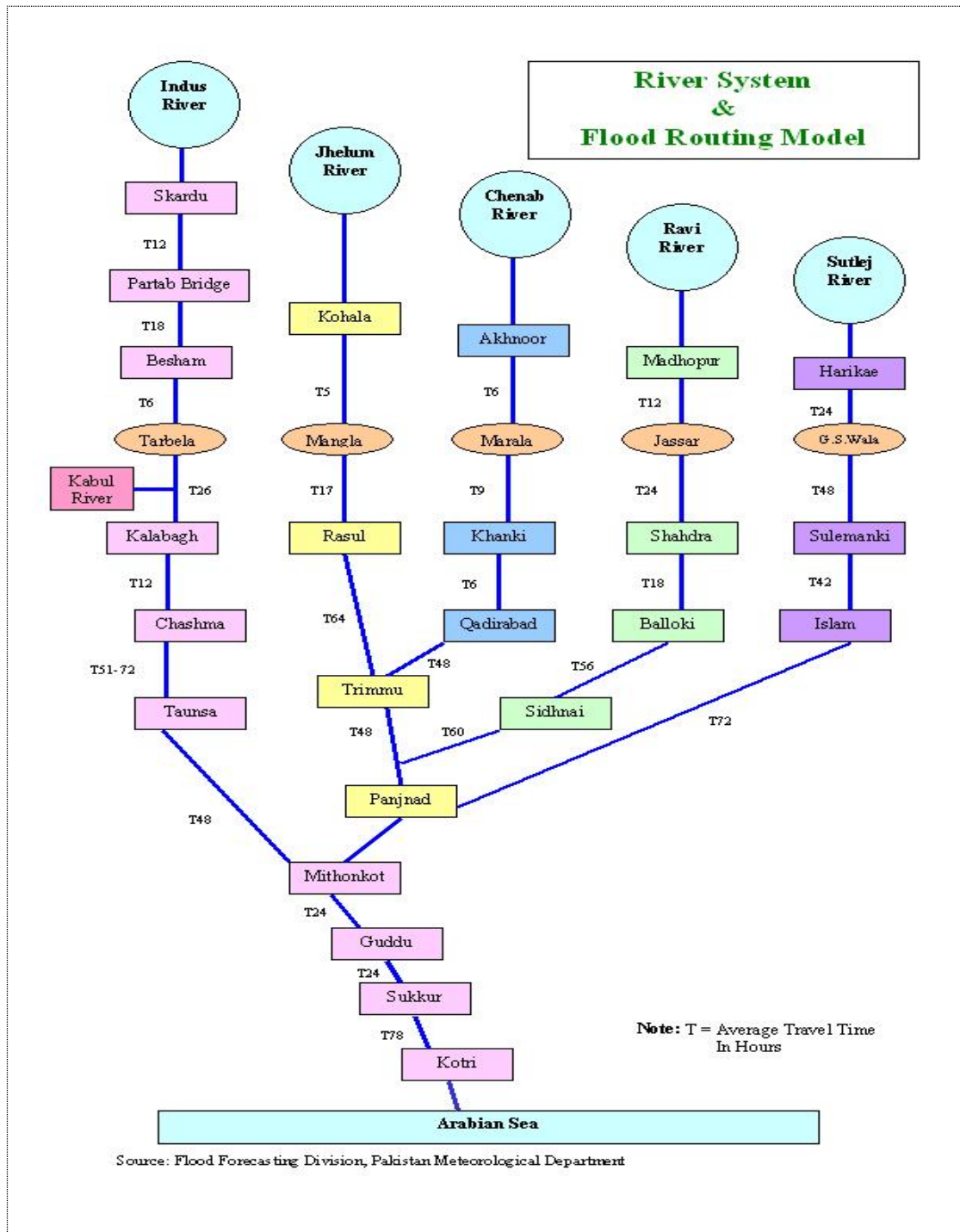
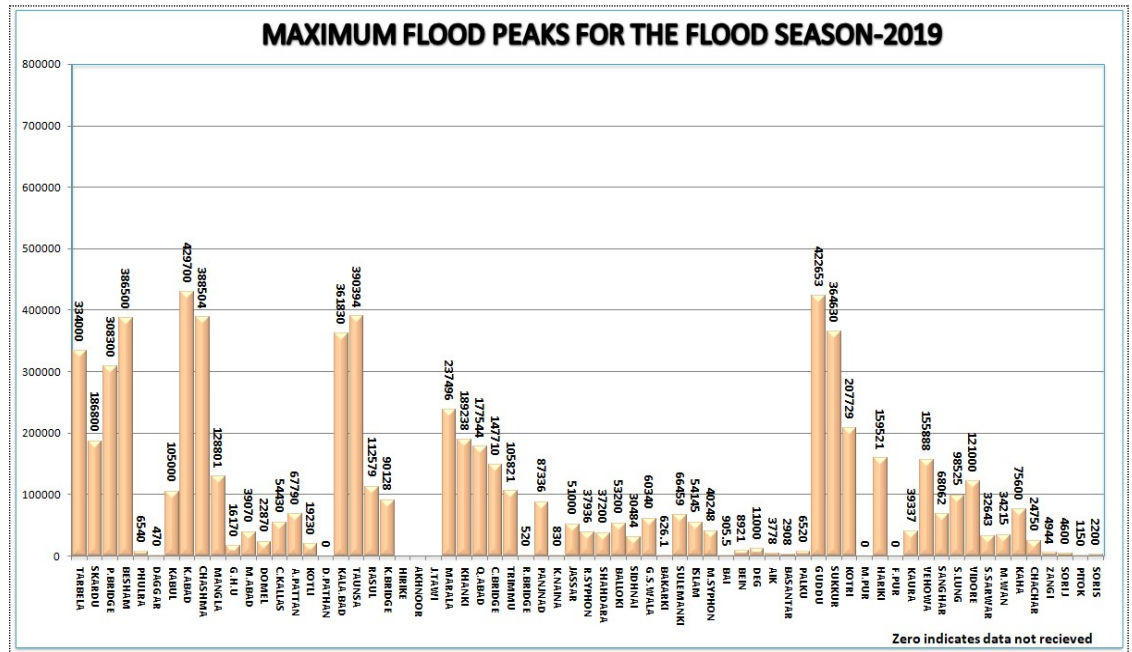
