



CAPABLE-NEPAL

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Application of Field and  
Remote Sensing  
Techniques for Snow and  
Glacier Studies

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2022- Kathmandu  
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# SUMMARY

The importance of cryosphere is critical as it holds snow, glacier, and permafrost in high altitude areas and gradually releases water to downstream, impacting billions of people. Understanding the hydrological regime of alpine glaciated basins is crucial for water availability and disaster risk reduction in a changing climate, despite limited knowledge and monitoring networks.

This document serves as a comprehensive summary of the Kathmandu Session of Winter School 2022, encompassing both theoretical and laboratory sessions. The event was structured to incorporate a combination of in-person and online lectures, demonstrations, hands-on exercises, and project work. It is important to note that the proceedings of the Field Session of Winter School 2022 have been prepared as a separate document, which shall be made available for further review.





The 1st Winter School on "Application of Field and Remote Sensing Techniques for Snow and Glacier Studies" took place from 13th to 23rd October 2022 at the Kathmandu Center for Research and Education, Chinese Academy of Sciences-Tribhuvan University (KCRE, CAS-TU), Kathmandu. This Winter School, jointly organized by the Central Department of Hydrology and Meteorology (CDHM) at Tribhuvan University (TU), the Institute of Research for Development, France (IRD-France), and KCRE, aimed to strengthen the capacity of young researchers in understanding cryospheric processes in high mountains. As part of the CAPAcity Building in glacio-hydro-meteorological research in NEPAL (CAPABLE-NEPAL) initiative generously supported by IRD-France, the Winter School marked the beginning of a planned three-year series.

The Winter School aimed to familiarize participants with glaciers and the field and remote sensing techniques used to monitor them. It employed a combination of laboratory and field methodologies, emphasizing hands-on experiential learning. The program was divided into two parts: a two-week laboratory and theoretical session held in Kathmandu and a 20-day field training on glaciers. The laboratory session, equivalent to 3 credit hours according to TU regulations, was recognized as an official non-credit course by CDHM-TU. In the field training, five motivated participants from the laboratory session received training in the Everest region, specifically on the Changri-Nup and Pokalde Glaciers. They acquired essential skills for glacial monitoring, including ablation and accumulation measurements, DGPS surveying, operation and maintenance of automatic weather stations, and installation of a Micro Rain Radar. The Winter School also incorporated theoretical aspects of glacier hydrology and climate modeling. Certificates were awarded upon completion of the Winter School.

This document serves as a comprehensive summary of the Kathmandu Session of Winter School 2022, encompassing both theoretical and laboratory sessions. The event was structured to incorporate a combination of in-person and online lectures, demonstrations, hands-on exercises, and project work. It is important to note that the proceedings of the Field Session of Winter School 2022 have been prepared as a separate document, which shall be made available for further review.

## OBJECTIVES

- Theoretical understanding of glaciers, glacier hydrology and climate modeling
- Field and remote sensing techniques available to monitor mountain glaciers
- Skills in remote sensing and GIS for glacier monitoring

## COURSE MODALITIES

- Online theory session from IRD-France
- Face to face theory sessions
- Face-to-face tutorial with hands-on exercises and field training
- Evaluation / assessment

## APPLICATION PROCESS AND SELECTION CRITERIA

The Winter School invited graduate students, government employees, and early career scientists from research institutes in Nepal to apply for participation in the training. Priority was given to research scientists and students with a specific focus on cryosphere studies in High-mountain Asia. The selection criteria for participants included the following:

- Demonstrated interest in cryosphere science and a basic understanding of earth science or environmental science.
- Basic knowledge of QGIS/ArcGIS and Python or a similar programming language.
- Familiarity with cryosphere, climate, meteorology, hydrology, climate change, and remote sensing.
- Background in hydrology and meteorology, environmental science, engineering, geology, or geography.
- Preferably holding at least an MSc degree in a relevant subject.

The Winter School announced an open and free application call on the CDHM-TU webpage on September 18, 2022. Within two weeks, an overwhelming response was received, with over 125 applications from various institutions, including government organizations, universities, research institutes, and non-governmental institutes. From the pool of applicants, the 25 most qualified participants were selected based on the aforementioned criteria. The selection process involved a review of CVs, motivation letters, and previous educational backgrounds to shortlist the applicants. In the second stage, the shortlisted applicants underwent interviews, which ultimately determined the final list of participants.



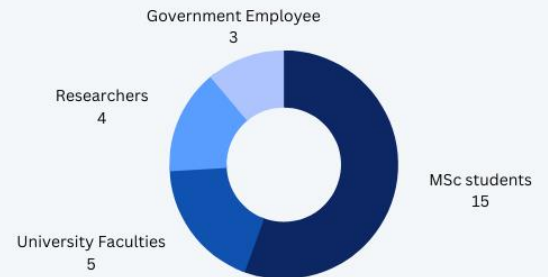
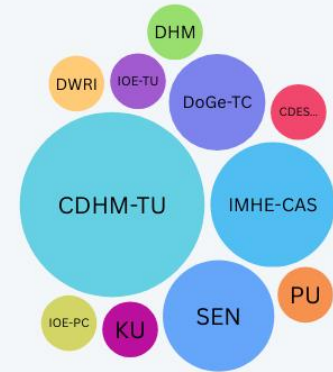


# OVERVIEW OF WINTER SCHOOL: THEORETICAL AND LABORATORY SESSION

Winter School 2022 was divided in two parts.

1. First laboratory and theoretical session was held in Kathmandu at Kathmandu Center for Research and Education, Chinese Academy of Science – Tribhuvan University (KCRE) from 13th to 23rd October for two-weeks.
2. Changri Nup Glacial Field Expedition was conducted from 17th November – 4th December 2022

Scientists from the Institute of Research and Development (IRD), France, under the direction of Dr. Adina Racoviteanu, served as the winter school's primary resource people. Additionally, there were three presentation sessions with a total of six presentations made by representatives from the CDHM, DHM, ICIMOD, KCRE, and KU.





