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Samina Kiran

TERMINAL REPORT

Glaciers & Students - A scientific-based approach to monitor climate and glacier in Pakistan mountains region to support hydrogeological prevention.

July 2022-September 2024

Contents

Acronyms

ABOVE SEA LEVEL	Above Sea Level
AICS	Italian Agency for Development Cooperation
AWS	Automatic Weather Station
CKNP	Central Karakorum National Park
EPA-GB	Environmental Protected Agency Gilgit Baltistan
GB	Gilgit Baltistan
GBDMA	Gilgit Baltistan Disaster Management Authority
GIS	Global Information System
GLOF	Glacial Lake Outburst Flood
HKKH	Hindu Kush, Karakorum and Himalayan
ICIMOD	International Centre for Integrated Mountain Development
KIU	Karakorum International University
QC	Quality Control
RS	Remote Sensing
UNDP	United Nations Development Programme
UOB	University of Baltistan

Executive Summary

The Glaciers and Students Project (July 2022- June 2024), implemented in the Gilgit-Baltistan (GB) region of Pakistan, has made a significant stride in addressing the profound impacts of climate change on mountain glaciers. The ambition initiative combined international collaboration, the state-of-the-art advanced technological intervention, and comprehensive capacity-building efforts to enhance environmental management and resilience among local communities at local level.

The key achievements of the project include installation and operationalization of eight (08) Automated Weather Stations (AWS) at carefully chosen strategic location within Karakoram region of GB. These AWS units are vital in providing high resolution microclimate data from glaciated zones, shedding light on local interplay between local topography, surface conditions and weather patterns. The resulting data has opened new avenues for understanding of localized climate phenomena critical for glacier monitoring and climate change adaptation strategies. The major milestone was creation of Glacier Inventory of Pakistan documenting 13,032 glaciers spanning 13,547 square kilometers across five significant basins including *Gilgit, Indus, Jhelum, Kabul, and Tarim.* This inventory serves as a foundational dataset for ongoing and future glaciological research and policy making.

Through **multi-temporal analysis and extensive field missions**, the project investigated glaciers melt patterns and assessed the harmful contaminants including microplastics and black carbon, which exacerbate glacier melting. . To support mountain research in the HKH ranges, the project also modernized **SHARE Geonetwork Platform** upgrading its new user-friendly interface to enhance accessibility. This advance Geoportal integrates metadata, datasets, maps and newly developed GBGeoApp for creating wider spectrum of users including both technical experts and non-experts (general public), This platform enhanced data sharing and collaboration for sustainable mountain research in the HKH region.

A **comprehensive training and capacity-building** program formed a cornerstone of the project through which 394 individuals including students, and faculty from Karakoram International University (KIU) and University of Baltistan (UoB), and as well as personnel from environmental Protection Agency Gilgit Baltistan (EPA-GB) received targeted trainings. Recognizing and prioritizing the importance of gender equality, the project ensured that 171 (out of 394) participants were women students and researchers Were included in the project to ensure gender inclusion across the training programs.

The project also emphasized critical operational lesson, including meticulous pre-planning for time-sensitive activities, effective coordination with local universities and government intuitions, safety protocols for researchers working in hazardous glaciated terrain. These measures have enhanced the project ability to deliver results withing realistic timeframe while ensuring safety and engagement of all participants.

With the funding allocation €1.1 million, of which €1,092,668, (99.33%) was utilized. The project demonstrated very good financial stewardship.

Long-term sustainability is ensured through active coordination and collaboration with local stakeholders, particularly EPA-GB which now leads the operational management of installed AWS and data process. The international partner Ev-K2-CNR, will continue providing the

technical support, ensuring the ongoing maintenance of AWS units and effective data management.

The Glacier and Student Project has successfully achieved all major deliverables, leaving a legacy in environmental research, policy research and community resilience in GB. By leveraging advance technology, strengthening gender inclusivity, and enhancing local capacities, the project has positioned the region at forefront to understand and mitigate the impact of climate change on mountain ecosystems.

Reporting Period	July 2022 – June 2024
Donor	AICS, Government of Italy
Project Title	Glaciers & Students - A scientific-based approach to monitor climate and glaciers in Pakistan mountains region to support hydrogeological prevention
Project ID (Quantum ID) **Strategic Plan and/or CPD** **CPD Outputs**	00132208 Strategic Plan Outcome 3: Resilience built to respond to systemic uncertainty and risk CPD Outcome 3: Climate change resilience and environment Output 3.1. In line with international conventions and national policy frameworks, implementation mechanisms are strengthened to promote, manage and conserve natural resources. Output 3.2. Efficient and sustainable use of fresh marine and terrestrial ecosystems, including the Indus Basin, for resilient communities through interventions for improved health, livelihoods, green economy and clean energy
Implementing Partner	Ev-K2-CNR Association
Project Start Date	July 2022
Project End Date	June 2024
Total Resources Required	1.1 million Euros
Revenue Received	1.1 million Euros
Expenditure	1,092,668 Euros
UNDP Contact Person	Dr. Samuel Rizk, Resident Representative, UNDP UNDP Country Office, 4th floor, Serena Business complex, Khayaban e Suharwardy, Islamabad Email: samuel.rizk@undp.org Tel.: +92518355638

I. Introduction/ Background

Gilgit-Baltistan in northern Pakistan is known for its stunning landscapes, including gigantic, towering mountains, valleys, lakes, and rivers. The region's unique culture is shaped by its diverse geography and rich history, with traditional farming and herding. The Hindu Kush, Karakoram, and Himalayan glaciers form one of the largest reserves outside the Polar Regions, providing vital water resources for Pakistan. The area's rich biodiversity, rare wildlife, and growing nature tourism offer significant scientific, economic, and cultural value, supporting local livelihoods and attracting visitors.

Despite their significance, Gilgit-Baltistan's glaciers are among the least monitored glaciers due to limited technology and accessibility in the region. These glaciers feed the Indus River, extremely vital for Pakistan's agriculture and hydropower. As "**barometers of climate change,"** these glaciers are highly sensitive to temperature shifts, with rising temperatures increasing disaster susceptibility and risks. Strengthening local capacities and institutions for glacier monitoring, drawing on global lesson learnt and experiences, are key for sustainable development, to make abilities for better climate change adaptation, and informed decision-making on the bases of scientific evidence in the targeted region.

The "**Glaciers and Students**" Project, supported by the Italian Agency for Development Cooperation (AICS), executed by UNDP with Ev-K2-CNR as the implementing partner, focused on monitoring glaciers in northern Pakistan, capacity building of local counterparts, development of bridging and linkages between local and international universities for exchange of ideas and developing the glaciers inventory of Pakistan. The project established a program for high-altitude climate monitoring and glacier change assessment, aiding environmental management and risk prevention through capacity building, remote sensing, GIS techniques, and a dedicated modernized web portal information system.

The project aimed to reduce glacier melt hazards by using advanced techniques to assess changes in glaciers and climate. Data was archived and shared via GIS for research, public awareness, and policymaking. The project also strengthened local scientific institutions to ensure long-term sustainability.

The project successfully developed partnerships at local and international levels

I. The project involves many provincial-level authorities like EPA-GB, GBDMA and the Department of Forests, Parks and Wildlife.
II. Local universities: Karakorum International University (KIU) and University of Baltistan, Skardu (UoBs)
III. International institutes like the University of Millan and University of Cagliari (**E1**)

Key Project Activities

The key deliverables and activities for this project were:

- Planning and installation of weather station restoration
- Multi-temporal analysis of 04 glacial bodies
- Update Glacier Inventory of Pakistan and in addition, development and submission of research articles
- Update and testing GB GeoApp and GEONetwork
- Training for glaciological activities, regarding Geomatics and Avalanche risk to local key stakeholders
- Research collaboration between national and international universities

II. Progress Review

The project contributes to UNDP Strategic Priority (SP) Outcome 03 Resilience built to respond to systemic uncertainty and risk and CPD Output 3.1 and 3.2. Output-wise project progress update is as under:

Output 1: Assessment and Monitoring: "Assessment and monitoring system of mountain glaciers and the climate improved in Pakistan mountain areas contributing to improved planning and management of water and other natural resources including the sustenance of biological diversity."

Output progress

Output statement	Baselines	Indicators	End of the project target	Status	Means of verifications
Output 1 Assessment and monitoring system of mountain glaciers and climate improved in Pakistan contributing to improved planning and management of water resources and natural resources including the sustenance	03 existing AWS	1.1 Number of climate monitoring stations in glacier region established and maintained to provide data on changing climate patterns for use by MET Deptt. and other concerned	08 AWS installed Results will be communicated to relevant government departments to supplement knowledge for adoption in devising applicable strategies in agriculture and livelihood sector.	Complete 08 AWS installed (05 new installed and 03 improved/restored) Data retrieved from newly installed and improved/restored AWS.	Field visits, monitoring and news reports, pictures
	0	1.2 Number of glacial bodies measured,	04 glacier bodies monitored and studied	Complete Results have been shared and	Field visits, surveys and assessments reports

Output statement	Baselines	Indicators	End of the project target	Status	Means of verifications
of biological diversity.		monitored and documented to monitor changes over time that can provide early warning for natural hazards and contribute in reducing risks faced by mountain communities, particularly women and marginalized groups, in downstream valleys		communicated to relevant government departments to supplement knowledge for adoption in devising applicable strategies in agriculture and livelihood sector.	
	Partial inventory of CKNP Glaciers exist	1.3 Update the Pakistan Glacier Inventory	01 Pakistan glacier inventory and 03 scientific research publications	Complete Pakistan new glacier inventory 02 research papers published and 02 research publication submitted in international journal for approval	Field visits and expert reviews 01 Pakistan glacier inventory

Activity 1.1: Install/improve and maintain climate monitoring network.

Target: 08 AWS

Results: 8 climate monitoring stations installed and/or improved

The Automatic Weather Station (AWS) installation was crucial for advancing scientific research on glaciers and hydrology in the mountainous regions, specifically focusing on the Karakoram, Hindu Kush, and Himalayan Mountain Ranges. These AWS installations provide numerous benefits, including enhanced glacial research capabilities and enabling scientists and professional researchers to study the effects of climate change on glacial retreat, mass balance, and melt rates in a more comprehensive and scientific manner.

Prior to the Glaciers and Students (G&S) project, there were very few numbers of weather stations in Gilgit Baltistan, resulting in sparse coverage and a lack of long-term meteorological records. This deficiency hindered the ability to assess the intensity of extreme weather events and climate change in the region and its potential consequences. Given the strategic touristic importance of the area, the G&S project prioritized the installation of new stations in Passu-Shispar-Ghulkin and the restoration of three AWS in the Baltoro Glacier area during its first and second years, respectively.

These activities represent a critical step toward building a reliable weather monitoring network and increasing data availability to monitor glacier melt and its relationship to climate change. The validated data acquired by the G&S AWS have been processed to investigate local meteorological patterns, providing valuable insights into the conditions influencing glacier melt. For instance, air temperature trends are similar among stations located within the same area, with expected variations due to altitude and proximity to glaciers. However, more significant differences are observed in relative humidity, wind regime, and precipitation, as these factors are heavily dependent on on-site characteristics. For example, glaciers can influence the development of katabatic winds, which are cold, dense air flows moving downhill.

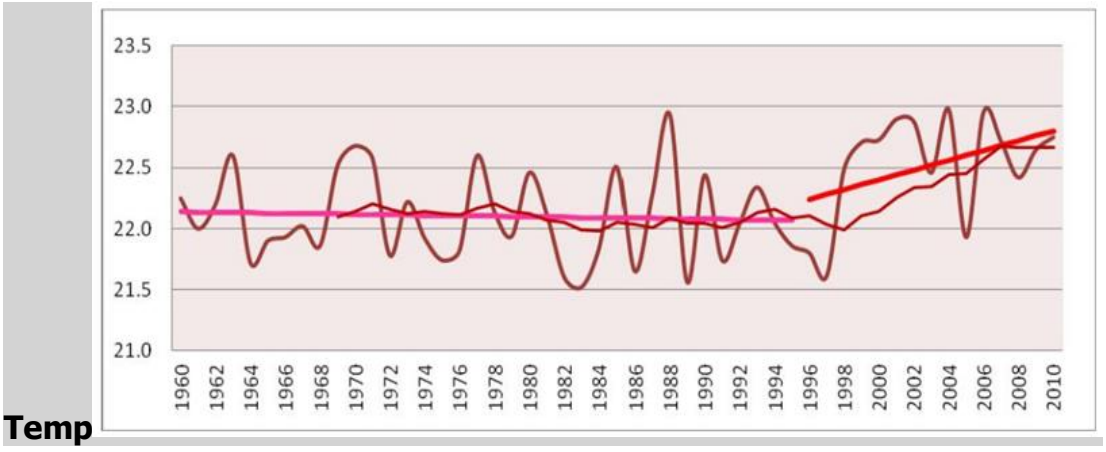


Figure 1: Graph showing air temperature records of meteorological observatories (1500-2900 m a.s.l.) located in the northern mountains of Pakistan from 1961 to 2010. The past decade has shown a sharp rise (Rasul et al. 2011).

The previous weather station network in glacier areas

There were unfortunately very few numbers of weather stations in northern Pakistan, resulting in sparse coverage. The remoteness of some areas, along with frequent flooding and rock falls that damage road infrastructure, makes maintaining these weather stations difficult. Consequently, there are few long-term records of meteorological observations available to help assess the intensity of climate change in the region and its consequences.

Prior to this project, the Central Karakoram National Park (CKNP) area, which is one of the country's key water sources, lacked in AWS network entirely, and three existing AWSs maintained by Ev-K2-CNR were non-operational.

The new weather stations network in the "Glaciers & Students" project

Eight (08) Automatic Weather Stations (AWS) were installed on the Passu, Ghulkin, Batura, Shisper, Minapin (Rakaposhi), Baltoro (Askole, Urdukas, Concordia), and Biafo Glaciers as part of the Glacier and Students Project. This successful deployment was made possible through the collaborative efforts among UNDP, Ev-K2-CNR, the GB Environmental Protection Agency, Karakoram International University, the University of Baltistan, and the University of Milan. These installations contribute significantly to climatic research and efforts to address climate change posed challenges.

Figure 2: AWS installed at Shispar and Passu glacier

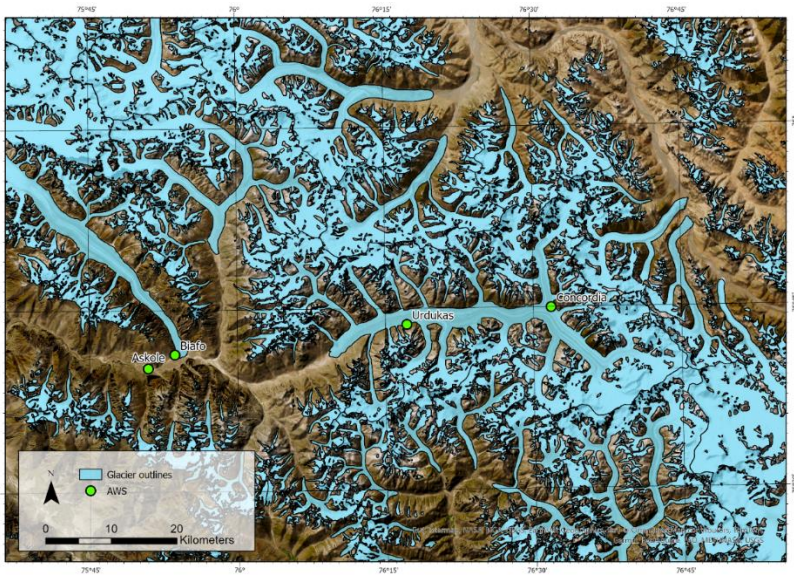


Figure 3: The map shows the automatic weather stations at Askole, Urdukas and Concordia (previously installed and made operational again in 2023) and the Biafo AWS (installed in 2023) as green dots.

The AWS units are equipped with all the necessary sensors to measure meteorological variables in accordance with the standards set by the World Meteorological Organization (WMO 2008). These units collect data around air temperature, relative humidity, atmospheric pressure, wind speed and direction, rainfall, and incoming and outgoing solar and infrared radiation.

Weather stations located outside glaciers (off-glacier AWS) are easier to maintain compared to on-glacier AWS. Glaciers are dynamic bodies, and it is estimated that glacier flow in the Karakoram region ranges from 50 to more than 200 meters per year, with even higher values during glacier surges, which are particularly frequent in this region.

In addition to glacier flow, uneven melt of the glacier surface can cause significant changes in surface topography in just a few weeks which affects the stability of the AWS and compromises the quality of data from different sensors. Therefore, different designs were developed for permanent and temporary AWS installations.

Permanent weather stations were designed with a 3-meter metal pole, complete with a tripod and powered by a solar panel and lead-acid sealed rechargeable batteries. The design and specifications for the solar panels and batteries were prepared in Italy and installed in Pakistan.

List of meteorological sensors on the automatic weather stations	
Instrument	**Meteorological parameter**
Radiometer	Shortwave and longwave radiation
Thermo-hygrometer	Air temperature and relative humidity
Barometer	Air pressure

Pluviometer	Rain
Anemometer	Wind speed and direction
Data logger	Logging sensor

These AWS units can also be utilized for early warning systems to mitigate glacial hazards, safeguarding vulnerable downstream communities exposed for potential hazards. Furthermore, the data collected from these AWS units can easily be made accessible to researchers and policymakers through the Gilgit-Baltistan Environmental Protection Agency, which will act as the custodian of both the AWS units and the data collected. Glacial meltwater significantly contributes to downstream rivers and lakes, and the AWS data will aid in understanding water resource availability and account in planning for sustainable water management.

The AWS are now owned by EPA-GB, as are the data. EPA-GB is the in charge of the AWS maintenance and data download. In the forthcoming Water for Development (W4D) project funded by AICS, a budget has been provided for maintenance of the AWS and to train personnel of EPA-GB for data analysis. During talks with stakeholders within the W4D project, an agreement with the Pakistan Meteorological Department is also being investigated for long-term activity of the AWS.

Up to now, the data have been used for a thesis at the university of Milan (Distribution of radiative fluxes governing ice melt for a third pole glacier), in preparation for the research to be undertaken in W4D, where the data from the AWS will be used for calibration of satellite and meteorological products for calculation of glacier melt for all the glaciers in Pakistan. The AWS data are further available to the scientific community and the general public through EPA-GB and have also been used by University of Baltistan for their work on Passu and Ghulkin glacier[1].

AWS were installed and hands-on training workshops conducted for students and faculty from Karakoram International University, the University of Baltistan Skardu, EPA-GB, and GB-DMA. These workshops took place in the summers of 2022 and 2023, covering both the mechanical and electrical aspects of AWS installation and their operational principles.

In 2022, three AWS units were installed at Passu, Ghulkin, and Shishpar Glaciers, while five more were set up in 2023 at Askole, Urdukas, Concordia, Biafo, and Minapin (Pissan). A total of 41 students participated in the training sessions. The AWS units record weather data hourly, including minimum, maximum, and average values, along with standard deviation and data validity percentages. An initial quality-control (QC) process was performed to filter out erroneous data and ensure accuracy.

