Supplementary information

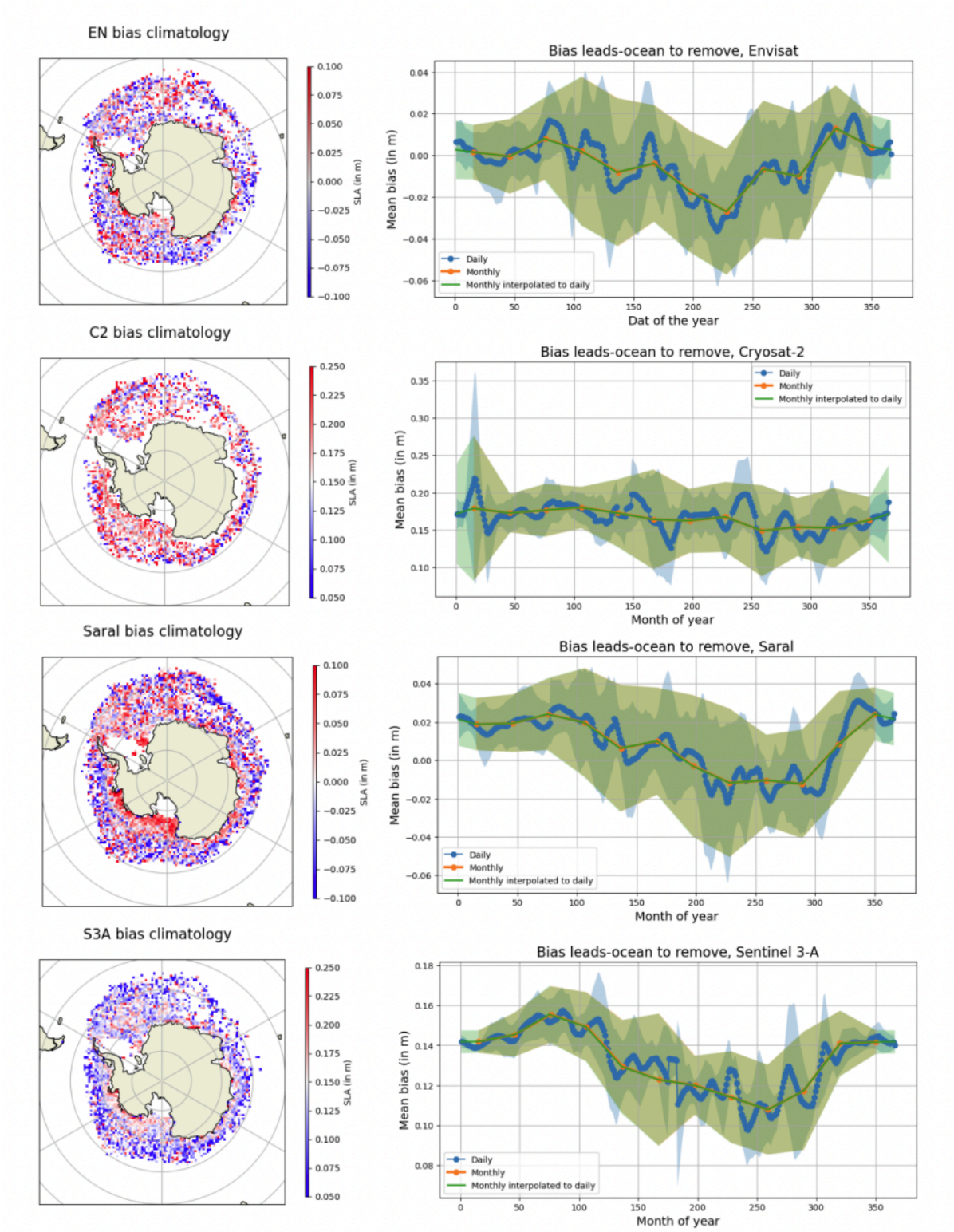

Figure S1 : Ocean/Leads (O/L) bias for each satellite mission. Open-ocean and lead data are aggregated every 10 days in maps with bins of 75kmx75km. At every time-step (10 day timestep), ocean and lead average are subtracted for each grid to obtain O/L delta maps. (Left) O/L delta spatial climatology, obtained with a time average of the beforementioned

maps. (Right) O/L delta monthly climatology, obtained with a time average of the beforementioned maps. The monthly climatology is interpolated to a daily timestep, which is then removed from the pointwise estimates of SLA.