# MEET THE RESOURCE PERSONNEL



Prof. Deepak Aryal,  
CDHM, TU



Dr. Adina  
Racoviteanu, IRD,  
France



Dr. Dibas Shrestha,  
CDHM, TU



Dr. Miriam Jackson,  
ICIMOD



Sudan Bikas  
Maharjan, ICIMOD



Dr. Binod Dawadi,  
CDHM, TU



Mr. Niraj Shankar  
Pradhananga  
, DHM, GoN



Dr. Fanny Brun,  
IRD, France



Amoury Dehecq,  
IRD, France



Dr. Ines Dussailant,  
WGMS, Switzerland



Dr. Martin Menegoz,  
IRD, France



Prof. Rijan Bhakta  
Kayastha, KU



Dr. Patrick Wagnon  
IRD, France



Dr. Yves Arnaud,  
IRD, France



Catherine Coulaud



# MEET THE PARTICIPANTS



Arnab Singh



Anita Tuitui



Anjana Paudel



Darwin Rana



Dipendra Rijal



Earina Sthapit



Insaf Aryal



Jayanti Karki



Jiwan Paudel



Kajol Basnet



Kaman Ghimire



Madan Pokhrel



Manoj Pantha



Navaraj Pokhrel



Nikita Khanal



Nirab Shrestha



Nitesh Khadka



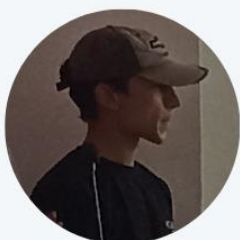
Pooja  
Lamichhane



Prasanna Dhakal



Roshan  
Manandhar



Sagar Khadka



Sandesh Tamang



Sangya Mishra



Santosh  
Chaudary



Smriti Adhikari



Sonika Adhikari



Sujan Khatiwada



Dipendra  
Lamichhane

## 01.

### Theory (10.5 hrs)

- Principles of Cryosphere: components; types of glaciers; glaciers as climatic indicators; glacier mass balance and dynamics, etc. ....(1.5 hrs)
- Principles of Remote Sensing: platforms, active/passive systems, principles of object identification, electromagnetic waves, Plank’s law, Wein’s law, radiation paths, etc. ....(1 hr)
- Mountain hydrology: Principles of glacio-hydrology, overview of field measurements, linkage between climate, glaciers and river flows .....(1.5 hrs)
- Recent mass balance evolution of HMA glaciers, at different scales, from glacier to regional scale, and processes controlling their recent evolution .....(1.5 hrs)
- Debris-covered glaciers: processes and field monitoring .....(1 hr)
- Glacier mass balance theory: field and geodetic .....(1 hr)
- Modelling the climate system, global and regional .....(1.5 hrs)
- Glacier fieldwork in High Mountain Asia .....(30 mins)
- Glacier monitoring and inventories in High Mountain Asia .....(30 mins)
- Cryospheric research in Nepal .....(30 mins)

## 02.

### Demo (3.5 hrs)

- Introduction to software: ArcGIS, QGIS, Python, RSGISLIB; Data management in RS/GIS applications; set up and installation, explore data .....(30 mins)
- Satellite data repositories (30’) and DEM(30’) searching and ordering .....(1 hr)
- Introduction to xDEM processing in Python .....(2 hrs)

## 03.

### Theory (10.5 hrs)

- Data explore and work with shapefiles, attribute tables .....(2 hrs)
- Image classification with band ratios in ArcGIS/QGIS (clean ice and snow, vegetation, clouds, etc.) .....(4 hrs)
- Supervised image classification (SCP plugin in QGIS) .....(3 hrs)
- Glacier dynamics by Feature tracking: IMCORR plugin.....(3 hrs)
- Terrain analysis: DEM pre-processing : clipping, re-projecting, merging, etc. ....(2 hrs)
- Hydrologic analysis with DEMs: mapping ice divides, watershed delineation ... (3 hrs)
- Multi-criteria analysis: debris cover mapping and/or optimal localization .....(3 hrs)
- Field glacier mass balance: basic skills needed to calculate point energy balance on glaciers, DGPS measurement and data processing .....(2 hrs)
- Processing of stereo data to calculate glacier mass and volume change; uncertainty analysis .....(2 hrs)
- Processing climate models and reanalysis data (python); LMDZ or MAR practical sessions (bash) with a python script to compute climate trends (online server) (2 hrs)

## 04.

### Projects and presentation (8 hrs)



# KATHMANDU SESSIONS

## INAUGURAL SESSION

The opening session was chaired by Prof. Dr. Deepak Aryal, Head of Department, CDHM, TU. The program was graced by Prof. Dr. Shiva Lal Bhusal, Rector, TU, as the Chief Guest, and Prof. Dr. Binil Aryal, Dean of Institute of Science and Technology, TU, served as the Special Guest.

The program was facilitated by Dr. Sunil Acharya, Asst. Prof. CDHM, TU



**Dr. Binod Dawadi, Deputy Director of KCRE (TU-CAS)**

Welcomed everyone to the Winter School and emphasized the importance of collaboration for enhancing research capabilities in Nepal



**Dr. Adina Racoviteanu, Lead Resource person, IRD**

Introduced the UNESCO program and its objectives



**Prof. Dr. Shiva Lal Bhusal, Chief Guest**

Emphasized the significance and timely organization of the event in the face of global challenges caused by recent climate change, expressed his strong willingness to commit to enhancing and extending such capacity-building programs

**Prof. Dr. Deepak Aryal, Chair**

Concluded with the vote of thanks



**Dr. Dibas Shrestha, Program Coordinator, CDHM, TU**

Provided an overview of the program and introduced the IRD PSF CAPABLE program, which aims to strengthen the capacity of local and regional researchers in glacio-hydro-meteorological research



**Prof. Dr. Binil Aryal, Special Guest**

Highlighted recent innovations in the field of science and technology, expressed his support for the successful commencement of the program





# Introduction and Structure of Winter School

The Winter School commenced with a technical session that began after a short tea break. Dr. Dibas Shrestha initiated the introduction session, which was followed by the introduction of all the participants. Subsequently, Dr. Adina Racoviteanu provided an overview of the structure, objectives, and learning outcomes of the Winter School.

The Winter School program was meticulously organized into 15 distinct sessions, each focusing on a specific area of study. These sessions encompassed a wide range of topics, including the Principle and Theory of Glaciology, Remote Sensing and GIS for Glaciology, Mountain Hydrology, Field-Based Monitoring of Clean and Debris-Covered Glaciers, Climate Modeling, and more. Each session was expertly led by individuals specializing in the respective field.

The training curriculum was designed to incorporate a comprehensive array of instructional methods. This included a series of informative lectures, practical demonstrations, hands-on exercises, evaluations, and project work presentations. By incorporating diverse teaching techniques, the Winter School aimed to foster a comprehensive and immersive learning experience for the participants.

