Near Real-Time Maritime Object Recognition using Multiple SAR Satellite Sensors

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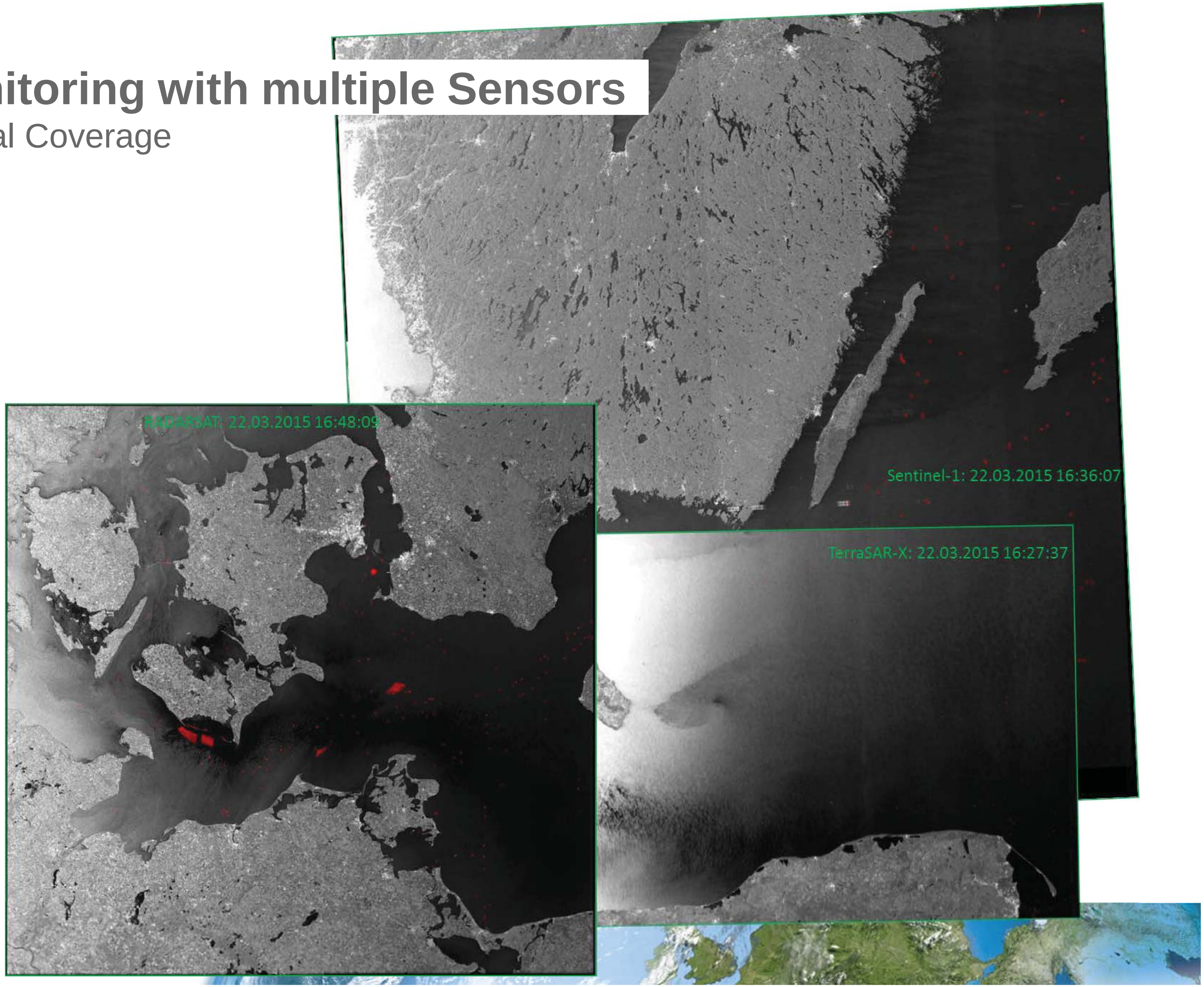
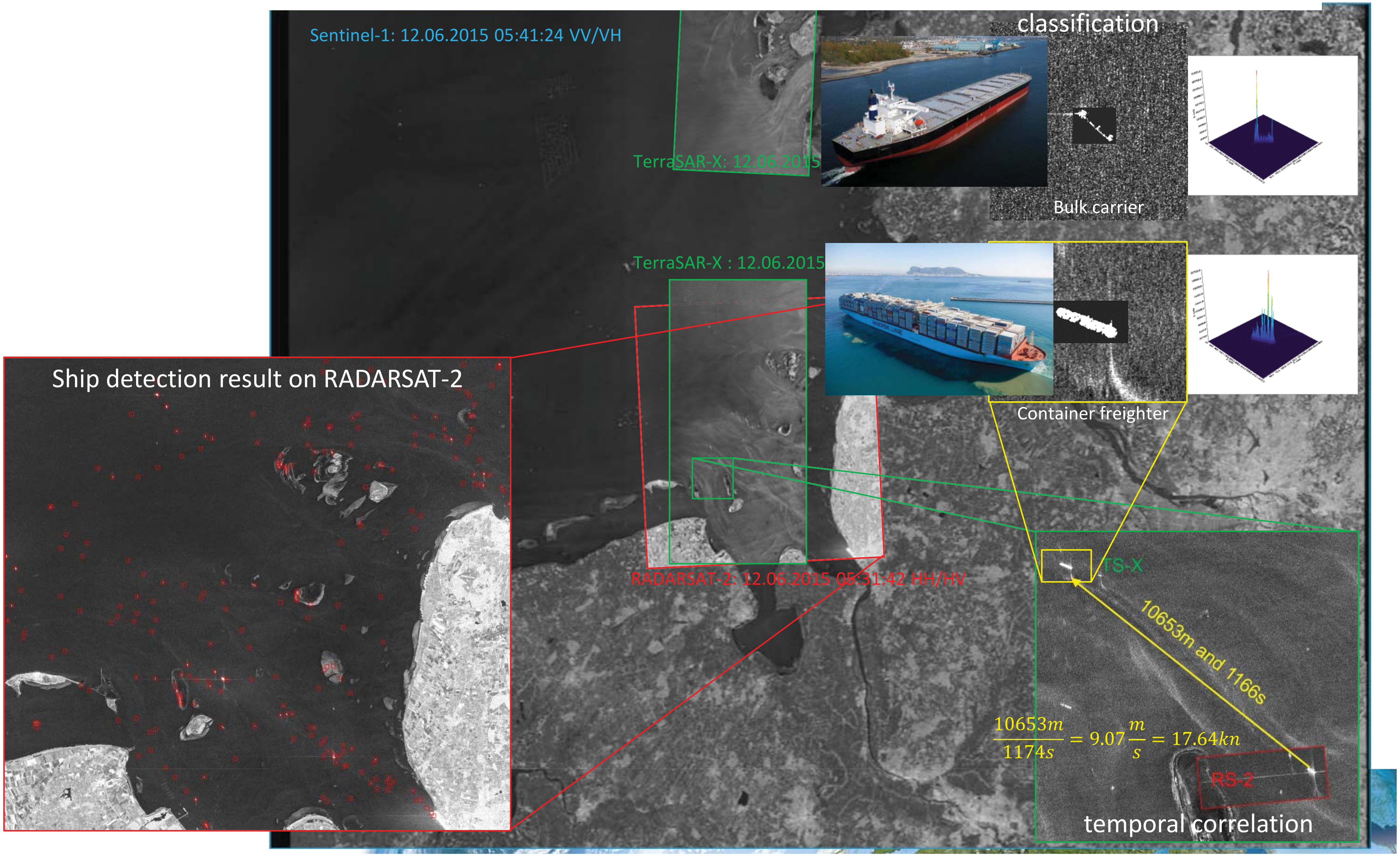
Monitoring with multiple Sensors

