POLITECNICO
MILANO 1863

Rutor glacier

Temporal classification using
Random Forest and MLP

Earth Observation - Advanced
Edoardo Pessina

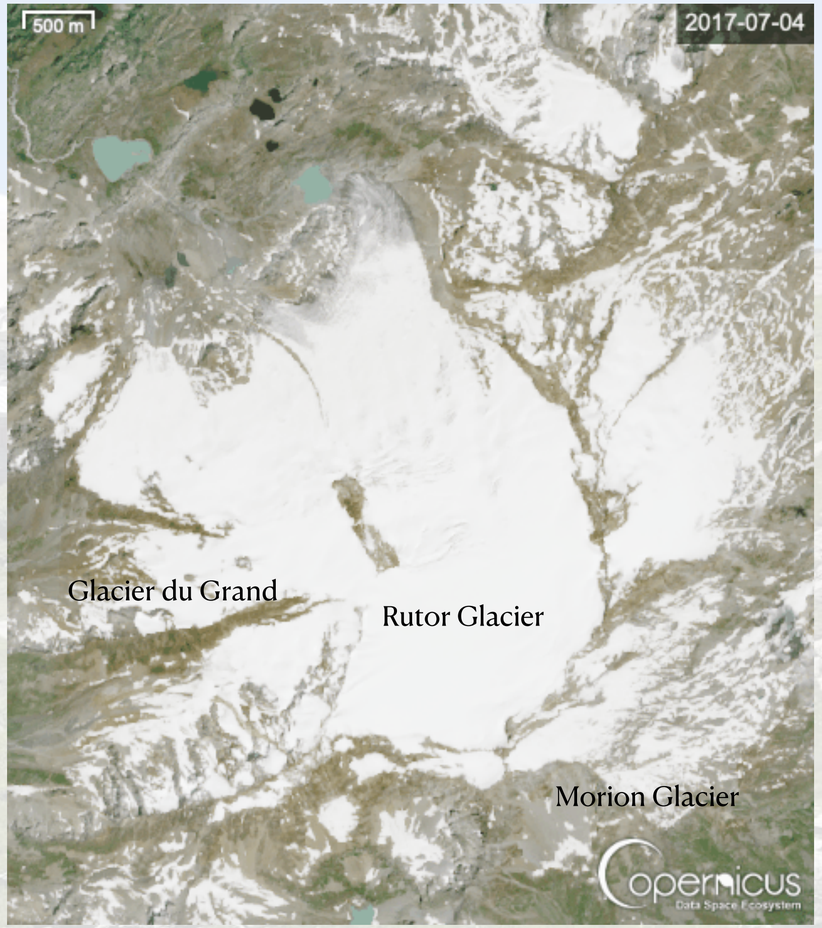
Study area: Rutor Glacier

Technical specifications

- Time range: August 1984 - September 2024
- 5 years time period
- Elevation 2500m - 3500m

Data characteristics

- Landsat 5 and Landsat 8
- Temporal resolution: 16 days
- Spatial resolution: 30m*
- Bands: {SR_1, SR 2, SR_3, SR_4, SR_5, SR_7, ST_B6}



Rutor Glacier temporal evolution [2017-2025]

