ALPSNOW

Advancements of satellite snow products for Alpine regions

Thomas Nagler & AlpSnow Team

Objectives and Main Activities

AlpSnow aims to advance measurements of the seasonal snow cover extent and its physical properties from satellite data and in the integration of EO-based snow cover information in snow process and hydrological models. It supports regional operational priorities and science initiatives in hydrology and environmental research.

Main Activities

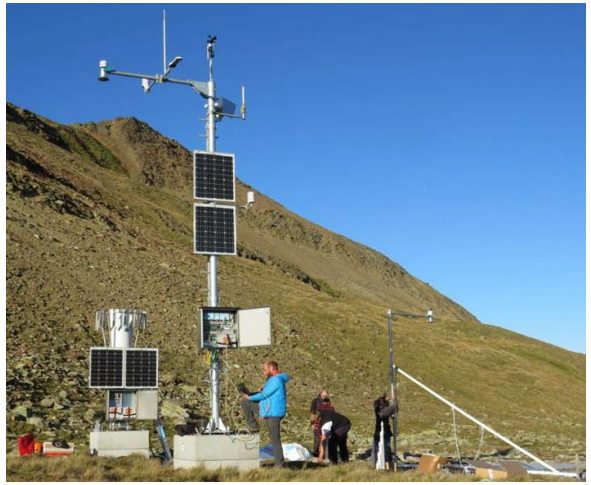
- Development, validation and implementation of innovative EO-based techniques and algorithms for retrieval of snow products, optimized for comprehensive applications in mountain areas: **snow area extent, snow albedo, snow grain size, snow water equivalent (SWE) / snow depth (SD), snow liquid water content / wet snow.**
- Generation of **coherent snow parameter products** covering the whole Alpine region with high temporal and spatial resolution, spanning at least 4 years from September 2017.
- Evaluation of the **potential impact of the products** on science, applications, and society through impact assessment studies in collaboration with scientific and operational institution.