Spatial Coverage



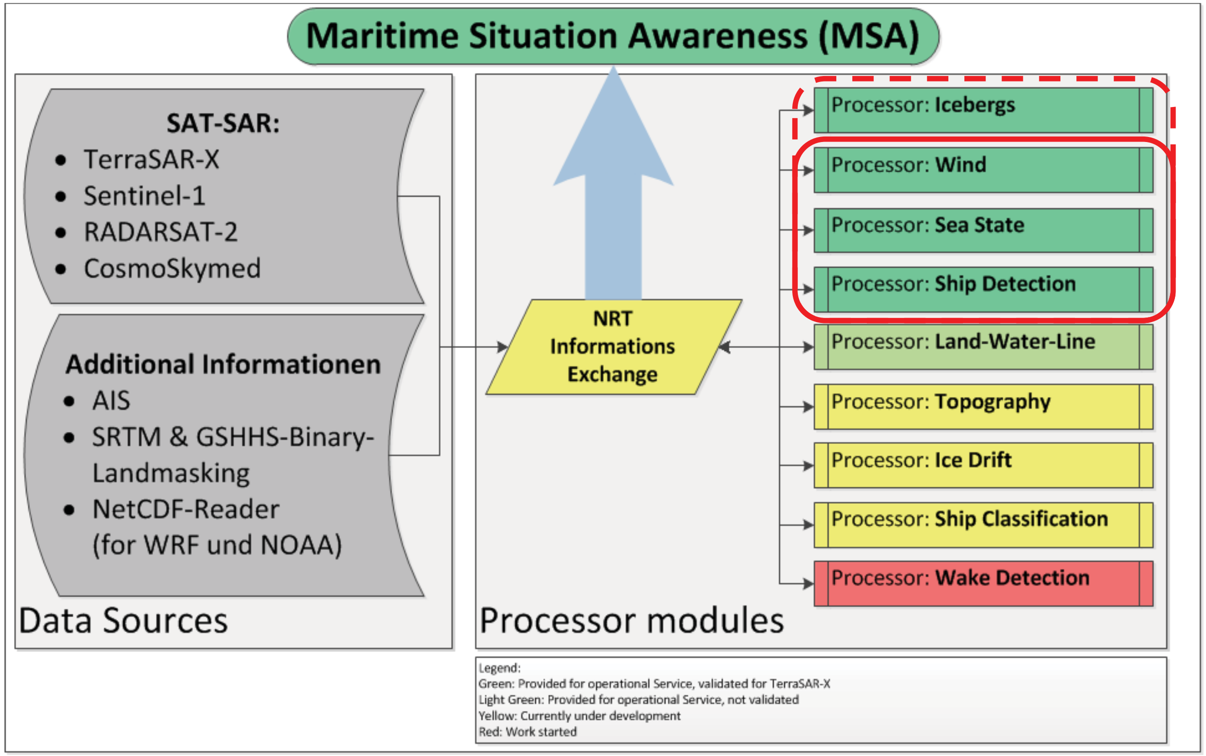
Monitoring with multiple Sensors

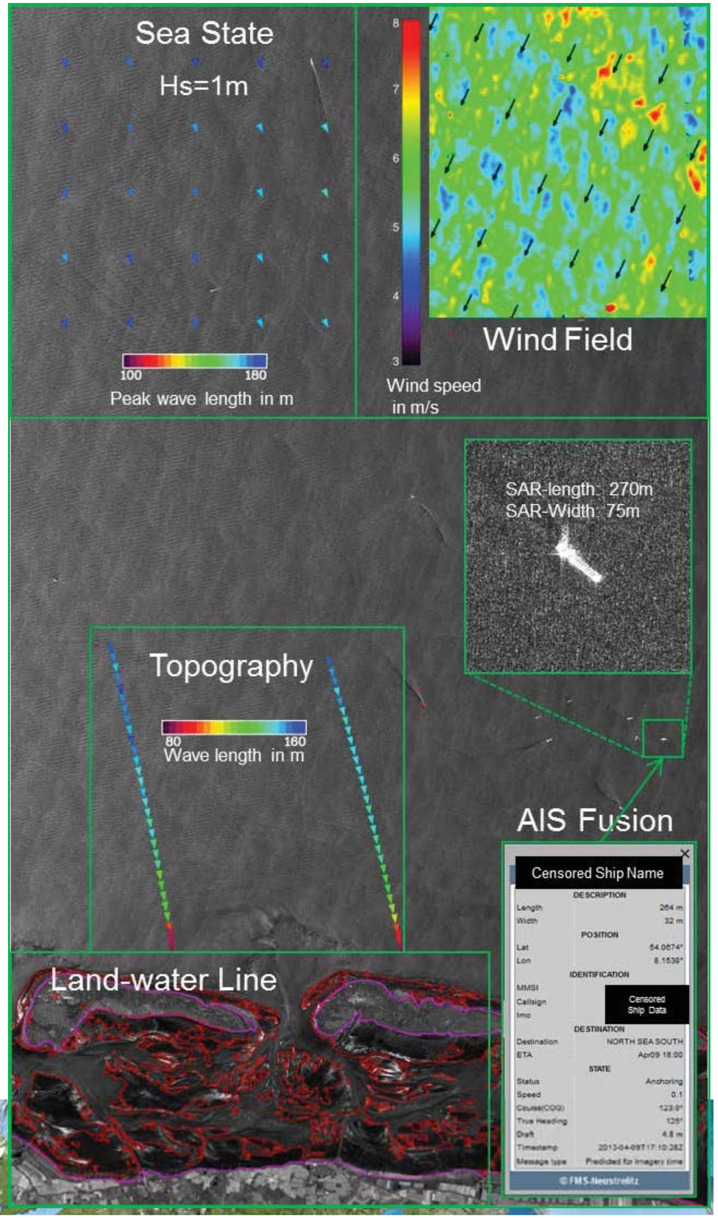
Temporal Resolution



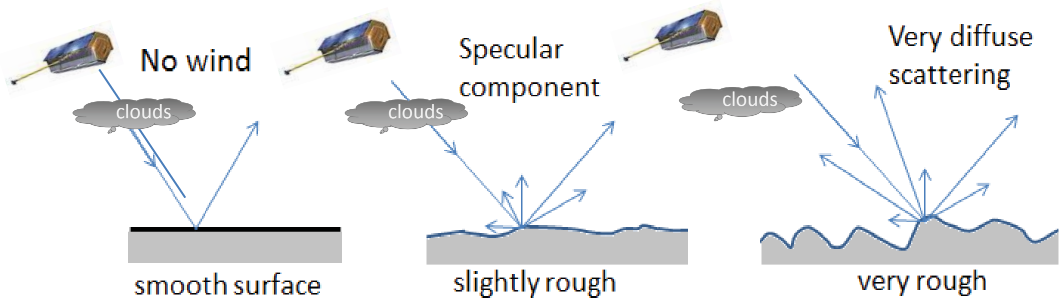
Near Real-Time Value-Adding Processing of SAR data

- SAR AIS Integrated NRT Toolbox (SAINT)
  - Near real-time (NRT) information extraction within 20 min maximum processing time



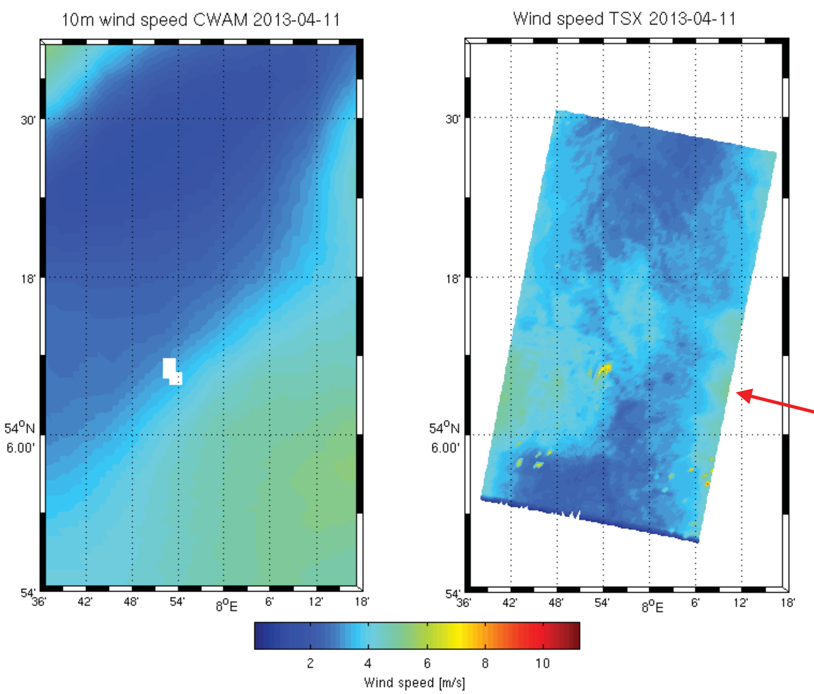


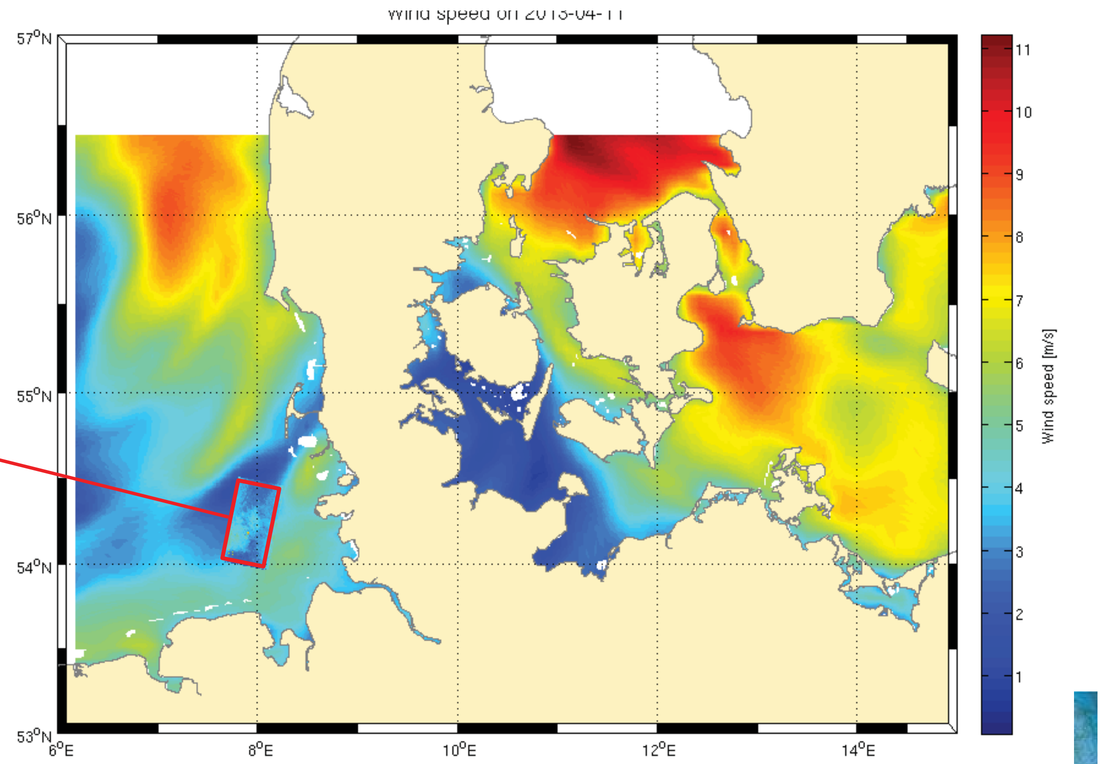
Wind Field Estimation (XMOD-2 / CMOD-5)



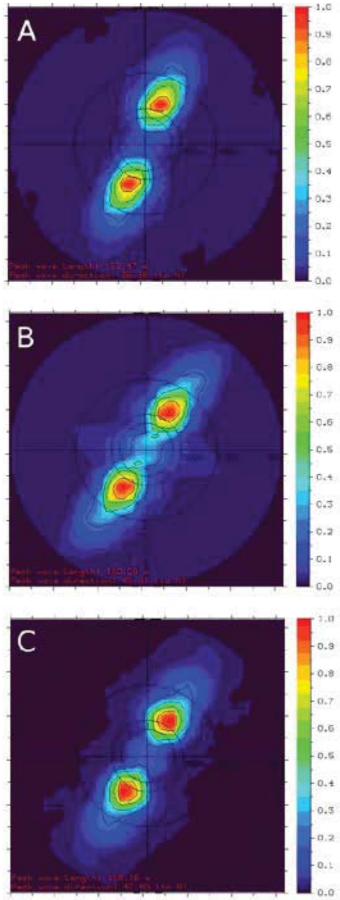
A geophysical model function is applied to derive wind speed fields from SAR measured sea surface roughness

DWD CWAM | TerraSAR-X Wind field | DWD CWAM Modell/TerraSAR-X wind field (overlayed)





Sea State Estimation (XWAVE)



- 2D-FFTs provide information about wave directions and wave lengths of wave signatures visible on SAR.
- The signatures can be used to model the underlying composition of wave systems.
- The automatic sea state retrievals concentrates on the dominant wave system and applies an empirical model function to derive wave heights

