ADVANCEMENTS IN SNOW COVER MONITORING BASED ON SYNERGY OF SENTINEL-1 SAR AND SENTINEL-3 SLSTR DATA

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… towards a Pan-European Snow Cover and Melt Extent Product

Outline

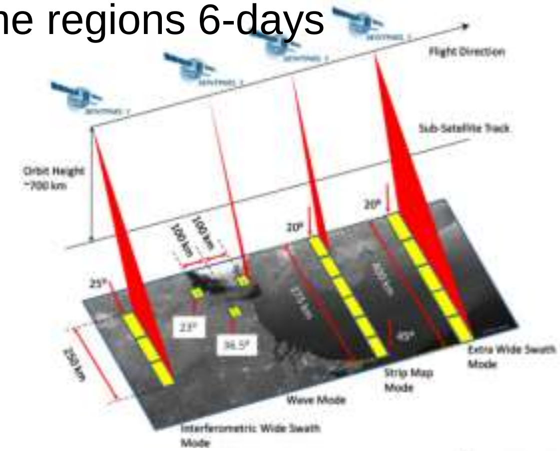
- Concept for synergistic use of Sentinel-1 and Sentinel-3 for snow monitoring
- Wet extent mapping by Sentinel-1 SAR IW mode data
- Prototype snow extent algorithm for Sentinel-3 optical sensors
- Towards a Pan-European snow extent and melt area product from S1 and S3 data
- Conclusions

Sentinel-1 and Sentinel-3 Sensor Overview

Polarisation	Dual (HH + HV, VV + VH)
Access (incidence angles)	31°–46°
Azimuth resolution	<20 m
Ground range resolution	<5 m
Azimuth and range looks	Single
Swath	>250 km
Maximum NESZ	−22 dB
Radiometric stability	0.5 dB (3σ)
Radiometric accuracy	1 dB (3σ)

S1 SAR IW Mode

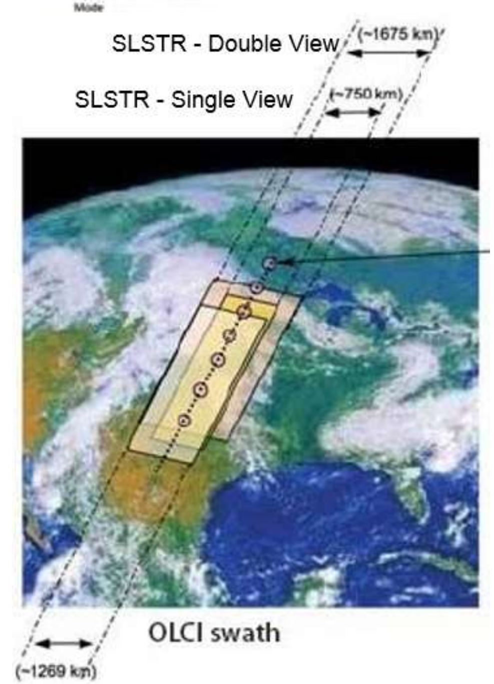
<u>Global Land (Status): </u>12 days repeat coverage wit IW mode; some regions 6-days



Sentinel-3

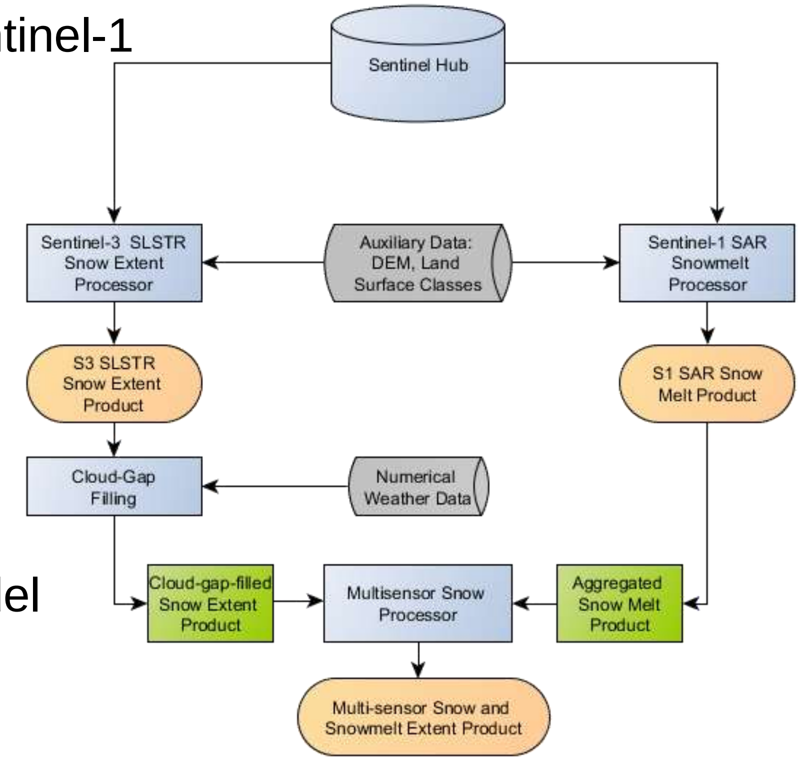
OLCI (Ocean and Land Colour Instrument)
- Swath width: 1270 km, with 5 tilted cameras
- Spatial sampling: 300 m @ SSP
- Spectrum: 21 bands [0.4-1.02] μm

SLST (Sea and Land Surface Temperature)
- Swath width: dual view scan, 1675 km (nadir) / 750 Km (backwards)
- Spatial sampling: 500 m (VIS, SWIR), 1 km (MWIR, TIR)
- Spectrum: 9 bands [0.55-12] μm



