Monitoring wet snow dynamics in Mediterranean mountains: Implication for water resources management

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Mediterranean Mountains: Snow

- The Mediterranean climate's variability increases the **complexity of snow dynamics** over mountain regions.
    - Highly variable snowpack, time and space, with several accumulation-melting cycles along the year.
    - Shallow snowpack with patchy distribution
    - High snowpack density
    - Non-negligible evaposublimation
- **Hinder the application in a straightfoward way the methodologies applied over Alpine environments.**

Mediterranean Mountains: Backscattering

This work **aims** to:

- Deepening in the relationship between the backscattering signal (S-1 SAR) and some physical parameters of the snowpacks in Mediterranean mountains.

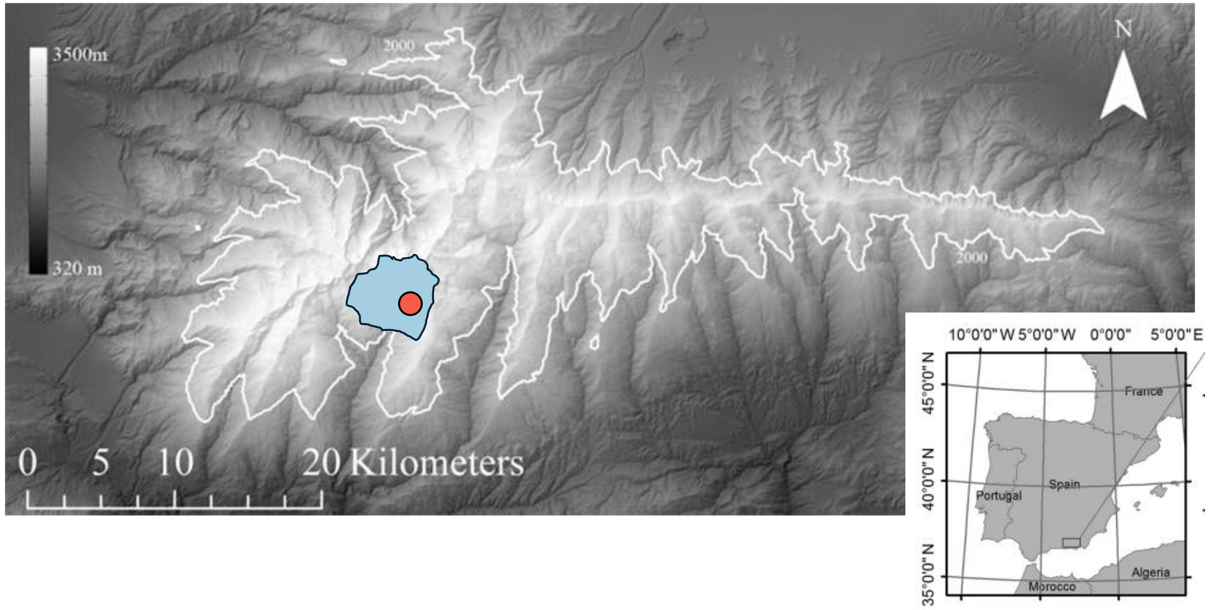
PLOT SCALE

- Assessing the connection between this wet-snow dynamics and streamflow response for water resources management.

CATCHMENT SCALE

Study Site

PLOT: The Refugio Poqueira experimental site
- 2500 m a.s.l.
- Pilot area used for monitoring snow processes in Mediterranean mountains since 2004
- Equipement *
  - Complete meteorological station
  - SWE and snow depth
  - Soil temperature profiles



CATCHMENT SCALE: Poqueira Alto

* **Polo, et al., 2019.** The Guadalfeo Monitoring Network (Sierra Nevada, Spain): 14 years of measurements to understand the complexity of snow dynamics in semiarid regions, **Earth Syst. Sci. Data**, 11, 393–407, https://doi.org/10.5194/essd-11-393-2019

PLOT SCALE

The Refugio Poqueira experimental site

Data

- **Period:** 2016/17 – 2020/21

Remote Sensing

- Sentinel 1
- C-band SAR imagery
- Two orbits overpass the study site
  - **Orbit 01 (18:10 GMT+1)**
  - Orbit 81 (07:15 GMT+1)
- VH polarization

- 298 scenes were processed and analyzed

Proximal Sensing

- Terrestrial photography
- 5 images per day every two hours (8:00 GTM – 16:00 GTM)
- Photo resolution 640 x 504 pixels
- Area photographed ~ 900 m^2
- Photo resolution 640 x 504 pixels

- 1461 images were processed

Wet snow retrieval (Sentinel-1)

General change detection approach (Nagler et al., 2000, 2004) addapted to semiarid environments *

SAR Preprocessing

- GRD border noise removal
- Thermal noise removal
- Radiometric calibration
- Terrain correction
- Noise floor correction
- Layover and shadowing
- GRD border noise removal

Reference Image selection

Sensitivity analsyis of different options

Average of all previous summer images

Wet Snow Threshold Definition

Comparison of the histograms of dry and wet pixels

Threshold = -3.00 dB

Cross Evaluation

Nagler et al., 2016

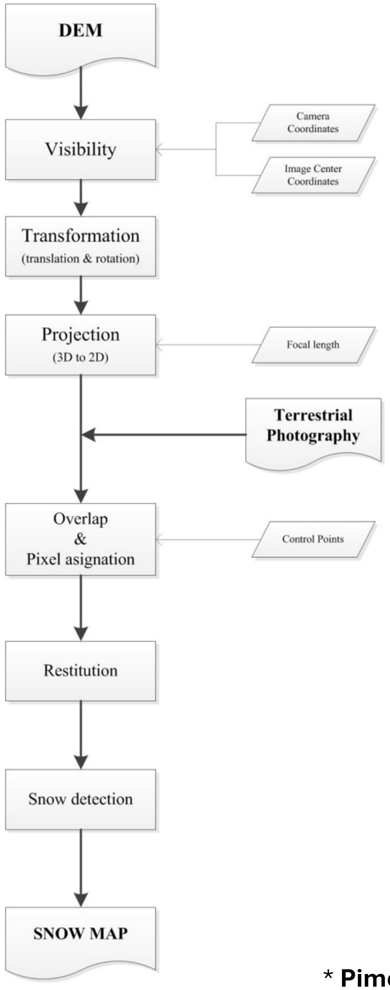
Accuracy = 0.79
(2017-2020)

