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Deep Change Vector Analysis (DCVA) Approaches for Forest Change Detection using Copernicus Sentinel Images

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Background and Motivation

Importance of automated forest change detection:

- Forests are subject to natural disturbances such as windstorms and snow load that can cause severe damage.
- Accurate and timely detection of forest change caused by natural hazards is crucial for effective management and conservation efforts.

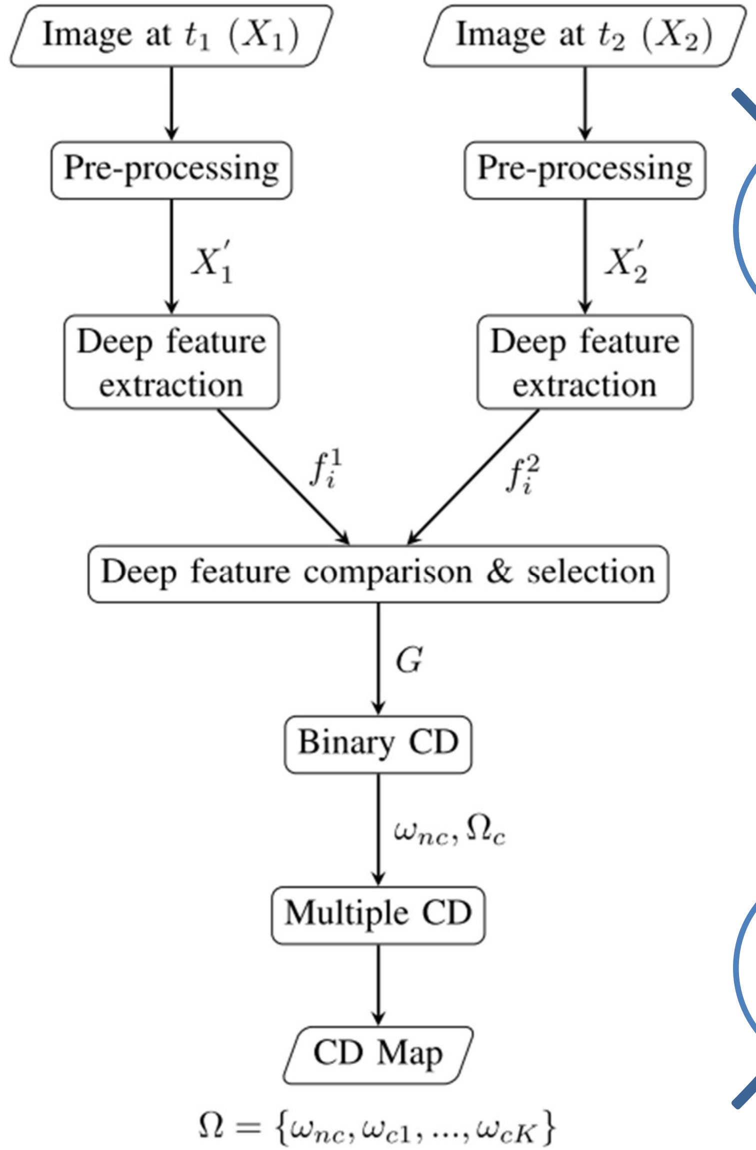
Prompt mitigation of forest hazards is crucial for:

- Forest health
- Ecosystem balance
- Biodiversity
- Habitat quality

Advantages of unsupervised learning for forest change detection:

- Capability to analyze large amounts of data quickly and efficiently
- Minimization of manual labor and time required for training data preparation
- Identifying potentially concerning areas for closer examination

