GEOKARTO 2024

5. – 6. SEPTEMBER 2024 | STARÁ LESNÁ

SENTINEL DATA IN HYDROLOGICAL RESEARCH OF SNOW COVER IN SMALL MOUNTAIN CATCHMENTS

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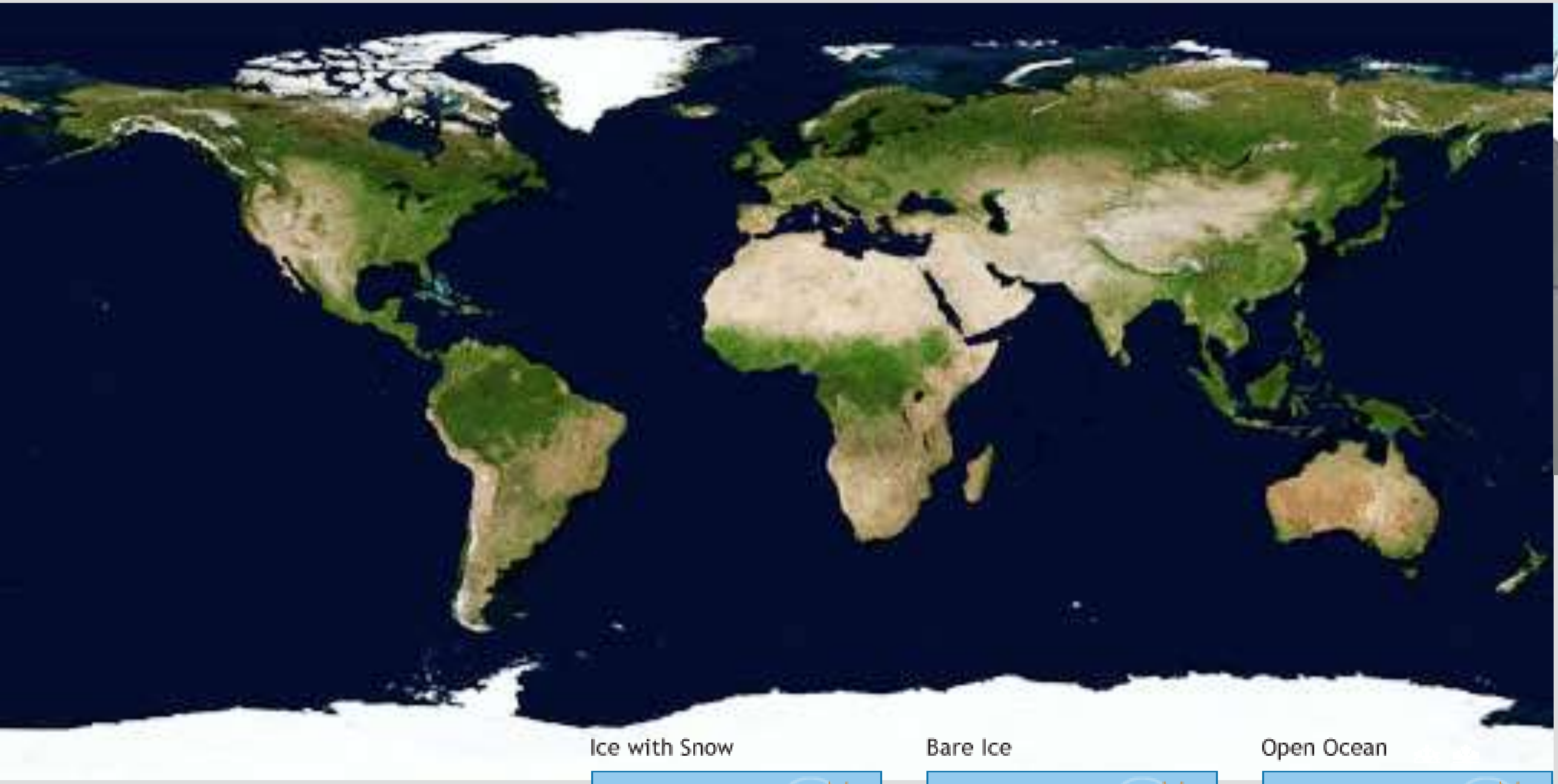
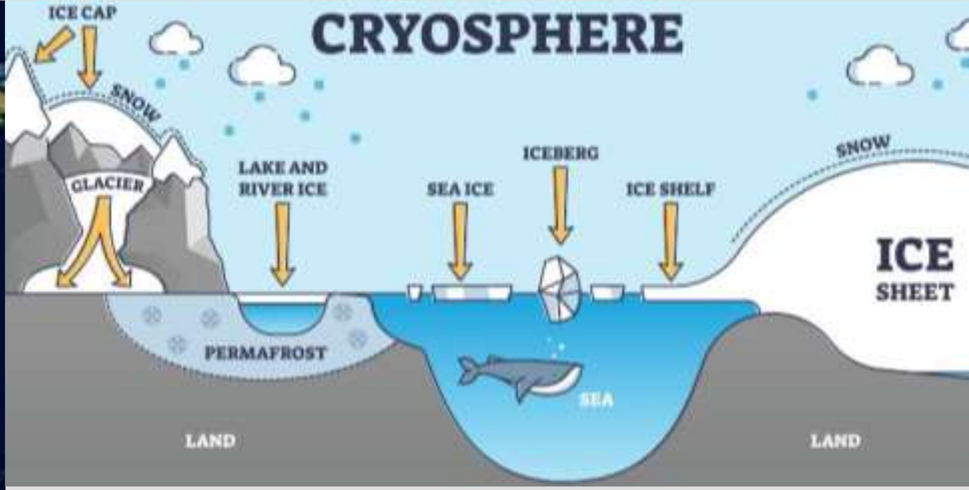
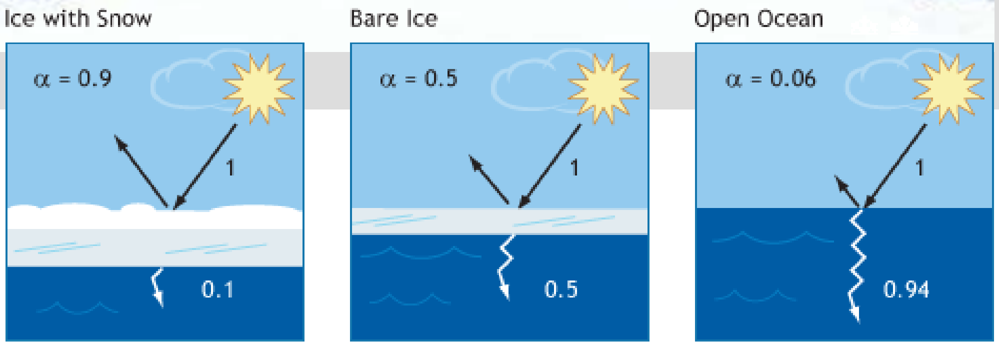
Cryosphere dynamics on Earth