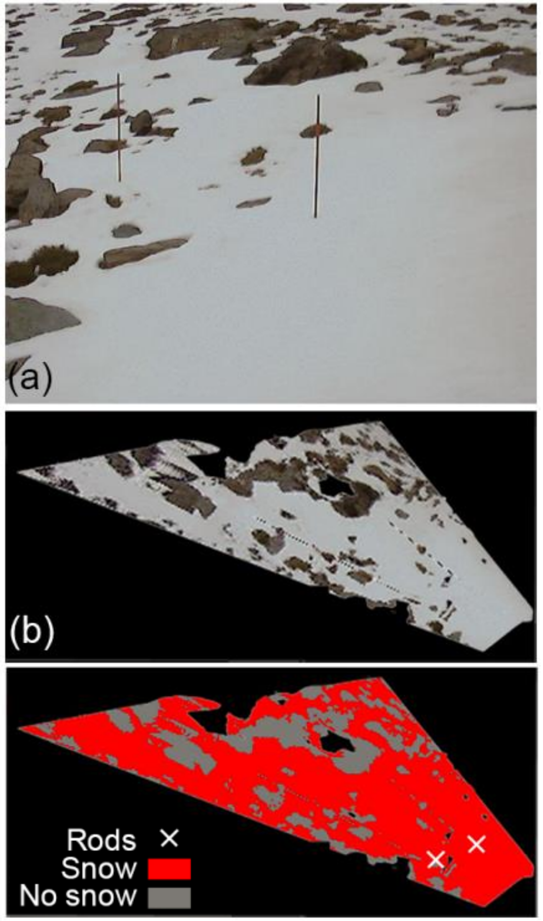
Optical snow cover extension discrimination

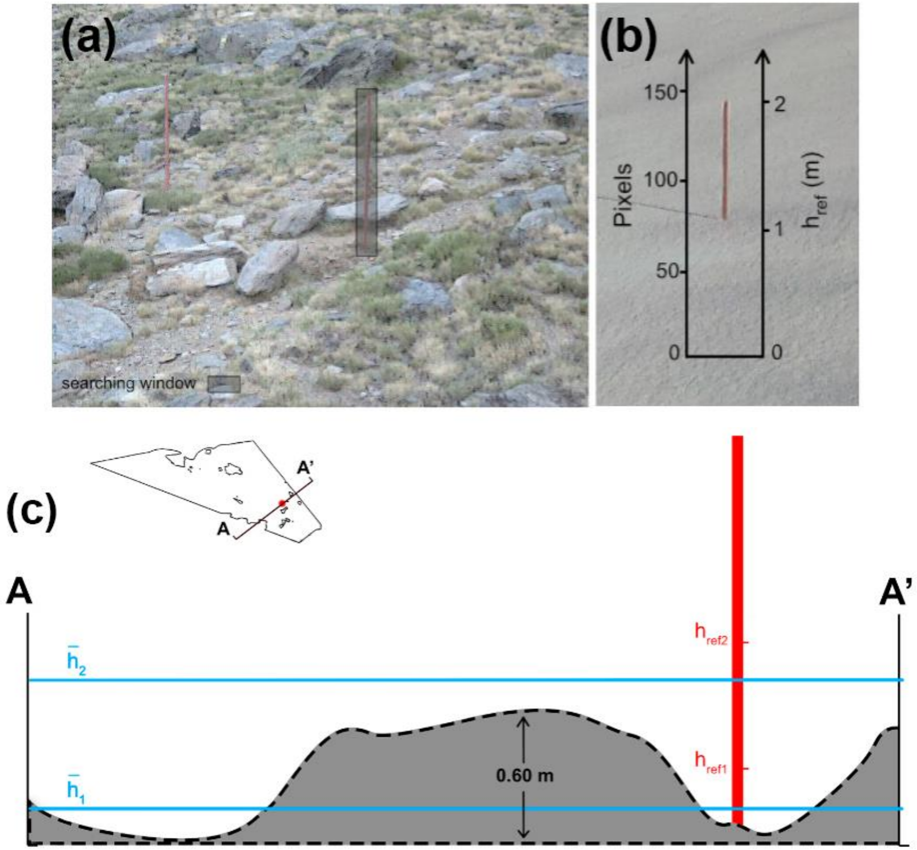
MOD10A2 version 006

* **Torralbo, P. et al., 2023**. Characterizing Snow Dynamics in Semi-Arid Mountain Regions with Multitemporal Sentinel-1 Imagery: A Case Study in the Sierra Nevada, Spain. **Remote Sens.** 15, 5365. https://doi.org/10.3390/rs15225365

FSC and snow depth retrieval (Terrestrial photography)

