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► **To cite this version:**

Zacharie Barrou Dumont. Pan-European snow cover products from Sentinel-2: algorithm and evaluation. Living Planet Symposium, May 2022, Bonn, Germany. 10.5194/tc-15-1343-. hal-03686189

HAL Id: hal-03686189

<https://hal.science/hal-03686189v1>

Submitted on 2 Jun 2022

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Pan-European snow cover products from Sentinel-2: algorithm and evaluation

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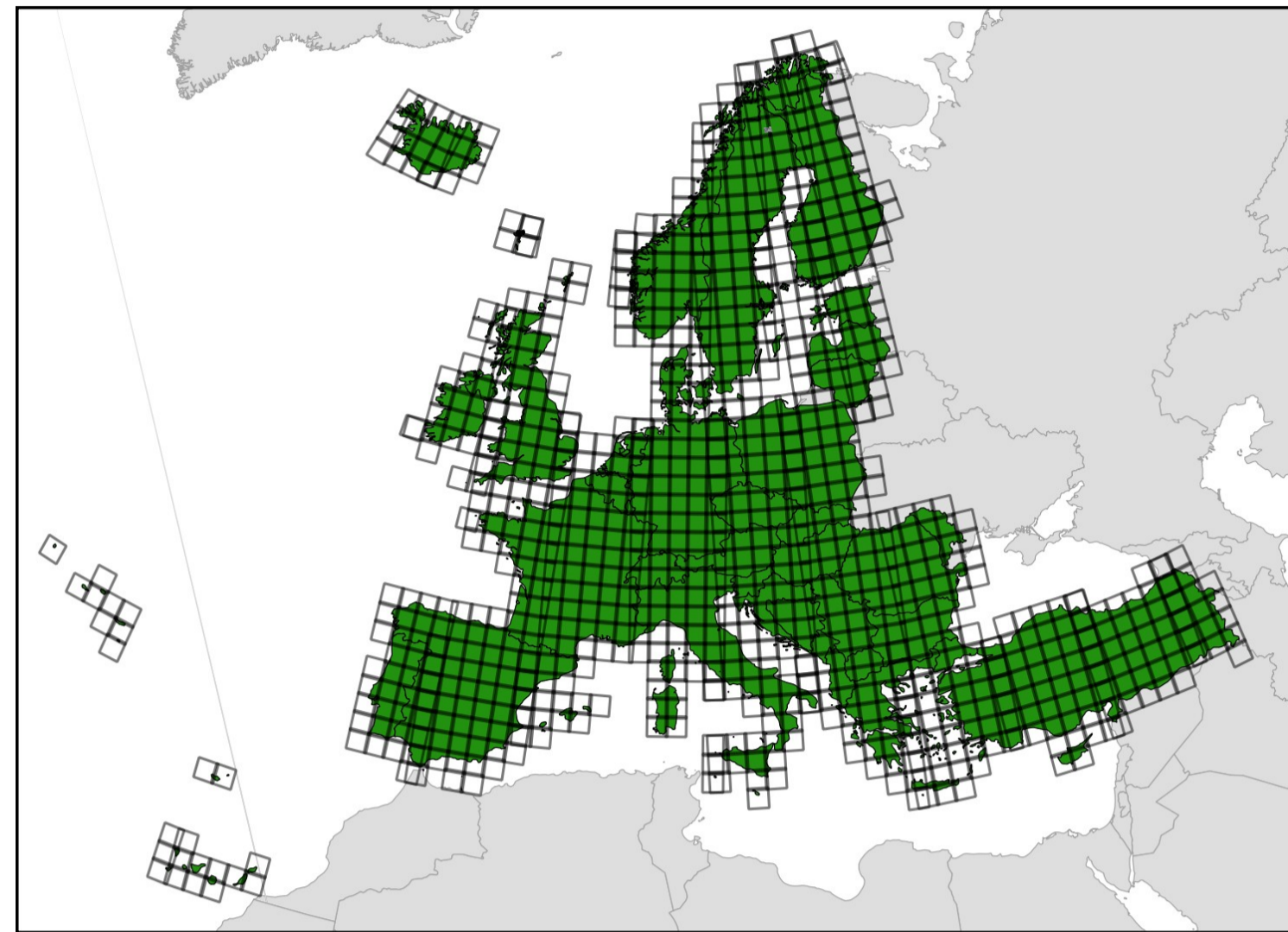
³ Magellium

