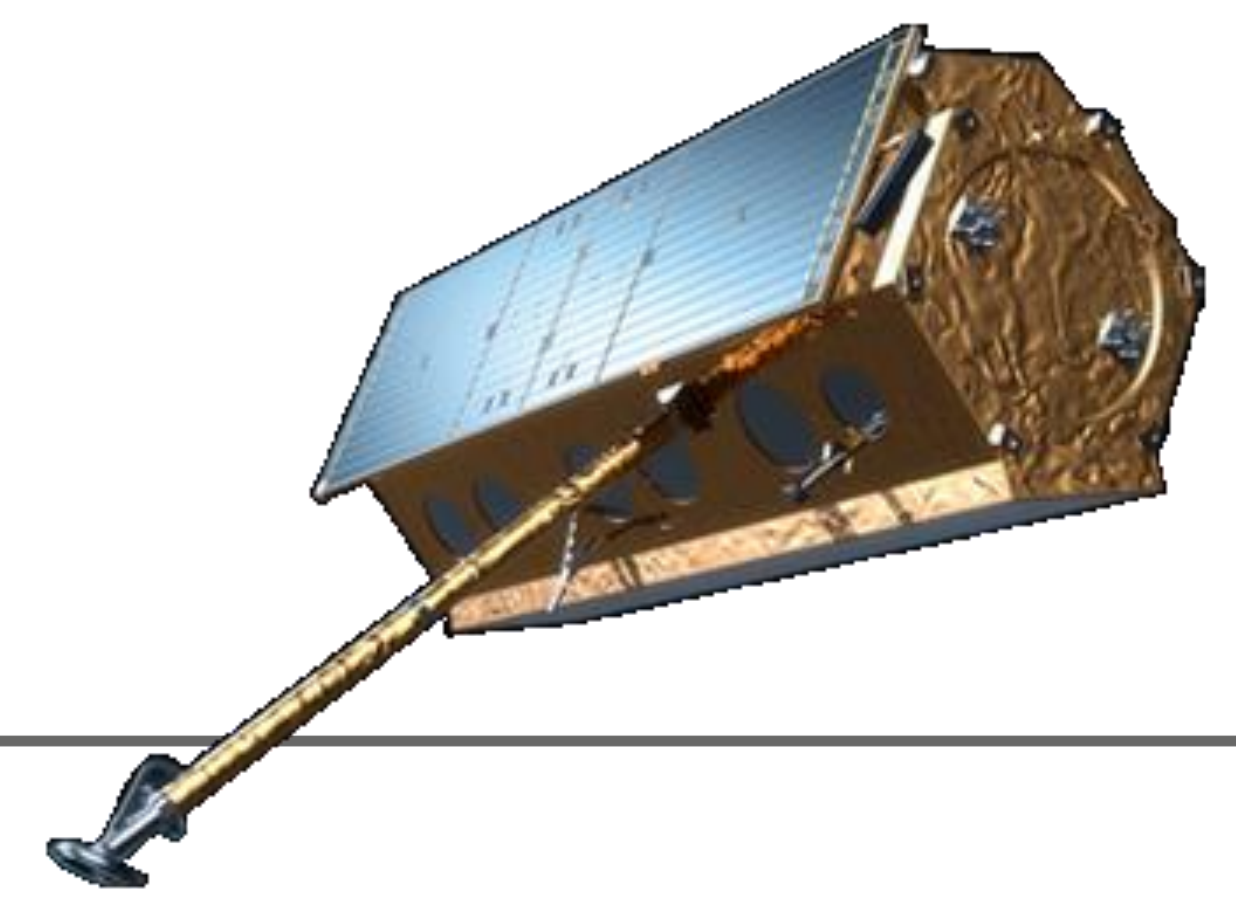


Towards automatic ship route calculation in ice covered waters by providing dynamic ice maps using spaceborne SAR data

