Climate Change: A Regional Perspective

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Dr. Furrukh Bashir
Meteorologist
Research and Development Division
OVERVIEW

• Indus Basin (1.12 million km$^2$)
• Spans in 4 countries
• 65% of Pakistan is Indus Basin
• Pakistan- an agriculture based economy
• Producing surplus grains
• Subsistence farming to corporate farming
• > 200 million population
• > 250 km$^3$ runoff capacity with around 50 km$^3$ discharge to Arabian Sea
• Is Indus Basin a closed basin?
Daily Climatology of Pakistan (1960-2013)

- Maximum Temperature
- Minimum Temperature
- Precipitation
HYDROMETEOROLOGICAL CHALLENGES IN PAKISTAN

Karakoram Anomaly

Sep 2016, IWMI
Melting Glaciers: An Indicator of Global Warming

• **Global warming** and the corresponding increase in energy flux towards the Earth surface have resulted in the **retreat of mountain glaciers** and continuous loss of ice worldwide.

• Climate Change Indicator (EPA)
HKH Glaciers
Eastern Hindukush, Western Karakoram, and Northwestern Himalayan Glaciers

• **Retreat** rates of HKH glaciers are **less** than the global average and some are either stable or growing.

• This anomalous behavior, widely referred to as “**The Karakoram Anomaly**”.

• Most important hydrometeorological challenge in Pakistan
The Karakoram Anomaly

“I began to see glacier thickening and advancing that I had not observed in the 35 years of field work before.”

Kenneth Hewitt
(a glaciologist at Wilfrid Laurier University, Waterloo, Canada.)

“Nowhere else on Earth could you find such a high concentration of surge-type glaciers.”

Christoph Mayer
(a glaciologist at the Bavarian Academy of Sciences and Humanities in Munich, Germany.)
Controversy

“Many people use advancing Karakoram glaciers to deny climate change or the overall ill health of Himalayan glaciers.”

Graham Cogley
(a remote-sensing expert, Trent University, Peterborough, Canada.)

“They may be advancing, but this does not necessarily mean they are gaining mass.”

“To surge or not to surge may have little to do with climate trends.”

Frank Paul
(a remote-sensing expert, University of Zurich, Switzerland.)
Malanguti Glacier, Shimshal Valley (March 29, 2018)
Yazgdil Glacier, Shimshal Valley (March 29, 2018)
Khordopin Glacier, Shimshal Valley

Yuskan Gardan Glacier, Shimshal Valley
Lake Formation and Drainage on Virjerab River
What we know of HKH Glaciers?

- Lack of long-term field investigation.
- Rugged inaccessible terrain.
- Long-term in-situ meteorological observations are limited mainly to valley-based stations that are situated away from the glaciers.
- Explanations of the Karakoram anomaly have been based mainly on analyses of long-term temperature, precipitation, and river flow records.
To bridge the gap

Problem Statement
What knowledge is the scientific community missing about change in in-situ meteorological variables, which may help to investigate the causes of the Karakoram Anomaly more effectively?

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<td>Quantify assessment of the change in in-situ meteorological variables that are playing role in establishment of the Karakoram Anomaly.</td>
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HKH POSITIVE MASS BALANCE

- Increase in Precipitation (Winter & Summer)
- Decrease in River Inflows (Summer)
- Positive Mass Balance (Summer and Annually)

DATA:
Monthly means of Synoptic Weather Observations from valley floors from 1961 - 2011

Observations: Maximum, Minimum Temperature, Dry Bulb Temperature, Relative Humidity, Surface Pressure, Near-surface Wind Speed, Cloud Cover Fraction, Precipitation

Derived Quantities: Net Radiation, Evapotranspiration, and Climate Moisture Index
Factors Facilitating Positive Mass Balance of a Glacier

- Net Radiation
- Cloud Cover Fraction
- Total Seasonal Precipitation
- Water Vapor Pressure
- Wind Speed
- Potential Evaporation
- Temperature
- River Inflow
- Climate Moisture Index
Another Controversy?

The Karakoram Anomaly

Extratropical Storm
Winter & Spring

Summer Monsoon
Conclusions

• An integrated signal
• Interplay in energy, mass, and momentum
• Increases in water vapor, cloudiness and precipitation, and decreases in net radiation, near surface wind speed, and potential evapotranspiration have resulted in a positive hydrologic mass balance at the annual scale.
• HKH watersheds
  Moisture surplus
  Energy deficient
A Hydrometeorological Perspective on the Karakoram Anomaly Using Unique Valley-Based Synoptic Weather Observations

Furrukh Bashir1,2, Xubin Zeng3, Hoshin Gupta4, and Pieter Hazenberg5

1Department of Hydrology and Atmospheric Sciences, University of Arizona, Tucson, AZ, USA; 2Pakistan Meteorological Department, Islamabad, Pakistan

Abstract Glaciers in the eastern Hindukush, western Karakoram, and northwestern Himalayan mountain ranges of Northern Pakistan are not responding to global warming in the same manner as their counterparts elsewhere. Their retreat rates are less than the global average, and some are either stable or growing. Various investigations have questioned the role of climatic factors in regard to this anomalous behavior, widely referred to as "The Karakoram Anomaly." Here, for the first time, we present a hydrometeorological perspective based on five decades of synoptic weather observations collected by the meteorological network of Pakistan. Analysis of this unique data set indicates that increased regional scale humidity, cloud cover, and precipitation, along with decreased net radiation, near-surface wind speed, potential evapotranspiration, and river flow, especially during the summer season, represent a substantial change in the energy, mass, and momentum fluxes that are facilitating the establishment of the Karakoram anomaly.

Plain Language Summary The "Karakoram Anomaly" is a term that is used to describe the fact that glaciers in the eastern Hindukush, western Karakoram, and northwestern Himalayan mountain ranges of Northern Pakistan are not responding to global warming in the same manner as their counterparts elsewhere. Specifically, their rates of retreat are less than the global average, and some of the glaciers are either stable or even growing. This remarkable phenomenon has therefore become a popular news topic, and even an excuse for some people to question whether global warming is actually occurring. Our analysis of in situ hydroclimatic variables and river inflows indicates that there is a clear scientific explanation for this localized phenomenon. It is true that glacier melt contributions to river flows during the summer season are decreasing, in spite of the fact that the precipitation has been increasing. But the reason that the glaciers in this region are not melting at increased rates is that summer season cloudiness has increased, which blocks the incoming solar radiation and thereby lowers the amount of heat energy available for the melting process. Combined with the facts that humidity has increased and near-surface wind speeds have decreased, this has also resulted in reduced moisture loss through evapotranspiration. Together, these conditions have resulted in reduced rates of glacier melting in this region. These findings explain and support the fact that "Karakoram Anomaly" is a real, albeit localized, phenomenon.
You have Questions
We have Answers