## Afternoon Lecture Session (Theory)

DAY-1

Principles and theory of glaciology (Dr. Patrik Wagnon, IRD, France)	<ul style="list-style-type: none"> <li>• Cryosphere consists - glaciers, ice sheets, sea ice, seasonal snow, permafrost, with glaciers and ice sheets being compacted snow turned into ice</li> <li>• Sea ice - influenced by climate change, significant positive feedback known as the albedo effect</li> <li>• lecture highlighted the decreasing extent of sea ice in the Arctic region.</li> <li>• Mountain glaciers differ from ice sheets in terms of area and thickness, with ice sheets covering larger areas in Polar Regions</li> <li>• Lecture covered topics such as ice cores, glacial dynamics influenced by gravity, mass balance, and the movement of glaciers driven by accumulation and ablation</li> </ul>
Principles of Remote Sensing (Dr. Yves Arnaud, IRD, France)	<ul style="list-style-type: none"> <li>• Remote sensing - acquisition of information without physical contact</li> <li>• Platforms used for remote sensing - aircraft, drones, and satellites</li> <li>• Object identification principles - shape, size, color, pattern, and texture</li> <li>• Topics discussed - radiative transfer, electromagnetic spectrum, atmospheric scattering, and image display</li> <li>• Lecture covered elements such as energy source, radiation, sensor recording, and interpretation</li> </ul>



## Morning Lecture Session (Theory)

Dr. Dibas Shrestha opened the second day of the program by providing a brief highlight of the previous day's events and discussions.

<p>Dr. Miriam Jackson, Coordinator, Cryosphere Initiative, ICIMOD</p>	<ul style="list-style-type: none"> <li>• Introduced ICIMOD, encouraged participants to focus on all cryosphere components, not just glaciers</li> <li>• Provided a brief explanation of the water cycle</li> <li>• Explained concept of glacial mass balance (MB) by comparing to an individual's personal MB</li> <li>• Discussed the influence of both climatic and non-climatic parameters on glacial mass balance</li> <li>• Highlighted the use of stakes (such as aluminum, bamboo, and plastic) to measure glacial MB, emphasized the importance of snow density measurements for converting it into meter water equivalent</li> <li>• Why so few glaciers are monitored in HKH compared with EU? -Challenges, avalanches, weather</li> <li>• Glacial monitoring in Nepal by ICIMOD - Yala, Rikha sambha, Ponkar</li> </ul>
<p>Mr. Bikash Bikas Maharjan, Remote Sensing expert, ICIMOD</p>	<ul style="list-style-type: none"> <li>• HKH region contains over 60,000 glaciers, with a concentration in the Indus, Ganges, and Brahmaputra basins</li> <li>• Total 3808 Nepalese glaciers, cryosphere serves as a crucial water source, is diminishing due to melting, exposing more rock</li> <li>• Reviewed ICIMOD's glacier inventory, produced in 2011 for Nepal, Bhutan, Pakistan</li> <li>• Mapping method used for glacier and lake inventories involves a semi-automatic objective-based image classification focusing on clean ice and debris classification</li> <li>• Ongoing work - glacier changes in HKH basin, assess impact of climate change on Nepalese glaciers</li> <li>• Mentioned Himaldoc and RDS, related to documentation and research activities in the context of ICIMOD</li> </ul>
<p>Mr. Niraj Shannkar Pradhananaga, DHM</p>	<ul style="list-style-type: none"> <li>• Emphasized importance of snow, glacier lakes, glaciers, and permafrost in Nepal; highlighted their significance for hydrology, flora and fauna, irrigation, drinking water, and industrial use</li> <li>• Discussed impact of climate change on Nepalese Himalaya, with glaciers serving as important indicators, noted the upward trend in temperature, decreased snow precipitation, and increased rainfall</li> <li>• Addressed consequences of glacial retreat, impact on the Imja Glacier, GLOFs</li> <li>• Described the activities of the DHM - regular cryospheric monitoring, field-based observations and remote sensing techniques</li> <li>• Outlined historical progress of DHM's monitoring efforts - collaborations with Japan in the 1960s, subsequent studies in the Khumbu region, ice core work in the 1980s., installation of meteorological stations in various locations of Khumbu, Langtang, Annapurna, Makalu, Kanjirowa, and Humla</li> </ul>

As the last speaker of introductory lecture series in the morning session, Prof. Dr. Deepak Aryal emphasized the CDHM-TU's initiatives in the fields of high-mountain meteo-hydro-cryospheric research and teaching. He also emphasized the significance of examining the effect of albedo on cryosphere components in the context of massive pollution transport to the High Himalayas.





## Afternoon Lecture Session (Theory)

<p>Dr. Michel Esteves, IRD, France</p>	<ul style="list-style-type: none"> <li>• Introduced glacio-hydrological principles, discussed need for in-situ measurements to understand the processes and link between climate, glaciers, river flows in HKH</li> <li>• Provided geographical context of HKH region - location, solid precipitation area, climate of Nepal, emphasis on monsoon and westerly influences</li> <li>• Highlighted different research activities initiated by IRD in Nepal to study mountain hydrology</li> <li>• Covered main hydrological processes, importance of AWS for measuring variables and precipitation (rain, snow, and mixed)</li> <li>• Discussed climate forcing factors, characteristics of High Mountain Climate, sources of streamflow, streamflow variability, modeling approaches for glacier/hydrology studies including Energy and Mass Balance models and the DHSVM-GDM model used in specific areas</li> </ul>
<p>Dr. Adina Racoviteanu</p>	<ul style="list-style-type: none"> <li>• Introduced ArcGIS, QGIS, python, and RSGISLIB as important tools for remote sensing and GIS applications in glacier studies</li> <li>• Discussed how glacier changes can affect sacred mountains and explored the socioeconomic impact of climate change on glaciers</li> <li>• Explained glacier behavior and its short-term (GLOF, flood) and long-term impacts (water resources for agriculture, consumption, and hydro-electricity) on local populations</li> <li>• Discussed IGCP project by UNESCO, its focus on glacial changes via remote sensing, risk assessment incorporating past events of South Asia and Andes, as well as its capacity building and training programs such as :             <ol style="list-style-type: none"> <li>1. Glacier hazard mapping using remote sensing (Dhulikhel, Nepal) -2018 (Nov 1-5)</li> <li>2. Field training on Ponkar Glacier, Nepal (Nov 2019)</li> <li>3. Field training on Drang Drung glacier (4780m) Zaskar, India (Sept 21-Oct 3, 2022)</li> <li>4. Advanced training program on water resources management, Glacier Monitoring and climate changes Gangtok, Sikkim (Oct 7-Oct 27)</li> </ol> </li> </ul>

DAY-2



Dr. Miriam Jackson



Mr. Niraj Shannkar  
Pradhananga



Dr. Adina Racoviteanu

## Lecture Session: Remote Sensing/ GIS for Glaciology (Theory)

The third day of the conference commenced with a brief recapitulation of the activities conducted on the second day.