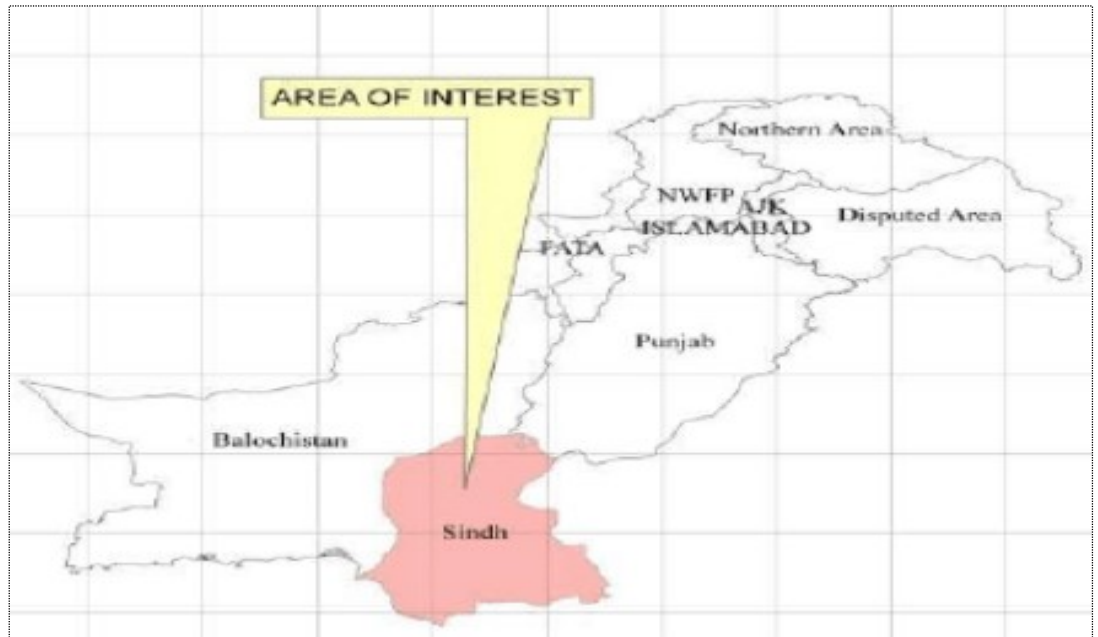


