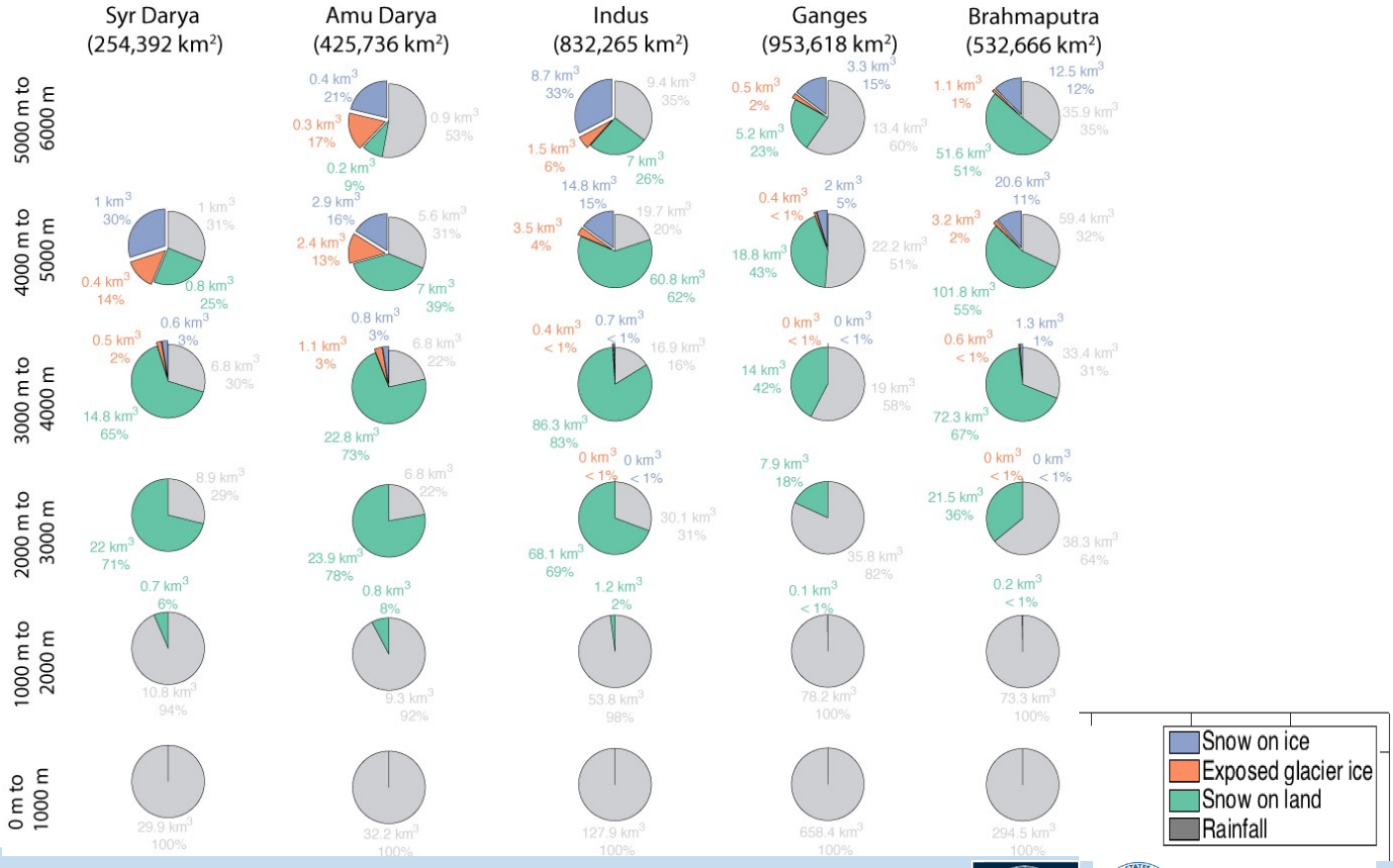
Annual mean melt contribution from snow on ice, exposed glacier ice, snow on land, and rainfall by elevation (0 to 6,000 m)



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Calibrated model across 5 full basins - melt contribution by elevation

- SOL melt apparent as low as 1,000 - 2,000 m in AM and SY, located 15^{o} further north than eastern CHARIS region.
- SOL makes significant contribution across the full region starting at 2,000 m, with GA at 3,000 m
- Contribution from SOL for AM, SY, IN, above 3,000 m = 60-65 % and 40-55% for GA and BR
- Contribution from glacier ice begins to make significant contribution > 4,000 m – 10-15% in SY and AM, 5-10 % for IN, and 3-5% for GA and BR

- melt contribution seasonal pattern

- Seasonal snow cover melt begins at lower elevations in Feb-Mar and continues through summer at higher elevations.
- Primary contribution from glacier melt across region is consistently during June-July-August.
- The contribution of glacier ice melt during this period 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 melt is considerably less (< 5%).

Basic Conclusions:

Importance of contribution from glacier ice melt varies seasonally, annually and regionally.

Contribution from glacier melt highly significant in Central Asia but less significant in eastern High Asian regions that are dominated by monsoon rainfall.

In general, snowmelt contributes 10 times more water than glacier ice melt.

No statistically significant decrease in seasonal snow covered area has been observed over the past 15 years across the CHARIS region.

Summary

CHARIS results:

- Success in capacity building and technology transfer among 11 partner institutions in 8 Asian nations.
- Developed satellite based method of identifying/separating snow and ice surfaces.
- Estimated specific contribution of snow and ice melt to 5 major river basins in High Mountain Asia.

