Navigating Icy Waters: Harnessing Earth Observation and AI for Optimal Polar Routes

Lasse Rabenstein (Drift Noise Polar Services GmbH)

Projekte **Fast-Cast2** und **EisKlass2**

DRIFT+NOISE
Polar Services

mFUND
Das Startkapital für die Mobilität 4.0

Ice Navigation in 2007 – ARK XXII/2

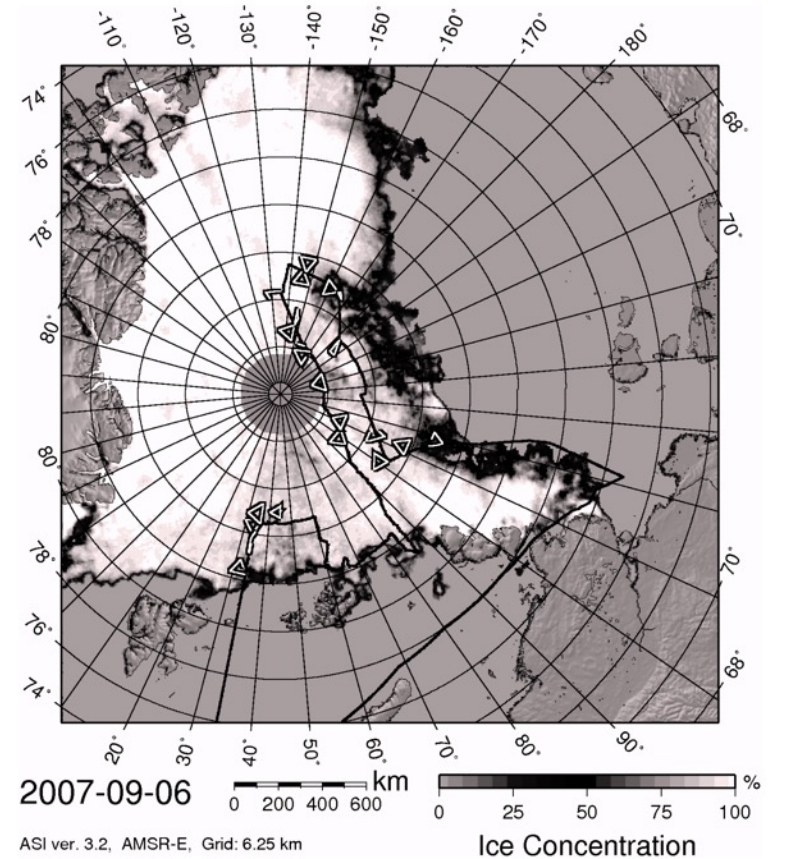

Fig. 3.1.2: Map of EM-Bird flight tracks(triangles)

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AWI Spin-off

esa business incubation centre
Northern Germany


Paul Cochrane


Alexandra Stocker


Jakob Belter


Hannah Jansen


Lasse Rabenstein


Henning Weidenhöfer


Bernhard Schmitz


Taib Hayat


Matthias Hegmann

ICY SEA

Software Development

Consulting, Expedition and Navigation Support

Research

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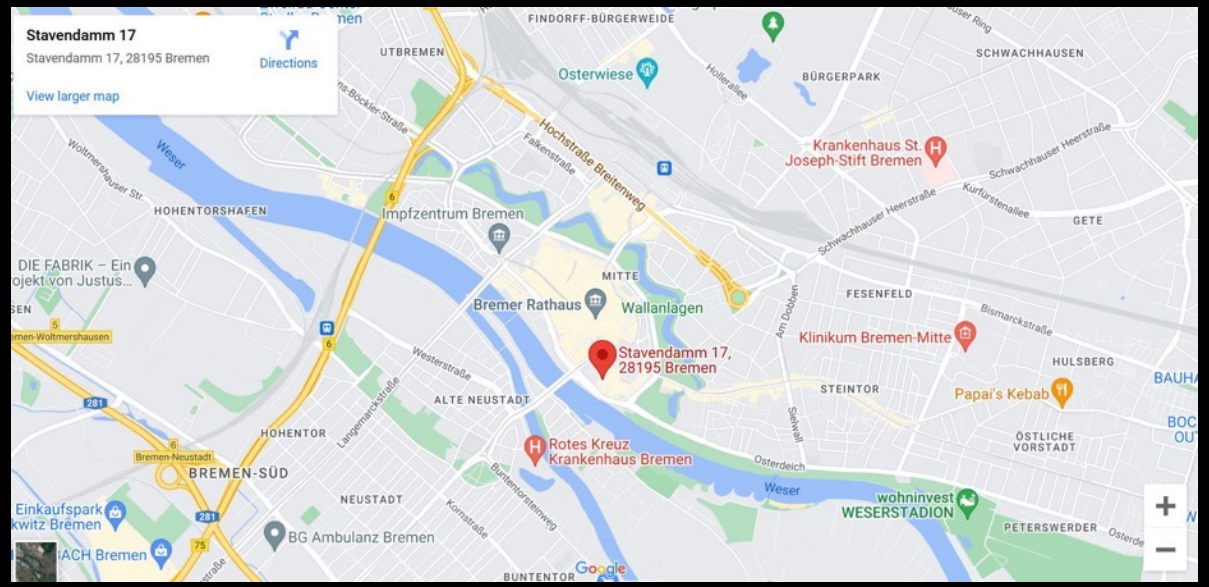
Where are we?



Paradigm change in EO data availability

- 20 new satellites and instruments
- 50‘000 Terrabyte of data in 2022
- €4.3bn spend in the period 2014 to 2020
- € 0 EUR access fees


esa
DRIFT+NOISE
Polar Services
0 days 00 hours 00 minutes
Sentinel-2 constellation:
summer solstice

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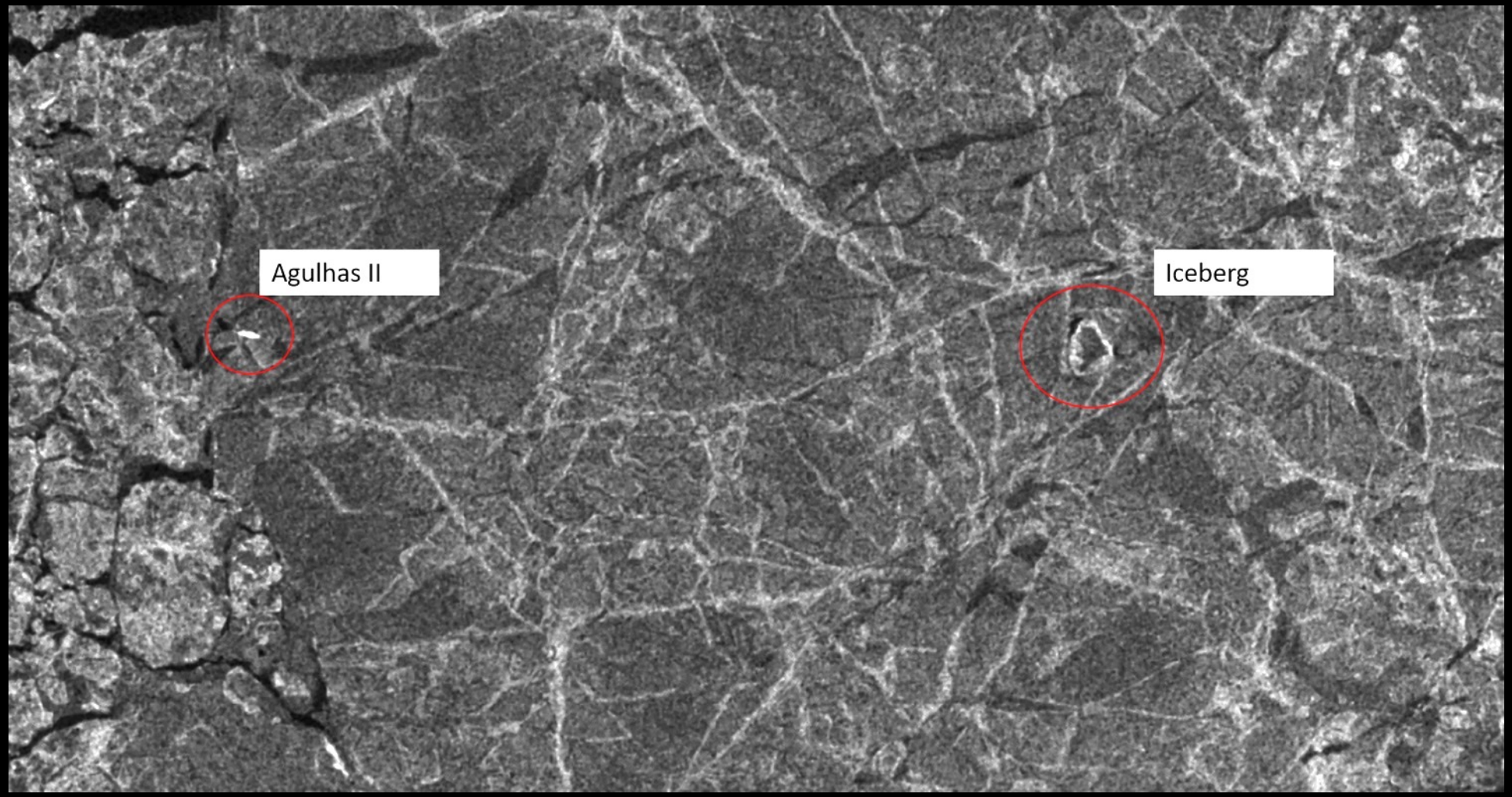
Polar Services

Private EO Industry



ICECYE SAR image / Endurance 22

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Private EO Industry

Copyright Planet Labs / Endurance 22

PS-101 (2016) automatic image delivery with FRAM-Sat

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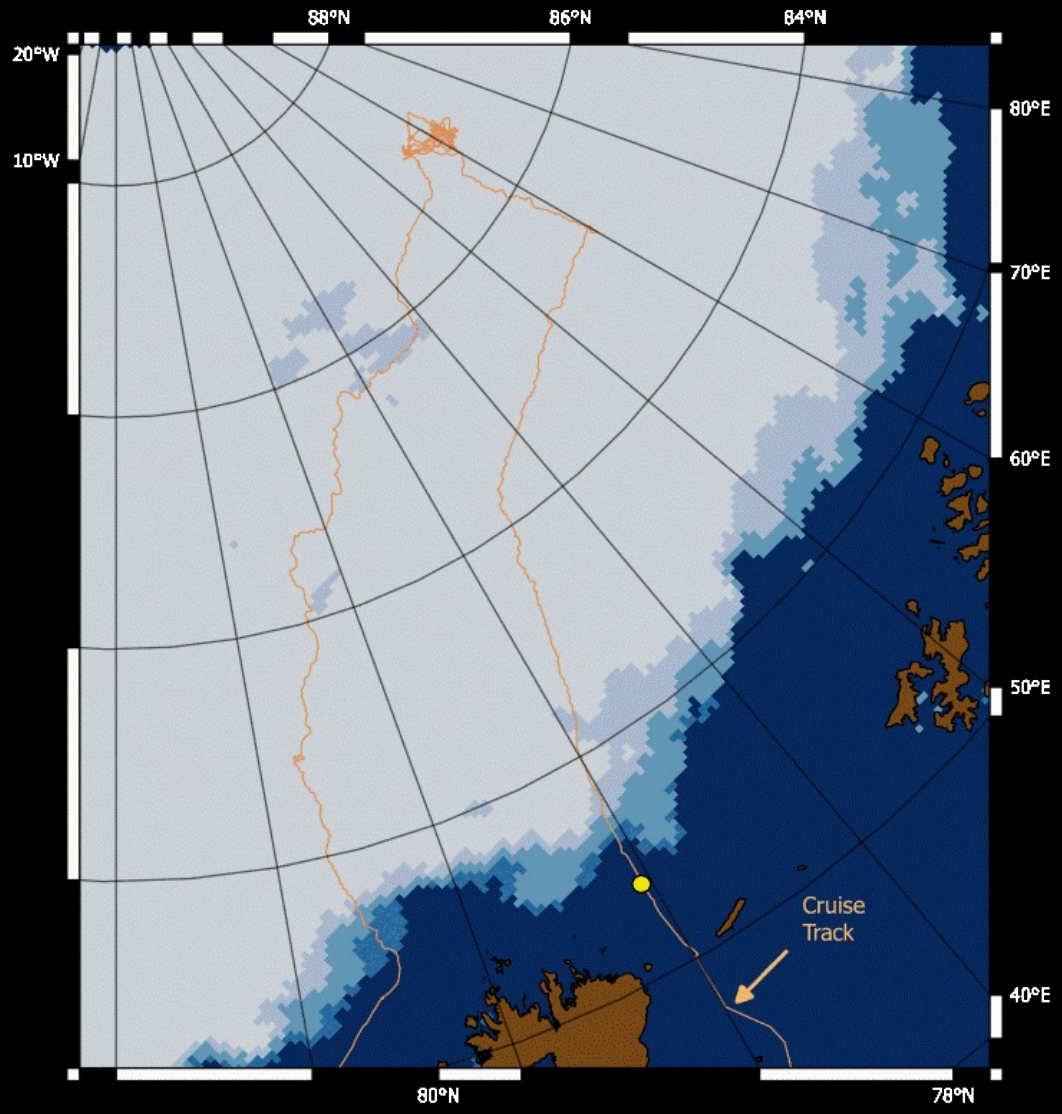
PS-101 (2016) automatic image delivery with FRAM-Sat

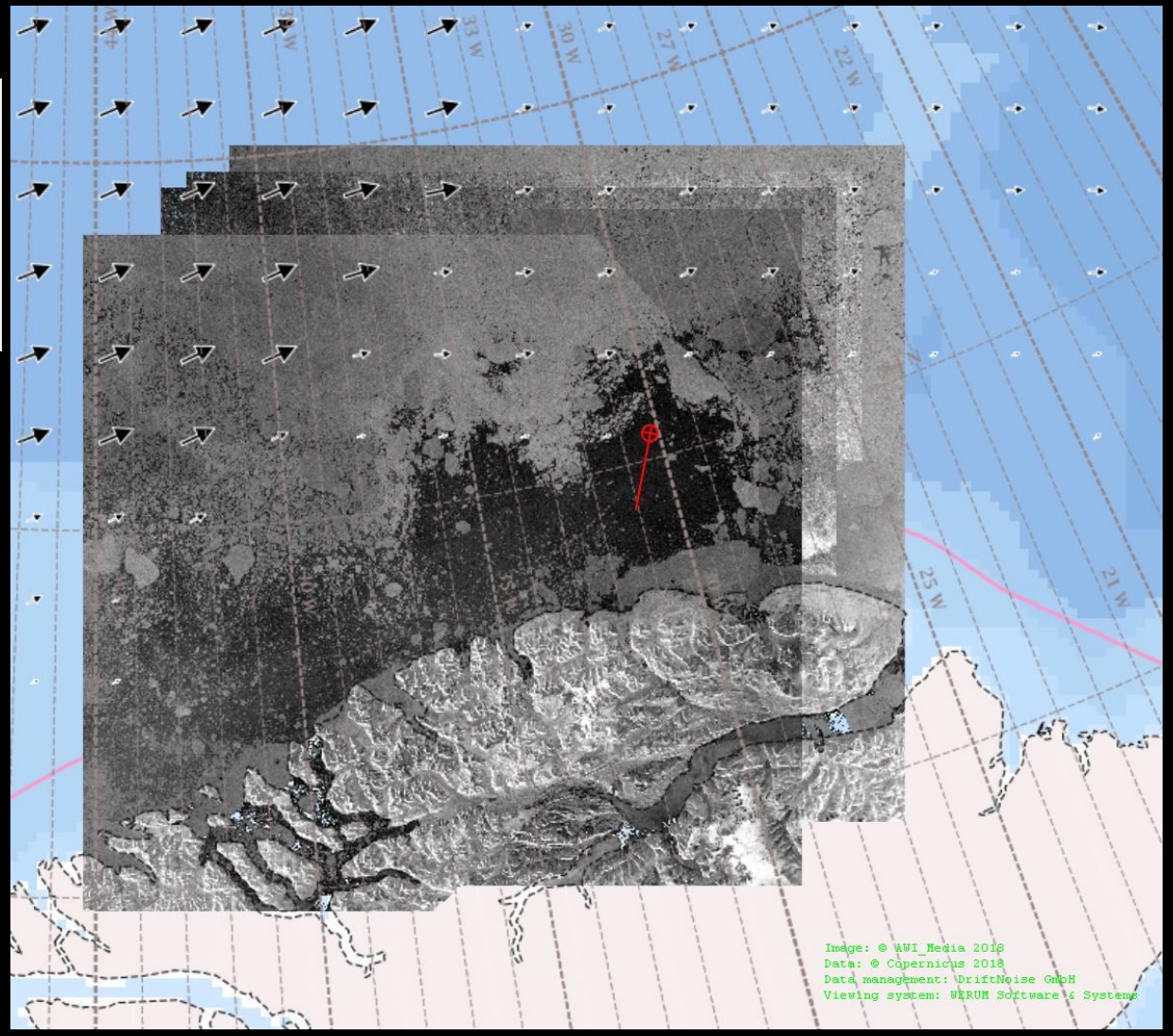


Mapviewer System on Polarstern Greenland 2018

PS115.1 - weekly report Nr. 3 | 20.08. - 26.08.2018

Surprising ice conditions favor measurements further north

[27. August 2018] **The second half of our cruise started with a northwesterly directed transit. To follow the originally planned seismic profiles we would have had to cross an ice field of approximately 40 nautical miles.**



