

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

POLAR MARITIME SEMINAR

23-24 January 2025

IMO Headquarters, London, UK

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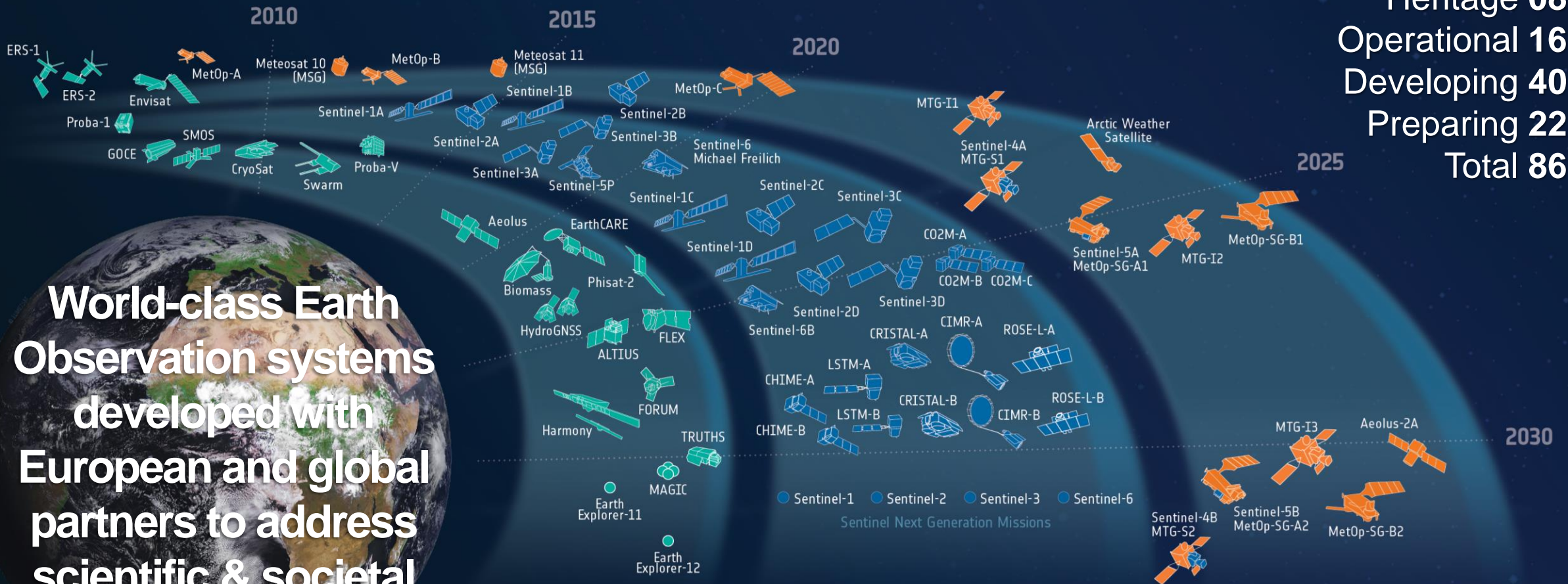
ESA's Earth Observation Missions

