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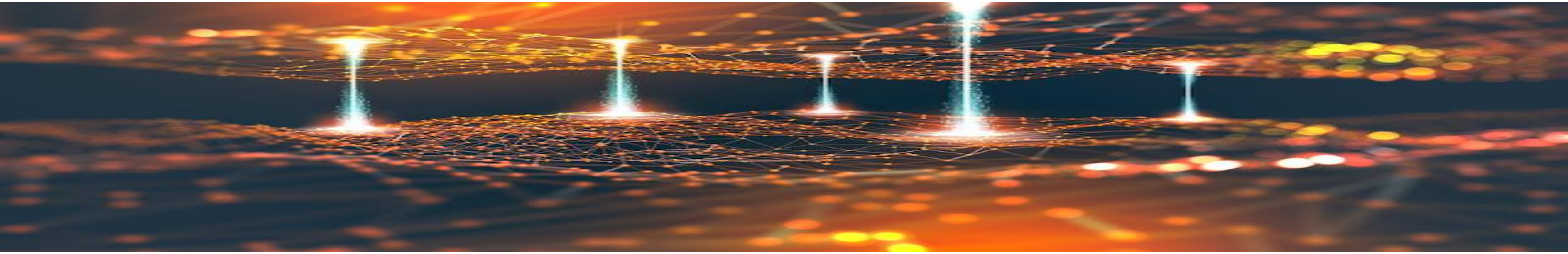

Quantum Machine Learning for Deformation Detection: Application for InSAR Point Clouds

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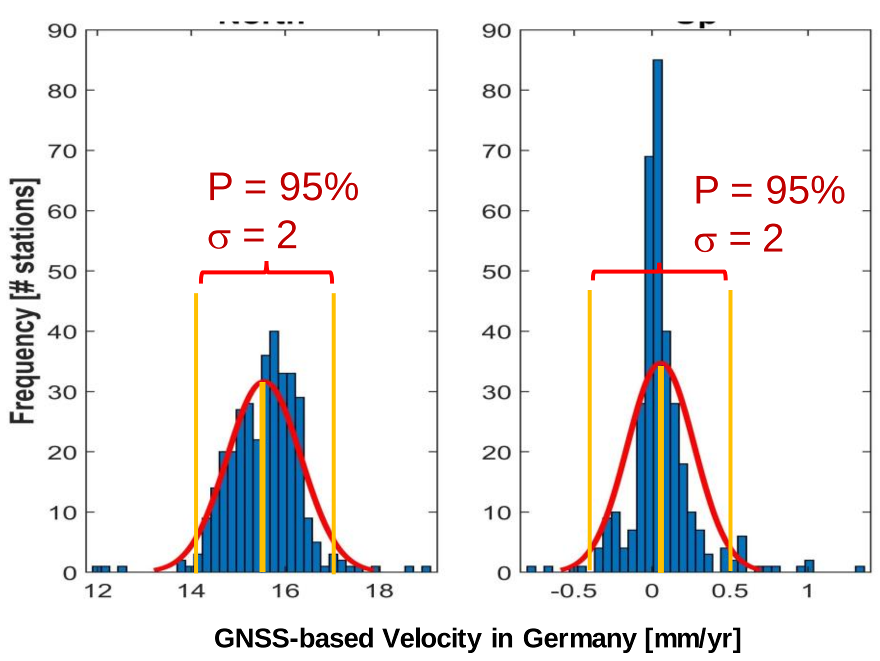
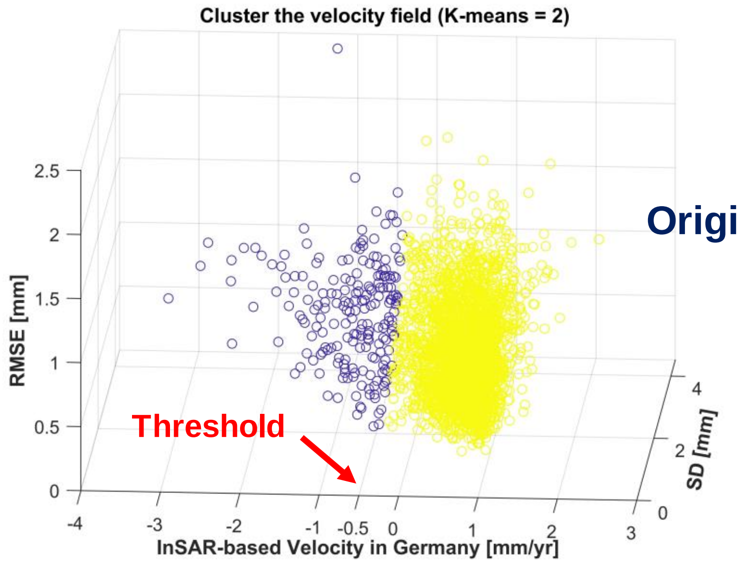
Motivation: Deformation Detection