[1] Hussain, I., Ali, M., Muhammad, S., Hassan, W., Ali, Salar, Hussain, Z., Ali, S.H., Ali, Shaukat, Khan, M.Y., 2023. A decline in snow cover area of Passu and Ghulkin valleys between 1995 and 2022. J. Mt. Sci. 20, 3542–3551. https://doi.org/10.1007/s11629-023-8037-2

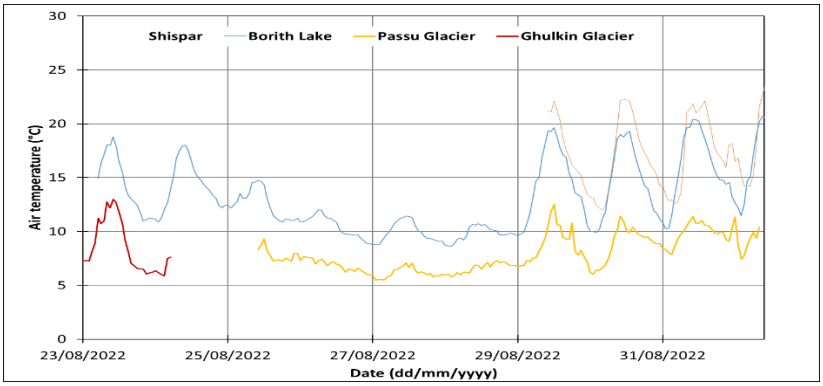


Figure 4: The hourly air temperature acquired by the on-glacier AWS at Ghulkin and Passu Glaciers and the off-glacier AWSs at Borith lake and Shispar, during the common period in August 2022.

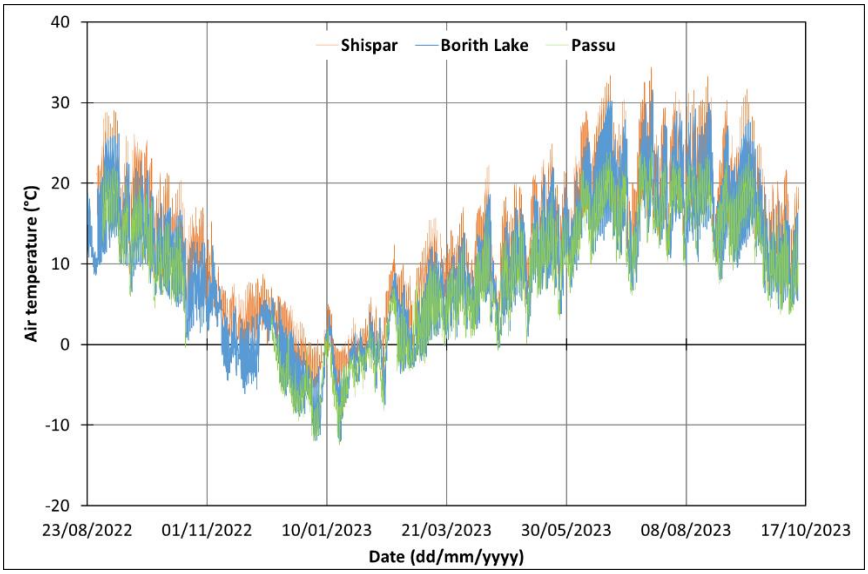


Figure 5: The hourly air temperature acquired by AWS at Borith lake, Shispar, and Passu from their installation in August 2022.

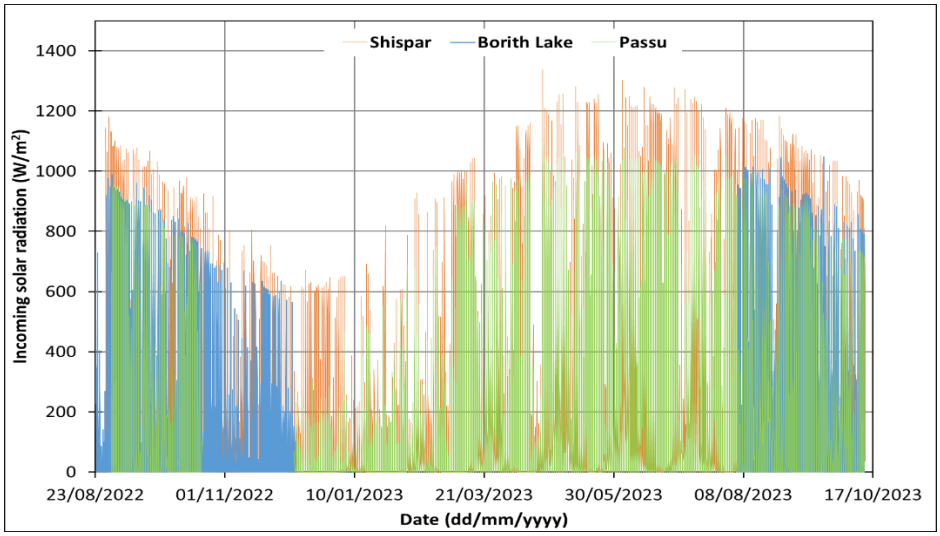


Figure 6: The hourly incoming solar radiation (SWin) acquired by off-glacier AWS at Borith lake, Shispar, and Passu from their installation in August 2022.

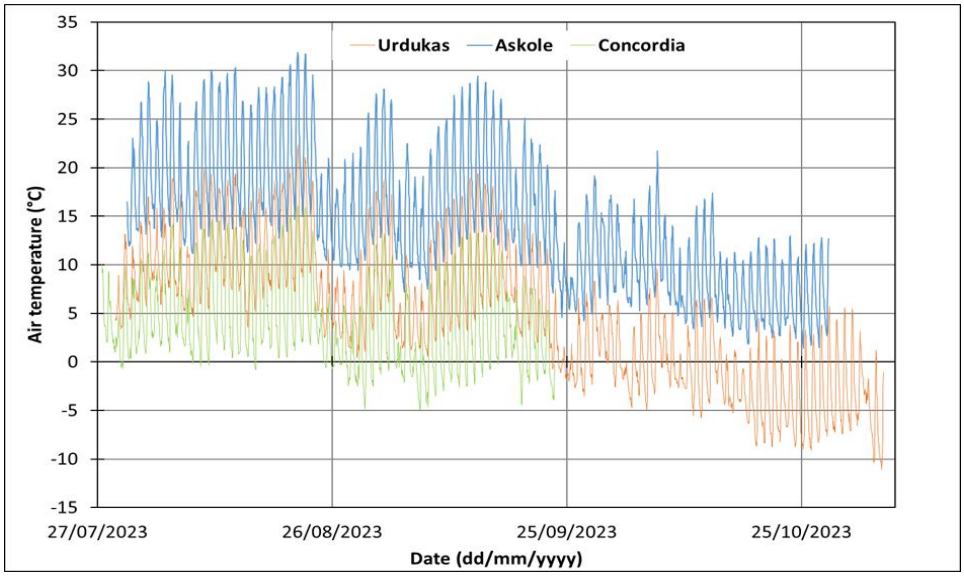


Figure 7: The hourly air temperature recorded by AWSs at Urdukas, Askole and Concordia from their maintenance at the end of July 2023.

Figure 8: Installation operations of Minapin AWS

Figure 9: The AWS installed on the moraine of Biafo glacier

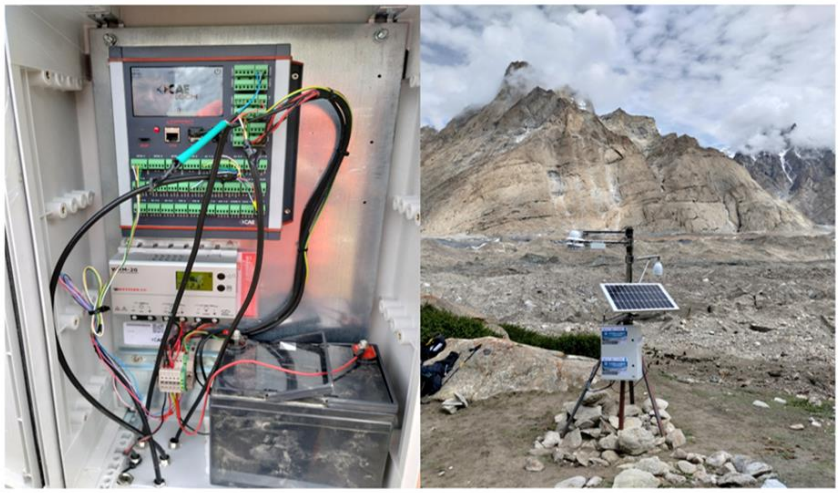


Figure 10: The AWS at Urdukas

Figure 11: Installation AWS at Askole

Activity Result: 1.2 Study and monitoring of glaciers and glacial bodies

Target: 04 Glaciers and glacial bodies monitored and studied

Result: Change assessed in various glacial bodies (04)

1.2 a. Study and monitoring of glaciers and glacial bodies a) Multi-temporal Analysis

The updated new glacier inventory for Pakistan, created using Sentinel-2 images from the European Space Agency, establishes a baseline for assessing the country's water resources across the Hindu Kush, Karakoram, and Himalayan ranges. Sentinel-2 satellites provide high-resolution images (10 m) with a high revisit rate of approximately every 5 days, which minimizes issues from cloud and transient snow cover. This allowed for a detailed snapshot of the glaciers as of summer 2022. Google Earth imagery was also used to refine the outlines in difficult cases, such as debris-covered glaciers and residual snow. This new inventory benefits from higher spatial resolution and a more focused time frame compared to previous inventories, which relied on less detailed images and data from multiple years. It also enables more accurate comparisons of glacier area changes over time.

Previous glacier inventories in Pakistan

Past efforts to document Pakistan's cryosphere include large-scale projects like the ICIMOD and GAMDAM inventories, which cover the glaciers of Asia. Additionally, there are several smaller regional studies focusing on specific mountain ranges or basins. This also provides an overview summarizing both the nationwide and regional past studies.

Several glacier inventories have contributed to understanding the HKH region. The ICIMOD Inventory (2011) provides a comprehensive overview of glaciers in the Hindukush-Karakoram-Himalaya region, including Pakistan, using Landsat images from 2005-2009. The GAMDAM Inventory, developed by Nagoya University, offers insights into glacier meltwater contributions to Asian rivers, with updates in 2019 (GGI18) improving accuracy for glaciers larger than 0.01 km². The Randolph Glacier Inventory (RGI), part of the GLIMS initiative, provides global glacier outlines, incorporating data from multiple sources, including ICIMOD. Regionally, the Karakoram has been a focal point, with inventories like the Central Karakoram National Park (CKNP) inventory, created by the University of Milan using 2010 Landsat data, offering detailed glacier metrics. Additional studies, such as Rankl et al. (2014) and Xie et al. (2023), have analyzed glacier changes in the Karakoram, with specific studies focusing on basins like Hunza and Shigar.

In contrast, less attention has been given to other mountain ranges. In the Hindukush, Sarikaya et al. (2012) found significant glacier retreat from 1976 to 2007. Similar findings were reported in the Hinduraj region (Sarikaya et al., 2013). The Himalayas have seen detailed studies of glaciers around Nanga Parbat/Diamir massif, analyzing changes from 1856 to 2020 (Nüsser and Schmidt, 2021

Glacier Changes in Selected Basins

The analysis emphasized the importance of consistent methodologies in glacier mapping to ensure accurate comparisons. It found that while different approaches led to varying measurements of glacier area changes, terminus shifts were indicative of local climate conditions and glacier dynamics. In the Palas Basin, glaciers were retreating in line with broader Himalayan trends, while in the Baltoro Basin, surge cycles influenced glacier stability,

with larger glaciers remaining unchanged. The Hindukush region showed significant glacier retreat, highlighting the need for more detailed mapping. Using high-resolution Sentinel-2 data, the new inventory offers a valuable snapshot and sets the path for improved future investigation and assessments. Frequent advancements happening in satellite technology that will help to overcome mapping challenges, especially for debris-covered glaciers, and enhance understanding of glacier mass changes and their impact on water resources.

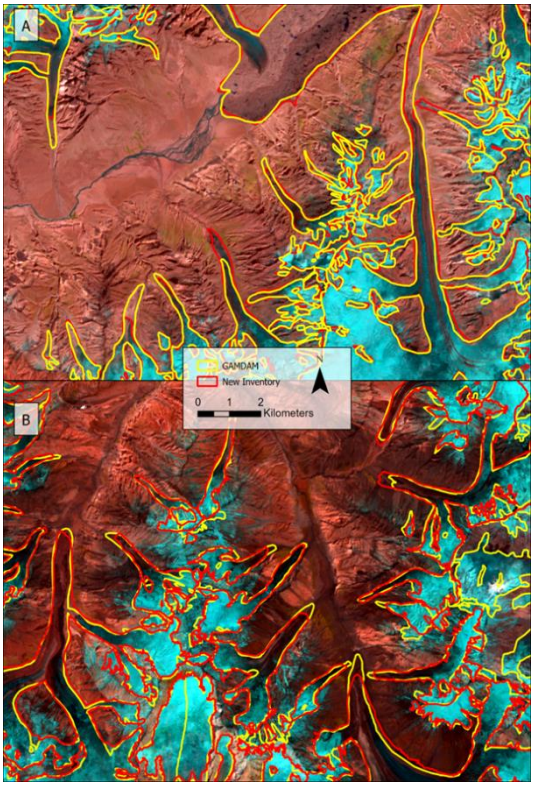


Figure 12: Comparison between the GAMDAM and the new inventory in Baltoro basin, with a focus on glaciers close to the terminus of Baltoro a) in Ching Kang valleys b), showing asynchronous advance and retreat patterns linked to surging. Background images are from the false colour Sentinel-2 mosaic.

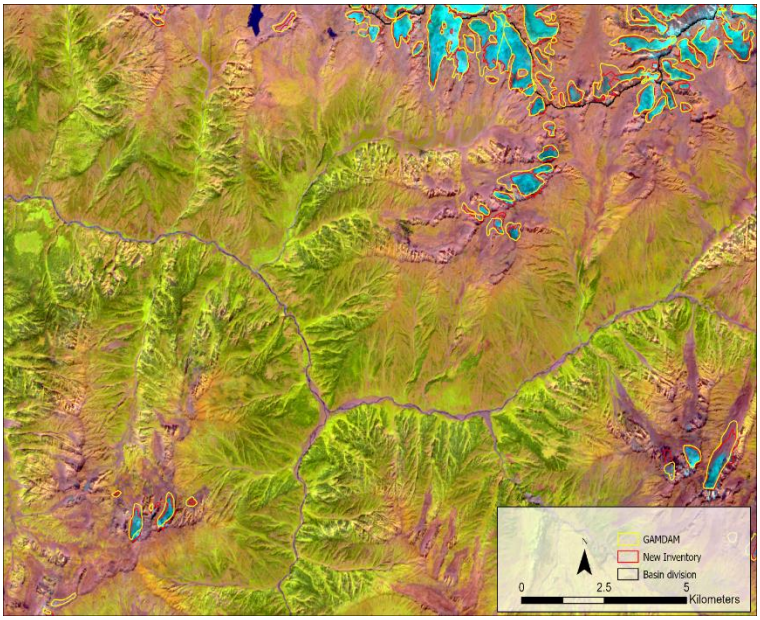


Figure 13: Retreating glaciers in Palas Valley (and Kohistan basin to the north) in the Himalayas. The background image is a false colour Sentinel-2 mosaic.

In the W4D project, one key aim is to quantify this meltwater through a modelling approach with further validation from the ablation stakes. On Baltoro and Shishpar glacier, the changes in glacier mass are being evaluated through the use of remotely sensed data from the TanDEM-X satellites, as shown in the following figure.

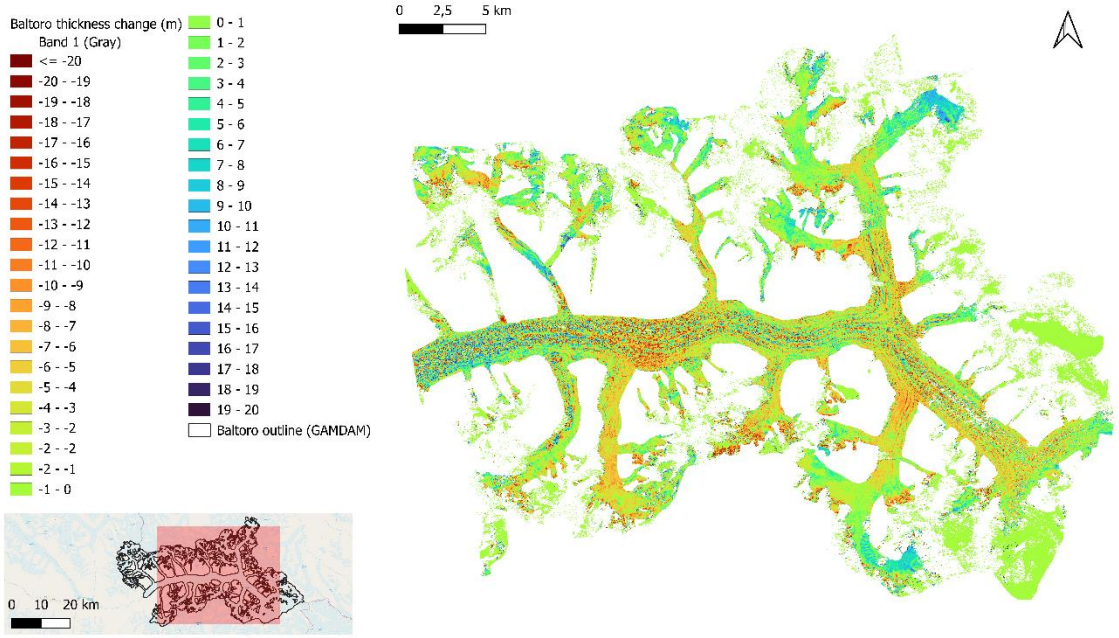


Figure 14: Thickness *changes of Baltoro glacier from 2011 to 2022 from TanDEM-X satellite*

Ice Drilling and Ablation Stake Installation at Passu and Ghulkin Glacier

On Passu and Ghulkin glacier, changes in the glacier mass were monitored by means of ablation stakes, which were drilled on the glacier in summer 2022 and 2023 and monitored at multiple intervals. As an example, we report the melt measured at the stakes in summer 2023. The observations show high values of ice melt at both glaciers, up to 10.9 cm per day at Passu Glacier between August and October 2023. This suggests huge amounts of meltwater can be released by the glaciers, affecting communities downstream in both positive and negative ways.

Table 1: Location of ablation stakes on Ghulkin glacier and measurements of glacier melt.