Conceptual Idea of Deep Change Vector Analysis



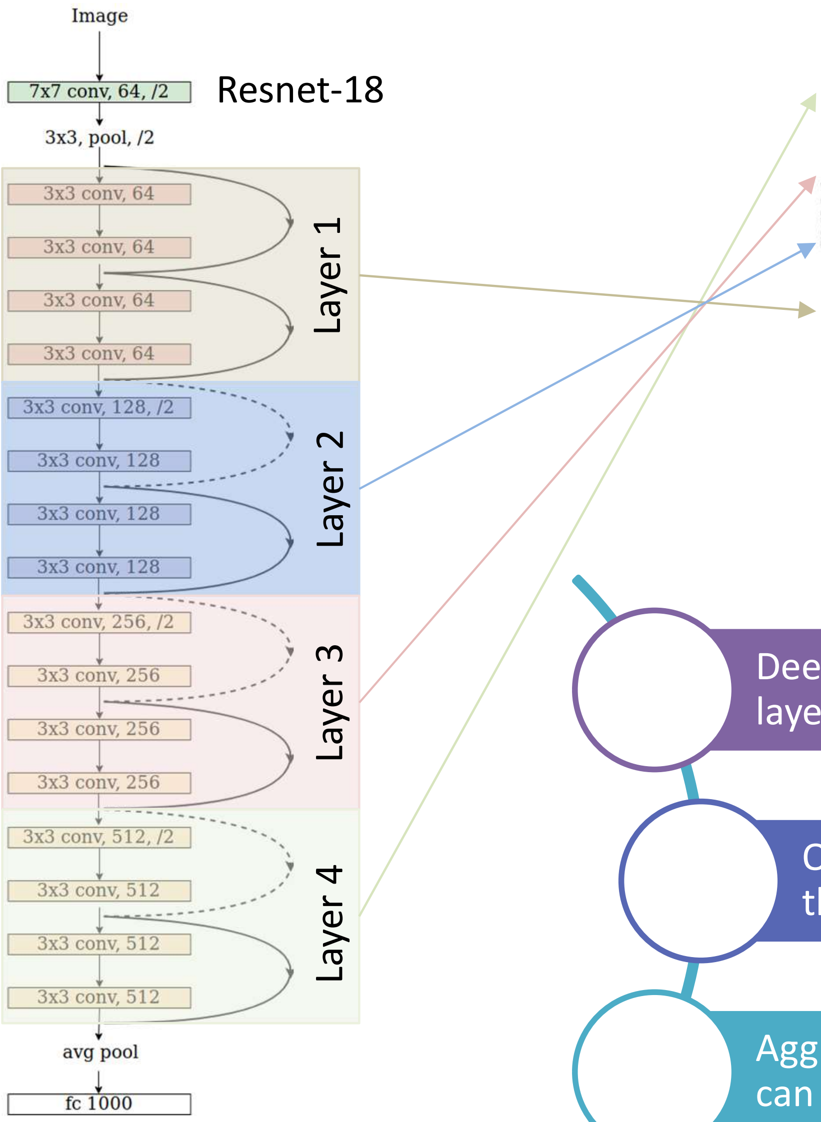
Given co-registered pre-change and post-change images I_1 and I_2 that represent a scene consisting of a set of pixels Ω, **the goal of DCVA is to group the Ω into two Ω_c** (set of changed pixels) **and Ω_{nc}** (set of unchanged pixels)

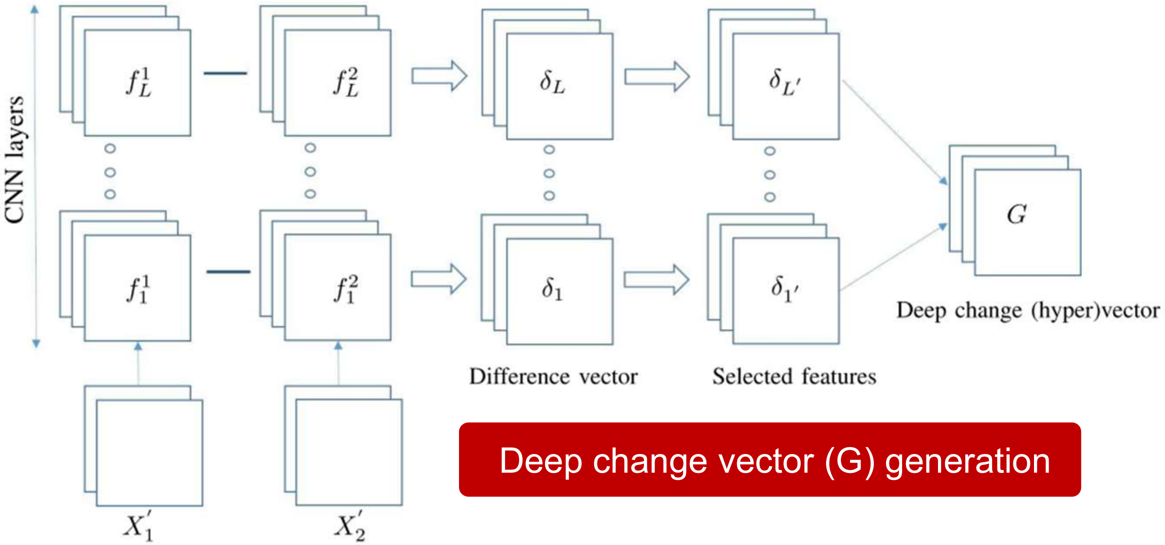
Changed pixels are expected to show higher magnitude of G (change vector) while the unchanged pixels are expected to show lower magnitudes.

