http://nsidc.org/charis

A Collaborative Effort to Assess the Role of Glaciers and Seasonal Snow Cover in the Hydrology of the Mountains of High Asia – The CHARIS Project

R. Armstrong, M.J. Brodzik, S.J.S. Khalsa, A. Racoviteanu, B. Raup, K. Rittger, A. Hill, B. Armstrong, M. Williams, A. Barrett, F. Fetterer, A. Wilson, A. Khan

Rijan Kayastha, Nepal (Asian Project Manager) and Larissa Kogutenko, Kazakhstan

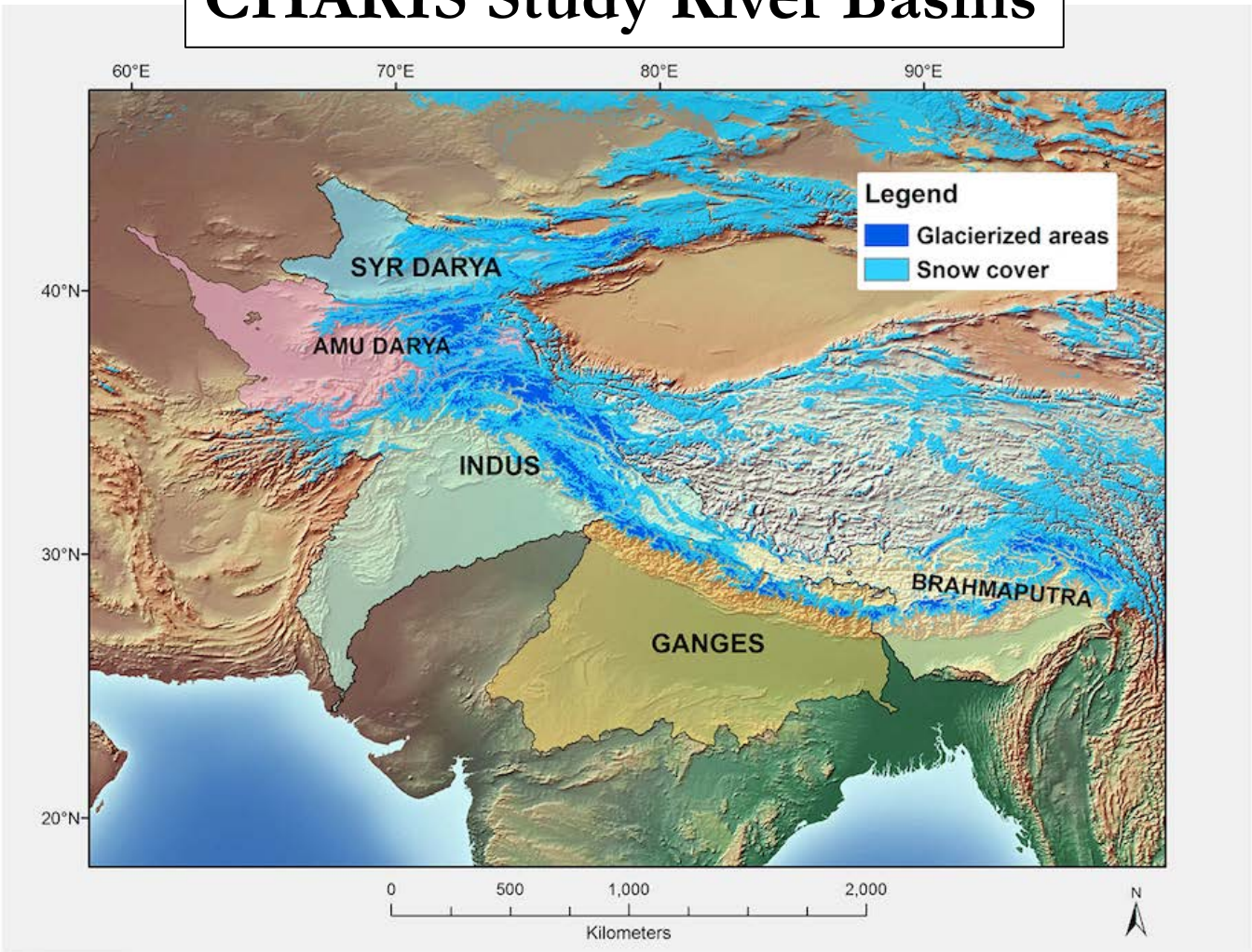
CHARIS Project is funded by USAID

CHARIS Project - Contribution to High Asia Runoff from Ice and Snow

CHARIS Project Concept –

- It is not possible to generate realistic, accurate, estimates of future availability and vulnerability of water resources across this very large mountain region until we have achieved a better understanding of the current hydrologic regime, specifically the large-scale spatial and temporal variability of snow and ice resources.

