Sea Ice Classification Using Satellite SAR: The lessons we learned

Wolfgang Dierking
CIRFA/University of Tromsø, Norway & Alfred Wegener Institute, Germany

Xi Zhang
The First Institute of Oceanography, Ministry of Natural Resources, P.R.China

Markku Similä
Finnish Meteorological Institute, Finland

Focus is on:

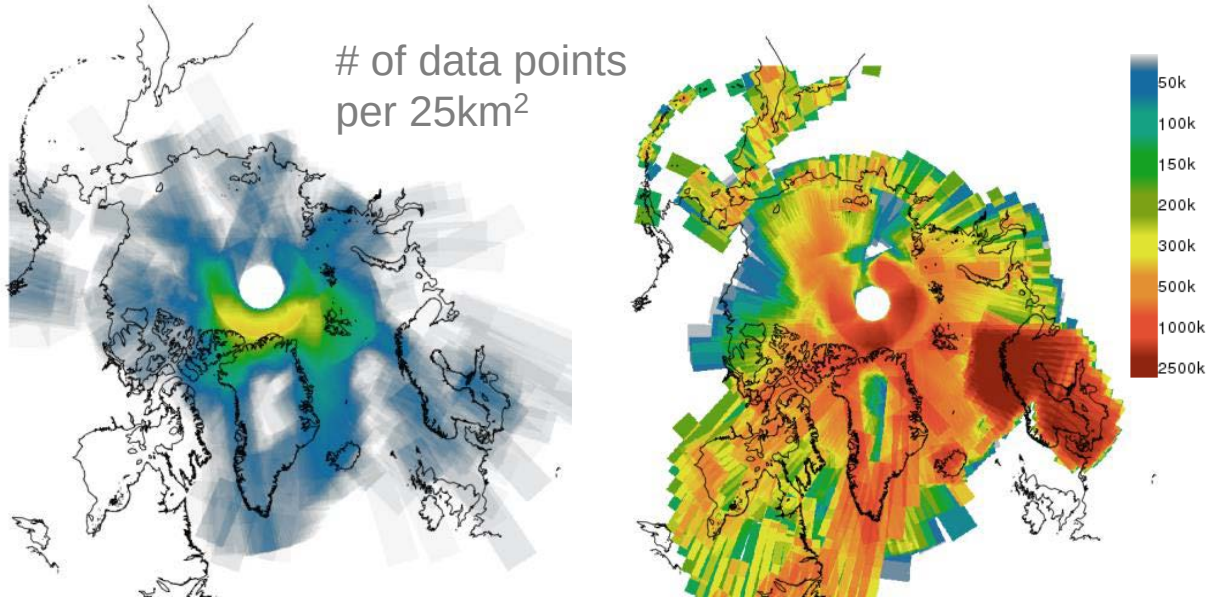
- Automated sea ice type mapping (ML, DL, ..)
- Feature extraction

Automated sea ice type mapping

- to handle many data within short time
- to optimize processing schemes
- to reduce time-consuming human interference

An intelligent system for SAR sea ice image classification: a preliminary study (Xi)

- We have SAR backscattering coefficients, texture and polarimetric parameters at different radar frequencies and polarizations
- We want to separate different ice types and features for operational ice charting and science studies
- Aim: create automated sea ice processing and classification systems



Aug 2011 Aug 2018

Andreas Cziferszky, 2018

Software development environment

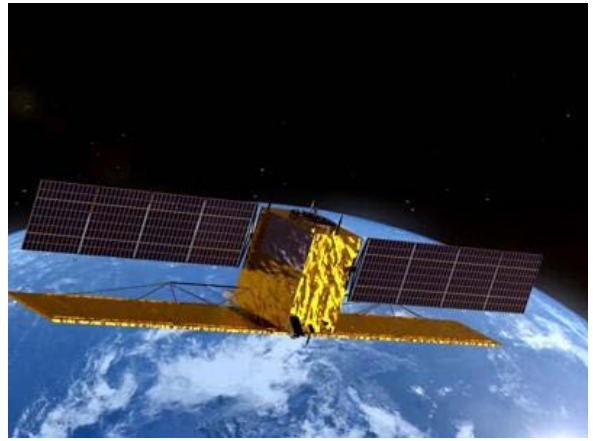
anaconda/python

SAR data and process

- **Sentinel-1 A/B GRD** data is auto-downloaded and pre-processed using Python modules '*sentinelhub*' and '*Nansat*' (@github)
- **GF-3 data** is access via ftp which is provided from National Satellite Ocean Application Service; the pre-processed is done by a self-code.

Training data: ice chart

- **Arctic: CIS Arctic Sea Ice Charts** (SIGRID-3 Format, weekly)
- **The Bohai sea: North China Sea Marine Forecasting Center** (MODIS and GOCI-based)



国家海洋局北海预报中心
North China Sea Marine Forecasting Center of State Oceanic Administration

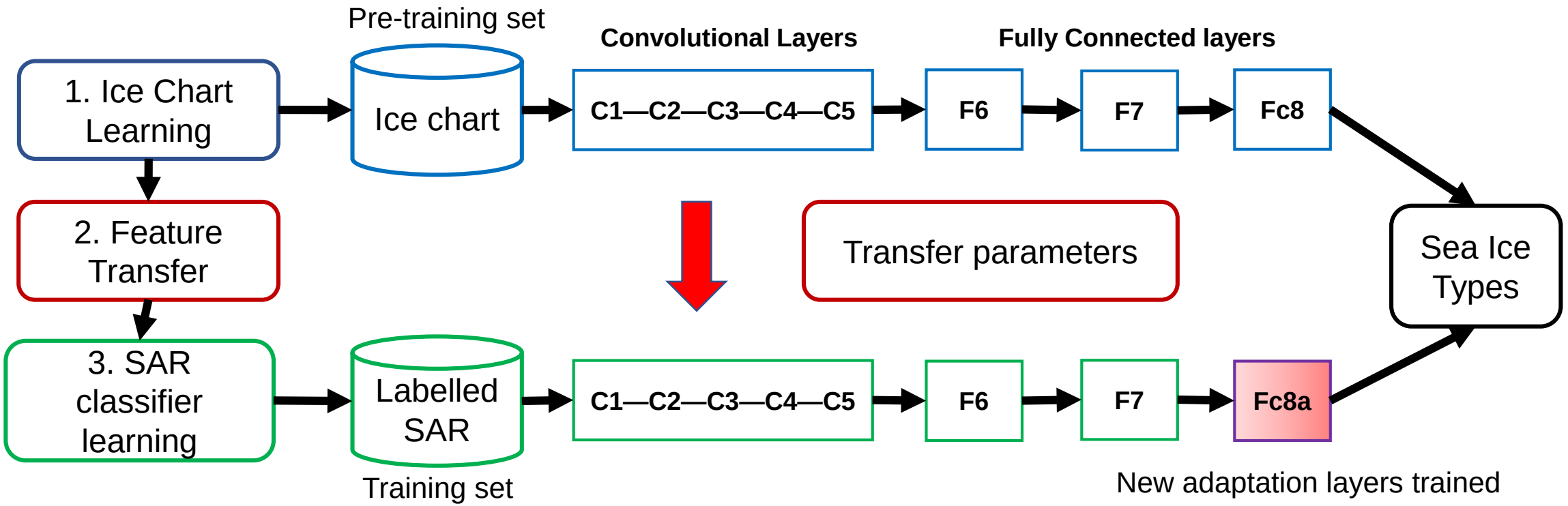
Training data set

- Pre-training sets: only ice chart
- Training sets: SAR image which is labelled based on ice chart.
- Only ice concentration > 70% in winter and early spring is considered to use as pre - or training data set.