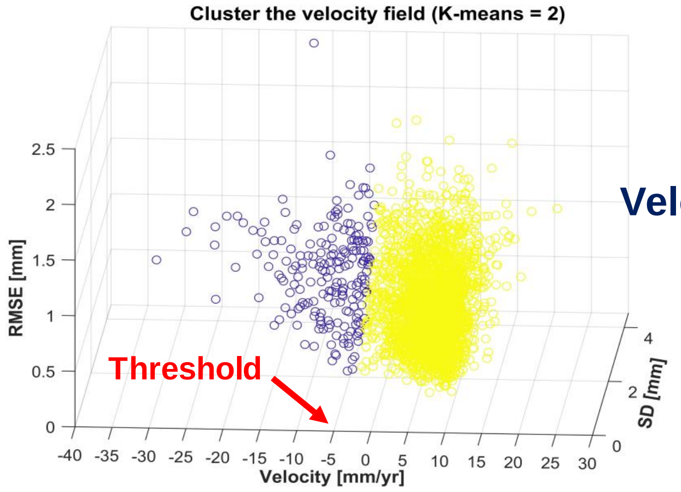
Using **statistical tests**



Using **unsupervised** ML (Clustering ML)



Original velocity



Velocity×10

Different datasets/timespans/regions

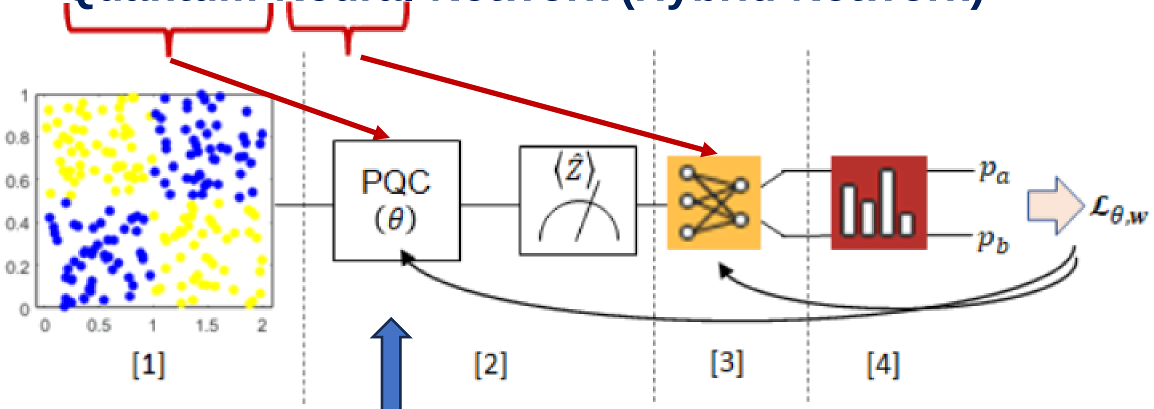
➔ The same statistical threshold but **different deformation thresholds**

➔ **Lack consistency**

➔ Should use the **supervised** ML **models** to detect deformation.

Quantum Machine Learning:

Quantum Neural Network (Hybrid Network)



