



Emergency Investigation and Assessment 2022 Pakistan Flood

Investigation Briefing

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Complexity of Summer Flood in Pakistan 2022 - ENSO Cycle does not explain it!

1. Pakistan 2022 and 2010 summer precipitation show significant spatial differences

Climate change has increased the frequency of extreme weather worldwide and shortened the cycle of El Niño/La Niña events, which are important causes of major meteorological and secondary disasters. Since the beginning of the 21st century, Pakistan has suffered from two severe floods caused by heavy rain. In 2010 summer, heavy rain led to mega-floods in Pakistan, while in 2022 summer, the southern region of Pakistan again suffered from a large-scale flood disaster due to heavy rainfall. The two severe floods affected many areas with heavy losses and great impact. According to MSWEP multi-source fusion precipitation data, the spatial distribution of precipitation anomalies in August 2010 and August 2022 across Pakistan was analyzed compared with historical observations in the same period from 1991-2020. The results showed that the high precipitation zone in August 2022 was mainly located in the southeastern province of Sindh, where the precipitation anomaly was more than twice that of the same historical period (**Fig 1**). On the other hand, the heavy precipitation zone in August 2010 was in the central area of Pakistan on the border of Balochistan and Punjab (**Fig 2**), where the precipitation anomalies were also more than twice.

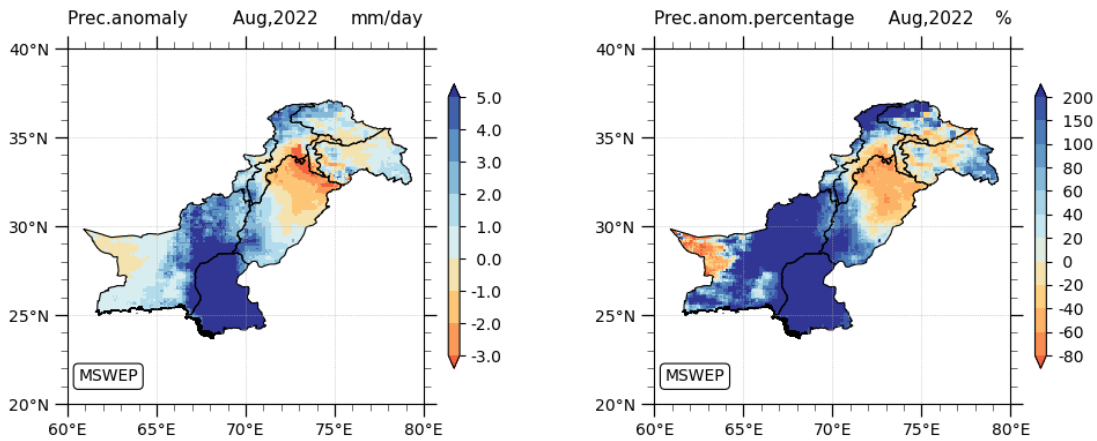


Figure 1 *Spatial distribution of precipitation anomalies in August 2022 in Pakistan*

Left figure shows the distance level (mm/day) of precipitation in August 2022 compared with the same period in history, while right figure shows the distance level percentage (%) of precipitation in August 2022 also compared with the same period in history

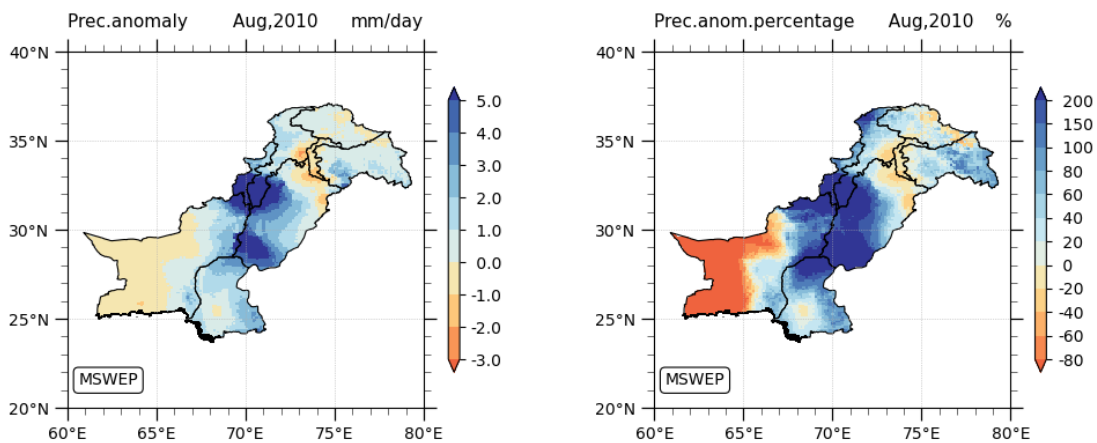


Fig. 2 *Spatial distribution of precipitation anomalies in August 2010 in Pakistan*

Left figure shows the distance level (mm/day) of precipitation in August 2010 compared with the same period in history, while right figure shows the distance level percentage (%) of precipitation in August 2010 compared with the same period in history

2. The winter before 2010 suffered from strong El Nino, while the winter before 2022 was influenced by strong La Nina

Based on the NOAA OISST SST (sea surface temperature) analysis data, the NINO3.4 SST index in the Pacific Ocean of the central and eastern equator was calculated from January 1991 to August 2022. The SST index in the tropical Pacific

under El Niño and La Niña generally reaches its highest in winter, so the Nino index of 2009 and 2021 winter were analyzed. The pre-winter of 2010 was influenced by El Niño, while the pre-winter of 2022 was affected by La Niña (**Fig 3**). However, during the same summer floods, the Nino3.4 index was less than -0.5 degrees Celsius in 2022 and 2010, both in the La Niña phase. Also, the SST negative anomaly in the tropical eastern Pacific in the 2010 summer was significantly stronger than in 2022.

