



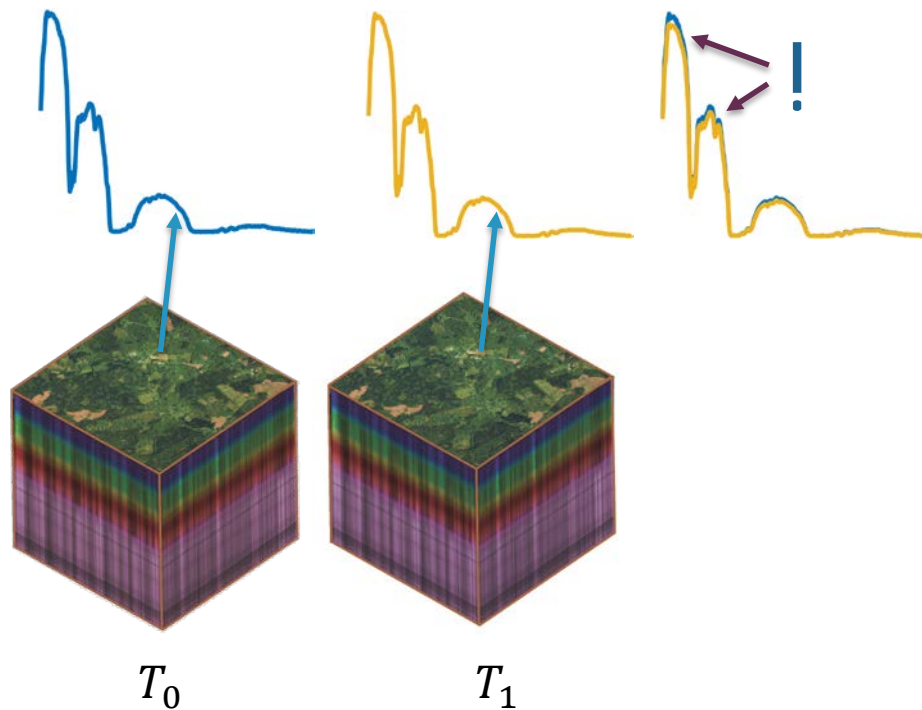
# Learning spectral detection of changes and anomalies

Niclas Wadströmer, Maria Axelsson, David Gustafsson and  
Jörgen Karlholm (Swedish Defence Research Agency (FOI))

(Distributed Multi-spectral and Multistatics Sensing NATO-SET-312/RSM,  
Bled, 2022-05-23--24)

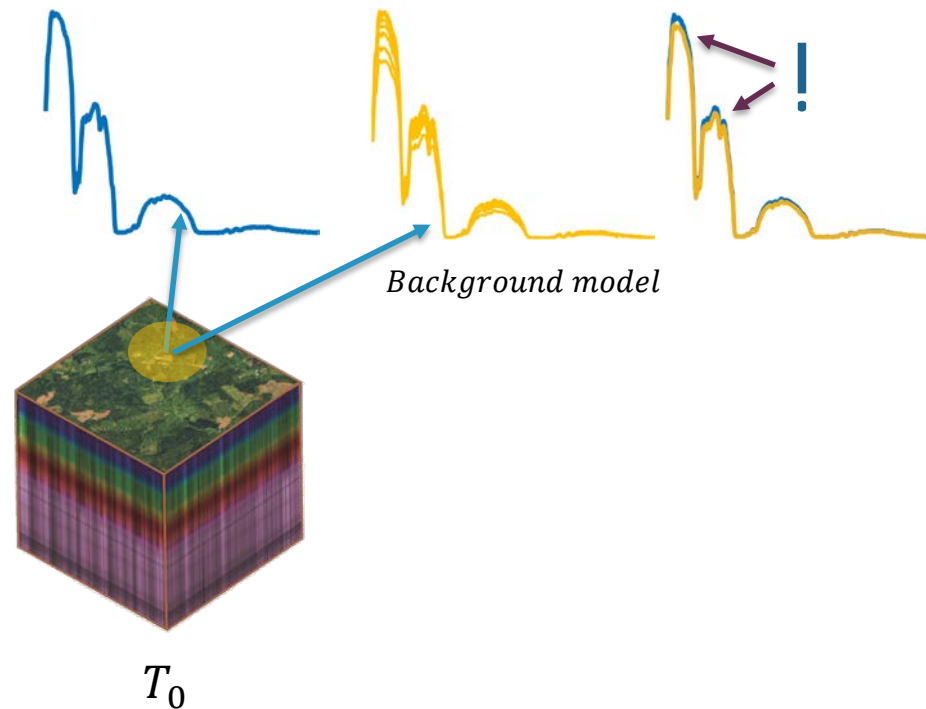
# Change and anomaly detection

- Important tools for intelligence, surveillance, and reconnaissance tasks
- Multi- and hyperspectral data can provide pixel-based detection
- Learning based approaches for change and anomaly detection



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# Learning spectral change detection

