Stable water isotopic evidence for the moisture source and composition of surface runoff in Ladakh, upper Indus river basin (UIRB)

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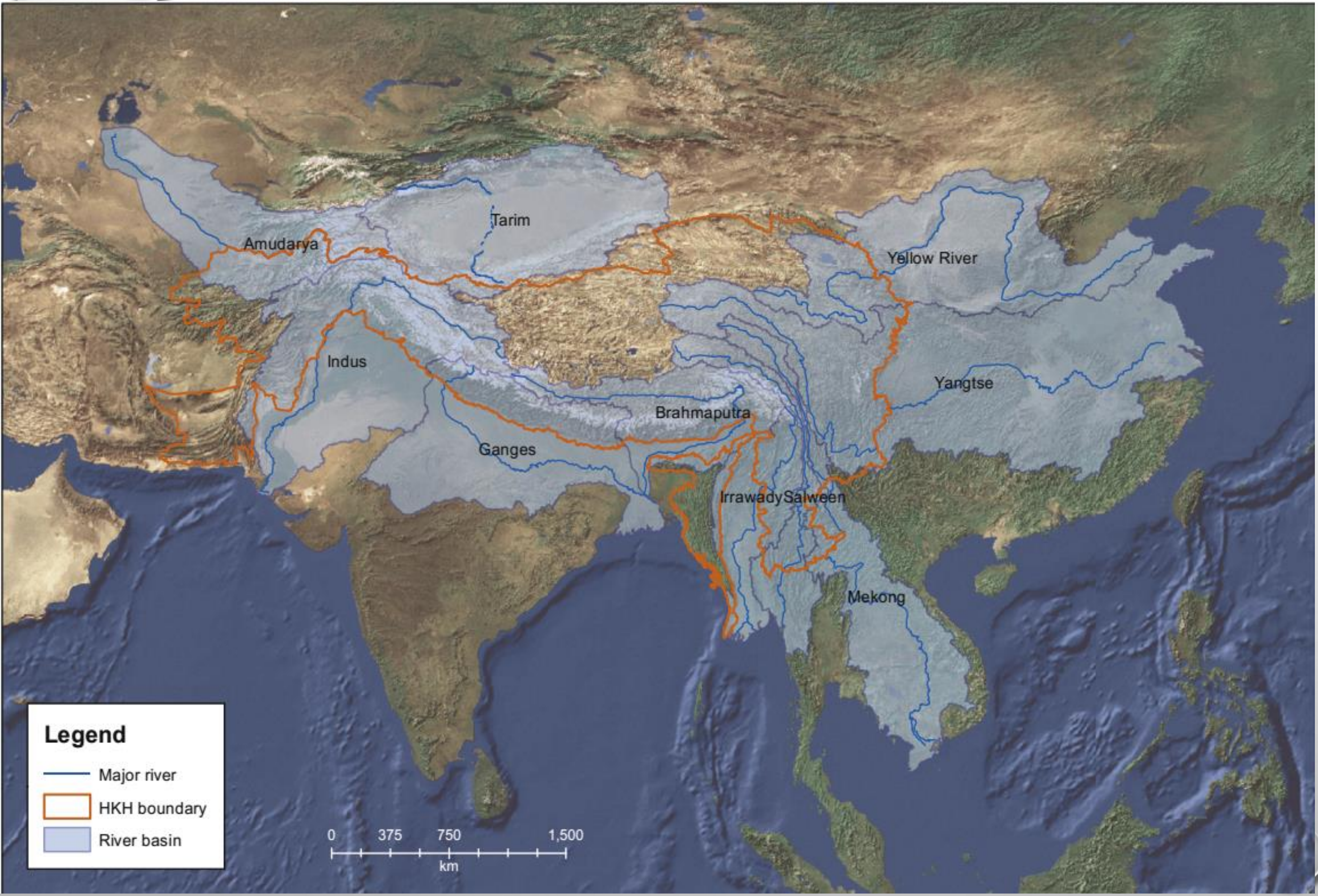
Field Photograph: 2018
Pangong Lake

Himalayan Cryosphere

- More than 1/6 of worlds population depends on snow and glacier fed rivers.
- Known as Water Tower of Asia
- Largest body of glaciers outside of polar regions, occupy 17% of mountain area (IPCC, 2007) hence also know as Third pole.
- 5000 glaciers in Himalayan-Hindu-Kush region with an area of 35,110 km^2.
- 1800 glaciers in J&K, cover an area of 997 km^2.

Satellite image of Himalayan Cryosphere

Significance



- ✓ These Glacier/Snow fed rivers supply fresh water to 500 million in Himalayas-Hindu-Kush region and 250 million people in China (IPCC,2007)