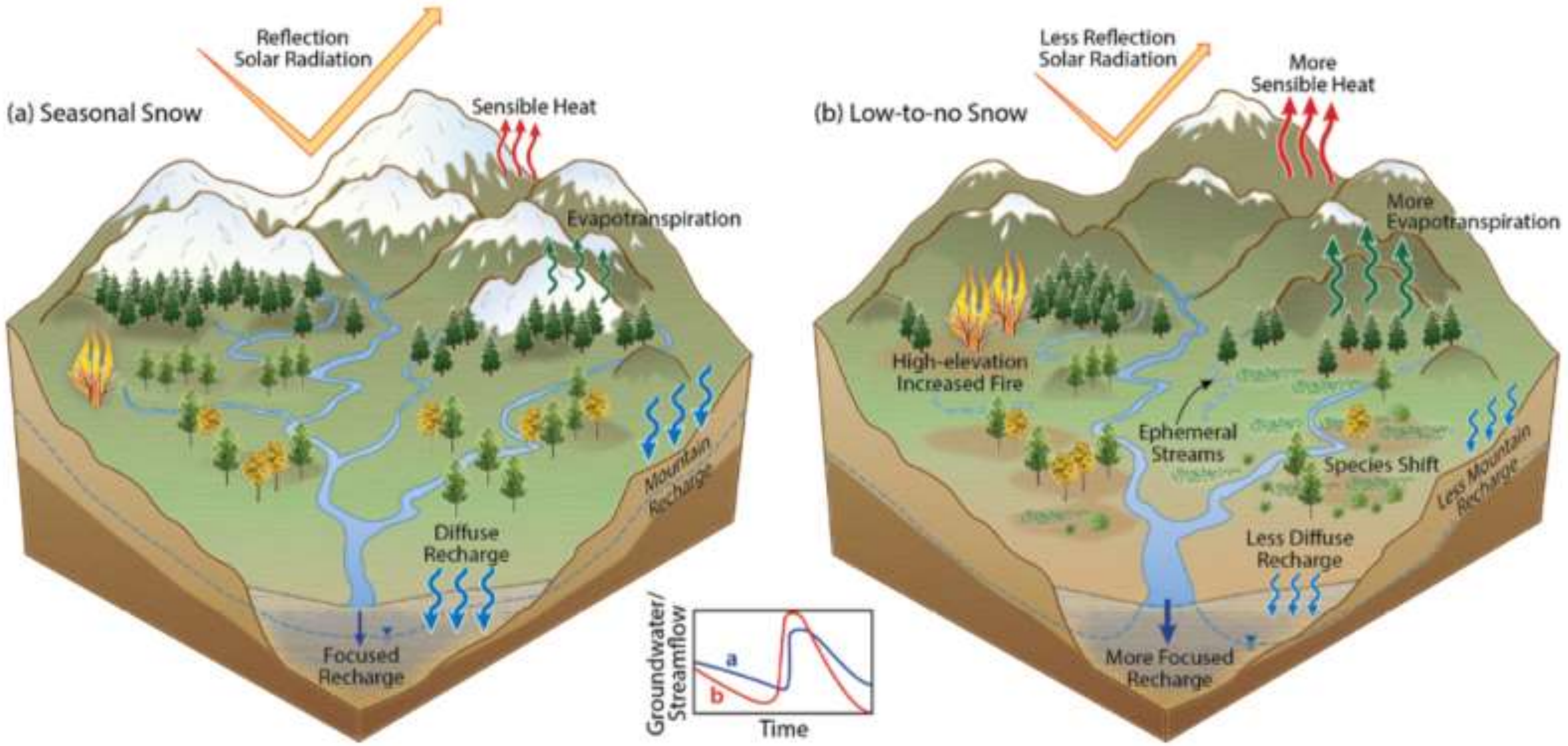


- key factor in hydrological cycle
- climate cooling and regulation
- surface energy fluxes
- water supply for ecosystems and people
- habitat and thermal regulation

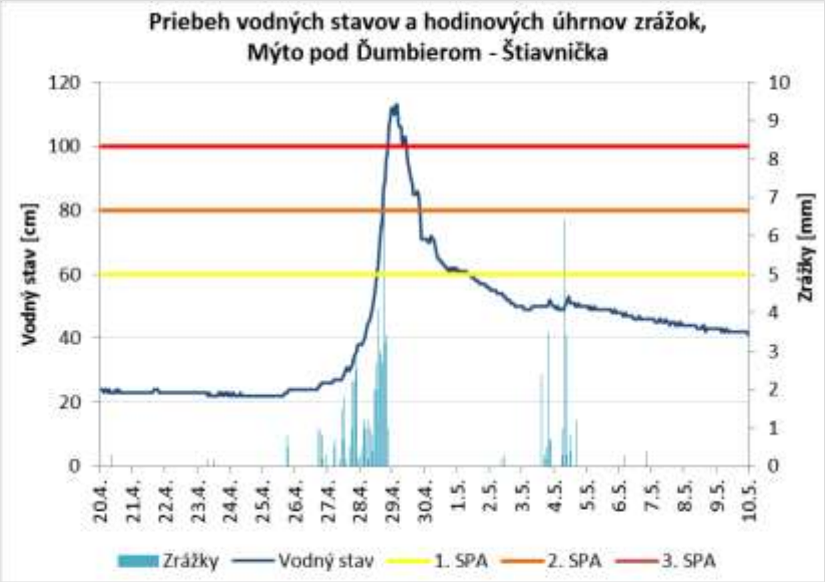
Albedo



Area of interest
Small mountain catchments



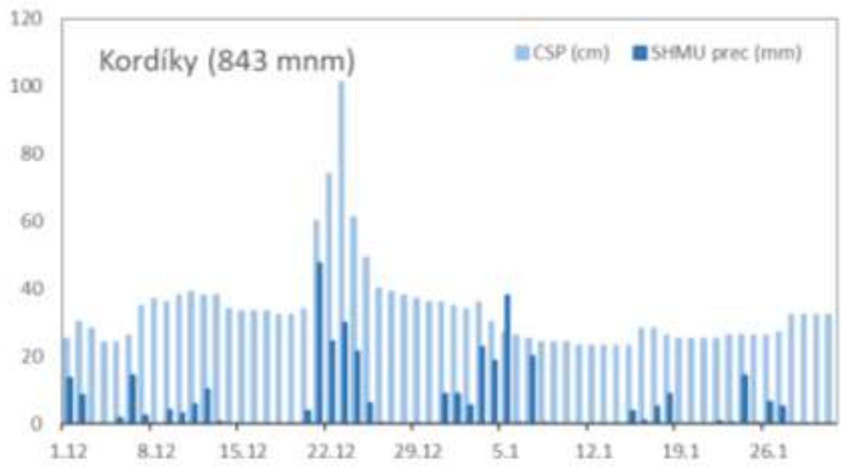
Basic spatial unit in hydrology, precipitation/runoff processes, station data, suitable size for combining methods (GIS analyses, field monitoring, modelling), elevation gradient, slope orientation, less variables, faster flow response...

