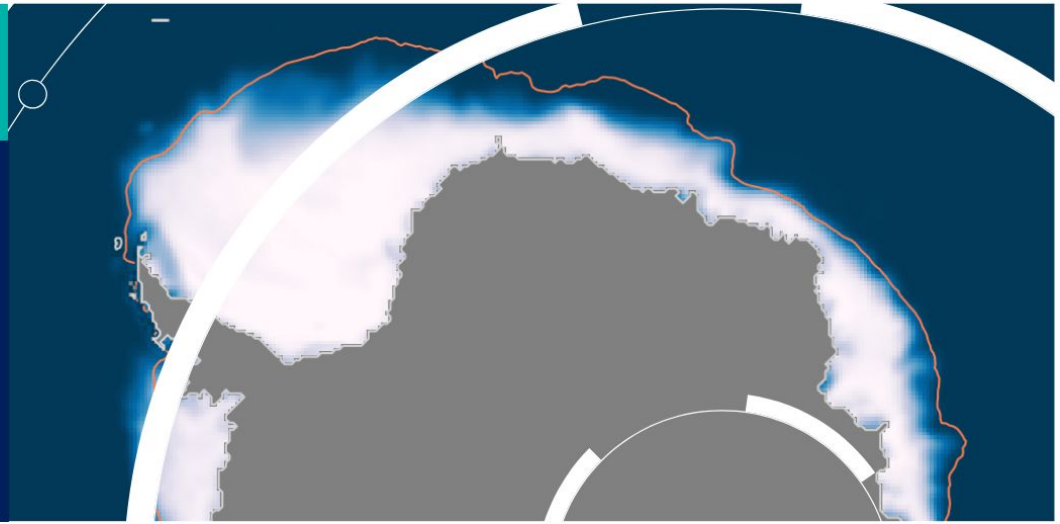
EUMETSAT

EUMETSAT OSI SAF
OCEAN AND SEA ICE

10 SEPTEMBER 2024
10:00 & 15:00 CET

SHORT COURSE

OSI SAF SEA ICE
CLIMATE RECORDS



Sea Ice Concentration CDRs

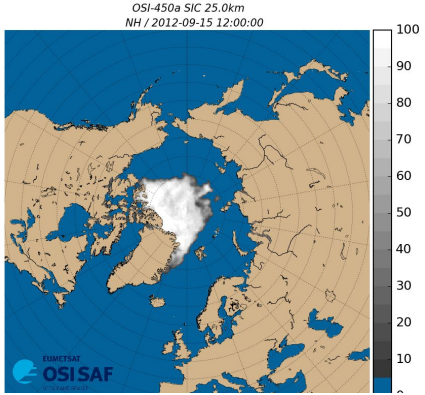
Thomas Lavergne & Atle Sørensen, MET Norway.

Meteorologisk institutt

Overview

1. Importance of the Sea Ice Concentration CDRs
2. Composition of the Sea Ice Concentration CDRs
3. Limitations of the Sea Ice Concentration CDRs
4. Future developments towards v4

1. Importance of the Sea Ice Concentration CDRs

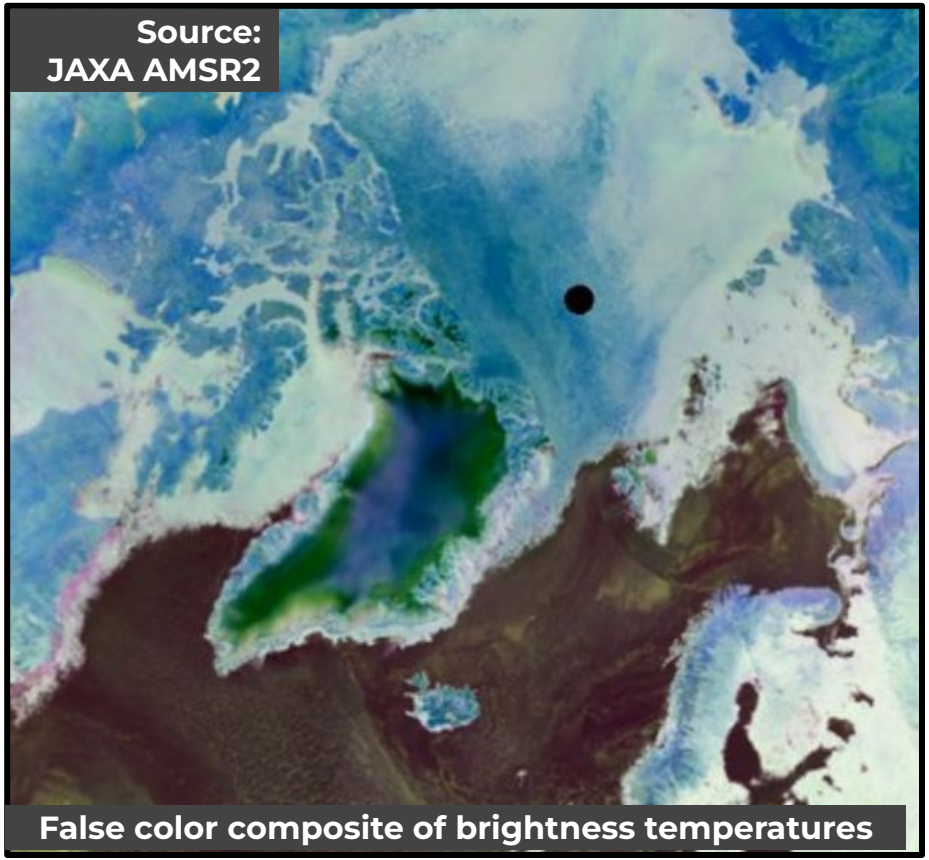


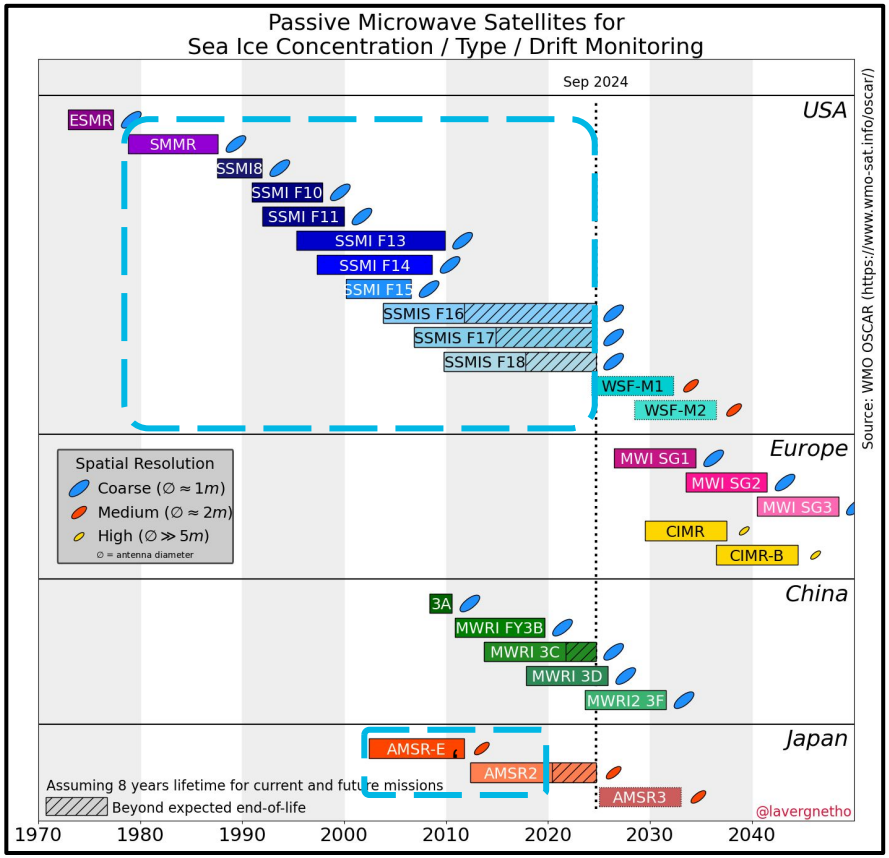
- Sea Ice Concentration is an Essential Climate Variable (ECV) product for the Global Climate Observing System (GCOS). Sea Ice Extent, derived from concentration, is a WMO headline indicator of climate change.
- “Human influence is very likely the main driver [...] the decrease in Arctic sea ice area between 1979–1988 and 2010–2019 (decreases of about 40% in September and about 10% in March)”. IPCC AR6 WGI.
- After a period of stable and even slightly increasing trends, Antarctic sea ice area abruptly dropped after 2014/15 with record low values in 2023.
- Climate Data Records of sea-ice concentration are maintained by several agencies. The OSI SAF data record is one of the multiple lines of evidence that the polar sea-ice cover is changing.

2. Composition of the Sea Ice Concentration CDRs

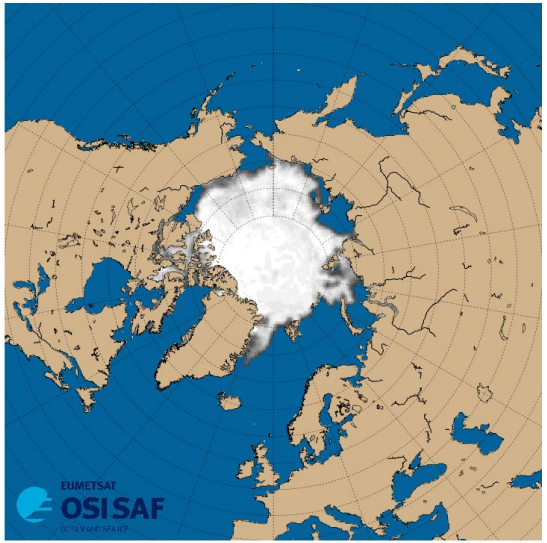
ID	OSI-450-a (CDR)	OSI-430-a (ICDR)	OSI-458
Content	**Sea-ice concentration**, its uncertainties (3 components), status flags, …		
Spatial coverage	Global (a NH and a SH product file per day)		
Temporal coverage and latency	25.10.1978 - 31.12.2020	01.01.2021 - present Nominal Latency: 16 days, fast-track: 2 days	01/06/2002 - 03/10/2011 24/07/2012 - 31/12/2020
Method	Evolutions from Lavergne et al. (2019) (EUMETSAT OSI SAF data, with R&D input from ESA CCI)		
Input data	• L1b data from SMMR, SSM/I, and SSMIS (CMSAF FCDR) • ERA5 fields	• Operational L1b data from SSMIS (NOAA CLASS) • ECMWF ERA5&IFS fields	• L1b data from **AMSR-E and AMSR2** (JAXA) • ERA5 fields
Product grid, resolution	Daily and Monthly files EASE2 25 x 25 km (true resolution more ~50 km)		Daily files EASE2 25x25 km (true resolution ~25 km)

2. Composition of the Sea Ice Concentration CDRs





2. Composition of the Sea Ice Concentration CDRs



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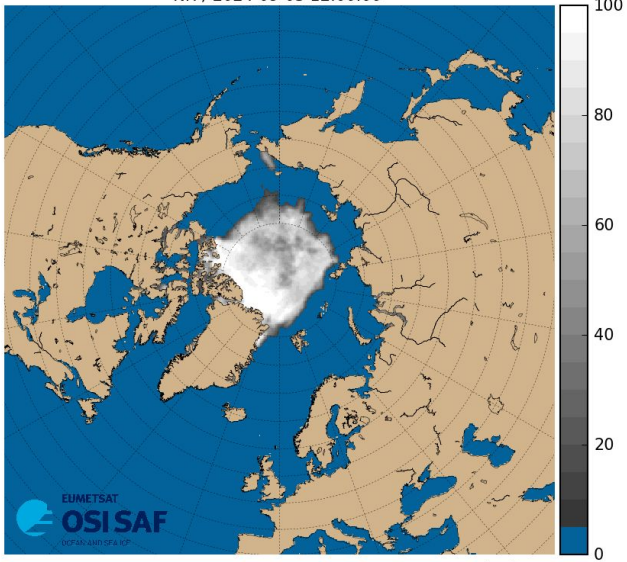

