Fully-automated navigation support for vessels in the Arctic:

An application and validation example of ice type mapping during the CIRFA cruise 2022

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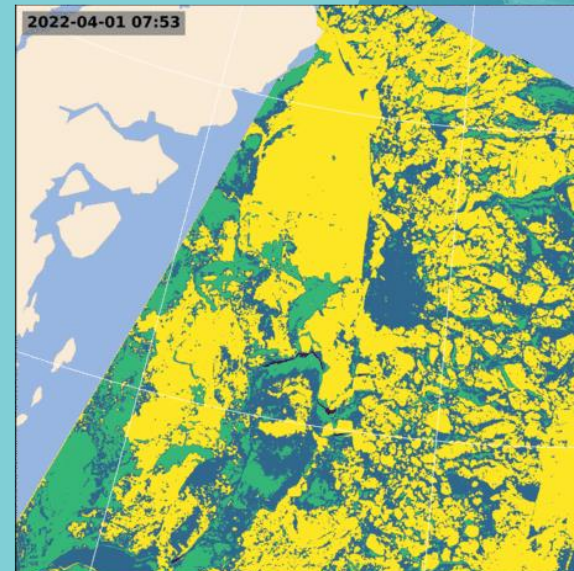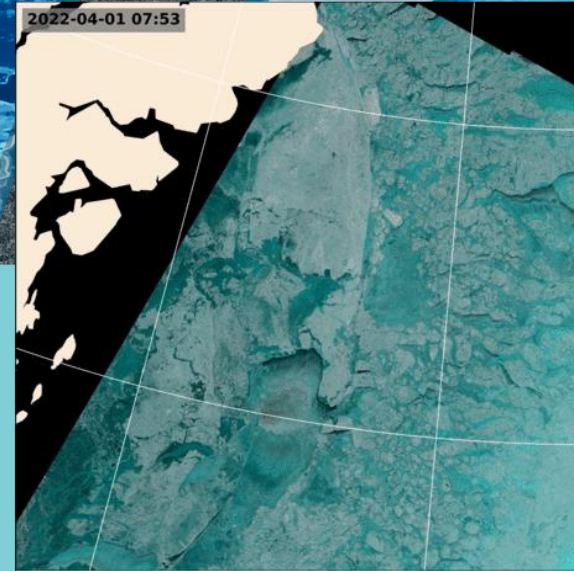
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[2] Norwegian Meteorological Institute - MET Norway Ice Service

Thanks to support and input from the crew and science team of the CIRFA-22 cruise

IICWG-DA-11 Workshop
March 2023

cirfa.uit.no

CIRFA
CENTRE FOR
INTEGRATED REMOTE SENSING
AND FORECASTING FOR ARCTIC OPERATIONS

THE ARCTIC UNIVERSITY OF NORWAY
UIT

sfi = Senter for forskningsdrevet innovasjon

2022-04-01 07:53

2022-04-01 07:53

Introduction

- Ice charts
- Automated sea ice mapping
- Research to operations in ice charting
- CIRFA-22 cruise

Automated ice type mapping during CIRFA-22

- Requirements, preparation, and setup
  - Sea ice conditions at Belgica Bank
  - Classifier and processing chain
  - Data transfer to KPH

Belgica Bank case study

- SAR + classification result
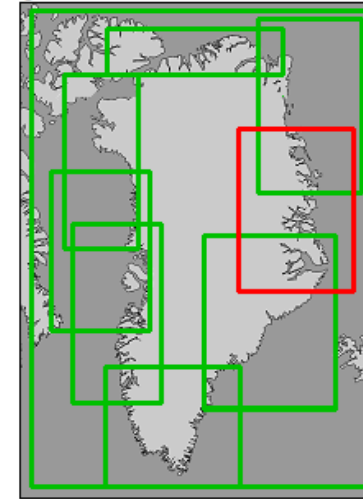- In-situ observation

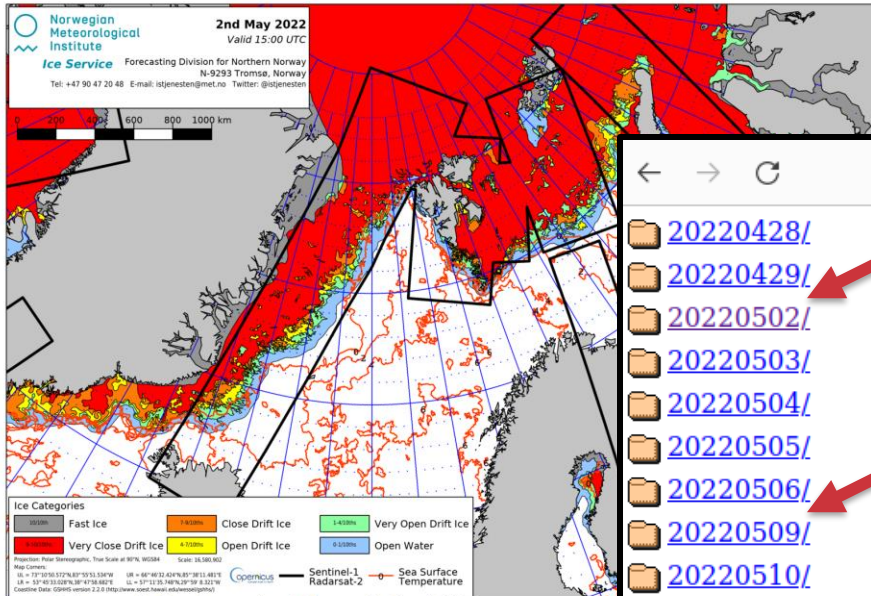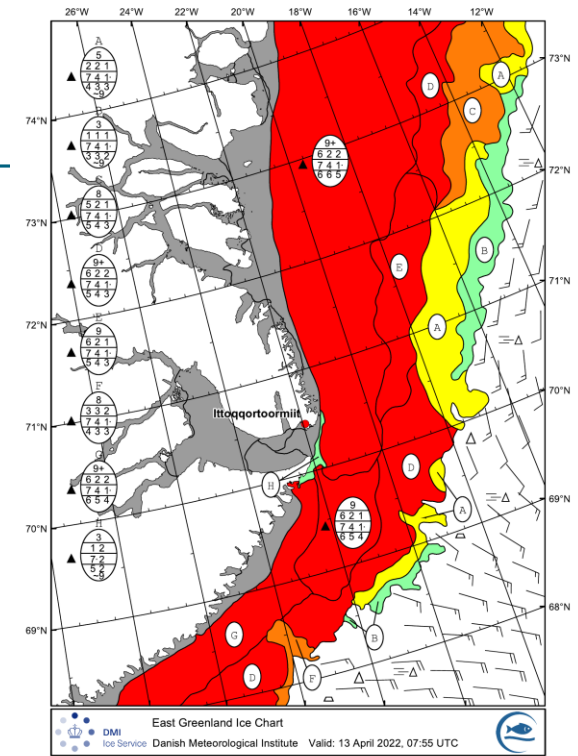# Navigation support for vessels in the Arctic

Ice Charts:

- SAR as primary data source

- Different type of information (SIC, SoD, egg code)

- Manually produced by expert analysts
    - -> Subjective, time-consuming

IcySea, Vixed, etc

Select region on the map below.
Unactive regions on the map, are
regions with no archived ice charts.

DMI Ice Charts

East Greenland Ice Chart
DMI Ice Service   Danish Meteorological Institute   Valid: 13 April 2022, 07:55 UTC

MET Norway Ice Service

https://cryo.met.no/		
20220428/	2022-04-28 15:05	-
20220429/	2022-04-29 15:05	-
20220502/	2022-05-02 15:05	-
20220503/	2022-05-03 15:05	-
20220504/	2022-05-04 15:05	-
20220505/	2022-05-05 15:05	-
20220506/	2022-05-06 15:05	-
20220509/	2022-05-09 15:05	-
20220510/	2022-05-10 15:05	-

Parameter	strategic		tactical	
	spatial	temporal	spatial	temporal
ice edge location	5 km	daily	< 1 km	6 hours
ice concentration	< 100 m	daily	< 25 km	6 hours
ice types	50-100 m	daily	< 20 m	6 hours
leads/polynyas	50-100 m	daily	< 20 m	6 hours
ridges	< 50 m	daily	< 10 m	6 hours
ice decay stage	20 km	weekly	< 5 km	daily
iceberg location	< 50 m	daily	< 5 m	hourly

User "wish list"

Automated sea ice mapping

"… can significantly improve the performance of the classifier."

"… can be successfully discriminated with an overall accuracy of 100% …"

"… a promising step toward operational, near-realtime ice charting."

"… demonstrate the potential for near-real-time service …"

"… can automatically produce more objective sea-ice interpretation maps …"

Lots of studies and papers on sea ice mapping from SAR

- For both ice/water and ice types
- Supervised, unsupervised, semi-supervised, automated, semi-automated, …
- Bayesian approaches, decision trees, support vector machines, random forests, neural networks, convolutional neural networks, …

"… robust enough to be used for operational tasks."

"… algorithm outperforms the existing product for each ice type."

"… show both qualitatively and quantitatively that our models produce accurate classification results."

"Compared with the manually generated ice chart of CIS, our method can work automatically and provide more detailed ice distribution …"

"… obtaining an overall accuracy of 99.67%…"

Ice Charting: Research to Operations
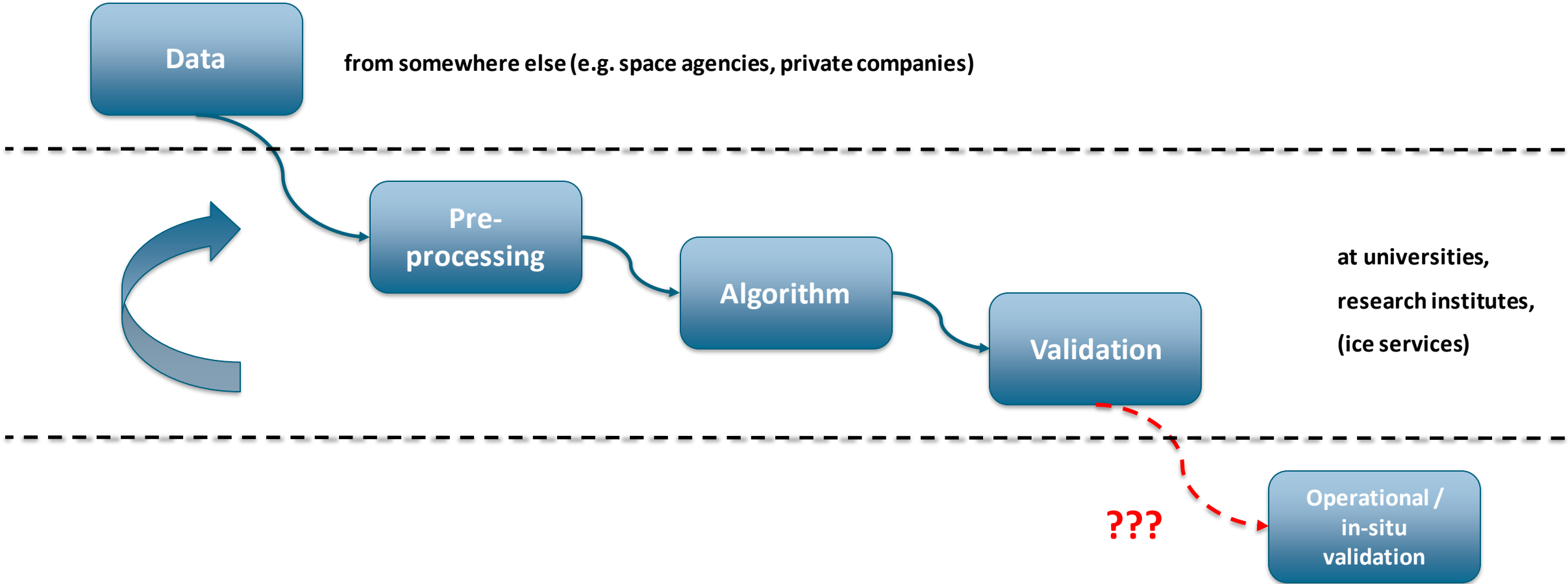
CIRFA-22 cruise

"...to perform measurements and make observations which allow for validation of information and forecast products resulting from CIRFA´s work."