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



Copernicus



Meteorology

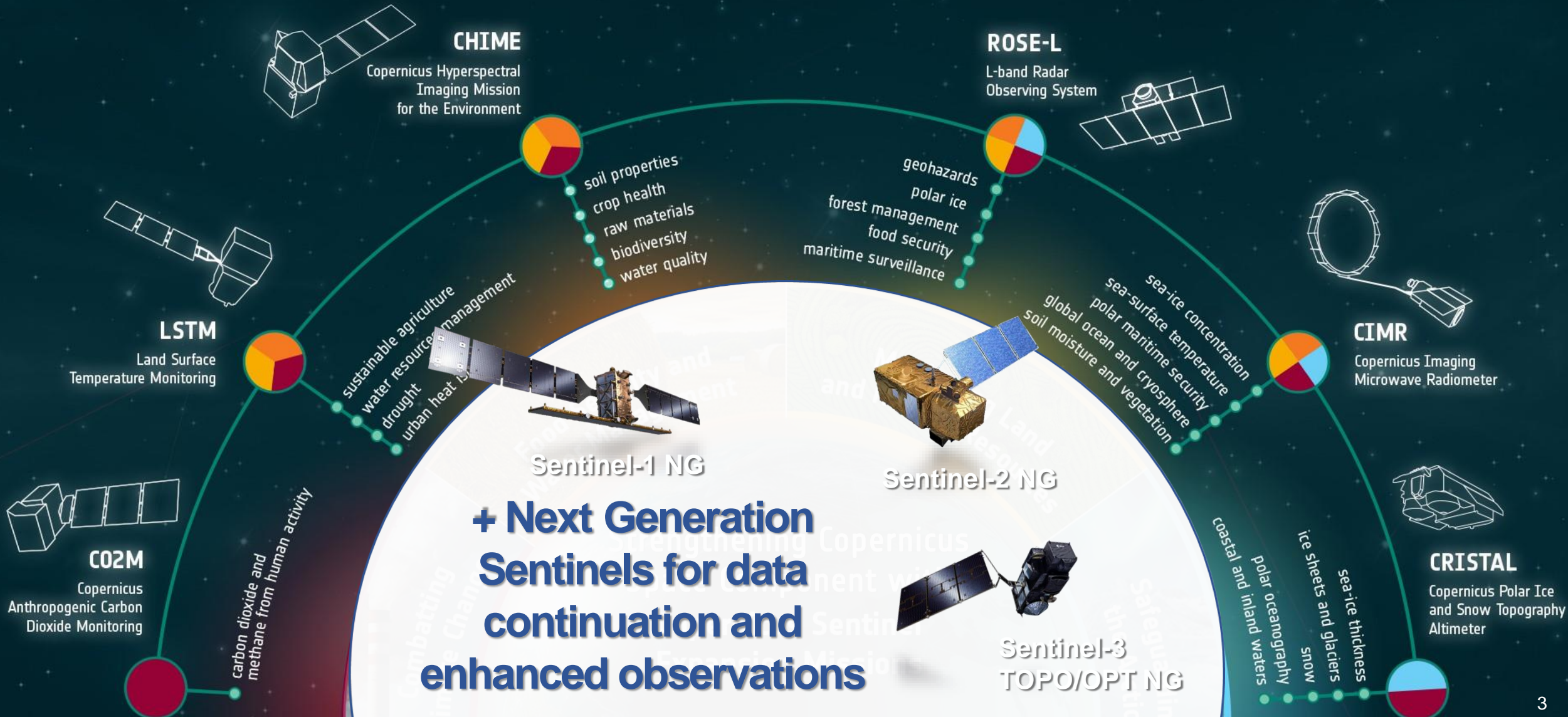


Copernicus Space Evolution

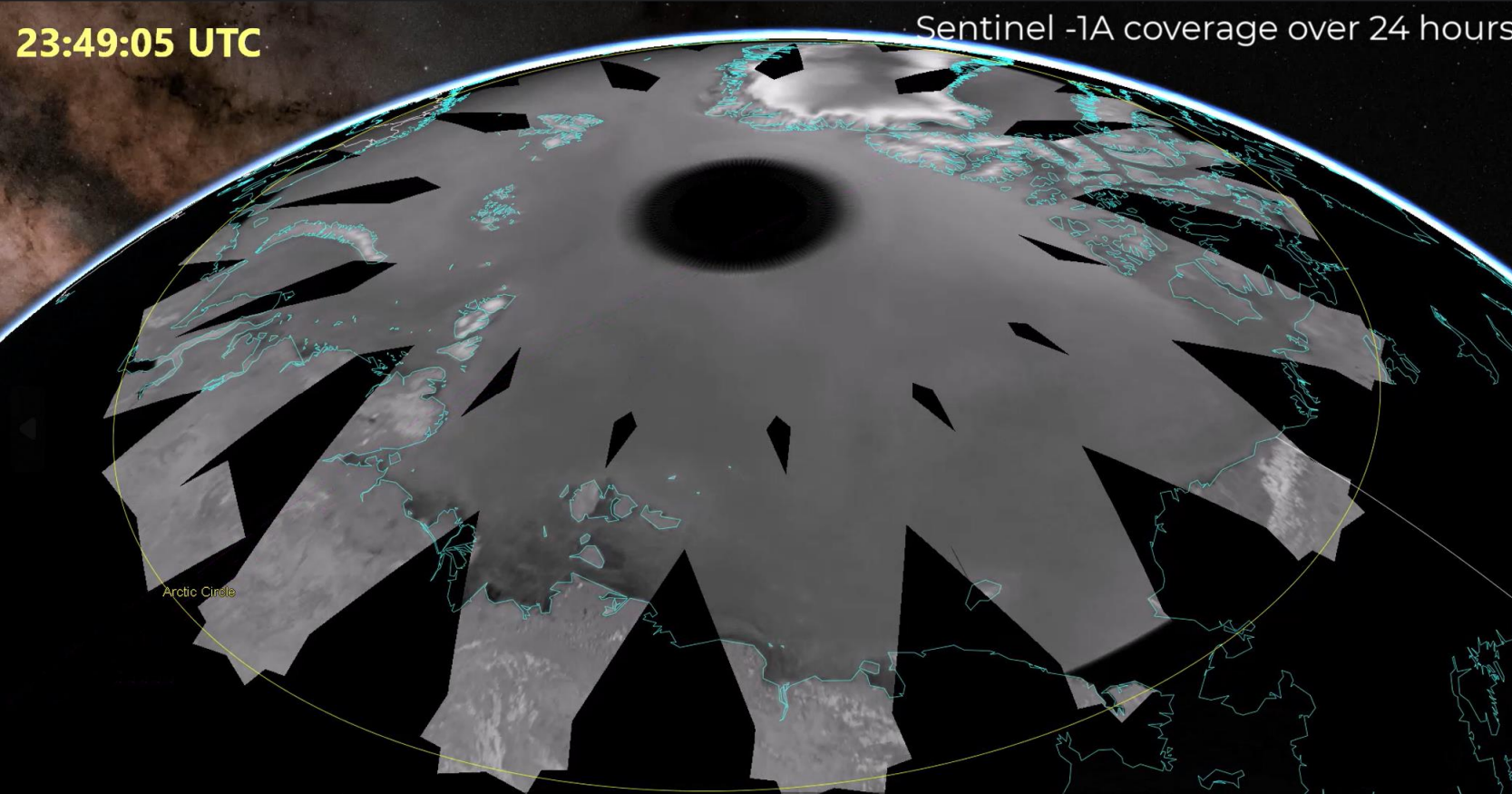


PROGRAMME OF THE
EUROPEAN UNION

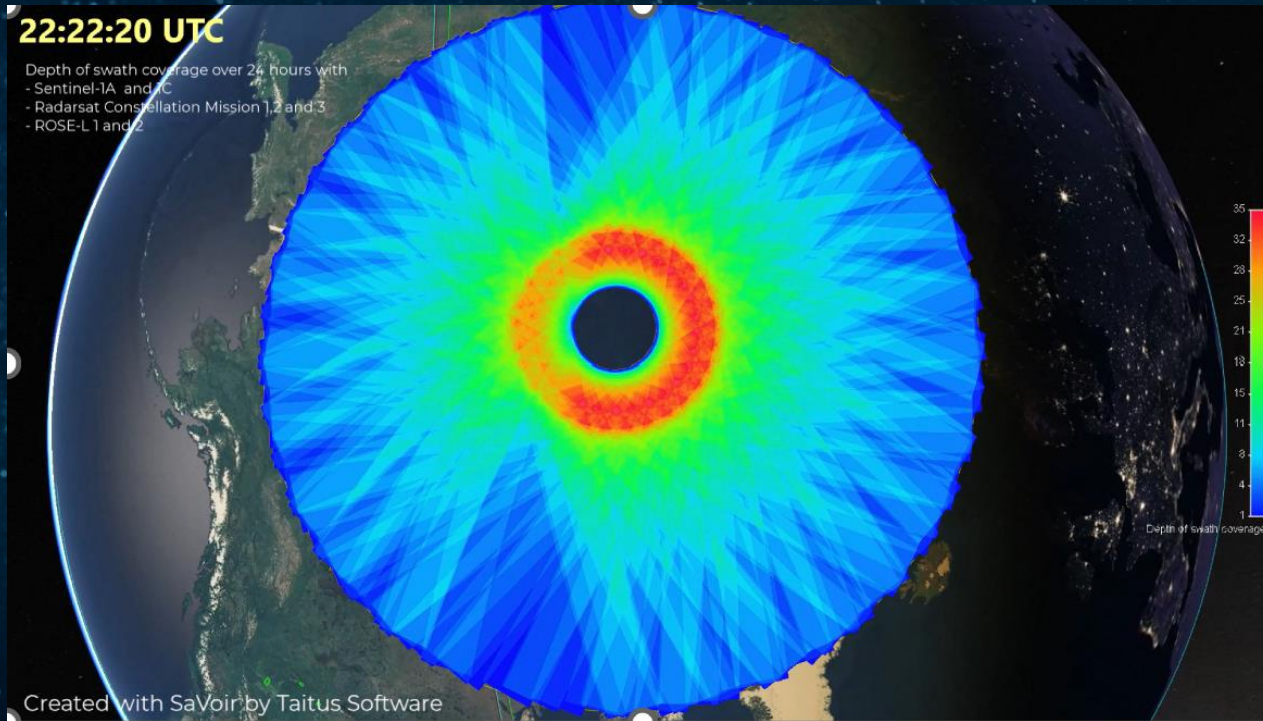
co-funded with



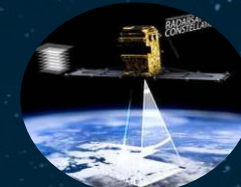
Arctic coverage over 24h with S1-A



