PAKISTAN METEOROLOGICAL DEPARTMENT

Heavy Rains and Urban Flooding in Sindh, Pakistan

A diagnostic study and future projections of precipitation characteristics

Contents

SUMMARY

The increase in sea surface temperature trends in the Arabian sea and Indian ocean is obvious during the last decade. This year, the northern Arabian Sea was up to 2-3°C warmer than usual in August. This makes the air above warmer, humid and unstable. This causes a huge amount of moisture to be available along with the coastal areas of Pakistan. This moisture further coupled with the low-pressure areas of the Bay of Bengal and the western disturbances, and that triggered the heavy precipitation in coastal and other regions of Pakistan.

From the detailed analysis of vertical profile of different diagnostic variables like geopotential height, wind vectors, moisture transport, absolute Vorticity, following conclusions have been deduced that caused massive urban flooding in Karachi:

i. During the events, a westerly trough was moving towards Pakistan at mid-tropospheric level.
ii. The combined effect of westerly trough and monsoon circulation attracted moisture from relatively warmer Arabian Sea region, and generated intense rains towards Pakistan coast during the event.
iii. Positive vorticity may cause the large-scale convergence.
iv. Vertically integrated moisture convergence / divergence was strong that converged moisture towards the region.

Description of August 2020 Rainfall Events:

An intense multiday rainfall over Karachi Pakistan has been observed in first and last week of August, 2020 and associated unprecedented urban flooding over the area caused causalities and heavy loss of property. Excessive rainfall occurred first week (6th to 9th) of August, 2020, the spell started from 6th August, 2020 and continued till 9th August, 2020. It is worth mentioning that maximum rainfall was received on 7th and 8th August, 2020 that was 67.9 and 40 mm/day. Second spell

started from 24th August till 28th August 2020. Maximum rainfall observed was on 28th August around 121.9 mm/day as shown in Figure 1. Total rainy days in this month were 16 and highest recorded rain was 121.9 mm/day.To investigate this unusual rainfall, analysis of different meteorological parameters has been done for these two events.