- ✓ Drinking Purposes
- ✓ Agriculture
- ✓ Hydropower generation

- ✓ Shrinking cryosphere?????
- ✓ Concern among the people

- ✓ Climate Change: everybody's cup of tea

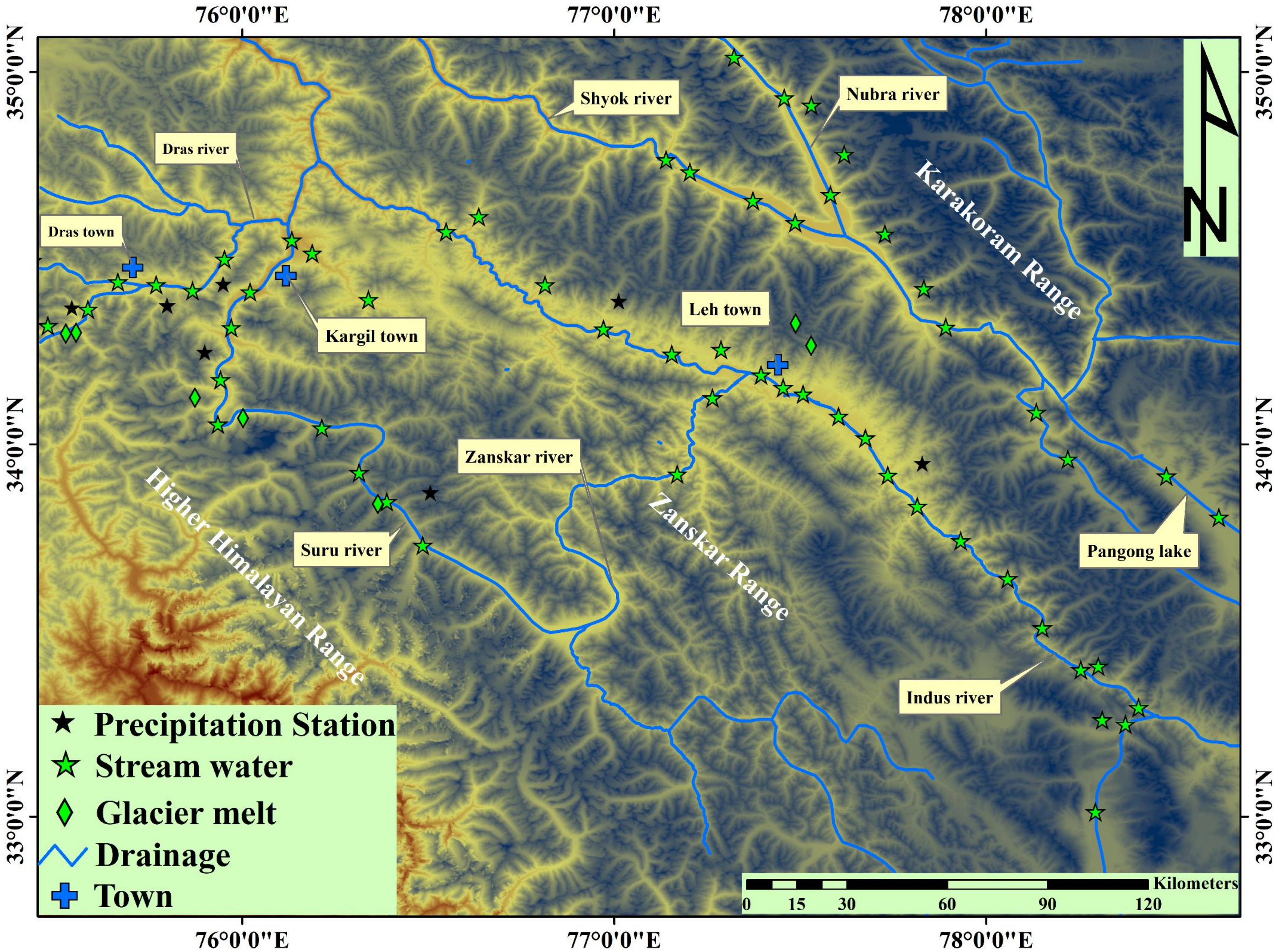
Study Area

Area: 59942 sq. kms

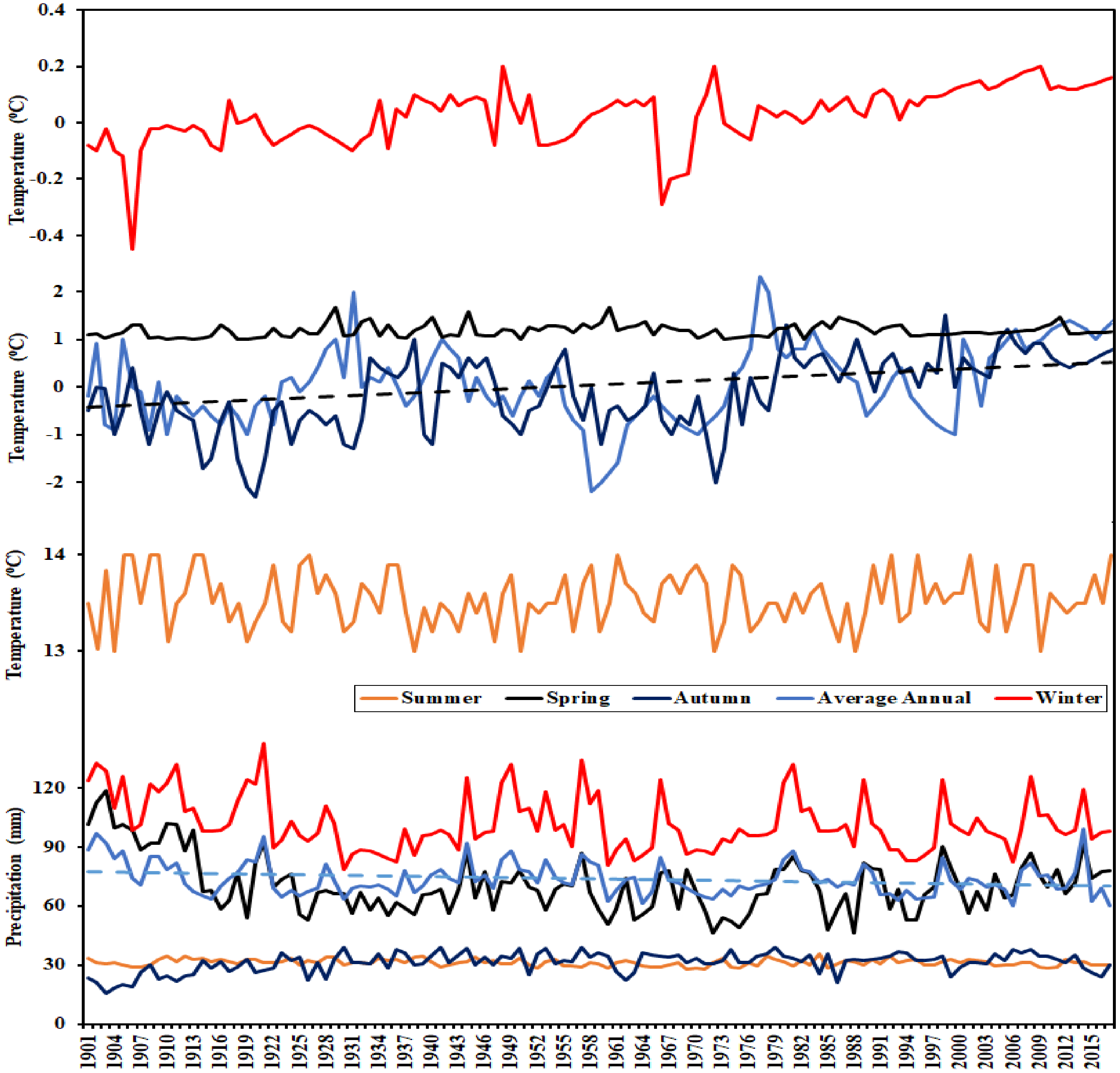
Elevations: 2500 a,msl in Drass to > 5000 m a,msl in Leh

Climate: Cold arid climate annual precipitation of about 115 mm (Weather station Leh)

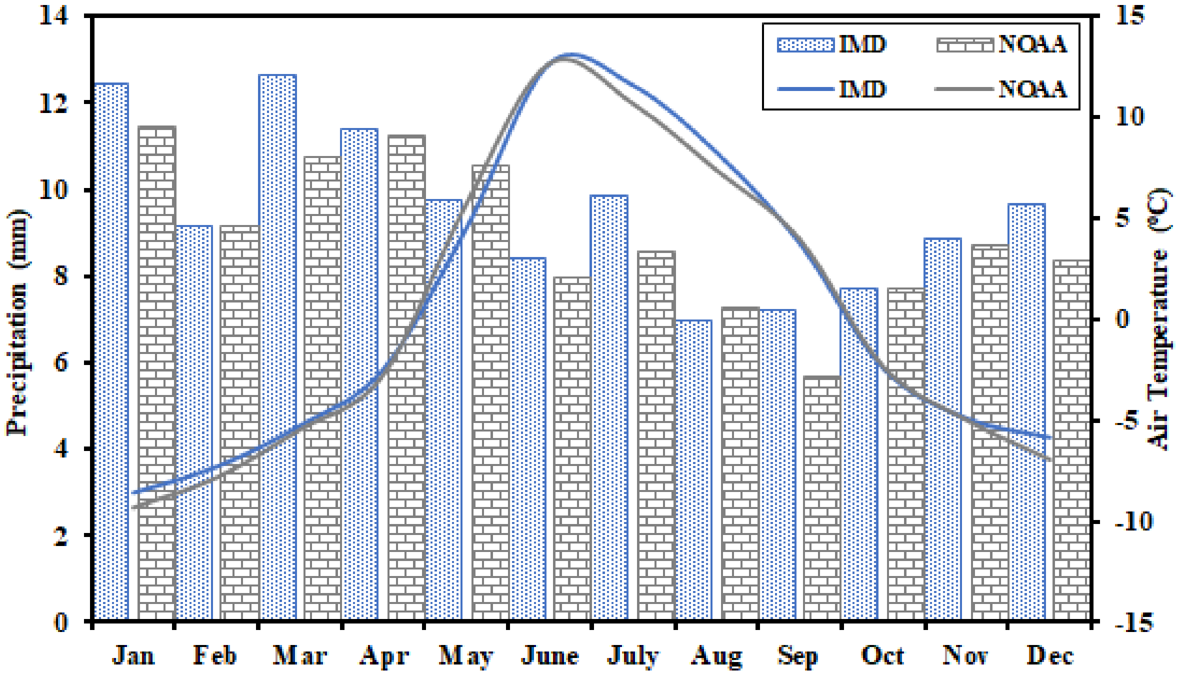
Temperature: 14°C in summer to -8°C in winter (Weather station Leh)



