UNIVERSITÀ DEGLI STUDI DI CAGLIARI

Terrain Analysis and Earth Observation:

Geospatial Technologies in Mountain Ecosystems

Prof. Maria Teresa Melis, Geomatics- EvK2CNR and University of Cagliari

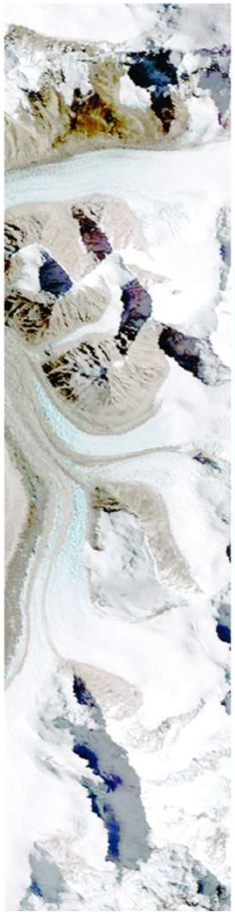


UNIVERSITÀ DEGLI STUDI DI CAGLIARI | POLITECNICO MILANO 1863 | UNIVERSITÀ DEGLI STUDI DI MILANO | EvK2CNR

TeleGIS Laboratory, Department of Chemical and Geological Sciences, University of Cagliari



Technology for all…









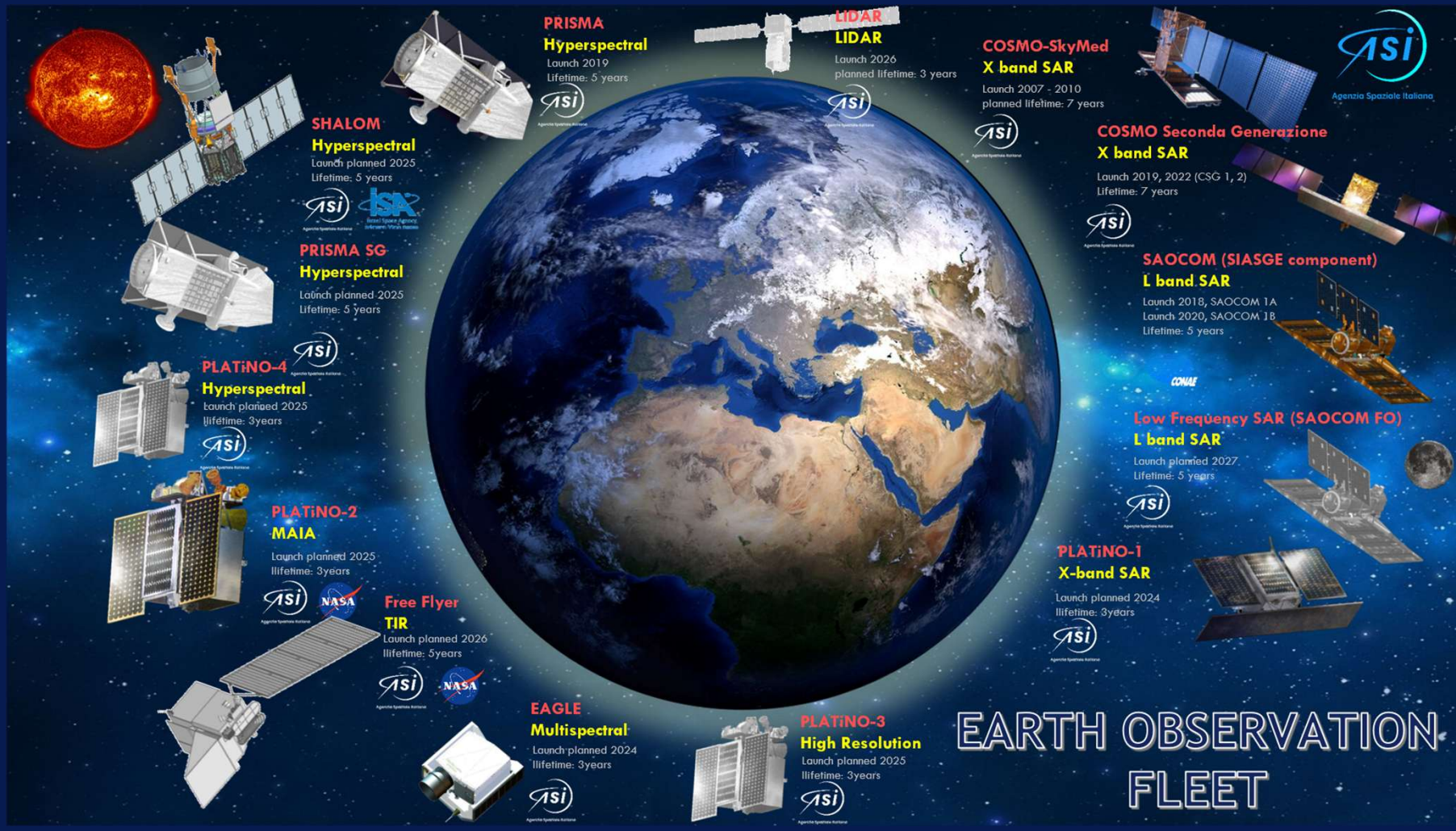
- *Geo-Data integration and sharing*
- *Involving the Students/ Communities into the Knowledge of Fragile High Mountains Ecosystem*










PRISMA
Hyperspectral
Launch 2019
Lifetime: 5 years
LIDAR
LIDAR
Launch 2026
planned lifetime: 3 years
COSMO-SkyMed
X band SAR
Launch 2007 - 2010
planned lifetime: 7 years
COSMO Seconda Generazione
X band SAR
Launch 2019, 2022 (CSG 1, 2)
Lifetime: 7 years
SHALOM
Hyperspectral
Launch planned 2025
Lifetime: 5 years
PRISMA SG
Hyperspectral
Launch planned 2025
Lifetime: 5 years
SAOCOM (SIASGE component)
L band SAR
Launch 2018, SAOCOM 1A
Launch 2020, SAOCOM 1B
Lifetime: 5 years
PLATiNO-4
Hyperspectral
Launch planned 2025
lifetime: 3years
Low Frequency SAR (SAOCOM FO)
L band SAR
Launch planned 2027
Lifetime: 5 years
PLATiNO-2
MAIA
Launch planned 2025
lifetime: 3years
PLATiNO-1
X-band SAR
Launch planned 2024
lifetime: 3years
Free Flyer
TIR
Launch planned 2026
lifetime: 5years
EAGLE
Multispectral
Launch planned 2024
lifetime: 3years
PLATiNO-3
High Resolution
Launch planned 2025
lifetime: 3years
EARTH OBSERVATION
FLEET

Agenzia Spaziale Italiana

UNIVERSITÀ DEGLI STUDI DI CAGLIARI

POLITECNICO MILANO 1863

UNIVERSITÀ DEGLI STUDI DI MILANO

EvK2CNR

IRIDE: Italy's Next-Generation Earth Observation Ecosystem

A €1.07 Billion 'Constellation of Constellations' driving the digital and ecological transition.



Gemini Notebook

UNIVERSITÀ DEGLI STUDI DI CAGLIARI
POLITECNICO MILANO 1863
UNIVERSITÀ DEGLI STUDI DI MILANO
EvK2CNR

esa

From Orbit to Action: 6 Thematic Services & Global Impact



The Copernicus Data Space Ecosystem

100% Free & Open Access

Empowers nearly **800 European companies** (96% SMEs and startups).

Generating **€1.8 billion** in current revenue, projected to scale to **~€6 billion** by 2033.

Secures over **1/3** of the global data processing market for Europe.

