Western Disturbances and associated weather

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Western Disturbance

- Western Disturbances are the extra-tropical baroclinic systems in the form of upper air troughs or cyclonic circulations (CCs) in mid-latitude westerlies that move west to east across northwest India (Das et al., 2002; Lang and Barros, 2004; Puranik and Karekar, 2009, Naresh et al. 2015, 2017).

- Under the influence of these systems at higher altitudes, sometimes CCs develop southeast of the system at lower levels and these are called as induced CC and

- rare cases low is also seen on surface chart in southeast sector of the system and called induced low.

- Movement of WDs and induced systems are five degrees in a day, sometimes much lesser.
Western Disturbance

- Firstly these systems cause weather over Iran, Afghanistan & Pakistan. Thereafter, it take fresh moisture feed from Arabian Sea and cause precipitation over WHR & adjoining plains.
- Thereafter while moving eastward, it cause some precipitation over Nepal, Bhutan and Arunachal Pradesh.
- In the absence of fresh moisture feed from Arabian Sea, it only cause light precipitation over higher reaches of WHR.
- Generally after passage of WD, Tmin falls significantly over adjoining plains due to cold northwesterly winds. As a result Cold Wave, Frost and FOG occurs over adjoining plains of Himalayas.
How WD originate?
Generally, the positions of these systems at lower tropospheric levels are 700-800 km away in southeastwards over central Pakistan & adjoining west Rajasthan area.
Strong lower level convergence and higher level divergence over Western Himalayan Region & adjoining plains are seen before commencement of widespread precipitation along with heavy falls.
Position of the westerly trough in mid-tropospheric level may also be analysed by using the vorticity field at 500 hPa level.
location of induced cyclonic circulation can also be identified by using vorticity field at 850 hPa level.
Precipitation variation with longitude in WHR

Tyagi, Naresh, Yadav (2012)
Precipitation variation with latitude in WHR

Zone I

Region I

Zone II

Region II

Zone III

Region III

35° N

33° N

31° N

29° N

73° N

75° N

77° N

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Precipitation variation with altitude in WHR

![Graph showing precipitation variation with altitude](image)

**Annual ppt (mm)**

- Upto 0.5: 1147.5
- 0.5 to 1.0: 1743.8
- 1.0 to 1.5: 1811.0
- 1.5 to 2.0: 1078.6
- 2.0 to 2.5: 1226.1
- 2.5 to 3.0: 1032.2
- 3.0 to 3.5: 1124.5
- 3.5 to 4.0: 583.9
- 4.0 to 4.5: 653.5

**Winter monthly ppt (mm)**

- Upto 0.5: 53.7
- 0.5 to 1.0: 55.0
- 1.0 to 1.5: 89.5
- 1.5 to 2.0: 133.9
- 2.0 to 2.5: 114.8
- 2.5 to 3.0: 164.8
- 3.0 to 3.5: 169.9
- 3.5 to 4.0: 99.9
- 4.0 to 4.5: 186.1

**Monsoon monthly ppt (mm)**

- Upto 0.5: 220.4
- 0.5 to 1.0: 356.3
- 1.0 to 1.5: 315.0
- 1.5 to 2.0: 67.9
- 2.0 to 2.5: 60.6
- 2.5 to 3.0: 80.2
- 3.0 to 3.5: 35.7
- 3.5 to 4.0: 62.2
- 4.0 to 4.5:
Seasonal precipitation variation with altitude

Pre-monsoon

Post-monsoon
Frequency of WDs over Indian region

![Graph showing frequency of WDs over Indian region with specific data points and trends.](image-url)
Winter (Dec – Mar) Trends over HP (1977-2006)

- **WDs frequency**
  - Equation: \( y = -0.804x + 12.47 \)
  - \( R^2 = 0.164 \)

- **Winter precipitation**
  - Equation: \( y = -1.178x + 18.27 \)
  - \( R^2 = 0.108 \)

- **Winter heavy precipitation (>64.5 mm)**
  - Equation: \( y = -2.634x + 40.83 \)
  - \( R^2 = 0.075 \)

Naresh et.al. 2015 (Atmosphera)
The intensity of extreme precipitation is higher in lower altitude stations compare to high altitude stations in monsoon season and vice-versa in winter season.