Upper Indus river basin Ladakh

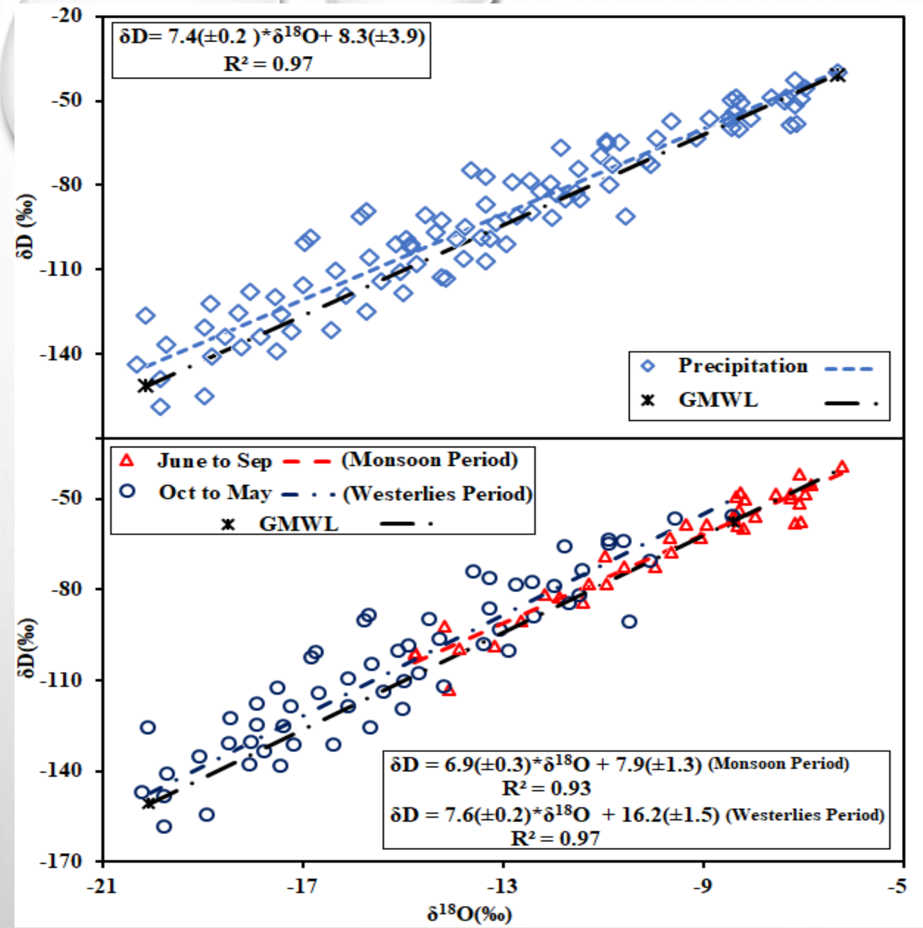


Long-term temperature and precipitation trends
IMD and NOAA

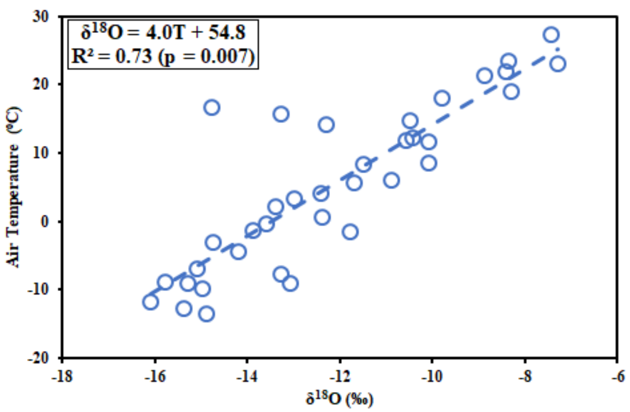


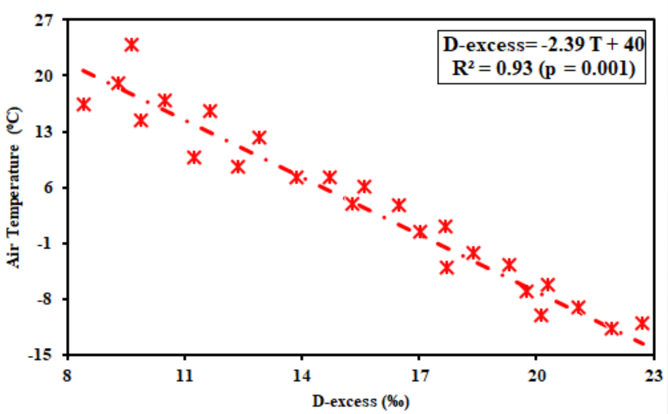
Source: Lone et al., 2019

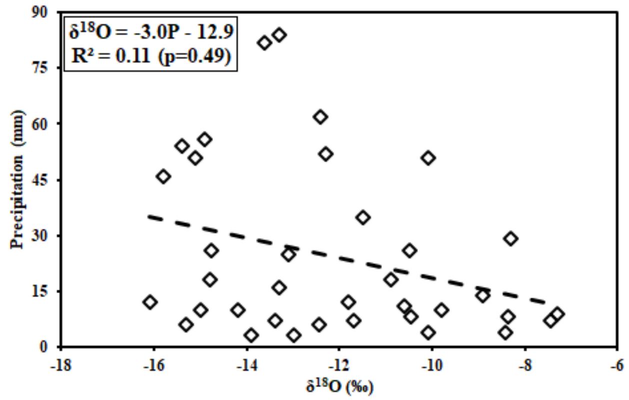
Variation of $\delta^{18}O$ and δ^2H in precipitation

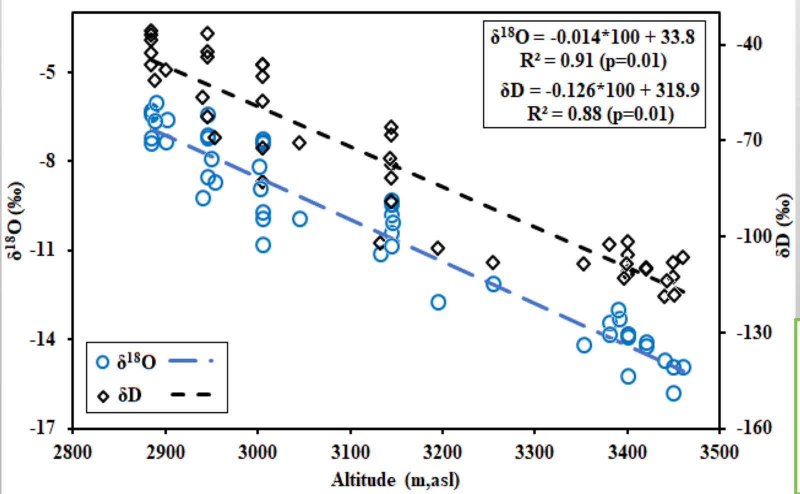


LMWL-Precipitation
(Monthly & Seasonal)