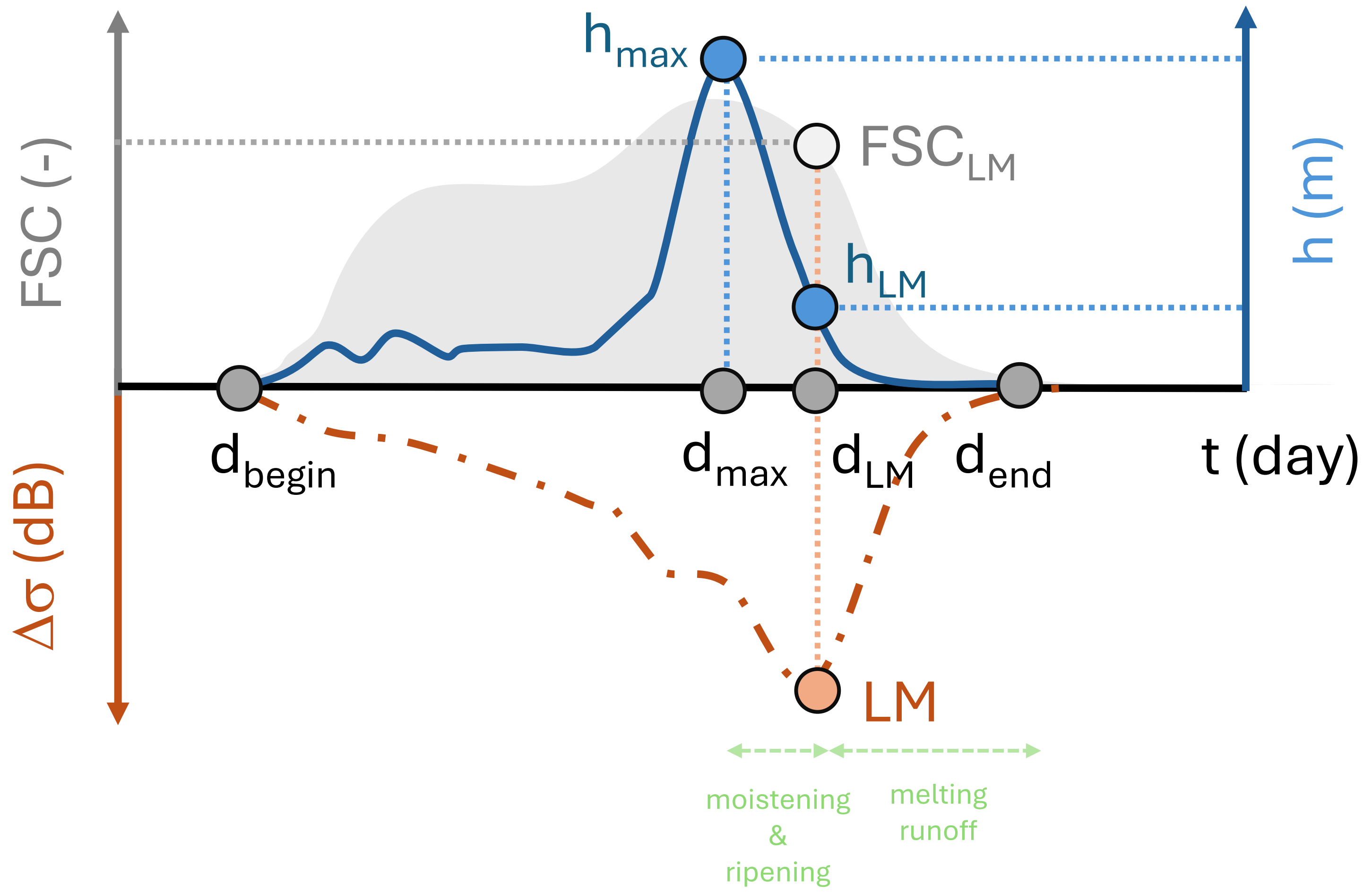






* **Pimentel, et al., 2017** Subgrid parameterization of snow distribution at a Mediterranean site using terrestrial photography, **Hydrol. Earth Syst. Sci.,** 21, 805–820, https://doi.org/10.5194/hess-21-805-2017

Snow dynamics' parameters

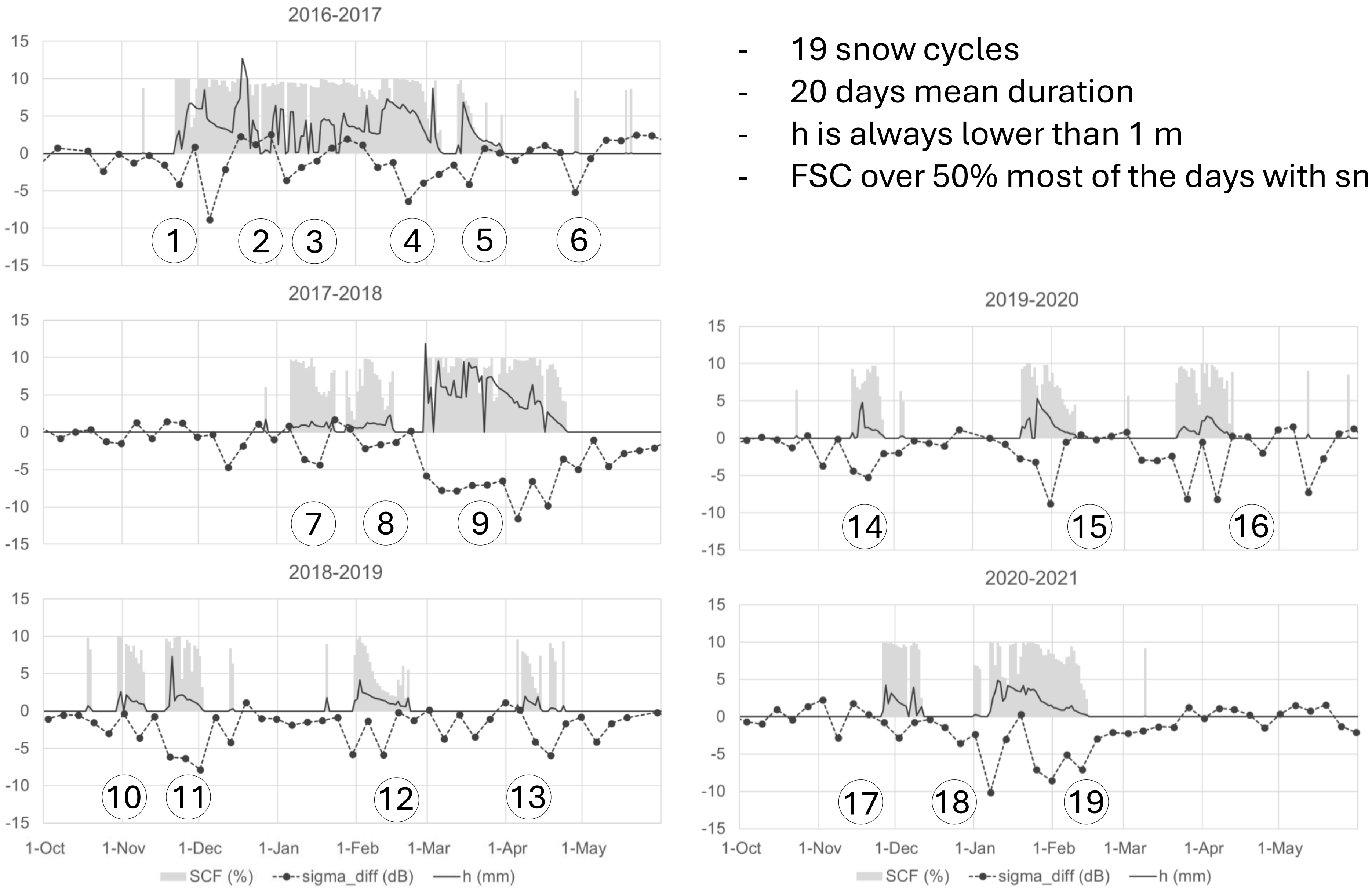


d_{begin}: begin of an snow cycle (date)
d_{end} : end of a snow cycle (date)
duration: $d_{end} - d_{begin}$ (days)

h_{max} : maximum snow depth (m)
d_{max} : day of maximum snow hight (date)