The analysis suggests that the intensity of extreme precipitation in general is higher along the foothills of Himalayas as compare to other stations of the region during monsoon season.

The risk of extreme precipitation events has become manifold from 1980 to 2014 specifically over lower altitude stations of WHR.
Features associated with extreme precipitation over Himalayas

- Daily precipitation data of all surface observatories located in Jammu & Kashmir for the winter season (December to March) from 1985-2016 are used to find the very heavy precipitation event over the region.

- During analysis, total 14 intense WDs cases are found that has caused very heavy precipitation over the region.
The composite mean charts of very heavy precipitation days associated with all the 14 WDs indicated that these are seen as CCs upto 850 mb over central Pakistan & adjoining west Rajasthan area along with a trough from the centre of CCs to deep in central Arabian Sea and as a deep north-south trough between longitude 63° to 67°E with its southern tip deep in central Arabian Sea between 700 to 200 mb resultant in huge moisture feed from Arabian Sea to Himalayan region from lower & upper levels.
Characteristics of intense WDs caused heavy ppt over Himachal Pradesh

- A trough roughly located along 68° E long. and south of 24° N lat. or a CC around 68° E long. and 31° N lat. at 500 hPa GPH.
- An induced CC located over Central Pakistan & adjoining Rajasthan area or a trough that extends from north Pakistan and the adjoining Jammu and Kashmir to the Arabian Sea at 850 hPa GPH.
- A high moisture incursion from the Arabian Sea over the region.

Naresh et al. 2015, Atmosfera
Many times, these systems produce well-distributed and large amounts of precipitation along with heavy snowfall/rainfall, snow avalanche etc. over the Himalayan region, while others pass across this area without causing precipitation, this happen in the cases, when there is no moisture feed to the system from Arabian Sea.

It is seen in the most of the cases that precipitation associated with these systems mainly confine over Jammu & Kashmir and Himachal Pradesh only.

The adjoining plains of northwest India receives rainfall only in the cases, when there is induced CC/Low over northwest India along with moisture feeding from the Arabian Sea at lower levels.

Only few of these systems cause precipitation over central & adjoining south peninsular India.

This has happened during 28 February to 2nd March, 2015. During this period, there was unprecedented precipitation along with heavy falls occurred over many parts of India. Many of the stations of northwest & central India received an all time high 24 hour cumulative precipitation of March during this period.
Actual, normal & anomaly of precipitation in past 24 hours of 1st, 2nd & 3rd March 2015 (reported at 0830 hours IST)

(Source: IMD Pune)
Warm core high with maximum intensity up to 226 Kelvin over south Pakistan and adjoining Iran & Arabian Sea. Consequently, a sharp pressure gradient built up over the region, which generated a high jet stream with core wind speed up to 160 knots over Indian region & its adjoining area.
Air Temperature (Kelvin) at 925 hPa of (a) 28.02.2015, (b) 01.03.2015 and (c) 02.03.2015
The WD was in the form of north-south deep westerly trough in middle & upper tropospheric levels with its southern end deep in Arabian Sea, which pumped huge moisture feed over Indian region.

Also, there was a Jet stream with core wind speed upto 160 knots that generated high positive divergence at upper tropospheric level over Indian region along with this there was high magnitude of negative vertical velocity & velocity convergence were there at middle tropospheric level. It caused intense upwards motion and forced lower levels air to rise and strengthen the lower levels CCs/Lows.

Moreover, the induced CCs/Lows at lower tropospheric levels associated with WD were very much south of its normal position.

Additionally, there was wind confluence over central parts India due to westerlies in association with WD and easterlies from anticyclone over north Bay of Bengal.
23 to 25 September 1988 (max ppt 31.6 cm)
It is observed in all the cases, there was WD in the form of trough or cc around 70° E and north of 20° N, Whereas in winter season trough around 65° E for J & K and 68° E and north of 24° N for H.P. with induced cc over West Rajasthan & adjoining Pakistan are favourable conditions for extreme weather over the region.

In all the cases of extreme weather events, there was interaction of mid- tropospheric westerly system with low level easterly systems along with the presence of low pressure area over northwest India & neighbourhood originated at BoB or over Arabian Sea or both.