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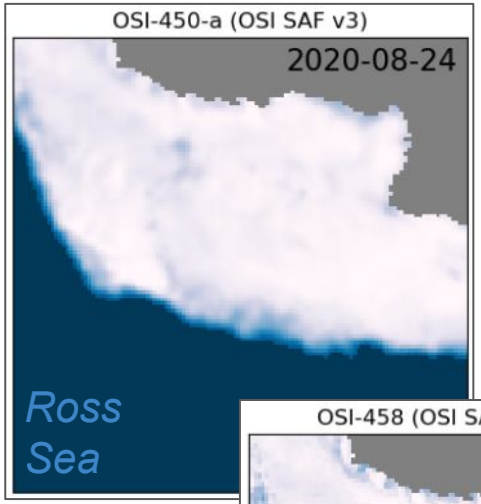

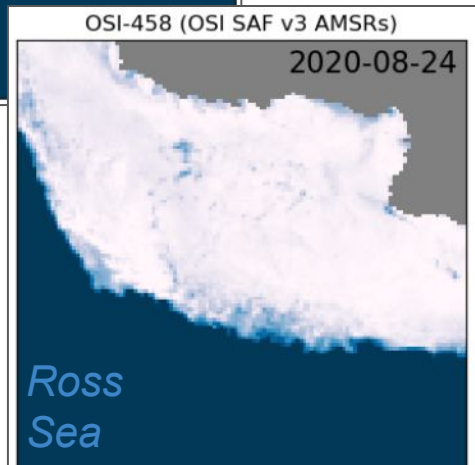

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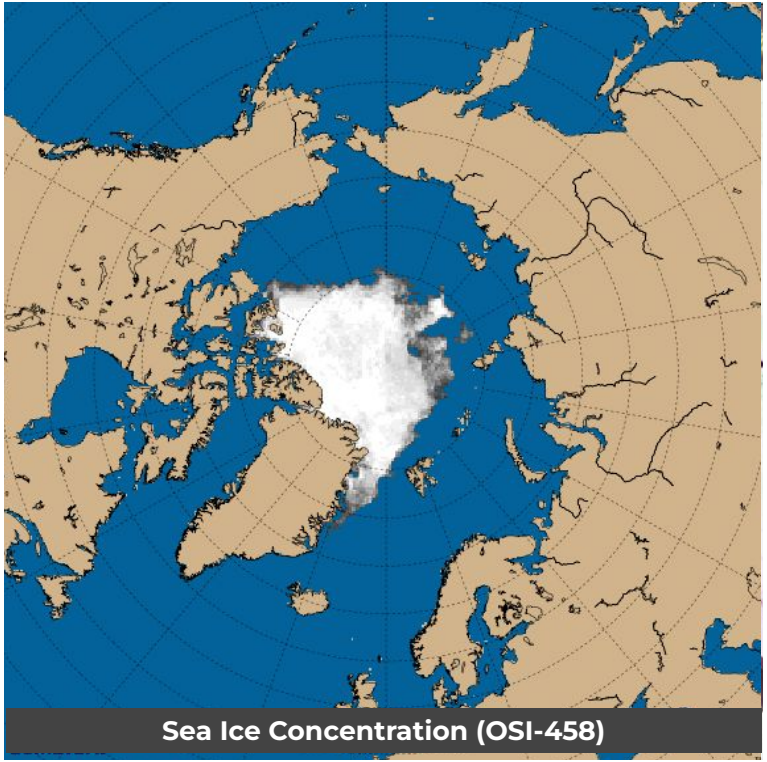
2. Composition: Sea Ice Concentration retrieval

- ➔ We correct the raw satellite observations (Level-1, the brightness temperatures) for the contamination by the atmosphere and by land.
- ➔ Sea-ice concentration is processed with our own algorithm, that we calibrate daily to the satellite data. ESA CCI contributed to the algorithms.
- ➔ Sea-ice concentration and their uncertainties are computed for each satellite pixel in each orbit (Level-2).
- ➔ They are finally composited to daily maps (Level-3), and data gaps are filled (Level-4).


Sea Ice Concentration (OSI-458)

2. Composition: Validation at low concentration

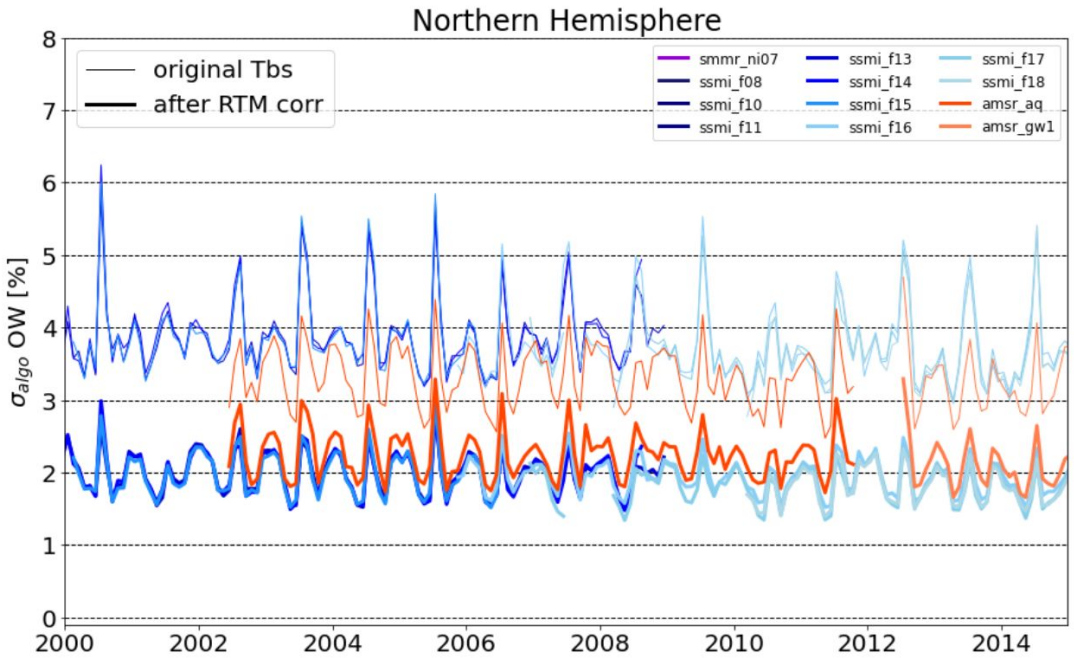


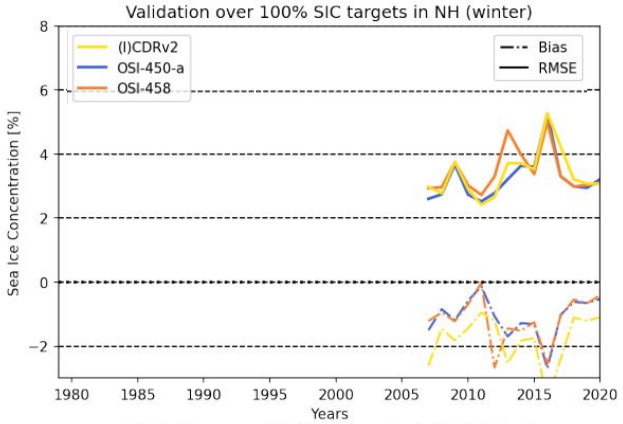
Figure 8: Timeseries of the SIC retrieval uncertainty σ_{algo} for OW conditions in the Northern Hemisphere over the period 2000-2015. Thin lines are for the SIC retrieval noise without atmospheric correction, and thick lines are with the atmospheric correction. Colors indicate the satellite missions

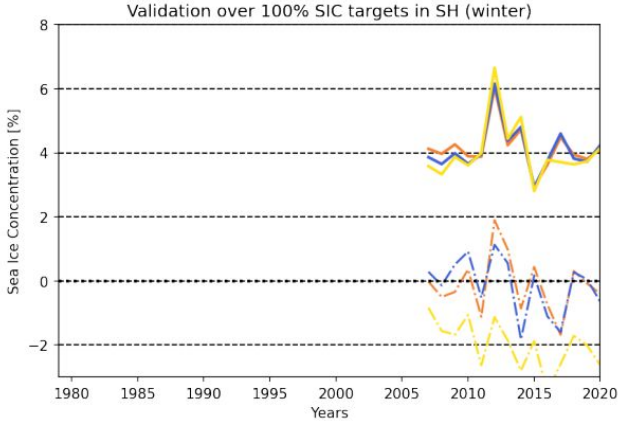
We use a Radiative Transfer Model (RTM) and ERA fields to correct the brightness temperatures before computing SIC.

Retrieval uncertainty at low SIC without RTM-correction.

Retrieval uncertainty at low SIC with RTM-correction using ERA5 (includes TCLW that had no skill with ERA-Interim).

2. Composition: Validation at high concentration





RMSE at high (100%) sea-ice concentration is 3-4 %.

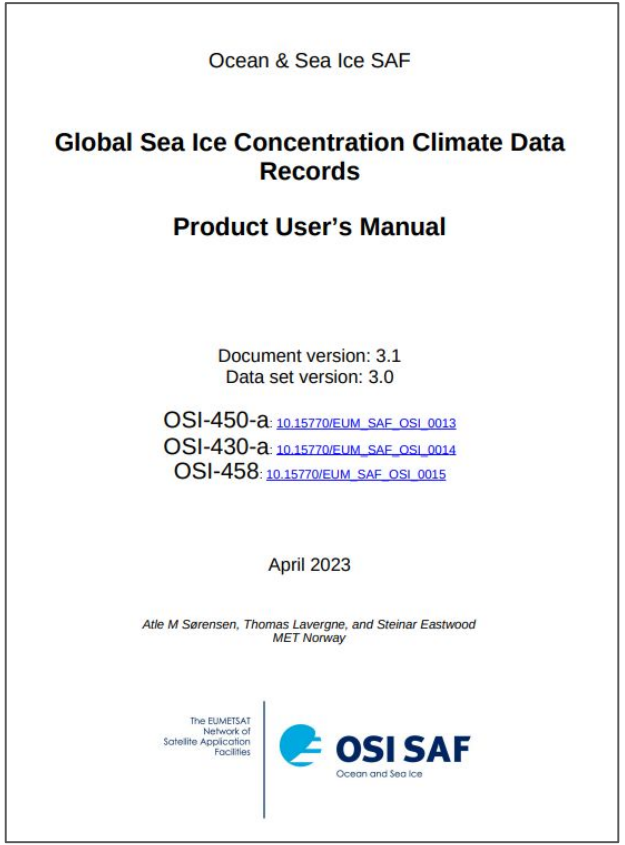
Small bias in the Arctic, -1%

No bias in the Antarctic

EUI

3. Known limitations of the Sea Concentration CDRs

- ➔ The early decade (1978 - 1987) has long data gaps. Use the interpolated values with caution (see `status_flag`).
- ➔ There is residual false ice along the coasts. Especially in lakes or smaller seas (Baltic, Caspian,...). Things are better with OSI-458 (AMSRs).
- ➔ In summer, surface melt and a wetter atmosphere contaminate the signal. Sea-ice concentration is underestimated for high melt-pond fractions.
- ➔ See the Product User's Manual (on the website).


Ocean & Sea Ice SAF

Global Sea Ice Concentration Climate Data Records

Product User's Manual

Document version: 3.1
Data set version: 3.0

OSI-450-a: 10.15770/EUM_SAF_OSI_0013
OSI-430-a: 10.15770/EUM_SAF_OSI_0014
OSI-458: 10.15770/EUM_SAF_OSI_0015

April 2023

Atle M Sørensen, Thomas Lavergne, and Steinar Eastwood
MET Norway

The EUMETSAT Network of Satellite Application Facilities

OSI SAF
Ocean and Sea Ice

4. Future developments towards v4

These OSI SAF Sea Ice Concentration CDRs (v3) were released in 2023. We want to hear from our users, what you liked and what we could improve, before preparing v4.