The first presentation of the day was delivered by Dr. Binod Dawadi, Associate Professor and Deputy Director of the Kathmandu Center for Research and Education (KCRE). Dr. Dawadi provided an overview of the ongoing and future research activities of KCRE, specifically focusing on high-mountain research in both the Northern and Southern regions of the Himalayas.

Following Dr. Dawadi's talk, Prof. Dr. Rijan Bhakta Kayastha from Kathmandu University (KU) presented an insightful overview of the history of cryospheric research in Nepal and highlighted various research initiatives undertaken by KU in this field.

After these informative sessions by Dr. Dawadi and Prof. Kayastha, Dr. Adina Racoviteanu conducted a demonstration and hands-on exercise on the practical application of remote sensing and Geographic Information System (GIS) techniques in the field of Glaciology. This interactive session provided participants with valuable insights into the use of these tools for studying glaciers and associated phenomena.

DAY-3



Dr. Binod Dawadi



Prof. Dr. Rijan  
Bhakta Kayastha



Dr. Adina Racoviteanu

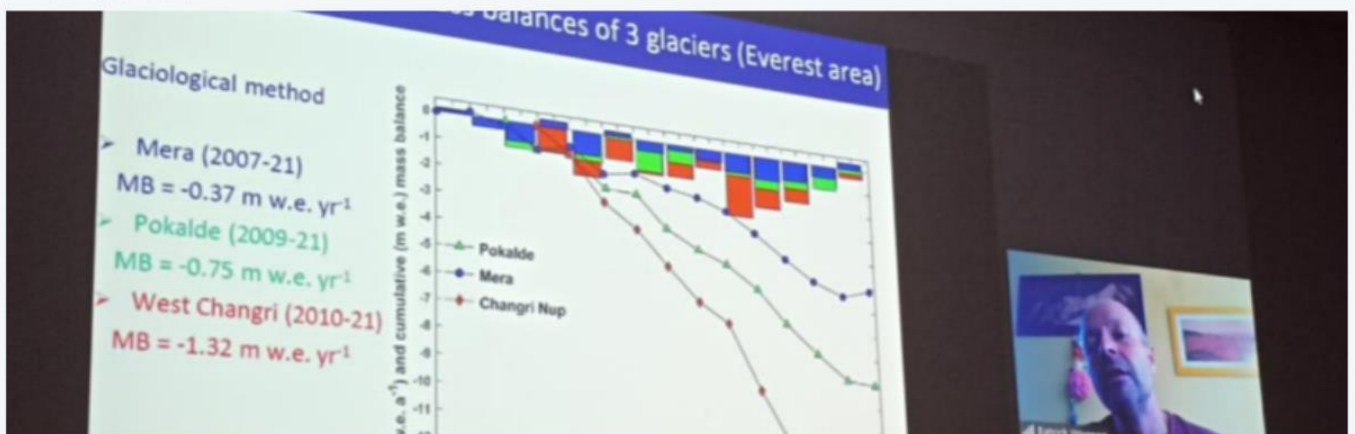


## Online Lecture Session: Remote Sensing for Glaciology (Theory)

In the first part of her talk on the 4th day, Dr. Adina Racoviteanu continued her hands-on demonstration and demo session with an emphasis on supervised image classification (SCP plugin in QGIS). By using the feature tracking IMCORR plugin, she later introduced glacier dynamics. Participants thought the session was quite fascinating.

During the afternoon session, Dr. Patrick Wagnon from IRD France delivered a comprehensive lecture on the recent mass balance evolution of glaciers in High Mountain Asia (HMA) and its correlation with climate. The lecture highlighted the significance of glaciers as indicators of climate change and their crucial role in water resource management. It introduced the GLACIOCLIM project, a global network that collects long-term glacio-meteo-hydrological observations from various regions. The focus was specifically on GLACIOCLIM activities in the Himalayas, including the establishment of monitoring networks in the Khumbu area. Glaciological monitoring techniques and cumulative mass balance results for specific glaciers were presented to demonstrate the ongoing changes. The lecture also discussed the regional-wide mass balance assessment in HMA through elevation change mapping. Dr. Wagnon explored the influence of debris cover on glacier mass balance, investigated the relationship between glacier morphology and mass balance variability, and examined the processes controlling the mass balance of debris-covered glaciers. The lecture underscored the necessity of combining field studies and remote sensing to obtain accurate mass balance data and highlighted the contrasting pattern of glacier-wide mass balance in HMA. The underlying reasons for this contrasted pattern of mass balance remains an open question, calling for further research and understanding in this area.

DAY- 4



Dr. Patrick Wagnon

# DAY- 5

## Morning Lecture Session: Terrain Analysis (Theory, Demo, Hands on)

The 5th day commenced with a concise recapitulation of the previous day's proceedings by Dr. Adina Racoviteanu, highlighting the key accomplishments. During the subsequent demo and hands-on session, she focused on terrain analysis using Digital Elevation Model (DEM) data. She provided participants with insights into the hydrological application of Geographic Information System (GIS).

## Online Afternoon Lecture Session: Terrain Analysis (Theory, Hands on)

In the afternoon, Dr. Amaury Dehecq delivered a brief introduction to xDEM software, accompanied by a demonstration. xDEM, a potent python-based application, proved to be valuable for geodetic mass balance assessment of glaciers. Dr. Dehecq encouraged participants to leverage this software library for their research endeavors.