Quantum Computing Package in MATLAB®

Launched: Mar 2023
Updated: Oct 2023
Environment: Matlab 2023a or **2023b**

Apply QML

Predicted Classes

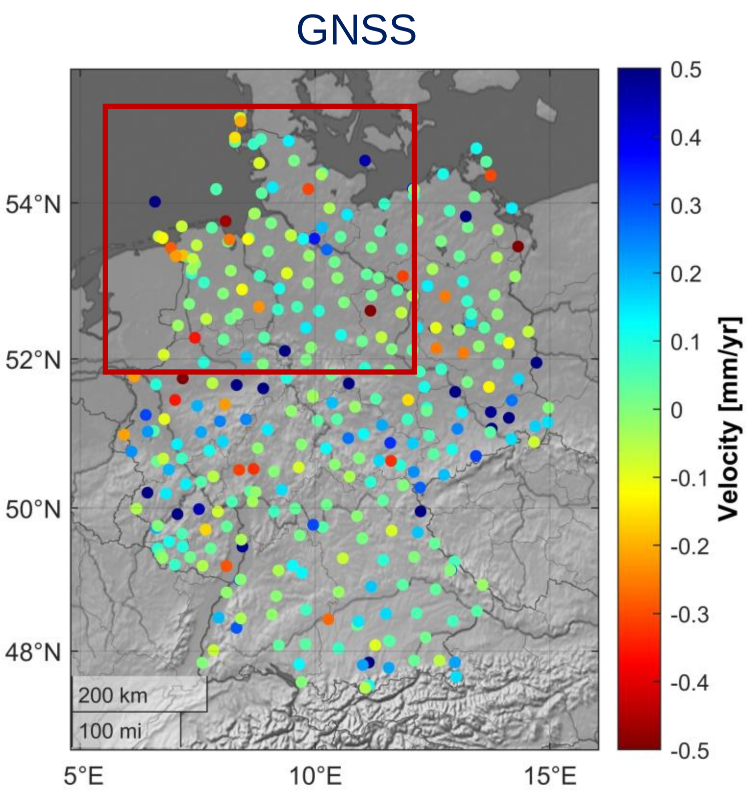
True Classes	Yes → Deformation	No → Stable
Yes → Deformation	True Positive (TP)	False Negative (FN) (Type II Error)
No → Stable	False Positive (FP) (Type I Error)	True Negative (TN)

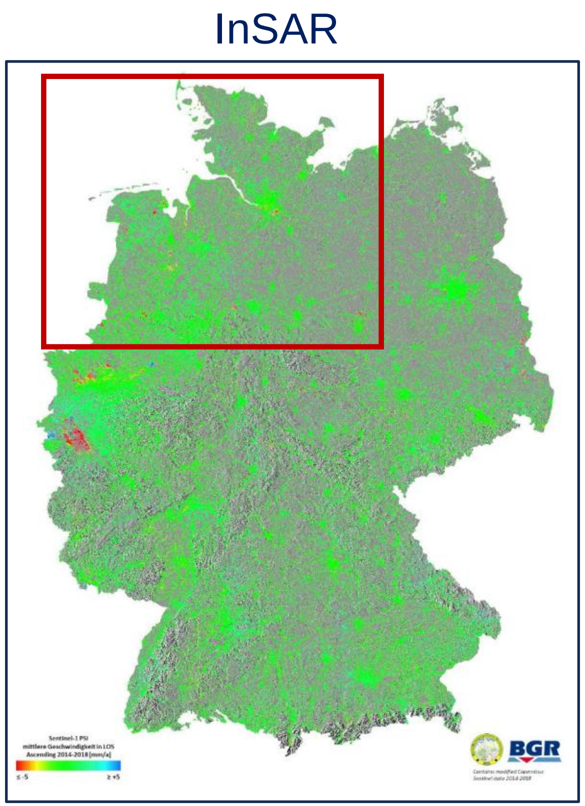
Confusion matrix of binary classification in the deformation detection models

<u>Application</u>:

Detection of surface deformation using GNSS-InSAR and QML

Experimental region





Reference: https://www.bgr.bund.de/

<u>Data:</u>

- ✓ **GNSS:** 346 monitoring stations (from 1994 to 2020) in Germany ➔ Networks of SAPOS, IGS, and EUREF,…
- ✓ **InSAR:** 3,500,000 raw time series (from 2015 to 2021) in Northern Germany ➔BGR