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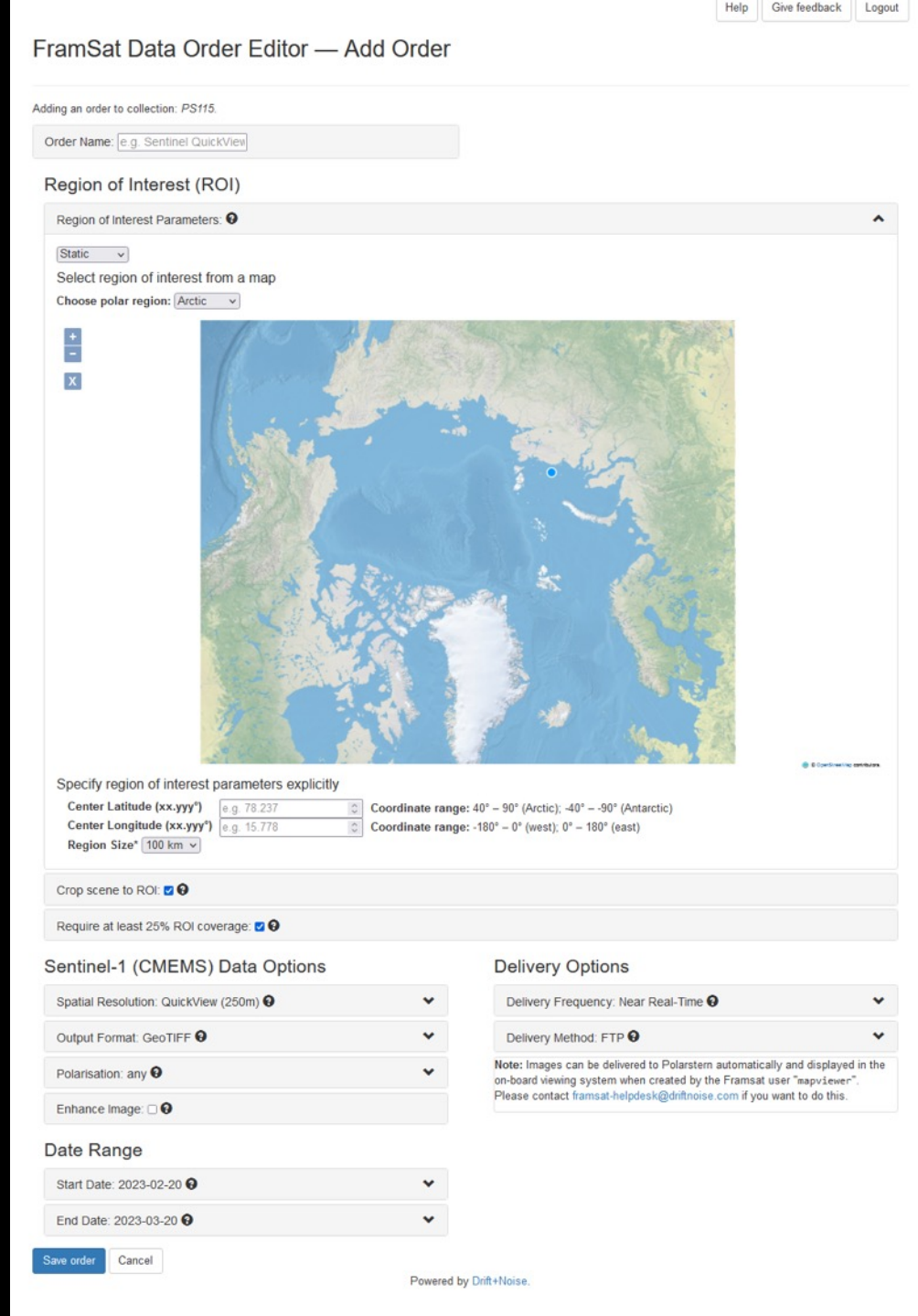
https://framsat.driftnoise.com/



Navigation mit Schiffsradar

Alfred-Wegener-Institut/Robert Ricker (CC-BY 4.0)

DRIFT+NOISE
Polar Services

85°N

16°E

A

26°E

24°E

14°E

B

84°N

Navigation mit Schiffsradar

Alfred-Wegener-Institut/Robert Ricker (CC-BY 4.0)

DRIFT+NOISE
Polar Services

85°N

16°E

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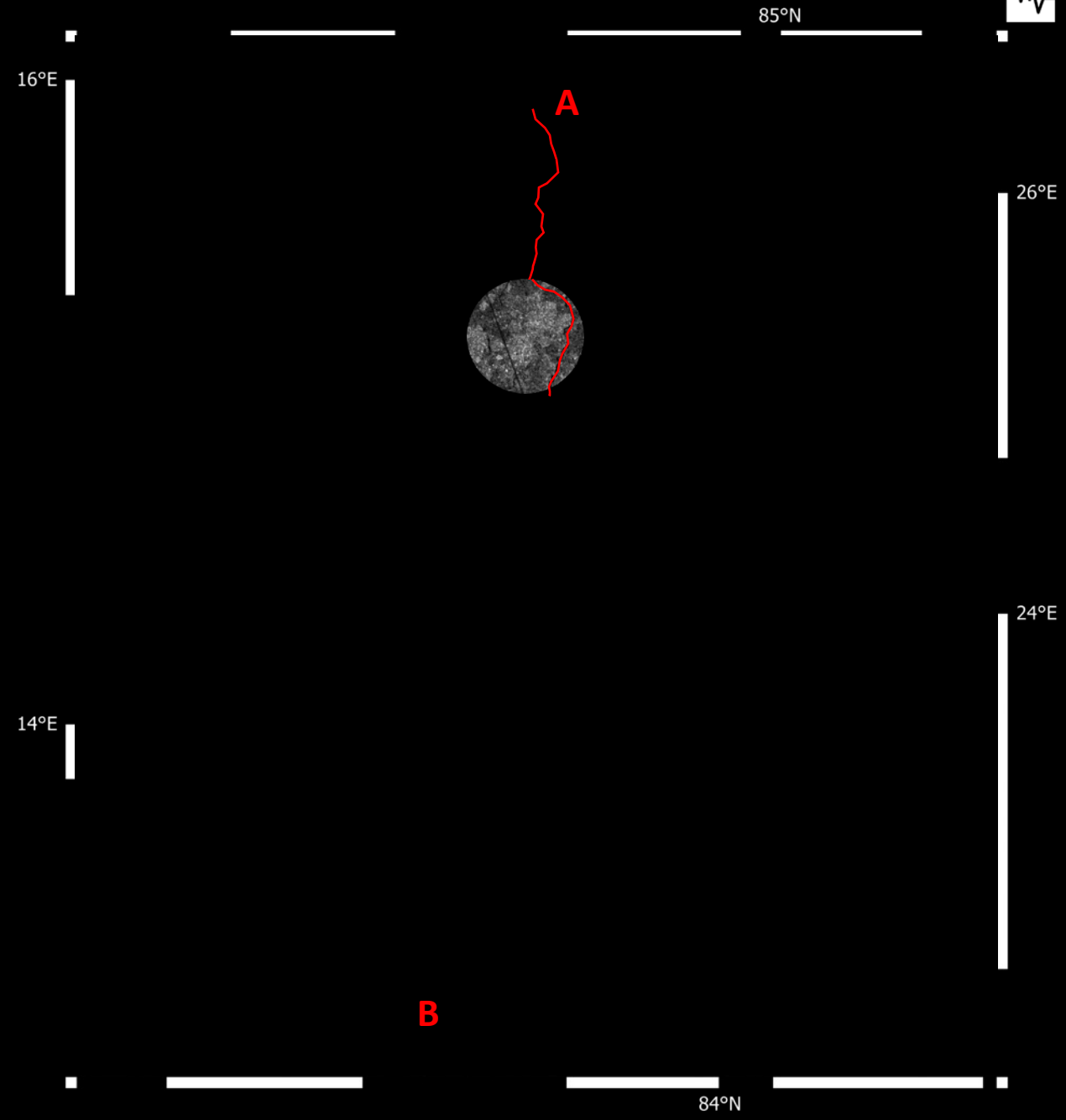
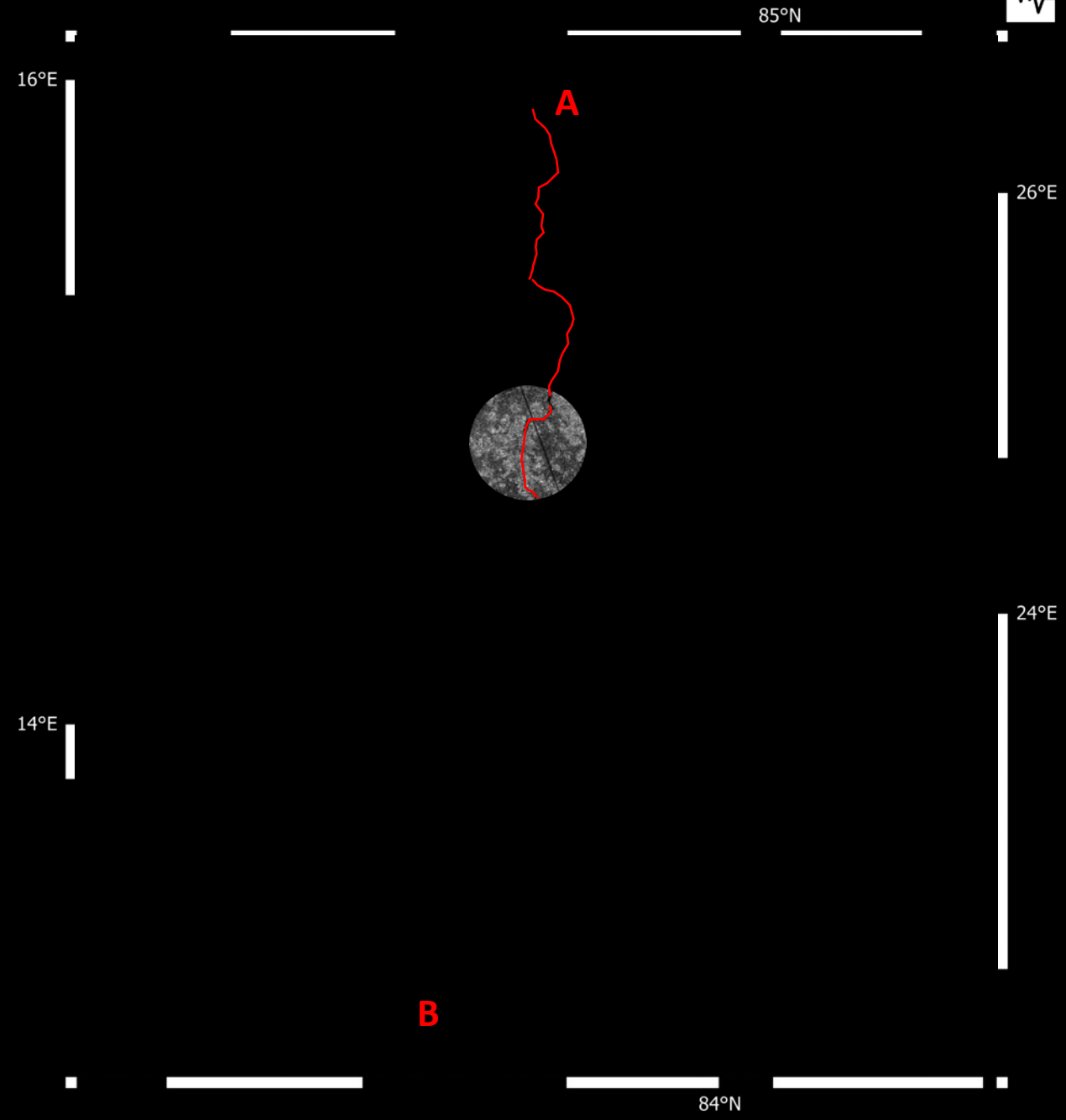
Alfred-Wegener-Institut/Robert Ricker (CC-BY 4.0)



Navigation mit Schiffsradar

Alfred-Wegener-Institut/Robert Ricker (CC-BY 4.0)



Navigation mit Schiffsradar

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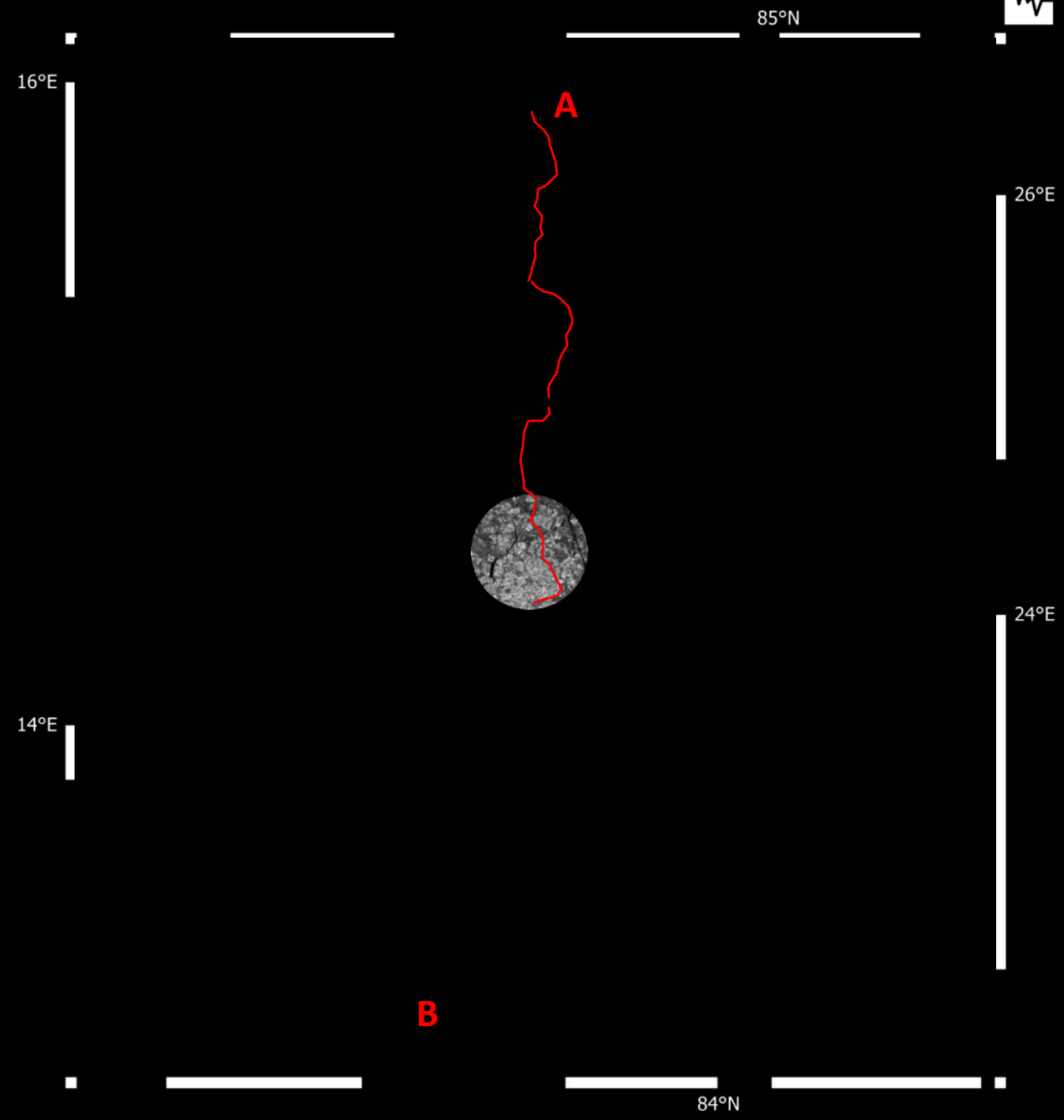

Navigation mit Schiffsradar

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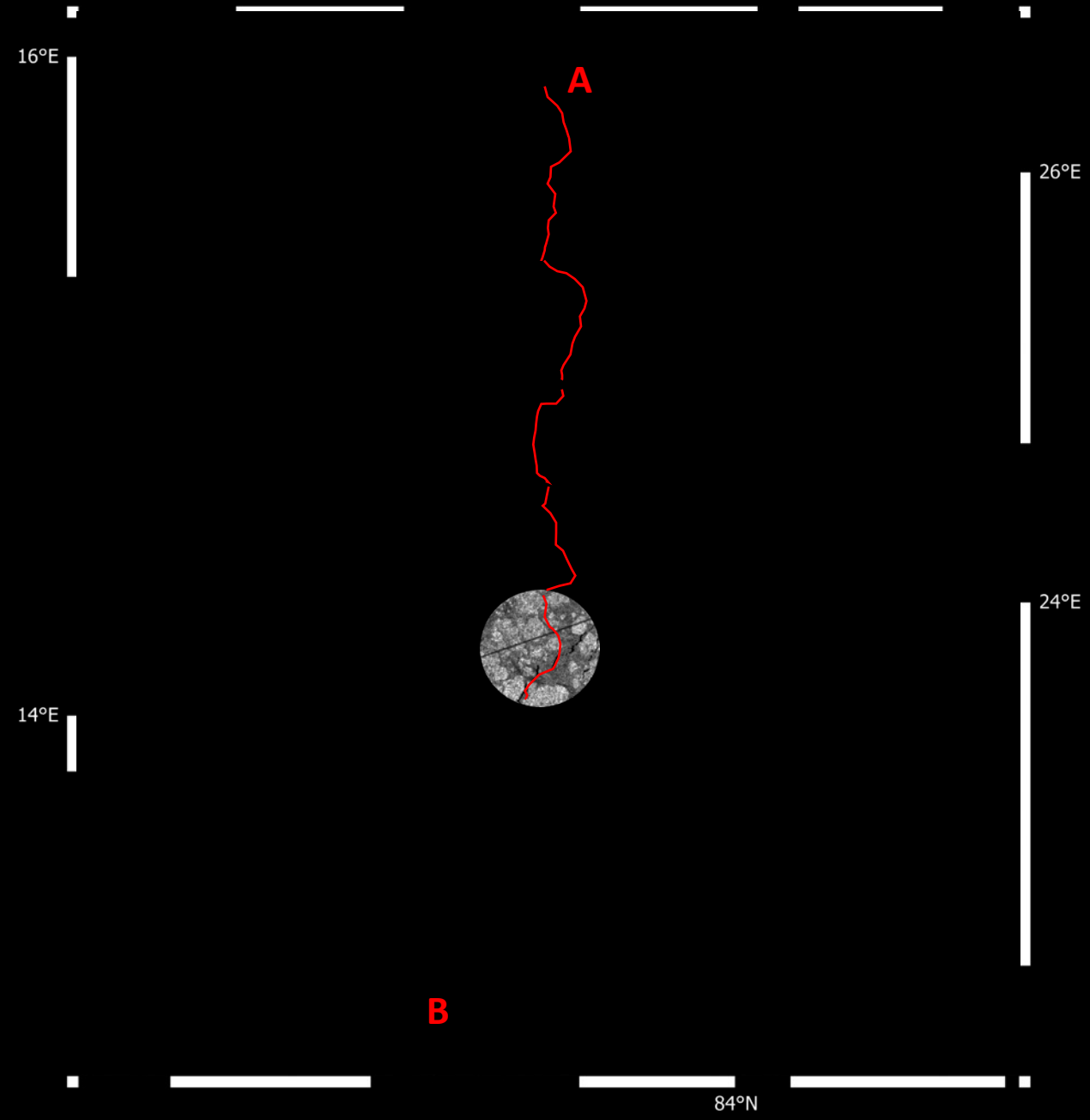