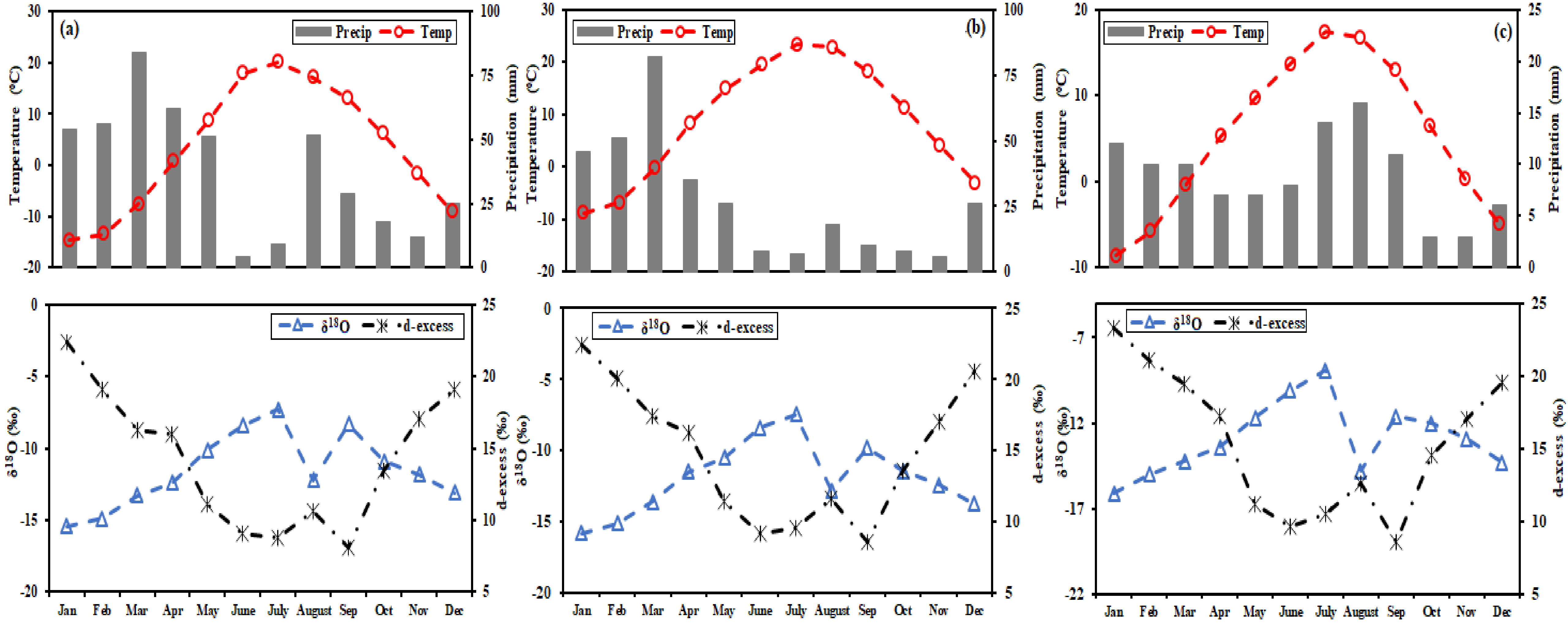






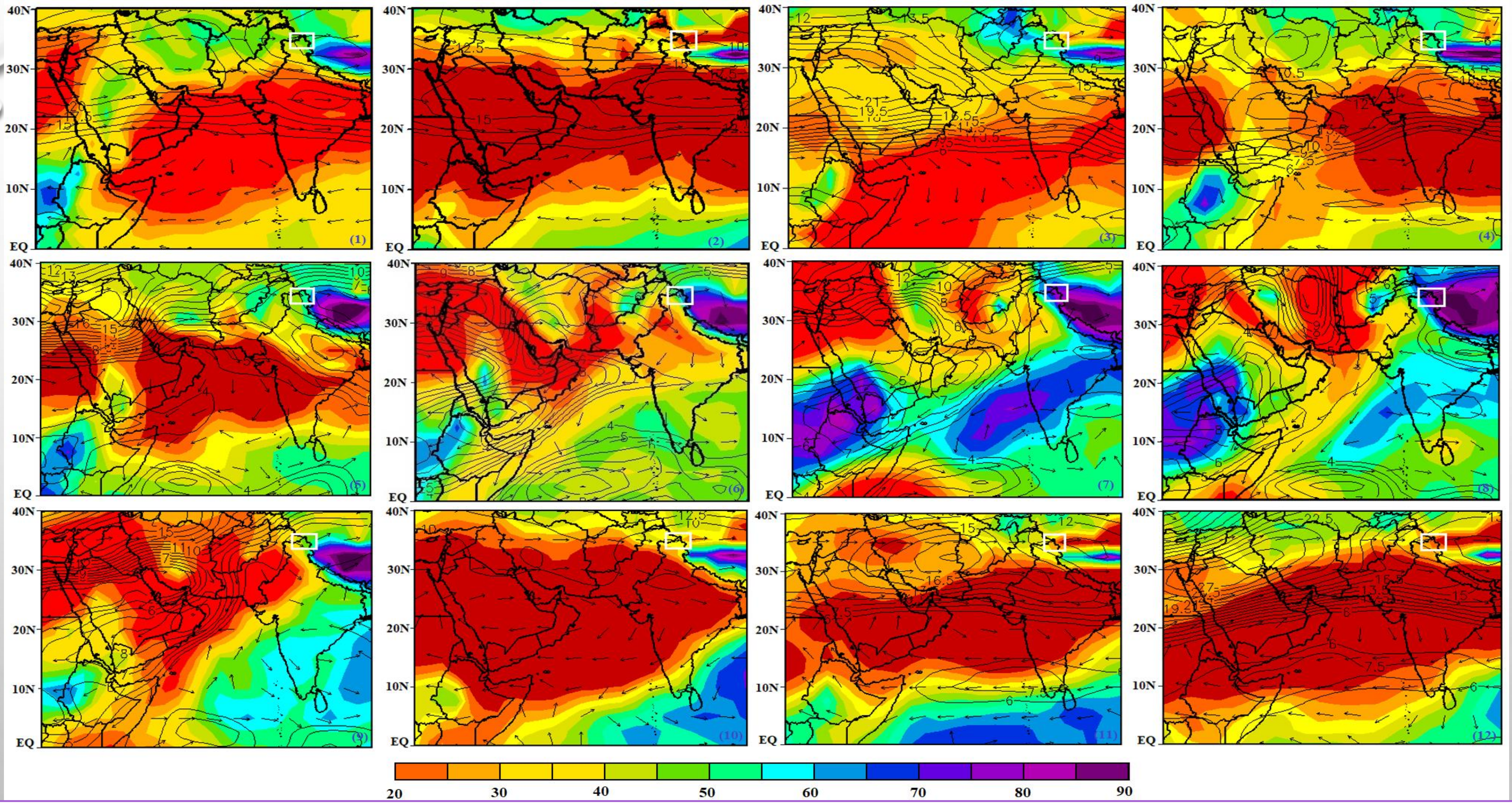
$\delta^{18}O$ vs. Altitude

$\delta^{18}O$ vs. air temperature, precipitation amount & d-excess

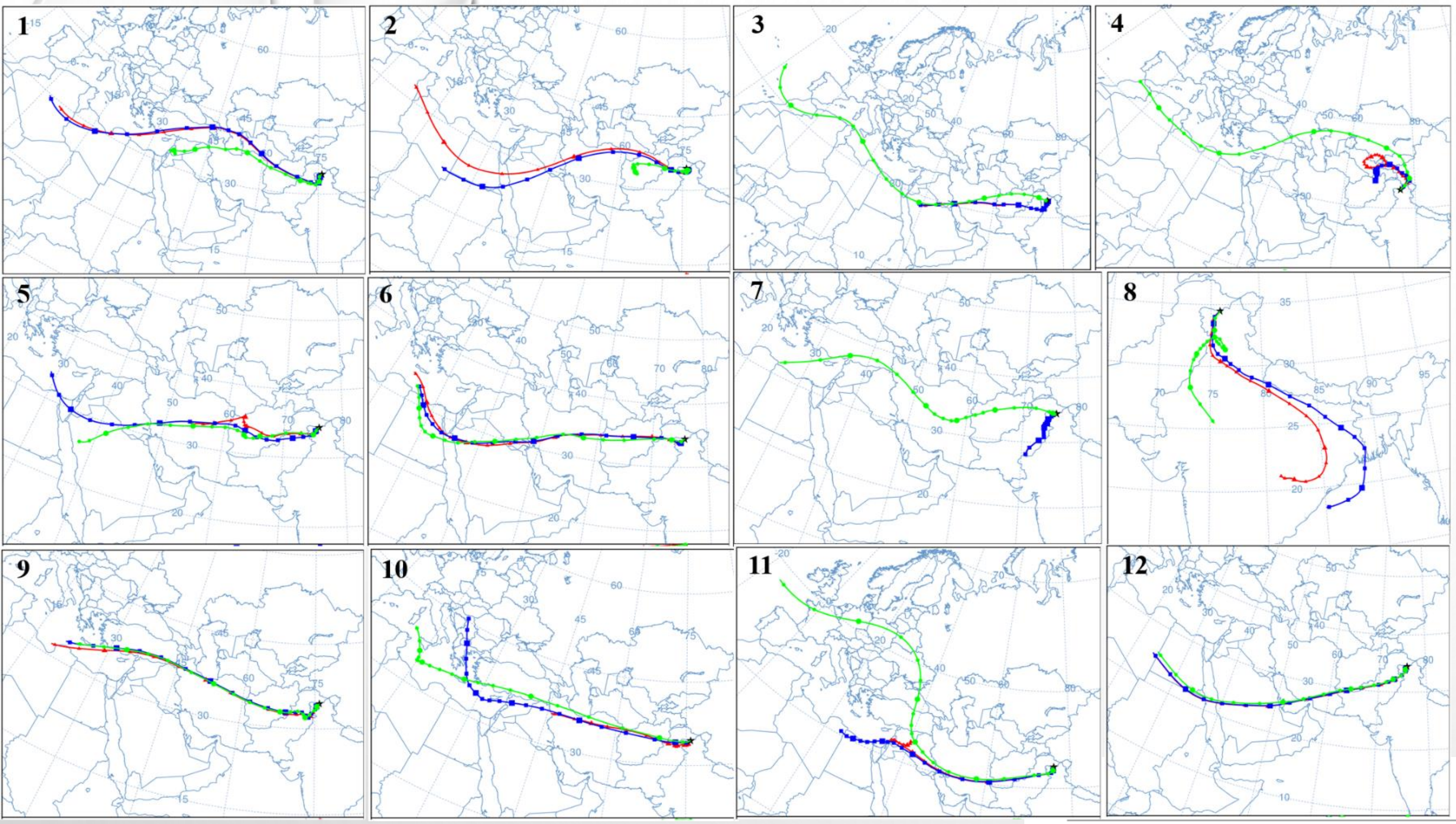


- ✓ The stable water isotopic value of precipitation abruptly drops at all the precipitation sites in August, without considerable variation in the ambient temperature and precipitation amount signifying the alteration in moisture source.

