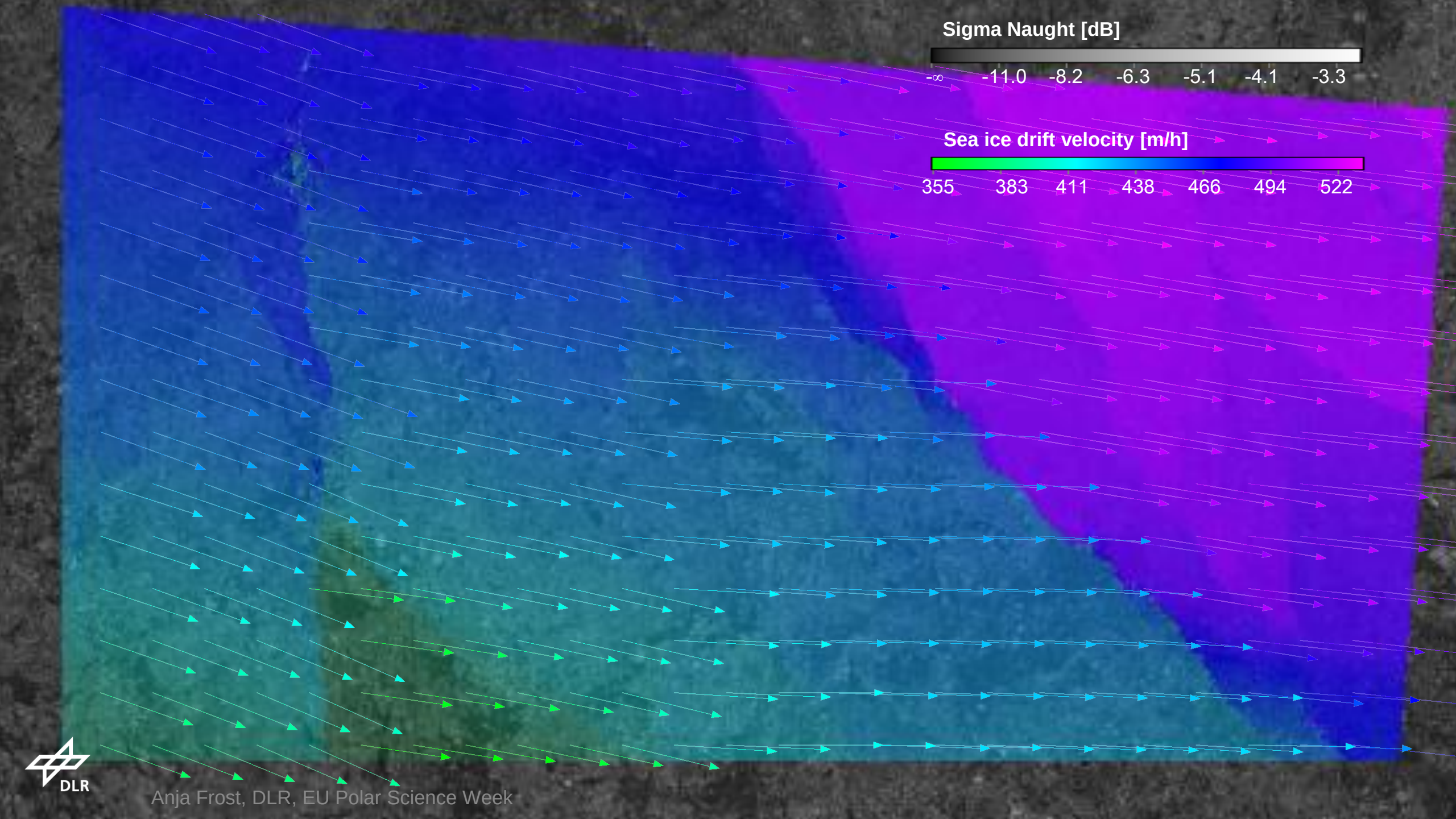
On the location accuracy of deformation zones retrieved from spaceborne SAR image time series