Navigation mit Schiffsradar

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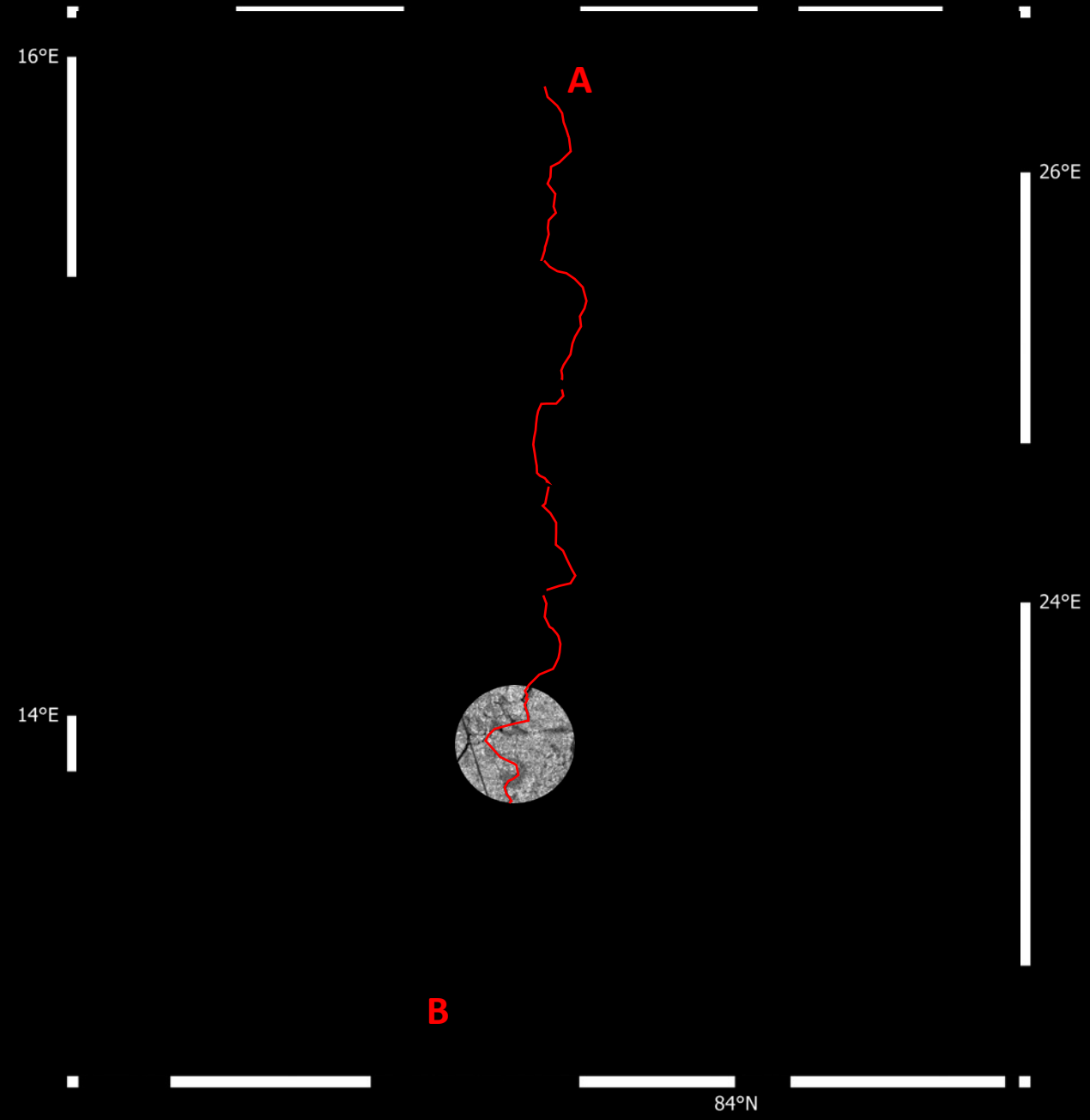

Navigation mit Schiffsradar

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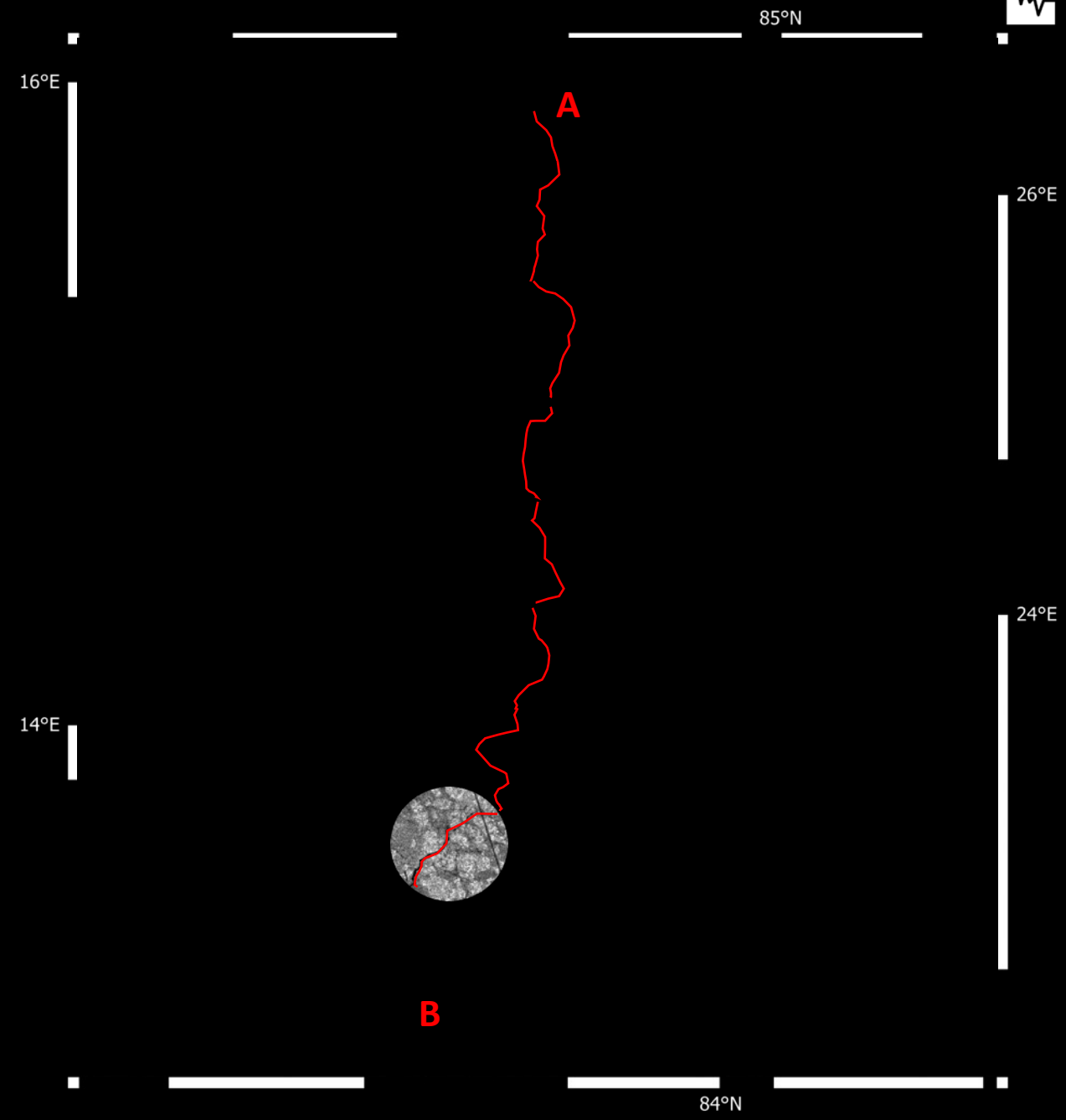
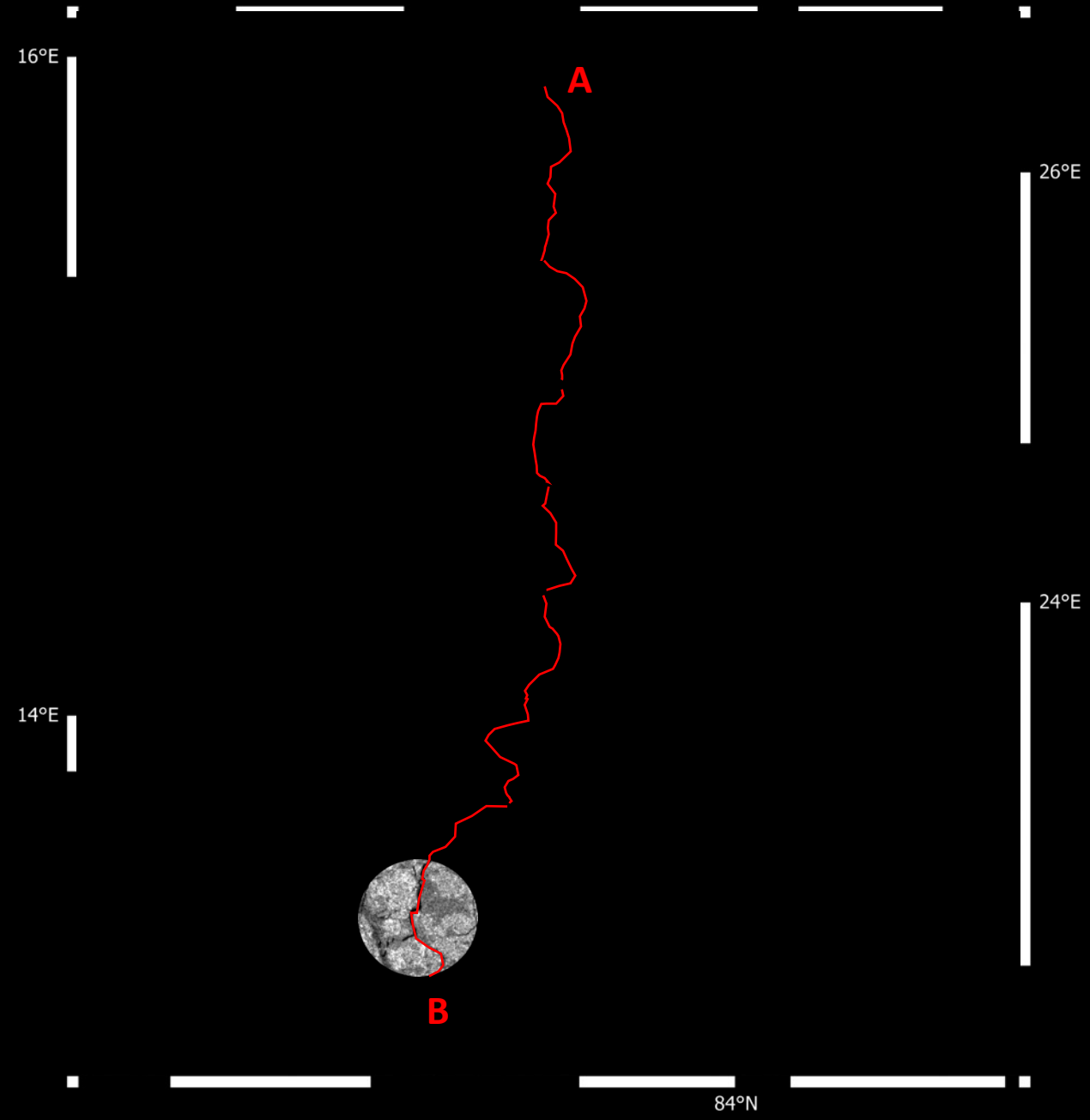


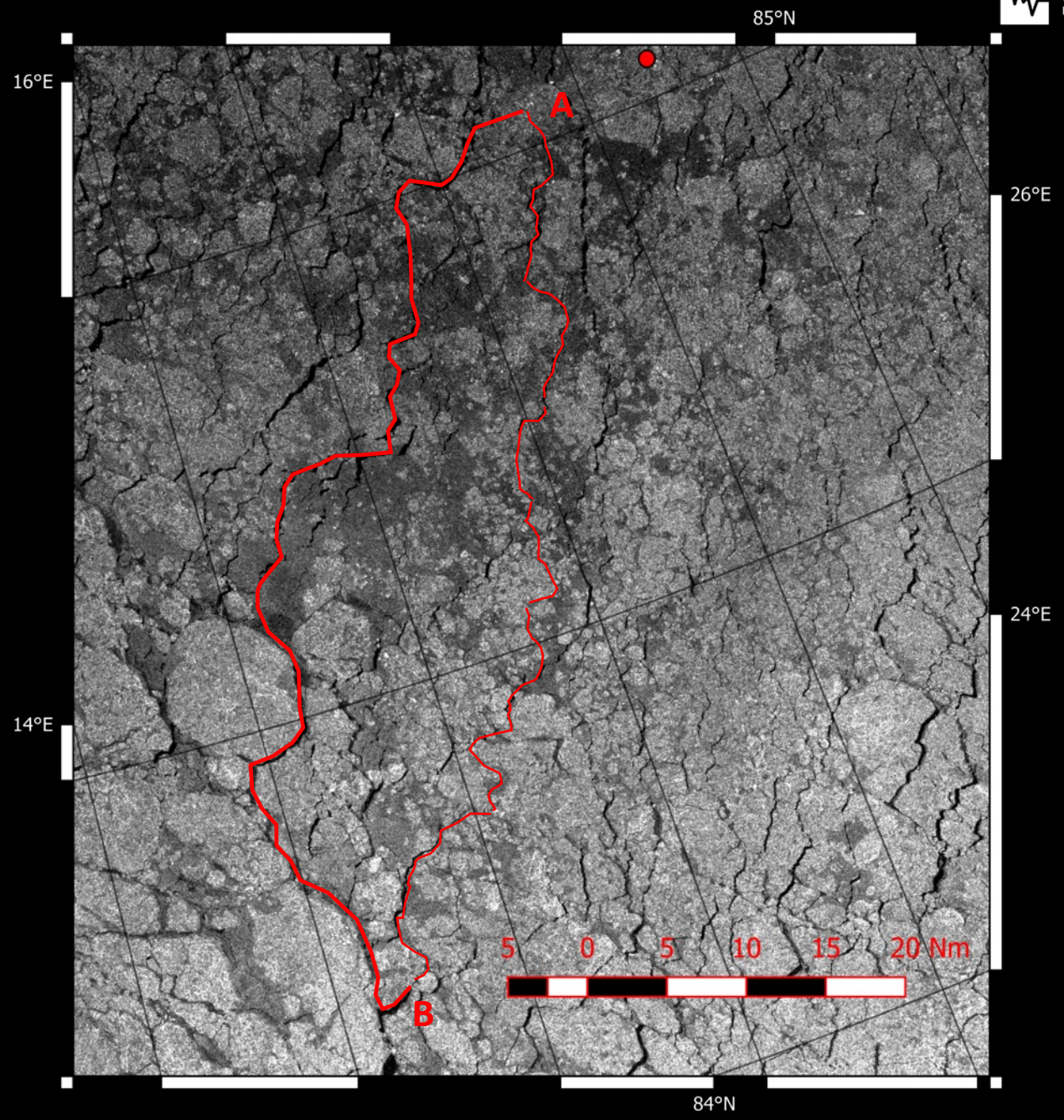
Navigation mit Schiffsradar

Alfred-Wegener-Institut/Robert Ricker (CC-BY 4.0)



Navigation mit Schiffsradar

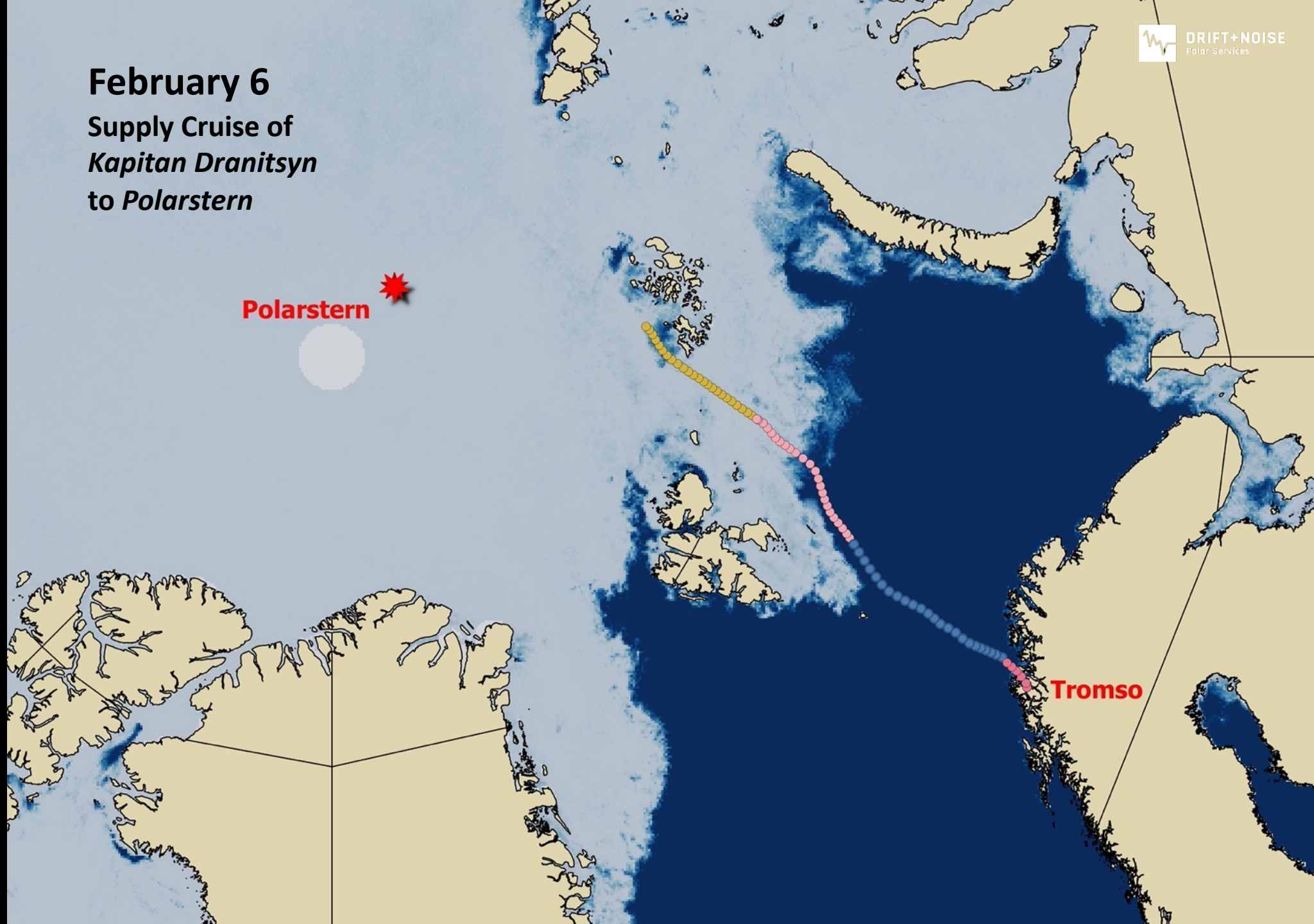
Alfred-Wegener-Institut/Robert Ricker (CC-BY 4.0)