In v4, we would like:

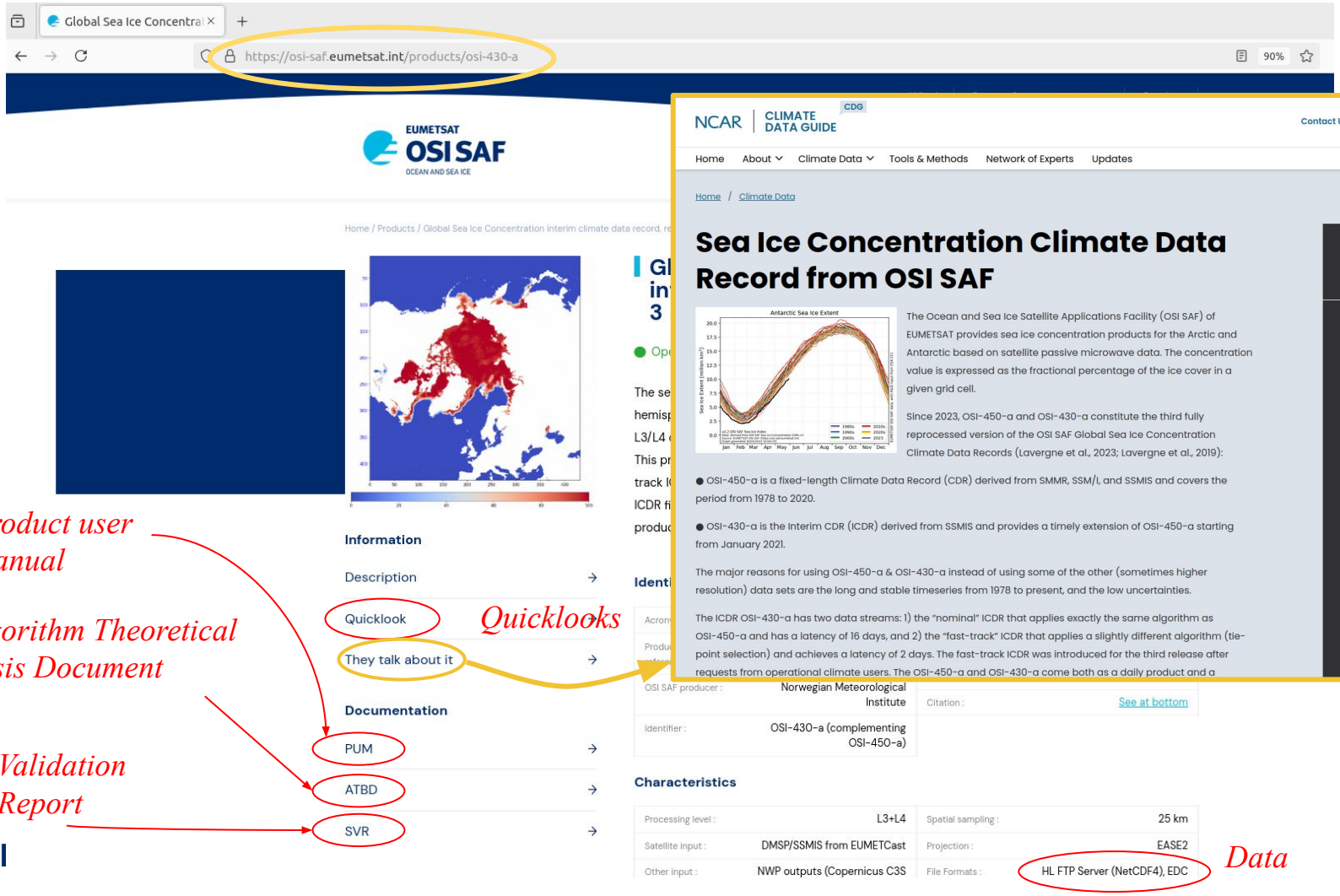
- ➔ **Higher Resolution** using the higher frequency channels of SSM/I (>= 1991). R&D was demonstrated in ESA CCI.
- ➔ **Better Accuracy** by using a better Radiative Transfer Model.
- ➔ Better **interpolation** of data gaps (especially in the first decade).

"We need higher-resolution (AMSR) SIC data from 2021 onwards, when is this coming?"

As of today, OSI-458 stops in Dec. 2020 and there is no official extension.

Work is on-going to make such an extension, with a nominal latency of 16 days, and a fast-track latency of 2 days. A prototype production (2021 - today) is already in place, but it is not yet an official product. Contact us if you want to test it.

AMSR2 is already 12 years old, and AMSR3 should launch early 2025.


Global Sea Ice Concentra
https://osi-saf.eumetsat.int/products/osi-430-a
90%
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Home / Products / Global Sea Ice Concentration interim climate data record,
Information
Description
Quicklook
They talk about it
Documentation
PUM
ATBD
SVR
Product user manual
Algorithm Theoretical Basis Document
Validation Report
Quicklooks
Identi
OSI SAF producer :
Norwegian Meteorological Institute
Citation :
See at bottom
Identifier :
OSI-430-a (complementing OSI-450-a)
Characteristics
Processing level :
L3+L4
Spatial sampling :
25 km
Satellite input :
DMSP/SSMIS from EUMETCast
Projection :
EASE2
Other input :
NWP outputs (Copernicus C3S
File Formats :
HL FTP Server (NetCDF4), EDC
Data
NCAR | CLIMATE DATA GUIDE
CDG
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Sea Ice Concentration Climate Data Record from OSI SAF
Antarctic Sea Ice Extent
The Ocean and Sea Ice Satellite Applications Facility (OSI SAF) of EUMETSAT provides sea ice concentration products for the Arctic and Antarctic based on satellite passive microwave data. The concentration value is expressed as the fractional percentage of the ice cover in a given grid cell.
Since 2023, OSI-450-a and OSI-430-a constitute the third fully reprocessed version of the OSI SAF Global Sea Ice Concentration Climate Data Records (Lavergne et al., 2023; Lavergne et al., 2019):
● OSI-450-a is a fixed-length Climate Data Record (CDR) derived from SMMR, SSM/I, and SSMIS and covers the period from 1978 to 2020.
● OSI-430-a is the Interim CDR (ICDR) derived from SSMIS and provides a timely extension of OSI-450-a starting from January 2021.
The major reasons for using OSI-450-a & OSI-430-a instead of using some of the other (sometimes higher resolution) data sets are the long and stable timeseries from 1978 to present, and the low uncertainties.
The ICDR OSI-430-a has two data streams: 1) the "nominal" ICDR that applies exactly the same algorithm as OSI-450-a and has a latency of 16 days, and 2) the "fast-track" ICDR that applies a slightly different algorithm (tie-point selection) and achieves a latency of 2 days. The fast-track ICDR was introduced for the third release after requests from operational climate users. The OSI-450-a and OSI-430-a come both as a daily product and a
Sea Ice Concentration Climate Data Record from OSI SAF
Years of record
1978-10 to 2023-08
Main variables
Cryosphere | Sea Ice Concentration | Ocean
Dataset collections
None
Type of data product
Satellite Data Products | Platforms | Other | SMMR | SSMI
Institution and PIs
Norwegian Meteorological Institute , Danish Meteorological Institute
About the experts

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OCEAN AND SEA ICE

Thanks for your attention!

Norwegian Meteorological Institute

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thomas.lavergne@met.no

https://osi-saf.eumetsat.int/

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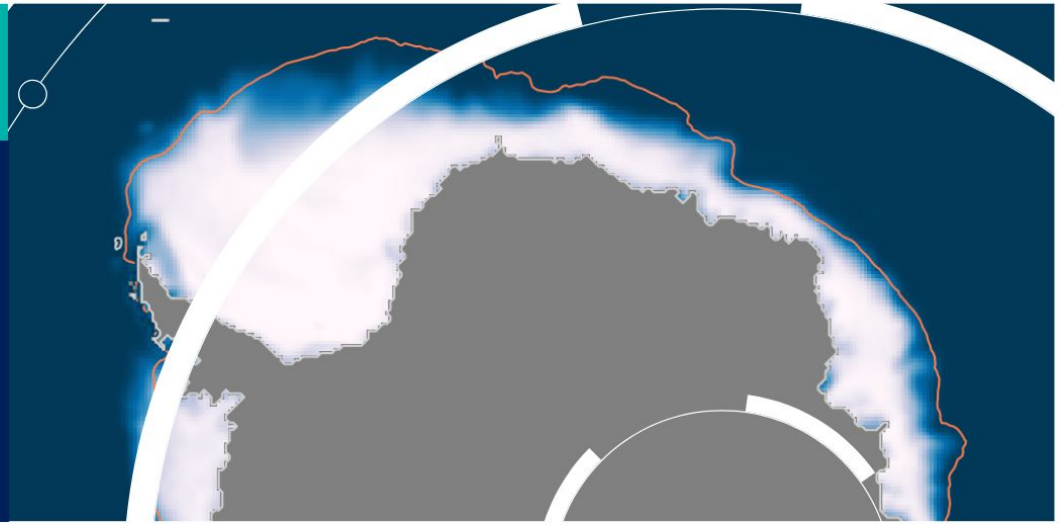


Sea Ice Drift

Emily Down & Thomas Lavergne, MET Norway.

Meteorologisk institutt

Overview

1. Importance of the Sea Ice Drift CDR
2. Composition of the Sea Ice Drift CDR
3. Limitations of the Sea Ice Drift CDR
4. Future developments of the Sea Ice Drift CDR
5. Example usages of the Sea Ice Drift CDR

1. Importance of the Sea Ice Drift CDR

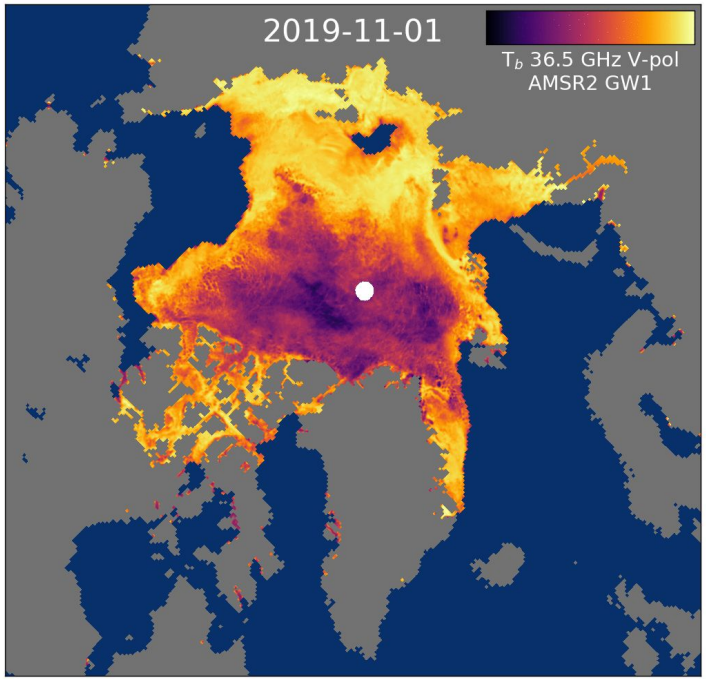


Image credit: Thomas Lavergne

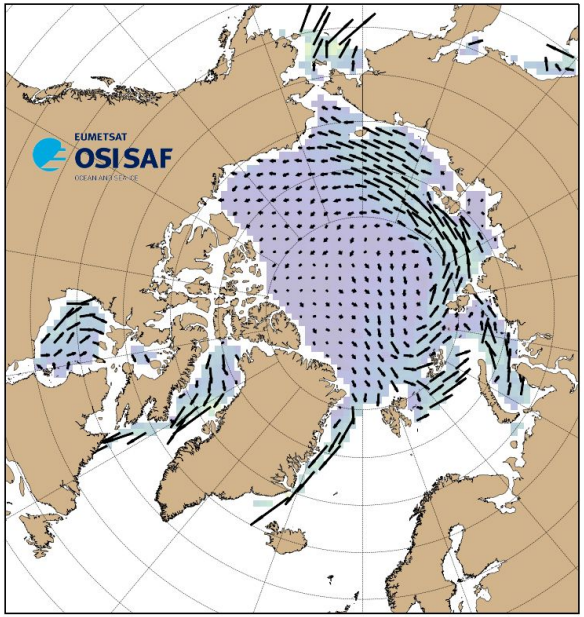
- ➔ Sea ice moves up to 10s of km per day, pushed by winds and currents
- ➔ Transports ice to lower latitudes where it melts, redistributing fresh water
- ➔ Motion of sea-ice can lead to aging and thickening of the ice pack in certain areas
- ➔ **Climate change is resulting in faster sea-ice drift**

