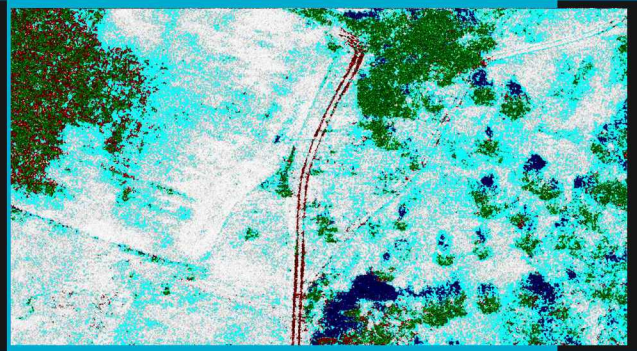
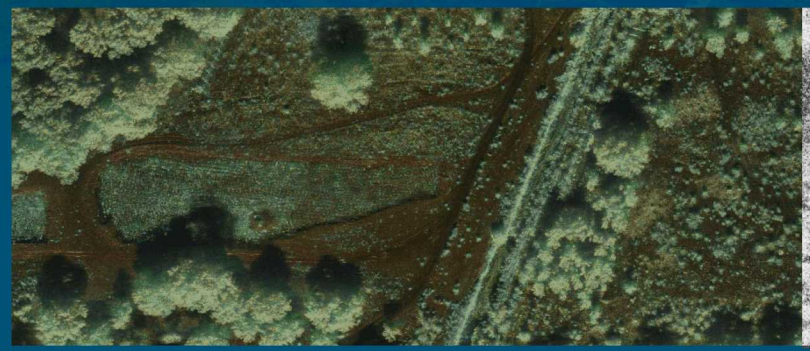
SAND2018-6379C

Polarimetric Synthetic-Aperture-Radar Change-Type Classification with a Hyperparameter-Free Open-Set Classifier





PRESENTED BY

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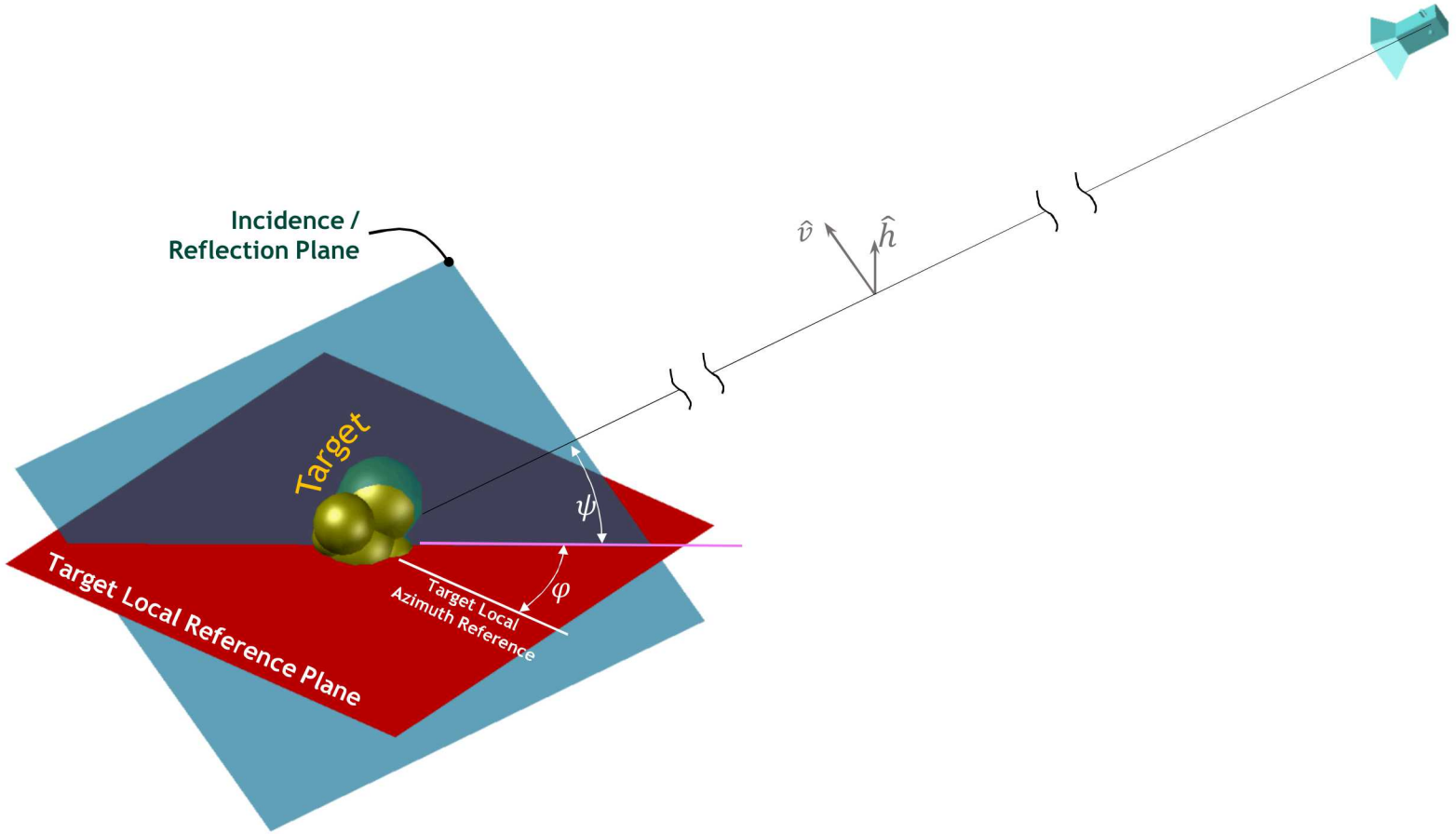
Single polarization synthetic aperture radar (SAR)

Radar can coherently transmit and receive two orthogonal E-Field polarization states (H or V), orthogonal to direction of propagation

Single polarization ⇒ transmit and receive only one polarization



Synthetic aperture radar (SAR) coherent change detection (CCD)

$$\left| \frac{\sum_{k=1}^{N} f_k^* g_k}{\sqrt{\sum_{k=1}^{N} |f_k| \sum_{k=1}^{N} |g_k|}} \right|$$