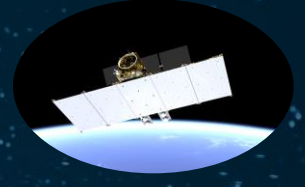
Arctic coverage over 24h with S1-A, S1-C, RCM & ROSE-L



Sentinel-1

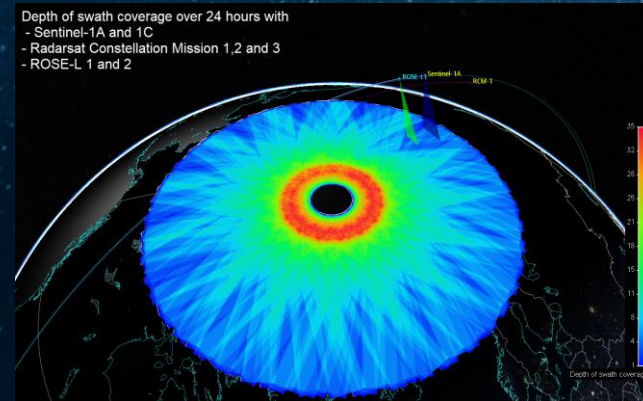
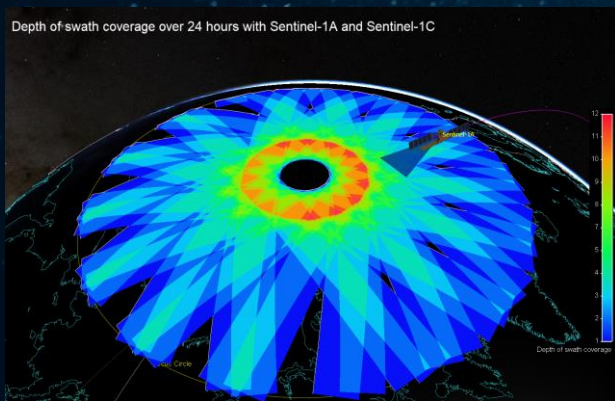


RCM

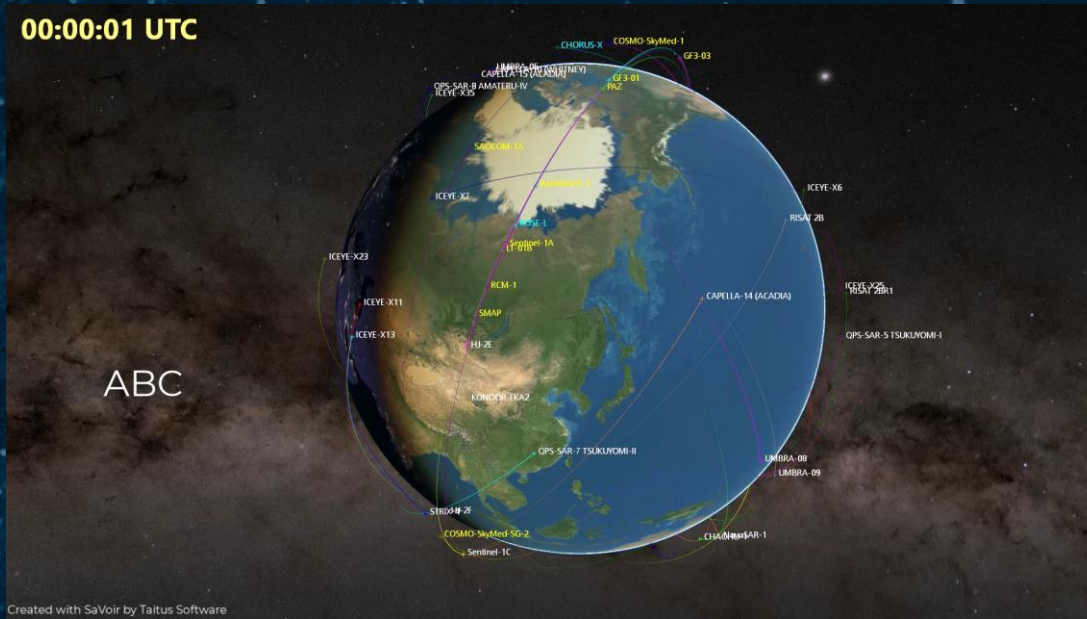


ROSE-L

- 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

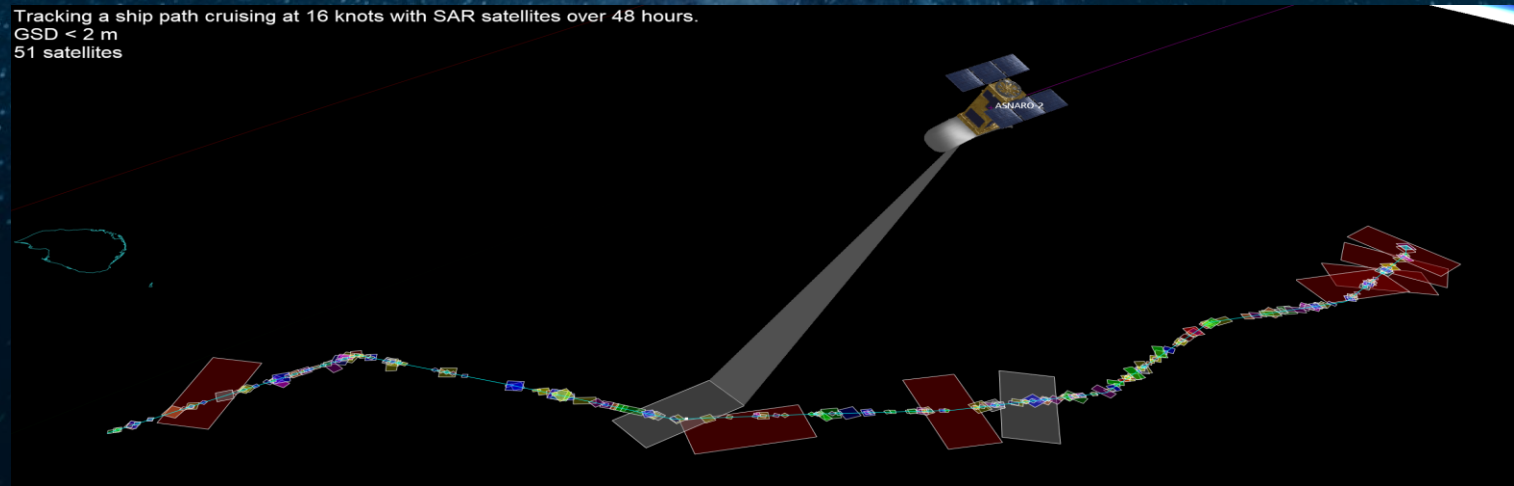
Frequent & global coverage – NRT capabilities