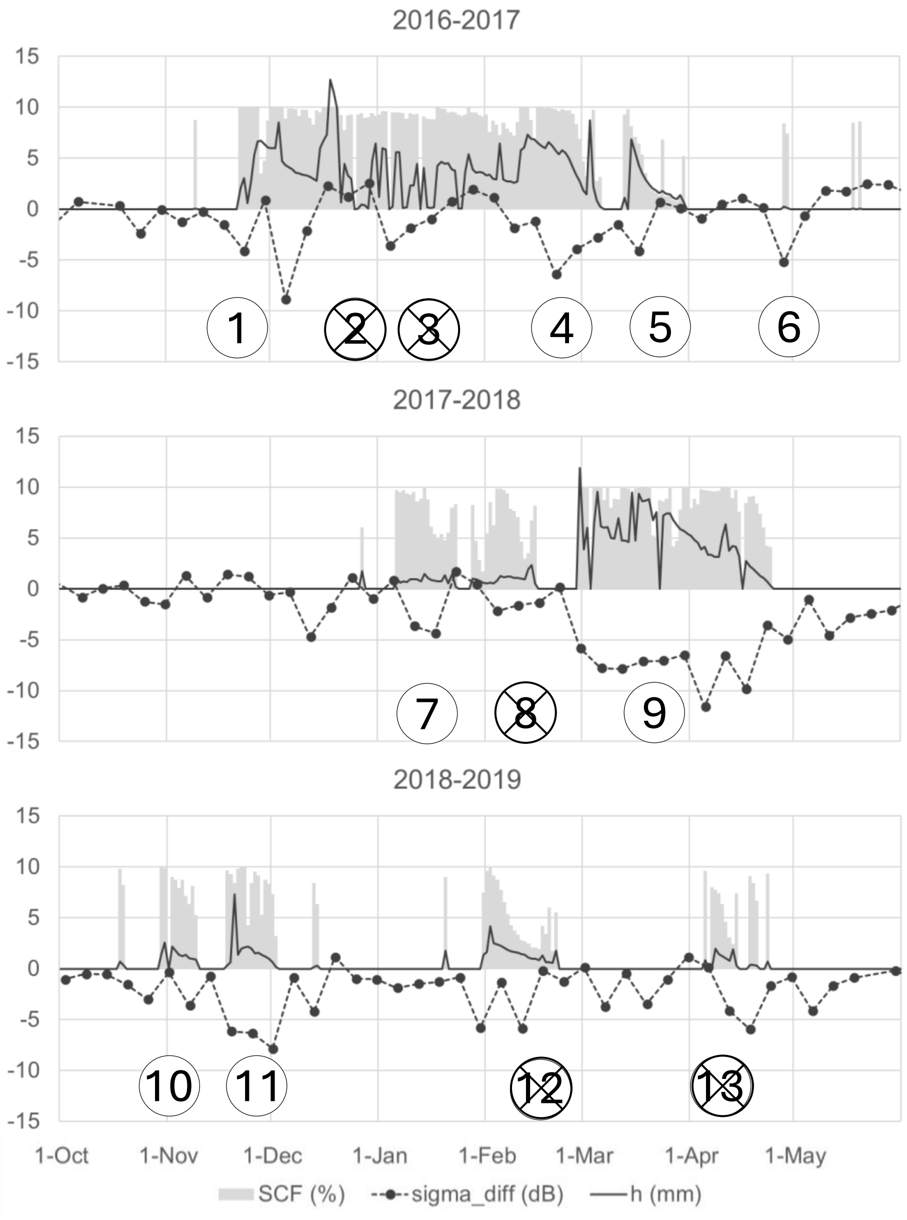
LM: backscatter local minimum (dB)
d_{LM} : day of local minimum (date)
h_{LM} snow depth of local minimum (m)
FSC_{LM} snow cover of local minimum(%)

Results

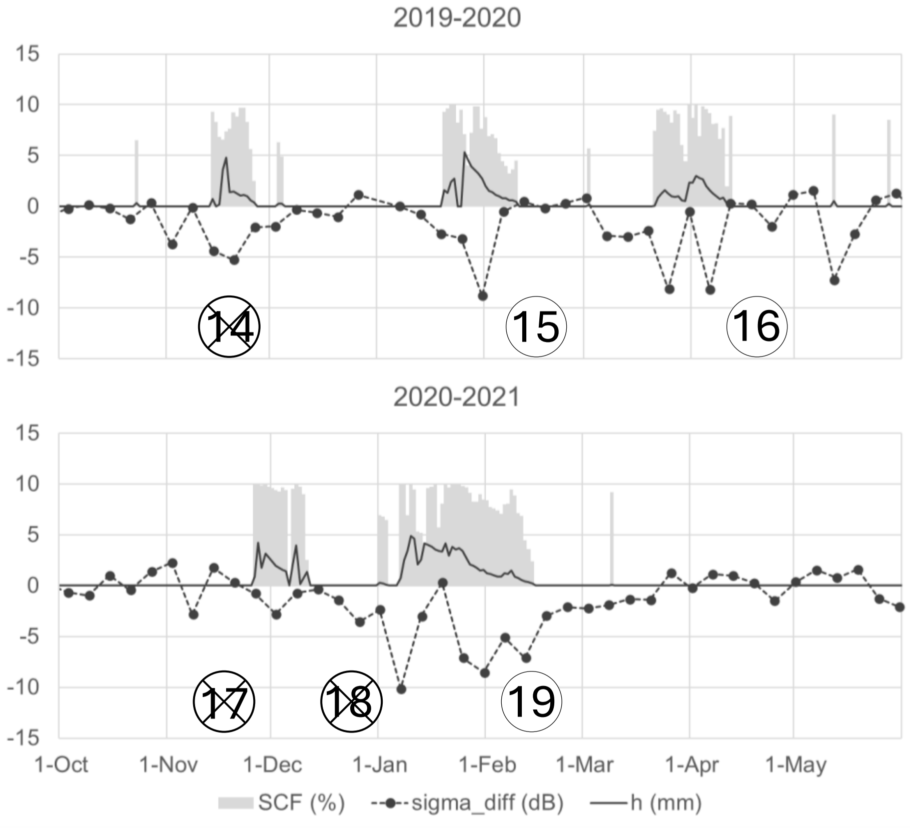


- 19 snow cycles
- 20 days mean duration
- h is always lower than 1 m
- FSC over 50% most of the days with snow

Results



- Wet conditions were not capture in the cycles 2, 3, 8, 17 and 18
- FSC_{LM} does not reach 50%
- **11 snow cycles** were analyzed