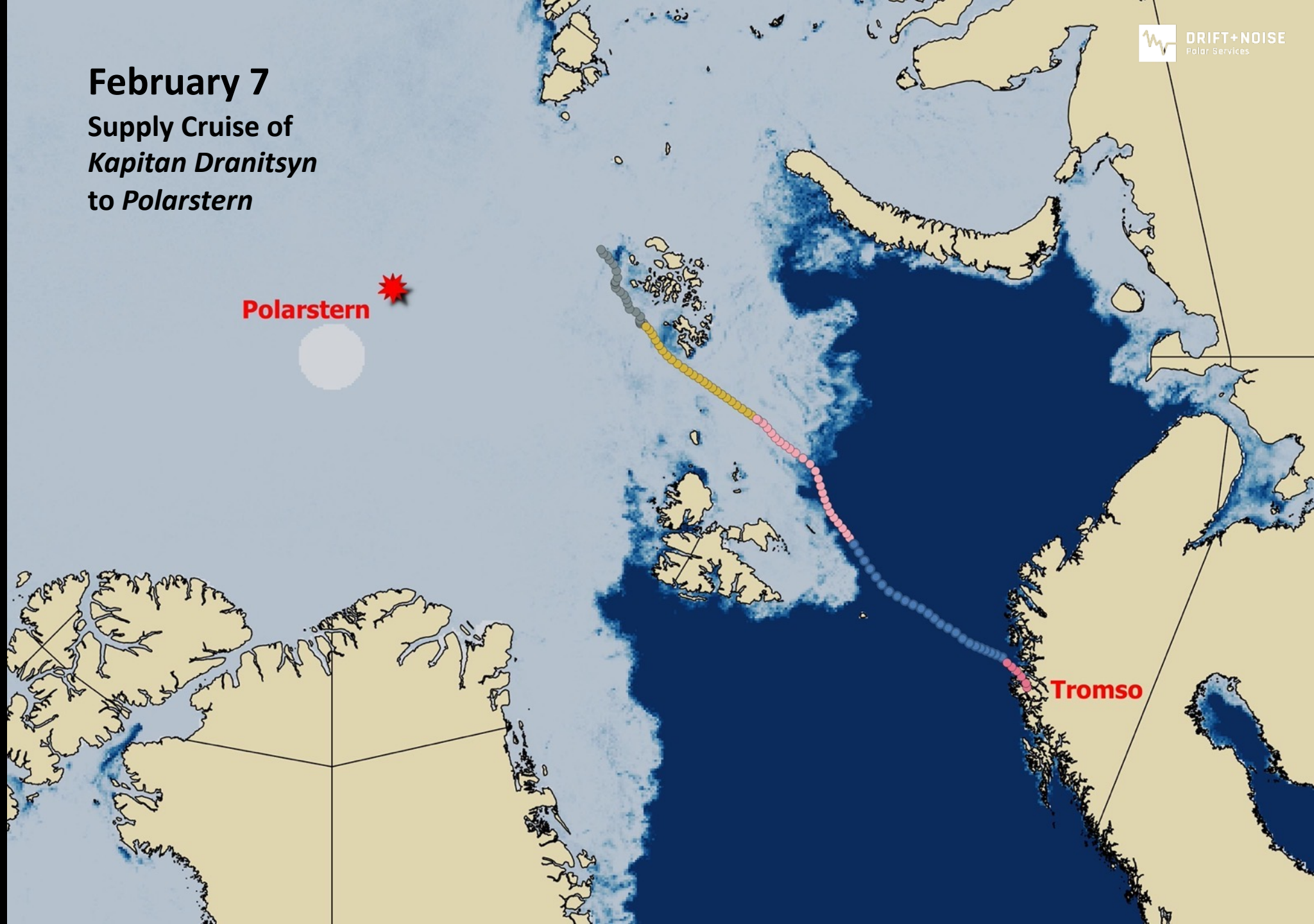



February 3
Supply Cruise of
Kapitan Dranitsyn
to *Polarstern*
Polarstern
Tromso
DRIFT+NOISE
Polar Services


February 4
Supply Cruise of
Kapitan Dranitsyn
to *Polarstern*
Polarstern
Tromso
DRIFT+NOISE
Polar Services


February 5
Supply Cruise of
Kapitan Dranitsyn
to *Polarstern*
Polarstern
Tromso
DRIFT+NOISE
Polar Services


February 6
Supply Cruise of
Kapitan Dranitsyn
to *Polarstern*
Polarstern
Tromso
DRIFT+NOISE
Polar Services


February 7
Supply Cruise of
Kapitan Dranitsyn
to *Polarstern*
Polarstern
Tromso
DRIFT+NOISE
Polar Services

- Ice Type


February 8
Supply Cruise of
Kapitan Dranitsyn
to *Polarstern*
Polarstern
First Year Ice
Multi Year Ice
Tromso
DRIFT+NOISE
Polar Services

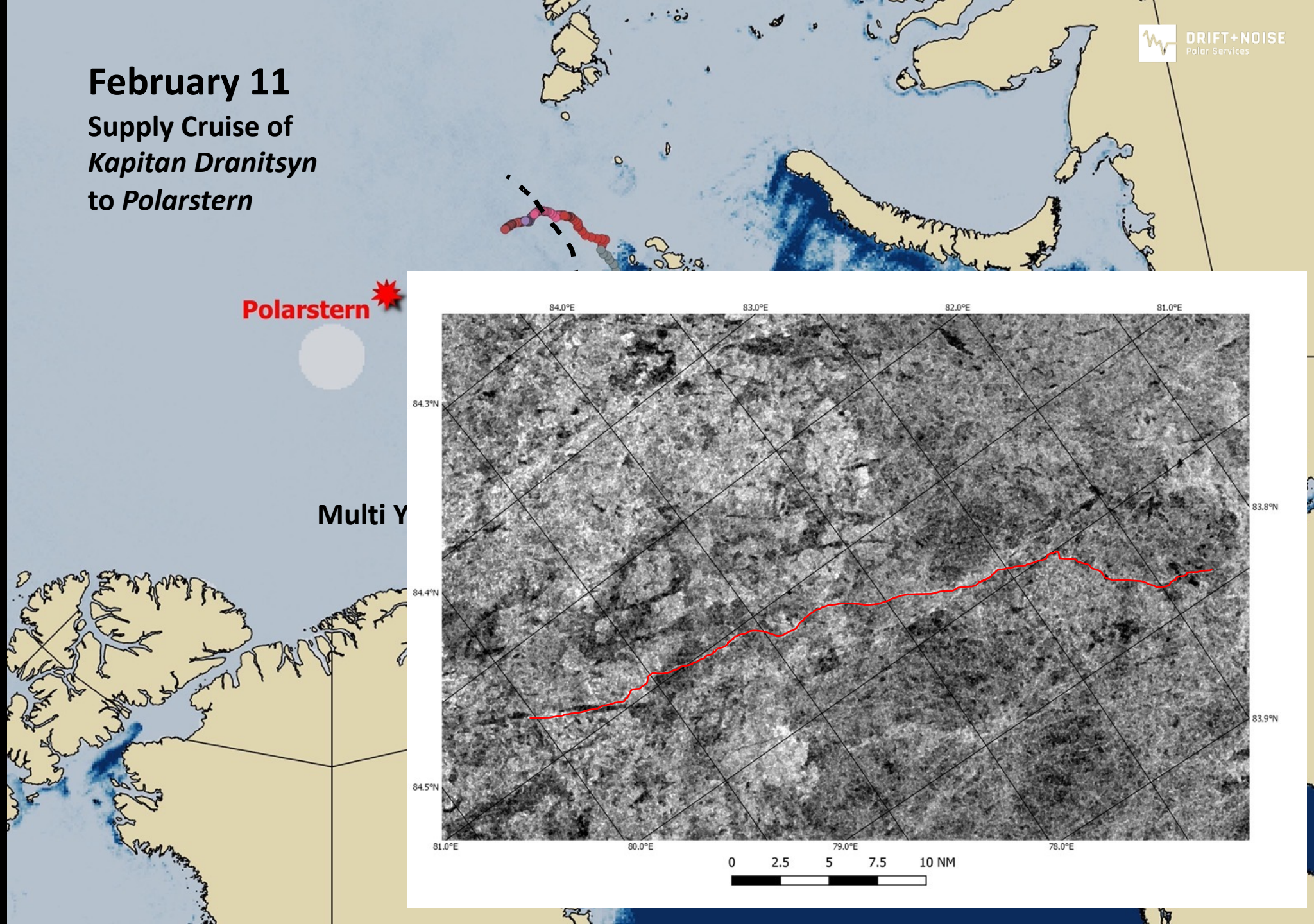
- Ice Type


February 9
Supply Cruise of
Kapitan Dranitsyn
to *Polarstern*
Polarstern
First Year Ice
Multi Year Ice
Tromso
DRIFT+NOISE
Polar Services

- Ice Type


February 10
Supply Cruise of
Kapitan Dranitsyn
to *Polarstern*
Polarstern
First Year Ice
Multi Year Ice
Tromso
DRIFT+NOISE
Polar Services

- Ice Type
- High Resolution



- Ice Type
- High Resolution

- Ice Type
- High Resolution

- Ice Type
- High Resolution

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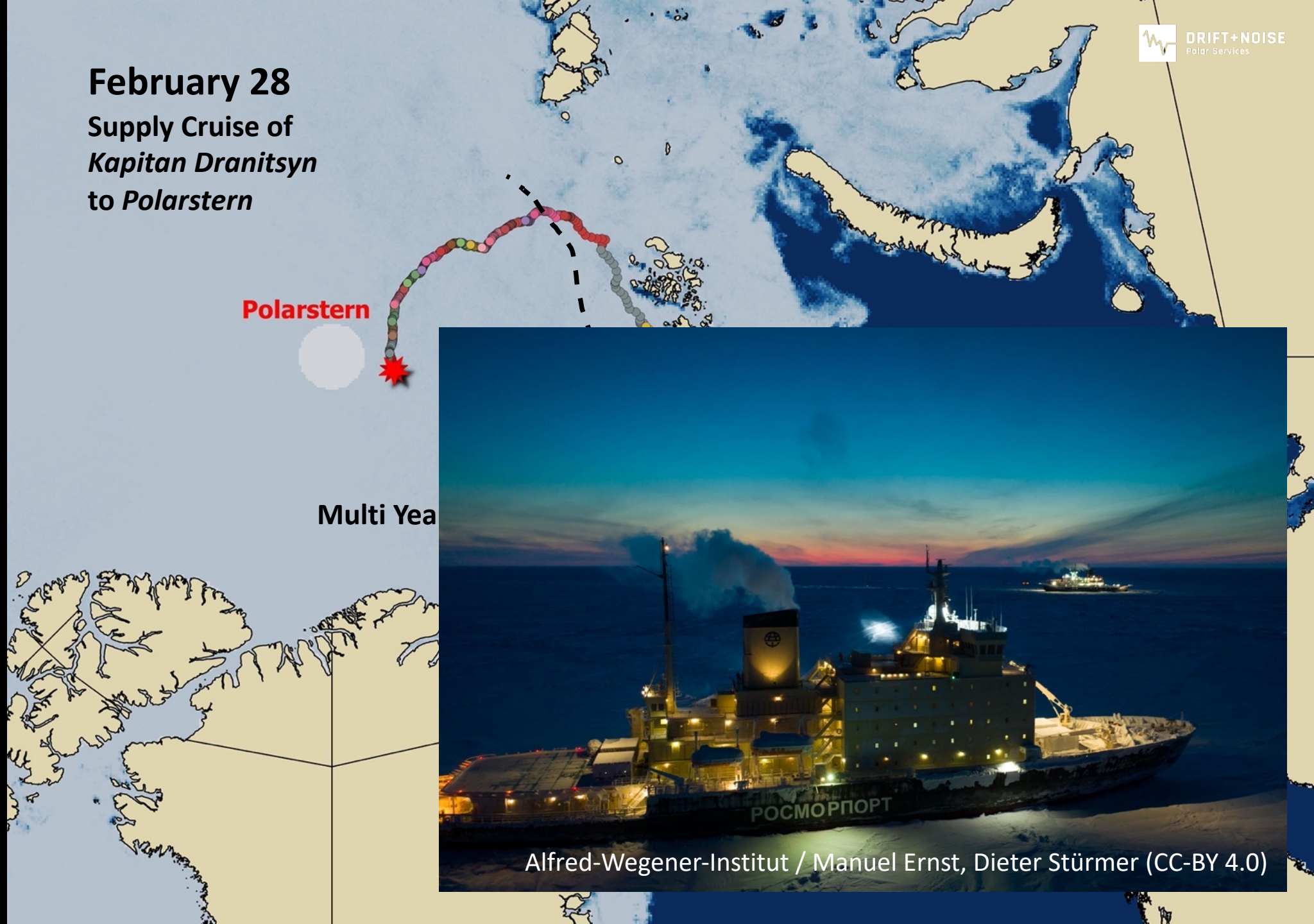
- High Resolution
- Ice Dynamic

- Ice Type
- High Resolution
- Ice Dynamic

- Ice Type
- High Resolution
- Ice Dynamic

- Ice Type
- High Resolution
- Ice Dynamic
- Ship Characteristics



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Icebreaker Needs Fuel After Record North Pole Voyage

Polarstern and Kapitan Dranitsyn (Credit: Rosomport)

BY **THE MARITIME EXECUTIVE** 03-04-2020 08:49:42

The Russian icebreaker *Kapitan Dranitsyn* was slowed for days by sea ice as she made her way to the North Pole to support the MOSAiC expedition icebreaker *Polarstern*, and she now requires assistance before returning. The icebreaker *Admiral Makarov* departed from Murmansk on March 3 with fuel for the vessel.

Alfred-Wegener-Institut/Steffen Graupner (CC-BY 4.0)

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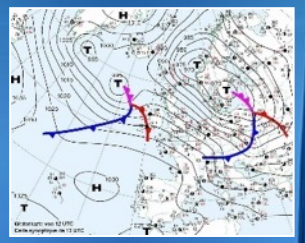
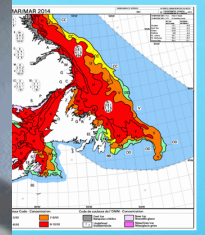
...data, data, data

ICY SEA

http://researchinprogress.tumblr.com/
by Emin Aksehirli



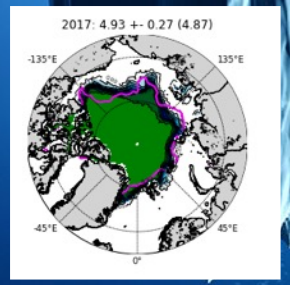
Weather Data



Ice Charts

Vessel Traffic Data

Ice Type



Sea-ice model forecasts

In-situ Data

Ice Bergs

Ice Thickness

Ice Age

Historical Data

Ice Drift

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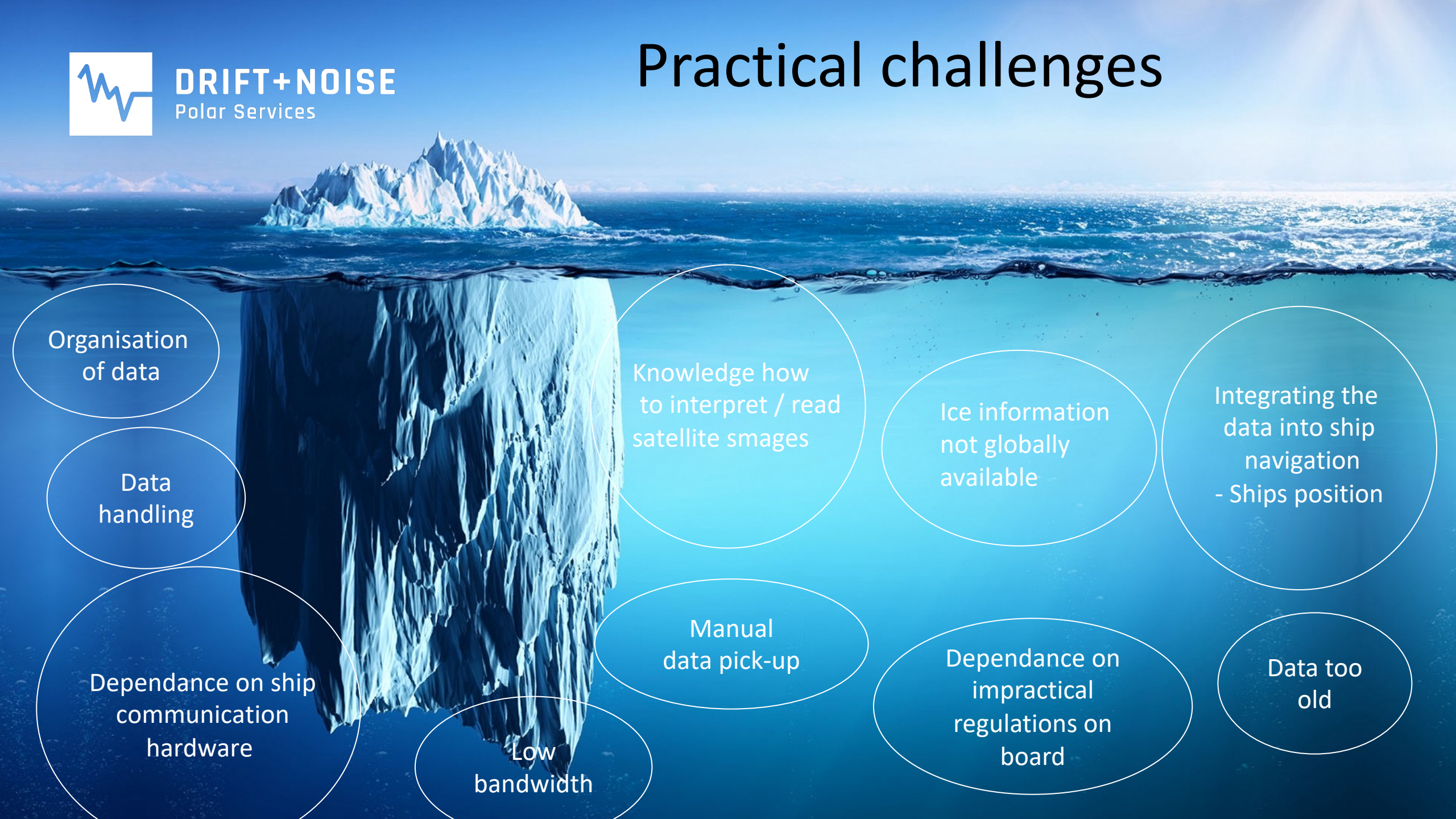
Polar Services