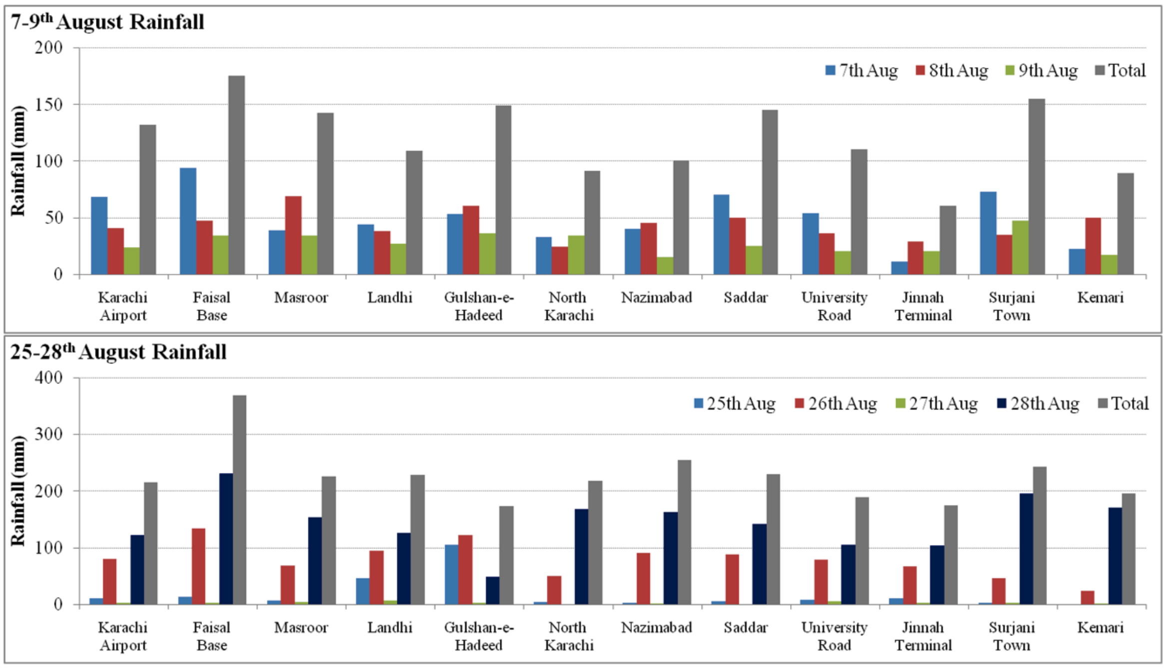


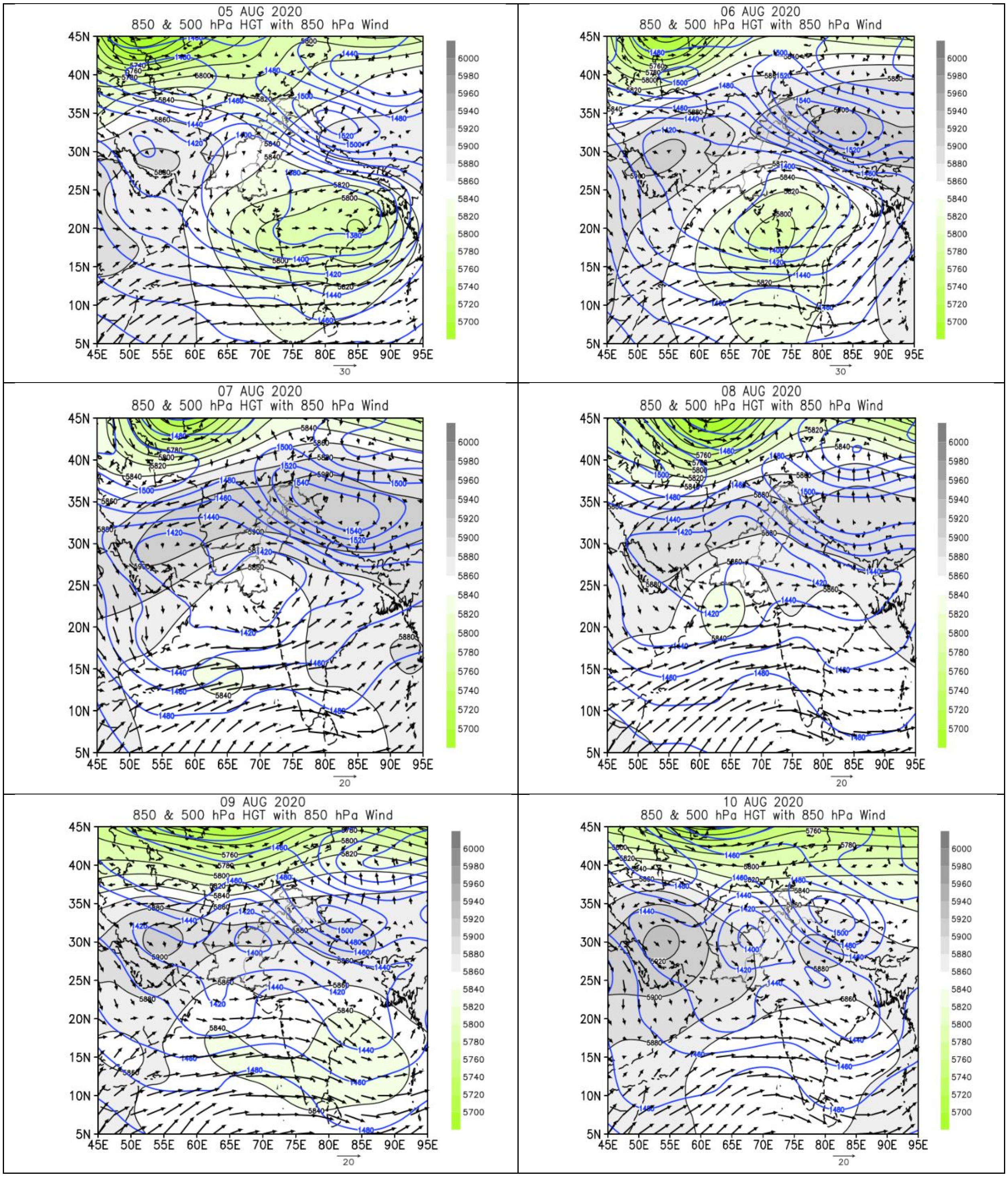
Figure 1: Observed Precipitation (mm/day) for Karachi Pakistan during (7-9th August 2020) and (24-25th August 2020).

Synoptic Condition and Spatial Distribution of Rainfall during August 2020

First Rainy Spell (7-10 August)

A low-pressure area developed over the Bay of Bengal on 3rd of August that turned into a well-marked low on the very next day. It moved towards west-northwestward and lay centred at Madhya Pradesh (India) on 5th August. It further moved westward merged with the cyclonic circulation over Gujrat and turned into well-marked low

on 6th August. On 7th August a cold wind from the north interacts with the approaching low. The low further moved towards westward and can be seen in the Arabian Sea in the charts below on 8th August.



