Climate Observation and Modelling Expertise Team

*Dorotea Iovino on behalf of **COMET team***

Colocation Day 1 BOG template
24/03/2026

Climate Obsertation and Modelling Expertise Team

ESA call: Climate-Space, Interfacing the Climate Observations and Modelling Communities

COMET objectives:

- to **enhance the integration of satellite-based data into climate models** to improve the quality of modelling products (ocean-sea ice reanalysis, Earth System model)
- to **strengthen the communication** between the climate modelling and observations communities

Zenithal **Blue** Technologies Science

COMET outcomes:

- extension of the ocean-ice **data assimilation scheme** (C-GLORS) by strongly coupling ocean and sea-ice variables (currently treated independently) including a **ML approach**
- **Green Function calibration tool** of sea ice model parameter

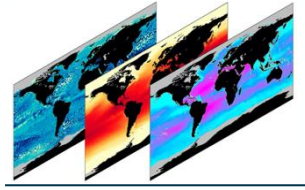
cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

COMET impacts:

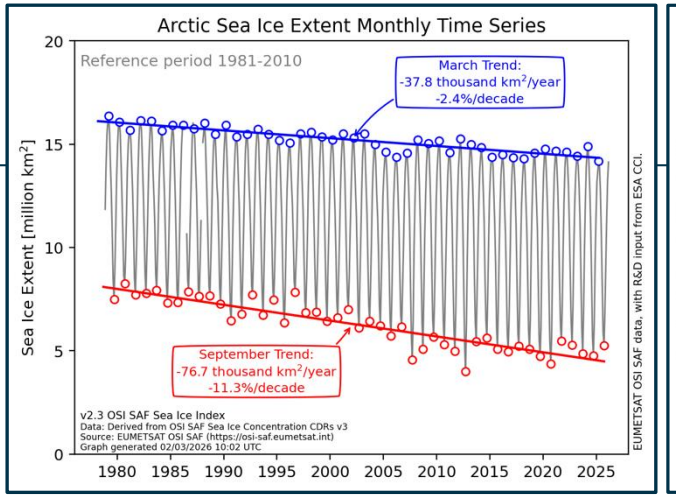
- reducing biases in global modelling systems *(Copernicus Marine Service - CMEMS, CMIP7)*
- improving the representation of extreme climate events and their predictability *(Copernicus Climate Change Service - C3S)*
- enhancing the accuracy of polar climate variability, and strengthen the coupling between sea ice and the ocean/atmospheric processes *(a series of European Horizon projects)*

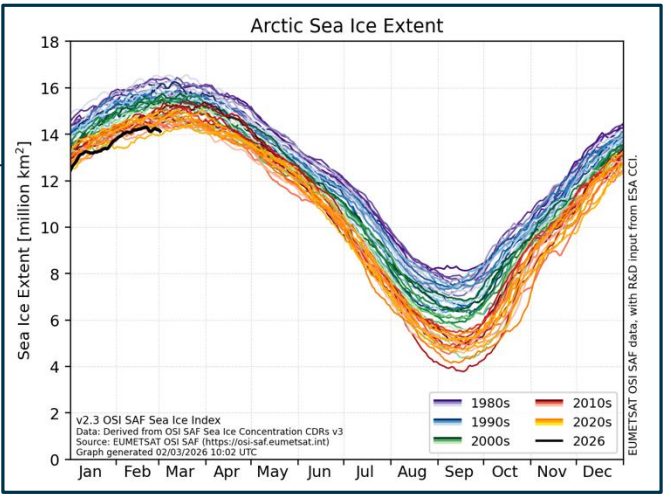
Institut de Ciències del Mar

CSIC Consejo Superior de Investigaciones Científicas



Sea ice as observed





Sea Ice Loss can be defined as a **decline over time** in one (more) standard sea-ice metrics based on EOVs

only coverage

- Sea ice extent (SIE): the default headline metric
- Sea ice area (SIA): "how much ice surface is actually there"

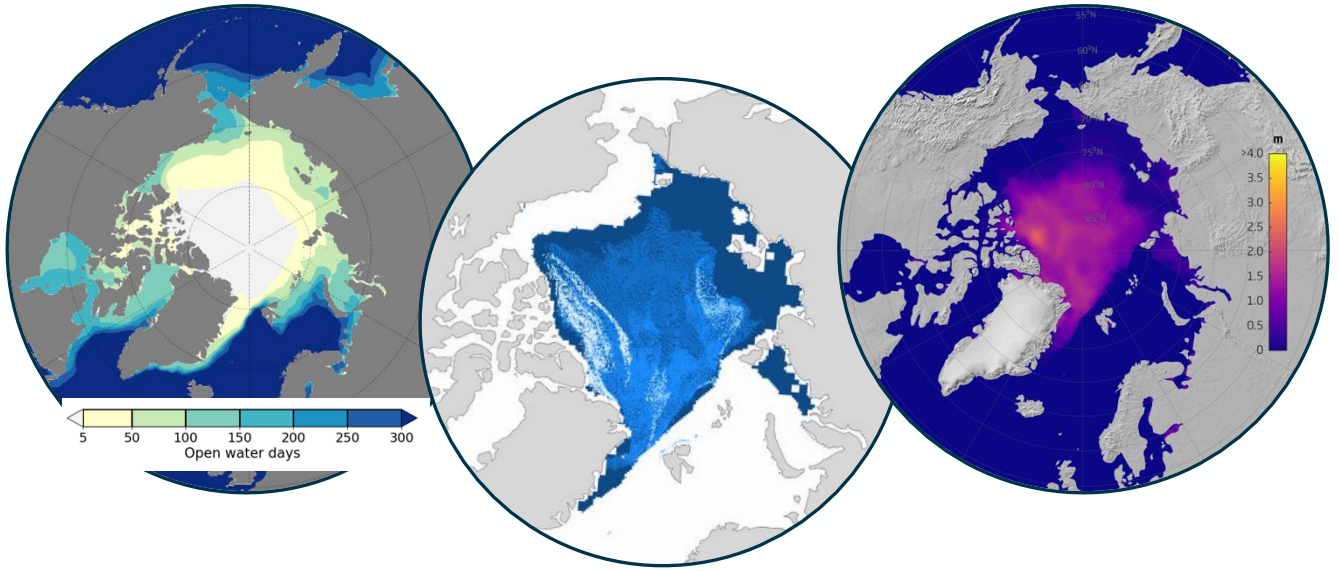
Large uncertainties

- Sea-ice thickness (SIT) — thinning as a form of loss
- Sea ice volume (SIV): the "mass" perspective