Thank you from the CHARIS team

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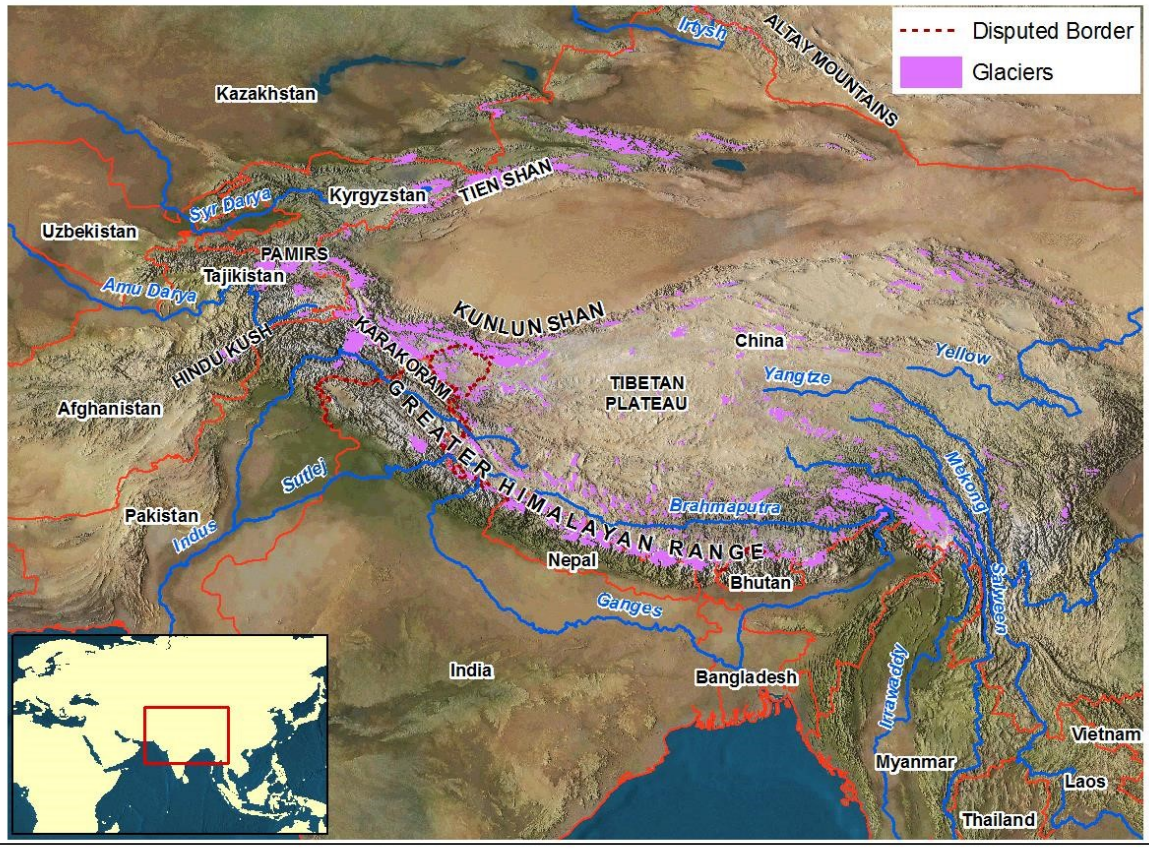
Kara-Batkak Glacier
Kyrgyz Republic

Extra slides --

CHARIS Areal Coverage of "High Asia"

