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TAKING THE PULSE OF OUR PLANET FROM SPACE

Monitoring the alpine cryosphere parameters by exploiting PRISMA hyperspectral imagery

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Introduction

Here we present the main concept of the project SCIA financed by the Italian Space Agency.

The main goal of SCIA project is the development and optimization of methods for the generation of products related to the cryosphere.

The project is based on the exploitation of **PRISMA hyperspectral** data for the estimation of **snow and glacier parameters in Alpine areas**, through the combined use of satellite images, in situ data and radiative transfer models.

The project is led by Eurac Research and includes the following partners:

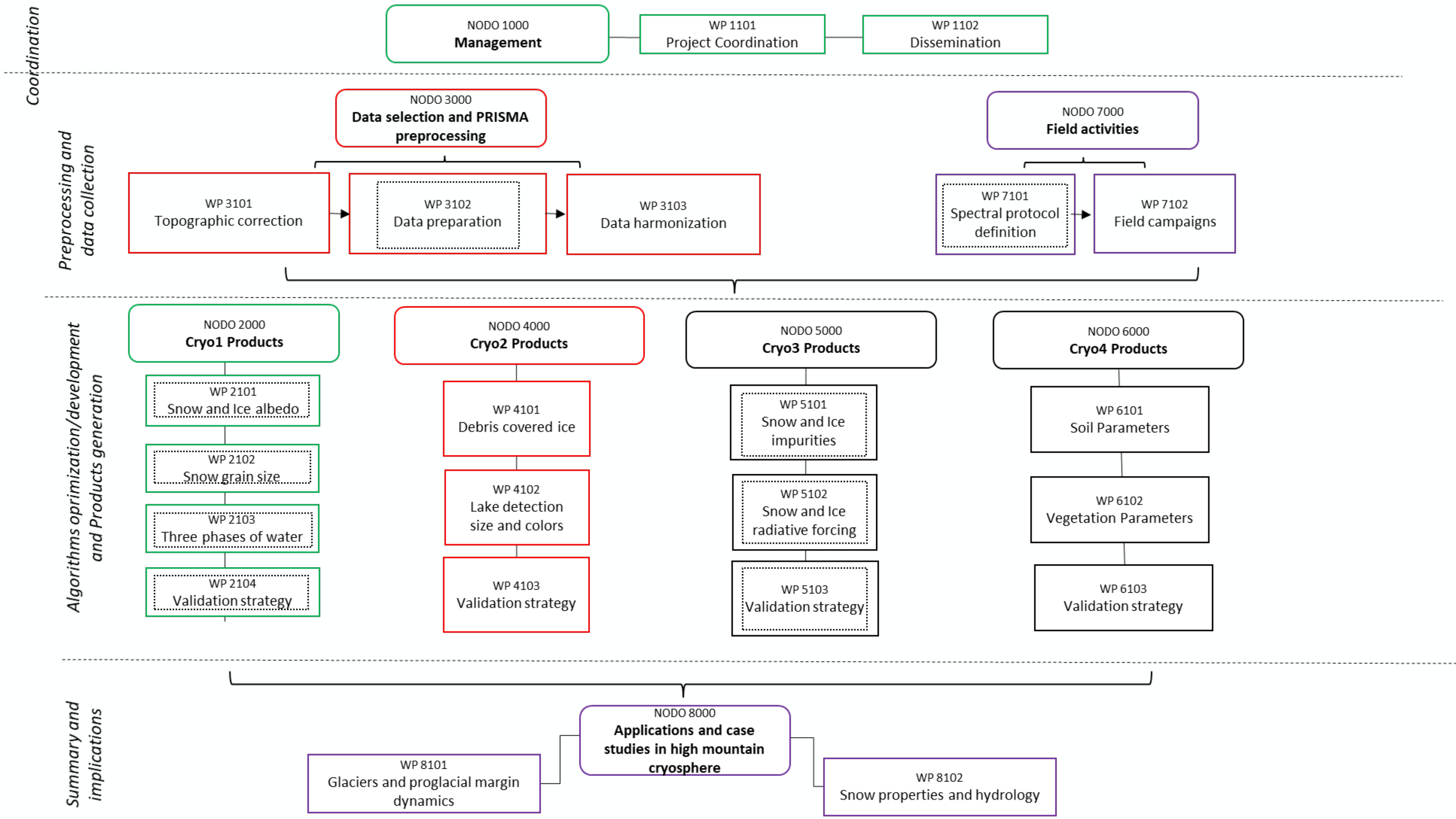
- University of Milano Bicocca (IT)
- CNR National Research Council – IREA (IT)
- Arpa Valle D'Aosta (IT)
- University of California, Los Angeles (UCLA) (USA)

