CPAZMAL : Cryosphere PAZ SAR Data for MAchine Learning

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LISTIC

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Outline

1. **Dataset**
   - Data acquisition and study area
   - Temporal evolution of the data
   - Dataset creation
2. **A new temporal classification method**
   - Dynamic Time Warping (DTW): existing method
   - Proposed method
   - Results and inference
3. **Conclusions**
4. **Appendix**

Study area

Area over the Mont Blanc Massif:

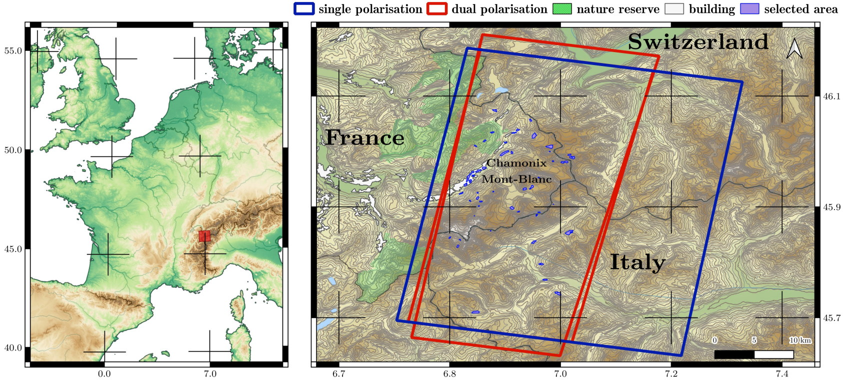

Figure 1: SAR extend and ground truth.

Glacier classes and labelling

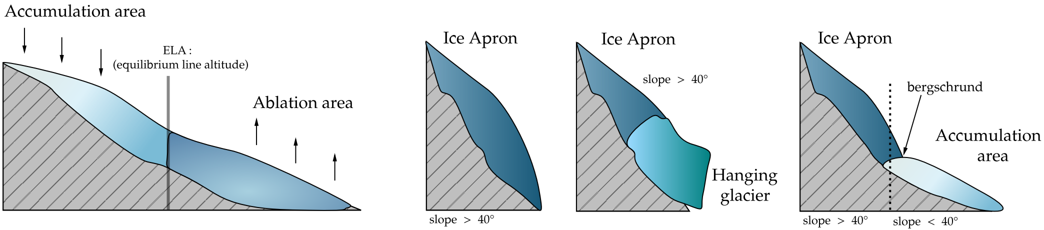

Figure 2: Four types of glacier surfaces. [Kaushik et al., 2022]

Glacier classes	Common classes
ABL: Ablation	FOR: Forest
ACC: Accumulation	CIT: City
HAG: Hanging Glacier	ROC: Rock
ICA: Ice Apron	PLA: Plain

Acquisition availability

SAR data from the PAZ satellite (X-band) in dual polarization (HH, HV) over 2020-2021.

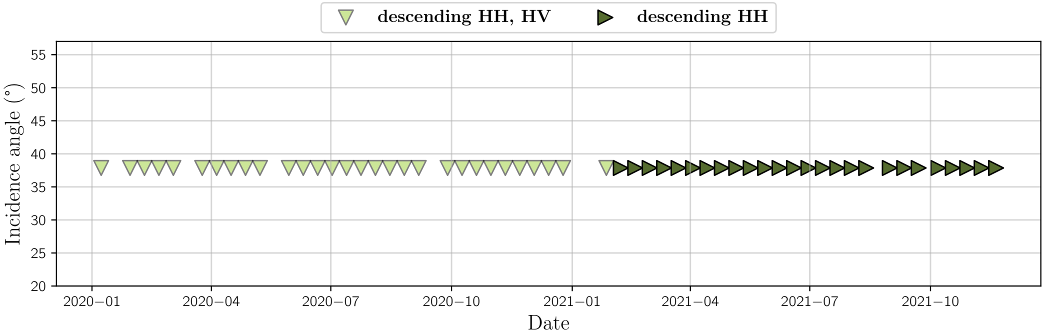

Figure 3: Temporal overview of the PAZ acquisition.

Data seasonal temporal evolution

Histogram distribution of the backscatter coefficient for all different classes in single (HH) and cross (HV) polarization.