Gemini Notebook

GIS RS ACTIVITIES IN PAKISTAN

UNIVERSITÀ DEGLI STUDI DI CAGLIARI

POLITECNICO MILANO 1863

UNIVERSITÀ DEGLI STUDI DI MILANO

EvK2CNR





ESA Sentinel2
Baltoro Glacier

GIS RS ACTIVITIES IN PAKISTAN

UNIVERSITÀ DEGLI STUDI DI CAGLIARI

POLITECNICO MILANO 1863

UNIVERSITÀ DEGLI STUDI DI MILANO

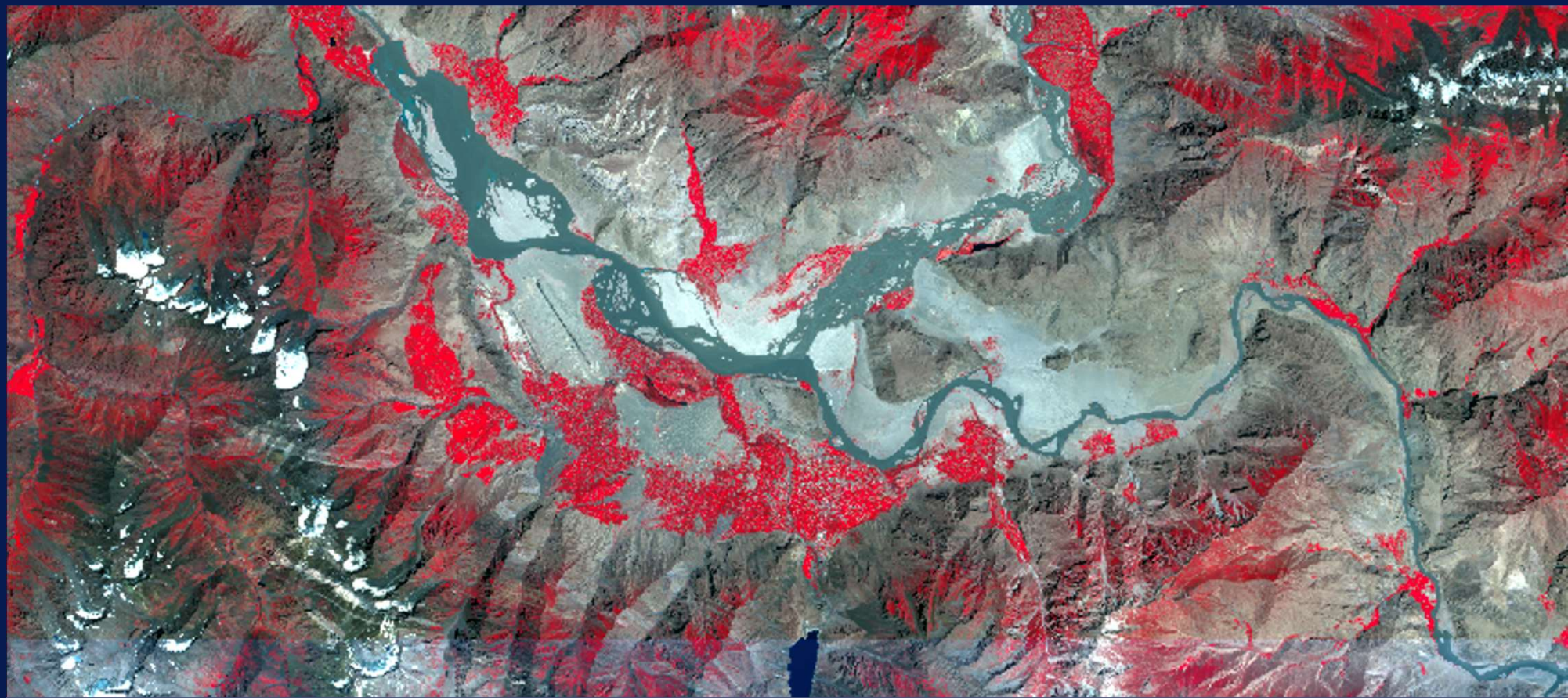
EvK2CNR



GIS and Remote Sensing activities in Pakistan

Skardu

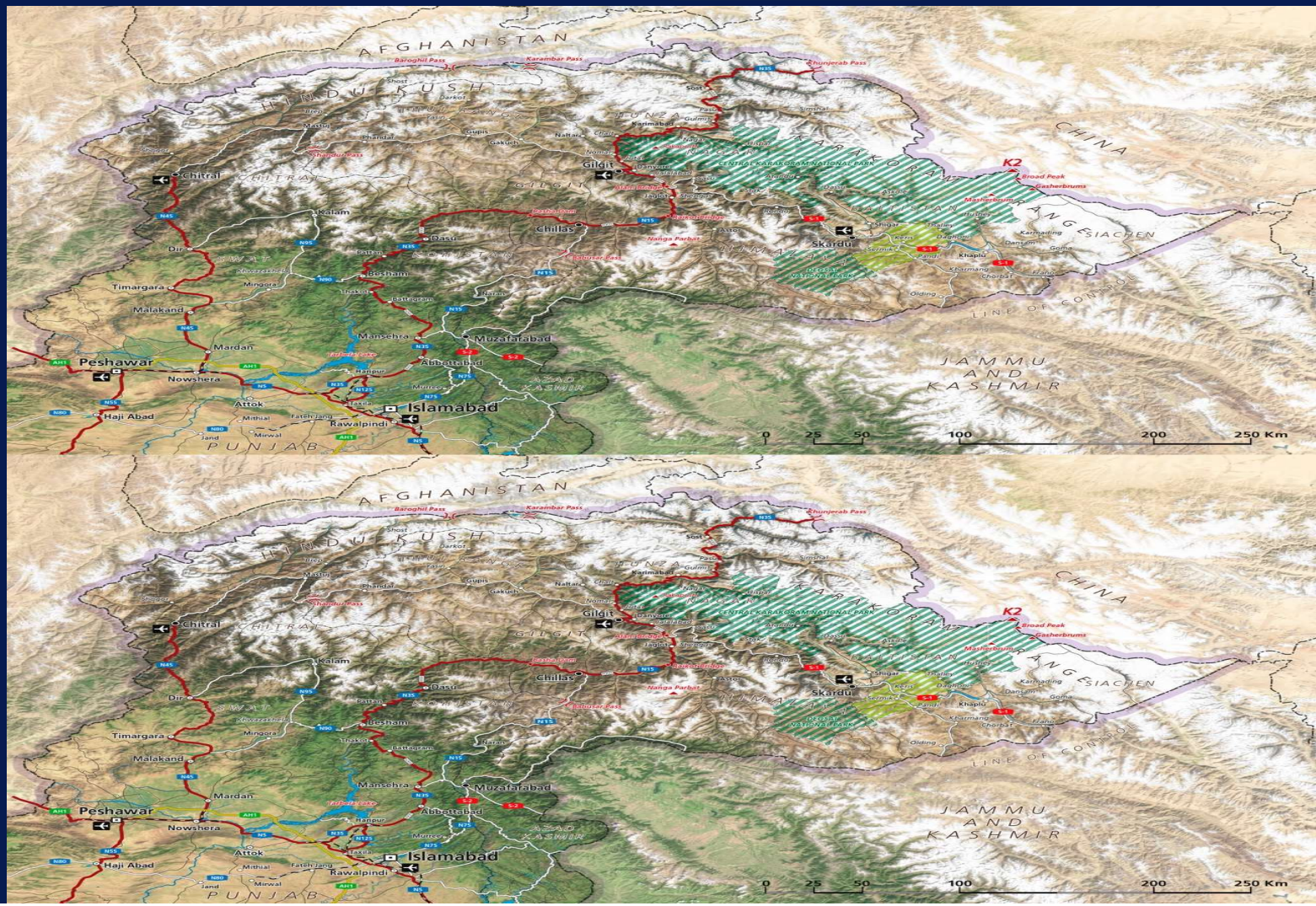
Sentinel data



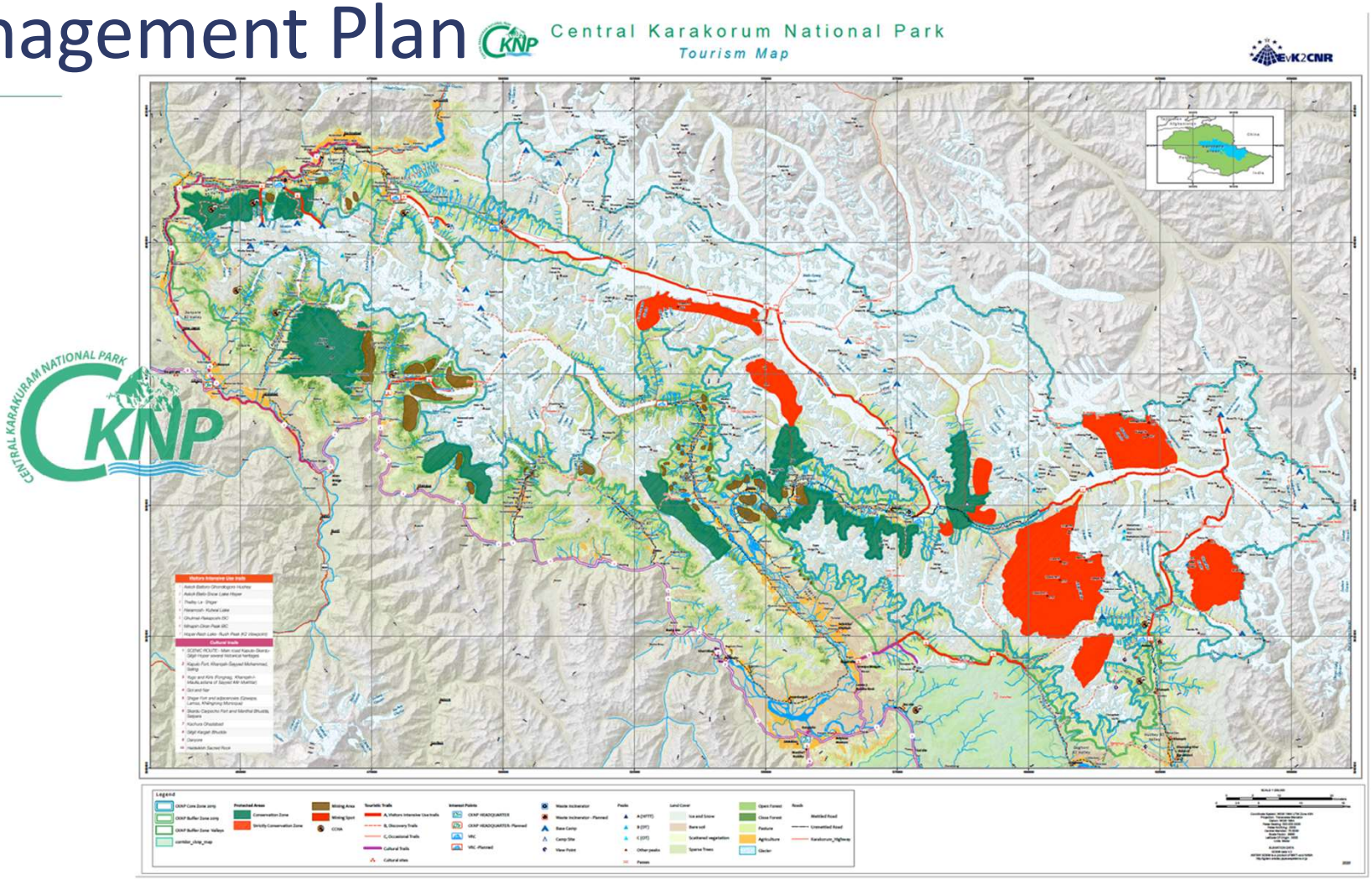
Data integration



Management Plans in Pakistan



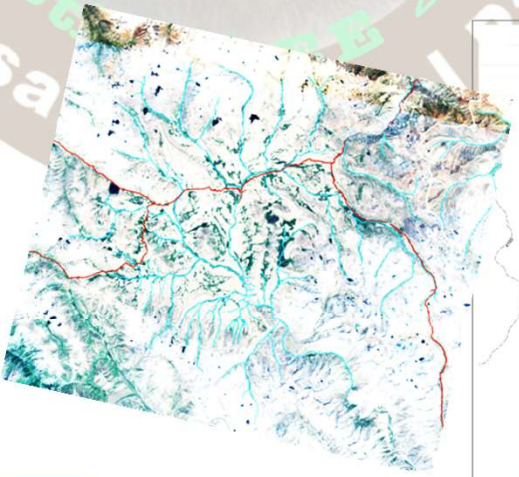
CKNP Management Plan

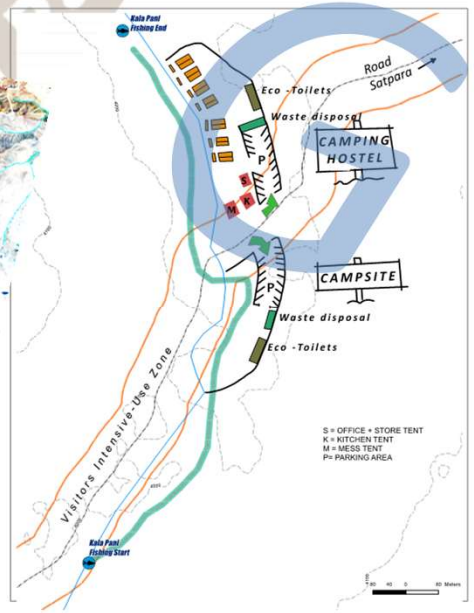


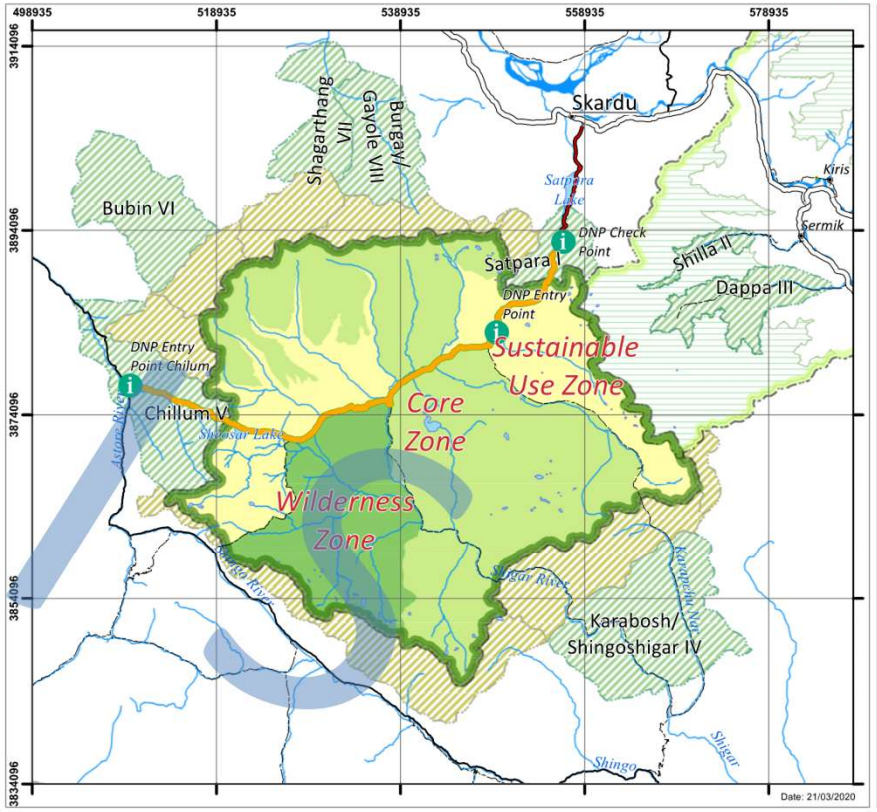
UNIVERSITÀ DEGLI STUDI DI CAGLIARI · POLITECNICO MILANO 1863 · UNIVERSITÀ DEGLI STUDI DI MILANO · EvK2CNR