Stake	Total length (cm)	Latitude	Longitude	Elevation	Height (cm)	Start date	End Date	Period	Ablation (cm)	Melt rate (cm)	Debris (cm)
GH20	1200	36.4196087 5	74.856159 38	2751.579	96.5	8/6/23 9:25 AM	10/13/23 8:23 AM	67.96	327.68	4.82	2

GH21	1200	36.4212407 8	74.8573701 5	2762.209	87	06/08/2023	10/13/23 8:33 AM	67.91	113.66	1.67	12
GH22	800	36.4175427 4	74.8563254 3	2772.086	93	06/08/2023	10/13/23 8:05 AM	67.80	188.94	2.79	2
GH18	1200	36.4183203 1	74.8586109 1	2728.206	170	06/08/2023	10/13/23 7:49 AM	67.75	338.00	4.99	1
GH15	1200	36.4189815 7	74.8612097 2	2732.106	90	06/08/2023	10/13/23 7:27 AM	67.68	191.94	2.84	4
GH10	1200	36.4193381 4	74.8640726 4	2701.061	90	06/08/2023	10/13/23 7:07 AM	67.62	148.76	2.20	6

Table 2: Location of ablation stakes on Passu glacier and measurements of glacier melt.

Stake	**Total length (cm)**	**Latitude**	**Longitude**	**Elevation**	**Height (cm)**	**Start Date**	**End Date**	**Period**	**Ablation**	**Melt Rate**	**Debris (cm)**
P1	1200	36.4574753 5	74.8521327 1	2898.105	92.5	05/08/2023	13/10/2023	69.08	539.96	7.82	0
P2	1200	36.4572084	74.8535991 8	2890.267	114	05/08/2023	13/10/2023	69.05	0.00	0.00	0
P3	1000	36.4572	74.8547724 2	2882.473	17	05/08/2023	13/10/2023	69.02	496.08	7.19	0

		8369									
P4	1200	36.4573142	74.85591032	2875.952	90	05/08/2023	13/10/2023	68.98	575.48	8.34	0
P5	800	36.45688369	74.85707976	2872.37	21	05/08/2023	13/10/2023	68.94	753.70	10.93	1
P6	1200	36.45639159	74.85642011	2859.624	98	05/08/2023	13/10/2023	68.91	559.86	8.12	1

Field activities were initiated in 2022 on four glaciers in Hunza Valley (Passu, Ghulkin, Shishpar, and Batura) which included installing weather stations and data collection, ablation stakes, and sampling for microplastics and micro black carbon.

June 2023: Maintenance and stake searches revealed over 7 meters of ice melt and 100 meters of glacier movement on Ghulkin.

August 2023: Stakes were re-drilled, and by October, melt measurements indicated more than 7 meters of ice loss at one stake on Passu Glacier during summer.

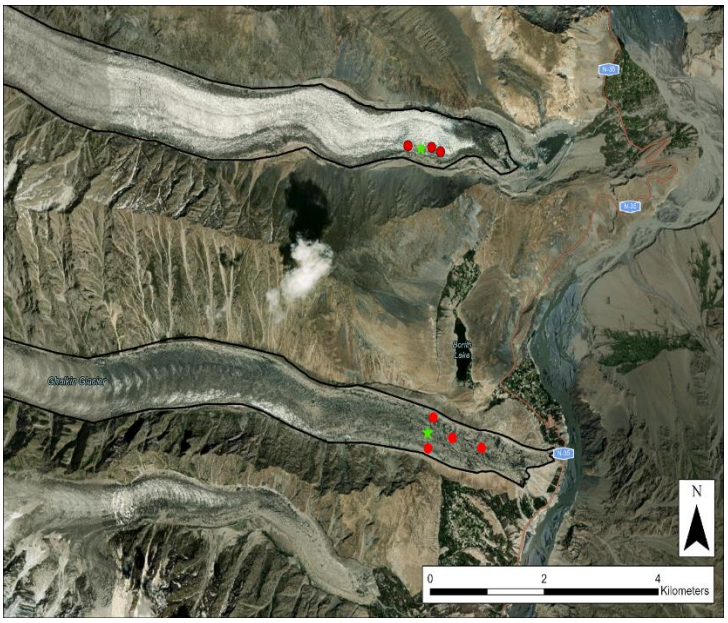


Figure 15: Location of the ablation stakes installed on Passu and Ghulkin glaciers

Microplastic Sampling

To assess micro plastic content, a systematic line transect sampling was conducted, comprising 10 samples collected using Falcon tubes. In addition, detailed microplastic surveys were also performed across multiple locations. Along, a single operator transects en route to the glacier, 8 microplastic items were detected with a total weight of 222 grams. Two additional surveys were conducted along different pathways around Borith Lake, yielding 21 items weighing 58 grams and 8 items weigh of 130 grams, respectively. Furthermore, 20 additional debris samples were gathered along another transect, earmarked for potential future analysis.

Figure 16: Field activities on Ghulkin glacier. From top left, clockwise: mounting of solar panel on temporary AWS; the AWS operational with the students from University of Baltistan and members of EPA-GB; drilling operations with the steam drill; sampling of debris for analysis of the plastisphere.

Glacier	Microplastics	Plastisphere	Black carbon	Cryoconite holes	Debris (extra)
Passu	10	10	10	2 × 15	/
Shisper	/	/	10	/	/
Ghulkin	10	10	/	/	20
Batura	10	10	/	2 × 15	/

Table 3: Performed sampling activities. Slashes indicate which samplings were not carried out.

Figure 17: Clockwise from top left: sample for Black Carbon analysis, cryoconite sample, samples for MPs with the respective plastisphere samples.

Result of the Glacier Field Activities Year 2022

In 2022, measurements from ablation stakes revealed high melt rates on debris-free ice, especially on **Passu Glacier**, where melt rates ranged from 8 to 12 cm per day. A similar rate was observed at **Ghulkin Glacier** with minimal debris cover (1 cm). In contrast, with 12 cm debris cover, the melt rate dropped to 3.1 cm per day. Contaminant samples were analyzed at the University of Milan, revealing spatial distribution patterns and the composition of microplastics. Unexpectedly, invertebrates from the subfamily Diamesinae were found in Passu Glacier's supraglacial debris, marking a first for the Karakoram region.

In 2023, significant changes were observed on the Ghulkin Glacier, with new crevasses, ice cliffs, and lakes forming in previously flat, debris-covered areas. These exposed zones are hotspots for glacier melt. Most stakes from 2022 were missing, likely due to ice movement or falling into crevasses. The remaining stake indicated a total ice melt of 7.26 meters, with stakes displaced 120 meters down the valley, reflecting the high ice movement rate.

Figure 18: AWS located at lake Borith.

Figure 19: AWS on the moraine close to Passu glacier

Like Ghulkin Glacier, Passu Glacier showed increased fragmentation and crevasses, complicating stake retrieval from September 2022. While some stakes were missing, some pieces of stake were found, indicating over 6 meters of melt. Melt rates were found to be more influenced by debris cover and local conditions than elevation. In August 2023, additional stakes were installed 10 meters deep on Ghulkin and Passu glaciers using a steam drill. Initial data showed higher melt rates on Passu Glacier, reaching up to 11 cm per day and over 7 meters during summer 2023.

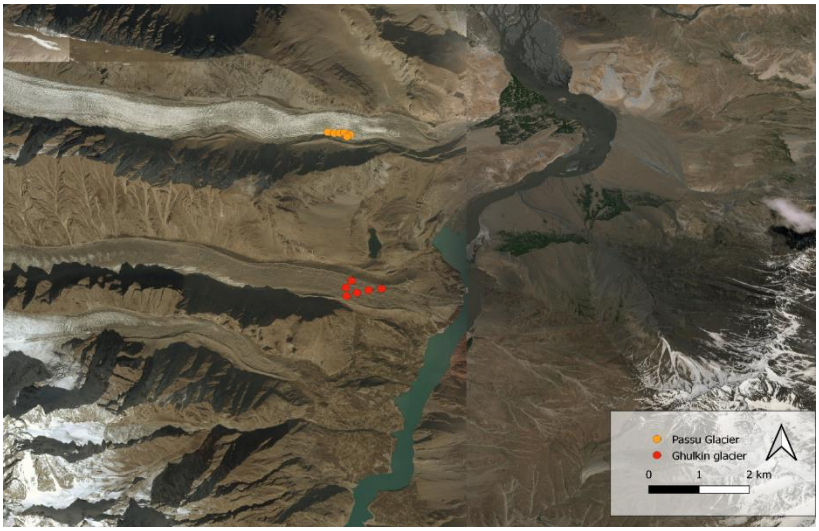


Figure 20: the ablation stakes installed on the surface of Ghulkin and Passu glacier in august 2023.

In October 2023, a joint mission of Ev-K2-CNR and GB-EPA team visited Ghulkin and Passu glaciers to measure ablation by assessing the emergence of ablation stakes installed in August. The team successfully located all six stakes on both glaciers.

At Ghulkin Glacier, the recorded melt ranged from 1.14 meters to 3.38 meters between August and October, 2023. The highest melt was observed, where the debris layer was about 1 cm thick, compared to a lower melt at a site with a 12 cm thick debris layer. The variability

in melt rates appears to be influenced by the debris thickness, topography, and solar radiation. The average ice melt at Ghulkin Glacier during this period was nearly 5 cm per day.

On Passu Glacier, melt rates were consistently higher at all stakes. Thin debris layers typically enhance ablation until a critical threshold is reached, beyond which the insulating effect dominates.

Figure 21: Carrying out measurements of ablation stakes on Passu glacier.

Activity 1.3: Pakistan Glacier Inventory

Target: Update Pakistan Glacier Inventory

Result: Pakistan glacier inventory updated

Under this activity, 13,032 glaciers were mapped, spanning considerable area of 13,546.93 km². This initiative aims to provide a comprehensive overview of Pakistan's glaciers, focusing on the northern regions Gilgit-Baltistan, Khyber Pakhtunkhwa, and Azad Jammu and Kashmir (referred to Pakistan Administered Kashmir by the UN)—were divided into three main basin categories:

1. **High-Level Basins:** Five major basins were identified:
    i. Gilgit
    ii. Indus
    iii. Jheelum
    iv. Kabul
    v. Tarim
2. **Intermediate-Level Basins:** These major basins were further subdivided into 12 lower-order basins

i. Astore
ii. Chitral
iii. Gilgit
iv. Hunza
v. Indus
vi. Jheelum
vii. Neelum
viii. Shaksgam
ix. Shigar
x. Shingo
xi. Shyok
xii. Swat.

3. **Detailed Basins:** The 12 lower-order basins were further divided into 62 detailed basins.

These subdivisions aid in assessing the country's water resources and glacier distribution.

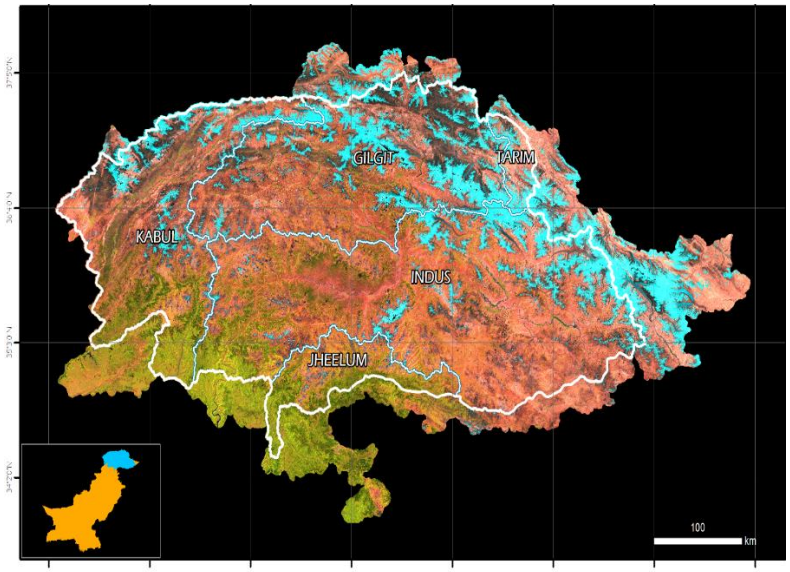


Figure 22: Subdivision of the region in 5 main basins

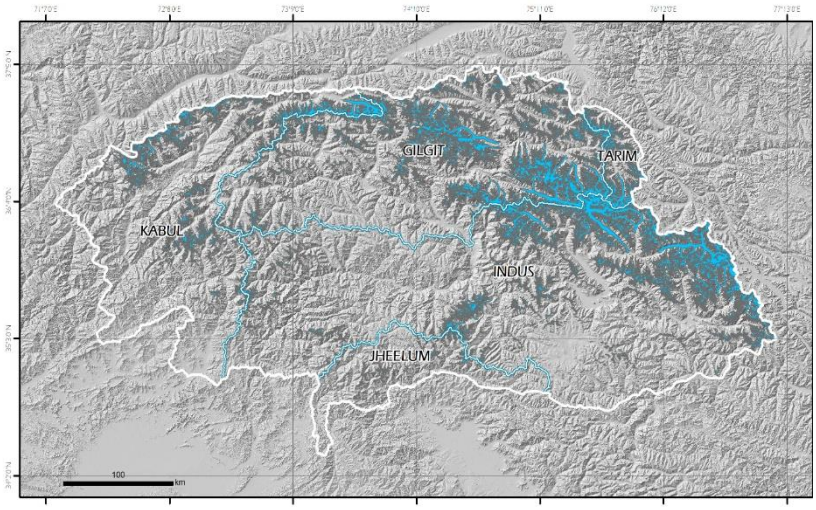


Figure 23: Map of the glaciers of the new inventory and subdivision of the 1st-order basins

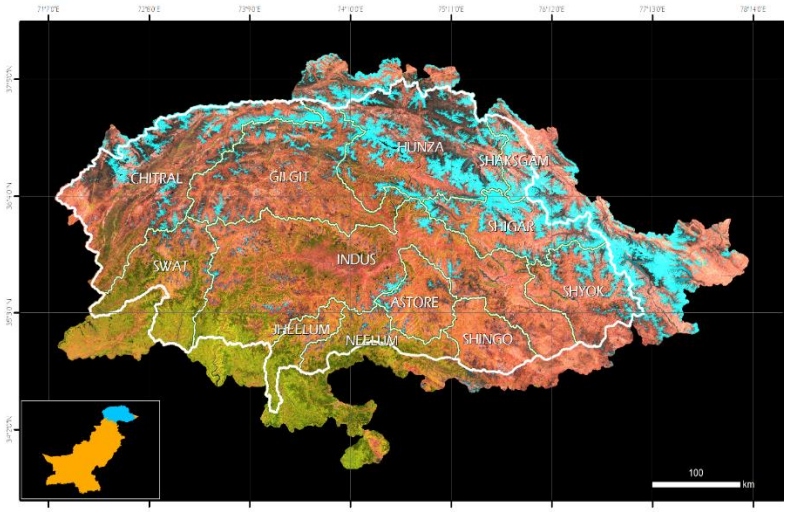


Figure 24: Subdivision of the region in 12 basins (2st order)

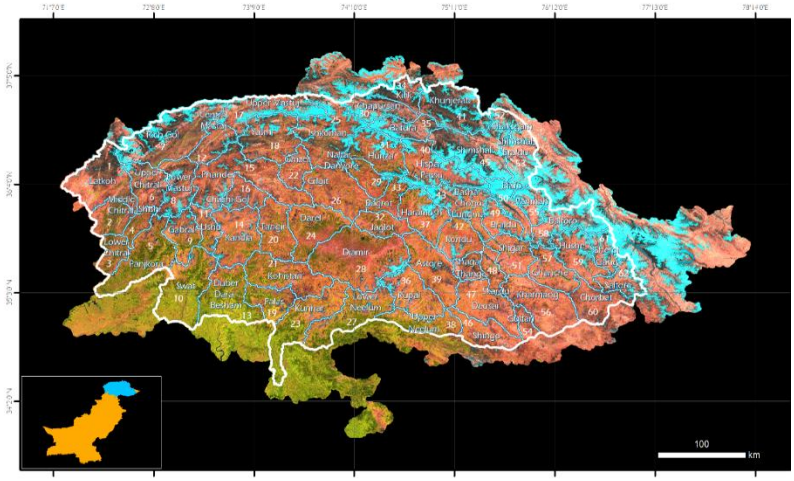


Figure 25: Subdivision of the region in 62 basins

The Gilgit basin, covering 27,280 km², extends across the northern part of the study area, from the headwaters at Shandur Lake and Khunjerab in the Hunza region to the confluence of the Gilgit River with the Indus near Jaglot. Major sub-basins within the Gilgit catchment include Ishkoman, Yasin, and notably the Hunza, which merges with the Gilgit River near Gilgit town. The Hunza region features some of Pakistan's largest glaciers, including Hispar (436.80 km²), Batura (273.12 km²), and Khurdopin (202.02 km²) in the Shimshal basin.

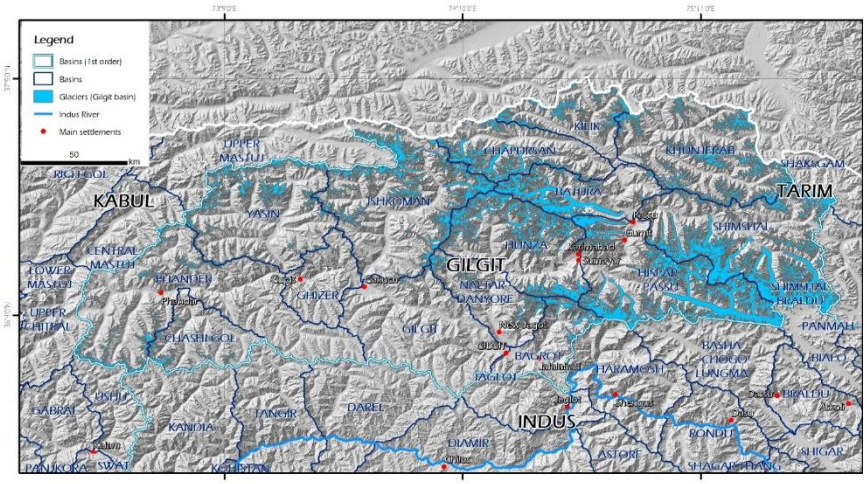


Figure 26: Map of the glaciers in the Gilgit basin

South of the Gilgit basin, the Indus River basin spans 45,984 km², making it the largest in northern Pakistan. The Indus flows through the Karakoram and Himalayas, with major tributaries including the Shyok, Shigar, and Shingo rivers, which are flanked by peaks such as K2, the highest mountain in Pakistan (8,611 m). The Shigar River receives meltwater from Pakistan's largest glaciers, Baltoro (756.35 km²), as well as the Biafo (524.60 km²), Panmah (312.17 km²), and Chogo Lungma (284.51 km²) glaciers. The Shyok basin hosts the Kondus Glacier (303.56 km²), the fifth largest in Pakistan. Further downstream, the Indus flows past the Nanga Parbat/Diamir Massif, which has large glaciers on its flanks.

West of the Kohistan region, the Kabul River basin covers 22,179 km², with Chitral and Swat as its primary tributaries. The basin is surrounded by the Hindukush and Hinduraj peaks. The Chiantar Glacier (198.20 km²) is the largest in this basin, located at the sources of the Chitral River, while other significant glaciers flow from the Tirich Mir peak (7,708 m).