Low coherence corresponds

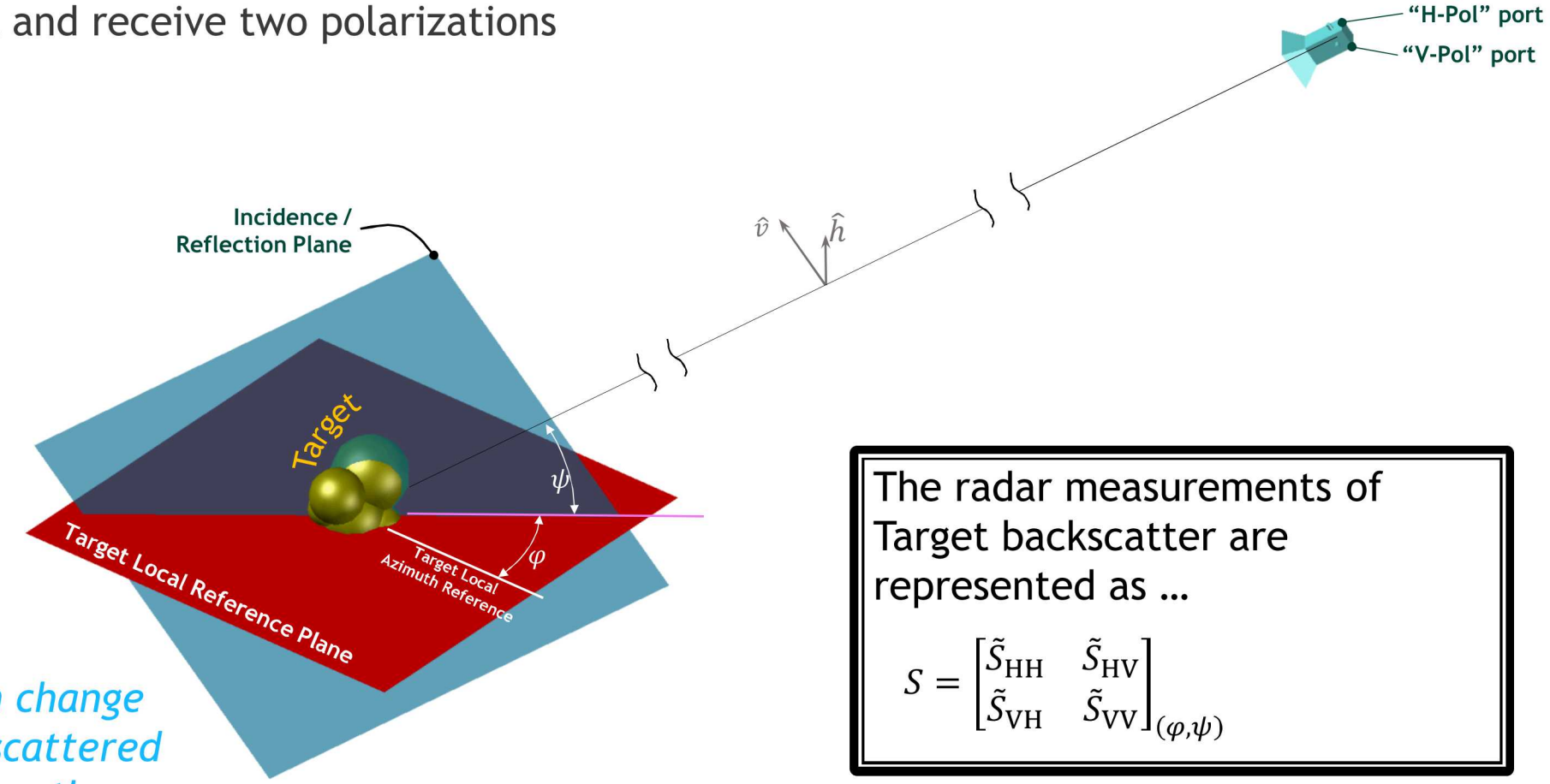
- Ground change
- Low return (shadows)
- Trees

How can we determine the type of change??

Polarimetric synthetic aperture radar (SAR)

Radar coherently can transmit and receive two orthogonal E-Field polarization states (H or V), orthogonal to direction of propagation

Polarimetric ⇒ transmit and receive two polarizations



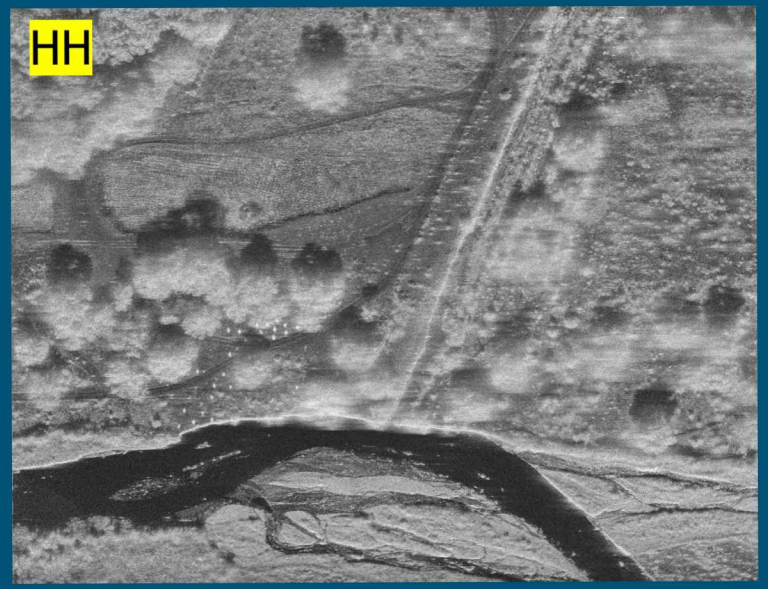
The radar measurements of Target backscatter are represented as …

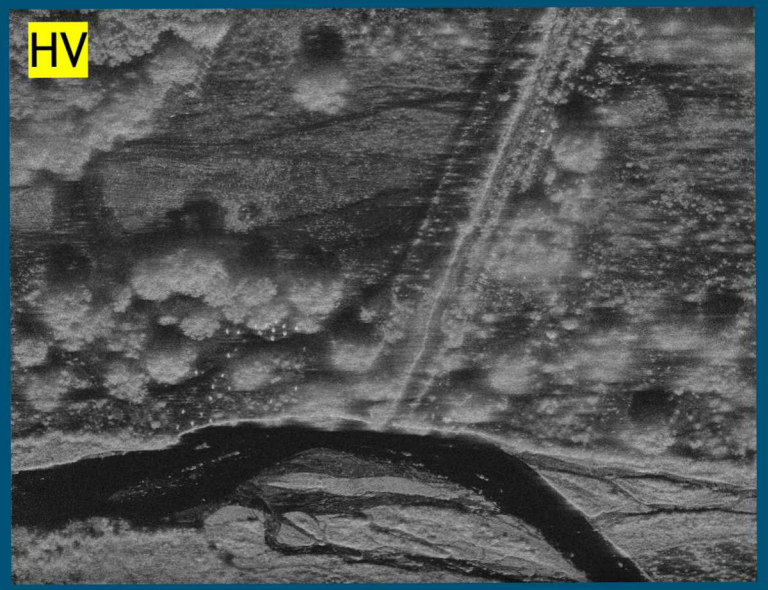
$$S = \begin{bmatrix} \tilde{S}_{\mathrm{HH}} & \tilde{S}_{\mathrm{HV}} \\ \tilde{S}_{\mathrm{VH}} & \tilde{S}_{\mathrm{VV}} \end{bmatrix}_{(\varphi,\psi)}$$