Architecture of the system

Transfer Learning + CNN

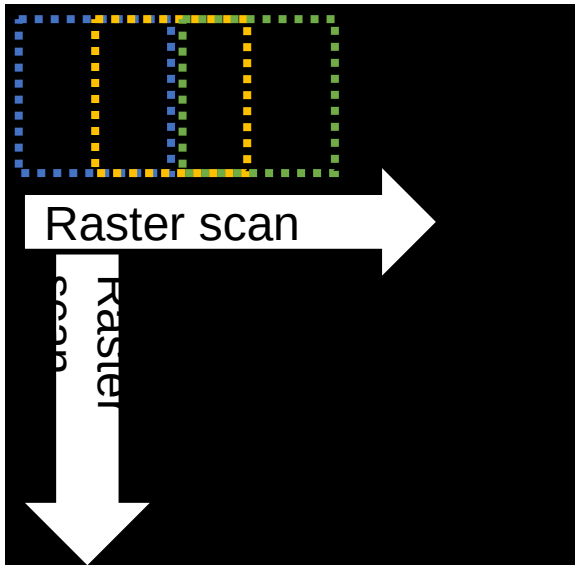
- Transfer learning: The system learns about sea ice feature characteristics from ice charts.
- CNN: inherits the knowledge from transfer learning and knowledge from SAR training set.



The input of Transfer Learning

Characteristic extracted from ice chart

- Area of the shapefile
- Perimeter of the shapefile
- Shape index of the shapefile
- Contiguity index of the shapefile
- Distance to the nearest neighboring type

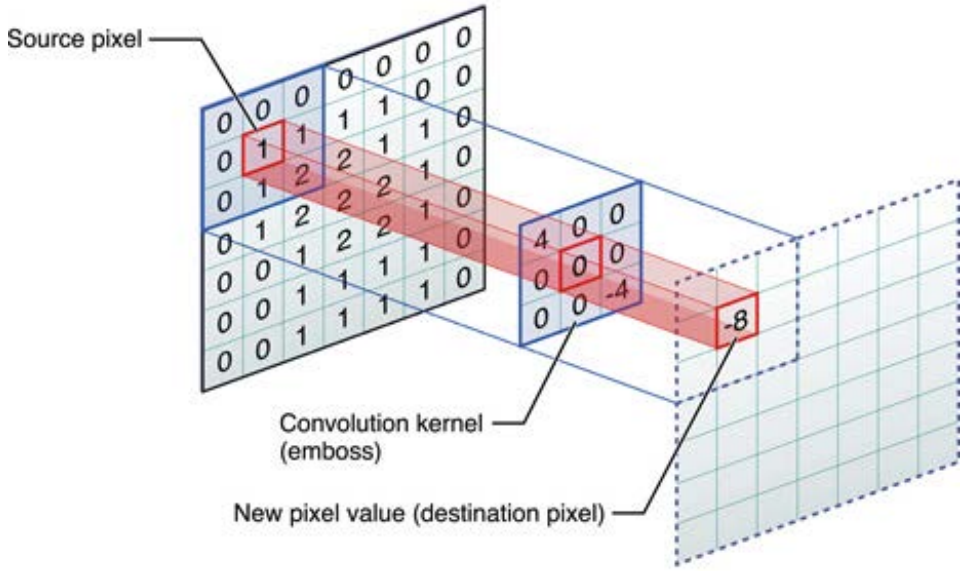


The input of CNN

The input of the CNN mode used requires 3 dimensional data

HH, HV and incidence angle.

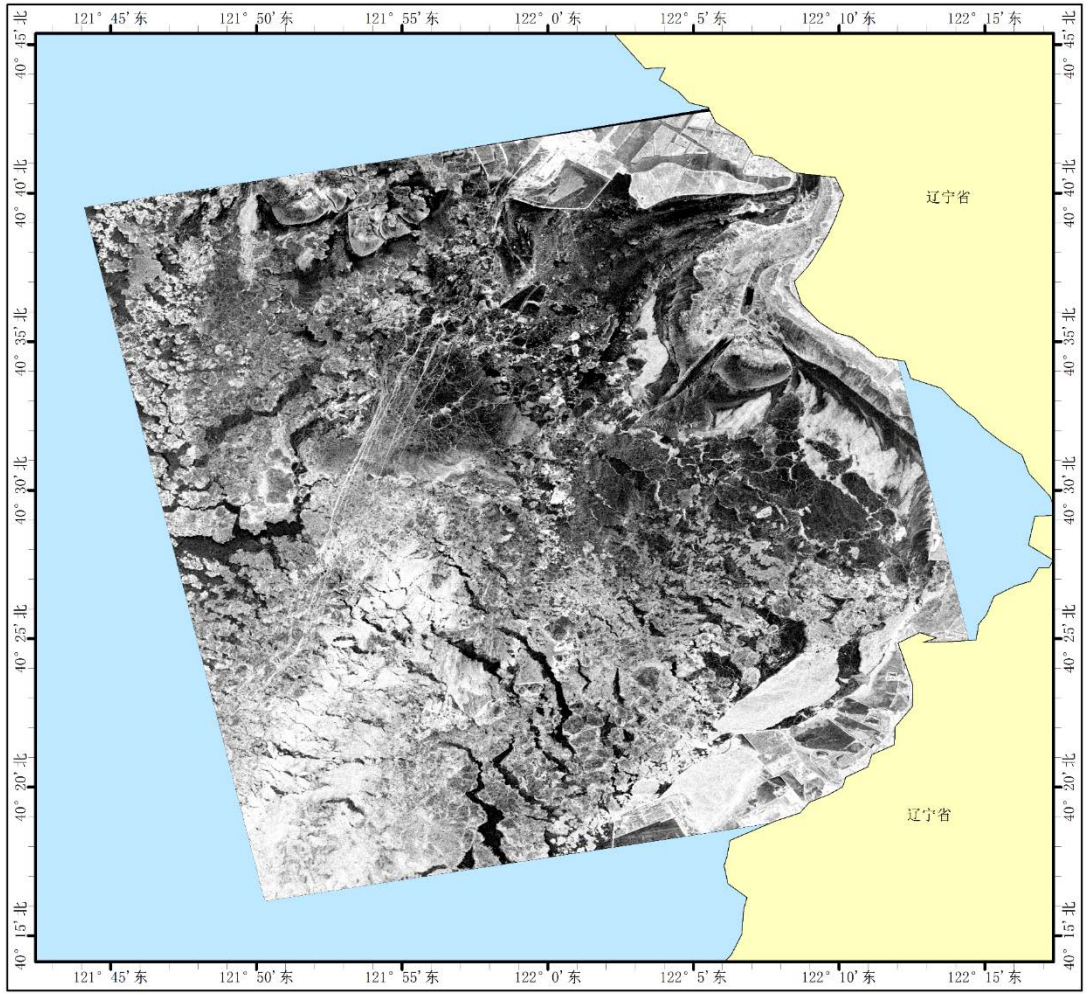
The size of each image patch is 45 pixels * 45 pixels