Geometric Diversity

Full polarimetric & Multi-frequency capabilities

Multi-Source fusion

Data continuity & Quick data delivery



Beyond satellite Development & Mission Management...

Satellite Design & Development



Missions Management



Cal/Val & Data Distribution



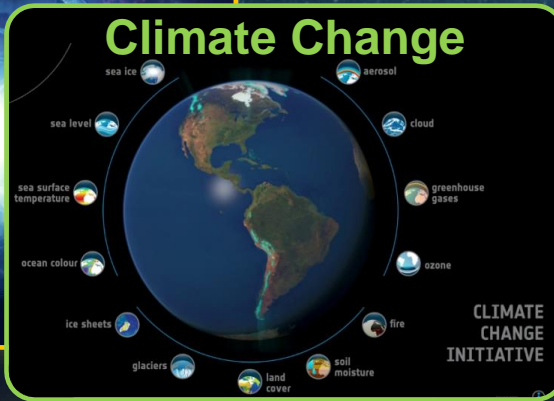
Earth System Science

Emergency Response

Digital Twins

Applying the Data for Earth Action

Climate Change



Innovation

Accelerate the future of EO Via transformative innovation & commercialisation actions

Future Systems & Instruments activities

Φ-lab

Accelerate the future of EO with cutting edge research

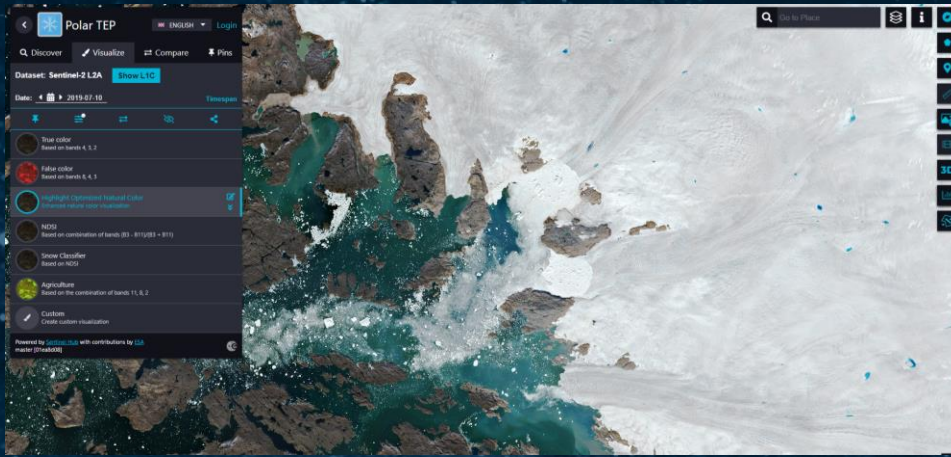
Commercialisation

InCubed



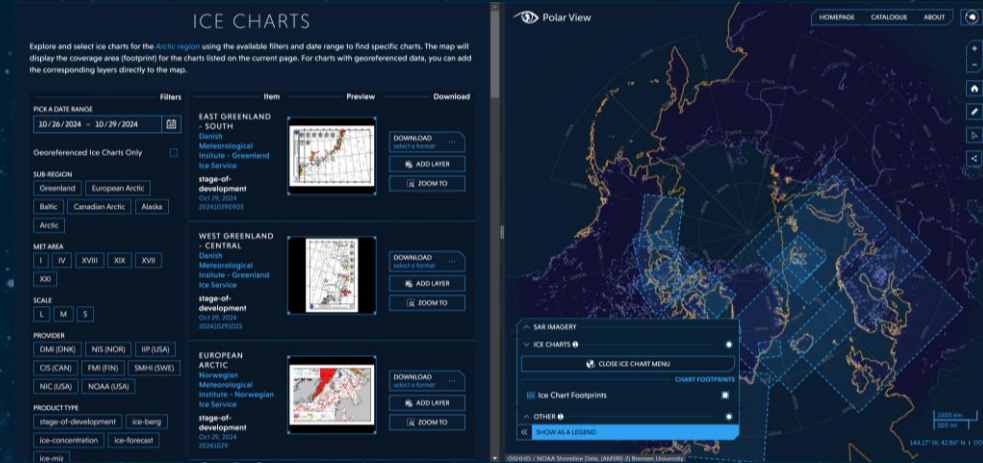
EO data made accessible

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

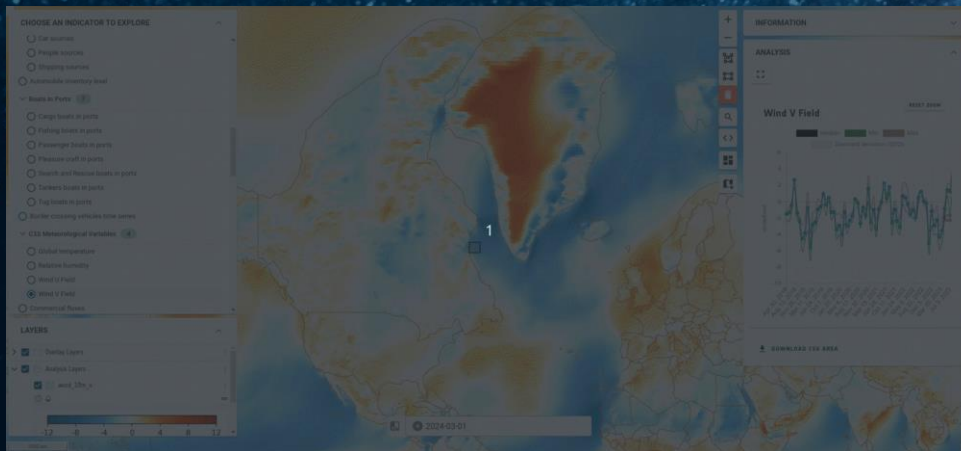