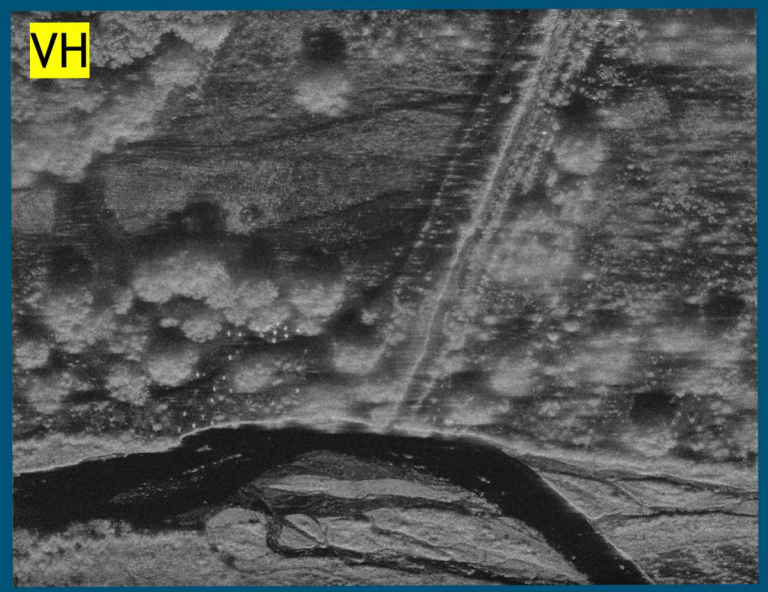
The target scatterer can change the polarization of the scattered wave to be different from the polarization of the incident wave

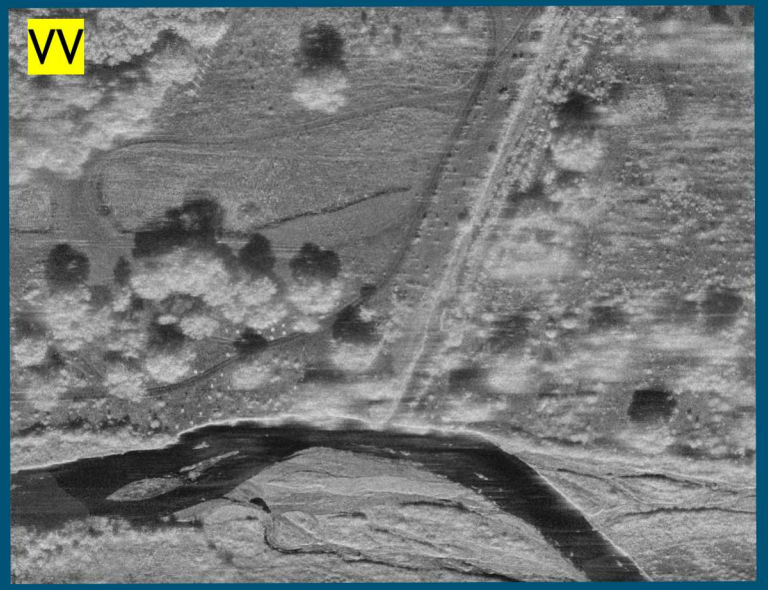
Order of polarization follows scattered / incident order

