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Importance of cryospheric reserves in sustaining streamflow of Himalayan mountainous catchments

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1. Introduction

- ✓ Meltwater generated from the cryospheric reserves of Himalaya plays a significant role in sustaining the livelihood of millions of people living in upstream and downstream regions (Scott et al., 2019; Lone et al., 2022).
- ✓ However, due to global climate change, the large-scale retreat of Himalayan glaciers posed a serious threat to water security (Bajracharya et al., 2019).
- ✓ It is, therefore, important to evaluate the stream water sources and different physiographic and meteorological processes that govern the link between the existing hydrological regimes that would help us to better understand and manage water resources across Himalaya.
- ✓ To describe this research gap in the present study we aimed to identify and estimate the sources of stream flow in Indus River Basin (IRB) based on new stable isotope dataset.

2. Materials and methods

2.1 Sampling and analysis

Water samples were collected from streams (n = 188), snowmelt (n = 35) and glacier melt (n = 27) across UIRB, Ladakh for stable water isotopic ($\delta^{18}O$ and $\delta^{2}H$) analysis.

The stable water isotopes were analyzed using isotope ratio mass spectrometer (IRMS) in continuous flow mode following the standard gas equilibration method. The results obtained are defined according to Vienna Standard Mean Ocean Water (VSMOW) and stated in standard δ-notation as:

$$\delta^{18}O, \delta^{2}H = \frac{R_{sample}}{R_{snow}}*1000$$

2.2. Bayesian mixing approach

To measure the contribution of different source waters to stream flow and their inter annual variability at sub-basin scale a Bayesian isotope mixing approach was used in R (SIMMR).

The Bayesian model considers the relative contribution from different sources (Precipitation, snow, glacier, base flow) and involves two tracers ($_{18}$O and d-excess).