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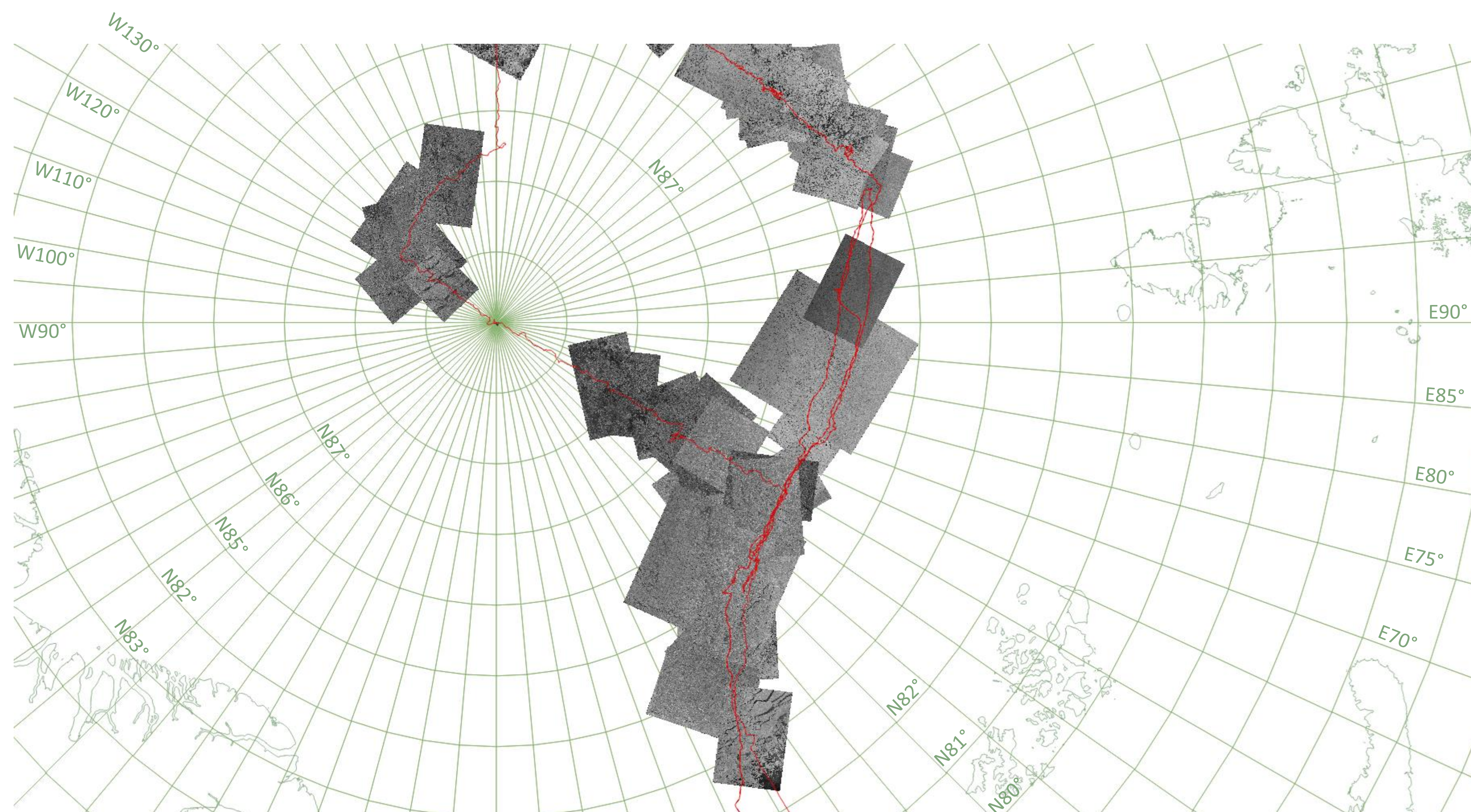
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TerraSAR-X provides high-resolution X-band data for use in climatology, environmental and disaster monitoring, hydrology, geology, oceanography and cartography.

Quick facts:

- 514 km altitude
- 15 orbits per day
- sun-synchronous repeat orbit
- 15°-60° incidence angle range
- **tasked on demand**
- **delivery in near real-time**