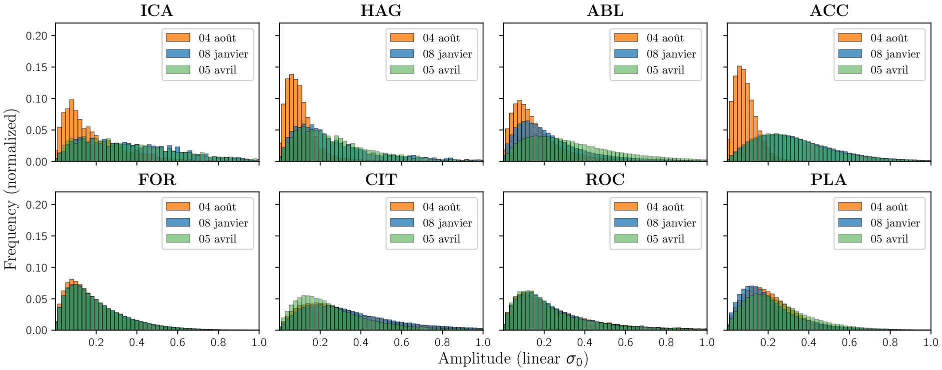

Figure 4: 2020 HH polarization

Data seasonal temporal evolution

Histogram distribution of the backscatter coefficient for all different classes in single (HH) and cross (HV) polarization.

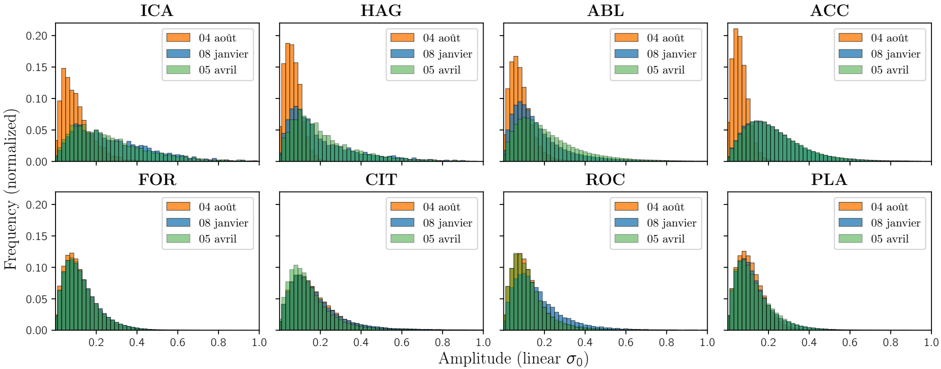

Figure 4: 2020 HV polarization

Data spatio-temporal evolution

Spatio-temporal and polarimetric comparison of the different classes over the year 2020.

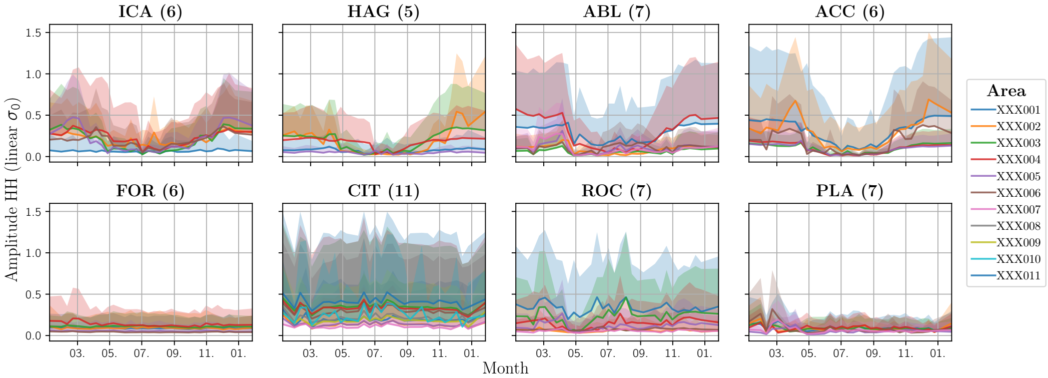

Figure 5: 2020 HH polarization

Data spatio-temporal evolution

Spatio-temporal and polarimetric comparison of the different classes over the year 2020.

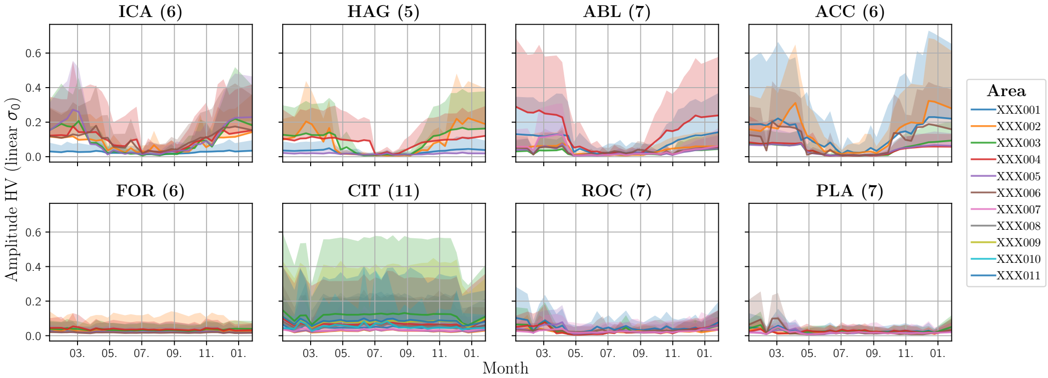

Figure 5: 2020 HV polarization

Glacier classes

- Ground truth extraction on SAR amplitude.
- 5 to 7 ground truth groups/polygons by class (over SPOT imagery).
- Stored with group ID to avoid random sampling strategy.
- Only calibrated data(no terrain correction).
- Full dataset available on Zenodo.
- Including data loader in python with SQL queries and windowing.