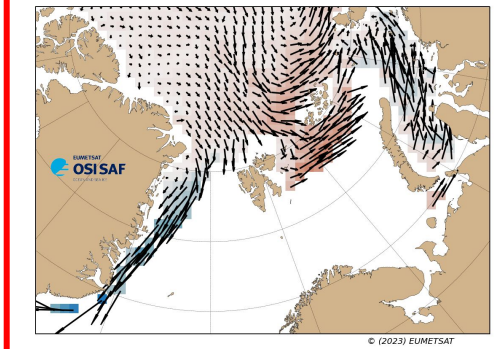
*Sea ice drift is an **Essential Climate Variable (ECV)** product for the **Global Climate Observing System (GCOS)***

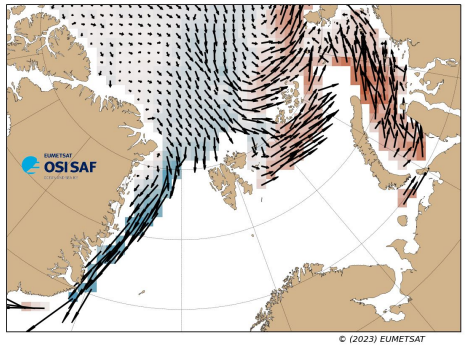
2. Composition of the Sea Ice Drift CDR

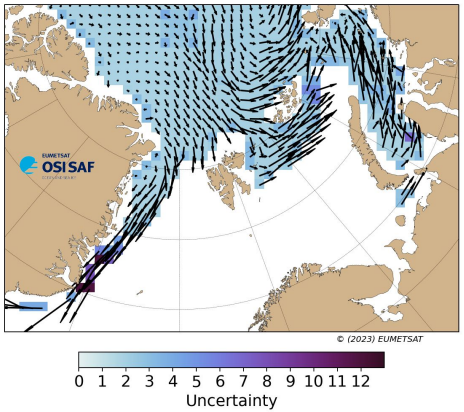
ID	**OSI-455 (CDR)**
Spatial coverage	**Global** (a NH and a SH product file)
Temporal coverage	**Jan 1991 - Dec 2020**
Product resolution	**EASE2 75 x 75 km** (~120 km “true” resolution)
Drift period	**~ 24 h** (actual drift period of each vector)
Product dependency	**Year-round**, but reduced accuracy during summer months
Method	**Continuous Maximum Cross Correlation** (Lavergne et al., 2010) & free-drift model
Input data	Daily average maps of : ● SSM/I (>= F10) and SSMIS (CMSAF FCDR) ● AMSR-E (NSIDC) ● AMSR2 (JAXA) ECMWF/C3S ERA5 10m winds

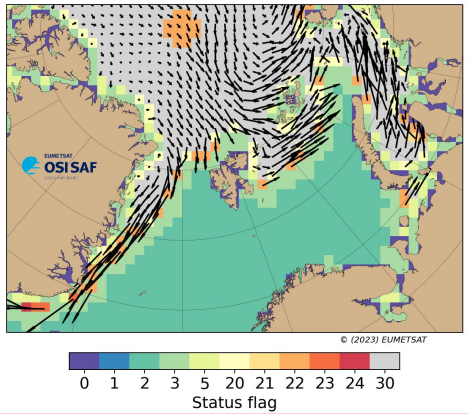
2. Composition: Example NH 16-17 January 2010











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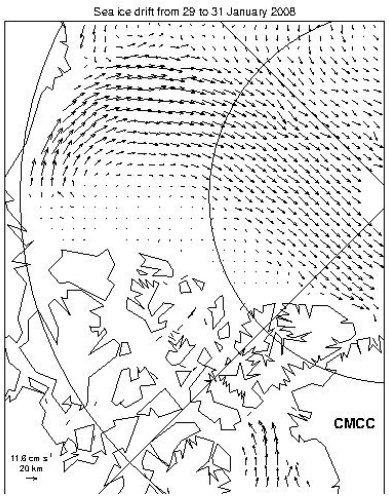
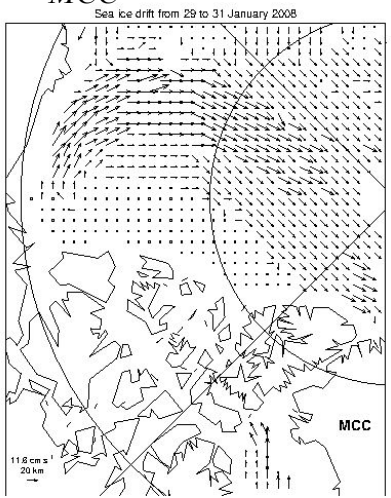
2. Composition: Motion Tracking (Single-sensor product)

Passive microwave satellite data offers great coverage and consistency, and captures the movement of the sea ice

CMCC



MCC



Note the more realistic vector field compared to the regular MCC method

- Daily average maps of satellite signal:
  - SSM/I, SSMIS - near 90GHz
  - AMSR-E, AMSR2 - 37GHz
- Laplacian filter applied to enhance the features in the images
- Motion tracking (**Continuous Maximum Cross-Correlation**, Lavergne et al. 2010) is used to pattern match the ice features in a consecutive pair of images for a fractional pixel solution
- Correction of erroneous vectors using neighbouring vectors

2. Composition: Summer gap-filling from Free Drift Model

In the summer, the CMCC algorithm is less reliable due to meltwater and increased atmospheric water content

➔ Hence, we gap-fill temporally with ice drift from a **free drift model**

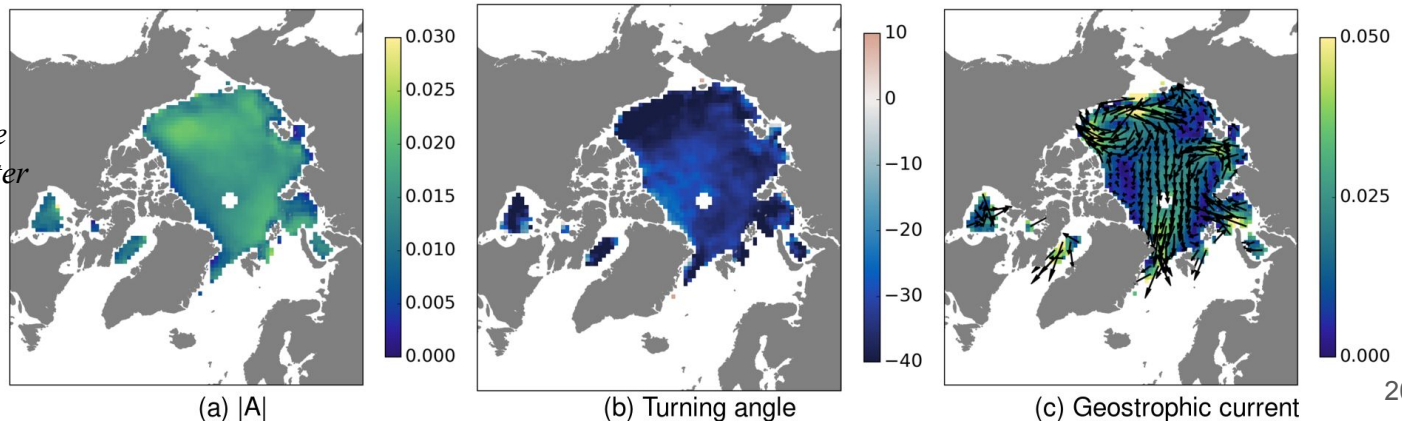
➔ ERA5 wind reanalysis as input

➔ AMSR-E and AMSR2 37GHz ice drift vectors used as training data

➔ Inverse wind model computes per-month parameter fields

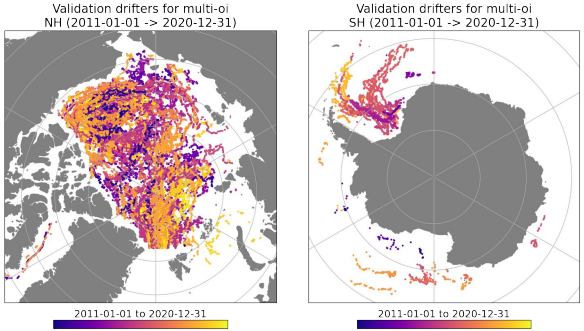
➔ Parameter fields and ERA5 wind used to calculate summer drift in the forward model

Example parameter fields



(a) |A| (b) Turning angle (c) Geostrophic current

2. Composition: Validation and Merged product



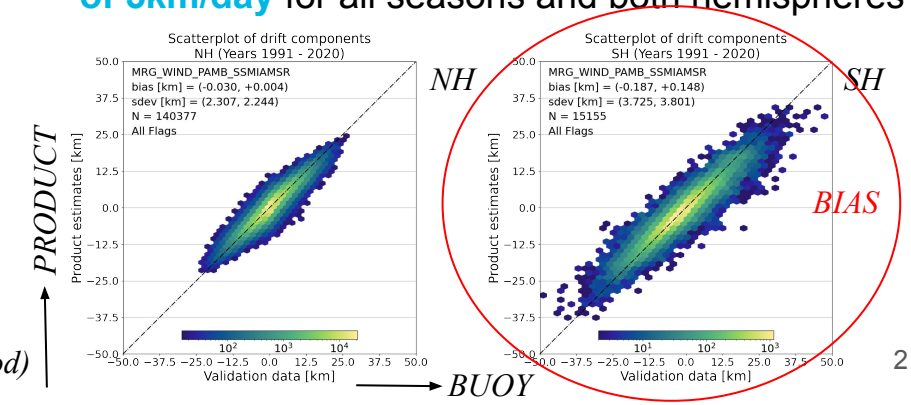
On-ice buoy coverage for 10-year period 2011-2020

Validation against on-ice buoys

- ➔ Sparse buoy coverage in Southern Hemisphere
- ➔ Vectors collocated in time and position
- ➔ dX, dY values are compared between buoy and product to retrieve RMSE errors and bias

Merged Product

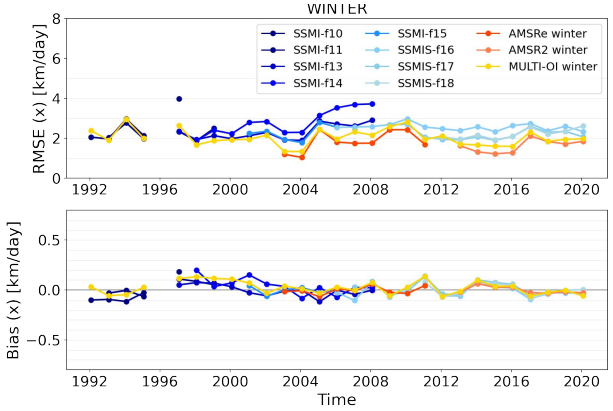
- ➔ Optimal merging of single-sensor products based on uncertainties
- ➔ Interpolation for spatial gap-filling
- ➔ In transition seasons, satellite drift is blended with wind drift
- ➔ Multi-sensor RMSE **exceeds target requirement of 5km/day** for all seasons and both hemispheres



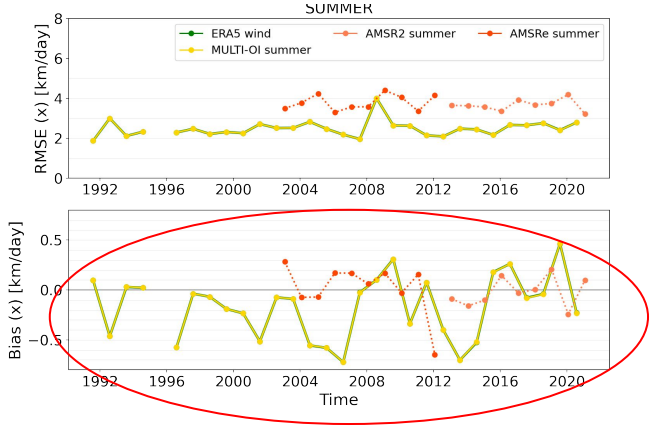
MULTI-SENSOR (Whole CDR period)

3. Known limitations of the Sea Ice Drift CDR

Winter (main algorithm)



Summer (Free Drift model gap filling)



Northern Hemisphere *timeseries for the X-component of drift (similar for Y-component)*

← *GOOD RMSE*

← *BIAS IN SUMMER*

1. **Negative bias for summer ice drift** (from Free Drift model) measured vs. buoys
2. **SH has small bias for very strong drift**, for which the CDR has lower drift than buoys

3. Lower drift accuracy in coastal and peripheral sea ice areas
4. Limited to 1991 - 2020 (no ICDR yet)
5. Limited spatial resolution

4. Future developments of the Sea Ice Drift CDR

- ➔ **Extension back in time** using coarser-resolution satellite data from SMMR (1978-1990)
- ➔ **Extension to an ICDR** (2021 onwards)
- ➔ Investigate if **finer spatial resolution** can be attained
- ➔ Investigate the bias in the SH drift for the winter period
- ➔ Improve the tuning of the Free Drift model for summer ice drift
- ➔ Improve the uncertainty model

"We need ice drift data from 2021 onwards, when is this coming?"

