CIMR L2PAD and DEVALGO
Open-source Level-2 Algorithms: Sea Ice as an Example

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CIMR is the Copernicus Imaging Microwave Radiometer. It is being developed by ESA for launch in the late 2020s.

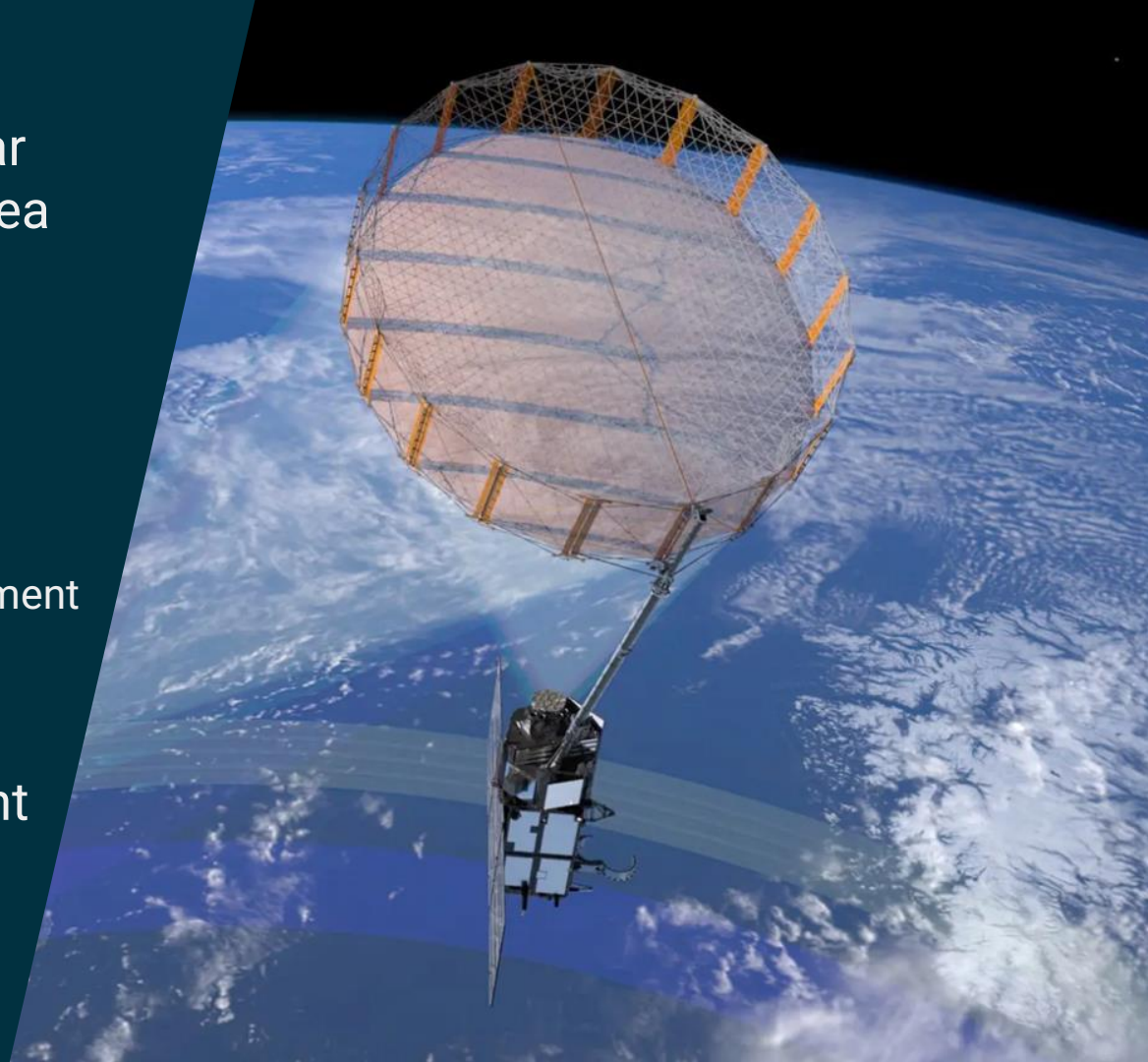
CIMR will excel at measuring sea ice and the polar ocean, and contribute to global monitoring of terrestrial surfaces at higher spatial resolution and accuracy.