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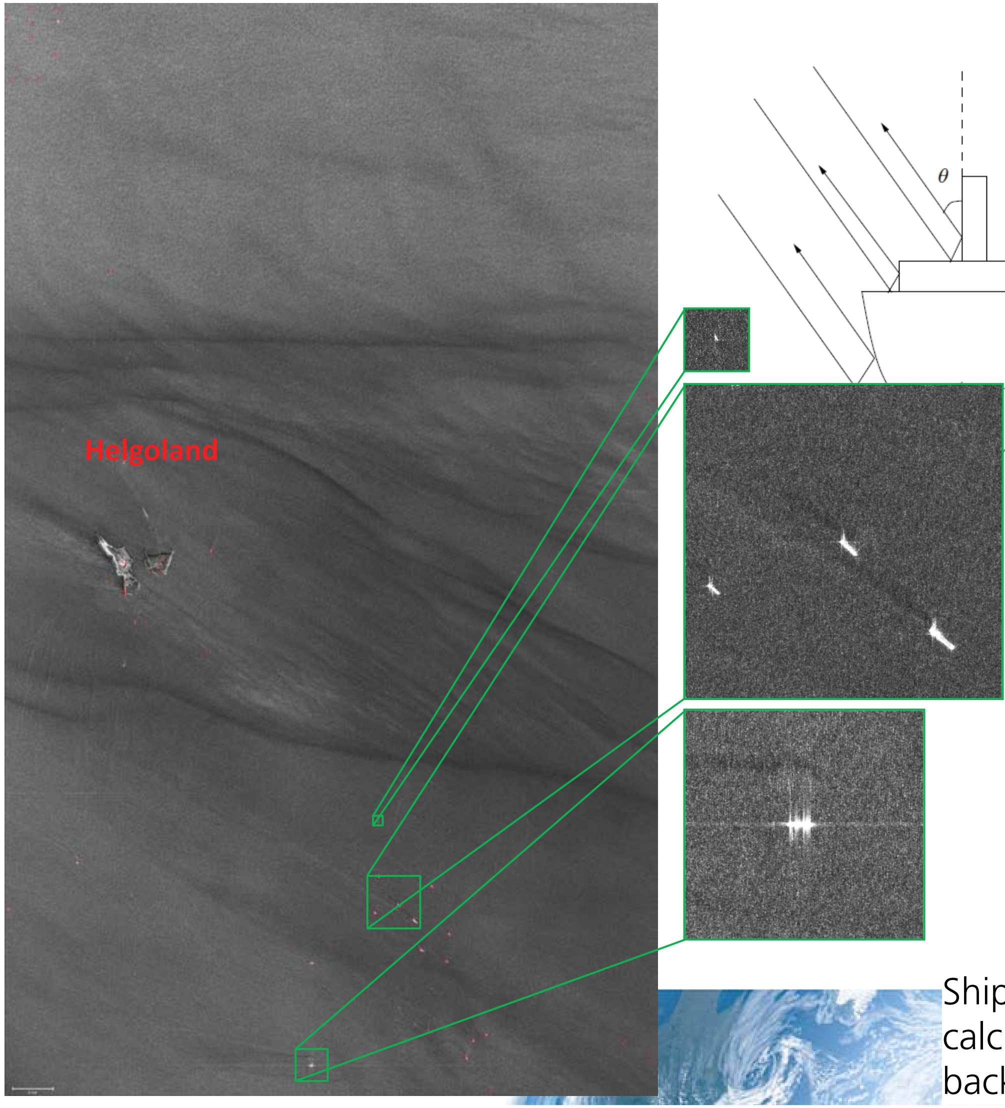
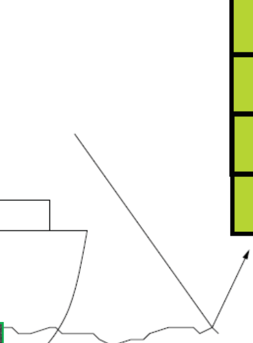
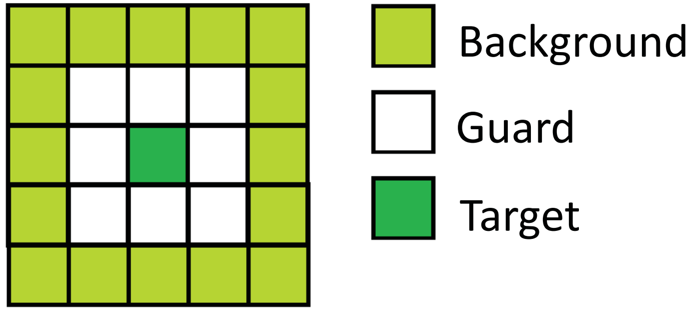
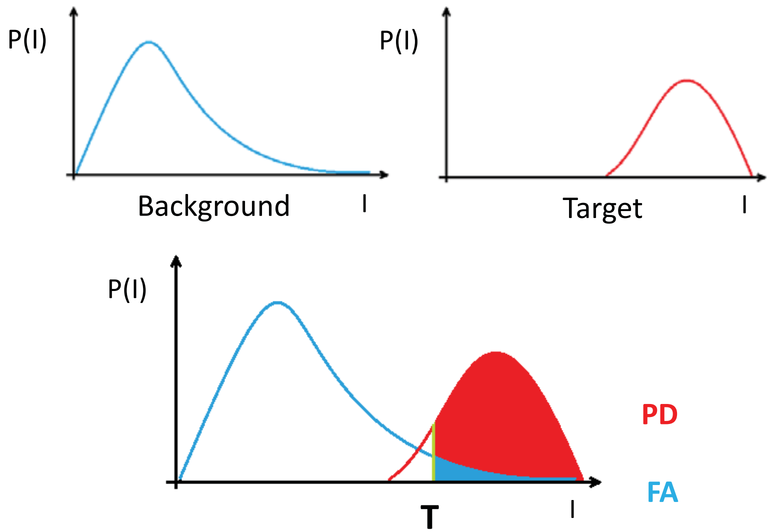
Ship Detection

Constant-False-Alarm-Rate-Algorithmus (CFAR)





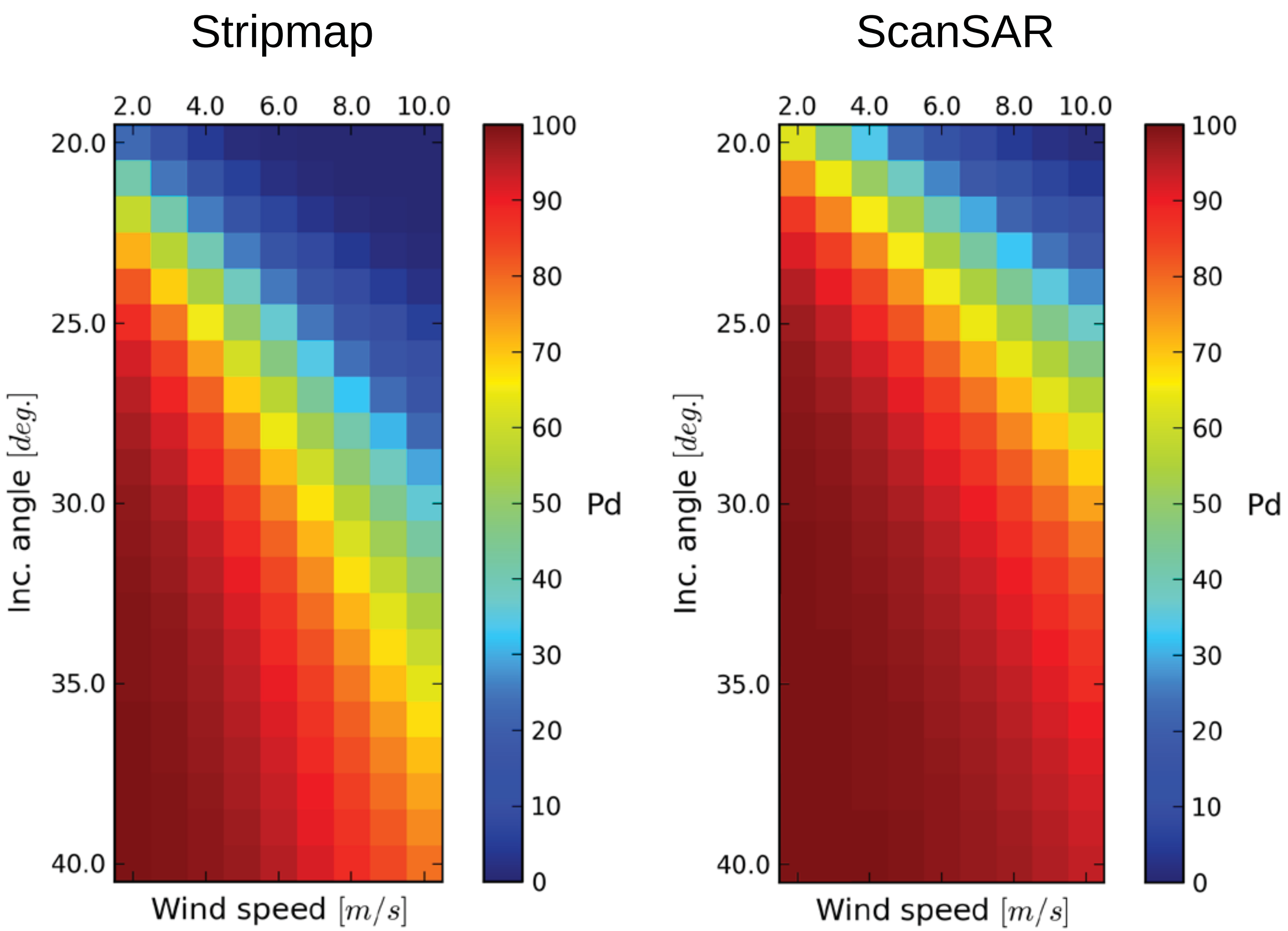




Ships are detected if their RCS exceeds a threshold, which is calculated based on the probability distribution of the ocean background backscatter and a fixed false alarm probability

Ship Detectability – Model Prediction

Model of Vachon applied for TerraSAR-X



The model of Vachon predicts the detectability of ships based on the ship length and the ocean background backscatter (Vachon et al. 2014)
Here the probability of detection is estimated for ships smaller than 15m and peak wave height lower than 1m.