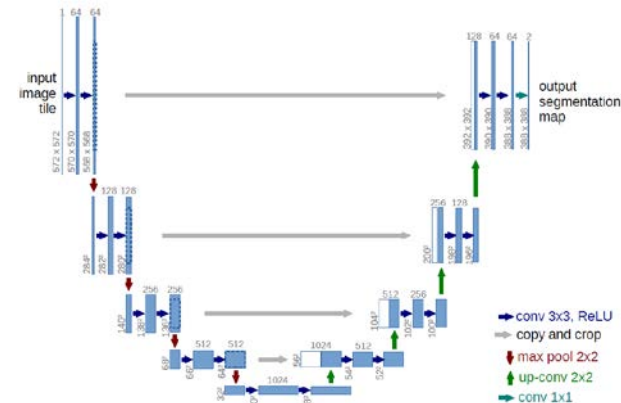
Changes in satellite data

- Synthetic changes
- Forest damage

Copernicus Sentinel-2

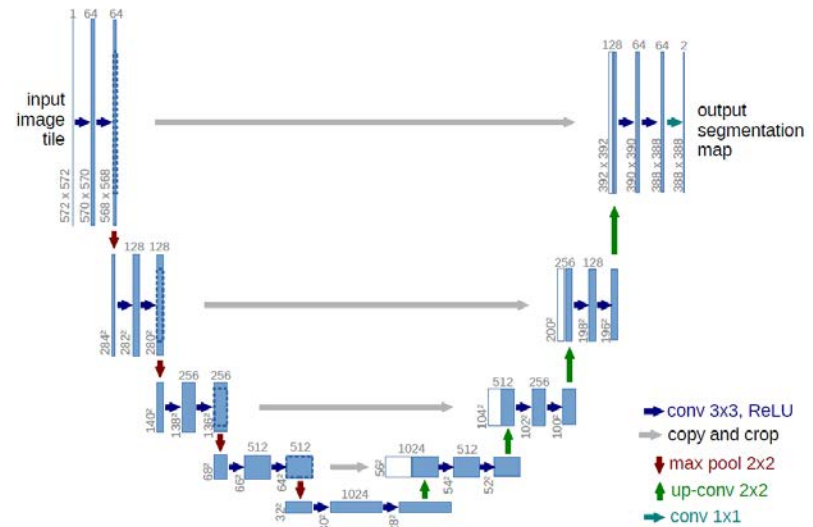
- GSD 10 m, 13 bands

U-net architecture



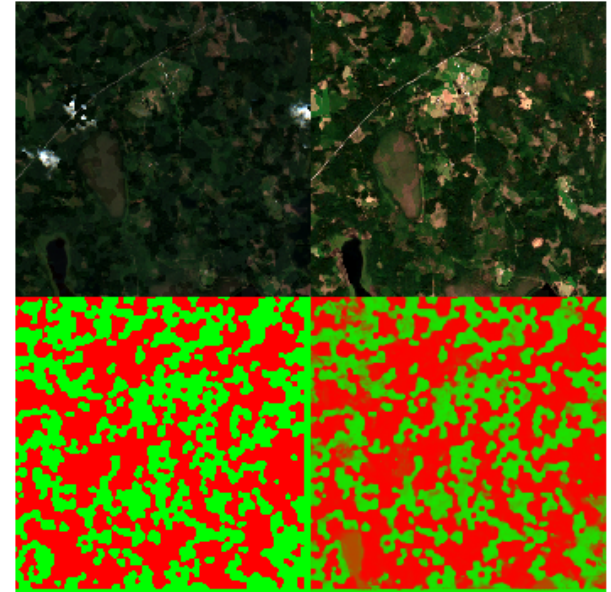
# U-Net – a family of networks for semantic segmentation

- Popular model with good performance
- Model complexity can be varied
  - Nr of downsamplings (scales)
  - Nr of channels for each layer
- Regularizations
  - Dropout
  - Batch normalization
  - Group normalization
  - ...



# Learning seasonal changes

- Synthetic mixes of real data from different seasons (spring, summer and autumn)
- Two mixed images are input
- Task: Same or different season?
- Training on 15 00 examples, three examples per 5 km-training example



