Polar Monitoring from Space: BEC SSS Data products

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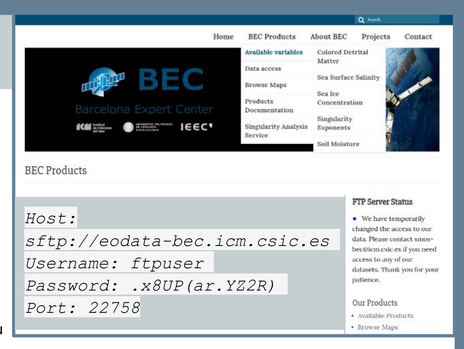
Motivation

Monitoring freshwater fluxes in polar regions is essential for understanding how global warming affects sea-ice melt and influences global ocean circulation.

These rapid environmental changes demand continuous monitoring; however, the extreme conditions in polar regions make sustained in situ observations particularly challenging.

In this context, L-band satellite observations provide a unique capability for continuous monitoring of sea surface salinity (SSS). Although the sensitivity of L-band brightness temperatures (TB) to salinity decreases in cold waters, significant efforts within the L-band remote sensing community have led to the development of advanced retrieval algorithms capable of providing increasingly accurate SSS estimates in polar regions.

Here, we present a summary of the work carried out at Barcelona Expert Center for the development of two new SSS products: Arctic+ Salinity v4 (García-Espriu et al., 2026) and SO-FRESH, focused on the Southern Ocean (González-Gambau et al., 2025).



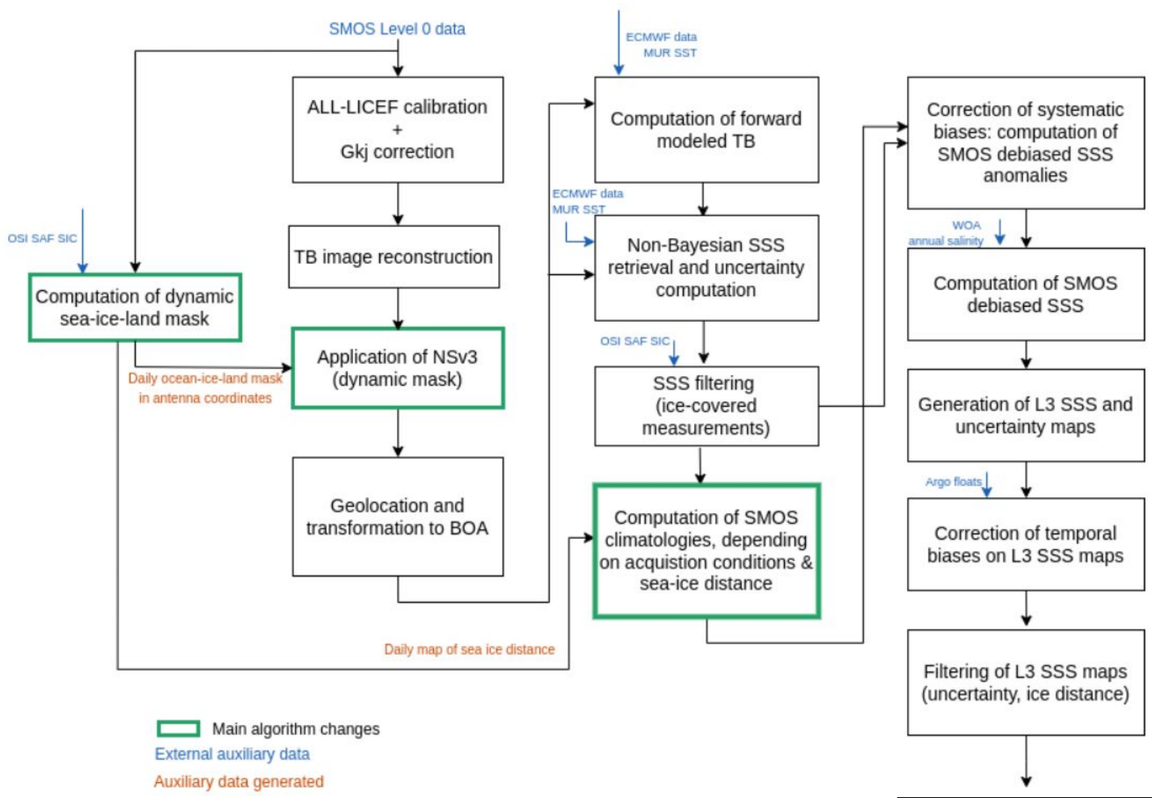
Arctic v4.0					
L3	25 km x 25 km	9-day	EASE 2.0 North	50º to 90º latitude	2011-2023
Southern Ocean v1.0					
L3	25 km x 25 km	9-day	EASE 2.0 South	-50º to -90º latitude	2011-2023