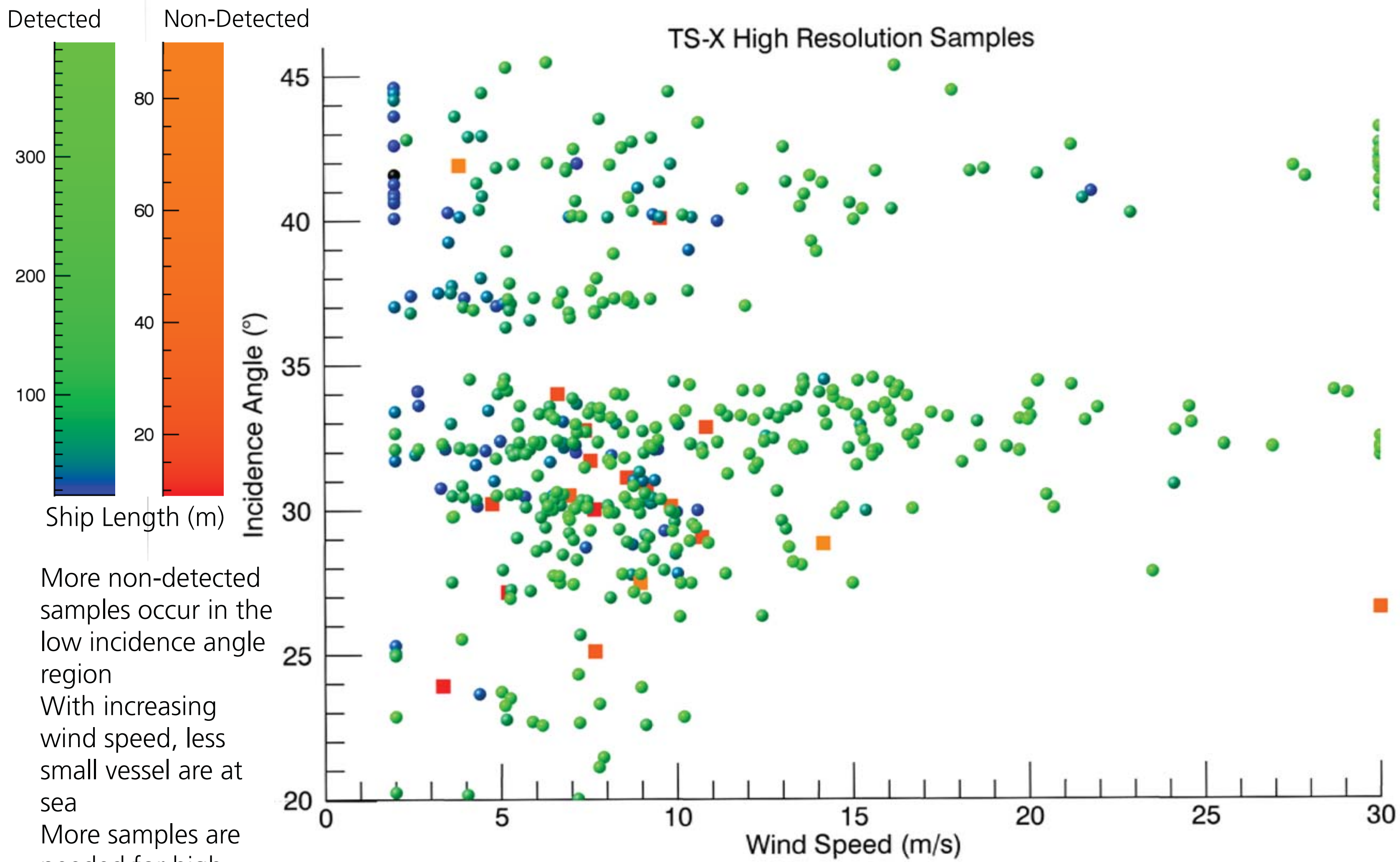
Data and Pre-Processing

- First results on large dataset:
  - 145 TerraSAR-X images (acquired 2013-2015)
    - 126 Spotlight/Stripmap and 19 ScanSAR images
    - 54 with VV-polarization and 91 with HH-polarization
    - 1095 manually checked AIS-SAR assignments
      - **876 with valid wind information**
      - 161 with valid sea state information
    - **471 manually checked AIS-wake assignments**
  - 29 Sentinel-1 Interferometric Wide Swath images with VV-polarization (acquired 2015)
    - 852 manually checked AIS-SAR assignments
      - **614 with valid wind information**
    - **286 manually checked AIS-wake assignments**

- Attributes relevant for the detectability have been ranked using attribute selection techniques like Principal Component Analysis (PCA)

Ship Detectability – AIS-Observations on TerraSAR-X

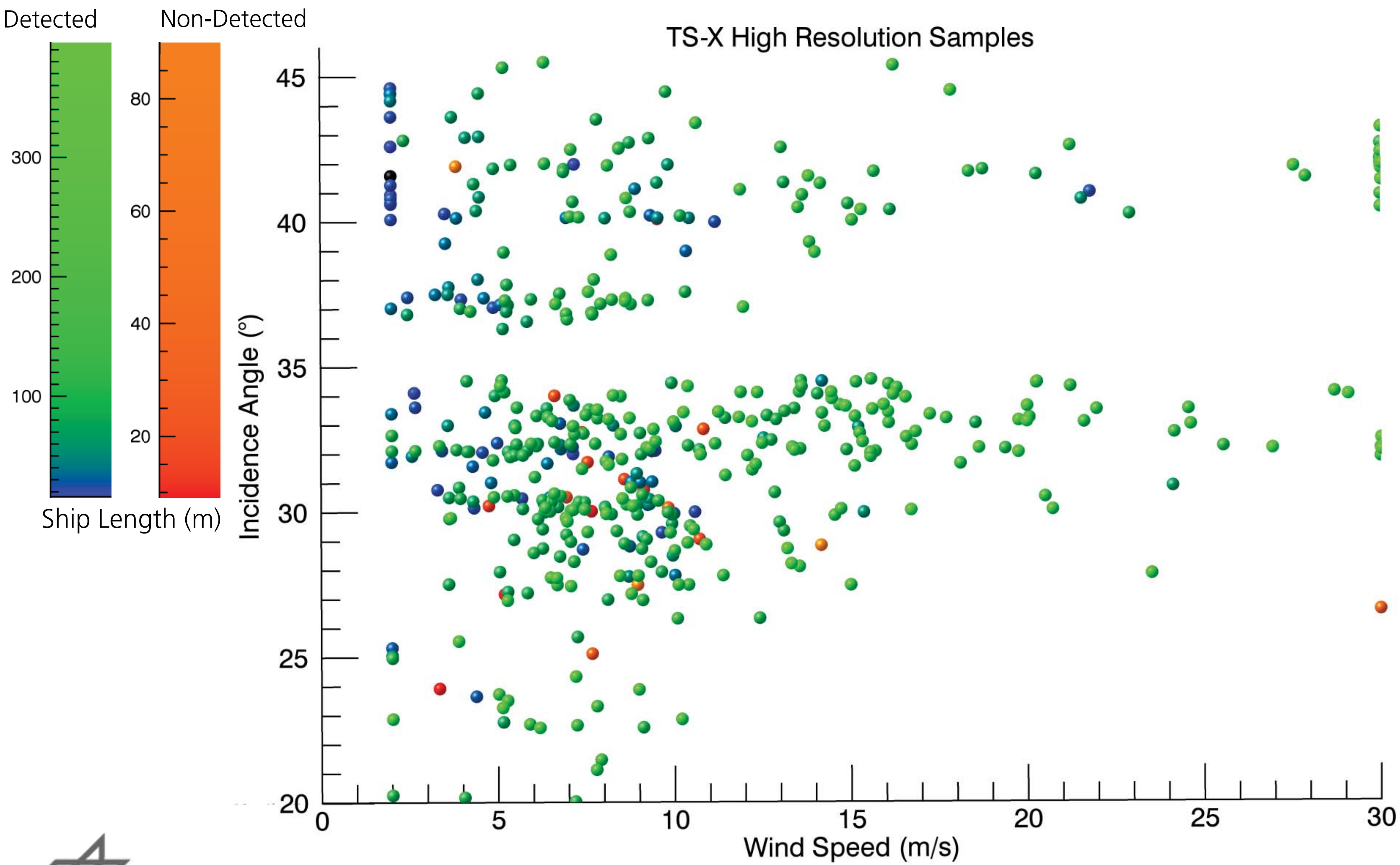
Visualization of TerraSAR-X high resolution samples



- More non-detected samples occur in the low incidence angle region
- With increasing wind speed, less small vessel are at sea
- More samples are needed for high wind speed