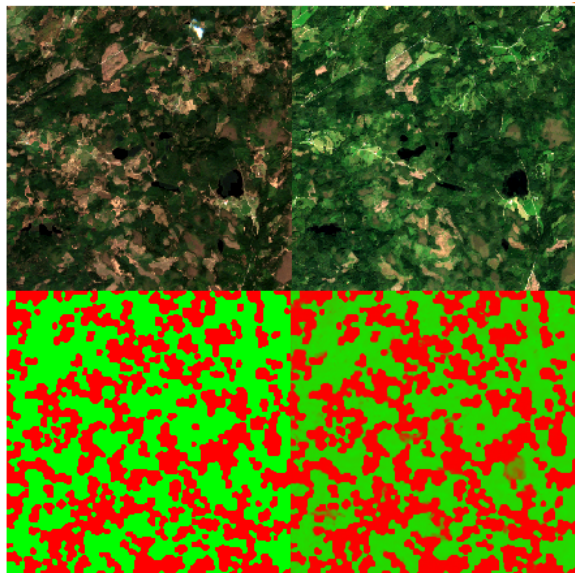
Mix1

Mix2

GT

Prediction

# Learning seasonal changes

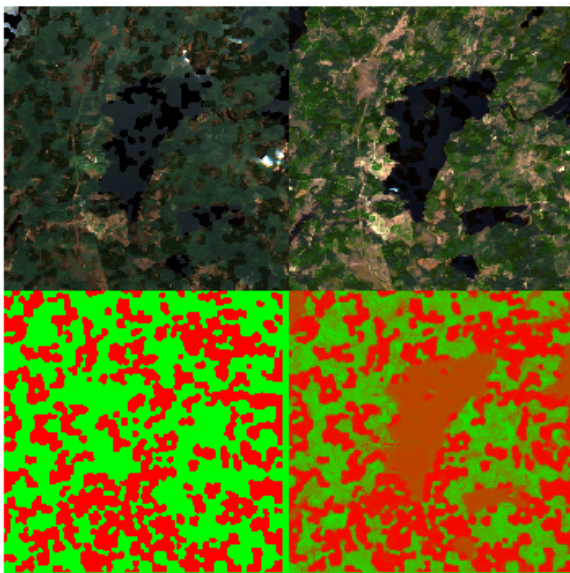


Mix1

Mix2

GT

Prediction

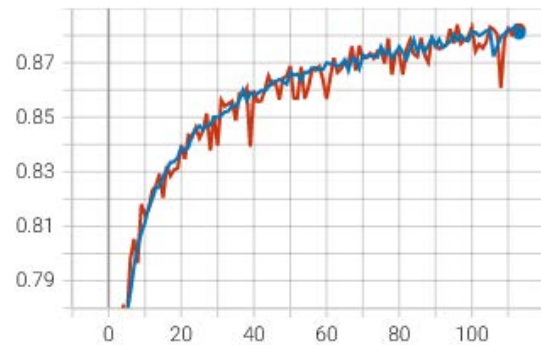


Mix1

Mix2

GT

Prediction



# Learning to detect forest damage

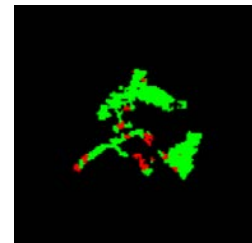
- Detection of forest damage due to the Spruce bark beetle
- Task: Is the tree/pixel infested by the beetle? Is there a spectral change due to infestation?



Satellite data 1 year before



Data right  
before harvest



Annotation  
from harvester



# Learning to detect forest damage

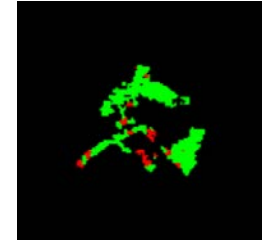
- Detect changes from year to year
- Satellite data is collected one year before harvest and right before harvest
- Basic forest data is added ... tree age, species, height, slope, ...
- Annotations by forest harvester with 6 million spruces, 300 000 infested