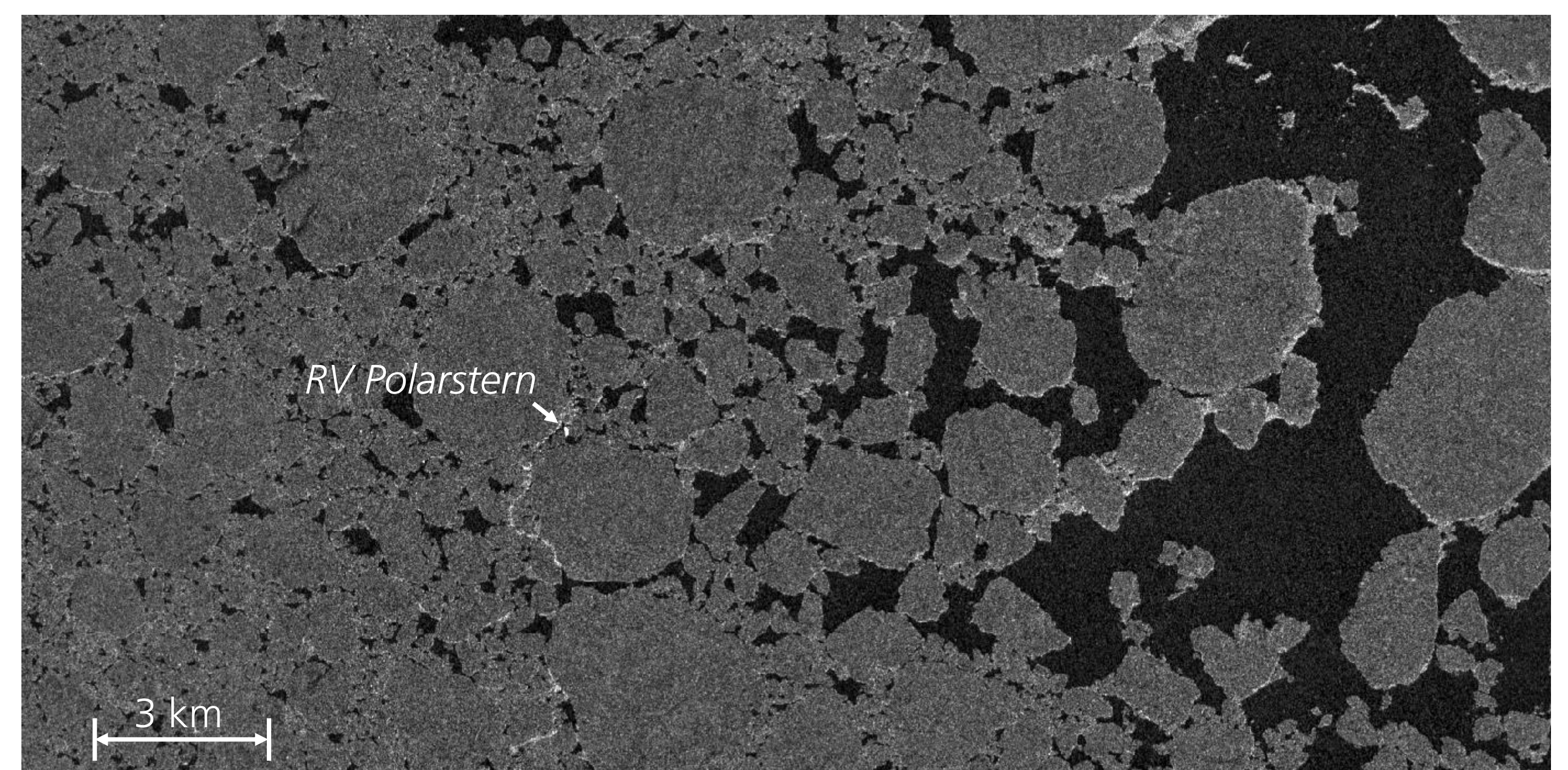
TerraSAR-X data acquired along the ship course of RV Polarstern during research expedition ArcWatch 2. Red line: Ship course from 9th August to 13th October 2024.

Shipping in ice-covered waters

Sea ice is subject to constant change. Wind and ocean currents interact with the sea ice. Converging forces can push large masses of ice together, closing off areas of open water. If the pressure process continues, ice floes can pile up on top of each other, forming an uneven and thick ice cover that can be impassable, even for icebreakers. Elsewhere, divergent conditions can break up the ice, creating open leads.