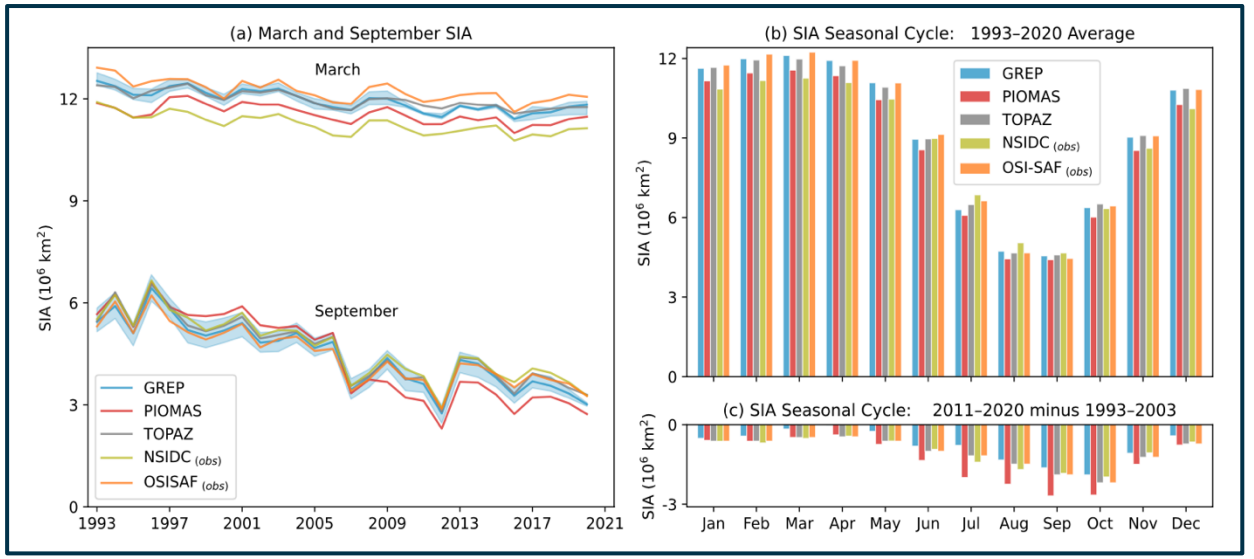
Strong assumptions

- Open-ocean days (freeze-up/break-up): the season-length
- …

Since late 70's, the Arctic region has been warming faster than the global average. ***Arctic sea ice has shown a clear and sustained decline.***