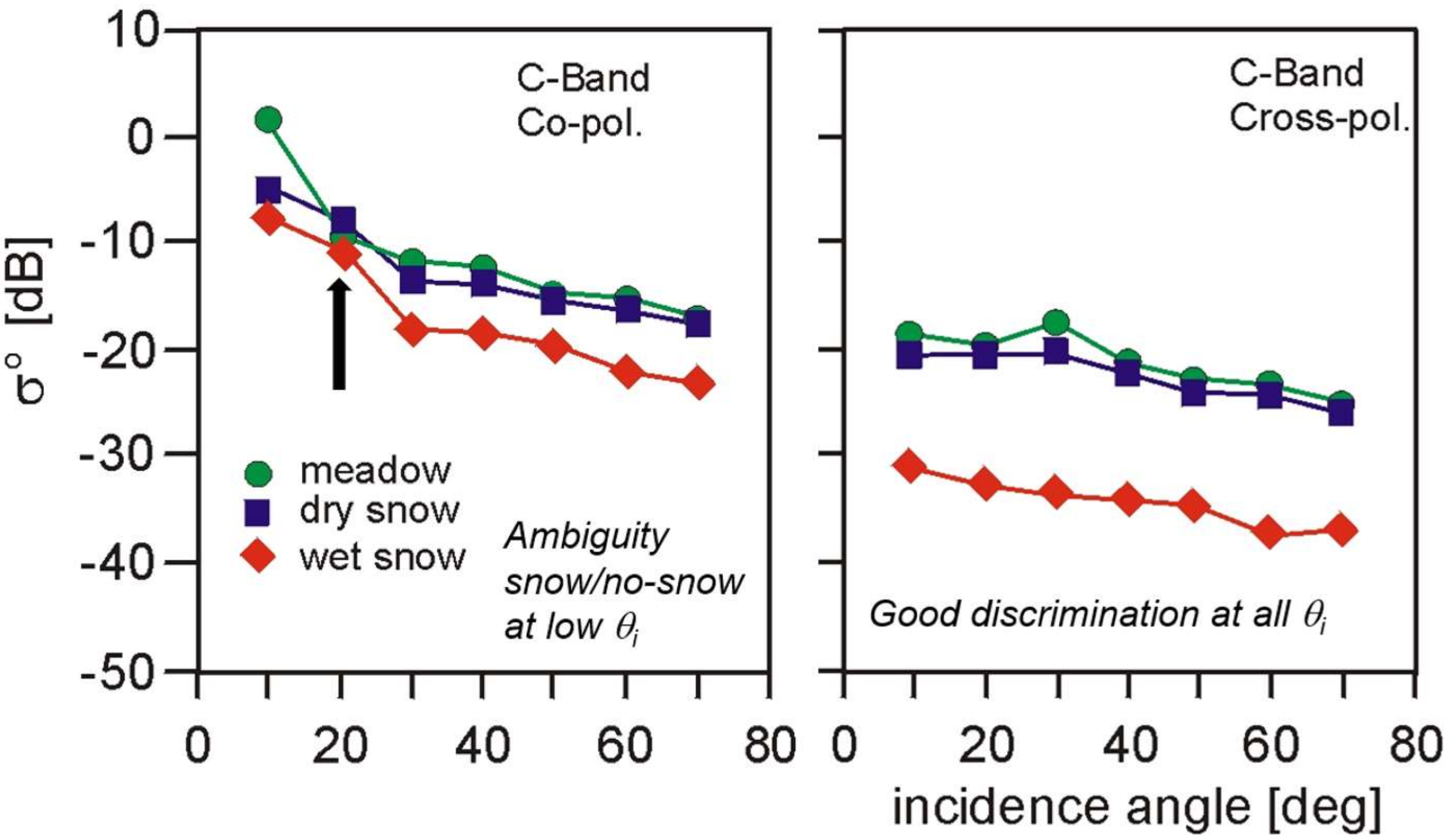
Concept for Pan-European Snow Extent and Melt Area product from S1 and S3 data

- **Module 1:** Generation of multi-temporal Sentinel-1 SAR snow melt extent map (100m x 100 m)
- **Module 2:** Generate Fractional Snow Cover Map from Sentinel-3 data
- **Module 3:** Apply cloud-gap filling to optical FSC product by assimilating snow pack model driven by NW data.