Following this, a threshold on the magnitude to group pixels into changed (Ω_c) and unchanged (Ω_{nc}) classes

Optionally, changed pixels can be further sub-grouped using any clustering method.

Deep change vector analysis with Resnet-18





Deep change vector (G) generation

- Deep features can be extracted from almost any convolutional layer of CNNs for detecting forest change with DCVA
- Our approach extracted features from ResNet-18's first, second, third, or fourth layer
- Aggregating deep change vectors generated from different layers can also improve accuracy and robustness of the approach

Studied Forest Change Use-Cases

Boreal forest snow damage using Sentinel-1 images

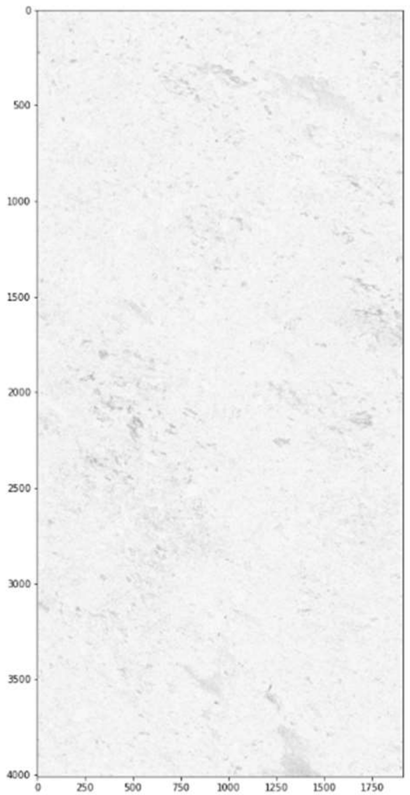
- Severe snow-load damage took place in North-Eastern Finland during winter 2017-2018 season. The damages were fairly well documented.
- EO dataset is represented by time series of Sentinel-1 images taken between November 2017 and March 2018.
- Detecting damage caused by snow can be a challenging use case, as there may be other observable changes that take place in the same region during the same time period
- Reference data included forest mask and ground reference indicating logging reports after snow-load damage, as well as sample of intact forest stands.

Windstorm damage in boreal forest

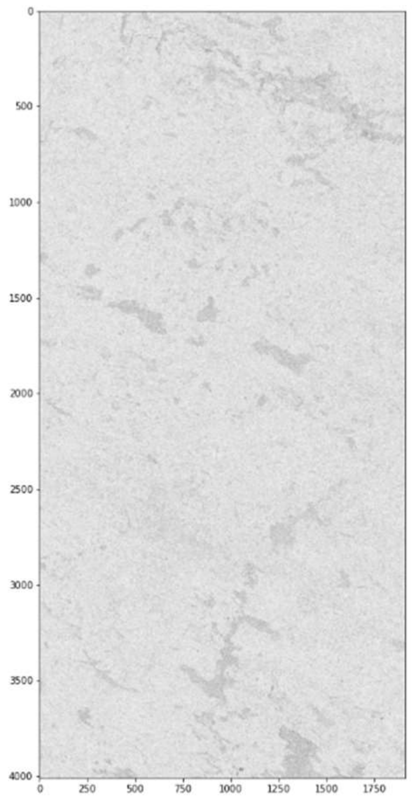
- A severe windstorm occurred on June 22, 2021, over Northern Finland, lead to extensive forest damages.
- The EO dataset includes one Sentinel-2 image taken before and one taken shortly after the event, enabling Sentinel-2 change detection to be performed. Additionally, several Sentinel-1 images taken both before and after the windstorm event are provided for analysis.
- Reference data included forest mask and ground reference indicating logging reports after snow-load damage, as well as sample of intact forest stands.