We hope to extend the CDR to the current day, but there is no timeline yet.

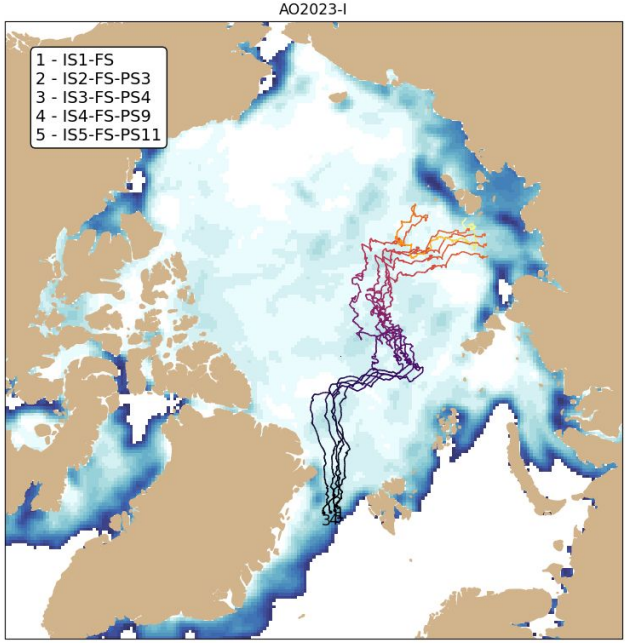
In the meantime, you can use the NRT product with the following caveats:

- Different gridding
- Different duration drift vectors
- Different format

There is a notebook at https://zenodo.org/records/8398399 which can provide a starting point for you to join these two datasets.

5. Example usages: Backtracking

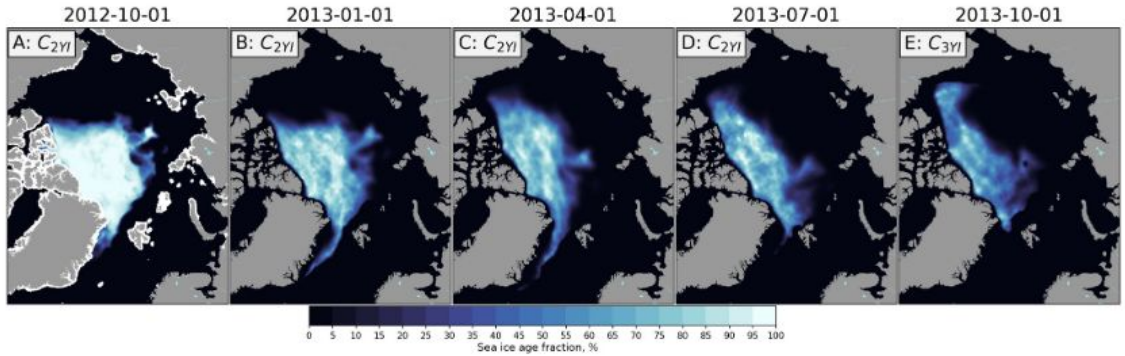
- The daily ice drift is used to trace back the trajectories of locations on the drifting ice, to determine the history of the ice
- OSI SAF sea ice concentration used together with the ice drift to check where the parcel of ice hits open water - this is the start of the trajectory where the ice formed
- A public software package for this purpose is being developed as part of the **SUDARCO** project - coming soon!



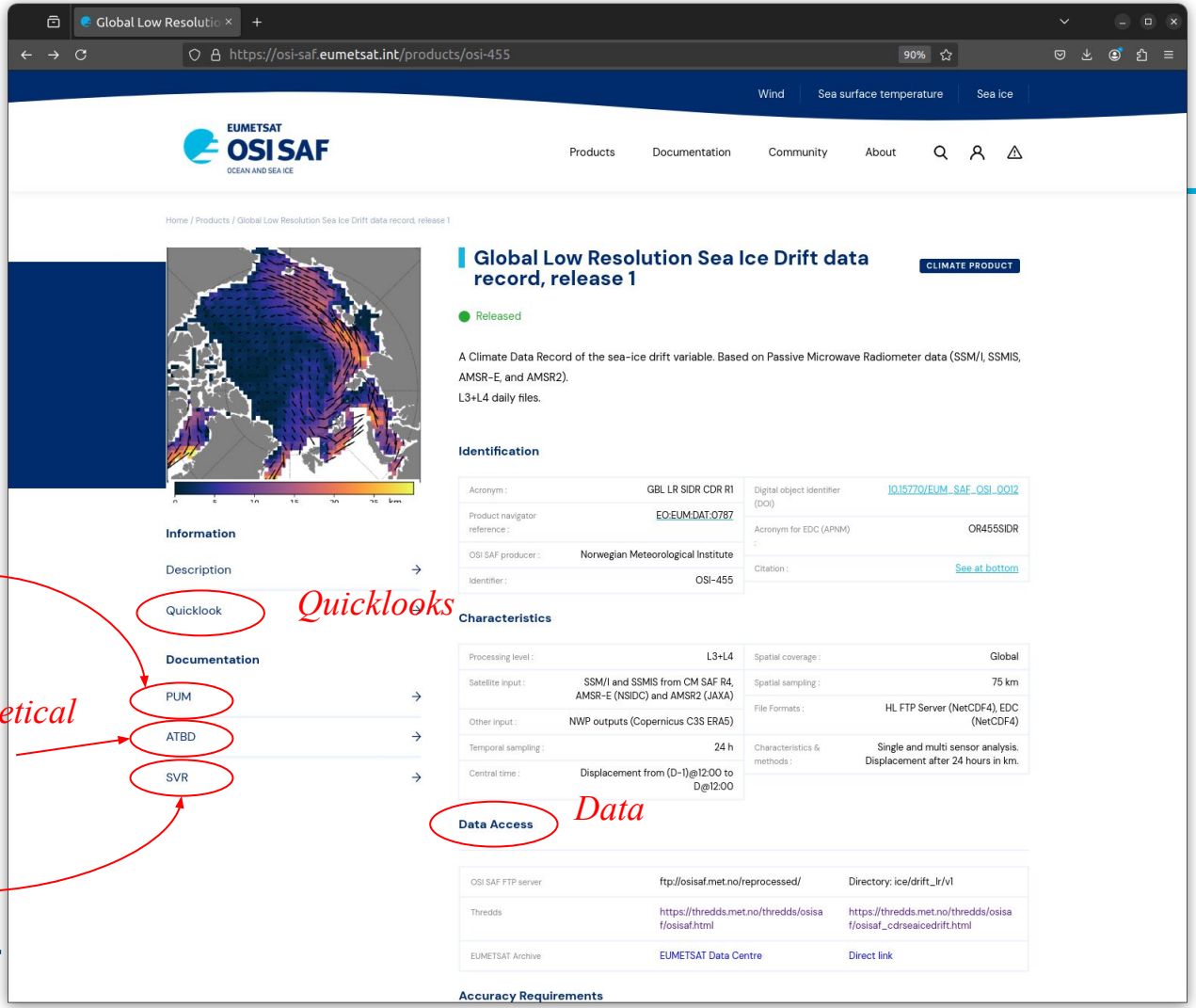
Backtracking ice station positions from the 2023 SUDARCO cruise

5. Example usages: Ice Age

- ➔ Similarly to trajectory tracking for single ice parcels, ice age can be calculated from the daily drift and ice concentration, plus an initialization (e.g. all ice at yearly minimum is 2+ year ice)
- ➔ The drift can be used in an advection scheme, see e.g. Korosov et al. 2018, which generates fraction maps
- ➔ Alternate methods can produce probability maps



From Korosov et al. 2018
Maps of sea ice age fractions on March 2015.



Product user manual

Quicklooks

Algorithm Theoretical Basis Document

Data

Validation Report

EUMETSAT

EUMETSAT
OSI SAF
OCEAN AND SEA ICE

Thanks for your attention!