RV Kronprins Haakon (KPH)

April 22nd – May 9th

Background: Sentinel-1 from May 3rd 2022

Legend:
- AOIs
- KPH in S1 footprint
- Landfast ice stations
- KPH track
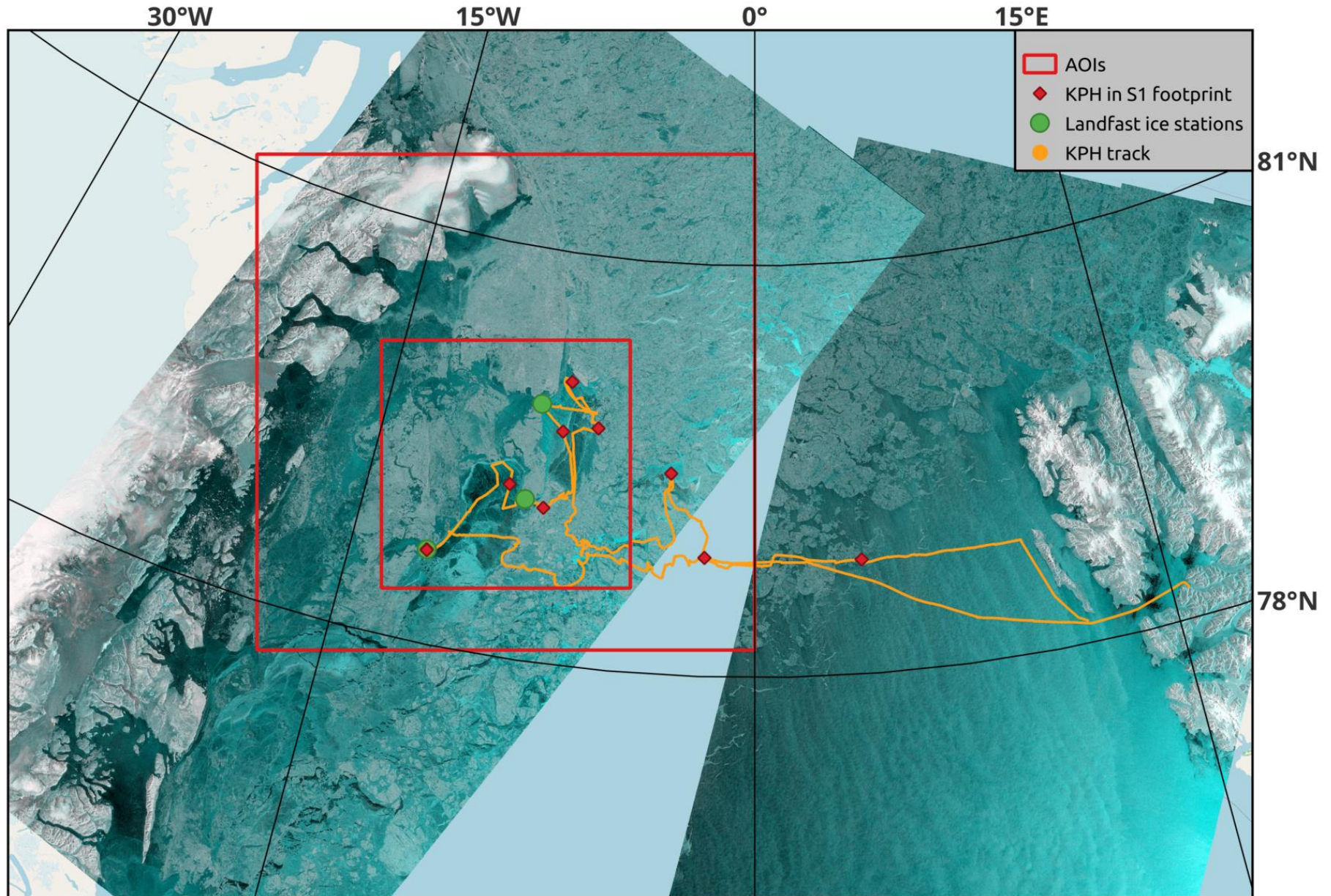
Automated ice type mapping during the CIRFA-22 expedition

Goal: Test automated ice type mapping in an "operational setting"

- Demonstrate that we can transfer classification results in NRT to the vessel

- Validate the results in the field

- Use images and classification results to assist in route planning

Data:

- Sentinel-1

- Data from a range of other sensors was available during the cruise, but not included in the automated processing chain

Before the cruise:

- What are the "typical" sea ice conditions and ice types in the area at this time of the year?

- Which ice types can we classify from S1?

- How do we transfer the data?

- What is useful/not useful to transfer?

Sea ice conditions at Belgica Bank in spring 2022
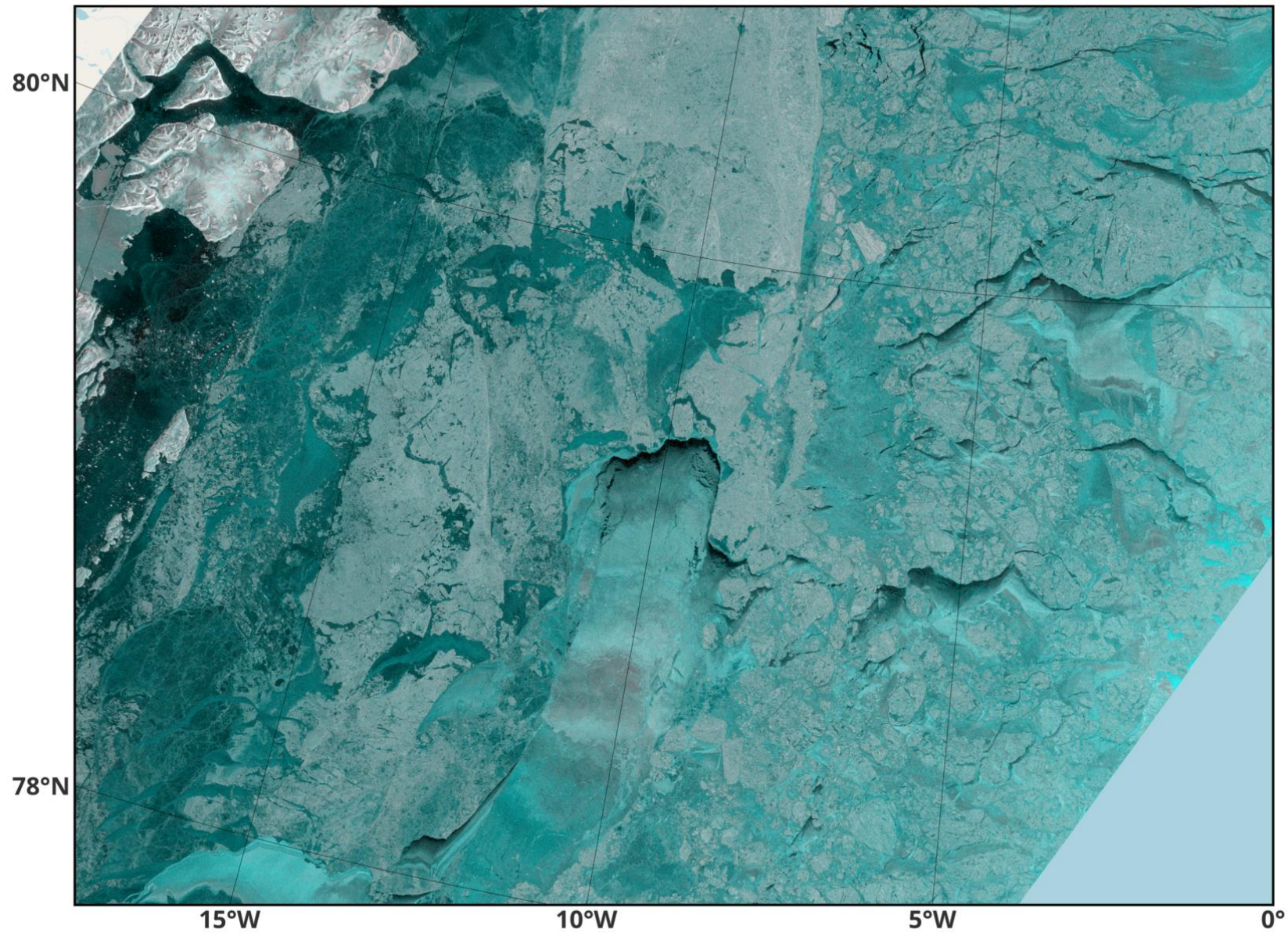
Sea ice conditions at Belgica Bank in spring 2022

Sea ice conditions at Belgica Bank in spring 2022

Optical image (Sentinel-2)   **time difference: 6h 19m**   **SAR image (Sentinel-1)**

**Open water/New ice**   **Young ice**   **Level ice**   **Deformed ice**

Sea ice conditions at Belgica Bank in spring 2022

Optical image (Sentinel-2)   time difference: 6h 19m   SAR image (Sentinel-1)