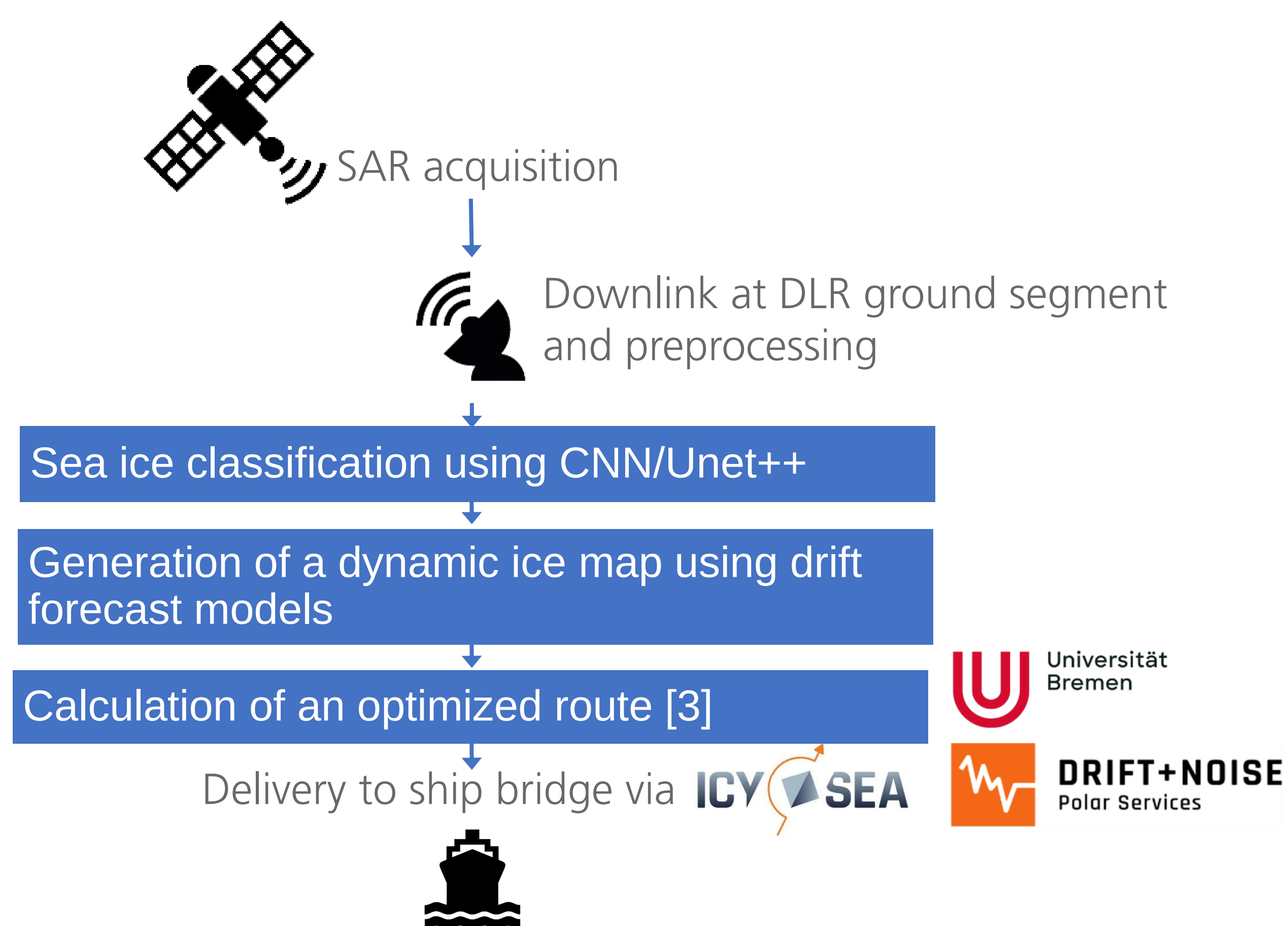
Navigation assistance from space

To support ship navigation, TerraSAR-X is tasked to acquire specific images along the ship route or from a target area. The satellite data is then downlinked, processed, and delivered to the ship bridge fully automatically and in near real-time. This processing chain was used on several polar expeditions where it has been demonstrated that providing up-to-date SAR images helps to optimize routes.