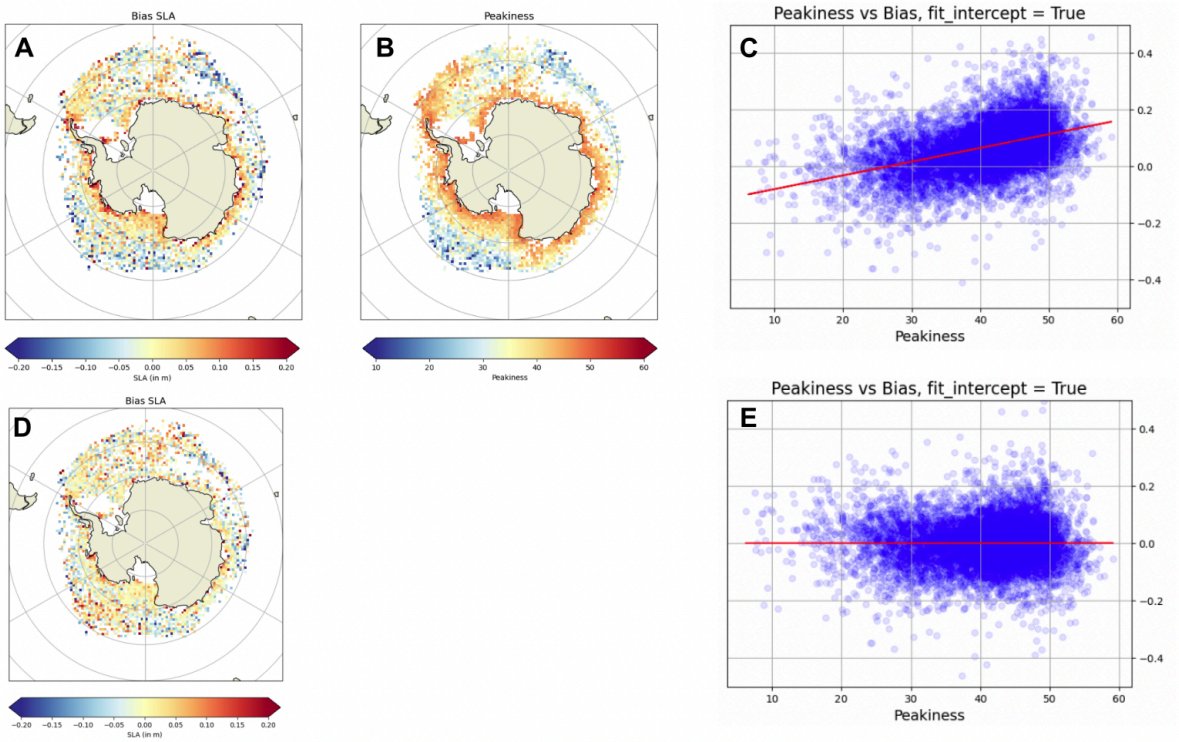

Figure S2 : Comparison between Envisat Ocean/Leads (O/L) bias (before the climatological correction discussed in Fig. S1) and the peakiness of the lead waveforms. (A) Climatological O/L bias for Envisat. (B) Climatology of the peakiness of lead waveforms. Only grids with both open-ocean and lead SLA estimates are kept when computing this climatology. Hence, in the O/L 75km/75km/10days maps, every grid point with an O/L bias estimate has an associated average lead waveform peakiness (C) O/L bias vs lead waveform peakiness, a linear fit is plotted in red, showing a correlation between the two variables. Based on this relationship, a correction for each lead SLA measurement is added, proportional to the waveform peakiness. (D) Climatological O/L bias for Envisat after the peakiness correction. (E) O/L bias vs lead waveform peakiness after the peakiness correction.