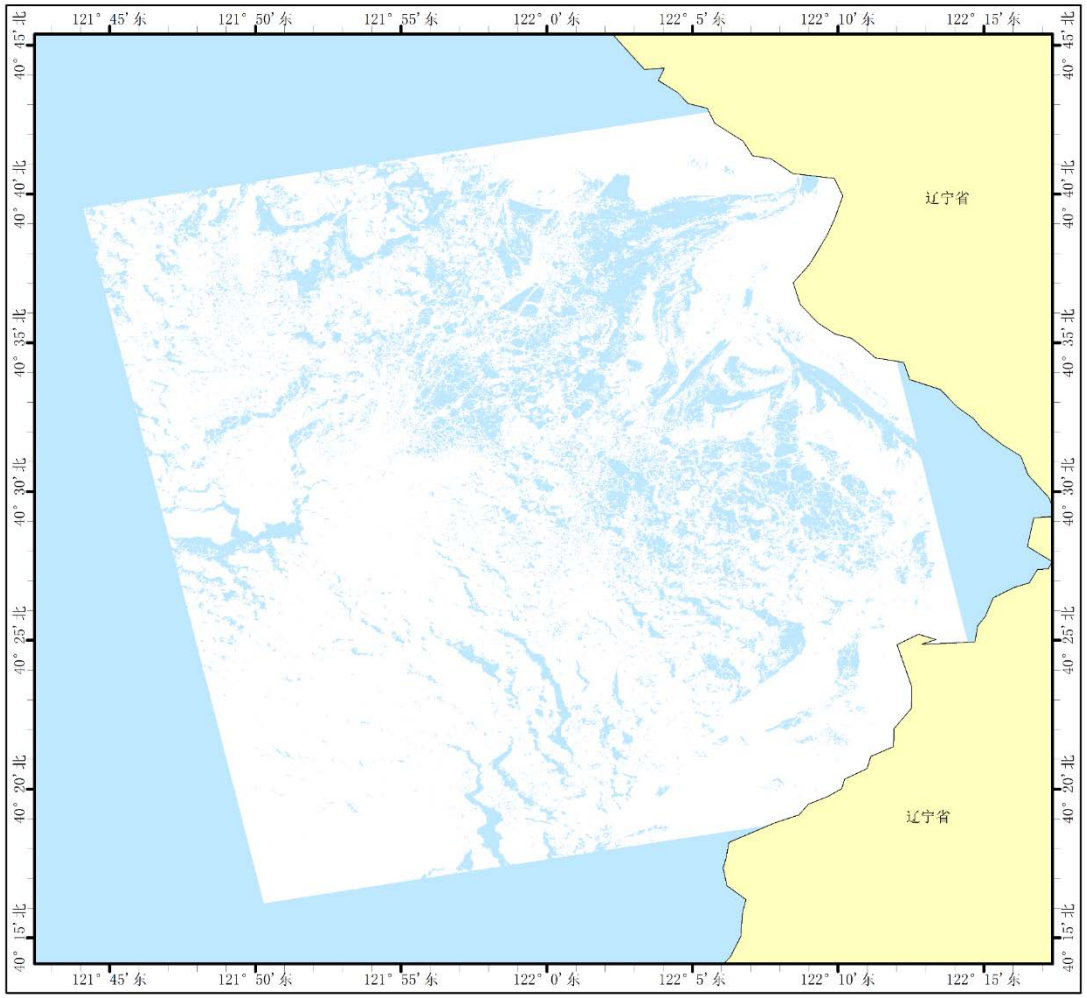
The work in process

1. Optimize network parameters and network structure
2. Detailed assessment of classification performance
3. Analysis of results with or without pre-training
4. Parallel processing accelerates compute speed