Selecting **features** for classification

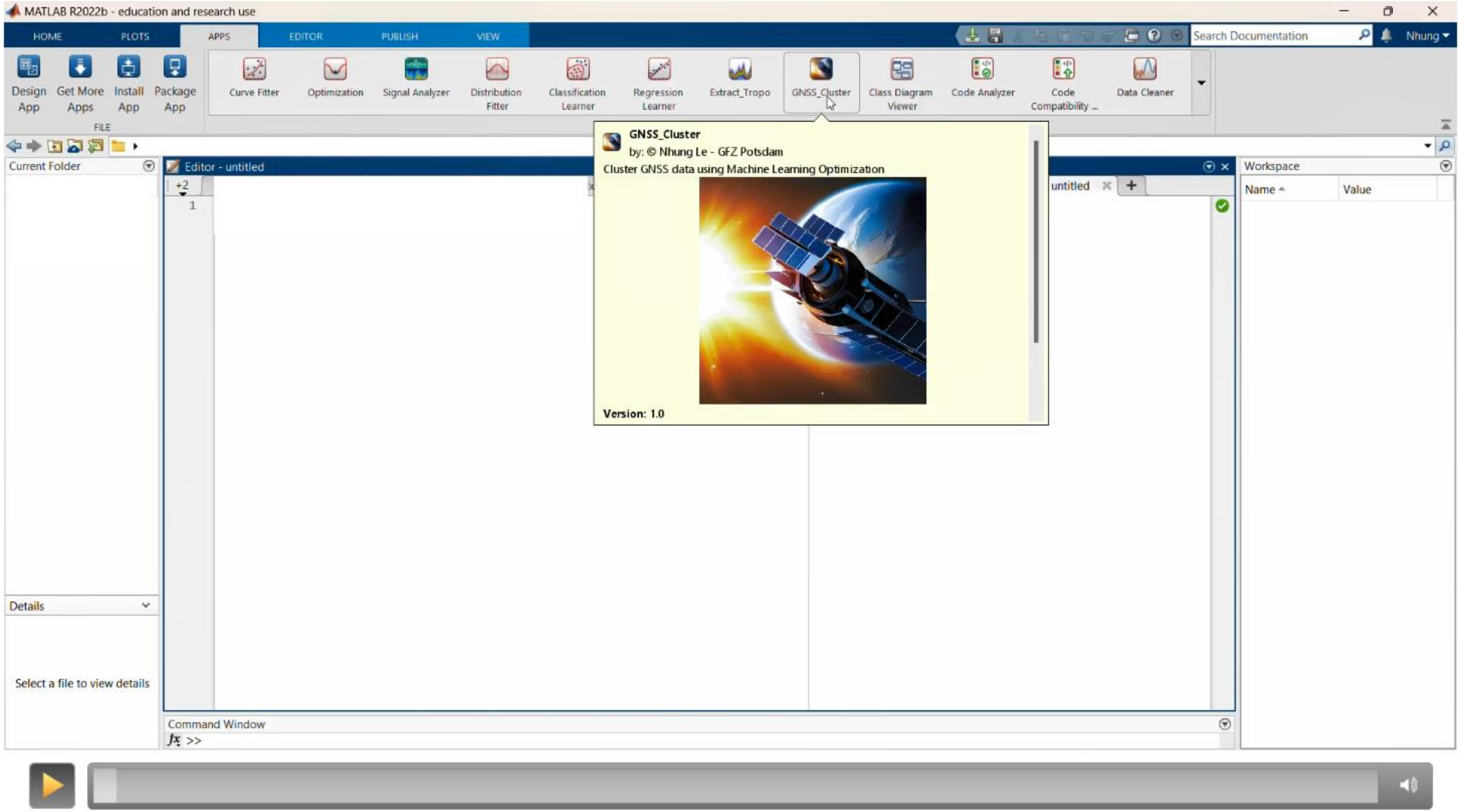
Statistics	RMSE				SD				InSAR time series
	Median	Mean	Min	Max	Median	Mean	Min	Max	
Clean (mm)	1.33	1.42	0.25	9.21	0.69	0.74	0.13	4.75	2,719,002
Raw (mm)	1.41	1.50	0.26	9.30	0.73	0.78	0.14	4.79	
Improvement (%)	5.6	5.4	2.1	0.9	5.6	5.4	2.1	0.9	

Statistics	Velocity (mm/yr)				Outliers					InSAR time series
	Median	Mean	Max subsi	Max uplift	Median	Mean	Min	Max	Sum	
Clean	-0.07	-0.19	-46.43	33.72	9	9.77	0	55	26,555,233	2,719,002
Raw	-0.10	-0.20	-46.00	32.40						
Changes	0.03	0.01	-0.43	1.32						

