Collaborative update Activities and Result

Hydrology, water availability and demand-basin scale (Group 4):

Yinsheng Zhang and Arun Shrestha
1. Observation network

2. Update result on understanding UIB hydrological process

1) Glacio-hydrology
2) Water resource-discharge
Meteorological & Hydrological Stations of PMD and WAPDA in UIB
Hydrological Observation in UIB

[Map of the region with various markers indicating AWS, Ablation Stakes, Rain Gauge, Water Level Gauge, UIB Boundary, UIB Sub-basins, and International Boundary. The map highlights the Indus River and its tributaries, with specific locations marked for observation purposes.]
b. Glacier’s Ablation Measurements & Mass Balance Studies in UIB

Ablation Stakes Network

Sachen Glacier (Astore) (4709m)
(3538m)
(3448m)
(4170m)

Barpu Glacier (Hunza) (2784m)

Gharko Glacier (Gilgit) (2928m)
(3827m)
(4610m)
(3455m)

Discharge measurement ★ AWS ★ Rain gauge ★ Ablation Stakes ● Snow pit ● Lake level gauge
Gharko Glacier Monitoring – ITPCAS & PMD

Present Observation

- AWS (ITP)
- AWS (PMD)
- Rain Gauge
- Isotope Rain Sample
- Discharge Station
- Isotope River Sample
- Ablation Stakes
- Destroyed Equipment
Isotope Sampling in UIB
1. Observation network

2. Update result on understanding UIB hydrological process

1) **Glacio-hydrology**
2) **Water resource-discharge**
Glacier Ablation – Ablation Rate in Summer

• Ablation Rate in Summer: Barpu > Gharko ≈ Sachen

• Ablation Rate has significantly negative correlation with debris depth, the negative correlation with elevation was not significant.

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<thead>
<tr>
<th></th>
<th>Ablation Rate</th>
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<tbody>
<tr>
<td></td>
<td>Correlation</td>
</tr>
<tr>
<td>Elevation</td>
<td>-0.379</td>
</tr>
<tr>
<td>Debris Depth</td>
<td>-0.562</td>
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</table>
Impact of Debris over Glacier Ablation

\[ y = -0.929\ln(x) + 5.3252 \]
\[ R^2 = 0.514 \]

\[ \alpha = \frac{A_b}{\sum_{n \text{day}} (T_a - T_0)'} \]

Where \( A_b \) is the total ablation (mm)
\( T_a \) is the mean daily air temperature
\( T_0 \) is the reference temperature
\( n \text{day} \) is the number of days for the reference period

- Clean ice 7 mm\text{d}^{-1}\text{C}^{-1}
- Debris cover ice 3.46 mm\text{d}^{-1}\text{C}^{-1}
- Snow 4.5 mm\text{d}^{-1}\text{C}^{-1}
Glacier movement rates on the surface in

- Gharko Gl.: $62.3 \pm 19.6$ m/year
- Sachen Gl.: $43.7 \pm 30.5$ m/year
- Barpu Gl.: $32.56 \pm 3.53$ m/year
Glacier Thickness (Barpu Gl.)

Cross Profile 01 in Barpu

Cross Section
Area $7.29 \times 10^4 \text{ m}^2$
1. Observation network

2. Update result on understanding UIB hydrological process

1) Glacio-hydrology
2) Water resource-discharge
Melt water source of discharge in UIB

Highly generalized diagram showing origin of two distinct types of melt water in UIB

- Melt water from high-altitude catchments in UIB, is a mixture of
  - glacial melts,
  - melts from seasonal snows that fall in the winter and spring prior to the melting season,
  - and summer snowfall that takes place concurrently

(Mukhopadhyay and Khan, 2014, JH)
Population growth and agriculture have stressed the Indus, which flows the length of Pakistan.

CLIMATE CHANGE

**Indus River waters shrinking**

Hashmi’s data, which are unpublished, come from a network of hydrological stations in Pakistan that span the main stem of the Indus and three of its tributaries. They show that the total water supply fell by 5% between 1962, when the hydrological stations were built, and 2014. "A reduction of 5% over five decades may not seem a lot," says Walter Immerzeel, a hydrologist at Utrecht University in the Netherlands, who led one of the studies that projected an increase in water supply in the Indus (A. F. Lutz et al. Nature Clim. Change 4, 587–592; 2014). “But if the trend persists, there could be devastating implications for water resources.”

Hashmi’s team finds that the river’s shrinkage is seasonal, with a decrease in flows between April and August that exceeds a slight increase during the rest of the year. And it reports a temperature drop across the four Pakistani river basins in the summer months — even though the region is getting warmer overall. Because snow- and glacier
Winter discharge features an increasing trend, while for the rest of seasons and on an annual time scale, sites mostly exhibit a mixed response.

Shift during the seasonal transitional month of June and within the high flow months July-September

- long term trend: eastern-, central- and whole Karakoram, UIB-Central, Indus at Kachura, Indus at Partab Bridge and Astore regions is increasing while rest of regions is decreasing
- May attribute to a multi-decadal variability of climatic processes over the region, which is driven by NAO and ENSO

Spatial Distribution trends of discharge trend in UIB

(Hasson et al., 2015)
Contribution of snow/ice to runoff
- Improvement of Lutz et al. 2014 work

- Extend the timeline to 2100
- Improve glacier/groundwater module
- Improve forcing data: reference
- Improve forcing data: future
- Consider extreme events
Contribution to total flow by glacier melt (a), snow melt (b) and rainfall-runoff (c) for major streams during the reference period (1998-2007).

Line thickness indicates the average discharge during the reference period [Lutz et al., 2014]
Reconciling high-altitude precipitation in the upper Indus basin with glacier mass balances and runoff


- Lack of high altitude precipitation observation
- Reanalysis products have high bias – gap in water balance
- Use of RS based glacier mass balance used to inversely infer the precipitation data
- Validation with observed runoff data shows the improved ppt data closes the water balance better
Extending to IGB basins

Uncorrected

Corrected
Future proposal

A. High altitude hydrology: precipitation
B. Integrate observation network
C. Collaborative model simulation

D. Learning from existing programmes, invitation of experts:
   - PMD WAPDA
   - EvK2-CNR
   - ICIMOD
   - NASA: real time precipitation data-Precipitation Measuring Mission (PMM)
   - Alpine experiences (SLF, ANETZ)
   - etc.

E. Responsibilities for programme- and schedule-design