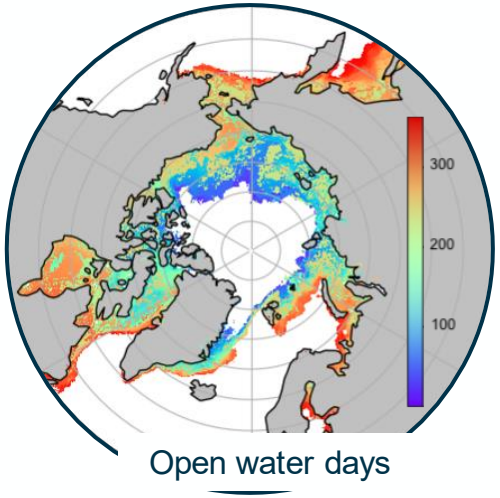


Reanalyses world

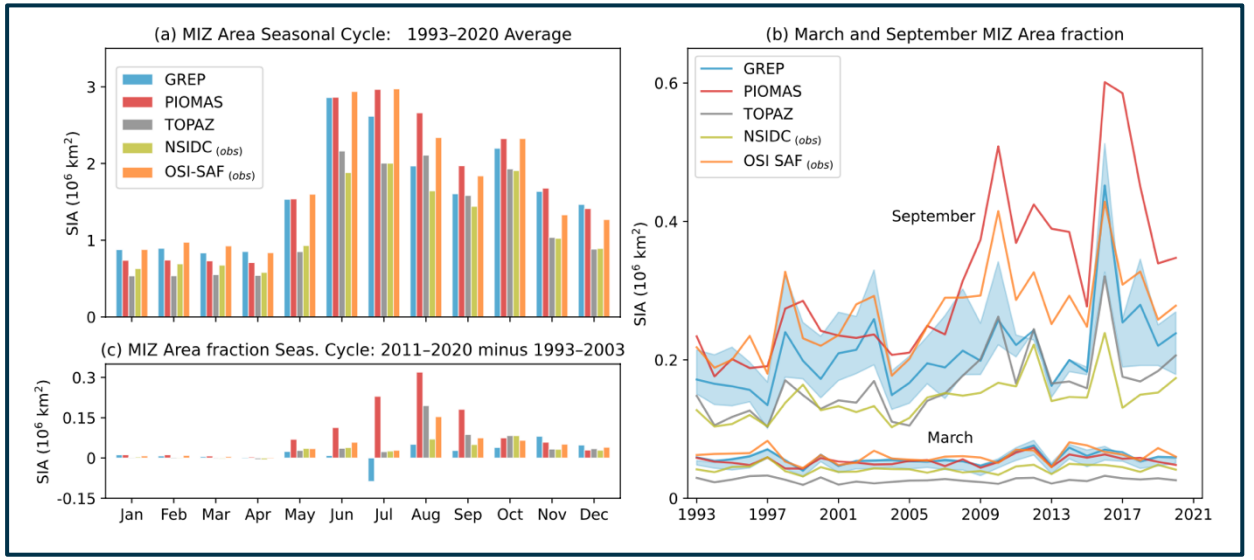


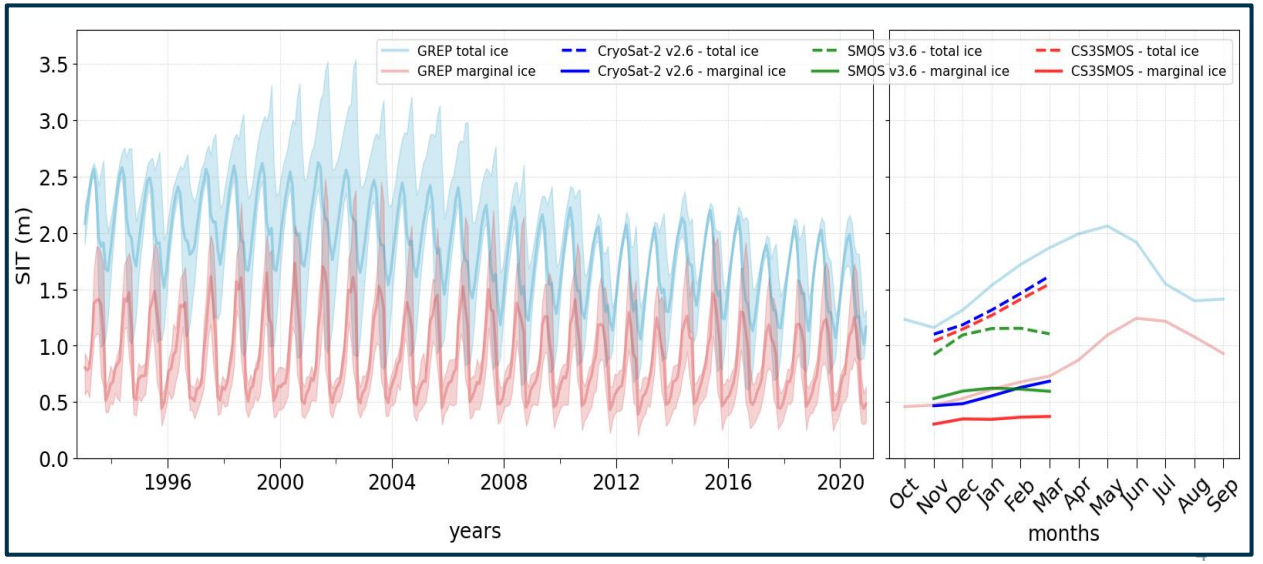
Data assimilation methods largely benefit the representation of Arctic sea ice in global and regional ocean/ice reanalysis.

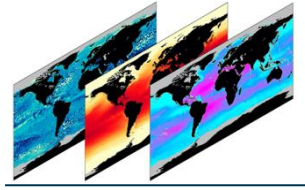
Dependence on observation quality – still differences among satellite datasets for a deeper analysis of ice characteristics.



Open water days







COMET workflow

Observation inputs

- CCI Sea Surface Temperature
- CCI Sea Surface Salinity
- CCI Sea Ice: concentration and thickness
- CCI Sea Level

What COMET does with them

- Reduce barriers to the use of satellite data in models by tailoring, harmonising and preparing datasets.
- Introduce the ECVs for model calibration, data assimilation and machine learning training.
- Strengthen the ocean and sea ice components of C-GLORS and CMCC-ESM

Expected outcomes

- Tailored datasets, tools
- improved model performance, better ocean and sea ice state estimates
- Advanced sea ice DA/ML, new calibration tool, inputs for the next CMCC-ESM generation.

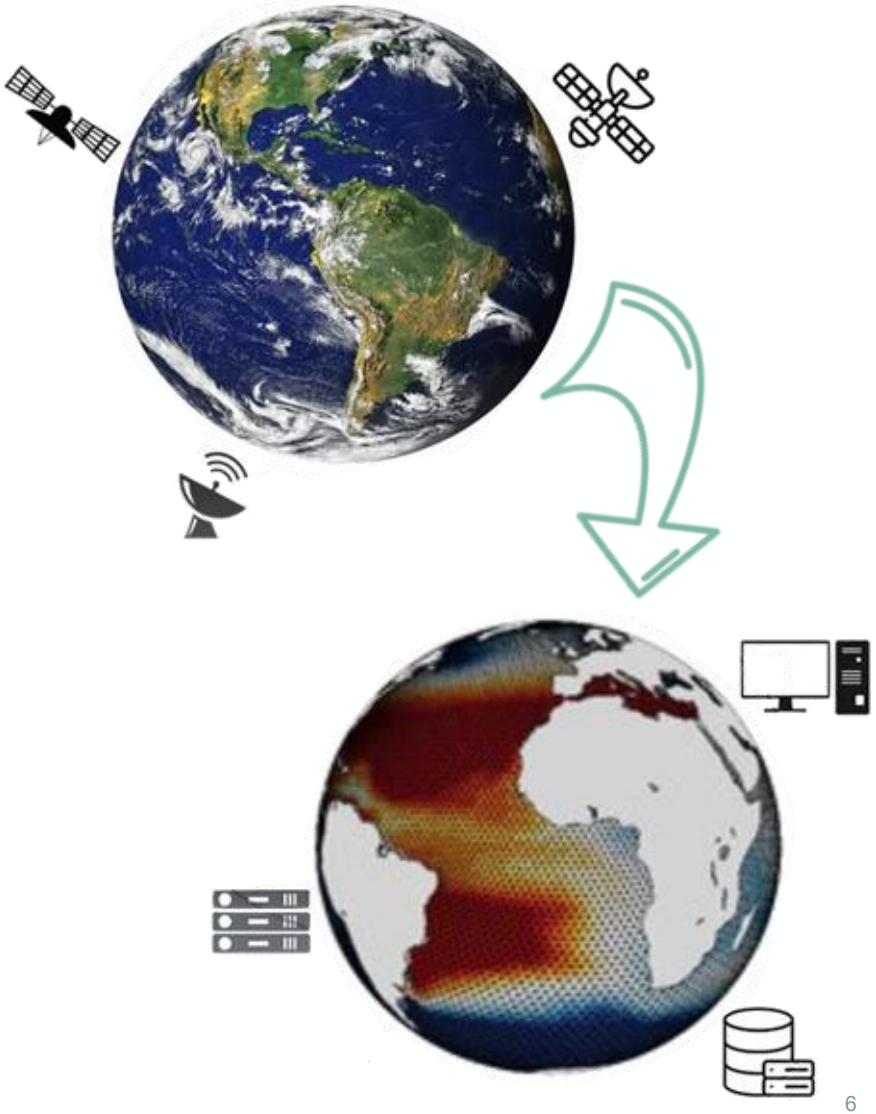
first year (from March 2025)