Anja Frost, Martin Bathmann, Dmitrii Murashkin



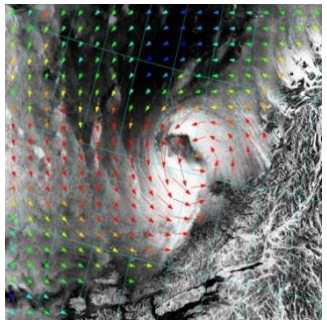
DLR

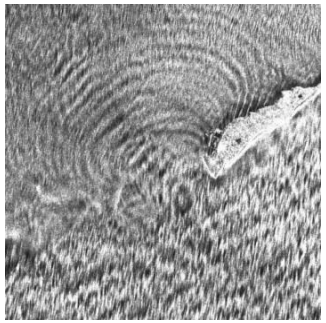
Anja Frost, DLR, EU Polar Science Week

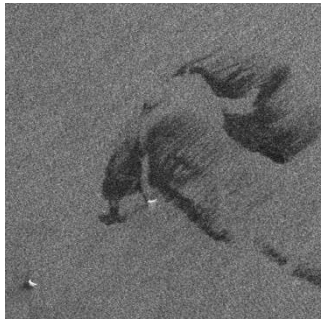
DLR - German Aerospace Center

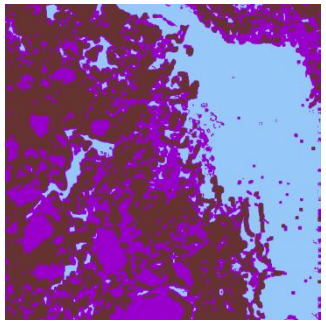
Team SAR Oceanography Bremen

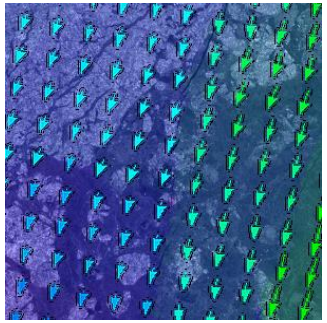
Development of algorithms to derive **maritime information** from **spaceborne SAR data** in **near real-time** on…


…wind

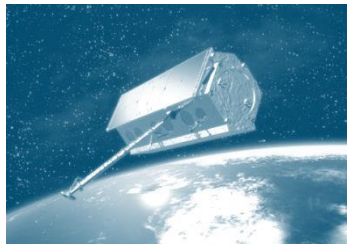

…sea state

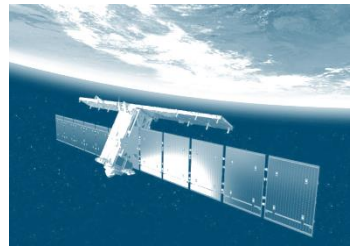

…oil spills


…sea ice types


…sea ice drift

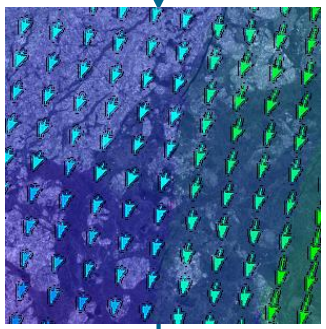
Support of campaigns


TerraSAR-X


Sentinel1


… and others

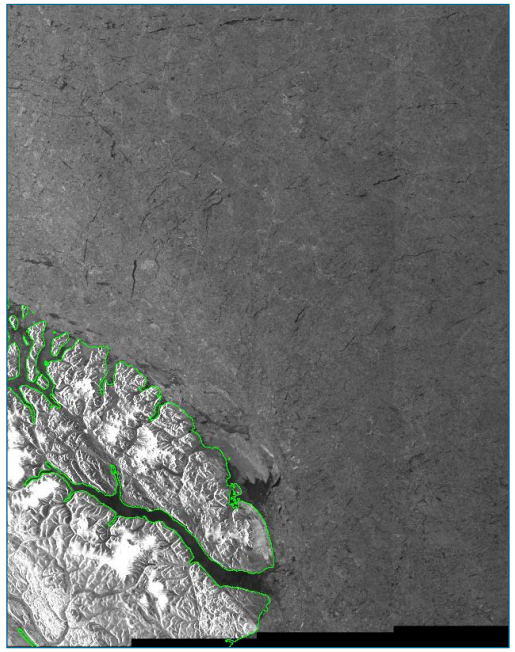

Downlink at DLR ground segment network site


L0 processing and value adding

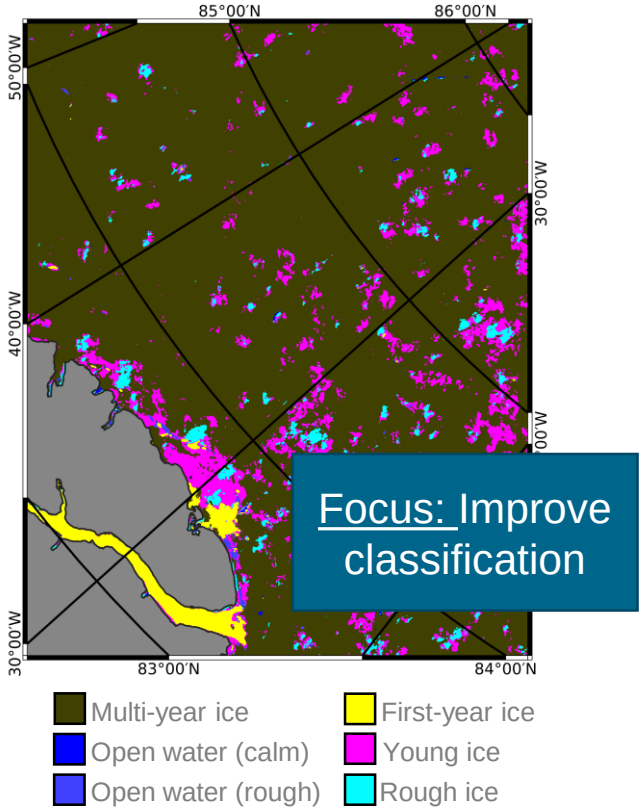
Delivery in NRT

AI based sea ice classification

Sentinel-1 acquisition
06/12/2021 11:25 UTC



Sea ice classification
based on UNET++ CNN [1, 2]