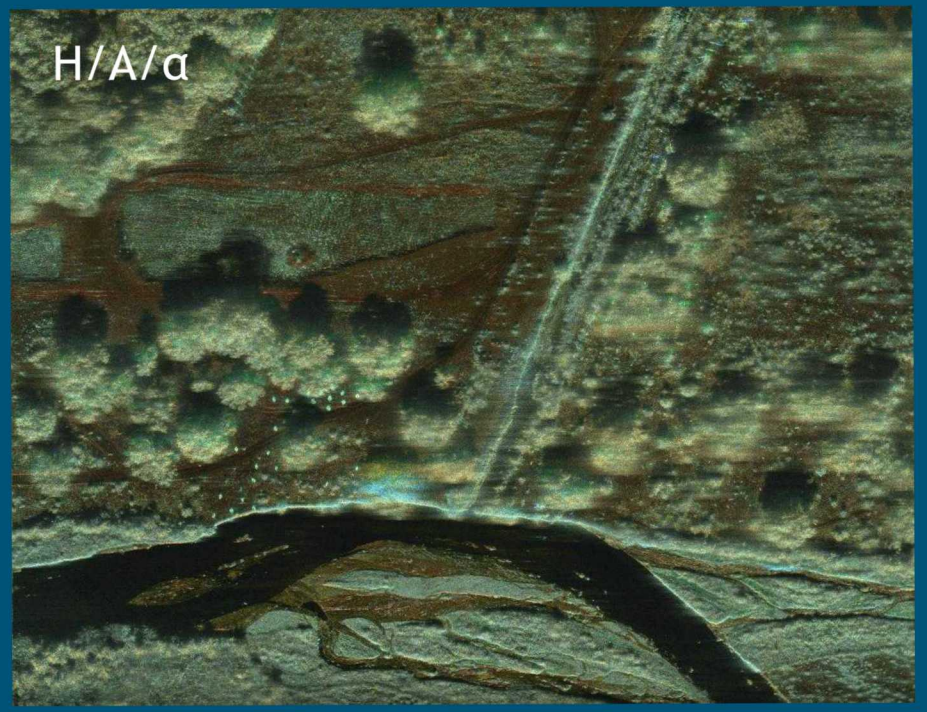
Pol SAR images







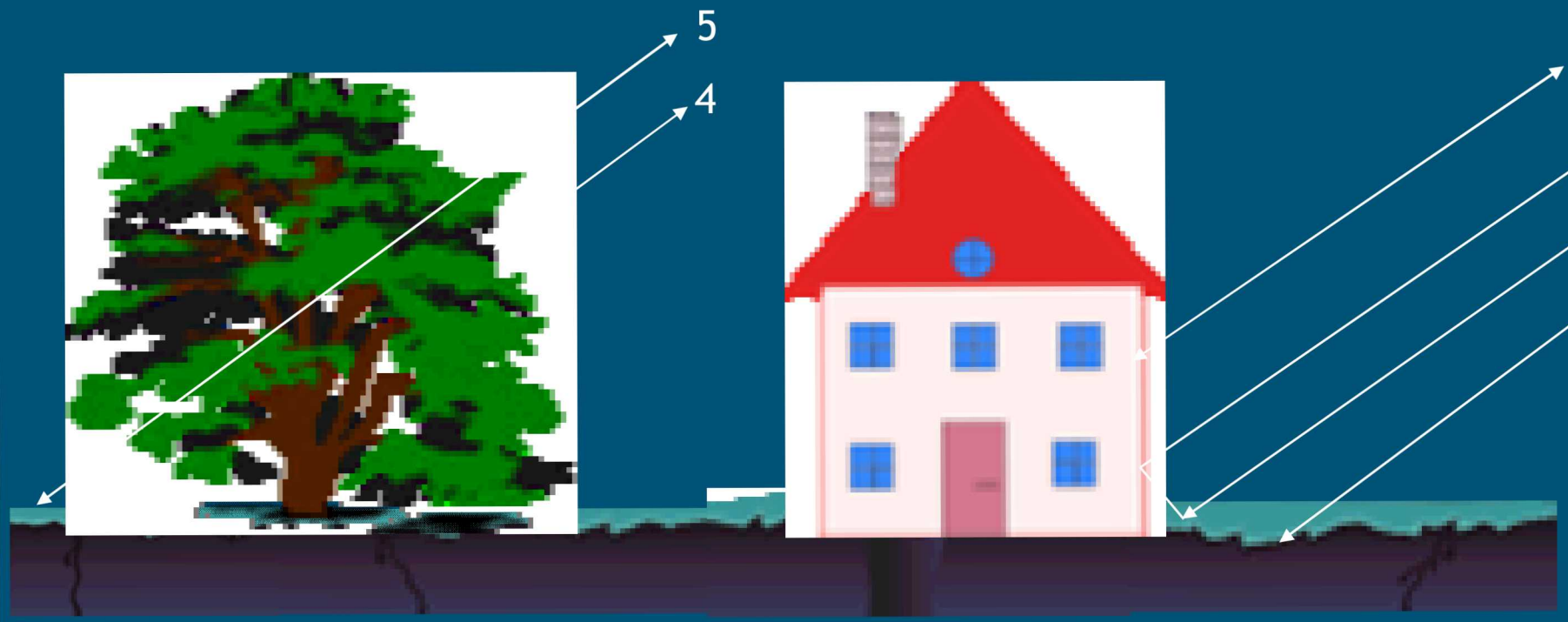




H/A/α decomposition

- Using scattering matrix determine the type of surface that created the radar return

SAR Scattering mechanisms



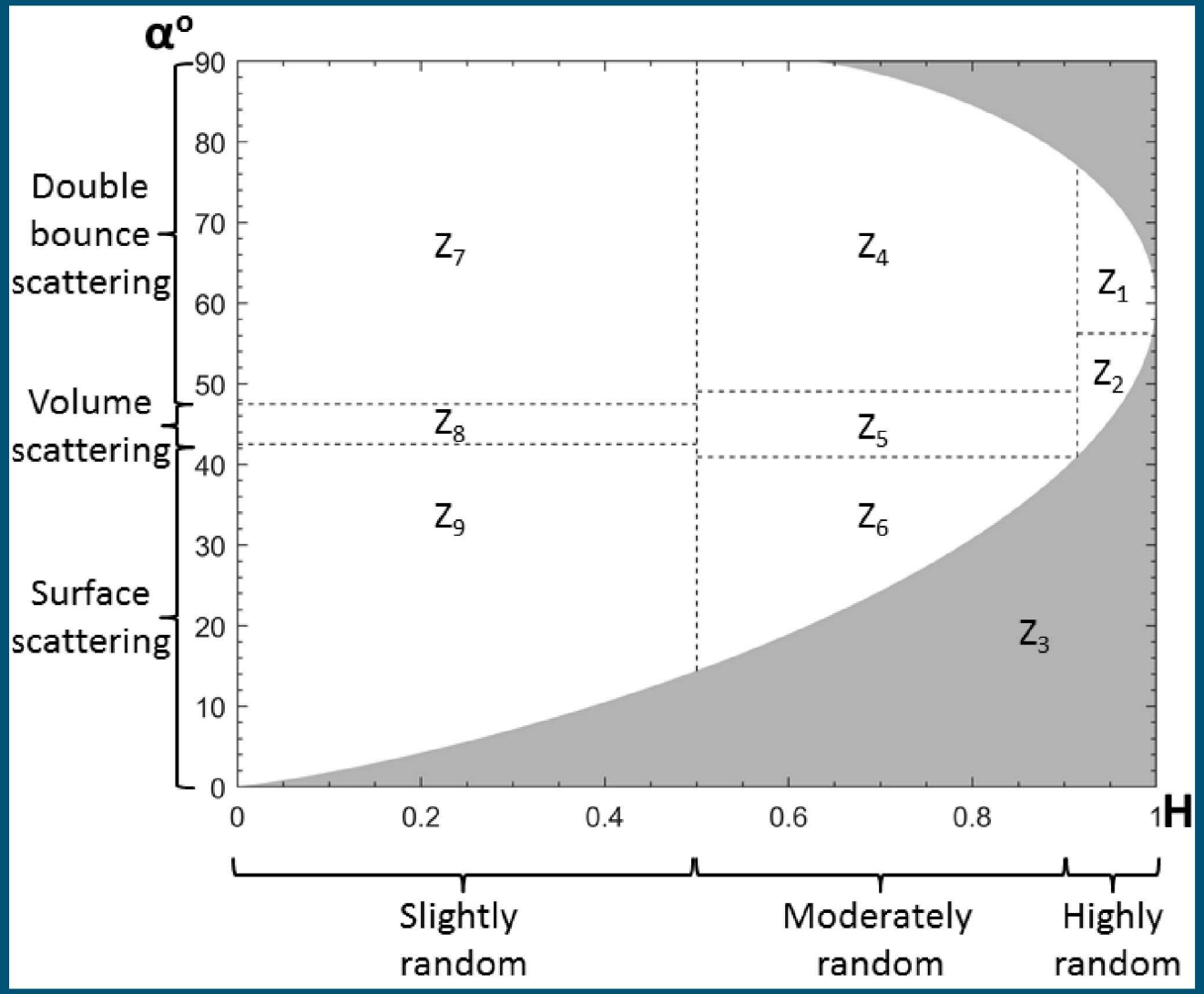
1. Rough surface
2. Dihedral
3. Single
4. Surface
5. Random volume

H/A/α decomposition

H
- Entropy or randomness of the scatter

A
- Anisotropy or the direction of scatter

α
- Scattering mechanism



Feature vector & data

Pixel magnitude in each polSAR image

H/A/α decomposition for each pixel at both passes

H/A/α decomposition for each pixel in an "optimal coherence" (OC) image OC values (1)