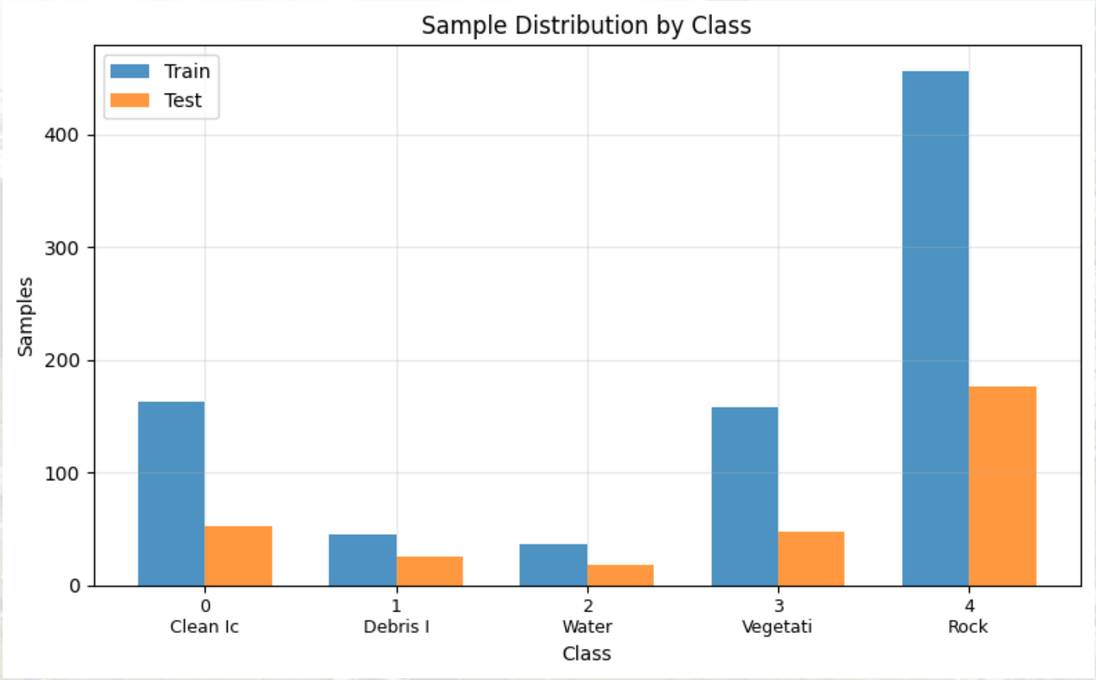
Methodology

Workflow

- **Data collection** [Landsat 5-8]
- **Preprocessing** [cloud masking, 3 spectral indices]
- **Training samples** [manual creation of polygons]
- **Training models** [RF vs MLP architecture]
- **Temporal classification** [8 time periods]
- **Validation**

Classes

- (0) - Clean ice
- (1) - Debris-covered ice
- (2) - Water
- (3) - Vegetation
- (4) - Rock



Machine learning approaches - RF

Random Forest implementation

Input

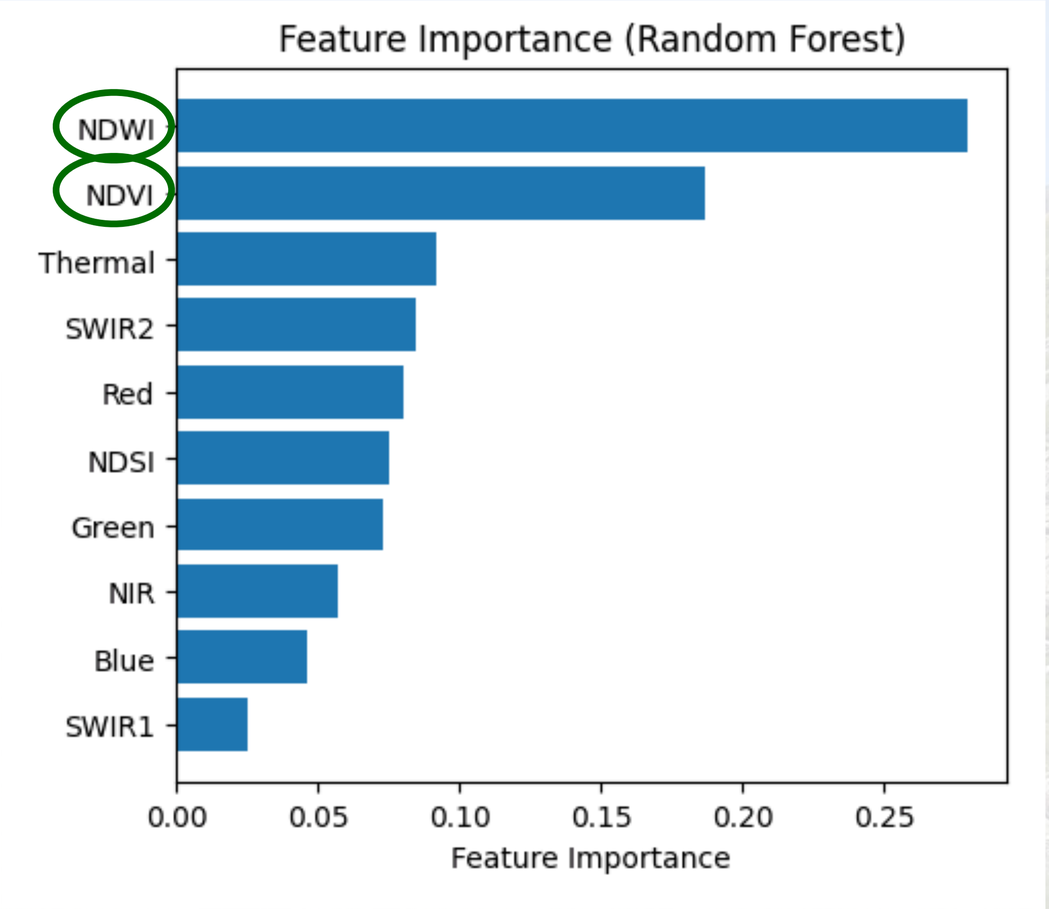
- 1178 samples
  - (75 %) - 858 training samples
  - (25 %) - 320 testing samples