Example of the dataset created with the 4 glacier classes and a 7x7 window.

Table 1: Average number of samples (7x7) per class for all training.

	ABL	**ACC**	**HAG**	**ICA**
train	134 ± 43	132 ± 46	126 ± 57	131 ± 39
test	67 ± 43	69 ± 46	75 ± 57	70 ± 39

Conclusion on the dataset

→ Dataset available on Zenodo.

Improvements in progress for a early release:

- DEM construction with LiDAR data (1m resolution).
- Radiometric and terrain correction.
- More ground truth polygons (11).
- Extended dataset with TerraSAR-X data on 2009/2011.
- Improvements of the data loader with more metadata (polarization, incidence angle).
- Full area with the 4 glacier classes to evaluate models.

Figure 6: QR code for dataset access.

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3 Conclusions

4 Appendix

Dynamic Time Warping (DTW): background

Let Q and S be two time series of the same length n.

Considering a cost matrix C of size $n \times n$:

$$C_{i,j} = (Q_i - S_j)^2 \tag{1}$$

The DTW distance between Q and S is [?]:

$$DTW(Q,S) = \min_{\pi} \left[\sum_{(i,j)\in\pi, K=1}^{K} C_{i,j} \right]^{\frac{1}{2}} \tag{2}$$

$$i(0) = 1, j(0) = 1, i(K) = n, j(K) = n$$

$$|i(k) - j(k)| \leq r, \forall k$$

with π an alignment path between Q and S, and K number of points on the warping function.

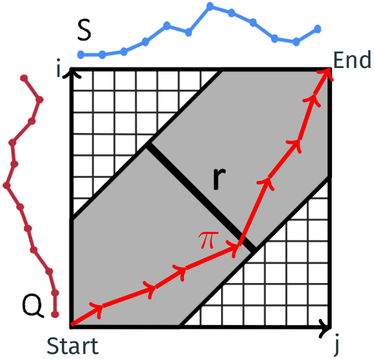

Figure 7: DTW alignment path with Sakoe-Chiba band constraint [Sakoe and Chiba, 1978].

Data spatio-temporal evolution: application of DTW

Comparison between DTW similarity and Euclidean metric.

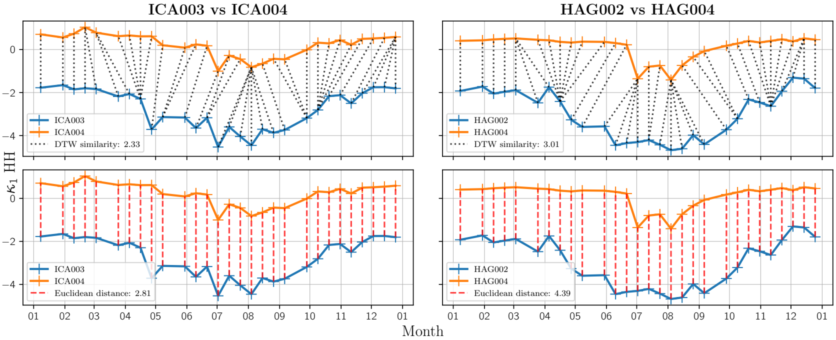

Figure 8: Ice apron and Hanging glacier in 2020 with HH polarization

→ Comparison with Euclidean distance: $Euc(Q,S) = \left[\sum_{i=1}^{n}(Q_i - S_i)^2\right]^{1/2}$

Data spatio-temporal evolution: application of DTW

Comparison between DTW similarity and Euclidean metric.