	Envisat	Saral	S3A
Cryosat-2	+23.82 cm	+13.66 cm	+3.23 cm

Table S1 : Intersatellite mean offset

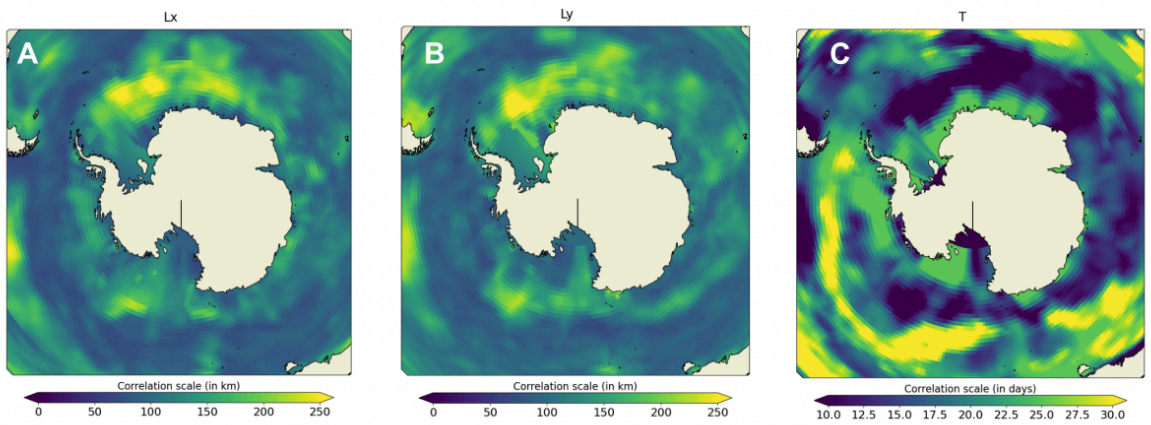

Figure S3 : Correlation scales of SLA, from Auger et al. 2022. (A) Zonal correlation scales. (B) Meridional correlation scales. (C) Temporal correlation scales.