✓ NCEP/NCAR (National centre for environmental prediction/National centre for atmospheric research:



- Westerly wind dominant from the October to May.
- southwest monsoons dominant from June to September.



HYSPLIT Model

1000

1500

2000

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Stable isotope ($\delta^{18}O$ and δD) dynamics of precipitation in a high altitude Himalayan cold desert and its surroundings in Indus river basin, Ladakh

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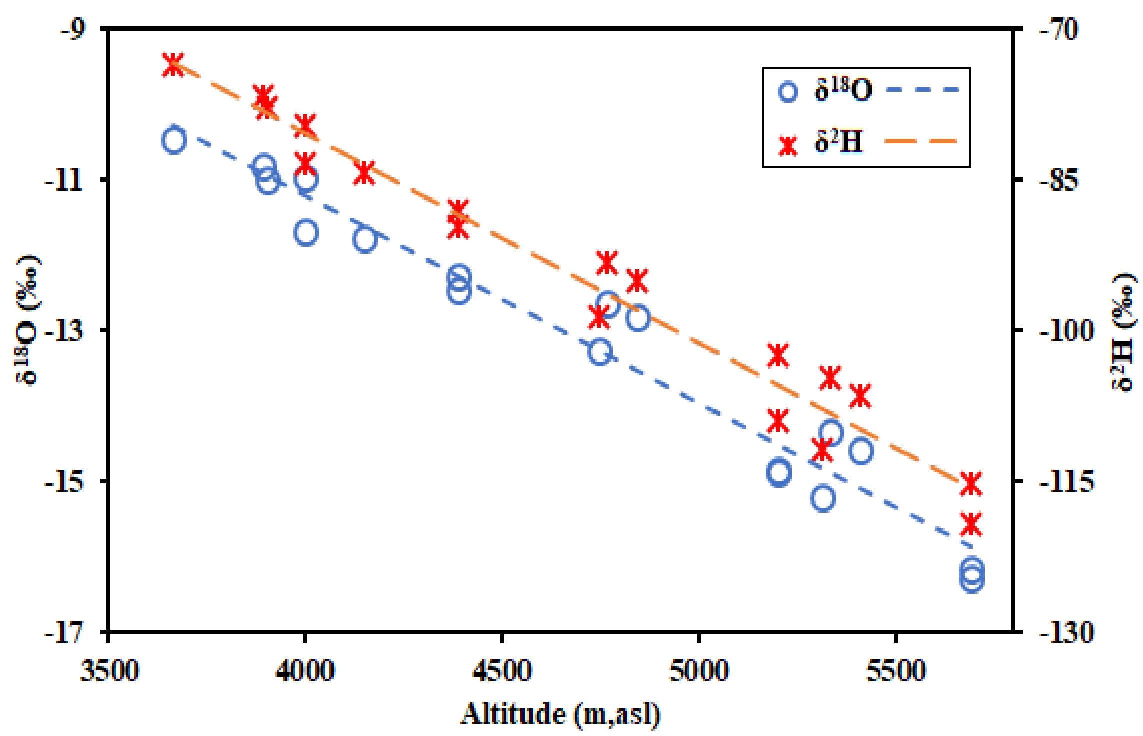
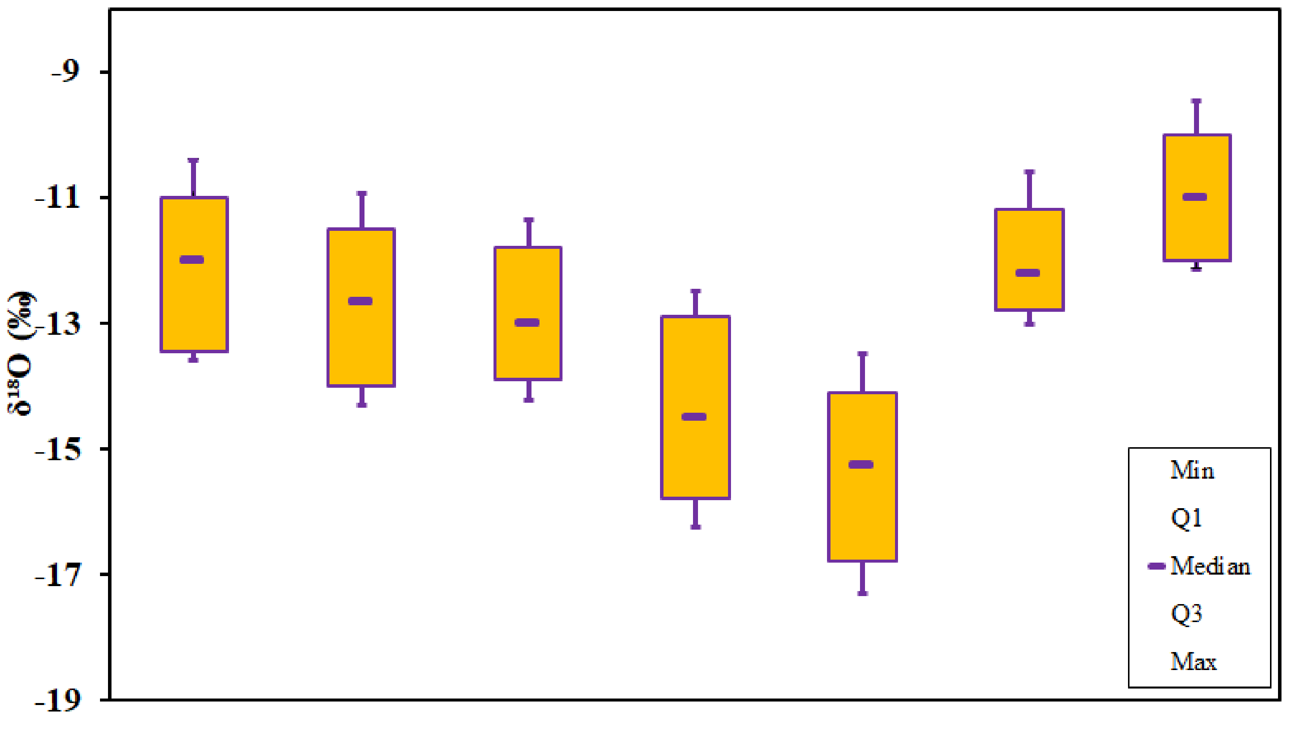
Stable isotopic variation ($\delta^{18}O$ and $\delta^{2}H$) in glacier melt

- Machoi and Galdar glaciers exhibit low isotopic values: $\delta^{18}O$ or / $\delta^{2}H$ -10.4 to -12‰ and -73 to -74‰, than Parachik, Drung-Durung and Khardung glaciers (Avg:: $\delta^{18}O$ or / $\delta^{2}H$ -13.6 to -16.8‰ and -95 to -110‰).
- Isotope altitude gradient (-0.27 ‰ and -2 ‰) for $\delta^{18}O$ and $\delta^{2}H$.