second year (till March 2027)

Exploring the ECV-related dataset jungle

Dataset Name	Purpose	Source
Sea Surface Temperature		
Sub-skin L3 AVHRR SST	ML training Assimilation	https://podaac.jpl.nasa.gov/dataset/AVHRR_SST_METOP_B_GLB-OSISAF-L3C-v1.0
ESA CCI L4 SST	ML training Assimilation	https://catalogue.ceda.ac.uk/uuid/debfbf49823f4eb99ab0a578f8b25136/
Wind		
Metop-A/-B Wind fields	ML training Assimilation	https://osi-saf.eumetsat.int/products/osi-150-b
ESA WOC ERA-star	ML training Assimilation	https://www.worldoceancirculation.org/Products#/metadata/3aae3973-48c4-43e6-8b11-65440e595613
Sea Ice Concentration		
OSI-SAF L3 sea-ice concentration data	Assimilation Sea Ice Calibration	https://osi-saf.eumetsat.int/products/osi-430-a
OSI-SAF global sea ice concentration interim CDR	Assimilation Sea Ice Calibration	https://osi-saf.eumetsat.int/products/osi-450-a
ESA CCI Sea Ice SIC CDR from the AMSR-E and AMSR-2 instruments at 25km and 50 km grid spacing	Assimilation Sea Ice Calibration	https://catalogue.ceda.ac.uk/uuid/d2112cfb5dab407599a64d9451d960b4
ESA CCI Sea Ice High(er) Resolution SIC CDR (SSM/I and SSMIS)	Assimilation Sea Ice Calibration	https://catalogue.ceda.ac.uk/uuid/d2112cfb5dab407599a64d9451d960b4
Sea Ice Thickness		
Arctic Thick ice SIT: Cryosat-2 L3 SIT	Assimilation Sea Ice Calibration	https://spaces.awi.de/display/SIRAL/Sea+Ice+Thickness+from+Satellite+Radar+Altimetry
Arctic/Antarctic Thin SIT: SMOS L3 SIT	Assimilation Sea Ice Calibration	https://spaces.awi.de/display/SIRAL/Sea+Ice+Thickness+from+Satellite+Radar+Altimetry
ESA CryoSat-2/SMOS merged product	Assimilation Sea Ice Calibration	https://earth.esa.int/eogateway/catalog/smos-cryosat-l4-sea-ice-thickness
ESA CCI Sea Ice SIT from Cryosat-2 and Envisat (on-swath) and monthly	Assimilation Sea Ice Calibration	https://catalogue.ceda.ac.uk/uuid/d2112cfb5dab407599a64d9451d960b4

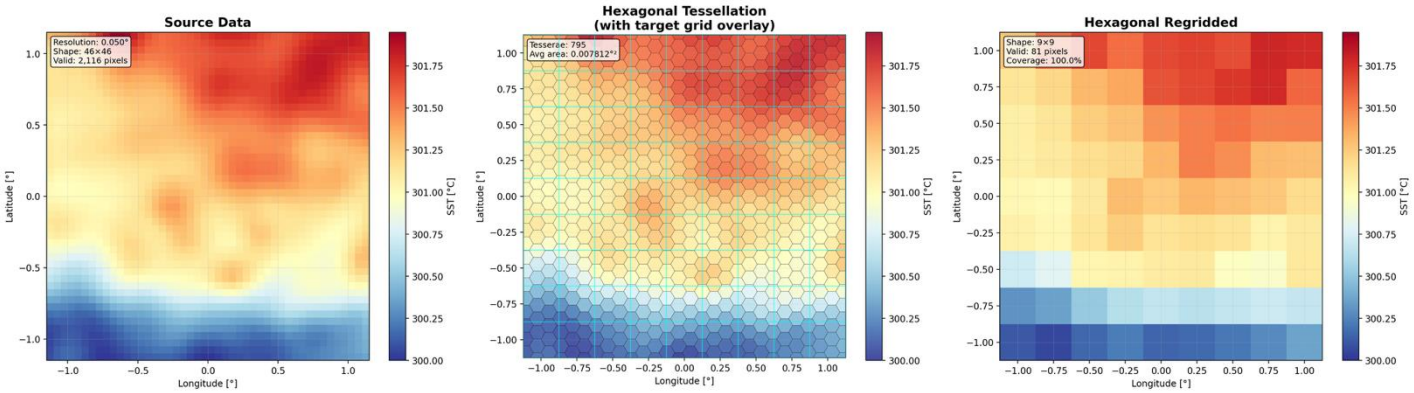
Dataset Name	Purpose	Source
Sea Ice Drift		
OSI-SAF L3/L4 global low-resolution sea ice drift data record	Sea Ice Calibration	https://osi-saf.eumetsat.int/products/osi-455
Sea Ice Surface Temperature		
Global Ocean OSTIA L4 Sea Surface Temperature and Sea Ice Reprocessed	Assimilation Sea Ice Calibration	https://data.marine.copernicus.eu/product/SST_GLO_SST_L4_REP_OBSERVATIONS_010_011
Sea Surface Salinity		
BEC SSS Global product	Assimilation Sea Ice Calibration	https://bec.icm.csic.es
ESA CCI SSS	Assimilation Sea Ice Calibration	https://catalogue.ceda.ac.uk/uuid/d0f4a942a144d9cab9263de3949a5d6/
Sea Level Anomaly		
L3 SLA along-track data from multiple satellites	Assimilation	https://data.marine.copernicus.eu/product/SEALEVEL_GLO_PHY_L3_MY_008_062/description
ESA CCI Sea Level Fundamental CDRs of sea level anomalies and altimeter standards	Assimilation Validation	https://catalogue.ceda.ac.uk/uuid/2785ee1ec6274be39d11e7e7ce51b381/ https://cds.climate.copernicus.eu/datasets/satellite-sea-level-global?tab=overview
In-situ		
EN4 Insitu dataset	Validation	https://www.metoffice.gov.uk/hadobs/en4/
PIOMAS	Validation	https://psc.apl.uw.edu/research/projects/arctic-sea-ice-volume-anomaly/data/model_grid
TOPAZ	Validation	https://doi.org/10.48670/moi-00007