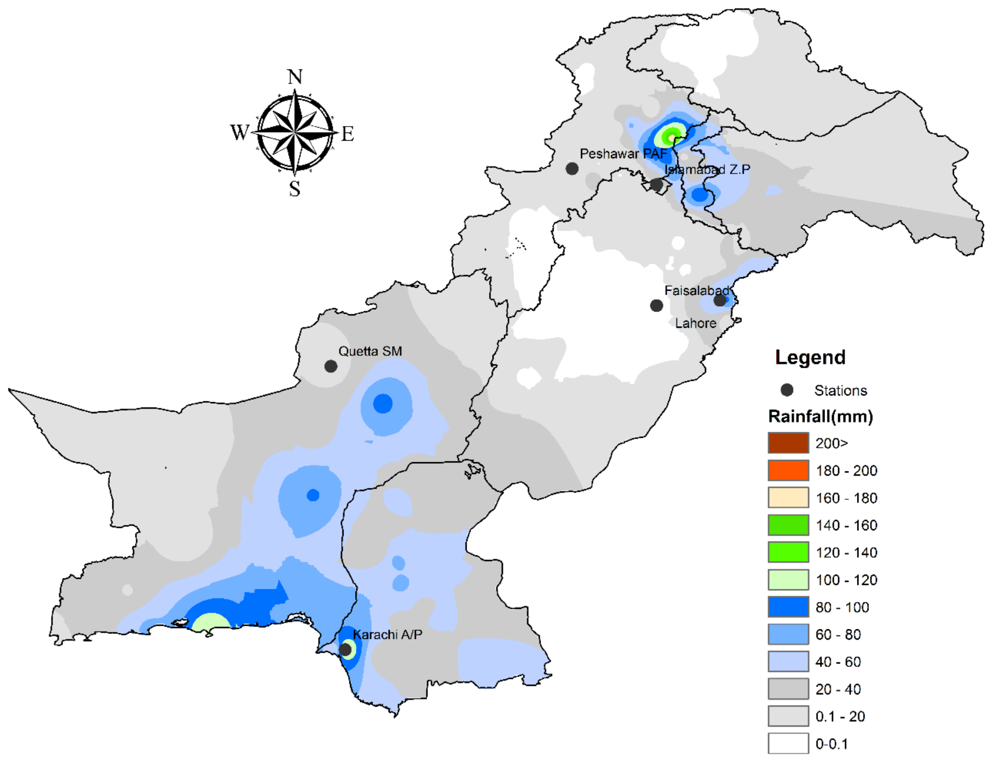


Figure 1 A spatial distribution of rainfall during the spell from 7th August to 10th August 2020

Figure 3 represents the rainfall output for Sindh from NCEP, FNL data (NOAA 2000). It shows maximum rainfall over Karachi on 7th August between 0000z and 1200z.