In preparation for launch, there is a need to develop open-source Level-2 algorithms and processing software.

CIMR will have 10 Level-2 products dedicated to the polar oceans, among which seven sea ice products:

- Sea Ice Concentration
- Thin Sea Ice Thickness
- Sea Ice Edge
- Sea Ice Drift
- Sea Ice Type / Stage of Development
- Snow Depth on Sea Ice
- Sea Ice Surface Temperature

Here we report on development activities for sea ice concentration and drift.



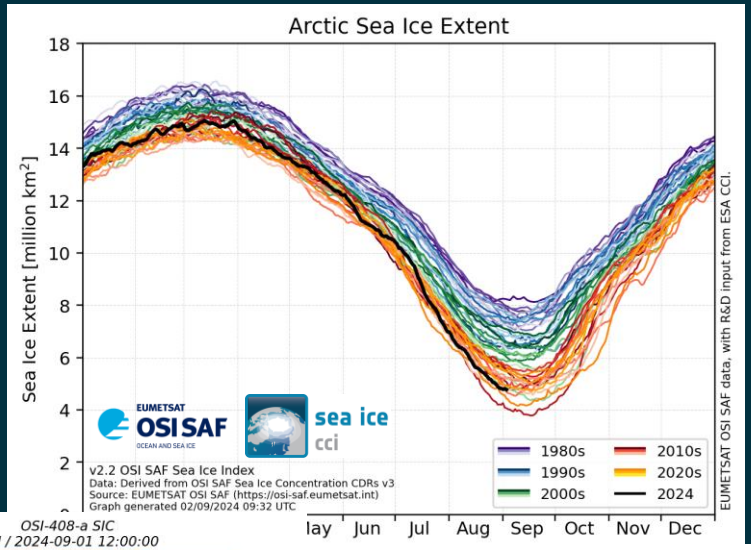
Sea Ice Concentration

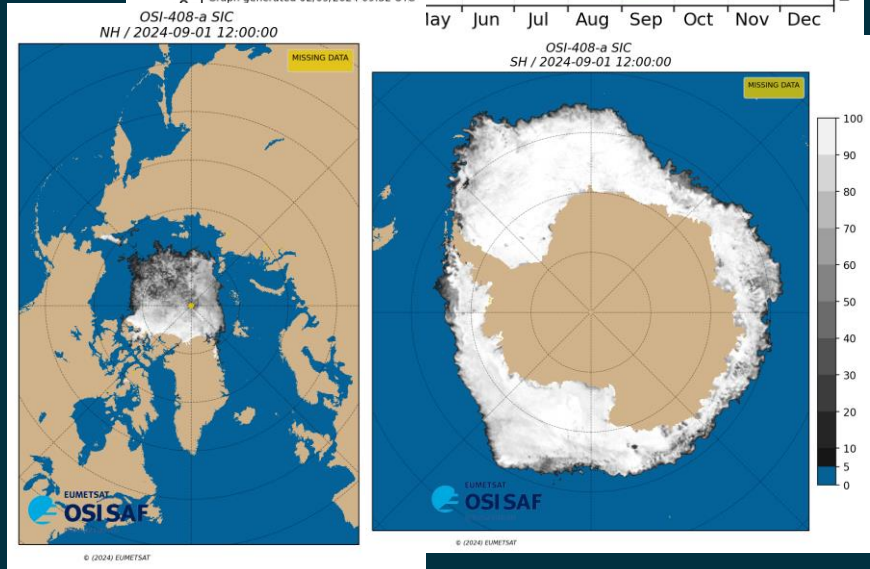
Sea Ice Concentration (*SIC*) measures the area coverage of sea ice in the polar ocean.

Polar SIC is routinely monitored using existing passive microwave missions.

Maps of SIC are assimilated by weather and ocean forecast systems, e.g. at ECMWF or Copernicus. These will benefit from higher resolution maps of SIC.

From SIC we derive sea-ice extent, a headline indicator of climate change.