Preliminary classification results from Bohai Sea



2017.1.22, GF-3

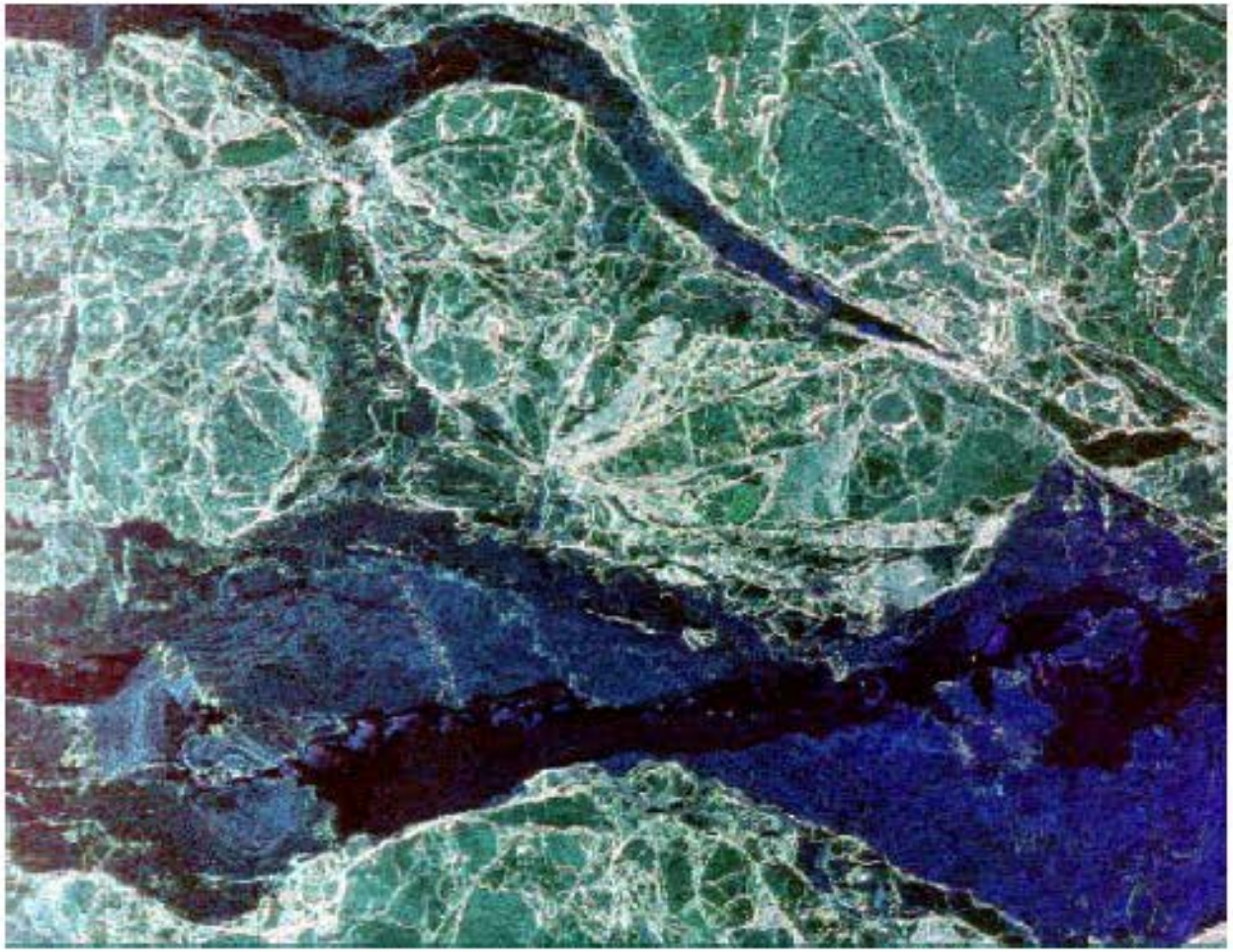


Sea ice detection

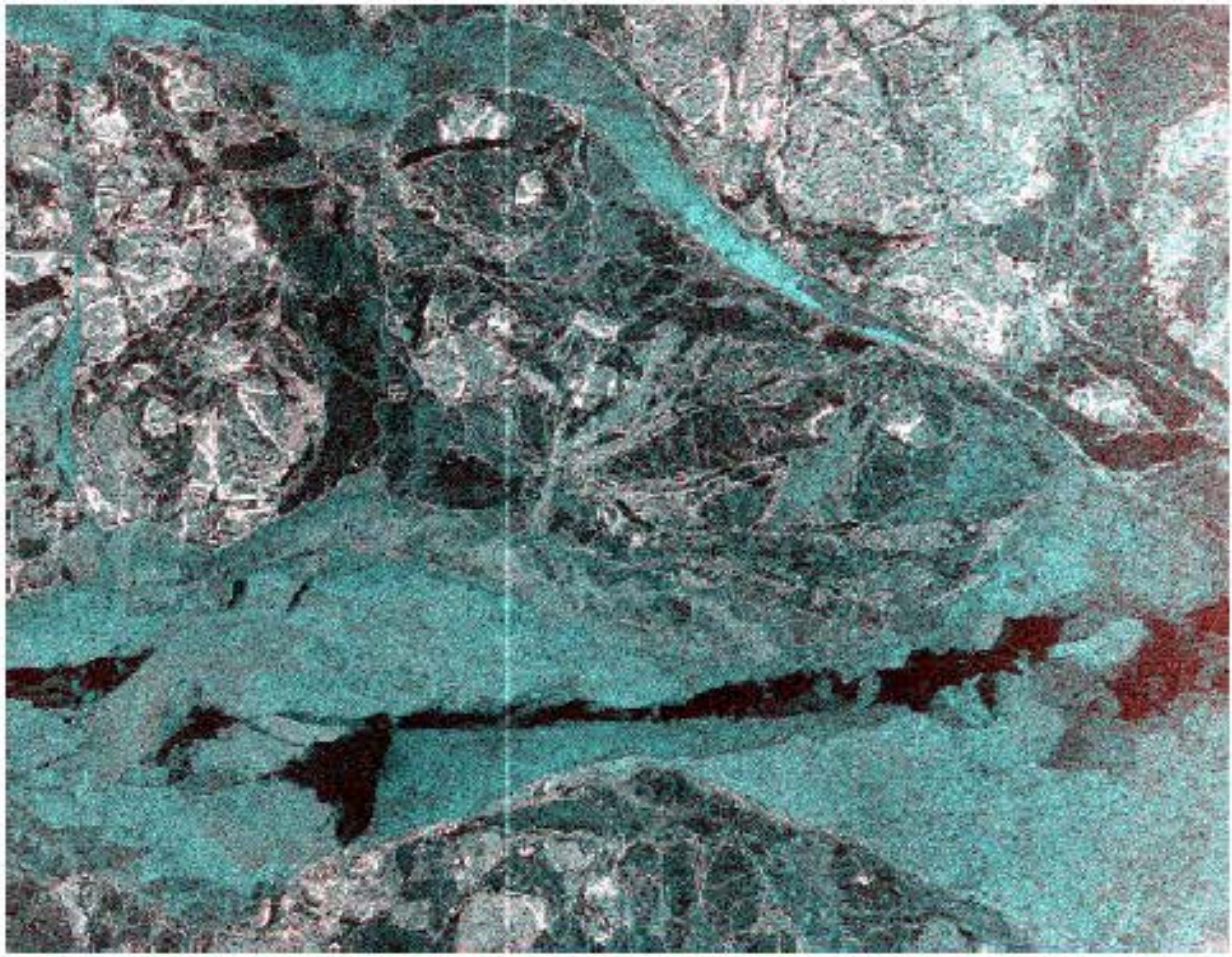
But: there are many fish(es) in the sea:

- Which segmentation / classification method is optimal? (reliability/accuracy, robustness, computation time)
- How much input information (i.e. parameters derived from SAR measurements) are needed?

ICESAR airborne SAR data (Wolfgang)