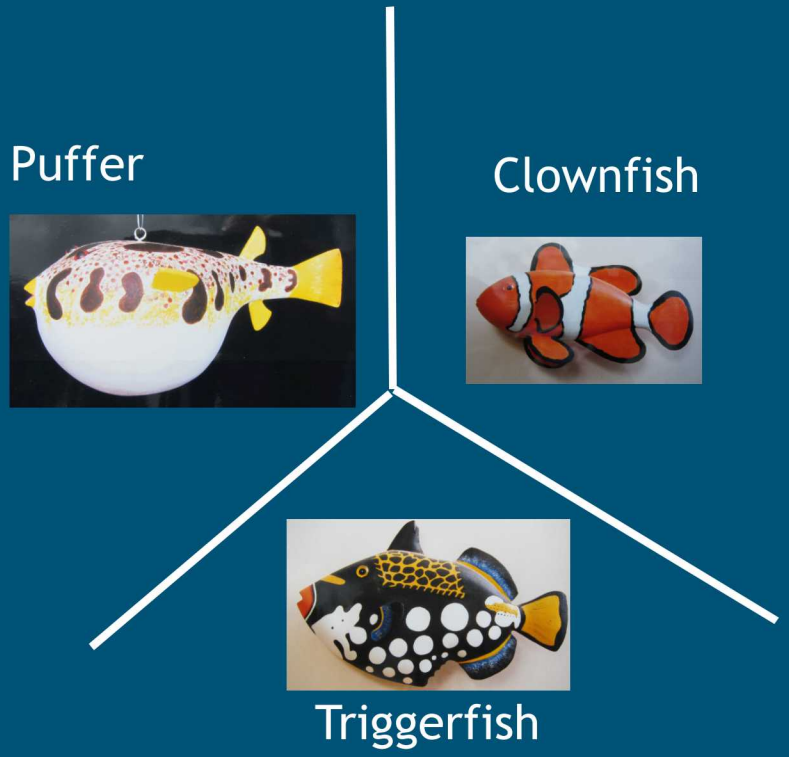
Total power

29 element feature vector total

Change-Type	Training Samples	Test Samples
Tree	97,862	73,098
Low	106,169	75,874
Grnd	5,816	5,763

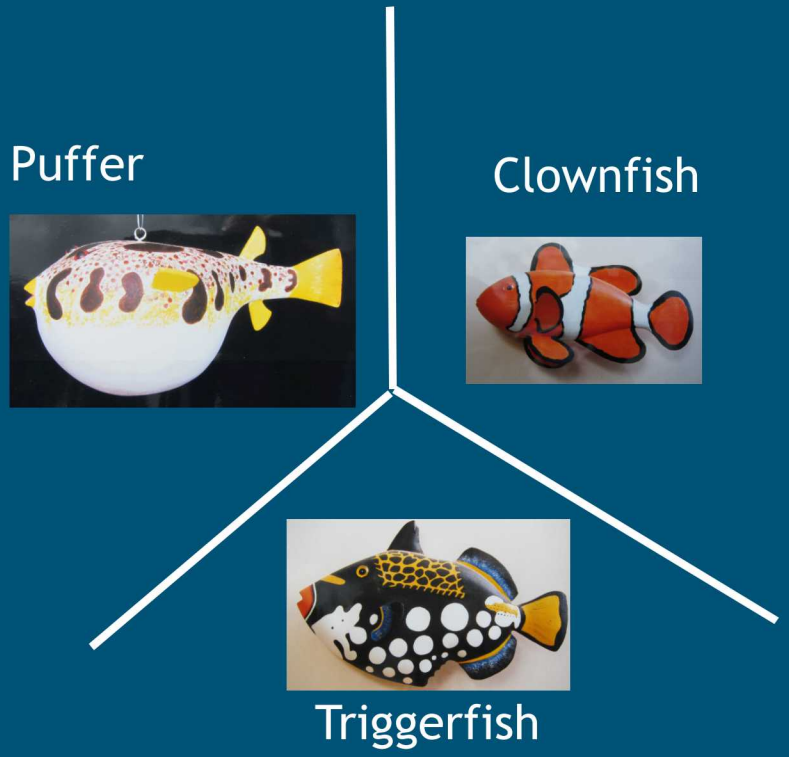
Train & test comes from different images

Closed set classifiers



Closed set: training and test sample come from known classes

What happens when an unknown class is in the test set??



Seahorse (unknown)

Closed set: training and test sample come from known classes

Open set classifier

Puffer

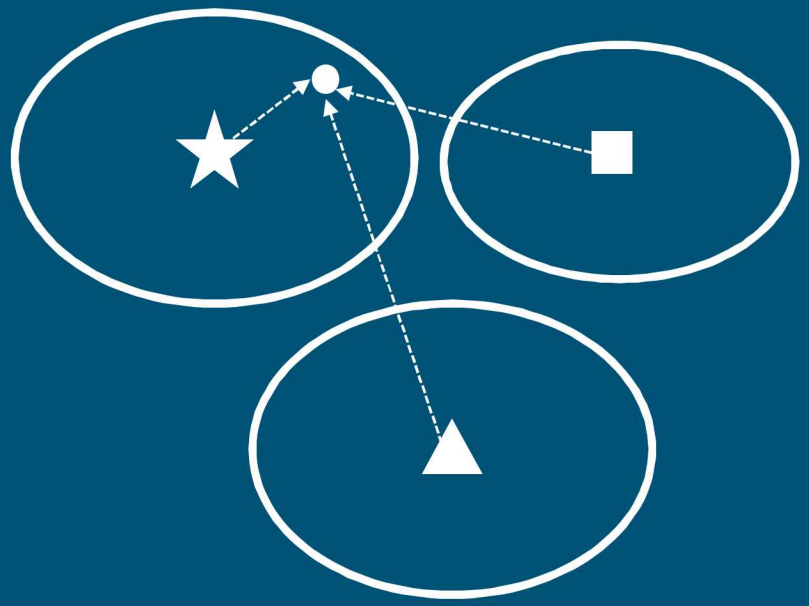
Clownfish

Triggerfish

Seahorse (unknown)

Open set: multiple known classes, but many unknown (optional add more classes)

Template based approach



Develop a template for each class

Use a distance metric to measure how close you test sample is to the template

Compare smallest distance to a threshold to determine class membership or unknown

Hyperparameter free classifier

Classifier has two types of parameters

- Learned parameters
  - Weights, biases, probabilities, means, …
- Hyperparameters (control learned parameters)
  - Learning rate, momentum, learning rate decay, epochs, minibatch size, weight initialization, regularization (dropout rate)
  - Selection is an empirical process