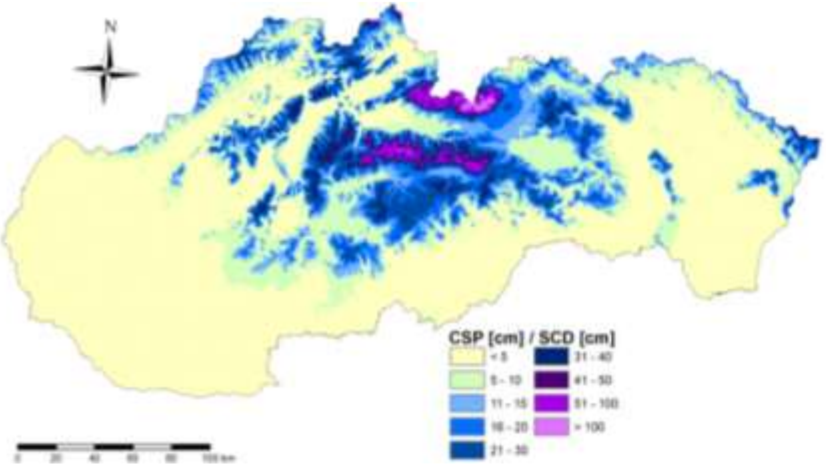


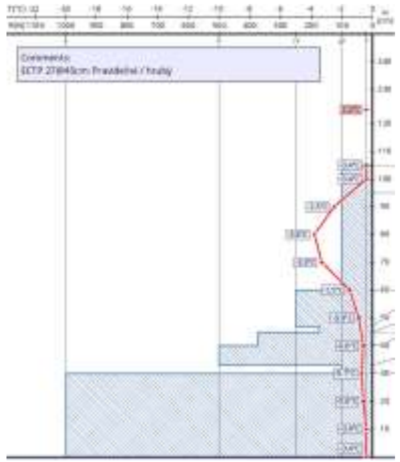
Mýto pod Ďumbierom - Štiavnička, 29.4.2017 ráno po kulminácii

SHMÚ (2017)