CHARIS Study River Basins



Ganges

943,238 km^2

Indus

816,846 km^2

Brahmaputra

514,170 km2

Amu Darya

449,320 km^2

Syr Darya

249,071 km^2

Total =

2,972,645 km ^{2}

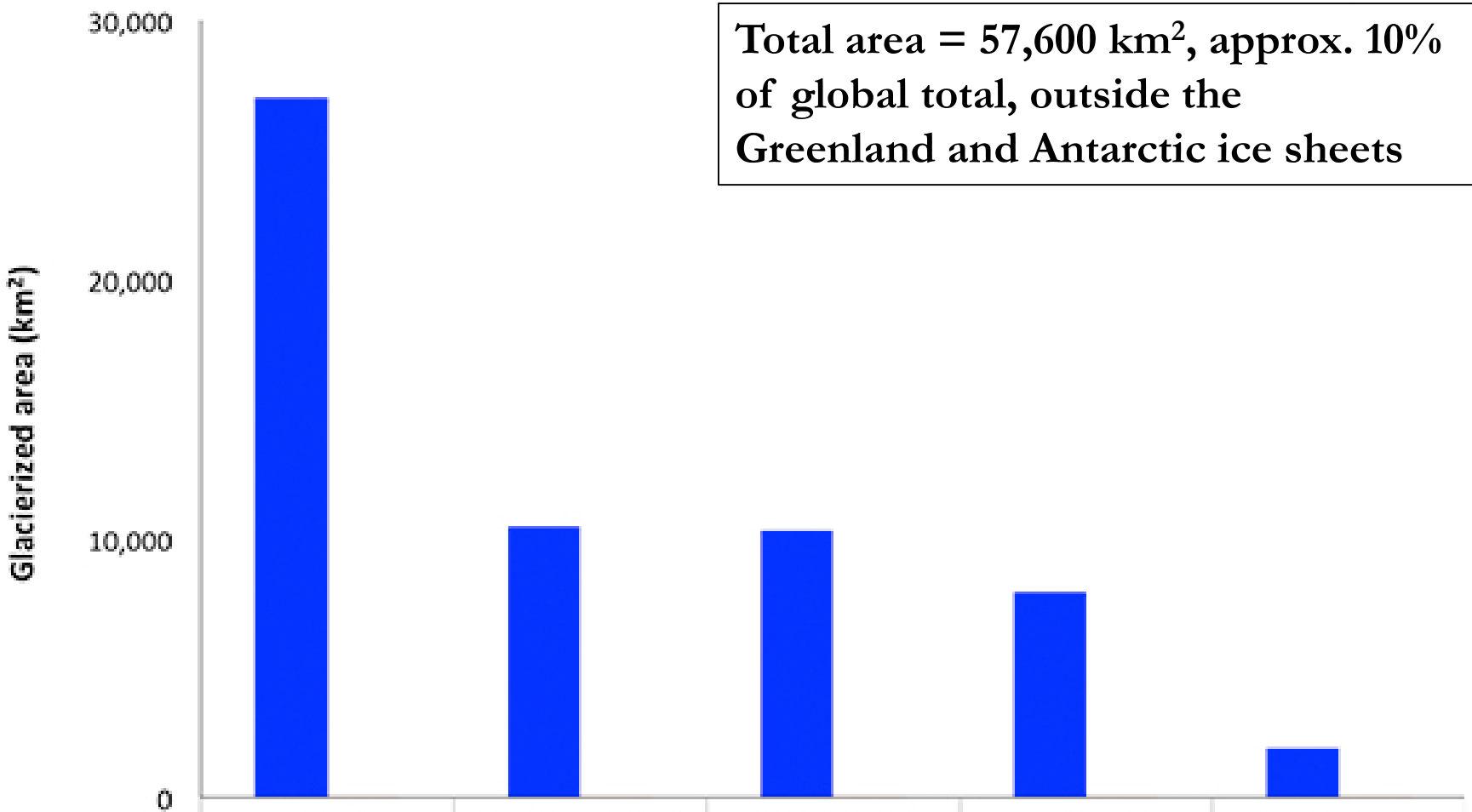
Snow cover (light blue) represents areas covered with snow for 20% of the time, for the period of record (2001-2014) based on MODIS data; MOD10A1 - snow cover and MOD44W- water mask at 500m resolution.
Glacierized areas (dark blue) represent glaciers from the Randolph Glacier Inventory (RGI v.5)