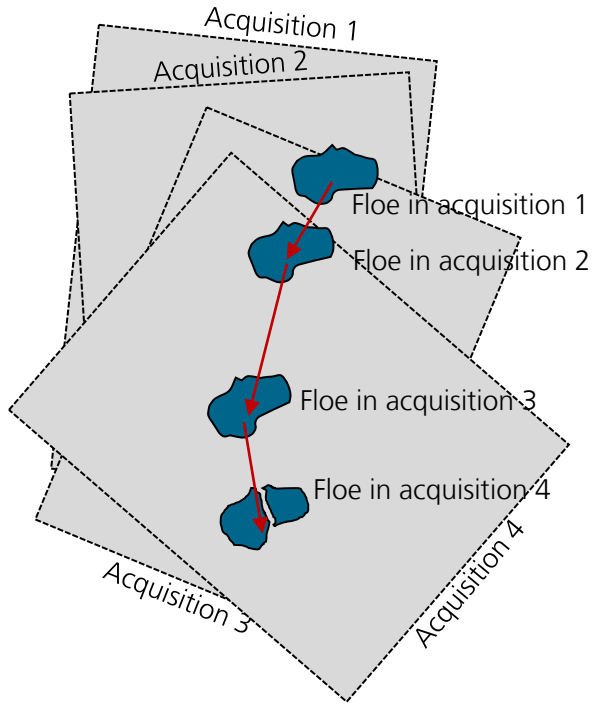
Focus: Improve classification

[1] Z. Zhou et al., IEEE 2020.
[2] Dmitrii Murashkin et al., "Arctic Sea Ice Mapping using Sentinel-1 SAR scenes with a Convolutional Neural Network" IGARSS 2021

Basic idea of multitemporal sea ice classification

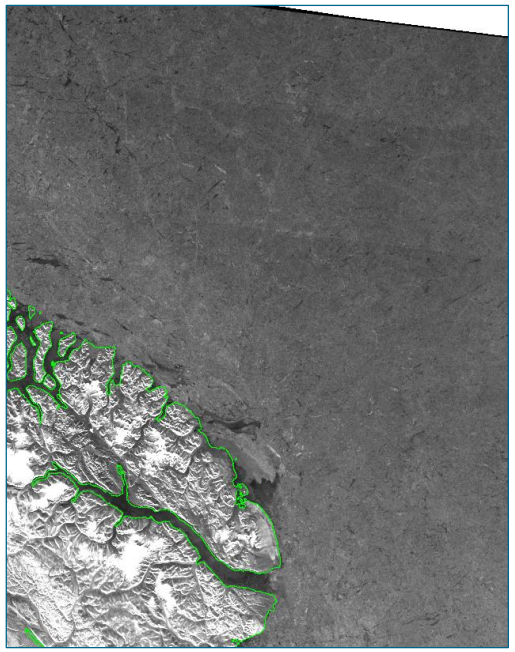
- Track sea ice from one SAR acquisition to the next and collect more measurements about e.g. a floe
- Use the collected data jointly to classify the ice

- Needed: Sea ice drift tracking (hintcast) with very high accuracy and high resolution