Norwegian Meteorological Institute

Emily Down
emilyjd@met.no

https://osi-saf.eumetsat.int/

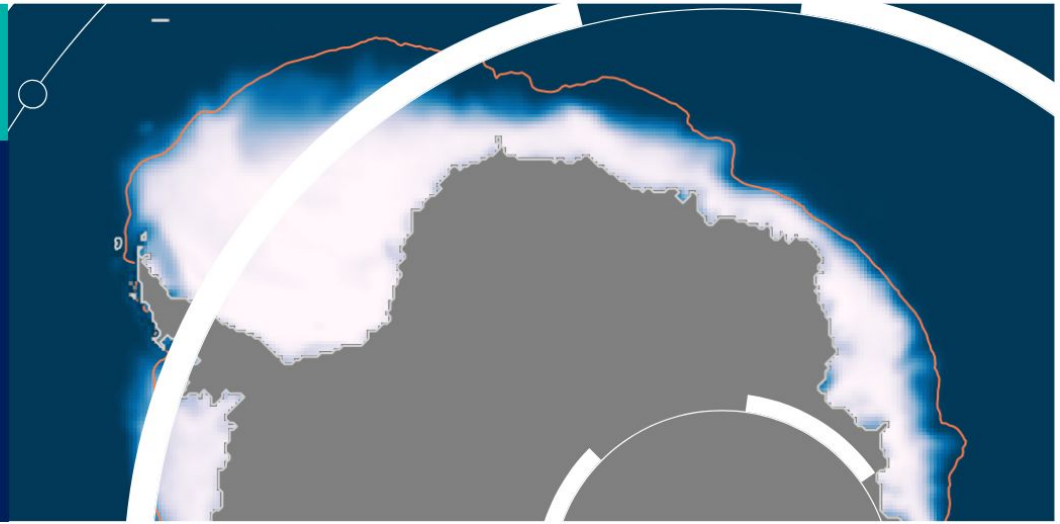
EUMETSAT

EUMETSAT OSI SAF
OCEAN AND SEA ICE

10 SEPTEMBER 2024
10:00 & 15:00 CET

SHORT COURSE

OSI SAF SEA ICE
CLIMATE RECORDS

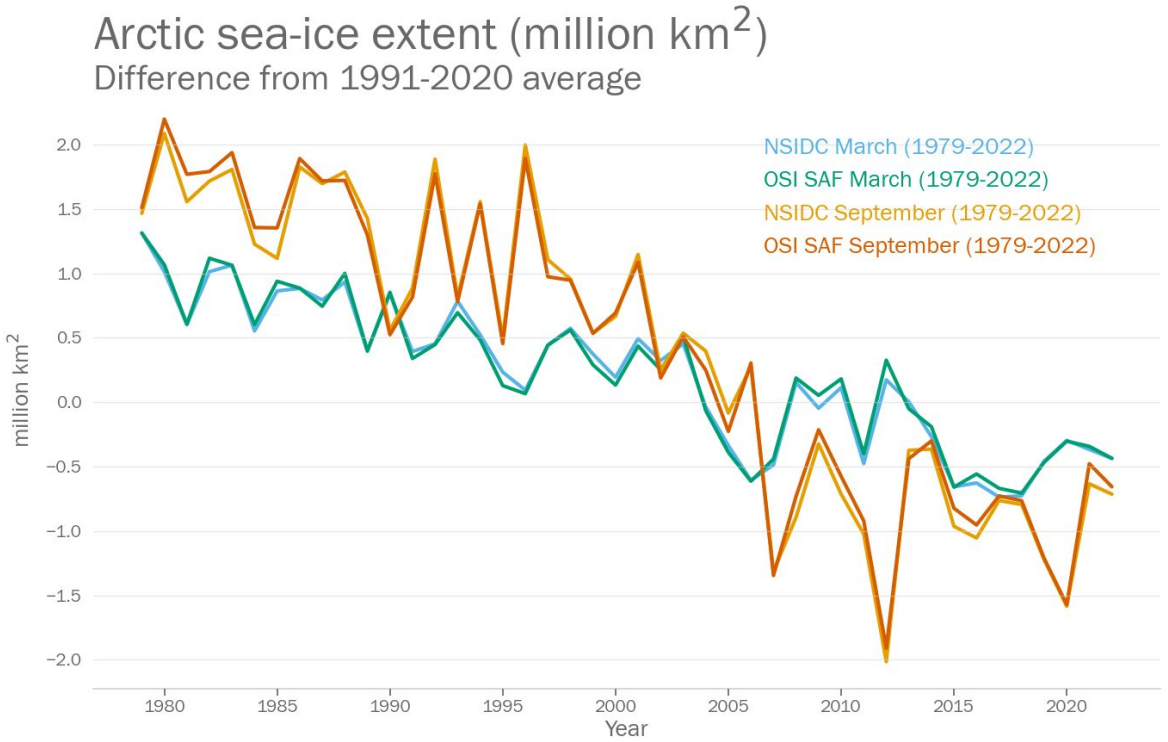


Sea Ice Index

Signe Aaboe, Thomas Lavergne & Atle Sørensen, MET Norway

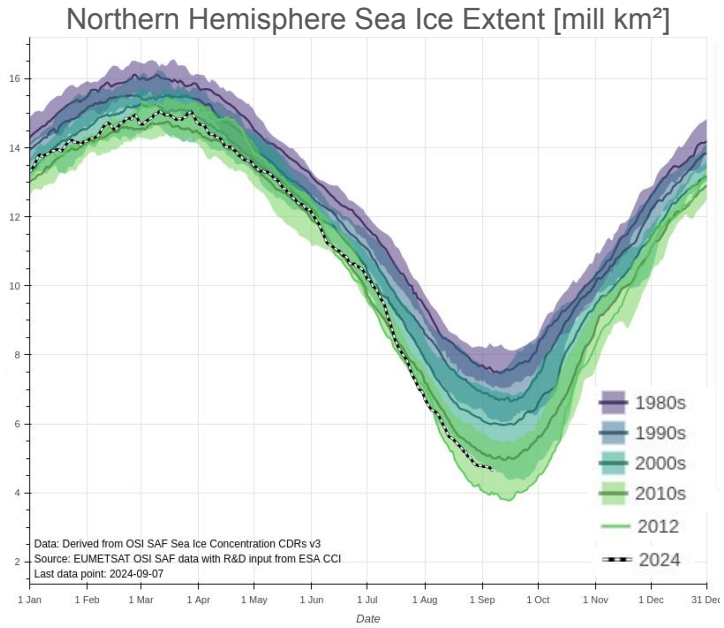
Meteorologisk institutt

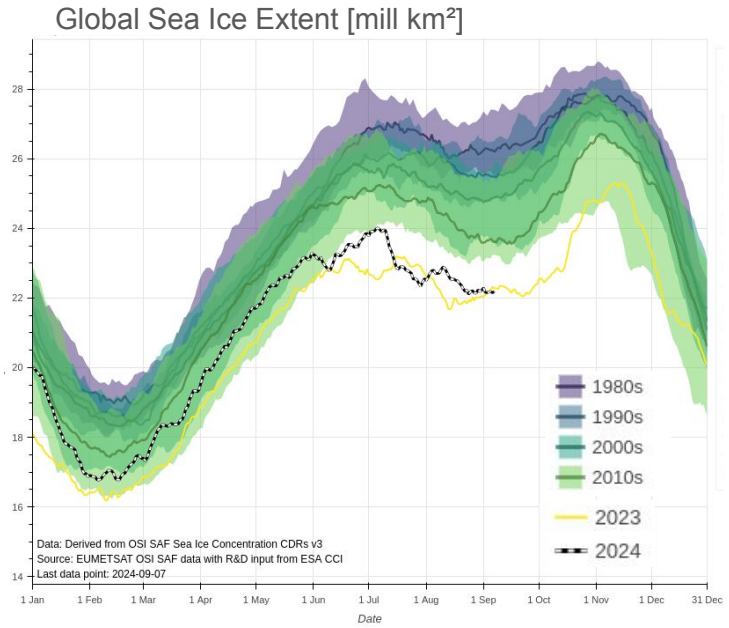
Importance of Sea Ice Index



Credit: WMO - State of the Global Climate
(additional material: Global Climate Indicators)

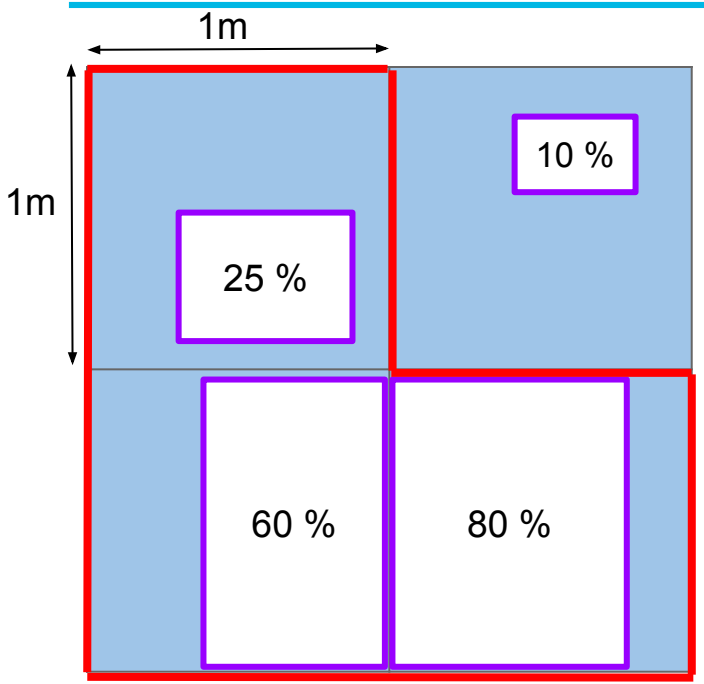
Importance of Sea Ice Index





Source: cryo.met.no

What is Sea Ice Index – Area vs. Extent



Sea ice

Open ocean (no ice)

Sea-ice AREA

Actual area covered by sea ice.

⟵ *Example:*

Area** = 0.25 + 0.10 + 0.8 + 0.6 = **1.75 m²

Sea-ice EXTENT

Area of grid cells in which sea-ice conc ≥ 15 %.

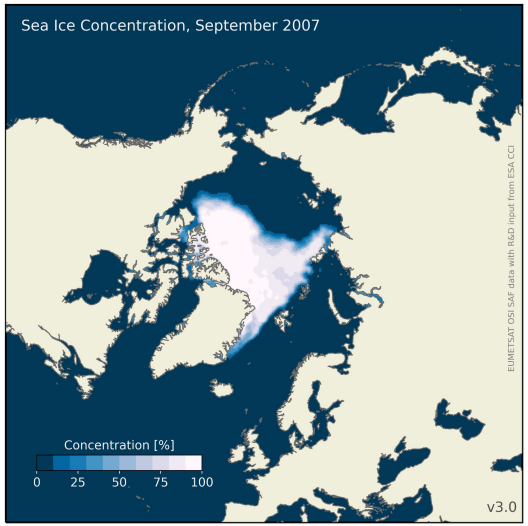
⟵ *Example:*

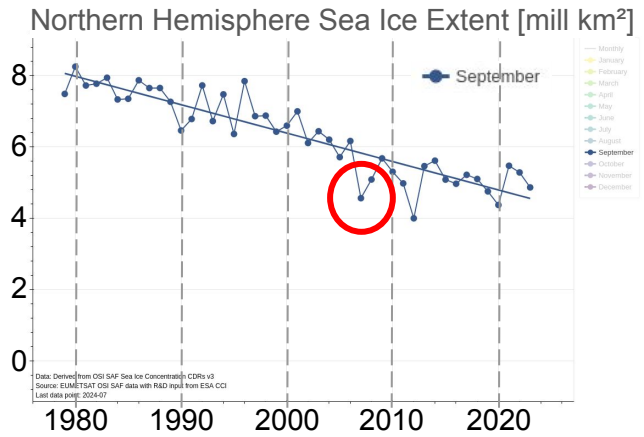
Extent** = 1 + 0 + 1 + 1 = **3 m²

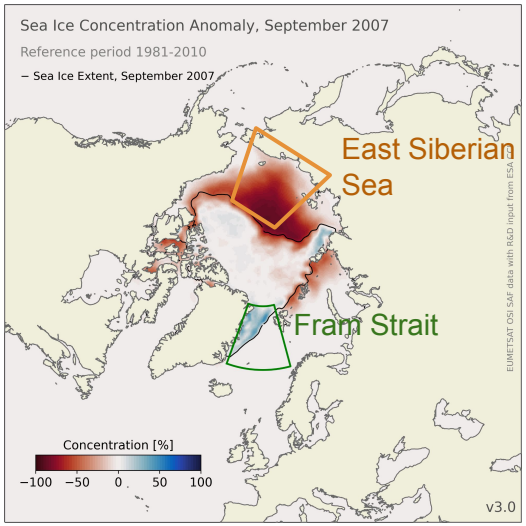
Sea-ice EXTENT ≥ Sea-ice AREA

Illustration inspired from *Burgard (2020) Did you know - the difference between sea-ice area and sea-ice extent?*

Sea Ice Index – Hemispheric vs. Regional



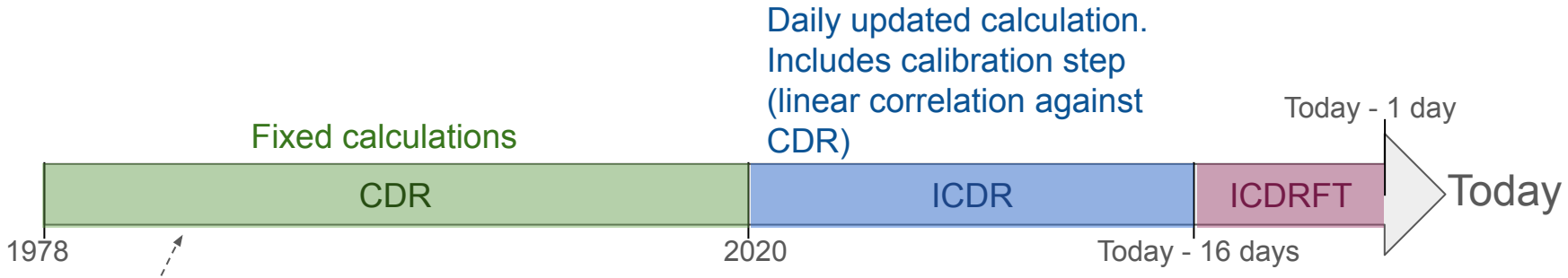




Summary of Sea Ice Index - OSI-420

ID / version	OSI-420 / v2.2 (demonstrational)	*InProg:* OSI-420 / v3.0 (official)
Input data	Daily maps of Sea-ice concentration v3 : ● CDR, OSI-450-a ● ICDR, OSI-430-a	Daily maps of Sea-ice concentration v3 : ● CDR, OSI-450-a ● ICDR, OSI-430-a
Spatial coverage	Global, Hemispheric, Regional (lat-lon bounded boxes)	Global, Hemispheric, Regional (**full-coverage gridded masks**)
Temporal coverage and resolution	25.10.1978 - present. Latency 1 day. Daily, monthly	October 25, 1978 - present. Latency 1 day. Daily, monthly, **yearly**
Statistics	Mean, trends (available in graphics)	Mean, trends, **median+, ranks, climatologies, uncertainty estimates. Available as data.**
Content data	Sea-ice extent, sea-ice area, status flag. Daily, monthly values. (.txt, .nc)	+ **Climatology data (.txt, .nc)** + **Yearly values.**
Content graphics	Time series, rank tables (.png) Interactive plotting (cryo.met.no)	+ **Climatology maps of sea-ice concentration (.png)**