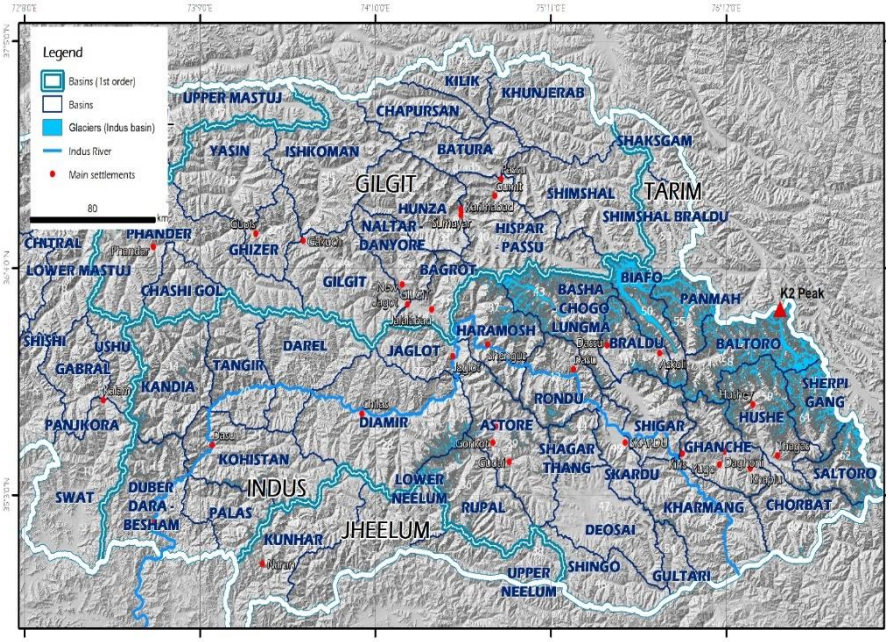


Figure 27: Map of the glaciers in the Indus basin

The smallest basins in this region are the Jhelum (6,291 km²), which includes the Neelum River flowing along the Pakistan-India border, and the Tarim (1,964 km²). Unlike other rivers

in northern Pakistan that flow into the Indus, the Tarim is an endorrheic river in Central Asia. The Tarim basin includes the Shimshal Braldu and Shaksgam basins, with the Braldu Glacier (166.37 km²) being the largest in Shimshal Braldu. Within Pakistan, glaciers from these basins drain into the Shaksgam River, which marks the border between Pakistan and China.

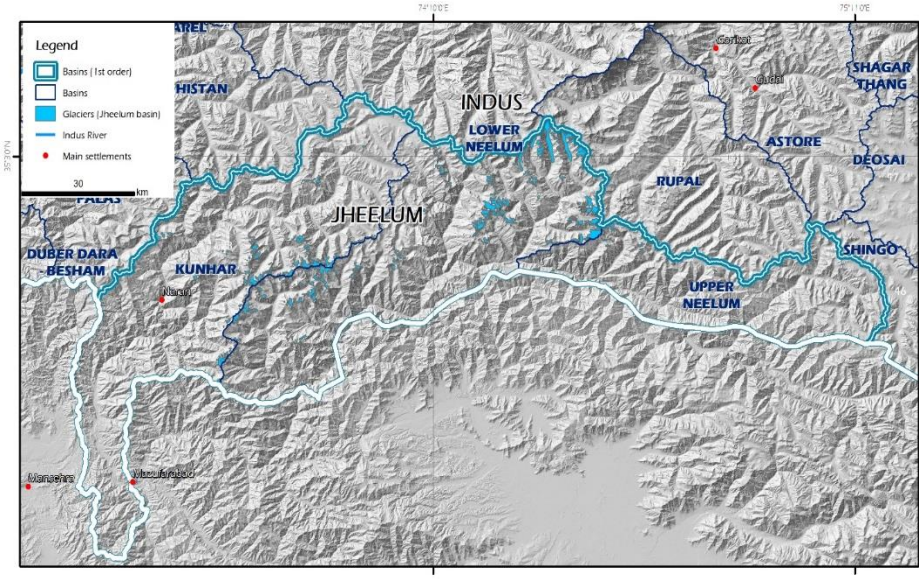


Figure 28: Map of the glaciers in the Jhelum basin

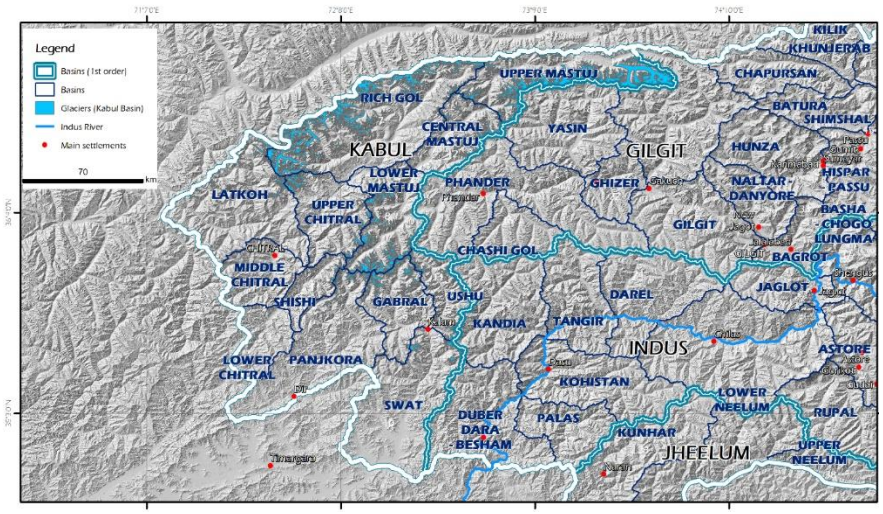


Figure 29: Map of the glaciers in the Kabul basin

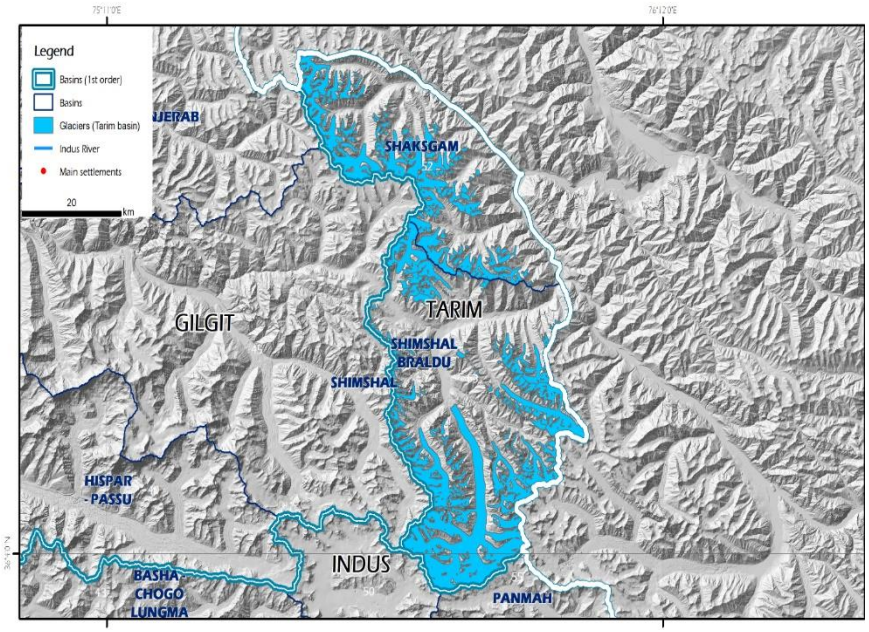


Figure 30: Map of the glaciers in the Tarim basin

In the highest order division, the Indus basin has the largest number of glaciers, totaling nearly 5,000, which represents 37.62% of the overall glacier count. This is followed by the Gilgit Basin with 4,443 glaciers and the Kabul Basin with 2,627 glaciers, accounting for 34.10% and 20.16% of the total, respectively (see Figure 12). This distribution is mirrored in the glacier area: glaciers in the Indus basin cover over 5,547 km², or 40.95% of the total glacier area. The Jhelum and Tarim basins show significant differences: glaciers in the Jhelum basin are relatively small, covering just 173 km², whereas those in the Tarim basin cover 671.36 km².

At the lower order basin level, the Hunza basin is the most glaciated, with 2,541 glaciers (19.50% of the total) and a glacier area of 3,882 km² (28.60% of the total). The Shigar basin follows, contributing 2,763.41 km² of glacier area, largely due to the presence of large glaciers like Baltoro. Excluding the Shigar and other Indus sub-basins, the 2,274 glaciers in the Indus basin proper contribute a smaller area of 986.59 km² (7.28% of the total). The Gilgit and Chitral basins are next, with 1,902 and 1,872 glaciers, respectively, with the Chitral basin having a larger glacier area of 1,822.07 km² (13.45%).

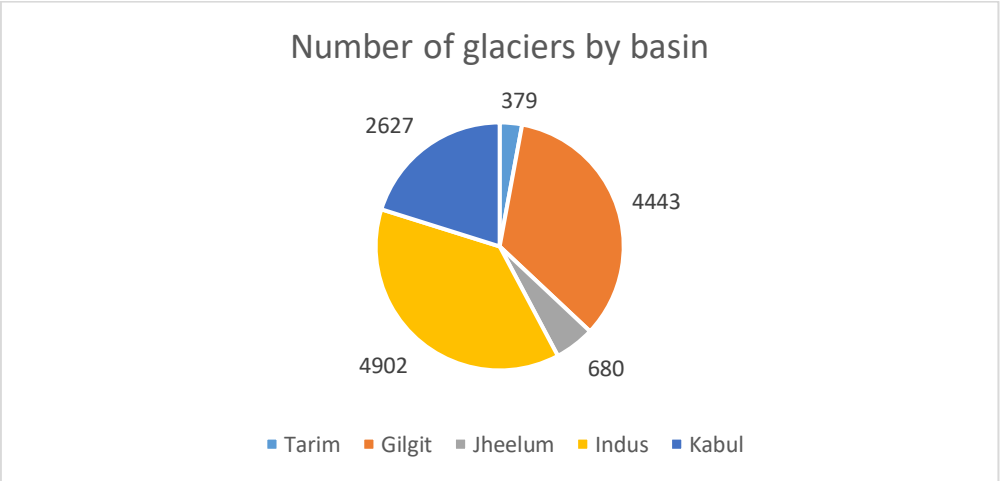


Figure 31: Number of glaciers in each basin of the 1st order.

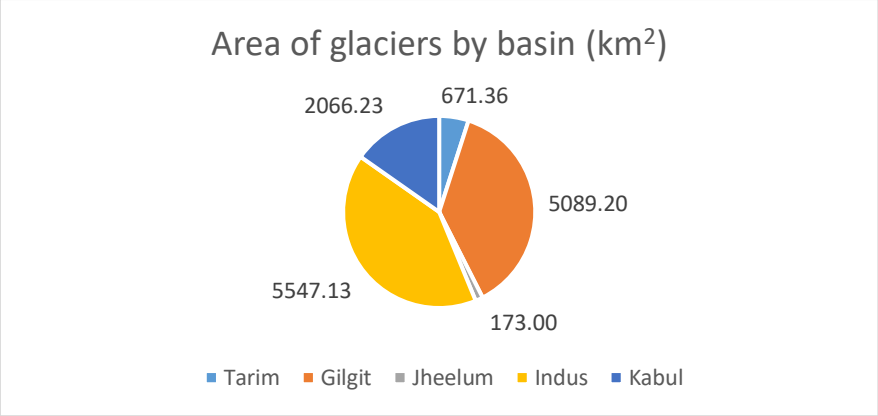


Figure 32: Area of glaciers in each basin of the 1st order.

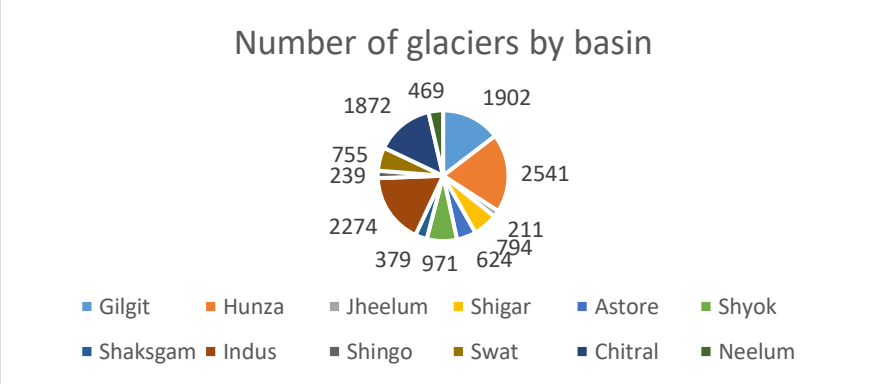


Figure 33: Number of glaciers in each basin of the 2nd order

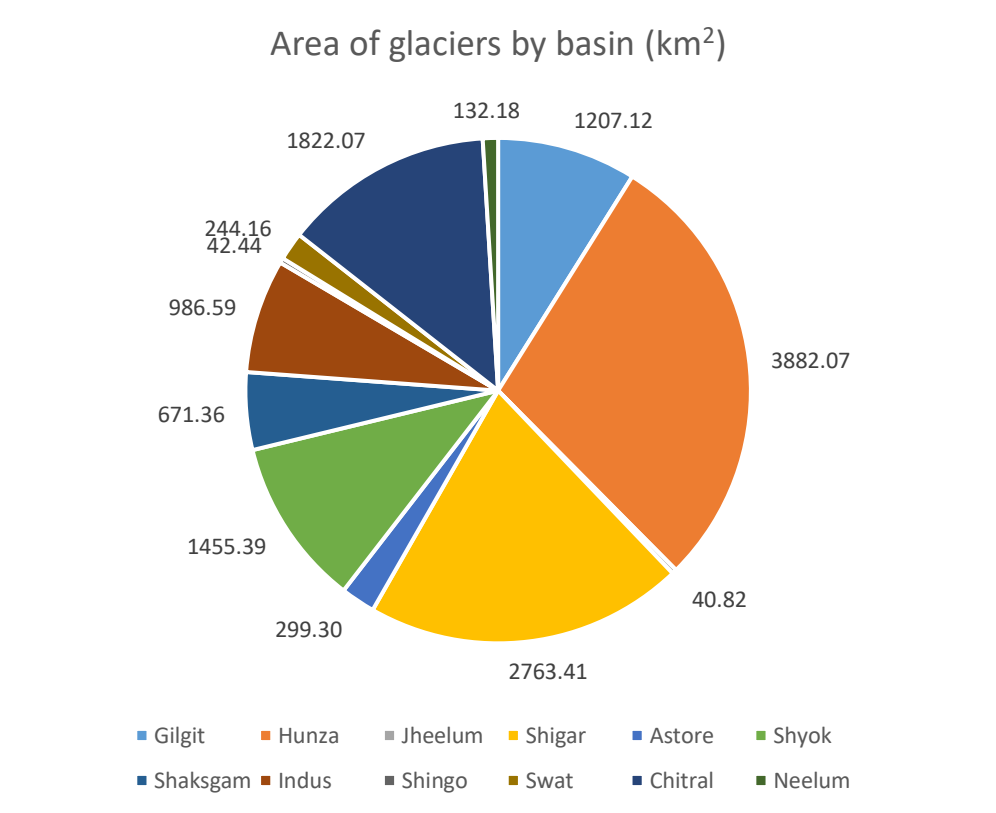


Figure 34: Area of glaciers in each basin of the 2nd order

The glacier distribution by size

The glacier size distribution is categories into nine categories: <0.1 km², 0.1-0.5 km², 0.5-1 km², 1-2 km², 2-5 km², 5-10 km², 10-20 km², 20-50 km², and >50 km². The largest number of glaciers are found in the smallest size classes, with 5,795 glaciers smaller than 0.1 km² and 4,585 between 0.1 and 0.5 km². In contrast, there are only 32 glaciers larger than 50 km². This distribution is typical of high mountain regions, where a small number of large glaciers contribute significantly to the total glacier area. Large glaciers cover 5,265 km², or 38.88% of the total area, while glaciers smaller than 0.5 km² account for just 9.73% of the area.

Among the main basins, the distribution by number is relatively homogeneous, with the Indus and Gilgit basins having more glaciers compared to the Jhelum and Tarim basins. Notably, the Jhelum basin lacks large glaciers, with none exceeding 10 km². **The Gilgit basin has 16 glaciers larger than 50 km², while the Indus basin has 12.** The Indus basin has a higher proportion of smaller glaciers, with 81.81% smaller than 0.5 km², compared to 75.74% in the Gilgit basin. However, the Gilgit basin has larger glaciers in absolute terms.

In terms of glacier area, the Gilgit basin dominates the intermediate size classes (0.5-20 km²). Despite having a higher number of large glaciers, the Indus basin has the largest combined glacier area (2,726 km²), mainly due to glaciers in the Shigar and Shyok basins. The Jhelum basin's contribution is limited due to its smaller glaciers, while the Kabul basin's contribution is evenly distributed across all size classes (1.24% to 2.65%). The Tarim basin shows an increasing contribution to glacier size.

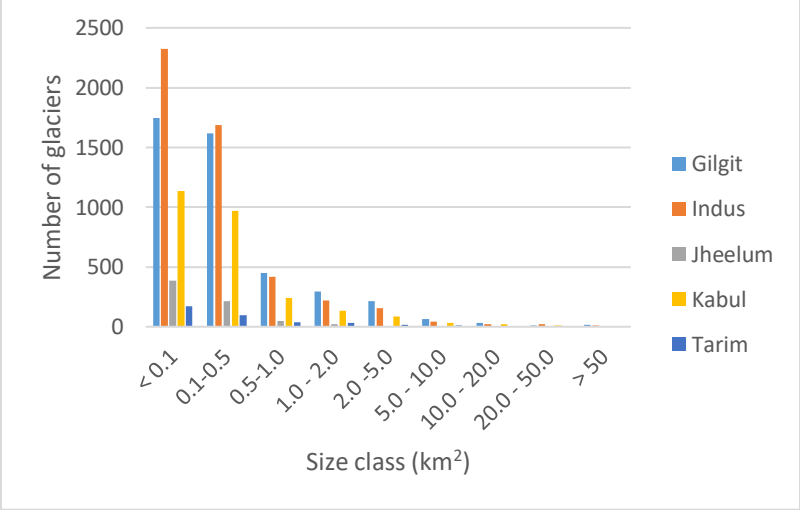


Figure 35: Number of glaciers in each size class for the 5 basins in the 1st order division

Figure 36: Area of glaciers in each size class for the 5 basins in the 1st order division

Glacier Distribution by Elevation and Aspect

In Pakistan, glaciers exhibit a remarkable variation in elevation. Some, like Batura (5153 m) and Pissan (5079 m), reach over 5000 m, while many smaller glaciers occupy niches with elevation ranges under 100 m. larger glaciers typically have elevations centered around 4919 m a.s.l., with a peak frequency around 5000-5100 m. Less than 10% of glacier area is below 4000 m, and just 5% exceeds 6000 m.