RF Model

- *ee.Classifier.smileRandomForest()*
- DT = 110
- Seed = 42

RF training performance

- Overall accuracy: 100%
- Overfitting: 0.9 %



Machine learning approaches - MLP

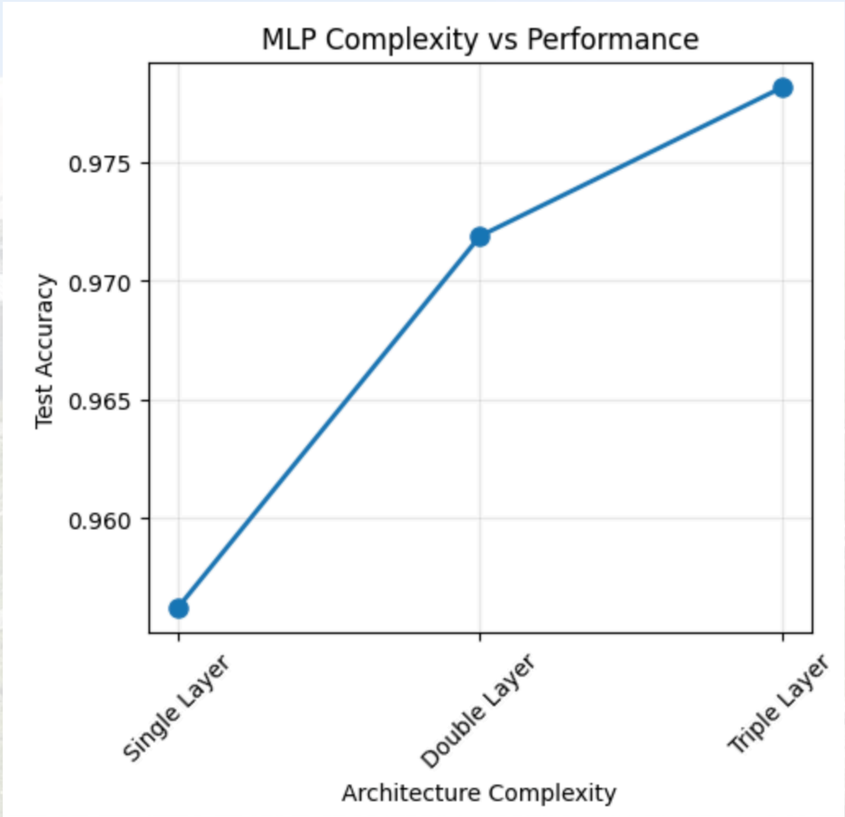
Multi-layer Perceptron implementation

MLP architecture

- Hidden layers: 128 | 128-64 | 128-64-32
- Learning rate: 0.001

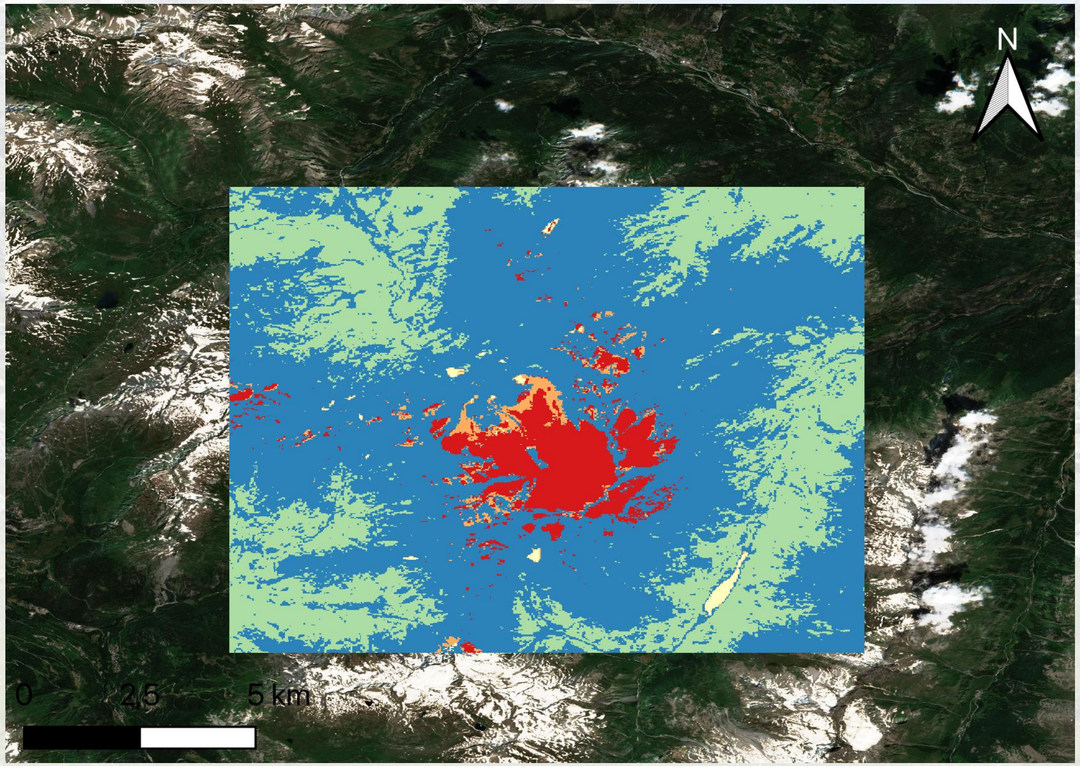
MLP Model

- *MLPClassifier()*
  - hidden_layer_size()
  - Activation = ‘relu’
  - Solver = ‘Adam