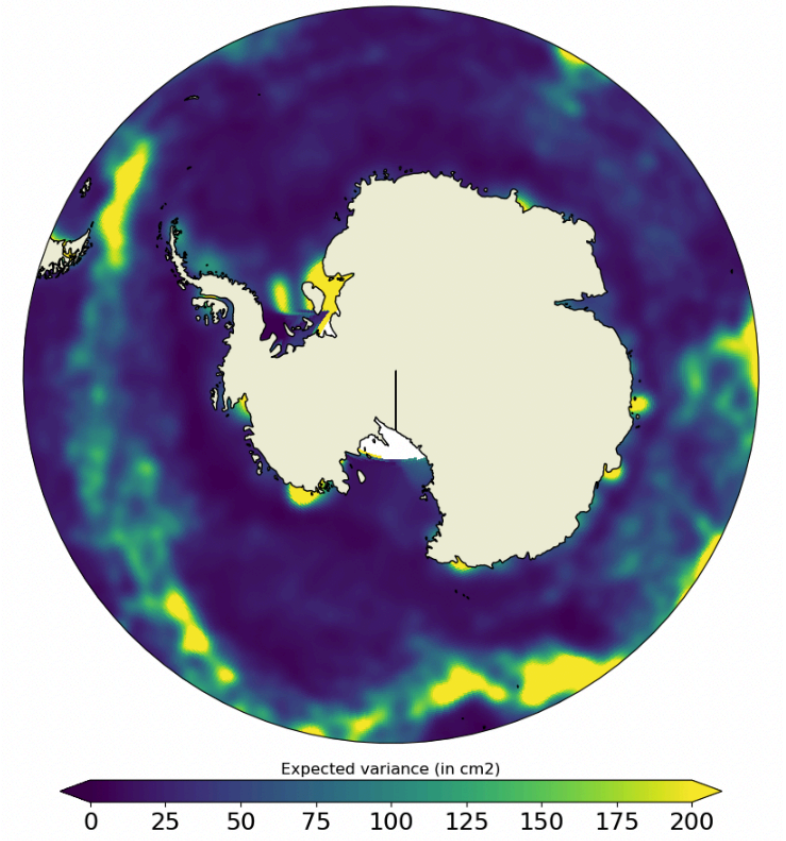

Figure S4 : Expected variance input for the Optimal Interpolation, from Auger et al. 2022.

Name of in-situ instrument	Start	Stop	Lat	Lon
Casey	2003-01-01	2008-12-31	-66.283	110.53
Davis	2003-01-01	2010-03-31	-68.45	77.967

Dumont d'Urville	2008-01-01	2020-12-31	-66.662	140.01
Faraday	2003-01-01	2021-12-31	-65.25	295.73
Mawson	2003-01-01	2009-12-31	-67.6	62.867
Syowa	2003-01-01	2020-12-31	-69	39.6
Myrtle B	1999-10-26	2003-11-03	-60.0497	-47.1700
Myrtle C	2005-12-12	2008-01-17	-60.6200	-53.8488
Drake Passage South Deep	2009-11-08	2013-12-31	-60.8249	-54.7264
Drake Passage South	1992-11-08	2011-12-06	-60.8570	-54.7147
ANT17	2010-12-14	2014-12-12	-64.007	0.002
JARE	2005-01-01	2008-01-31	-66.8	37.8

Table S2 : Comparison metrics with Bottom Pressure Recorders

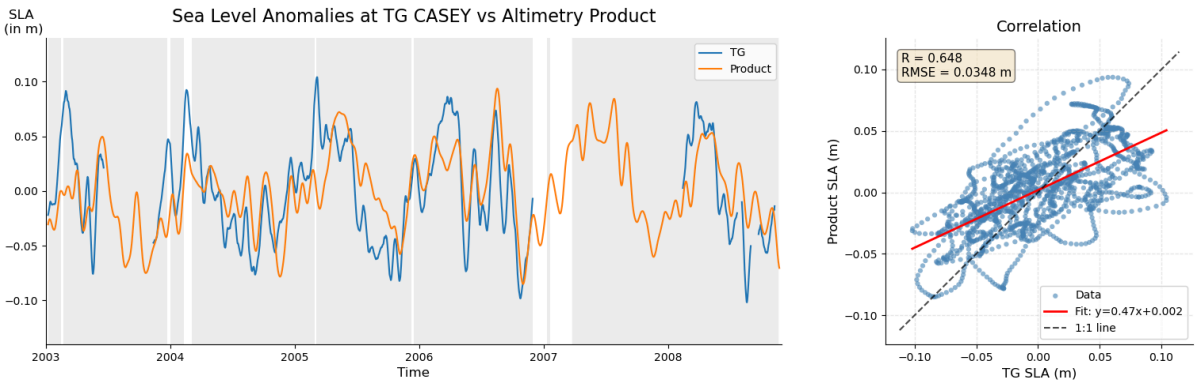

Figure S5 : (Left) SLA time series for the Casey tide gauge (blue) and altimetry product (orange). A 15-day rolling average is applied to both time series. (Right) Scatter plot of altimetry SLA vs tide gauge SLA, regression line in red and associated metrics in the top left corner