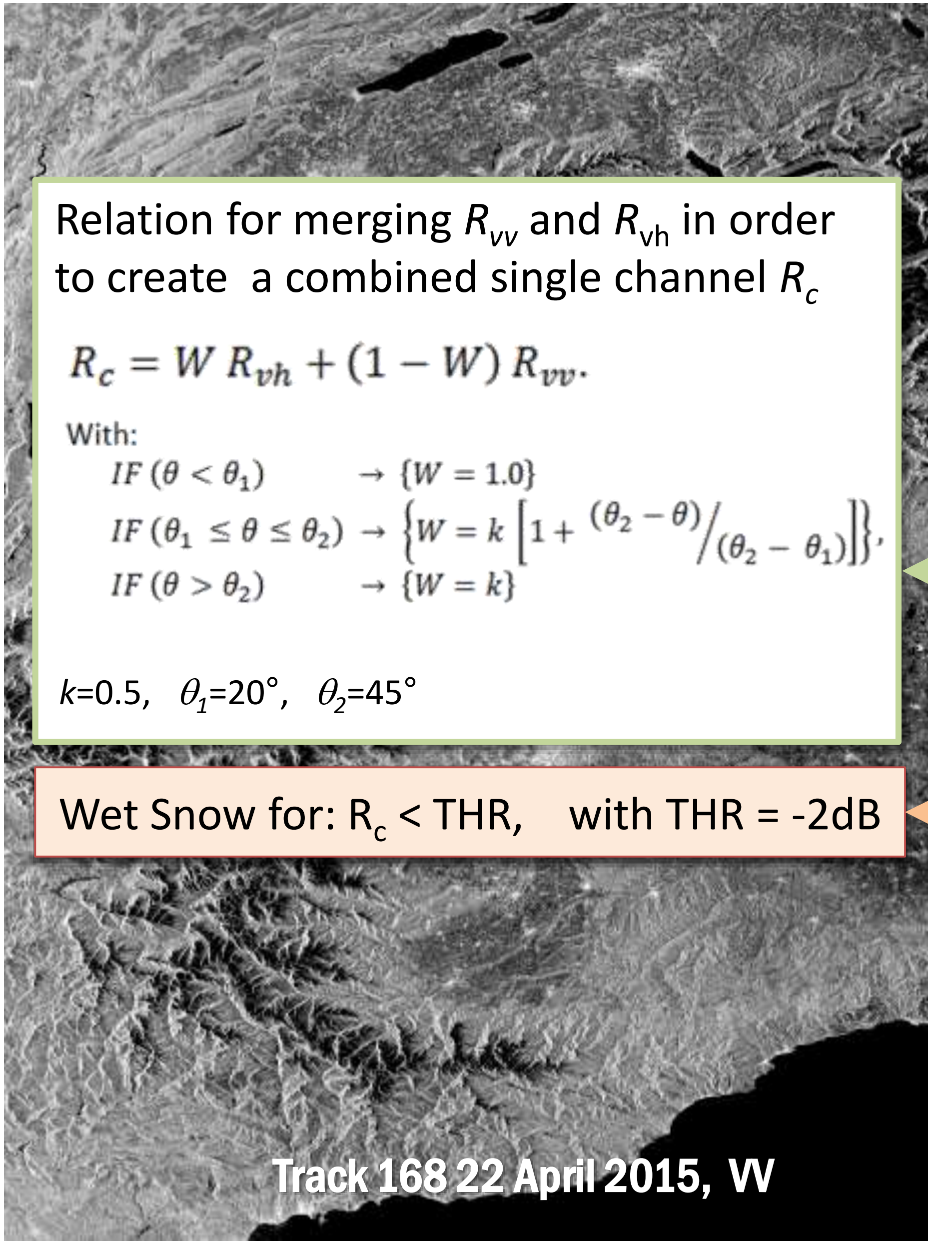


- **Module 4**: Combination of snowmelt and optical FSC map: as a pre-condition for the presence of wet snow from SAR data, the FSC > THR in the optical snow product is required. We propose a THR value of 70%, derived from intercomparison with high resolution snow extent product from Landsat

Groundbased Backscatter Signatures – Leutasch/Alps



Sentinel-1 SAR Snow Melt Extent



Relation for merging R_{vv} and R_{vh} in order to create a combined single channel R_c

$$R_c = W\,R_{vh} + (1 - W)\,R_{vv}.$$

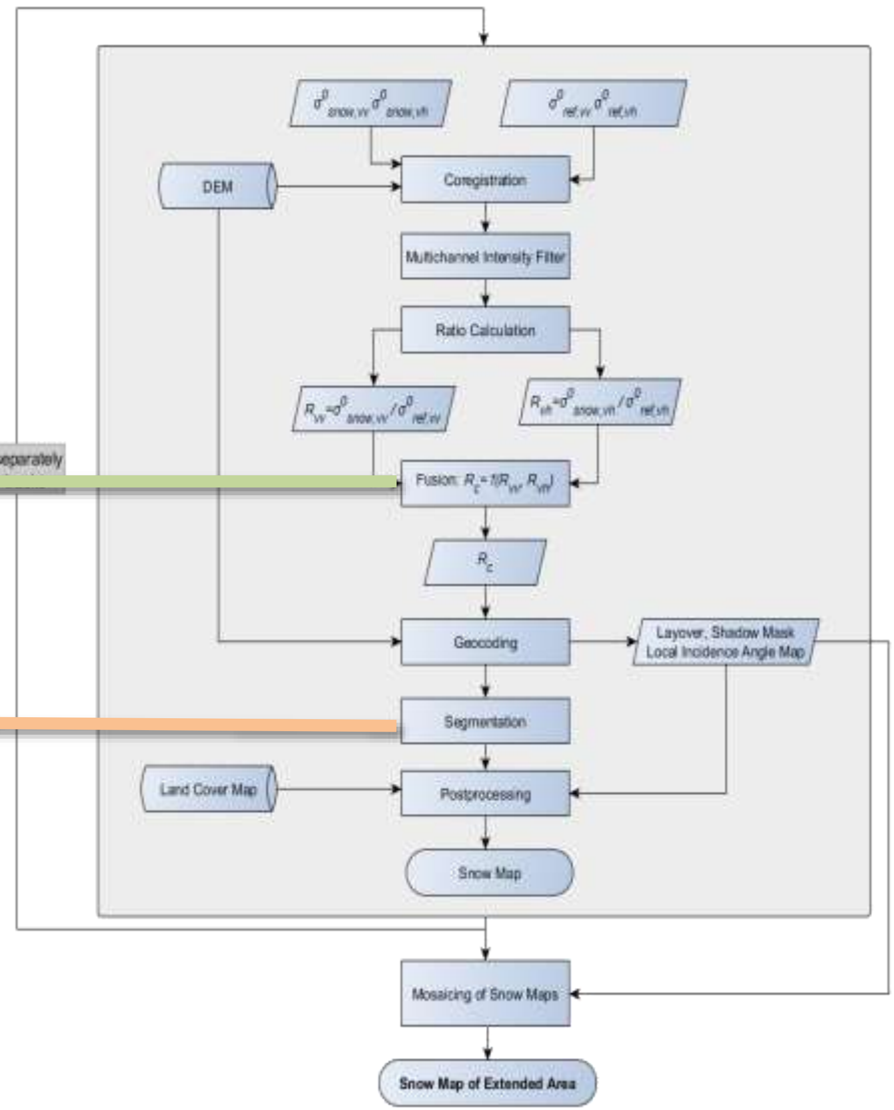
With:

$$IF\ (\theta < \theta_1) \rightarrow \{W = 1.0\}$$
$$IF\ (\theta_1 \le \theta \le \theta_2) \rightarrow \left\{W = k\left[1 + \frac{(\theta_2 - \theta)}{(\theta_2 - \theta_1)}\right]\right\},$$
$$IF\ (\theta > \theta_2) \rightarrow \{W = k\}$$

k=0.5, θ_1=20°, θ_2=45°

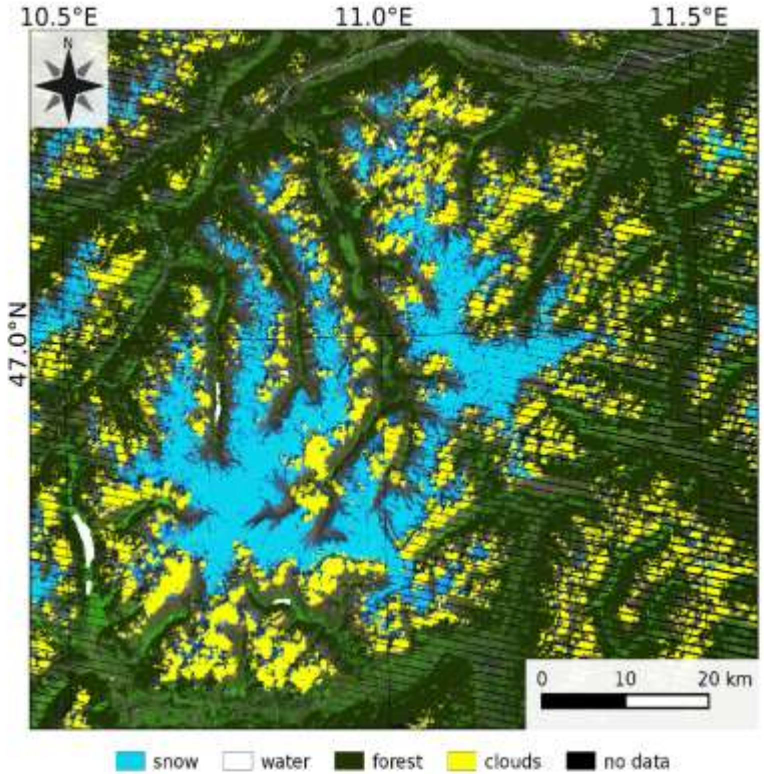
Wet Snow for: R_c < THR, with THR = -2dB