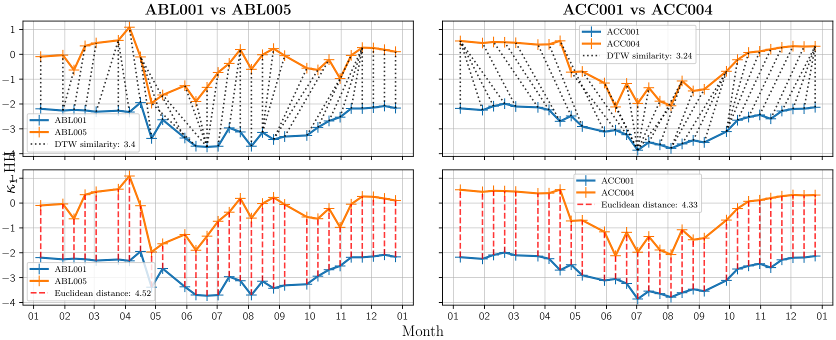

Figure 8: Ablation and Accumulation in 2020 with HV polarization

→ Comparison with Euclidean distance: $Euc(Q, S) = \left[\sum_{i=1}^{n} (Q_i - S_i)^2\right]^{1/2}$

Centroid estimation on monovariate time series with DBA

- Combinaison of HH and HV polarizations with the normalized cross-polarisation ratio given by $(HH - HV)/(HH \cdot HV)$
- Patches (7x7) features extraction with
- 3 statistics: log cumulants of order 1, 2 and 3 (κ_1, κ_2, κ_3) [Nicolas and Anfinsen, 2002].
- Barycenters DTW Barycenter Averaging (DBA) estimation [Petitjean et al., 2011].

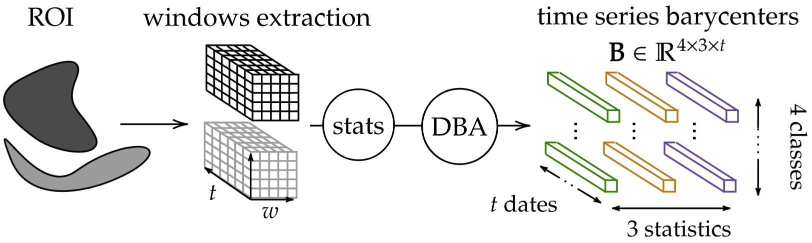

Figure 9: Barycenters DBA estimation.

Classification with DTW probabilities

- DTW probabilities inference with estimated barycenters:

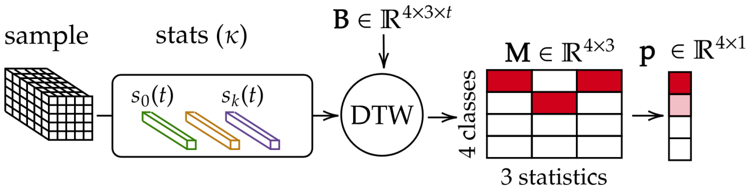

Figure 10: DTW probabilities inference

Majority vote on DTW distances $\mathcal{D}$ of time series barycenters $\mathbf{M}_{c,k}$

$$\mathbf{p}_{s(t)} = \sum_{i=1}^{c} \begin{bmatrix} \mathcal{D}\left(\mathbf{B}_{0,0}, s_0(t)\right) & \cdots & \mathcal{D}(\mathbf{B}_{0,k}, s_k(t)) \\ \vdots & \ddots & \vdots \\ \mathcal{D}(\mathbf{B}_{c,0}, s_0(t)) & \cdots & \mathcal{D}(\mathbf{B}_{c,k}, s_k(t)) \end{bmatrix} \tag{3}$$

Classifying and inference results

Table 2: F1-score and accuracy performances (in %). Average is 35.6%.

ABL	ACC
39.0	20.4

HAG	ICA
45.3	31.8

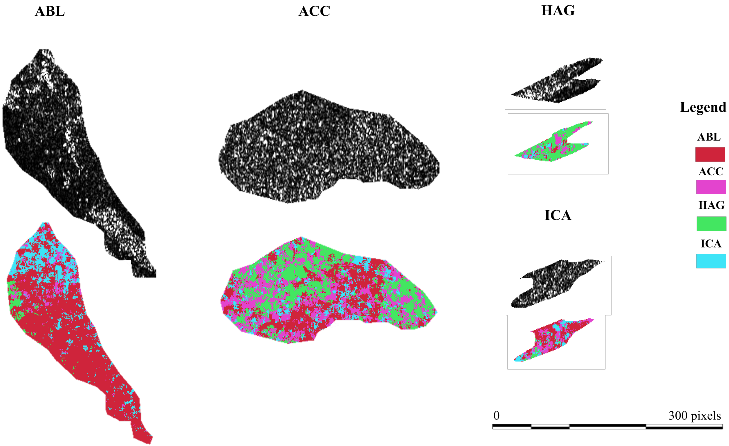

Figure 11: Pixel-wise inference.

Outline

Conclusions

- New dataset (CPAZMAL) for **glacier** classification with PAZ SAR data in the Mont Blanc Massif over 2020-2021.
- **Temporal** classification with **DTW method** given good and **comprehensive** results.
- Improvements on the dataset in progress for a early release.

Outline

Bibliography

[allowframebreaks,noframenumbering]

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