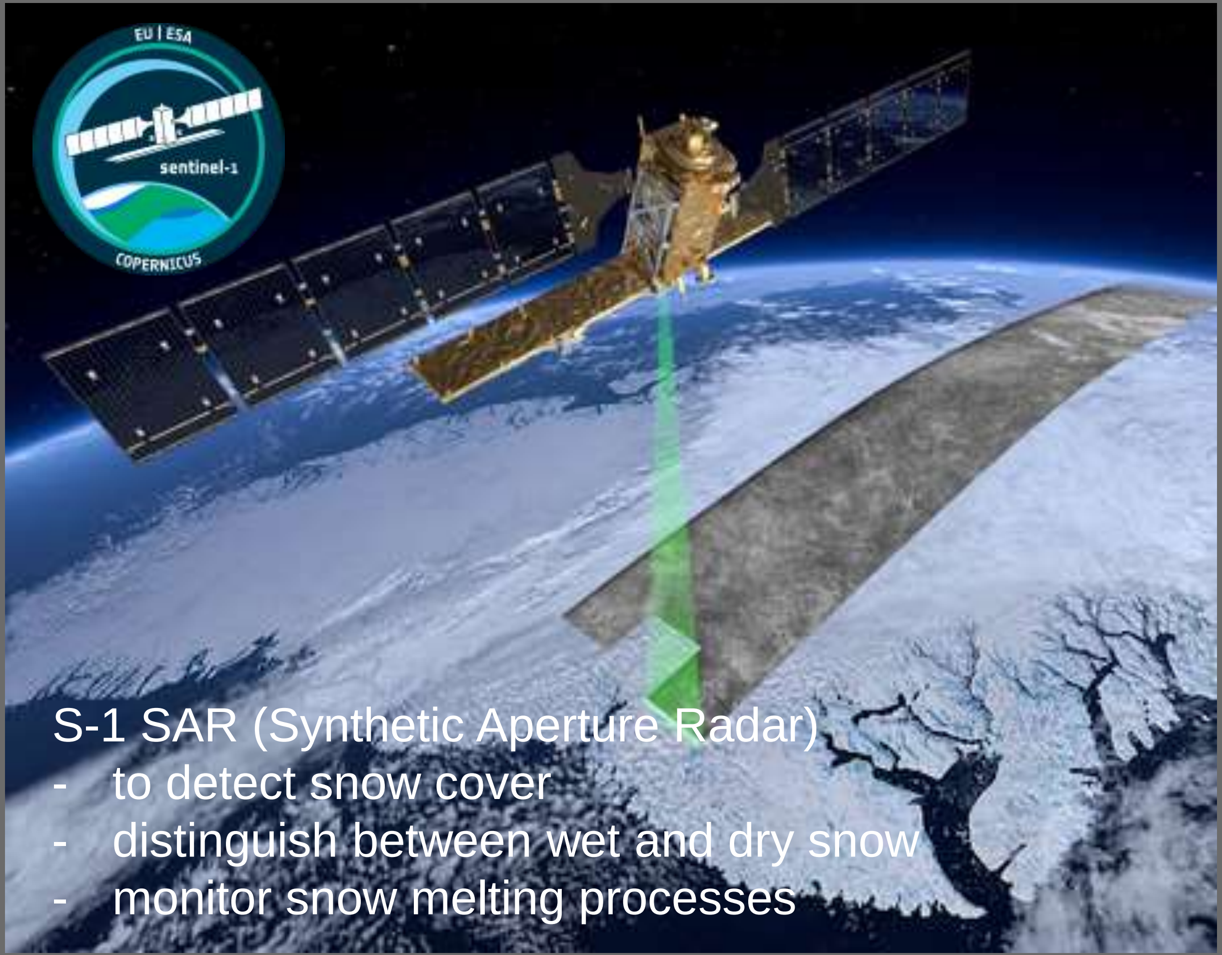
Snow monitoring in Slovakia



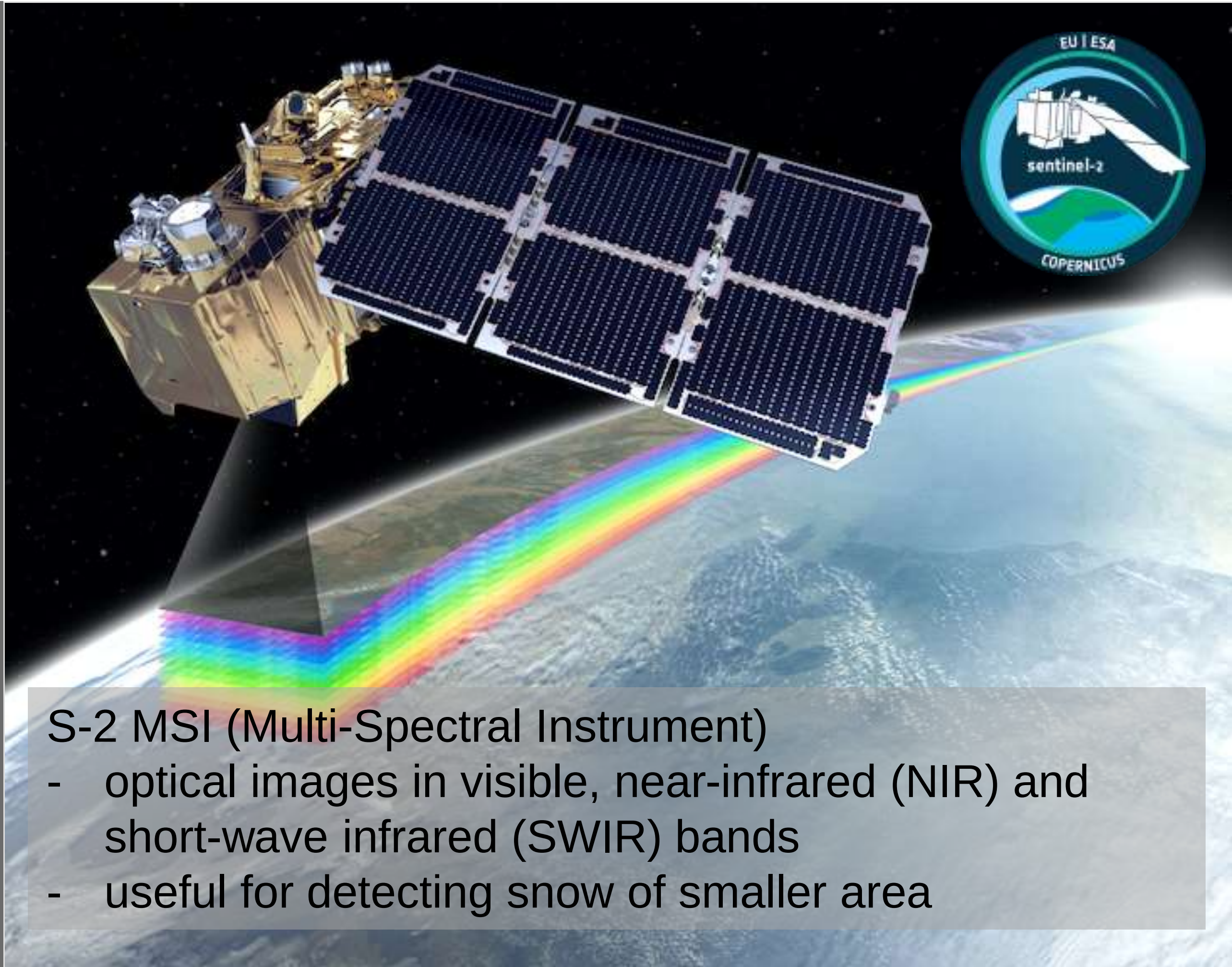




Sentinel 1 and Sentinel 2 missions
Satellite constellations used for snow mapping

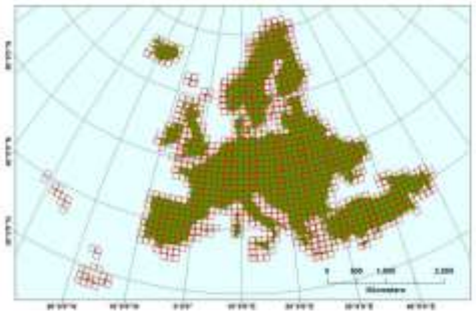


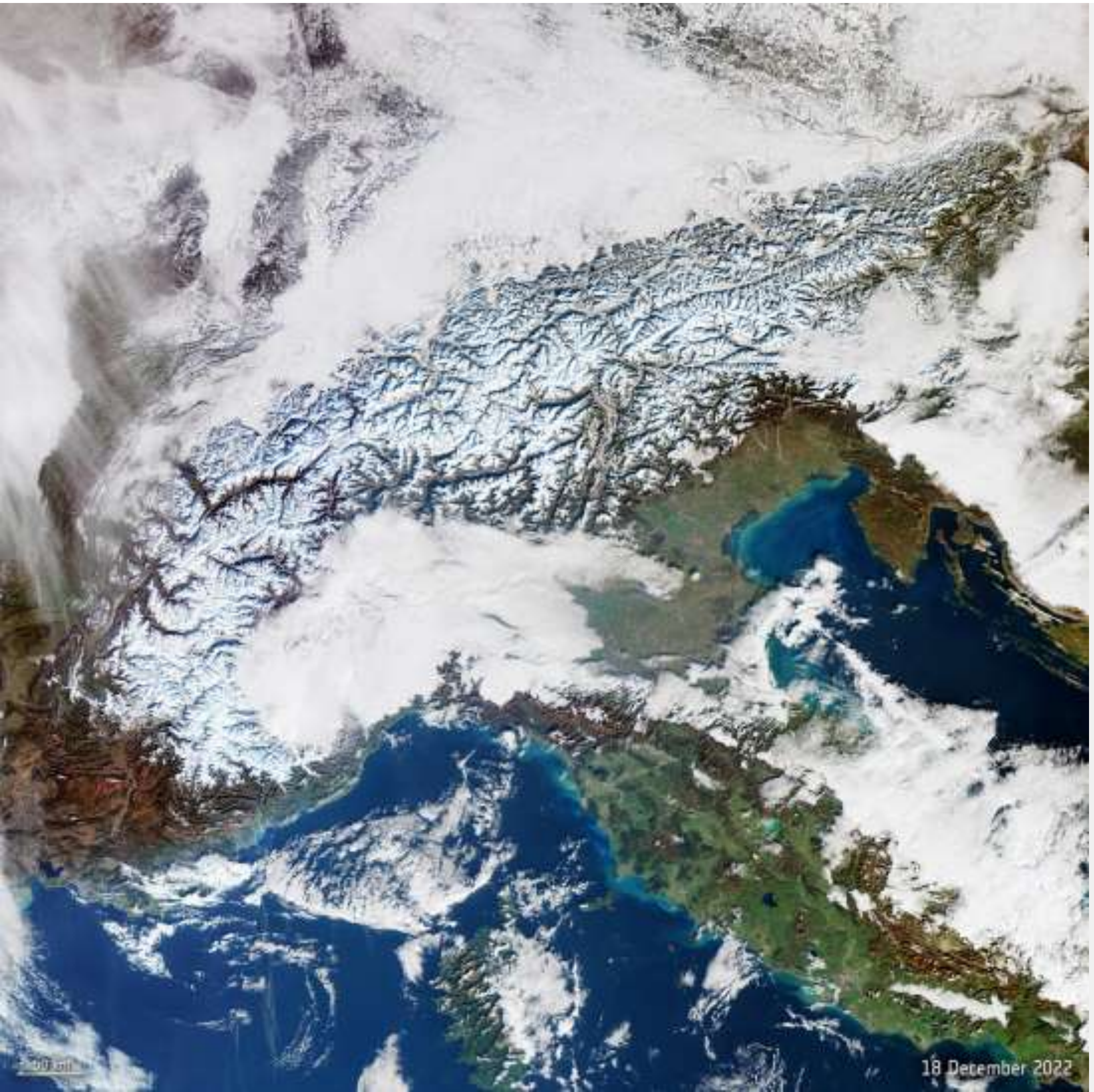
S-1 SAR (Synthetic Aperture Radar)
- to detect snow cover
- distinguish between wet and dry snow
- monitor snow melting processes



S-2 MSI (Multi-Spectral Instrument)
- optical images in visible, near-infrared (NIR) and short-wave infrared (SWIR) bands
- useful for detecting snow of smaller area

Snow products
Pan-European HR-S&I of the CLMS





SNOW COVER

- **Fractional Snow Cover (FSC)** product provides the snow fraction at the **Top of Canopy (FSCTOC)** and **On the Ground (FSCOG)**
- The daily cumulative **Gap-filled Fractional Snow Cover (GFSC)** - gap-filled FSC both at spatial and temporal scales.