⁴ Centre National d'Etudes Spatiales (CNES)

Background

On behalf of the European Commission, the European Environment Agency has commissioned the development and real-time production of the Copernicus High Resolution Snow & Ice products (HRSI), including a snow cover component to address these needs.

In particular, this service provides a canopy-adjusted fractional snow cover (FSC) at 20 m resolution along with a cloud and cloud shadow mask and quality flags. The products are derived from Sentinel-2 observations, resulting in a revisit time less than or equal to 5 days (except during low illumination periods in winter at high latitude).



Algorithm

The products are generated using the MAJA-LIS pipeline :

MAJA is a level 2A processor which provides slope corrected surface reflectance images including a coarse resolution cloud and cloud shadow mask.

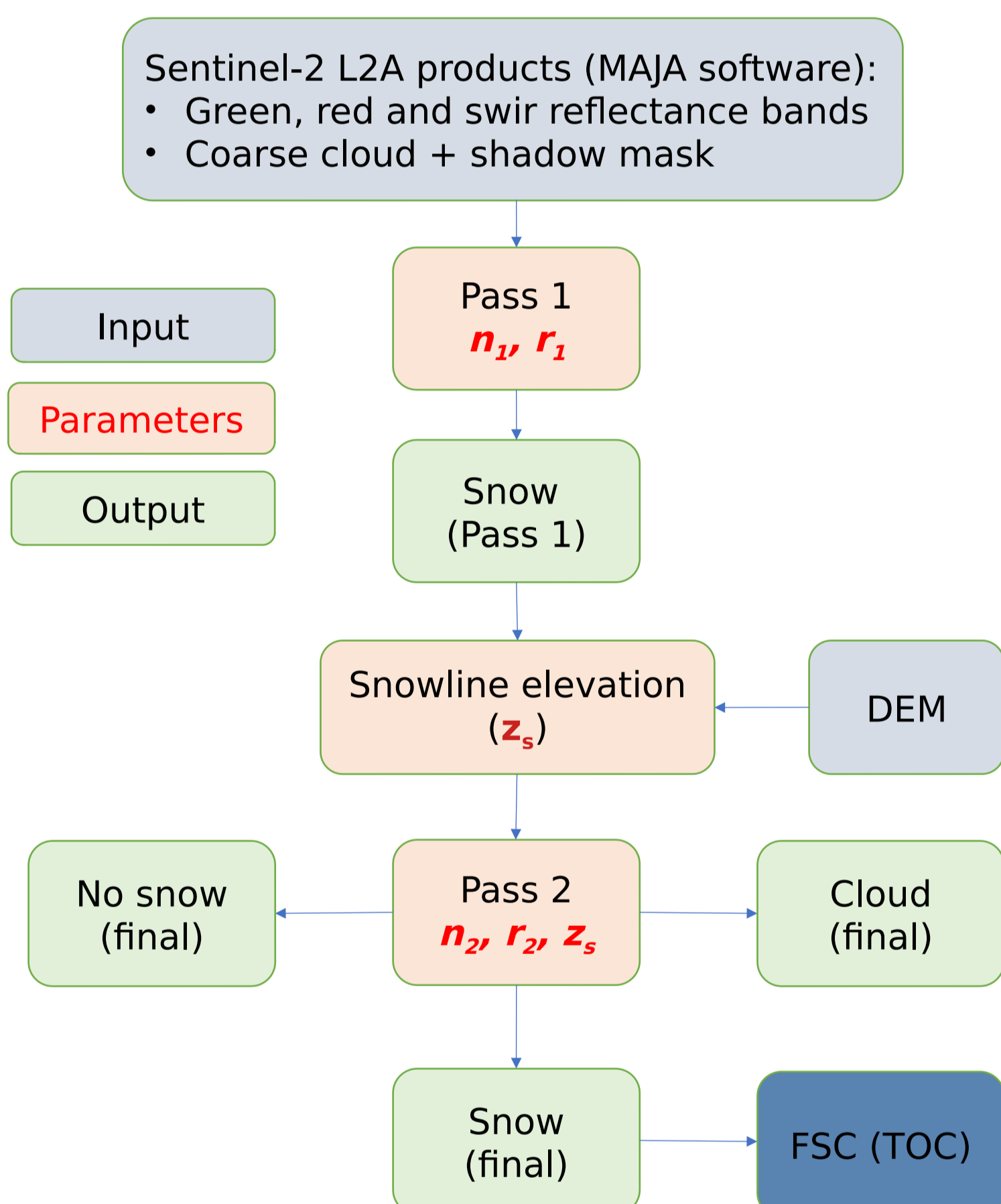
Let-It-Snow (LIS) provides the fractional snow cover (FSC) of every pixel identified as containing snow and a refined cloud mask :