Overlapping/uncertain InSAR grid points have already been removed

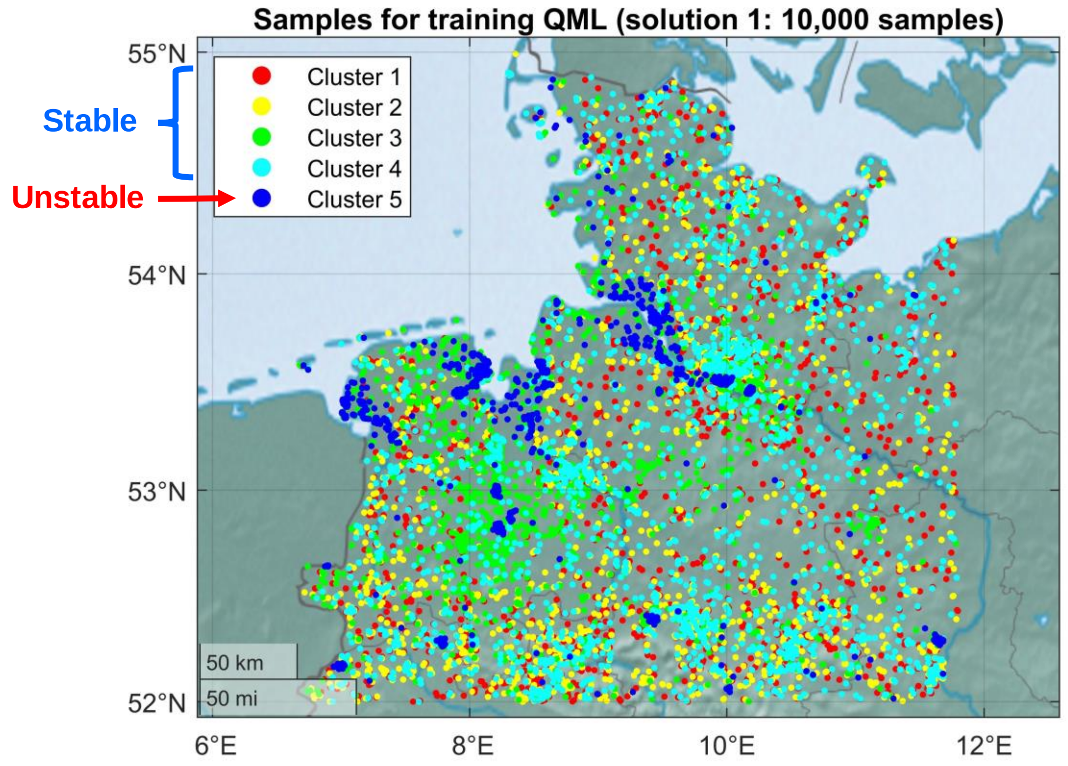
Features: Velocity, Variations, Errors, Outliers, Entropy, Monitoring timespans,…