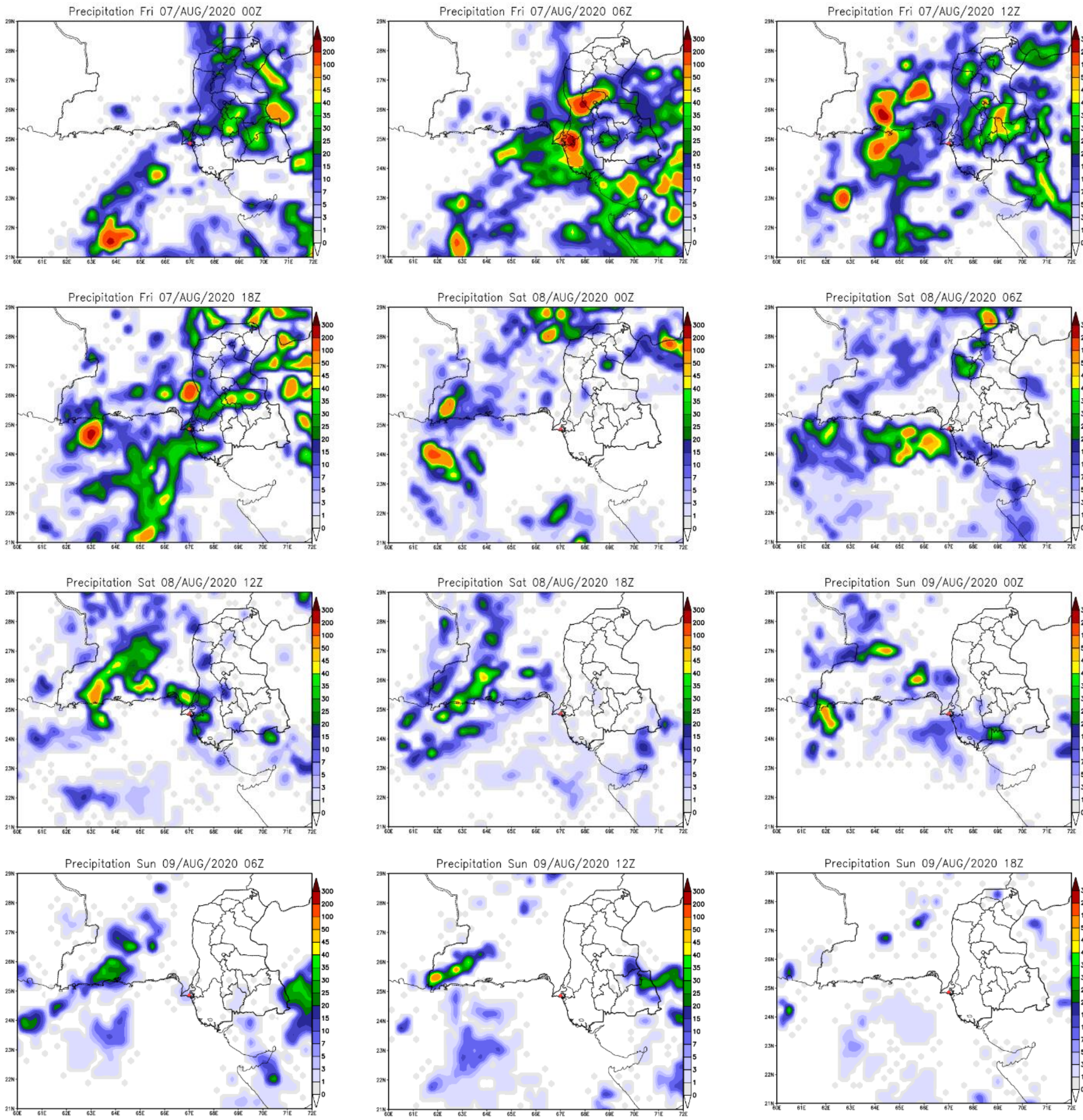
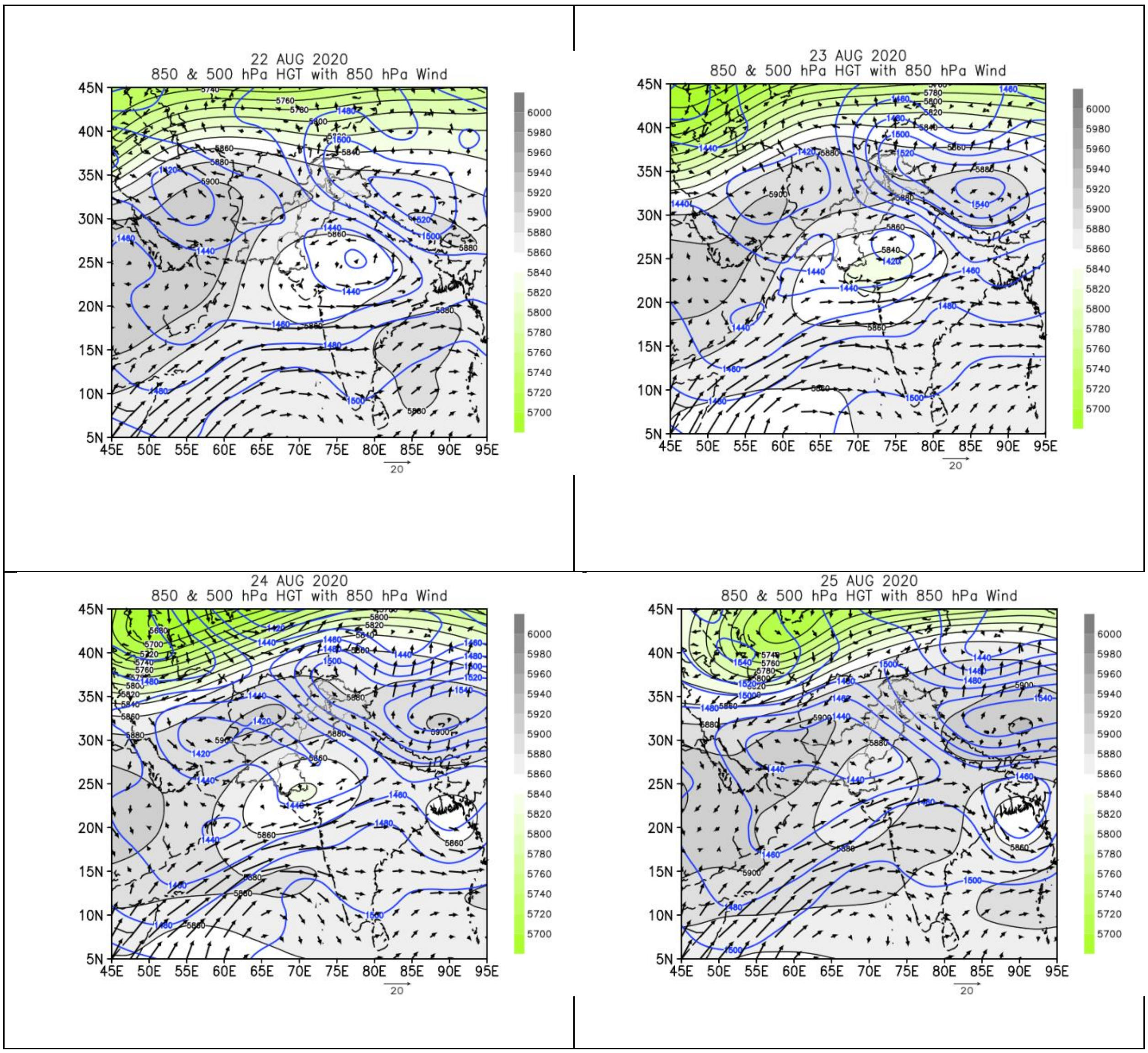