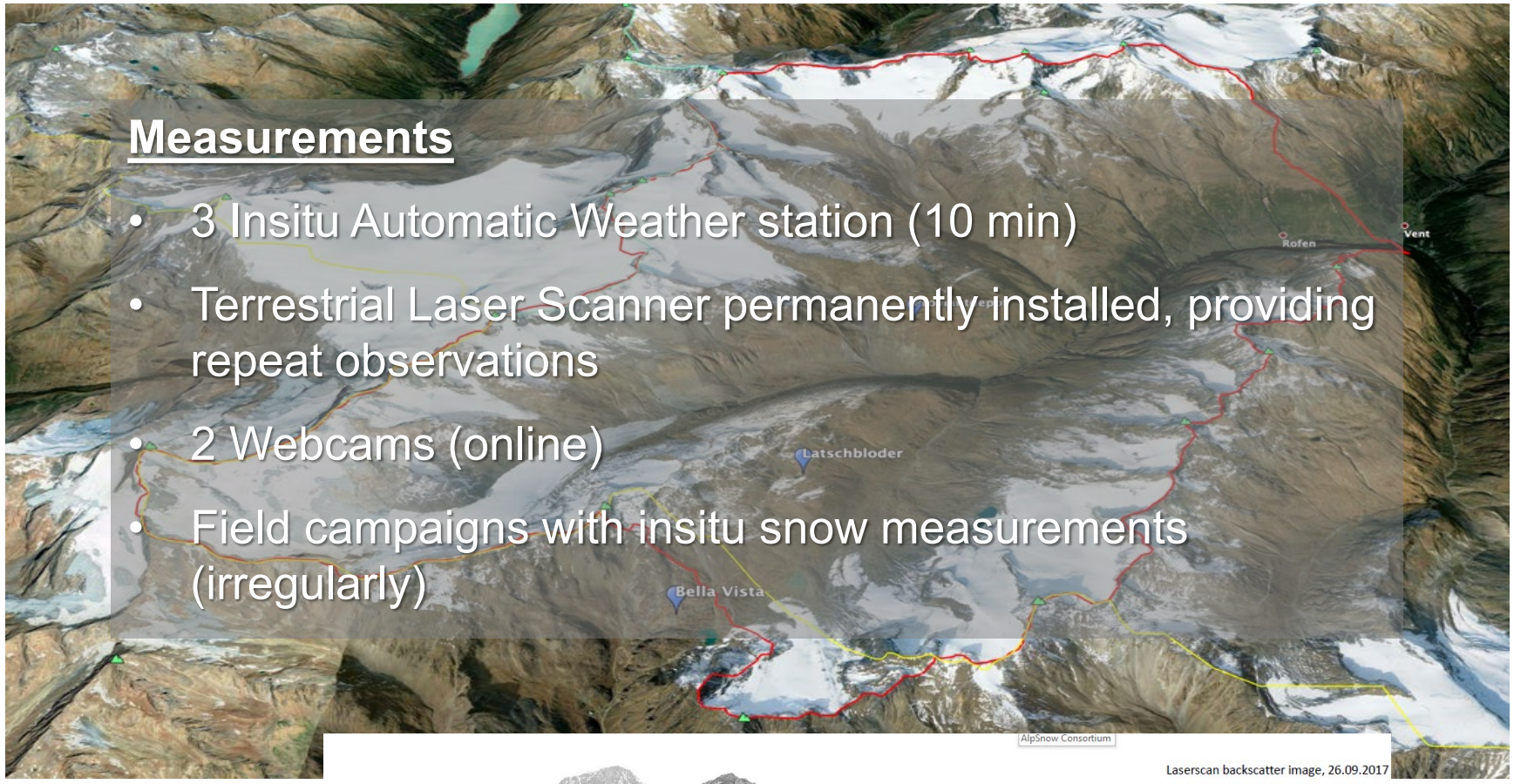
AlpSnow Consortium

enveo	ENVEO	ENVEO IT GmbH	Project management EO Team
eurac research	EURAC	EURAC Research	EO Team
DLR	DLR	German Aerospace Center	EO Team
ZAMG	ZAMG	Zentralanstalt für Meteorologie & Geodynamik	EO-Snow Model Int. Demo Case
SLF	SLF	WSL Institute for Snow & Avalanche Research	EO-Snow Model Int. Science Case
ARPA Valle d'Aosta	ARPA	ARPA Valle di Aosta	Demo Case
The University of Edinburgh	UED	University of Edinburgh	Science Case
universität innsbruck	UIBK	University of Innsbruck	Science Case
Autonome Provinz Bozen - Südtirol / Provincia Autonoma di Bolzano - Alto Adige / Provinzia Autonoma de Bulsan - Südtirol	OHDB	Office for Hydrology and Dams of the Autonomous Province of Bolzano	Demo Case

Test Sites for Algorithm Development and Validation

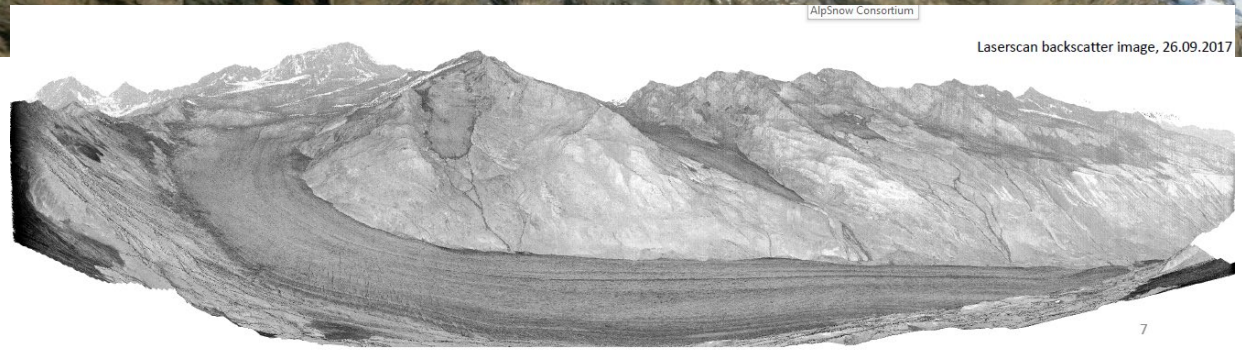
The Rofental Research Basin





Measurements

- 3 Insitu Automatic Weather station (10 min)
- Terrestrial Laser Scanner permanently installed, providing repeat observations
- 2 Webcams (online)
- Field campaigns with insitu snow measurements (irregularly)