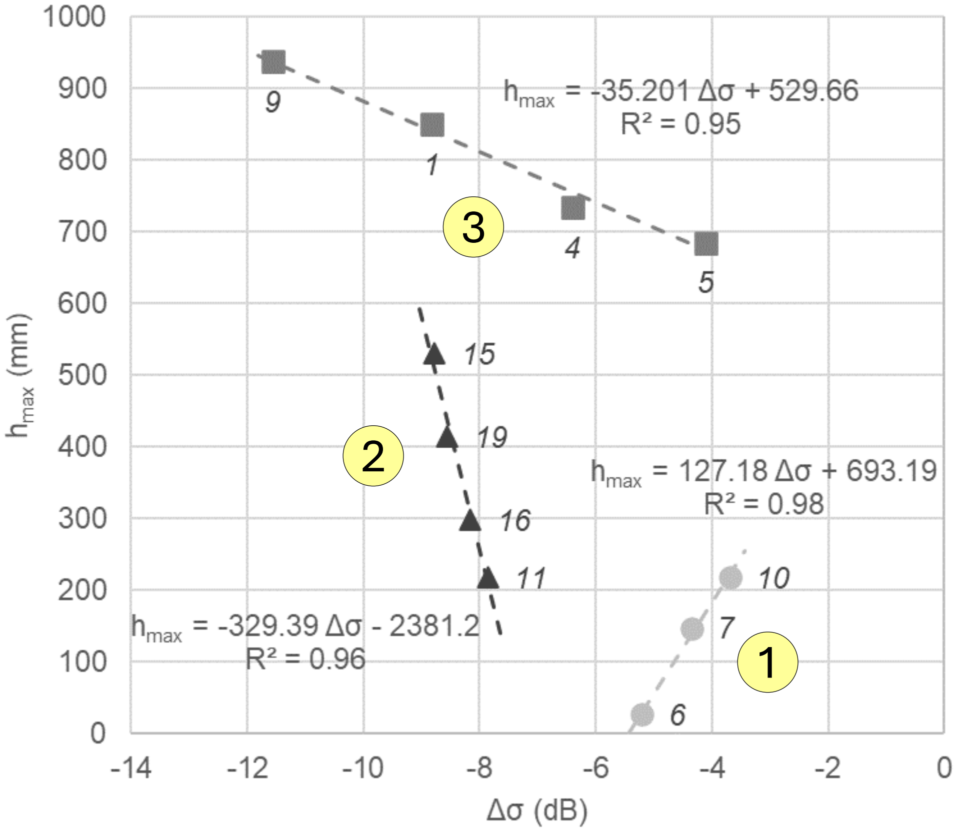


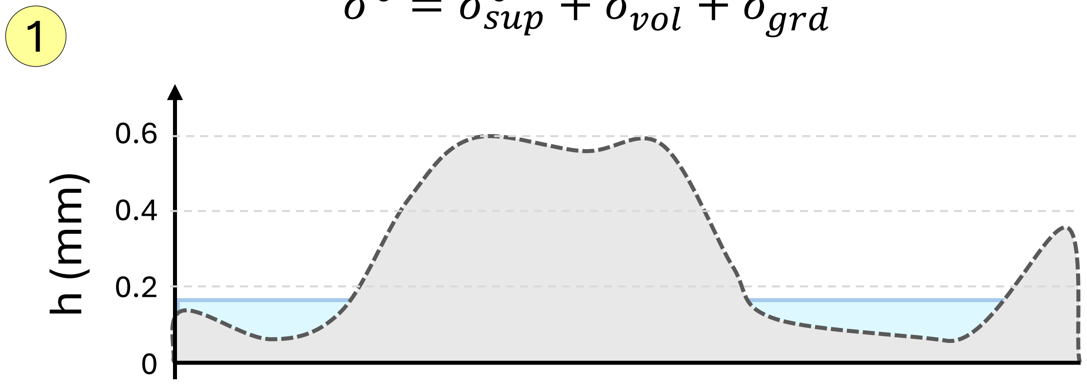
Results

ID	$date_{begin}$	$date_{end}$	duration (day)	h_{max} (mm)	$date_{hmax}$	LM (dB)	$date_{LM}$	h_{LM} (mm)	FSC_{LM} (%)
1	22/11/2016	24/12/2016	33	850	03/12/2016	-8.82	05/12/2016	433	99
4	14/01/2017	06/03/2017	52	734	13/02/2017	-6.39	21/02/2017	579	90
5	13/03/2017	30/03/2017	18	685	15/03/2017	-4.11	17/03/2017	433	75
6	28/04/2017	29/04/2017	2	28	28/04/2017	-5.20	28/04/2017	28	70
7	06/01/2018	23/01/2018	18	148	14/01/2018	-4.37	17/01/2017	83	72
9	04/03/2018	24/04/2018	52	937	17/03/2018	-11.57	05/04/2018	414	85
10	03/11/2018	09/11/2018	7	219	03/11/2018	-3.63	07/11/2018	105	72
11	18/11/2018	21/12/2018	34	219	24/11/2018	-7.86	01/12/2018	62	80
15	20/01/2020	10/02/2020	22	530	26/01/2020	-8.78	31/01/2019	273	95
16	21/03/2020	12/04/2020	23	299	02/04/2020	-8.16	06/04/2020	167	94
19	07/01/2021	14/02/2021	39	414	14/01/2021	-8.55	31/01/2021	155	88

- We compared LM with the h_{max} of the cycle that generates this local minimum, which is always achieved earlier and with higher depth than the LM.

Results





$$\sigma^0 = \sigma^0_{sup} + \sigma^0_{vol} + \sigma^0_{grd}$$

Shallow snowpacks

- Positive relationship, the higher Δσ the higher h_{max} in the snow cycle
- Reference image corresponds to summer period, soil water content is null
- Backcattering signal can be related to soil moisture.

* **Pimentel. et al., 2024.** Combining Terrestrial Photography and Sentinel-1 Imagery for Assessing Wet Snow Dynamics in Ephemeral Snowpack over Semiarid Mountain Areas," *IGARSS 2024 - 2024 IEEE International Geoscience and Remote Sensing Symposium*, Athens, Greece, 2024, pp. 635-638, https://doi.org/10.1109/IGARSS53475.2024.10641534

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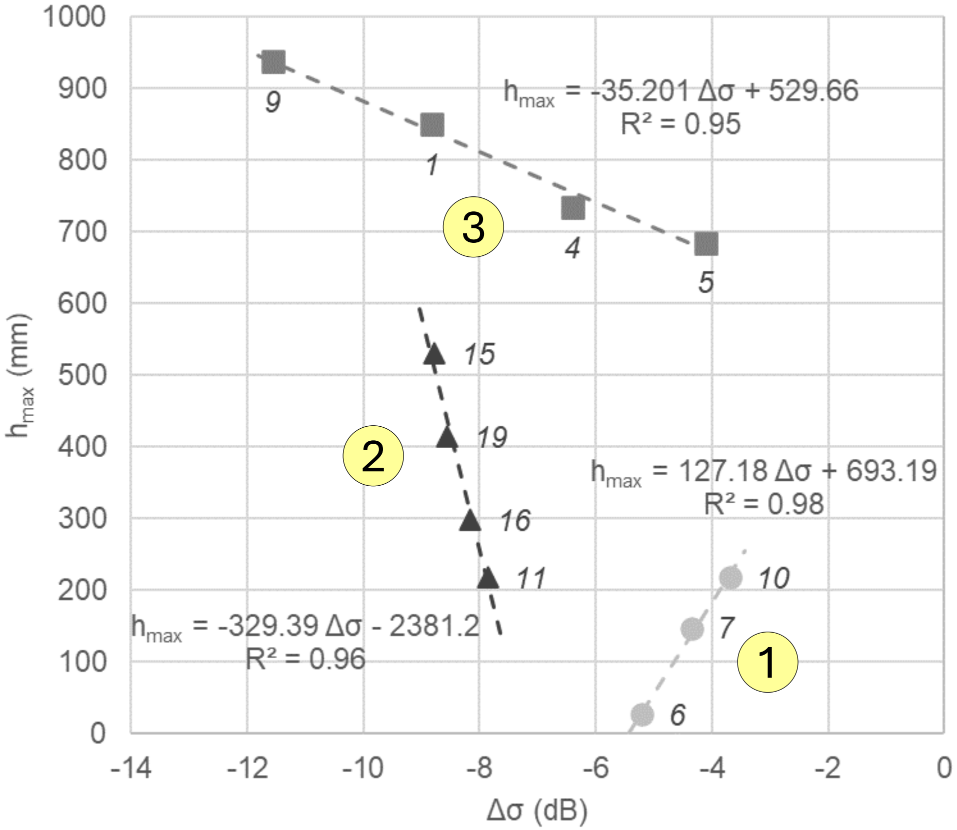