Open water/New ice   Young ice   Level ice   Deformed ice

Sea ice conditions at Belgica Bank in spring 2022

Optical image (Sentinel-2)　　　　　**time difference: 6h 19m**　　　　　**SAR image (Sentinel-1)**
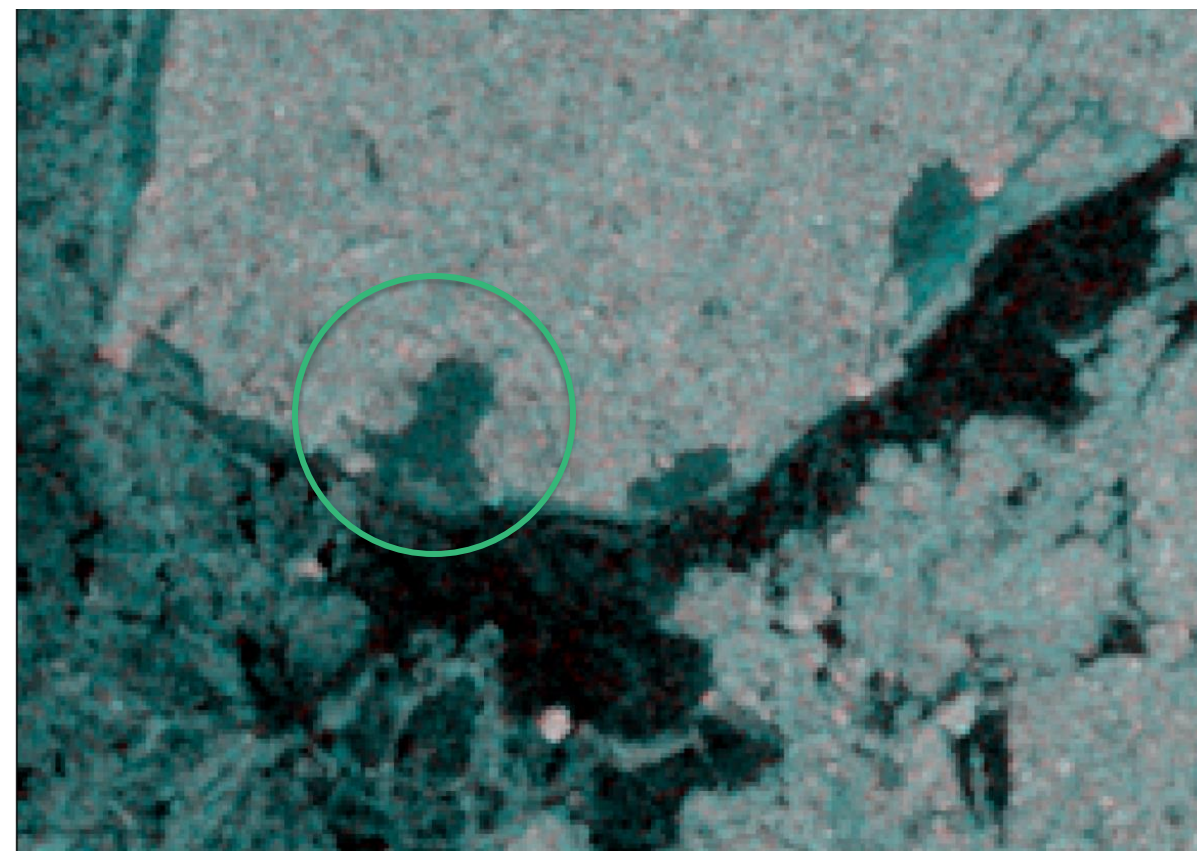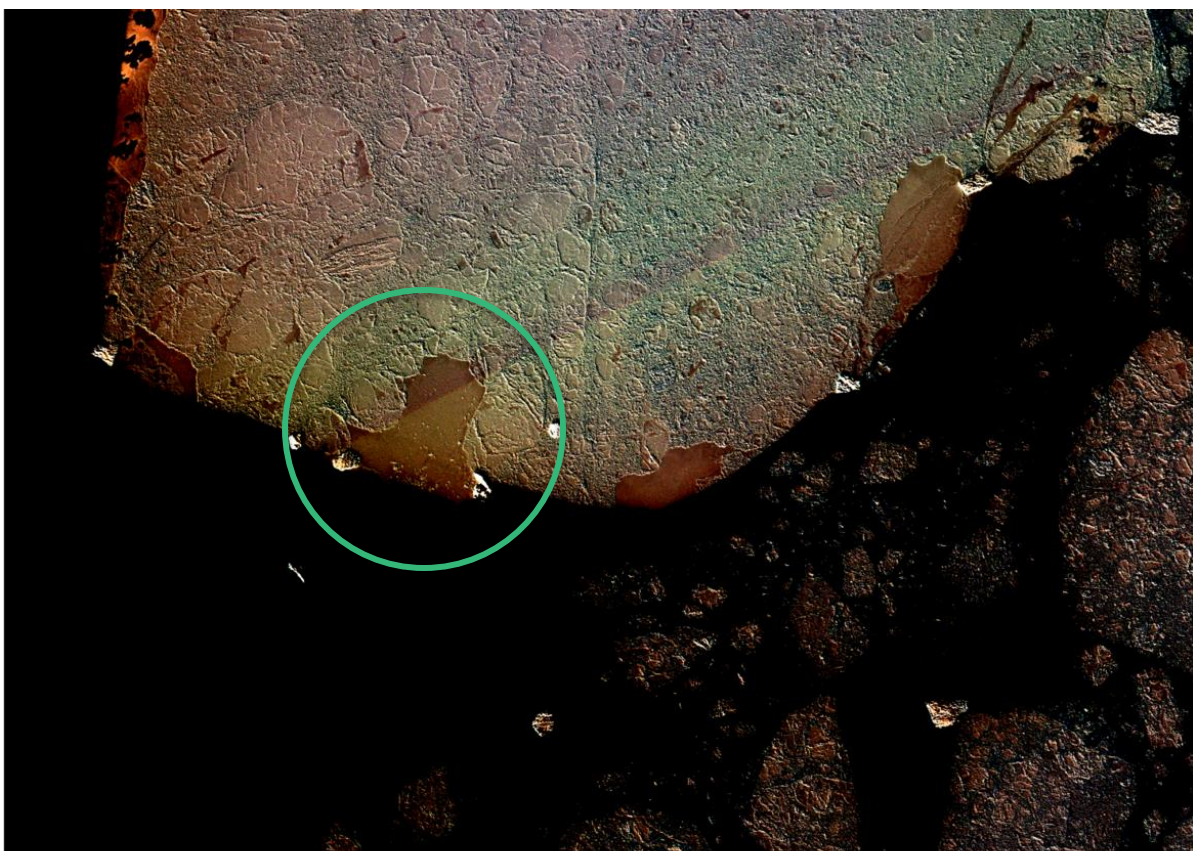
Open water/New ice　　　　**Young ice**　　　**Level ice**　　　**Deformed ice**

Processing chain

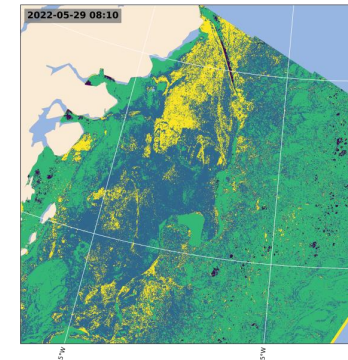**Sentinel-1**
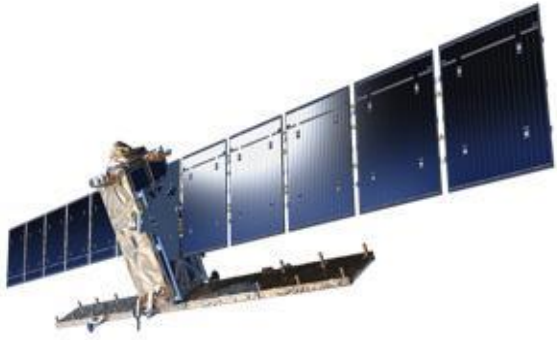
Statistical classifier developed at UiT

```
jo@gizmo: ~/work/cirfa_cruise
import ice_type_classification.classification as cl

import config.cirfa_cruise_folder_structure as CIRFA22

# -------------------------------------------------------------------
# -------------------------------------------------------------------

p = argparse.ArgumentParser(
    formatter_class=argparse.RawDescriptionHelpFormatter,
    description=__doc__
)
p.add_argument(
    'S1_base',
    help='S1 image basename'
)
p.add_argument(
    'classifier_model_path',
    help = 'path to classifier model pickle file'
)
```

Geo-referenced classification results
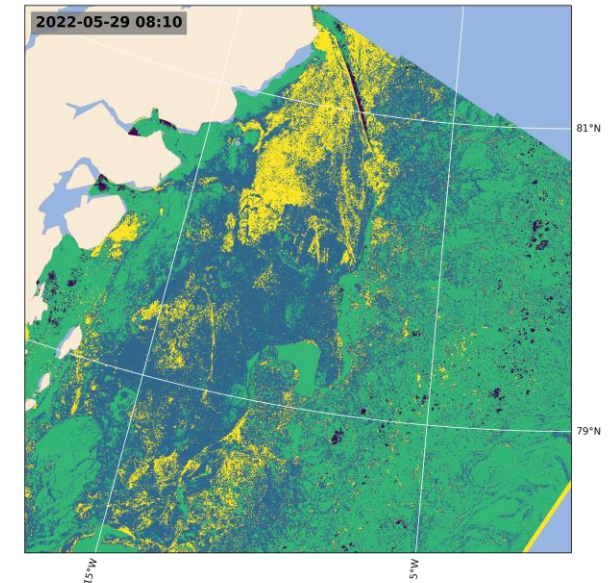
Processing chain to KPH

Statistical classifier developed at UiT

Sentinel-1

Git Lab

UiT/CIRFA

MET Norway Ice Service

S3 store

FTP server

Validation

Ship
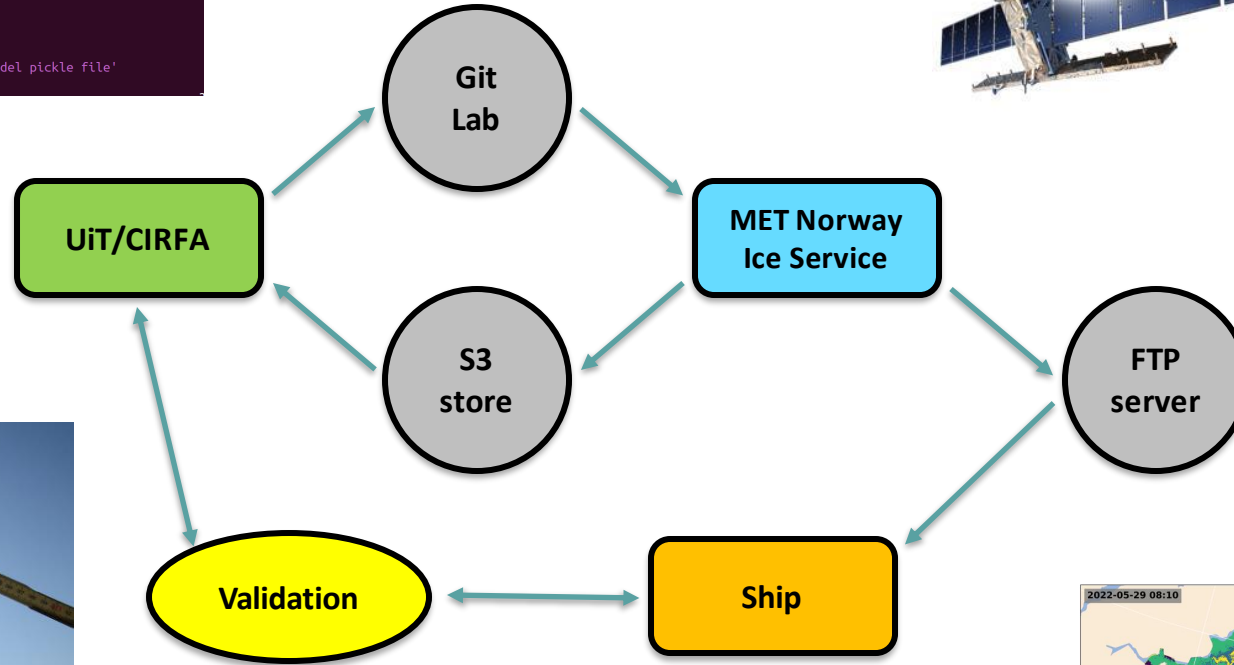
Ice observations, drone imagery, in-situ data

results available on KPH within 2-5 hours

Geo-referenced classification results

At different spatial resolution (and file size)

Processing chain to KPH

Goal: Test automated ice type mapping in an "operational setting"

- Demonstrate that we can transfer classification results in NRT to the vessel ✔
- Validate the results in the field
- Use images and classification results to assist in route planning for KPH