Fractional Snow Cover

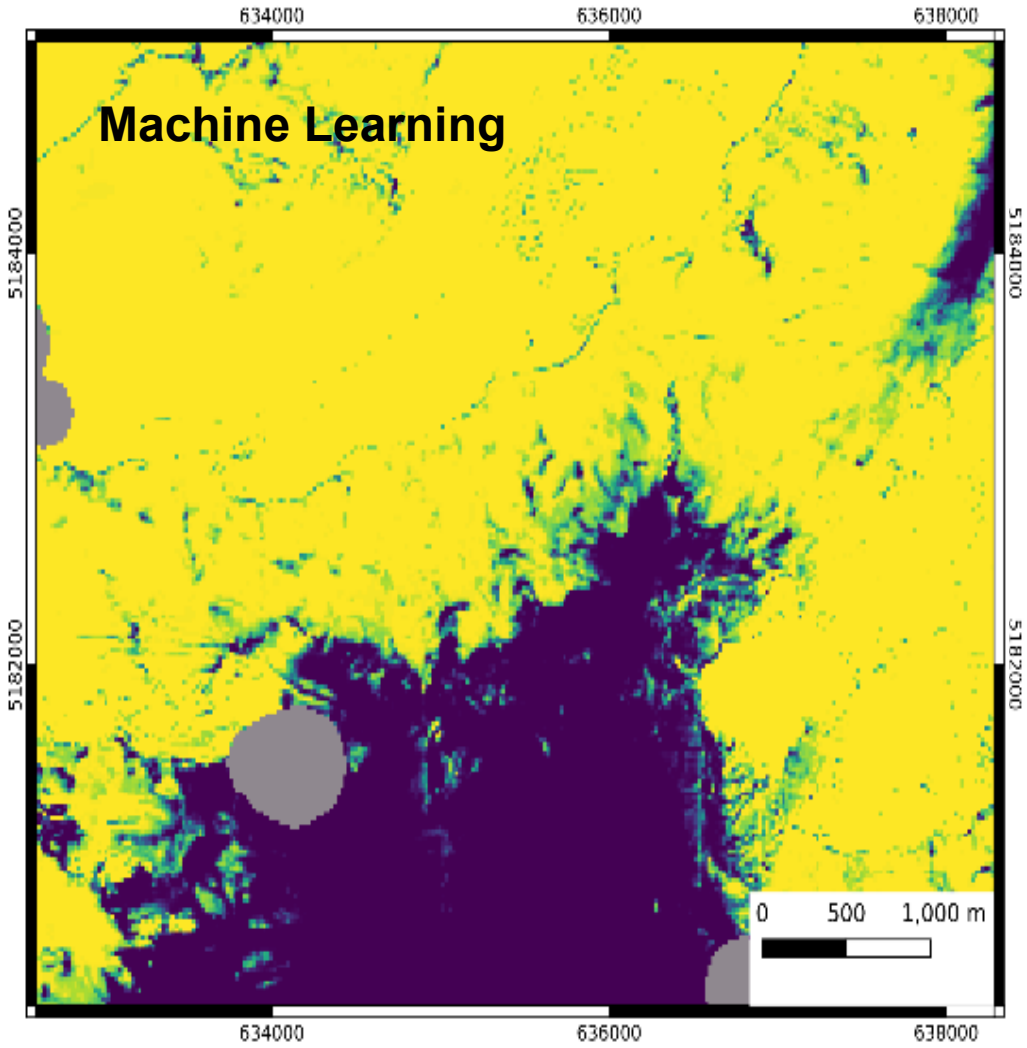
Sensors: S2, Landsat, S3 SLSTR&OLCI, PRISM

Candidate Algorithms

- NDSI based regression
- Machine Learning
- Multispectral unmixing with local adaptive endmember selection

Challenges:

- Illumination and viewing geometry (topography)
- FSC retrieval in shadowed areas
- Correction for canopy/forest layer
- Cloud / snow discrimination