Project workflow

Phase 1: Preprocessing

Phase 2: Algorithm development and validation

Phase 3: Use cases based on the developed products



Test sites

Site 1: Torgnon (Valle d'Aosta, IT)

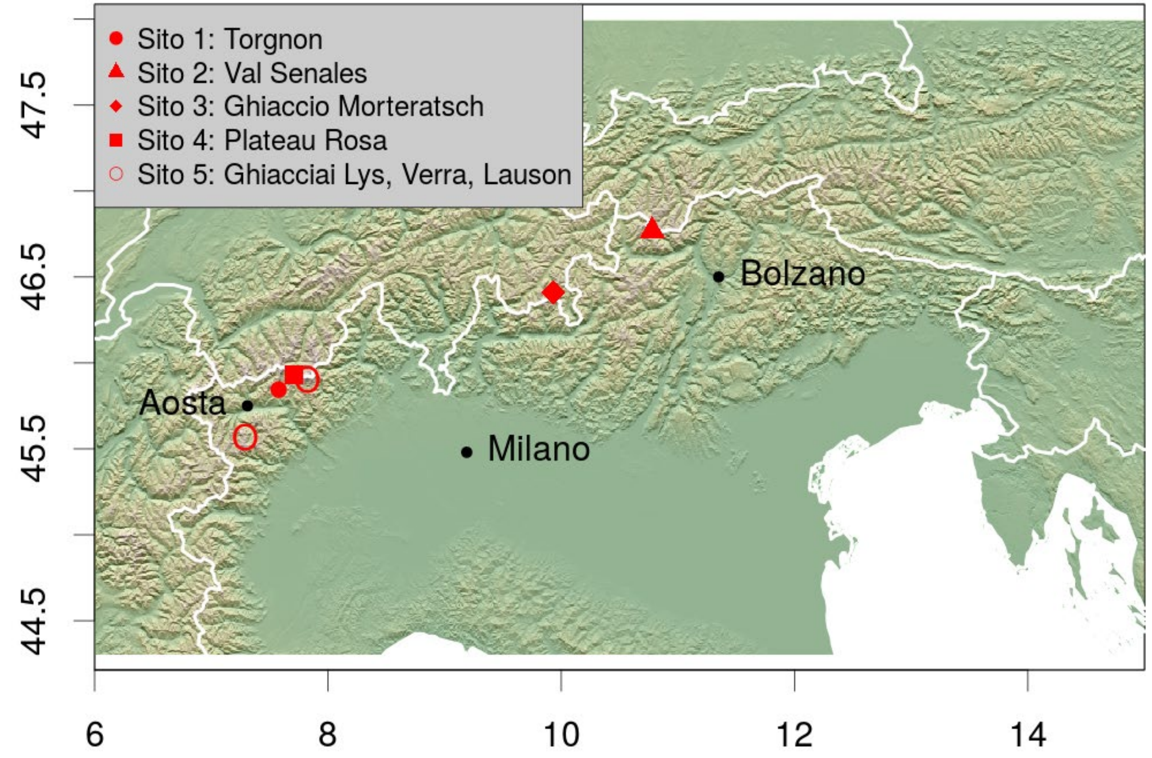
Site 2: Val Senales/Schnalstal (Alto Adige/Südtirol, IT)

Site 3: Morteratsch Glacier (CH)

Site 4: Plateau Rosa glacier (Valle d'Aosta, IT)

Site 5: Glaciers and proglacial margins of Lauson, Lys and Verra Grande (Valle d'Aosta, IT)

Site 6: USA sites



In addition to the listed sites, two sites in the United States of particular interest to the American partner will also be investigated, and three backup sites (in India and Canada) will be identified where there are active collaborations and possibilities for ground-based measurements.

