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Unsupervised classification of multi-mission altimetry data for open water detection in the Greenland Sea

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Motivation Estimating sea surface heights by satellite altimetry in the Greenland Sea is challenging because of rapid changing ice coverage and ocean conditions. To obtain reliable and accurate sea surface heights in this region, it is necessary to identify altimeter echoes reflected by leads and polynyas (small water openings between the sea ice). We analyze reflected altimeter pulses, also called waveforms, from different conventional pulse-limited satellite missions in order to distinguish between open water returns and waveforms contaminated by ice. For this purpose, we implement an unsupervised classification approach that does not require any training data. The classification process is based on a set of parameters derived from the waveform shapes, for example the peakiness or the maximum power. After waveform clustering, the classification is validated by several SAR images near the north-east coast of Greenland with small time lags between altimeter pass and the SAR measurements. To allow for a quantitative validation an automated approach for detecting open water in the SAR images has been developed.

Altimetry waveform classification

Input Data

- High-frequency data (Envisat, Saral/AltiKa)
- Waveform shapes provide information about surface types

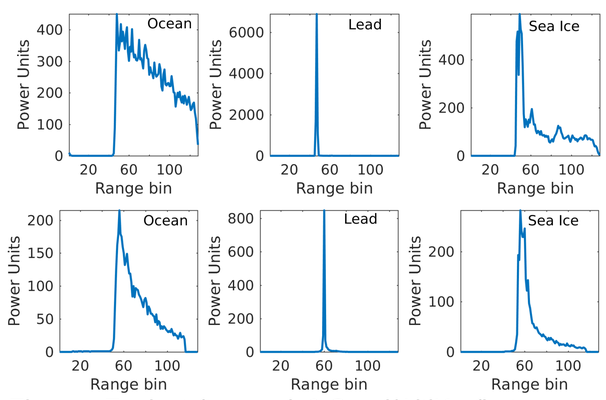


Figure: Envisat (top row) & Saral/AltiKa (bottom row) waveforms showing three different surface types

Clustering of sample waveforms

- Waveform-derived parameters (e.g., max. power, peakiness etc.) are input data of a K-medoids based cluster algorithm.
- Clustering creates the model for the classification (separately for each altimetry mission).
- The clustering process is based on six waveform parameters and uses all radar returns of a specific area
- Cluster model contains 20 classes describing different scatter properties.