Time series of SAR and classification result

400x400km
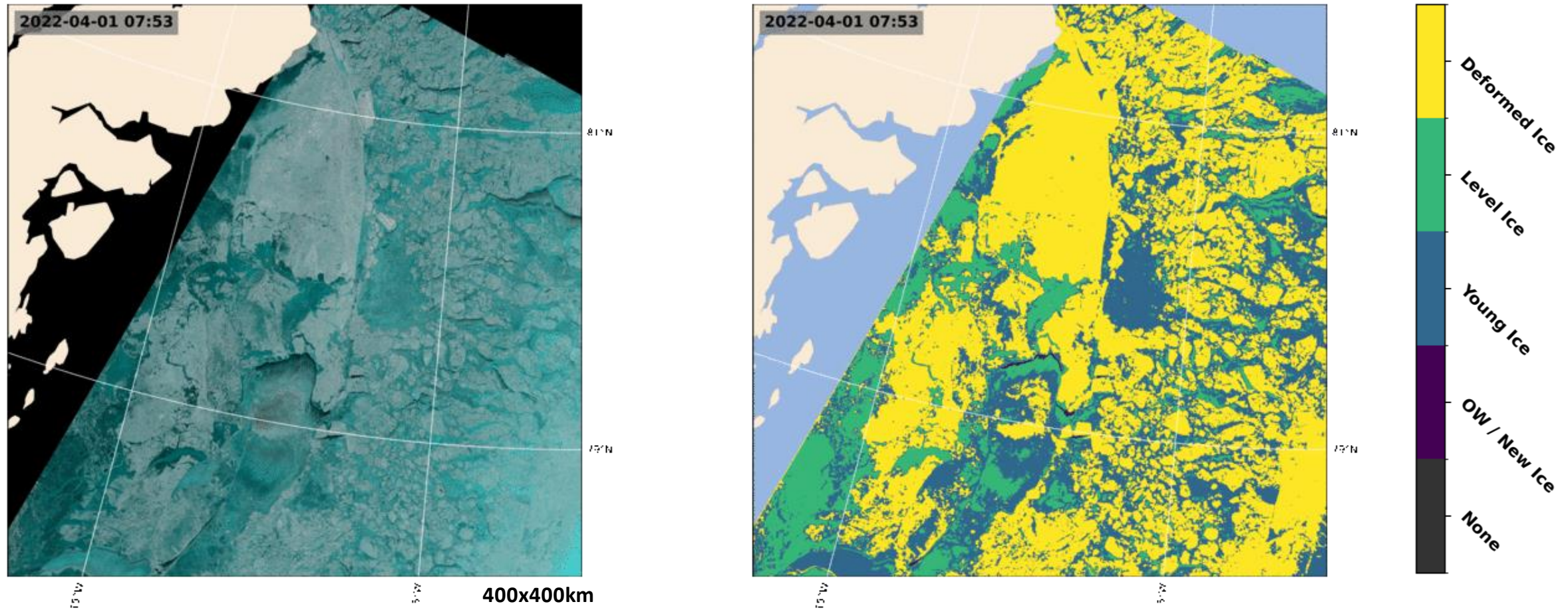
- Landfast area easy to identify in SAR and classification result
- Classification of landfast areas robust across the swath
- Patterns of 2 polynyas are captured by classification
- Some mis-classification of very smooth level landfast ice as OW
- Ice types become inseparable with melt onset

16

Sentinel-1: 2022/04/28 08:18 UTC

- KPH at fast ice station

- **IceObs:** Level FY fast ice

- **Clf:** Level Ice

  Results correct. Mix of OW and Young Ice behind ship
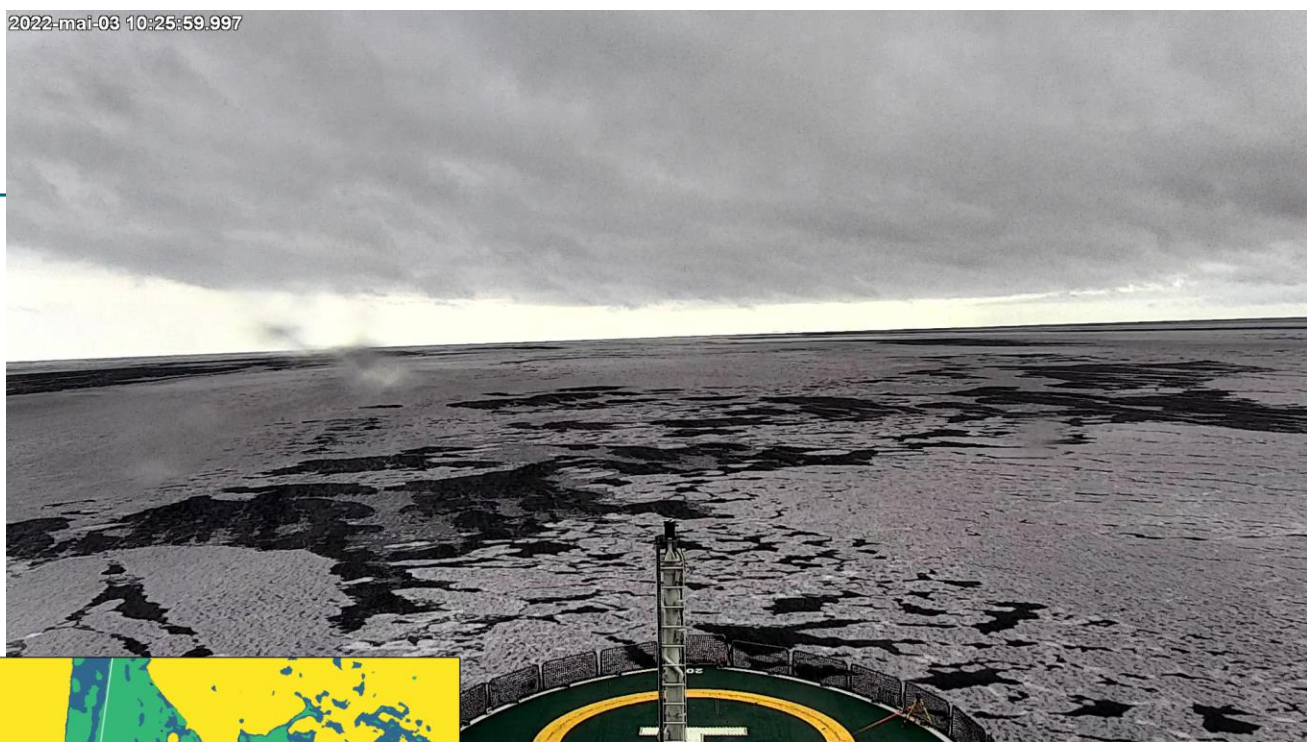 also correctly identified.

25x25km
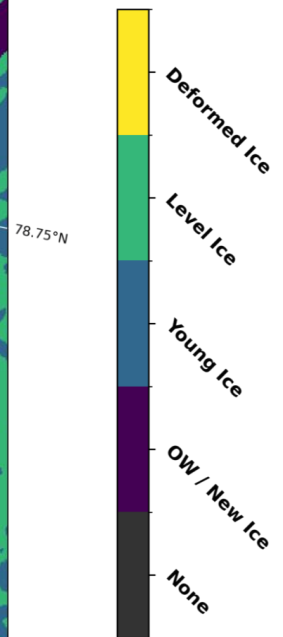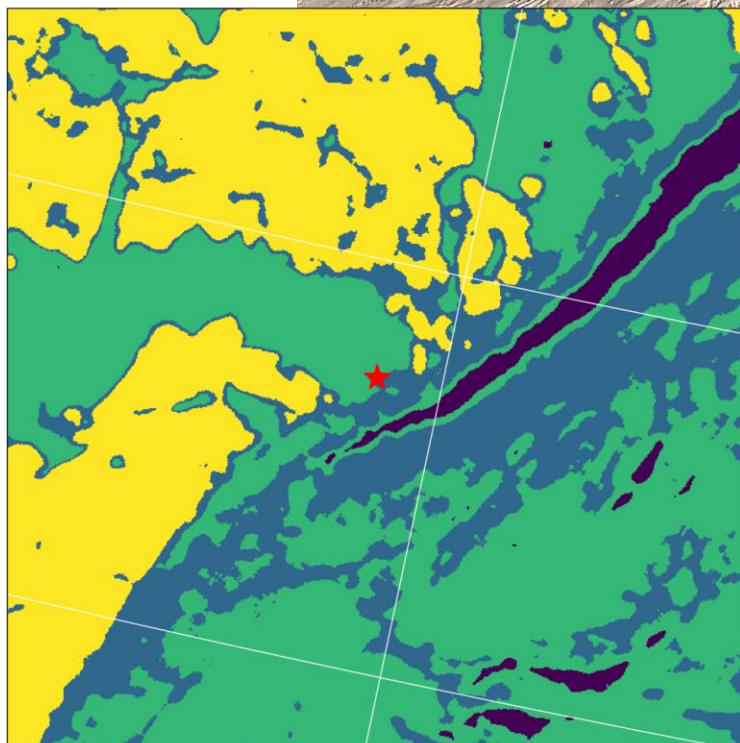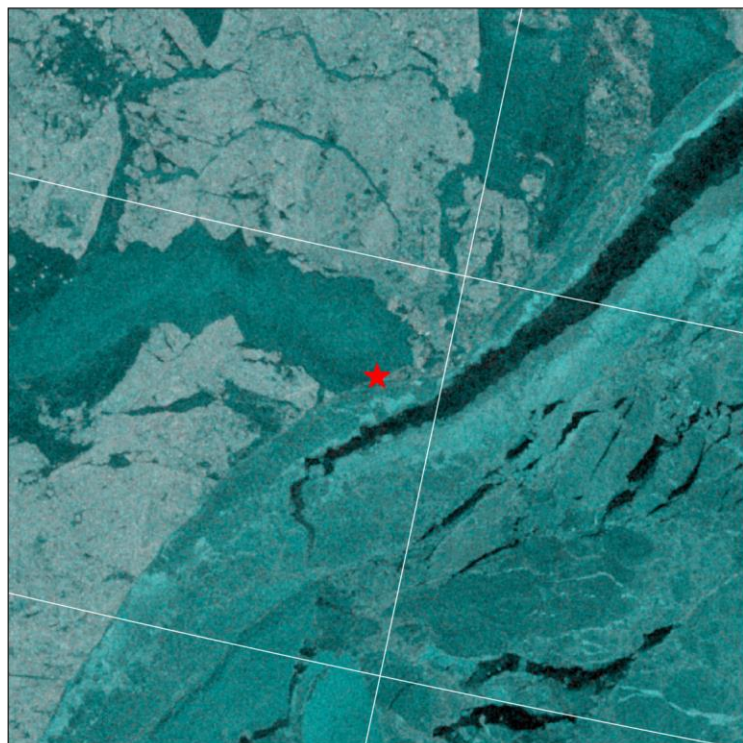
Sentinel-1: 2022/04/30 08:01 UTC