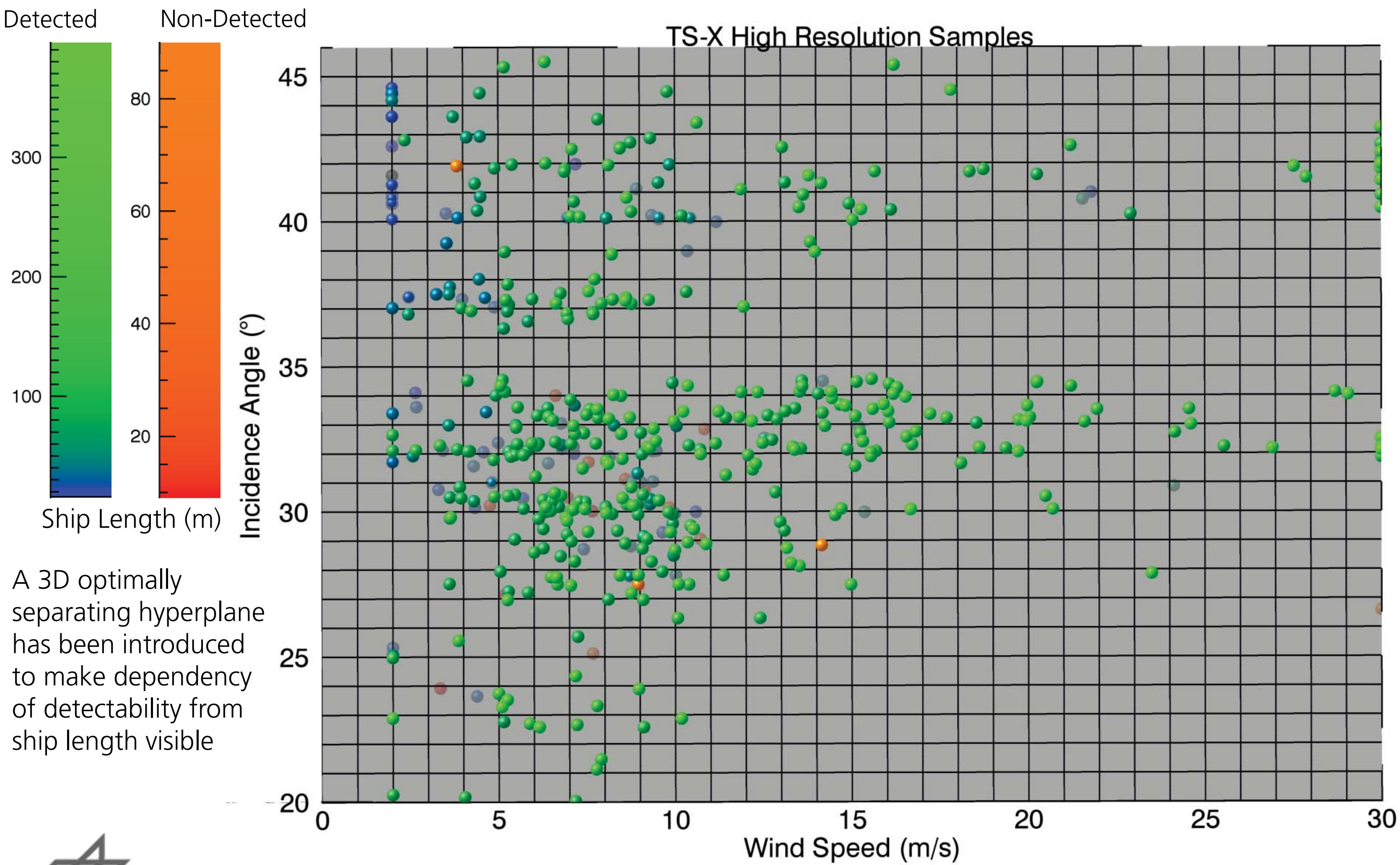
Ship Detectability – AIS-Observations on TerraSAR-X

Visualization of TerraSAR-X high resolution samples



Ship Detectability – AIS-Observations on TerraSAR-X

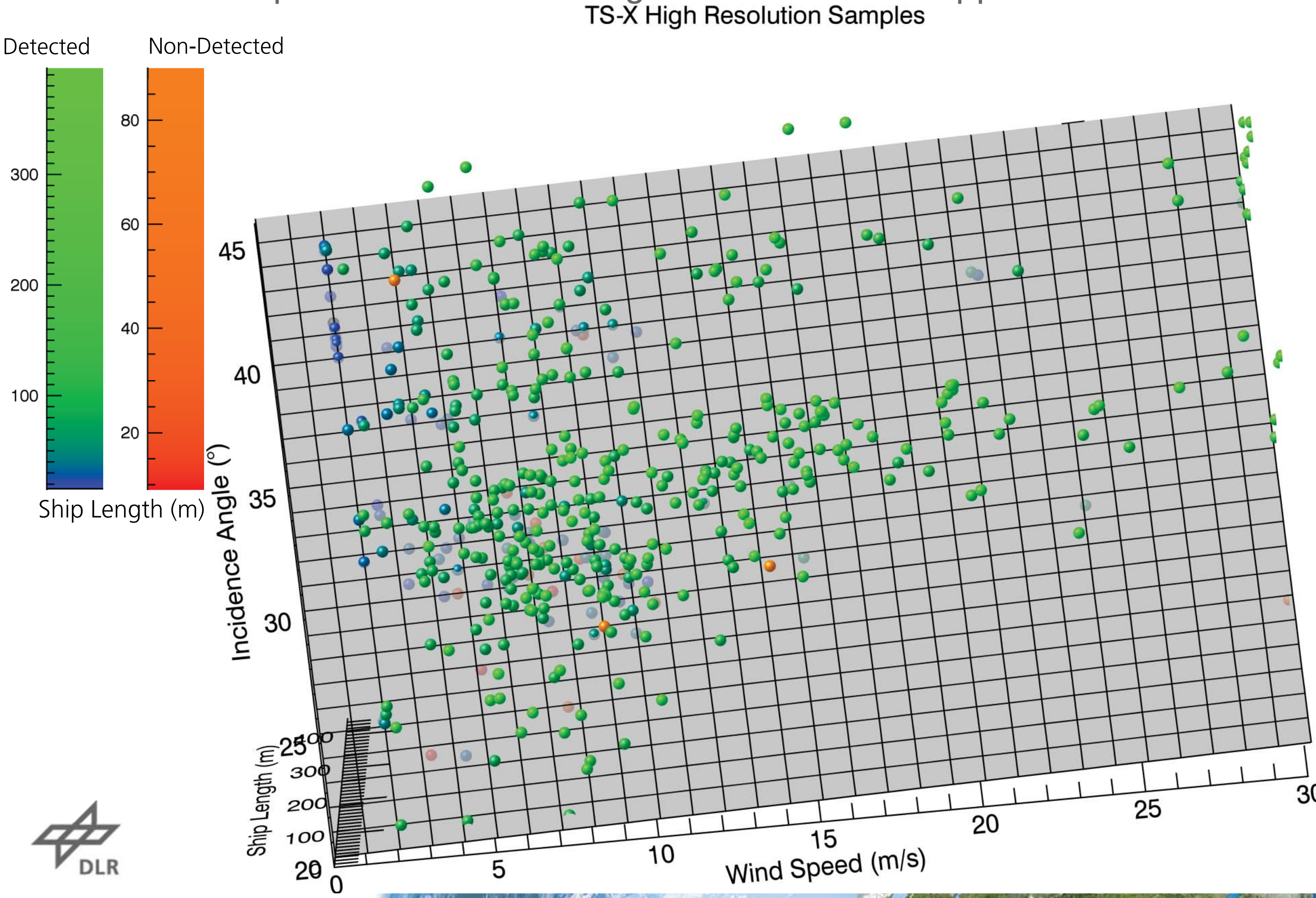
Visualization plane based on L2-regularized L2-loss support vector classification



A 3D optimally separating hyperplane has been introduced to make dependency of detectability from ship length visible

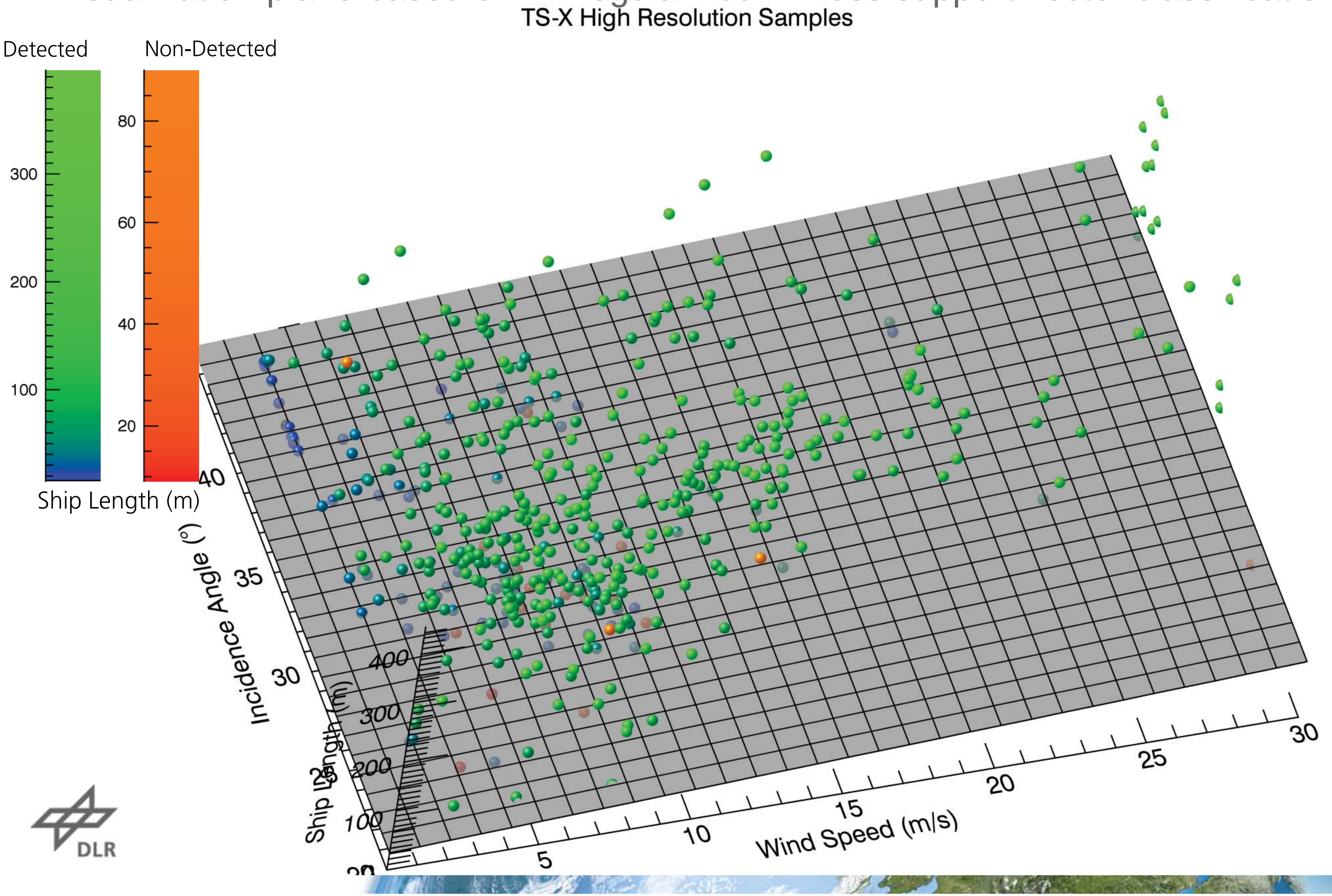
Ship Detectability – AIS-Observations on TerraSAR-X

Visualization plane based on L2-regularized L2-loss support vector classification