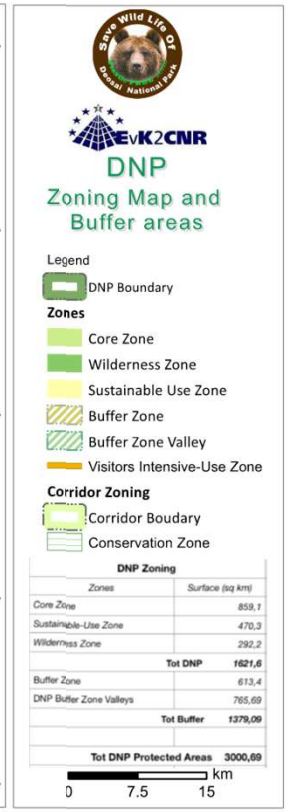
DNP Management Plan

Satellite data
Geo-data layers
Human effort









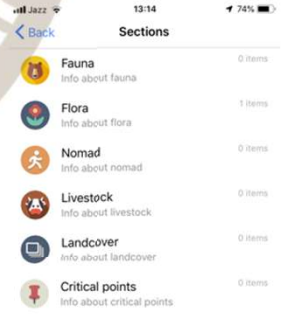
UNDP

AGENZIA ITALIANA PER LA COOPERAZIONE ALLO SVILUPPO

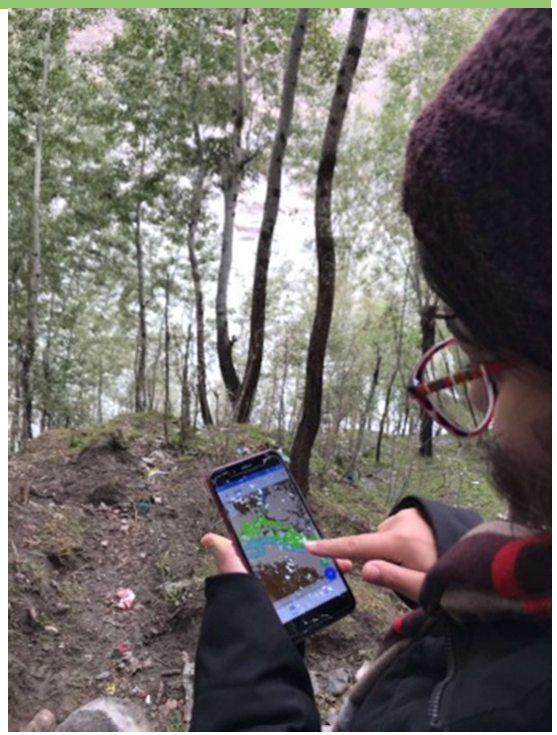
DNP Management Plan

Field work: training and *validation*









GBGeoapp, and data collection

UNDP

AGENZIA ITALIANA PER LA COOPERAZIONE ALLO SVILUPPO

UNIVERSITY OF BALTISTAN SKARDU

Karakoram International University

DNP Management Plan

Training activities: field work

- Training on land cover map interpretation
- Discussion and suggestions for improvements