Site	Latitude	Longitude	Elevation (m)
Mammoth/Sherwin, CA USA	**37.627188**	**-118.971337**	**2400**
Senator Beck Basin, CO USA	**37.906890**	**-107.726272**	**3722**
Dhundi, India	*32.355223*	*+77.126187*	*2900*
Fortress Mountain, AB Canada	*50.824220*	*-115.199752*	*2060*
Clavet, SK Canada	*51.991734*	*-106.375376*	*524*

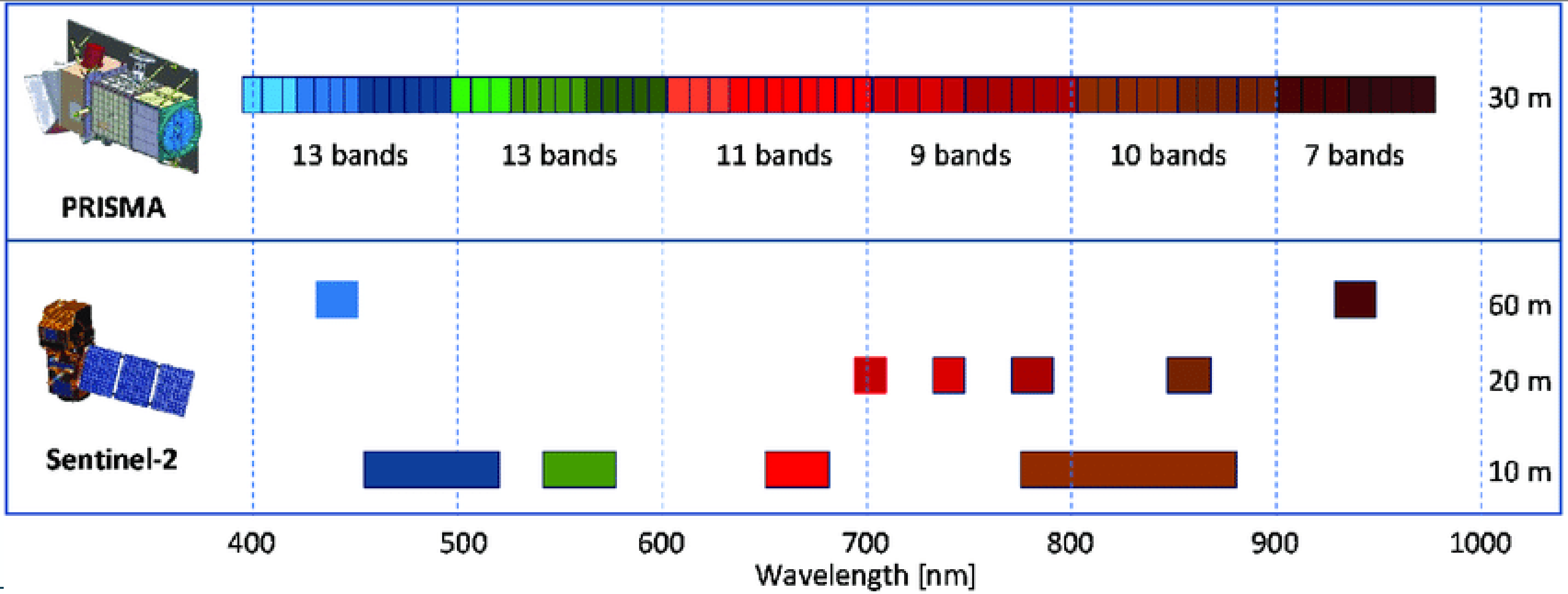
Satellite imagery

Data type	Acquisition period	Area investigated	Spatial resolution	Temporal resolution
PRISMA	2021-2023 Winter - summer period depending on products (e.g., winter for snow, summer for ice and proglacial margins)	All areas (at least one L1A image per test area)	30 m x 30 m 5 m x 5 m (PAN), depending on the product type	No constraints
CosmoSkyMed	2021-2023 winter and spring period	Torgnon	Resampled data to increase SNR	time series as dense as possible
Sentinel 1	2021-2023 winter and spring period	All areas	Data resampled to PRISMA resolution (30m x 30m)	6 days