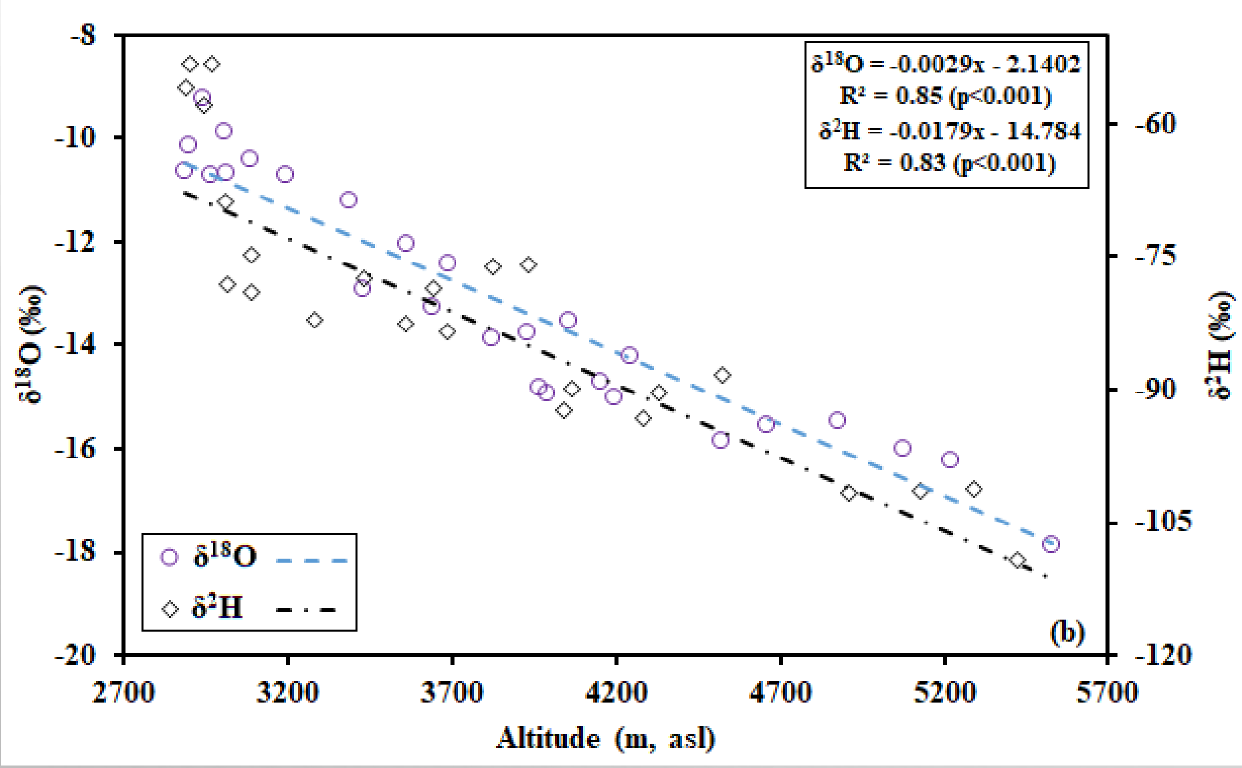
$\delta^{18}O$ and $\delta^{2}H$ v/s altitude in glacier melt



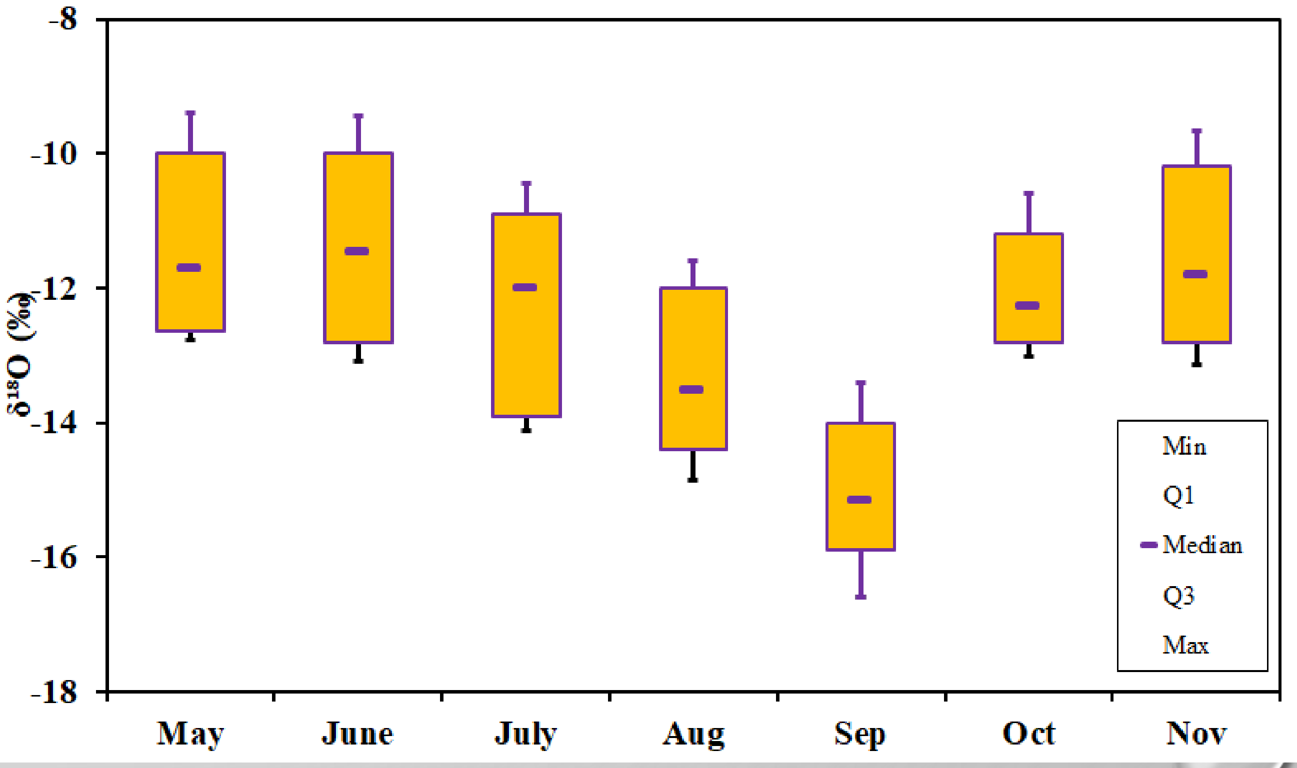
Temporal variation in glacier melt

Stable isotopic variation ($\delta^{18}O$ and δ^2H) in snowpacks:

- ✓ Snowpack samples taken from the winter-accumulated snowpacks along various transects in all the basins ranged from −15.38 to−11.48 ‰ (S.D.: 1.6) and −112.76 to −70.28 ‰ (S.D.: 12.2) with an average values of −94.05‰ and −13.43‰.
- ✓ The estimated isotope altitude gradient of snowpack samples varied from −0.24 to −0.42 ‰ and −2.4 to −3.9‰ for $\delta^{18}O$ and δ^2H.