Create a quantized feature vector

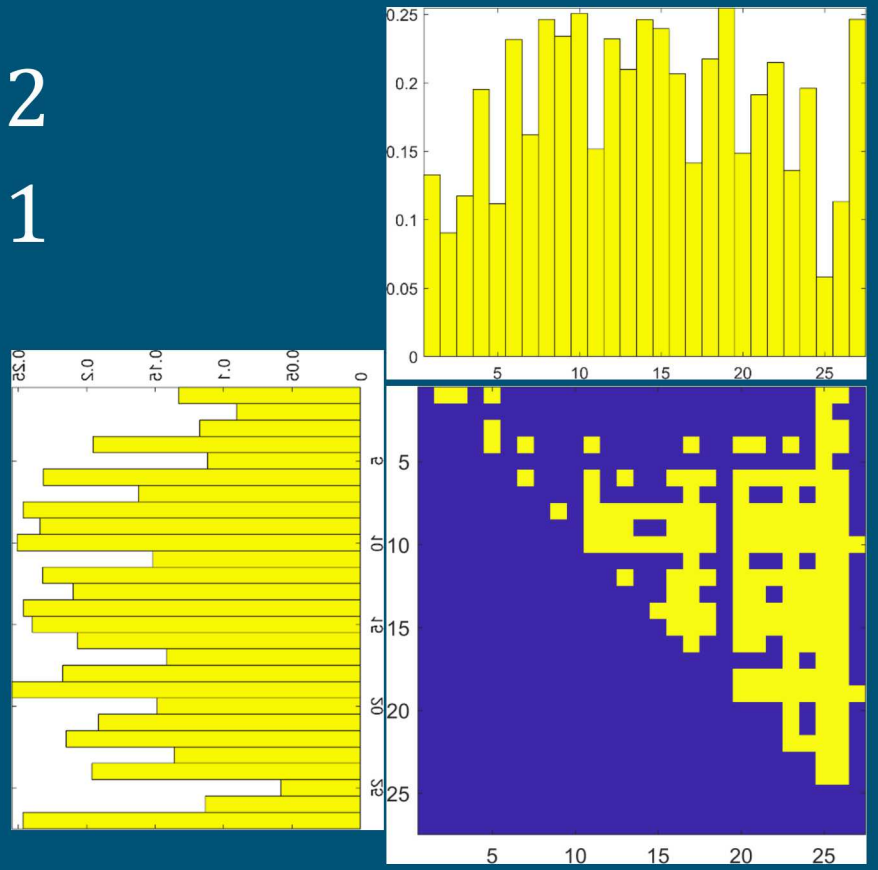
$$\text{for } i > j \quad \begin{matrix} \text{if } d_i > d_j & y_k = 2 \\ \text{otherwise} & y_k = 1 \end{matrix}$$

g is the feature vector

Creates a binary feature vector

Can estimate probabilities of $\boldsymbol{y_k}$, $\boldsymbol{P_{kq}}$ (q=1 or 2)

Probabilities are used to create a template



Quantized distance metric

$$Z_{MPM} = \sum_{k=0}^{B-1} \frac{\left(1 - \hat{P}_{k,yk}\right)^2 - \hat{E}_k}{\sqrt{C \times \hat{V}_k}}$$

Penalty Function

$$\hat{E}_k = \sum_{q=0}^{Q-1} \tilde{P}_{kq}\left(1 - \hat{P}_{kq}\right)^2$$

$$\hat{V}_k = \sum_{q=0}^{Q-1} \tilde{P}_{kq}\left(1 - \hat{P}_{kq}\right)^4 - \hat{E}_k^2$$

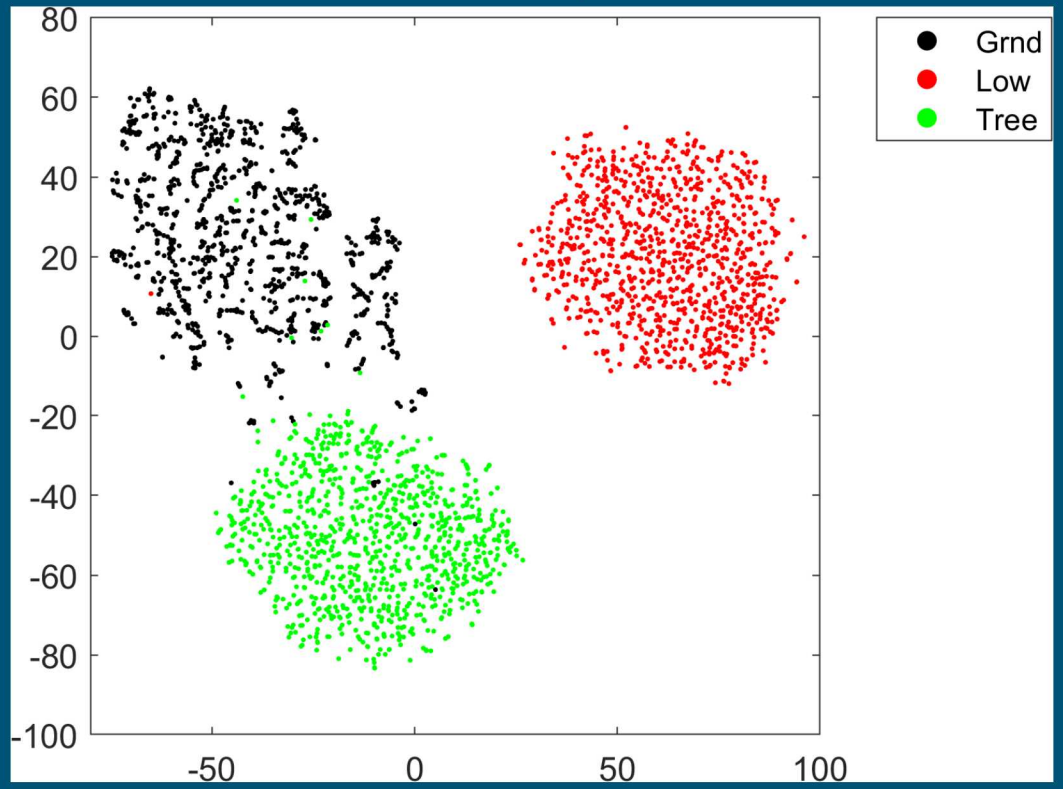
C accounts for the correlation between the features