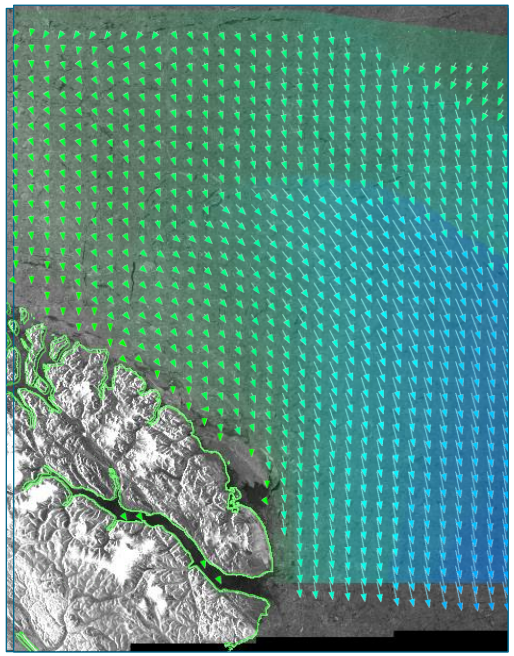


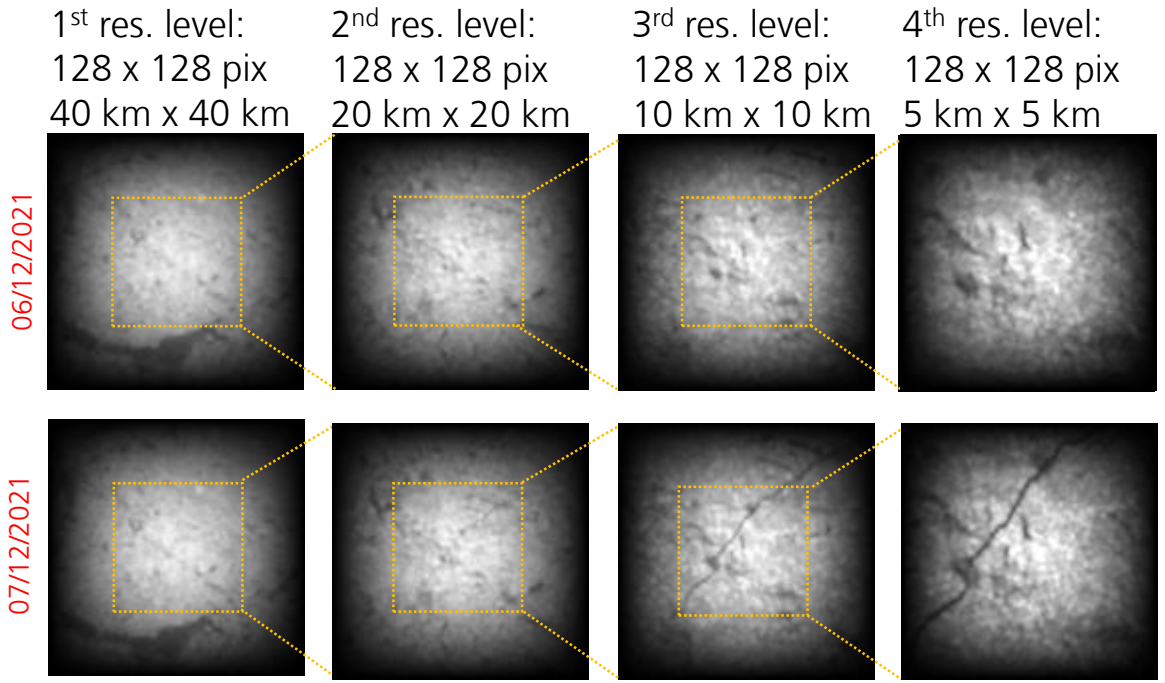
Sea ice drift tracking using phase correlation

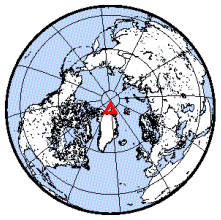
Sentinel-1 acquisition
06/12/2021 11:25 UTC