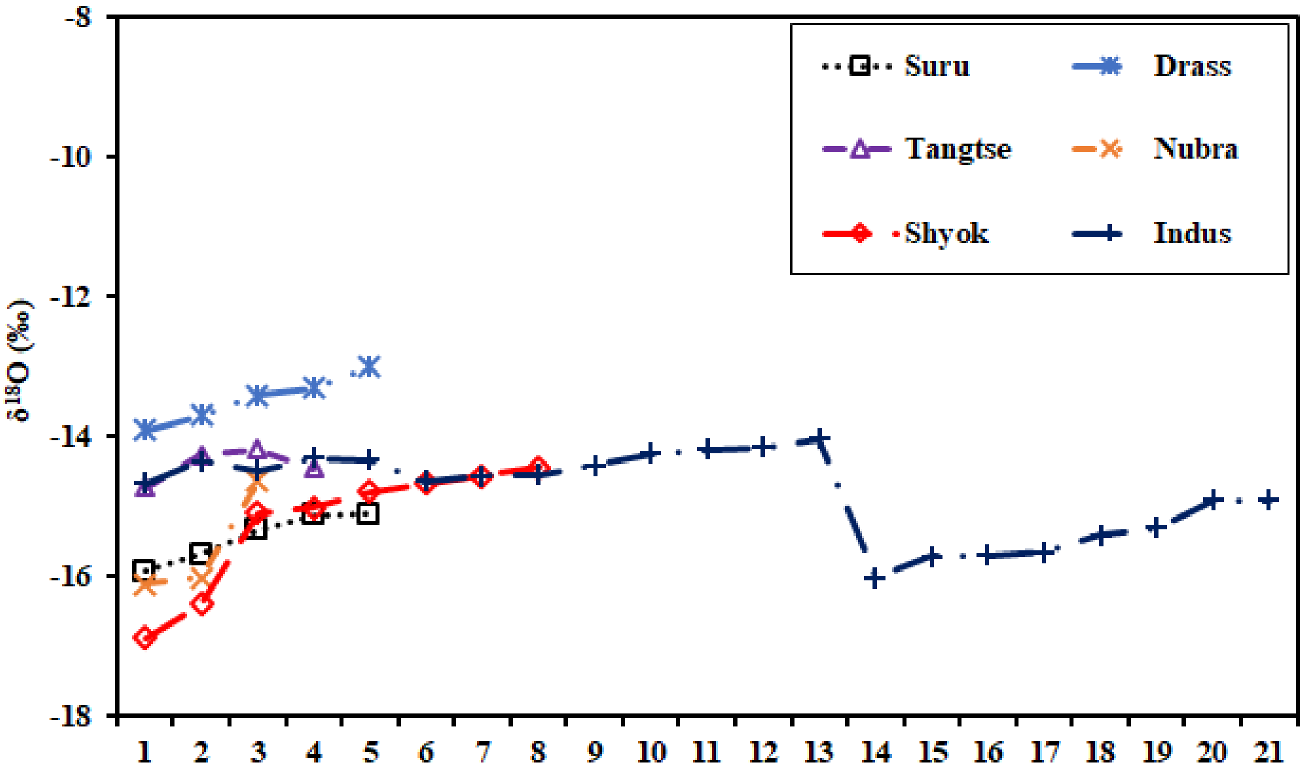


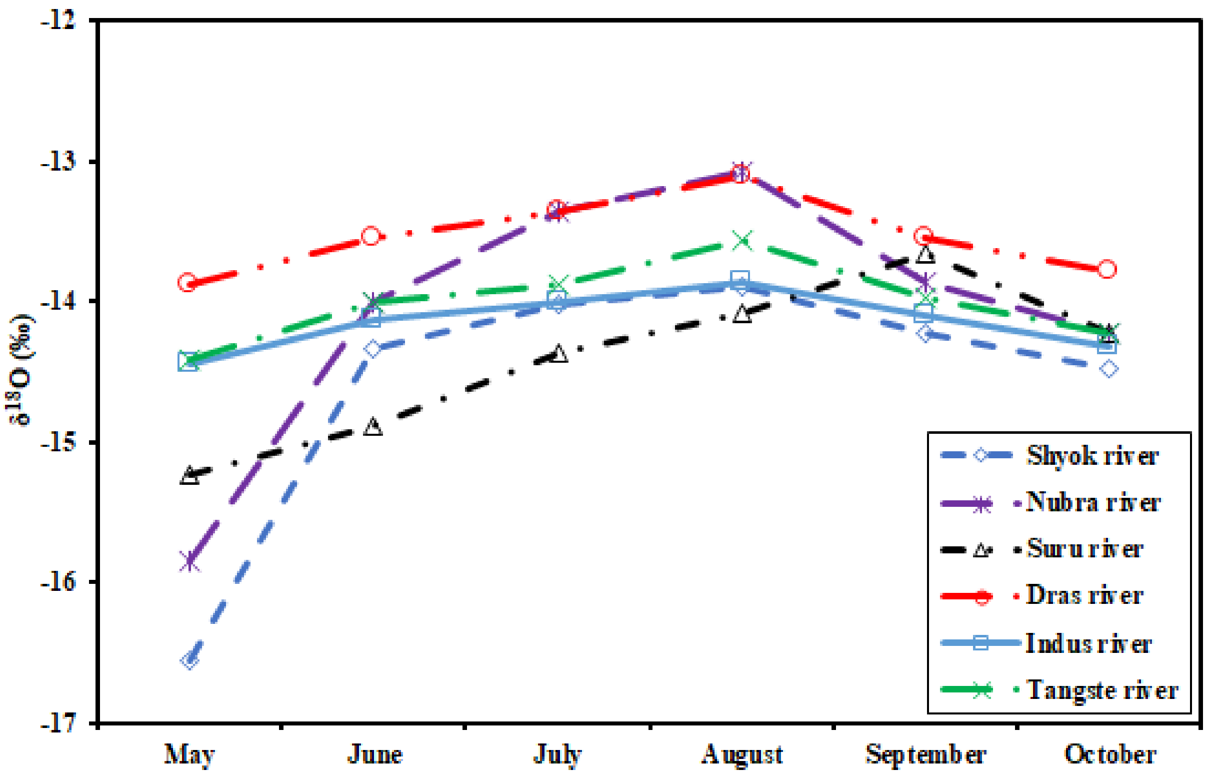
$\delta^{18}O$ and δ^2H v/s altitude in glacier melt



Temporal variation in glacier melt

Stable isotopic variation ($\delta^{18}O$ and $\delta^{2}H$) in Stream water





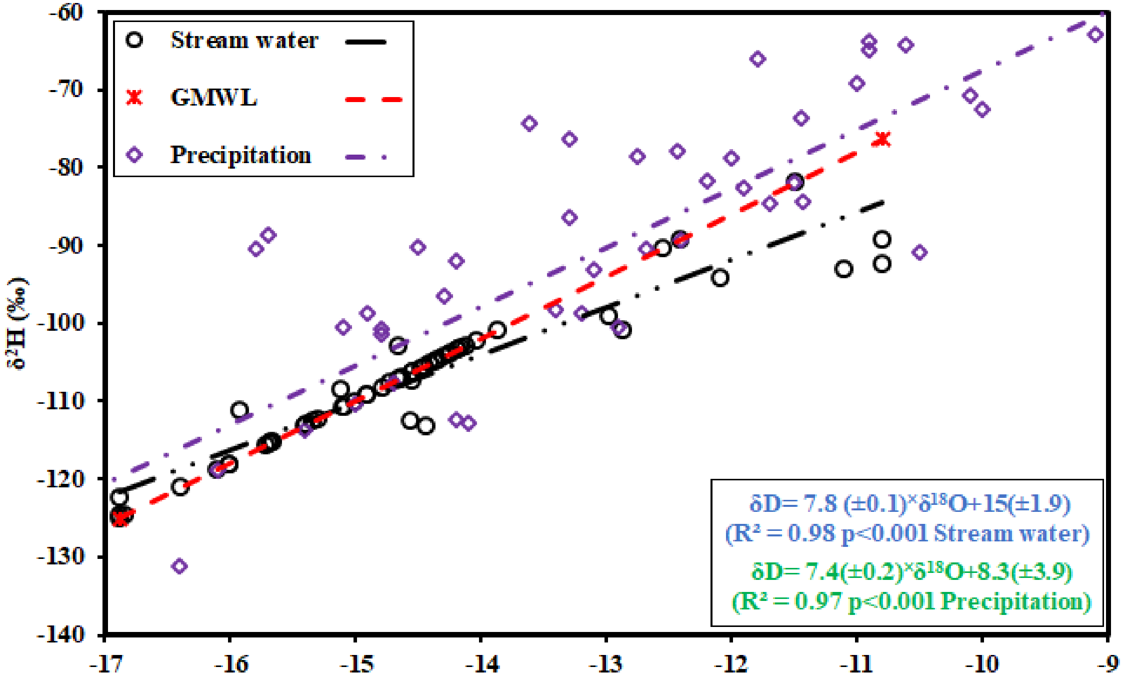
$\delta^{18}O$ & $\delta^{2}H$ variation in stream water in different rivers of upper Indus basin