Z_{MPM} – should be N(0,1) for target data

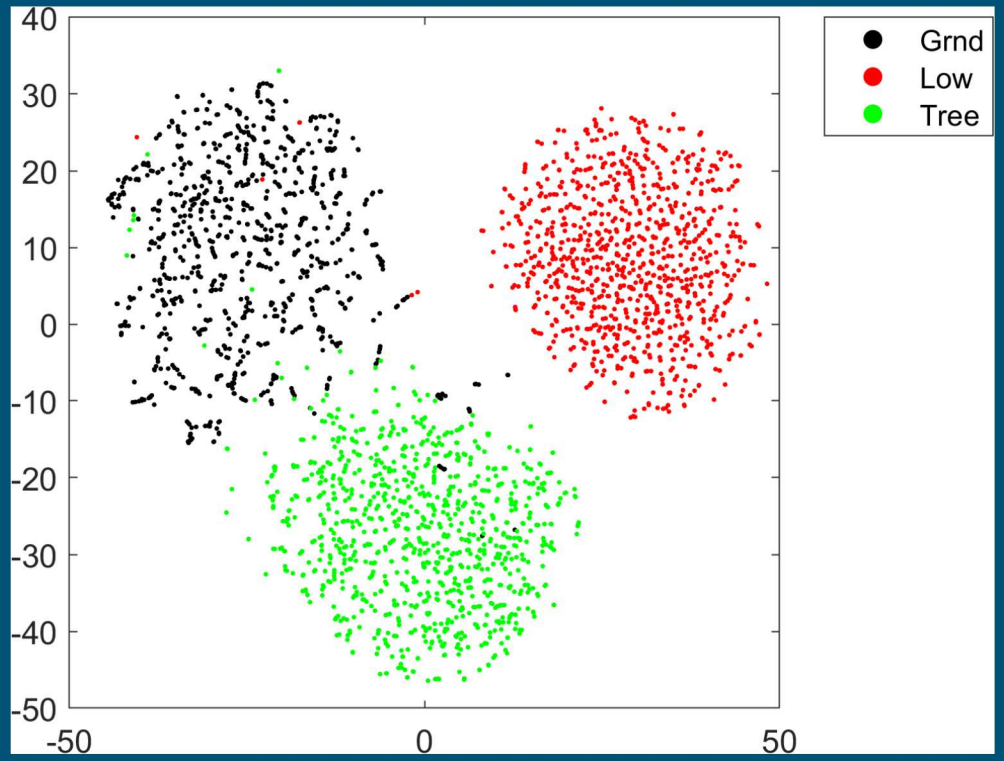
- Central limit theorem

Do we lose any information? tSNE plots

Raw feature space

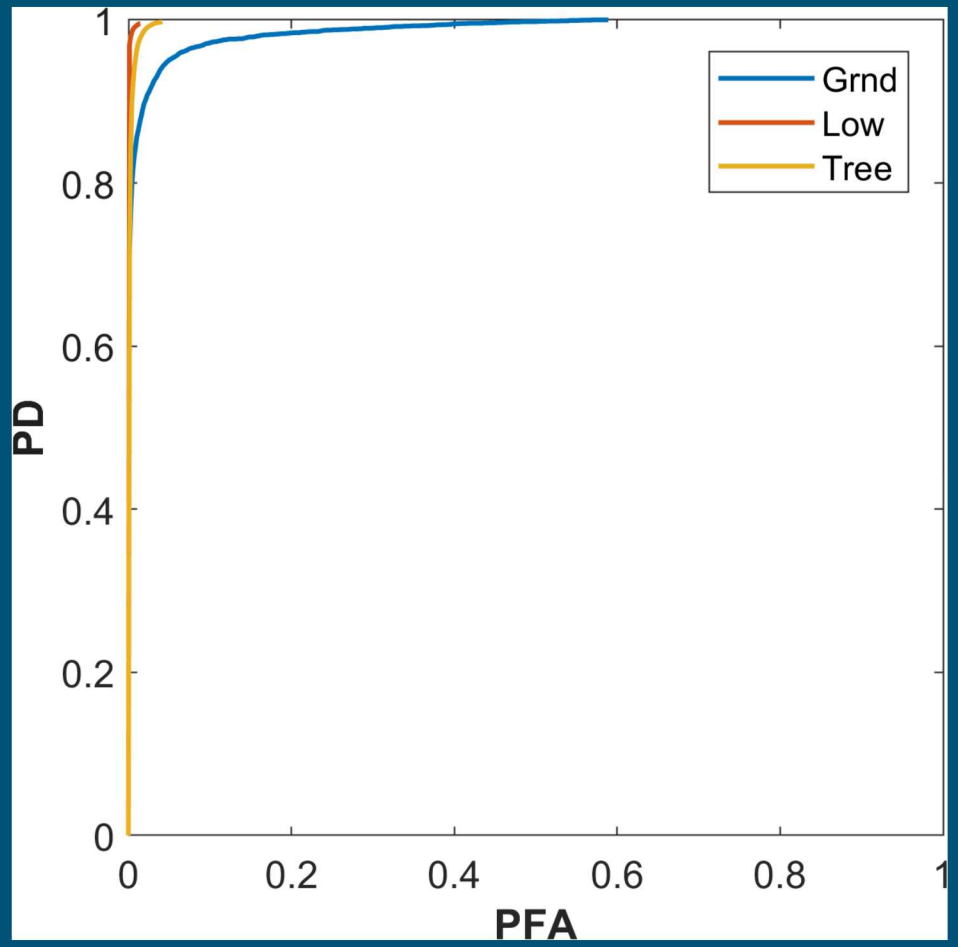


Quantized feature space

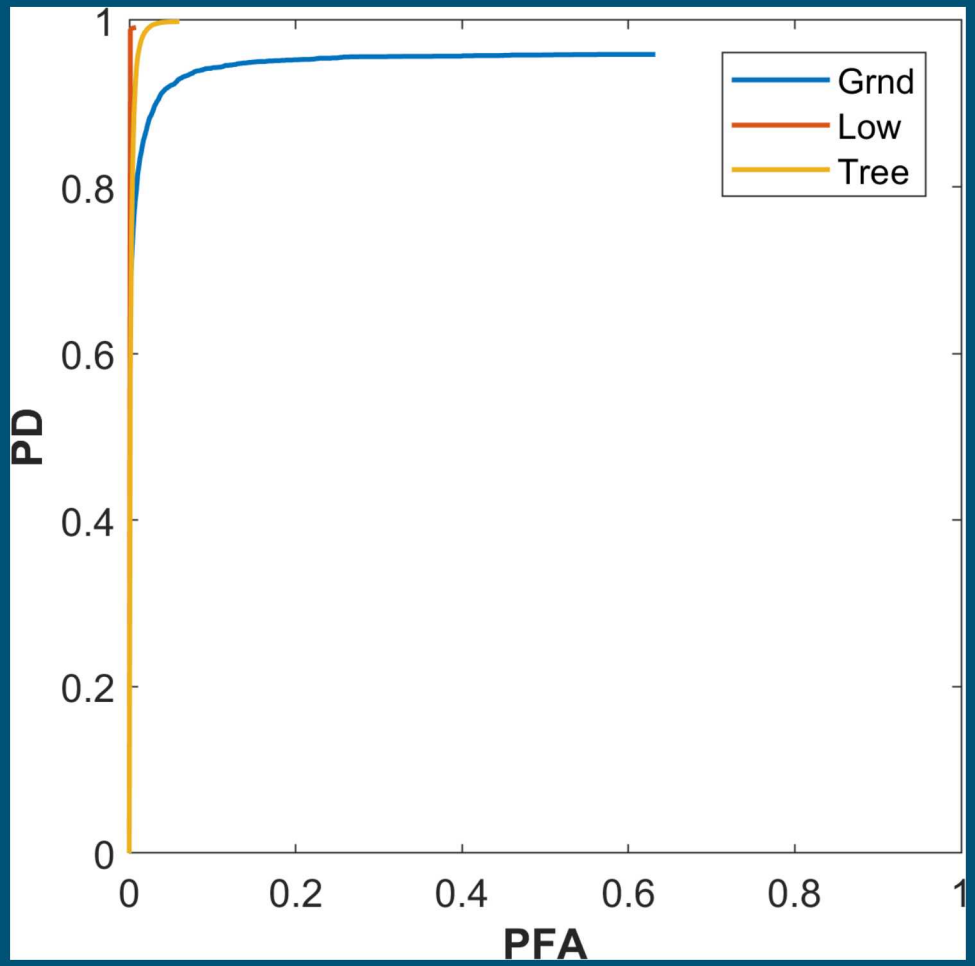


tSNE: Unsupervised algorithm for dimensionality reduction and for visualizing high-dimensional data on a 2 or 3 dimensional manifold