- Threshold parameters :
 - Normalized Difference Snow Index (NDSI) pass: n_1, n_2
 - $NDSI = f(\text{green}, \text{swir})$
 - Red band reflectance pass: r_1, r_2

- Pass 1 step: First snow detection
 - Snow if $> n_1$ and $> r_1$ and not in cloud mask
 - Used to calculate snowline

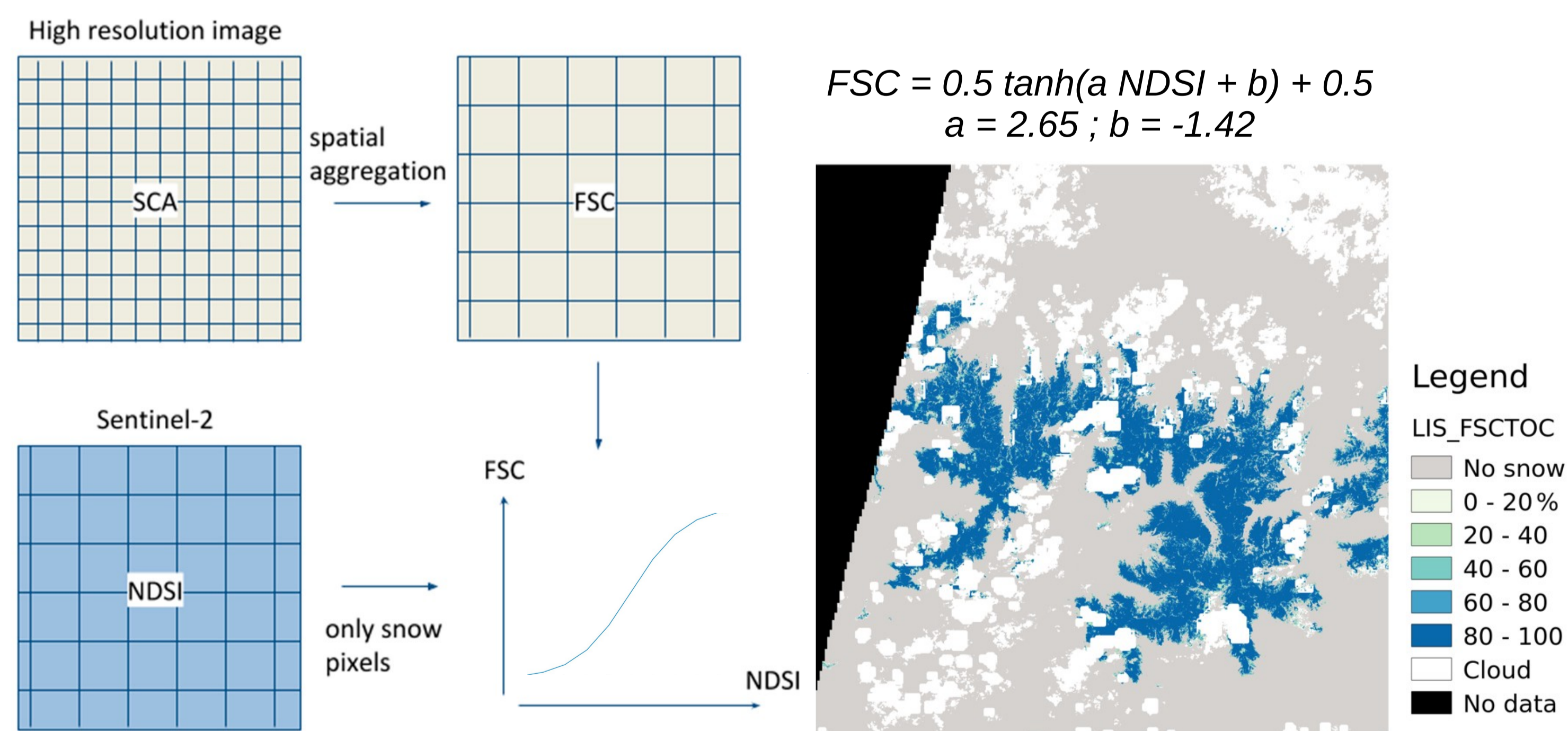
- Snowline elevation step: calculate lowest elevation with significant snow amount z_s .