Snow Albedo and Grainsize

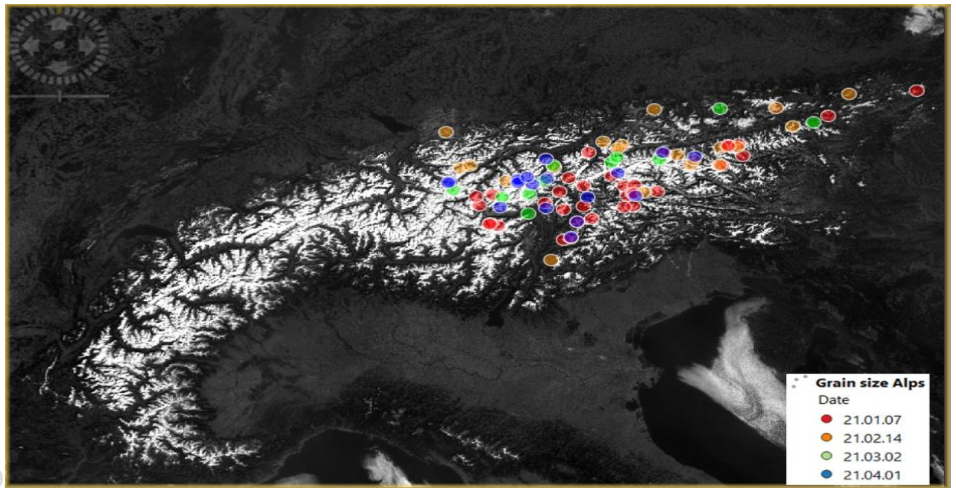
Sensors: S2, Landsat, S3 SLSTR&OLCI, PRISMA