3. Results and discussion

3.1. Variation of isotopes in source waters

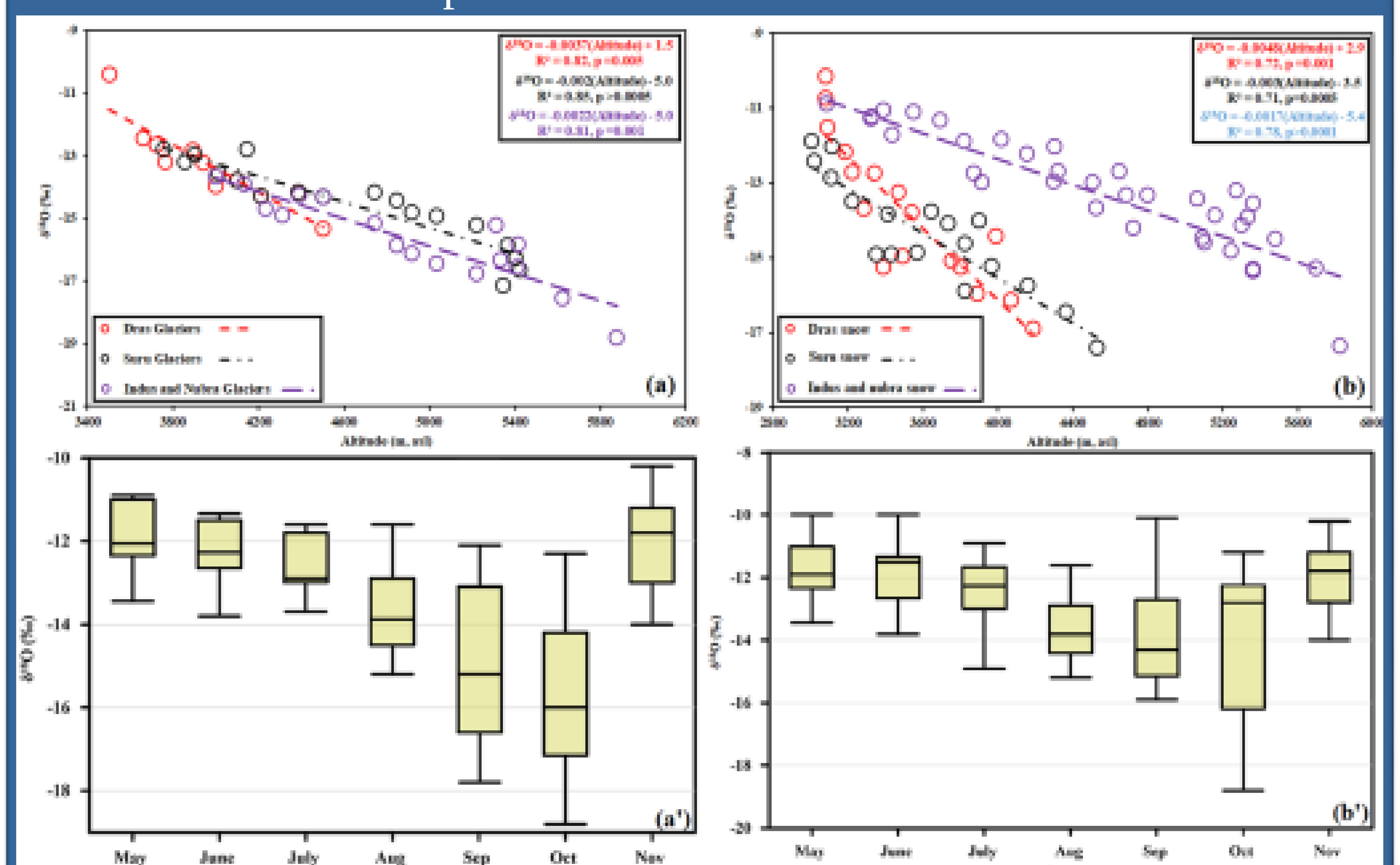

Fig. 1. (a and b) Scatter plots showing the relationship of $\delta^{18}O$ values of glacier melt and snowmelt with sampling site elevation. The lower and higher $\delta^{18}O$ values tend to characterize the glacier melt and snowmelt collected from higher and lower elevations respectively. (a' and b') Box and whisker plots show the temporal variation of $\delta^{18}O$ values among the glacier and snowmelt samples. $\delta^{18}O$ values of glacier melt and snowmelt tend to be higher in May than September.