Training activities: Laboratory work



REGIONE AUTÒNOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA



Training on new system for data sharing at GB-EPA in Gilgit

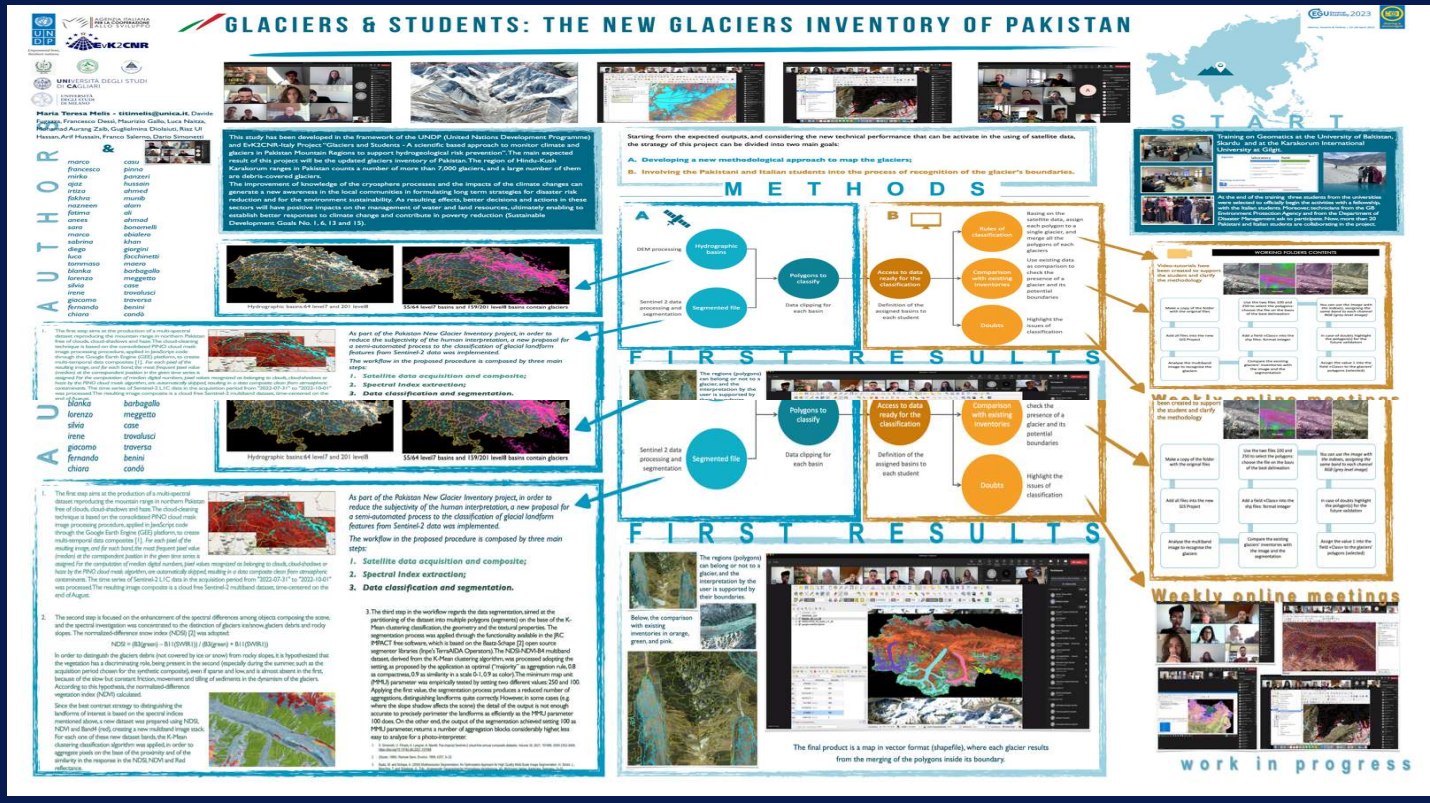


Glaciers & Students

UNIVERSITÀ DEGLI STUDI DI CAGLIARI · POLITECNICO MILANO 1863 · UNIVERSITÀ DEGLI STUDI DI MILANO · EvK2CNR

Collaboration between Italian and Pakistan Universities

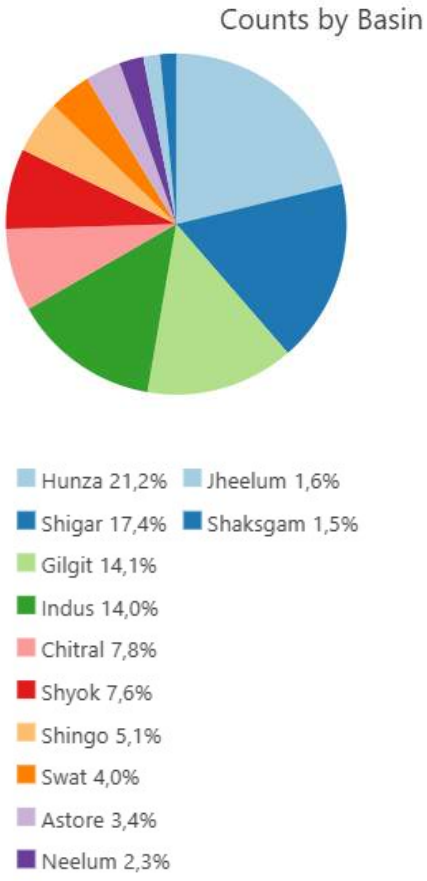


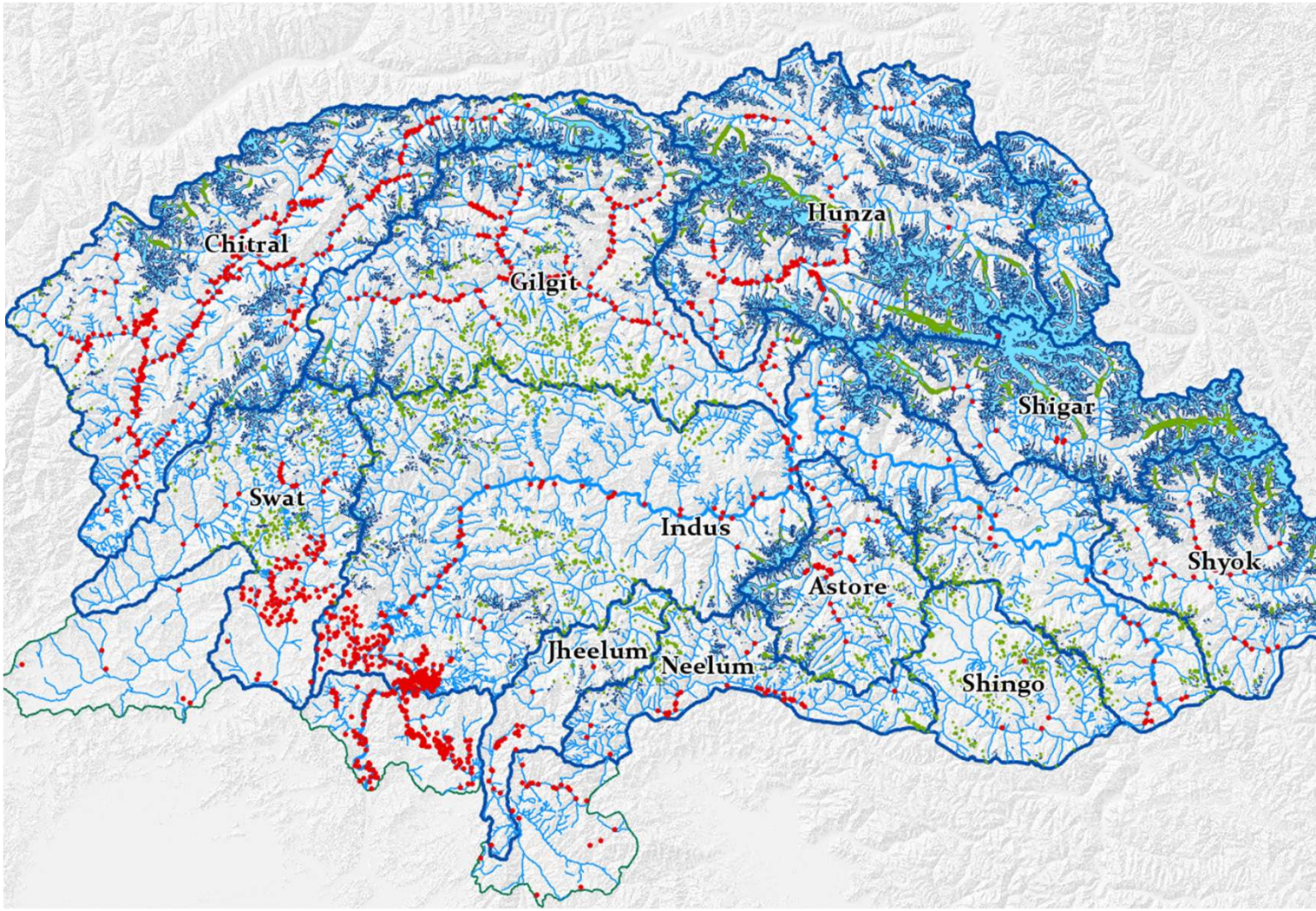


Glacial Lakes – *first draft 2020*

UNIVERSITÀ DEGLI STUDI DI CAGLIARI · POLITECNICO MILANO 1863 · UNIVERSITÀ DEGLI STUDI DI MILANO · EvK2CNR

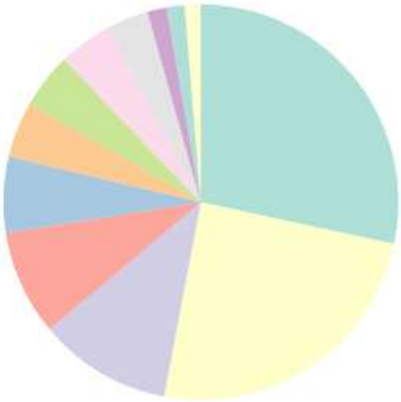
5,078 Glacial lakes





Glacial Lakes

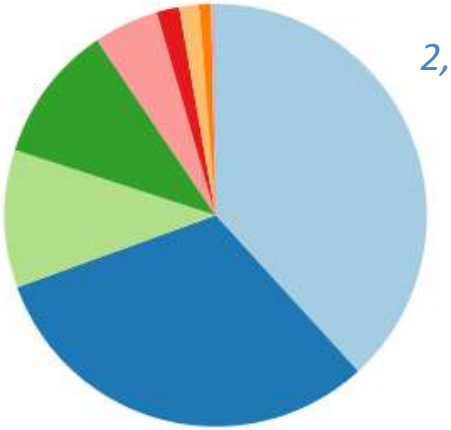
Proglacial Lakes Counts by Basin



2,357

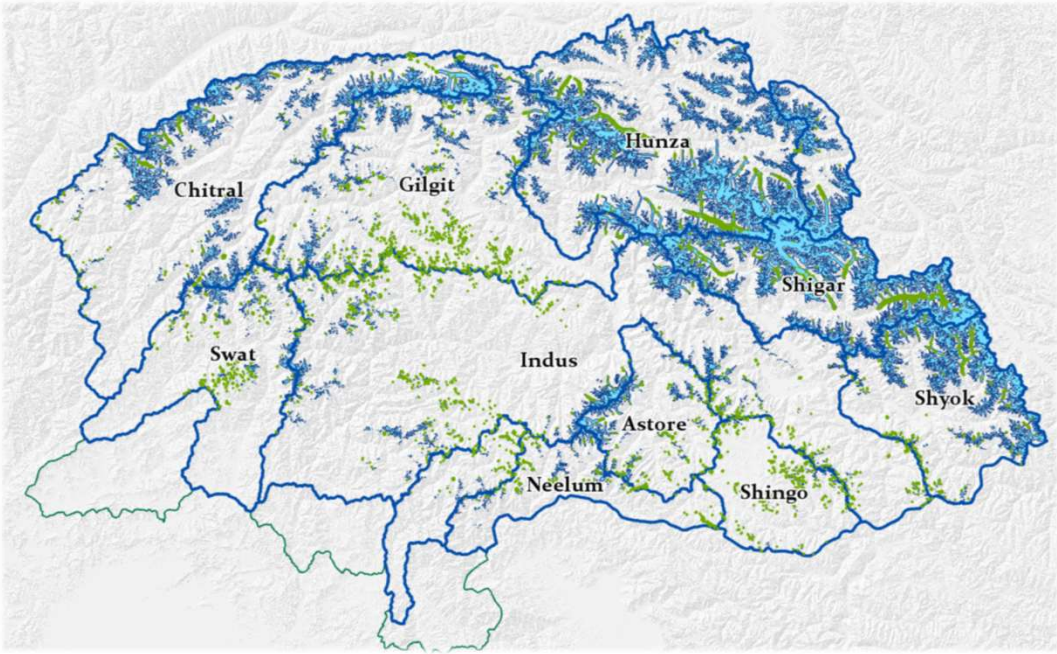
- Indus 28,4%
- Hunza 1,5%
- Gilgit 24,6%
- Shaksgam 1,3%
- Shingo 10,9%
- 0,0%
- Swat 8,6%
- Astore 6,2%
- Chitral 4,6%
- Neelum 4,5%
- Shyok 4,4%
- Jheelum 3,4%
- Shigar 1,6%

Supraglacial Lakes Counts by Basin

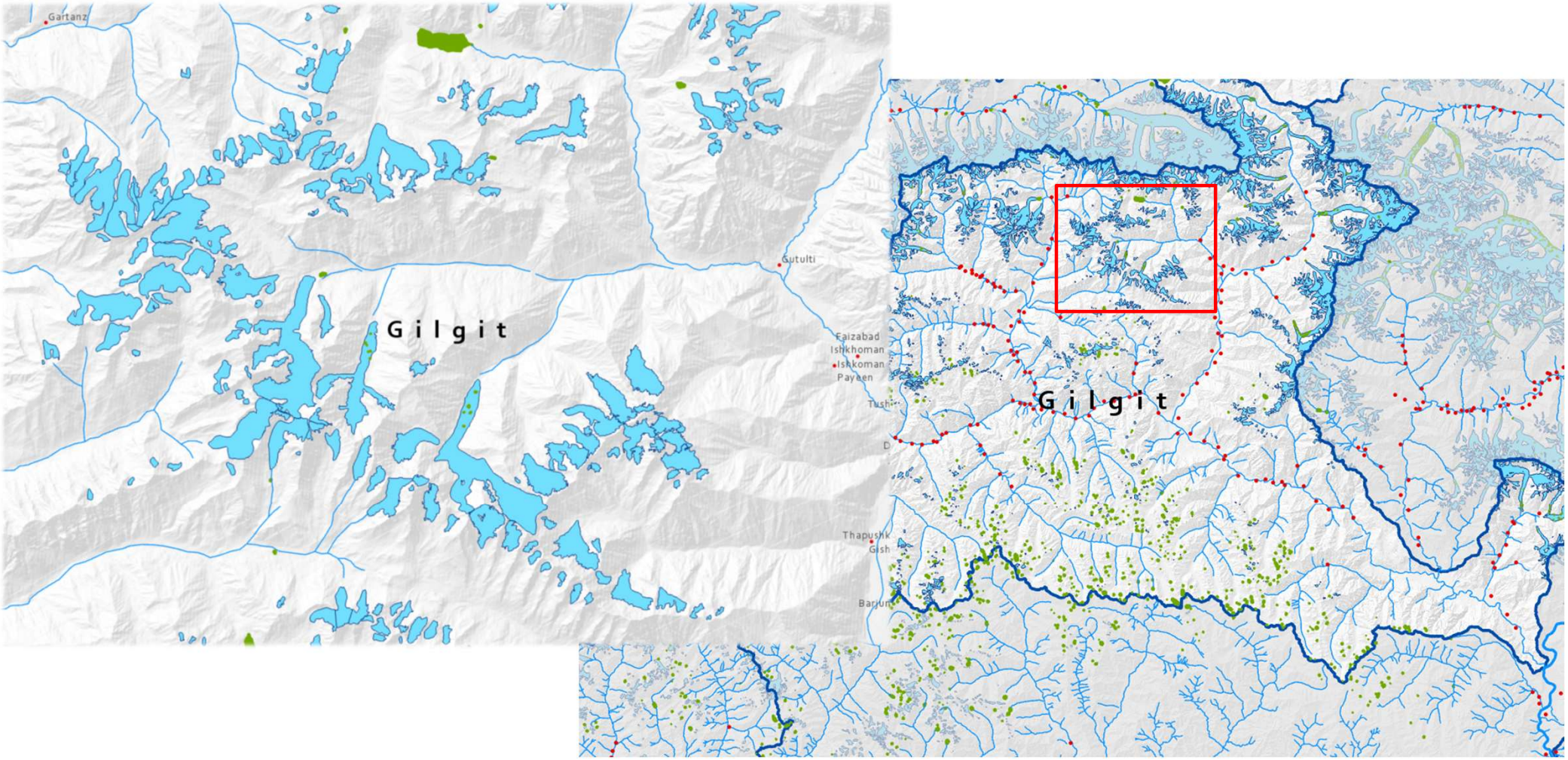


2,711

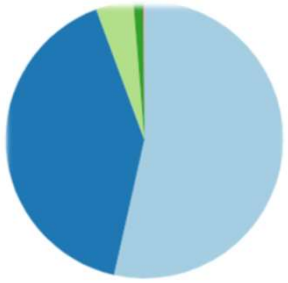
- Hunza 38,2%
- Shigar 31,2%
- Chitral 10,5%
- Shyok 10,5%
- Gilgit 5,0%
- Shaksgam 1,7%
- Indus 1,5%
- Astore 0,9%
- Neelum 0,3%