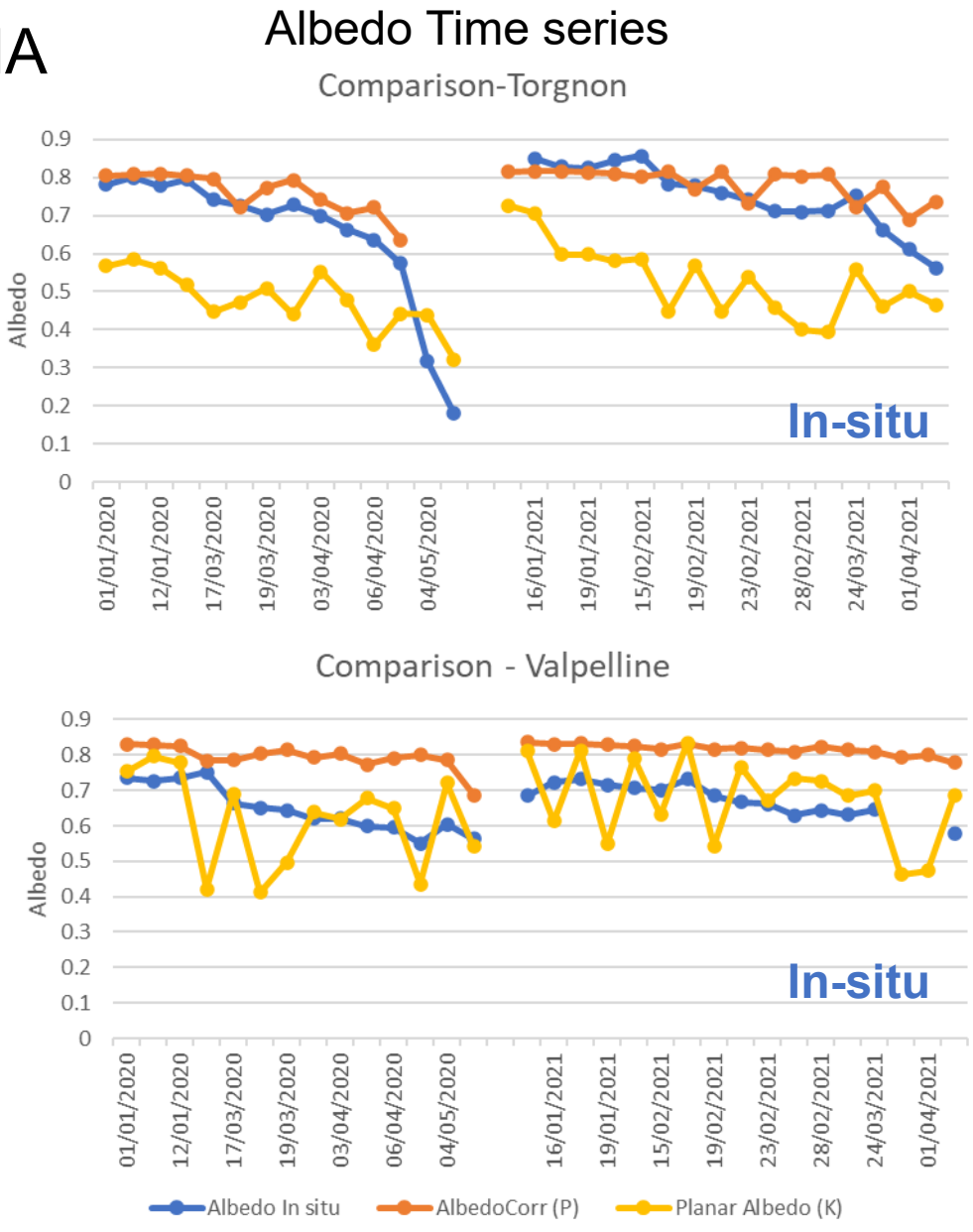
Candidate Algorithms

- Adapted Painter et al. 2009
- Kokhanovsky et al. 2019

Challenges:

- Illumination / viewing geometry in mountains
- Dark shadowed pixels
- Validation / intercomparison with in-situ data