- KPH traveling through Polynya area

- **IceObs:** Young Ice, finger rafting and small ridging

- **Clf:** Mixture of OW/New Ice, Young Ice, Level Ice

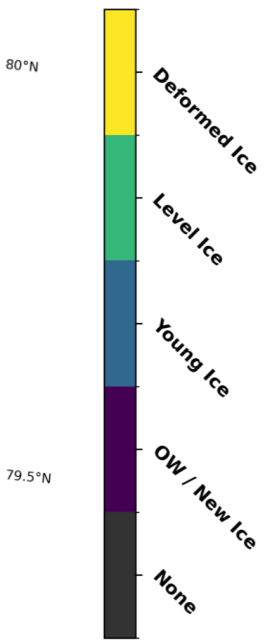 Results ok. Ice types not entirely correct. Area for easy travel correctly identified.
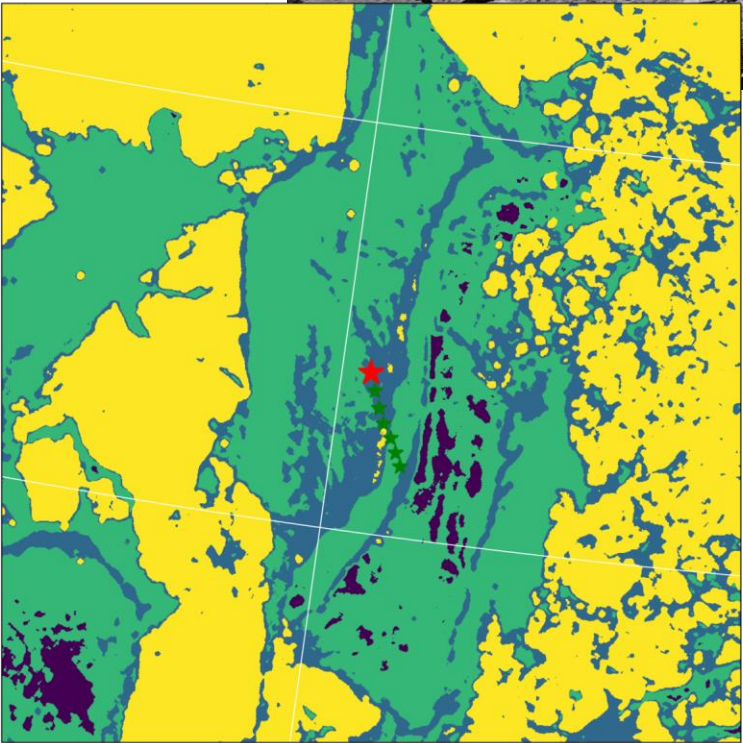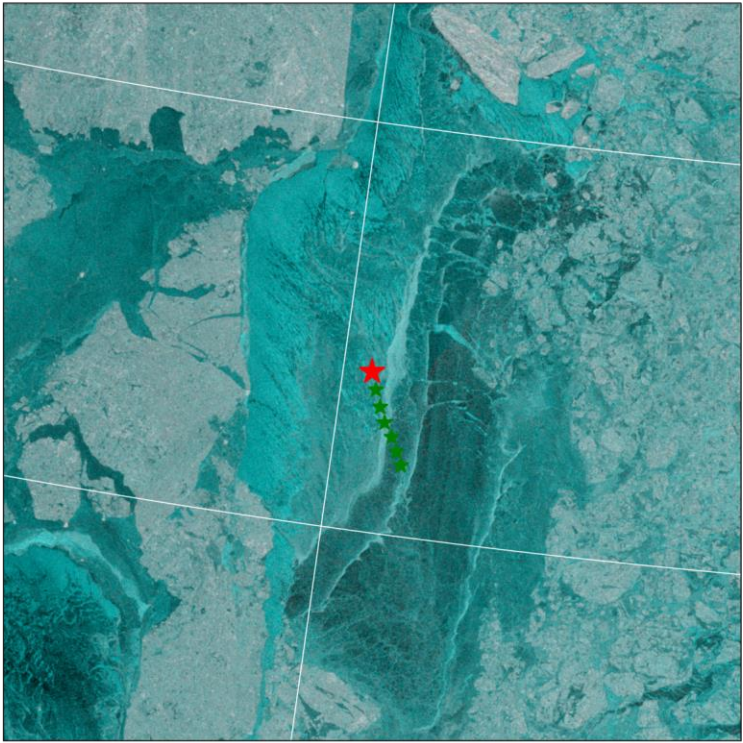
50x50km
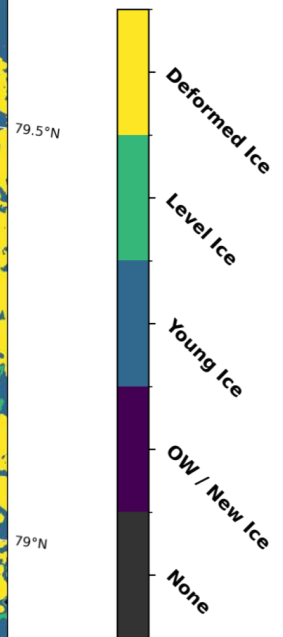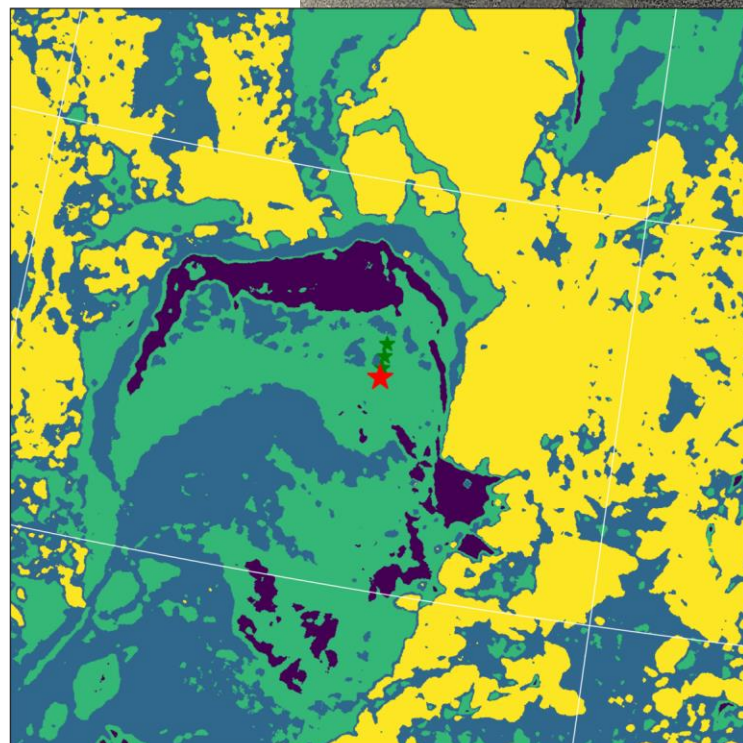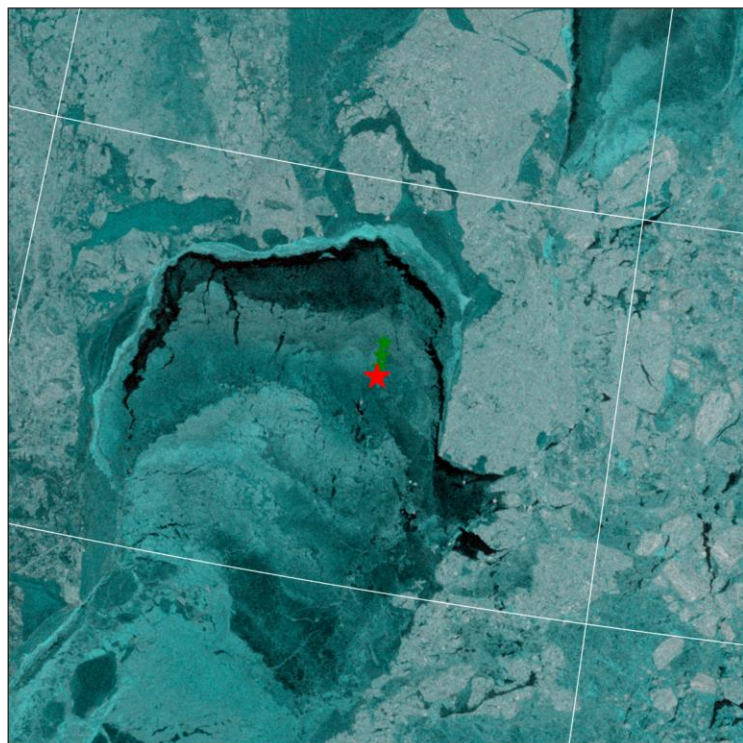
Sentinel-1: 2022/05/03 08:26 UTC

- KPH traveling through Polynya area
- **IceObs:** Young Ice with FF, finger rafting/ridging, some OW spots
- **Clf:** Young Ice, small patches of Level Ice

  Results ok. Ice types correctly identified. OW spots are missing, probably because of small size
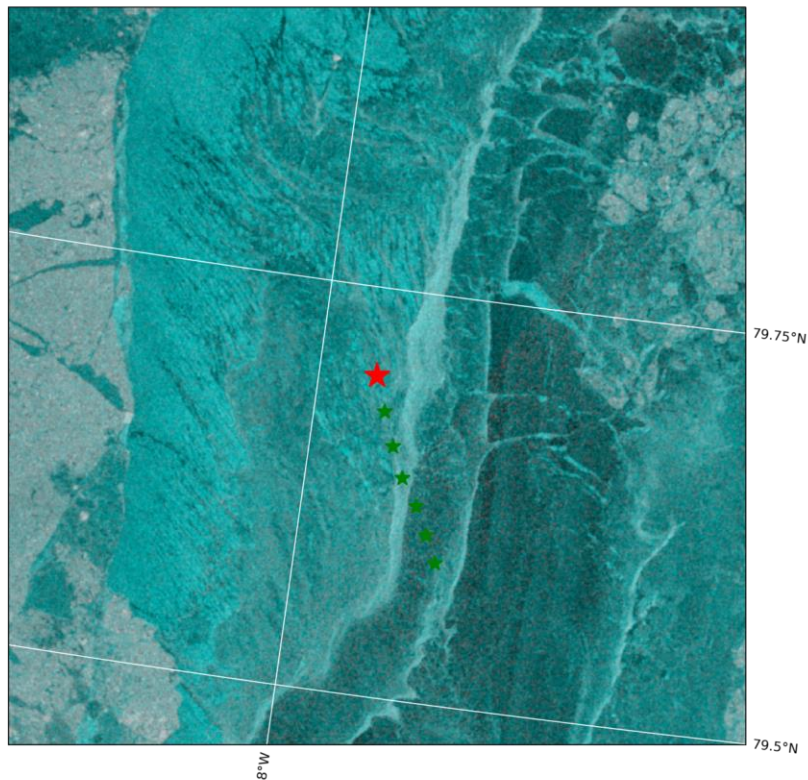
50x50km