PRISMA main characteristics

Sensor	Spatial Resolution (m)	Number of Bands	Swath (km)	Spectral Range (nm)	Spectral Resolution	Launch
Hyperion, EO-1 (USA)	30	196	7.5	427–2395	10	2000
CHRIS, PROBA (ESA)	25	19	17.5	200–1050	1.25–11	2001
HyspIRI VSWIR (USA)	60	210	145	380–2500	10	2020
EnMAP HSI (Germany)	30	200	30	420–1030	5–10	Not launched yet
TianGong-1 (China)	10 (VNIR) 20 (SWIR)	128	10	400–2500	10 (VNIR) 23 (SWIR)	2011
HISUI (Japan)	30	185	30	400–2500	10 (VNIR) 12.5 (SWIR)	2019
SHALOM (Italy–Israel)	10	275	30	400–2500	10	2021
HypXIM (France)	8	210	145–600	400–2500	10	2022
PRISMA (Italy	30	240	30	400–2500	10	2019

(Vangi et al., 2021)



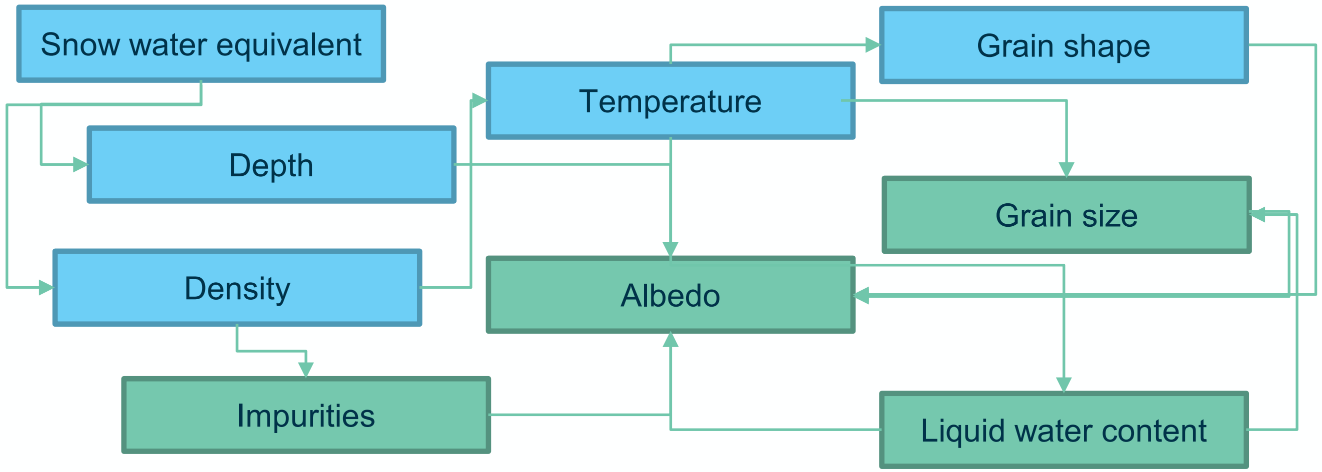
Phase 1: Preprocessing

This initial phase involves the **PRISMA data processing** to prepare them for the subsequent phases of algorithm development and application.

- ***Topographic correction***: we plan to normalize data for the topographic effect by using accurate digital terrain models provided by the consortium partners. Some methods will be tested.
- ***Data preparation***: PRISMA hyperspectral data will be processed not only for topographic corrections, but also to ensure the input quality for information extraction processes and transfer models (bad pixels removal, cloud mask etc.).
- ***Data harmonization*:** the PRISMA data obtained, once corrected and pre-processed, will be managed and archived through a specific structured model based on file system and naming convention.