- Pass 2 step: final snow/cloud discrimination
 - Refine cloud + shadow mask
 - Snow if $> n_2, > r_2$ and $> z_s$



Fractional Snow Cover

A sigmoid-shaped empirical function for estimating the top-of-canopy (TOC) FSC from the NDSI of the level 2A pixels was calibrated using snow maps classified from Pléiades very high resolution images.



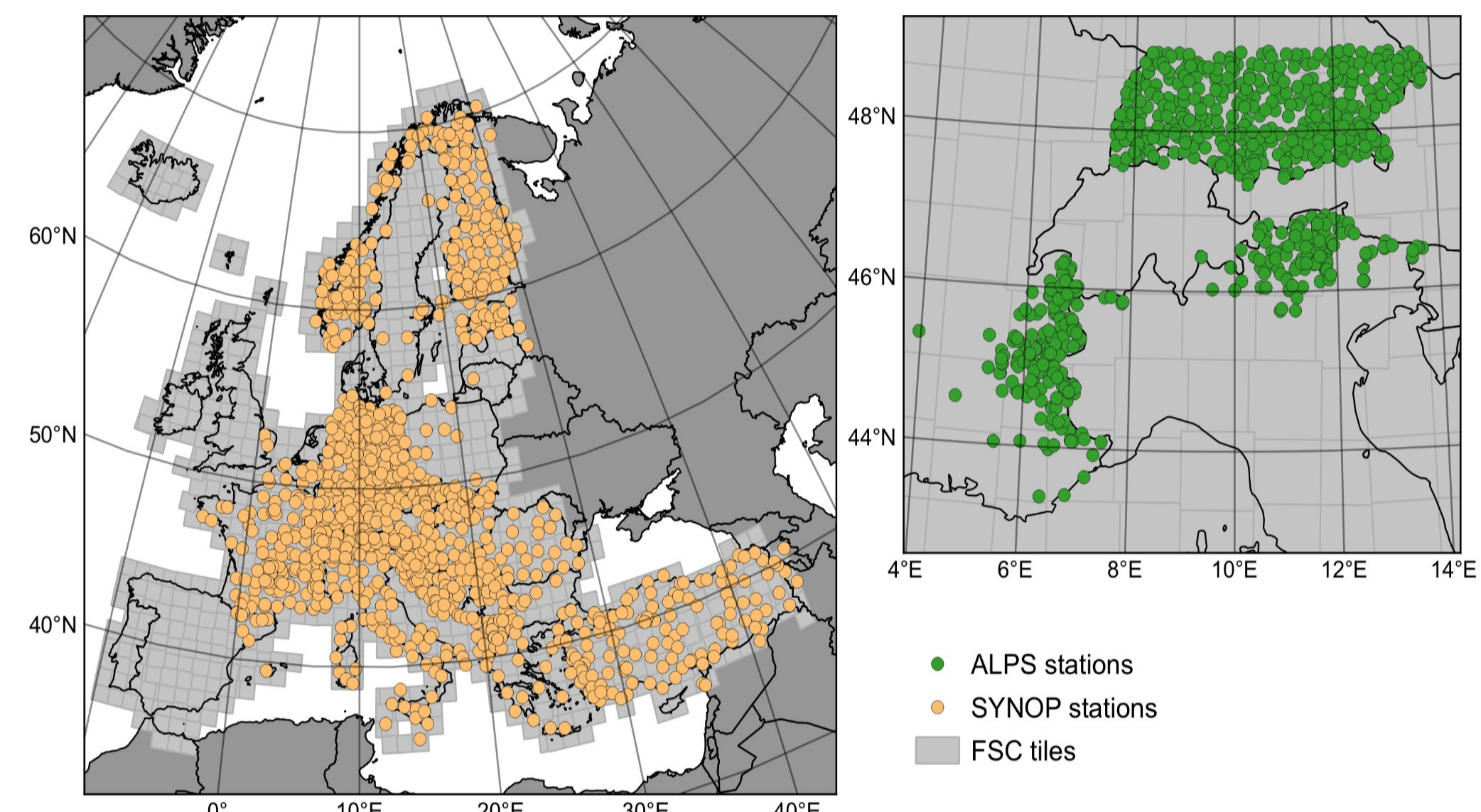
In forest regions, the FSC is adjusted to subcanopy "on-ground" FSC using the Copernicus Sentinel-2-derived tree cover density (TCD).

$$FSC_{OG} = \frac{FSC_{TOC}}{1 - TCD}$$

Evaluation

Snow detection evaluation

The snow cover detection was evaluated over Europe using *in situ* snow depth observations at 1764 stations from 36 countries, totaling 26933 datapoints and covering a wide range of climate and topographic conditions. The evaluation database was prepared by merging two datasets of *in situ* snow depth (height of snow, HS) measurements : SYNOP data (WMO automatic weather station) and a compilation of measurements in the Alps (ALPS) from [Matiu et al., 2021]. The evaluation period spans a hydrological year from 1 September 2017 to 31 August 2018.