Processing Line

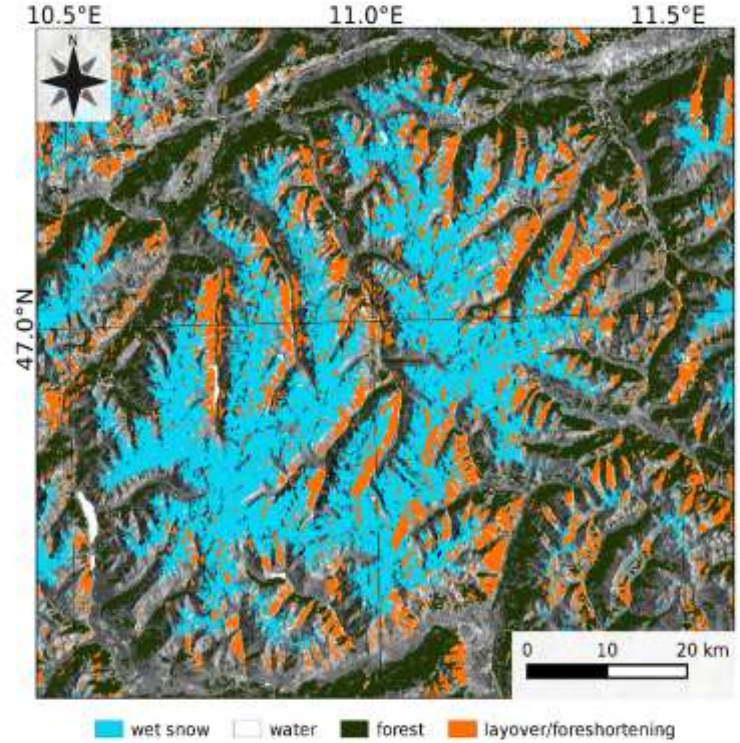


S1 versus Landsat TM Snow Extent – Ötztal Alps

Landsat-7, 5 June 2015



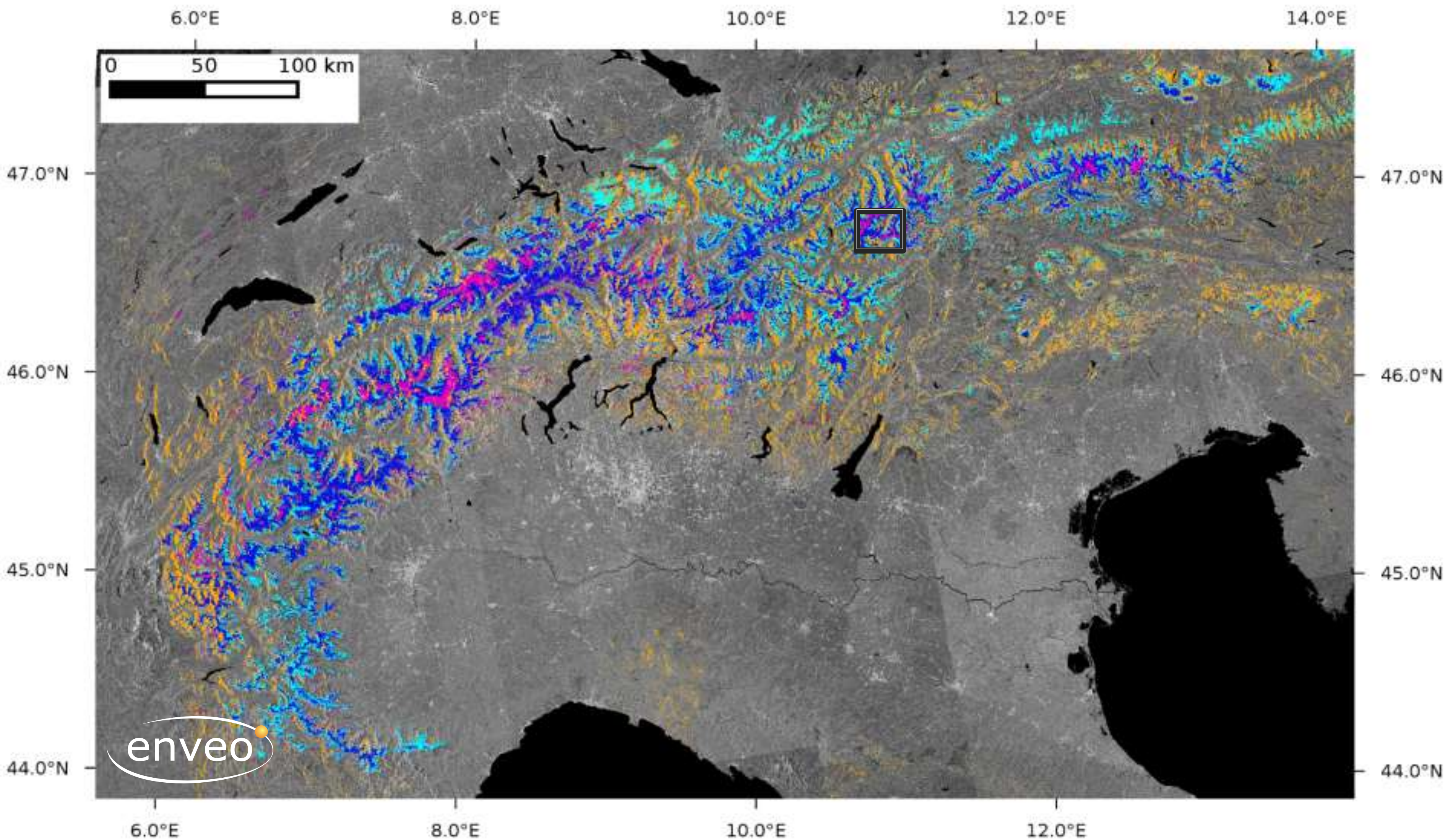
Sentinel-1, 2 June 2015



	R_{vv}			R_{vh}			R_c		
	S1-S	**S1-F**	AR	**S1-S**	**S1-F**	AR	**S1-S**	**S1-F**	AR
LS-S	80.7	19.3		94.5	6.4		94.7	5.3	
LS-F	4.2	95.8		5.3	94.7		3.2	97.8	
			0.882			0.946			0.962

Confusion matrix for the classes snow (S) and snow-free (F) in Ötztal test site, for snow classification based on Landsat (LS) and Sentinel-1 (S1) data. AR — overall agreement rate ($0.0 \leq AR \leq 1.0$).