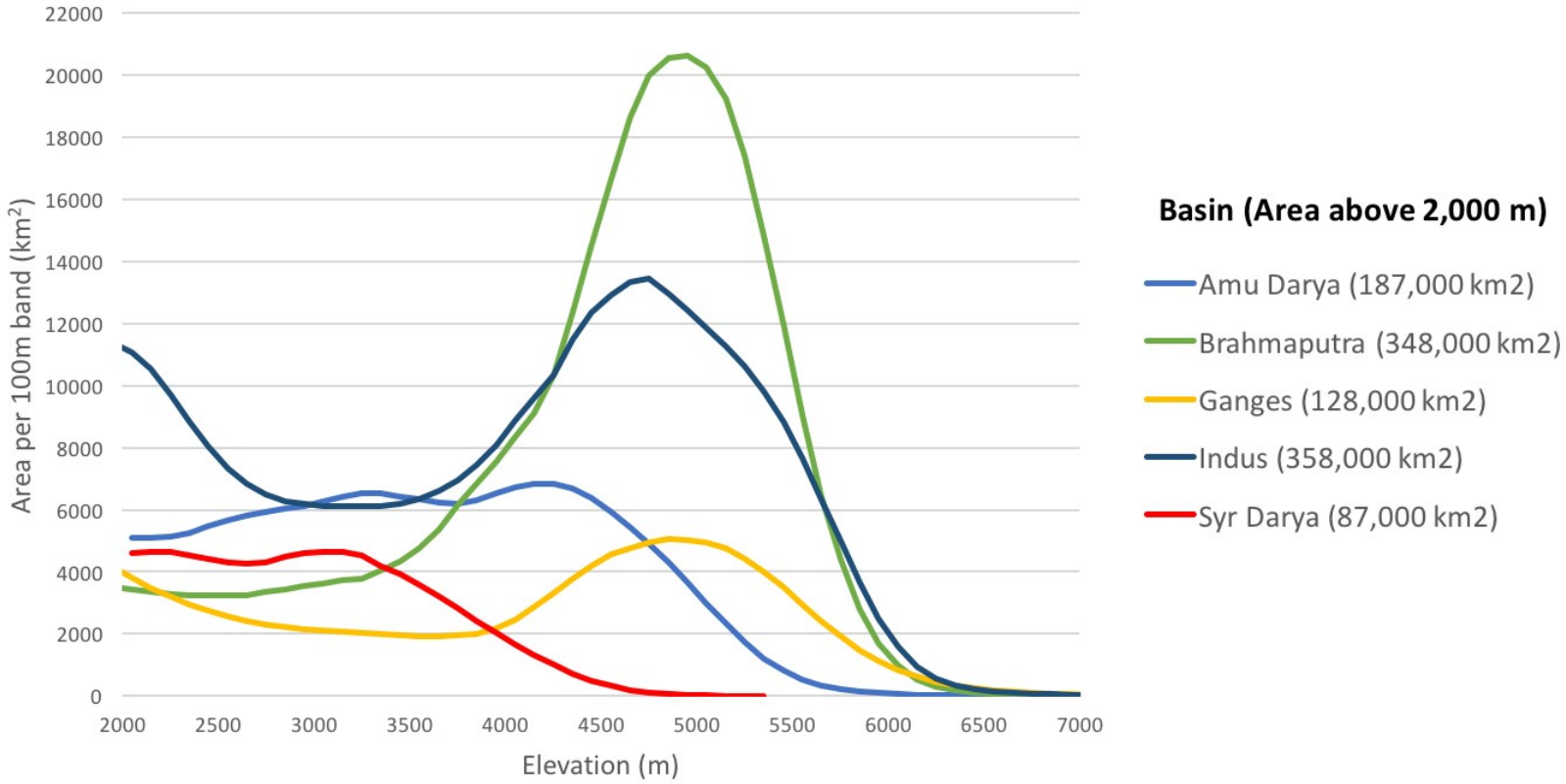


Brahmaputra
Ganges
Indus
Amu Darya
Syr Darya

Bhutan
Nepal
India
Pakistan
Afghanistan
Kazakhstan
Tajikistan
Kyrgyzstan

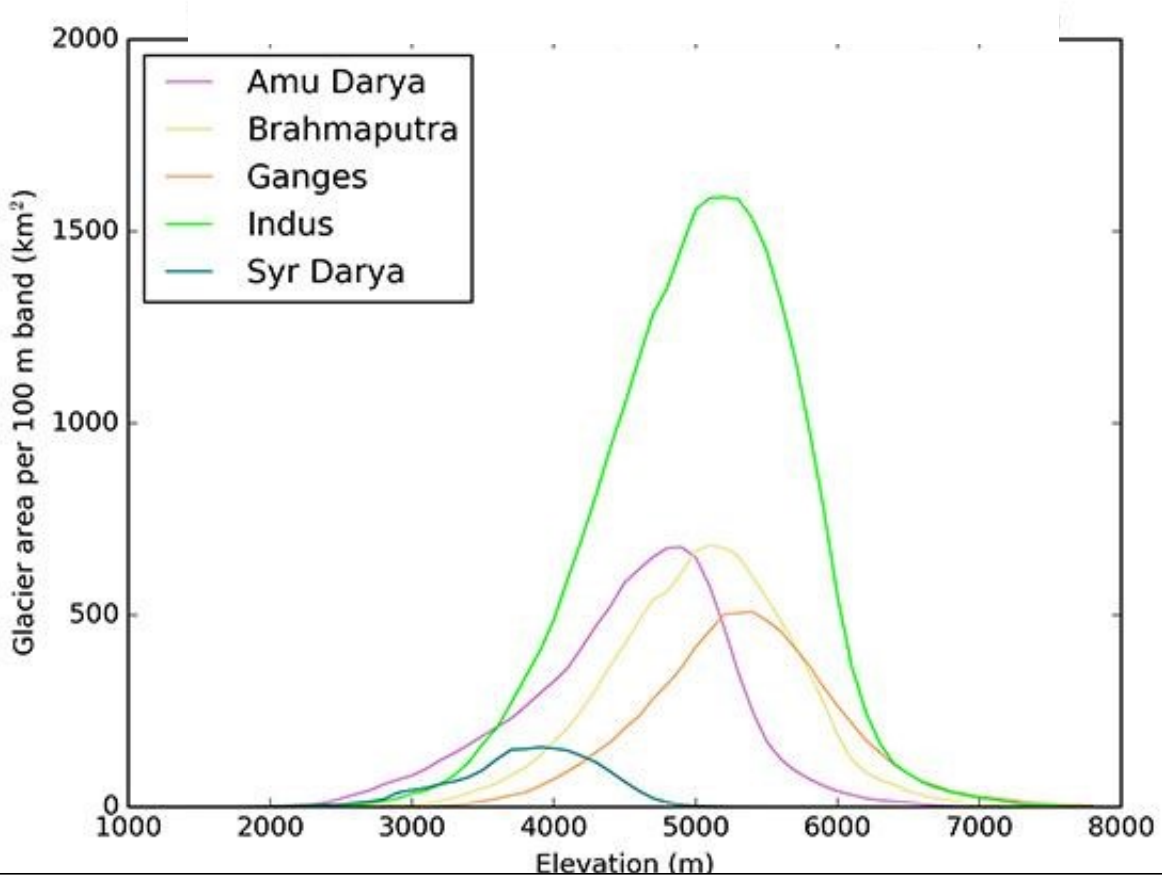
River basins, countries, mountain ranges – 2,000 km arc from Bhutan in the southeast to Kazakhstan in the northwest.