Methodology

Level 1 TB Generation:
Data processing starts from ESA SMOS Level 0 data (observations and telemetry) in order to introduce several critical corrections aimed at improving the characterization of sea-ice transition regions, which are not included in the official ESA TB product (v724). In particular, we apply the All-LICEF calibration approach (Corbella et al., 2016), which enhances the consistency between zero-baseline measurements and visibilities, and the Gkj correction (Corbella et al., 2015), which reduces contamination near coastal areas (González-Gambau et al., 2017) and along the ice edge.

In addition, Nodal Sampling (NS) (González-Gambau et al., 2016) is applied to minimize radiometric errors. We further improve the nodal point selection (i.e., points where contamination is minimized) by distinguishing among ocean, land, and ice regions. This enhancement requires the use of a daily sea-ice mask (OSISAF, 2022).

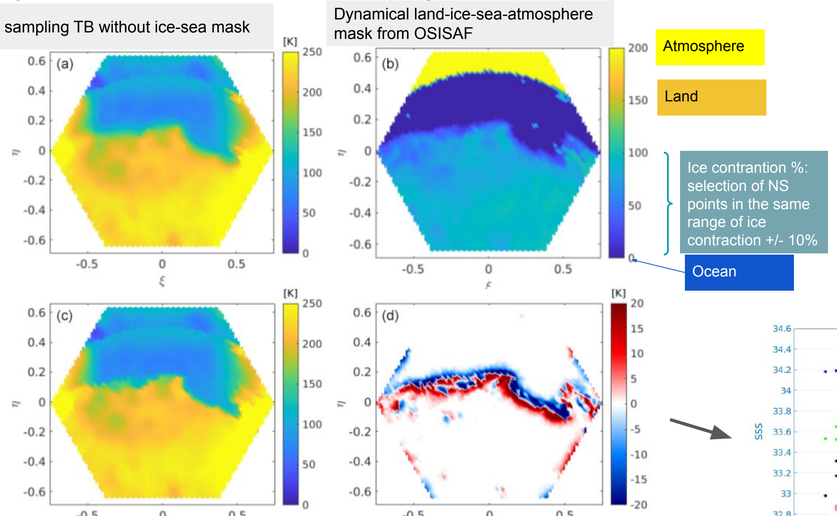
Level 2 SSS Retrieval:
For the SSS retrieval, we use the debiased non-Bayesian approach (Olmedo et al., 2017). An additional enhancement has been introduced into the algorithm by incorporating the distance to the ice edge as an extra parameter in the definition of the SMOS climatologies used to correct retrieval errors.



Dynamical ice-sea mask in the Nodal Sampling:

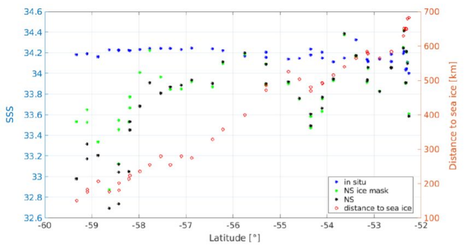
Nodal sampling TB without ice-sea mask

Dynamical land-ice-sea-atmosphere mask from OSISAF



Nodal sampling TB with ice-sea mask

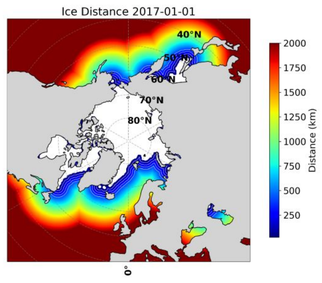
TB differences when applying the mask:
- Decrease in TB->increase in SSS in ocean
- Increase in TB over ice



These differences are translated into an inprovement in the SSS biases close to the ice-edge