Practical challenges

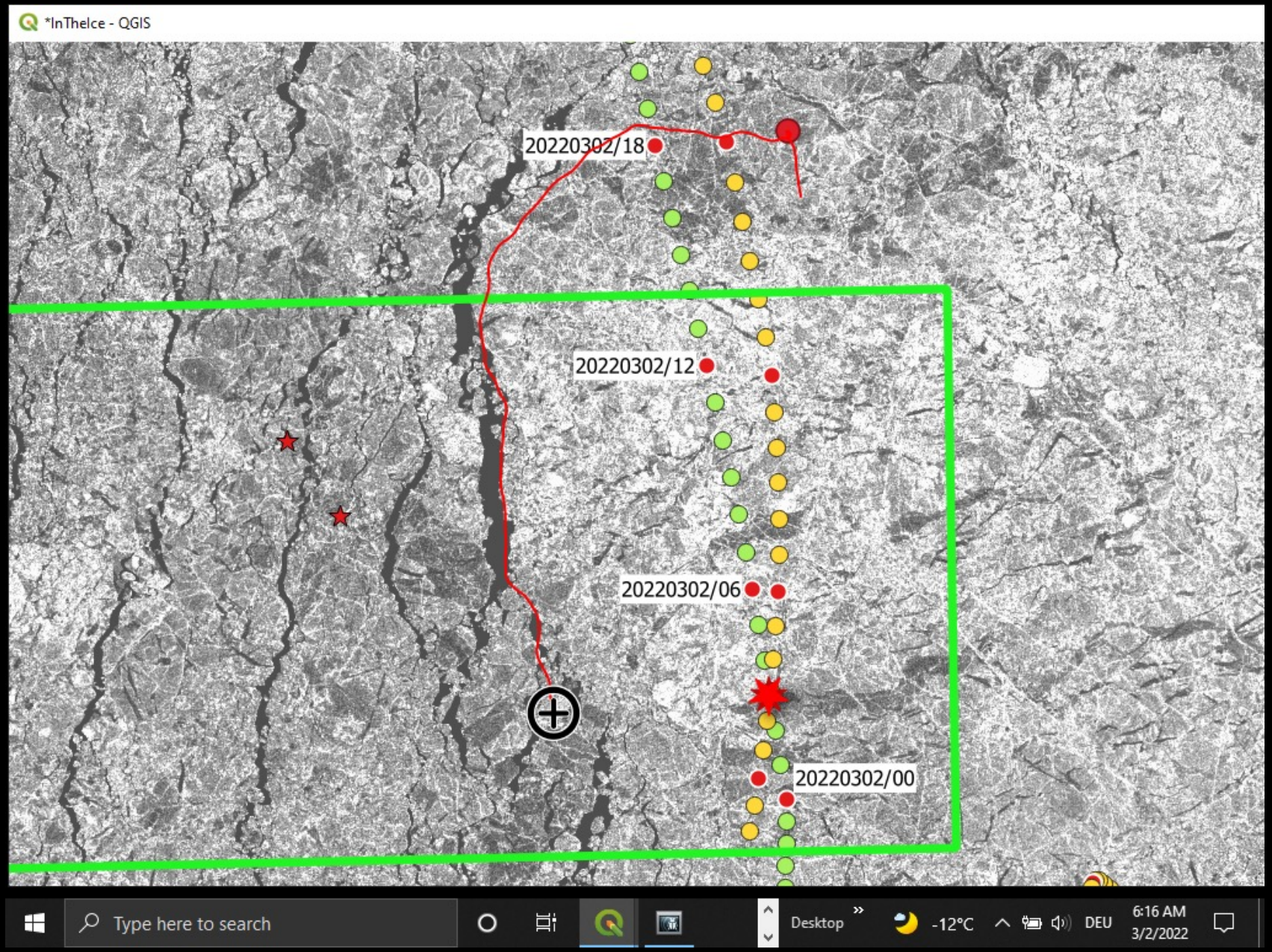


During Endurance 22

- 6 persons
- 24 hour shifts
- 30.000 EUR monthly internet costs

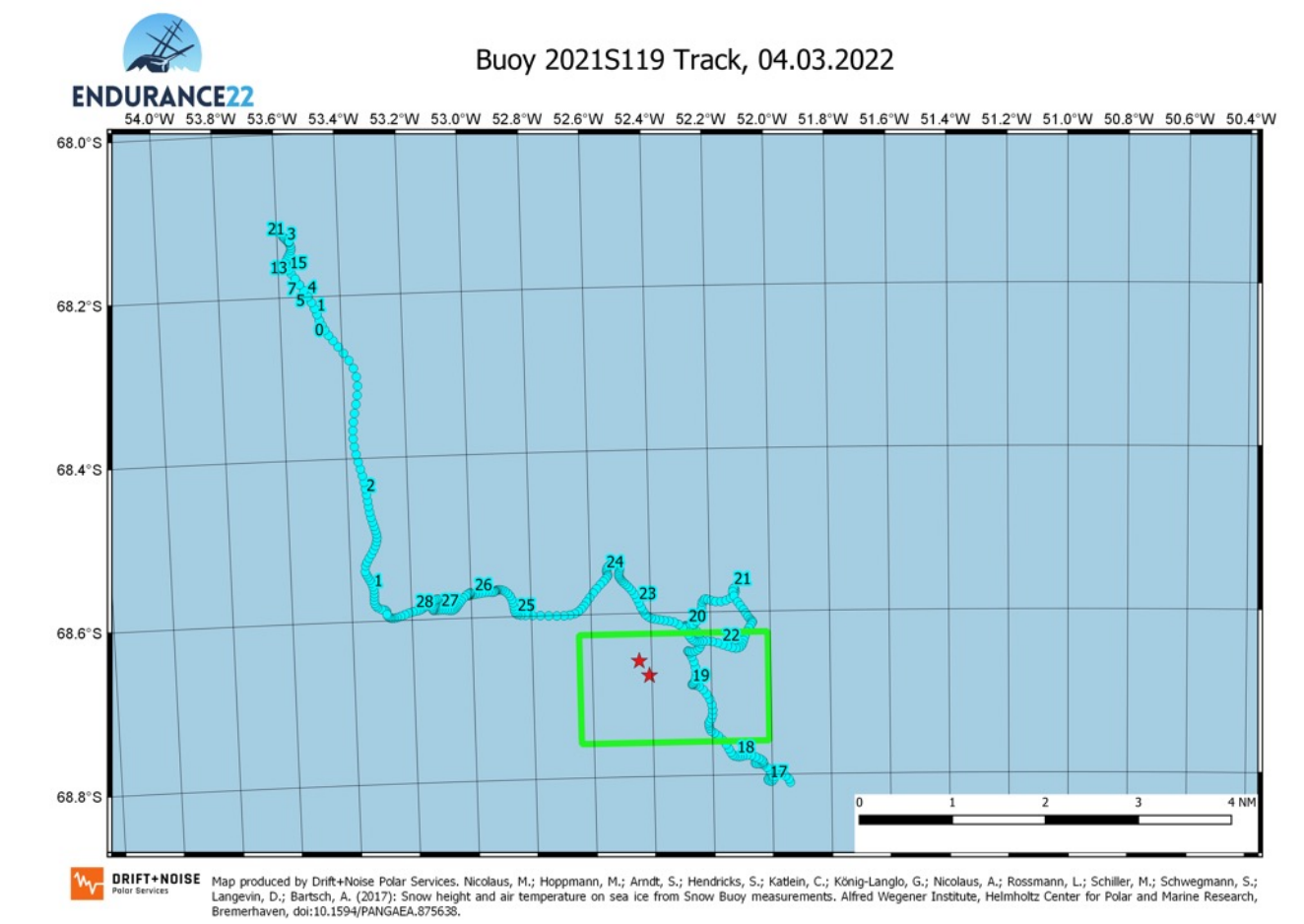
AUV operations in ice

Photo: Esther Horvath



Screenshot: Drift+Noise Polar Services, Satellite image: DLR TerraSAR-X

Measuring the ice drift in real time



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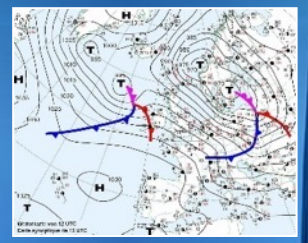
Polar Services

...data, data, data

ICY SEA



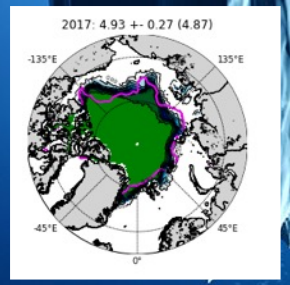
Weather Data

Satellite images / -data

Actionable Information

Vessel Traffic Data

Ice Type



Sea-ice model forecasts

Ice Bergs

In-situ Data

Ice Thickness

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Ice Drift

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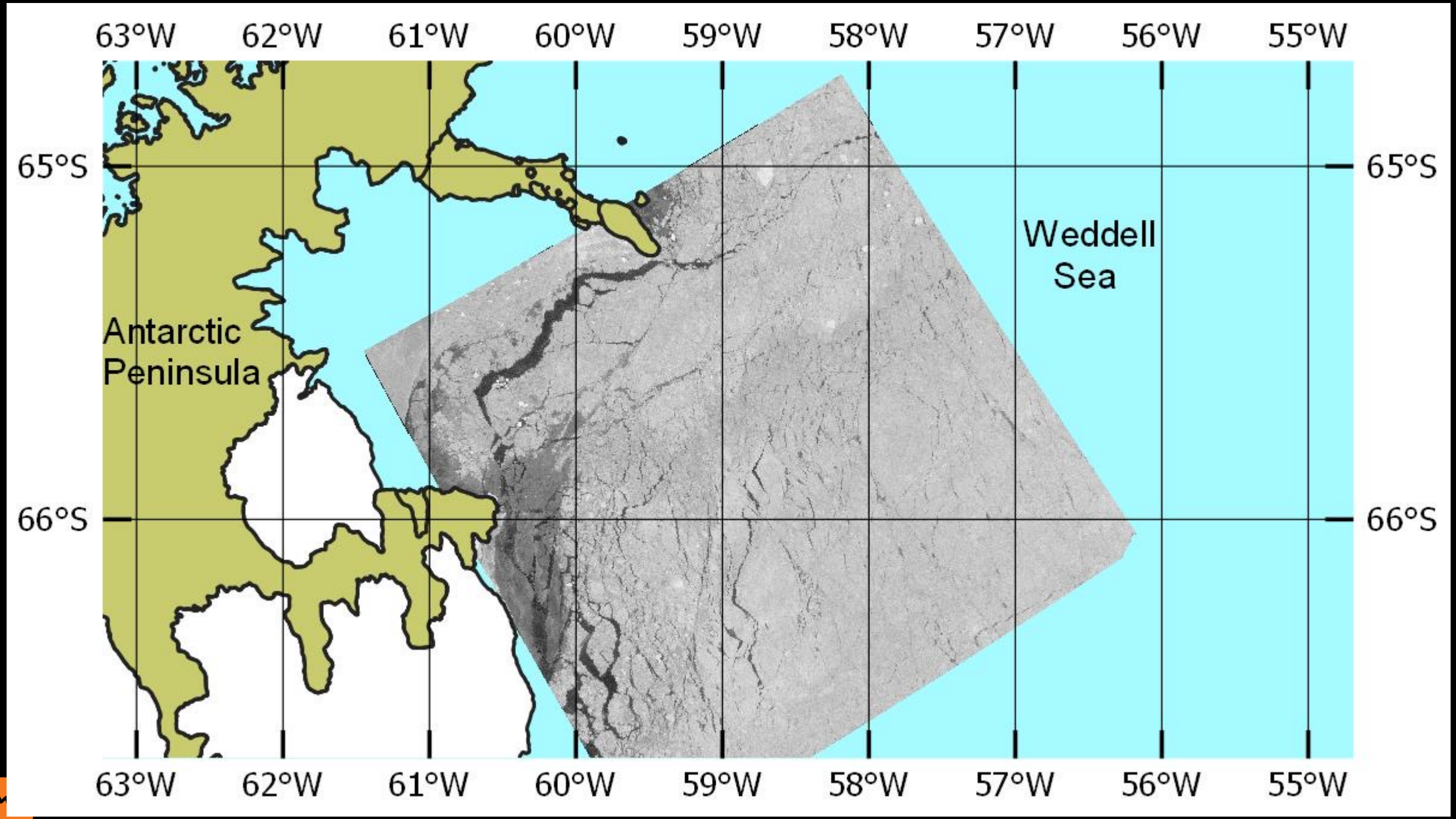
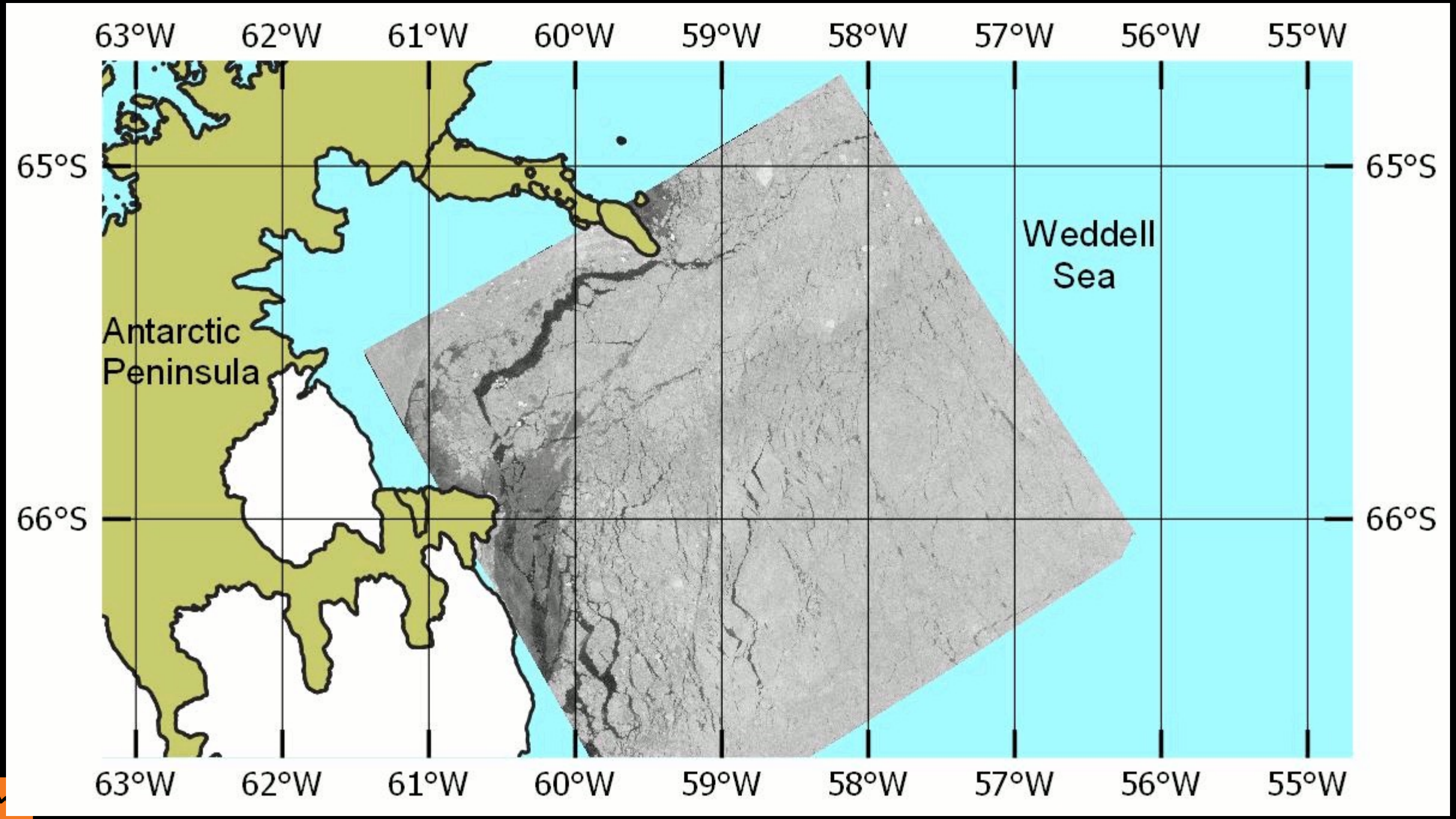
Polar Services

ICY SEA


63°W
62°W
61°W
60°W
59°W
58°W
57°W
56°W
55°W
65°S
66°S
Antarctic
Peninsula
Weddell
Sea


63°W
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58°W
57°W
56°W
55°W
65°S
66°S
Antarctic
Peninsula
Weddell
Sea

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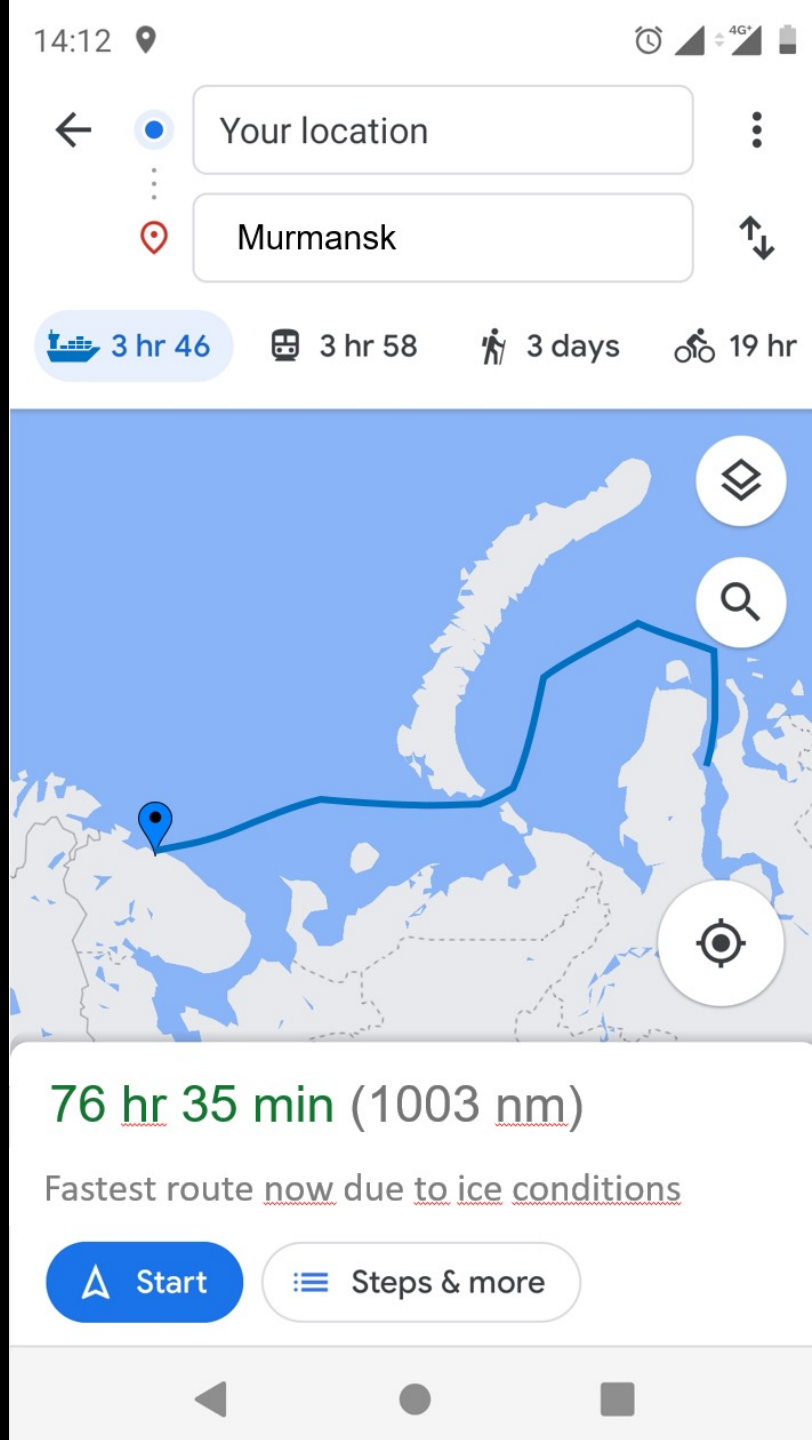
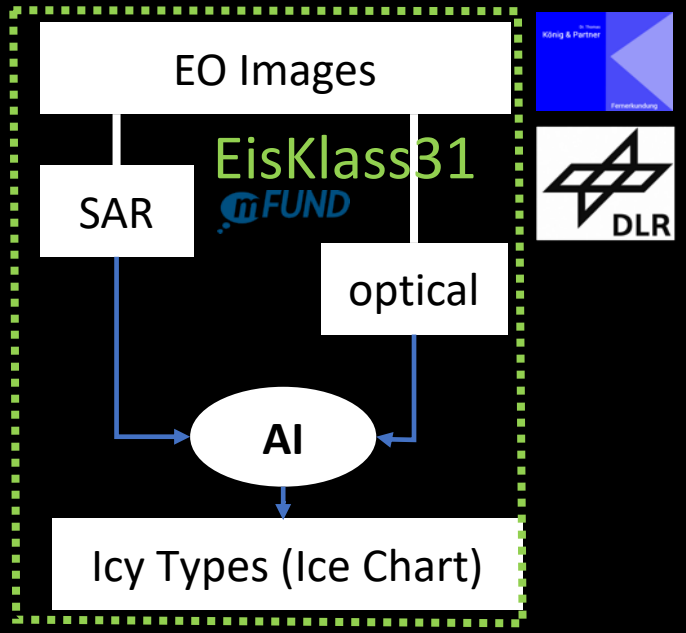
Ultimately:

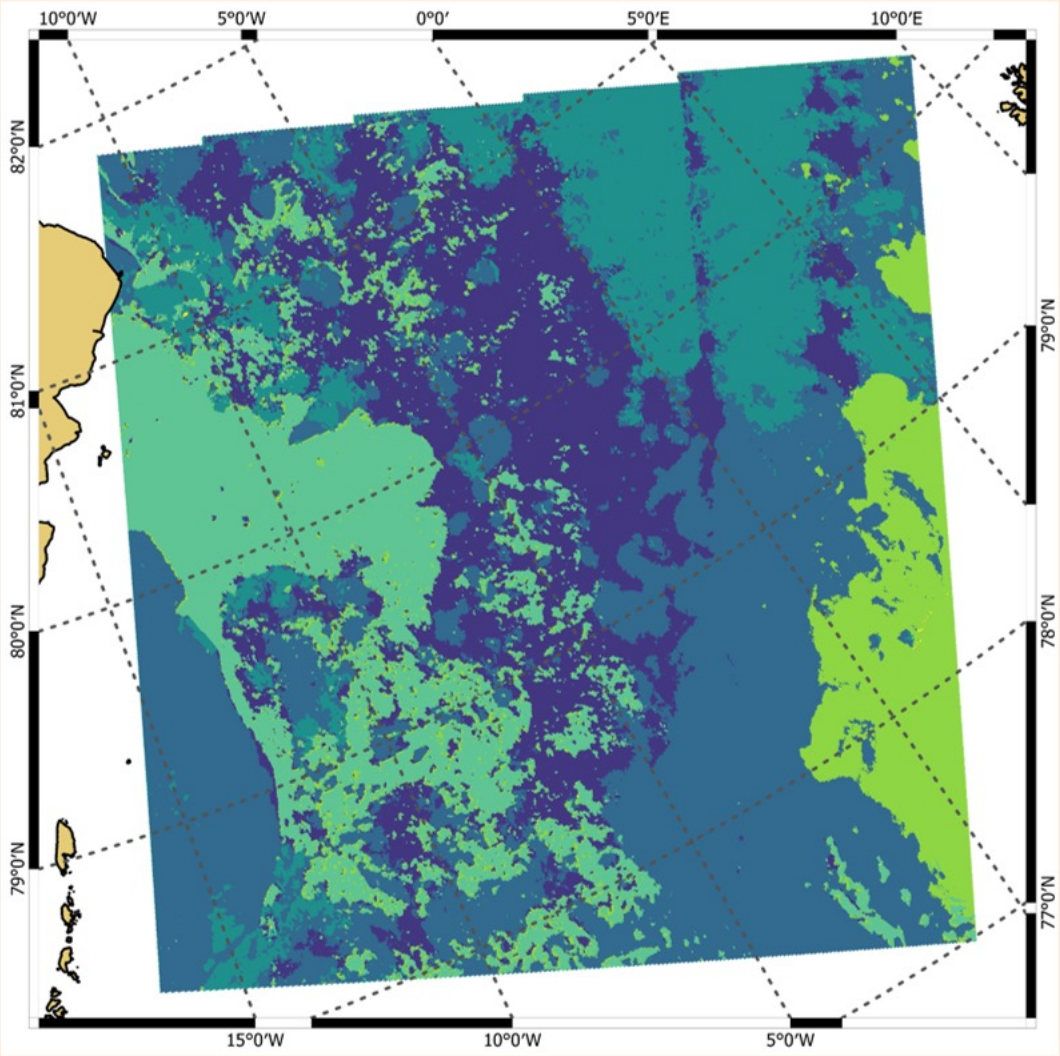
Google Maps of the Polar Regions



Building a Comprehensive Ice Navigation System



Sentinel-1 SAR sea-ice classification



- Based on Convolutional Neural Network (CNN)
- Using Sentinel-1 EW images at 410 km swath
- Using both channels HH/HV
- Counteracting tile-edge effect by using 4 classifications with offsets
- Resulting classification resolution: 160 m
- Six classes distinguished by surface roughness

Multi-year ice	Leads (smooth)
First-year ice	Leads (rough)
New ice	Rough ice

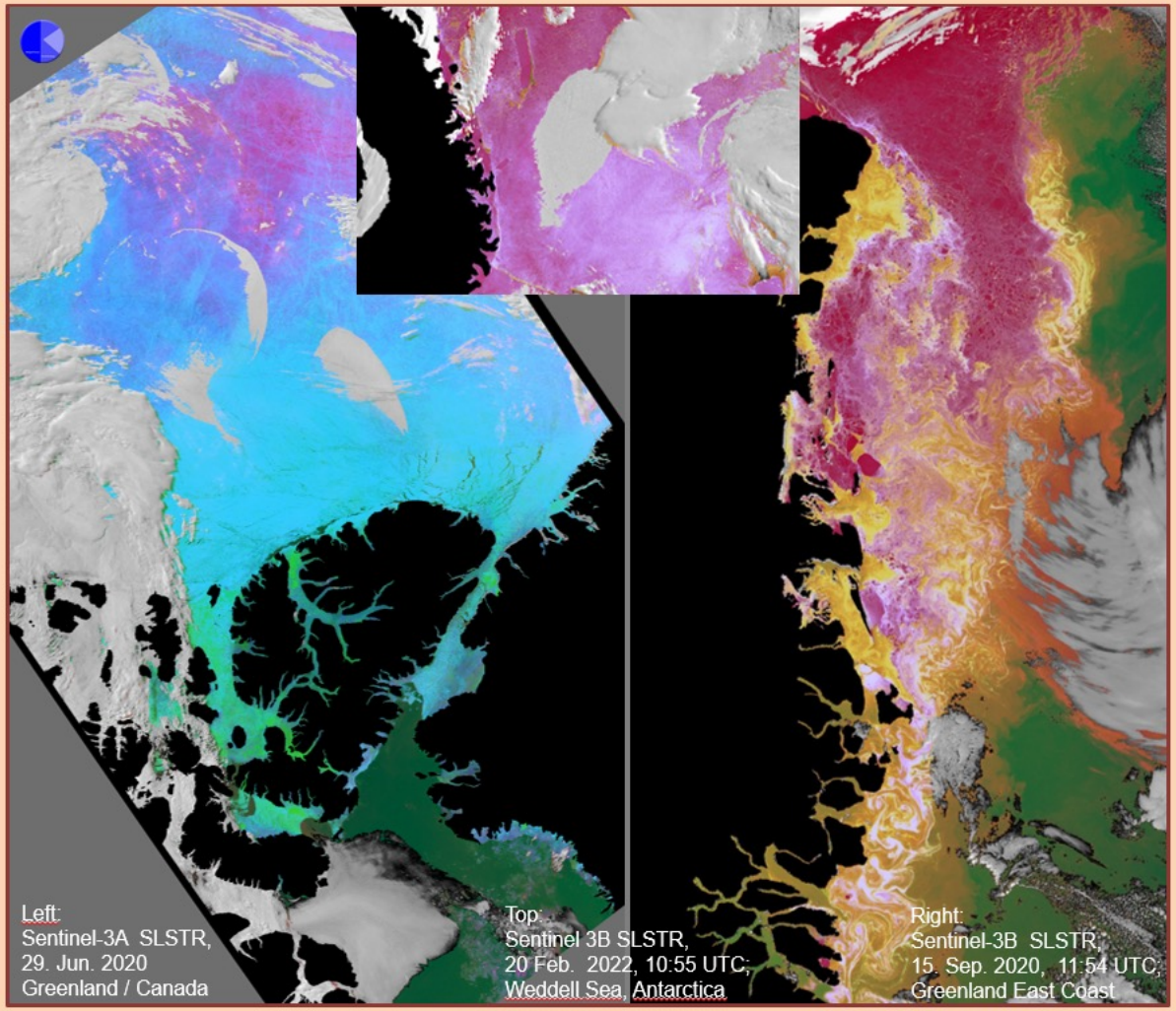
Images by Stefan Wiehle and Dmitrii Murashkin, DLR

Sentinel-3 SLSTR sea-ice classification

Dr. Thomas König & Partner Fernerkundung

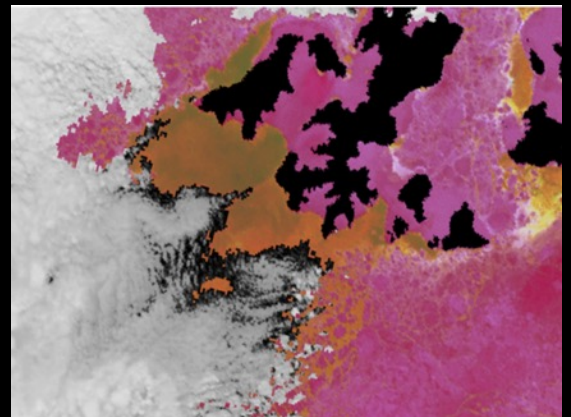
- Single pixel classification with 500 m resolution and 1400 km swath (same as original product)
- Sensitive for ice thickness up to 50 cm
- Sensitive for age and humidity of snow cover
- Filtering of clouds and cloud shadows
- Continuous classification with 16 main classes:

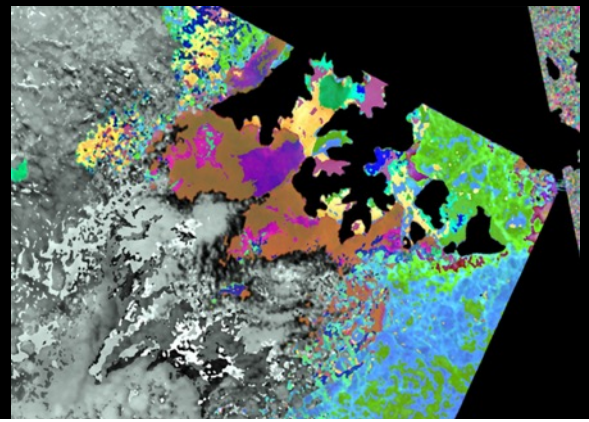
- Open water
- nearly freezing water or mixed ice/water Pixel or very thin ice (e.g. frazil ice)
- ice without snow cover especially: dark and light nilas (<10cm)
- young ice without snow cover especially: grey ice (10-15 cm)
- young ice without snow cover especially: grey-white ice (15-30cm)
- ice of uncertain thickness with dry snow cover
- ice of uncertain thickness with aged dry snow cover
- ice of uncertain thickness with less aged snow cover
- ice of uncertain thickness (most likely between 20 and 50 cm) covered by aged snow (increased grain size of snow)
- ice of uncertain thickness (most likely between 20 and 50 cm) covered by further aged snow compared to dark pink
- ice of uncertain thickness (most likely between 20 and 50 cm) covered by snow fallen more recently
- ice of uncertain thickness (most likely between 20 and 50 cm) covered by aged snow but with increasing temperatures than with the color pink
- ice of uncertain thickness (most likely between 20 and 50 cm) covered by aged snow but with increasing temperatures than with the color dark violett
- thick ice covered by slightly wet snow; (thickness not well defined)
- ice covered by encreasingly wet snow; partial pixel coverage by meltponds possible
- ice with standing water on the surface either flat or in the form of meltponds or re-frozen water

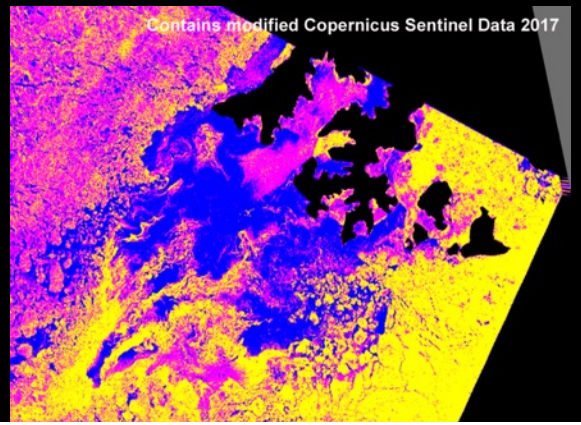


Classification K&P 2020-2022. Contains modified Copernicus Sentinel data (2020, 2022)

Combined ice classification Sentinel-1 and Sentinel-3







		Sentinel-1	Sentinel1	Sentinel-1
		Offenes Wasser-Nilas (bis 10 cm)	Junges Eis 10-30 cm	Glattes erstjähriges Eis 30-200 cm
Sentinel-3	Sentinel-3	Kombi	Kombi	Kombi
Offenes Wasser		offenes Wasser	offenes Wasser	Inkonsistente Angaben
Gefrierbereites Wasser		gefrierbereites Wasser	Inkonsistente Angaben	Inkonsistente Angaben
Nilas <10cm		Nilas	Nilas	Inkonsistente Angaben
Graues Eis 10-15cm		Inkonsistente Angaben	Graues Eis bis 15cm	Inkonsistente Angaben

Grauweißes Eis 15-30cm		Inkonsistente Angaben	Grauweißes Eis	Glattes Grauweißes Eis bis 30 cm
Dunkelrot Eis unbekannter Dicke mit trockener Schneeauflage		Nilas mit trockener Schneeauflage	Junges Eis 10-bis 30 cm mit trockener Schneeauflage	Glattes einj. Eis 30-200cm mit trockener Schneeauflage
Mittelrot Eis unbekannter Dicke mit gealterter Schneeauflage u. tiefen Temperaturen		Inkonsistente Angaben	Junges Eis 10 bis 30 cm mit gealterter Schneeauflage	Glattes einjähriges Eis 30-200 cm mit gealterter Schneeauflage
Hellrot Eis unbekannter Dicke mit gealterter Schneeauflage		Inkonsistente Angaben	Junges Eis 10 bis 30cm mit gealterter Schneeauflage	Glattes erstj. Eis 30-200cm mit gealterter kalten Schneeauflage

Dunkles Pink Gealterter Schnee mit tiefen Temperaturen auf Eis		Inkonsistente Angaben	Junges Eis 10 bis 30cm mit gealterter Schneeauflage	Glattes erstj. Eis 30-200cm mit gealterter kalten Schneeauflage
Mittleres Pink Gealterter Schnee mit tiefen Temperaturen auf Eis		Inkonsistente Angaben	Junges Eis 10 bis 30cm mit gealterter Schneeauflage	Glattes erstj. Eis 30-200 cm mit gealterter Schneeauflage
Helles Pink Gealterter Schnee mit tiefen Temperaturen		Inkonsistente Angaben	Junges Eis bis 10 30 cm mit gealterter Schneeauflage	Glattes erstj. Eis 30-200 cm mit gealterter Schneeauflage
Dunkelviolett mit Temperaturen zwischen -17°C und -4°C		Inkonsistente Angaben	Junges Eis 10 bis 30 cm mit alter Schneeauflage	Glattes erstj. Eis 30-200 cm mit alter Schneeauflage
Hellviolett		Inkonsistente Angaben	Junges Eis 10 bis 30 cm mit alter Schneeauflage	Glattes einj. Eis 30-200 cm mit alter Schneeauflage

Hellblau Gesunkene Reflektivitäten und Temperaturen um den Gefrierpunkt		Nilas mit feuchter Schneeauflage	Junges Eis bis 10 30 cm mit feuchter Schneeauflage	Glattes einj. Eis 30-200cm mit feuchter Schneeauflage
Dunkelblau Geringe Reflektivitäten und Temperaturen über dem Gefrierpunkt		Inkonsistente Angaben	Junges Eis 10 bis 30 cm mit Wasserauflage	Glattes erstj. Eis 30-200cm mit Wasserauflage
Hellgrün Geringe Reflektivitäten und Temperaturen zwischen -5°C und 0°C		Inkonsistente Angaben	Junges Eis 10 bis 30 cm mit wiedergefrorener Oberfläche	Glattes einj. Eis 30-200 cm mit wiedergefrorener Oberfläche
Zusatzklassen	Für Klassenbildung der Sentinel-3 Eisklassifikation zur Erstellung der Klassifikations-Kombinationen			
Auflösendes Eis, bräunlich Wasser-Eisgemisch		Wasser Eisgemisch	Wasser Eisgemisch mit Eis bis 30cm	Inkonsistente Angaben

Helles Grauweißes Eis		Inkonsistente Angaben	Grauweißes Eis bis 30cm, sehr hell	Glattes einjähriges Grauweißes Eis, dicker als 30 cm

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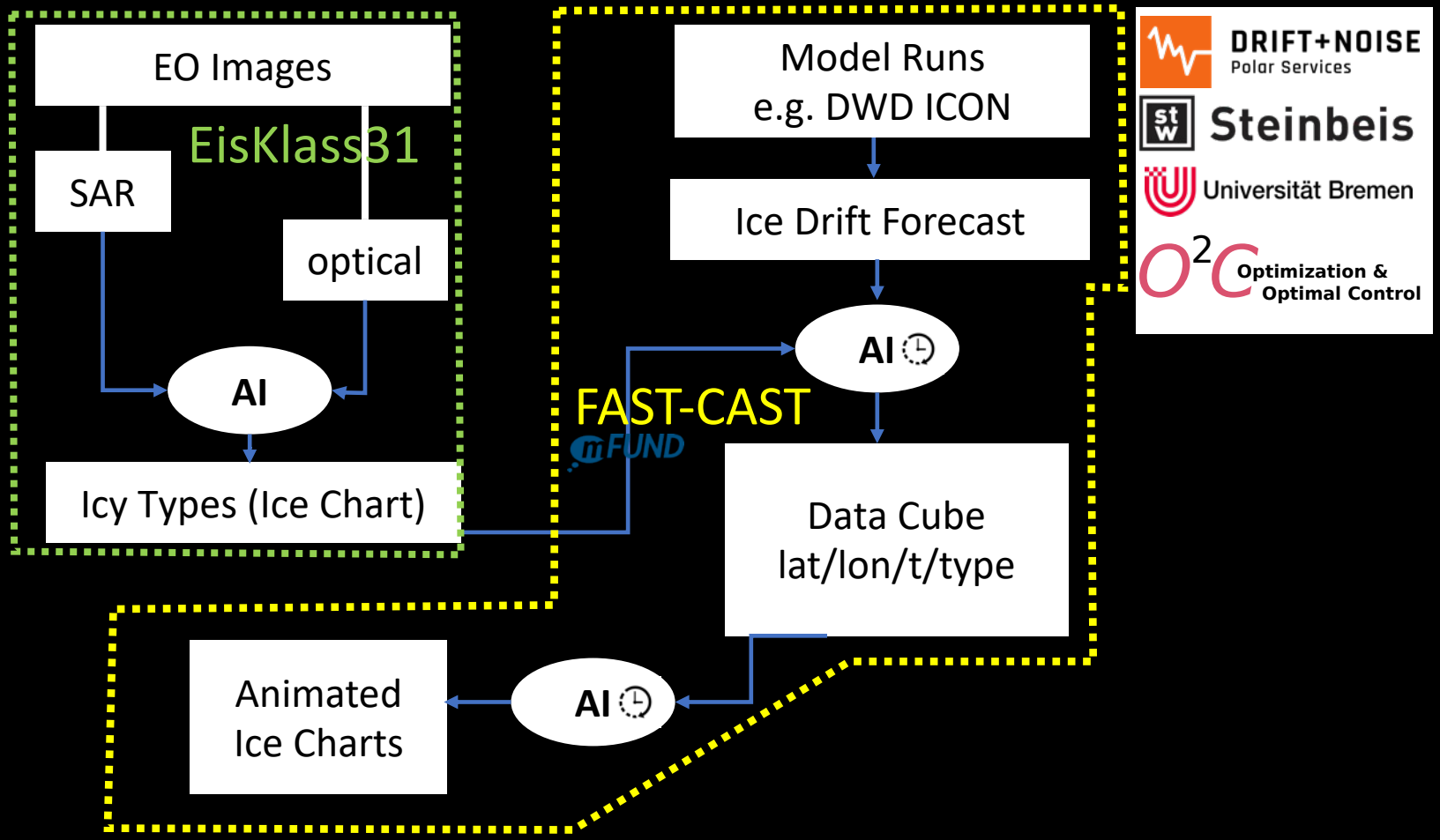