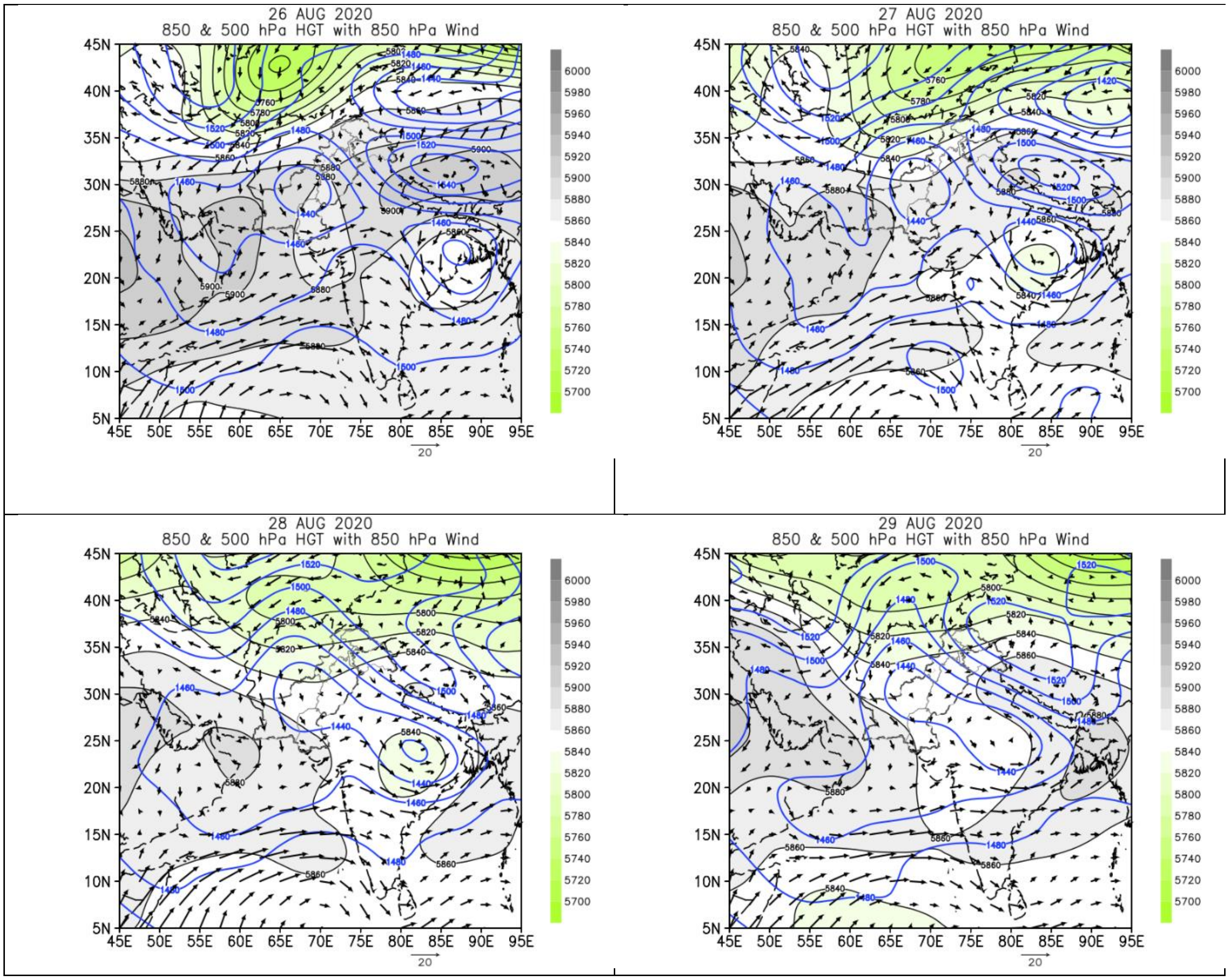