Satellite data 1 year before



Data right  
before harvest

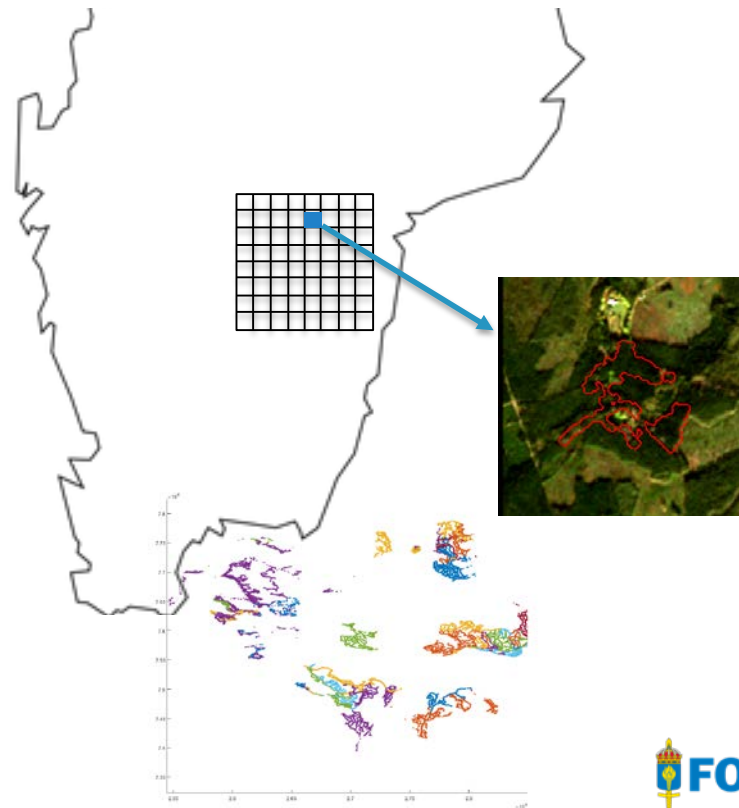


Annotation  
from harvester

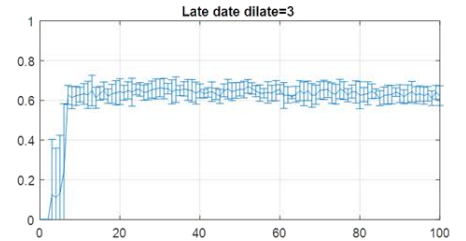
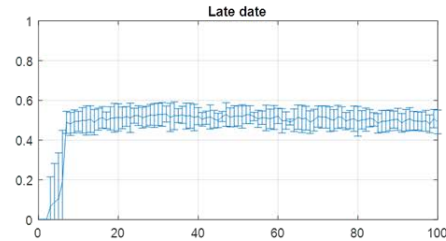
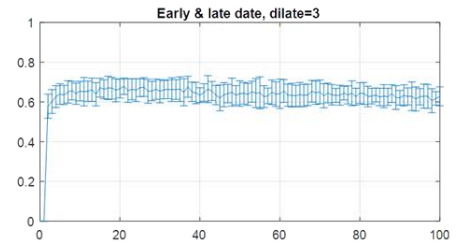
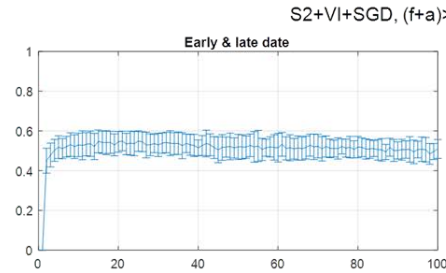
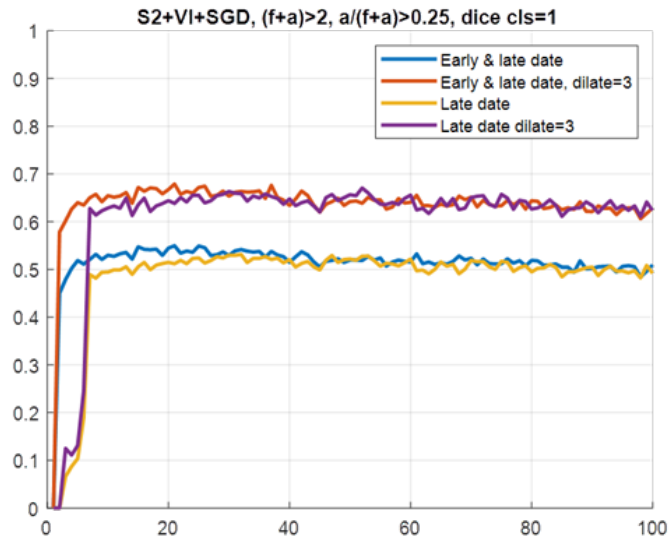
# Learning to detect forest damage

## Training examples

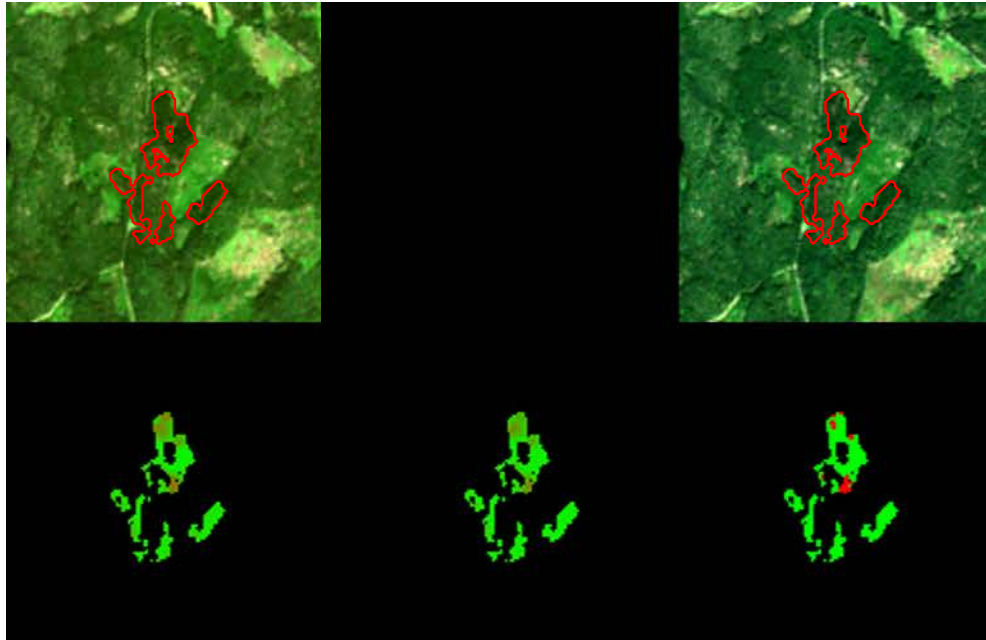
- Pairs of images of size 128x128 pixels for one weeks harvest in that region
- Ground truth is set to change or no change per pixel
  - Healthy – healthy (no change)
  - Healthy – infested (change)
- Nr of training examples is 17 000