Sentinel-1 acquisition
07/12/2021 17:51 UTC



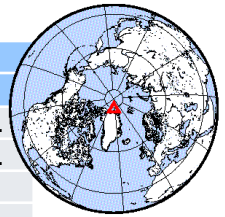




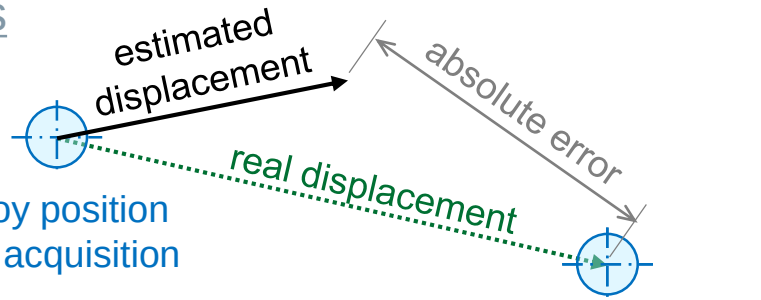
Evaluation of a whole patch

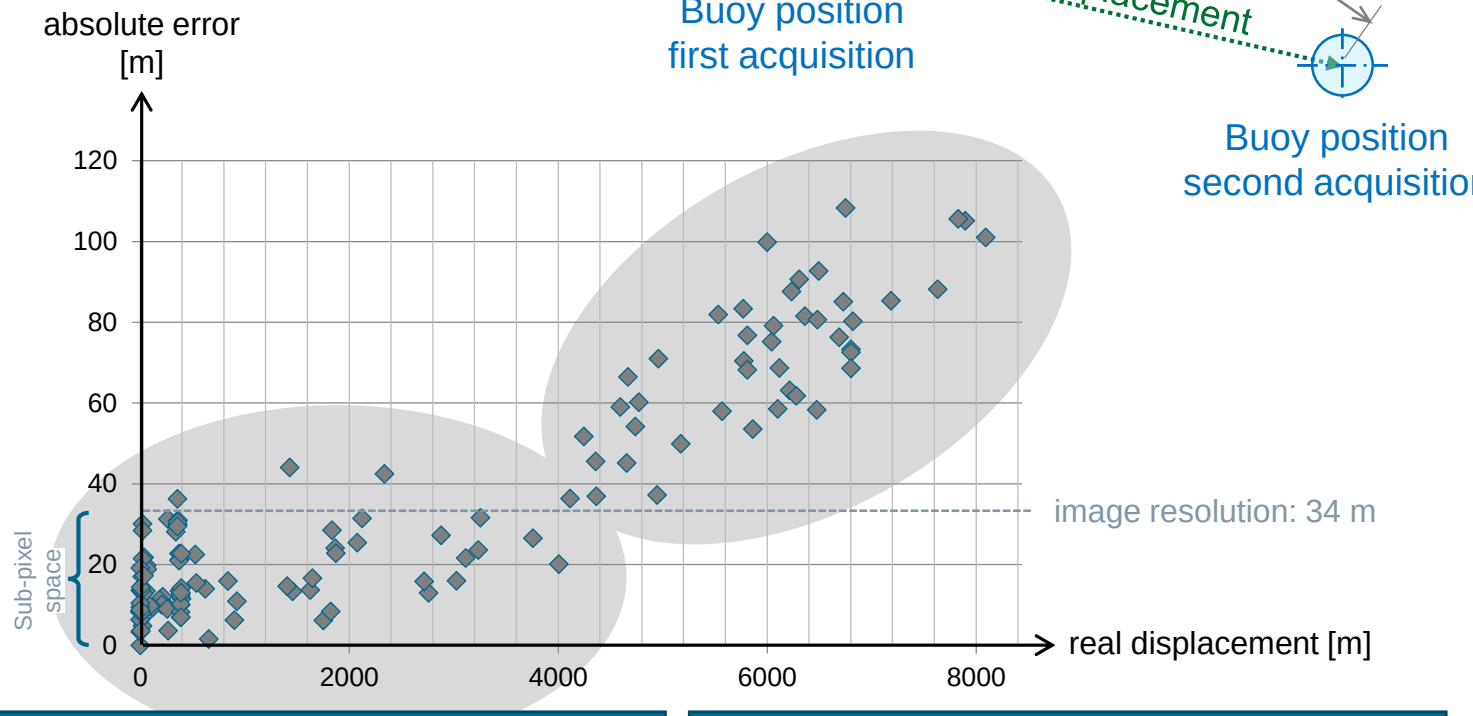
Accuracy based on buoy measurements

TerraSAR-X acquisition				
Date	Time [UTC]	Incidence angle	Heading angle	Orbit
03.03.2018	13:45	42°-34°	246°	desc.
03.03.2018	15:19	39°-30°	269°	desc.
03.03.2018	16:54	34°-42°	293°	asc.
04.03.2018	13:28	42°-34°	243°	desc.
04.03.2018	16:36	32°-41°	289°	asc.
05.03.2018	13:10	44°-36°	240°	desc.
05.03.2018	14:45	39°-30°	265°	desc.
06.03.2018	12:53	44°-36°	236°	desc.
06.03.2018	17:36	36°-44°	305°	asc.
07.03.2018	14:11	39°-30°	254°	desc.
07.03.2018	15:45	27°-37°	277°	asc.
08.03.2018	15:28	30°-39°	272°	asc.
08.03.2018	17:02	34°-42°	296°	asc.
09.03.2018	15:11	39°-30°	269°	desc.
09.03.2018	16:45	32°-41°	292°	asc.
10.03.2018	18:02	38°-46°	310°	asc.
12.03.2018	17:28	36°-44°	304°	asc.
13.03.2018	17:11	34°-42°	299°	asc.
14.03.2018	13:45	40°-32°	246°	desc.
14.03.2018	15:19	37°-27°	266°	desc.
14.03.2018	16:54	30°-39°	287°	asc.
15.03.2018	13:28	41°-32°	242°	desc.
16.03.2018	13:10	42°-34°	238°	desc.
16.03.2018	14:45	39°-30°	260°	desc.
17.03.2018	16:02	25°-35°	275°	asc.
17.03.2018	17:36	34°-42°	302°	asc.
20.03.2018	16:45	30°-39°	288°	asc.
20.03.2018	18:19	38°-46°	312°	asc.
21.03.2018	16:28	27°-37°	289°	asc.
23.03.2018	17:28	34°-42°	304°	asc.
24.03.2018	17:11	32°-41°	300°	asc.
26.03.2018	16:36	27°-37°	291°	asc.