Figure 2 Precipitation (6 hourly) 00UTC August 7, 2020 to 18UTC August 9, 2020. District boundaries of Sindh are shown with black lines whereas Karachi is represented as red dot.

Second Rainy Spell (22-29 August)

A low-pressure area developed over the Bay of Bengal that moved very rapidly towards westward and can be seen in the charts given below over Central India on both 850hpa and 500hpa geopotential heights on 22nd of August. The low turned into well-marked low and remained persistent for the next two days with its extension over Southeast Sindh. Meanwhile, another Low-Pressure system was developed over the Bay of Bengal and moved very rapidly towards westward and merged with the seasonal low on 29th of August.




26 AUG 2020
850 & 500 hPa HGT with 850 hPa Wind
27 AUG 2020
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28 AUG 2020
850 & 500 hPa HGT with 850 hPa Wind
29 AUG 2020
850 & 500 hPa HGT with 850 hPa Wind
45N 40N 35N 30N 25N 20N 15N 10N 5N
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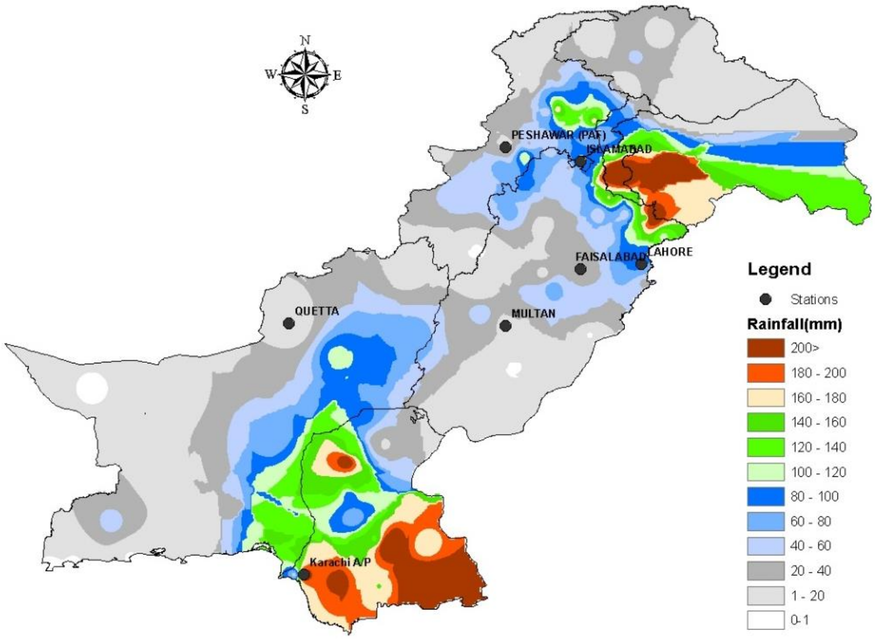

Figure 3 The spatial distribution of rainfall during the spell that lasted for many days from 22nd to 29th August.

Analysis of Diagnostic Variables of Events:

To investigate the meteorological conditions under abnormal rainfall, wind pattern and geopotential height contours has been plotted at 200 hPa as shown in Figure 2(a & b). It clearly shows that westerly was dominant making this area prone for variable air circulations leading to abnormal rainfall. Strongly positive vorticity at 500 hPa strengthened air at low levels to rise which helped the convective stormsas shown in Figure 2 (b & c). High relative humidity and wind vectors at 500 hPa shows that moisture penetration from Arabian Sea Figure 2 (e &f). Also, some cyclonic circulations have been observed at 500 hPa which is slightly different from the climatology of the region as monsoon prevails at low level. The vertically integrated moisture fluxes were calculated and plotted from surface pressure level to 300 hPa for selected events(g &h). Results shows winds penetrating moisture from Arabian Sea to convective centers over Pakistan and neighboring regions showing strong low-level convergence and upper level divergence. Strong divergent force over India and Arabian Sea contributed to moisture convergence over study area as shown in Figure 2(h). From studying the diagnostic variables, it is concluded that strong westerly was present in both events helped to uplift the moisture over study area.