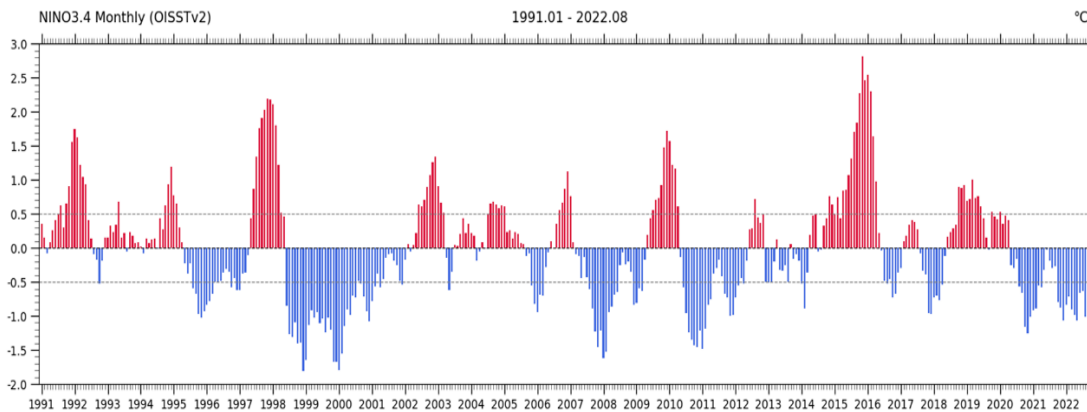


Figure 3 *NINO3.4 Index Series of Equatorial Central-eastern Pacific, 1991-2022*

3. The ENSO cycle significantly influenced the 2010 summer floods in Pakistan but was not a major controlling factor for the 2022 floods

To further analyze the effect of SSTA in the tropical Pacific Ocean on summer precipitation in Pakistan, **Fig 4** shows the relationship between the Pakistan precipitation in Aug. 2022 and its pre-winter Nino3.4 index (Left) and the correlation between Pakistan precipitation and the Nino3.4 index in Aug. 2022 (Right). Strong positive correlation was found between August precipitation anomalies and the pre-winter Nino 3.4 index in Punjab province (**Fig 4, Left**), with the main significant positive correlation area located in the central-western part of the Punjab province. Comparing the precipitation anomalies in August of 2010 and 2022 (**Fig 1 & 2**), the floods in Pakistan in August 2010 is closely related to the early El Niño event in the tropical Pacific, while the floods in August 2022 is apparently cannot be explained by the La Niña event in the tropical Pacific in the previous winter.

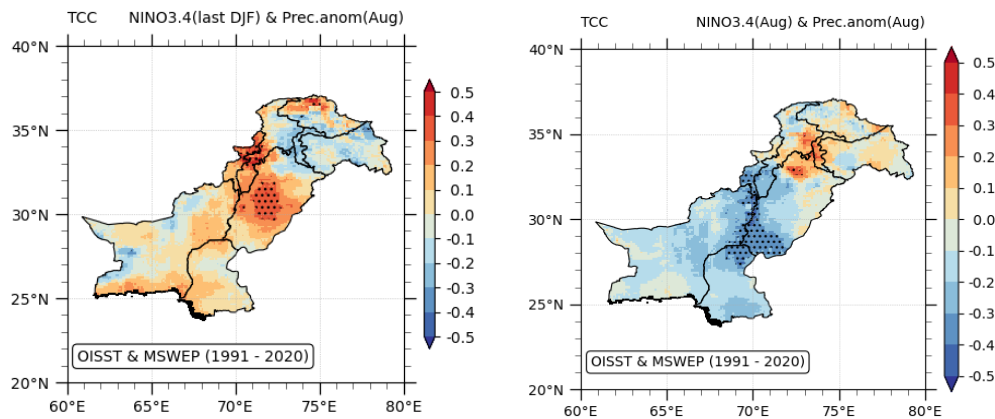


Figure 4 Temporal correlation of August precipitation anomalies with pre-winter Nino3.4 (Left) and that with Nino3.4 index (Right) for the same period, from 1991 to 2020

It is also found that there is a negative correlation between August SSTA in Nino3.4 and precipitations in central and southern Pakistan during the same period (**Fig 4 Right**). But the areas of significant correlation were on the western border and south of Punjab. There was a negative correlation in Sindh province, but it did not pass the significance test.

Therefore, the flood disaster in August 2010 is closely related to the SSTA event in the tropical Middle East Pacific in August 2010. However, for August 2022, the flood center was mainly located in Sindh Province of southern Pakistan, and the cold SSTA in August was weaker than in 2010. As a result, it is difficult to explain the flood disaster in south Pakistan in 2022 and by La Niña event in the same period.

In summary, based on the correlation of historical precipitation and the evolution of SST index, the 2010 Pakistan mega-floods can be better explained by the co-occurrence of a strong El Niño event in the pre-winter of 2010 and a La Niña event in August, which led to the extremely high precipitation in central Pakistan in August 2010.

However, the phenomenon in August 2022 was different. Neither the continuous negative SSTA in the equatorial Middle East Pacific during the previous winter nor the occurrence of a La Niña event in August could explain the extreme flood disaster in southern Pakistan. In the next step, we will focus on analyzing the changes of SSTA in the Indian Ocean adjacent to Pakistan and in-depth investigate the climatic conditions and causes of the extreme precipitations and floods in August 2022.

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