Validation with drift buoys



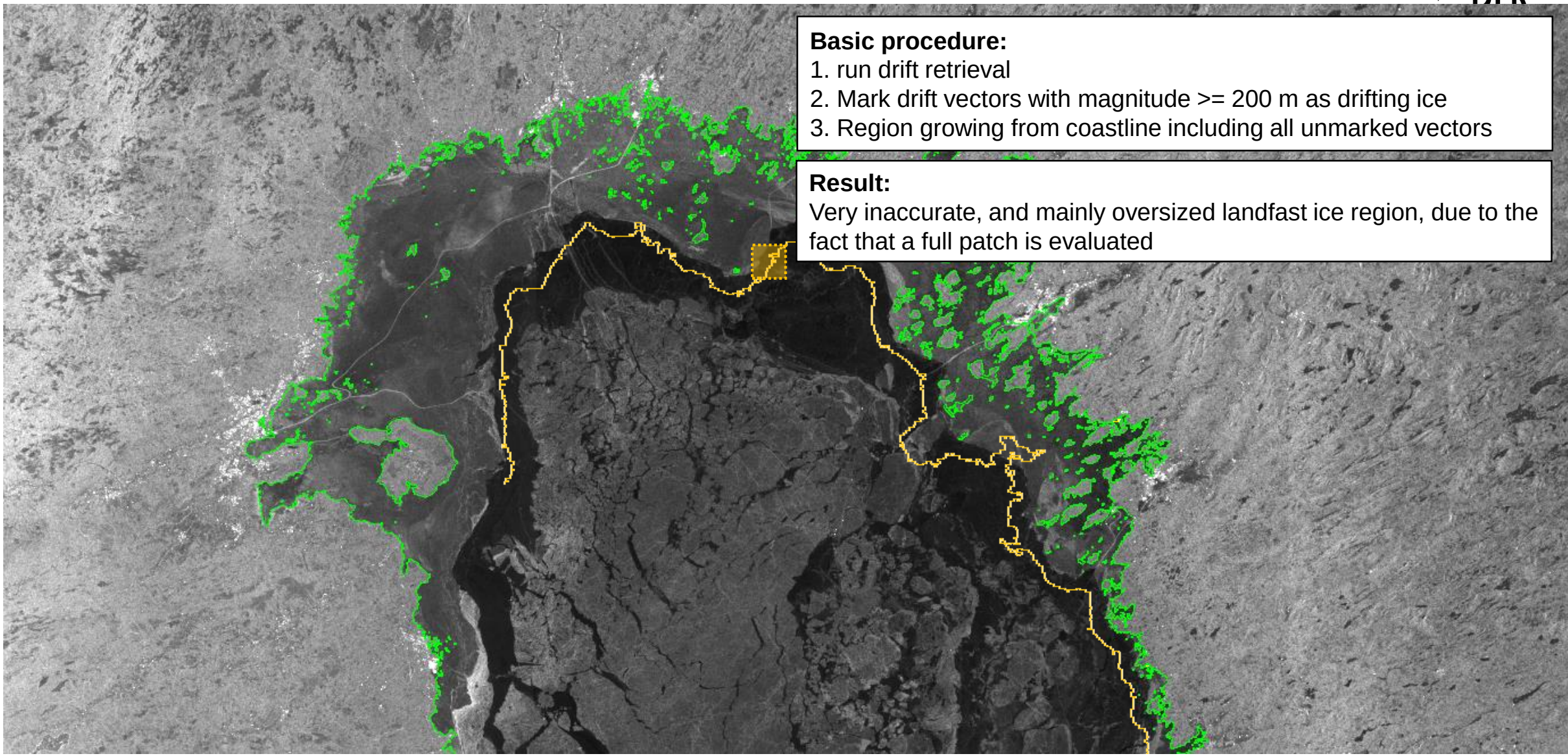


Up to a displacement of approx. 4 km: Absolute error ranges from 0 m to 44 m

Displacement between 4 km to 9 km: Absolute error ranges from 32 m to 108 m

… but drift buoys are usually deployed in the middle of an ice floe

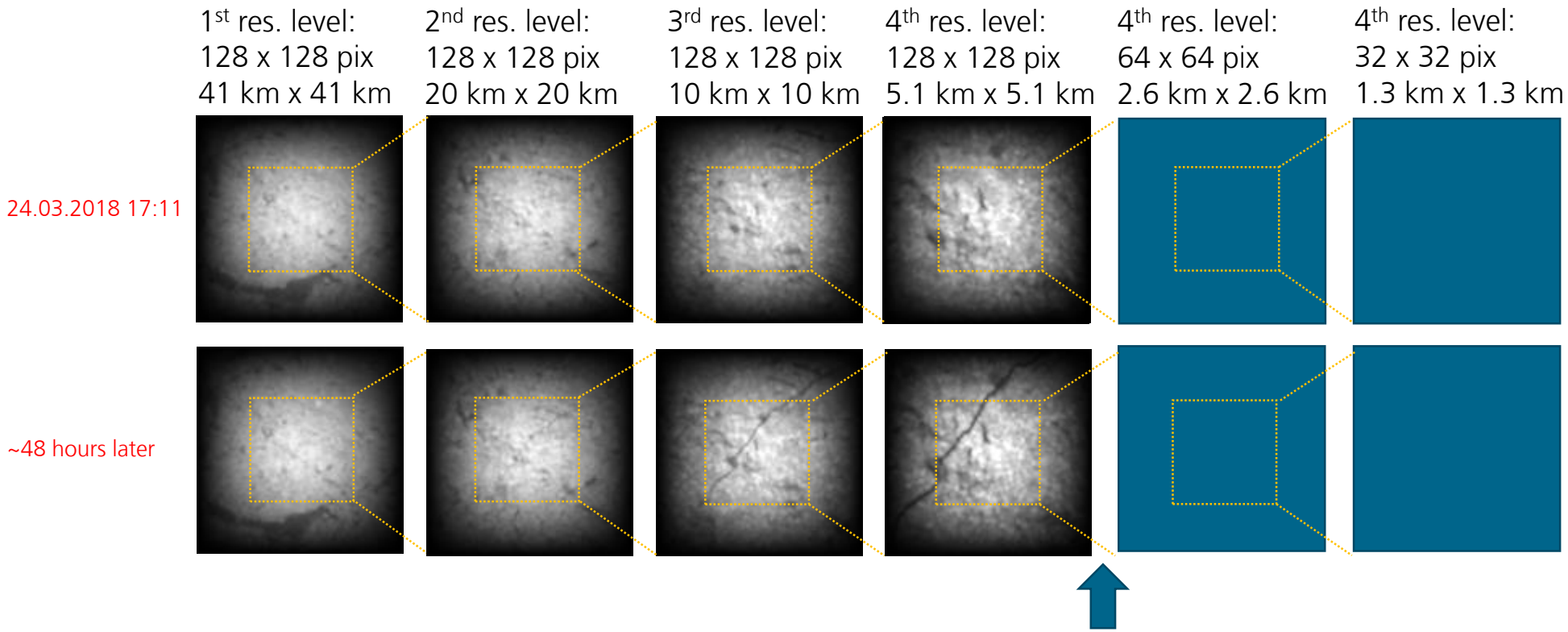
Accuracy in deformation zones (landfast ice boundary)