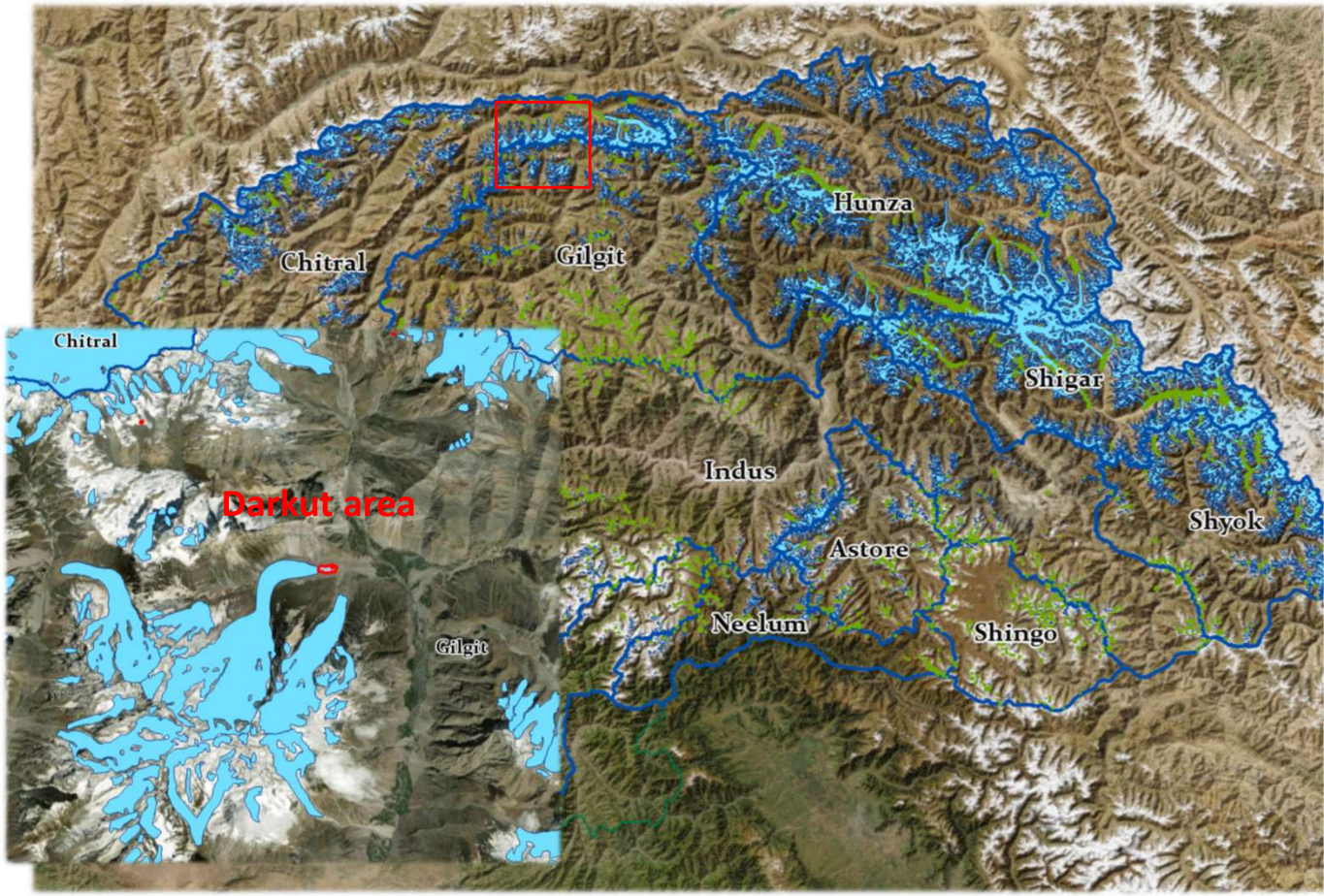
Glacial Lakes: classification



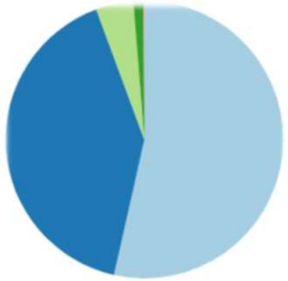
Glacial Lakes: classification



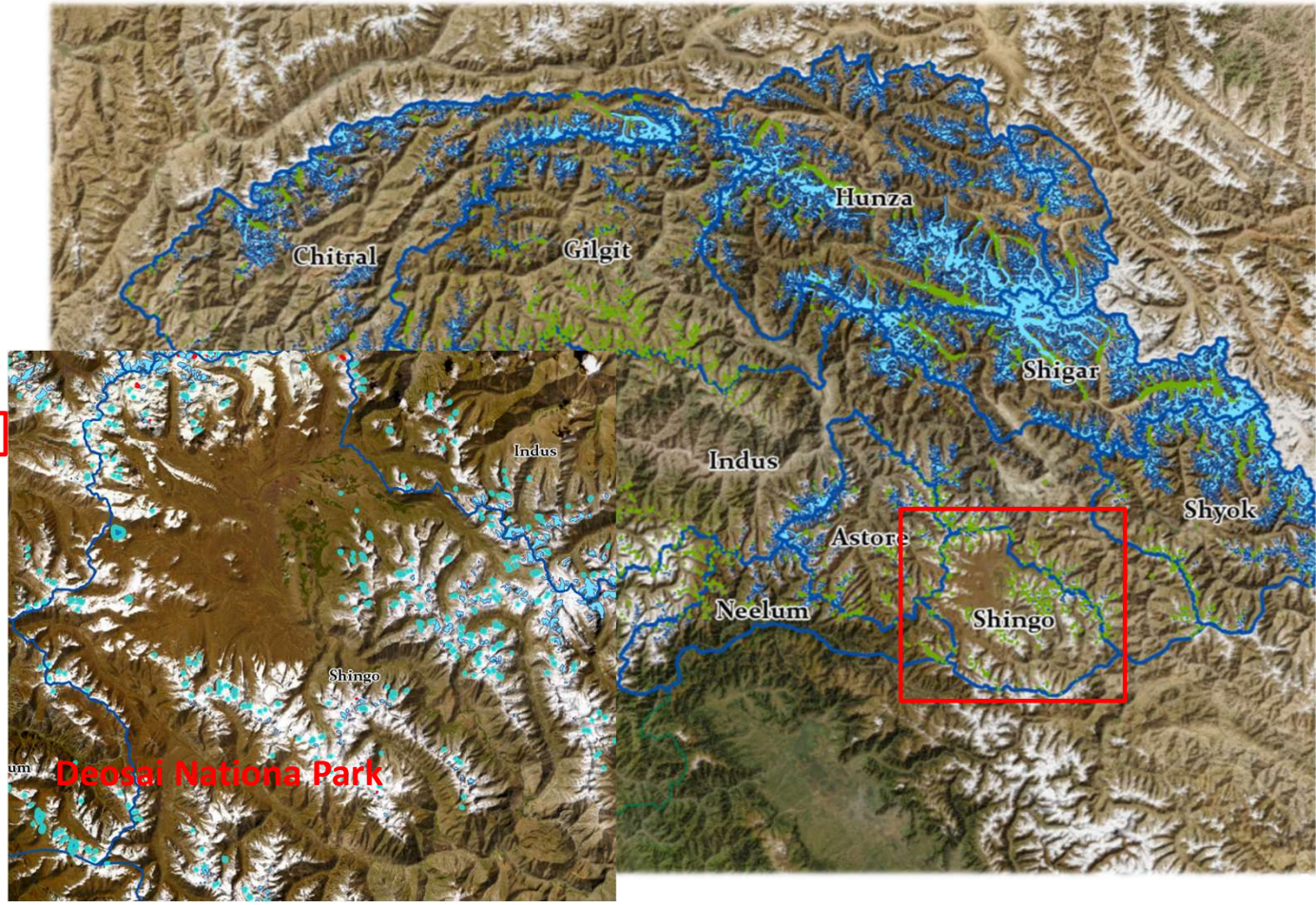
SGL 53,5%	SGL: Supraglacial Lakes
GE 40,8%	GE: Glacial Erosion
EMD 4,4%	EMD: End-Moraine Dammed
LMD 1,2%	LMD: Lateral-Moraine Dammed
ID 0,1%	ID: Ice Dammed



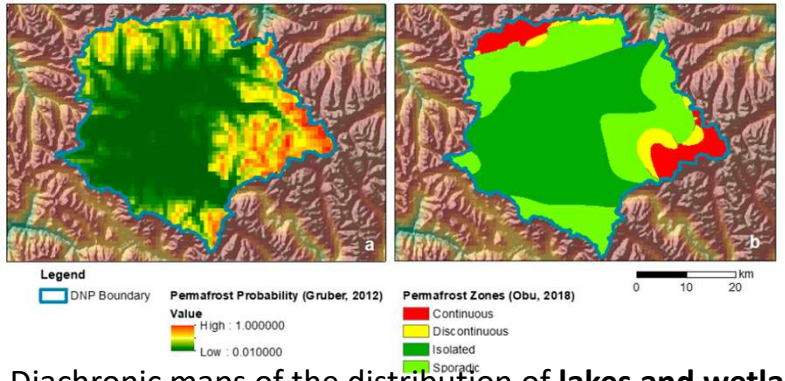
Glacial Lakes and Permafrost



SGL 53,5%	SGL: Supraglacial Lakes
GE 40,8%	GE: Glacial Erosion
EMD 4,4%	EMD: End-Moraine Dammed
LMD 1,2%	LMD: Lateral-Moraine Dammed
ID 0,1%	ID: Ice Dammed

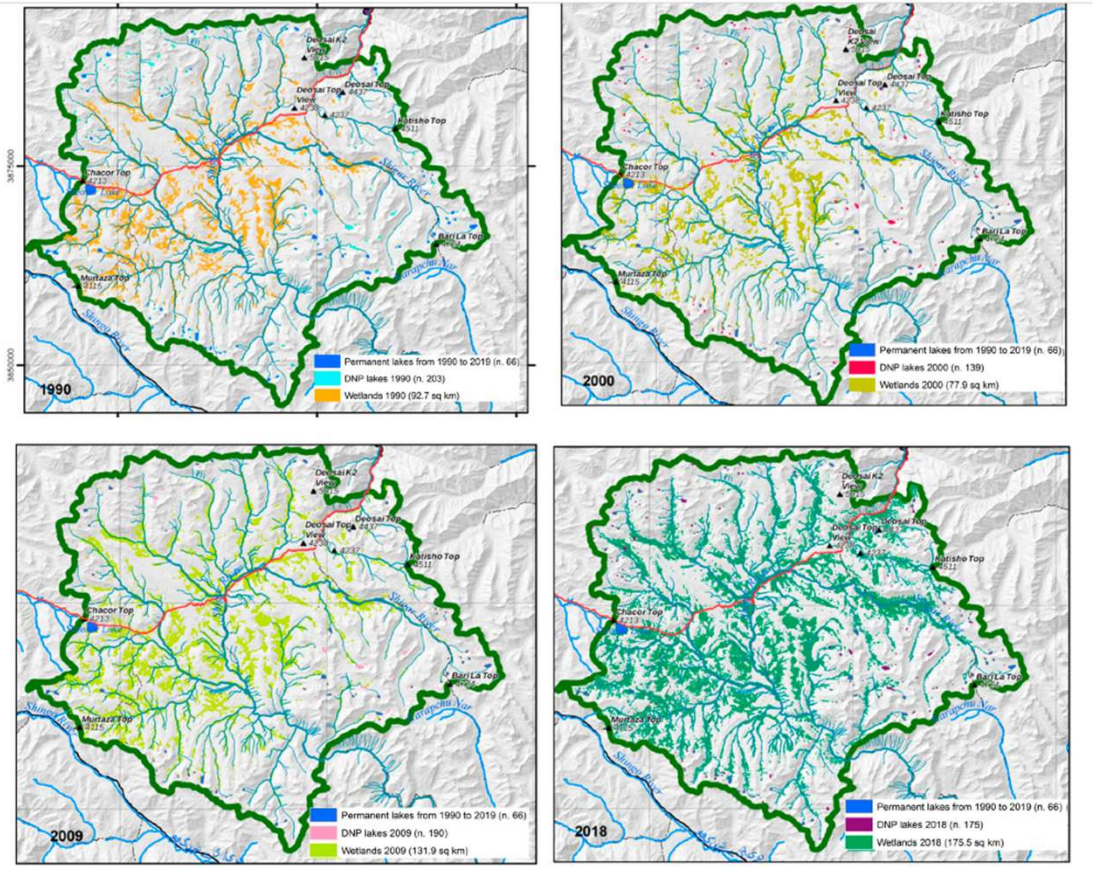


Glacial Lakes and Permafrost

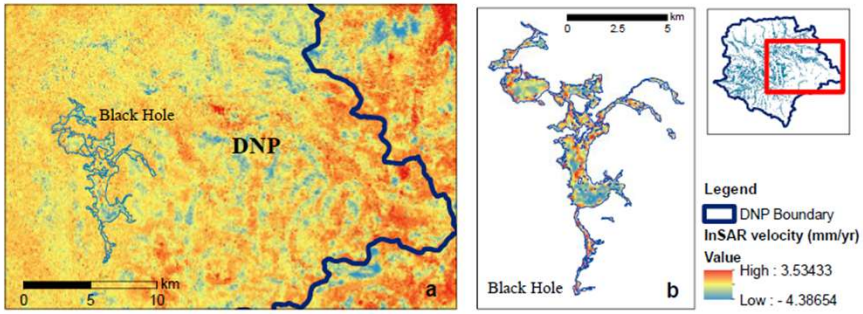


Diachronic maps of the distribution of **lakes and wetlands** in DNP in 30 years.

