The Role of Satellites in Voyage Planning: Current and Future Information Products to Support Polar Shipping

POLAR MARITIME SEMINAR
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IMO Headquarters, London, UK

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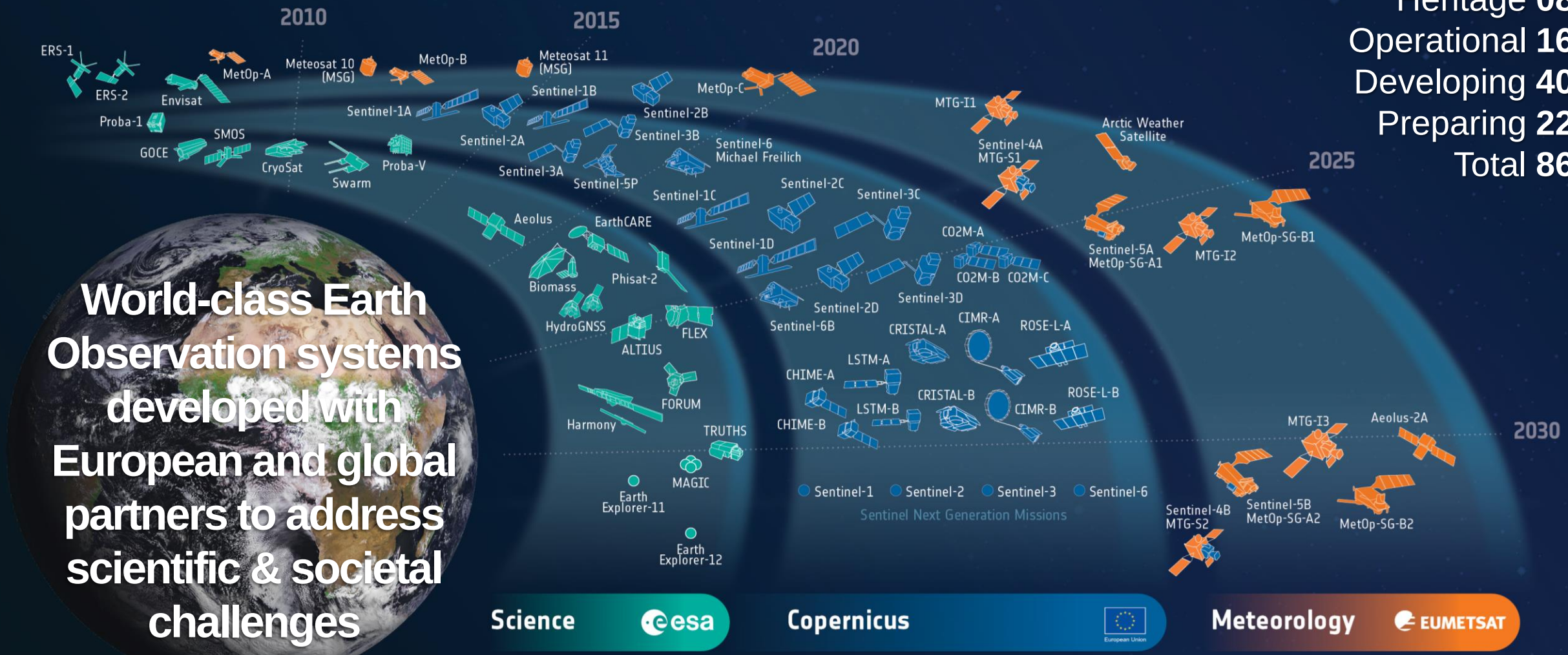
ESA's Earth Observation Missions

Taking the Pulse of our Planet

Satellites

Heritage **08**
Operational **16**
Developing **40**
Preparing **22**
Total **86**



World-class Earth Observation systems developed with European and global partners to address scientific & societal challenges

Science esa | Copernicus European Union | Meteorology EUMETSAT

Copernicus Space Evolution

PROGRAMME OF THE EUROPEAN UNION

co-funded with esa

CHIME
Copernicus Hyperspectral Imaging Mission for the Environment

soil properties
crop health
raw materials
biodiversity
water quality

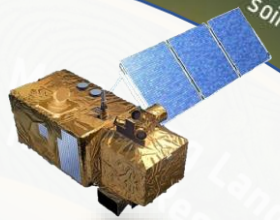
ROSE-L
L-band Radar Observing System

geohazards
polar ice
forest management
food security
maritime surveillance

LSTM
Land Surface Temperature Monitoring

sustainable agriculture
water resource management
drought
urban heat

Sentinel-1 NG



Sentinel-2 NG

sea-ice concentration
sea-surface temperature
polar maritime security
global ocean and cryosphere
soil moisture and vegetation

CIMR
Copernicus Imaging Microwave Radiometer

CO2M
Copernicus Anthropogenic Carbon Dioxide Monitoring

carbon dioxide and methane from human activity

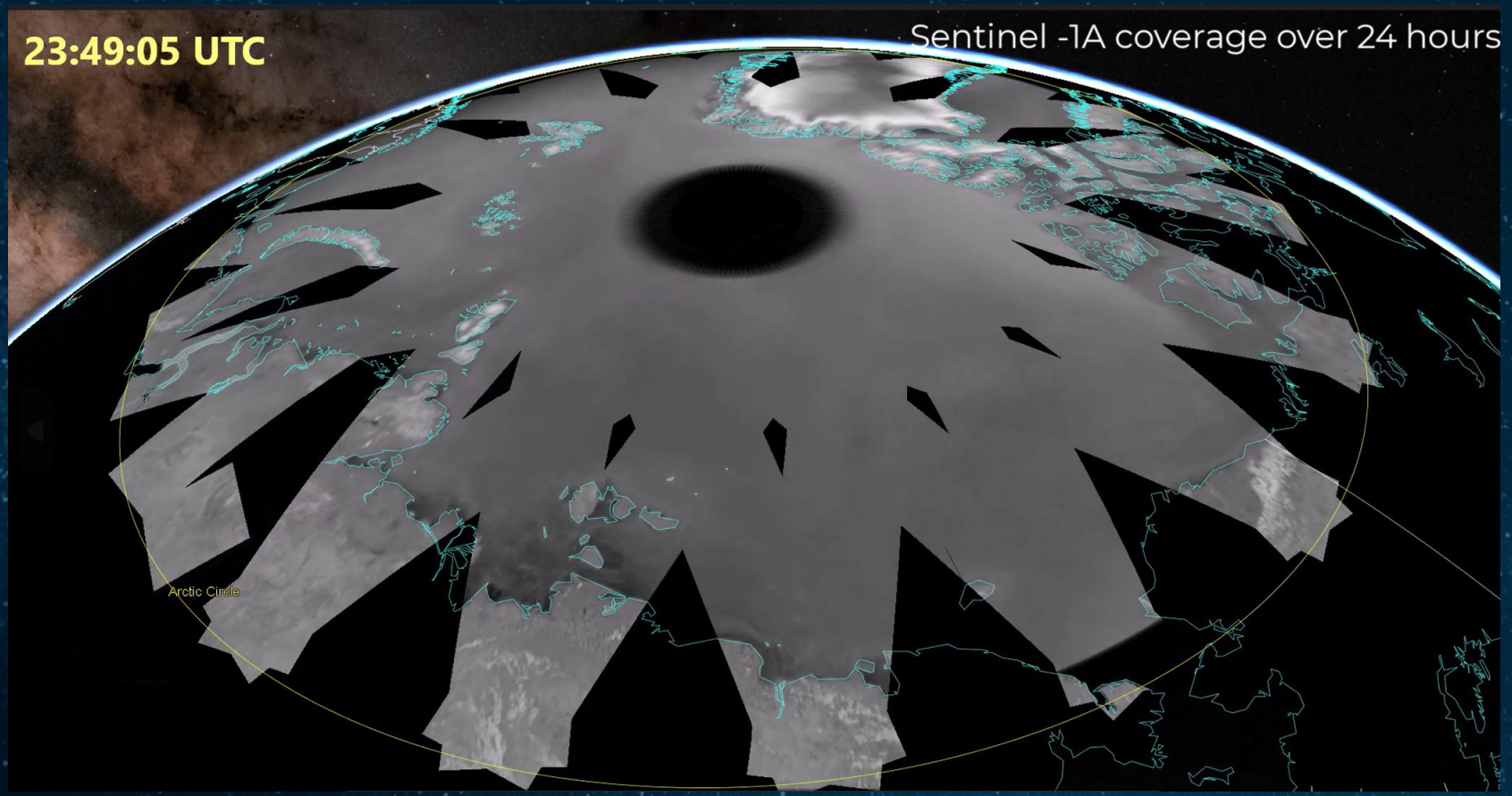
+ Next Generation Sentinels for data continuation and enhanced observations