Create samples for training ML models using the clustering ML App



Sampling strategies for training and validating QML

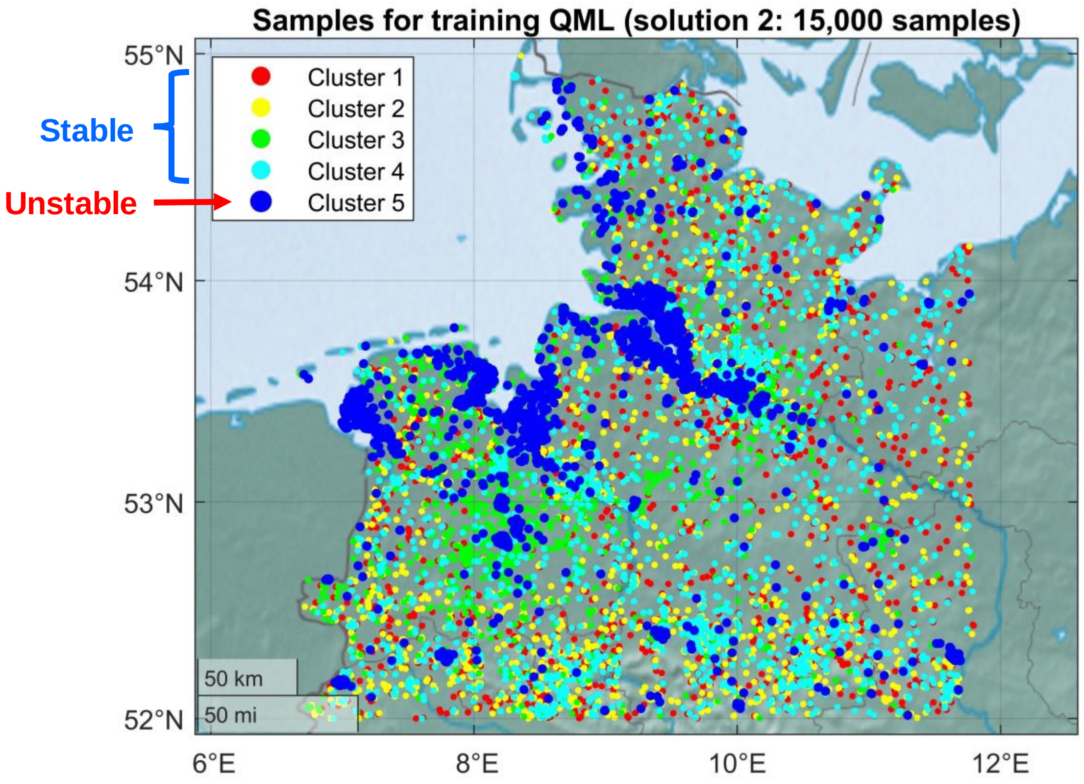
× Systematic sampling



Pick out randomly 2000 samples in each Class from 1 to 5

× **Biases** due to the samples of **stable** category

✓ Stratified sampling

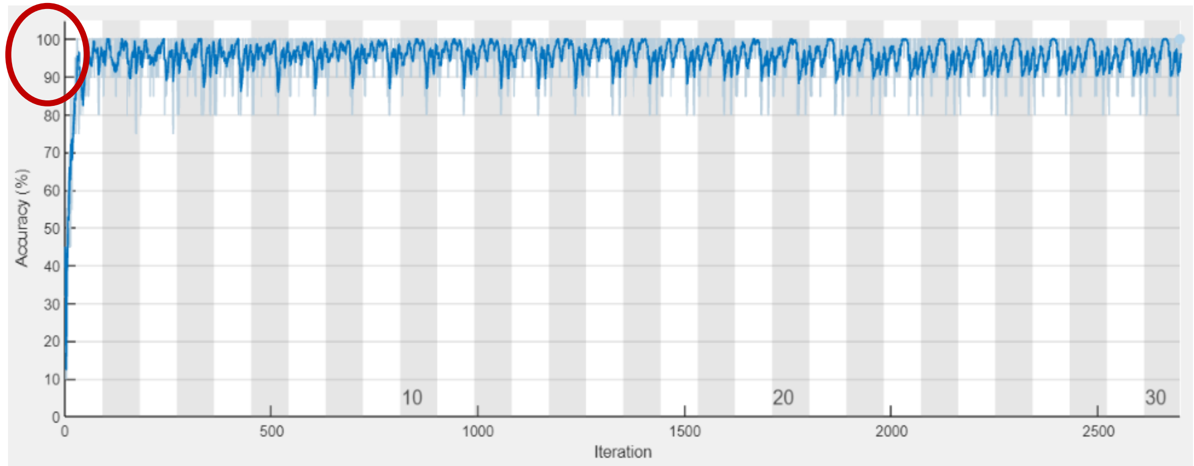


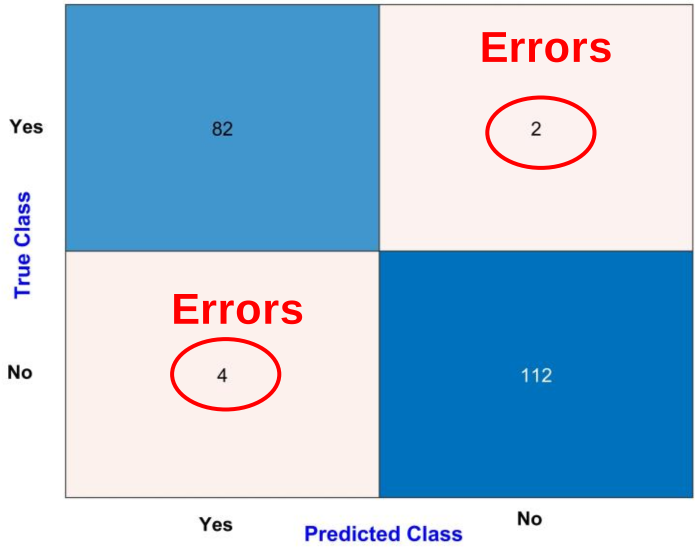
- ✓ 2000 samples in each Class from 1 to 4
  ➔ **8000 samples** ➔ **Stable** category
- ✓ Using all samples of Class 5
  ➔ **7300 samples** ➔ **Unstable** category

Compare:

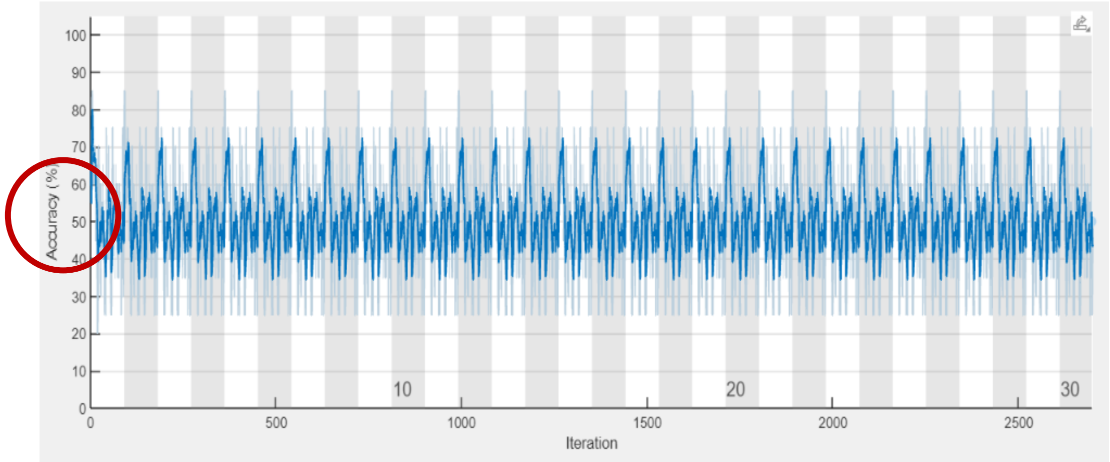
QML vs Pure ML
(Hybrid Network vs Neural Network)

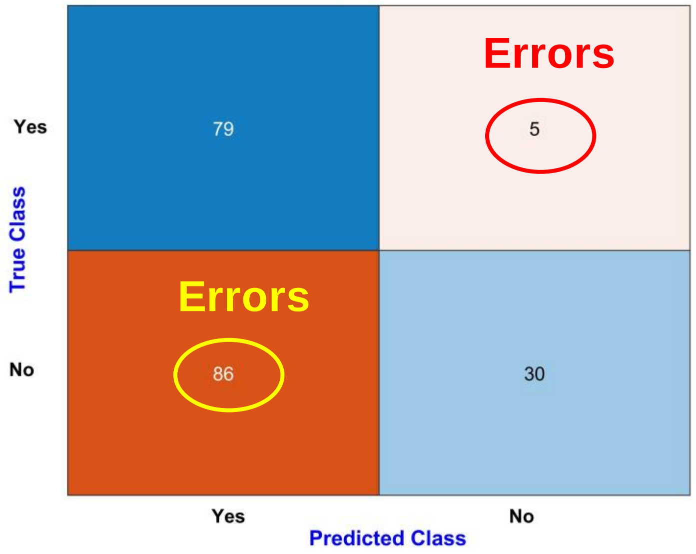
Hybrid Network (QML)



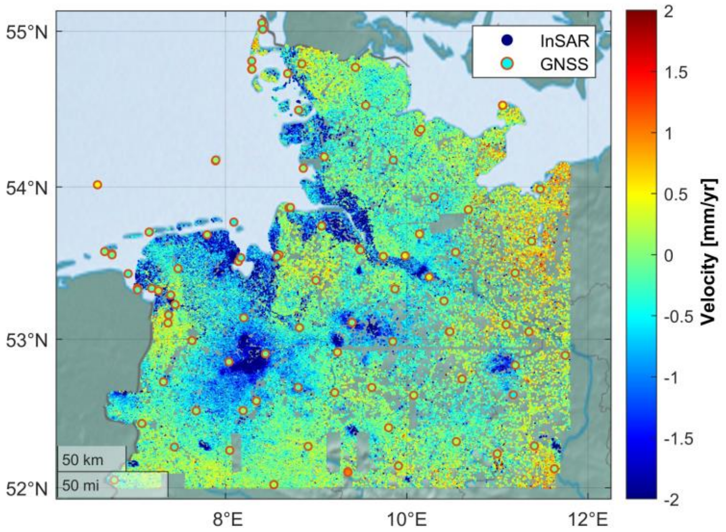


Neural Network (Pure ML)