polar
tep

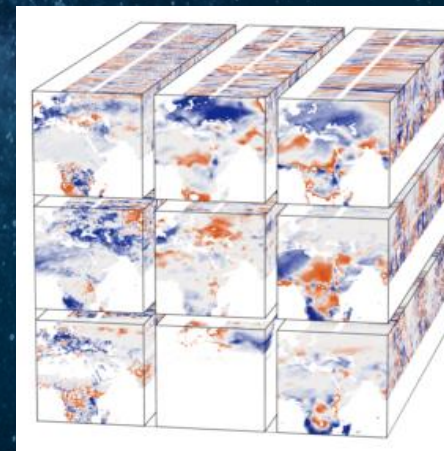
Research platform for private, academic, and public sectors



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

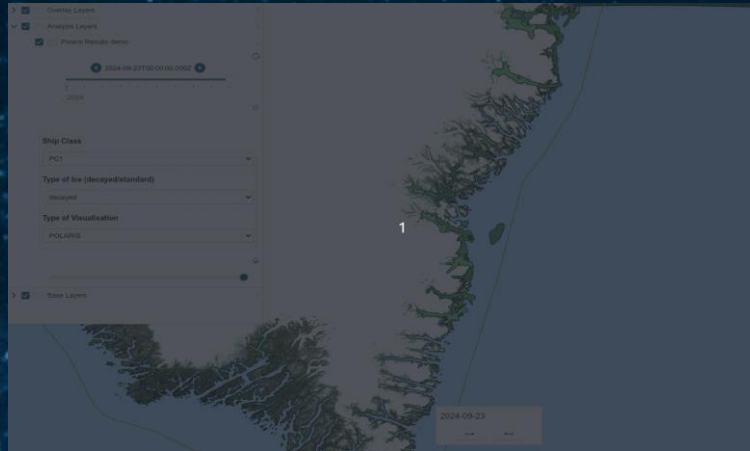


Sea Ice Chart Data Cube: Combining sea ice charts with other relevant data layers (SAR imagery, Metocean data, models, value-added products)

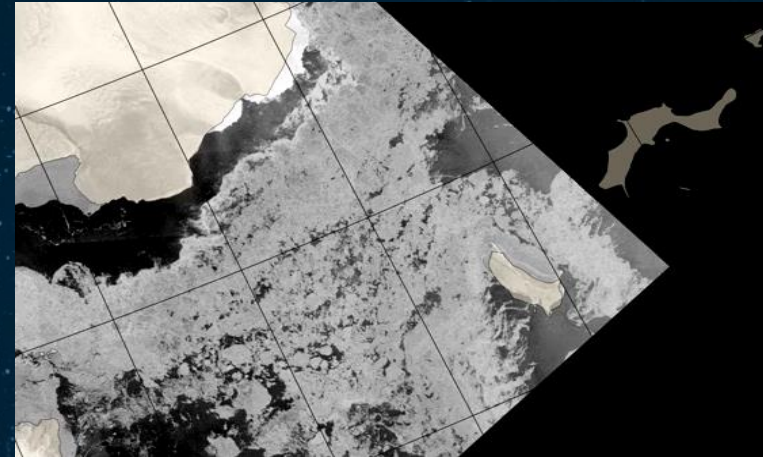
Optimized data access and Interoperability

From Data to Insights

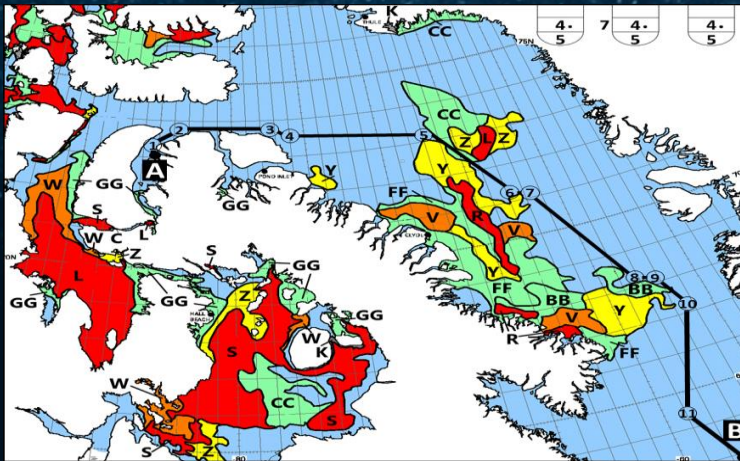
Examples of Value-added products and services to Support Polar Shipping



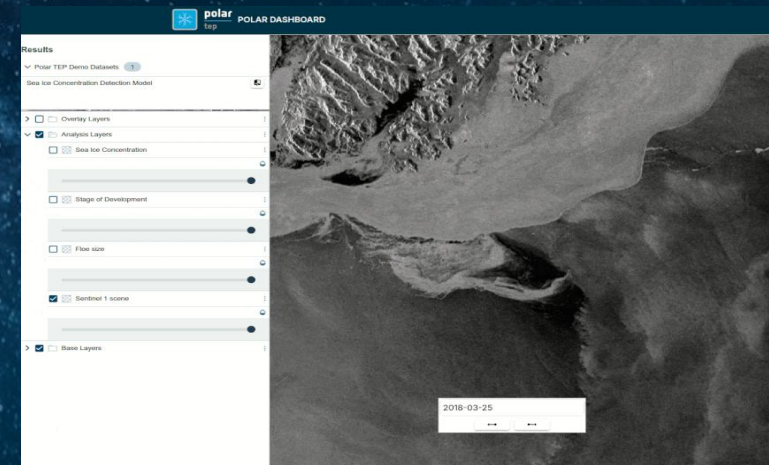
POLARIS calculation and overlaying with relevant data layers



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



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



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.