# Results, forest damage



# Results, forest damage



Early

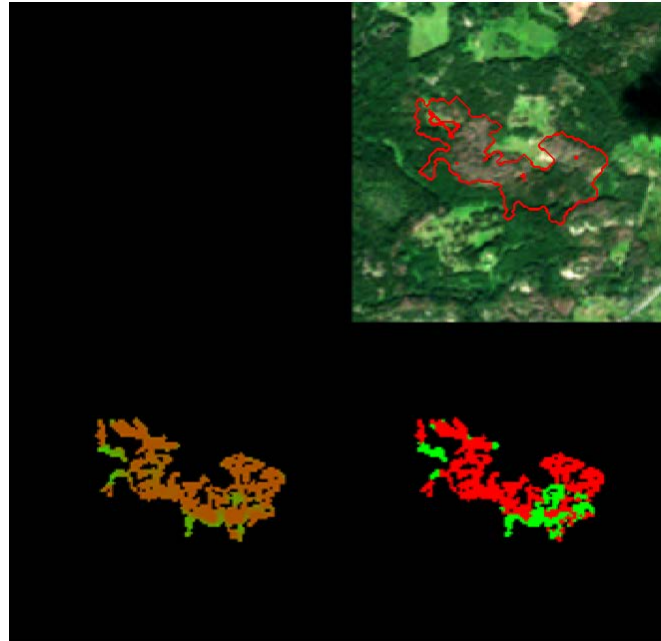
Late

Prediction  
pair

Prediction  
single

GT

# Results, forest damage



Early

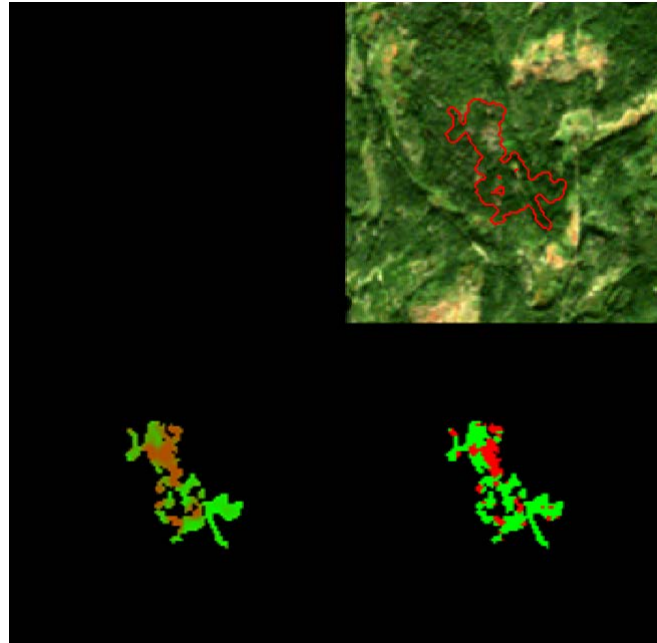
Late

Prediction  
pair

Prediction  
single

GT

# Results, forest damage



Early

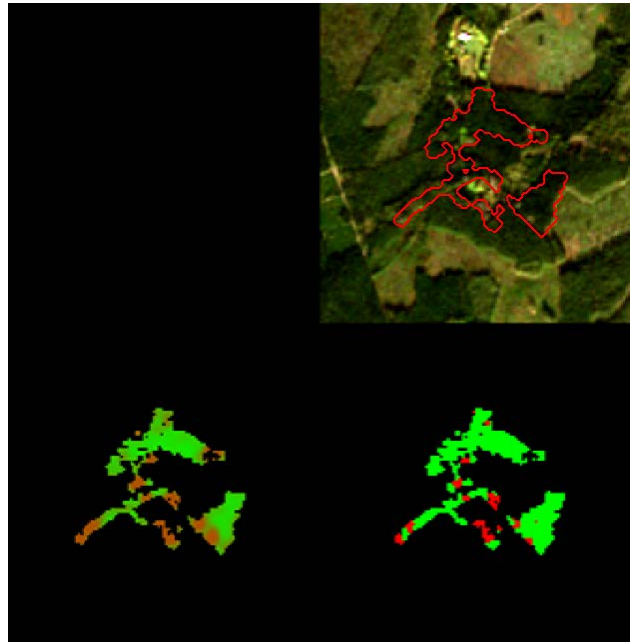
Late

Prediction  
pair

Prediction  
single

GT

# Results, forest damage



Early

Late

Prediction  
pair

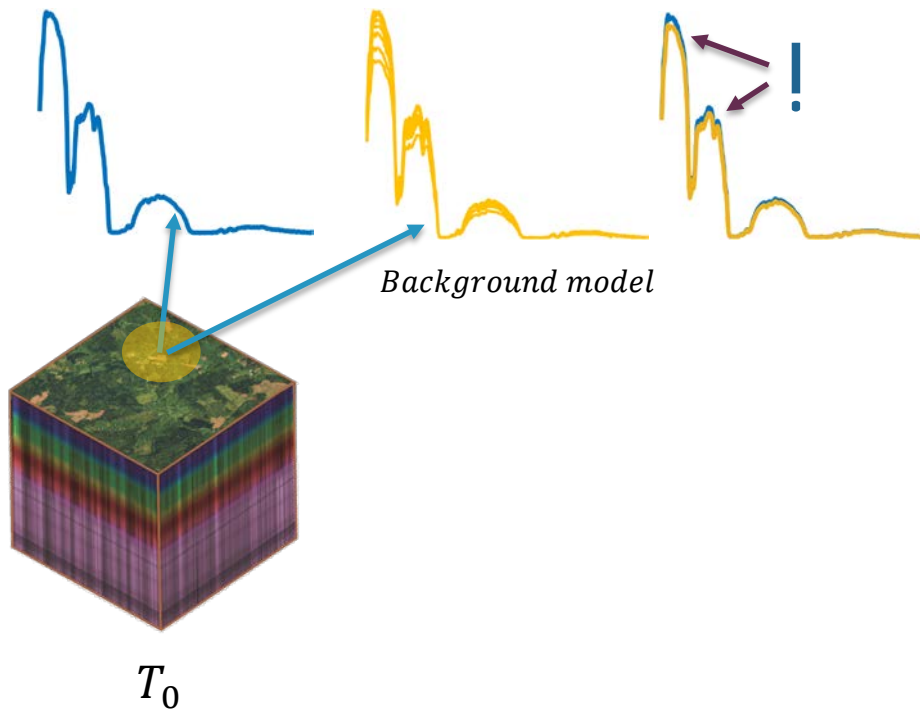
Prediction  