Sentinel-3 TOPO/OPT NG

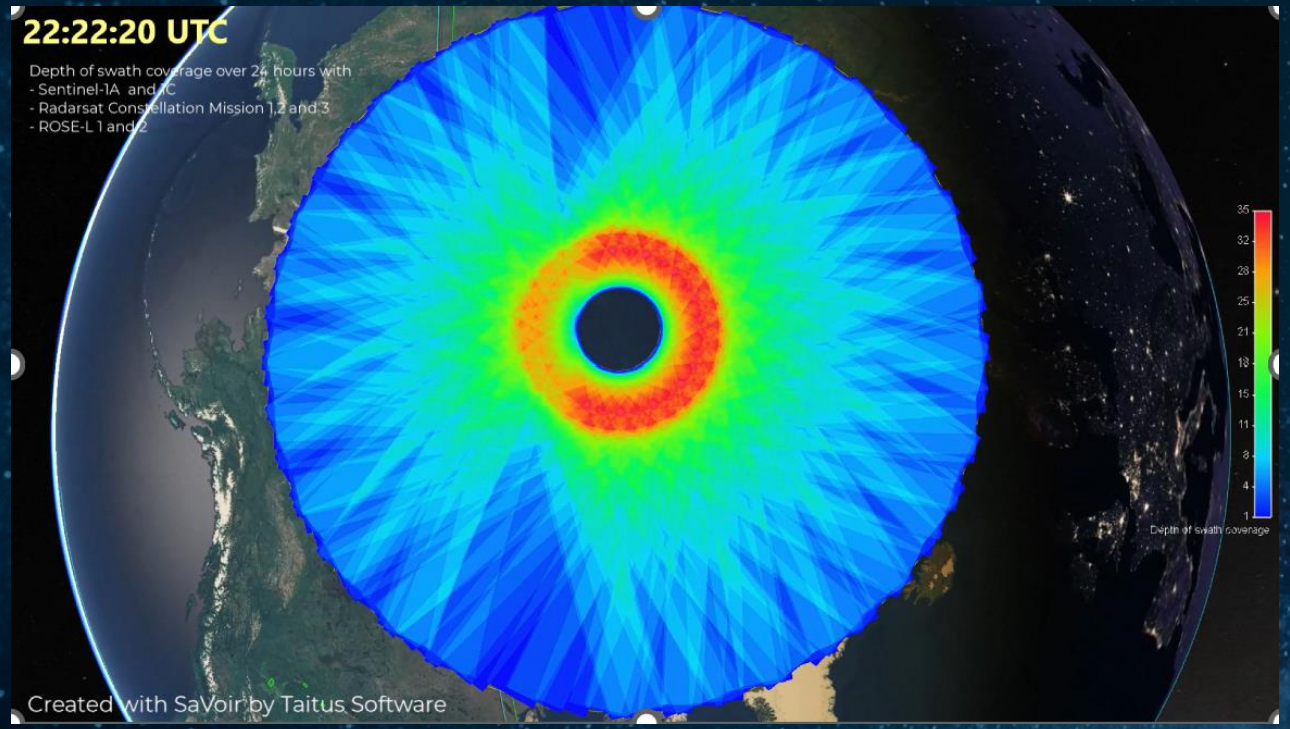
CRISTAL
Copernicus Polar Ice and Snow Topography Altimeter

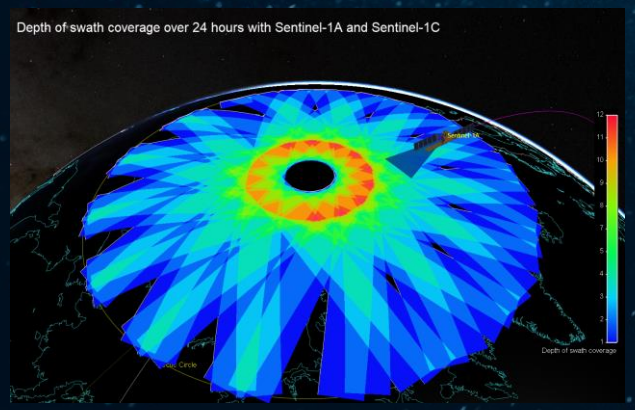
coastal and inland waters
polar oceanography
snow
ice sheets and glaciers
sea-ice thickness