Area elevation distribution of CHARIS basins



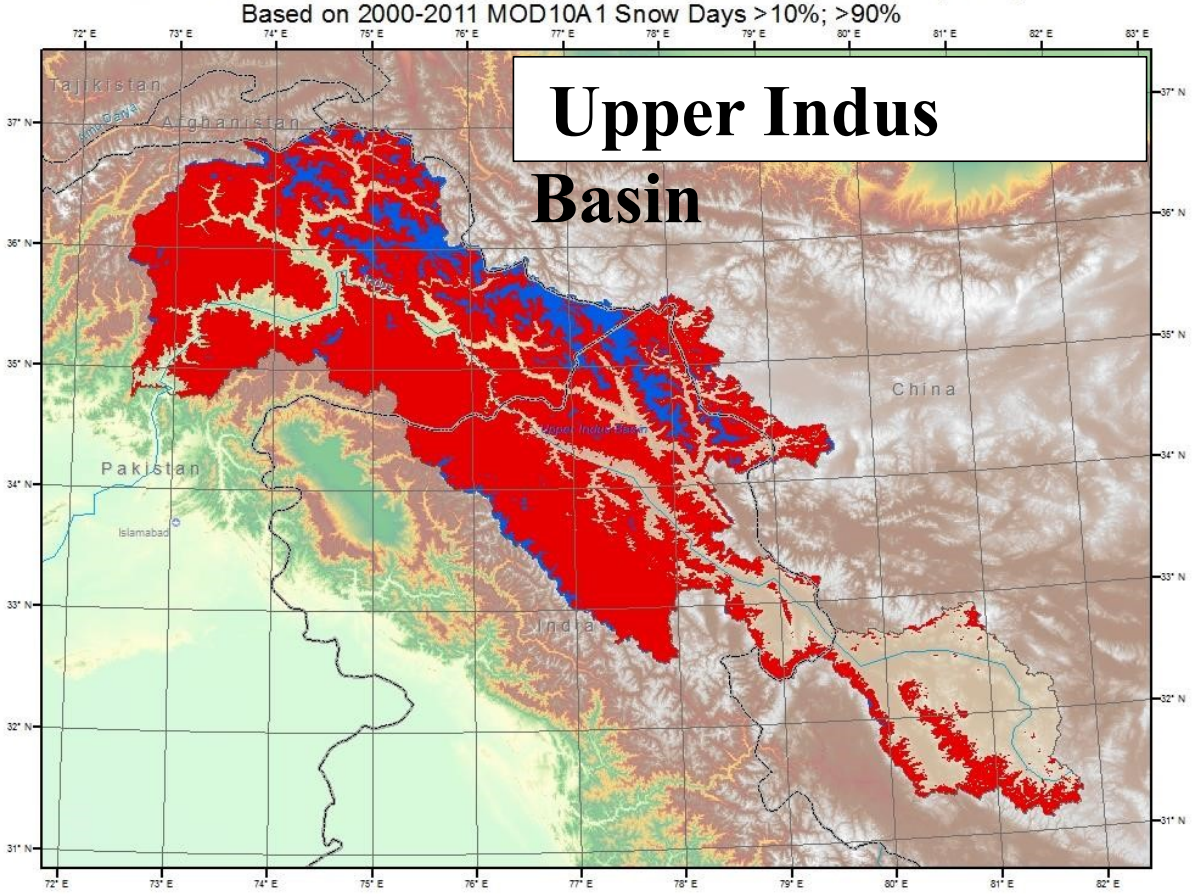
BR has about half the total area of GA but nearly 3 times the area above 2,000 m

Glacier area by elevation for 5 CHARIS basins



Areas primarily concentrated between 3,000 m and 6,500 m except SD

CHARIS Basins and Maximum snow extent (RED); Persistent snow/ice (BLUE)
Based on 2000-2011 MOD10A1 Snow Days >10%; >90%



UIB above Tarbela Dam -Average maximum snow extent (red): 72%, glaciers (blue): 8% of total basin area (166,553 sq. km)

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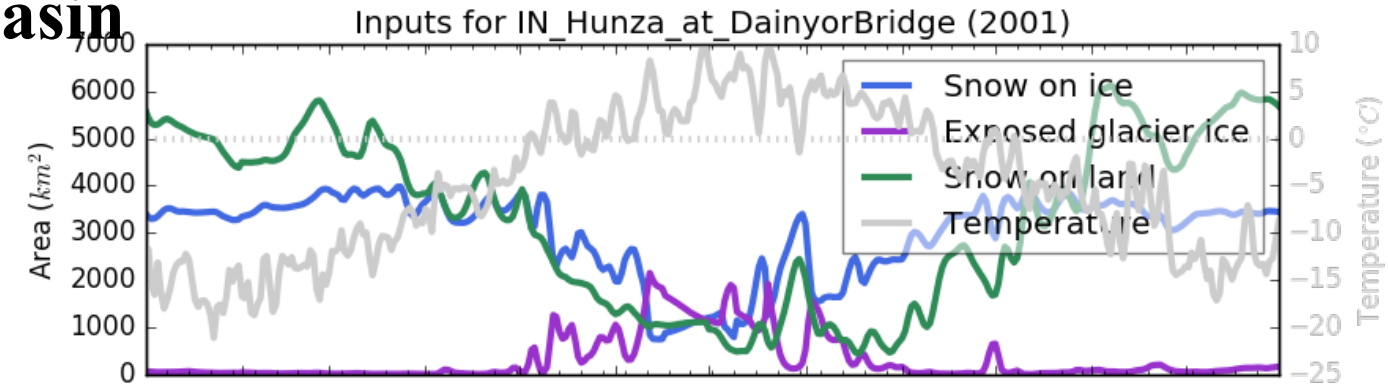
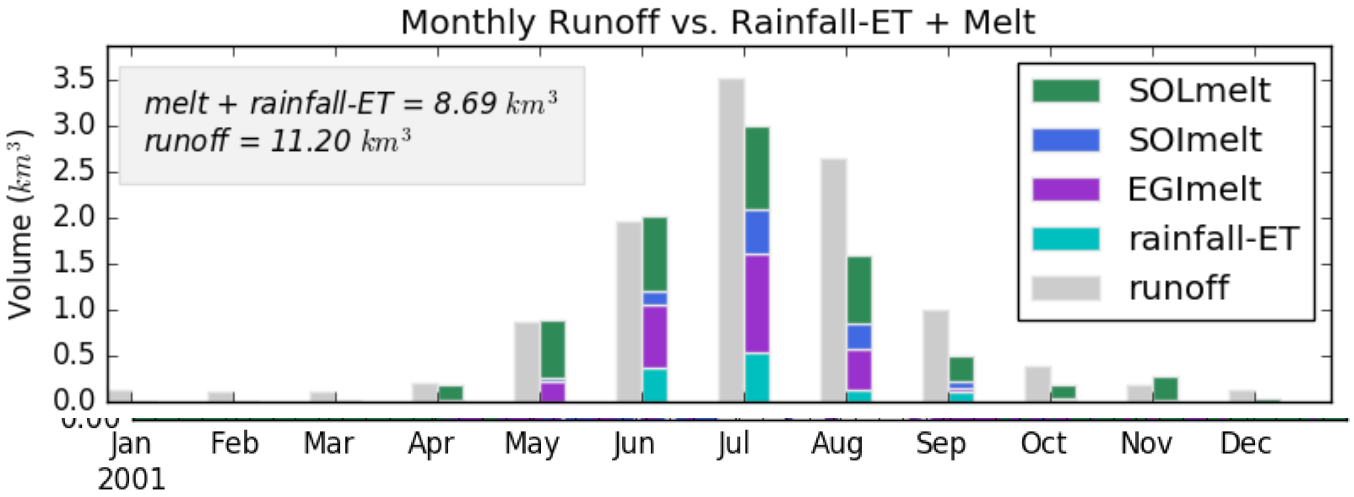
Daily calibration model example for Hunza basin