single

GT

# Learning anomaly detection

## Anomaly detection

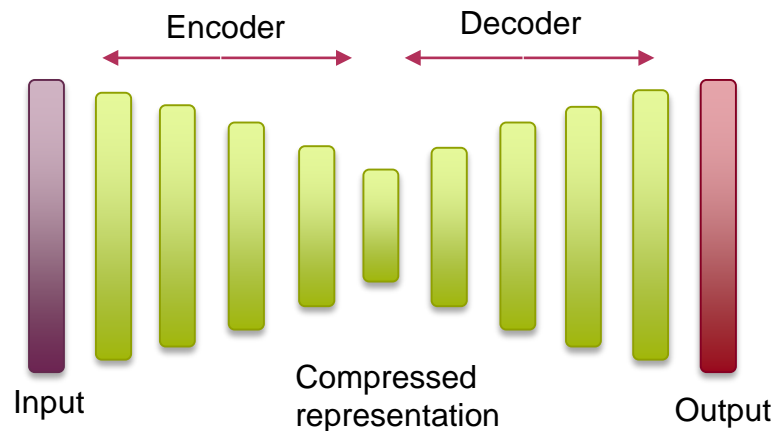
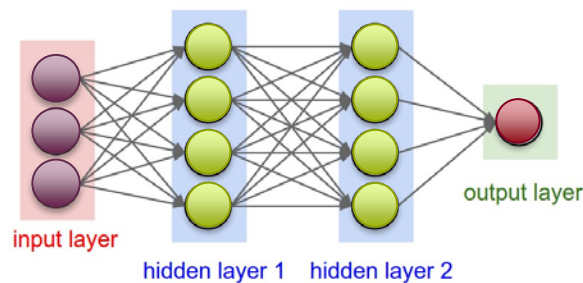
- Model the background
- Compare new spectra to model
- Pixel-wise detections





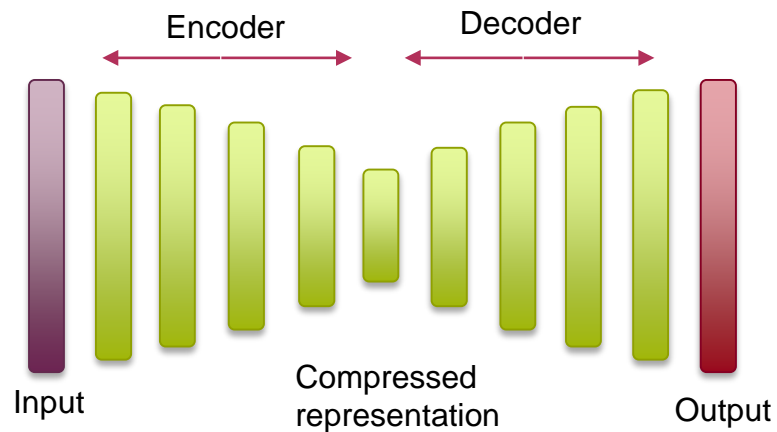
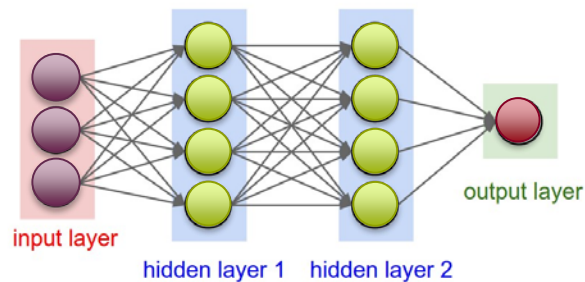
# Deep autoencoder

- Artificial neural network
- Many hidden layers
- Trained to reconstruct input in output
- Unsupervised learning approach
- Encoder and decoder
- Low dimensional space in center