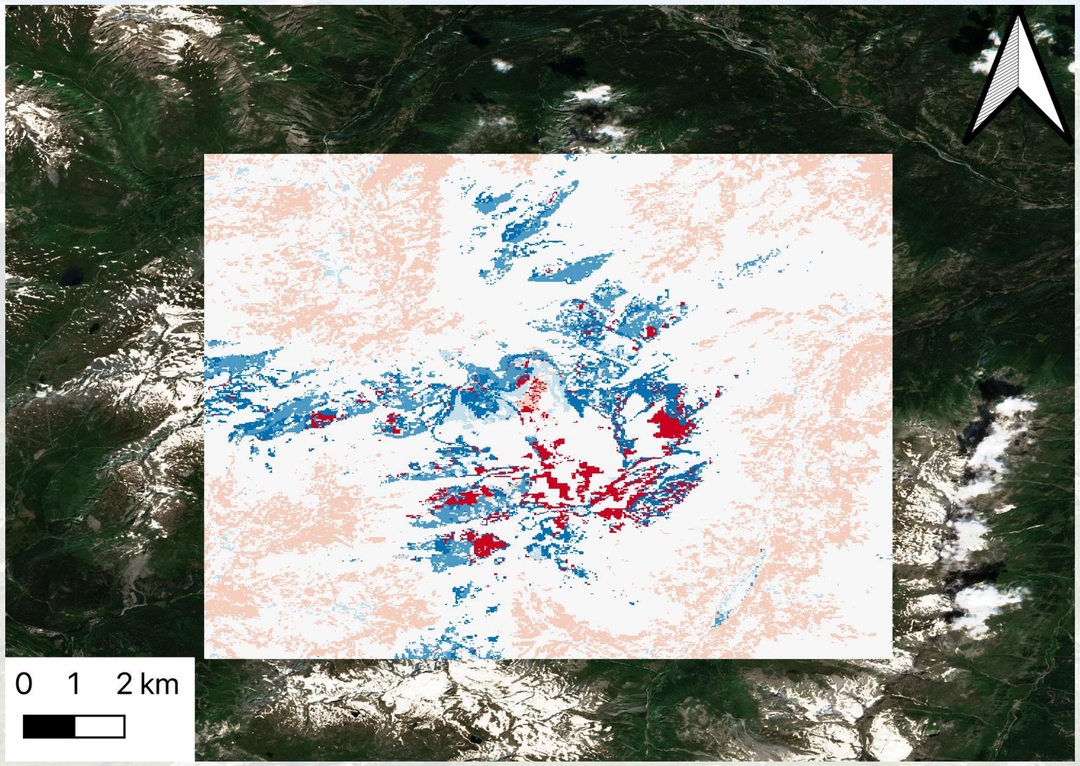


Results RF

Random Forest classification

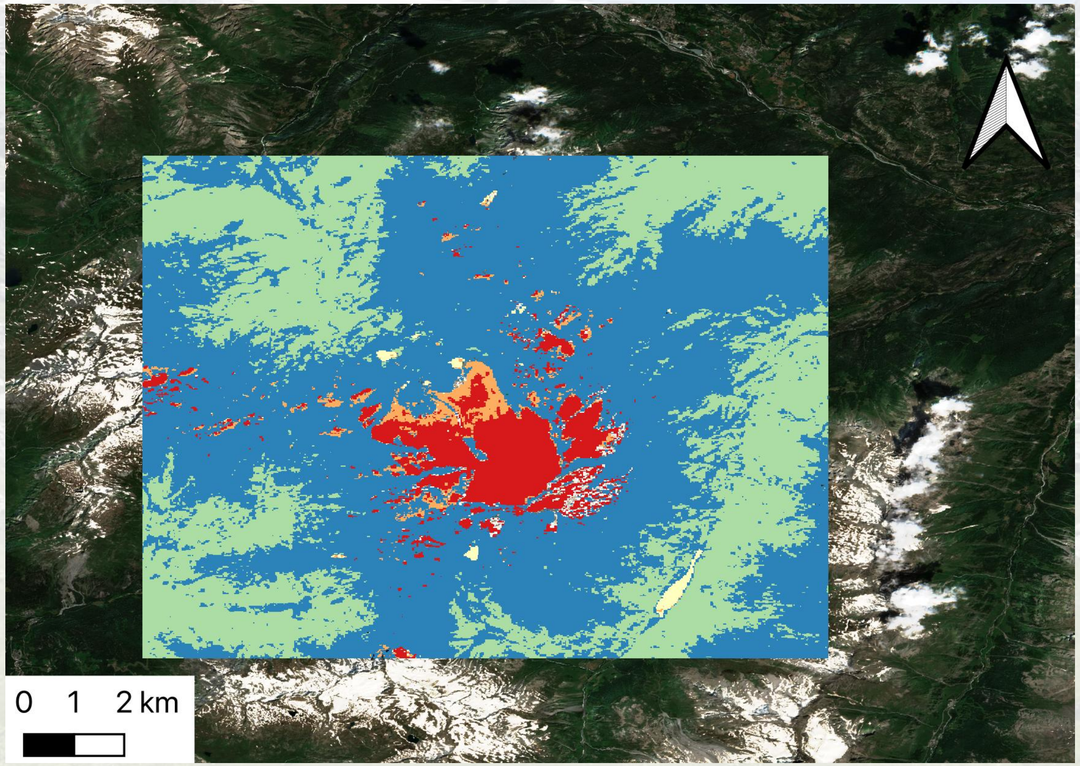


RF difference = 2024 - 1984

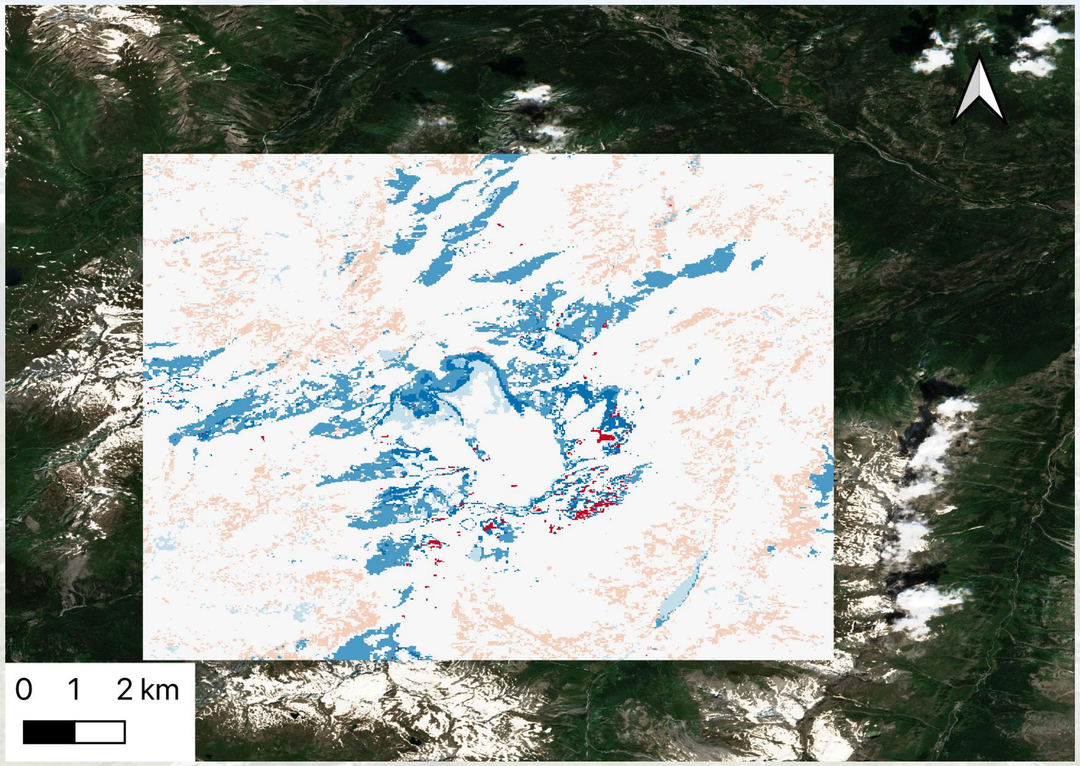


Results MLP

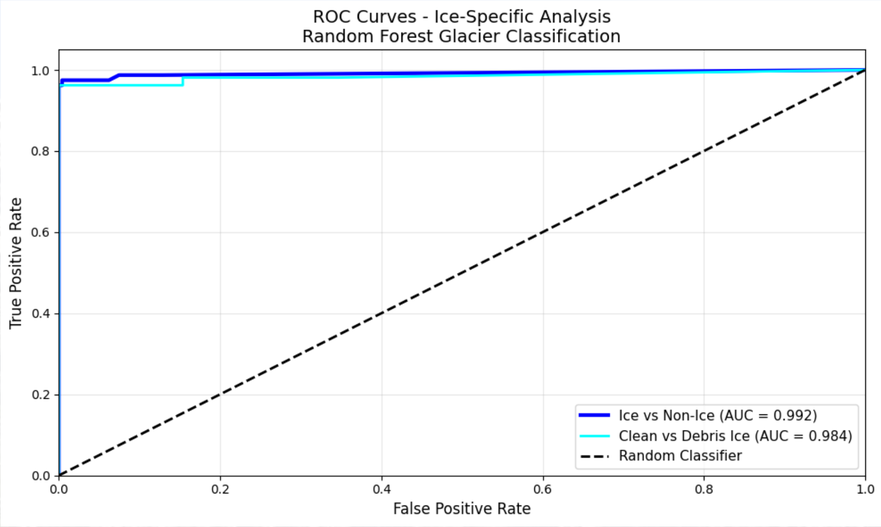
MLP classification 2024

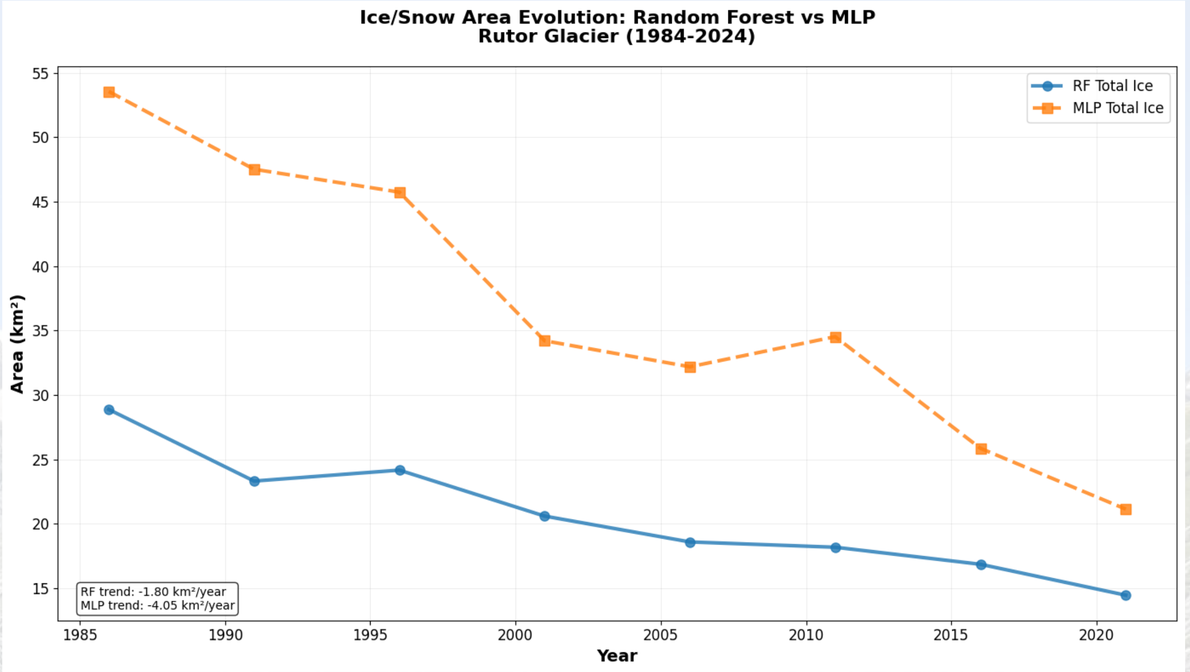


MLP difference = 2024 - 1984



RF vs MLP



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=== DETAILED ANALYSIS: Random Forest ===

Classification Report:
              precision    recall  f1-score   support

   Clean Ice       1.00      0.96      0.98        53
 Debris Ice        1.00      0.96      0.98        26
       Water       1.00      1.00      1.00        18
  Vegetation       1.00      1.00      1.00        47
        Rock       0.98      1.00      0.99       176

    accuracy                           0.99       320
   macro avg       1.00      0.98      0.99       320
weighted avg       0.99      0.99      0.99       320


Confusion Matrix:
[[ 51   0   0   0   2]
 [  0  25   0   0   1]
 [  0   0  18   0   0]
 [  0   0   0  47   0]
 [  0   0   0   0 176]]
```

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=== DETAILED ANALYSIS: MLP Triple Layer ===

Classification Report:
              precision    recall  f1-score   support

   Clean Ice       1.00      0.92      0.96        53
 Debris Ice        0.89      0.96      0.93        26
       Water       1.00      0.94      0.97        18
  Vegetation       0.98      1.00      0.99        47
        Rock       0.98      0.99      0.99       176

    accuracy                           0.98       320
   macro avg       0.97      0.96      0.97       320
weighted avg       0.98      0.98      0.98       320


Confusion Matrix:
[[ 49   2   0   0   2]
 [  0  25   0   0   1]
 [  0   1  17   0   0]
 [  0   0   0  47   0]
 [  0   0   0   1 175]]
```
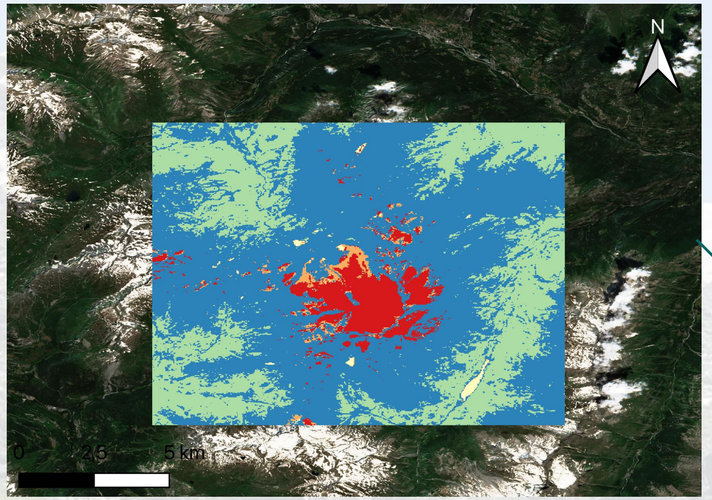
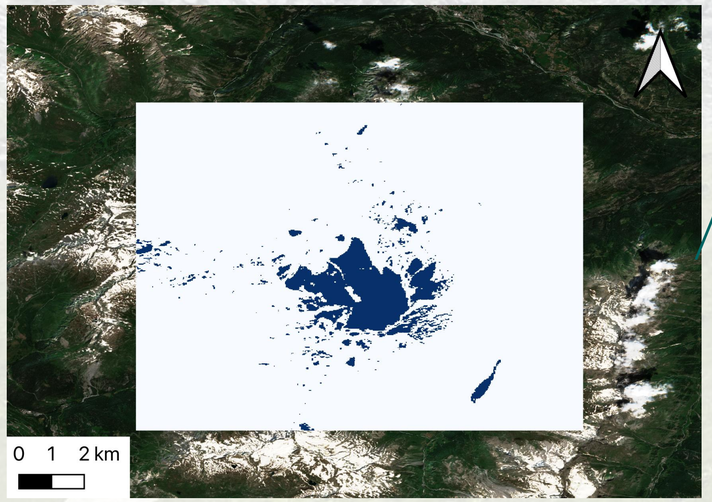
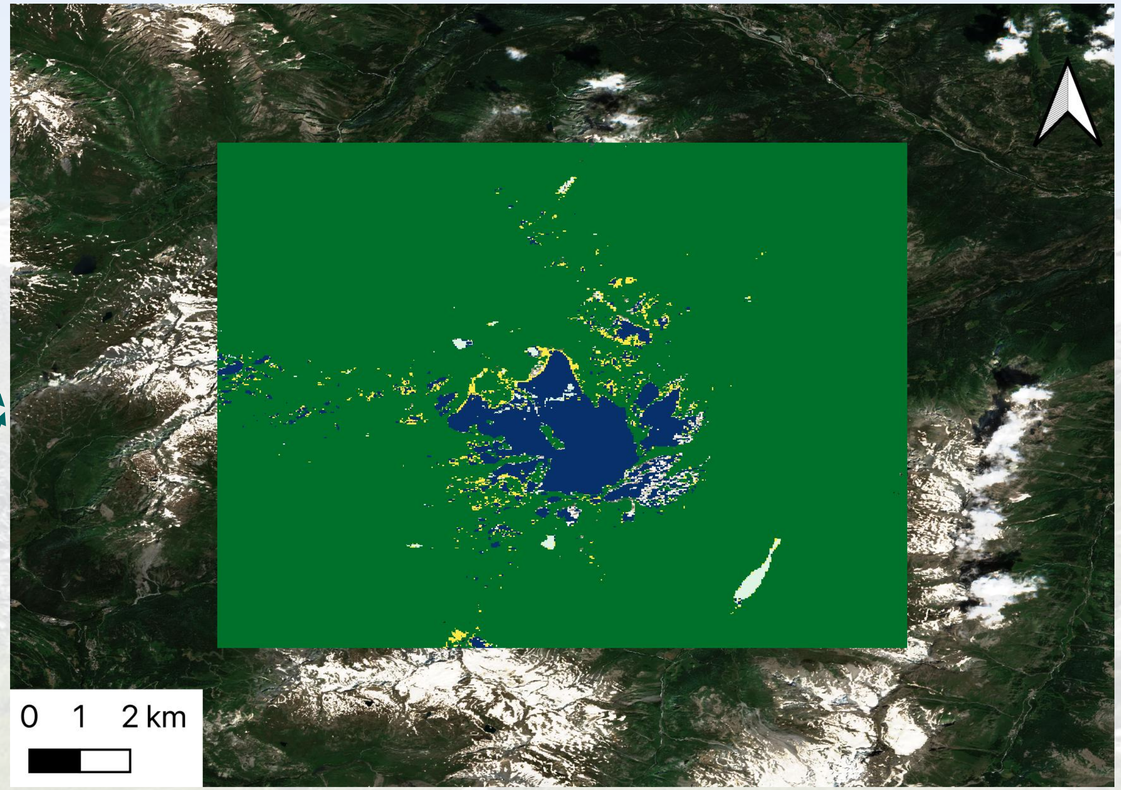