EO Data Tailoring Tool for Climate Modelling

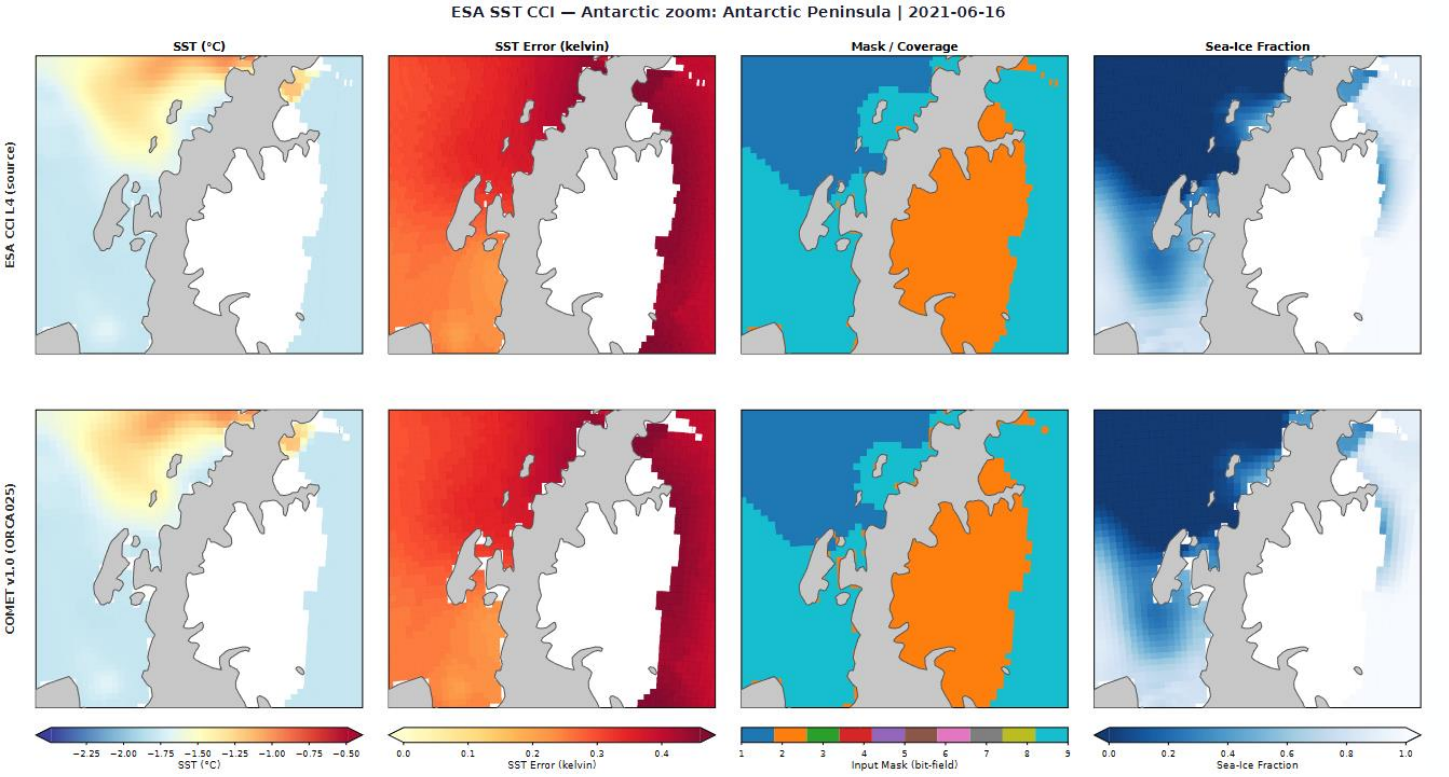
Variable-agnostic advance mapping tool for minimal information loss from native to model grid

- *Tessellation techniques for data propagation*
- *Embedded representativity error*
- *Accurate gradients preservation*
- *Adapted mask propagation*



