# Changing monsoon and midlatitude circulation interactions over the Western

Himalayas and possible links to occurrences of extreme precipitation

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### Abstract

Historical rainfall records reveal that the frequency and intensity of extreme precipitation events, during the summer monsoon (June to September) season, have significantly risen over the Western Himalayas (WH) and adjoining upper Indus basin since 1950s. Using multiple datasets, the present study investigates the possible coincidences between an increasing trend of precipitation extremes over WH and changes in background flow climatology. The present findings suggest that the combined effects of a weakened southwest monsoon circulation, increased activity of transient upper-air westerly troughs over the WH region, enhanced moisture supply by southerly winds from the Arabian Sea into the Indus basin have likely provided favorable conditions for an increased frequency of certain types of extreme precipitation events over the WH region in recent decades.

#### Results Long term changes in precipitation Extreme rain event over north-west India-Pakistan 29<sup>th</sup> July 2010 Linear trend of (a) JJAS mean precipitation rate over WH (b) Count of heavy rain activity (c) Percentage contribution of heavy precipitation activity to seasonal precipitation (d) JJAS mean precipitation rate. Upper Indus | ① EOF analysis on count of heavy precipitation activity Seasonal mean precipitation Central India Occurrence of WH heavy precipitation % contribution of WH Frequency of extreme rain events [64°-76°E, 32°-38°N] heavy precipitation to seasonal total ☐ Trend in heavy precipitation occurrences and EOF2 exhibit similar spatial pattern. ☐ Times series of PC2 shows increasing trend. Regression of PC2 50-d SLP ✓ Above normal precipitation activity over WH and below normal precipitation activity over Central India and Western Ghats region. ✓ Strong southerly wind over north Arabian Sea and e SST north easterly wind over BoB & Western Ghats at 700 hPa. ✓ Cyclonic Circulation over WH at 500 & 200 hPa. ✓ Westerly-southwesterly wind over Indian region at 200 hPa A do mada a a sala a la sala de la 11 po massa de la sala de la sa ✓ High pressure over BoB and Central Indian region ✓ Warm SST over Western and equatorial Indian Ocean

## Results Cyclonic vorticity > 1 SD [55°-75°E, 20°-55°N] Meridional Moisture Flux Convergence 9000 8000 7000 6000 (a) Number of days with strong and weak vertical Weak monsoon phases wind shear based on the Webster-Yang Index $[(U850 - U200) \text{ over } (40^{\circ} - 110^{\circ} \text{E,EQ} - 20^{\circ} \text{N})]$ Heavy precipitation activity calculated using NCEP zonal wind. associated with weak monsoon phase (b) Total number of heavy precipitation events (black line), the count of heavy precipitation Midlatitude trough activity events coinciding with strong (blue line) and weak (red line) phases of the monsoon as Southerly wind over Arabian Sea defined by the Webster-Yang Index.

#### Conclusion

Moisture flux convergence over WH

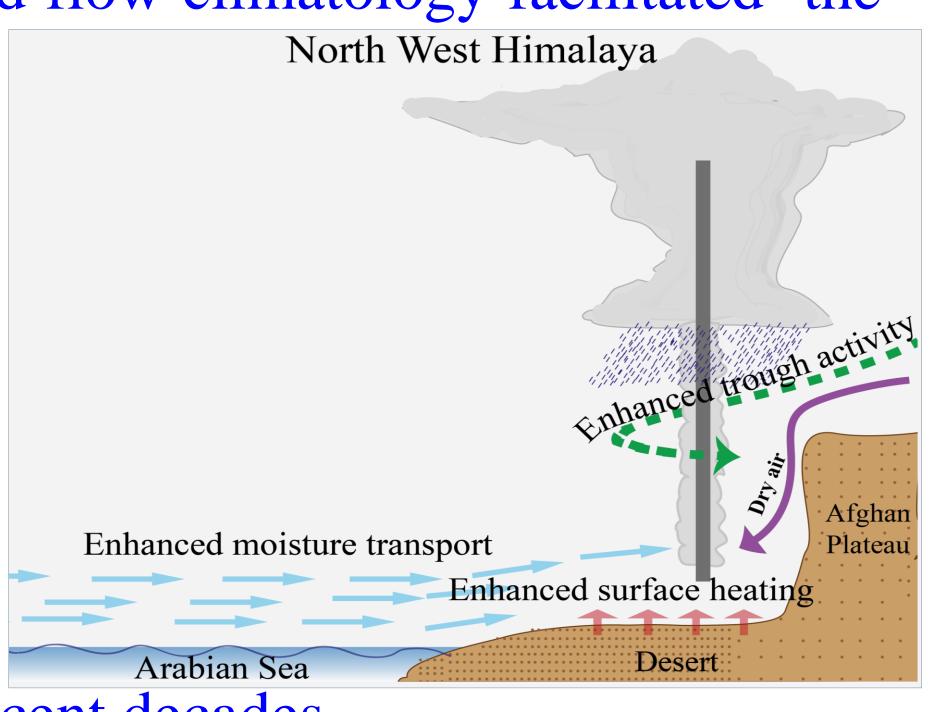
- Positive trend in the occurrence of heavy precipitation activity is located primarily over the upper Indus basin while the trend is opposite in the lower eastern Indus basin and adjoining Indian landmass.
- ☐ The spatially non-homogeneous pattern of trends in daily precipitation extremes is captured by the second EOF/PC component of the frequency of heavy precipitation.
- A significant decreasing trend in the overall seasonal summer monsoon precipitation over India and a weakening trend of the monsoon large-scale circulation is evident in our analysis of the post-1950s.
- □ Changes in background flow climatology facilitated the

enhancement of cyclonic trough activity over the WH and increases moisture convergence over the WH region associated with stronger southerly flows from the

(c) Total counts of heavy precipitation coinciding

with strong and weak monsoon days for

different decades.



Arabian Sea during the recent decades.

☐ These two results suggest an increasing probability of the type of extreme precipitation event that results from the combination of large-scale moisture flux (associated with a westward extended monsoonal trough) and a southward protruding midlatitude westerly trough.

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