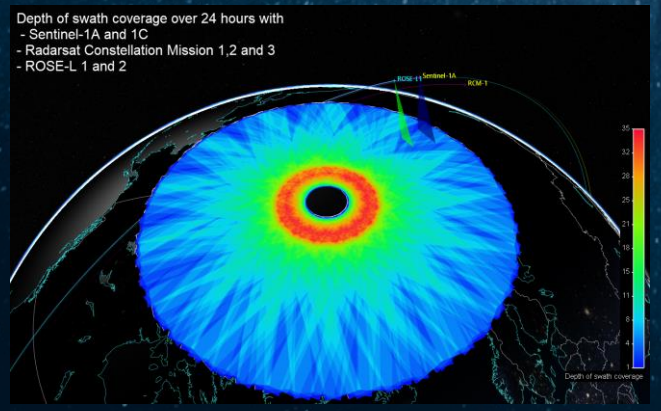
Arctic coverage over 24h with S1-A



Arctic coverage over 24h with S1-A, S1-C, RCM & ROSE-L







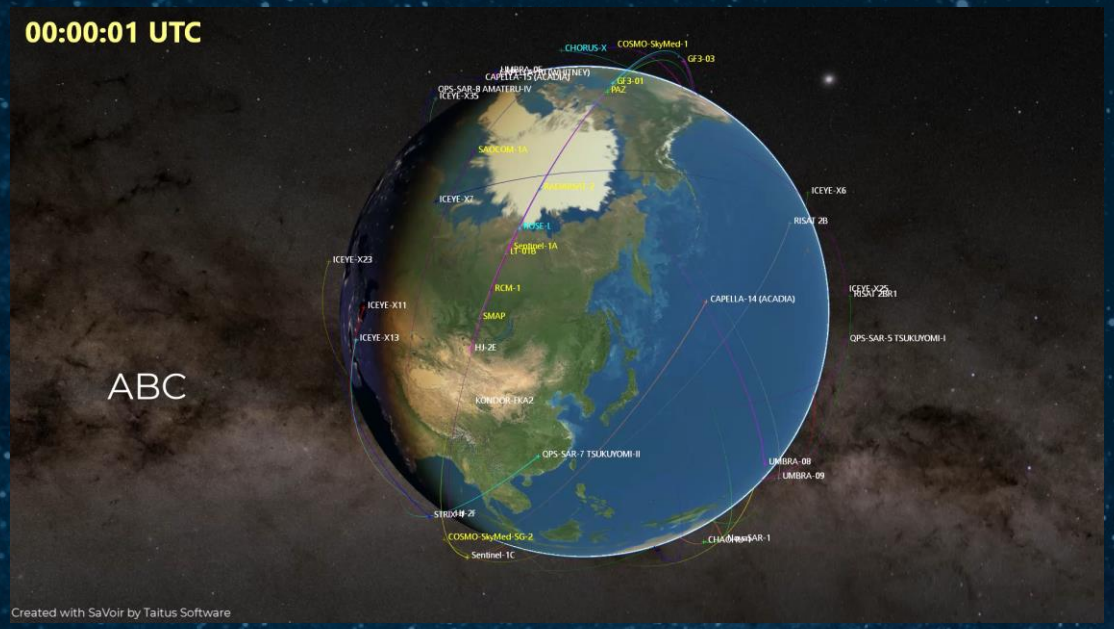
Sentinel-1

RCM

ROSE-L

- Increased revisit frequency and overlap at higher latitudes
- Enhanced Monitoring capabilities of rapid changes, NRT applications

An Evolving Landscape of SAR capabilities



More than 71 SAR missions in orbit, including national and commercial missions

- Frequent & global coverage – NRT capabilities
- Geometric Diversity
- Full polarimetric & Multi-frequency capabilities
- Multi-Source fusion
- Data continuity & Quick data delivery

TAITUS SOFTWARE

Beyond satellite Development & Mission Management…

Satellite Design & Development

Missions Management

Cal/Val & Data Distribution

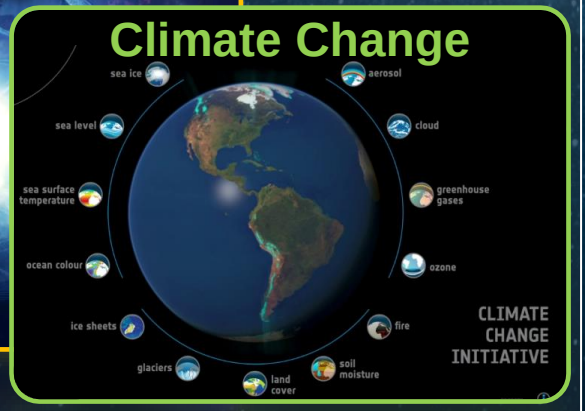
Applying the Data for Earth Action

Earth System Science

Emergency Response

Digital Twins

Climate Change



Innovation

Φ-lab

Accelerate the future of EO Via transformative innovation & commercialisation actions

Future Systems & Instruments activities

Accelerate the future of EO with cutting edge research

Commercialisation

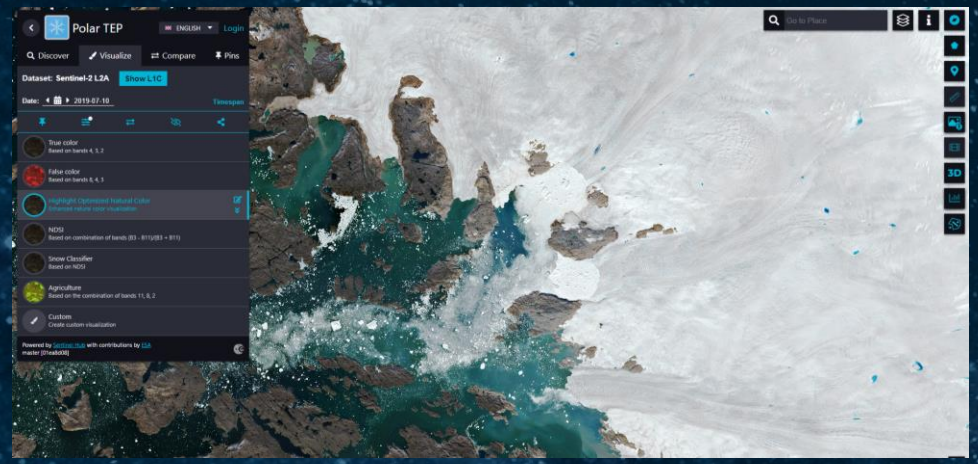
InCubed

EO data made accessible

Empowering users with Digital Platforms and services for easy Data access and exploitation