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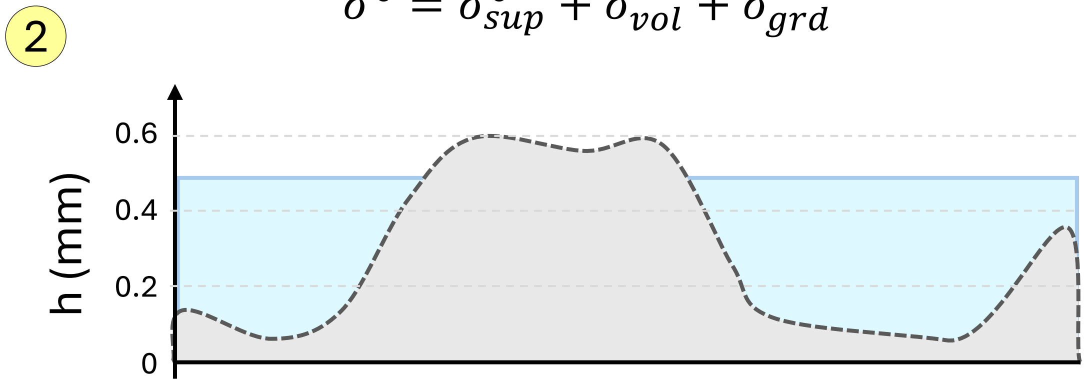

Snowpacks not fully cover the microtopography

- Negative relationship between Δσ and h_{max}
- High slope, volumetric backscatter (σ^0_{vol}) plays a role but surface (σ^0_{sup}) and ground (σ^0_{grd}) backscattering are still important.
- The shallower the snowpack, the higher the roughness and the lower the backscatter.

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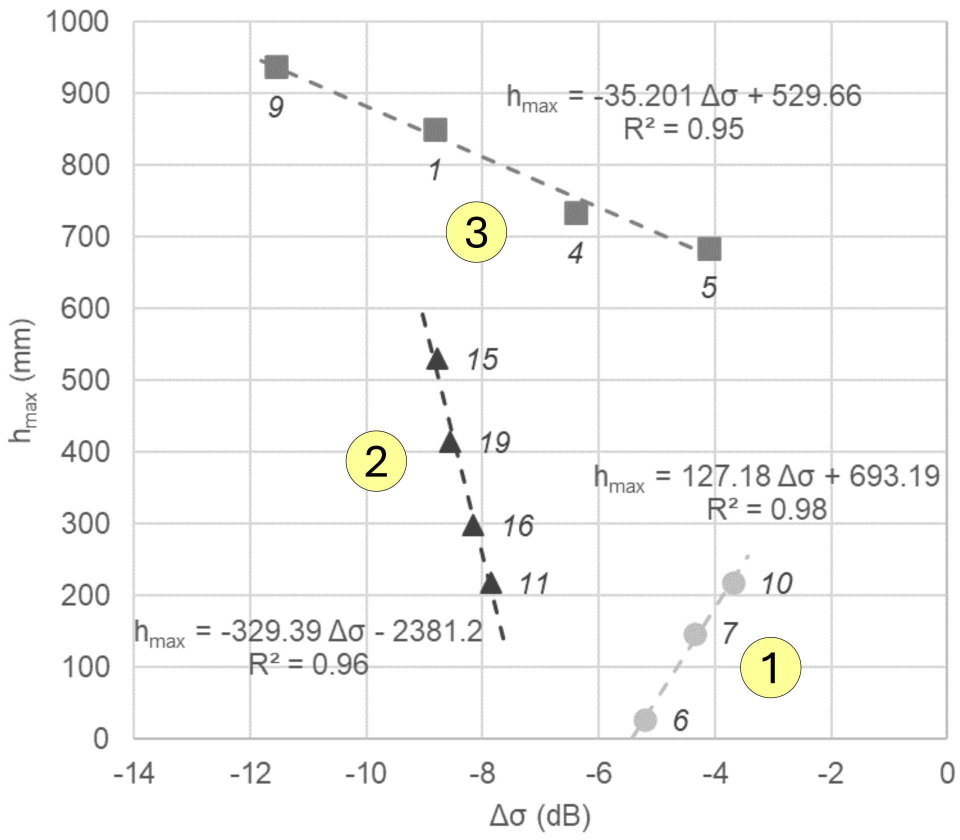

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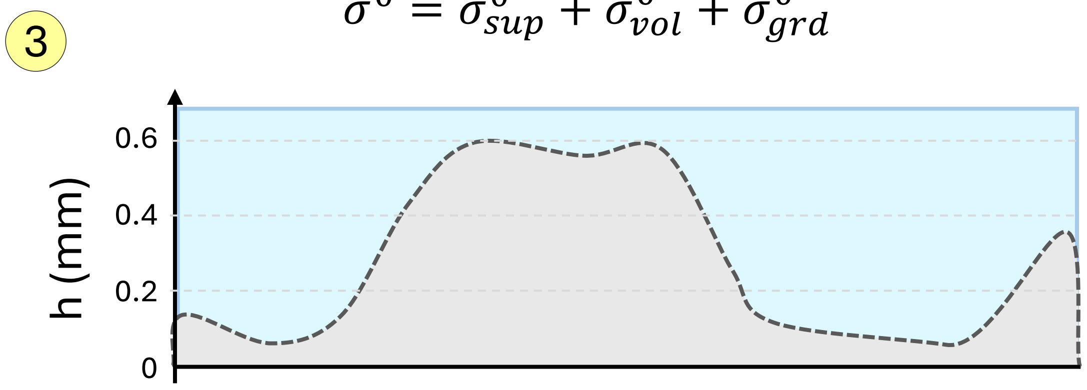

Snowpacks fully cover surface topography

- Less steeper slope, roughness of topography does not play a role.
- This relationship can be connected to a higher water content in the snowpack, since the higher the snow depth the higher the capacity of the snowpack for storing water.
- More complex backscattering signal response.
- It needs further research: other datasets and physical modeling using Radiative Transfer Modelling