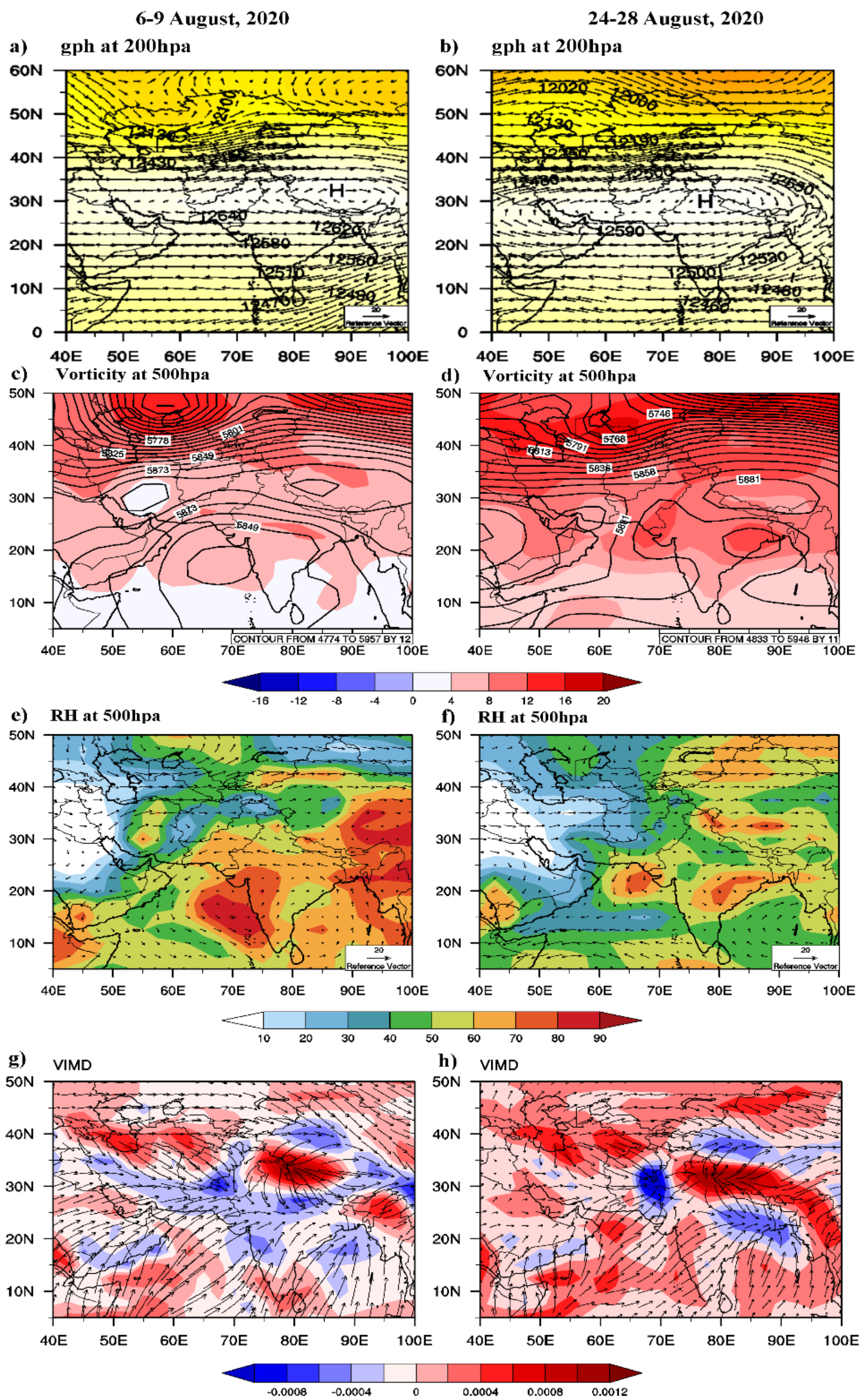

Figure 2: NCEP datasets: a &b) wind vectors (m/s) and geopotential height contours (m) at 200hPa. c&d) absolute vorticity (multiplied by 10^{-5}; unit: s^{-1}; shaded) at 500 hPa. e&f) relative humidity (%) shaded at 500 hPa along with wind vectors (m/s). g&h) vertically integrated moisture flux VIMD: shaded) along with divergent wind component vectors (units: 10^{-5} kg m^{-2} s^{-1}).

Climate Change Perspective

To assess regional climate change and the possible impacts on agriculture water resources, etc., it is important to have a clear comprehensive view of the observed climate variability and change over the region. Similarly, we need to differentiate between modes of natural variability from changes induced by human actions (Rajeevan and Nayak 2017).

It has been observed that the rainfalls as well as the rainy days are comparatively increasing in recent years after 2000. Whereas, in the past especially before 1990, the intensity and the duration of wet spells remained quite lower (see Figure &5). These trends suggested that the number of heavy precipitation events may increase in the future. The possible reasons for the increase in extreme events are discussed in the next section.