Sentinel-1: 2022/05/03 08:26 UTC

- KPH traveling through Polynya area

- **IceObs:** Young Ice with FF, finger rafting/ridging, some OW spots

- **Clf:** Young Ice, small patches of Level Ice

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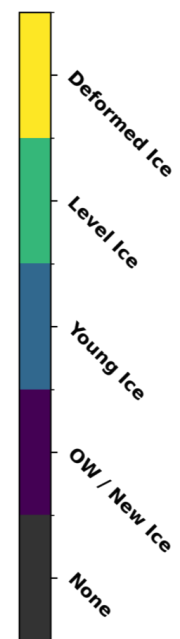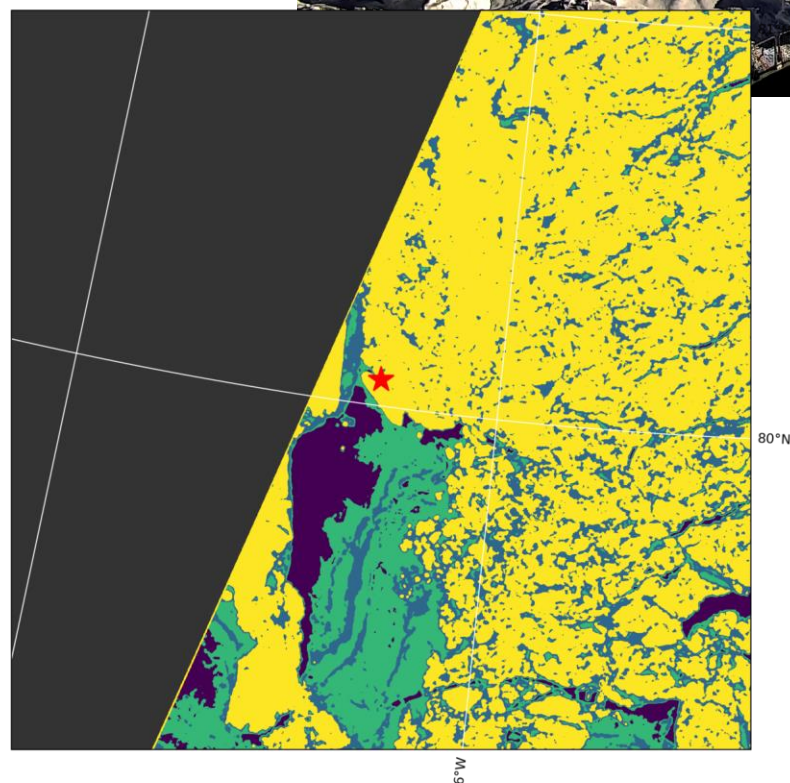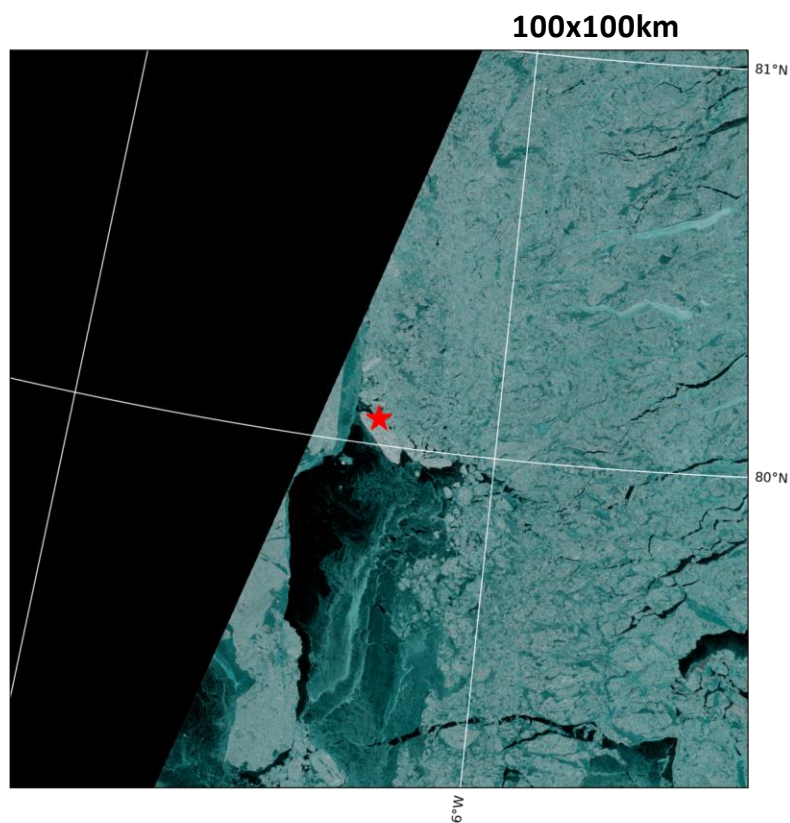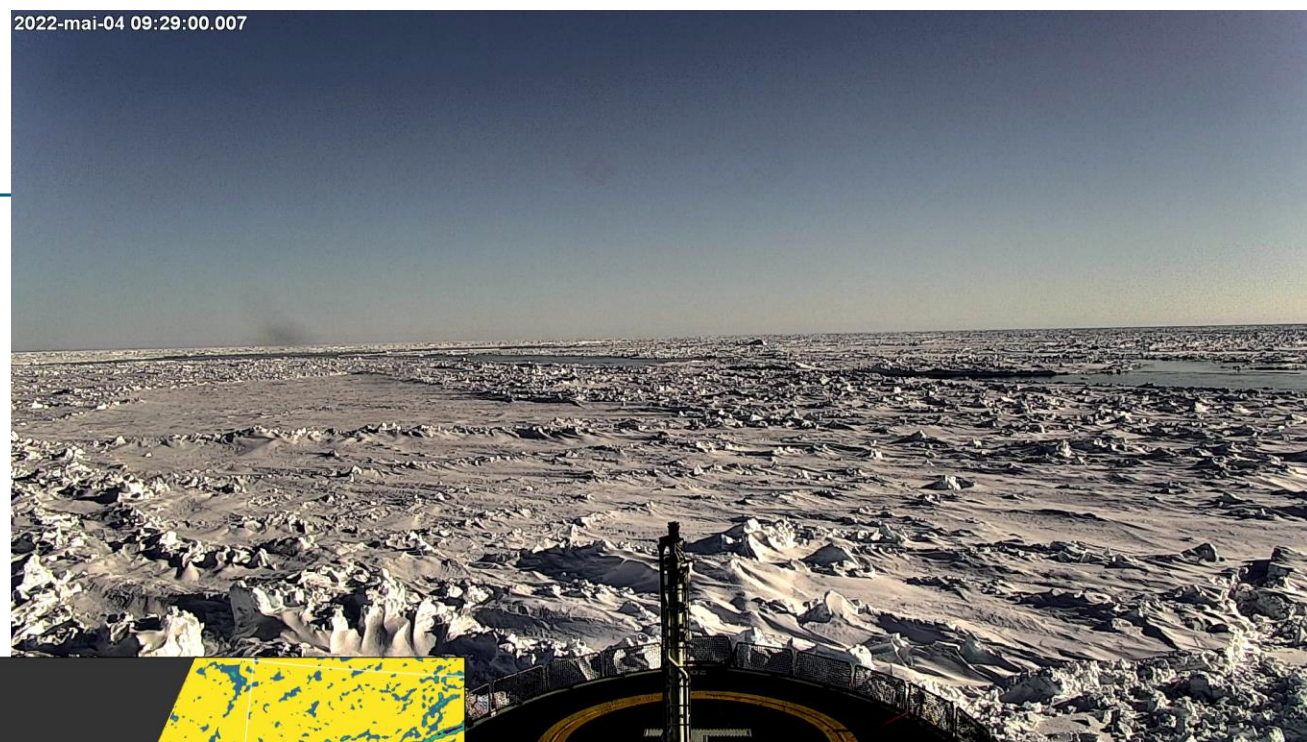
  probably because of small size

25x25km
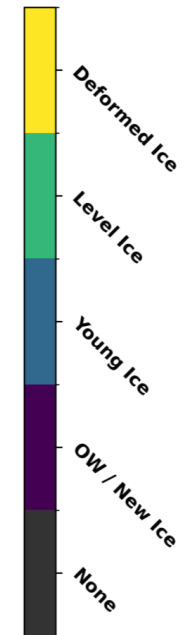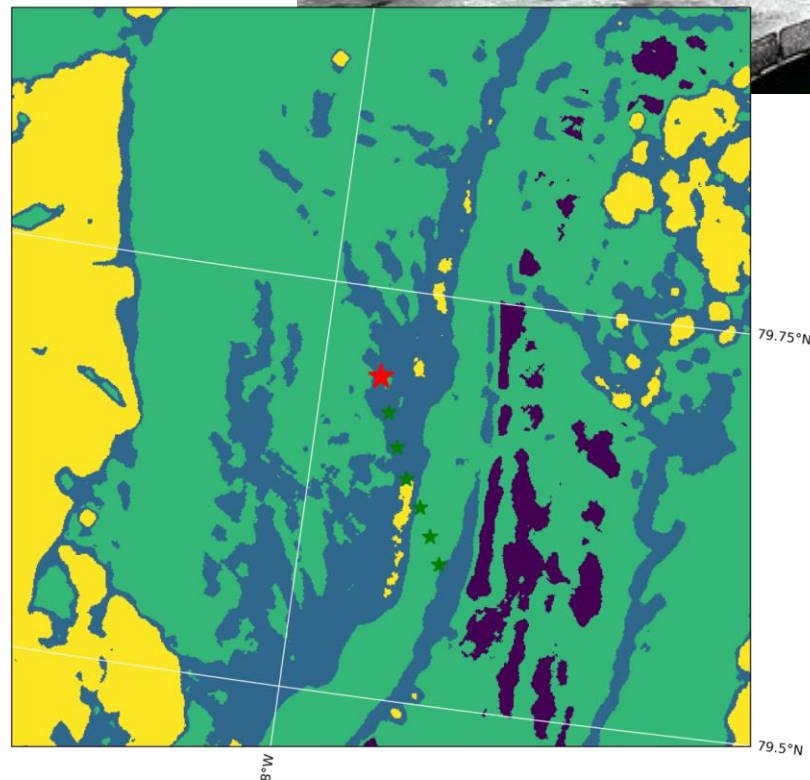
- Deformed Ice
- Level Ice
- Young Ice
- OW / New Ice
- None

20

Sentinel-1: 2022/05/04 07:29 UTC

- KPH stuck in deformed ice

- **IceObs:** Deformed Ice, small patches of Level Ice or OW

- **Clf:** Deformed Ice

  Results correct

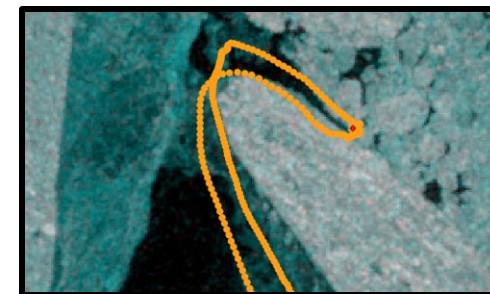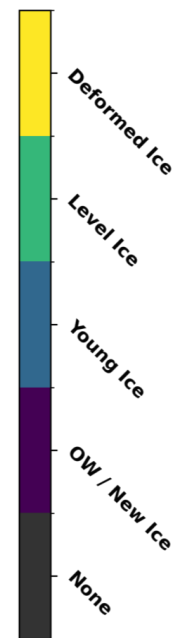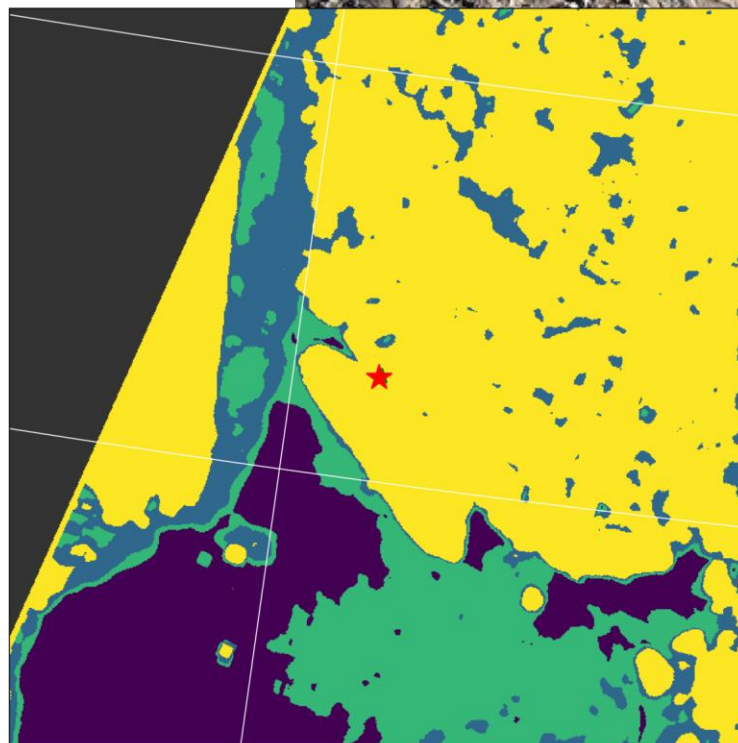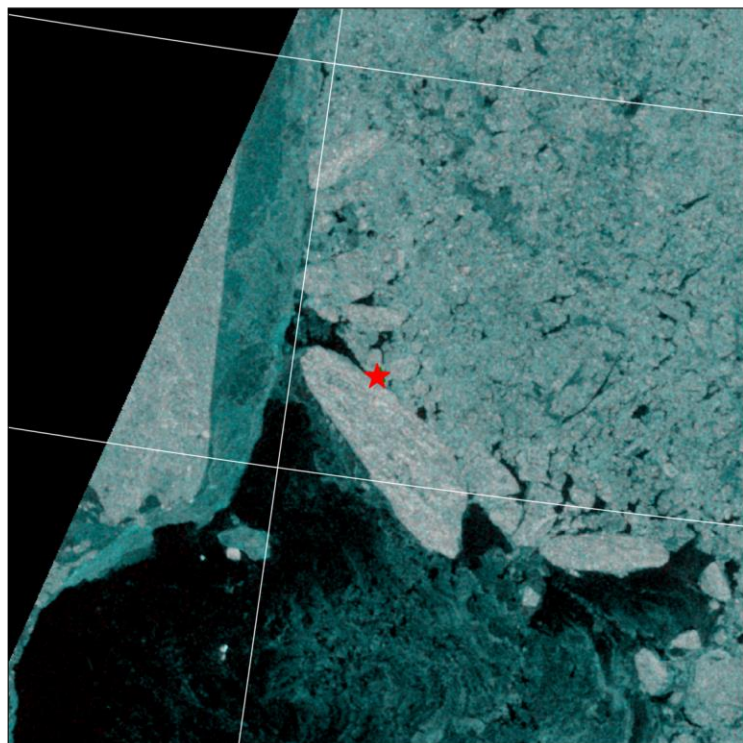100x100km