Dynamical ice-sea mask in the retrieval:

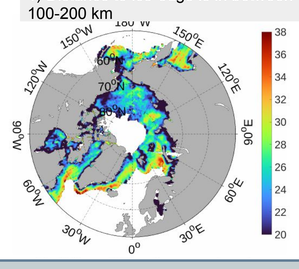
Daily computation of the distance to the ice-dege



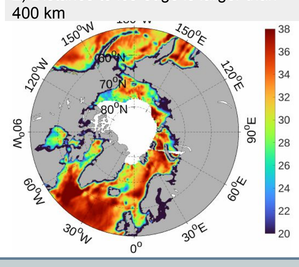
Characterization and correction of SSS biases as a function of the geographical position, satellite overpass direction, antenna position and distance to the **ice-edge:**

Characterization of errors with incidence angle 20º and 300 km across-track distance when:

1) Distance to ice-edge is in between 100-200 km



2) Distance to ice-edge is larger than 400 km



Under identical acquisition conditions errors are very different depending on the distance to the ice-edge!

Validation of Arctic + Salinity v4 product

We validate the products using two complementary metrics:
1) **Comparison with in situ observations**: to assess biases and the standard deviation of the errors. For this purpose, we use the PI-MEP platform (https://www.salinity-pimep.org/), which provides comparisons with in situ measurements from surface drifters, ICES, marine mammals, GOSUD ship campaigns, LEGOS datasets, and Polarstern observations.
2) **Spectral analysis**: to evaluate the effective spatial resolution of the products.

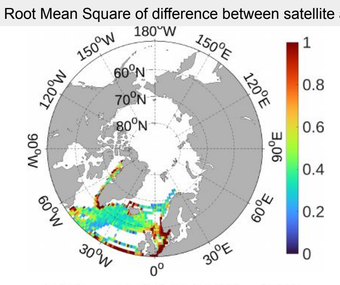
We assess the improvement of v4 with respect its former version (v3.1).

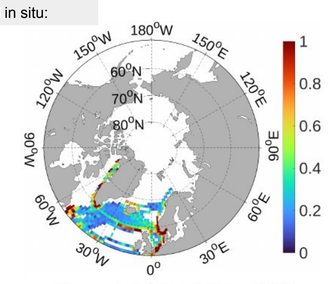
Comparison with in situ

- General reduction in the standard deviation of the differences with in situ observations across all regions.
- Bias reduction is not observed in all regions, likely due to the change in the multi-year climatology used (v4: WOA2023; v3.1: WOA2018).

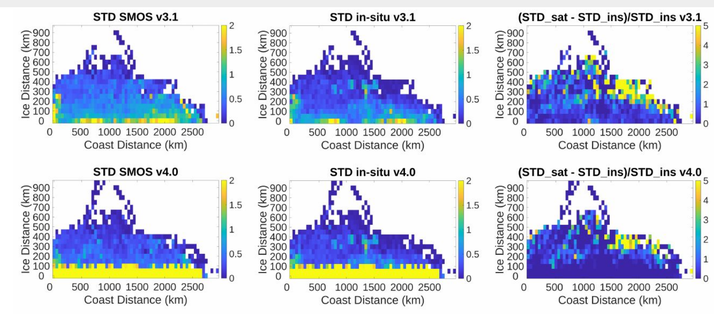
Datasets	#	Mean	Std	RMS	R
Polastern+v4.0	6516	0.35	1.40	1.45	0.88
Polastern+v3.1	6516	0.17	2.49	2.5	0.57
LEGOS+v4.0	57704	-0.48	0.75	0.89	0.63
LEGOS+v3.1	57704	-0.01	1.01	1.01	0.40
GOSUD+v4.0	7599	-0.21	2.53	2.55	0.89
GOSUD+v3.1	7599	0.59	2.53	2.59	0.89
MM+v4.0	258	-0.53	0.82	0.97	0.18
MM+v3.1	258	-2.69	1.86	3.27	-0.08
ICES+v4.0	2104	0.05	0.71	0.71	0.71
ICES+v3.1	2104	0.03	1.09	1.09	0.51
Drifters+v4.0	622	-0.36	0.68	0.77	0.37
Drifters+v3.1	622	-0.68	1.29	1.47	0.02