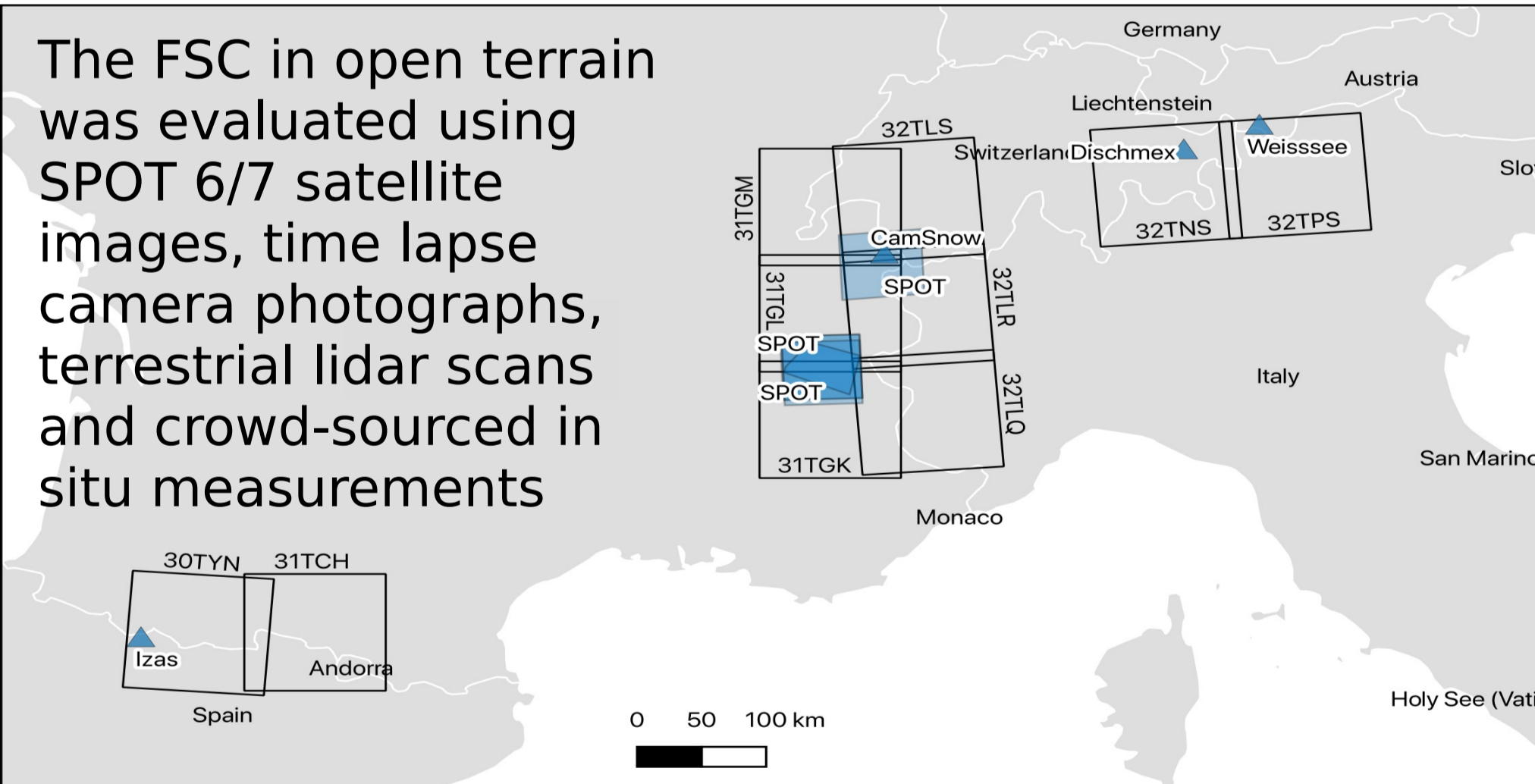
We found a good agreement between both datasets with an accuracy (proportion of correct classifications) of 94 % and kappa of 0.81.

More accurate (+6 % kappa) retrievals were obtained by excluding low-quality pixels at the cost of a reduced coverage (-13 % data).

Performances decreased at sites with higher tree cover density due to the obstruction of the ground surface by the tree canopy.

		QC filter off	
FSC	SNOW	4192	339
	no SNOW	15.56 %	1.26 %
no SNOW	SNOW	1191	21211
	no SNOW	4.42 %	78.75 %
In-Situ			
		QC filter on	
FSC	SNOW	3428	217
	no SNOW	14.56 %	0.92 %
no SNOW	SNOW	733	19163
	no SNOW	3.11 %	81.40 %
In-Situ			

FSC evaluation



The root mean square error (RMSE) on the retrieved FSC is consistently estimated close to 25%

[Muhuri et al., 2021] showed that the algorithm yielded similar performances (25-30% RMSE) as a computationally intensive spectral unmixing approach while retrieving the subcanopy ground FSC over a forested site in Sierra Nevada (USA).

REFERENCES

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