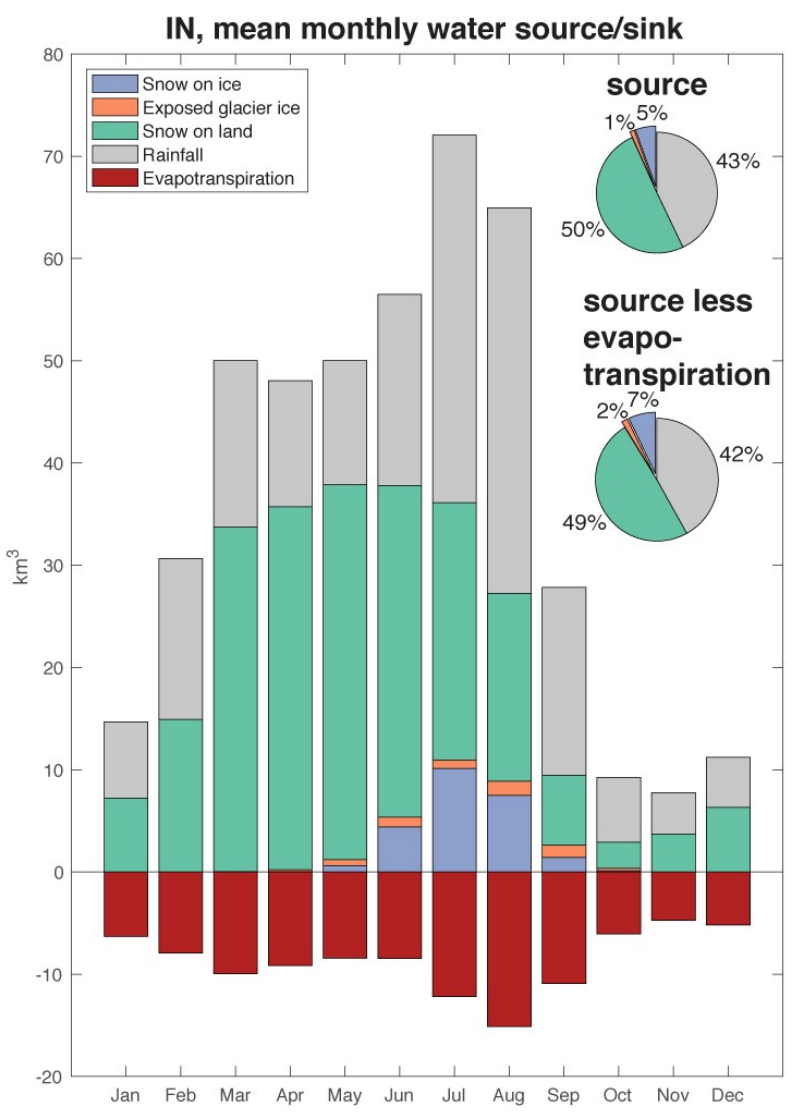


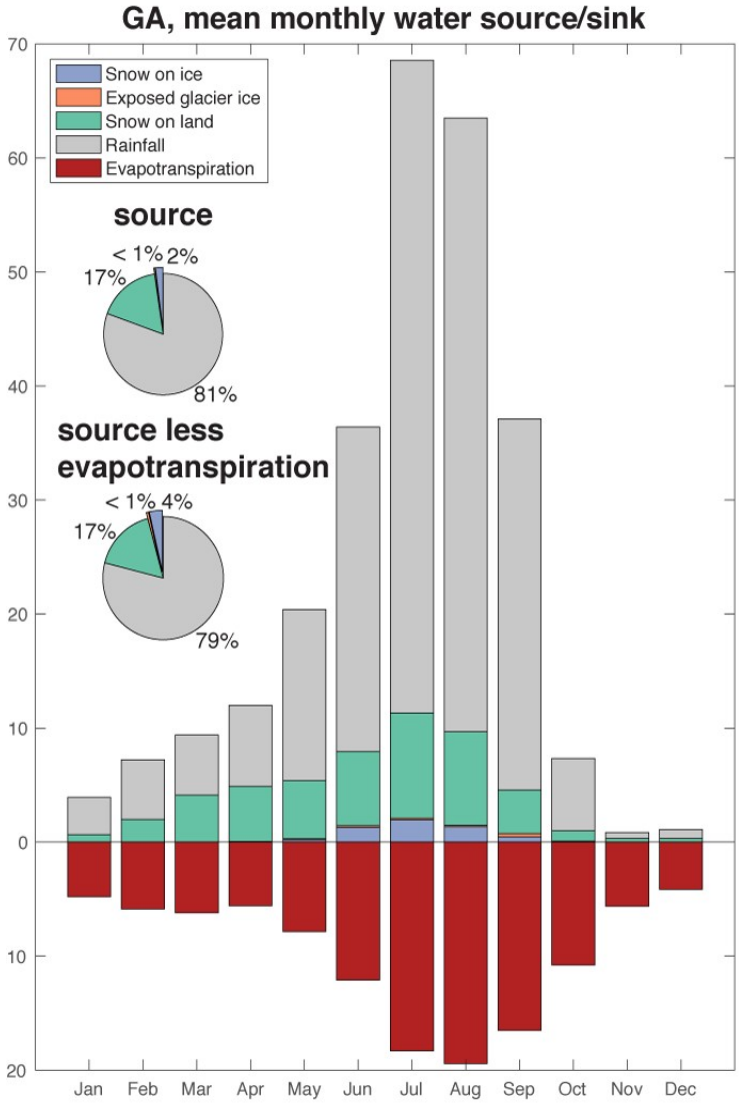
Monthly Total Runoff Components