Sentinel-1 Map of Snow Melt Extent - Alps



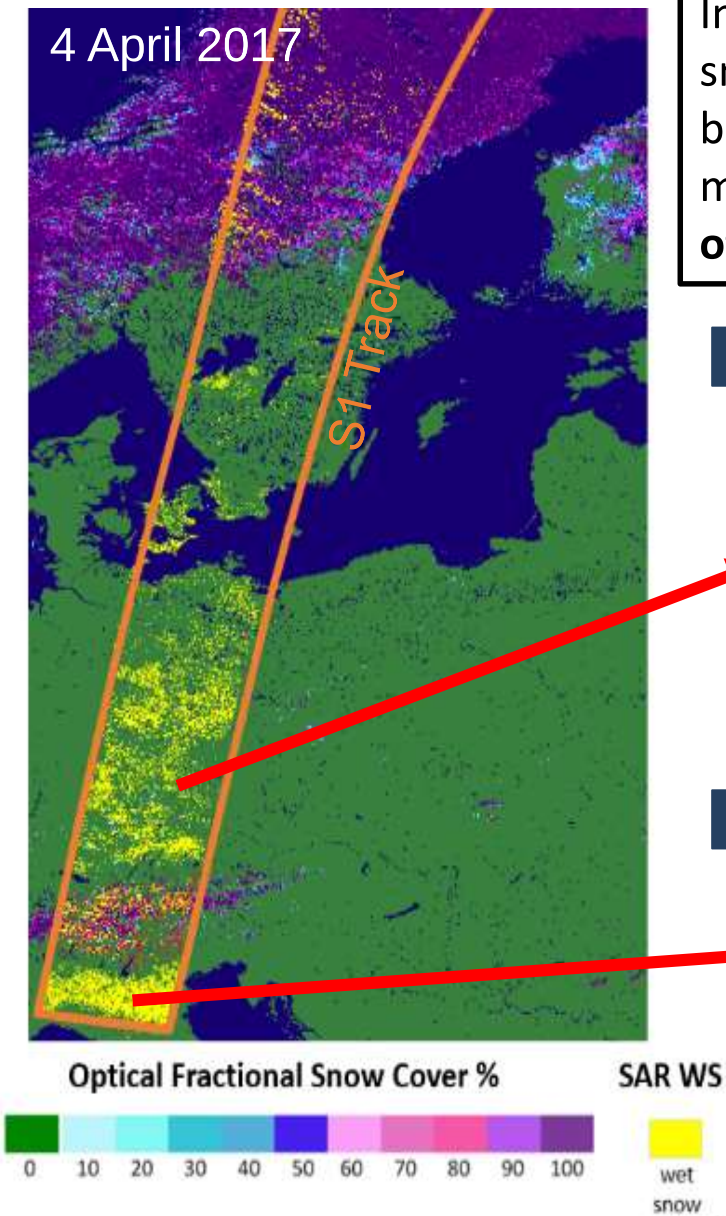
decrease of wet snow extent from April 20-23 to May 14-17, 2015

decrease of wet snow extent from May 14-17 to July 1-7, 2015

wet snow extent, July 1-4, 2015

layover / foreshortening

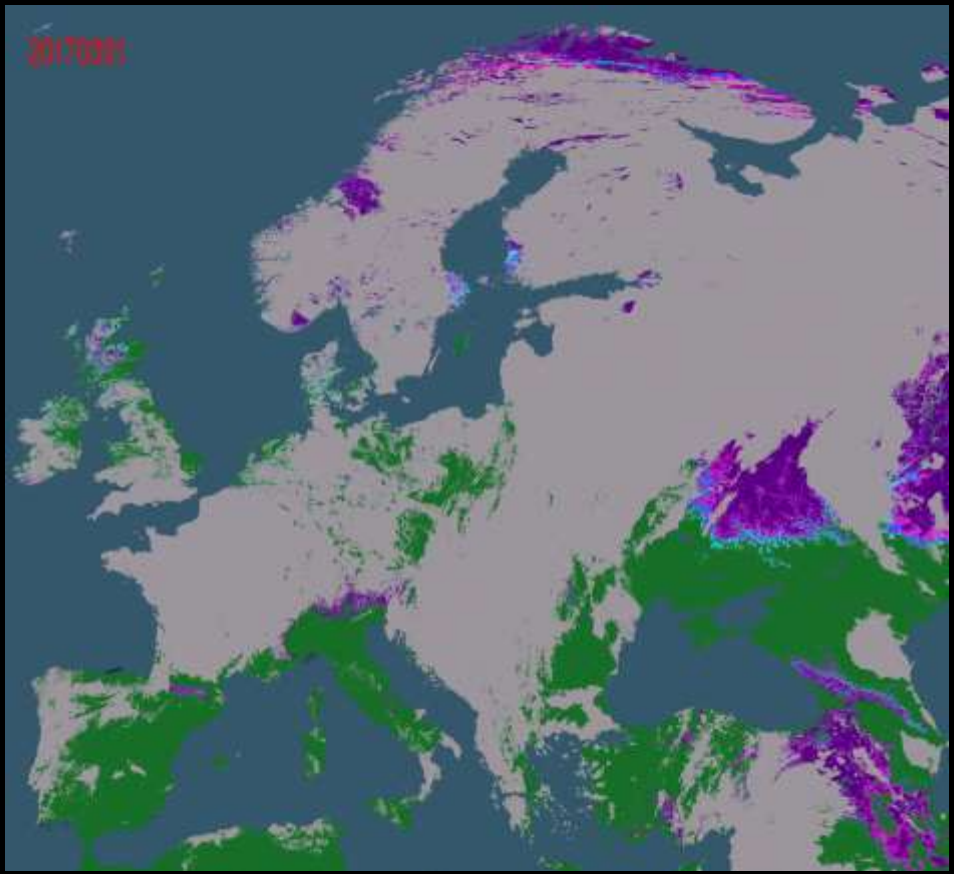
Towards a Multi-Sensor Snow and Melt Extent product from Copernicus Satellite Data for the Pan-European Domain