- ✓ 66 lakes are permanent from 1990;
- ✓ The number and the total surface of the small lakes show a gentle decrease from 1990 toward 2019;
- ✓ The surface of the wetlands shows a clear increasing in the considered interval.



Surface deformation from SAR data



Remote Sens. **2023**

Climate Warming & Permafrost Unstability

Loss of Ice Cement Bonding

Rising temperatures melt interstitial ice, reducing shear strength in steep rock walls and glacial moraines.

Increased Rockfall Frequency

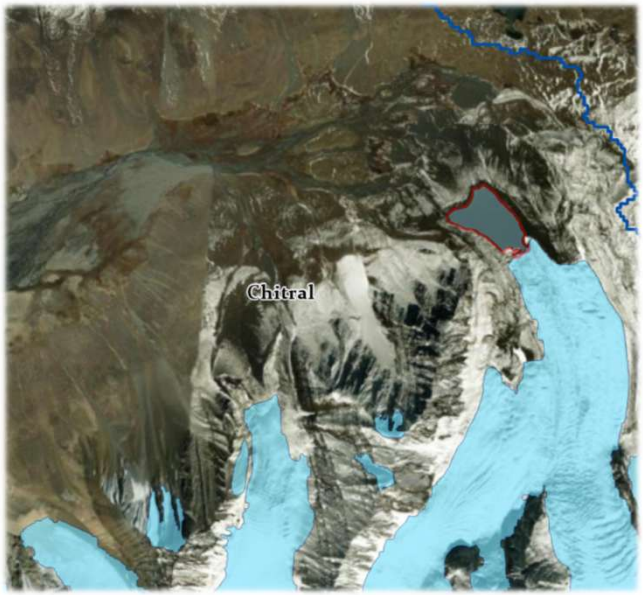
Deepening active thaw layers trigger large-scale rock avalanches and accelerated creep in rock glaciers.

Cascading Downstream Threats

Landslides impacting proglacial lakes generate displacement waves, breaching moraine dams.

Satellite Tracking of GLOF Dynamics

GLACIAL LAKE OUTBURST FLOODS



Proglacial Lake Expansion

Optical sensors track rapid lake surface area expansion driven by accelerated glacial meltwater input.

Moraine Dam Integrity Assessment

SAR interferometry detects structural seepage, piping erosion, and displacement across natural ice-core dams.

Downstream Flood Inundation Modeling

Digital Elevation Models (DEMs) simulate peak breach discharge paths to protect mountain communities.

DEFORMATION ANALYTICS

Millimeter Displacement Velocity

Multi-temporal InSAR calculates subtle ground motion along line-of-sight in rugged alpine slopes.

Seasonal Thaw Acceleration

Detects late-summer velocity spikes when active-layer thawing reaches maximum annual depth.

Pre-Failure Anomaly Warnings

Identifies non-linear acceleration patterns serving as precursors to massive slope collapse.

RAPID SATELLITE ASSESSMENT • AUGUST 2026

Surface Deformation Analysis: 2026 Rasuwa Glacier Collapse

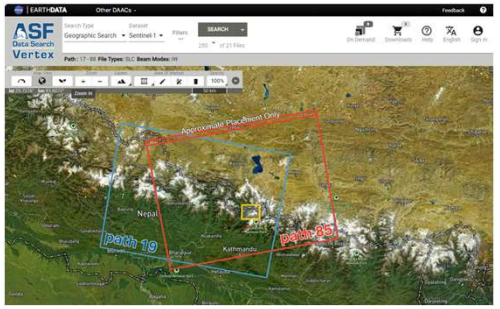
Multi-Temporal Sentinel-1 SAR Interferometry for Precursor Instability Detection over Langtang Lirung (Nepal–Tibet)

first results

AUTHORS
Claudia Collu, Marco Casu, Maria Teresa Melis

METHODOLOGY
Persistent Scatterer Interferometry (PSI / StaMPS)

Catastrophic Collapse Context & Sentinel-1 Data



THE EVENT (26 AUG 2026)

Tsampu Ri Ice-Rock Collapse

Triggered debris flow and flash floods along the Bhote Koshi–Trishuli river system across the Nepal–Tibet border.

25
Sentinel-1 SLC Images

5 Mo.
Spring–Summer 2026 Window

DUAL-ORBIT GEOMETRY

- **13 Descending:** Path 19, Frame 497
- **12 Ascending:** Path 85, Frame 88

PROCESSING WORKFLOW

1. **snap2stamps Integration**
   Automated burst splitting and interferogram generation.
2. **StaMPS PSI Processing**
   Phase noise evaluation, PS selection, and unwrapping.
3. **Atmospheric Corrections**
   TRAIN toolbox application for tropospheric mitigation.

Ascending Orbit Results (Path 85)

CRITICAL OBSERVATION

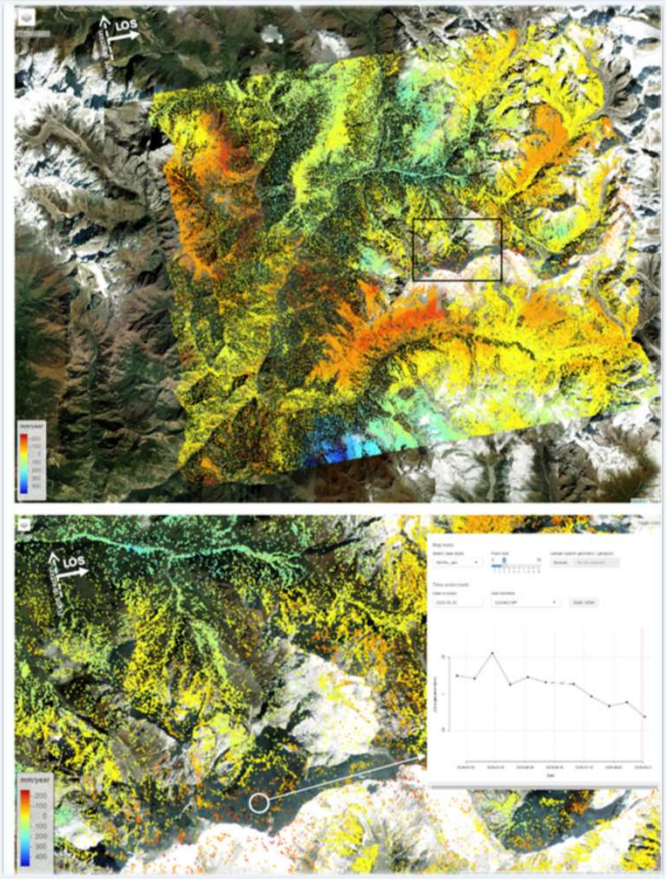
Precursor Displacement Trend

Ascending LOS velocities reveal localized line-of-sight movement near the collapse source on the northern slope.

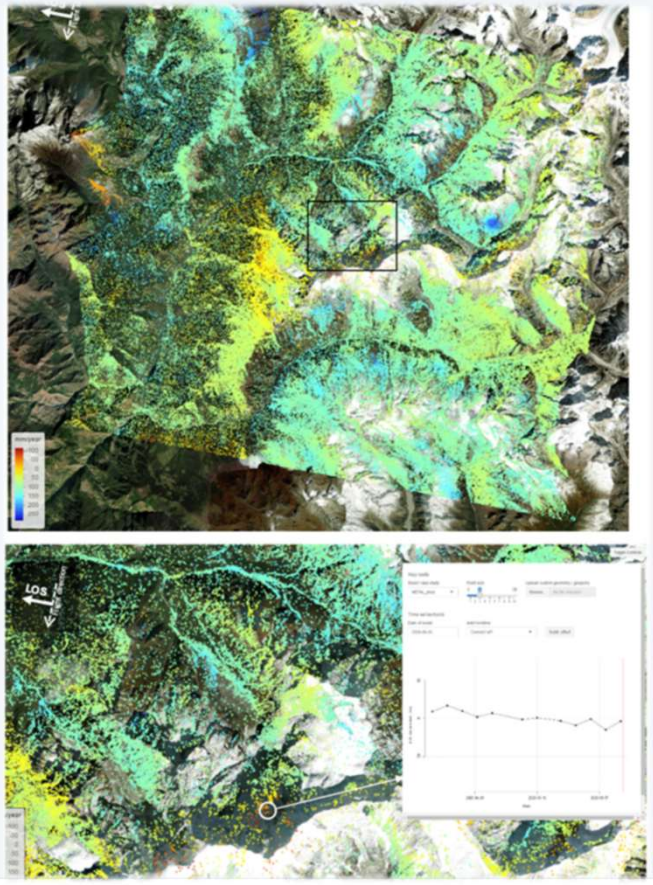
TIME SERIES METRICS

Period: Apr 2026 – Aug 2026

Trend: Steady acceleration prior to the 26 August failure event.



Descending Orbit Results (Path 19)



COMPLEMENTARY VIEW

Geometry & Slope Aspect

Descending acquisition geometry provides cross-validation of ground point stability and motion along opposite LOS directions.

KEY TAKEAWAYS

Coherence: High temporal coherence maintained during snow-free months.

Validation: Confirms regional slope stability baseline surrounding the active failure zone.

Key Findings & Future Directives

01 • RAPID SCREENING

Precursor Detection

Proven effective for rapid post-event assessments within 1–3 days to trace preparatory slope movements.

02 • CLIMATE ADAPTATION

Hazard Mitigation

Essential monitoring tool for accelerated glacier retreat and permafrost degradation in high Himalayas.

03 • FUTURE WORK

3D Decomposition

Combining ascending/ descending modes with in-situ data and numerical modeling for true 3D vector fields.

TERRITORIAL PLANNING INTEGRATION

PSI provides quantitative evidence **to prioritize critical zones** for early warning & land-use safety.

RISK MITIGATION STRATEGY

Integrated Cryosphere Risk Management Framework

Step 01

Baseline Mapping

Inventorying permafrost distribution and landslides and identifying high-risk glacial lakes globally.

Step 02

Continuous Monitoring

Combining InSAR time series with autonomous ground-based GNSS sensors.