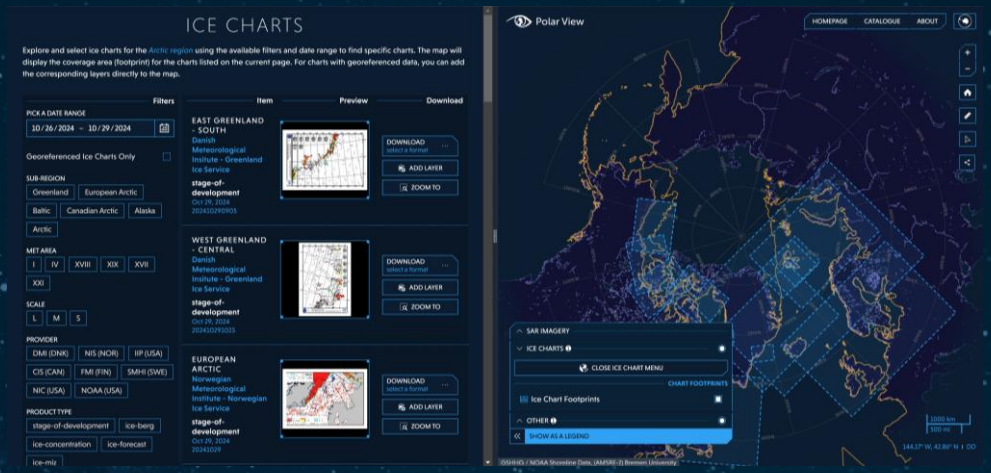
Polar View

esa

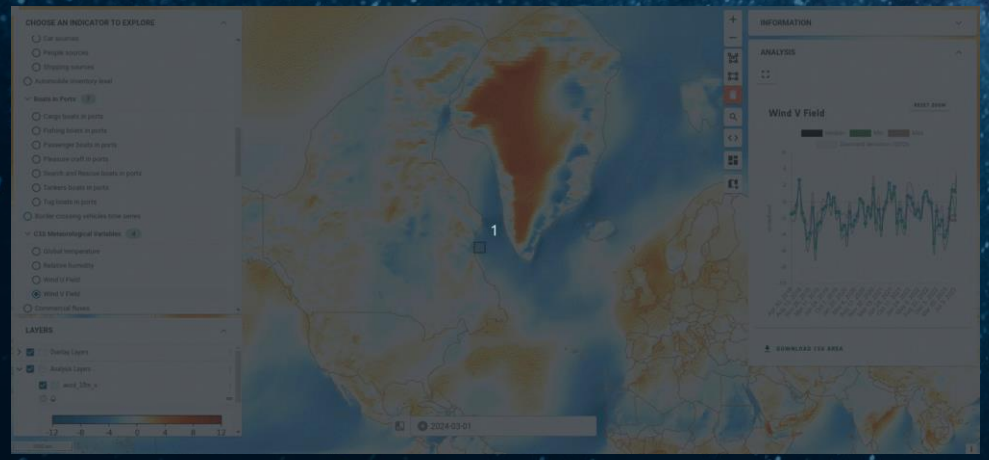


polar tep

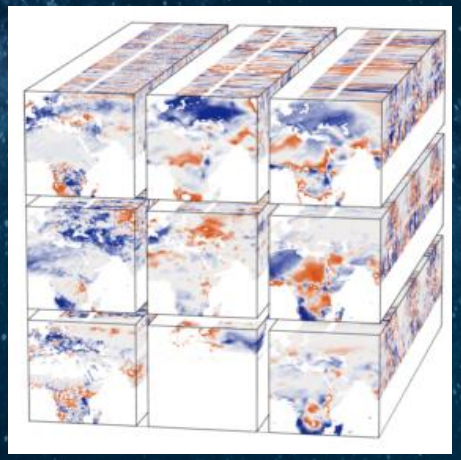
Research platform for private, academic, and public sectors



Central source for ice charts supported by **ESA** and implemented on behalf of the **IICWG**
https://www.icelogistics.info/



Polar Dashboard – Decision support interactive tools : Curated Data Interaction, Statistics, Story Telling

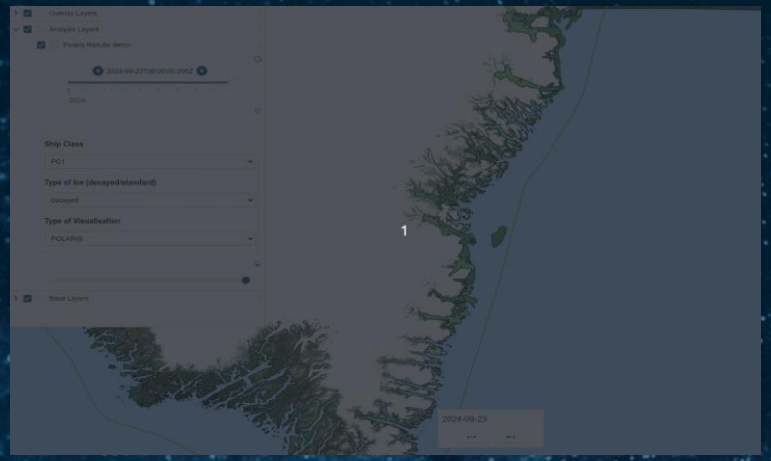


Sea Ice Chart Data Cube: Combining sea ice charts with other relevant data layers (SAR imagery, Metocean data, models, value-added products)

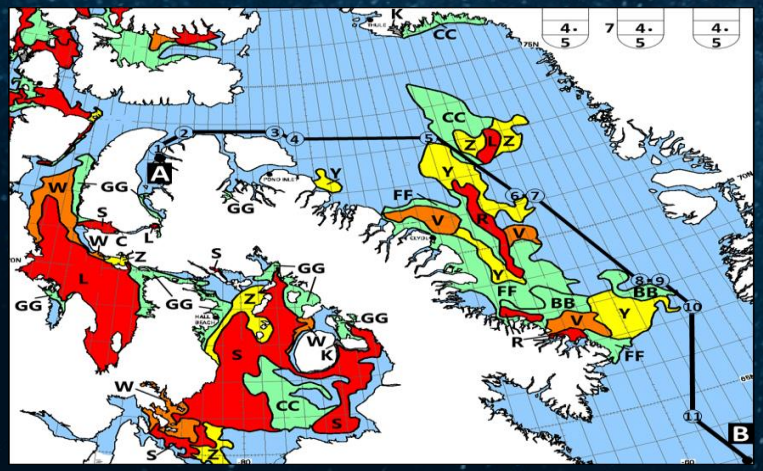
Optimized data access and Interoperability

From Data to Insights

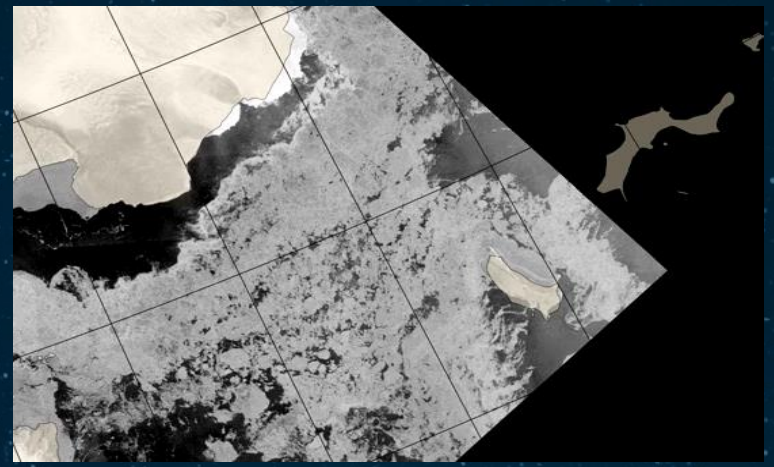
Examples of Value-added products and services to Support Polar Shipping