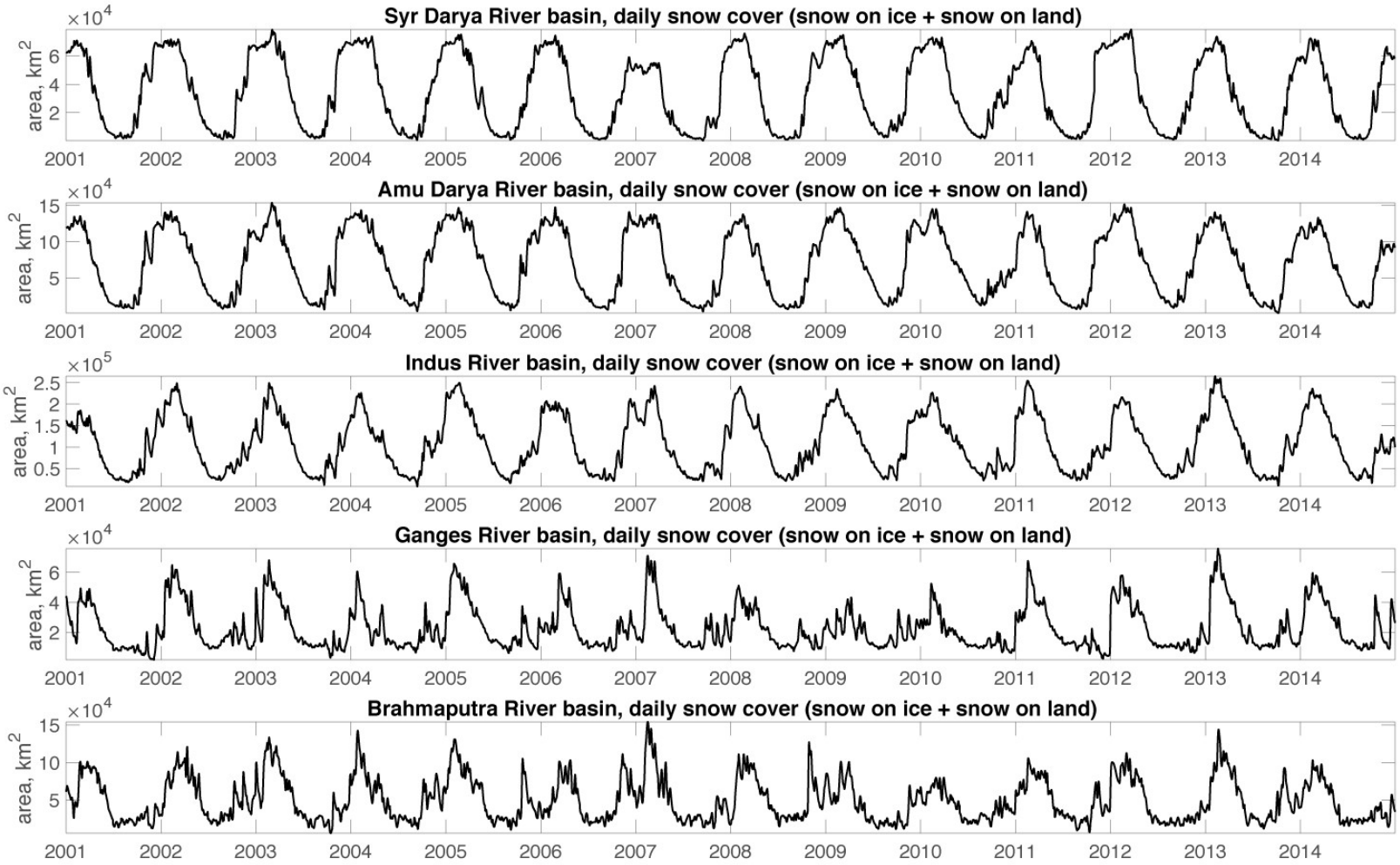
Indus and Ganges water sources

(APHRODITE rainfall & MODIS ET)