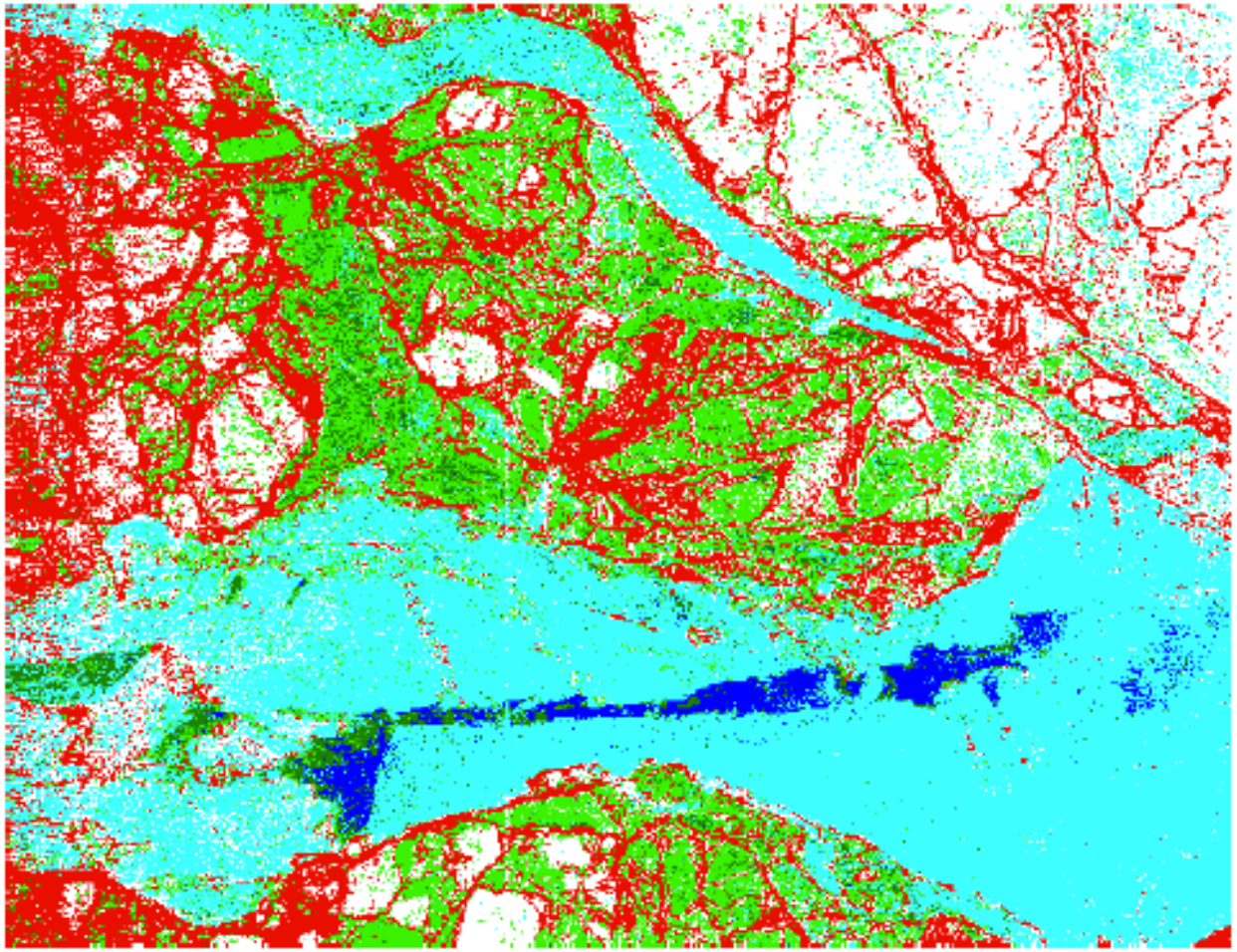


L-band RGB: Cross-HH-VV

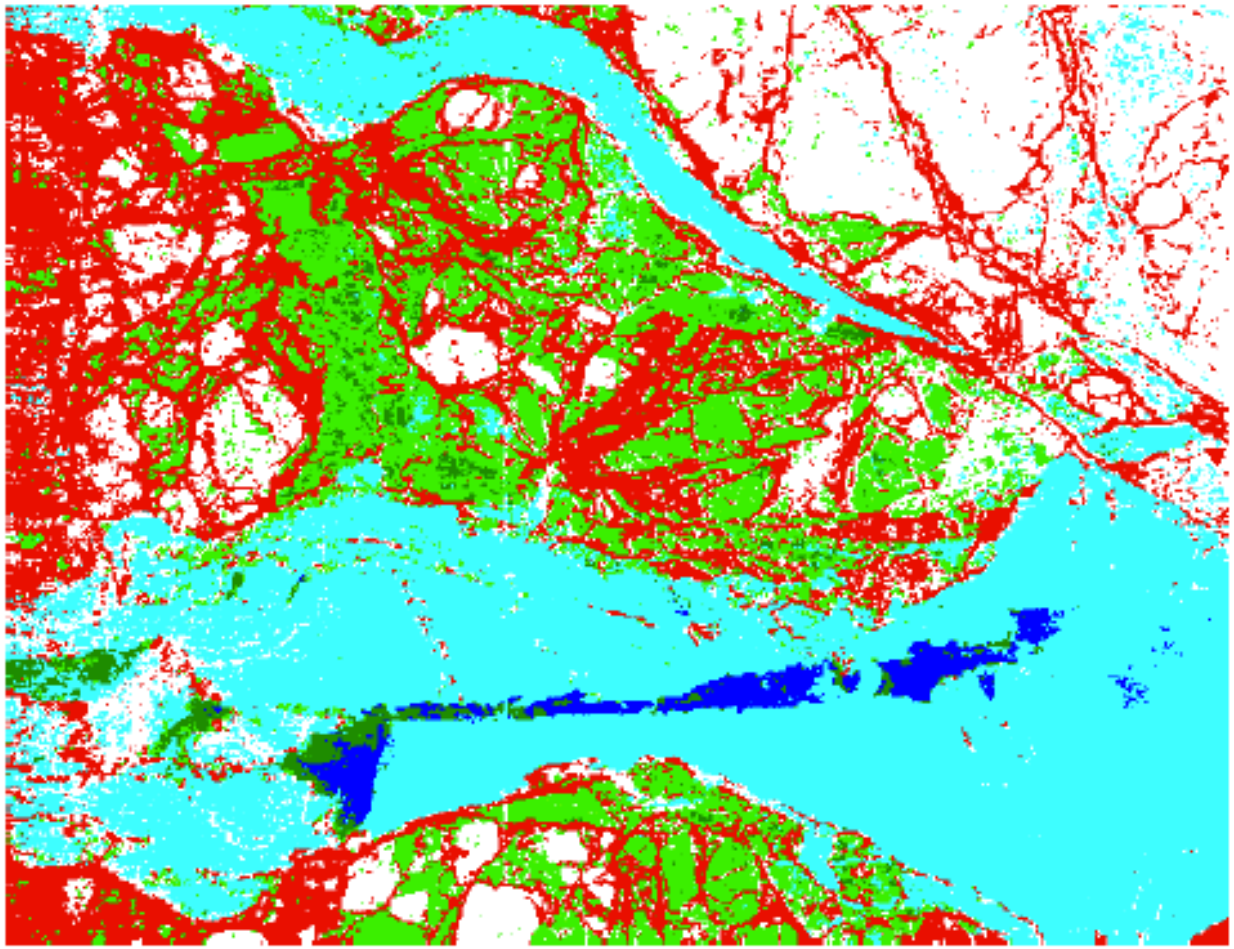


C-band RGB: Cross-VV-VV

ICESAR airborne SAR data, classified

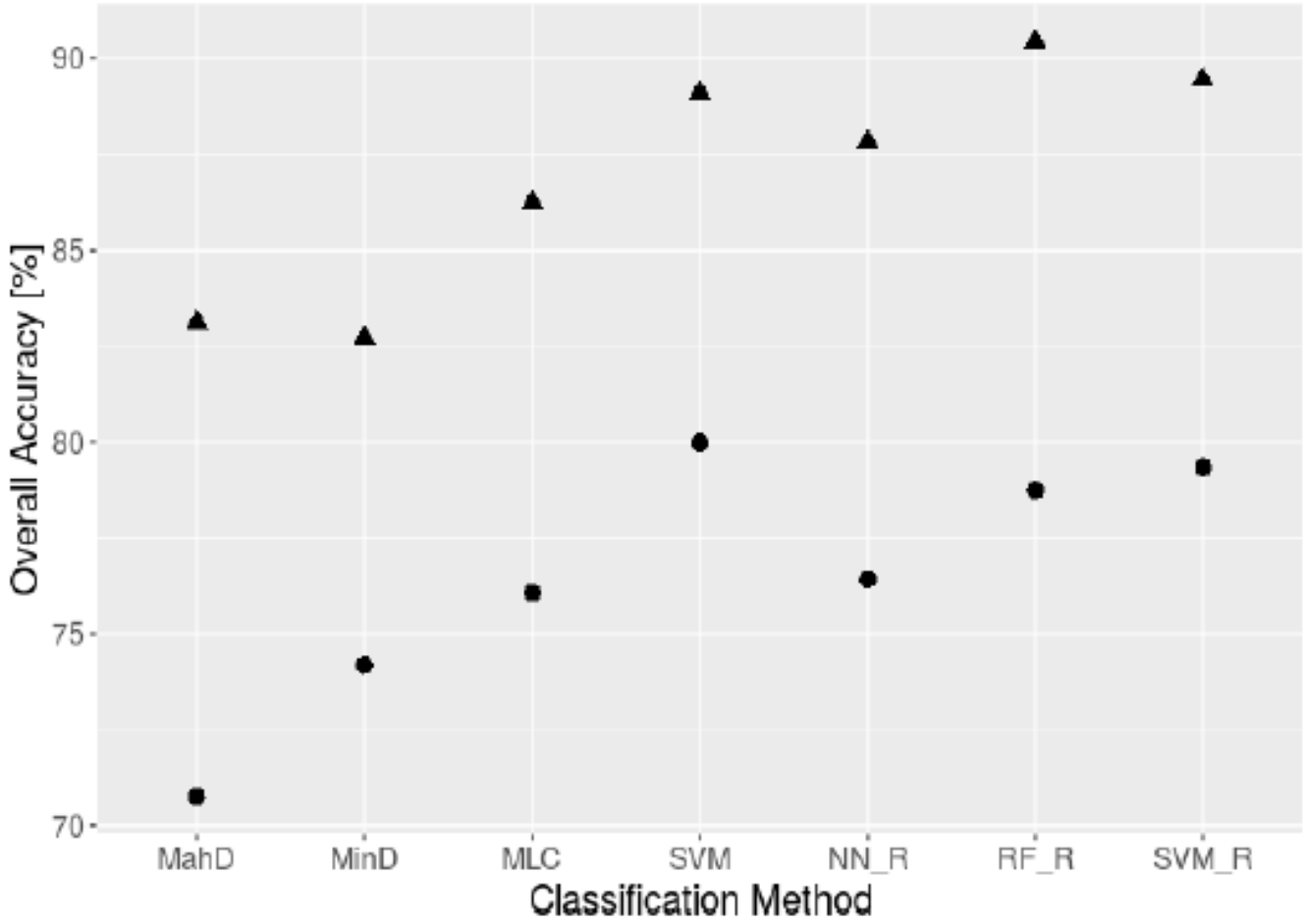


Support Vector Machine



Support Vector Machine with Majority Filter 5x5

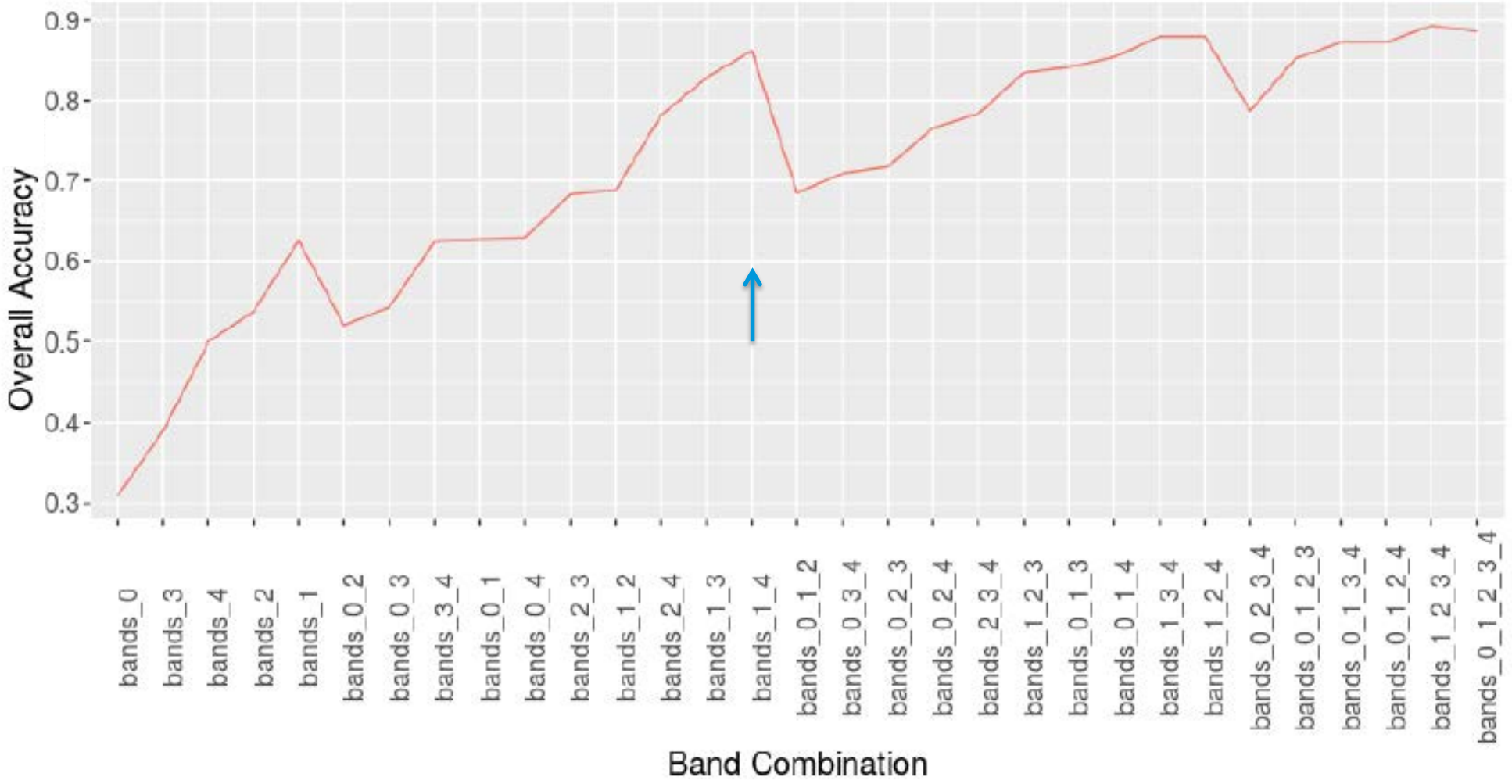
Different classification algorithms: results



Buchelt 2019, Internship Report

MahD	Mahalanobian Distance
MinD	Minimum Distance
MLC	Maximum Likelihood Classification
SVM	Support Vector Machine
NN_R	Neural Network in R
RF_R	Random Forest in R
SVM_R	Support Vector Machine in R

Different input parameters: results



0	L cross-pol
1	L HH
2	L VV
3	C cross-pol
4	C VV

Buchelt 2019, Internship Report

Optimal input data for classification

- depends on the available data
- difficulty to asess optimal choice grows with increasing number of parameters derived from the measurements
- airborne systems versus satellite systems