3.2 Variation of isotopes in stream water

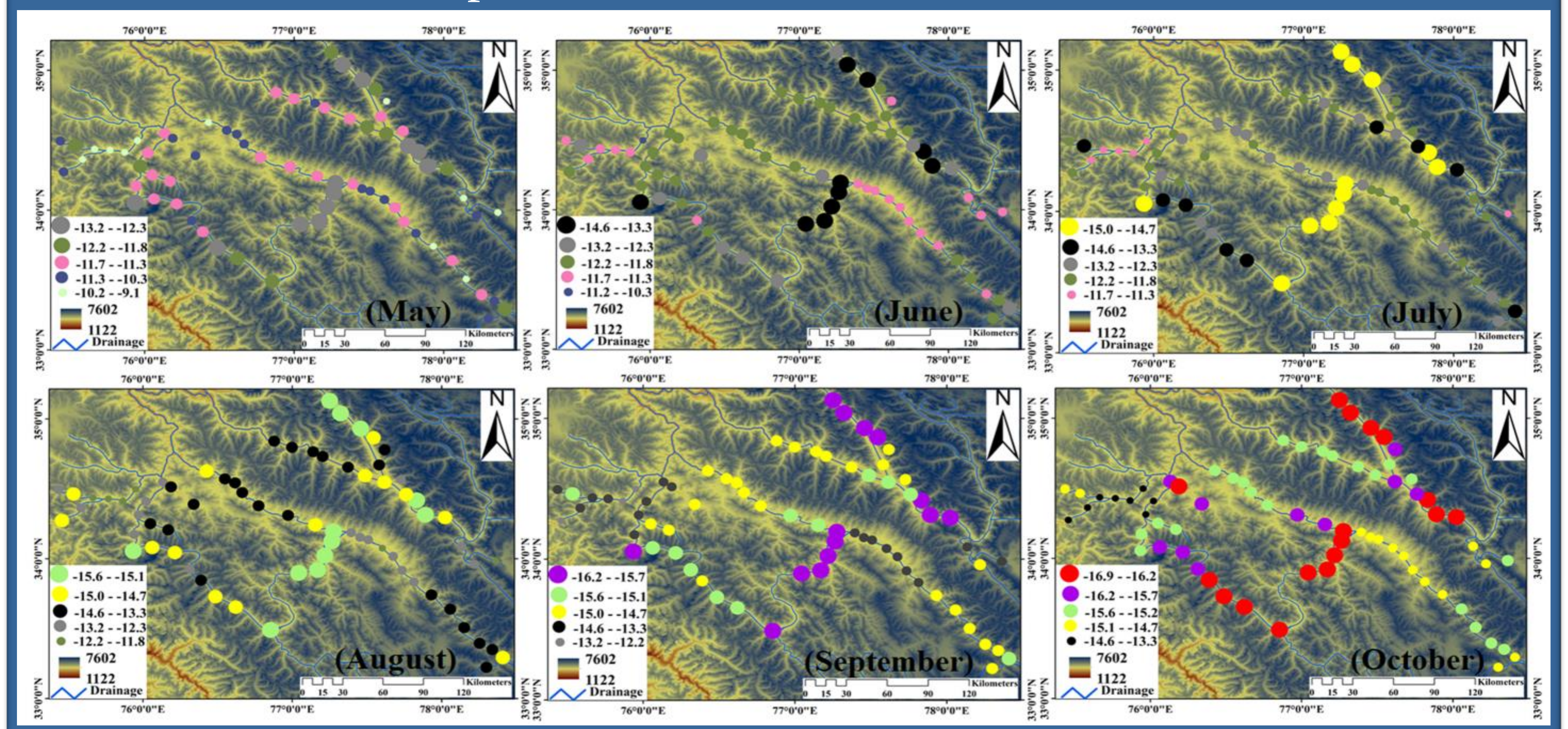

Fig. 2. Spatial variation of stable water isotopic values in the Indus River and its tributaries in each sampling interval. It can be observed from the figure that higher/enriched values were obtained in May and lower/depleted in October. Also, it can be perceived that the lower/depleted stable water isotopic values were observed at higher altitudes and higher/enriched at lower altitudes in every tributary except Indus. The large and small circles with different colors are depicting the depleted and enriched stable water isotopic values in each sampling interval and every tributary. The Aster DEM of 30 m resolution was used as a base map. The color variability in figures is indicating the elevation change.