Regarding aspects, glaciers predominantly face north (26.15%), north-west (18.51%), and north-east (16.80%), benefiting from reduced solar radiation. South-facing glaciers, while less common (12.42%), include large glaciers like Biafo and Kondus. North-facing glaciers generally have lower elevations (median: 4760.54 m a.s.l.) compared to south-facing ones (median: 5151.15 m a.s.l.), reflecting their exposure to varying solar radiation and topographic influences.

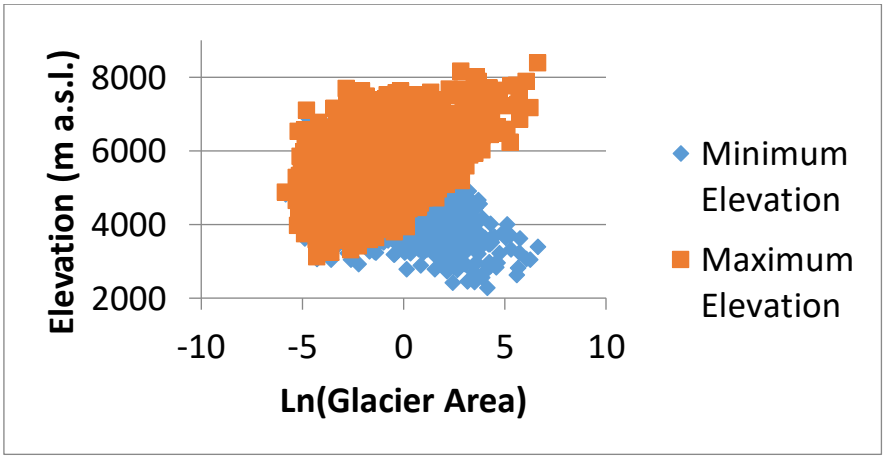


Figure 37: Minimum and maximum elevation with respect to area for all glaciers in Pakistan.

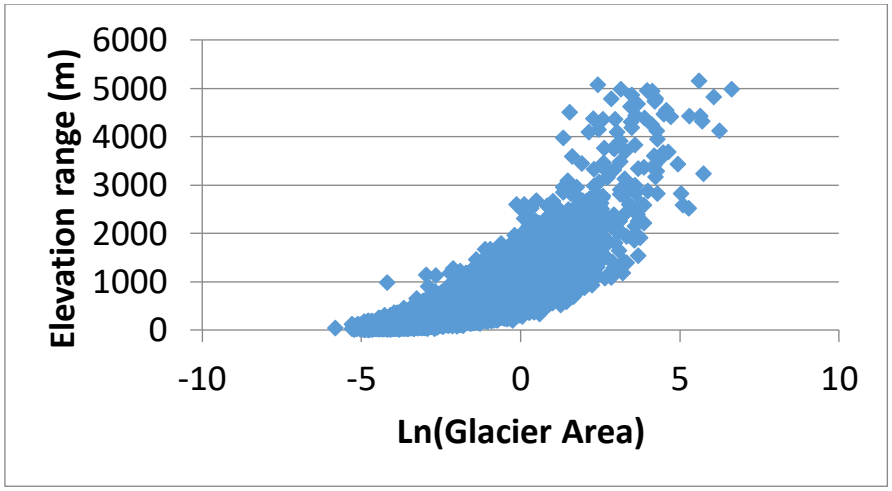


Figure 38: Relationship between glacier area and elevation range for all glaciers in Pakistan.

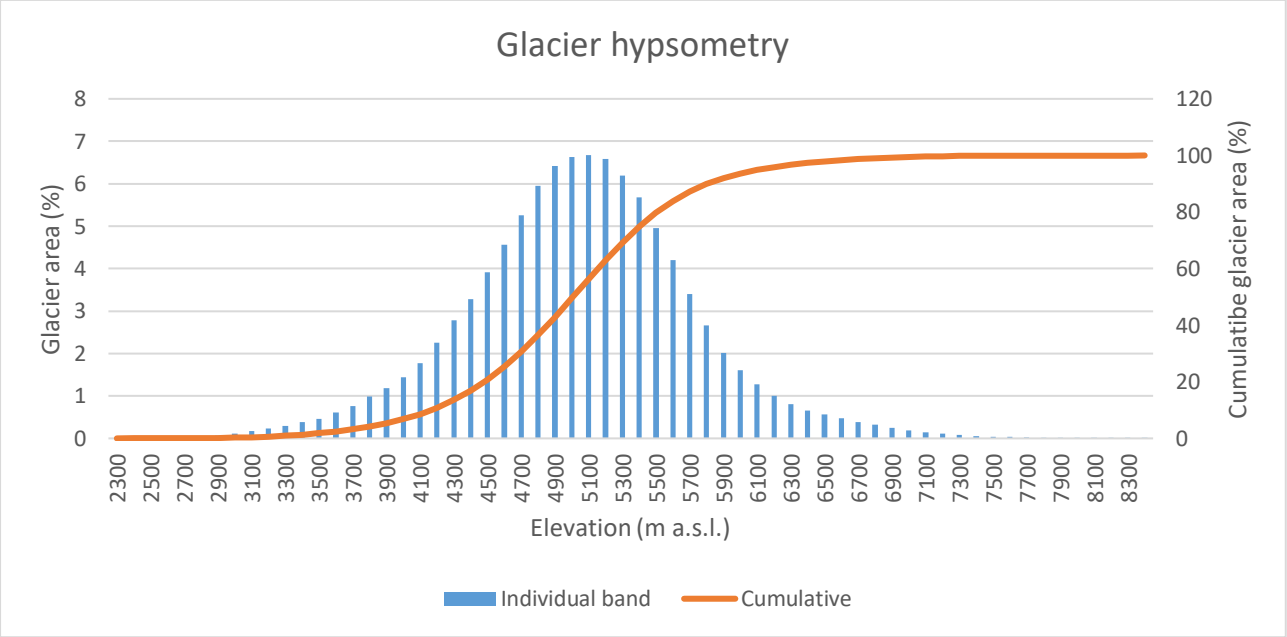


Figure 39: Hypsometric distribution of all glaciers in Pakistan in 100 m elevation bands.

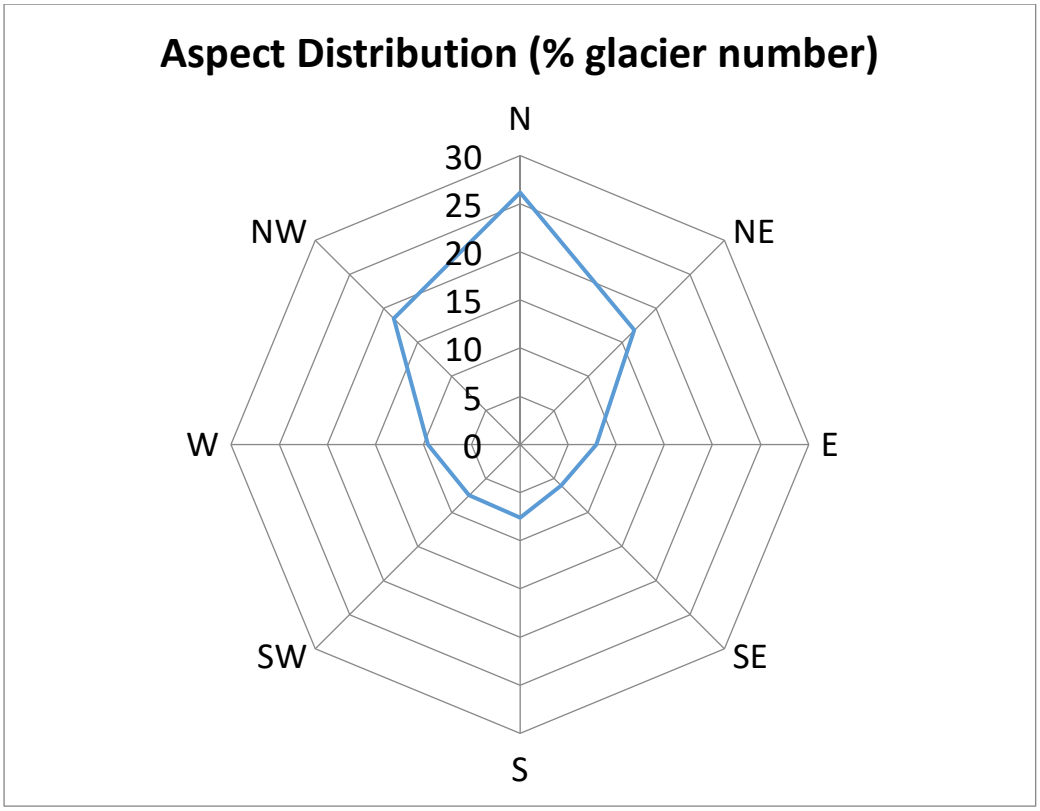


Figure 40: Percentage of glaciers in each aspect class (8 directions).

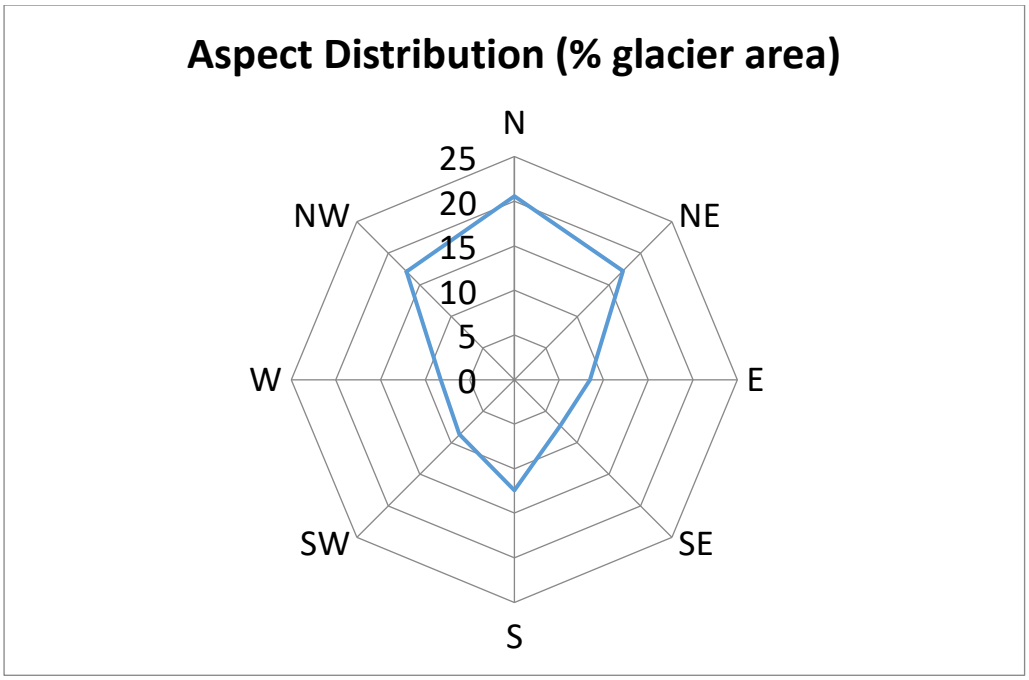


Figure 41: Percentage of glacier area in each aspect class (8 directions)

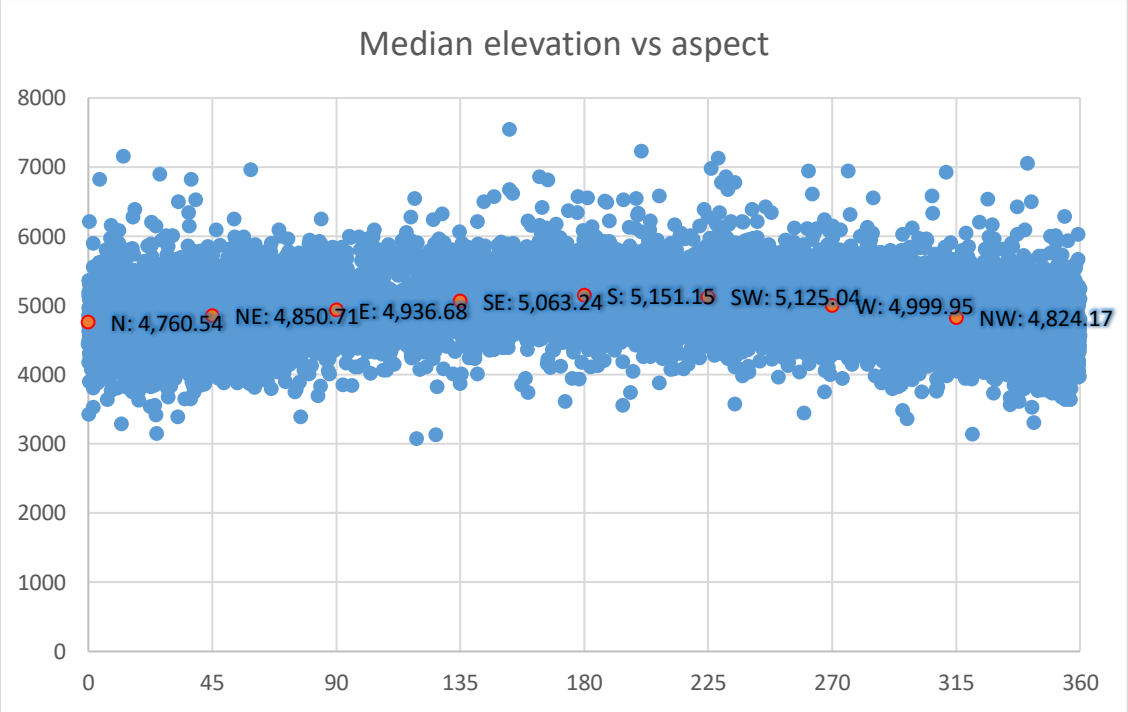


Figure 42: Relationship between glacier median elevation and aspect. Red dots show the average median elevation for each aspect class.

Basin Mapping

Understanding Earth's physical components and dynamics is crucial for interpreting and comprehending environmental changes. This Glacier Inventory and its associated maps serve as a comprehensive cartographic tool, providing thematic insights and statistical data to offer an accurate portrayal of the region.

The inventory includes maps of 62 basins in northern Pakistan, designed at scales that clearly depict glacier distribution. For better clarity in expansive basins, zoom panels are included. The maps use Sentinel2 satellite imagery, processed to reflect true colors, and are complemented by topographic information gathered from various sources, including:

- OpenStreetMap
- Google Earth
- 1:200,000 scale topographic maps
- Data from previous projects on Central Karakorum National Park and Deosai National Park
- Digitized hydrographic networks from Sentinel2 images

Additionally, the Digital Elevation Model (ALOS AW3D30) at 30 m resolution was used to create contour lines and hill shade maps for enhanced morphological interpretation.

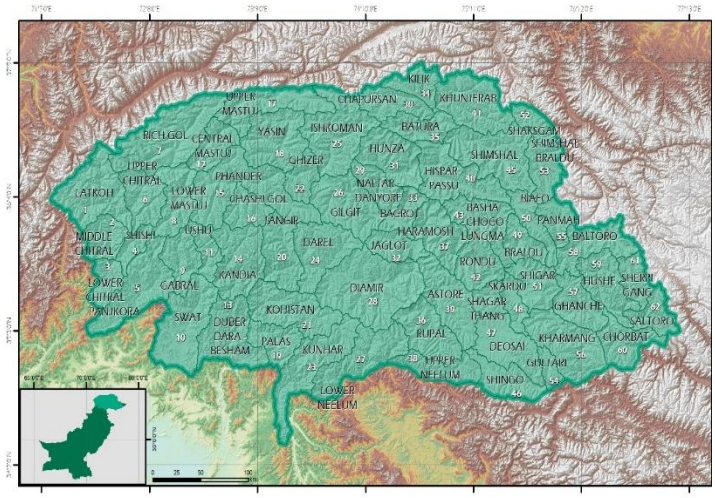


Figure 43: Subdivision of the region in 62 basins

Table 4: List of the 62 basins

1	Latkoh	**17**	Upper Mastuj	**33**	Bagrot	**49**	Braldu
2	Middle Chitral	**18**	Yasin	**34**	Kilik	**50**	Biafo
3	Lower Chitral	**19**	Palas	**35**	Batura	**51**	Shigar
4	Shishi	**20**	Tangir	**36**	Rupal	**52**	Shaksgam
5	Panjkora	**21**	Kohistan	**37**	Haramosh	**53**	Shimshal Braldu
6	Upper Chitral	**22**	Ghizer	**38**	Upper Neelum	**54**	Gultari
7	Rich Gol	**23**	Kunhar	**39**	Astore	**55**	Panmah
8	Lower Mastuj	**24**	Darel	**40**	Hispar – Passu	**56**	Kharmang
9	Gabral	**25**	Ishkoman	**41**	Khunjerab	**57**	Ghanche
10	Swat	**26**	Gilgit	**42**	Rondu	**58**	Baltoro
11	Ushu	**27**	Lower Neelum	**43**	Basha – Chogo Lungma	**59**	Hush
12	Central Mastuj	**28**	Diamir	**44**	Shagar Thang	**60**	Chorbat
13	Duber Dara – Besham	**29**	Naltar - Danyore	**45**	Shimshal	**61**	Sherpi Gang
14	Kandia	**30**	Chapursan	**46**	Shingo	**62**	Saltoro
15	Phander	**31**	Hunza	**47**	Deosai		

16	Chashi Gol	**32**	Jaglot	**48**	Skardu		

Glacier Inventory Methodology

The Pakistan glacier inventory leverages optical data from the European Space Agency's Sentinel-2 satellites. Ensuring comprehensive and uniform coverage with minimal cloud interference, and high spatial resolution for precise glacier mapping. This approach makes significant improvement over the earlier datasets derived from the Landsat program. (Landsat 5 TM and Landsat 7 ETM+), which faced limitations in revisit time, limited data availability, and image quality due to technical issues and lower spatial resolution (30 m compared to Sentinel-2's 10 m). This often required combining images from different years, affecting temporal consistency and complicating landform recognition. Sentinel-2 satellites provide improved data quality and consistency, supporting future updates and monitoring of glacial perimeters.

The following inventories were available for Pakistan;

Inventory name	Geographic coverage	Acquisition dates	Image source	Spatial resolution (m)	Mapping methodology
GAMDAM v2	Asia	1993-2009	Landsat 5 TM/ Landsat 7 ETM+	30	Manual delineation
ICIMOD	Hindukush-Karkaoram-Himalaya	08/2005-09/2009	Landsat 5 TM/ Landsat 7 ETM+	30	Object-based image analysis
CKNP glacier inventory	CKNP (Central Karakorum National Park)	08/2010 – 10/2010	Landsat 5 TM/Landsat 7 ETM+	30	Manual delineation

For the Pakistan New Glacier Inventory, a semi-automated classification process for glacier boundaries from Sentinel-2 data has been implemented to reduce human interpretation bias. Traditional glacier mapping has relied on multispectral data from Landsat, which has limitations in identifying debris-covered glaciers and requires manual adjustments.