# DAY- 6

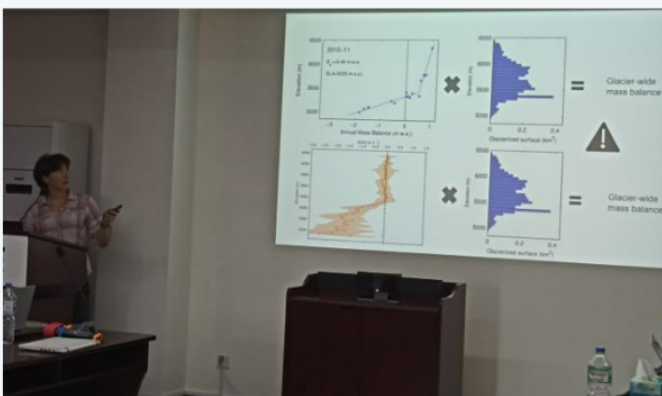
## Morning Lecture Session: Field based monitoring of Debris cover (Theory, Demo, Hands on)

During the morning session of day 6, Dr. Fanny Brun presented field-based glacier mass balance techniques, covering topics such as measurement methods, geodetic mass balance, ice fluxes, and acquisition of DEMs.

Dr. Ines Dussailant from the World Glacier Monitoring Service (WGMS) provided an overview of glacier monitoring history and WGMS activities. The day concluded with a hands-on exercise led by Dr. Adina on the multi-criteria mapping analysis of debris-covered glaciers.

## Afternoon Lecture Session: Multi-Criteria Analysis (Hands on)

Towards the end of the day, participants were divided into eight different groups of 3-4 individuals for project work. Potential topics for the projects were also discussed, setting the stage for further exploration and research.



Dr. Fanny Brun



Dr. Ines Dussailant



# DAY- 7

## Morning Lecture Session: Field Glacier Mass Balance (Theory)

During the morning session of Day 7, Dr. Fanny Brun delivered a lecture on the theory of glacier field data analysis. She discussed methods for calculating surface glacier mass balance and energy balance using field-collected data, with a specific focus on debris-covered glaciers. Dr. Brun introduced models such as Nicholson and Benn's model and multilayer models for simulating surface energy balance. The role of convection and wind in the melt process was highlighted. The lecture concluded with the need for further research and understanding of debris-covered glaciers, including the impact of debris thickness on ablation/melt and the presence of ponds and ice cliffs.

Although significant progress has been made in "pond and ice cliff science," many unknowns remain regarding their contribution to ablation at larger scales and overall variability. The modeling of the debris layer's impact on the ice beneath is still an active research topic. Exciting questions persist about the feedbacks between surface mass balance and dynamics, large-scale ponds and cliffs, and other related topics.

## Online Afternoon Session: Geodetic Mass Balance (DEMs)(Hands on)

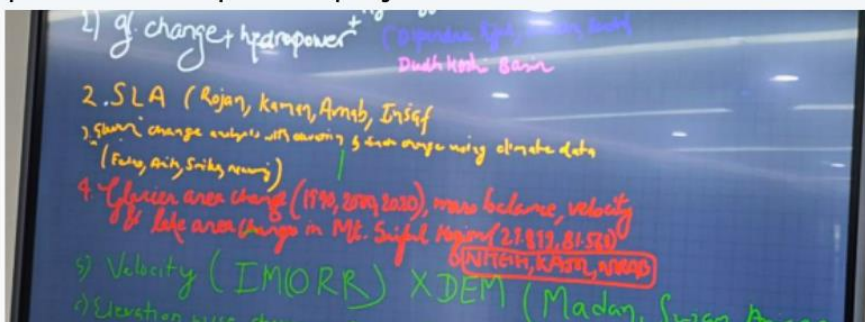
Following the morning lecture, an extensive hands-on session took place. It focused on "field glacier mass balance," covering the fundamental skills required to calculate point energy balance on glaciers, DGPS measurement, and data processing. Dr. Fanny Brun facilitated this session.

After lunch, another hands-on session took place with a specific focus on "Processing of stereo data to calculate glacier mass and volume change," including uncertainty analysis. Dr. Adina, Dr. Fanny, Dr. Ines, and Dr. Amaury facilitated this session, providing guidance and expertise in the topic.



## Project work

Each group identified topics for project work and started to work in the topics.





## DAY- 8

### Lecture Session: Climate Data and Modeling (Theory, Demo, Hands on)

On Day 8, the morning session focused on climate modeling. Dr. Adina provided an overview of the climate data repository, including examples such as ERA, and demonstrated the installation of Miniconda Python for both Windows and MacOS.

In the afternoon session, Dr. Martin Menegoz from IRD, France, began with a lecture on "Modelling the climate system, global and atmospheric models." This was followed by hands-on practice, where participants engaged in processing climate models and reanalysis data using Python. Practical sessions on LMDZ or MAR, along with a Python script to compute climate trends, were conducted using a bash environment or an online server.



## DAY- 9

### Evaluations & Project Presentations

On Day 9, the morning session was dedicated to finalizing the project work. Participants were actively engaged in their respective projects and preparing presentation slides.

After lunch, a project presentation session took place, with each of the 8 different groups presenting their work within a 10-minute time frame, followed by a 5-minute discussion. Resource persons provided comments and suggestions to the participants. All the groups performed excellently in their presentations.

At the conclusion of the project work, the resource persons provided their evaluation and feedback to the participants.

# CLOSING SESSION

The Winter School 2022 concluded with a closing ceremony after nine days of intensive work. The ceremony was graced by the presence of Assoc. Prof. Binod Joshi, Executive Director, Centre for International Relations, Tribhuvan University. During the ceremony, participants shared their experiences and provided valuable suggestions for further improvement of the program. Certificates of achievement were distributed to all participants, acknowledging their successful completion of the Winter School.

The closing remarks were delivered by the special guest, Assoc. Prof. Binod Joshi, who emphasized the importance of international collaboration in enhancing the research capacity of young scholars in Nepal. His remarks highlighted the significance of such educational initiatives in fostering knowledge exchange and growth.

To conclude the event, a refreshing program was organized, allowing participants to enjoy authentic Nepali cuisine at the Tukuche Thakali Restaurant in Jhamshikhel, Lalitpur, Nepal. This provided an opportunity for informal networking and further discussions among the participants.

The Winter School 2022 served as a platform for intensive learning, knowledge sharing, and collaboration. It is hoped that the skills acquired and the connections made during this event will contribute to the professional development of the participants and pave the way for future research endeavors.





# NEXT STEPS

Where do we go from here? It's not just about looking back, but also looking forward.

Winter School 2022 was a significant event that brought together young researchers, promoted international collaboration, and enhanced research capabilities. It served as a stepping stone for further academic development through fostering collaborations and paving the way for future Winter Schools. The impact of this educational initiative is expected to extend beyond the event itself, positively influencing the careers and research outcomes of the participants.