SNOW STATE

- **Wet/Dry Snow (WDS)** product differentiates the snow state within the snow mask defined by the FSCTOC information.
- The **SAR Wet Snow (SWS)** product provides information on the wet snow extent in high-mountain areas.

AGGREGATED INFORMATION

- The **Persistent Snow Area (PSA)** is generated on a yearly basis from FSC products and provides the extent of persistent snow cover during the hydrological year.

NDSI - Normalised Difference Snow Index

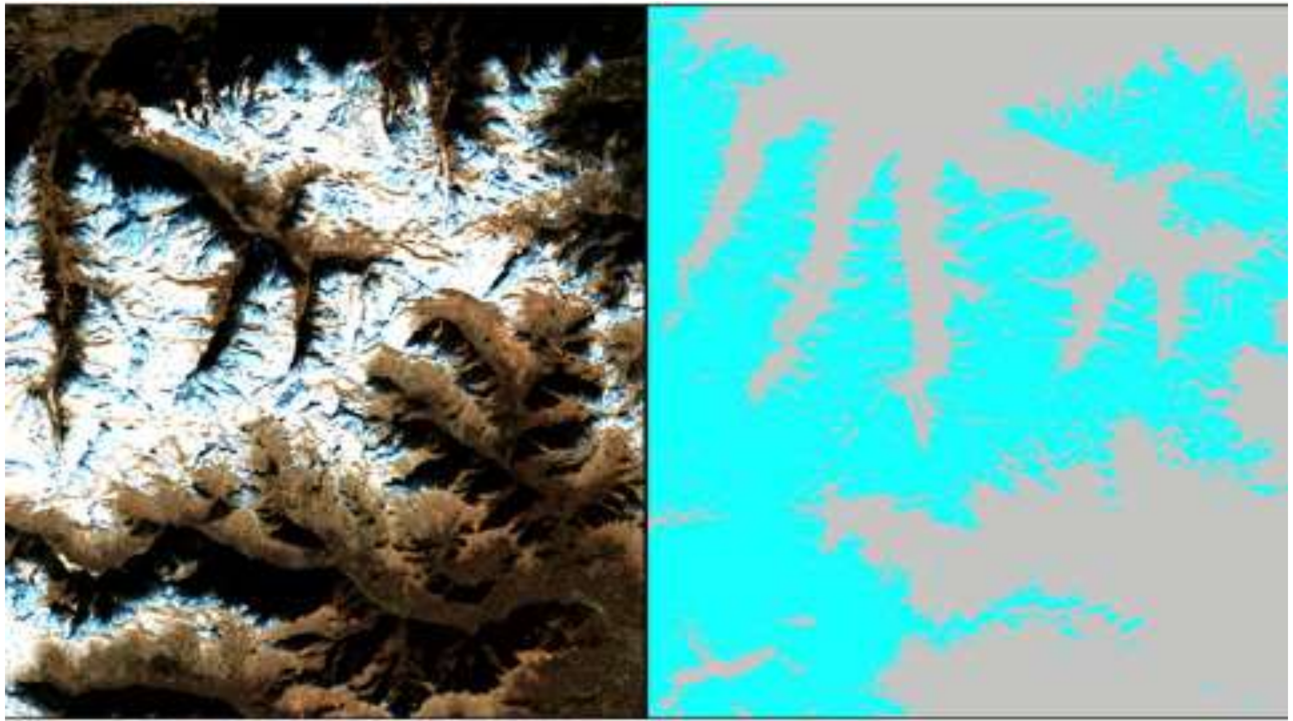
$$NDSI = \frac{B3 - B11}{B3 + B11}$$

$$NDSI = \frac{Green - SWIR}{Green + SWIR}$$

- Sentinel 2A, 2B
- Ratio of two spectral bands: VIR (B3) and SWIR (B11), values above 0.42 indicate snow
- Distinguishes between clouds and snow (snow absorbs SWIR, clouds reflect both bands of radiation)

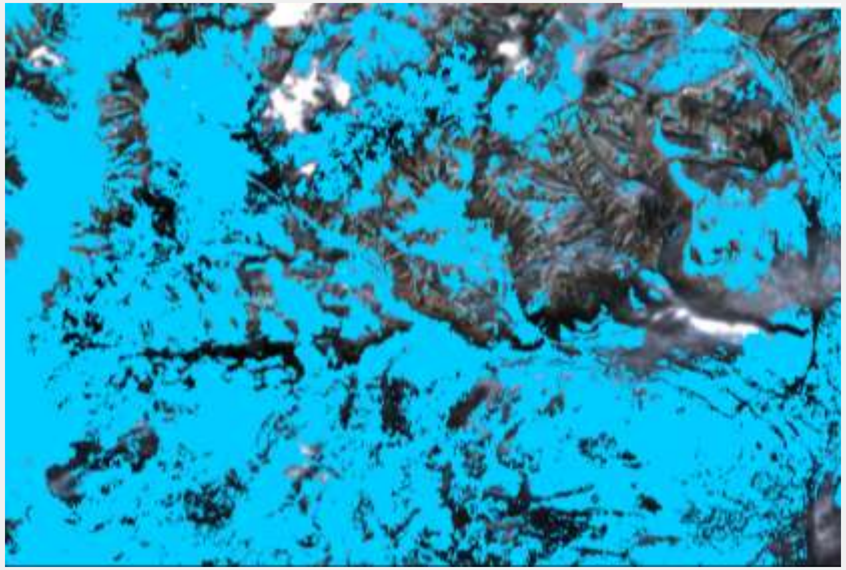
- < value 0.20 = pixels without snow
- 0.20 - 0.42 = pixels potential snow
- value ≥ 0.42 = pixels with snow

(ESA,2024)