Phase 2: Snow parameters

- Snow and ice albedo
- Snow grain size
- Three water phases

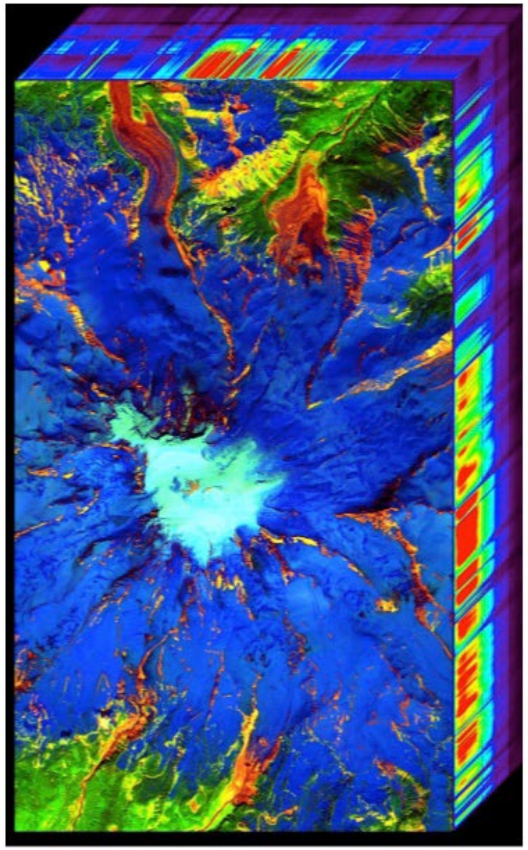


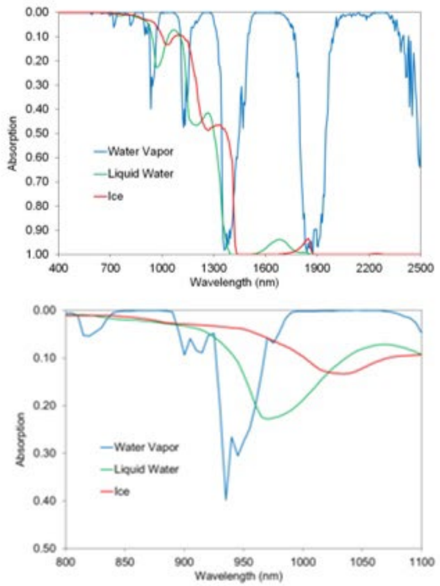
These three parameters are interrelated because:

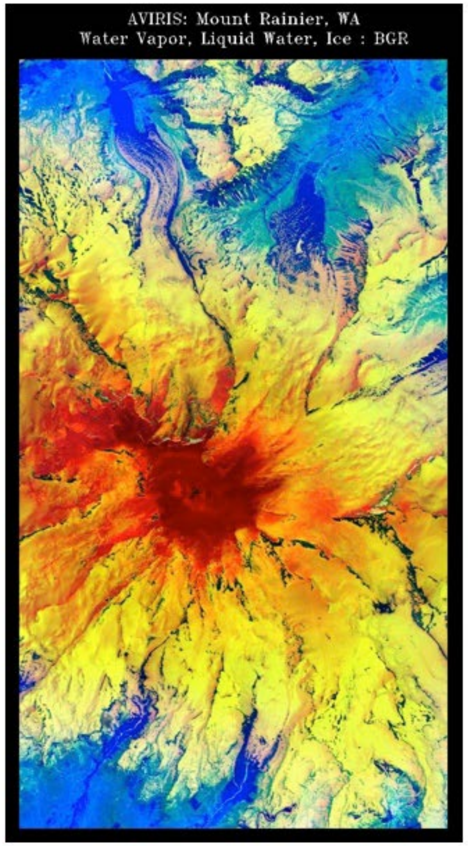
- **Albedo values** are affected by the **grain size** and, especially in the infrared part of the electromagnetic spectrum, they decrease as grain size increases.
- The introduction of liquid water into the snowpack leads to rapid changes in **grain shape**, grain fragmentation and **density increase**.

Further details on snow grain size/temperature interaction in the Poster 66955 / board 395 , Wed. 25 May 2022

Example







Snow and Ice map of Mount Rainier obtained with AVIRIS images (left)

Spectral signature of three phases of water in the region VNIR-SWIR (centre)

Map of the three phases of water (vapour in blue, luquid in green, solid in red). Melting snow is represented in yellow.(right) (Green et al., 2006)

Phase 2: Ice and lake parameters

- Debris covered ice
- Lake detection size and color

Debris covered ice: The correct mapping of glaciers also in their debris-covered parts has become of increasing importance. In this study, PRISMA data will be used to explore their potential to distinguish glacier debris coverage.

Lake detection size and color: PRISMA data will be used to explore the glacier-lake interaction, also making use of panchromatic data whose spatial resolution is a significant element to map glacial lakes and proglacial lakes.