Figure 51: Time Lag

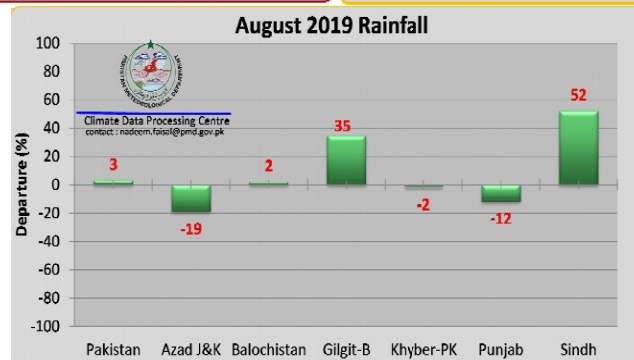
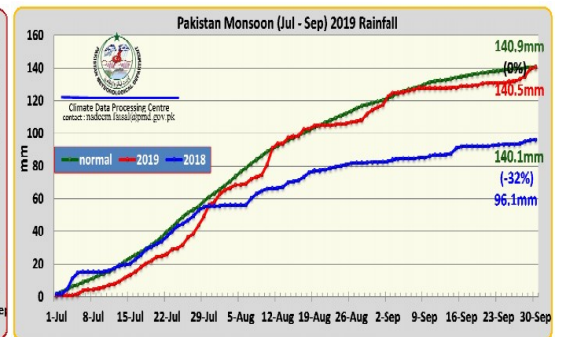
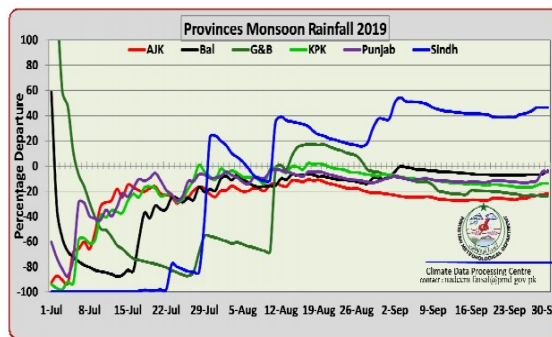
## 17 Maximum Flood Peaks Discharge during Flood Season-2019.

Maximum Flood Peaks recorded during Flood Season-2019 is shown below





Source: Cheema, S. B., Q. Zaman, and G. Rasul. "Persistent heavy downpour in desert areas of Pakistan in South Asian Monsoon 2011." Pakistan Journal of Meteorology 9.17 (2012). The following graphs are showing the monsoon comparison with normals at the province and national level. The overall monsoon 2019 rainfall remains normal. However, the Sindh province received about 50% above normal.



Source: CDPC-PMD

## 19 Monsoon and Uncertainties

Southwest Monsoon is a synoptic-scale weather pattern that covers south Asia and adjacent areas from June to September. The seasonal prediction of monsoon depends on various climatic factors and teleconnection around the globe, like

ENSO (El Niño Southern Oscillation)

IOD (Indian Ocean Dipole)

MJO (Madden-Julian Oscillation)

NAO (North Atlantic Oscillation)

SOI (Southern Oscillation Index)

Sea-Surface Temperatures

Climate Change Impact, etc.

All these global phenomenon have uncertainties in prediction and impacts. So, prediction over a season invariably involved dealing with uncertainty and unrealistic detail of GLOBAL climate affecting factors. These factors and climate circumstances occur because seasonal anomalies are fast-changing in nature. As a result, we have uncertainties in the seasonal forecast all around the world. These uncertainties maybe amplified when the complex climate system like monsoon need to be predicted.

### **Major reasons for above-normal rainfall in Sindh and failure in prediction**

Initial analysis suggest that the climatic models did not well capture the variability in the Positive phase of Indian Ocean Dipole and above normal sea surface temperature in north Arabian-Sea. Similarly, ENSO transition from weak to normal was also not well predicted.

Therefore, we can say that among various climatic factors, the most prominent are fast changes in IOD and ENSO conditions and its linkage with the monsoon in Sindh is not well captured by the climatic models. Similarly, there are also large uncertainties in the Sea surface temperature prediction from various models and a method has to be developed to incorporate these uncertainties while making seasonal predictions using prescribed SSTs.

Besides model performance and climatic complexities, the monsoon prediction in Sindh is also difficult due to the complex land-sea interaction. The same chaotic monsoon prediction is observed in India, where the model underestimates more than 40% rainfall in the adjacent region of Sindh Province.

Moreover, the global models use for monsoon prediction are not specialized for the Pakistan region; many studies support the idea of dealing the monsoon in Pakistan separately from southwest monsoon in the whole region.

## **20 Above Normal Rainfall During Monsoon 2019, a short Review.**

### **Introduction**

PMD issued the seasonal monsoon forecast on 17th of July 2019, as below,

“Most of the global models are indicating weak El-Nino conditions over the Pacific Ocean and the positive phase of the Indian Ocean Dipole (IOD). Keeping in view, global and regional atmospheric circulations, following is the monsoon weather outlook for the year 2019.