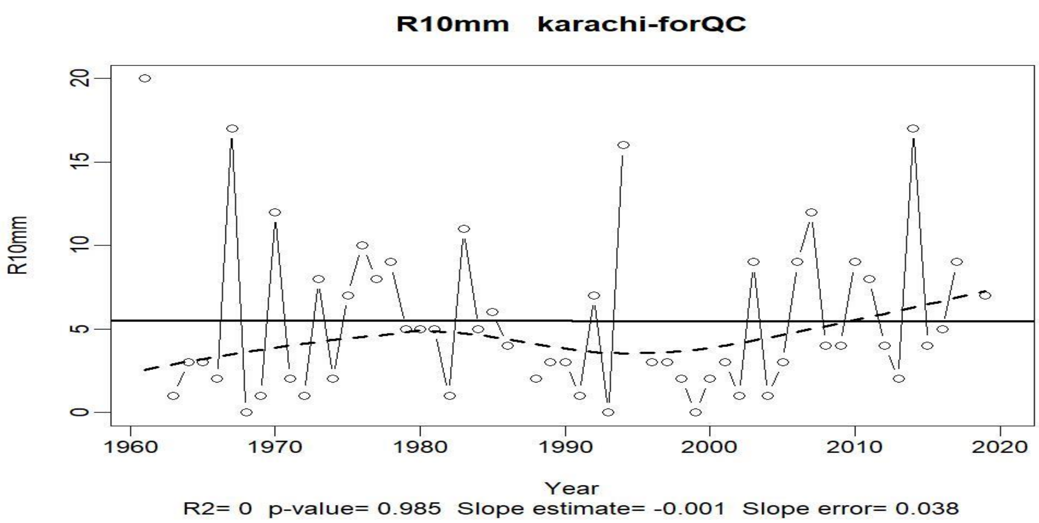

Figure 4 shows the number of heavy precipitation days or Annual count of days when PRCP>=10mm.

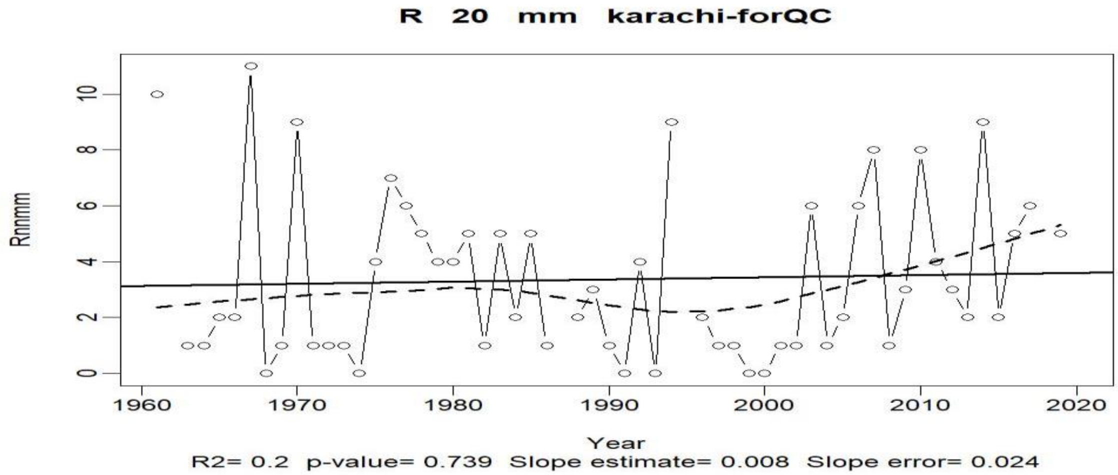

Figure 5 shows the number of very heavy precipitation days or Annual count of days when PRCP>=20mm.

Conclusions and Recommendations

1. The consistent strong positive anomaly in sea surface temperature over the Arabian Sea could be considered as a warning that may lead to an increase in extreme rainfall events in the future.

2. Rapid urbanization, increased population and poor drainage network could intensify the heavy rainfall impacts and may cause more severe and frequent urban flooding in future.

3. The Global warming and the increase in sea surface temperature may cause extreme weather events; droughts, cyclones, floods and other hydrometeorological disasters. The climate change impact base study by (Eckstein et al. 2020) states that "Pakistan that are recurrently affected by catastrophes continuously rank among the most affected countries both in the long-term index and in the index for the respective year (2020)".

4. This monsoon, the low-level jet has shifted southward, allowing successive areas of low pressure to dominate the southern Pakistan. These 'blocking' patterns of low-pressure are the main reason for the extended periods of rainy days. The blocking pattern and stalled low-pressure system over the south-

eastern parts of Pakistan along the Arabian Sea contributed towards unprecedented wettest monsoon on record.

5. Roof top water harvesting must be extensively practiced in metropolitan cities as a mitigation and adaptation tool for managing urban floods.

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