01

## Knowledge Enhancement

Winter School 2022 effectively enhanced participants' knowledge, skills, and understanding in glacier mass balance, climate modeling, and data analysis, empowering them for professional growth and impactful contributions to their research fields.

02

## International Collaboration

Winter School 2022 fostered international collaboration, enabling participants to establish connections, build relationships, and explore potential joint research projects and publications, promoting a global perspective and cultivating a strong sense of community among young researchers.

03

## Capacity Building

Winter School prioritized capacity building through hands-on training, practical skills development, and exposure to advanced research methodologies, empowering participants to address complex research challenges and make valuable contributions in their fields.

04

## Winter School 2023

The success and positive outcomes of Winter School 2022 lay the foundation for the planning and organization of Winter School 2023, fostering continuous learning and knowledge exchange among participants.

# ACKNOWLEDGEMENTS

The Winter School team expresses heartfelt gratitude to all the participants for their active engagement and valuable contributions, which played a pivotal role in the success of the event.

We extend our sincere appreciation to the resource persons and special guests for sharing their expertise and invaluable insights throughout the program.

Furthermore, we sincerely thank our esteemed partner institutions, including the Institut de Recherche pour le Développement, France, for their invaluable support in enhancing the quality and scope of our initiatives. Our deep appreciation also goes to the Kathmandu Center for Research and Education, Chinese Academy of Science, Tribhuvan University (KCRE), and the University Grants Commission Nepal for their generous financial support, exceptional venue, and collaborative efforts, which significantly contributed to the overall success of our initiatives.

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*We thank you for your continued support for Winter School.*

## CONTACT

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# ANNEX 1

## Agenda

# ANNEX

Day 1: Thursday (October 13)			
Time	Type	Topic	Speaker/Instructor
MORNING: OVERVIEW OF THE WINTER SCHOOL			
9:30-10:00		Registration	
10:00-10:05	<b>OPENING</b>	Welcome Remarks	Assoc. Prof. Dr. Binod Dawadi, Deputy Director, KCRE (TU-CAS)
10:05-10:10		Program highlights and about IRD PSF CAPABLE program	Asst. Prof. Dr. Dibas Shrestha, CDHM, TU
10:10-10:15		Remarks from IRD Representative	Dr. Adina Racoviteanu, IRD, France
10:15-10:20		Remarks from Special Guest	Prof. Dr. Binil Aryal, Dean, IoST, TU
10:20-10:25		Opening Remarks from Chief Guest	Prof. Dr. Shiva Lal Bhusal, Rector, TU
10:25-10:30		Remarks from Chair	Prof. Dr. Deepak Aryal, HoD, CDHM, TU
10:30-10:50	COFFEE BREAK/GROUP PHOTO		
10:50-12:00	Introduction and Structure of Winter School		
12:00-13:00	LUNCH BREAK		
PRINCIPLES AND THEORY AFTERNOON: GLACIOLOGY			
13:00-14:30	<b>LECTURE</b>	Principles of Cryosphere components ; types of glaciers; glaciers as climatic indicators; glacier mass balance and dynamics etc.	Patrick Wagon, IRD, France
14:30-15:00	COFFEE BREAK		
15:00-16:30	<b>LECTURE</b>	Principles of Remote Sensing	Yves Arnaud , IRD, France
16:30-17:00	QUESTIONS and software installation		
Day 2: Friday (October 14)			
Time	Type	Topic	Speaker/Instructor
MORNING: REMOTE SENSING / GIS FOR GLACIOLOGY			
9:30-10:00		Arrival and Setup	
10:00-10:30	<b>PRESENTATION</b>	Glacier fieldwork in the HKH	Miriam Jackson ,ICIMOD
10:30-11:00		Glacier monitoring and glacier inventories in the HKH	Sudan Bikas Maharjan, ICIMOD
11:00-11:30		Overview of DHM activities on snow, glacier, and glacier lake monitoring in Nepal	Niraj Shankar Pradhananga, DHM, GoN
11:30-12:00		Overview of CDHM activities on high-mountain research	Prof. Deepak Aryal, CDHM, TU
12:00-13:00	LUNCH BREAK		
AFTERNOON: MOUNTAIN HYDROLOGY - THEORY			
13:00-14:30	<b>LECTURE</b>	Mountain hydrology: introduction to glacio-hydrology principles, and overview of field measurements needed to understand the processes and the link between climate, glaciers and river flows	Michel Esteves, IRD, France
14:30-15:00	COFFEE BREAK		
15:00-16:00	<b>DEMO/HANDS-ON</b>	Introduction to software: ArcGIS, QGIS, python, RSGISLIB; Data management in RS/GIS applications; set up and installation, explore data (Exercise #1)	Adina Racoviteanu, IRD, France
16:00-17:00	<b>DEMO/HANDS-ON</b>	Satellite data repositories, searching and ordering (Exercise #2)	
Day 3: Sunday (October 16)			
Time	Type	Topic	Speaker/Instructor
MORNING: REMOTE SENSING / GIS FOR GLACIOLOGY			
9:30-10:00		Arrival and set-up	
10:00-10:30	<b>PRESENTATION</b>	Cryospheric Research in Nepal	Prof. Rijan Bhakta Kayastha , KU
10:30-11:00	<b>PRESENTATION</b>	KCRE initiatives on high-mountain research and education	Binod Dawadi, KCRE (TU-CAS)
11:00-12:00	<b>DEMO/HANDS-ON</b>	Global glacier inventory data (GLIMS, RGI.) · Downloading data, projecting, clipping · Evaluating differences (working with attribute tables)	Adina Racoviteanu, IRD, France
12:00-13:00	LUNCH BREAK		
AFTERNOON: REMOTE SENSING FOR GLACIOLOGY			