- Ø Rainfall over the country as a whole for monsoon, 2019 (July-Sep), is likely to remain near Normal.
- Ø Normal to above normal rainfall is expected in the upper half of Pakistan due to the strong incursion of monsoon currents and their interaction with the westerly weather system. The extreme weather event is also expected during the period and may cause flooding in the rivers and its adjoining tributaries.
- Ø Slight to moderate, below normal rainfall is expected in the provinces of Sindh and Balochistan.
- Ø Average temperature is likely to remain 2-3 oC above normal in the plain areas of the country.”



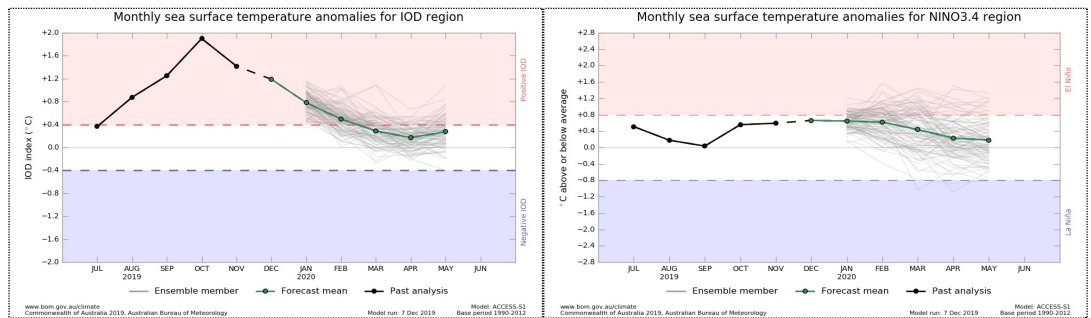
Overall, the seasonal forecast is in good agreement with the actual rainfall. However, the monsoon rainfall recorded in Sindh is about 40% above normal. Similarly, the rainfall in AJK and Gilgit-Baltistan was recorded more than 20% below normal. The rainfall anomaly in Sindh was prompt and also caused urban flooding as well.

In this study, we have tried to find the seasonal monsoon anomaly in the forecast for the Sindh region. However, before discussing the global phenomenon, which could possibly affect the monsoon regime, one should also consider the rainfall normal's values in Sindh and the frequency of extreme weather events due to climate change or so-called global warming. Similarly, the small quantitative change in rainfall amount could cause greater variation when compare with the normal rainfall values.

Several studies ((Ashok *et al.*, 2004; Mahmood, Khan and Faisal, 2004; Ashok and Saji, 2015)) emphasize the importance of ENSO and IOD relationship with the Southwest summer monsoon but only a few of them describe their impact on Pakistan region.(Ahmad *et al.*, 2014). It is important to understand the monsoon rainfall distribution at the regional level and its variation due to so-called global warming/climate change. This study will only review and analyses the relevant literature, including limited data, to give a future research direction and about the

rainfall anomalies, as mention above. It is also worth to mention that this assignment carried out in limited time.

The seasonal forecast is based on the complex algorithms (equations) and these complexities become more uncertain when considering the forced convective systems like summer monsoon under climate change scenarios. Therefore, the climate forecast may not be accurate or in line with the prevailing global meteorological conditions(Dam, 2003). The prevailing conditions of IOD and ENSO during the summer monsoon 2019 are given below



These conditions show the strong IOD during summer monsoon with very weak El-Nino. The ENSO and IOD impact over Pakistan rainfall is not well established(Shi and Wang, 2019). However, strong El-Nino suppresses the rainfall while Strong positive IOD enhances the monsoon activity in the southern Pakistan region(Mahmood *et al.*, 2006; Ashok and N H Saji, 2007; Iqbal and Hassan, 2018). Further, the ENSO index is negatively correlated with summer monsoon and positively with IOD rainfall in most parts of the southwest monsoon regime. There is no sufficient supporting evidence/research found for the Pakistan region(Ashok and N. H. Saji, 2007).

By considering the literature review, IOD and ENSO conditions along with literature review and regional monsoon patterns. We can conclude that the southwest monsoon strength increased due to a strong positive IOD phase with warming trends in the Arabian sea under the weak ENSO conditions. The same results are also supported by (Anderson, Overpeck and Gupta, 2002; Kim et al., 2019). Future research should continue focusing on revealing the possible causes of the rainfall anomalies in Pakistan during monsoon due to IOD, ENSO and climate change. Similarly, the failure of seasonal forecast is the subject of seasonal model bias evaluation or sensitivity analysis.