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Dynamik des Eises – Projekt FAST-CAST

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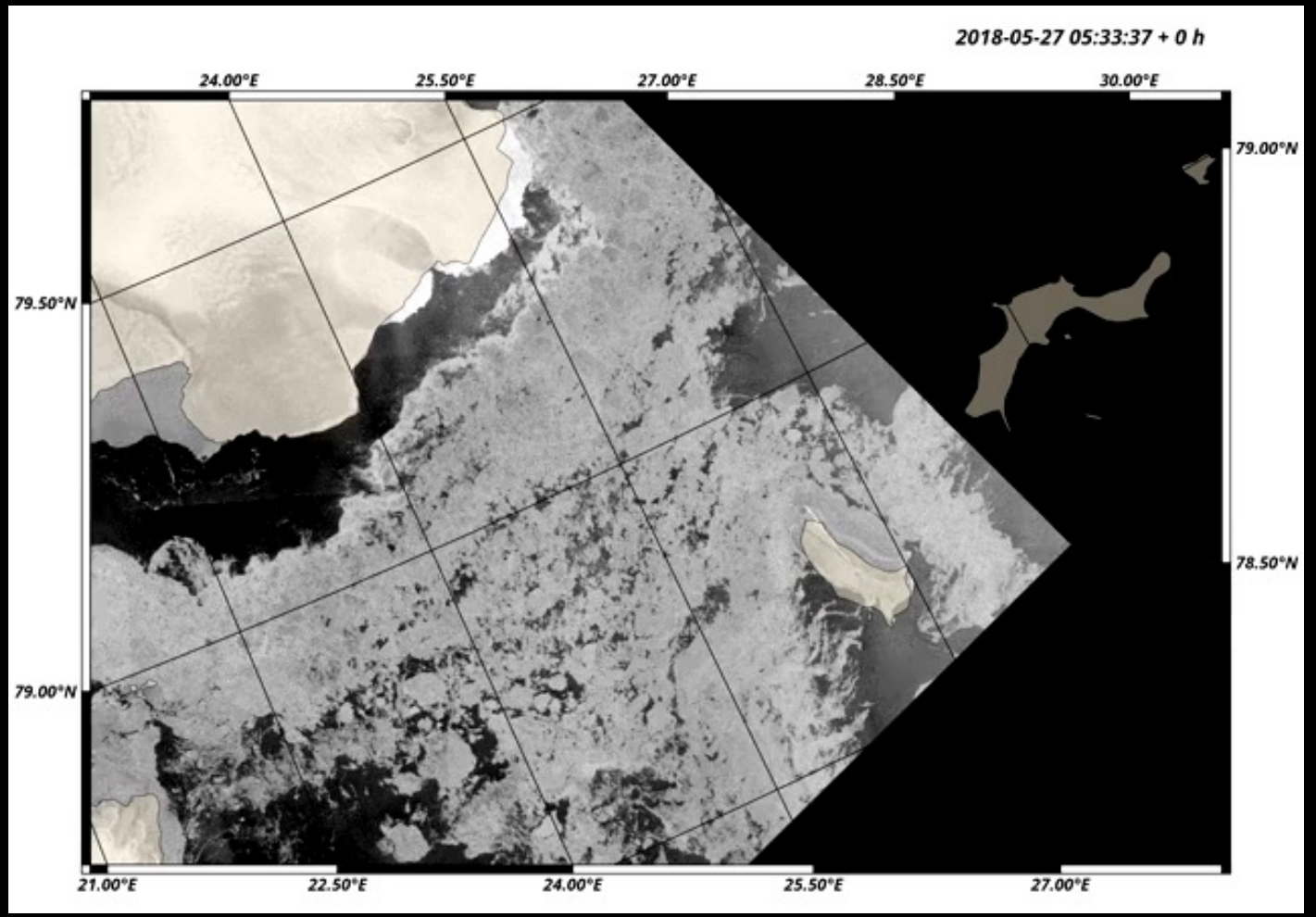
st w Steinbeis



DWD

ICON Wettermodell

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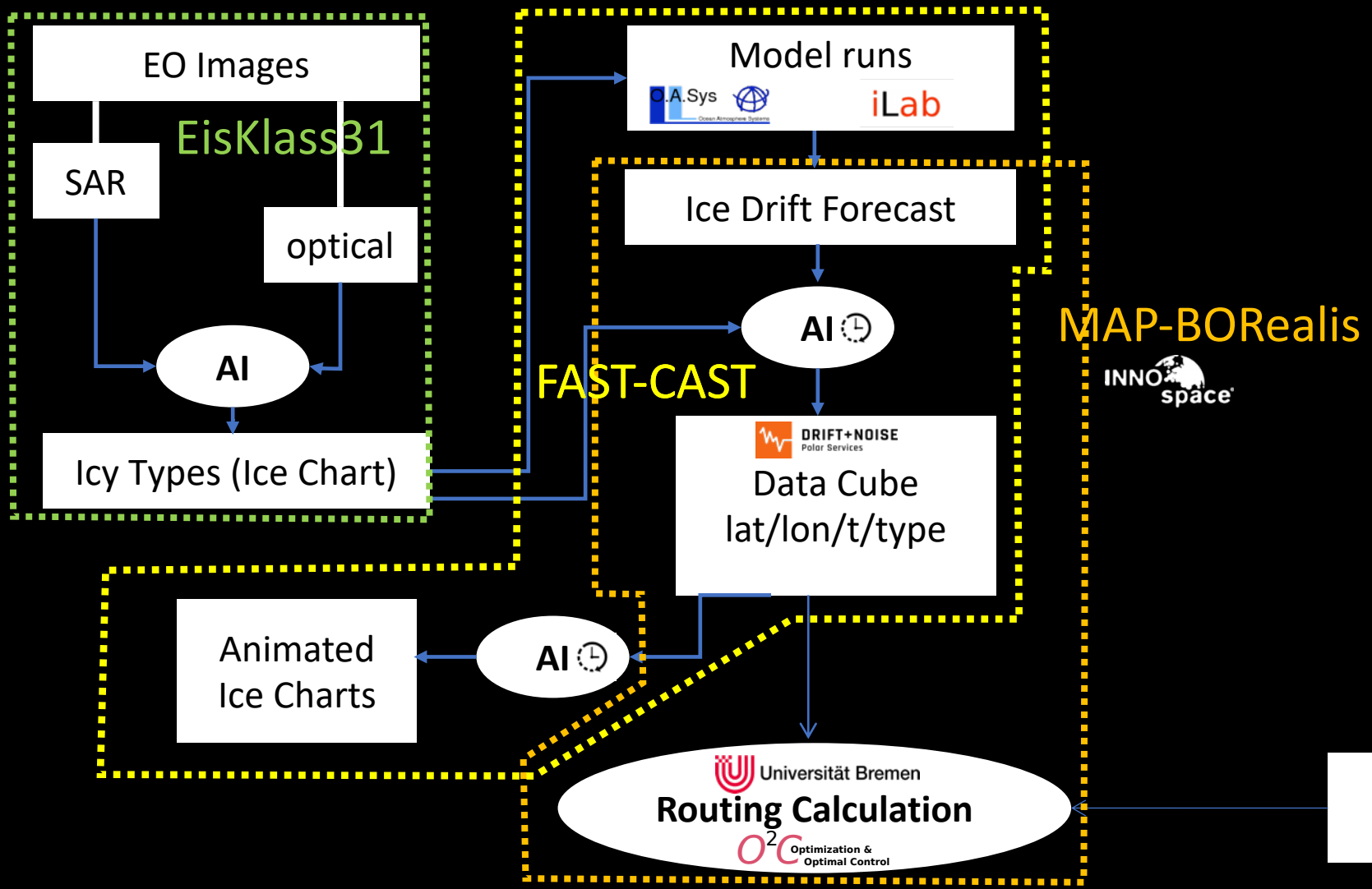

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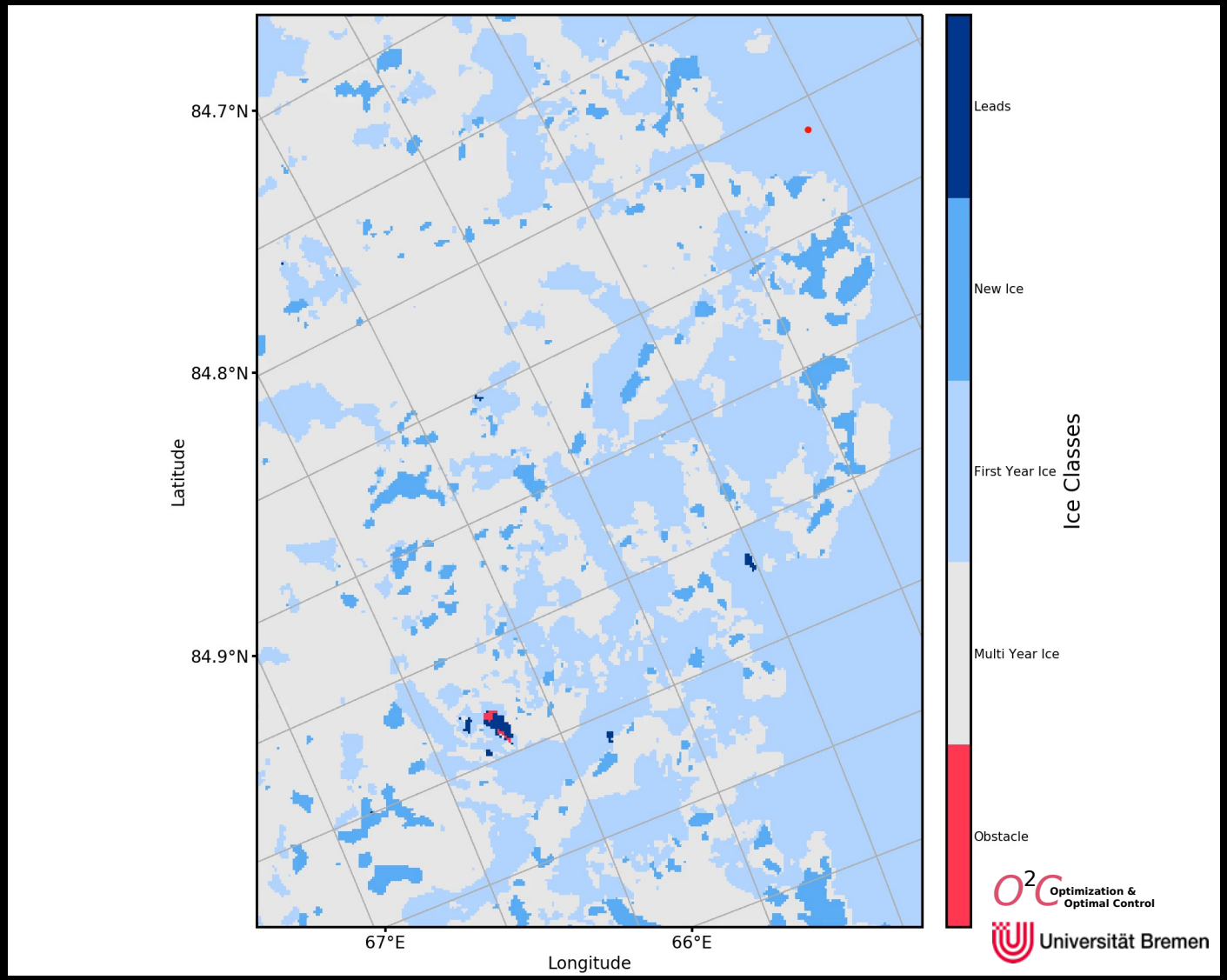
Visualization of a Route Calculation



Animation by:
Dr. Christine Eis,
University Bremen

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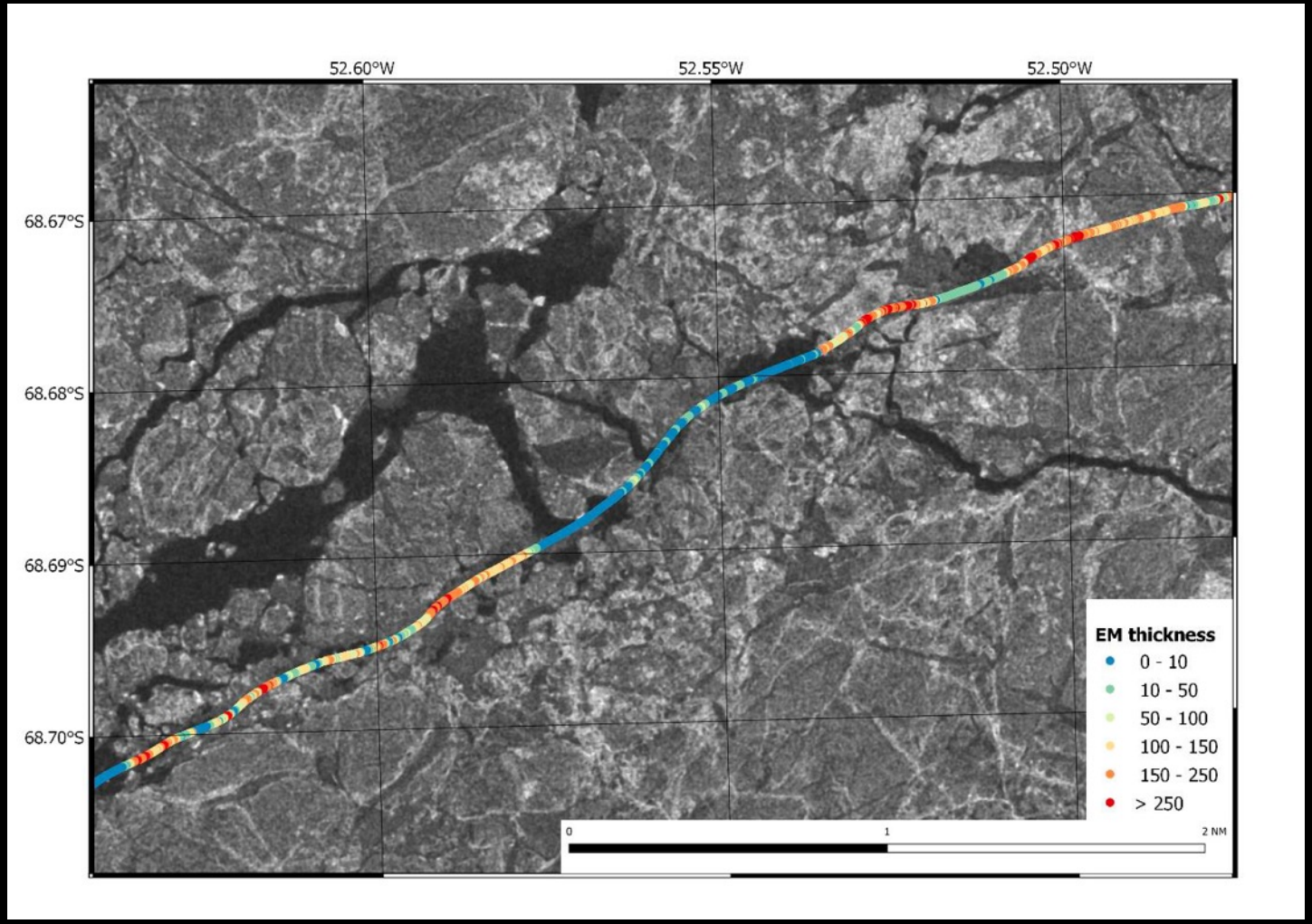
Analysing ship performance



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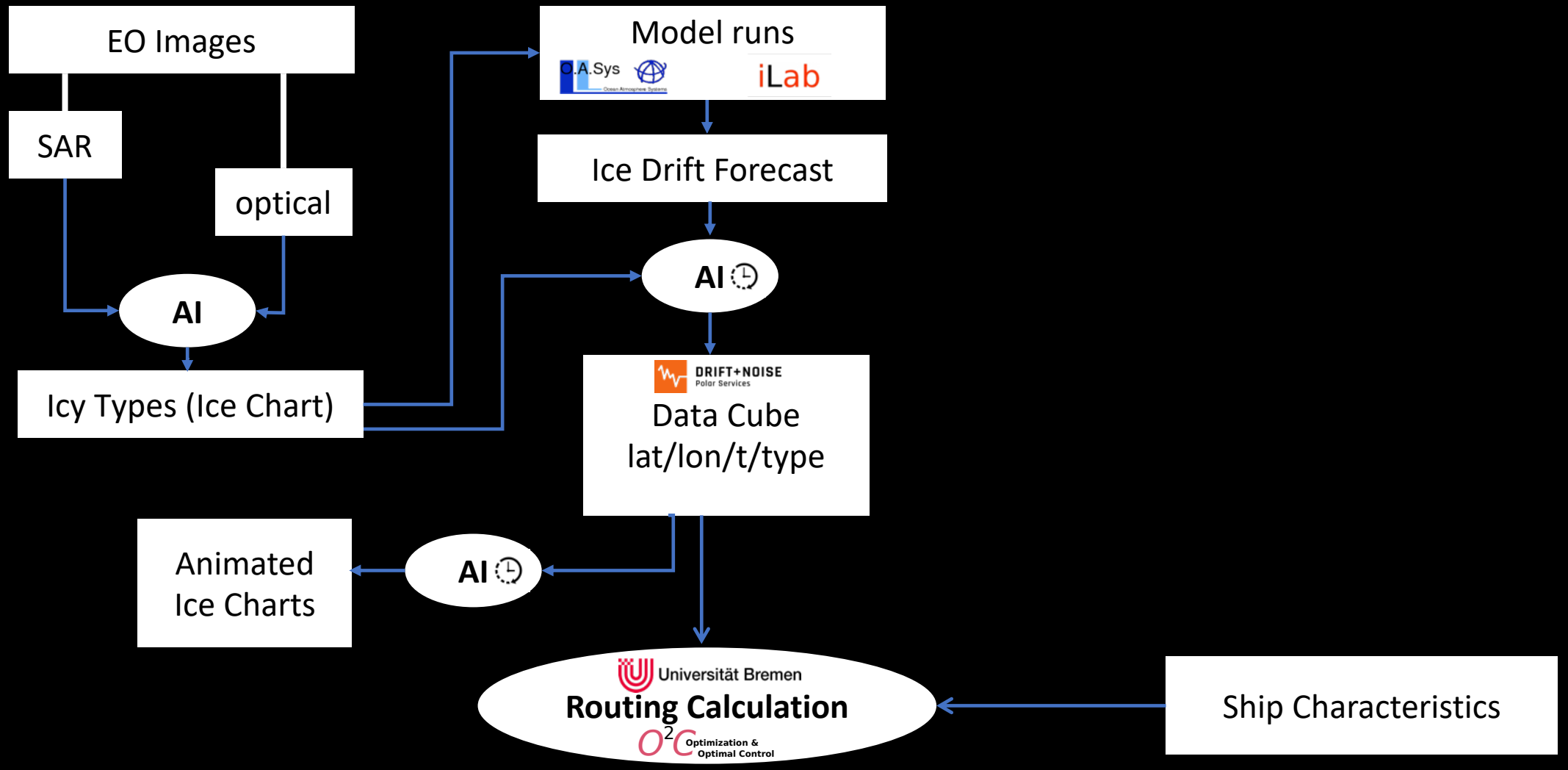