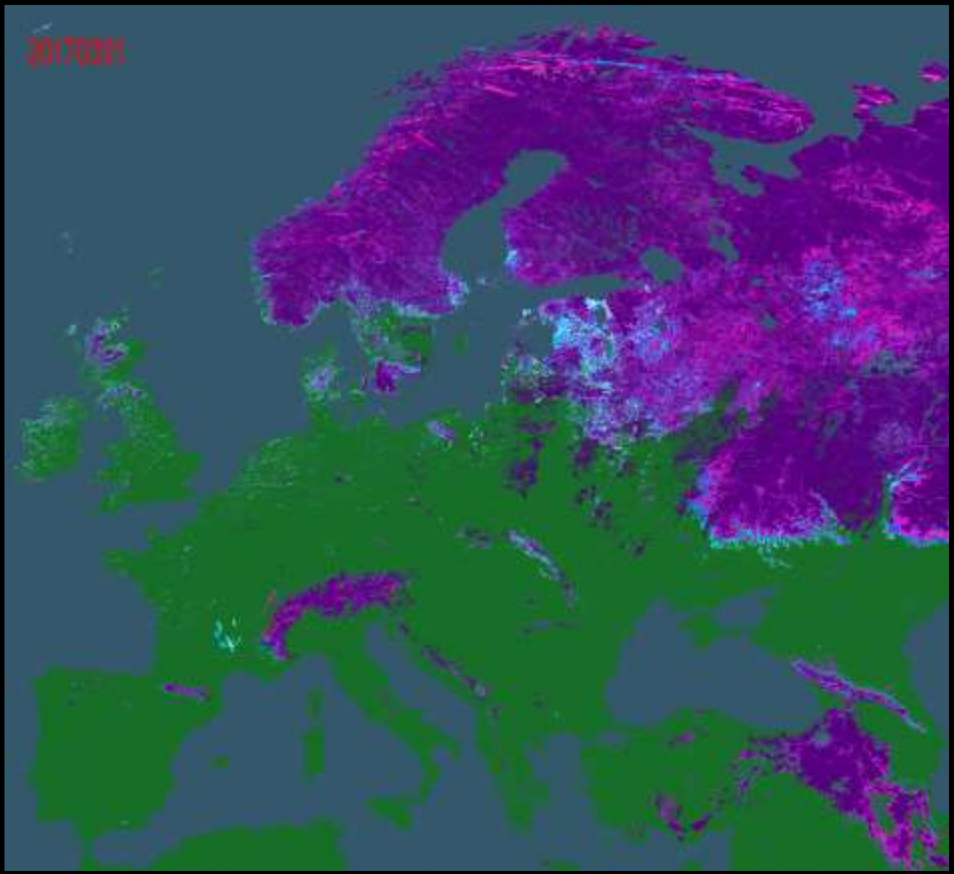
In areas with agricultural activities ambiguities for wet snow segmentation may arise from temporal changes in backscatter related to vegetation state, tilling and soil moisture. **This ambiguity can be solved by synergistic use of coincident optical and SAR data.**