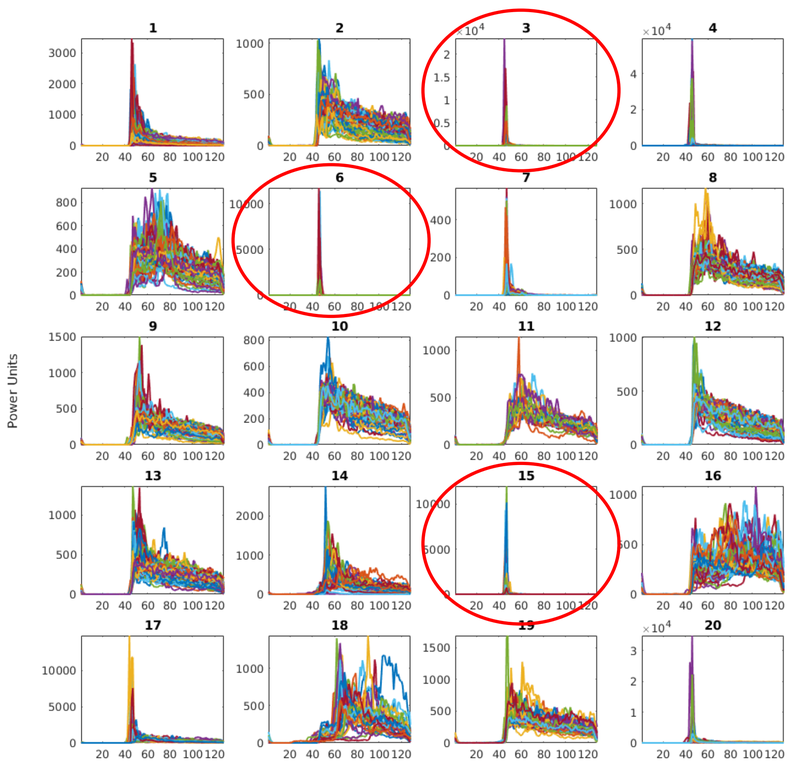


Figure: Envisat waveform classes after K-medoids clustering showing grouped waveforms. Red circled classes indicate lead or polynya radar returns.

Classification of all waveforms

- All waveforms are classified by K-nearest neighbor classifier based on the performed clustering
- Clusters are merged manually to represent four main classes: ocean, lead/polynya, sea-ice, and undefined.

SAR image processing

Input Data

- Sentinel-1A
- ALOS
- wide-Swath data
- medium resolution
- HH polarized

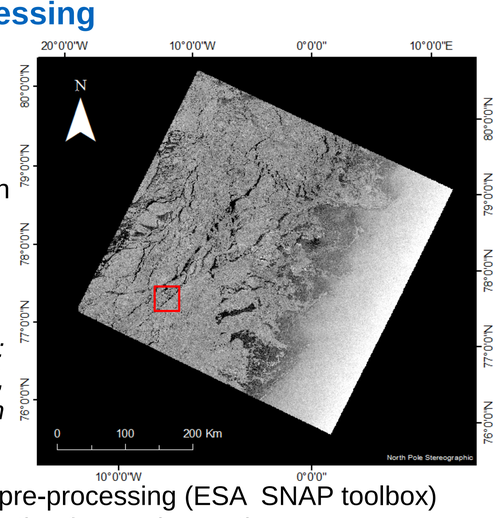
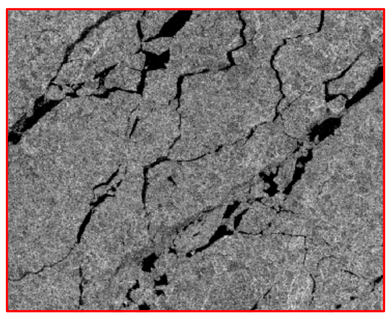
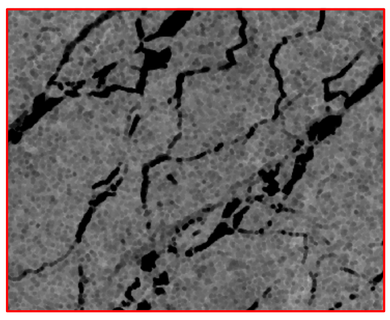


Figure: Sentinel-1A C-Band, extra-wide-swath

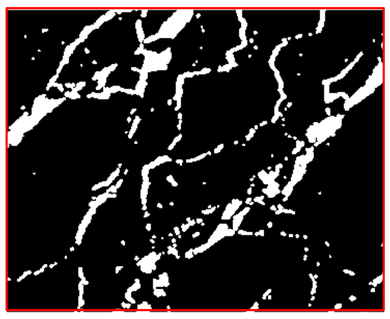
- SAR pre-processing (ESA SNAP toolbox)
- Correction for sea ice motion



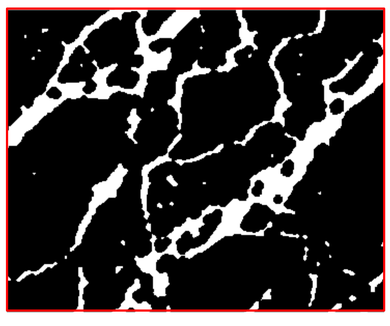
- Median and Minimum filtering
- Noise reduction
- Dark pixel emphasizing



- Conversion to binary image
- Adaptive thresholding
- Considering SAR illumination changes