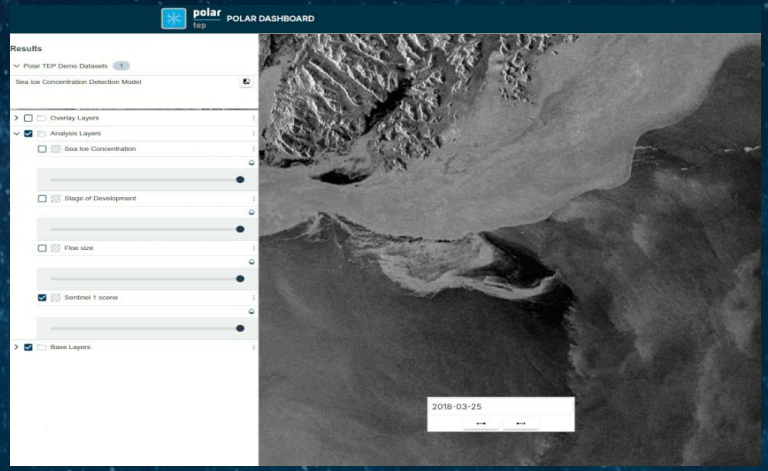
POLARIS calculation and overlaying with relevant data layers



Route Optimization: Minimizing fuel consumption, emissions and voyage time. Constraints: POLARIS requirements (safety requirements), Carbon Intensity Indicator (CII-Environmental requirements)



SAR image Morphing: Using sea ice drift models, the image can be morphed to simulate the ice position between images



AI-powered SAR Image interpretation : AI algorithms for sea ice parameters retrievals, Direct comparisons with the SAR images

From Data to Insights

Automatic AI sea ice product retrieval

A new and comprehensive AI-based methodology to retrieve high-resolution sea ice concentration with accompanying uncertainties from satellite data -**Pan-Arctic scale for all seasons**

Manually drawn **regional ice charts** are used as the "ground-truth"/labels for the supervised learning algorithm.

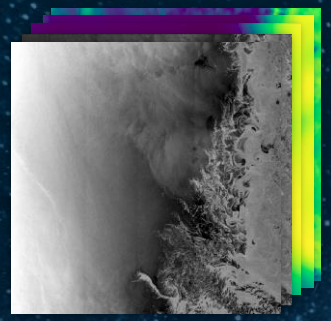
Advantages:

- Abundance
- Geographical/Seasonal coverage
- Often drawn on the basis of a SAR image, enabling the generation of a timely match-up training dataset

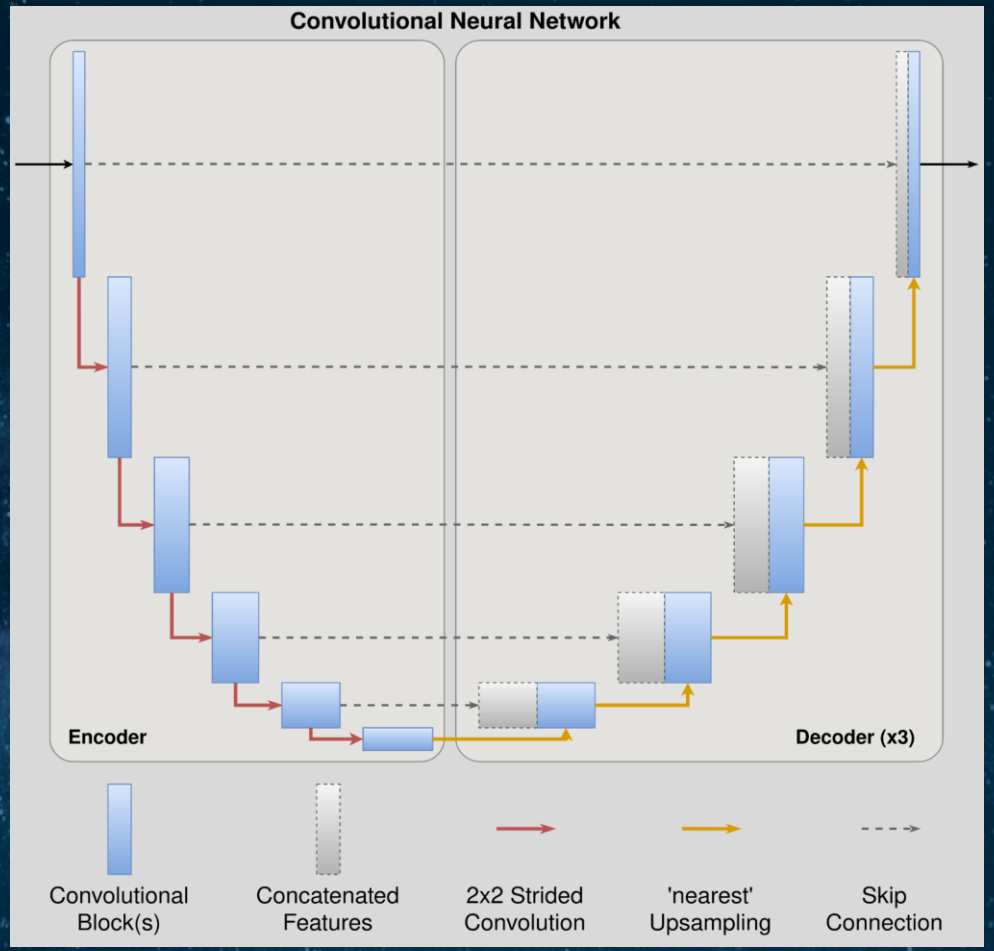
Disadvantages:

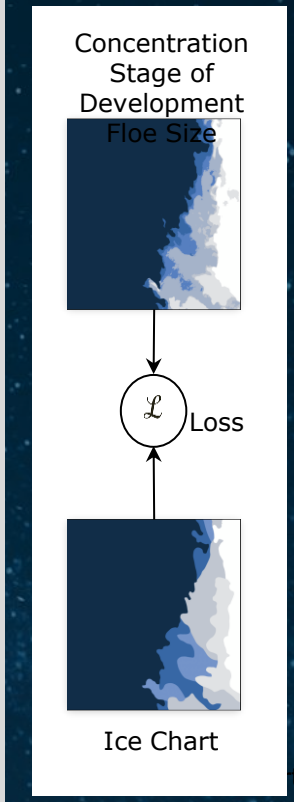
- Human subjectivity
- Uncertainty estimates are not provided
- Large polygons (relative to SAR resolution)

S1 + AMSR2. data.