Sentinel-1: 2022/05/04 07:29 UTC

- KPH stuck in deformed ice

- **IceObs:** Deformed Ice, small patches of Level Ice or OW

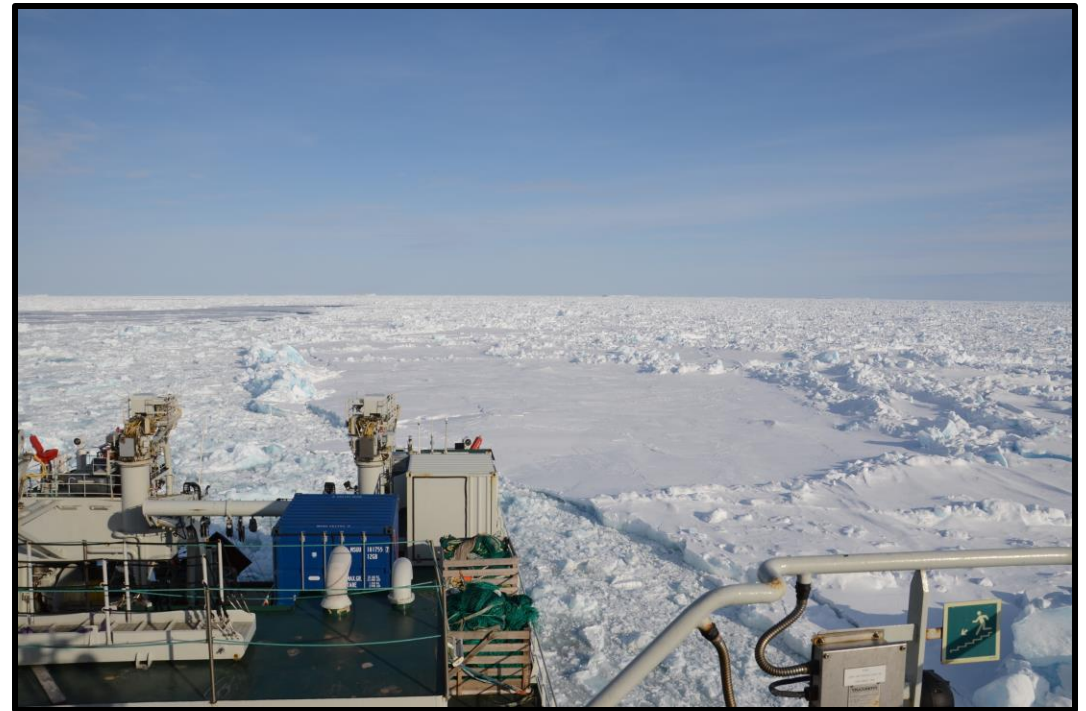- **Clf:** Deformed Ice

  Results correct

25x25km

Legend:
- Deformed Ice
- Level Ice
- Young Ice
- OW / New Ice
- None

KPH turns around at this point

How can this help for navigation and route planning?

Goal: Test automated ice type mapping in an "operational setting"

- Demonstrate that we can transfer classification results in NRT to the vessel ✔

- Validate the results in the field ✔ (qualitatively...)

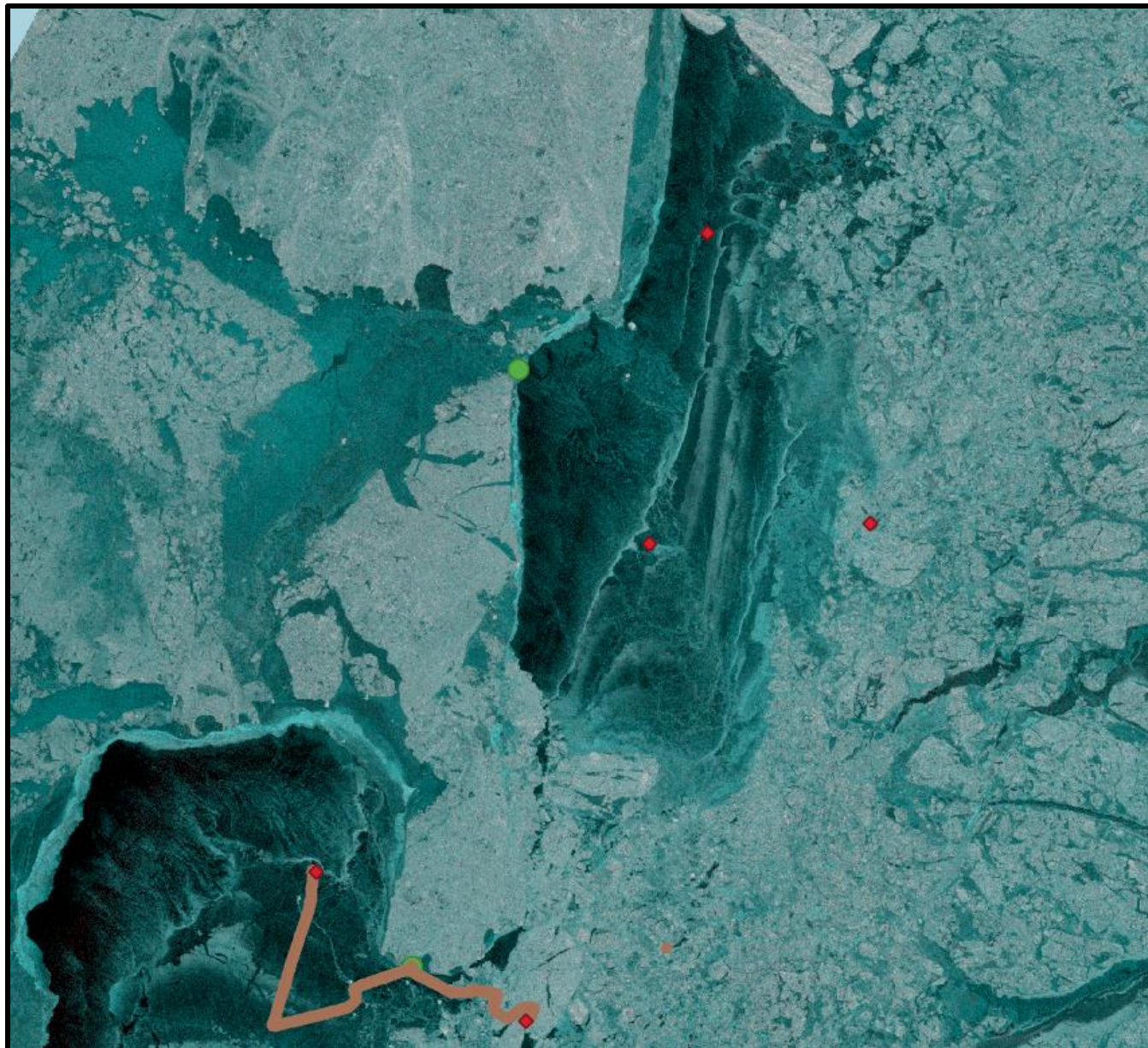- Use images and classification results to assist in route planning

Sentinel-1 for route planning and navigation

2022/05/02 07:45

- Work in "Southern Polynya" and at fast ice stations "south" and "middle" finished

- Plan to push north through area of deformed ice to try and reach planned station "fast ice north"

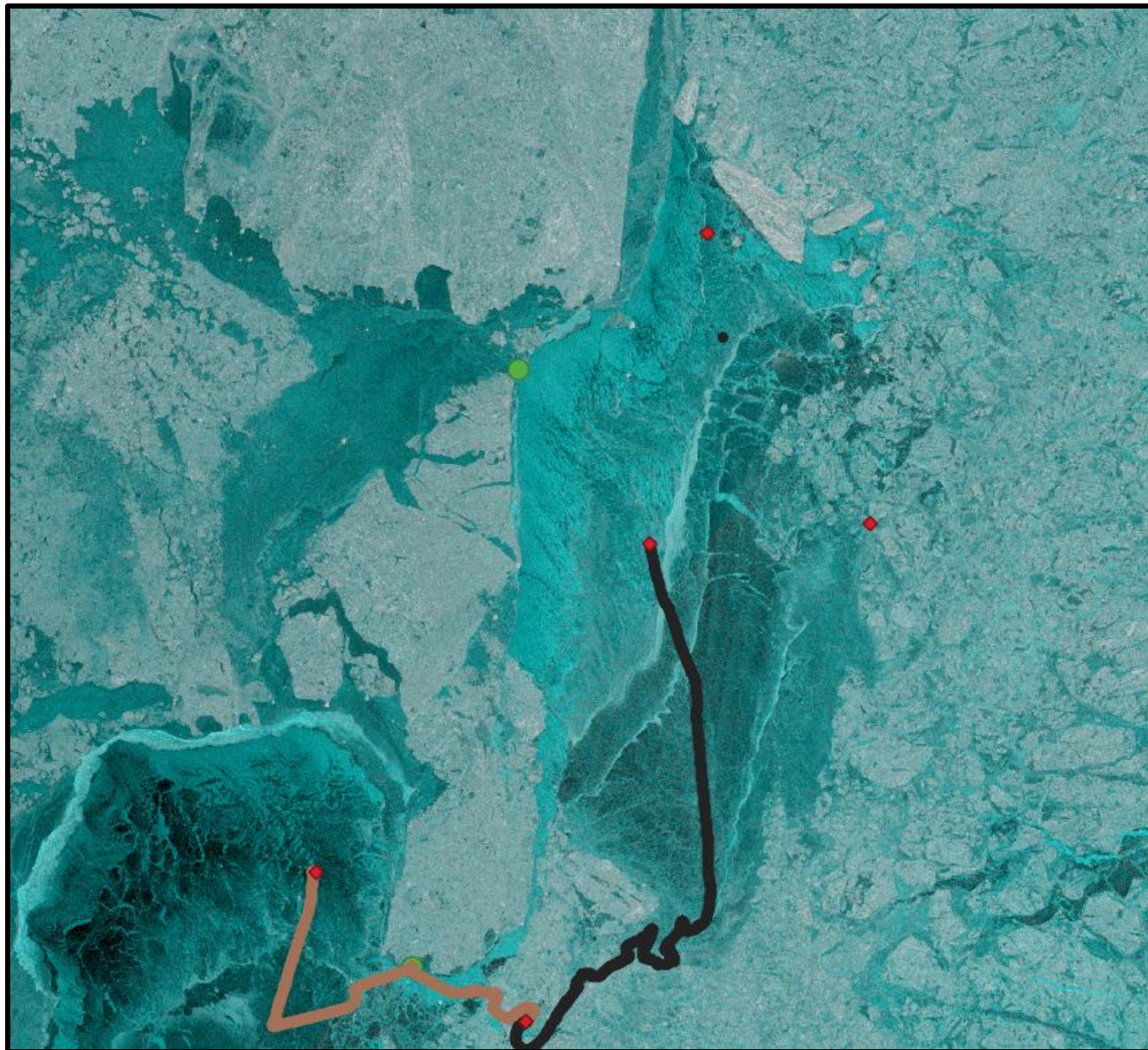- Assuming good progress in "Northern Polynya"

Sentinel-1 for route planning and navigation

2022/05/03 08:26

- Fast progress in "Northern Polynya"

- Polynya appears to form because of large ice floe blocking drift ice from the north