Phase 2: Snow and ice impurities

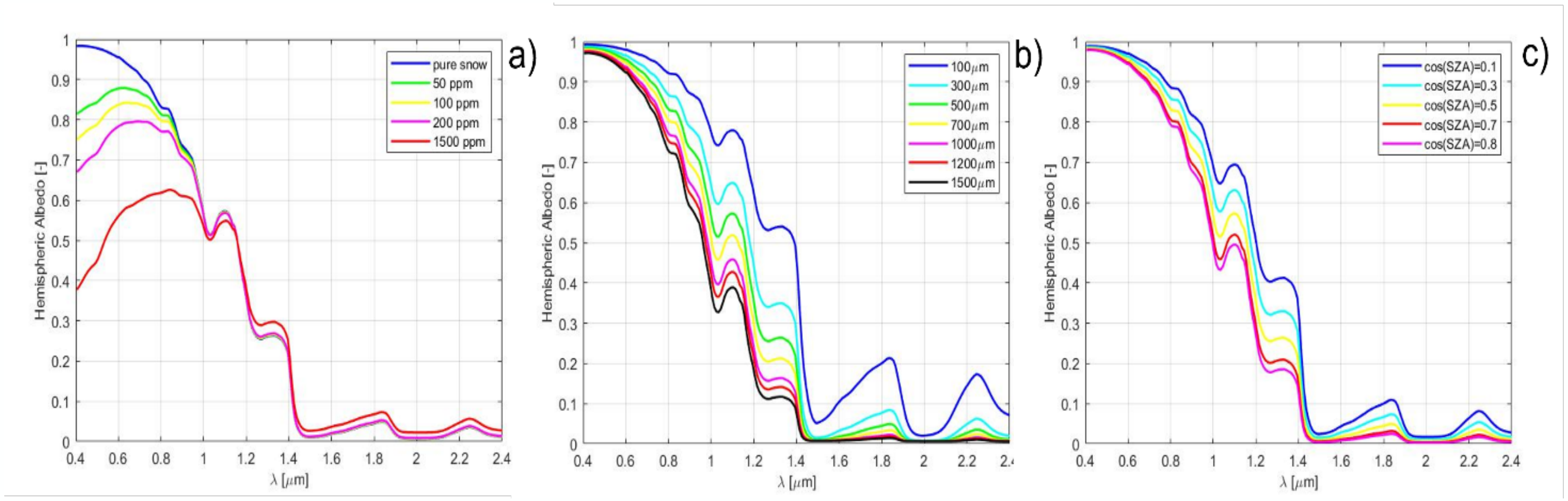
- Snow and ice impurities
- Snow and ice radiative forcing

The main objective of this part is to estimate the surface concentration of different types of impurities (organic and inorganic) by exploiting the spectral resolution of PRISMA.

Once the impurity concentration is obtained, the surface radiative forcing induced by the impurities will be estimated. This last variable is of fundamental importance for the development of new hydrological, glaciological and climate models that include the effect of impurities on the cryosphere dynamics.

Some preliminary results by dr. Di Mauro in the same session at 4.10 pm

Examples of signatures: SNICAR simulations



Simulated Spectral Hemispherical albedo for different Saharan dust concentrations, grain effective radius and for different SZA

Phase 2: Vegetation parameters

- Soil parameters
- Vegetation parameters

The main objective of this part is to investigate bio-geophysical parameters of the proglacial margins. These products will create the basis for future studies on the dynamics of habitats for high-altitude plant and animal species.

The investigated parameters of these ecosystems are represented by (i) texture and structure of detritus, (ii) soil organic material, (iii) fractional vegetation cover and (iv) identification of vegetation types. Both VNIR-SWIR hyperspectral measurements and the spatial component of the PAN channel will be used to estimate these parameters in combination with a series of field measurements collected in the selected test sites.

Phase 3: Use cases and cross-comparison

This phase aims at testing and evaluating the applicability of the products developed within the project in the context of case studies relating to the cryosphere in high mountains.

The potential use of the generated products for:

- creation of glacier cadasters;
- Glaciers and proglacial margin dynamics
- lake recognition in glacial areas;
- glacial melting modelling; snow hydrology modelling;
- comparison with products from other sensors e.g. wet snow maps from SAR (COSMO-SkyMed, Sentinel-1), over selected areas.

Conclusions

- The expected results of SCIA project are the development of processing methods and algorithms based on PRISMA hyperspectral data.
- The importance of PRISMA data for applications related to the cryosphere is very high as they will allow the development of highly innovative and unique products to help understanding cryosphere processes.
- The motivations of this project are connected to the context of global temperature variations, increasing anthropogenic activity and the risk of water and energy resources loss in the Alpine environment.

- The project is expected to start mid-2022