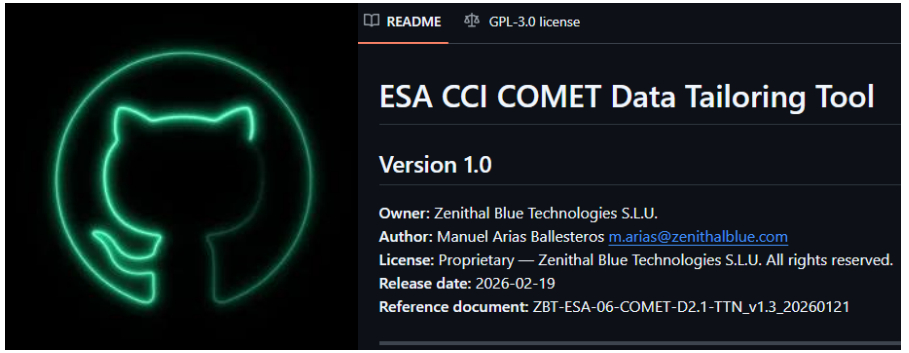
Harmonized temporal sampling via Lagrangian interpolation schemes

- *Backward/forward mechanism for time centric kinematic representations.*
- *Gap filling capability*



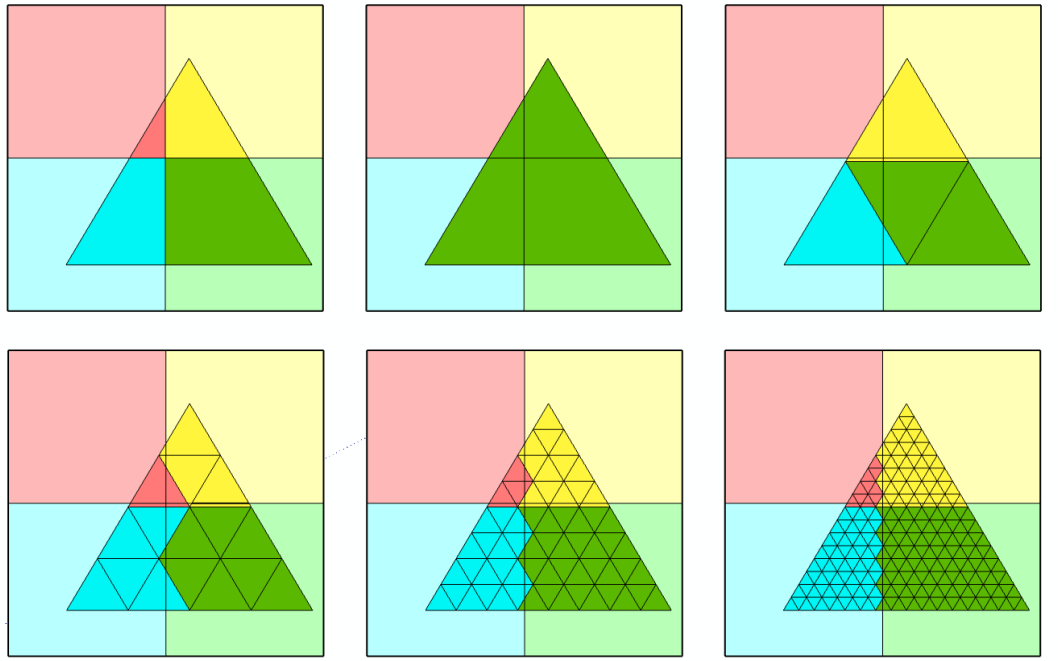
Metadata harmonisation and consolidated flagging based on EO expert assessment

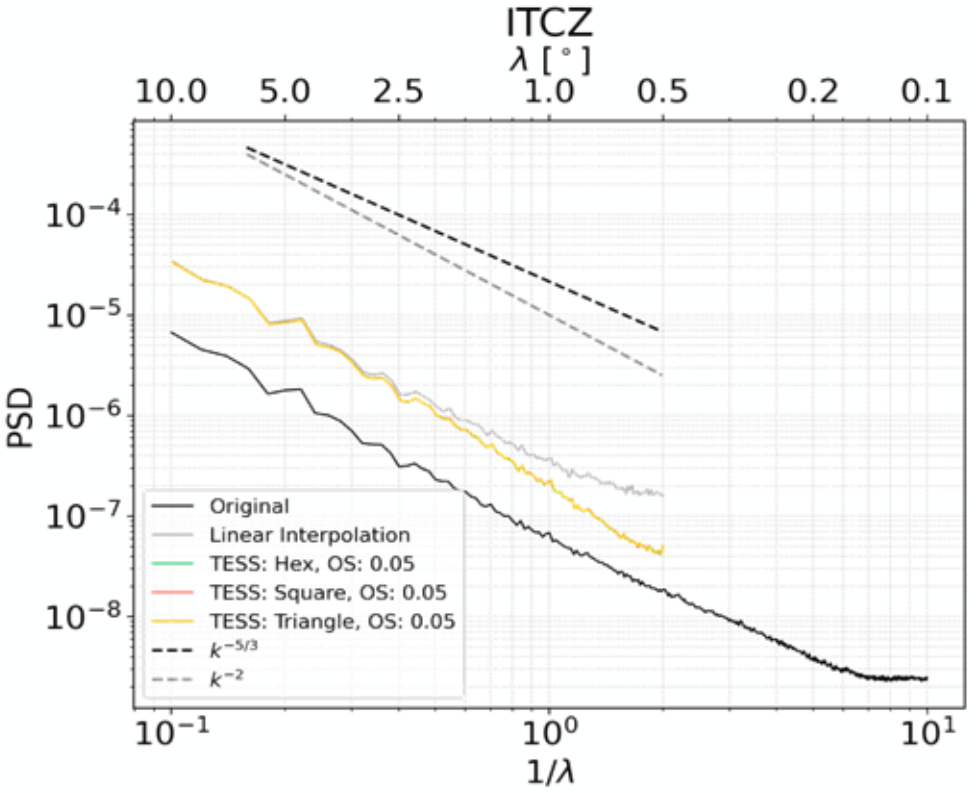
ESA CCI and CF conventions applied



Interpolation by area projection: Oversampling pixels with tesselles to approximate the actual overlapping area.

This algorithm improves the representation of gradients at the projection scale.