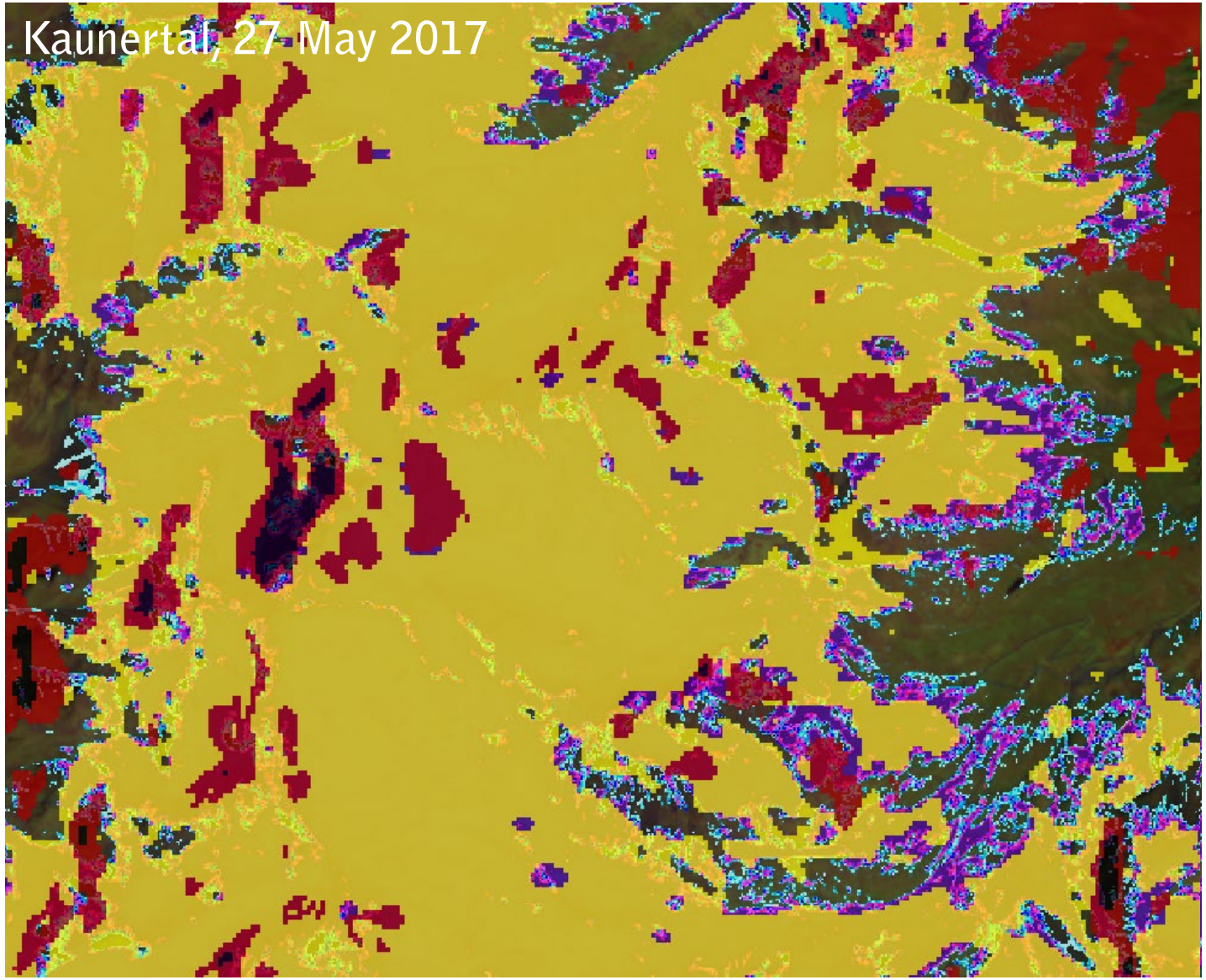
Wet Snow Extent

Sensor: S1 SAR

Dual Pol Wet Snow Algorithm, (selected by round robin within SEOM-S14Sci Snow)

Further Developments:

- Dependence of wet snow threshold on imaging geometry
- Investigate possibilities for detecting wet snow in sparse forests