Snow-load forest damage

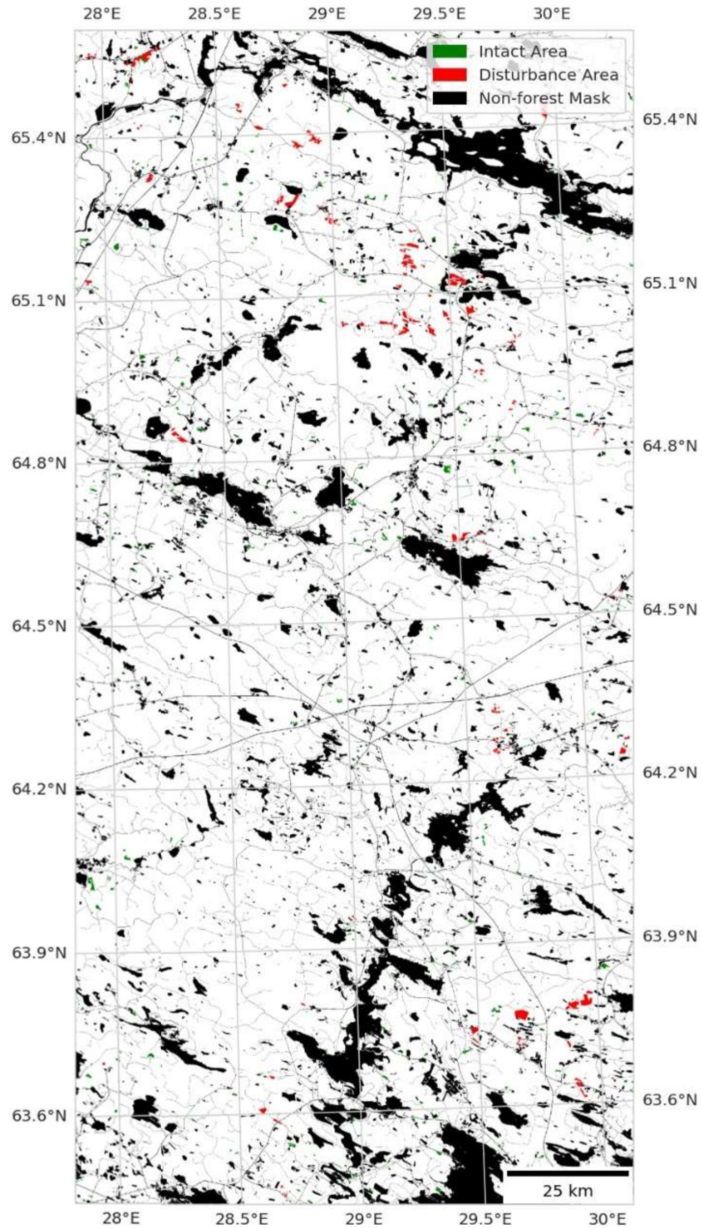
While continuous monitoring is necessary for assessing snow damage, DCVA can only be applied to two images - the before and after event images. As a result, deep change vectors are generated using these two images.