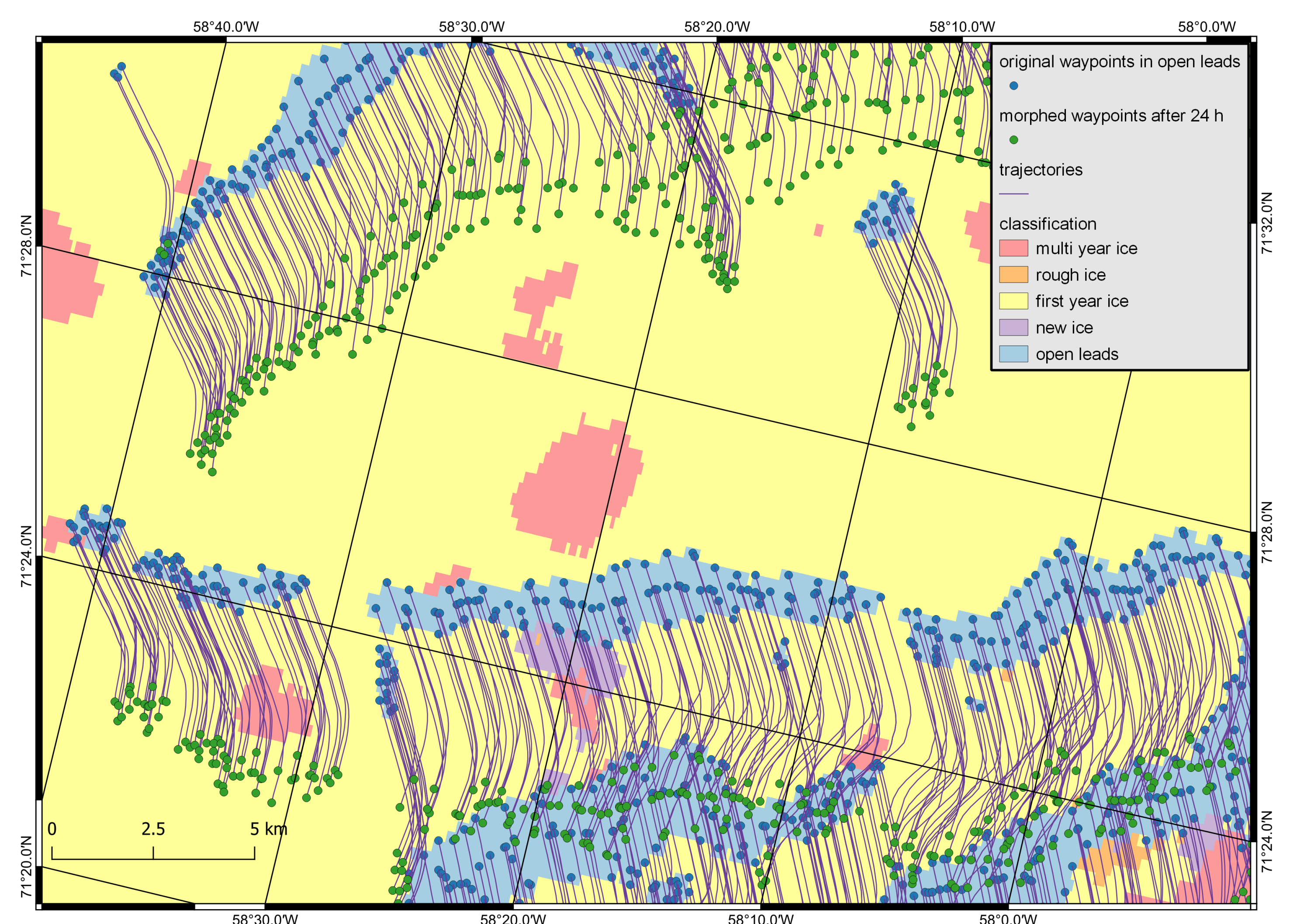


Section of a TerraSAR-X acquisition taken during Polarstern expedition ArcWatch 2. The position and extend of ice floes and open leads become visible. In addition, the SAR data contain detailed information about the properties of the sea ice, which can be used to classify the ice.

In our latest work, we use a CNN/Unet++ to classify SAR images, thereby generating high-resolution ice maps that outline different ice types, as well as areas of open water [1]. Furthermore, we use a newly developed method [2] to incorporate the time dimension in these ice maps using sea ice drift prediction models. The result is a spatio-temporal dataset that shows the expected ice motion up to the next 9 days. **The dataset forms the basis for automatic calculation of optimized ship routes through ice-covered waters.**



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The dynamic ice map has hourly temporal resolution and 160 m spatial resolution

[1] Murashkin & Frost: Arctic sea ice mapping using Sentinel-1 SAR scenes with a convolutional neural network. In IEEE IGARSS (pp. 5660-5663), 2021

[2] Bathmann et al.: Dynamic Ice Map: Combining High-Resolution Sea Ice Type Classification With Sea Ice Drift Forecast. ESA Living Planet Symposium 2025

[3] Schmitz et al.: Optimizing shipping routes based on dynamic ice maps. Arctic Frontiers 2025, Tromsø, Norway