3.3. Source water contribution using Bayesian approach

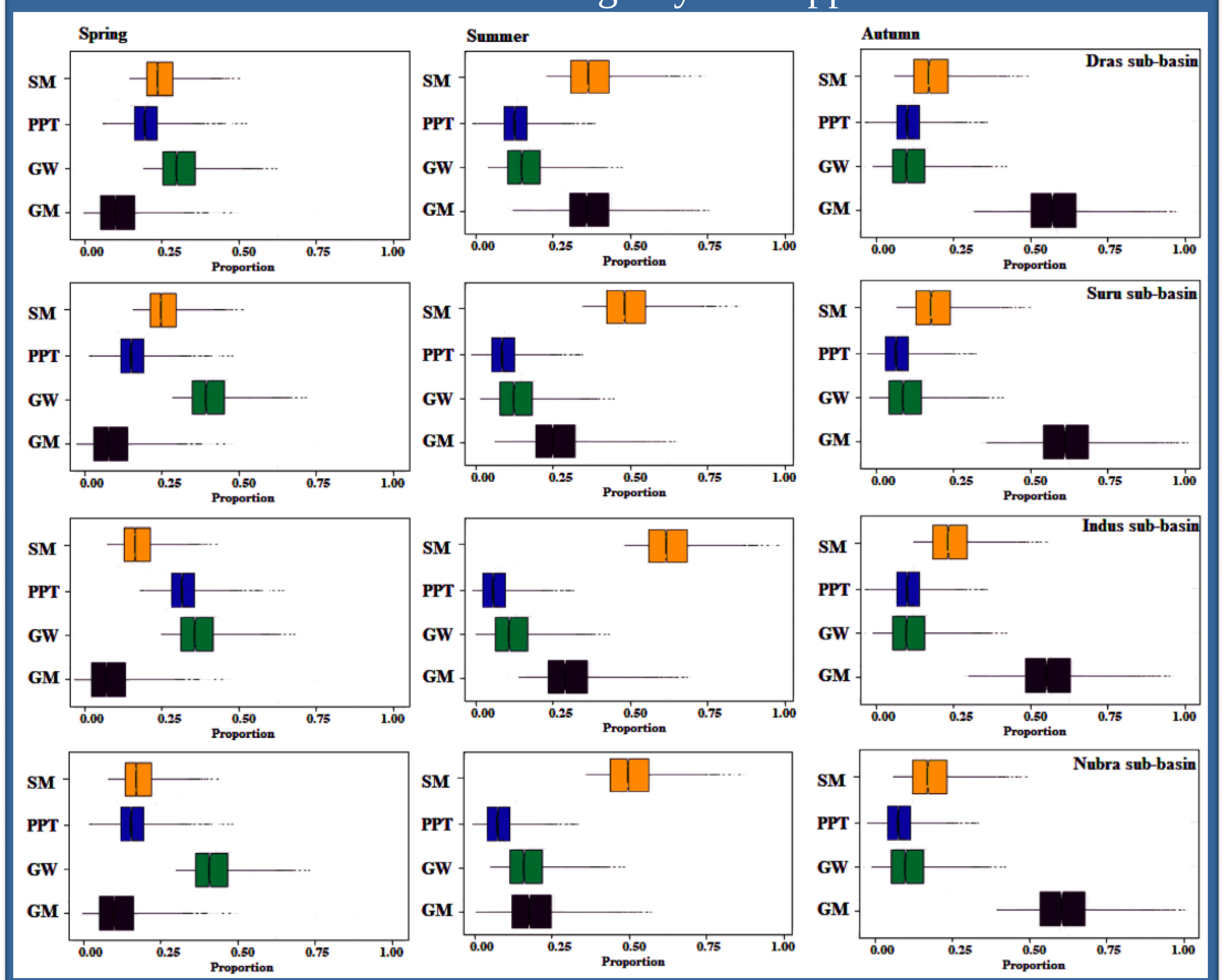

Fig. 3. Box plots obtained from the SIMMR analysis show the contribution of snowmelt (SM), glacier melt (GM), groundwater (GW), and precipitation (PPT) to streams over three-time intervals. Snowmelt is the dominant source of stream water among spring samples, whereas glaciers and snowmelt appear dominant in the summer and autumn seasons. Groundwater although having less contribution to annual flow but makes a significant component in maintaining the flow in the spring season. Rainfall is the least contributor in each time interval.

4. Conclusion

- ✓ The isotope data presented wide spatial and temporal variability without the distinct isotopic signature of various sources of river flow.
- ✓ These variabilities are ascribed to changing physiographical, meteorological, and local climatic conditions prevailing within the sub-basin. The distinct local factors including altitudinal variability, aspects, and slope governing the spatio-temporal variability of source waters and streamflow at sub-basin scale, thus different lapse rates.
- ✓ In the present study, the Bayesian mixing approach was used to model the contribution of different source water to river flow. The modeled results indicated that meltwaters generated from snow and glacier fields supply ~70% of stream flow highlighting the importance of the cryosphere in supplying freshwater to billions of people living in the Indus River Basin

References

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