before the event



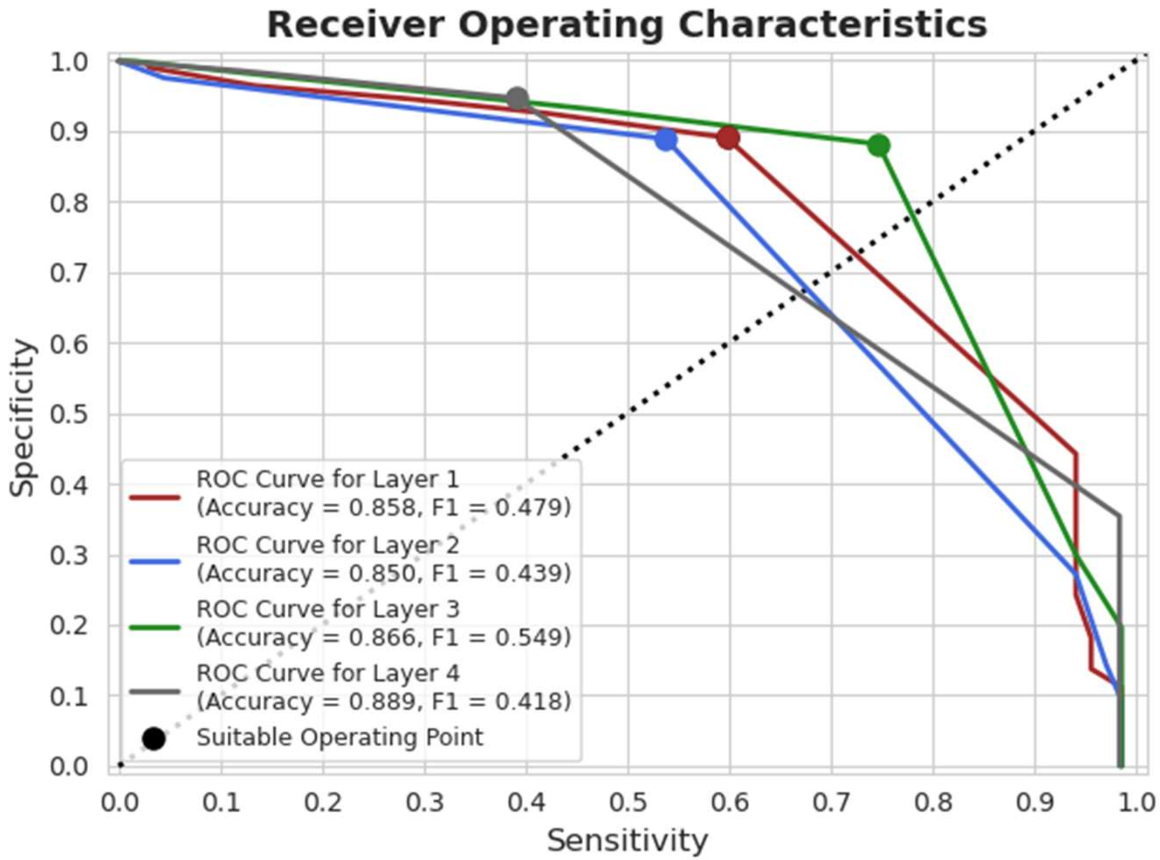
after the event



ground reference

Snow-load forest damage

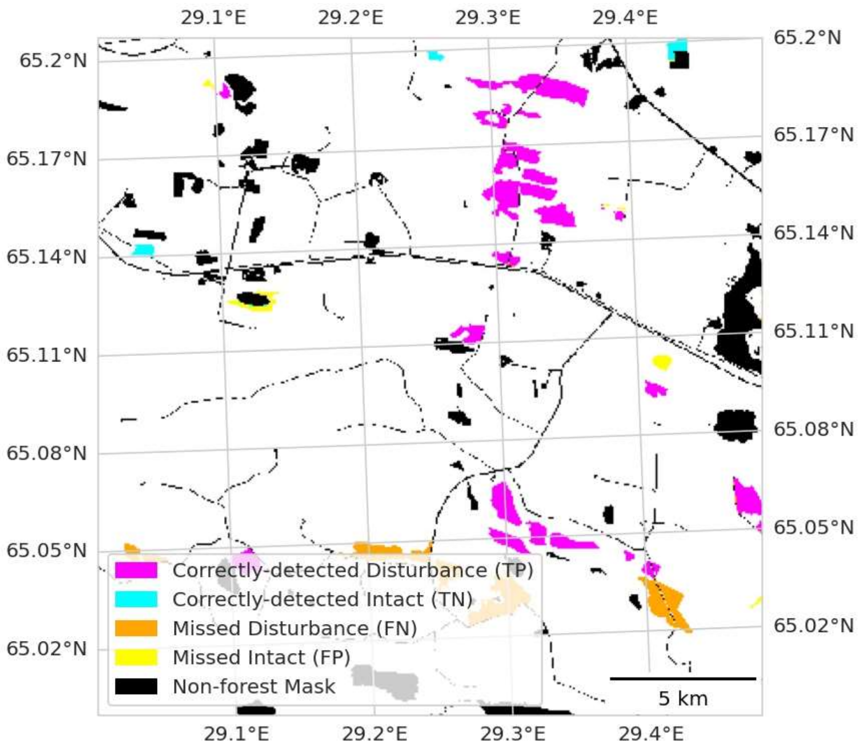
Prediction results when the pretrained Resnet-18 has been utilized as feature extractor:

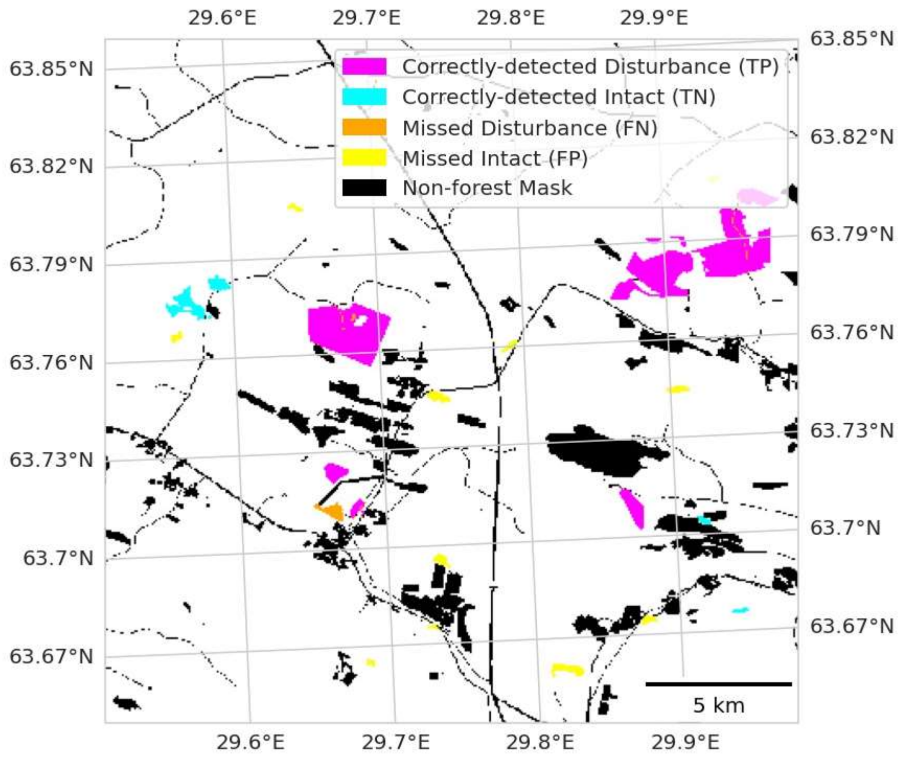


Our experimental results showed that the best performing deep change features come from the 3rd layer of the model.

Snow-load forest damage

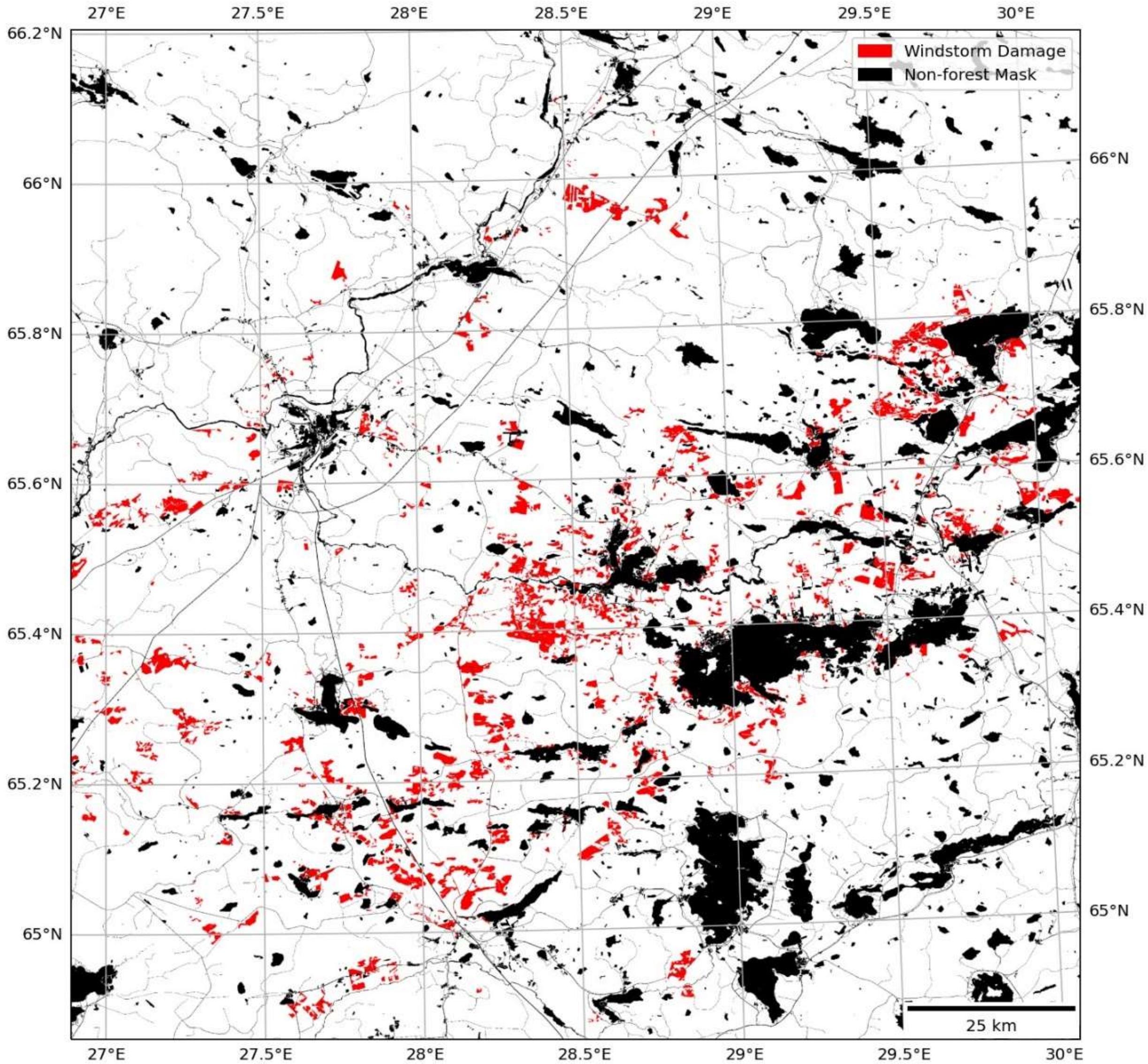
Prediction results when the pretrained Resnet-18 has been utilized as feature extractor:





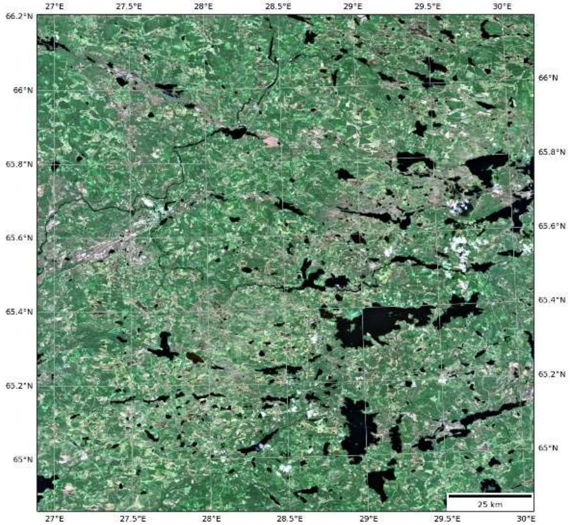
- *Data:* 2-channel Sentinel-1 imagery (VV-VH)
- *Pre-processing*: image normalization, cropping saturated values.
- *Deep feature extraction:* 3rd layer of the model with BigEarthNet for weights.
- *Post-processing:* eliminating small objects using morphological operations