Sentinel-2 satellites provide high-resolution optical data (10 m in visible/NIR, 20 m in SWIR), enhancing the accuracy of glacier mapping. The aims were:

1. Develop a new methodological approach for glacier mapping.
2. Involve Pakistani and Italian students in glacier boundary recognition.

The methodology includes:

- **Data Preparation:** Organizing satellite data and DEM for focused analysis.
- **Glacier Mapping:** Using semi-automated classification with manual oversight.

The final phase involved validating glacier outlines, creating a database with geometric, descriptive, and morphometric attributes, and producing a shapefile of glacier features.

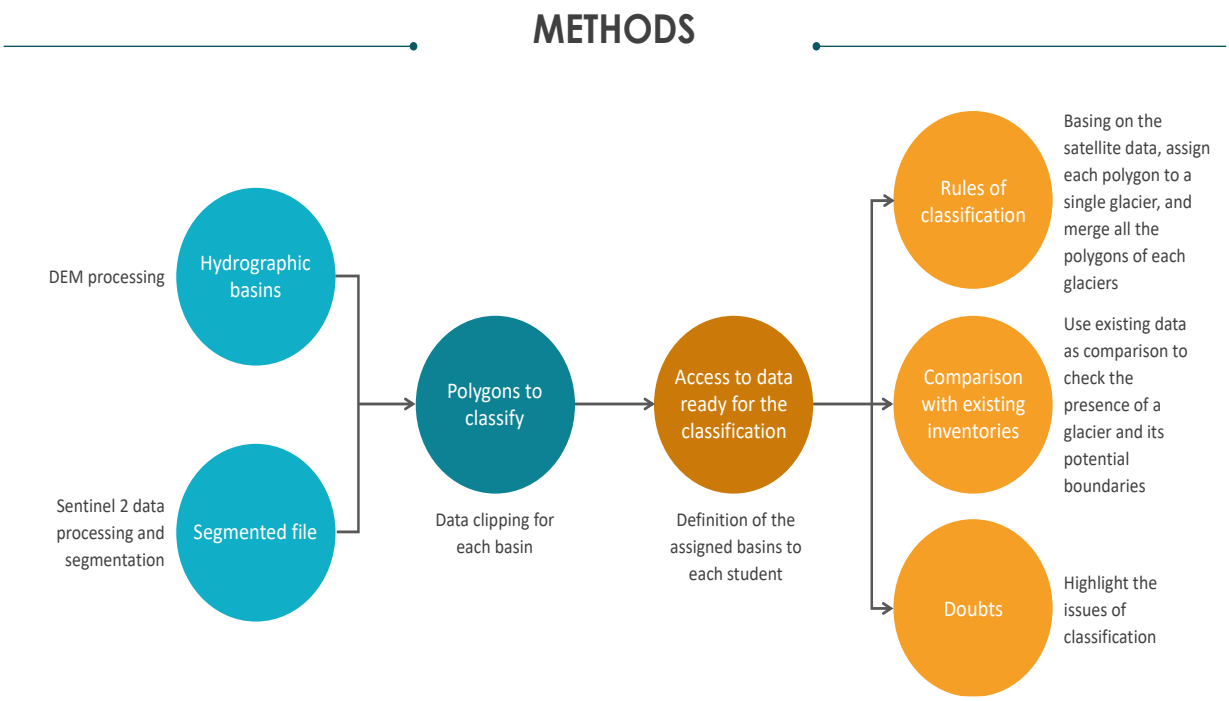


Figure 44: Scheme of the approach with the steps of the adopted methodology

The following scientific papers have been published up to now within the Glaciers and students project, describing the methodology and the preliminary results from the glacier inventory:

Ahmad, A., Fugazza, D., 2023. Fusion of Sentinel-1 Interferometric Coherence and Sentinel-2 MSI for Debris-Covered Glacier Boundary Delineation: Case Study of Batura, Passu, Ghulkin, and Gulmit Glaciers, Pakistan. Geografia Fisica e Dinamica Quaternaria 46, 229–240. https://doi.org/10.4454/76ghdjt5

Melis, M.T., Fugazza, D., Naitza, L., Gallo, M., Dessì, F., Casu, M., Ahmad, A., Barbagallo, B., Diolaiuti, G., Senese, A., Hassan, U., Zaib, M.A., Munir, S., Hussain, A., Simonetti, D., 2024. NEW REMOTE SENSING METHODOLOGY TO MAP THE GLACIER EXTENT: THE NEW INVENTORY OF GLACIERS IN PAKISTAN, in: Trends in Earth Observation. pp. 46–49.

Additionally, two scientific papers have been submitted to scientific journals and are awaiting review and publication:

Almagioni C., Manara V., Diolaiuti G., Maugeri M., Spezza A., Fugazza D. Snow cover variability and trends over Karakoram, Western Himalaya and Kunlun Mountains during the MODIS Era (2001-2024)

Diolaiuti G., Melis T., Senese A., Ahmad A., Barbagallo B., Casu M., Fugazza D. A contribution to the study of evaluation processes of educational activities within international cooperation programs: the case study of the "Glaciers & Students" project

Output 2: Collaboration and Sharing

Collaboration and Sharing mechanisms among Pakistani and international institutions and students strengthened to build capacities for longer-term glacier monitoring through innovative

Output statement	Baseline	Indicators	End of the project target	Status	Means of verifications
Output 2 Collaboration and sharing mechanism among Pakistani and international institutions and students strengthened to build capacities for longer term glaciers monitoring through innovative approaches and technologies.	0 number of systematic web-based GIS data arching and sharing mechanism exist	2.1. Web based GIS climate and glaciers data archiving and sharing system developed and maintained to enable knowledge and data sharing among the authorities responsible e.g. Met Deptt, Disaster Management Authorities, Agriculture Deptt, Water Mgt. Deptt & EPA at GB and national level.	systematic web-based GIS data archiving and sharing mechanism developed	Complete Data, georeferenced maps, trend and scenarios have been processed and are available through the information system.	Quarterly report. Data, georeferenced maps, trend and scenarios

Output statement	Baseline	Indicators	End of the project target	Status	Means of verifications
	0	2.2: Number of students and faculty members of the local universities in Gilgit-Baltistan trained in glacier inventory and monitoring	100 (End target with 40% female student's participation)	Complete 394 students and faculty members participate with 43% female participation	Quarterly reports Training reports

Activity 2.1: Implementation of the Information System

Target: 01 number of systematic web-based GIS data Archiving and sharing mechanisms exist.

Result: Web-based GIS information system was developed, and data was successfully archived

A state-of-the-art web GIS information system based on Ev-K2-CNR/SHARE GeoNetwork has been developed to collect, analyze and share critical environmental data as part of the project. This innovative platform empowered authorities, local stakeholders, and beneficiaries by providing tools for monitoring glaciers dynamics, assessing risk associated with Glacial Lake Outburst Floods (GLOFs) and hydrogeological hazards. Leveraging satellite imagery and remote sensing technologies and systems generated comprehensive maps, dataset, and metadata offering actionable insight to support proactive risk management and environmental conservation efforts.

The system is a comprehensive repository of dataset and information, supporting glacier and water resources management, and risk assessment. It adheres to international standards for metadata, dataset formats, and QA/QC procedures, ensuring reliable information and facilitating data exchange. Relevant government departments/institutes/authorities and international agencies will benefit from this platform by accessing and sharing valuable knowledge and data.

The activity focused on improving database systems by migrating from a cloud service to a dedicated on-premises server at the University of Cagliari. The new server, equipped with advanced hardware (Intel® Xeon® Silver CPU, 64GB memory, and 2.4TB storage), offers better performance.

The project upgraded the main database (Postgres and PostGIS) and successfully transferred and imported the data to the new server. The data migration was done in two parts: one for Geoserver data and another for GeoNetwork data. A full dump of the old database was

completed, and after successful compatibility testing, the dataset was imported into the new system.

GeoPortal has undergone a graphic redesign and content update, including metadata, datasets, and maps. The upgraded system now catalogs geospatial resources and allows users to search, access, and download datasets. The core structure of the catalog remains the same, with a focus on metadata for resource retrieval.

New features include highlighting interesting datasets on the homepage, interactive map visualizers for querying and exploring data, and direct download options in various formats (shapefile, .csv, JSON, .kml). GeoPortal also supports AWS data and GIS web tools.

New templates and layouts have been tested to enhance clarity and responsiveness. Exclusive functions include direct dataset access through a dedicated search tab. Datasets from new automatic weather stations are also available through this updated interface.

The development of the project and the operational methods in the field were discussed and shared with the local partner with whom EvK2CNR already had consolidated collaborative relationships.

At the beginning of the project, the technicians from the local agencies were invited to participate in the training sessions in lab and in the field. During these activities, the technicians from GB-EPA, GB Disaster Management Authority, CKNP were involved to discuss and suggest the methods for an effective data sharing and access to the resources of the new platform.

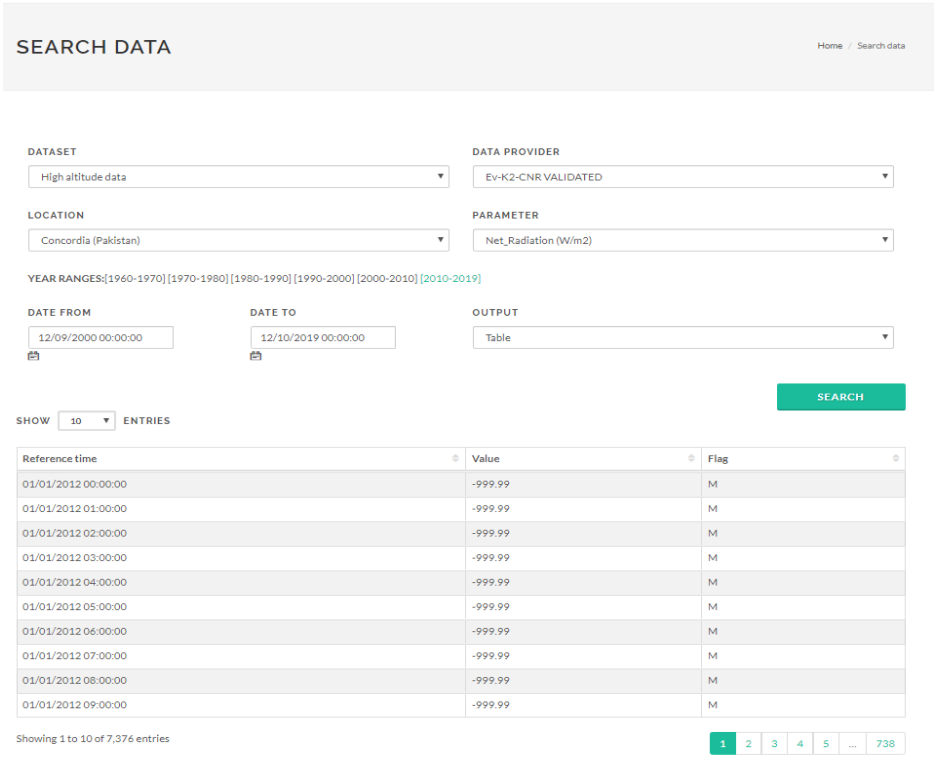
Moreover, the technicians participated to the remote sessions planned for the knowledge transfer, the sharing of a common methodology, and the monitoring of the glaciers mapping. Furthermore, these online meetings were organized to understand how to plan the activities and to be able to reach students engaged in their study activities at local universities and the technicians in their office located in different places.

To understand the importance of the sustainability of the project Glaciers&Students, the University of Cagliari, involved in the project, co-financed the Project Be-CLIMATE (BEyond-Citizens Life Involvement into hand-made MAps creation for Environmental awareness), funded by the Region Sardinia in the framework of the international cooperation activities and dedicated to the improvement of environmental knowledge and data management. Indeed, specific activities were organized at the office of the GB-EPA at Gilgit, involved in this last project. A dedicated system was installed composed of a workstation with advanced processing performance and the possibility of also being used as a server through access to a NAS (Network Attached Storage) unit.

The setup of the laboratory was completed with the purchase of three laptops with configurations dedicated to use in the field, as well as naturally in the laboratory. The availability of these laptops was particularly appreciated also due to the problems related to temporary electricity interruptions which can sometimes compromise processing activities. Furthermore, the laptops were also chosen for their robustness and battery life.

The data obtained during the project and in the future can be archived in a dedicated space on the server and available to users via the web. It was agreed that the working group will begin to use this web system following the training activities, guaranteeing remote support from University of Cagliari specialists.

Fig. 45 Interface of the data searching tool of the Geoportal



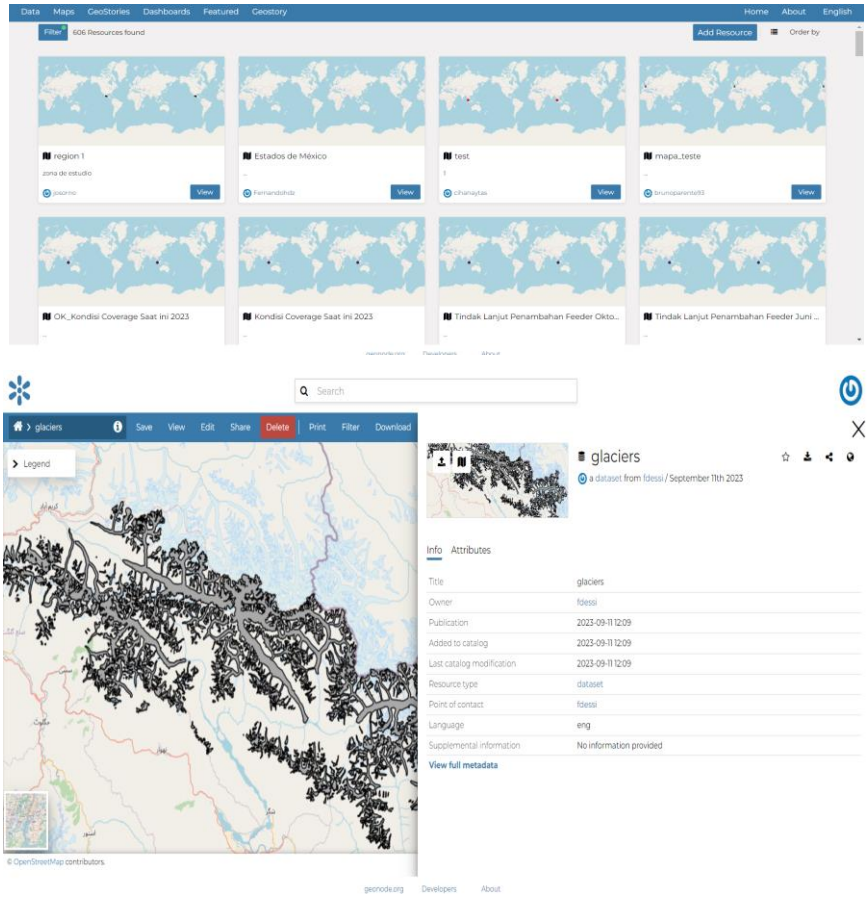
The new SHARE GeoNode Core system

One of the main improvements of this project is adopting of an innovative approach to data sharing, prioritizing a user-friendly interface that empowered non-specialized users to share data and create interactive maps. To achieve this transformation, the GeoNode platform was selected for its robust capacities and intuitive design.

GeoNode is a geospatial content management platform for managing and publishing geospatial data. It provides tools for creating and visualizing data, metadata, and maps. Users can control access to datasets, either sharing them broadly or restricting access to specific groups. Social features, such as user profiles, comments, and ratings, help build a community around the platform, enhancing data use, management, and quality control. Additionally, GeoNode is designed to be flexible, allowing developers to customize and integrate it into their applications.

The core resource in GeoNode is the dataset, which represents spatial information that can be displayed on maps. With this new functionality, registered users can easily share their datasets using the "Add Resource" feature available on their personal page.

Fig. 46 Geonode environment, the tool for the uploading of geo-data



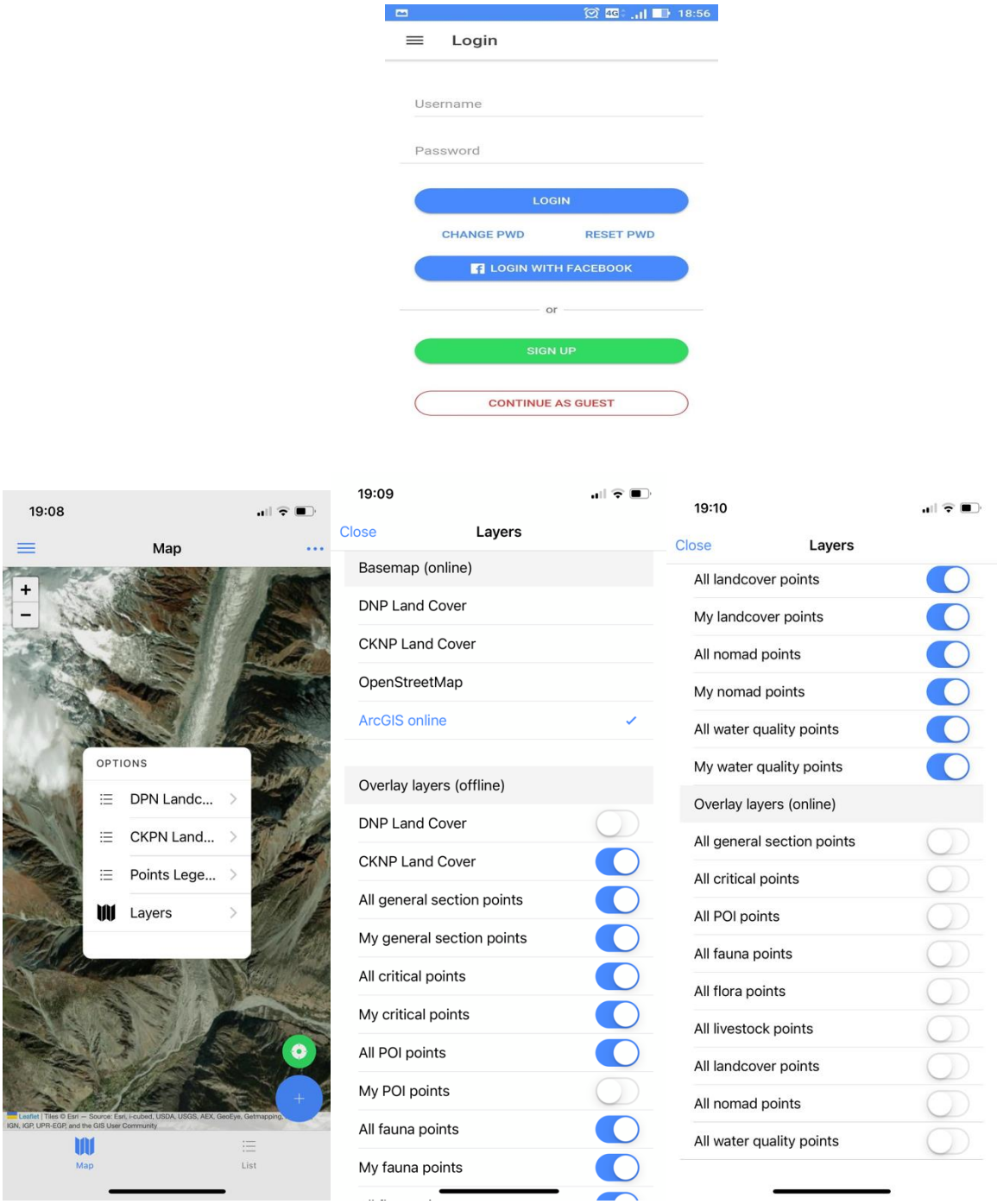
Updating of the GeoApp

Focuses on enhancing the GB GeoApp with new features for glacier data acquisition. The app (https://geoportal.mountaingenius.org/portal/index.php/gbgeoapp/) now includes a section for collecting points of interest. Users, once authenticated, can geolocate their position, classify points of interest using a data input form, and attach images from their device's camera. Additionally, the app supports glacier census and attribute definition.