Step 03

Early Warning Alerts

Automated triggers based on threshold displacement or sudden lake level changes.

Step 04

Adaptation Planning

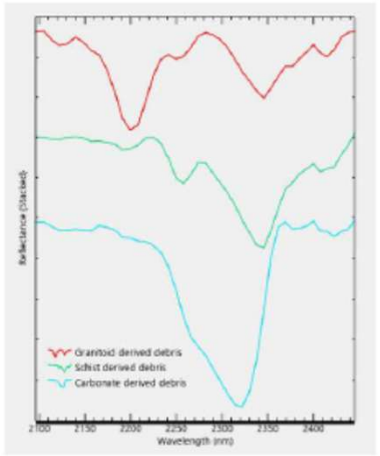
Informing valley zoning, infrastructure relocation, and protective engineering.

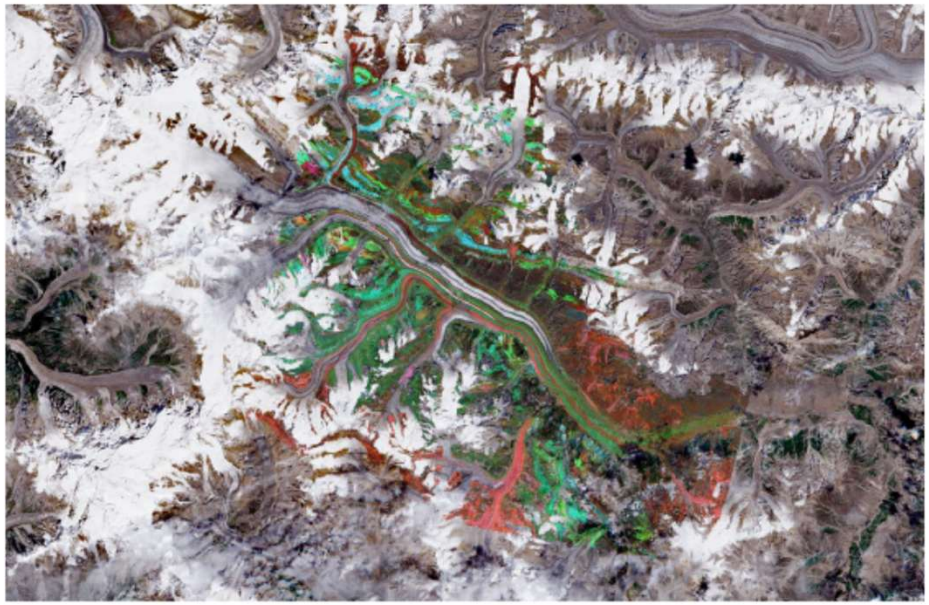
Spantik lab: Chogolungma

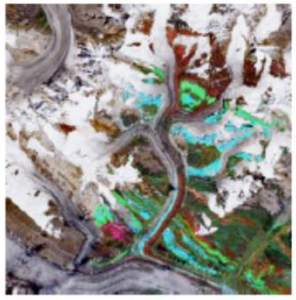
Mineralogical mapping of supraglacial debris

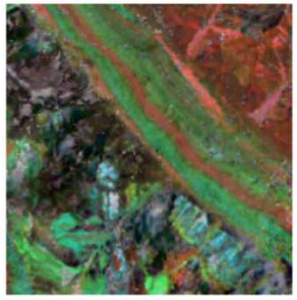
- Identification and **spatial delineation** of debris flows' **unique mineralogical signatures (granitoids, schists, carbonate rocks)**
- Discrimination of **debris provenance** zones, linking surface flows to specific source lithologies in the surrounding catchment
- Characterization of **debris mixing** and **flow evolution patterns** along the glacier tongue
- Production of **mineralogical maps** usable as input layers for describing debris-covered glacier flows





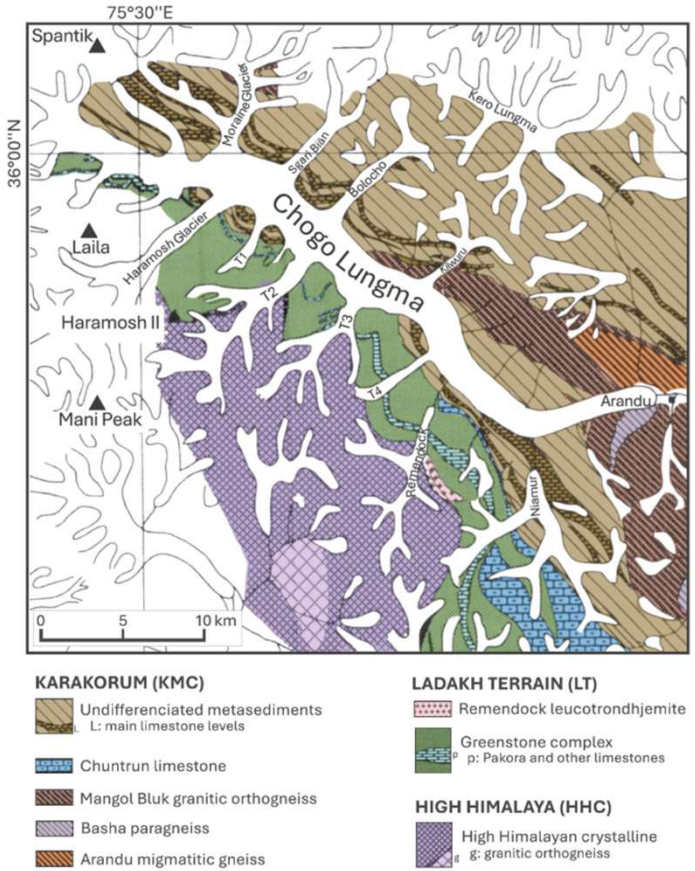








First results



KARAKORUM (KMC)

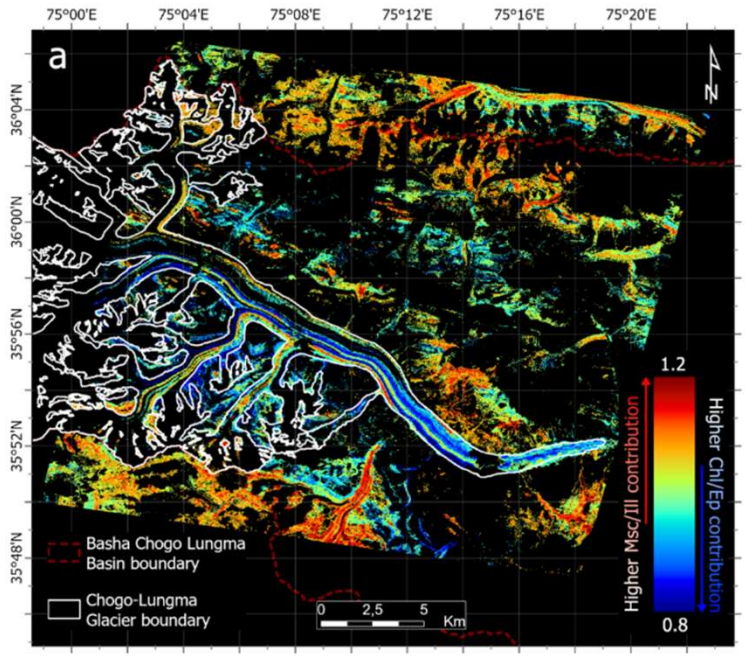
- Undifferenciated metasediments (L: main limestone levels)
- Chuntrun limestone
- Mangol Bluk granitic orthogneiss
- Basha paragneiss
- Arandu migmatitic gneiss

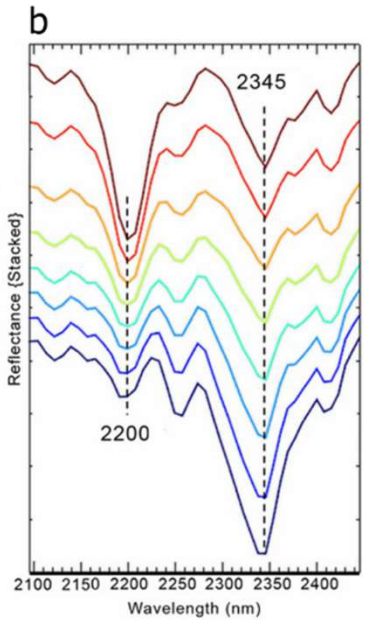
LADAKH TERRAIN (LT)

- Remendock leucotrondhjemite
- Greenstone complex (p: Pakora and other limestones)

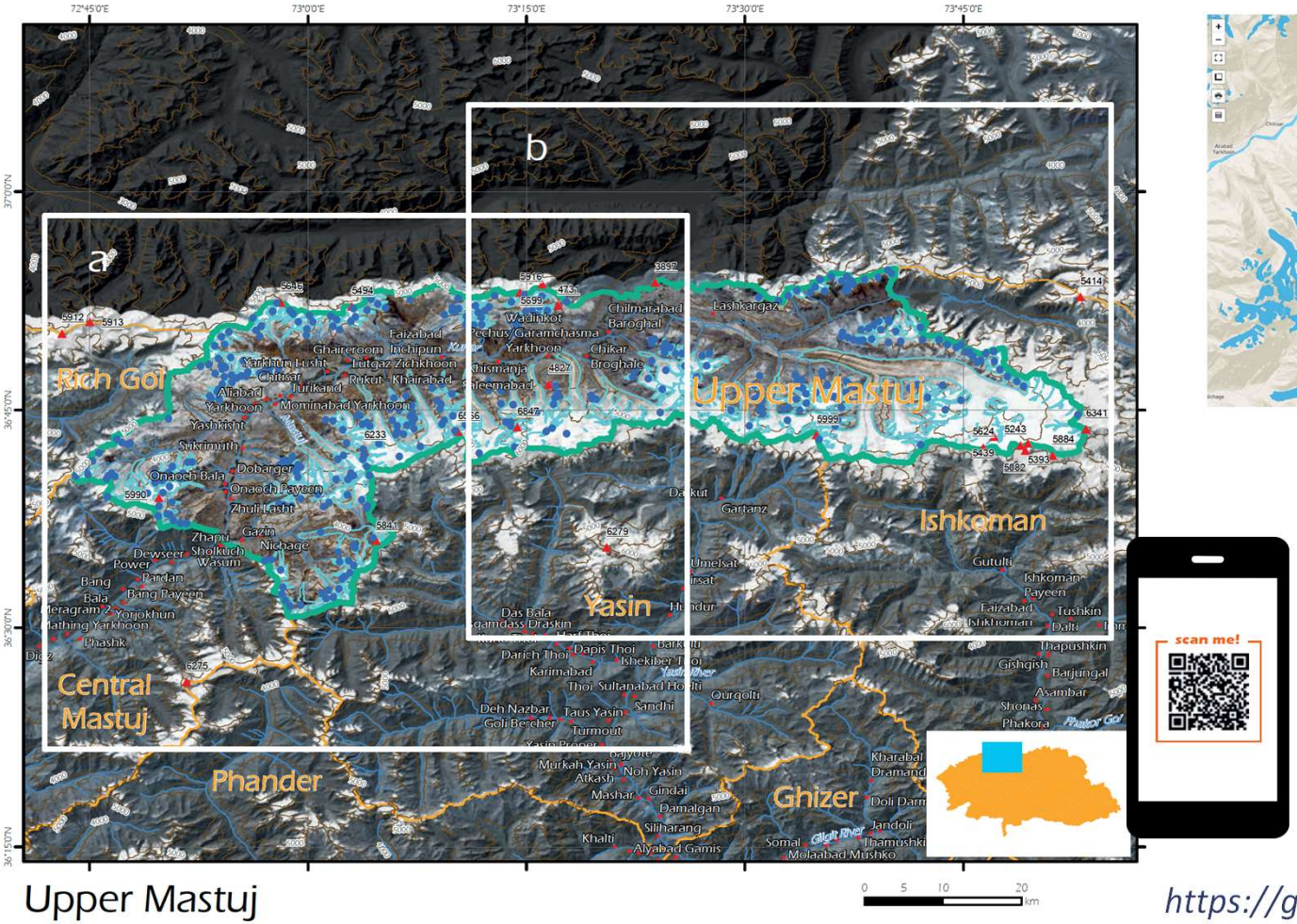
HIGH HIMALAYA (HHC)