Root Mean Square of difference between satellite and in situ:

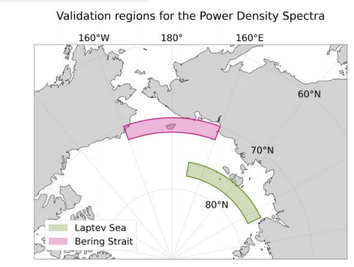




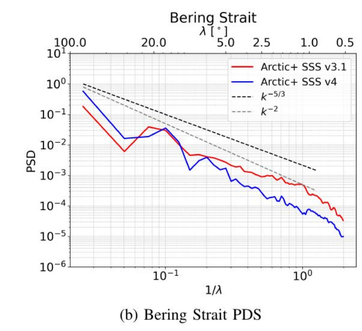
v4 provides 25% more retrievals close to the ice edge, enabling the capture of larger SSS variability in the marginal ice zone compared with v3.1, while still maintaining a lower relative error.



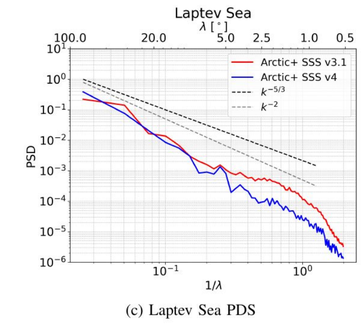
Spectral analysis:



(a) Bering Strait and the Laptev Sea boxes.



(b) Bering Strait PDS



(c) Laptev Sea PDS

V4 presents a more consistent spectral slope than v3.1

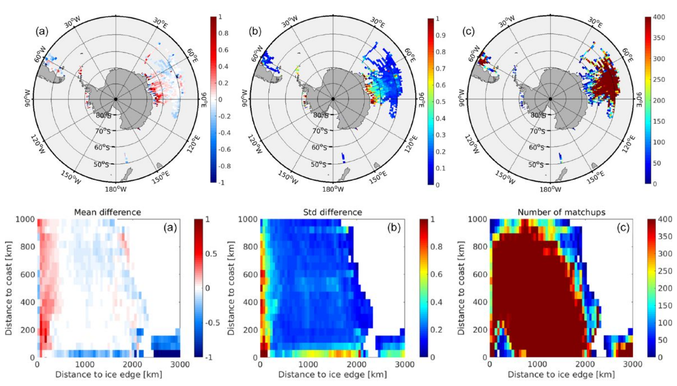
Validation of the Southern Ocean Product

We validate the products using two complementary metrics:
1) **Comparison with in situ observations**: we used in situ observations from:
- Thermosalinograph (TSG) data provided by the Università degli Studi di Napoli Parthenope: (Aulicino et al., 2018a, Aulicino et al., 2025)
- TSG data from the Astrolabe vessel (Morrow and Kestenare,2014
- Marine mammals (MEOP-CTD database, 2024-02 release, (Roquet et al.,2024)
- Barcelona World Races (BWR) 2011 and 2015 (Umbert et al., 2023, Umbert et al., 2022)

2) **Comparison with regional models** The Biogeochemical Southern Ocean State Estimate (B-SOSE) (Verdy and Mazloff, 2017).