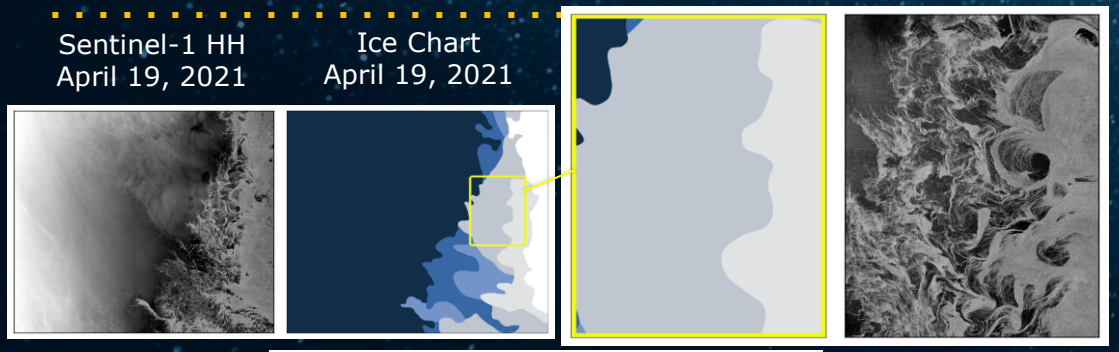
DMI-ASIP





Sentinel-1 HH
April 19, 2021

Ice Chart
April 19, 2021

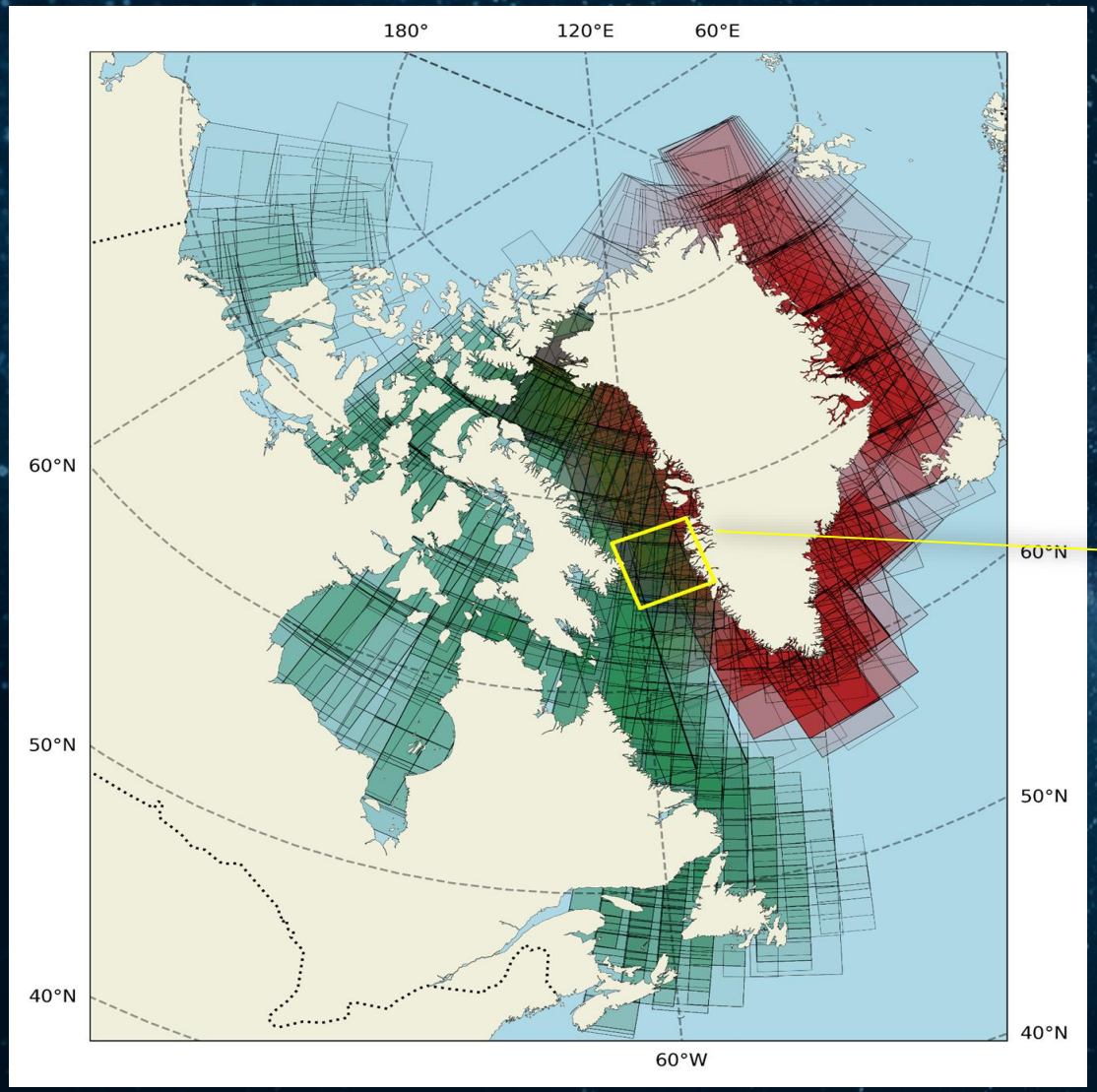


Wulf et al., "Pan-Arctic Sea Ice Concentration from SAR and Passive Microwave"
DOI: https://doi.org/10.5194/egusphere-2024-178

From Data to Insights

Automatic AI sea ice product retrieval

ASIP/AI4Arctic Sea Ice Dataset



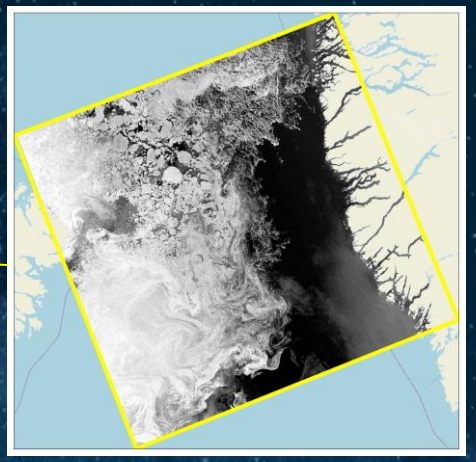
5382 unique matches of Sentinel-1 EW/IW imagery and manually produced ice charts from 2018 up to and including 2021, covering Greenland waters (DMI ice charts) and the Canadian Arctic (CIS ice charts).

Auxiliary observations:

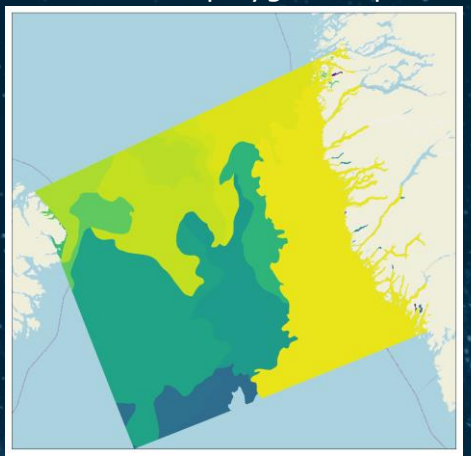
- AMSR-2 brightness temperatures for frequencies {6.9, 7.3, 10.7, 18.7, 23.8, 36.5, 89.0} GHz and polarisations {H, V}