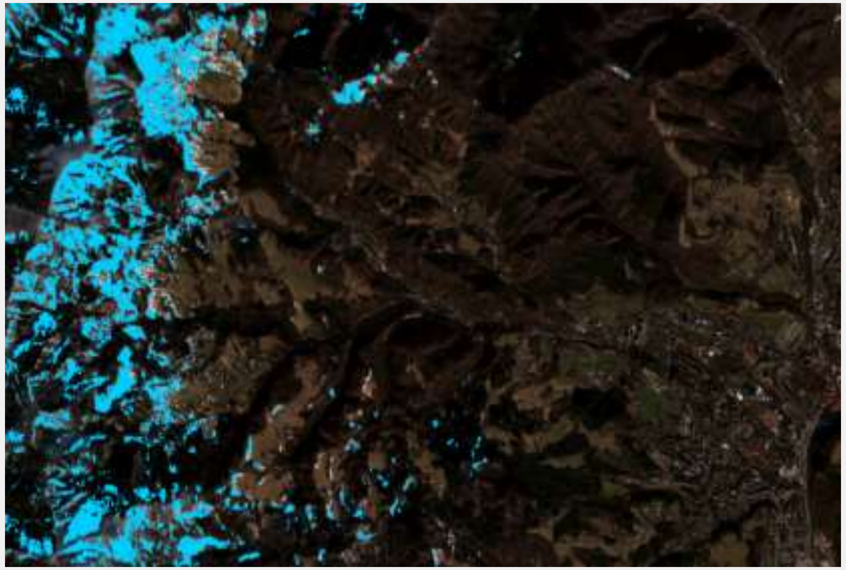


Gran Paradiso National Park, ESA 2024

Case study 1: Tajovský brook catchment, Kremnické hills –TC&NSDI



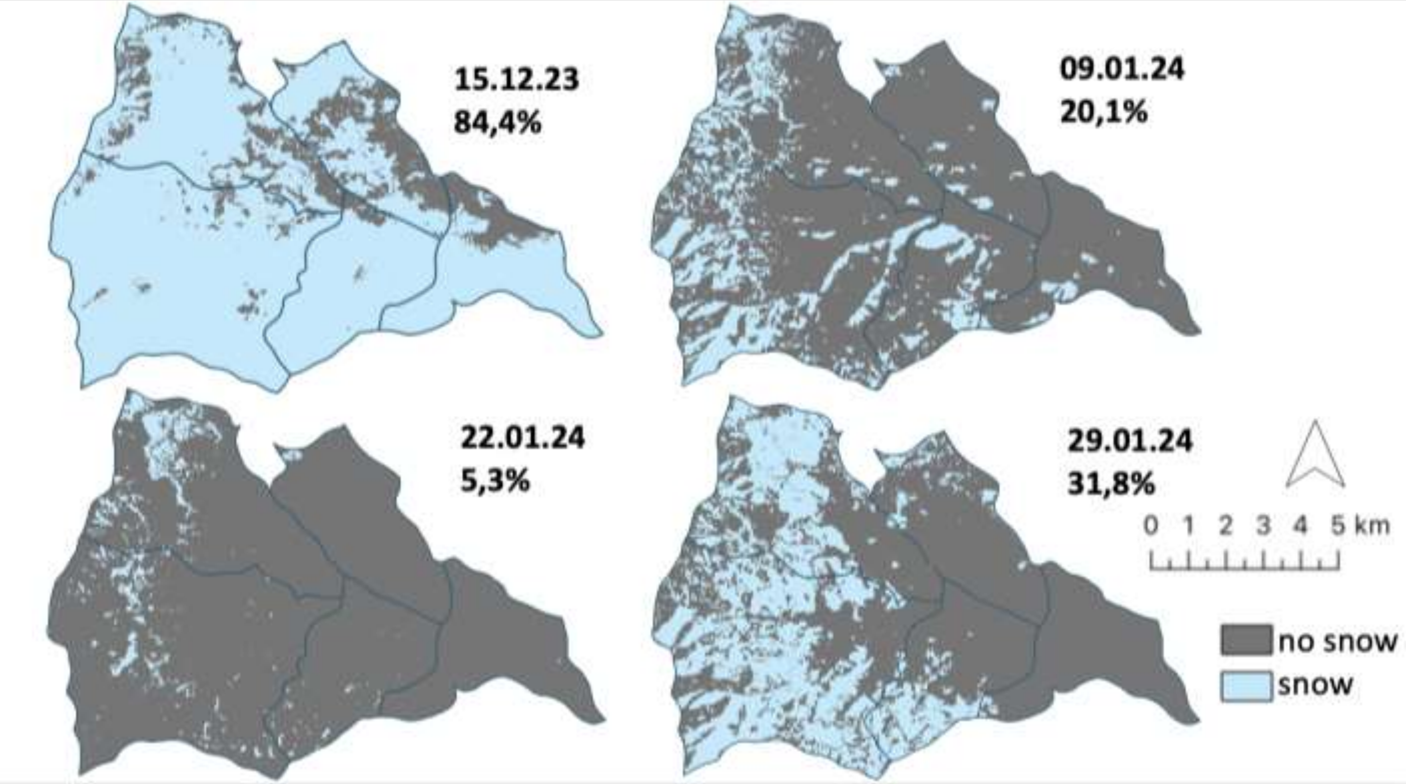
SENTINEL 2-2LA
15.12.2023

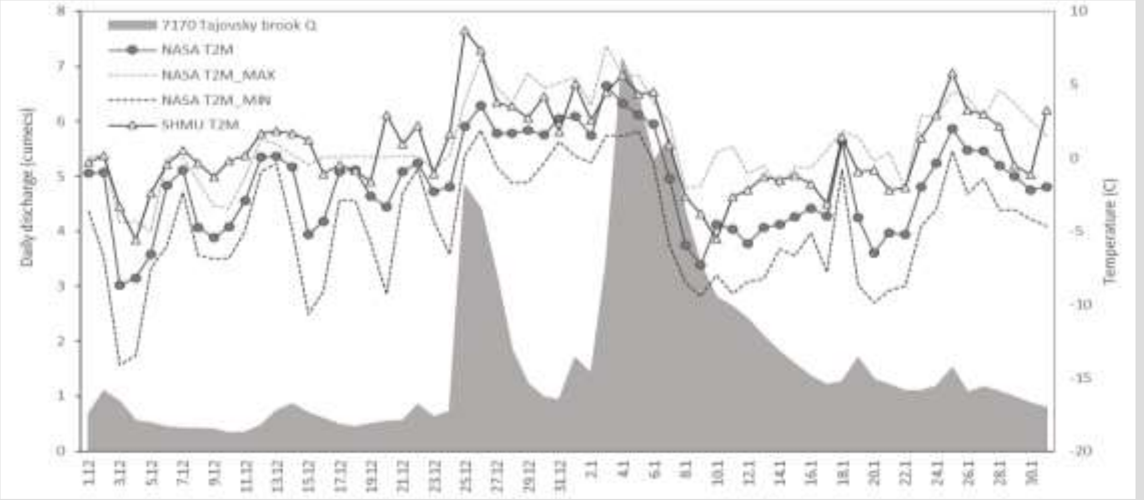


SENTINEL 2-2LA
9.1.2024

https://dataspace.copernicus.eu/browser

Tajovský brook catchment snow cover dynamics 12/23-02/24