http://nsidc.org/charis

Glacier area by basin in the CHARIS region

(Randolph Glacier Inventory, RGIv5/GLIMS/NSIDC)

Total area = 57,600 km^2, approx. 10% of global total, outside the Greenland and Antarctic ice sheets



	INDUS	BRAHMAPUTRA	AMU DARYA	GANGES	SYR DARYA
Glacier Area [km2]	26,982	10,483	10,321	7,931	1,881
% Basin glacierized	* 3.24	1.65	2.29	0.94	0.86

NSIDC USAID FROM THE AMERICAN PEOPLE

Project Goals for CHARIS

- Apply satellite remote sensing data to develop a thorough and systematic assessment of extent of snow and ice resources across the CHARIS region.
- Estimate the amount, timing and spatial patterns of snow and ice melt, which play a key role in providing water for downstream irrigation, hydropower and general consumption.
- Collaborate with Asian partner institutions: recognize common goals, share methods, compare results.

Collaboration with Asian Partners

- CHARIS has established formal research partnerships between the University of Colorado and 11 key scientific institutions in 8 nations across the region of High Mountain Asia.
- These partnerships provide a two-fold benefit to the regional research capabilities through both capacity building and data sharing.
- The partnerships promote and facilitate the international cooperation required for successful cross-boundary water resources management on a regional, not just a national basis.

CHARIS Partner Institutions

Nepal, Kathmandu University
Afghanistan, Kabul University
Bhutan, National Center for Hydrology and Meteorology
Bhutan, Sherubtse College, Royal University of Bhutan
India, Jawaharlal Nehru University
India, Sharda University
Kazakhstan, Institute of Geography
Kyrgyz Republic, Institute of Water Problems and Hydropower
Pakistan, Karakoram International University
Pakistan, Water and Power Development Authority WAPDA
Tajikistan, Institute of Water Problems, Hydropower, Ecology

CHARIS training and education

- All partner institutions have consistently participated in the annual training workshops
- 237 total participants, 29 women
- Recent workshops have included surveys for participants to evaluate success and to plan for the subsequent training
- With CHARIS support, 8 students from partner institutions have graduated from the Kathmandu University M.S. in Glaciology program, plus 4 more were enrolled in single semester glaciology courses, under the direction of Professor Rijan Kayastha

Specific examples of partner capacity building

- Field training in data collection methods
- Training workshop topics: taught by U. of Colorado research scientists (in 2018 selected best University in the World for Geosciences – *US News-Education*)
  - Mountain hydrology
  - Water chemistry
  - Downscaling of reanalysis temperature data
  - GIS and remote sensing for glacier mapping
  - DEM evaluation and application
  - Snow/ice melt modeling

Research - methodology for estimating the individual contribution of seasonal snow and glacier ice melt to total flow:

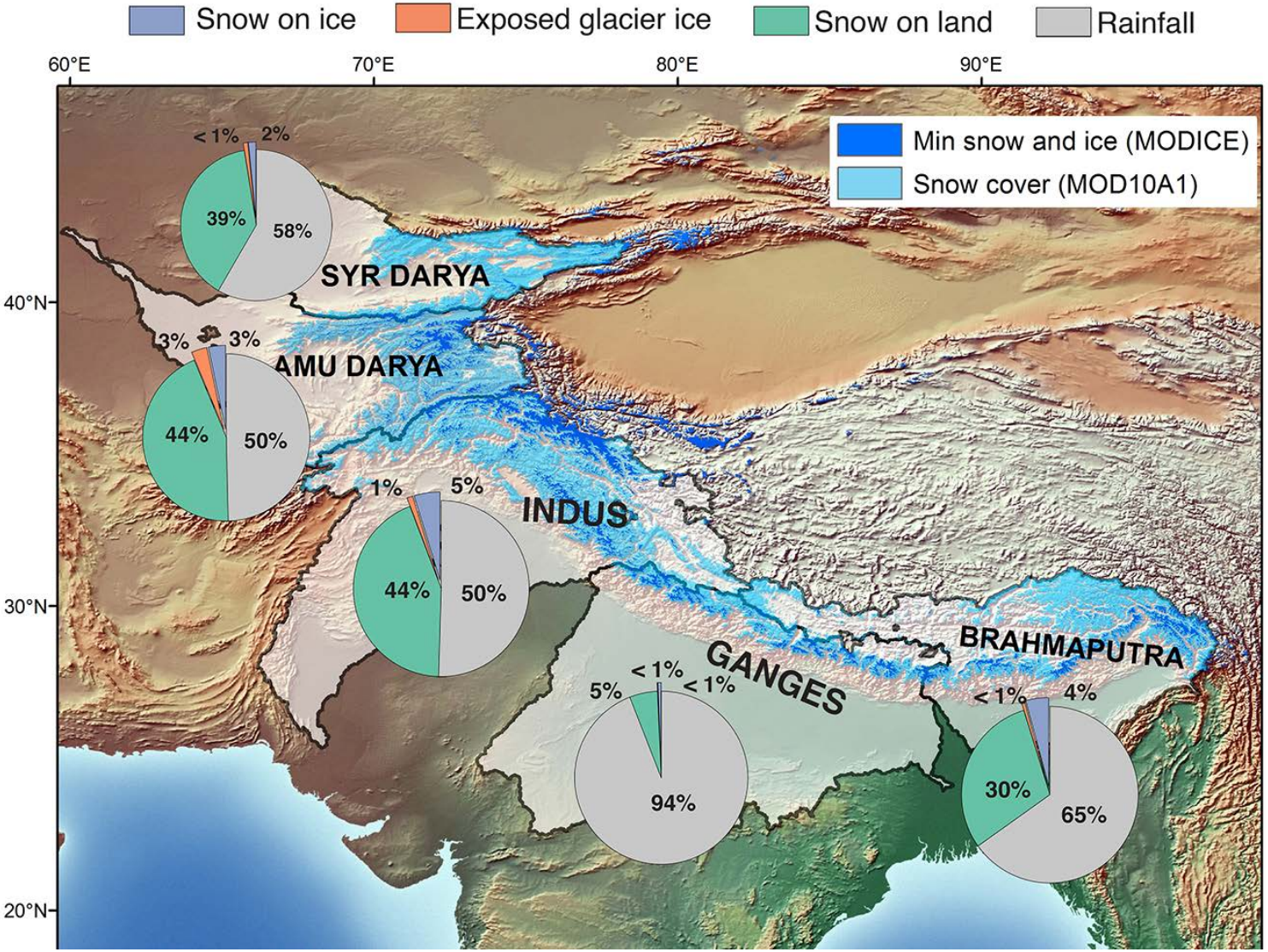
1. Identify and partition areas of snow on land, snow on ice and exposed glacier ice using MODIS (500 m) data calibrated to Landsat (30 m) images.

2. Generate gridded maps of snow and glacier ice area by elevation as input to melt model.

3. Melt areas of ice and snow using downscaled temperatures in a temperature index model.

See research results in the 2018 publication: "Runoff from glacier ice and seasonal snow in High Asia" Regional Environmental Change – Springer 10.1007/s10113-018-1429-0

Annual mean melt contribution of snow, ice and rainfall to runoff in CHARIS full basins – 2001 - 2014