As a result there was huge amount of moisture incursion over the northwest India from Arabian Sea as well as from Bay of Bengal.
In 2016, a multi-institutional initiative is taken to understand & study the various characteristics of
- WDs & its associated weather i.e. heavy rain/snow, spatial distribution of precipitation
- Dense Fog
- Cold wave/day
- Ground frost etc.

mainly for the northern parts of the country (north of 20°N), so that a better weather forecast & warnings advisories at least five days in advance may be issued.
Forecast and Warning Guidance for Winter Weather

Precipitation and its associated synoptic features:

- The western disturbance (WD) as an upper air cyclonic circulation (CC) over Pakistan and adjoining Jammu & Kashmir between 3.1 km & 4.5 km above mean sea level is very likely to move over Jammu & Kashmir and adjoining Pakistan by tomorrow. It is very likely to cause light snowfall activity over higher reaches of Jammu & Kashmir on 12th night & 13th.

- In quick succession, another active WD is very likely to affect Western Himalayan region (WHR) from 14th and its adjoining plains of northwest India from 15th onwards.

- The 2nd WD is very likely to be seen as trough in mid-tropospheric westerlies somewhere around Longitude 60°E and north of Latitude 20°N on 14th with high moisture feed from the Arabian Sea in the forward sector of the WD and strong winds of order more than 50 knots in right entrance of the trough. In result, the system is very likely to mention its intensity upto 18th.

- Therefore, in the presence of remnant of 1st WD and likely divergence field of 2nd WD over WHR, light to moderate precipitation at a few places is very likely to occur over WHR on 14th. Thereafter, WD would move eastwards gradually with very deep trough in mid-tropospheric westerlies (south of 20°N) and high moisture feed from Arabian Sea on 15th & 16th.

- Also, under its influence an induced CC circulation very likely to develop over Central Pakistan & neighbourhood on 15th. As a result, widespread precipitation activity with heavy falls at isolated places are very likely to occur over WHR on 15th & 16th and scattered to fairly widespread activity over Punjab and Haryana, Chandigarh & Delhi. Light rainfall at isolated places is also likely over northern parts of Rajasthan and northwest Uttar Pradesh during same period.
Minimum temperature and its associated synoptic features:
Currently strong northwesterly/westerly dry cold winds of order 10 to 15 knots are prevailing over Indo- Gangetic Plains (IGP) at 10m height above mean sea level with RH less than 60% over plains of northwest India. With speed is very likely to reduce to 5 to 10 knots over most parts of IGP and less than 5 knots over parts of central Uttar Pradesh and over northeastern states on 13th morning. RH is also most likely to be less than 60% over above regions on same day. Thereafter, strong northerly/northwesterly winds of order 10 to 15 knots are very likely to prevail over most parts of northwest and east India with RH less than 60% on 14th & 15th morning.
Due to prevailing above mentioned features, no significant change in minimum temperatures is observed over northwest India except East Uttar Pradesh, where they have dropped by 2-4°C in past 24 hours.
Hence, the prevailing below normal minimum temperatures trend over plains of northwest India are very likely to continue during next 3 days.

Cold Wave Warning:
In the influence of above mentioned scenario, Cold wave conditions at a few places over Punjab, Haryana, Chandigarh & Delhi and Uttar Pradesh most likely to continue to prevail till 14th morning.

Ground Frost Warning:
Considering the prevailing and forecast trends in minimum temperatures, ground frost conditions are also very likely to continue to occur over isolated pockets over Punjab, Haryana, north Rajasthan and Uttar Pradesh during next 2 days.
Forecast and Warning Guidance for Winter Weather

**Fog:**
Strong winds (10-15 knots) are very likely to continue to prevail over most parts of Indo-Gangetic plains during next 4 days (at 10 m above mean sea level).
RH is also very likely to be less than 60% over most parts of Indo-Gangetic plains during next 4 days.
Considering wind pattern at lower levels, RH and likely minimum temperature pattern, no dense fog is likely over Indo-Gangetic plains during next 4 days.

**Maximum temperature:**
Considering prevailing synoptic & dynamical conditions and NWP model guidance, no significant change in maximum temperatures likely over northwest India during next 3-4 days.

**Cold day condition:**
No Cold day conditions are likely over any parts of northwest India during next 3-4 days.
Thanks