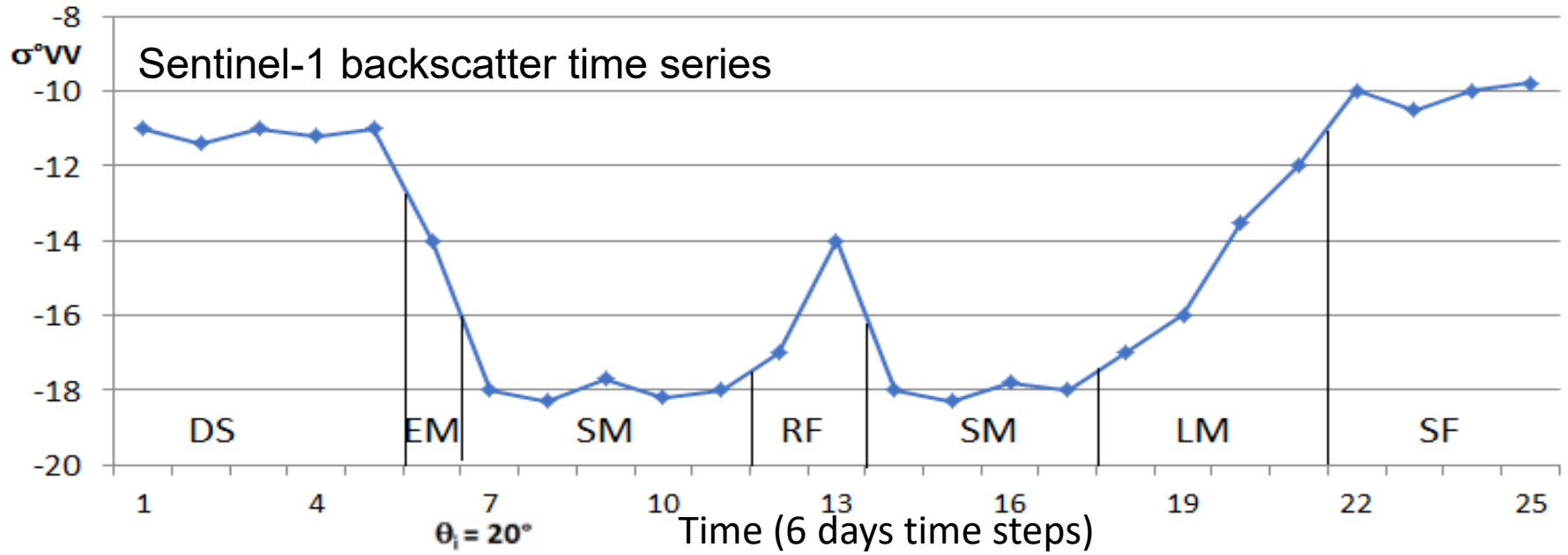
S1 - Wet snow Radar shadow

S2 snow product
- Fractional SC
- 10 m pixel

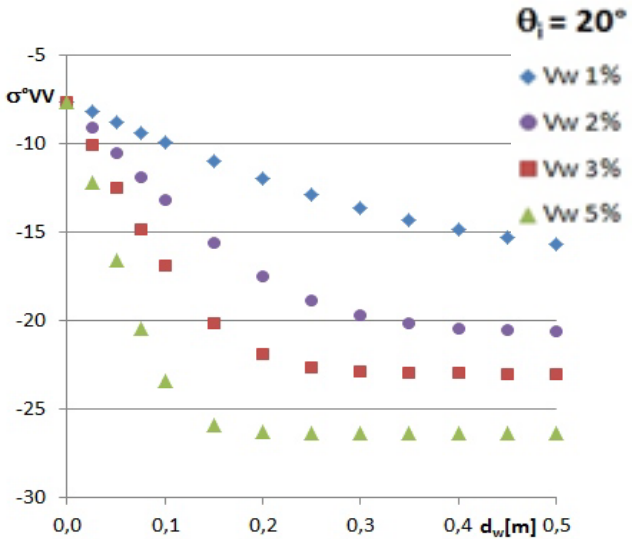
S1 Snow Melt product:
- binary
- 20 m pixel

Seasonal Evolution of Snow Wetness State

Dense time series of C-band backscatter enable to map different melt states of the seasonal snow cover.



DS	Dry snow
EM	Early melt
SM	Saturated melt signal
RF	Refreezing
LM	Late melt season
SF	Snow-free

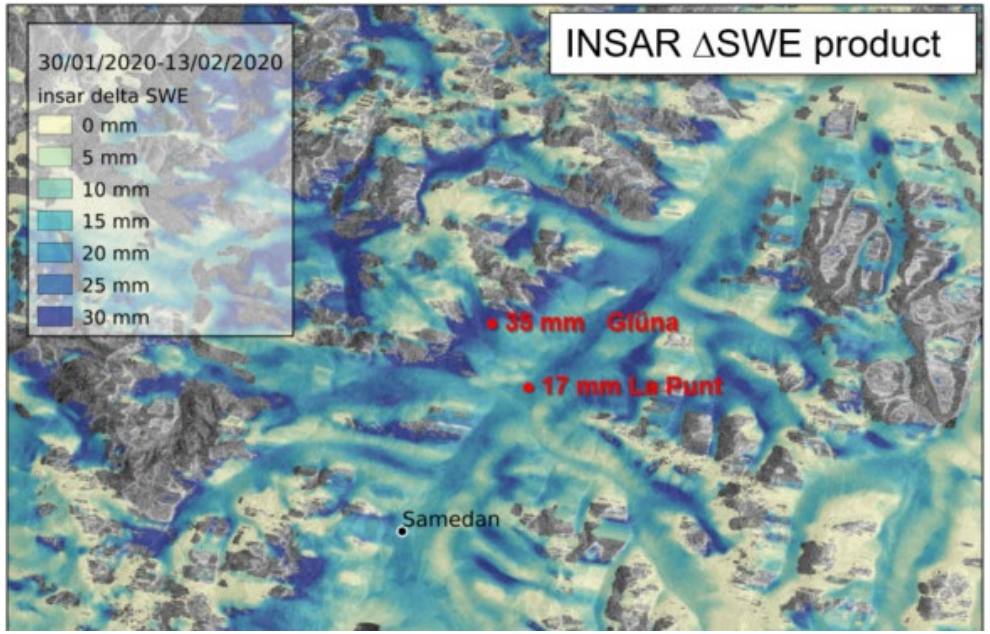


Backscatter simulations show that signal saturation at C-band in respect to wet layer depth is reached rapidly for V_w > ca. 2 %.