Sea Ice Concentration

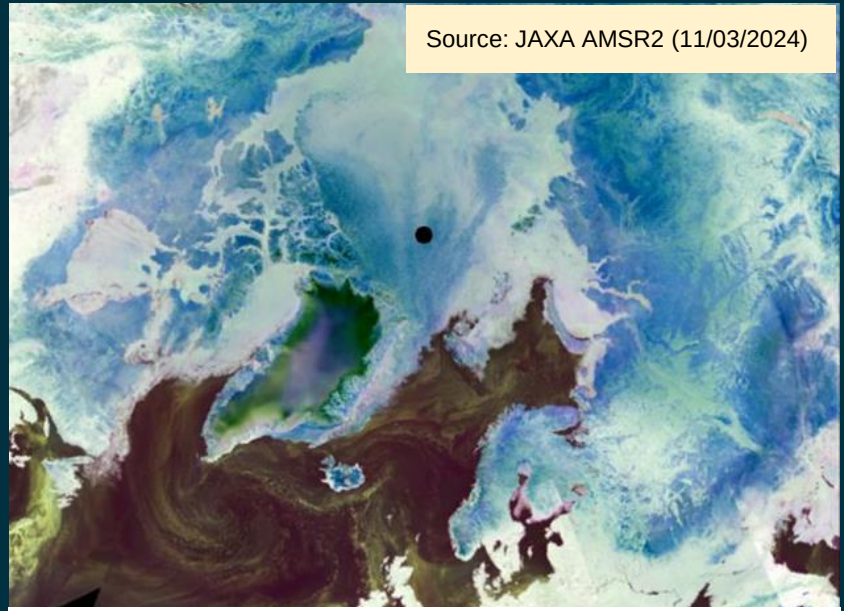
We measure Sea Ice Concentration (*SIC*) as the contrast between the brightness temperature (TBs) of the ocean (darker) and the sea-ice (brighter).

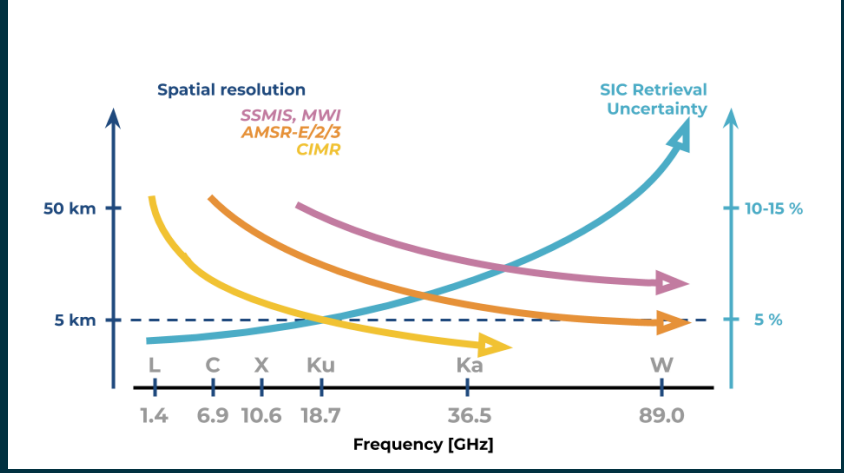
To the right: a composite of K and Ka-band TBs classically used for SIC (here JAXA AMSR2).

Higher microwave frequencies (e.g. 89 GHz) offer better spatial resolution, but larger uncertainties.

Lower microwave frequences (e.g. C-band) lead to coarser resolution, but smaller uncertainty.

CIMR offers a unique balance, and aims at high spatial resolution (< 5km) and low uncertainty (<5% RMSE) for Level-2 SIC.





Sea Ice Concentration

We developed a SIC algorithm tailored for CIMR.