CATCHMENT SCALE

Poqueira Alto

Data

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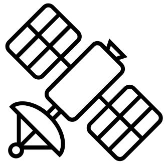

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- VH polarization

- MODIS10A2
- Fractional Snow Cover Discrimination

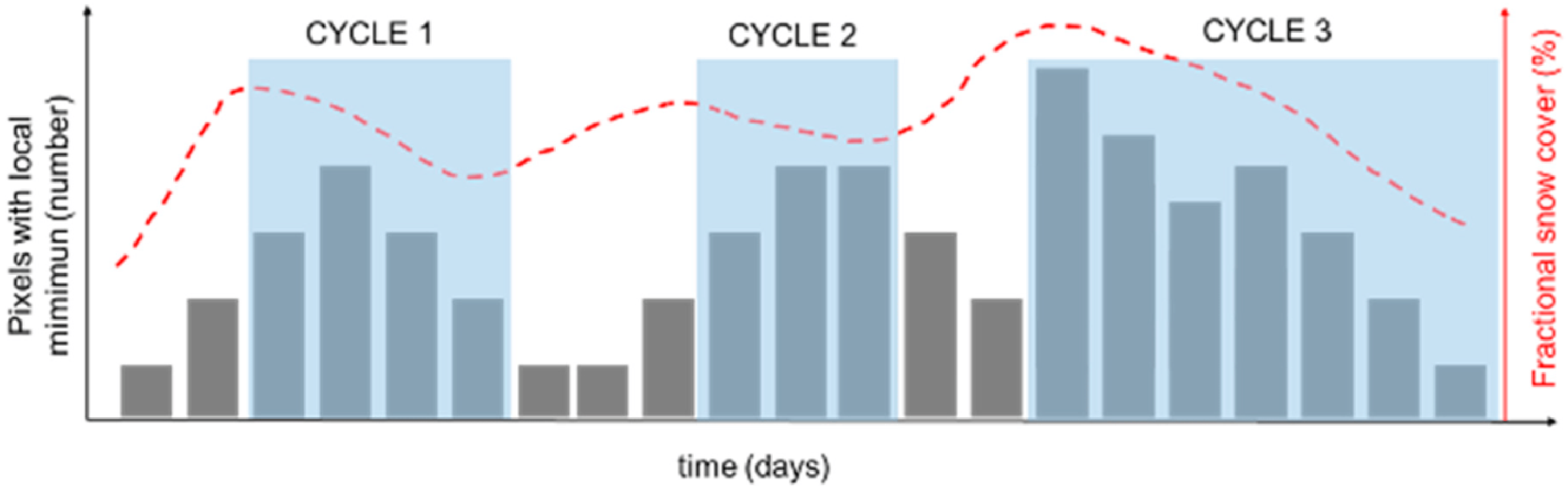
- 298 scenes were processed and analyzed

Streamflow Simulation

- WiMMed (Watershed Integrated Model for Mediterranean Environments)
- Distributed Hydrological Model
- Physcally based

Methodolgogy

A melting cycle was defined if there was an increase in the number of pixels with **ΣLM** and **FSC** was maintained or decreased



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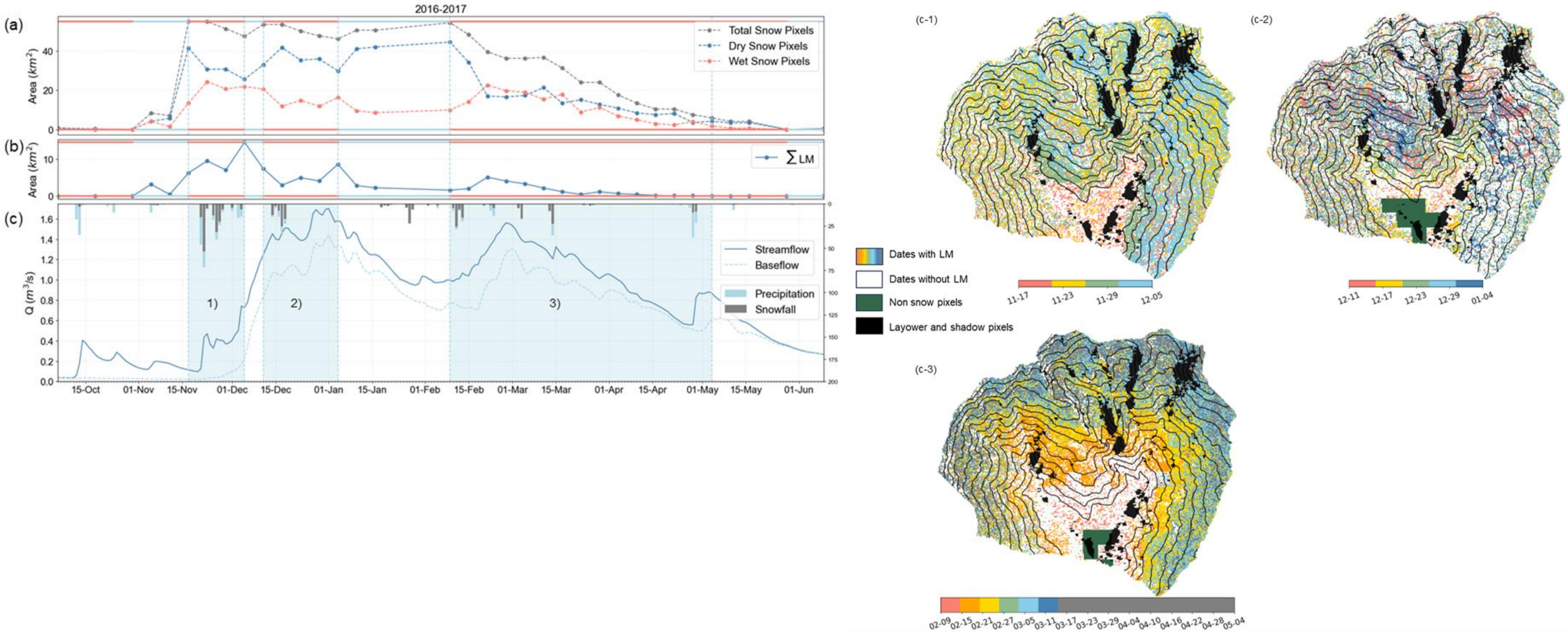