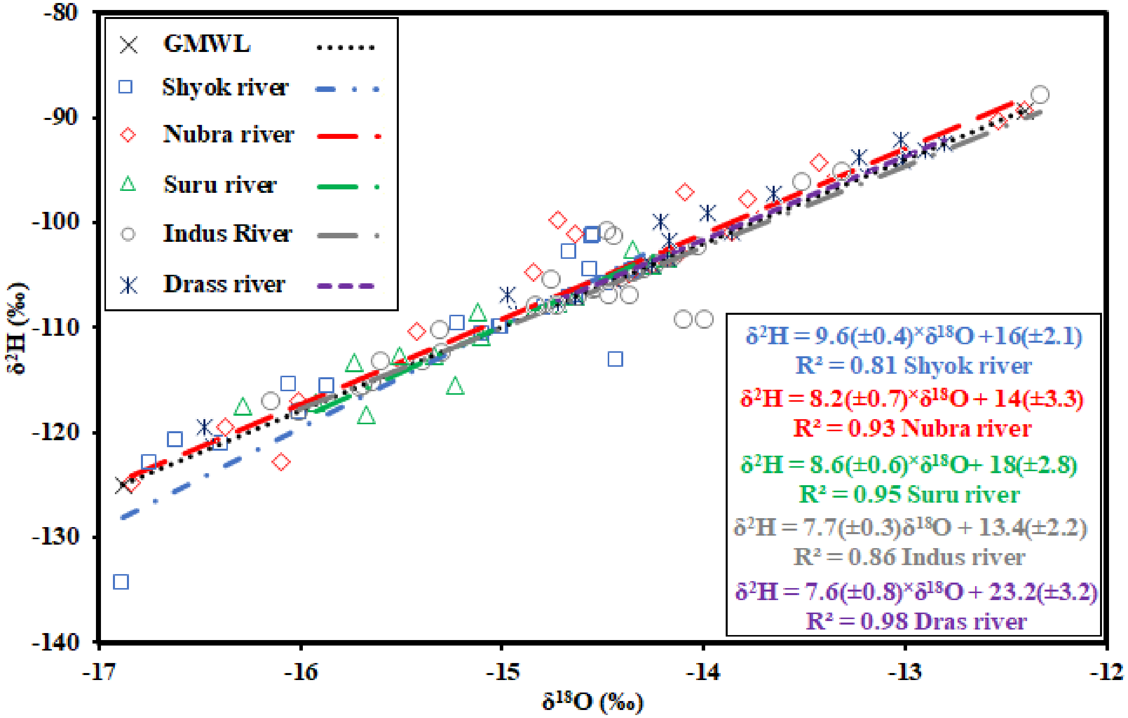
Temporal variation of $\delta^{18}O$ & $\delta^{2}H$ in stream water in different rivers of upper Indus basin

Relation between LMWL & GMWL

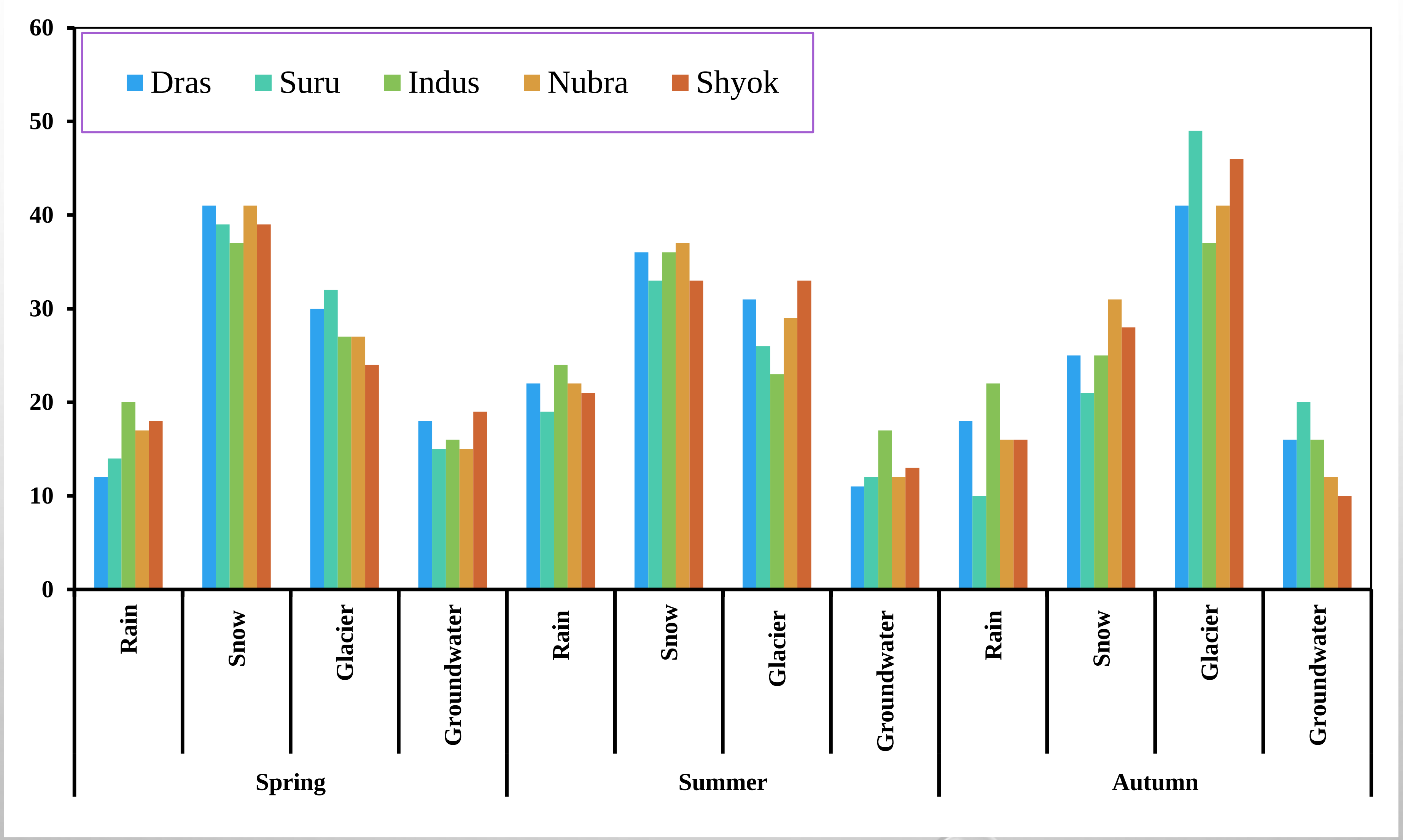
The slope of all stream water is higher than LMWL but lower than GMWL.

- ✓ Dras river: $\delta^2H=7.6(\pm0.8)^{\times}\delta^{18}O+23(\pm3.2)$ $R^2=0.98$
- ✓ Suru river: $\delta^2H=8.6(\pm0.6)^{\times}\delta^{18}O+18(\pm2.8)$ $R^2=0.95$
- ✓ Shyok river: $\delta^2H=9.6(\pm0.4)^{\times}\delta^{18}O+16(\pm2.1)$ $R^2=0.81$
- ✓ Nubra river: $\delta^2H=8.2(\pm0.7)^{\times}\delta^{18}O+14(\pm3.3)$ $R^2=0.93$
- ✓ Indus river: $\delta^2H=7.7(\pm0.3)^{\times}\delta^{18}O+13(\pm2.2)$ $R^2=0.86$





Contribution from rain, snow, glacier melt and groundwater to regional hydrology:



Contribution from rain, glacier melt, snowmelt and groundwater in (%):

Rivers	Spring				Summer				Autumn			
	r	sn	gm	gw	r	sn	gm	gw	r	sn	gm	gw
Dras	12±0.2	41±1.2	30±1.4	18±0.8	22±0.9	36±1.6	31±1.7	11±0.1	18±0.8	25±1.1	41±2.1	16±0.2
Suru	14±0.4	39±1.9	32±1.1	15±0.2	19±0.7	33±1.9	26±1.5	12±1.1	10±0.1	21±0.6	49±2.7	20±0.5
Indus	20±0.4	37±2.1	27±0.6	16±0.6	24±0.7	36±1.2	23±0.7	17±0.3	22±0.8	25±0.9	37±1.1	16±0.7
Nubra	17±1.1	41±1.9	27±0.8	15±0.5	22±0.9	37±1.8	29±1.7	12±0.3	16±0.5	31±0.6	41±2.3	12±0.5
Shyok	18±0.9	39±1.8	24±0.4	19±0.3	21±0.7	33±1.7	33±1.9	13±0.1	16±0.8	28±0.8	46±2.6	10±0.2

The contribution of rain, snow, glacier melt and groundwater to stream flow in different rivers of Ladakh (UIRB) with uncertainty

Field photograph: 2018
Drang-Drung Glacier