Ship Detectability – AIS-Observations on TerraSAR-X

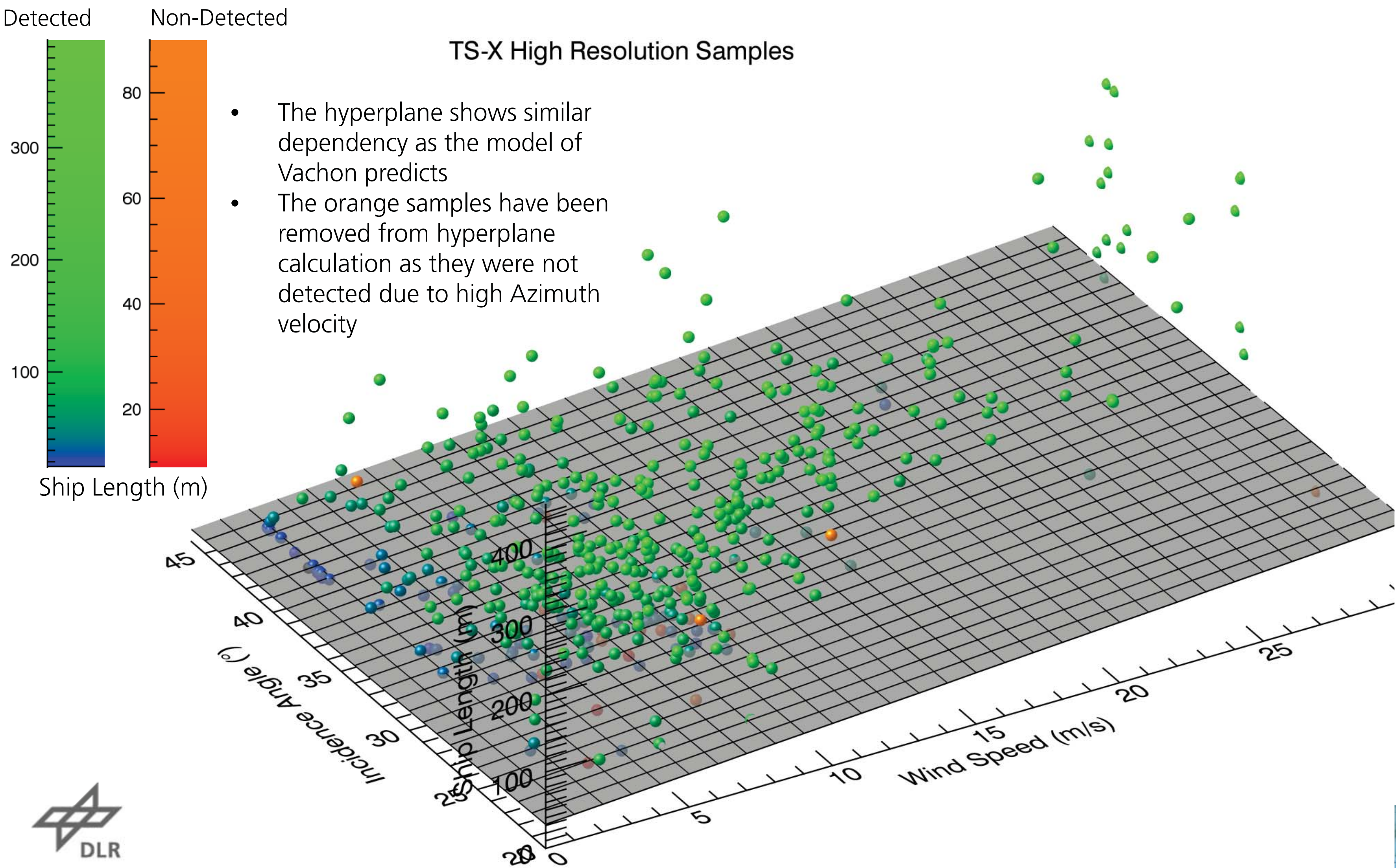
Visualization plane based on L2-regularized L2-loss support vector classification



Ship Detectability – AIS-Observations on TerraSAR-X

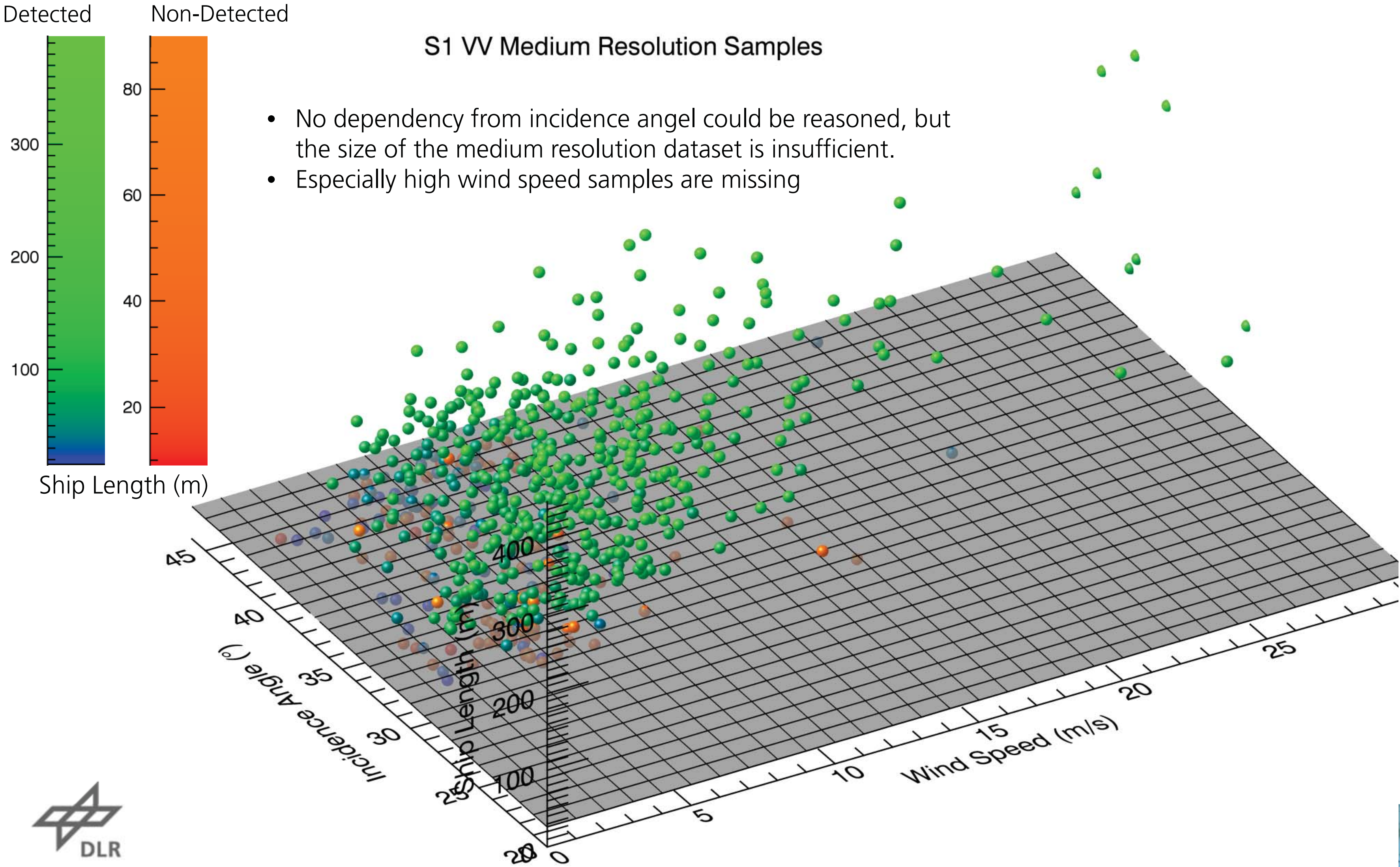
Visualization plane based on L2-regularized L2-loss support vector classification

- The hyperplane shows similar dependency as the model of Vachon predicts
- The orange samples have been removed from hyperplane calculation as they were not detected due to high Azimuth velocity



Ship Detectability – AIS-Observations on Sentinel-1

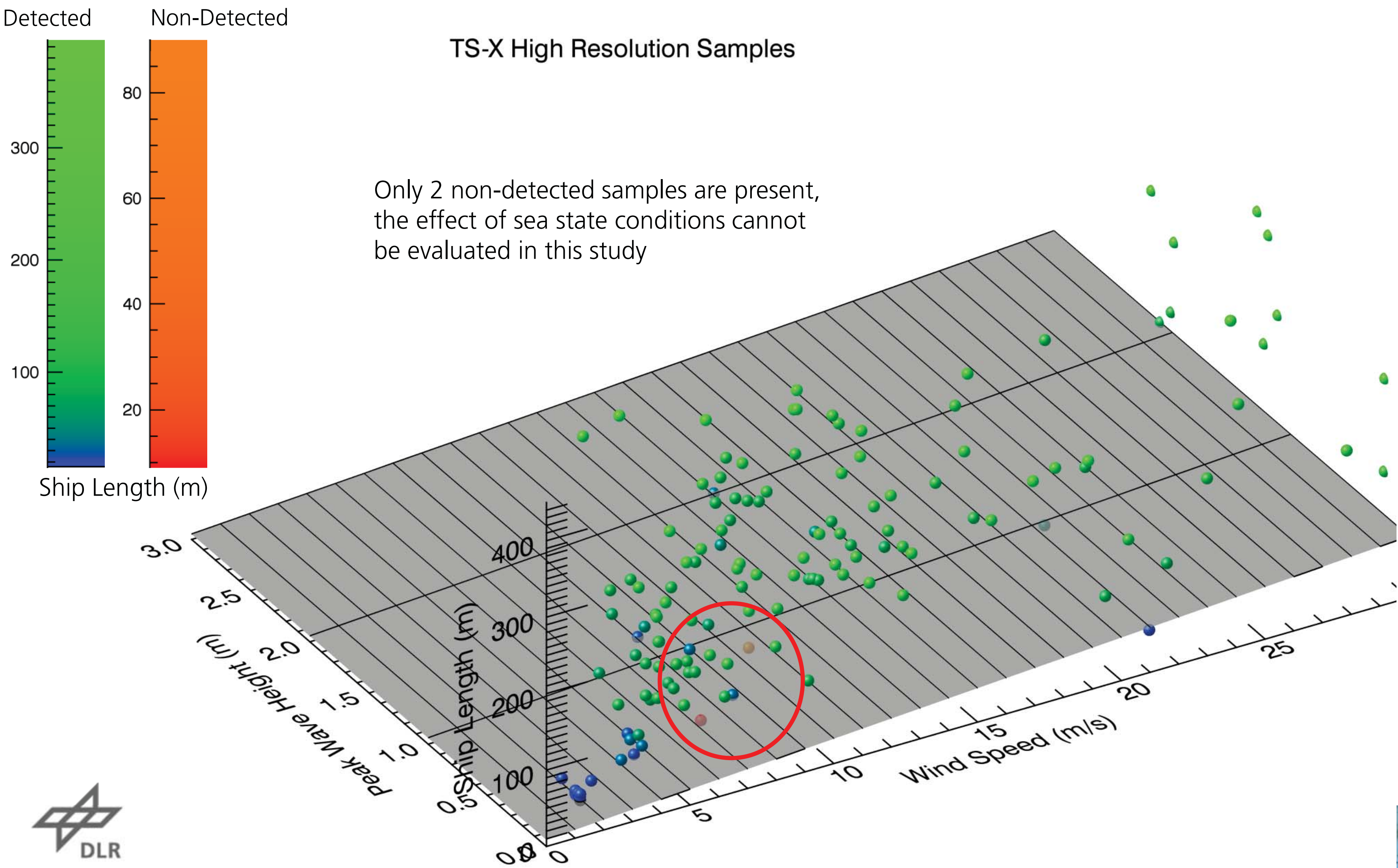
Visualization plane based on L2-regularized L2-loss support vector classification