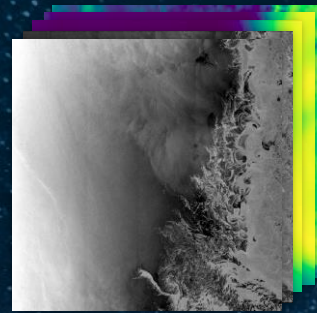
Advantages:

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

Disadvantages:

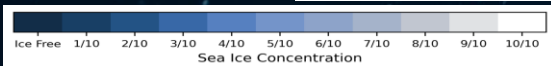
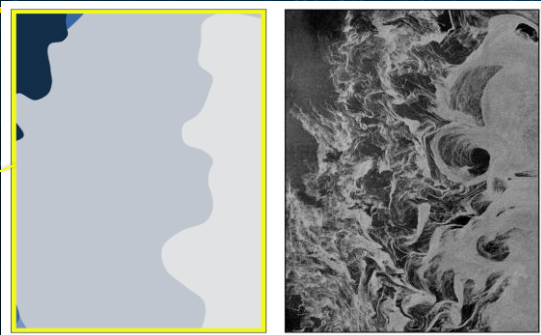
- Human subjectivity
- Uncertainty estimates are not provided
- Large polygons (relative to SAR resolution)

S1 + AMSR2: data.

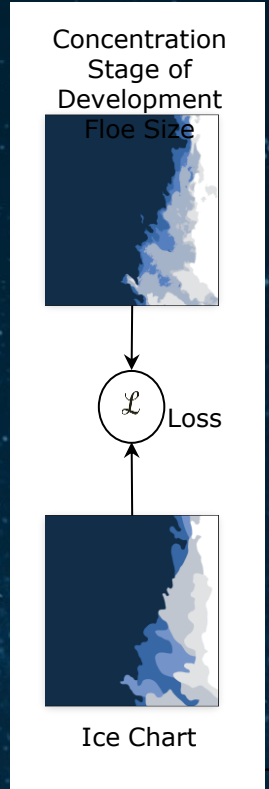
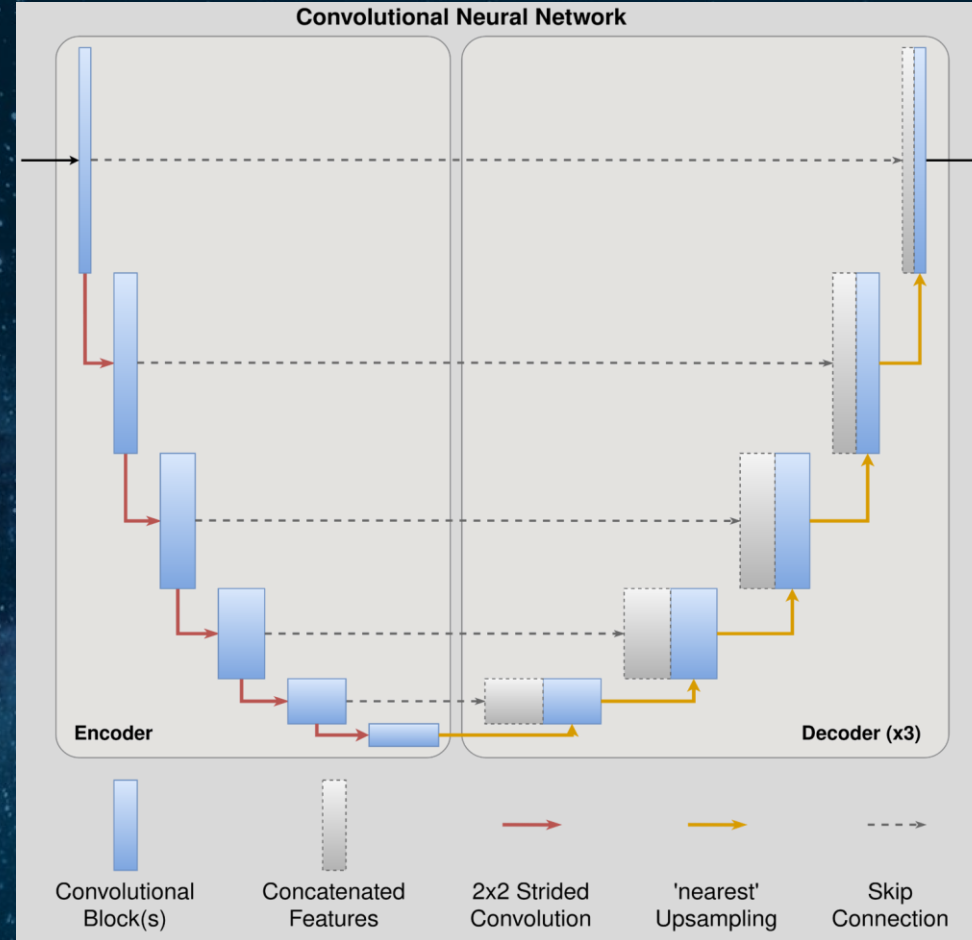