Daily snow covered area – 5 CHARIS basins



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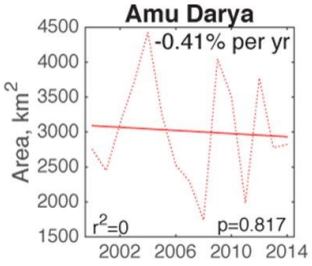
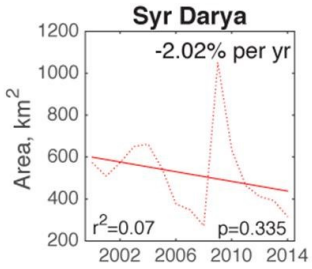
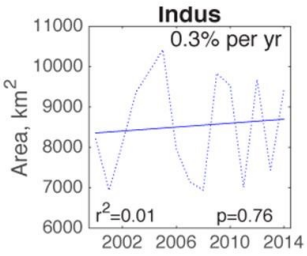
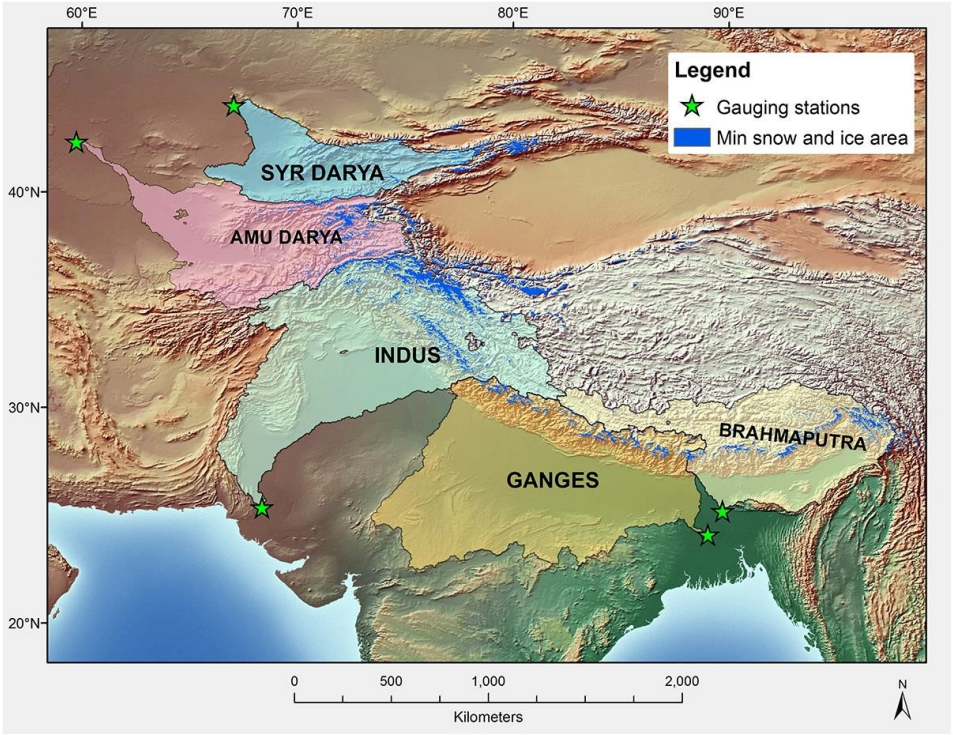
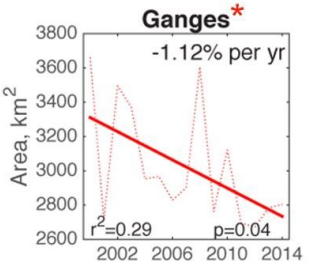
Trends in annual minimum snow and ice area in the CHARIS region river basins based on the MODICE algorithm 2000-2014.

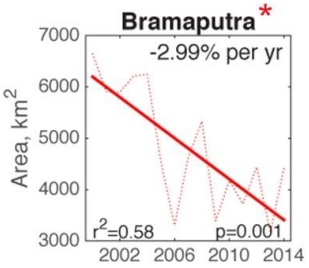












* *Indicates statistically significant trends in annual minimum snow and ice areas (Ganges and Brahmaputra basins)*

Data Sources: *MODICE v.3 - minimum snow and ice areas (map) and annual trends (figures); Global Runoff Data Centre (GRDC)- basin outlines and river gauging locations; Natural Earth (background shaded relief image).*