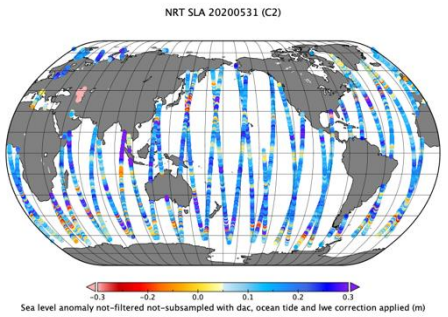


Spectral analysis of the interpolated products:
Original data presents white noise saturation at small scales (the spectrum becomes horizontal).

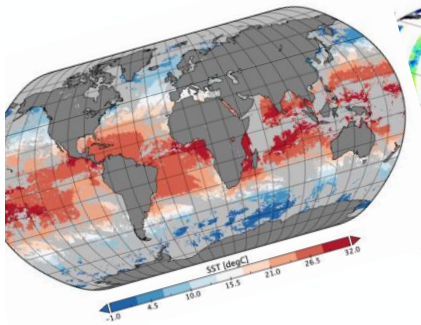
Simple linear interpolation creates white-noise like at interpolation scale.

Area projection removes white noise at resolved scales, improving the slope.

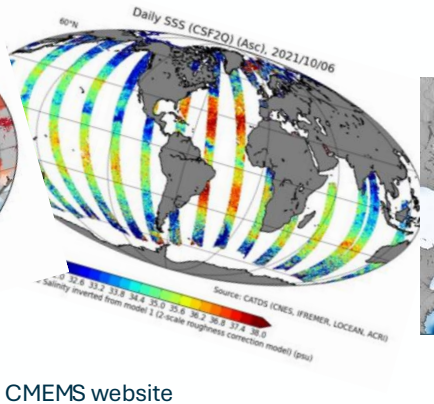
DA background



SLA

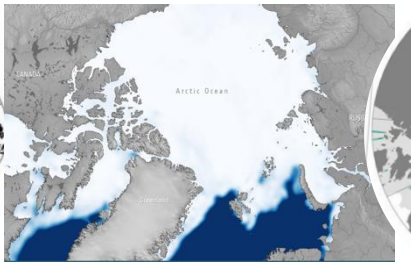


SST



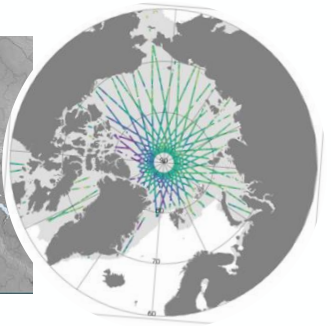
CMEMS website

SSS



ESA website

SIC



SIT

+…

Tilling et al, 2016

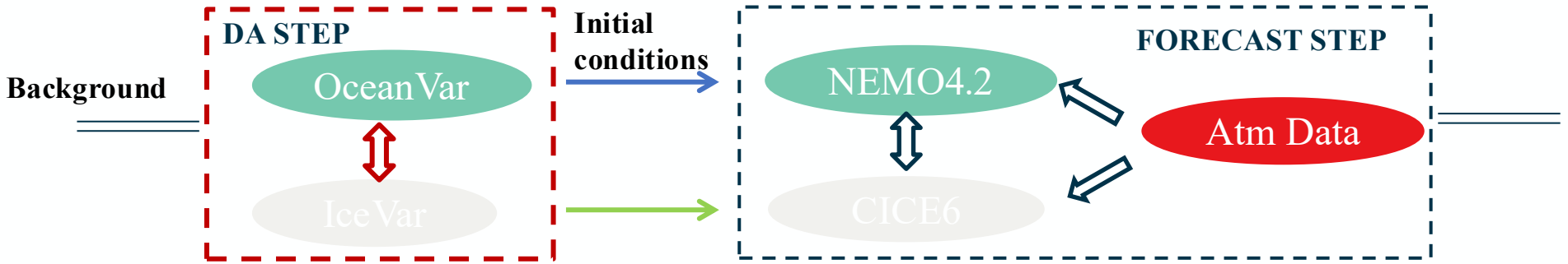
Present state-of-the-art global ocean/sea-ice reanalyses are **limited to** the assimilation of **Red** types and the use of **Green** optimally interpolated products, because of the need of **complex** observation operators (skin/subskin SST, non-gaussian sea-ice variables, etc)

In COMET, we intend to :

- explore the **benefit** of assimilating **diverse surface satellite datasets** (SLA, SST, SSS, SIC, SIT) in a **strongly coupled** fashion, paving the way for future production.
- analyze the model **sensitivity** to observations, quantifying which dataset is **more informative** for the model point using dedicated metrics (Cardinali et al 2004; Cipollone et al 2024)

C-GLORS structure

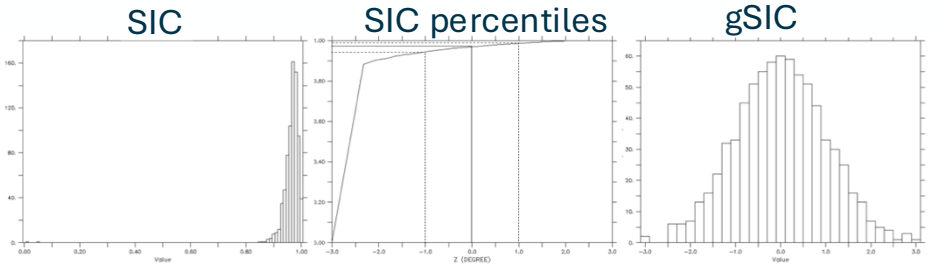
The CMCC Reanalysis System (C-GLORS) has been used in the last decades to simulate consolidated versions of realistic state of the ocean (Storto,2016;2019). Structure for the last product (to be released in 2026):