Indices

How ML model compares against NDSI







Legend

- RF, NDSI
- RF no, NDSI
- RF, NDSI no
- RF no, NDSI no

Agreement

- Overall agreement : 97, 71%
- Clean ice agreement: 95, 9%
- Debris ice agreement: 42, 2%

Testing

How RF compare with other glacier testing

Lys glacier

- 2250 samples
  - 755
  - 65
  - 36
  - 35
  - 1359
- Overall accuracy: 96, 9 %

$$\begin{bmatrix} 755 & 0 & 0 & 0 & 0 \\ 7 & 27 & 0 & 0 & 31 \\ 1 & 0 & 34 & 0 & 1 \\ 0 & 0 & 0 & 30 & 5 \\ 1 & 1 & 0 & 23 & 1334 \end{bmatrix}$$

Géant Glacier

- 2369 samples
  - 1209
  - 458
  - 2
  - 111
  - 589
- Overall accuracy: 78, 4 %

$$\begin{bmatrix} 1172 & 13 & 0 & 0 & 24 \\ 160 & 19 & 0 & 0 & 279 \\ 0 & 2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 86 & 25 \\ 8 & 3 & 0 & 0 & 578 \end{bmatrix}$$

Conclusion

How RF compare with other glacier testing

- Glacier melting
- Vegetation and water area increasing
- RF is a strong model
- MLP performed not as much as RF since it’s non-linear
- NDSI underperformed since it detect also water (glacier lake)
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Thanks for the attention