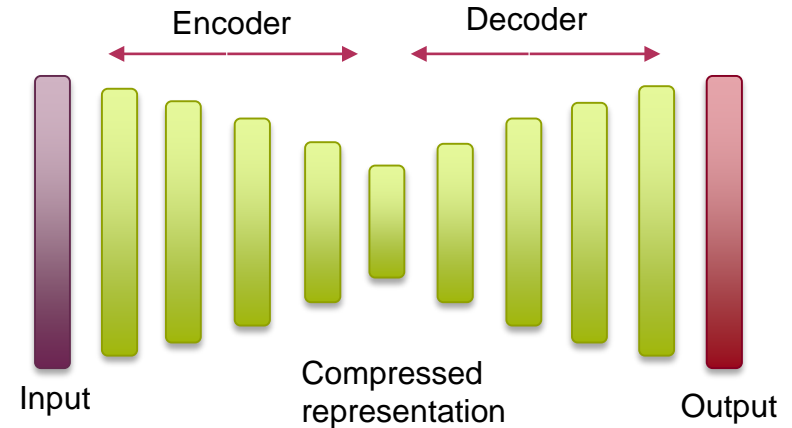
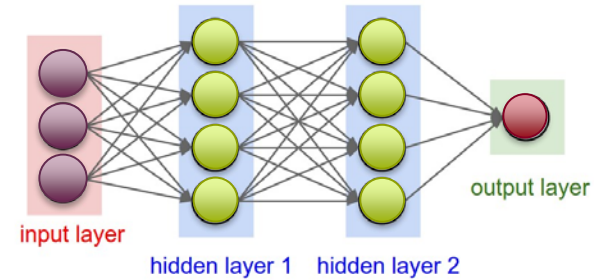
# Deep autoencoder

- Applications
  - Dimensionality reduction
  - Feature learning
  - Anomaly detection

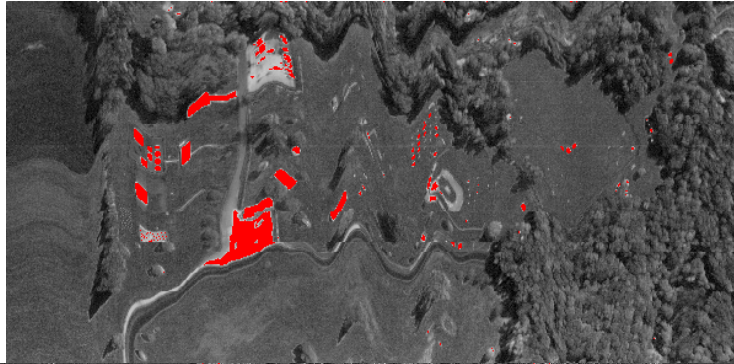


# Deep autoencoder

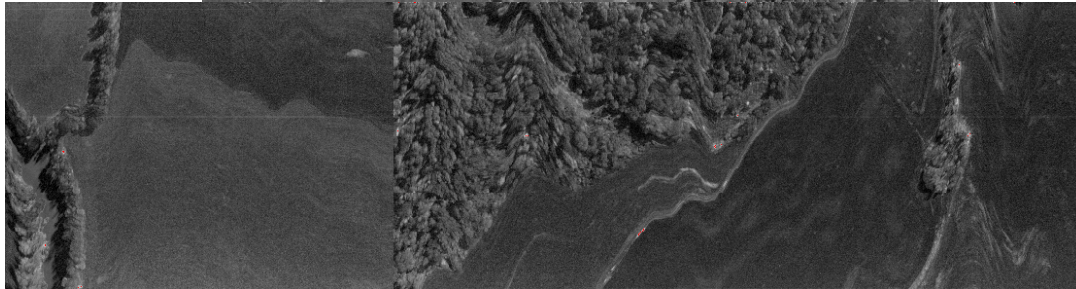
- Anomaly detection
  - Train on individual spectra
  - Learn the spectral mixture of the background
  - Reconstruct new data and use the reconstruction error as an anomaly score