Comparison with in situ

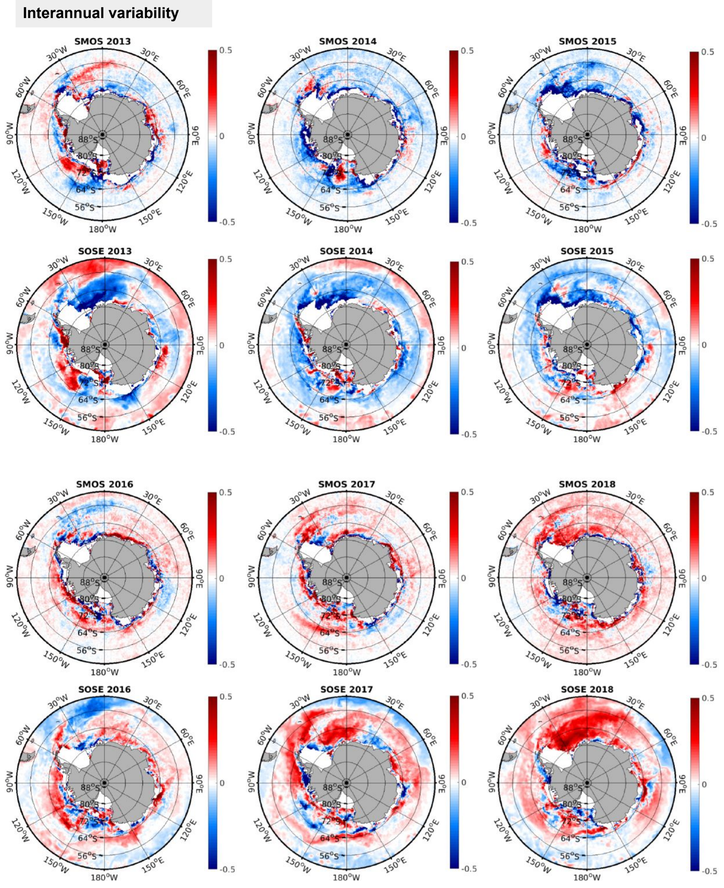
- Beyond the first 150 km from the ice edge, the standard deviation with respect to in situ observations is approximately 0.2, with near-zero bias.
- Within the 100–150 km region from the ice edge, the standard deviation generally increases and positive biases with respect to in situ observations appear.
- Part of these biases can be attributed to representativeness errors, since in situ and satellite observations do not sample the same depth (several meters vs. several centimeters), spatial scale (point measurements vs. a 25 km² area), or acquisition time (instantaneous measurements vs. a 9-day integrated period).



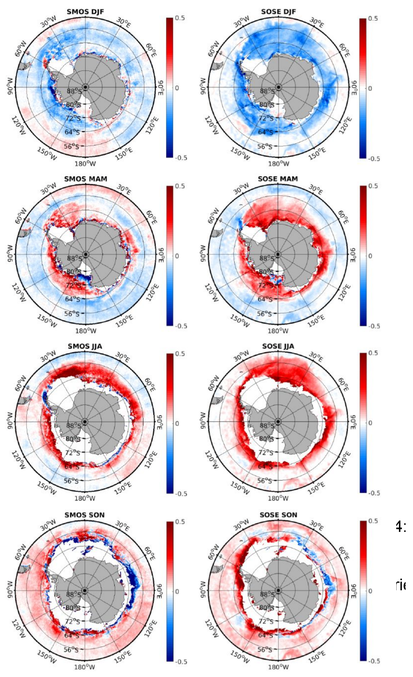
Comparison with SOSE model

- Consistent interannual variability between SMOS and SOSE
- Patterns close to the ice edge remain consistent with the ones of the models, demonstrating that demonstrating that, despite larger errors in the satellite prod-uct close to the ice, the satellite-derived SSS is capable of capturing the SSS variability in close proximity to the ice edge.

Interannual variability



Seasonal variability



References

This poster is based in two published articles:

- A. Garcia-Espriu, V. González-Gambau, E. Olmedo, M. Sánchez-Urrea, C. González-Haro, M. Umbert, E. De Andrés, C. Gabarró, A. Turiel, S. Guimbard, L. Bertino, R. P. Raj, R. APPLIED EARTH OBSERVATIONS AND REMOTE SENSING
- V. González-Gambau, E. Olmedo, A. García-Espriu, C. González-Haro, A. Turiel, C. Gabarró, A. Silvano, A. Narayanan, A. Naveira-Garabato, R. Catany, N. Hoareau, M. Umbert, fluxes in the Southern Ocean", Earth System Science Data, 17, 5089–5111, https://doi.org/10.5194/essd-17-5089-2025

All the references appearing in this poster are included in the references of these articles.

Acknowledgements: This work has been carried out thanks to part of the Southern Ocean Freshwater (SO-FRESH) project (grant no. AO/1-10461/20/I-NB) and Arctic+ Salinity project (AO/1-9158/18/I-BG) and Arctic+ SSS CCN 4000125590/18/I-BG), funded by the European Space Agency. It has been also supported by the EU H2020 CRices project (grant no. 101003826) and by the Spanish R&D projects INTERACT (grant no. PID2020-114623RB-C31) and EO4TIP (grant no. PID2023-149659OB-C21).