Example scene, May 16th, 2021

Sentinel-1 HH

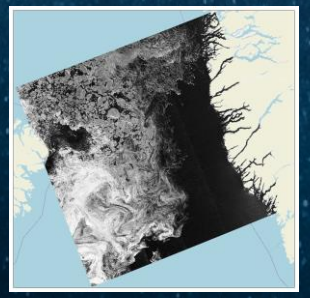


Ice chart polygon map



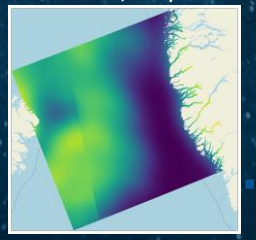
Ice chart look-up table

Sentinel-1 HV

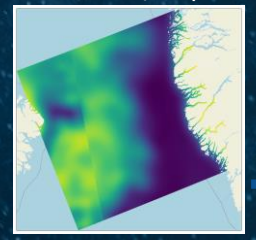


AMSR-2 brightness temperatures

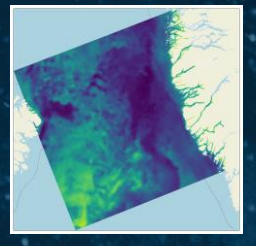
6.9 GHz, H-pol



18.7 GHz, H-pol



89.0 GHz, H-pol

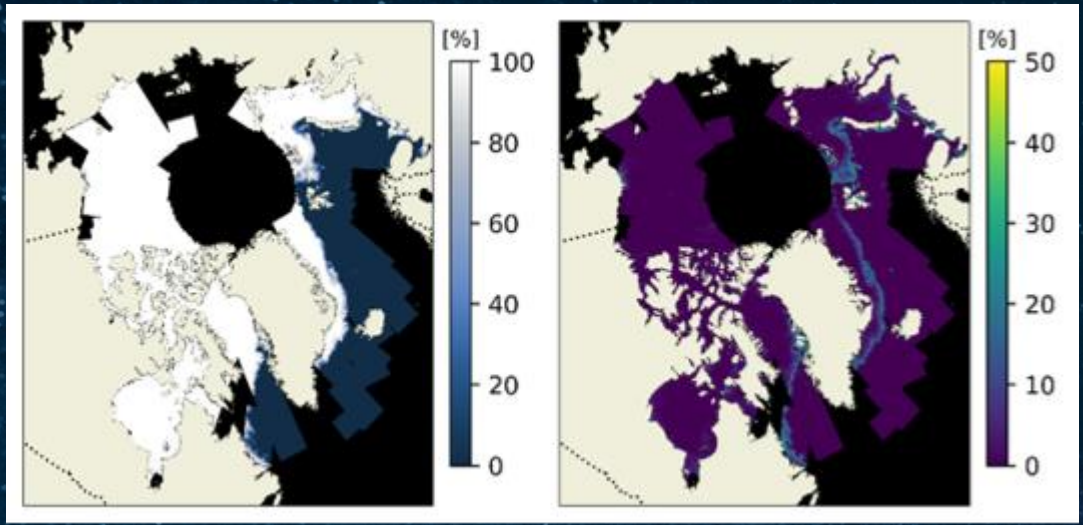


Buus-Hinkler et al., "AI4Arctic Sea Ice Challenge Dataset", DOI: https://doi.org/10.11583/DTU.c.6244065.v2

From Data to Insights

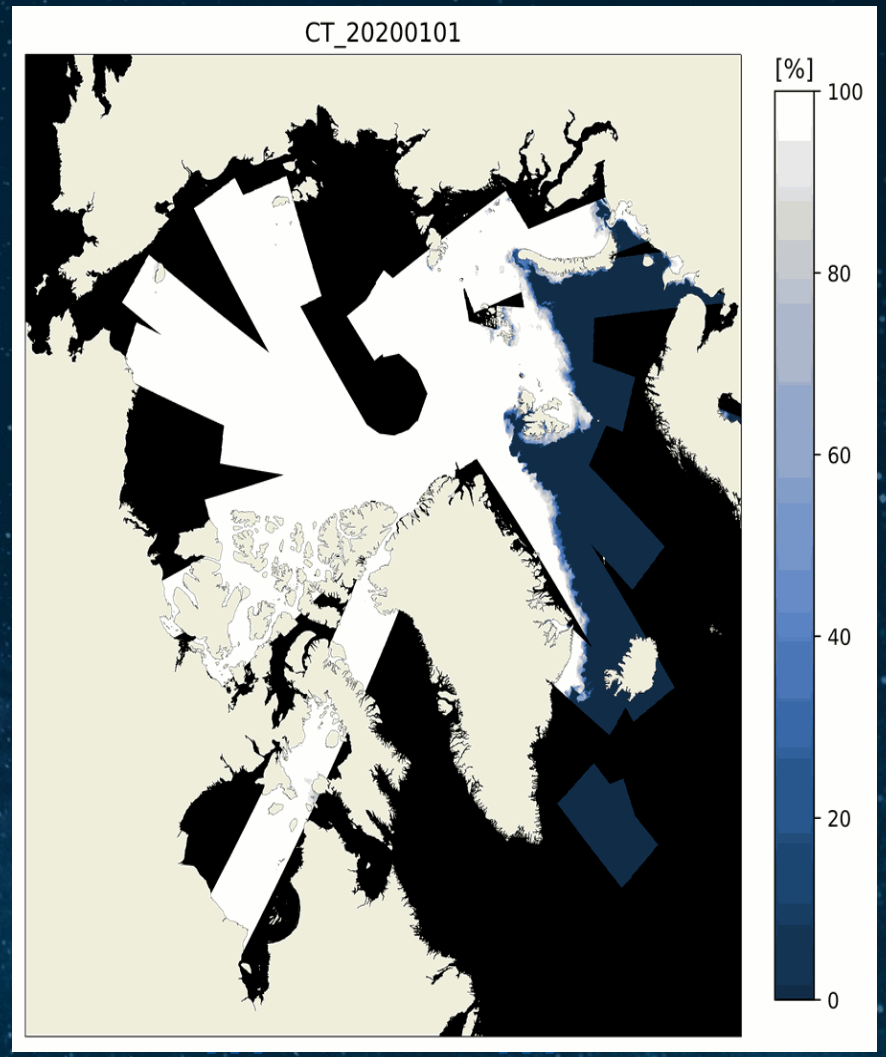
Automatic AI sea ice product retrieval

Example of a 7-day mosaic from Jan. 9th - Jan 15th, 2023 - Pan-Arctic scale



DMI-ASIP SIC DMI-ASIP Uncertainty

- **Well-calibrated uncertainty mosaics**: tendency of the ASIP retrieval to be very certain in regions of open water and densely packed sea ice, while being the most uncertain in the marginal ice zone, where sea ice concentration is highly variable
- **ASIP products used operationally at DMI** (e.g the output ASIP sea ice maps are continuously assimilated into DMI operational ocean and sea ice model)
- **ASIP ice maps distributed as daily mosaics to CMS** since November 2024
- **ASIP products under evaluation at DMI Greenland Ice Service** - plans for further operational use (e.g to marine users from late-2025).