Sentinel-1 HH
April 19, 2021

Ice Chart
April 19, 2021



DMI-ASIP



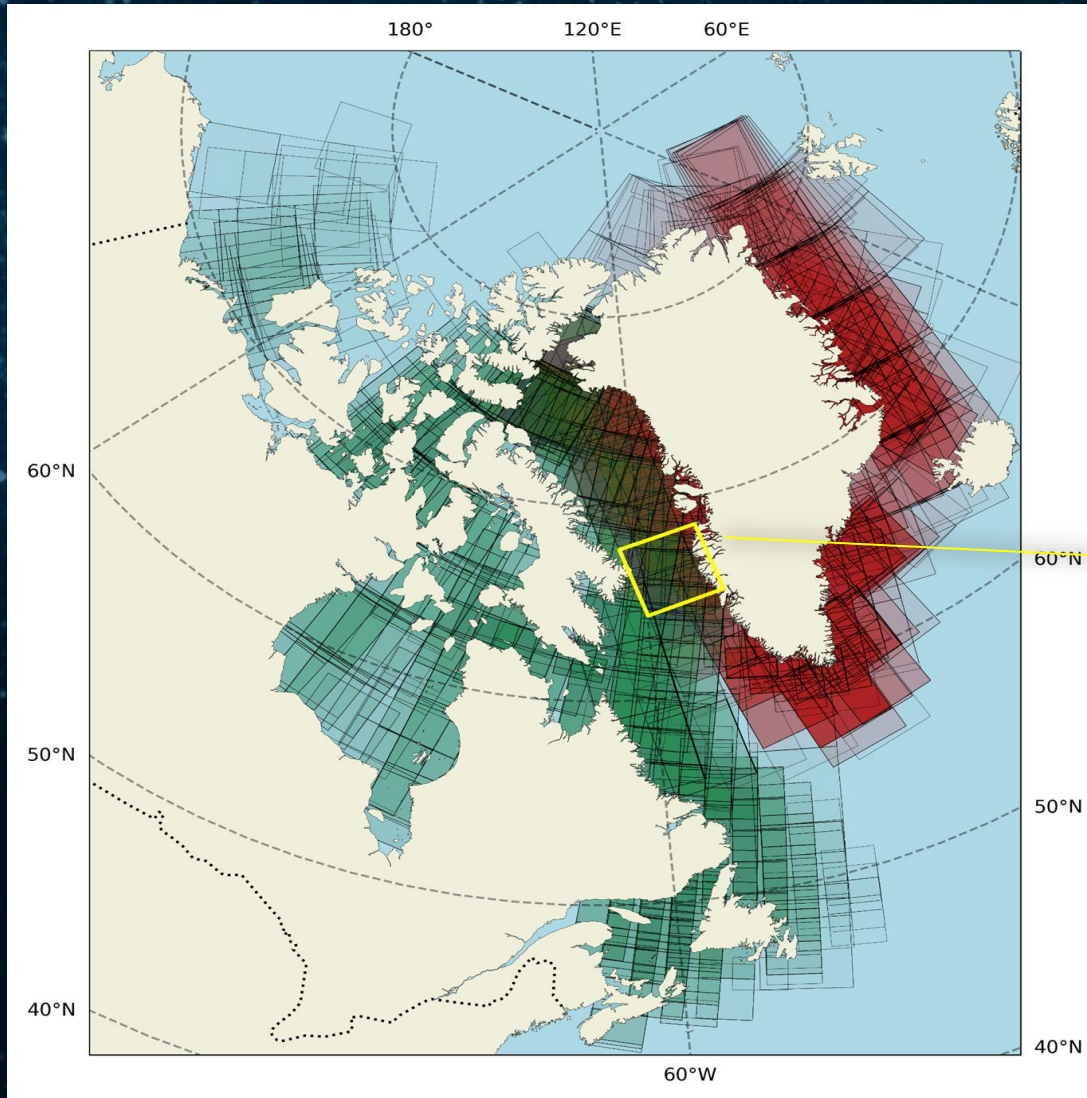
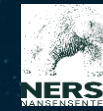
Wulf et al., "Pan-Arctic Sea Ice Concentration from SAR and Passive Microwave"

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

poly_id	CT	CA	SA	FA	CB	SB	FB	CC	SC	FC	CN	CD	CF	POLY_TYPE
1	60	20	95	3	20	93	3	20	91	3	98	-9	-9	-9
4	60	20	95	3	20	93	3	20	91	3	98	-9	-9	-9
7	90	40	95	3	30	93	4	20	91	3	98	-9	-9	-9
10	91	30	91	4	40	87	3	30	83	2	98	-9	-9	-9
12	90	40	95	3	30	93	4	20	91	3	98	-9	-9	-9
13	91	30	91	4	40	87	3	30	83	2	98	-9	-9	-9
14	70	20	95	3	30	93	4	20	91	3	98	-9	-9	-9
15	30	10	95	3	10	93	3	10	91	2	-9	-9	-9	-9
16	92	80	83	8	20	82	-9	-9	-9	-9	-9	-9	-9	-9
17	92	80	83	8	20	82	-9	-9	-9	-9	-9	-9	-9	-9
18	92	-9	87	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
19	80	30	95	4	30	93	4	20	91	3	-9	-9	-9	-9
20	92	-9	87	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
21	10	-9	95	4	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
22	92	-9	87	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
23	92	-9	87	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
24	10	-9	83	3	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
25	91	30	95	4	30	87	4	40	91	3	98	-9	-9	-9
26	92	-9	87	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
27	92	-9	87	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
28	92	-9	91	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
29	92	-9	87	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
30	92	-9	91	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
31	80	10	98	10	90	87	3	20	83	2	-9	-9	-9	-9
32	10	-9	83	3	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
33	91	90	98	10	10	87	3	-9	-9	-9	-9	-9	-9	-9
34	92	-9	91	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
35	92	-9	91	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
36	10	-9	95	4	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
37	30	10	95	4	10	93	4	10	91	3	-9	-9	-9	-9
38	92	-9	91	8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
39	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
40	91	40	95	4	30	93	4	30	91	3	98	-9	-9	-9

Sentinel-1 HV

AMSR-2 brightness temperatures

6.9 GHz, H-pol

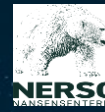
18.7 GHz, H-pol

89.0 GHz, H-pol

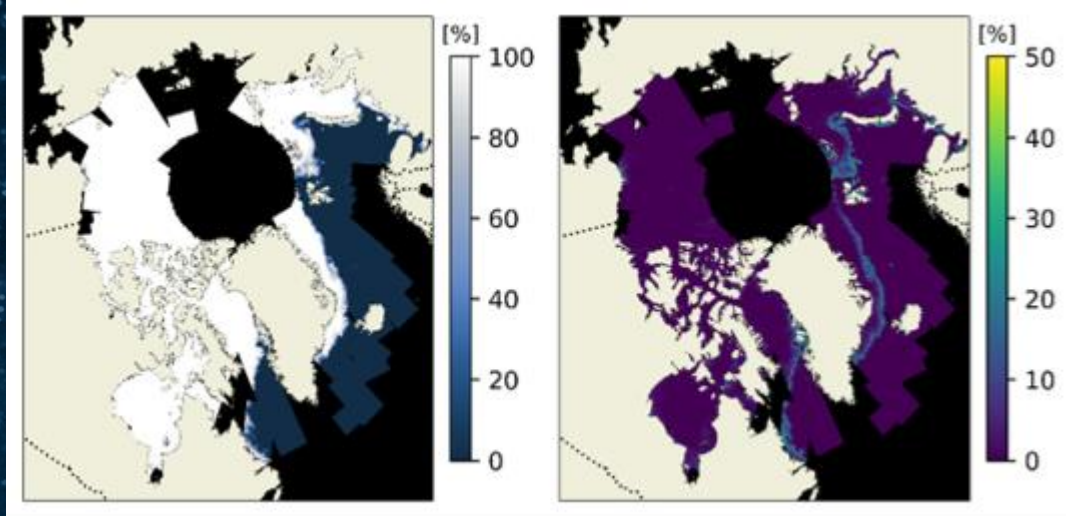
Buus-Hinkler et al., "AI4Arctic Sea Ice Challenge Dataset", DOI: <https://doi.org/10.11583/DTU.c.6244065.v2>