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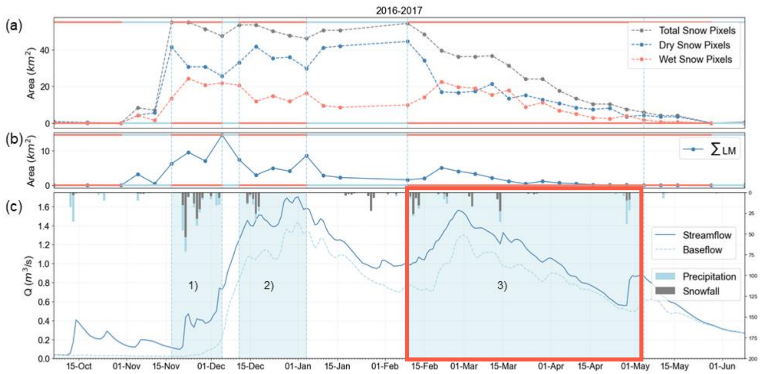
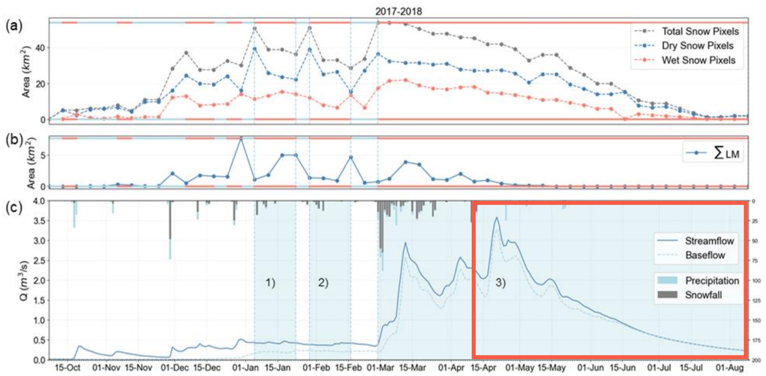
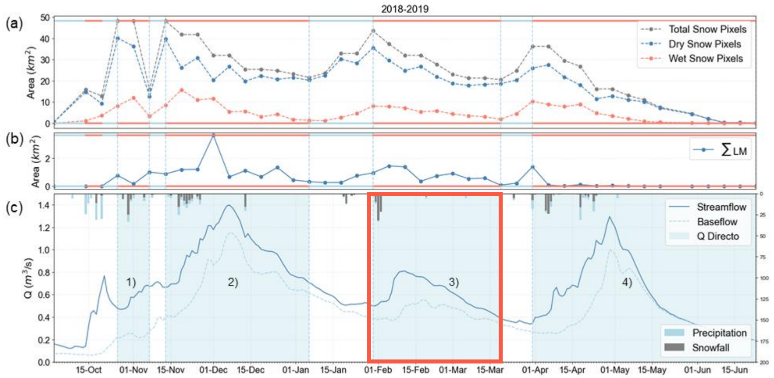
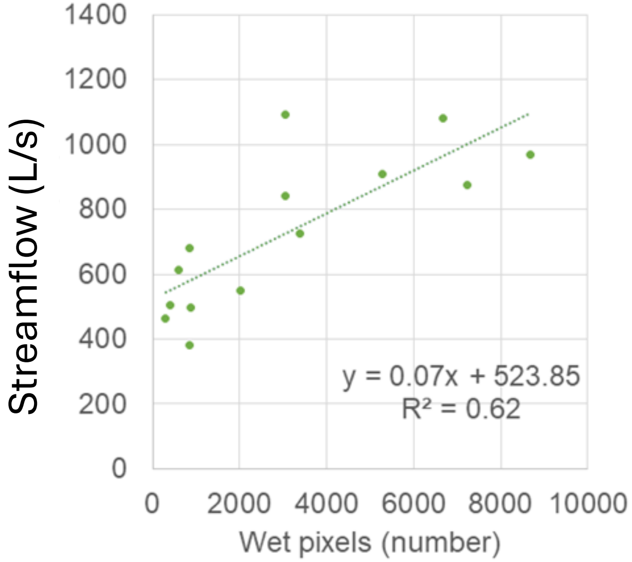
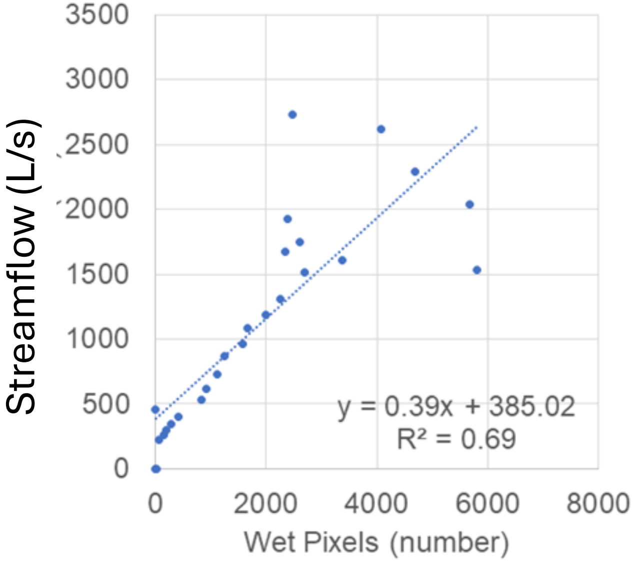




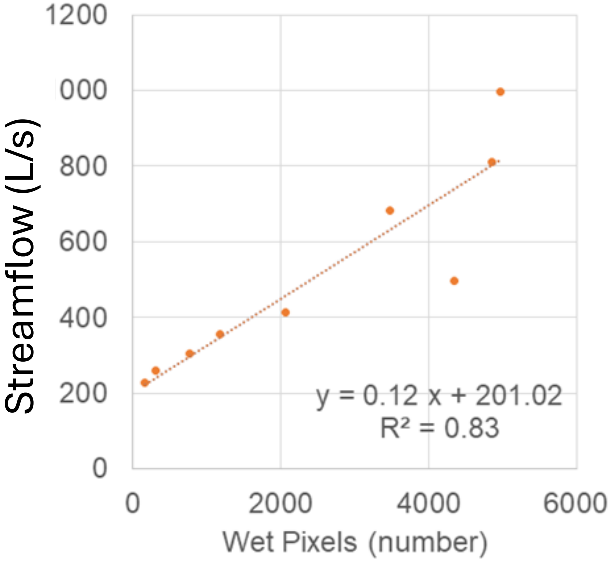




21 Days



13 Days



30 Days

Conclusions

The results show :

- Three relationships were defined between the minimum backscattering and the maximum snow depth achieved for a specific melting cycle. The slope of this linear relationship changes depending on the contribution of the ground to the backscattering signal, being positive for shallow snowpacks and negative for thicker ones. Further investigation needs to be carried out to validate these results.
- At the catchment scale, a novel approach was introduced to delineate melting cycles throughout the year using Sentinel-1 SAR imagery. A linear relationship with an average delay of approximately 21 days between the melting onset and the peak streamflow

謝謝 !!

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2023 HELPING 2032

IAHS Drought in mountain regions working group