# ANNEX 1 Agenda

# ANNEX

14:00-14:30	<b>DEMO</b>	<b>Image pre-processing:</b> · atmospheric/topographic correction · stacking, clipping, (re-)projecting, georeferencing	<i>Adina Racoviteanu, IRD, France</i>	
14:30-15:30	<b>HANDS-ON</b>	<b>Image classification with band ratios in ArcGIS/QGIS (Exercise #3a/3b)</b> · ice and snow mapping, : Single band ratios and indices · masking vegetation and clouds · change analysis and uncertainty		
15:30-15:45	<b>COFFEE BREAK</b>			
15:45-16:30	<b>HANDS-ON</b>	<b>Image classification -band ratios cont'd (Exercise #4)</b>	<i>Adina Racoviteanu, IRD</i>	
16:30-17:00		<b>Summary and discussion</b>		
<b>Day 4: Monday (October 17)</b>				
<b>Time</b>	<b>Type</b>	<b>Topic</b>	<b>Speaker/Instructor</b>	
<b>MORNING: REMOTE SENSING FOR GLACIOLOGY</b>				
9:30-10:00		Arrival and set-up		
10:00-12:00	<b>HANDS-ON</b>	<b>Supervised image classification (SCP plugin in QGIS) (Exercise #5)</b> · Data access and download · Pre processing (atmospheric correction etc.) · Spectral signatures, ROIs and classification	<i>Adina Racoviteanu, IRD, France</i>	
12:00-13:00	<b>LUNCH BREAK</b>			
<b>AFTERNOON: REMOTE SENSING FOR GLACIOLOGY</b>				
13:00-15:00	<b>HANDS-ON</b>	<b>Glacier dynamics by Feature tracking: IMCORR plugin (Exercise #6)</b> · checking data, accessing IMCORR plug in · correlation points and displacement vectors · interpolation to raster	<i>Adina Racoviteanu, IRD, France</i>	
15:00-15:15	<b>COFFEE BREAK</b>			
<b>Day 5: Tuesday (October 18)</b>				
<b>Time</b>	<b>Type</b>	<b>Topic</b>	<b>Speaker/Instructor</b>	
<b>MORNING: TERRAIN ANALYSIS</b>				
9:30-10:00		Arrival and Setup		
10:00-10:30	<b>LECTURE/ DEMO</b>	<b>Working with DEMs (demo)</b> · Data repositories, searching and ordering · DEM types and accuracy	<i>Adina Racoviteanu, IRD ,France</i>	
10:30-12:00	<b>HANDS-ON</b>	<b>Working with DEMs (exercise #7)</b> · Projecting, clipping, mosaicking, resampling, differencing		
12:00-13:00	<b>LUNCH BREAK</b>			
<b>AFTERNOON: TERRAIN ANALYSIS cont'd</b>				
13:00-15:00	<b>HANDS-ON</b>	<b>Mapping ice divides/hydrologic applications (exercise #8)</b> · hydrologic tools in GIS · delineating basins and watersheds · zonal analysis	<i>Adina Racoviteanu, IRD, France</i>	
15:00-15:15	<b>COFFEE BREAK</b>			
15:15-17:00	<b>DEMO</b>	<b>Introduction to xDEM processing in python</b>		<i>Amaury Deheca, IRD, France</i>
<b>Day 6: Wednesday (October 19)</b>				
<b>Time</b>	<b>Type</b>	<b>Topic</b>	<b>Speaker/Instructor</b>	
<b>MORNING: Field based monitoring of debris cover</b>				
10:00-10:30	<b>LECTURE</b>	<b>Overview of debris-covered glaciers</b>	<i>Fanny Brun/Adina Racoviteanu, IRD, France</i>	
10:30-12:00	<b>LECTURE/DEMO</b>	<b>Field - based methods for debris cover monitoring</b>	<i>Fanny Brun, IRD, France</i>	
12:00-13:00	<b>LUNCH BREAK</b>			
<b>Criteria analysis</b>				



# ANNEX 1 Agenda



# ANNEX

13:00-15:30	<b>HANDS-ON</b>	<b>Choice 1: Multi-criteria debris cover mapping (exercise #9)</b>	<i>Adina Racoviteanu, IRD, France</i>
		<b>Choice 2: Optimal localication (exercise #10)</b>	
		Decision tree approach (conditional statements, raster overlay)	
		Using topographic indices	
		Weighted overlay	
15:30-15:45	<b>COFFEE BREAK</b>		
15:45-17:00	Discuss project topics and form groups; gather data		
<b>Day 7: Thursday (October 20)</b>			
<b>MORNING: Field glacier mass balance</b>			
<b>Time</b>	<b>Type</b>	<b>Topic</b>	<b>Speaker/Instructor</b>
10:00-12:00	<b>LECTURE</b>	<b>Field data anlysis theory: methods to calculate surface glacier mass balance and energy balance based on data collected in the field (ablation, accumulation data and in-situ meteorological records)</b>	<i>Fanny Brun, IRD, France</i>
	<b>HANDS-ON</b>	<b>Field glacier mass balance: basic skills needed to calculate point energy balance on glaciers, DGPS measurement and data processing (exercise #11)</b>	
12:00-13:00	<b>LUNCH BREAK</b>		
<b>AFTERNOON: Geodetic mass balance (DEMs)</b>			
13:00-15:00	<b>HANDS-ON</b>	<b>Processing of stereo data to calculate glacier mass and volume change; uncertainty analysis (exercise #12)</b>	<i>Fanny/Ines/Amaury/ Adina, IRD, France and WGMS Switzerland</i>
15:00-15:15	<b>COFFEE BREAK</b>		
15:15-17:00	Continue work on projects (methodology)		
<b>Day 8: Friday (October 21)</b>			
<b>Time</b>	<b>Type</b>	<b>Topic</b>	<b>Speaker/Instructor</b>
<b>MORNING: CLIMATE DATA</b>			
10:00-11:00	<b>DEMO/HANDS-ON</b>	<b>Miniconda Python installation (Windows/MacOS)</b>	<i>Adina Racoviteanu, IRD, France</i>
11:00-12:00	<b>LECTURE</b>	<b>Overview of climate data sources (ERA5, etc.)</b>	<i>Adina Racoviteanu, IRD, France</i>
12:00-13:00	<b>LUNCH BREAK</b>		
<b>AFTERNOON: CLIMATE MODELING</b>			
13:00-14:00	<b>LECTURE</b>	<b>Modelling the climate system, global and atmospheric models</b>	<i>Martin Menegoz, IRD, France</i>
14:00-15:00	<b>HANDS-ON</b>	<b>Processing climate models and reanalysis data (python); LMDZ or MAR practical sessions (bash) with a python script to compute climate trends (online server) (exercise #13)</b>	
15:00-15:15	<b>COFFEE BREAK</b>		
15:15-17:00	<b>HANDS-ON CONT'D</b>	<b>Processing climate models and reanalysis data (python); ERA5 practical sessions (bash) with a python script to compute climate trends (online server)*</b>	<i>Martin Menegoz, IRD, France</i>
<b>Day 9: Sunday (October 23)</b>			
<b>Time</b>	<b>Type</b>	<b>Topic</b>	<b>Speaker/Instructor</b>
<b>MORNING: Evaluations</b>			
10:00-12:00		Work on projects (results)	
12:00-13:00	<b>LUNCH BREAK</b>		
<b>Afternoon: project presentations</b>			
13:00-15:00		Student presentations	
15:00-15:30	<b>COFFEE BREAK</b>		
15:30-17:00		Experience Sharing and Certificate Distribution	
17:00	Refres		