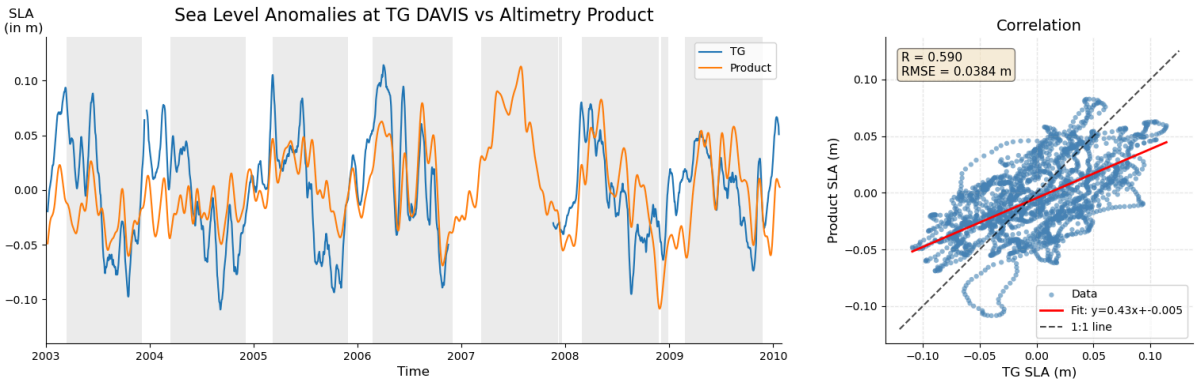

Figure S6 : Same than Fig. S5 but for Davis tide gauge.

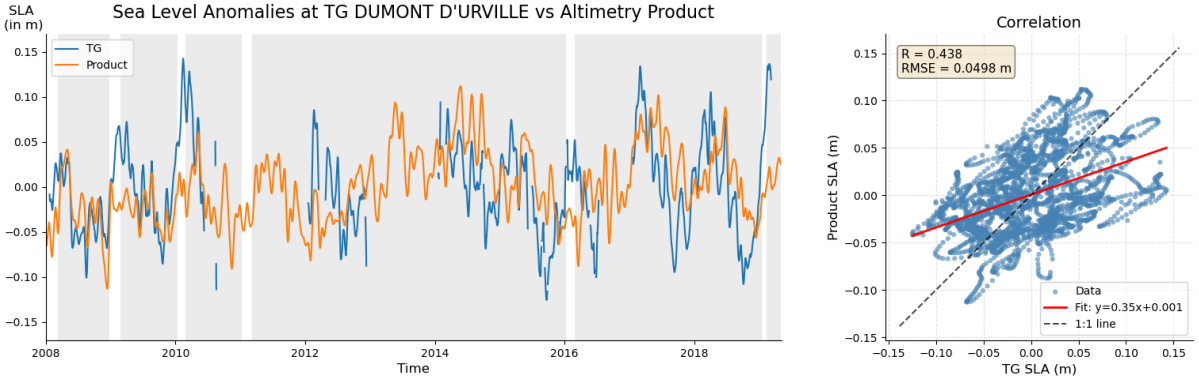

Figure S7 : Same than Fig. S5 but for Dumont d'Urville tide gauge.