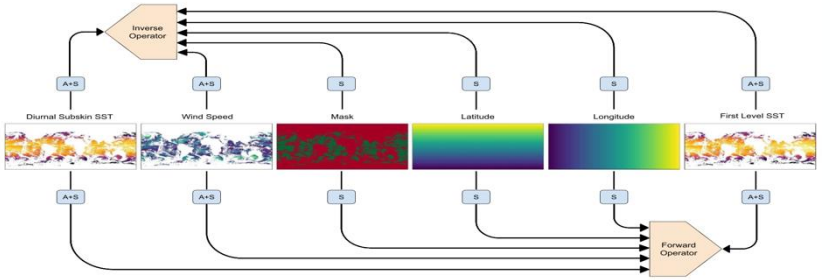
Developed configuration

	Ocean	Sea-Ice
OGCM	NEMO v4.2	CICE6 (5 cat)
DA scheme	3dvar (Multivariate)	
DATA	Insitu T/S, SLA, SST, SSS, SIC, SIT	
Data frequency	Heterogeneous	
DA window	5days	

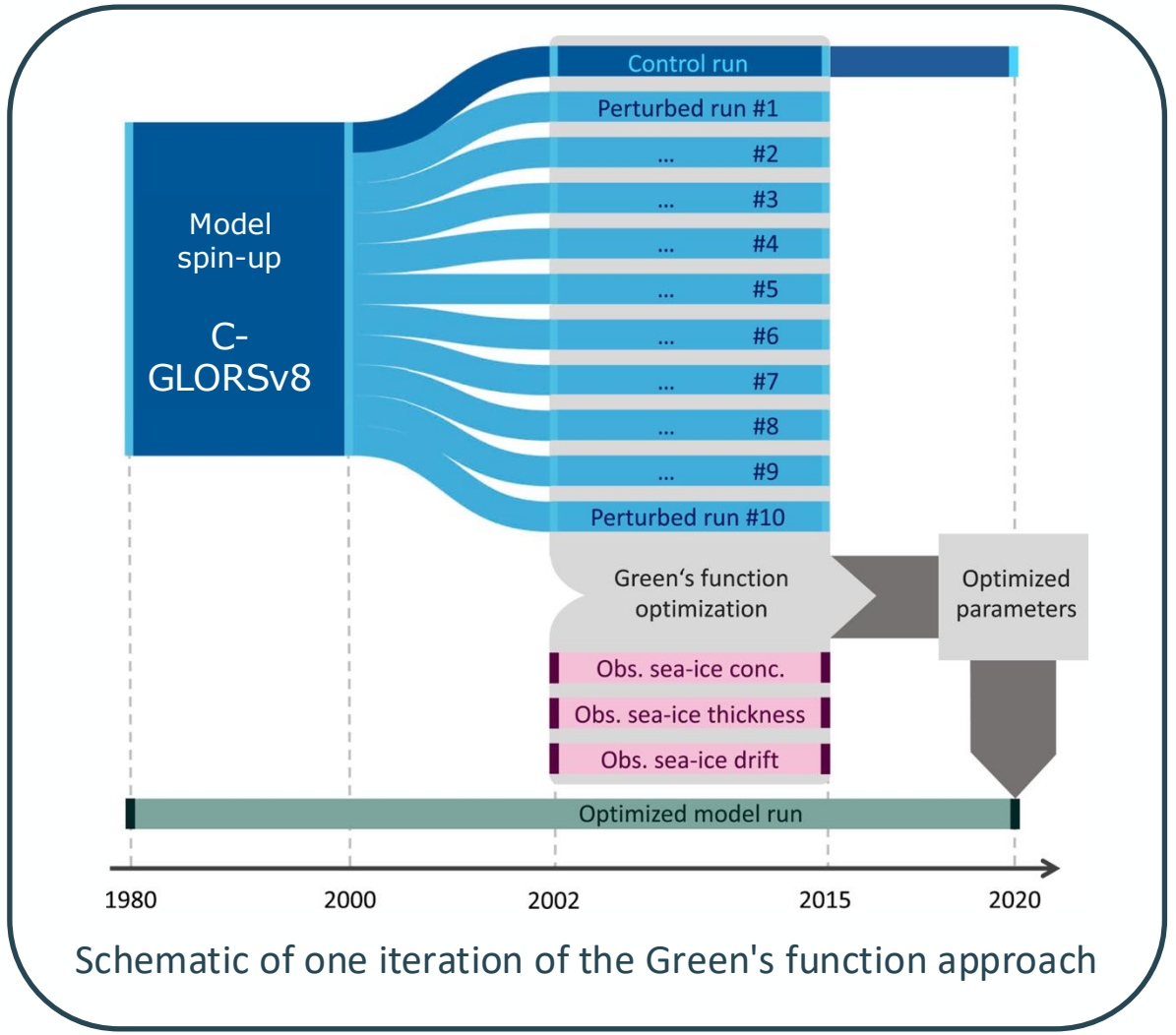
Sea ice variables assimilated via anamorphism *(Cipollone et al. 2023)*



SST via CNN *(Broccoli et al. 2025)*



Sea ice model calibration



Schematic of one iteration of the Green's function approach

Green's Function (GF)

Utilizes sensitivity simulations to optimize parameters with a focus on minimizing discrepancies between model outputs and observational data

Efficient for high-resolution models, requiring only one model run per parameter

Ideal for quick iterations to achieve convergence

Experimental design

C-GLORS simulation as spin-up (*1980–1999*)

The years *2000-01* are additional spin-up years for ensuring a full response to each sea-ice parameter perturbation.

The model optimization window is set to ~10y, the cost function is evaluated in this period.

Software shared via github

Upcoming workshop

Organized by the COMET

Location: Barcelona (Spain), *hybrid*
Date: November 2026

- Key notes + BOG
- Observation-informed methods (data assimilation, AI approaches) for ocean, sea ice and others.
- ESA, Copernicus Marine, CMIP communities