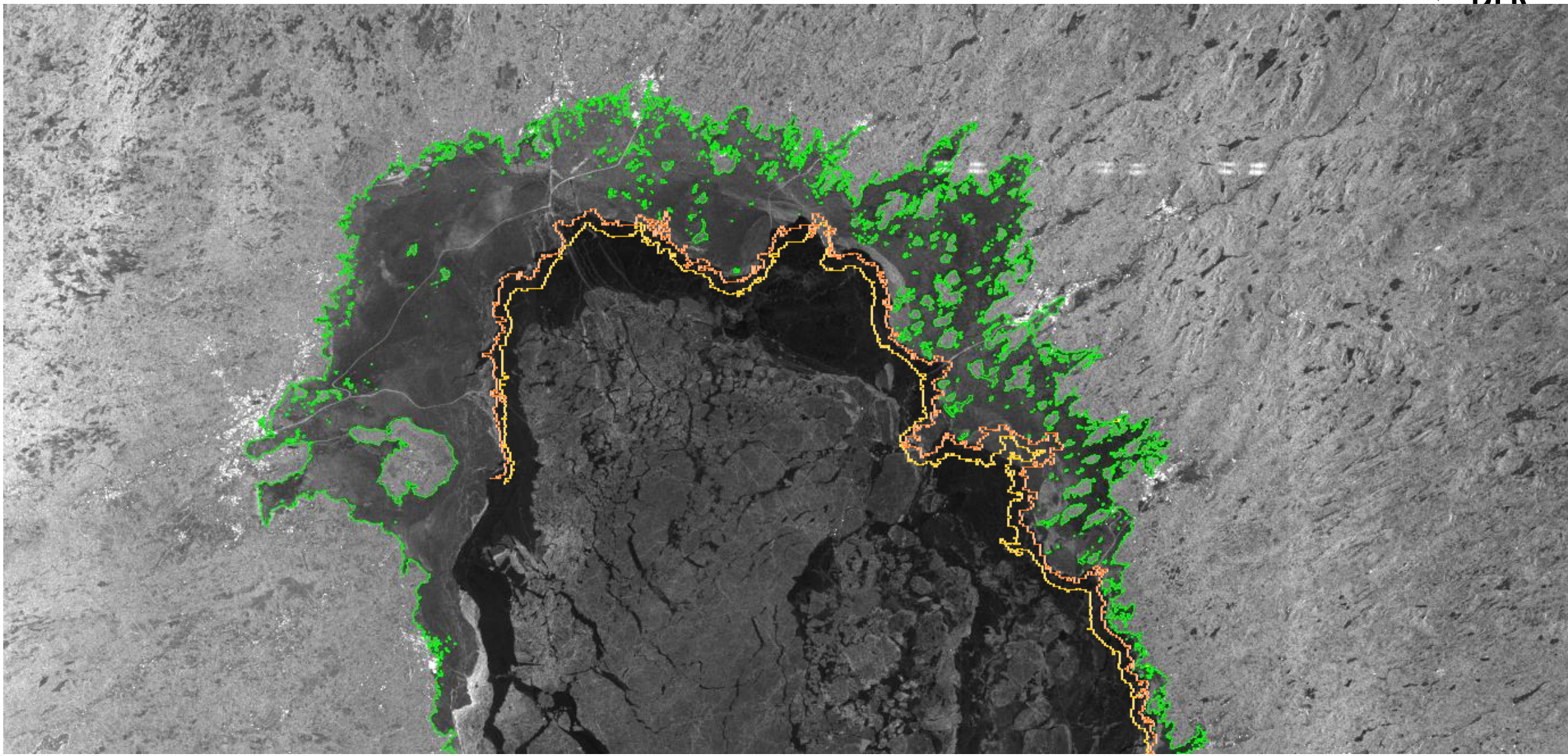
Basic procedure:
1. run drift retrieval
2. Mark drift vectors with magnitude >= 200 m as drifting ice
3. Region growing from coastline including all unmarked vectors

Result:
Very inaccurate, and mainly oversized landfast ice region, due to the fact that a full patch is evaluated

How can results be improved by processing with way smaller patch sizes?



Accuracy in deformation zones (landfast ice boundary)



Summary

- Within an ice sheet, sea ice drift can be tracked with very high precision
- Due to the block matching approach, boundaries of different moving ice sheets (i.e. deformation zones) can be misplaced by several kilometers, depending on block size
- First approach: Re-estimation of drift vectors with smaller patch sizes narrows down the deformation zones

Ongoing

- For multitemporal sea ice classification, handle boundaries separately (anyhow, introduce new ice class “deformation zone”)
- Separate handling of boundary regions:
  - Interferometric analysis of landfast ice (vs. operational use)
  - Include other approaches for sea ice drift tracking

A. Frost et al., IEEE OCEANS 2023
(first results on multitemporal sea ice classification including drift validation with >1000 buoy measurements)

Knowledge gaps and deficiencies

- lack of in situ data
- free ice floe drift hard to track and predict

Recommondation

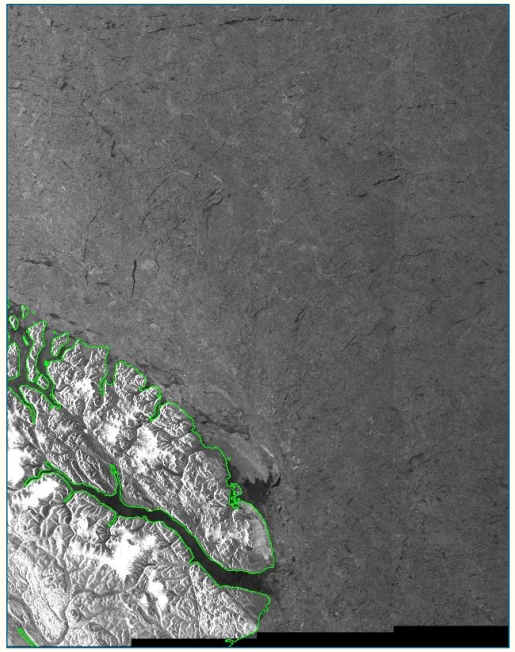
- More campaigns to collect in situ data
- Sea ice classification: Creation of open-source high-resolution dataset