Operational NRT and reprocessed (2014-2024) datasets

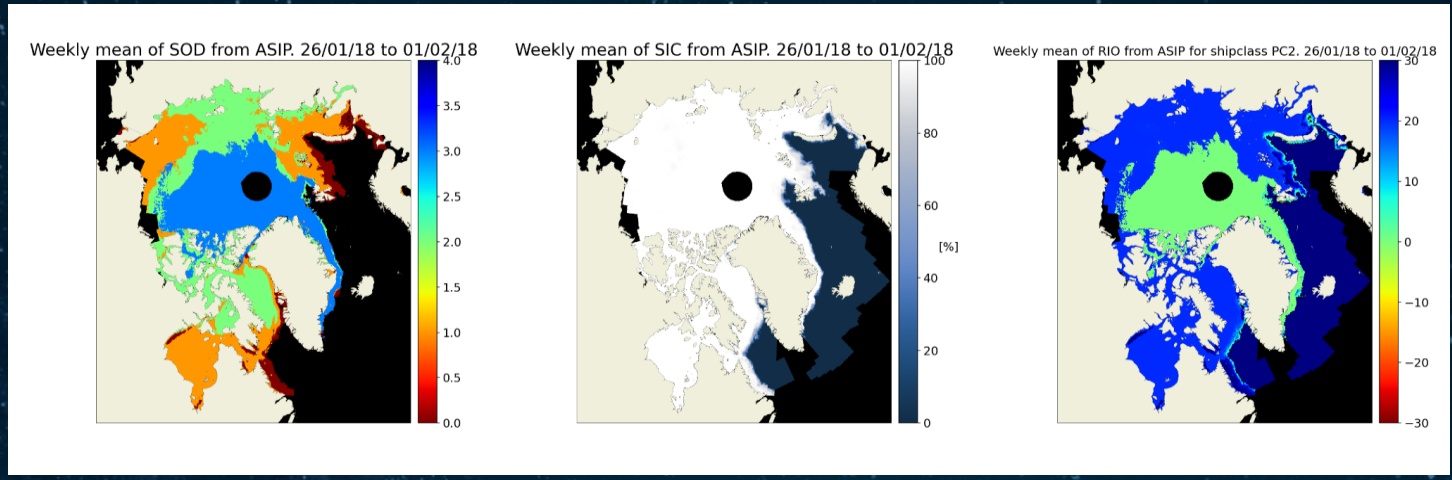
From Data to Insights

Automatic AI sea ice product retrieval

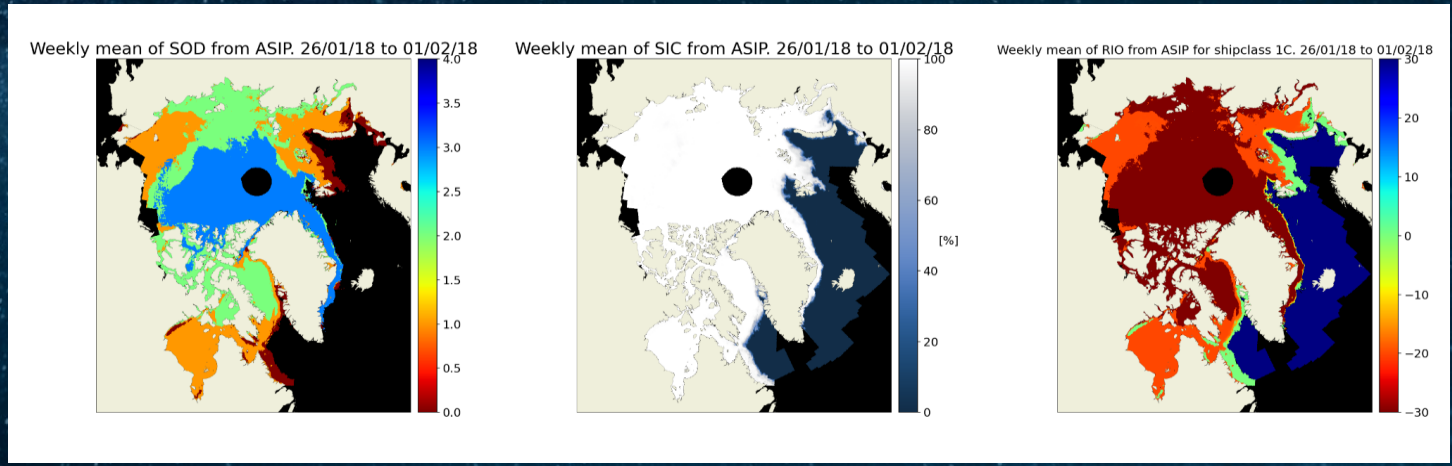
Risk Values (RVs)						
Polar Ship Category	Ice Class	Ice Free	New/Young Ice	Thin FY Ice	Thick FY Ice	MY Ice
		-	0 - 30 cm	30 - 70 cm	70 - 200 cm	>200 cm
		SOD = <0	SOD = 0	SOD = 1	SOD = 2	SOD = 3
A	PC1	3	3	2	2	1
	PC2	3	3	2	2	0
	PC3	3	3	2	2	-1
	PC4	3	3	2	1	-2
	PC5	3	3	2	0	-2
B	PC6	3	2	1	-1	-3
	PC7	3	2	1	-2	-3
C	1A Super	3	1	1	-2	-4
	1A	3	1	0	-3	-5
	1B	3	1	-1	-4	-6
	1C	3	0	-2	-5	-8
	No Class	3	-1	-3	-6	-8

- **ASIP daily pan-Arctic sea ice maps of SOD and SIC available in CMS** as a 10-year reprocessed dataset, based on the S1 era (Oct. 2014 - Oct. 2024) and continued by a NRT dataset (product DOI: https://doi.org/10.48670/mds-00343).

- **The AP-RIO dataset:** weekly risk assessment maps for a given ship class => support the establishment of a 10-year climatology => assessment of RIO variability in the years covered by the input ASIP products.



ASIP Stage of development, Sea Ice Concentration and RIO risk map for Ship class PC2.



ASIP Stage of development, Sea Ice Concentration, and RIO risk map for Ship class 1C.

From Data to Insights

Tactical decision support for ships operating in the polar regions

DRIFT+NOISE Polar Services

ICY SEA

https://icysea.app

esa

NRT sea ice information

Handles low and intermittent bandwidth areas.

Intuitive user interface and user support

Example of POLARIS calculation, overlaying relevant data and value-added layers: Sea Ice Concentration, Ice charts, Optimized Sea Ice Drift Forecast, Radar and Optical images etc

DRIFT+NOISE
Polar Services

ICY SEA
https://icysea.app

> 30 vessels are using IcySea in 2024

Ice information On
Le Commandant Charcot

Working together for a Safe and Sustainable future in Polar regions

ESA is part of the POLARIS Review Project

Ongoing discussions to inform the review process and leverage EO to shape the future of polar code

Demonstration and Showcase Opportunities

Follow-up discussions, interactive demos and showcases

Collaboration and Funding opportunities

Studies and activities to support EO uptake for Polar activities

Thank you!

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