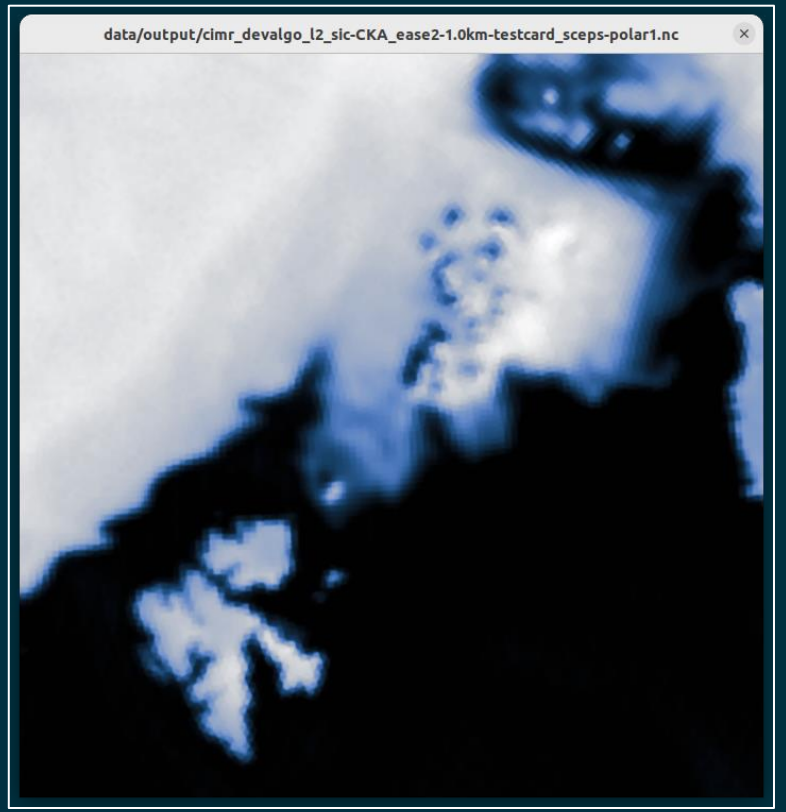
It builds upon strong heritage from EUMETSAT OSI SAF and ESA CCI, including 3 steps:

1. Compute a low-noise, coarse-resolution SIC (using C- and Ka-band) : SIC_{LR}

CIMR does not fly yet! We must use simulated data when testing our algorithms.

This simulated test scene was prepared by Estellus (FR) and their partners in a parallel CIMR study (SCEPS). They used a parametrized radiative transfer, and a simulator of the CIMR instrument.

SIC_{LR} (6.9V, 36.5V, 36.5H)



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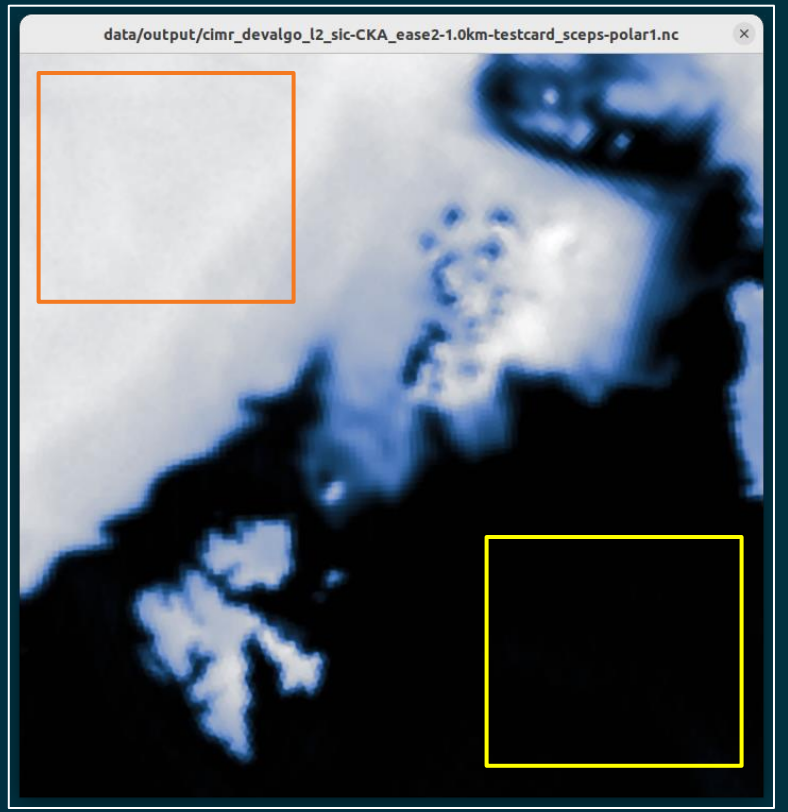
We evaluate the retrieval uncertainty of the algorithms as the RMSE of the SIC over know homogeneous regions: 100% SIC (Closed Ice) and 0% SIC (Open Water). The in-flight total uncertainty will be larger.