Snow Water Equivalent / Snow Depth

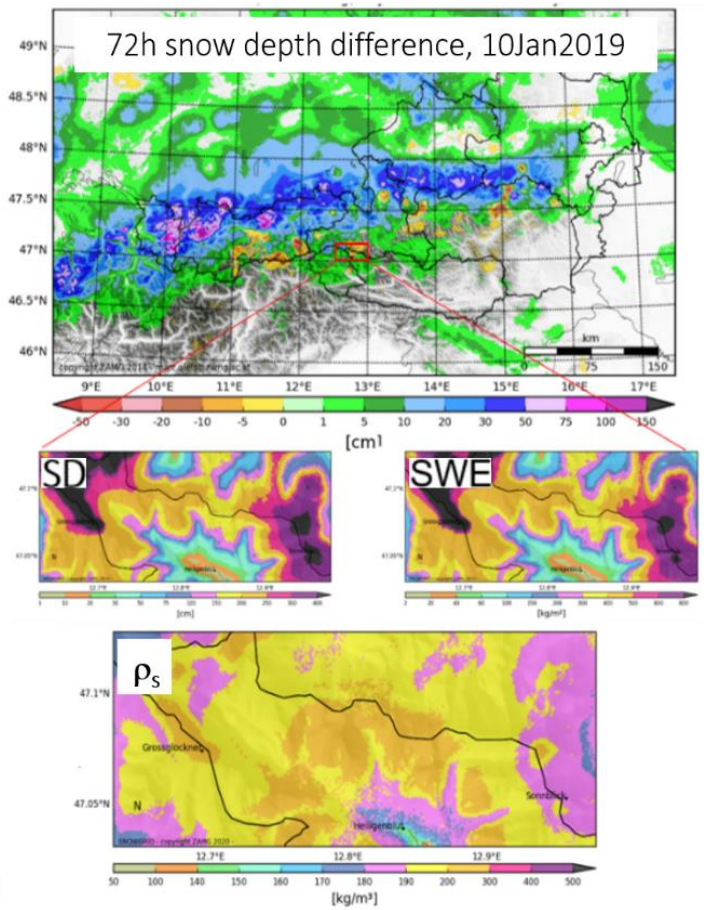
L-Band InSAR SWE Retrieval

- Direct physical measurement of snow mass
- Signal decorrelation due to snow accumulation less critical at L-Band than at C-Band
- Limited access to suitable L-Band SAR data with a few days repeat cycle (SAOCOM A/B)
- Methods works for dry snow only → Synergy between L- and C-Band; C-Band used to detect wet snow (S1 & ROSE-L)



Snow Model SNOWGRID

- Direct Insertion Assimilation of various EO products (FSC, wet snow, etc)
- SWE Reconstruction



Use Cases of AlpSnow Products

The use cases aim to demonstrate and to evaluate the potential of the developed AlpSnow products for research and for operational applications and to assess the impact and added valued of the products for these applications.

SCIENCE CASES

- ***Case #1 performed by UED*** – Use of AlpSnow products in high-resolution land surface and atmosphere modelling
- ***Case #2 carried out by UIBK*** – Snow Modelling and Runoff using the Model AMUNDSEN in Rofental
- ***Case #3 carried out by SLF*** – Analysing SAR wet snow maps in the context of high-resolution snow hydrological simulations

DEMONSTRATION CASES WITH EARLY ADOPTERS

- ***Case #4 performed by ZAMG*** – Initialization experiments of the numerical forecast model AROME using AlpSnow products.
- ***Case #5 performed by ARPA*** – Use of AlpSnow products for runoff modelling for water management in Valle d'Aosta
- ***Case #6 performed by OHDB*** – Use of AlpSnow products for runoff modelling for water management in South Tyrol

Challenges and Recommendations

- Variation of illumination and viewing geometry has strong impact on retrieval of snow parameters from optical satellite data. Further developments of algorithms are required to account for these effects.
- Snow / clouds discrimination is still an issue, and additional spectral bands at upcoming sensors (S3-NG, S2-NG) should be discussed.
- C-band saturates quickly with wetness, which restricts retrieving the LWC to the top surface layer. But C-Band is promising to monitor the evolution of seasonal snow including refreeze events.
- InSAR provides a physically direct measurement of snow mass. Better access to short repeat pass L-Band data are needed to further test and demonstrate the method in mountain regions, associated with field campaigns to collect dedicated validation data.
- Retrieval methods developed and validated for the Alps should be tested in other mountain regions in different environments.