Results: operating characteristics



Train



Test

Confusion matrices

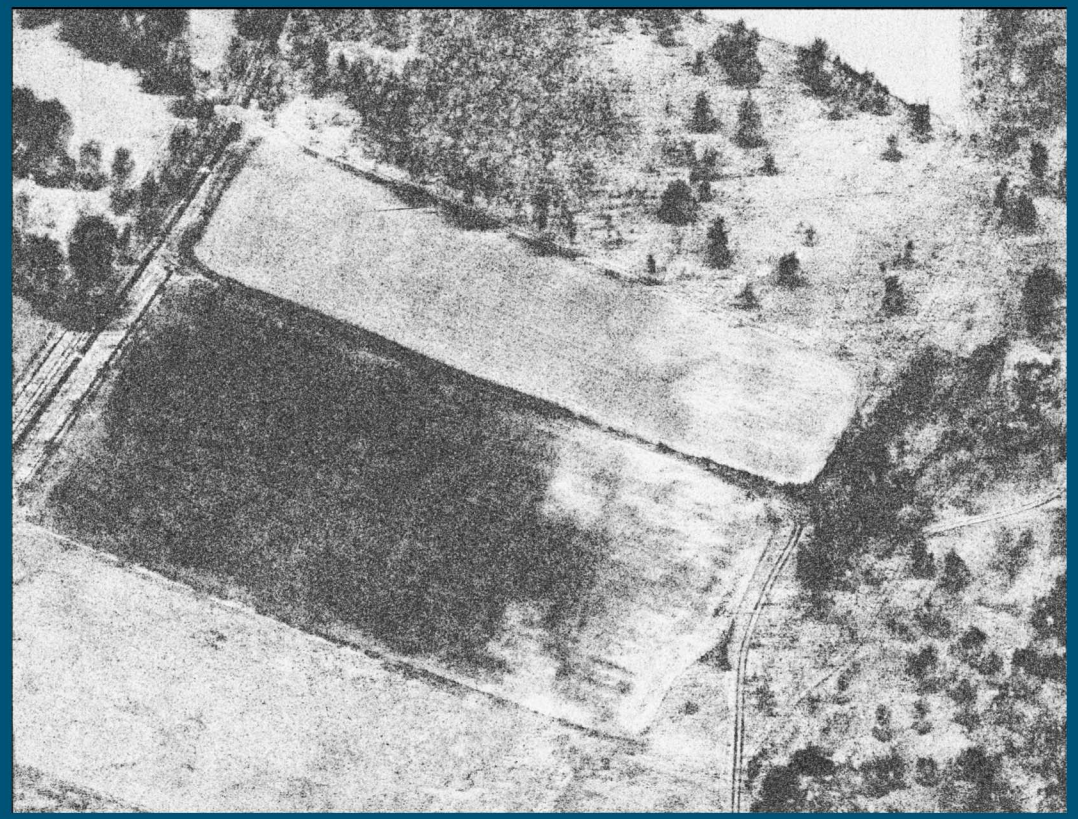
Train

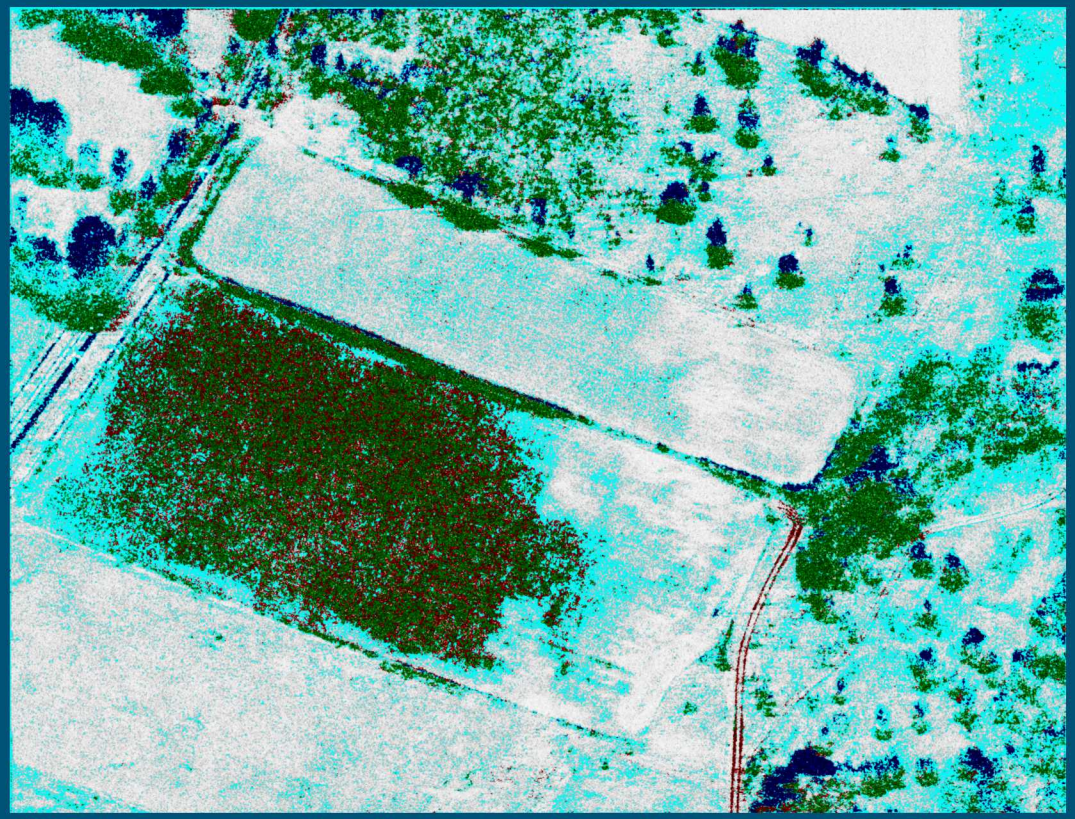
	Grnd	Low	Tree	UNK
Grnd	93%	0%	6%	1%
Low	0%	97%	0%	3%
Tree	2%	0%	96%	3%

Test

	Grnd	Low	Tree	UNK
Grnd	74%	0%	17%	9%
Low	0%	96%	0%	4%
Tree	0%	0%	99%	1%

Confusion images





Tree – green
Low – blue
Ground – red
Unknown – cyan
White – no change

Conclusion

Extend H/A/α polarimetric decomposition to detect the type of change in CCD images

Identified three type of change

- Low return
- Ground
- Trees

Open set classification is important when you can't train with all the possible classes