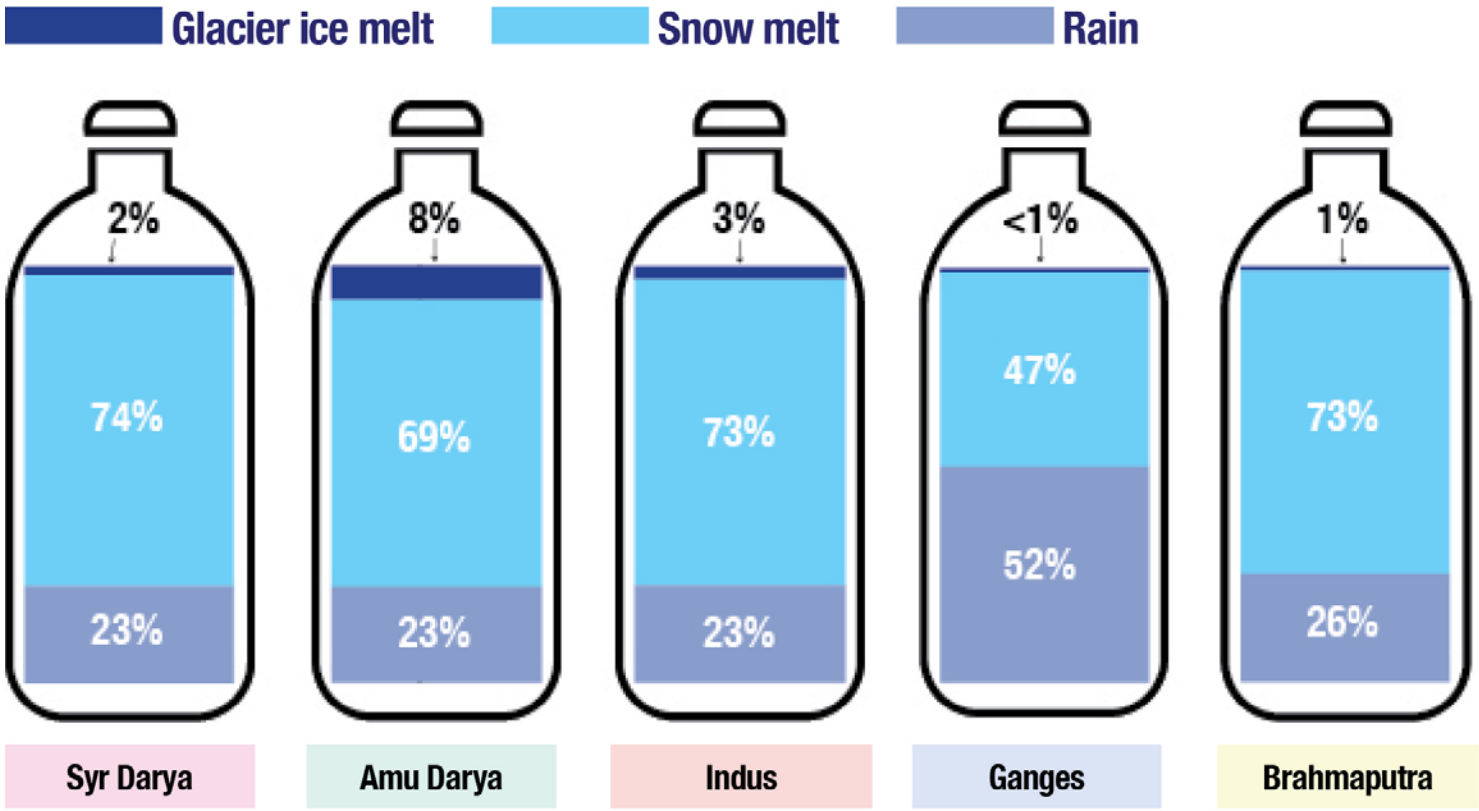
http://nsidc.org/charis

NSIDC

USAID FROM THE AMERICAN PEOPLE

WHERE THE WATER COMES FROM, BASIN BY BASIN — ANNUAL AVERAGES

Figures rounded to nearest %



GLACIERS

contribute little to river flow, and less in the east (Ganges and Brahmaputra) than in the west (Syr Darya, Amu Darya, Indus).

SNOW MELT

contributions drive river flow in all basins but the Ganges.

MONSOON RAIN

dominates inputs in the Ganges.

Basins above 2,000 m elevation

Melt Contribution Seasonal Pattern

- Primary contribution from glacier ice melt across region is consistently during June-July-August.
- This contribution represents a significant source in west (15-20%) but because this period coincides with the maximum monsoon rainfall in the east the percentage contribution from glacier ice melt is considerably less (< 5%).