Sea Ice Index – Daily Computation



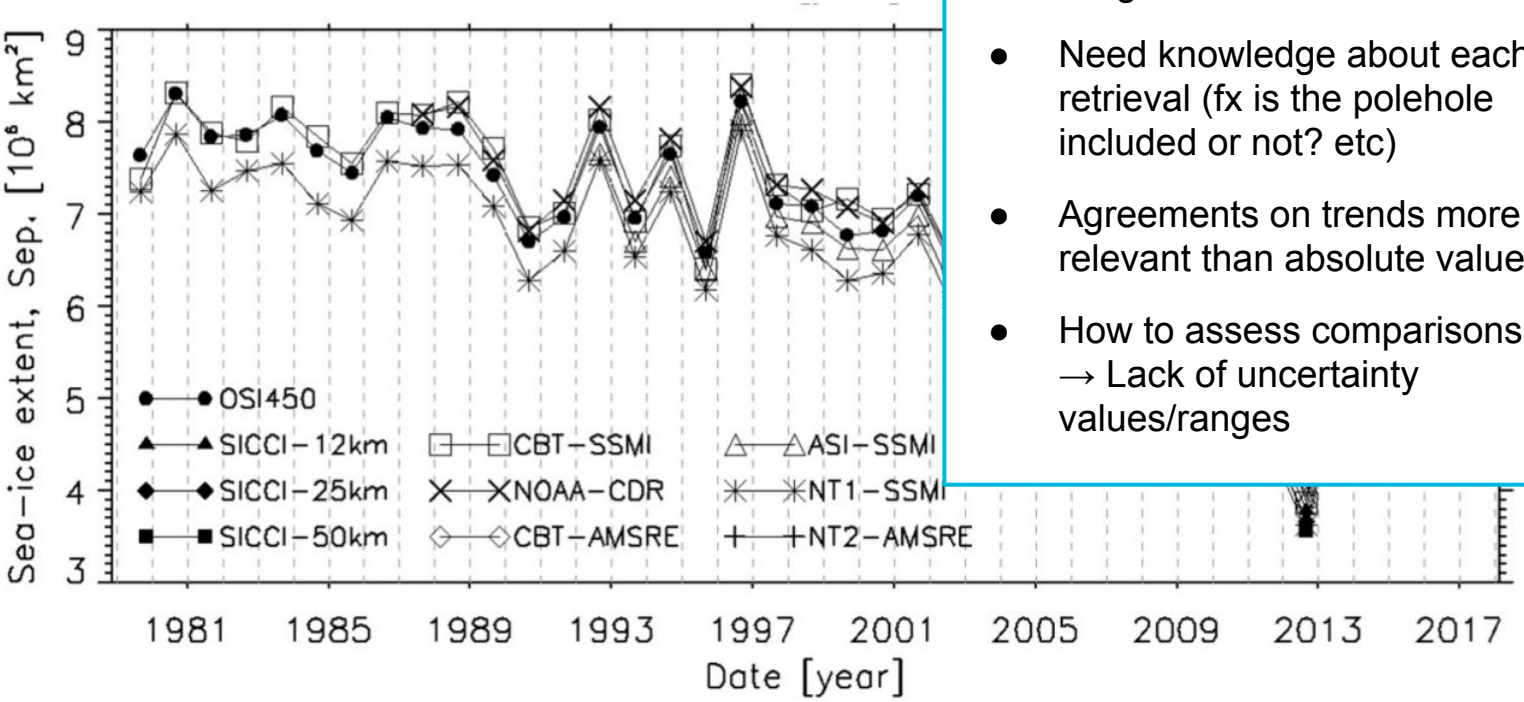
Non-linear timeline

Type of input data is marked in the status flag

Daily updated calculation.
Note, ICDR overwrites
ICDR-Fast-Track!

Validation

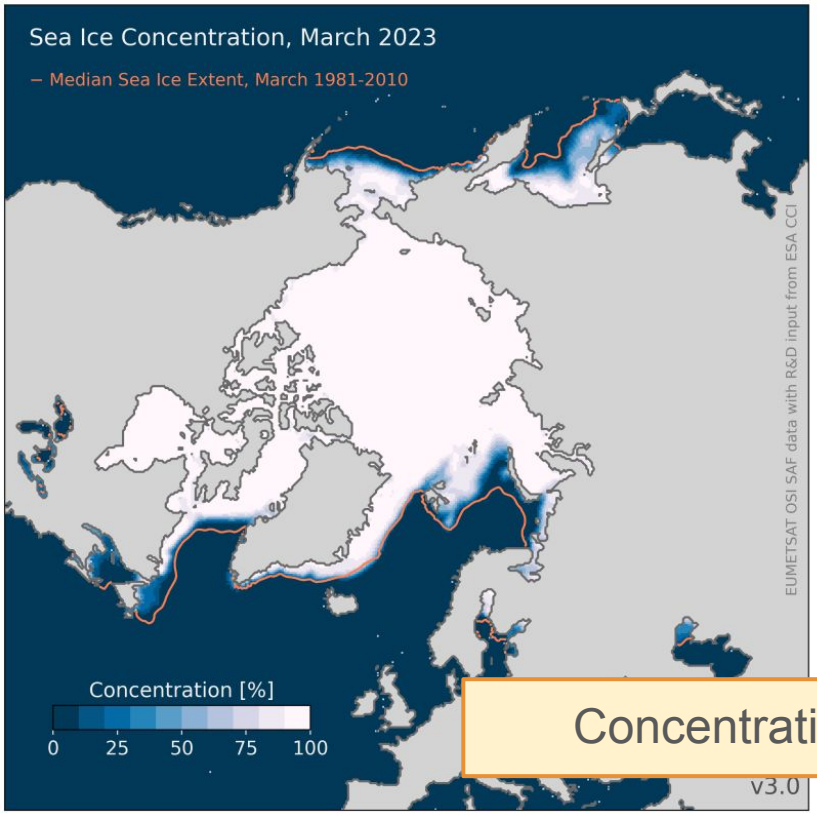
⇒ Comparison to other similar indexes

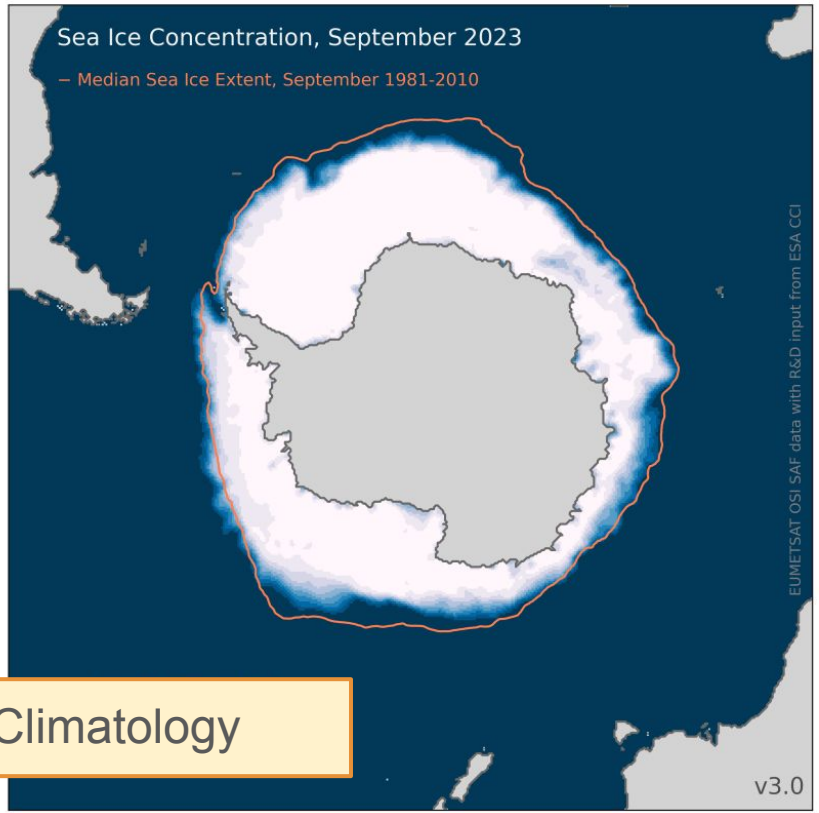


- No ground-truth
- Need knowledge about each retrieval (fx is the polehole included or not? etc)
- Agreements on trends more relevant than absolute values
- How to assess comparisons? → Lack of uncertainty values/ranges

Credit: Kern et al., 2019 (Fig. 6)

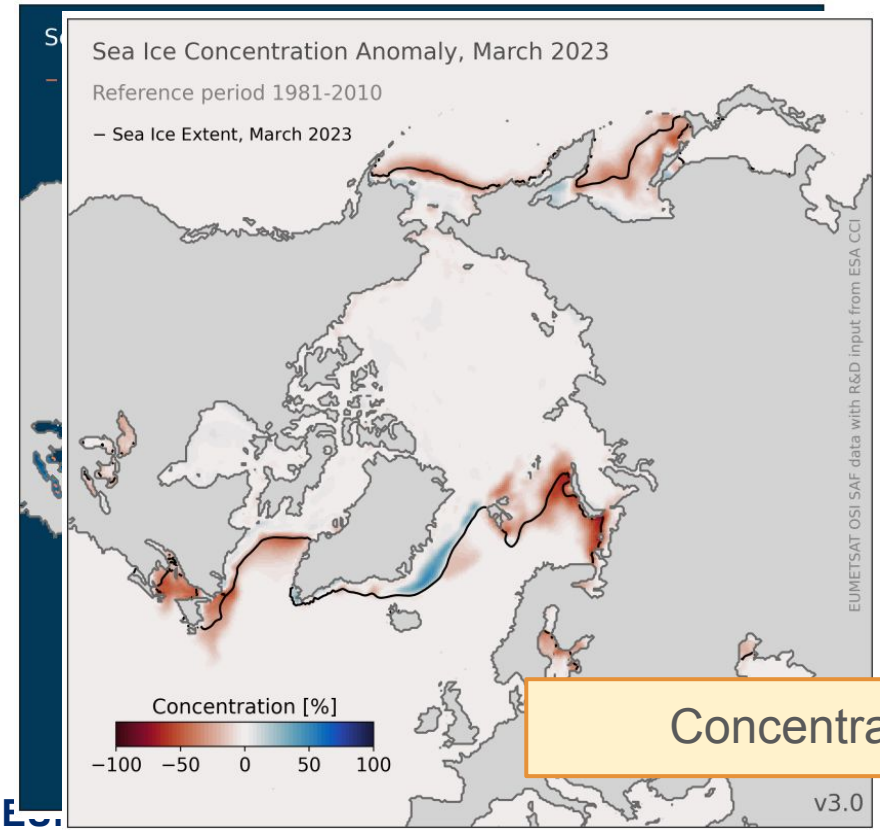
Maps of climatologies and anomalies (upcoming v3.0)