- Decision to abandon originally planned fast ice station further north
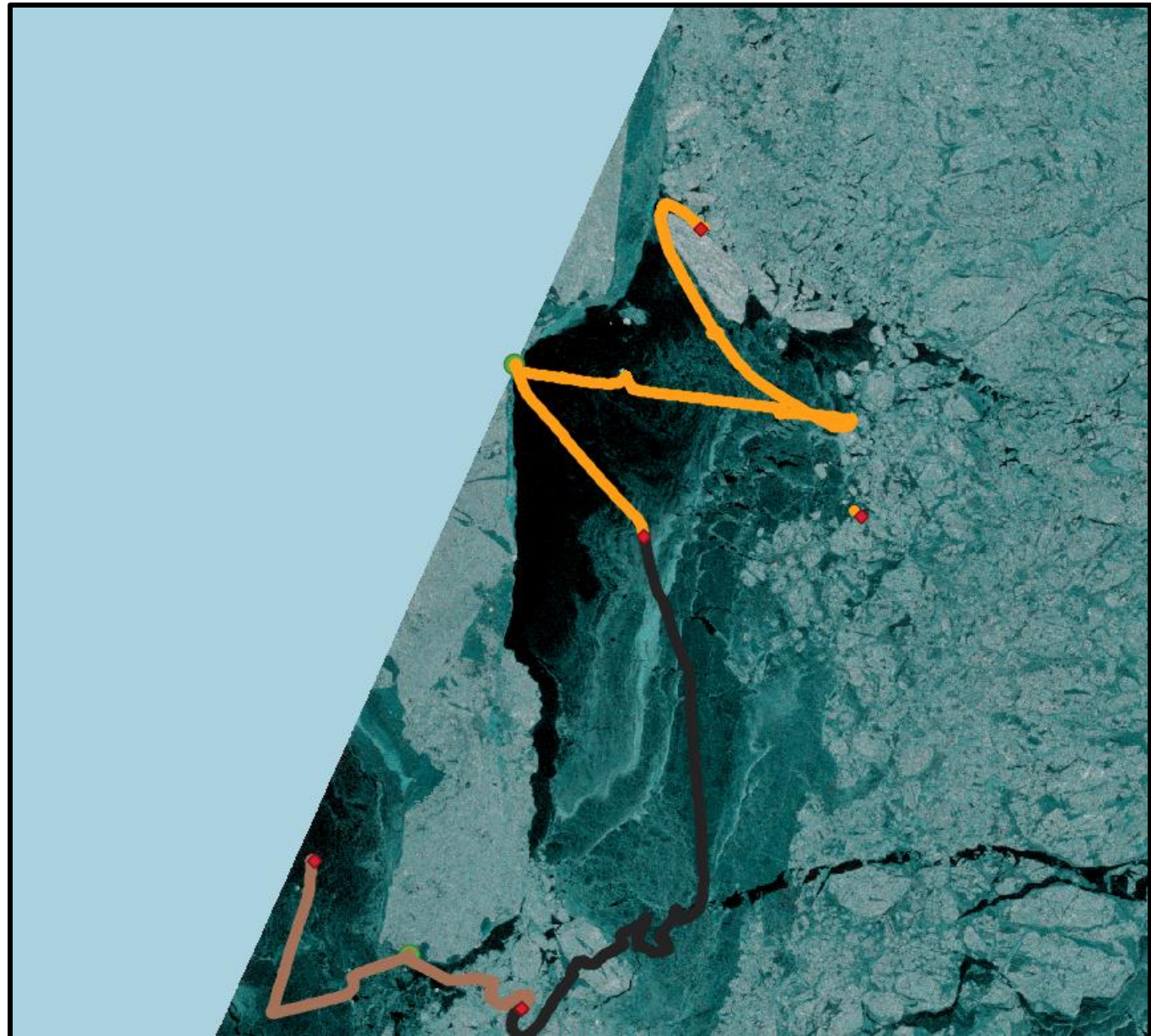
- New "fast ice north" station

140x140km

2022/05/04 07:29

- Completed new "fast ice north" station

- Plans to sample ice north of large floe

- While traveling, the floe drifts more eastward and will likely collide with the fast ice

- Danger of KPH being trapped

140x140km

2022/05/04 07:29

- Completed new "fast ice north" station

- Plans to sample ice north of large floe

- While traveling, the floe drifts more eastward and will likely collide with the fast ice
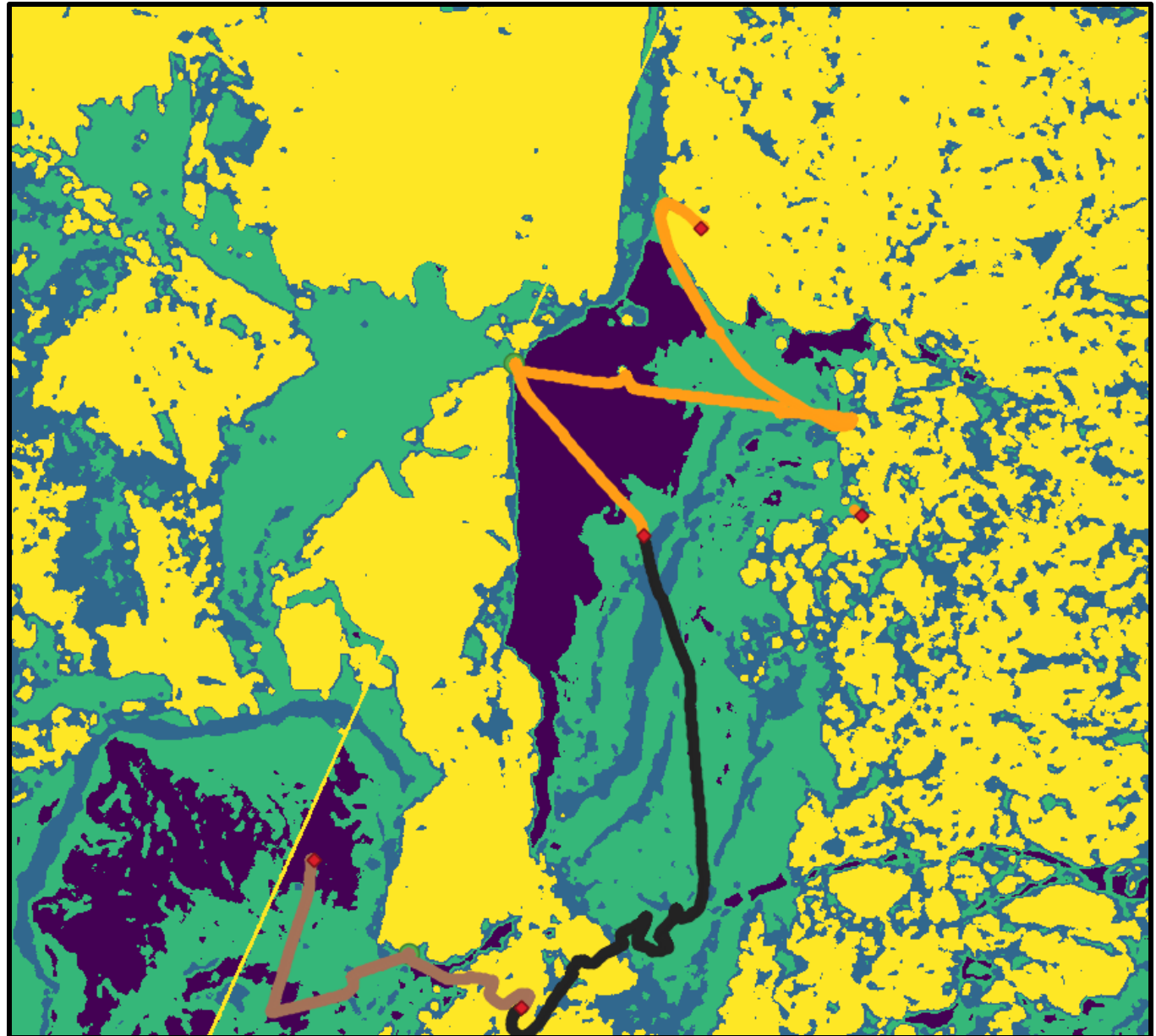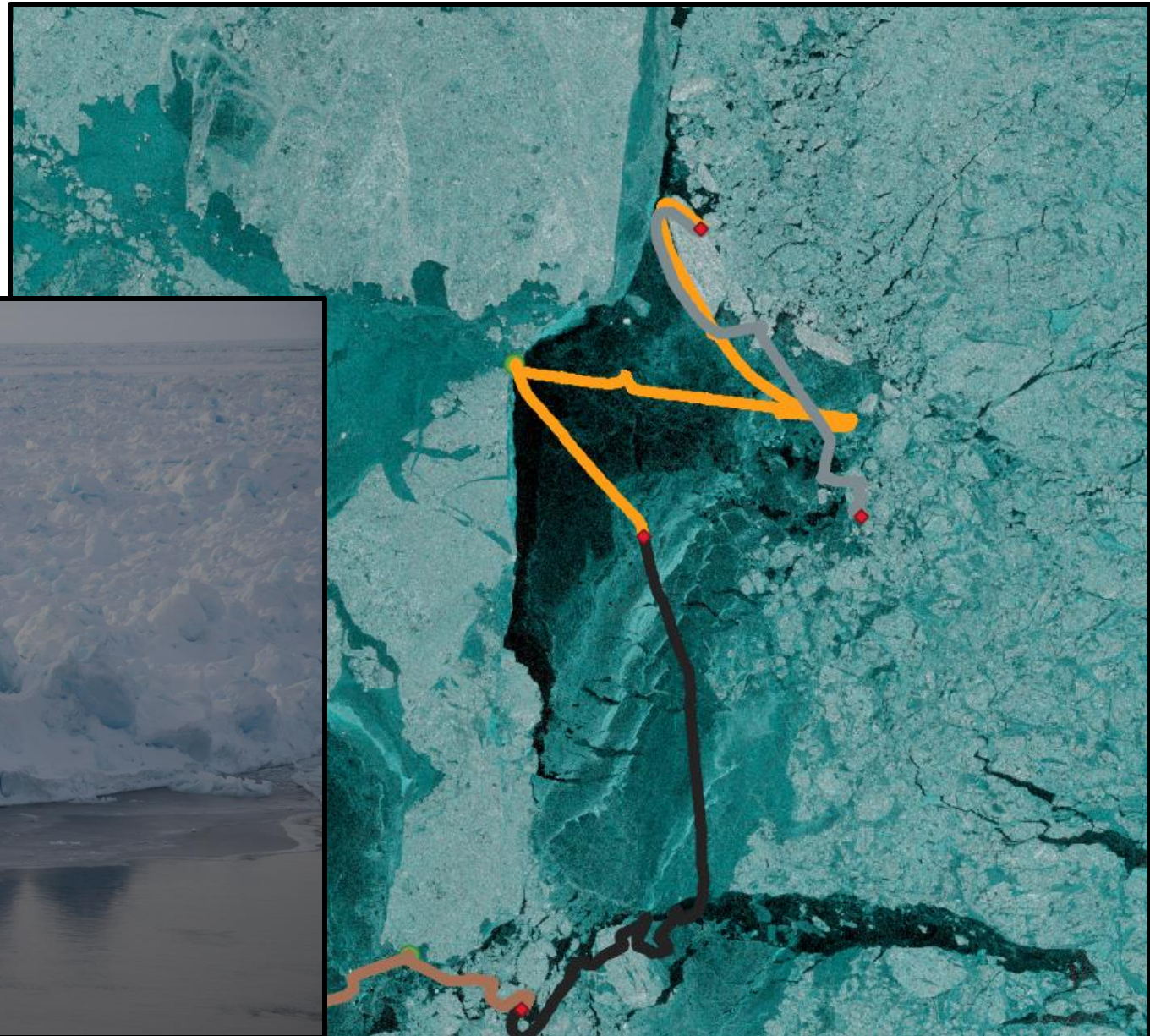
- Danger of KPH being trapped

Sentinel-1 for route planning and navigation

2022/05/05 08:10

- Let's get out of here....

Summary

Goal: Test automated ice type mapping in an "operational setting"

- Demonstrate that we can transfer classification results in NRT to the vessel ✔

- Validate the results in the field ✔

- Use images and classification results to assist in route planning for KPH ✔

What's next:

- Use drone observations for qualitative validation of results

- Include classification result as regular layer in NPI's Vixed system and/or as standard product at MET Norway Ice Service

- Combine statistical ice type classifier with CNN ice/water separation

- Combine classification with automated detection of fast ice edge

- Use ice drift estimates to predict "tomorrow's" ice situation

- . . .

Thank you

Picture courtesy: Morten Einarsve (Maritime Robotics)
CIRFA Cruise 2022