Rescue of crew from the "Northguider". Screenshot of video from JRCC/NRK

Drama in Arctic waters as trawler runs aground at Svalbard

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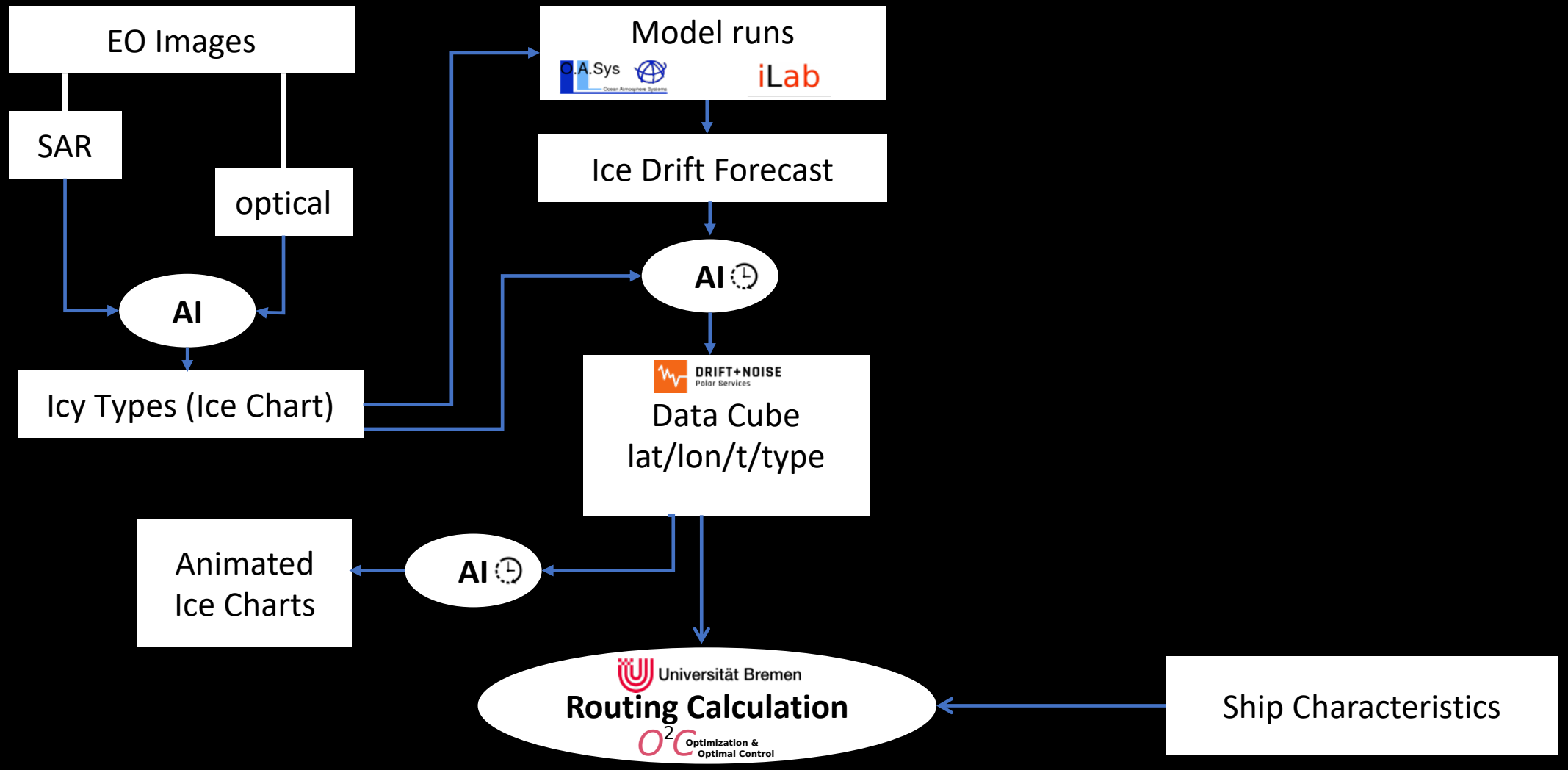

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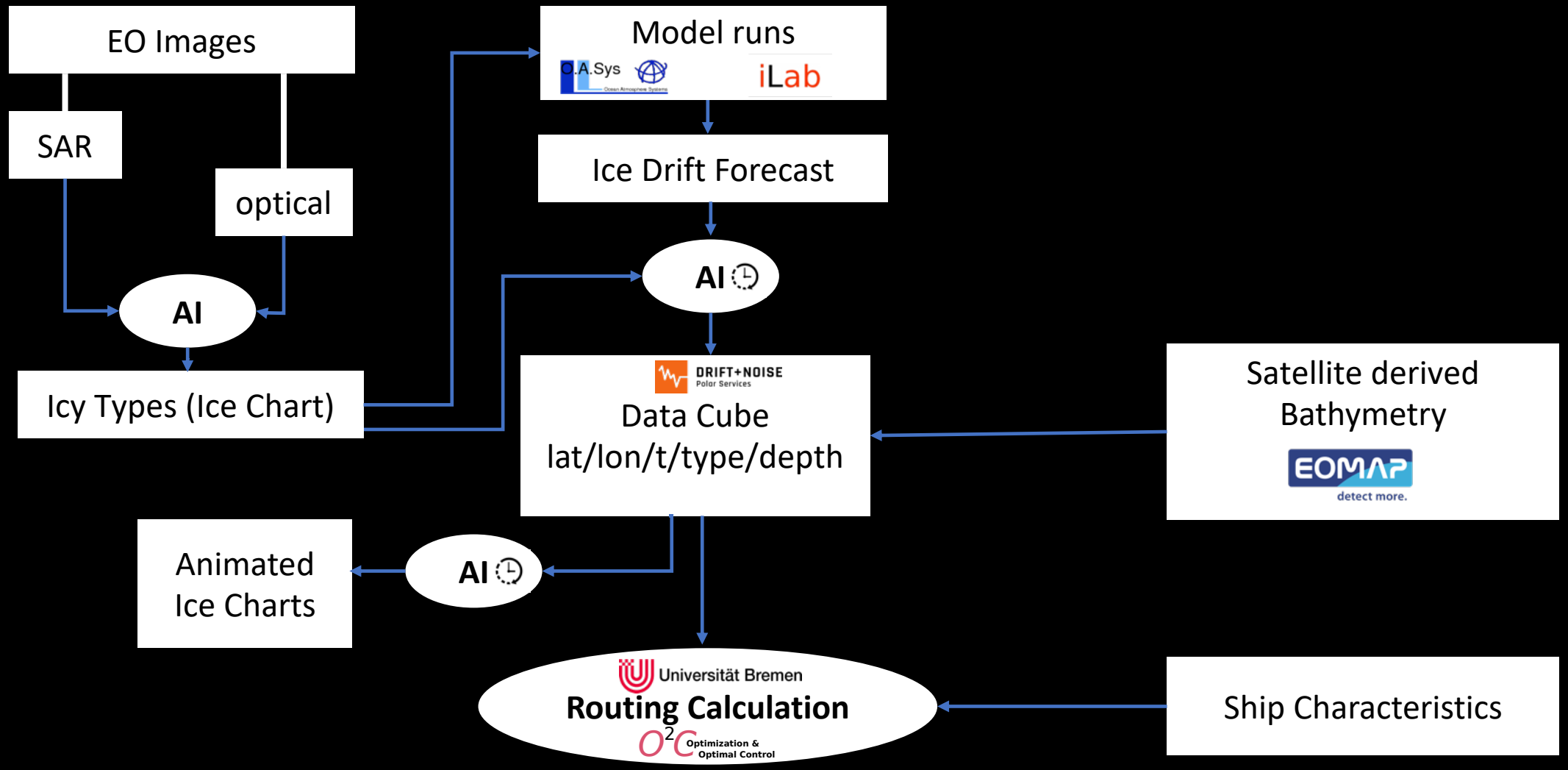

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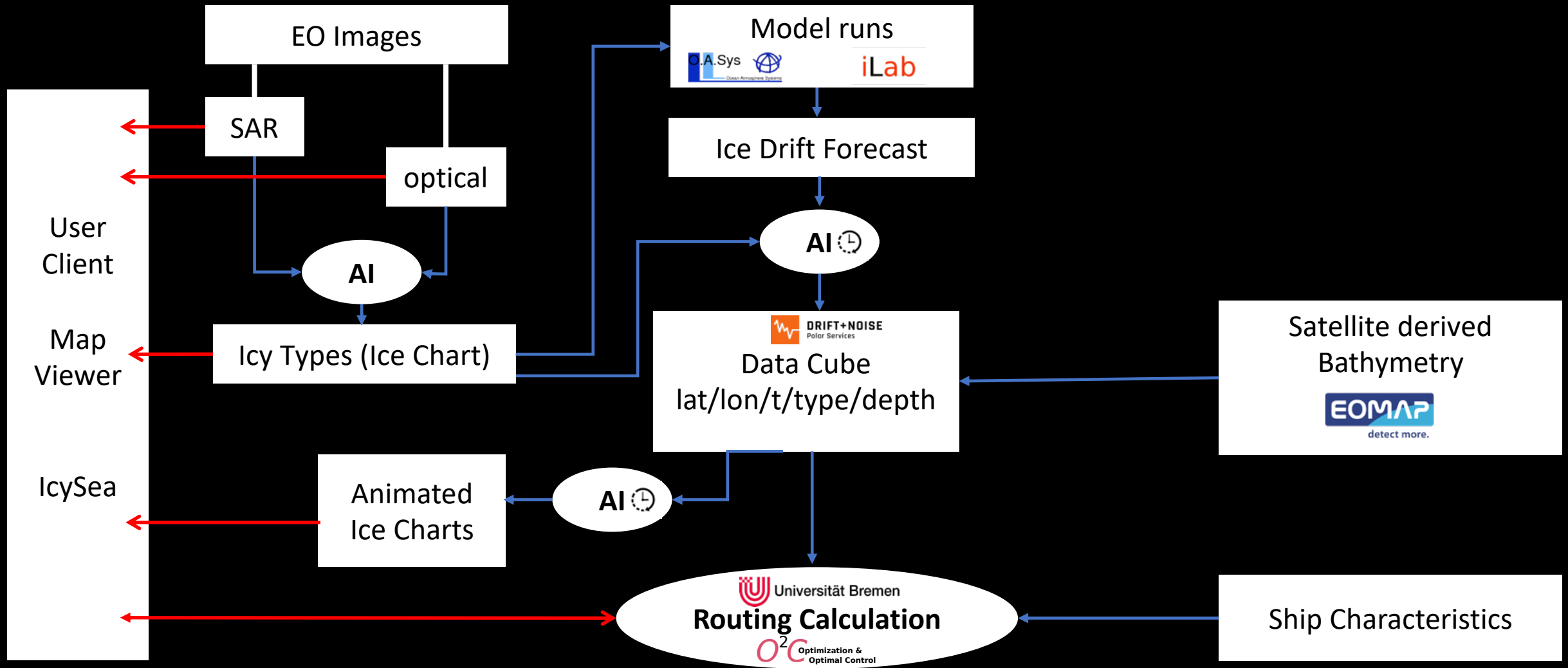
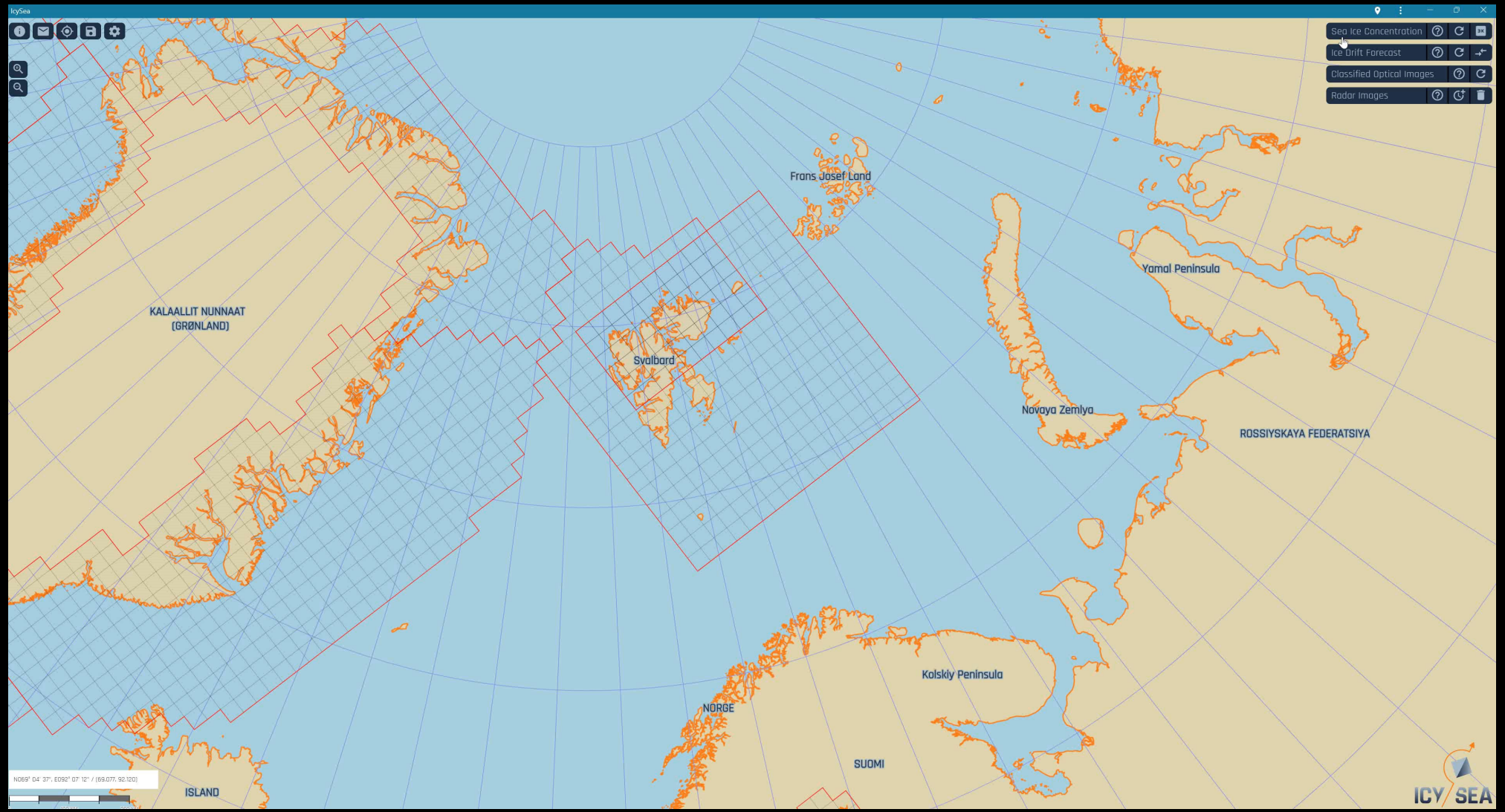


IcySea – an App delivered via the web
Goto https://icysea.app



ICY SEA

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Contract 110-DEM5-L6
Until 31 March 2021

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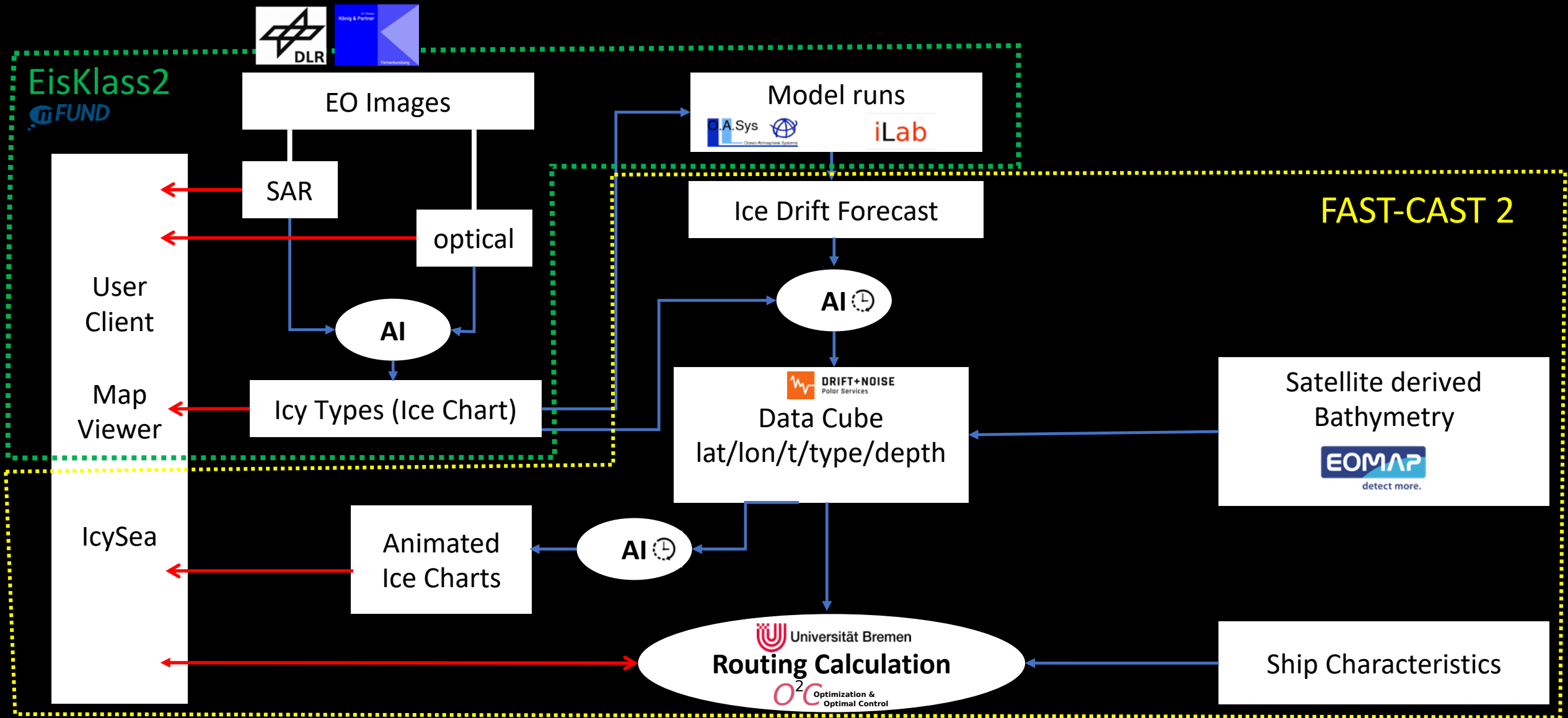
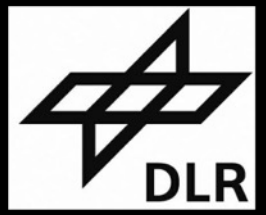


Wanted

Early adopters for a new ice navigation system made in Bremen



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Ice information on Polarstern 2 ?

- More than daily updates of SAR and optical images
- Inclusion of several satellite missions
- Animated ice information: Forecasts and past drift
- AI based interpretation
- Trafficability maps
- A to B type route suggestions
- Continuous evaluation of ship performance in relation to ice regime
- …

Concluding messages

- Message from Polarstern 10.1.2023: *“Leider komme ich gleich mit einer Bitte: Die Sentinal1 Bilder kommen nicht in der gewohnten Frequenz.“*
  - Daily updates with SAR and optical images is possible today

- A digital ice information system is not far away!
  - A lot of know-how is located in Bremen (DLR, University, DNPS, AWI)

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Is AWI O2A strategy open for such a system?