Opportunities

- Several large shipping companies could use Northwest passage to save costs, potential for marketable solution
- Large AI models incorporating multiple data sources might increase quality of EO-based sea ice information

AI based sea ice classification morphed into the future

Sentinel-1 acquisition
06/12/2021 11:25 UTC



Sea ice classification
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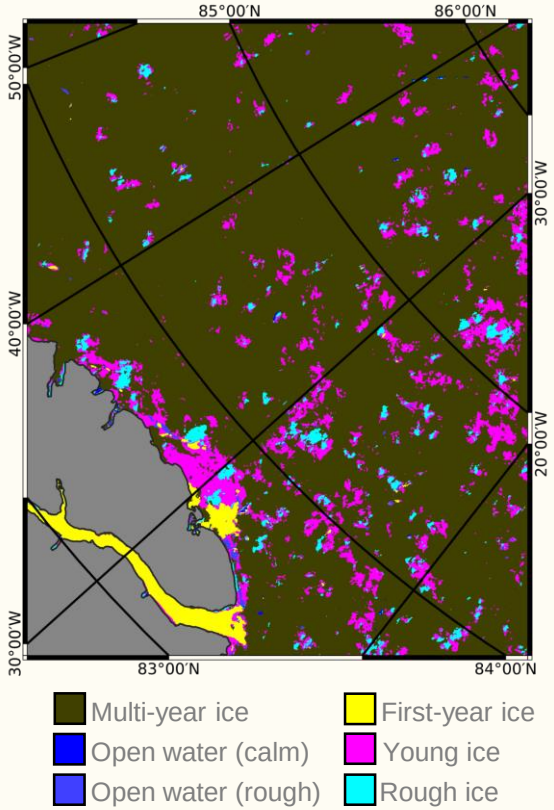
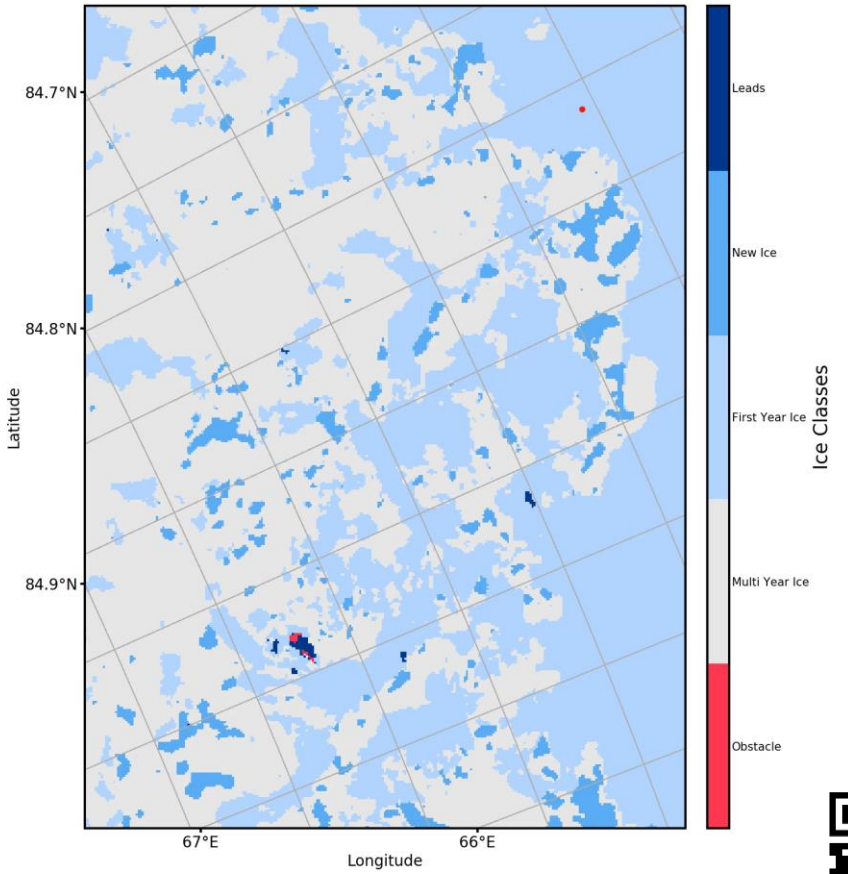


High resolution sea ice types
+
Drift forecast
+
Ship capabilities
=
Route suggestion



Animation by Christine Eis, University of Bremen

Ongoing in joint project **FAST-CAST 2** →

[1] Z. Zhou et al., IEEE 2020.
[2] Dmitrii Murashkin et al., "Arctic Sea Ice Mapping using Sentinel-1 SAR scenes with a Convolutional Neural Network" IGARSS 2021