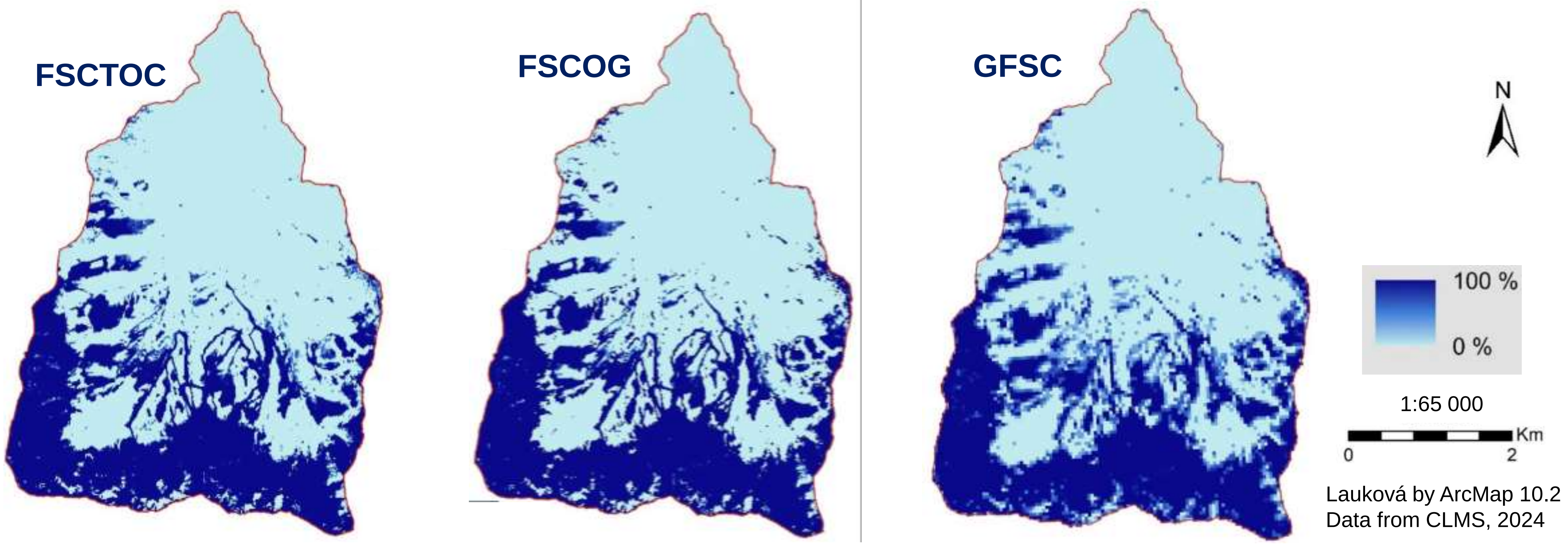




Significant warming (24.12)
Max. precipitation 21.12. (47 mm)
Max. station snow height 23.12. (101 cm)
Max. river discharge (Qave max= 7.135 m3/s – 4.1.2024)
SWE was higher in January (old snow) by 75 mm

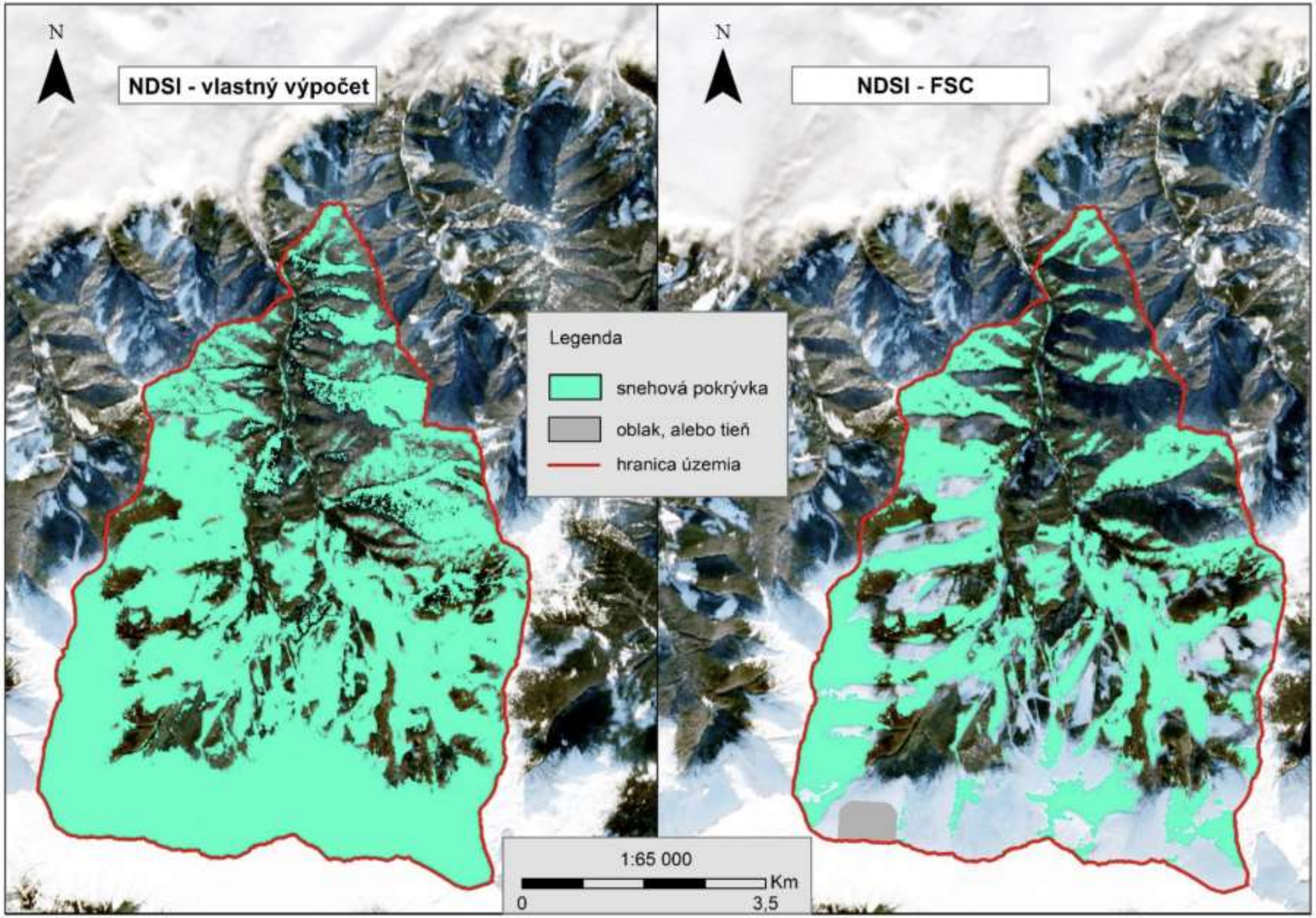
Balážovičová by QGIS 3.28
Data from CLMS, 2024