Cloud-gap filling of optical Snow Extent Products

FSC from optical satellite data

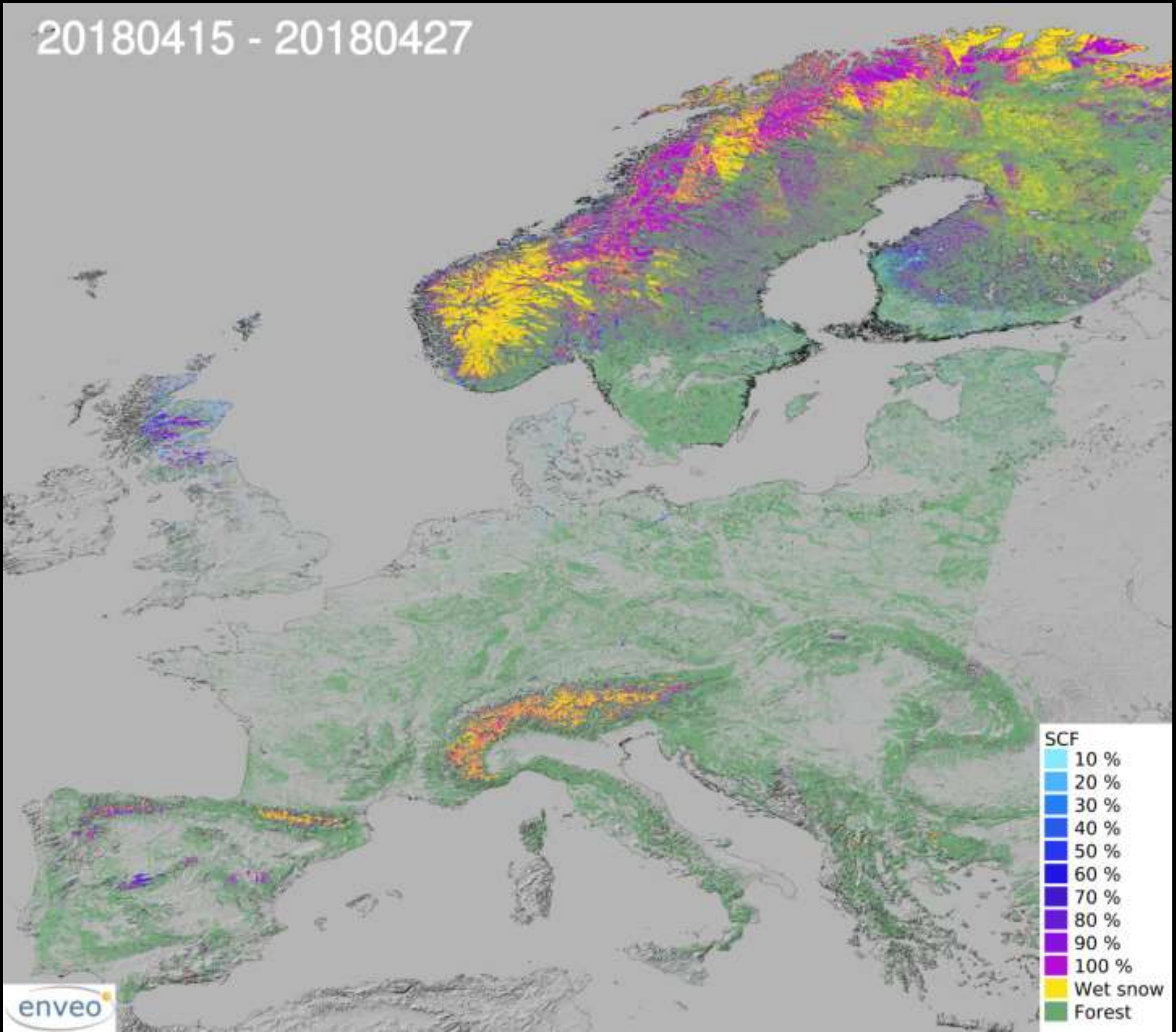


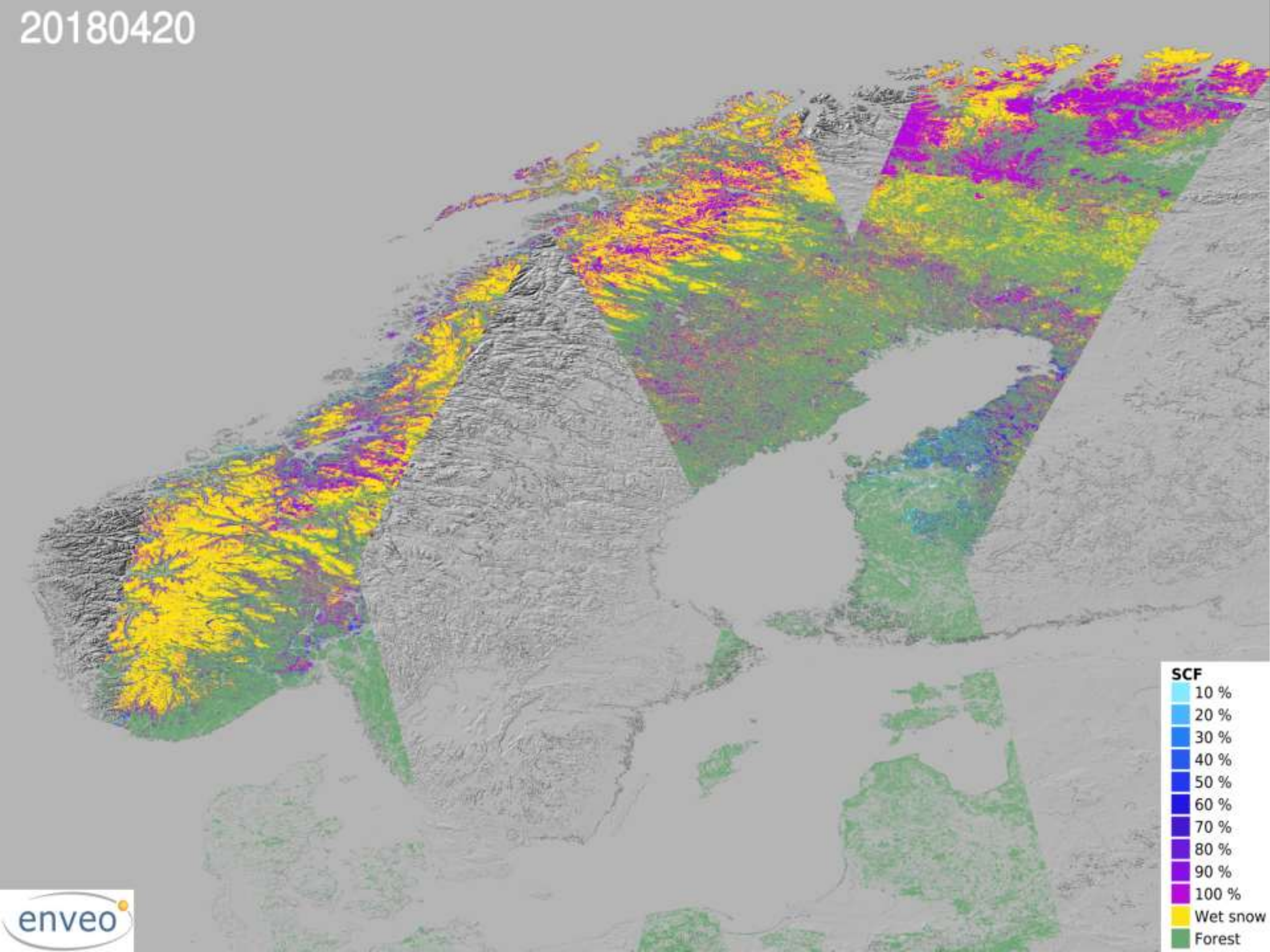
Assimilated FSC



To fill gaps in the time sequence of optical FSC maps due to cloudiness we apply a data assimilation procedure using a snow pack model, driven by numerical meteorological data of ECMWF for estimating daily changes in the snow extent in cloudy areas.

Pan-European Snow extent and Melt Area product




20180420
SCF
10 %
20 %
30 %
40 %
50 %
60 %
70 %
80 %
90 %
100 %
Wet snow
Forest
enveo

Conclusions

- A dual pol (Co-, Cross) Snow Melt Algorithm for Sentinel-1 IW was developed and validated in mountainous regions like Alps and Scandinavia, showing a very high agreement with snow maps from high resolution optical data.
- In low elevated, flat areas of Europe with agricultural activities ambiguities for wet snow segmentation may arise from temporal changes in backscatter related to vegetation state, tilling and soil moisture. This ambiguity can be solved by synergistic use of coincident optical and SAR data.
- Intercomparsion of S1 melt extent products with Reference snow maps from Landsat-8 and Sentinel-2 together with weather data in different environments in Europe and dates shows an typically an overall agreement of 80%.
- The synergy of Sentinel-1 and Sentinel-3 sensors is a powerful approach for comprehensive snow monitoring for the Pan-European domain in terms of snow cover and melt extent useful for hydrology, water management and meteorology.