Feature extraction

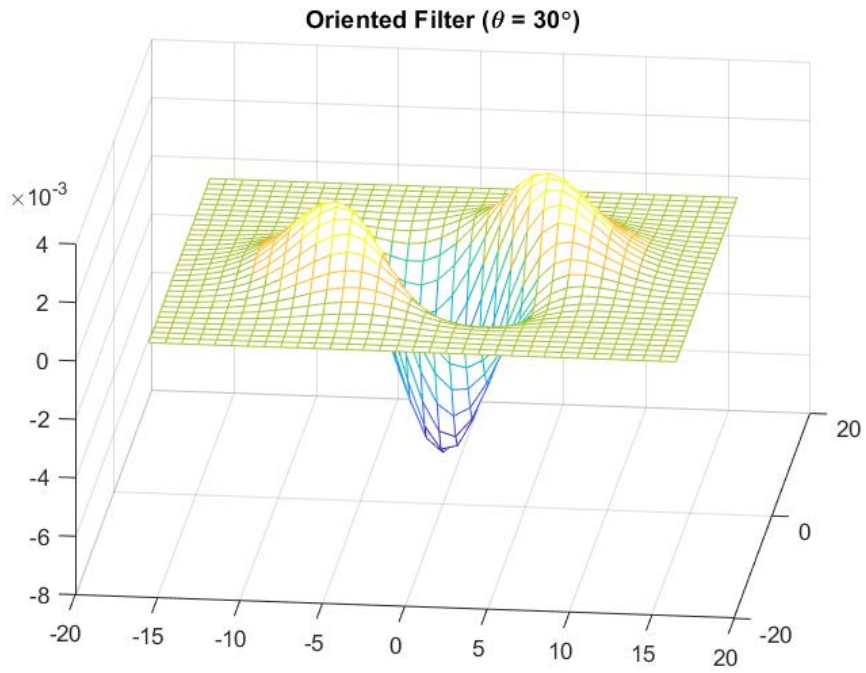
- special information required (e.g. ridges, icebergs)
- only a fraction of the image content is of interest
- how can this fraction be separated from the rest?

Extracting ridges from coarse resolution SAR images (Markku)

- Goal: extract ridging information from operational SAR data.
- SAR images: EW Sentinel-1 images (40 m pixel, 90 m spatial resolution)
- Test sites: Baltic Sea, Kara Sea (future).
- Evaluation of results: using Radarsat-2 data combined with HEM data collected during the winter 2010-2011.

Principles of the analysis

- Sign of the second derivative reveals if some location is a peak.
- 2-D directional filters which detect line fragments in different orientations.
- The theoretical foundation of the approach is presented in *Freeman and Adelson, The Design and Use of Steerable Filters, IEEE PAMI,1991.*



S1 EW 11 March 2016

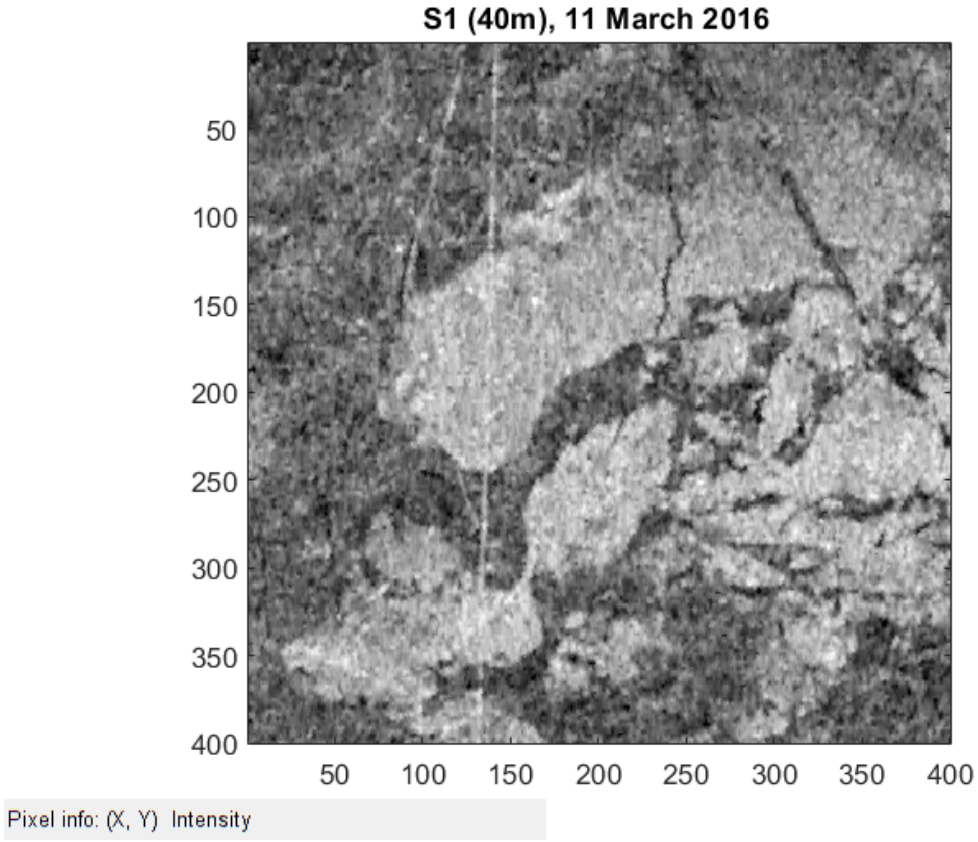
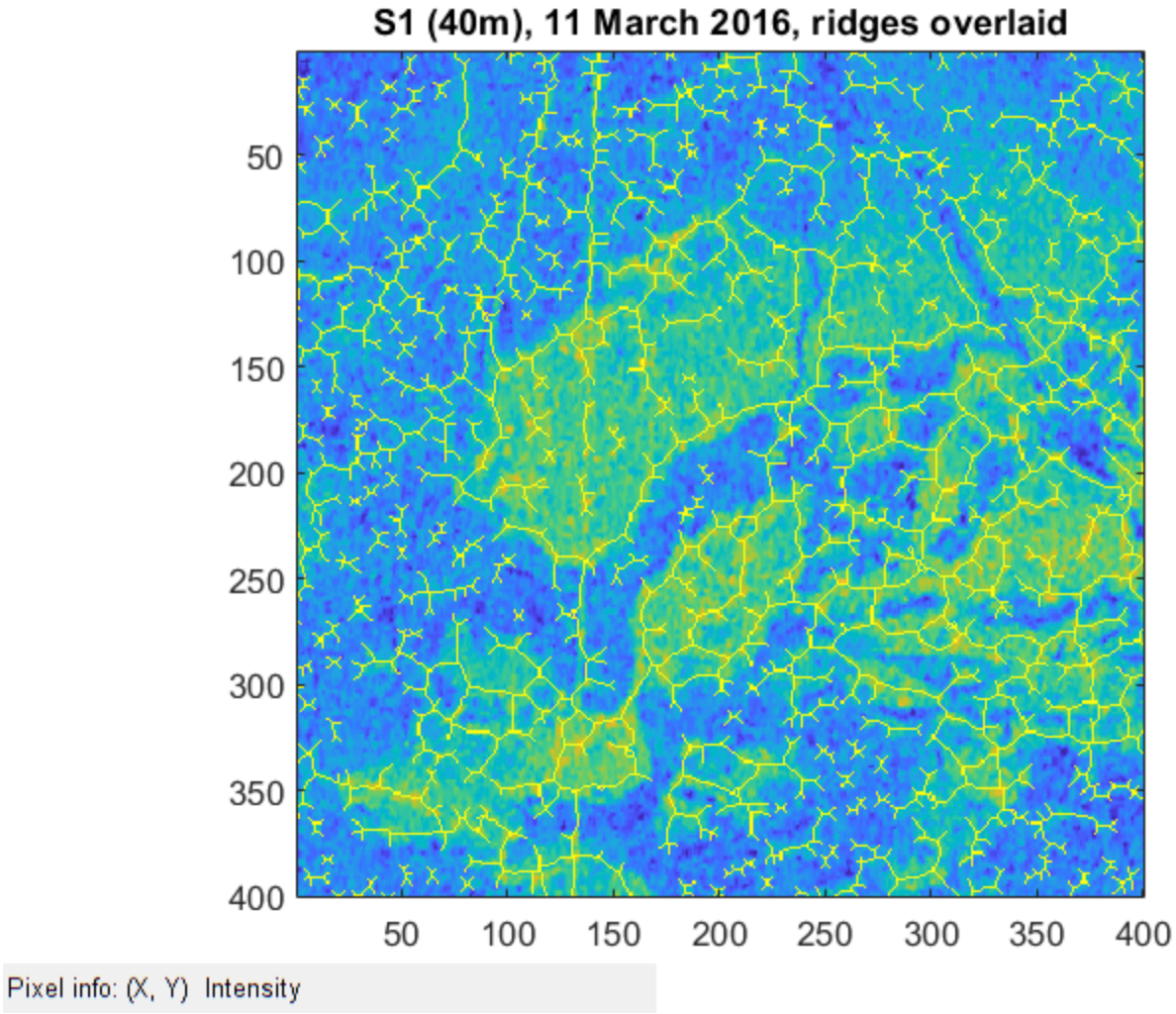