The GB GeoApp is developed using the Ionic framework (Angular and Cordova) and is backed by Java services, with a complete backend overhaul in Node.js. The updated web GIS tool allows users to visualize data on maps or in tabular format. Features include a Table of Contents (TOC) for layer management, map querying, tabular display with filters, and various data download options (shapefile, KML, GeoJSON). A new measurement tool helps users measure distances and areas on the map.

The app functions in both online and offline modes. In offline mode, users can collect data as guests without authentication. Online users can authenticate via the app or Facebook, and registered users can change or reset their passwords. The app allows users to choose their base map and collect data in the field. The interface of the app is as below;

Fig. 46 In this picture, the GB GeoApp login page and an example of the list of the available layers for the data collection.



The App Testing

The app was tested during a two-day training course at universities in Skardu and Gilgit. Approximately 55 students participated, learning to install and use the GB GeoApp to collect

and upload data on points of interest. The training demonstrated the app's user-friendliness and functionality.

Fig 47 Students during the training session in the field for the collection of data through the GBGeoApp.

Activity 2.2: Capacity building

Target: Project target: 100 students with 40% female involvement

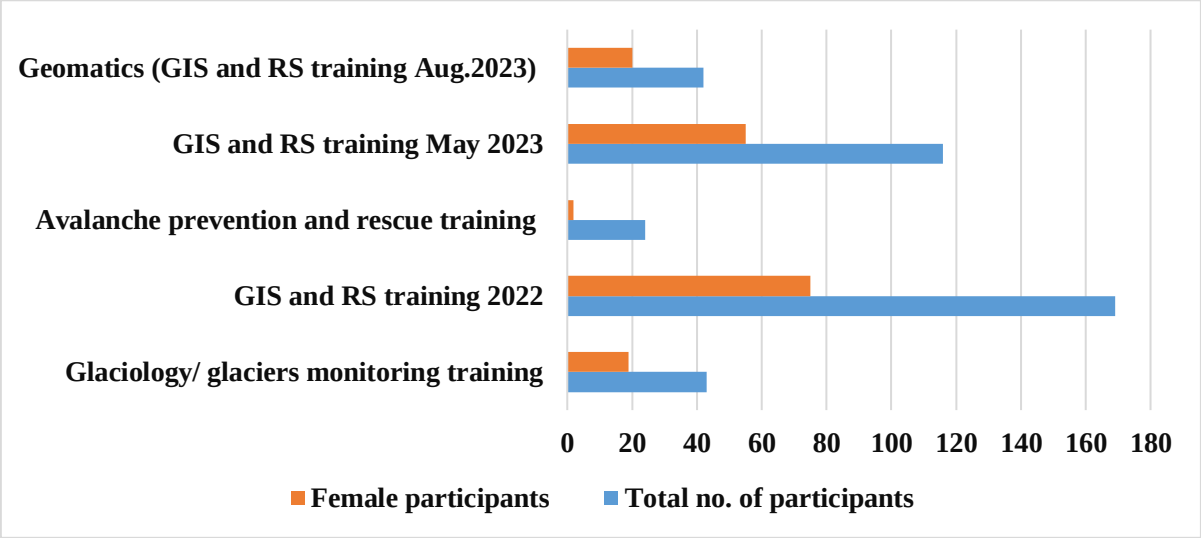
Result: 394 students, researchers and staff of various line departments received training with 43% female involvement

Training serves as cornerstone for enhancing performance, efficiency, decision-making, and skill development across various sectors such as education, business, and technology. In the digital era, empowering youth through targeted capacity-building and skill-development initiatives is crucial for strengthening innovation and competitiveness. Educational institutions and organizations play vital role by creating opportunities for innovation, hand on learning, and engagement in activities like technology based competitions and collaborative projects. Among the most sought-after skill globally, proficiency in GIS & RS (Geographical Information Systems and Remote Sensing), which has its versatile applications across multiple sectors including education, environment, business, agriculture, and transportation. Providing training in GIS & RS equips students with valuable skills needed in today's job market.

Given this perspective, training related to glaciology, avalanche risk, geometry, installation of weather stations, GIS &RS were arranged under the project 'Glacier and Students' at Karakoram International University. One of the primary objectives of this project is the empowerment of youth and stakeholders through training programs leading to developing the capacities to address the impact of climate change on various ecosystems including the glacier ecosystem.

Students from Karakoram International University, the University of Baltistan, and various stakeholders from different organizations participated in these training sessions. These stakeholders included the Environmental Protection Agency (EPA), Gilgit Baltistan Disaster Management Authority (GBDMA), Rescue 1122, the Forest Department, GB Police, Pakistan Air Force, and Aga Khan Agency for Habitat.

The total number of participants in these training sessions was 394, which encompassed both students and stakeholders. A significant proportion of female participants was actively engaged. Trainees expressed their deep appreciation for the training programs and recommended the continuation of such programs in the future.



Training Beneficiaries

Training sessions	Dates	Duration	Location/ Venue	Trainer	Participant	
					Male	Female
Workshop on AWSs Installation and Sustainability	19th August, 2022	03 hours	Musharraf Hall, KIU Gilgit	Dr. Davide Fugazza Ms. Ariana	23	19
Training for AWS Installation on Glaciers	2022		Ghulkin, Passu, Shishper, Baltoro, Biafo	Dr. Davide Fugazza Ms. Ariana	29	12
Training on Glaciological Field Activities	2023		Upper Hunza	Dr. Davide Fugazza	23	10
Training on GIS-RS	3rd–4th October, 2022	02 days	UOBS, Skardu	Dr Titi Melis	43	33

Training sessions	Dates	Duration	Location/ Venue	Trainer	Participant	
					Male	Female
	5th- 6th October, 2022	02 days	KIU, Gilgit	Dr Titi Melis	60	42
	2nd – 10th May, 2023	09 days	KIU, Gilgit	Mr. Anees Ahmad	50	26
	15th- 19th May, 2023	05 days	UOBS, Skardu	Mr. Anees Ahmad	18	25
Avalanche prevention and rescue training	6th- 10th March, 2023	04 days	Gilgit & Naltar	Mr. Maurizio Gallo Mr. Giovanni Songini Mr. Sergio Albanello	22	02
Training on Geomatics	10th-11th August, 2023	02 days	KIU, Gilgit	Dr. Davide Fugazza	19	21

One of the most distinguishing features of the G&S project has been its inclusive approach, bringing all stakeholders on board to achieve each set project objective. This strategy encompassed institutions mandated to address climate change and environmental conservation in Gilgit-Baltistan (GB), making it imperative to enhance the capacity of partner organizations in various critical areas. This comprehensive effort included training on AWS installation, maintenance, and data collection, as well as extensive sessions on GIS and RS to facilitate the development of Pakistan's glacier inventory. In this regard, the pivotal role played by the **Gilgit-Baltistan Environmental Protection Agency (GB EPA)** remained instrumental in extending these initiatives beyond the project timeline, ensuring their long-term sustainability. Furthermore, the active involvement of **Karakoram International University (KIU)** and the **University of Baltistan (UOB)** in this research-oriented journey is poised to make glacier studies an integral and enduring part of future initiatives.

The establishment of a dedicated training program was a fundamental component of this project, with the overarching goal of preparing students to address the pressing challenges of negative impact of climate change and glacier preservation initiatives. Students, viewed as the vanguards of the future, hold the potential to become catalysts for safeguarding our natural heritage and resources. If equipped with enhanced knowledge and skills, they can

play a pivotal role in the scientific exploration of core issues related to mountain area sustainability.

Training Missions

The Glaciers and Students (G&S) project was conceived with a primary objective of sharing knowledge. This involved active participation from local academia, students, government line departments, and dedicated researchers in the realm of glacier analysis.

The project placed a significant emphasis on generating and disseminating knowledge, as well as best practices in glacier and climate monitoring, with a particular focus on their applications for environmental risk assessment.

Through a series of dedicated training missions within the project, participating institutions, students, and specialized staff were equipped with new skills and expertise in the domain of environmental monitoring and glacier inventory development. Ev-K2-CNR hopes that even after the project's conclusion, these elevated levels of knowledge will persist and serve as a valuable resource for similar initiatives in the future. This collective wealth of expertise stands as an enduring testament to the project's lasting impact.

Training Components

- AWS installation
- Glaciological Field Activities
- GIS and Remote Sensing (RS)
- Avalanche Prevention and Rescue
- Geomatics

Workshop on AWSs Installation and Sustainability

Prior to the AWS field interventions, it was necessary to organize a session which could bring together all the stakeholders, students and G&S project staff.). This first training session functioned as an informative session for both instructors and students, offering insights into the project and upcoming field trips. The workshop provided comprehensive information about the Automatic Weather Stations, including their components, functions, data, parameters, and data collection procedures. Apart from the selected students, the representatives from EPA, Forest & Wildlife Department, KIU and UOB were the participants, with a total of **43 attendees, consisting of 19 females and 23 males.**

Training Workshop Content
• Introduction to the AWS • AWS Installation and uninstallation • Data retrieval

Training for AWS Installation on Glaciers

AWS installation has been one of the major goals of the "Glaciers and Students" project, using cutting-edge technology to investigate climate change effects and to adopt measures accordingly in the future. In the practical and field training, technical personnel EPA, students and faculty of KIU, UOB and field staff CKNP were involved. Various teams were composed for various project locations, and they worked in collaboration with the joint effort of Ev-K2-

CNR and the University of Milan to install AWSs at various glacier sites including Shisper, Ghulkin, Passu, Minapin, Askole, Biafo, Urdukas and Concordia.

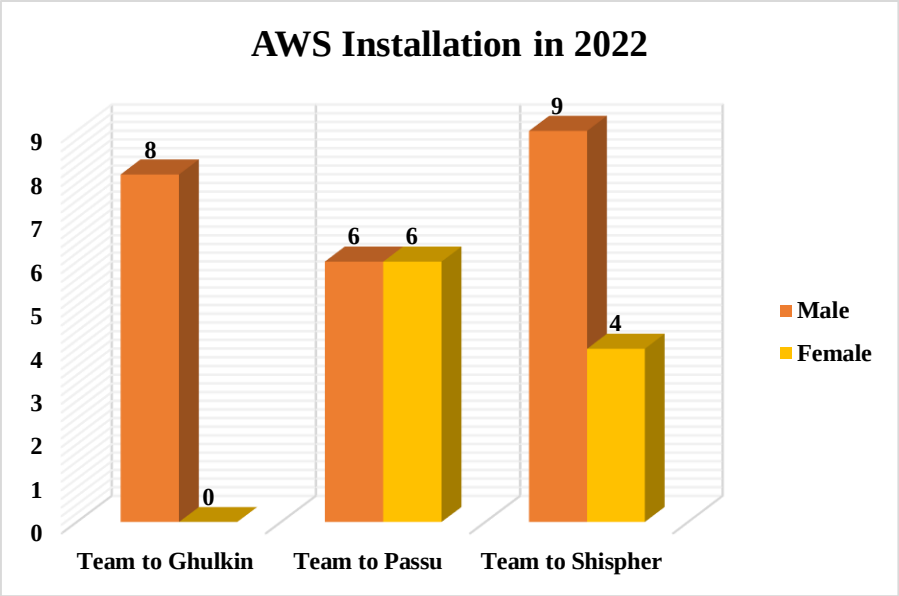
International experts shared their knowledge with training participants, illustrating how Automatic Weather Stations (AWS) play a pivotal role in assessing long-term climate trends while monitoring critical meteorological data. Participants received comprehensive information about various meteorological parameters, including temperature, barometric pressure, humidity level, wind speed and direction, precipitation, and solar radiation. They were also trained on data storage in loggers and retrieval methods, which could be executed either through a cellular network or on-site, using computers or mobile devices. This data is instrumental for modeling and informed decision-making.

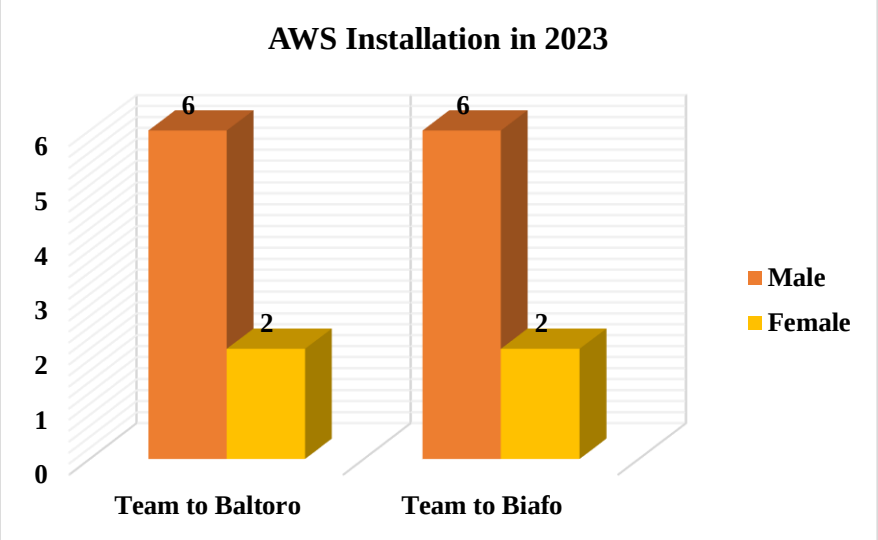
The training sessions comprised a total of **41 participants,** with a gender-diverse composition of **12 females and 29 males.** To facilitate an optimized learning experience, the participants were subdivided into three distinct groups. These teams effectively harnessed the power of collaborative efforts, with the valuable support and guidance of both Ev-K2-CNR and the University of Milan. This approach allowed for a more comprehensive and enriched understanding of the subject matter, ensuring that each participant could contribute to collective knowledge and skill development.

The installation of AWS on glaciers brings a multitude of advantages, primarily bolstering glacial research efforts. It empowers scientists and researchers to delve into the intricate effects of climate change on glacial retreat, mass balance, and melt rates. Furthermore, AWS systems serve as early warning tools for potential glacial hazards, offering critical protection to vulnerable communities downstream.

The data collected by AWS will be made accessible to researchers and policymakers through the Gilgit Baltistan Environmental Protection Agency, which will assume the role of custodian for AWS and the amassed data. The installation of eight AWS on various glaciers within Gilgit Baltistan represents a groundbreaking step in advancing climate research and deepening our comprehension of glacial environments. These AWSs will continuously monitor real-time meteorological data, providing invaluable insights into weather conditions and their influence on glacial dynamics.

The active involvement of academia and the Gilgit Baltistan Environmental Protection Agency in the project, along with their responsibilities as custodians of AWS and its data, is integral to ensuring the project's success and long-term sustainability.





Training on Glaciological Field Activities

The glaciological field training in Gilgit-Baltistan is instrumental in providing a holistic and comprehensive understanding of the region's glacial landscapes. Covering a spectrum of vital subjects, including glacier dynamics, field techniques, safety protocols, ablation stake installation for glacial melt measurement, microplastics analysis, carbon deposits, data collection and analysis, and environmental considerations, these trainings equip participants with a multifaceted skill set. This knowledge empowers individuals to engage in meaningful research and practical initiatives related to glaciology and climate change, thereby fostering a deeper connection to the region's environment. The beneficiaries of these training sessions, comprising a total of **33 trainees, including 10 females and 23 males**, were drawn from KIU, UOB and GB-EPA, all operating under the aegis of the Glaciers and Students Project.

It's noteworthy that these participants had previously been involved in the installation of Automatic Weather Stations (AWS) in the upper Hunza region, showcasing their commitment

to enhancing their skills and understanding of glaciology and environmental research. This integrated approach seeks to develop a cadre of experts capable of contributing significantly to glaciological research, environmental conservation, and glacier management in this unique and fragile region.

Training Content
• Glacier dynamics • Field techniques • Safety protocols • Ablation stakes installation for glacial melt measurement • Micro plastics analysis and carbon deposits • Data collection and analysis Environmental consideration

Training on GIS-RS

The GIS and RS training programs hold immense significance for students, researchers, and the Gilgit-Baltistan Environmental Protection Agency (EPA) in the context of glacier studies and glacier inventory development. Equipping students and researchers with the knowledge and skills to harness Geographic Information Systems (GIS) and Remote Sensing (RS) technologies is a vital step towards advancing glaciological research. These tools enable in-depth analysis, monitoring, and modelling of glaciers, providing invaluable insights into glacial dynamics, changes, and their impact on the environment. Furthermore, the EPA's involvement in this training fosters local expertise and empowers the agency to effectively manage and protect the region's fragile glacial ecosystems. With an increasingly urgent need to understand and mitigate the effects of climate change on glaciers, GIS and RS training is a cornerstone in promoting sustainable practices and informed decision-making, essential for safeguarding vulnerable communities and the environment in Gilgit-Baltistan.

Training Content

- Introduction to glaciers
- Knowledge and comprehension of Glacier Inventory
- Monitoring techniques
- Understanding of GIS-RS
- Components of RS
- Data supply and users
- Characteristics and Resolution of RS
- Software tools and installation
- Spectral-based classification
- Object-based image analysis
- Image classification and validation

Throughout the course of the Glaciers and Students (G&S) project, four (04) comprehensive training sessions were conducted on Geographic Information Systems (GIS) and Remote Sensing (RS), tailored for students and faculty from Karakoram International University (KIU) and the University of Baltistan (UOB). These sessions were attended by a diverse array of participants, encompassing not only students but also representatives from critical organizations such as the Gilgit-Baltistan Environmental Protection Agency (GB EPA), the GB Disaster Management Authority, GLOFII, and the Central Karakoram National Park. These training endeavors marked the active engagement of **119 female participants and 131 male participants** in the acquisition of both theoretical and practical knowledge and experience related to GIS and RS, underlining the inclusive approach of the project towards fostering expertise in glacier studies and inventory development.