SIC_{LR} (6.9V, 36.5V, 36.5H)



Resolution: ~15 km | RMSE: 1.1% 0.7%

Sea Ice Concentration

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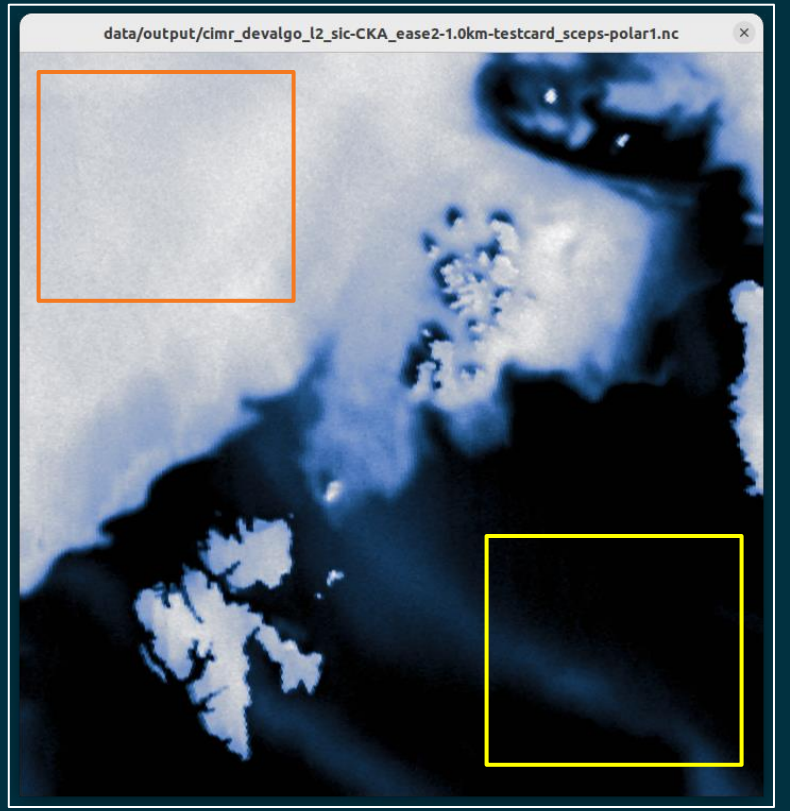
1. Compute a low-noise, coarse-resolution SIC (using C- and Ka-band) : SIC_{LR}
2. Compute a high(er)-noise high-resolution SIC (using Ka-band only) : SIC_{HR}

SIC_{HR} (36.5V, 36.5H)