Windstorm forest damage



ground reference

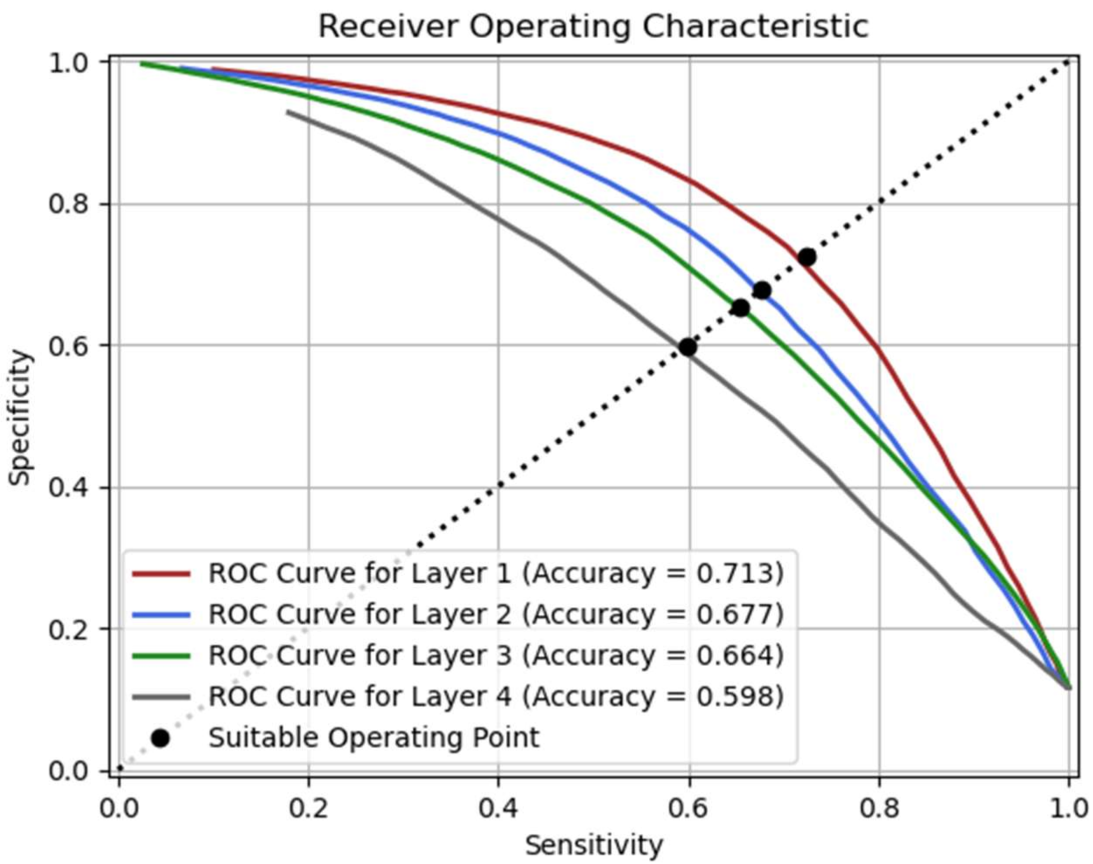
before the event



after the event

Windstorm forest damage

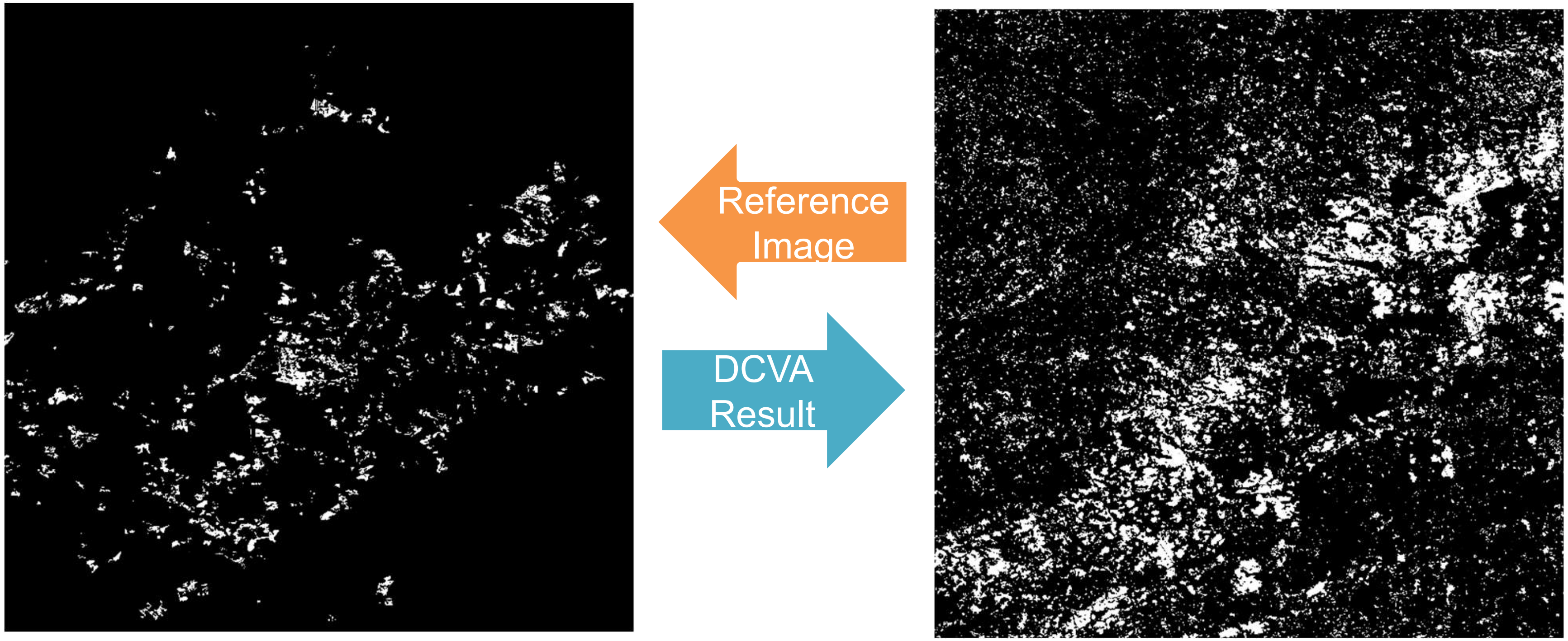
Prediction results when the pretrained Resnet-18 has been utilized as feature extractor:



Our experimental results showed that deep change features coming from the low layers of the model perform better for windstorm detection.

Windstorm forest damage

Method	Sensitivity	Specificity	Accuracy
DCVA – Sentinel 2	52.22	86.22	85.19



- *Data:* 4-channel Sentinel-2 imagery
- *Pre-processing*: image normalization, cropping saturated values.
- *Deep feature extraction: 1st* layer of the model with BigEarthNet for weights.
- *Post-processing:* eliminating small objects using morphological operations

Conclusions

Snow damage

- Competitive results for unsupervised bitemporal change detection, comparable to supervised methodologies
- Ways to adapt the methodology to image time series need further exploration.

Windstorm damage

- DCVA was successful in detecting change areas, it is expected that specificity can be further improved. Performance of DCVA is **dependent on the capabilities of feature extractor**.
- Further, potential of **forest-specific feature extractor can be examined to improve** the retrieved features and thus prediction performance.

RepreSent project

Thank you!