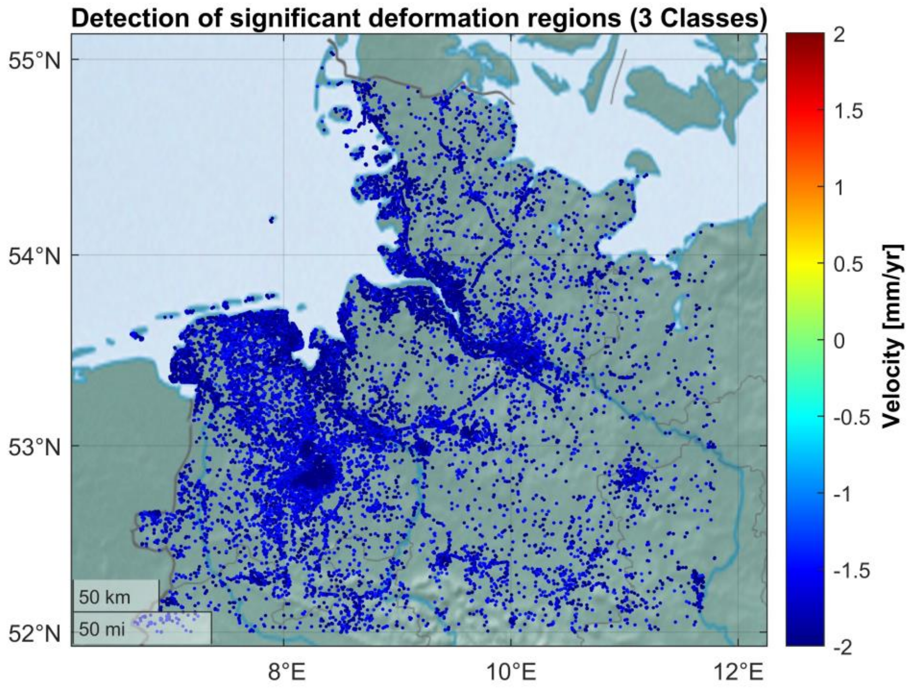


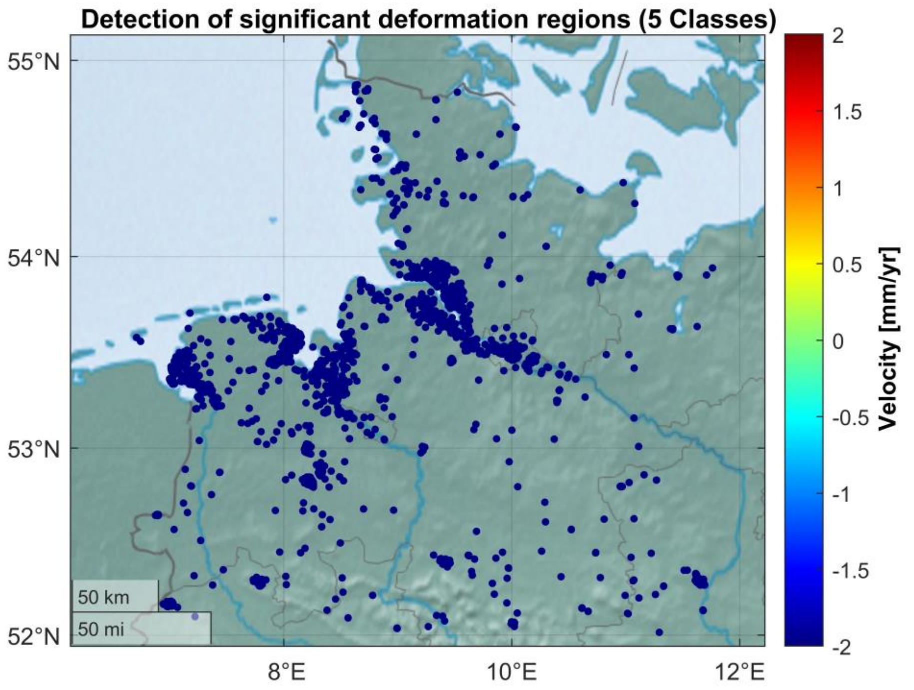
Detection of significant deformation regions



Actual data

Detection of deformation regions





× 3 classes: Included noise

✓ **5 classes: More focused**

Conclusions and suggestions

- The QML-based **Hybrid Network** is **recommended** for improving the performance of the pure ML-based **Neural Network**.
- The study suggests a workflow of the Hybrid Network-based binary classification to implement the QML technique for **better sensitivity** of deformation detection.
- **Extend investigations** on other ML techniques for a more comprehensive assessment.

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