Resolution: <5 km | RMSE: 2.7% 8.7%

Sea Ice Concentration

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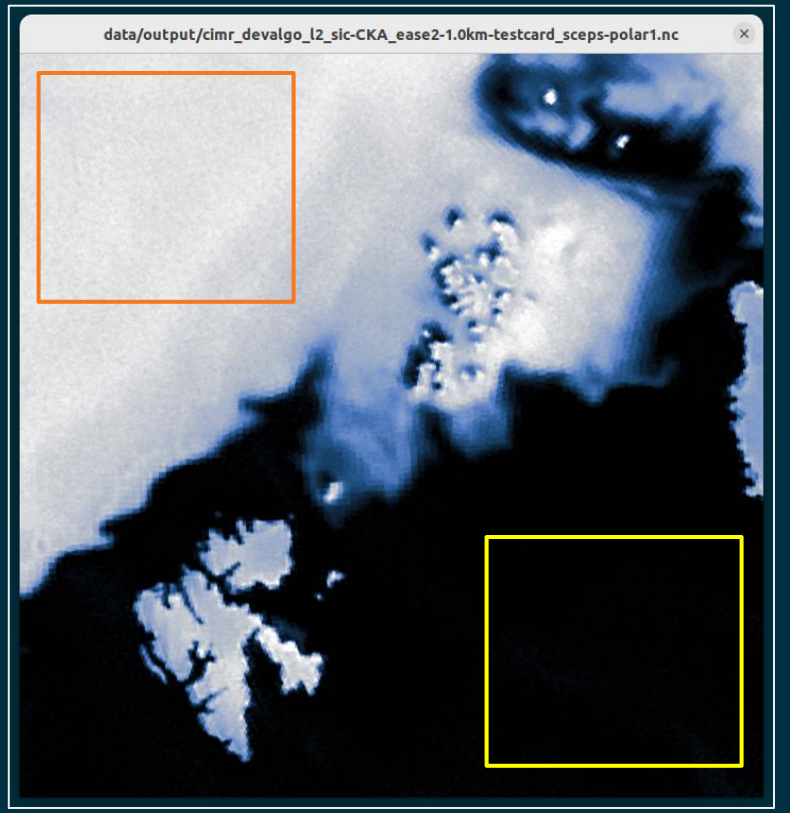
It builds upon strong heritage from EUMETSAT OSI SAF and ESA CCI, including 3 steps:

1. Compute a low-noise, coarse-resolution SIC (using C- and KA-band) : SIC_{LR}
2. Compute a high(er)-noise high-resolution SIC (using Ka-band only) : SIC_{HR}
3. Pan-sharpen SIC_{LR} with SIC_{HR}: results in a low-noise, high-resolution SIC.

Comes with SIC uncertainty propagation (not shown).

We evaluated against one simulated scene, and found RMSE < 5%. <u>These are promising albeit preliminary results.</u>

Final L2 SIC (6.9V, 36.5V, 36.5H)

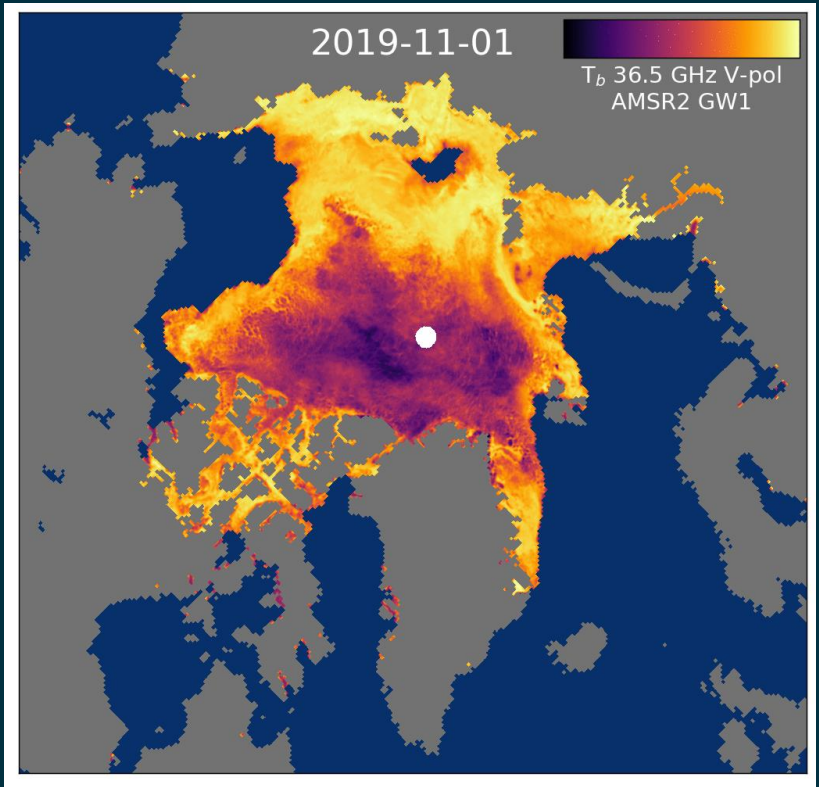


Resolution: ~5 km | RMSE: 1.4% 1.2%

Sea Ice Concentration (Summary and Way Forward)

- CIMR offers a unique balance between resolution and retrieval uncertainty, and aims at high spatial resolution (< 5km) and low uncertainty (<5% RMSE) for Level-2 SIC.
- We designed an algorithm tailored for CIMR, exploiting C- and Ka-band imagery.
- We tested it against synthetic and realistic simulated scenes, and the results are promising.
- Future R&D needs:
  - Improve uncertainty propagation;
  - Add atmospheric correction of the TBs;
  - Multi-scale pan-sharpening (image fusion) to better exploit all CIMR channels.