- High Himalayan crystalline (g: granitic orthogneiss)





Glaciers Inventory



Upper Mastuj



Geoportal

Info

1 Pag 1 di 4 4

gn:glaciers

glacier_id: B17G263

latitude: 36.73183143

longitude: 73.19555565

name: Kotalkash

area: 26416763.339

min_ele: 3534

max_ele: 6666

range_ele: 3132

mean_ele: 5100.12

median_ele: 5127

mean_slope: 21.43

mean_asp: 10.35

asp_sector: N

https://geoportal.mountaingenius.org/portal/

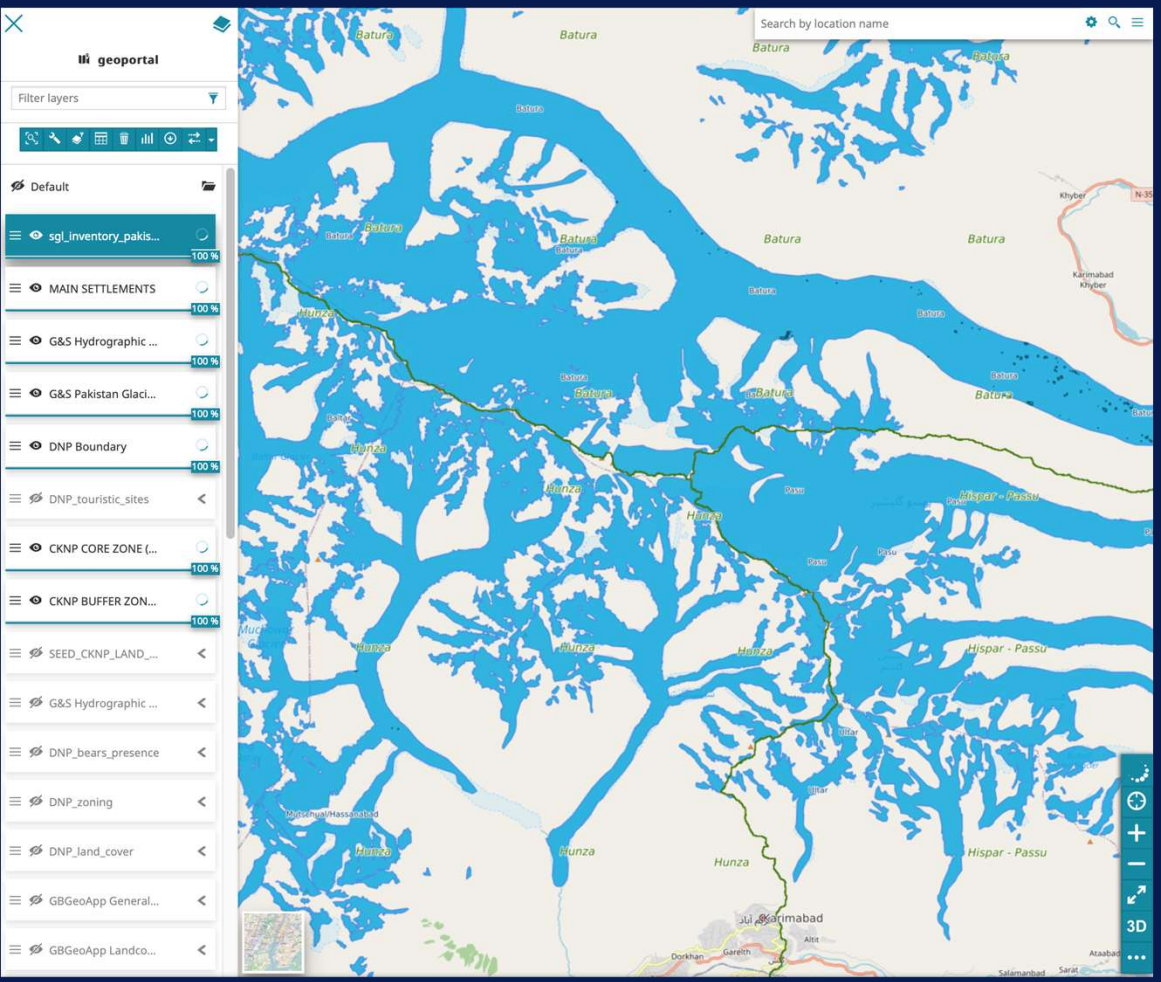
EvK2 Geoportal

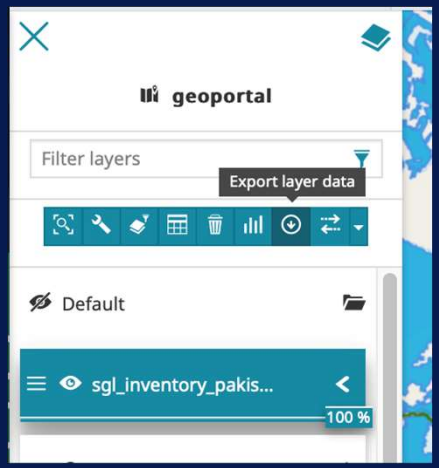


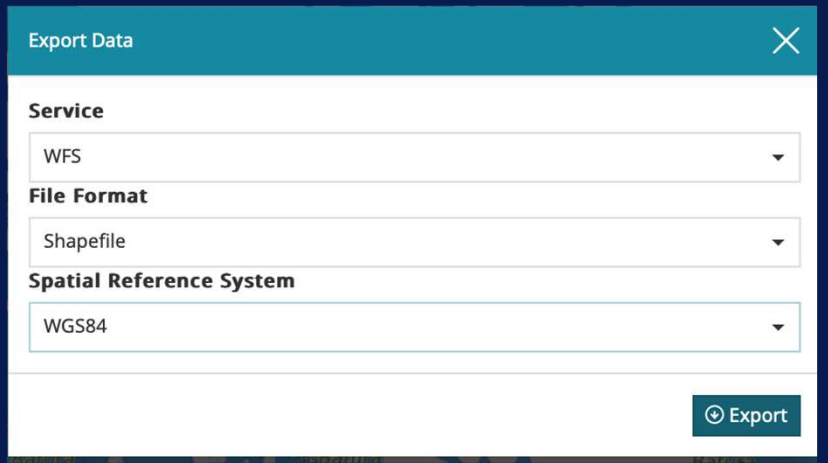
https://geoportal.mountaingenius.org/portal/

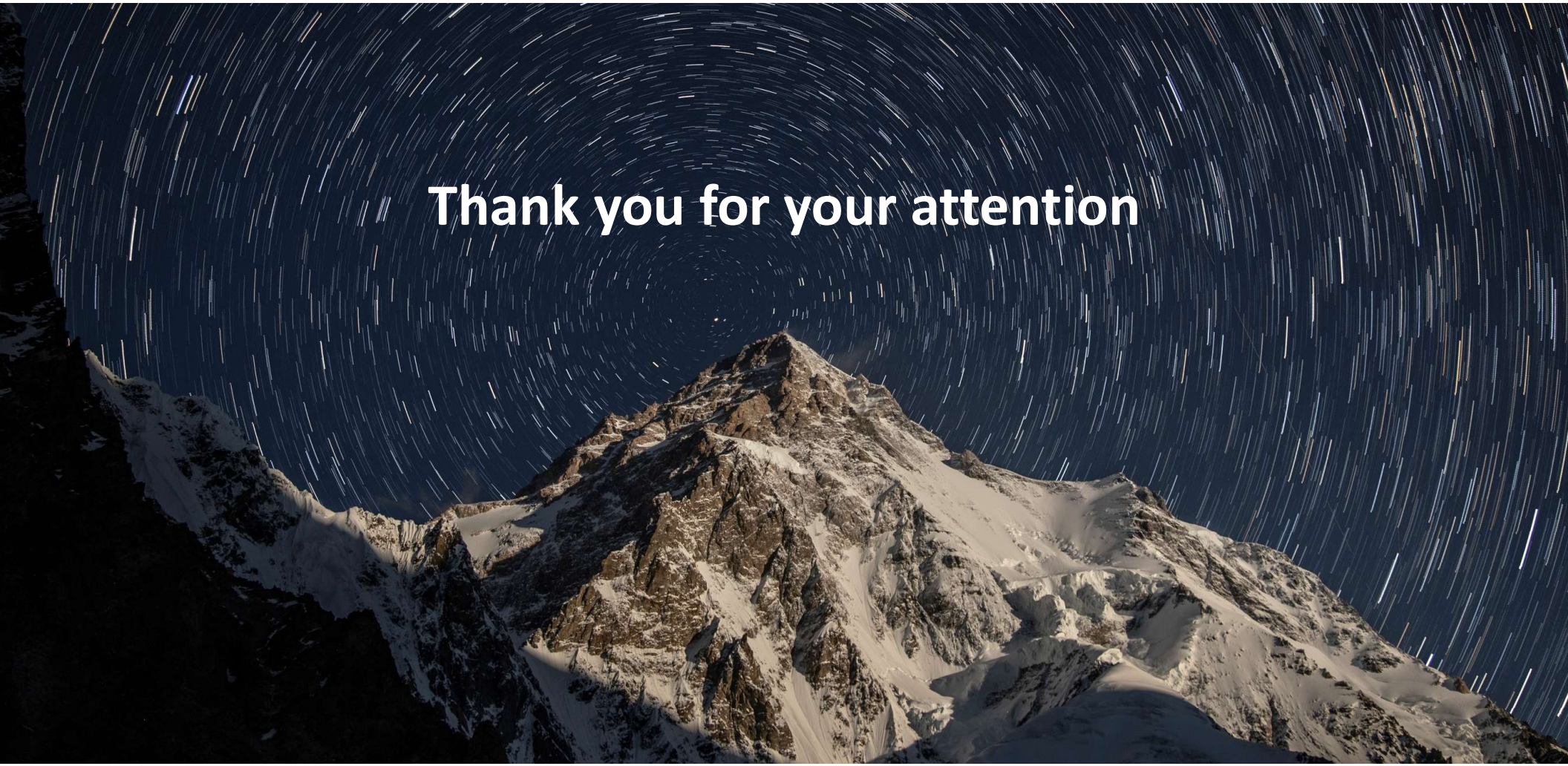
Raw data are available only for Pakistan offices.
Validated data are open to all interested users

EVK2 Geoportal









UNIVERSITÀ DEGLI STUDI DI MILANO

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

Ministero degli Affari Esteri e della Cooperazione Internazionale

EvK2CNR