CHARIS project, 2016

K. Rittger

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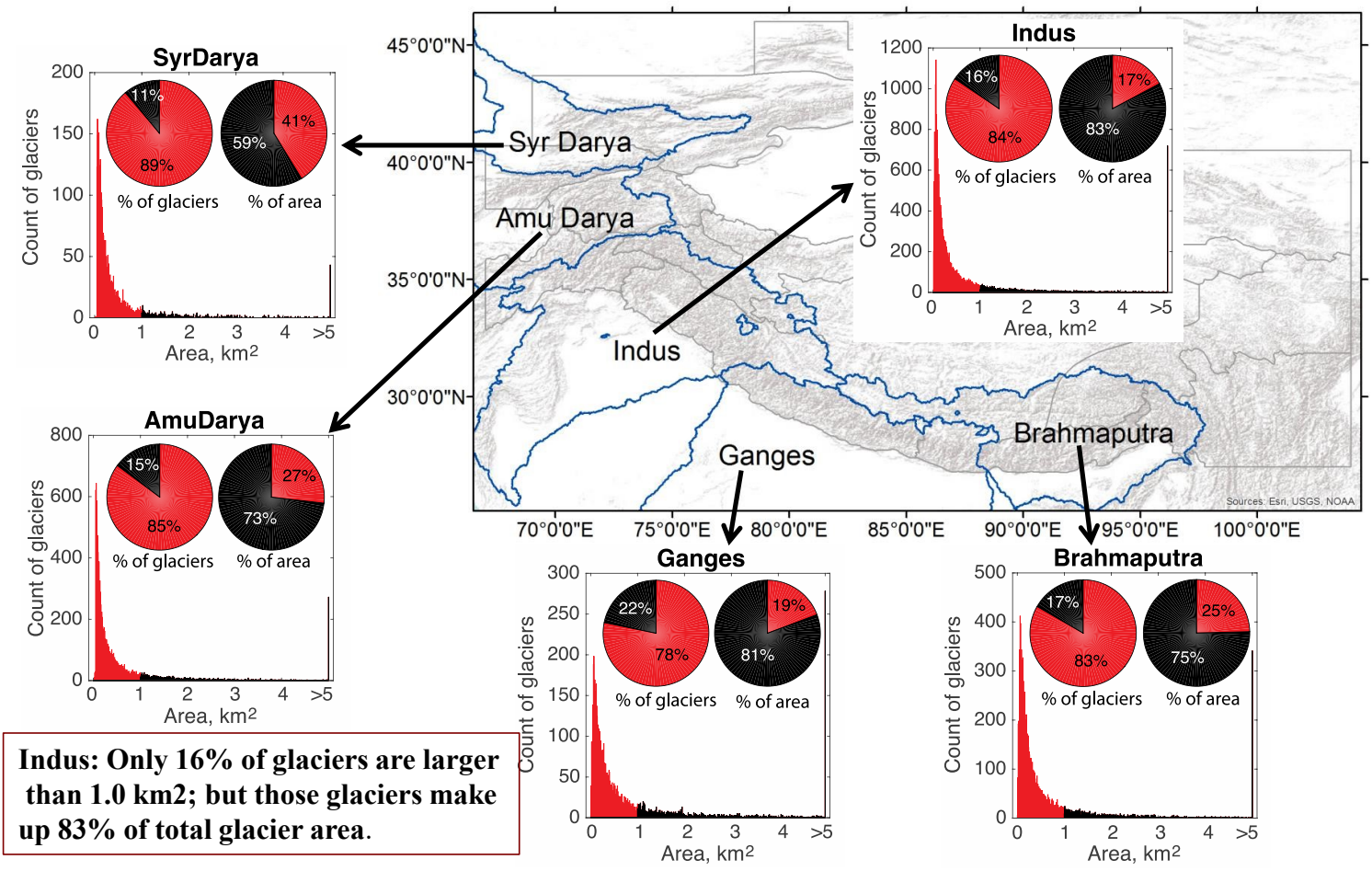
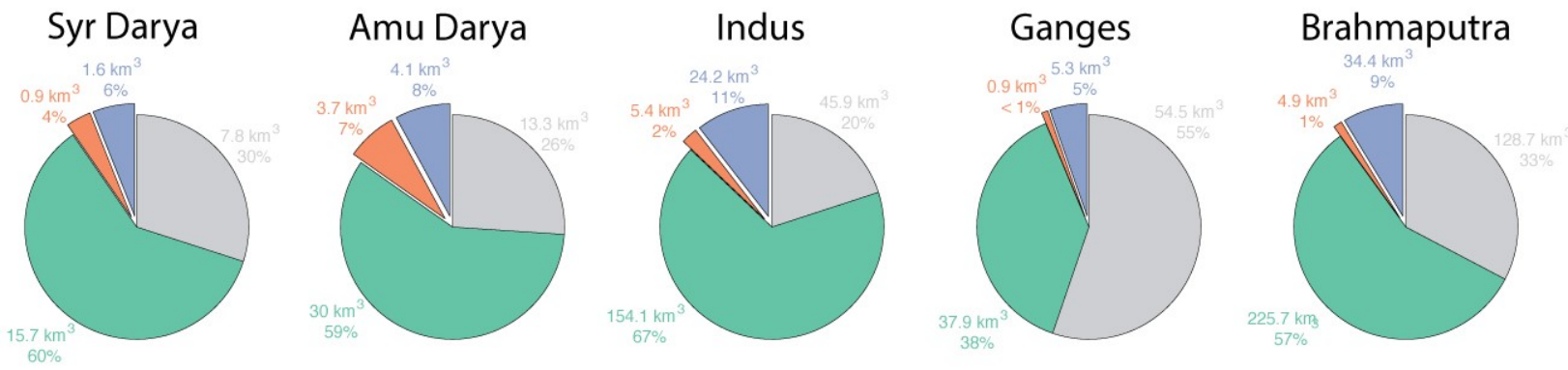
RGI v5.0: Distribution of glacier sizes

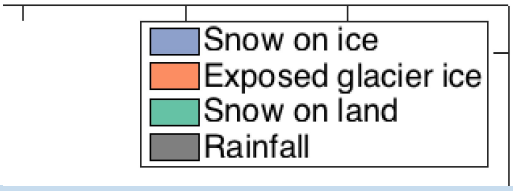


Indus: Only 16% of glaciers are larger than 1.0 km2; but those glaciers make up 83% of total glacier area.

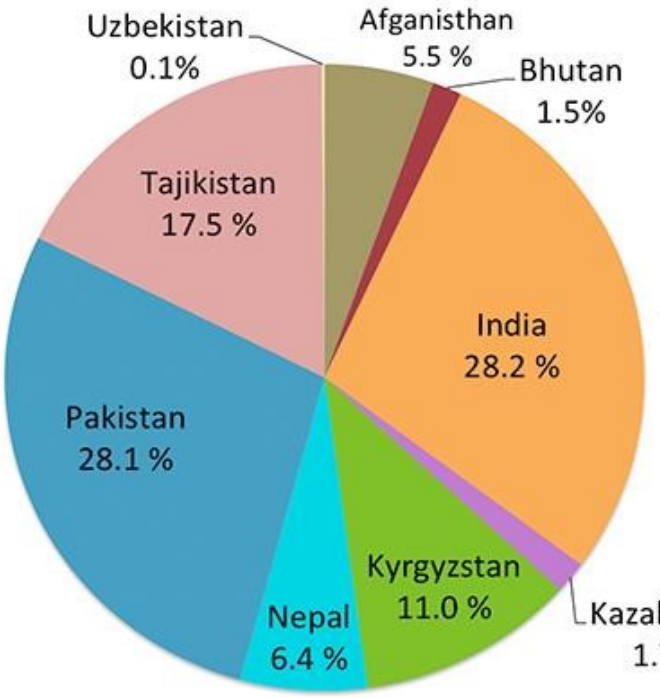
Annual mean melt contribution from snow on ice, exposed glacier ice, snow on land and rainfall to the 5 CHARIS study basins – 3,000 m to 6,000 m.



EGI % (EGI + SOI%)				
~4 (~10)	~7 (~15)	~2 (~13)	~1 (~6)	~1 (~10)



All reanalysis data tend to overestimate rainfall at the higher elevations



Glacierized area by country as percent of the total glacierized area of the 9 countries in the CHARIS region

The CHARIS project collaborates with 11 research partner institutions through formal agreements in 8 countries across High Asia to achieve the above goal.

Collaboration includes technology transfer and capacity building: 5 training workshops have been conducted over past 5 years with all 8 partner institutions participating.

The partnerships promote and facilitate the international cooperation required for successful cross-boundary water resource management.

Coordination with villagers in Upper Kabul River Basin – Hedayatullah Arian and Abeer Sajood, Kabul University faculty


Marmot