Sea Ice Drift



Left: Animation of daily 36.5 GHz TBs over a winter season (source: JAXA).

Pushed by winds and ocean currents, sea-ice is always on the move. The contrast of TBs within the ice cover reveals day-to-day motion.

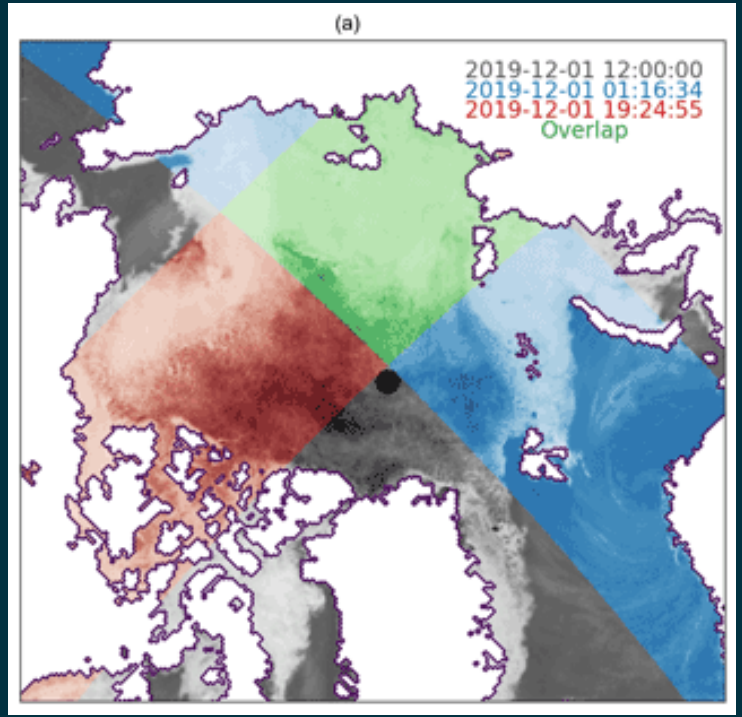
We want to track the TB details: we will use the high-resolution 36.5 GHz (and 18.7 GHz) imagery of CIMR to do the job.

Sea Ice Drift

The CIMR SIDrift product will be a “swath-to-swath” product with ~25 km spacing between the vectors (right).

We selected the Continuous Maximum Cross-Correlation (CMCC) algorithm, used in the EUMETSAT OSI SAF.