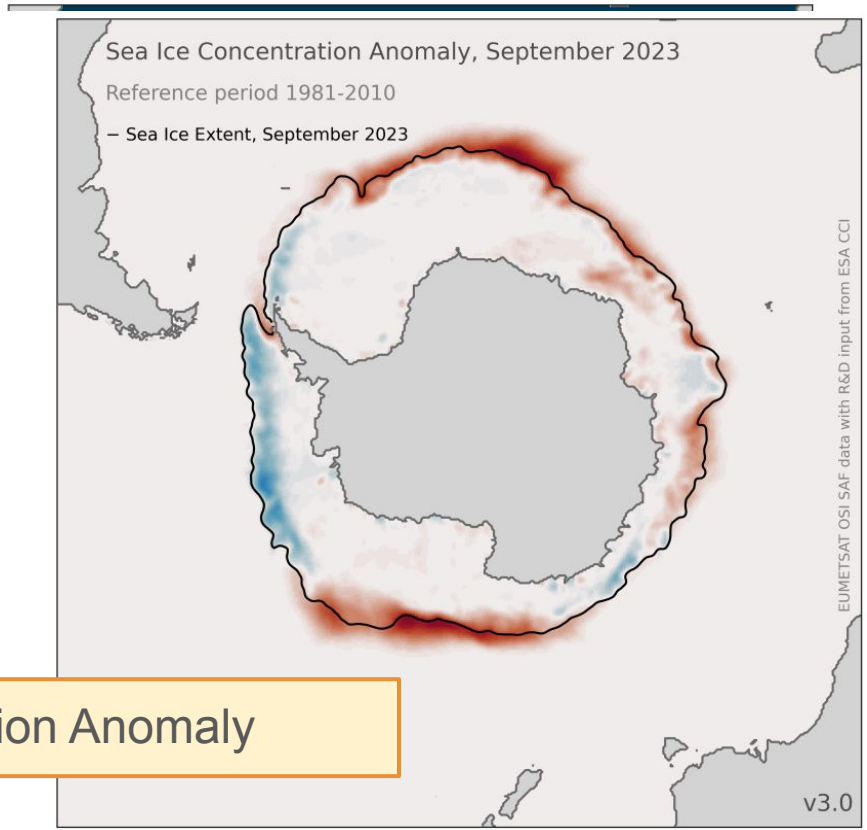




Concentration Climatology

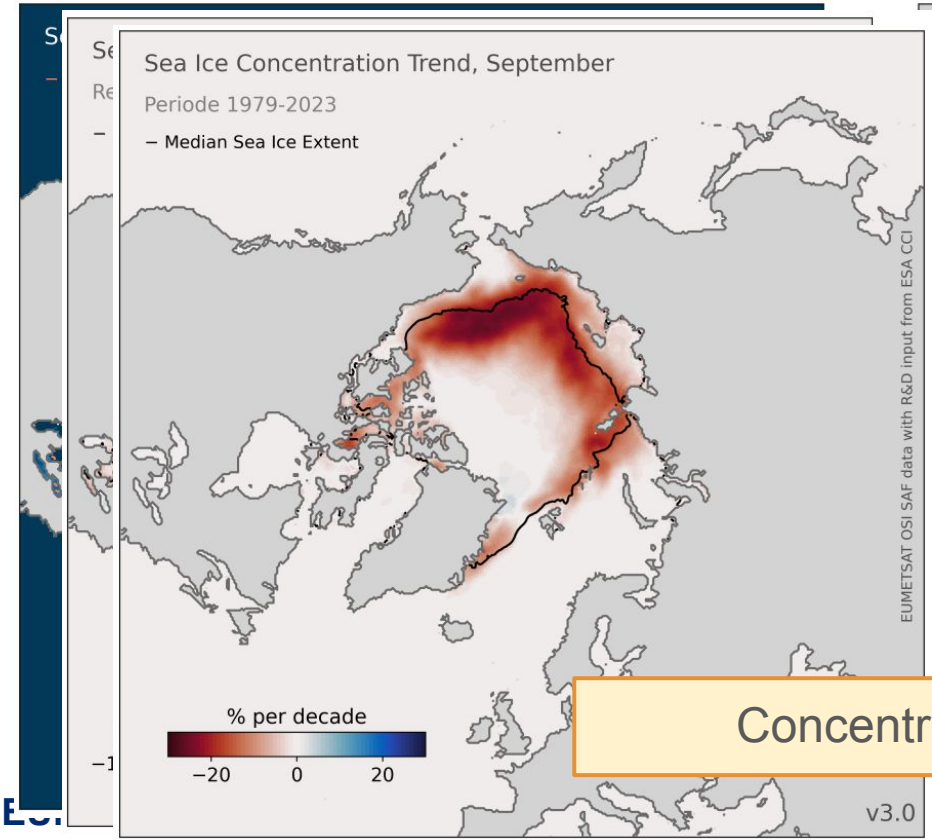
Maps of climatologies and anomalies (upcoming v3.0)

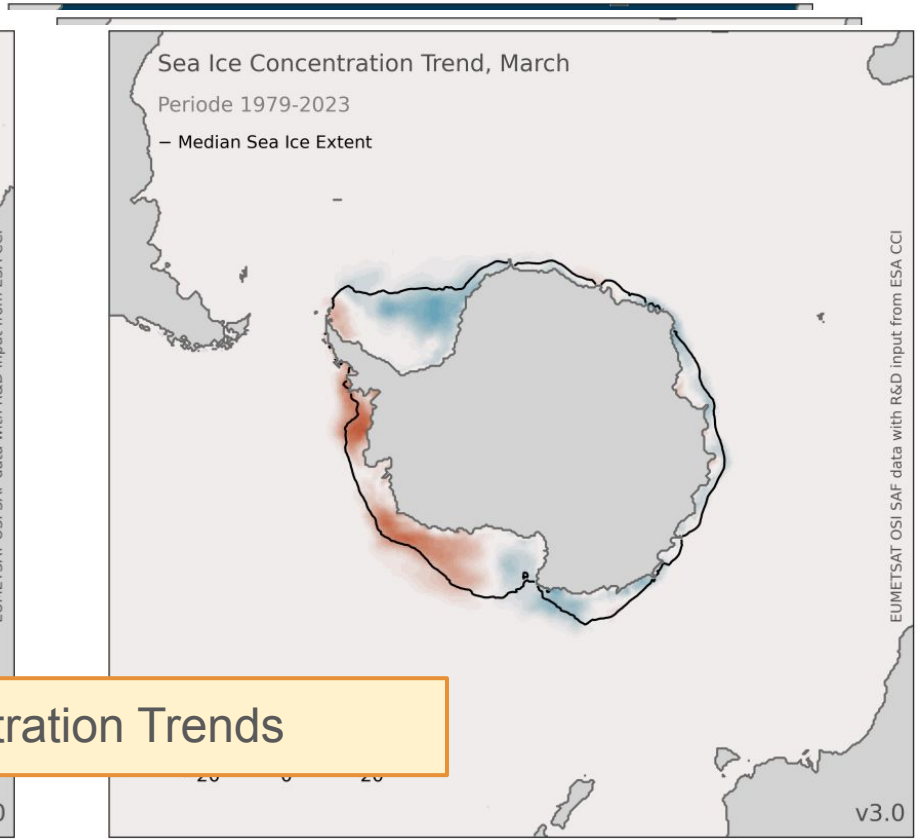




Concentration Anomaly

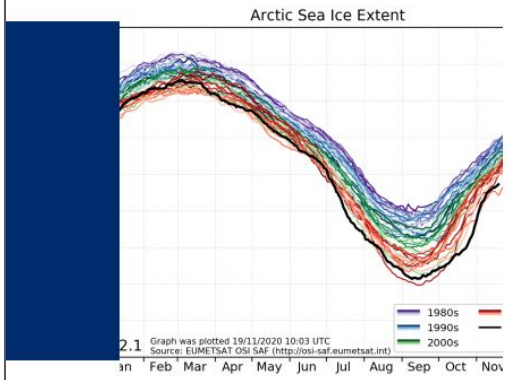
Maps of climatologies and anomalies (upcoming v3.0)





Concentration Trends

https://osi-saf.eumetsat.int/products/osi-420



Sea-ice index

CLIMATE PRODUCT

Demonstrational : we invite users to give feedback on the index before we make it operational.

The Sea Ice Index is a climate indicator of sea-ice coverage. The index covers both the sea-ice extent and area over the last 40+ years and is continuously updated to present time. It consists of an updated series of graphs (.png) visualising the trends and evolution of sea ice at hemispheric, global and regional scales. In addition, the data files (.txt and .nc) are available for users who are interested in analysing and plotting the data themselves. The Sea Ice Index is derived from the OSI SAF Global Sea Ice Concentration data, with R&D input from ESA CCI.

Identification

...

Characteristics

...

Information

Description →

Quicklook →

Documentation

PUM →

Data Access

OSI SAF FTP server	ftp://osisaf.met.no/prod_test/	Directory: ice/index/v2p2
OSI SAF HTTPS	https://osisaf-hl.met.no	https://osisaf-hl.met.no/archive/osisaf/sea-ice-index/v2p2/
OSI SAF Thredds	https://thredds.met.no/thredds/osisaf/osisaf.html	https://thredds.met.no/thredds/osisaf/osisaf_seaiceindex.html
Interactive plotting tool	on cryo.met.no	https://cryo.met.no/en/sea-ice-index

Product user manual

Quicklooks

Data

Interactive plotting!

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Thanks for your attention!

Norwegian Meteorological Institute

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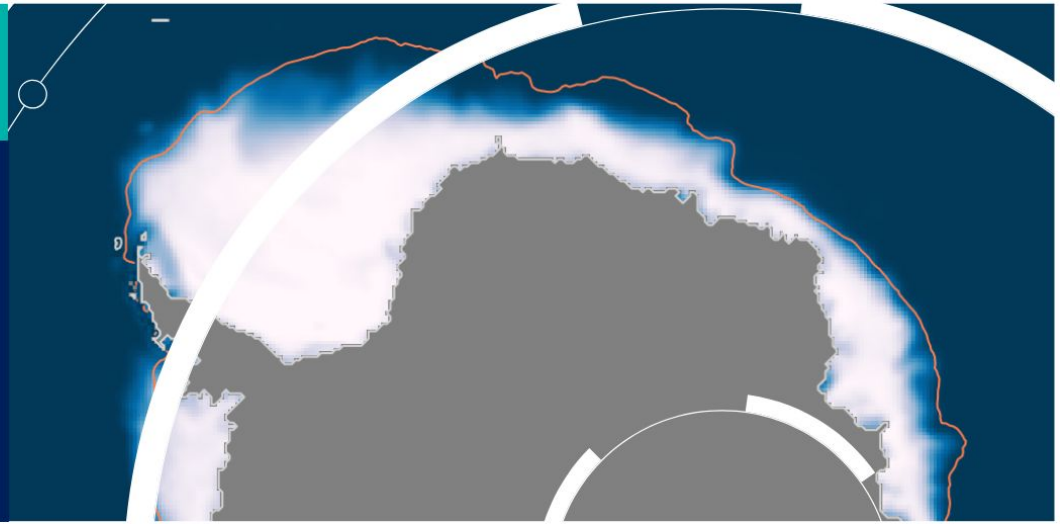

Computational Notebooks

Thomas Lavergne, MET Norway.

Meteorologisk institutt

Jupyter Notebooks

- Several notebooks were made to teach how to use the OSI SAF sea-ice products (e.g. EUMETSAT Training resources).

- Here I present 2 python notebooks from my personal GitHub repository (https://github.com/TomLav/snippets):
  - snippets/Read OSISAF CCI Sea Ice Concentration CDR.ipynb
  - snippets/Sea Ice Spiral with EUMETSAT OSI SAF data.ipynb

- Other notebooks you might want to check out by yourself:
  - snippets/Remap OSI SAF and CCI SIC CDRs.ipynb
  - snippets/Monthly Sea Ice Concentration Anomalies.ipynb

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