Case study 2: Demänovská valley, Low Tatras, 31.03.2019



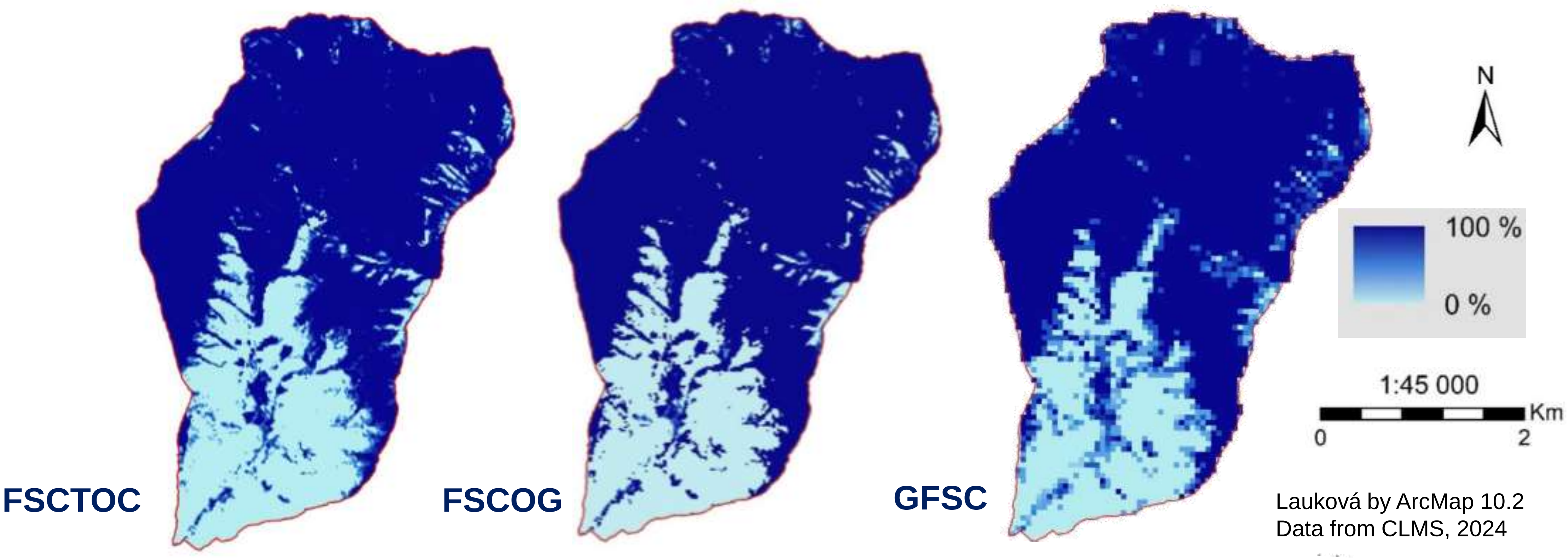
Snow coverage (%)	31.03.2019	02.04.2020	26.02.2021	28.03.2022	29.01.2024
FSCTOC	39	39	42	44	36
FSCOG	39	39	42	44	36
GFSC	47	46	49	53	45
NDSI - own calc.	37	36	47	42	**67**
NDSI - Copernicus	39	39	42	44	**36**

Comparison of NDSI indices for Demänovská valley on 29.01.2024



Lauková by ArcMap 10.2
Data from CLMS, 2024

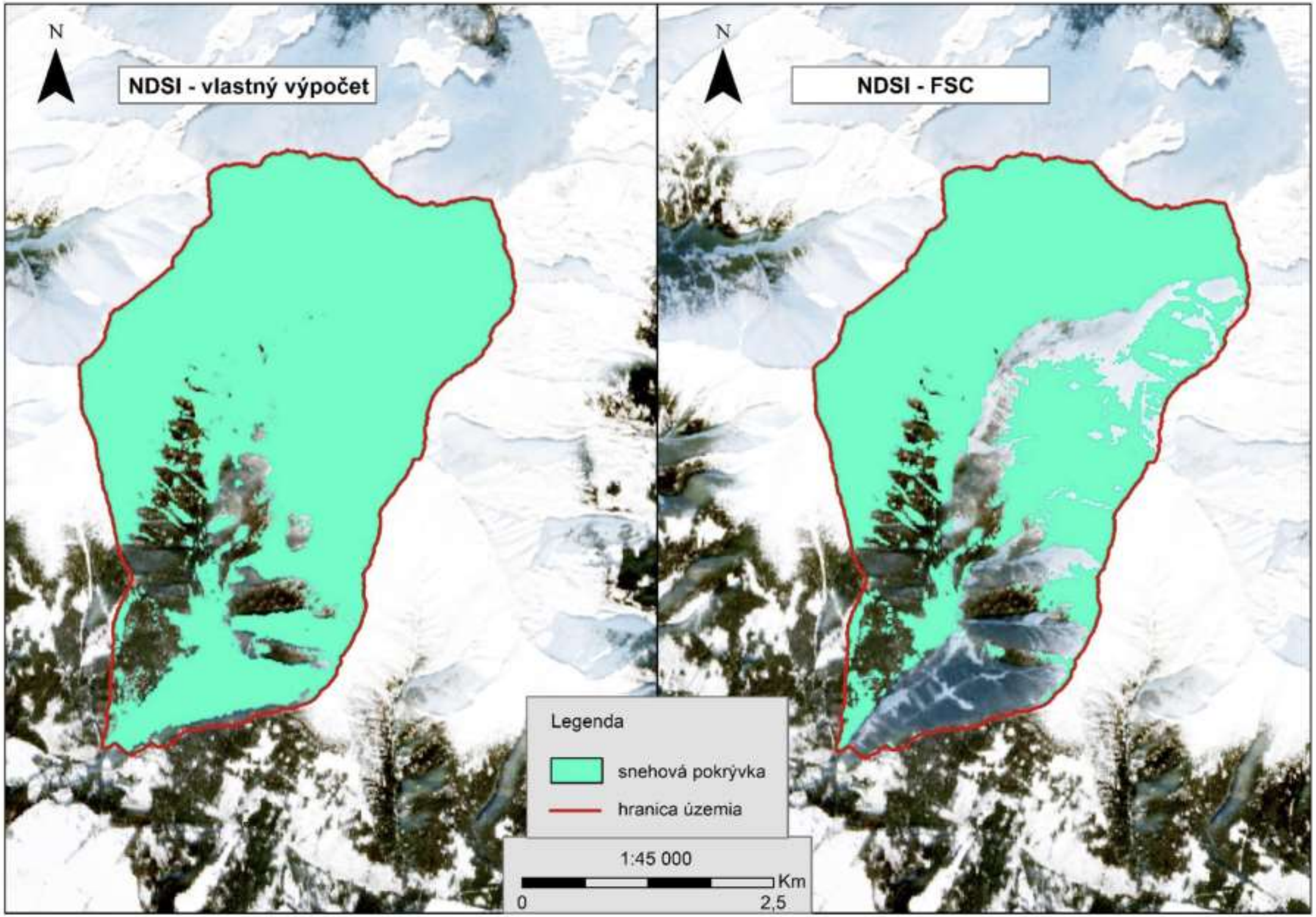
Case study 3: Žiarska valley, Western Tatras, 31.03.2024



Lauková by ArcMap 10.2
Data from CLMS, 2024

Snow (%)	31.03.2019	02.04.2020	26.02.2021	28.03.2022	29.01.2024
FSCTOG	74	71	62	78	64
FSCOG	74	71	62	78	64
GFSC	80	75	68	84	71
NDSI - own calc.	71	68	73	72	**83**
NDSI - Copernicus	74	71	62	78	**64**

Comparison of NDSI indices for Žiarska valley on 29.01.2024



Lauková by ArcMap 10.2
Data from CLMS, 2024

Challenges in snow monitoring and next steps

- Satellite may well complement not so dense network of weather stations and field measurements in mountains
- **Low time frequency of usable images** due to cloudiness (there were only 4 usable images in 2 months)
- **Errors in data:** NDSI underestimates snow cover in forested areas, on shaded slopes (topographic shade) and due to the cloud cover – insufficient corrections form MAJA software – better utilization of radar images
- **Different spatial resolution** of snow products (20x20 m for FSC as 60x60 m for GFSC)
- **Low resolution** of other products (SWE is 1x1 km)
- **Data not available** for Slovakia (SAR WS product)
- **Snow elevation gradient anomalies** (due to the wind, landform, slope orientation, avalanches, microclimatic conditions etc.)
- **Field verification** of NDSI may be necessary
- **Combination of data and methods** including modelling is needed to estimate the water content of snow in a catchment

QUESTIONS ?

GeoKARTO 2024

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THANK YOU FOR YOUR ATTENTION

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