Training on Avalanche prevention and Rescue

Avalanches are unquestionably recognized as one of the foremost challenges confronting the rugged landscapes of Gilgit-Baltistan. The region's unique amalgamation of towering mountain peaks, precipitous slopes, and substantial snowfall during winter months gives rise to a complex avalanche hazard that requires earnest attention. To address this formidable menace, a concerted effort was undertaken to enhance the capacity of pertinent institutions. Leveraging the extensive international experience of trainers from Italy, a comprehensive 10-day training program on Avalanche Rescue was meticulously orchestrated by Ev-K2-CNR.

Training Objectives
• Prepare a group of skilled rescuers for GB who will handle avalanche disasters • Make participants aware of the usage of technology during avalanche disasters • Prepare master trainers to raise awareness in the community • Use of tools and equipment during avalanche rescue
Training Content
• Snow and snowpack definitions and characterization • Avalanche phenomenon description and classification • Avalanche defense systems • Avalanche search and rescue methods and technologies

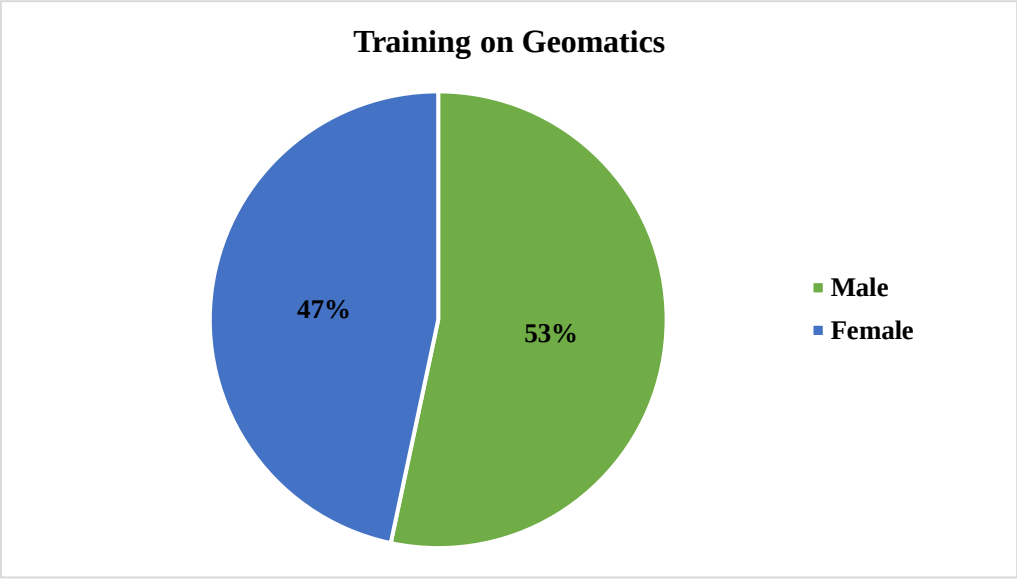
This vital initiative attracted participants from a spectrum of relevant departments within Gilgit-Baltistan, including the GB Tourist Police, the Aga Khan Agency for Habitat, Rescue 1122 GB, Karakoram International University (KIU), and the University of Baltistan (UOB). While the invitation was extended to both men and women, the challenging practical segments of glacier training in Naltar valley did somewhat limit the participation of women in this critical endeavor, with a total of **02 females (8%) and 22 males (92%) in attendance**. Nevertheless, this training endeavor epitomizes a proactive step toward mitigating the perils posed by avalanches in this geographically distinctive and challenging terrain.

Training on Geomatics

Geomatics training holds pivotal importance for students, researchers, and the Gilgit-Baltistan Environmental Protection Agency (EPA) within the context of glacier studies and glacier inventory development. By imparting essential skills in surveying, mapping, and geospatial data management, Geomatics equips individuals with the capacity to accurately measure and analyze the dynamic nature of glaciers. For students and researchers, this proficiency is a catalyst for advancing their scientific inquiries, enabling comprehensive glacier assessments, and offering invaluable insights into the effects of climate change. For the EPA, this knowledge serves as a base for effective environmental management, aiding in the protection of vulnerable ecosystems and communities while fostering data-driven decision-making. The long-term impact of Geomatics training is felt through the sustainable preservation of Gilgit-Baltistan's unique glacial landscapes and their vital contributions to the region's ecosystem.

Training Content
• Elements of data processing using QGIS • Working with vectors: editing and classification • ESA Sentinel data access • Image processing: band combinations and interpretation • Image processing: spectral indices • Presentation of the GBGeoApp • Installation in the student's mobiles • Data collection • Discussion and suggestion for the improvement of the app

The Geomatics training sessions conducted as part of the project, participants from Karakoram International University (KIU), the University of Baltistan (UOB), the Gilgit-Baltistan Environmental Protection Agency (EPA), and the United Nations Development Programme (UNDP) converged to enhance their expertise in this critical field. The University of Milan, played a pivotal role in facilitating the session, ensuring that participants received a comprehensive understanding of Geomatics. This endeavor underscores the project's dedication to equipping students, researchers, and EPA representatives with the knowledge and practical skills needed to engage in glacier studies and contribute to the development of a robust glacier inventory. The acquired Geomatics proficiency empowers them to make informed decisions, safeguard vulnerable ecosystems, and effectively manage the unique glacial resources of Gilgit-Baltistan, thereby fostering sustainability and the preservation of this vital natural heritage.



Training Impact and Reviews of Beneficiaries

In the glaciers and students project, several training sessions were conducted remotely and on-site, as listed in the following table. At the end of each session, the participants received a certificate.

Phase	Who	How	Topic
First	Pakistani Bachelor's students	Remotely, asynchronous	Remote sensing, GIS, meteorology, and applied glaciology
First	Italian Master's students	In the presence of attending Master University Courses	Remote sensing, GIS, meteorology, and applied glaciology
Second	Pakistani Bachelor's students	In presence (Pakistan)	Theoretical and practical GIS and remote sensing activities with Italian Professors
Second	Italian Master's students	In presence (Italy, attending UNIMI and UNICA Labs)	Theoretical and practical GIS and remote sensing activities
Third	Pakistani Bachelor's students	Remotely with synchronous periodic meetings (via Zoom)	Practical activities of individual Pakistani students or small groups of Pakistani students related to the analysis of satellite images and the identification and delineation of glacier features using the methods and techniques introduced in the classroom by Italian professors during their stay in Pakistan
Third	Italian Master's students	Both in presence and remotely	Practical activities of individual students or small

		(Italy, attending UNIMI and UNICA Labs and working from home with their laptops and sharing doubts and results with Italian professors via zoom meetings)	groups of students related to the analysis of satellite images and the identification and delineation of glacier features using the methods and techniques introduced in the Labs by Italian professors

To evaluate the efficacy and robustness of the proposed training approach, we had developed activity-specific questionnaires that we distributed to the students. The first one was distributed at the beginning of the training activity to get to know them and their scientific and technical background. The other questionnaires have been proposed after their participation at each project phase. All the questionnaires have been developed using the Microsoft Forms application.

The first questionnaire was developed to find out the basic knowledge level of the students in the Glaciers & Students project prior to the courses delivered in order to understand their background (types of schools and university courses attended in Pakistan), their prior knowledge of glaciers, hydrology, meteorology and GIS, and their expectations for educational and professional development. Questionnaires were then developed and proposed for the individual teaching units delivered, both online in synchronous mode and in-presence in Pakistan, to assess the students' understanding and enjoyment of the course.

To ensure the sustainability of the proposed training scheme, as part of the W4D project, further trainings will be carried out on 1) the usage of scientific equipment on the field, including GPS and drone data and automatic weather stations 2) data processing for the aforementioned instruments

A total of 394 participants attended the sessions, with a balanced representation of 171 women (43%) and 223 men (57%). Trainees expressed appreciation for the programs and recommended their continuation. A distinguishing feature of the G&S project is its inclusive approach, engaging all stakeholders to achieve project objectives. The comprehensive effort included training on AWS installation, maintenance, data collection, and GIS & RS sessions to develop Pakistan’s glacier inventory.

One of the key components of the G&S project has been the active involvement of researchers and students at every project stage, commencing with the installation of AWSs on glaciers, followed by capacity building through training and workshops. This participation has culminated in students contributing to the achievement of significant project milestones, including AWS installation and the development of a glacier inventory.

The GB-EPA and GB-DMA researchers, university students and faculty found the GIS and RS training to be exceptionally valuable for their learning and research endeavors. GIS and RS offer applications across diverse fields and study areas, proving essential in analyzing data related to glaciers, lakes, plants, streets, buildings, and more. The ability to visualize this multifaceted data on a single map greatly enhances the quality and significance of research.

It empowers individuals to discern, assess, and comprehend complex patterns and relationships, thereby amplifying the overall understanding and value of their work.

Mr. Ejaz Ali, a Scientific Officer at the GB Environmental Protection Agency, lauded the training as exceptionally well-designed, offering valuable insights into the fundamentals of GIS, "**The training was exceptionally well-designed for anyone seeking to grasp the fundamentals of GIS. The delivery of knowledge and skills during the training was highly effective**."

Ms. Palwasha from the Disaster Management Department expressed her thoughts, stating, "**The course was truly remarkable in enhancing one's understanding of GIS and RS. It provided a solid foundation and highlighted their practical applications as invaluable research tools**."

Ms. Zubaida, a student from KIU, participated as a team member in the field visit to Passu Glacier for AWS installation. She shared her thoughts on the training and field visit, stating, "Ev-K2-CNR adopted an incredible approach by actively involving students in the entire project. This allowed us to bridge the gap between our theoretical knowledge of AWSs and the practical aspects of their installation, functioning, and data processing. Working on the glaciers was certainly challenging but being on Passu Glacier provided me with the most remarkable experience of my life. The beauty of nature and the awe-inspiring Passu Cones left me breathless. It made me truly appreciate the dedication of researchers who work in such harsh environments to conduct studies in these extreme climatic conditions."

The G&S project underscores the importance of training to empower students and stakeholders and foster a new generation of researchers and conservationists to address urgent challenges related to glaciers and climate change in Gilgit-Baltistan.

III. Communication

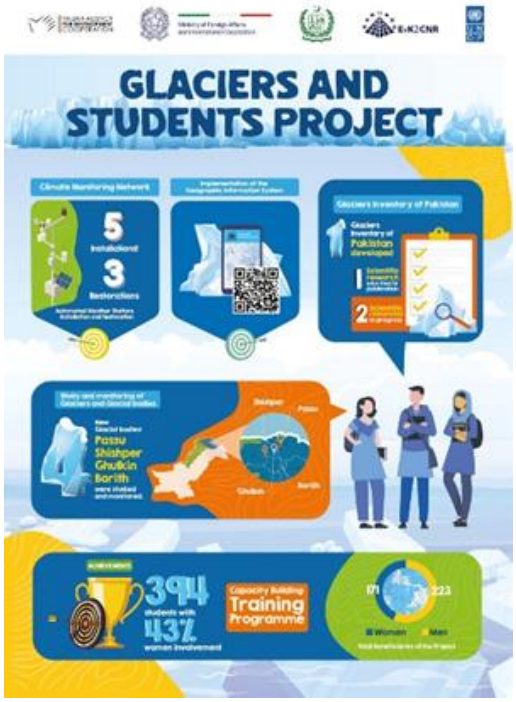
The Glaciers and Students Project's interventions, since its commencement, have received a great deal of attention and coverage from national and provincial newspapers, national news channels social media etc.

News and updates are posted on the official pages of EvK2CNR Pakistan, GB EPA, KIU, and the University of Baltistan on social media. Furthermore, the official pages of the Chief Secretary GB, Information Department GB have also posted news on their pages expressing their appreciation for several initiatives under the project G&S.

It has constantly strived to highlight the project activities, interventions, and achievements and to give credit to the Italian Agency for Development Cooperation (AICS) as the donor of the project, UNDP as the executing agency and EvK2CNR as the implementing partner. (**E2**).

As part of COP 29, project partner Ev-K2-CNR released a special edition of *Mountain News*, highlighting the critical role of Pakistan's glaciers in climate resilience. The edition covered key topics, including *Glaciers: The Water Reserve for Our Life*, *Cooperation for the Himalayas and Karakoram*, and an in-depth feature on Pakistan's first *Inventory of Glaciers*, developed

under the *Glaciers and Students* project. This publication provided valuable insights and resourceful content on the significance of Pakistan's glaciers in the global fight against climate change.



IV. Project Risk Log

Project Risk log has been updated quarterly with identification of risks and mitigation **(E3)**.

V. Lesson Learned

1. Field activities in glacial regions faced significant logistical challenges due to the remote and rugged nature of terrain. These challenges were compounded by the short summer window, which was crucial for glacier inventory and multi-temporal analysis. To ensure success of such time sensitive operations required careful pre-planning, and contingency measures are essential.

2. The effectiveness of field activities in glacier research is highly dependent on utilizing the limited and short summer season efficiently. Delays in planning and execution can lead to missed opportunities for data collection, negatively impacting project outcomes. Robust project management framework, including timelines tailored to environmental constraints are critical for maximizing research productivity.

3. Building partnerships with local universities and research institutes are fundamental to the success of glacier related projects. However, the process required substantial time investment and multiple rounds of discussions and meetings to navigate complex administrative procedures. Strengthening institutional ties through early engagement and clear communication strategies can help streamline collaboration.

4. High quality and successful meteorological studies in glacier regions relay on precise data collection and regular maintenance of instruments. Addressing issues such as sensor malfunctions or nonsensical readings swiftly is vital. The frequency and continuous

monitoring of data validity, including calculating valid data frequencies and percentages ensure robust and actionable findings.

5. Meteorological variables exhibit distinct seasonal and spatial variation influenced by topographical features like elevation and proximity to glaciers. The comparative analysis of data collected from on-glacier versus off-glacier locations highlight unique seasonal patterns, especially during the ablation period. Accurate interpretation of these patterns necessitates detailed and context awareness analysis to inform broader climate and glacier dynamics research.

6. The integration of Sentinel-2 satellite imagery has significantly improved accuracy of glacier inventory by mitigating issues such as cloud and snow cover. Further advancements in satellite technology, such as the introduction of higher-resolution and thermal imaging capabilities, offer promising prospects for more detailed glacier mapping and monitoring, including challenges like debris-covered glaciers and precise mass change analysis. Incorporating these innovations can enhance the granularity and reliability of glacier monitoring projects.

7. The field work in glacier terrain poses inherent risk, emphasizing the requirement for all field personnel to possess basic rescue and mountaineering skills. For instance, an incident involving G&S project manager falling into a glacial riverine underlines critical need for emergency preparedness. Including practical knowledge of terrain hazards like snowfalls, landslides, stream crossing and flash floods. Stream crossings should be planned for early in the day, as water levels rise in the afternoon due to higher temperatures and increased glacial melt. This practical knowledge is vital for safety and operational success.

8. The use of ablation stakes for measuring glacier melt faced challenges in upper Hunza region. However, due to glacier movement and melting, several of the installed stakes either disappeared or buried due to glacier dynamics. Future installations should utilized more longer and robust stakes designed to withstand glacier movements and varying melt rates, ensuring reliable data collection over extended period.

9. The project's ambitious goal of mapping over 1,300 glaciers within a constrained timeframe proved challenging. While involving students enriched the project and added value but also increased operational workload. Additionally, the preparation of the final comprehensive final document (volume) requires more time than initially anticipated. A well-planned and justified time frame for such projects is essential to ensure production of high-quality thorough outputs.

10. Upgraded the SHARE Geonetwork Platform with a user-friendly interface, integrating metadata, datasets, maps, and the newly developed GBGeoApp, enhancing accessibility for both experts and the public.

11. Conducted multi-temporal analysis and field missions to study glacier melt patterns and the impacts of contaminants like microplastics and black carbon on glacier melting.

12. Trained 394 individuals, including students, faculty, and environmental professionals, with 171 women participants, addressing gender disparity in scientific education and professional development.

13. Collaborated with Karakoram International University (KIU), University of Baltistan (UoB), and the Environmental Protection Agency Gilgit-Baltistan (EPA-GB) for impactful capacity-building initiatives.

VI. Conclusion and Way Forward

Overall, the project successfully achieved all its major objectives and deliverables. Culminating in a comprehensive inventory of 13,032 glaciers across three administrative regions of Pakistan—Gilgit-Baltistan, Khyber Pakhtunkhwa, and Azad Jammu & Kashmir (referred to Pakistan Administered Kashmir by the UN). This milestone represents significant step forward in understanding and managing Pakistan's cryosphere within remarkably short timeframe. Recognizing the critical gap in high altitude metrological data the project addresses this challenge by establishing a couple of Automatic Weather Stations (AWSs) at elevations of 4,000 meters above sea level, a critical threshold for generating precise metrological data, such data is indispensable for analyzing climate trends, glacier behavior and their cascading effects on downstream ecosystem and water resources.

The project ensures long-term sustainability by transferring AWS operational management to EPA-GB, with Ev-K2-CNR providing ongoing technical support for maintenance and data management. This project has positioned Gilgit-Baltistan as a leader in climate resilience and glacier research by leveraging advanced technology, promoting gender inclusivity, and strengthening local capacities. The Water for Development project, funded by AICS in partnership with UNDP and Ev-K2-CNR, scales up efforts initiated under the G&S project. Additionally, collaboration with the Economic Transformation Initiatives (ETI) project fosters synergies to enhance the resilience of fragile ecosystems.

The project also invested in capacity building efforts, enhancing the technical expertise of regional universities and the Gilgit-Baltistan Environmental Protection Agency (EPA-GB). Further specialized training in glaciology and the provision of essential equipment have empowered these institutions to better monitor, analyze and interpret glaciological and metrological data. al equipment.

The sustainability of the project in the medium to long term depends on the active involvement and coordination of local stakeholders. As the primary custodian of environmental protection in the Gilgit-Baltistan region, EPA-GB is well positioned to oversee the installed AWSs, mange data collection, and facilitate data sharing and dissemination. Academia and researchers can access this data through EPA-GB. A formalized handover process ensure management by EPA-GB While Ev-K2-CNR will maintain close coordination with EPA-GB and provide ongoing technical support for the maintenance of AWSs and the ongoing data collection and sharing of data protocols.

Looking ahead, the upcoming Water for Development Project will build upon the achievement of this initiative. This successor project will expand the scope of metrological monitoring by

maintaining existing AWSs and installing additional ones, thereby broadening the spatial and temporal coverage of critical data collection. The project will closely work with universities and EPA-GB. Furthermore, the project will strengthen the glaciology centre and the water quality lab at Karakoram International University (KIU). Equipping them with advanced tools and resources to continue impactful research and capacity building efforts. All these future interventions will significantly contribute to sustaining the G&S project results.

VII. Financial Status

In the Glaciers and Students project, a total of €1,100,000 (One Million One Hundred Thousand euros) was received. Of this amount, €1,092,668 (one million ninety-two thousand six hundred sixty-eight euros), representing 99.33% of the total budget, was utilized.

Total Funds Received -	€ 1,100,000
Total Utilization of Funds-	€ 1,100,000
Balance	€ 0
Utilization %	100%

Annexures

E 1: Partnership

E 2: Communication products

E 3: Project risk log

E 4: Pakistan Glaciers inventory

E5: Pictures of Glaciers and Students project