From Data to Insights

Automatic AI sea ice product retrieval



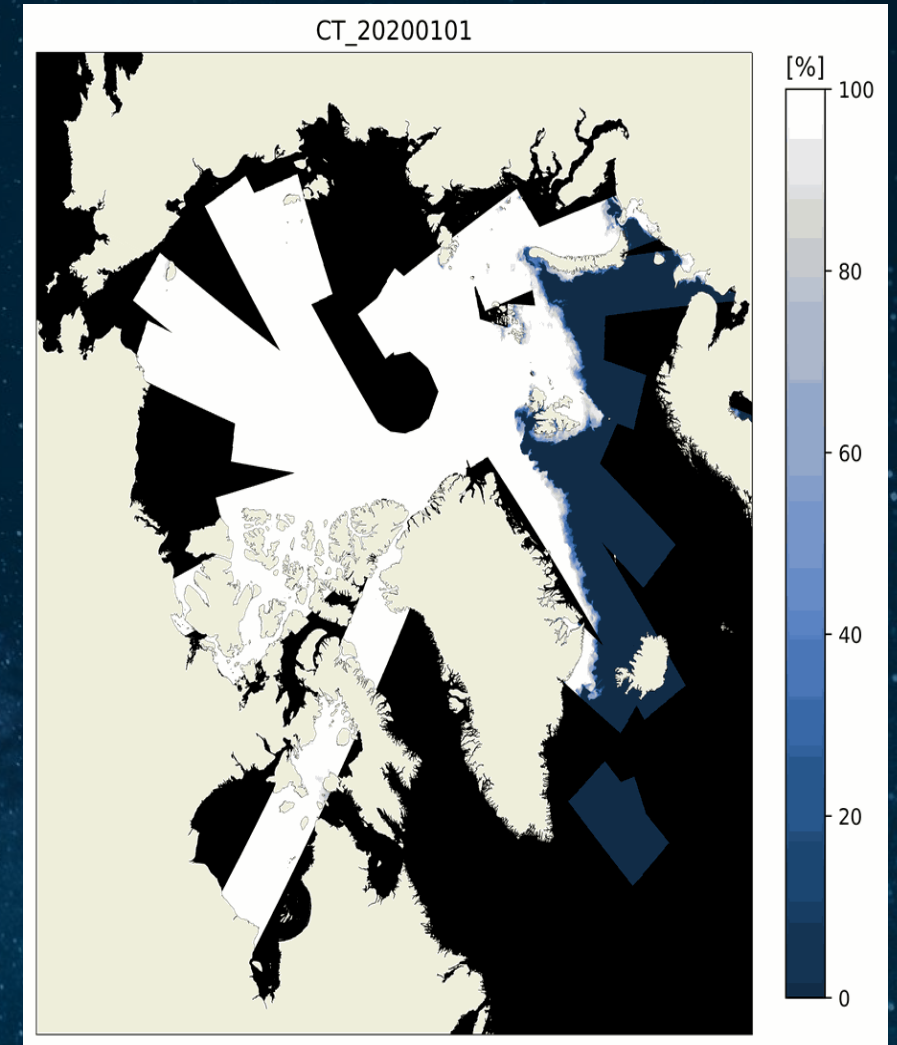
Example of a 7-day mosaic from Jan. 9th - Jan 15th, 2023 - Pan-Arctic scale



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



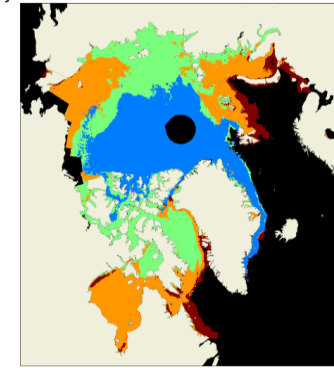
From Data to Insights

Automatic AI sea ice product retrieval



		Risk Values (RVs)				
		Ice Free	New/Young Ice	Thin FY Ice	Thick FY Ice	MY Ice
Polar Ship Category	Ice Class	-	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

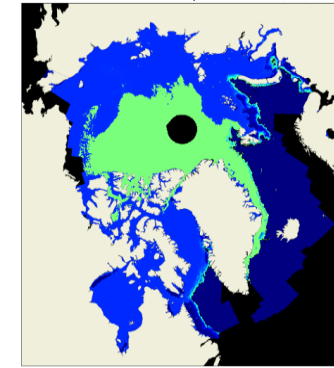
Weekly mean of SOD from ASIP. 26/01/18 to 01/02/18



Weekly mean of SIC from ASIP. 26/01/18 to 01/02/18

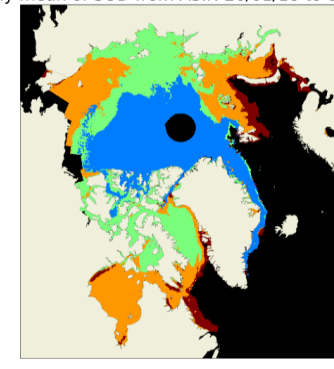


Weekly mean of RIO from ASIP for shipclass PC2. 26/01/18 to 01/02/18

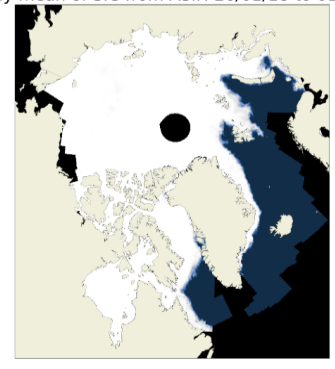


ASIP Stage of development, Sea Ice Concentration and RIO risk map for Ship class PC2.

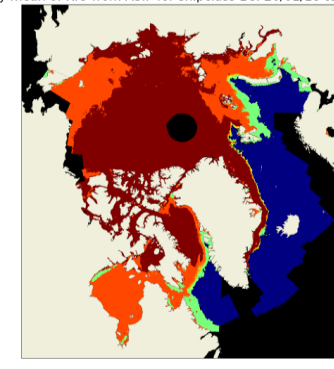
Weekly mean of SOD from ASIP. 26/01/18 to 01/02/18



Weekly mean of SIC from ASIP. 26/01/18 to 01/02/18



Weekly mean of RIO from ASIP for shipclass 1C. 26/01/18 to 01/02/18



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

- **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.



From Data to Insights

Tactical decision support for ships operating in the polar regions



DRIFT+NOISE
Polar Services



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



<https://icysea.app>

> 30 vessels are using IcySea in 2024



Ice information On *Le Commandant Charcot*



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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