# Learning anomaly detection



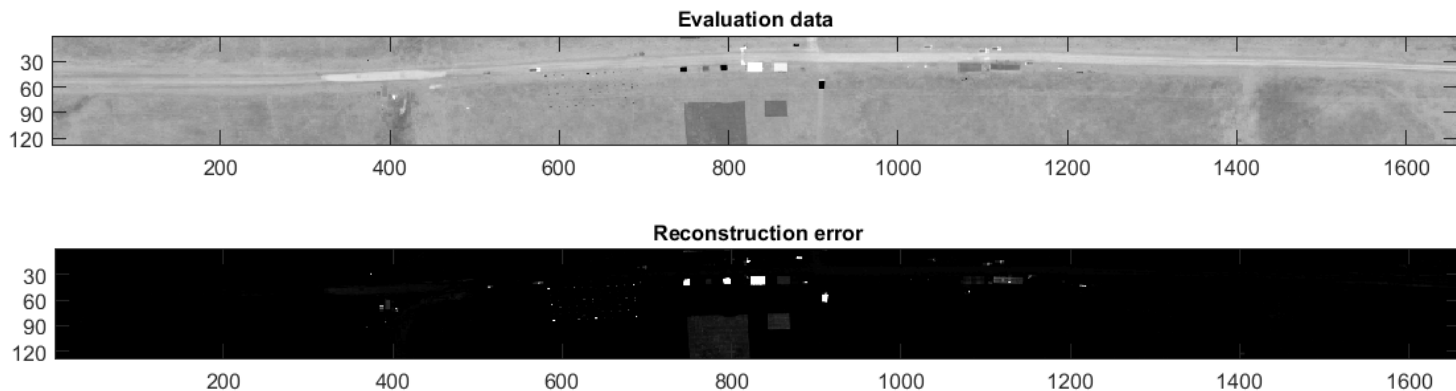
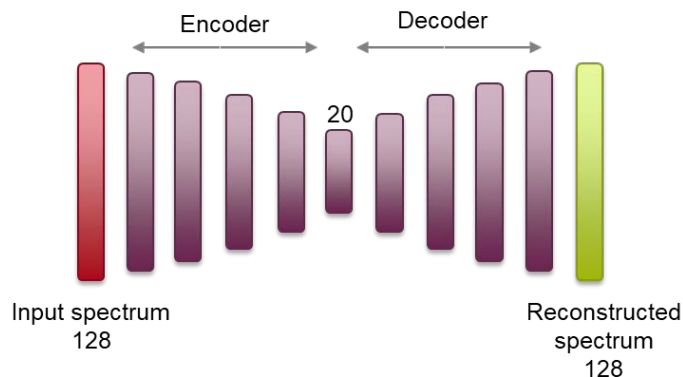
Anomaly detections using a deep autoencoder



Region for training background model

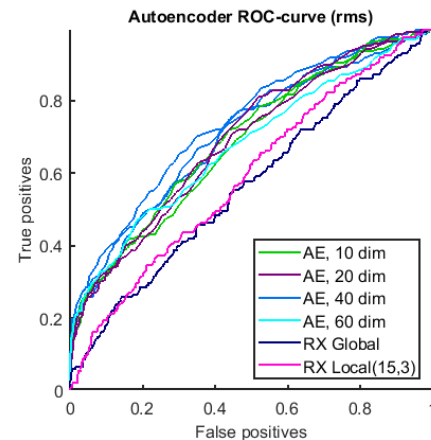
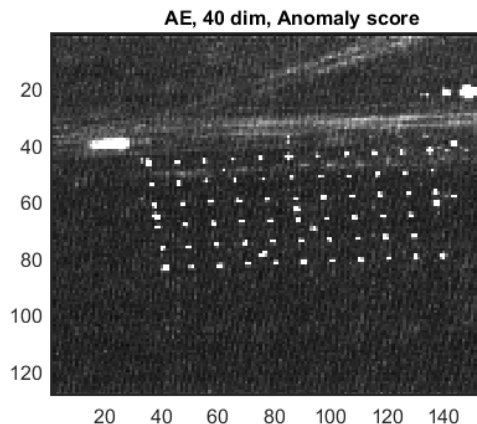
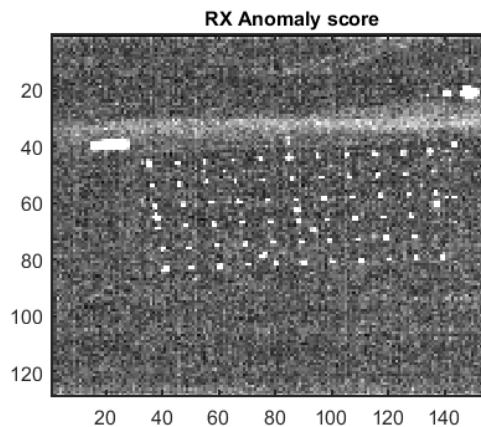
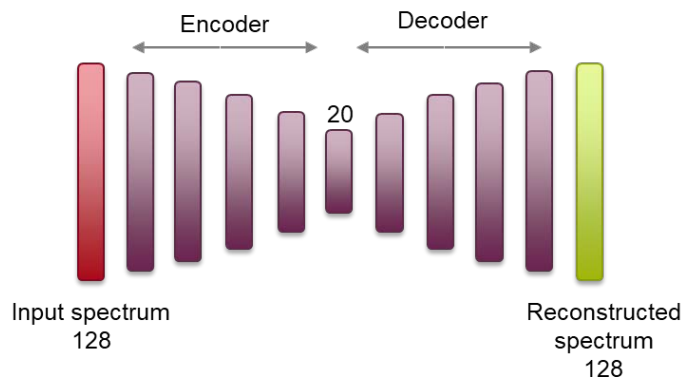
# Anomaly detection in LWIR

- LWIR data from the US SEBASS sensor,
- 128 bands



# Anomaly detection in LWIR

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- 128 bands



Maria Axelsson, Niclas Wadströmer, David Gustafsson, Henrik Petersson, David Bergström  
*Anomaly Detection in Hyperspectral LWIR Imagery using Autoencoders*

NATO SET-277 Workshop on Phenomenology and Exploitation of Hyperspectral Sensing within NATO, 2019



# Thank you!

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