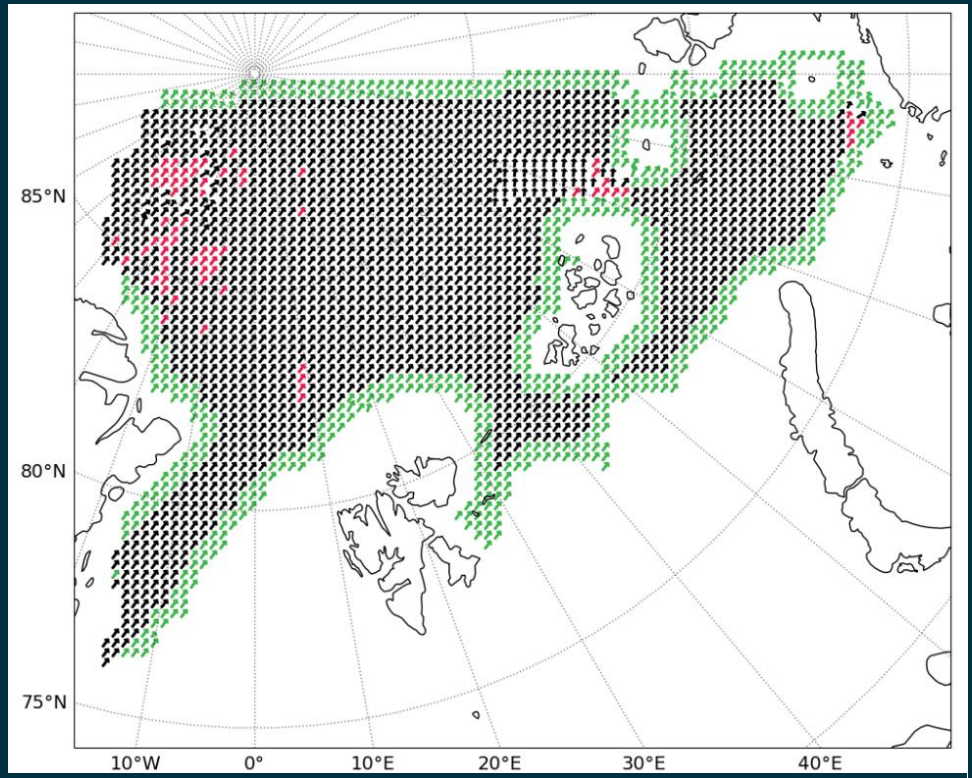
We implemented CMCC for CIMR data, and tested on a simulated scene with uniform motion.



See Lavergne et al. 2021.

Sea Ice Drift (Summary and Way Forward)

- Test on a simulated scene with uniform motion.
- The results are as expected for such a simple test card. More efforts are needed to create realistic scenes, for example using NeXtSIM model simulations.
- Future developments:
  - Uncertainty propagation;
  - Exploit other frequencies;
  - Optimize for faster runs.



Resulting motion vector field. The color encodes a status_flag (green = close to land, ocean, or edge of the swath, red: corrected using neighboring vectors).

From CIMR DEVALGO to CIMR L2PAD

- CIMR DEVALGO (2022-2024) is an ESA-funded study to develop selected Level-2 algorithms for CIMR. We publish the algorithm's blueprints (the Algorithm Theoretical Baseline Documents - ATBDs) as web documents on Github, together with the open-source software implementation. See https://github.com/CIMR-Algos for final releases soon.
- CIMR L2PAD (2023-2027) is a larger effort to cover ALL (20+) Level-2 products for the Polar Oceans and Terrestrial domains, with an open-source approach (see next slide).

CIMR L2PAD

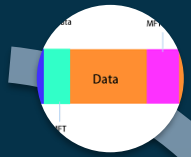
CIMR Level-2 Product and Algorithm Development (L2PAD)

5 years activity started in Nov 2023

More details and a list of Level-2 variables covered by L2PAD:
https://github.com/CIMR-L2PAD

L2 PAD Consortium (Prime: MET Norway)

Norwegian Meteorological Institute
deimos
Finnish Meteorological Institute
OceanDataLab
University of Bremen
The Danish Meteorological Institute
Universitat de València
Institut de Ciències del Mar
s[&]t
Universitat Politècnica de Catalunya BarcelonaTech
AWI
H2O Geomatics



To define a first version of the **Level-2 product format for CIMR,** including **fully traceable uncertainty**

To carry on **R&D activities** to support the definition and implementation of the **most advanced geophysical retrieval algorithms**

To adapt and implement **geophysical retrieval algorithms** in order to develop the open-source **CIMR Level-2 Ground processor prototype**

To provide a **set of CIMR Level-2 product cases** to be distributed to the **community**

To define methods for the pre-flight and in-flight **validation of the CIMR Level-2 product**

Author: M. Scagliola (ESA)

Summary

- CIMR will offer a unique opportunity to monitor the changing polar regions with higher spatial resolution and accuracy.
- CIMR is a new mission, it requires new algorithms.
- During the DEVALGO study, we developed open-source algorithms for several Level-2 variables (here only SIC and SIDrift were shown).
- Now, a larger team works in the CIMR L2PAD project to develop open-source algorithms for 20+ Level-2 variables.
- We are looking forward to growing a community of enthusiasts, users, and experts around the CIMR mission: interact with us at https://github.com/CIMR-L2PAD !

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