Image area 16 km by 16 km.



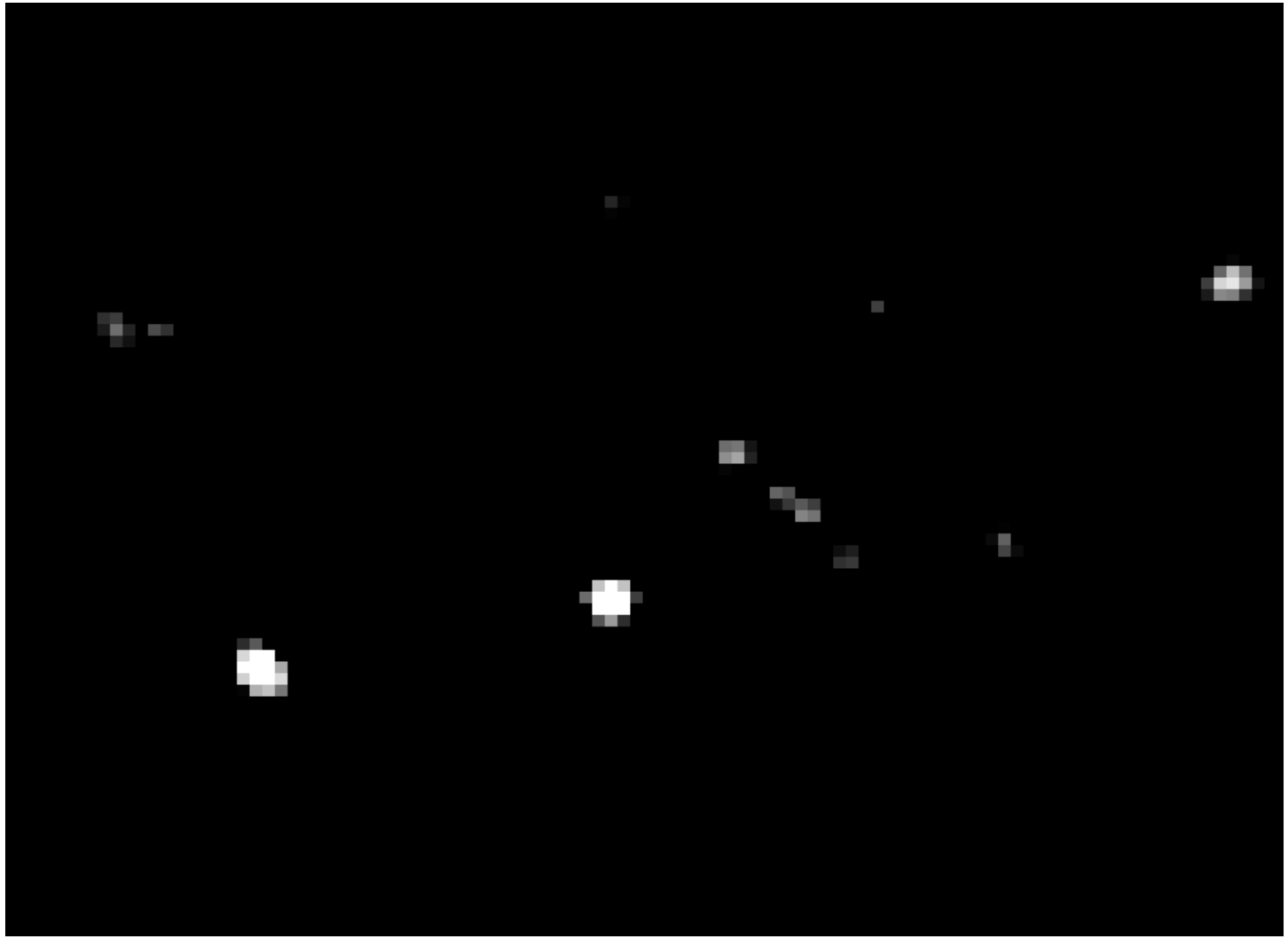
Comments

- The approach generates several false alarms with a great likelihood .
- False ridge-like structures (e.g. brash ice channels created by ships) are hard to identify.
- Due to the coarse resolution a large fraction of ridges remain hidden.
- Which thresholds are optimal?

Iceberg detection in Sentinel-2 images

Soldal et al.
Remote Sensing,
2019

Iceberg detection in Sentinel-1 EWS images



Soldal et al.
Remote Sensing,
2019

Also tested with
S1-IWS mode

Iceberg detection

- some icebergs identified in optical images cannot be seen in C-band SAR images!
- difficult detection in deformed ice and rough waters

Iceberg detection

- wide coverage required (=> coarse resolution)
- icebergs can be small: growlers < 5m, bergy bits 5-15m, small bergs 15-60m, ... (=> high resolution)

So: what did we learn?

- For operational use we have to find the best methods for ice mapping and feature extraction
- “Best” => criteria for selection?
- We know examples of good input parameters but do yet not know the optimal choice(s)
- => this may require to re-think strategies of data acquisitions (multi-frequency, multi-resolution,...)

So: what did we learn?

- Urgently required: reference / validation data (mostly used until now: man-made ice charts)
- Possible scenario: (a) build-up of a free available data set consisting of different SAR and complementary data, (b) establishment of necessary criteria for algorithm selection, (c) multi-group approach to find the best algorithm