# ANNEX 2

## Attendance of Participants

 Institut de Recherche pour le Développement FRANCE  


**Winter School 2022**  
**Application of Field and Remote Sensing techniques for Snow and Glacier Studies**  
*CAPacity BuiLding in glacio-hydro-meteorological rEsearch in Nepal (CAPABLE-NEPAL)*  
 13-23 October 2022  
 Kathmandu Centre for Research and Education (KCRE CAS-TU), Kirtipur

**Attendance Sheet**

S. N	Full Name	Affiliation	Email	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct	21-Oct	22-Oct	23-Oct
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27	Sujan Khatiwada	TC, TU	sujan.khatiwada4@gmail.com											
28	Dipendra Lamichhane	CAS, CHINA	dipendra.lamichhane@cas.ac.cn											
29	Prof. Dr. Deepak Aryal	CDHM, TU	deepak.aryal@cdhm.tu.edu.np											
30	Dr. Adina Racoviteanu	IRD, France	adina.racoviteanu@ird.fr											
31	Dr. Binod Dawadi	CDHM / KCRE	binod.dawadi@cdhm.tu.edu.np											
32	Dr. Dibas Shrestha	CDHM, TU	dibas.shrestha@cdhm.tu.edu.np											
33	Dr. Sunil Acharya	CDHM, TU	sunil.acharya@cdhm.tu.edu.np											
34	Dr. Fanny Brun	IRD, France	fanny.brun@ird.fr											
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39	Rajan Lamichhane	DHM (MFD)	rajan.lamichhane@cdhm.tu.edu.np											
40	Mr. Ilya Yakusov	ICIMOD	ilya.yakusov@icimod.org											
41	Sudan Mahajan	ICIMOD	sudan.mahajan@icimod.org											
42	Dr. Rajan B. Kayaatho	KU	rajanku@ku.edu.np											
43	Dr. Ines Dussailbaut	IRD France	ines.dussailbaut@ird.fr											
44	Mr. Madan Kumar Shrestha	CDHM, TU	madan.shrestha@cdhm.tu.edu.np											
45														
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ANNEX



# ANNEX 3

## Certificate of Achievement Sample

### CERTIFICATE OF ACHIEVEMENT

Central Department of Hydrology and Meteorology, Tribhuvan University (CDHM, TU)  
Institute of Research for Development, France (IRD-France)  
Kathmandu Center for Research and Education, Chinese Academy of Sciences-Tribhuvan University (KCRE, CAS-TU)  
hereby acknowledge the successful participation of

# Sandesh Tamang

at the

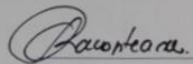
## Winter School 2022

### "APPLICATION OF FIELD AND REMOTE SENSING TECHNIQUES FOR SNOW AND GLACIER STUDIES"

An initiative of CAPAcity BuILding in glacio-hydro-meteorological rEsearch in Nepal (CAPABLE-NEPAL)

from 13 to 23 October 2022 at Kathmandu

This certificate accounts for **3 credit points**.



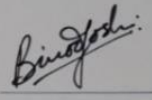
Dr. Adina Racoviteanu  
Resource Person  
IRD-France



Dr. Xiaobo LIU  
Deputy Director  
KCRE, CAS-TU



Prof. Dr. Deepak Aryal  
Head  
CDHM, TU



Mr. Binod Joshi  
Executive Director  
Centre for International Relations,



### Course Contents

#### Lectures (10.5 hrs)

- Principles of Cryosphere: components; types of glaciers; glaciers as climatic indicators; glacier mass balance and dynamics, etc. (1.5 hrs)
- Principles of Remote Sensing: platforms, active/passive systems, principles of object identification, electromagnetic waves, Planck's law, Wein's law, radiation paths, etc. (1 hr)
- Mountain hydrology: Principles of glacio-hydrology, overview of field measurements, linkage between climate, glaciers and river flows (1.5 hrs)
- Recent mass balance evolution of HMA glaciers, at different scales, from glacier to regional scale, and processes controlling their recent evolution (1.5 hrs)
- Debris-covered glaciers: processes and field monitoring (1 hr)
- Glacier mass balance theory: field and geodetic (1 hr)
- Modelling the climate system, global and regional (1.5 hrs)
- Glacier fieldwork in High Mountain Asia (30 mins)
- Glacier monitoring and inventories in High Mountain Asia (30 mins)
- Cryospheric research in Nepal (30 mins)

#### Demo (3.5 hrs)

- Introduction to software: ArcGIS, QGIS, Python, RSGISUB; Data management in RS/GIS applications; set up and installation, explore data (30 mins)
- Satellite data repositories (30') and DEM(30') searching and ordering (1 hr)
- Introduction to xDEM processing in Python (2 hrs)

#### Exercises (hands-on) (26 hrs)

- Data explore and work with shapefiles, attribute tables (2 hrs)
- Image classification with band ratios in ArcGIS/QGIS (clean ice and snow, vegetation, clouds, etc.) (4 hrs)
- Supervised image classification (SCP plugin in QGIS) (3 hrs)
- Glacier dynamics by Feature tracking: IMCORR plugin (3 hrs)
- Terrain analysis: DEM pre-processing: clipping, re-projecting, merging, etc. (2 hrs)
- Hydrologic analysis with DEMs: mapping ice divides, watershed delineation (3 hrs)
- Multi-criteria analysis: debris cover mapping and/or optimal localization (3 hrs)
- Field glacier mass balance: basic skills needed to calculate point energy balance on glaciers, DGPS measurement and data processing (2 hrs)
- Processing of stereo data to calculate glacier mass and volume change; uncertainty analysis (2 hrs)
- Processing climate models and reanalysis data (python); LMDZ or MAR practical sessions (bash) with a python script to compute climate trends (online server) (2 hrs)

#### Projects and presentation (8 hrs)

ANNEX