- Morphological closing operation
- Linking of segmented lead and polynya fragments



Binary-coded SAR image
(black=sea ice / white=water)

Validation

- Nearest-neighbor interpolation of altimetry observation locations to the binary coded SAR image

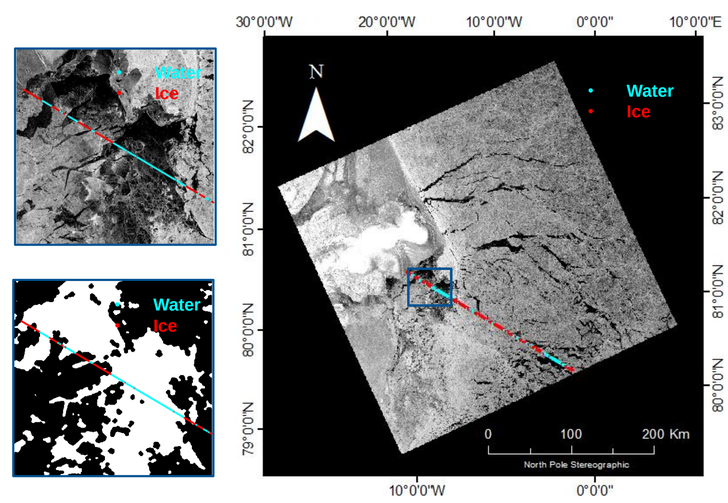


Figure: ALOS L-Band wide-beam image (original and processed) and Envisat track showing classification results.

- Evaluation of classification performance by comparing binary coded SAR to classified altimetry returns

	Altimetry Water	Altimetry Ice	∑
SAR Water	**159**	61	220
SAR Ice	106	**292**	398
∑	265	353	618

Table: 2D contingency table based on one Envisat/ALOS validation: The table shows the points classified as water/ice from altimetry with the corresponding classification from SAR.

Results and Conclusion

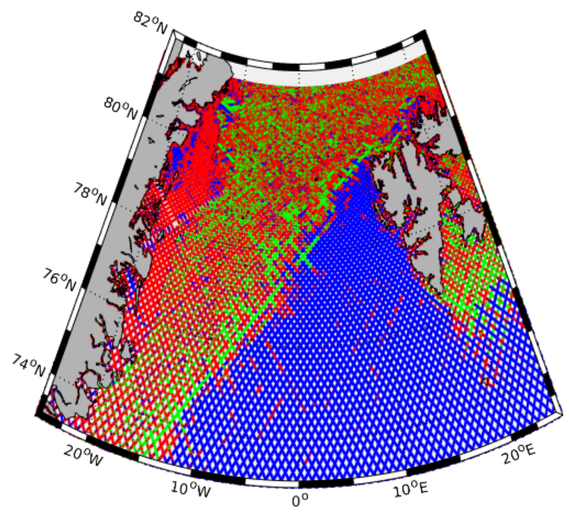


Figure: Classification of Envisat Cycle 68 (05/2008). blue: ocean / green: lead/polynya / red: sea-ice / black: unclassified detections

- Unsupervised classification allows separation of different waveforms and surface types.
- Waveform classification provides reliable results in the Greenland Sea.
- Automated SAR image processing allows for quantitative validations.
- Classification method is applicable to all pulse-limited altimetry missions.

References and Acknowledgements:

- Envisat and Saral/AltiKa waveforms are provided by ESA
- Sentinel-1A data: Sentinel-1 GRD EW data provided by ESA Scientific Data Hub
- ALOS data: © JAXA/METI ALOS-1 PALSAR L1.5 2008. Accessed through ASF DAAC https://www.asf.alaska.edu 28.04.2016
- Detailed information on the SAR images processing can be found in *Passaro et al: Lead Detection using Cryosat-2 Delay-Doppler Processing and Sentinel-1 SAR images (submitted to The Cryosphere)*