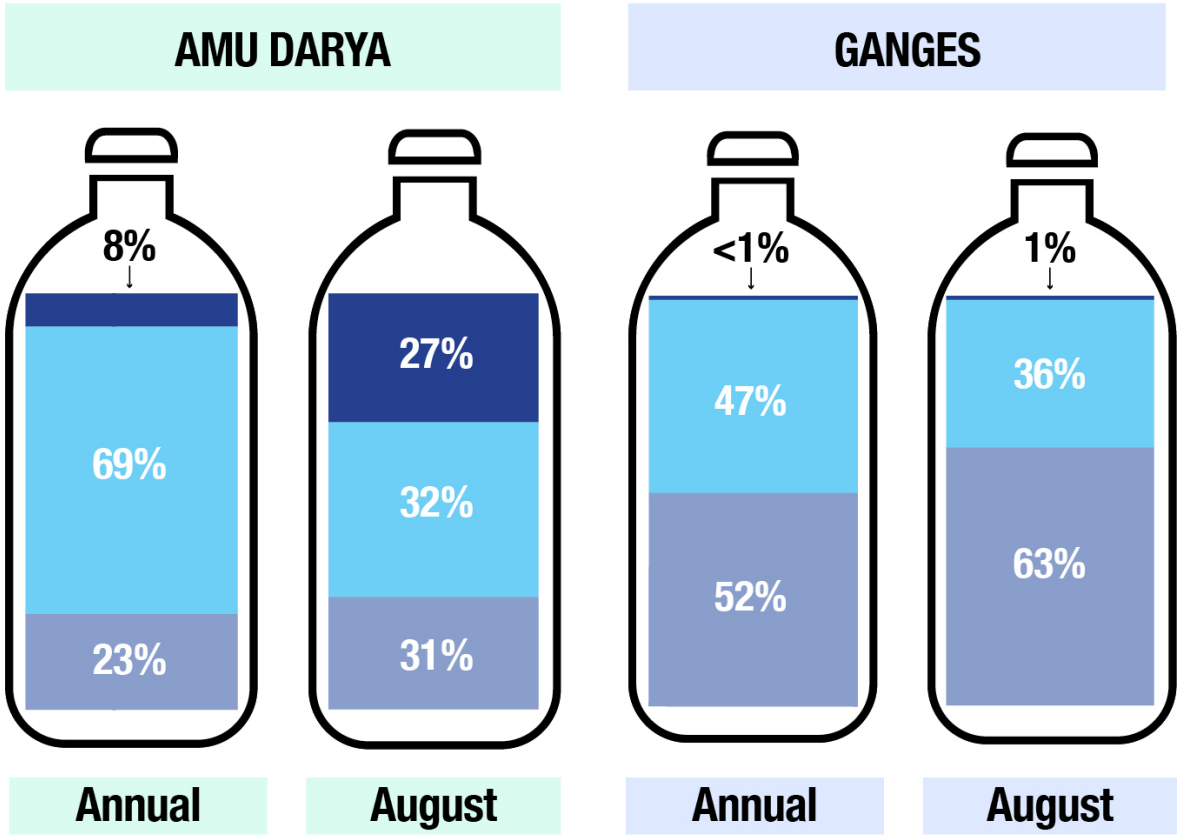
SEASONAL PATTERNS OF MELTWATER SOURCES

Glacier ice melt

Snow melt

Rain

While annual water supplies may not be highly dependent on glacier melt, late summer river flow can be. For example, in the Amu Darya River, 27% of August river flow is sourced by glacier ice melt. In contrast, Ganges River flow is primarily dependent on snowmelt and rainfall.



Basic Results

- Contribution from glacier ice melt highly significant in Western High Asia during summer but less significant in eastern regions that are dominated by summer monsoon rainfall.
- In general, snowmelt contributes 10 times more water than glacier ice melt across the region.
- Recent trends in snow covered area, and glacier volumes, will be presented by the next two speakers.

Summary

- CHARIS has achieved success in capacity building and technology transfer among 11 partner institutions in 8 Asian nations.
- Quantified the separate contributions of snow and ice melt to 5 major river basins in High Mountain Asia.
- Results support the development of models to determine how snow and ice melt contributions may change within future climate projections.
- Changes in precipitation trends, amount of rain vs. snow, need to be considered to make accurate water resource projections.