- No dependency from incidence angel could be reasoned, but the size of the medium resolution dataset is insufficient.
- Especially high wind speed samples are missing

Ship Detectability – AIS-Observations on TerraSAR-X

Visualization plane based on L2-regularized L2-loss support vector classification



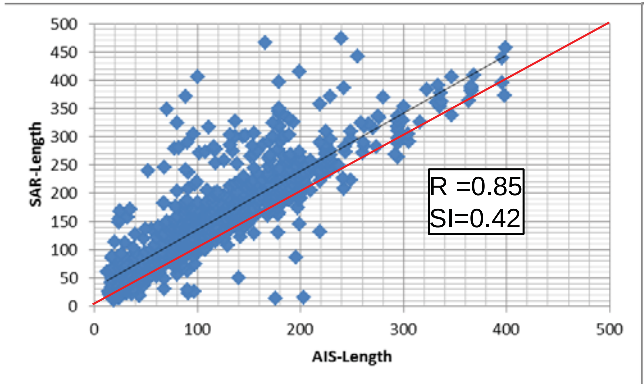
Only 2 non-detected samples are present, the effect of sea state conditions cannot be evaluated in this study

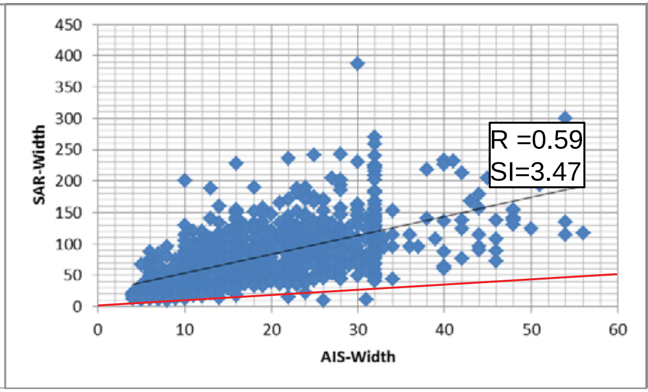
Ship Detectability and Accuracy of Ship Parameter Estimation

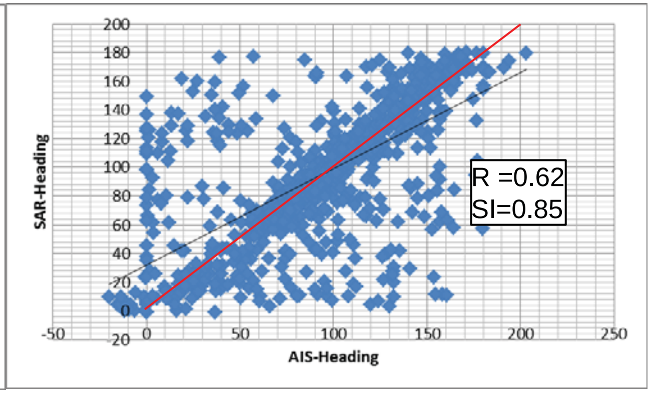
Probability of Detection

	High Resolution TS-X	Medium Resolution TS-X	Low Resolution TS-X	Medium Resolution S1
Small (Vessels ≤ 15m)	63%	20%	9%	14%
Medium (Vessels 15m ≤ 50m)	90%	59%	27%	54%
Large (Vessels > 50m)	99%	99%	96%	99%

Accuracy of Ship Parameter Estimation







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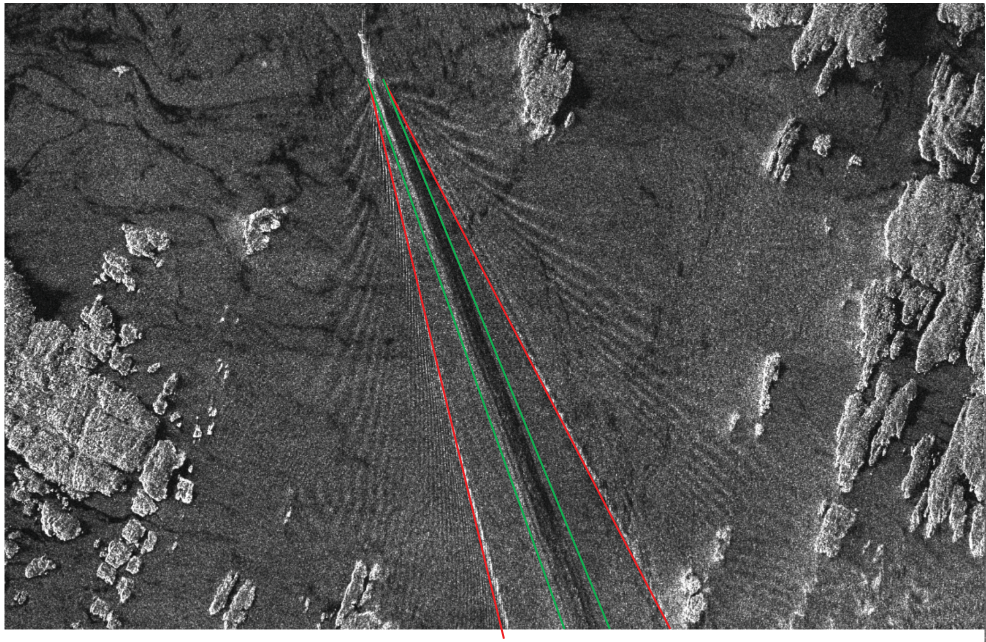
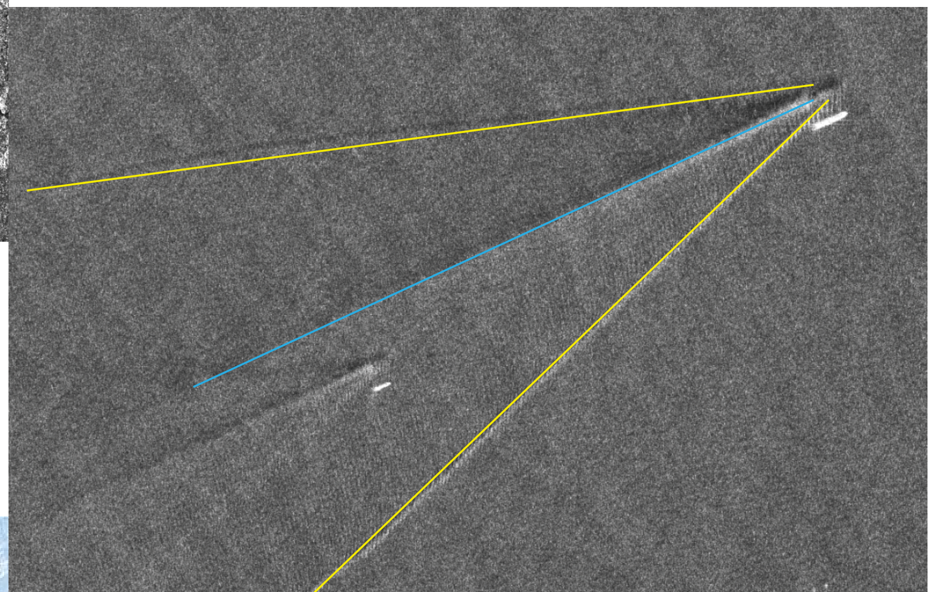
Analysis of Wake Signatures on TerraSAR-X and Sentinel-1

Detectability and visibility of structural features of wakes are analyzed based on meteo-marine data



- Red: V-Narrow Wake
- Green: Internal Waves

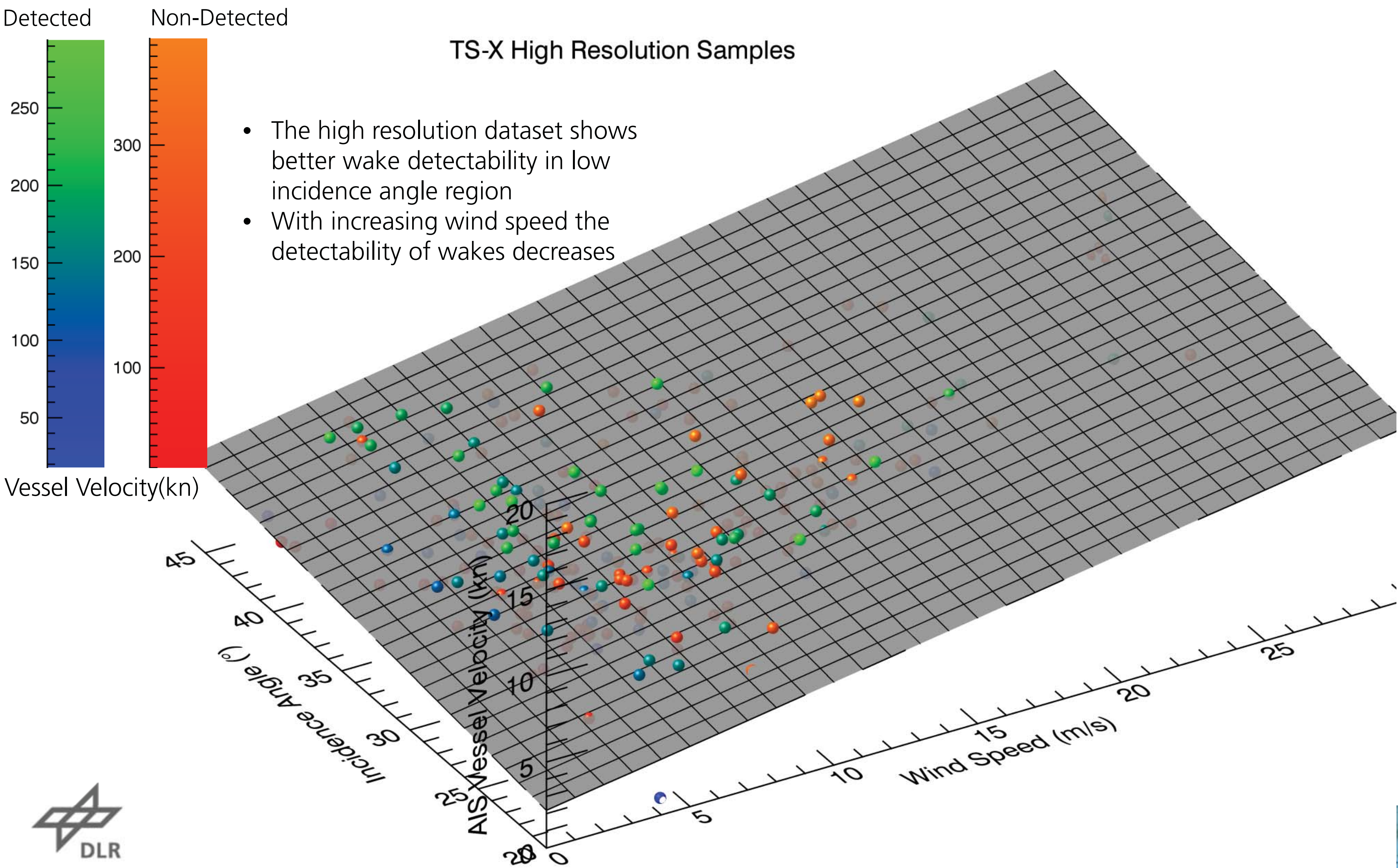
- Yellow: Kelvin Wake
- Blue: Turbulent Wake



Ship Wake Detectability – Observations on TerraSAR-X

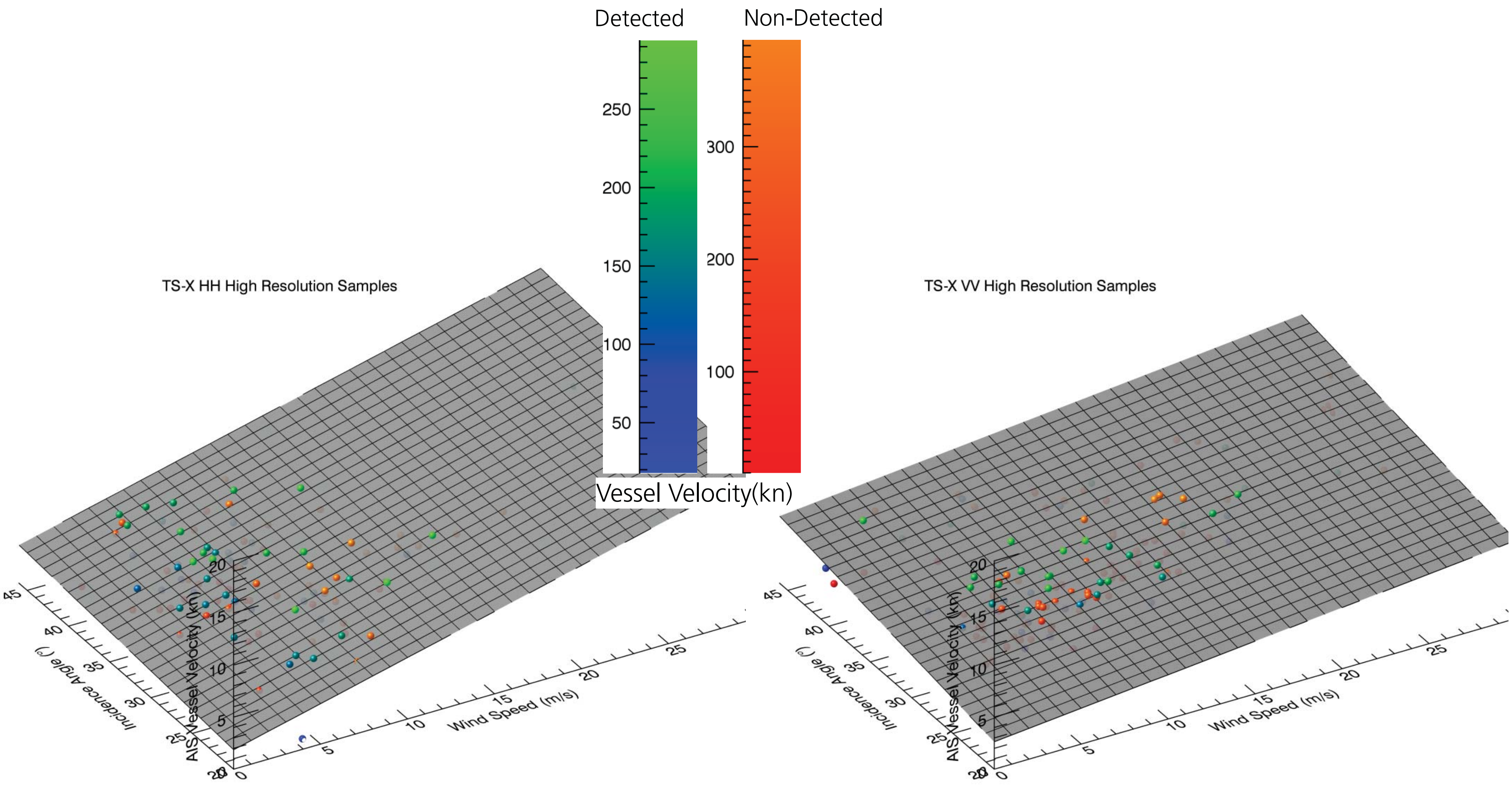
Visualization plane based on L2-regularized L2-loss support vector classification

- The high resolution dataset shows better wake detectability in low incidence angle region
- With increasing wind speed the detectability of wakes decreases



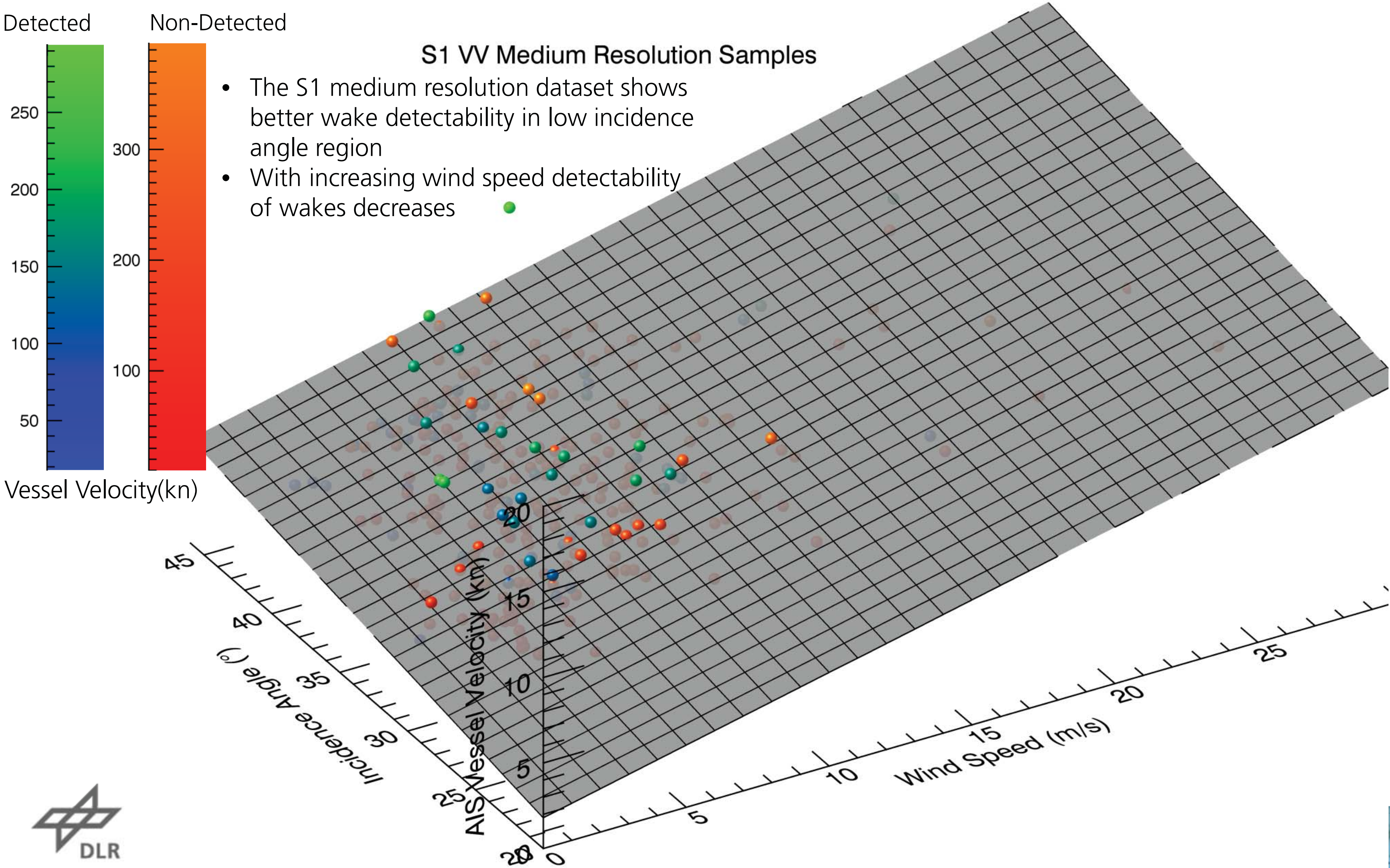
Ship Wake Detectability – Observations on TerraSAR-X

Visualization plane based on L2-regularized L2-loss support vector classification



Ship Wake Detectability – Observations on Sentinel-1

Visualization plane based on L2-regularized L2-loss support vector classification



- The S1 medium resolution dataset shows better wake detectability in low incidence angle region
- With increasing wind speed detectability of wakes decreases

DLR

Conclusion & Outlook

- Observations on ship detectability for TerraSAR-X high resolution reveal similar dependencies as model of Vachon predicts
- Observations on ship wake detectability reveal that wakes are better detectable in low incidence angle conditions
  - This can support detection of ships
- More data in high wind speed regions is required to support these statements
- As AIS-width and AIS-length correlate strongly and have strong impact on ship detectability, the ship area should be taken into account