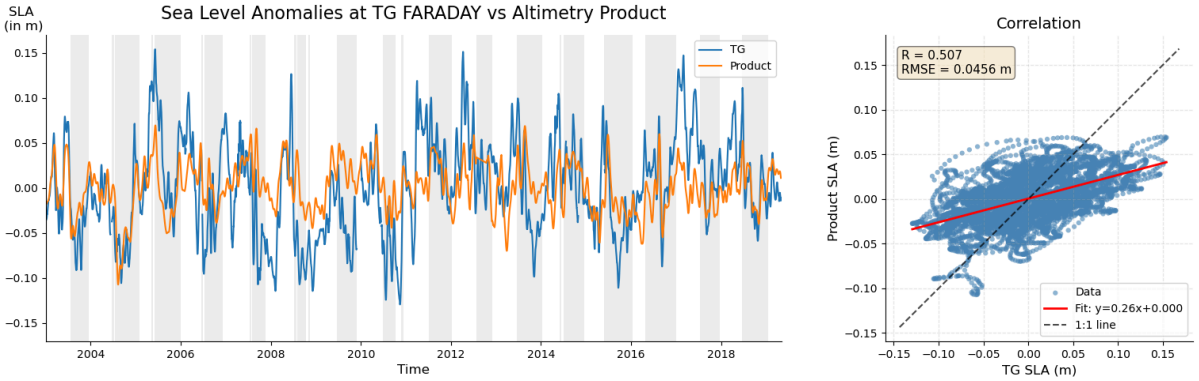

Figure S8 : Same than Fig. S5 but for Faraday/Vernadsky tide gauge.

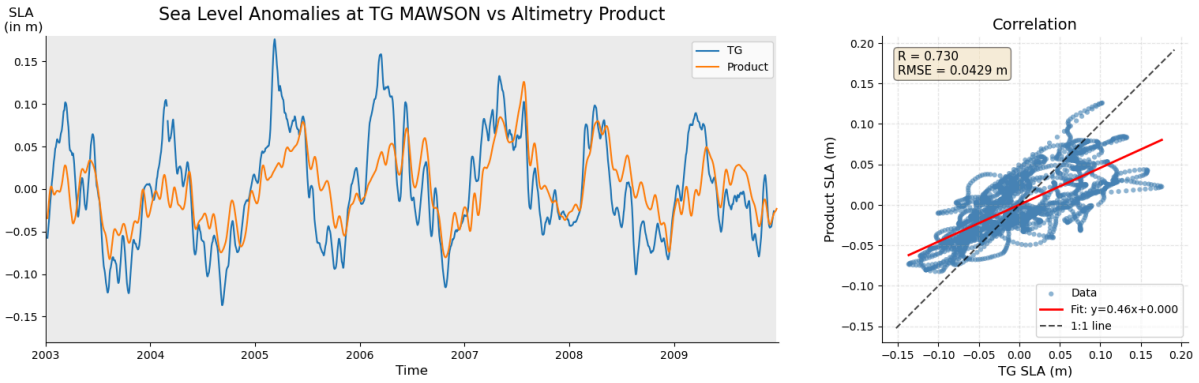

Figure S9 : Same than Fig. S5 but for Mawson tide gauge.

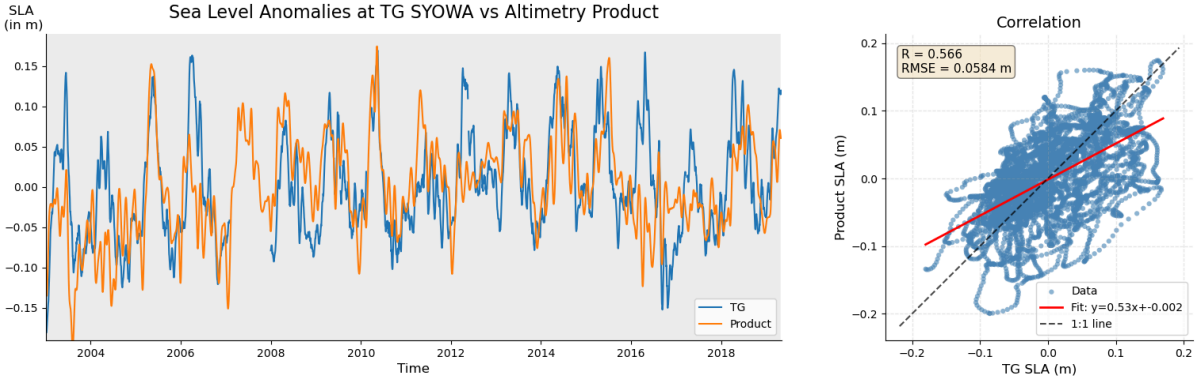

Figure S10 : Same than Fig. S5 but for Syowa tide gauge.

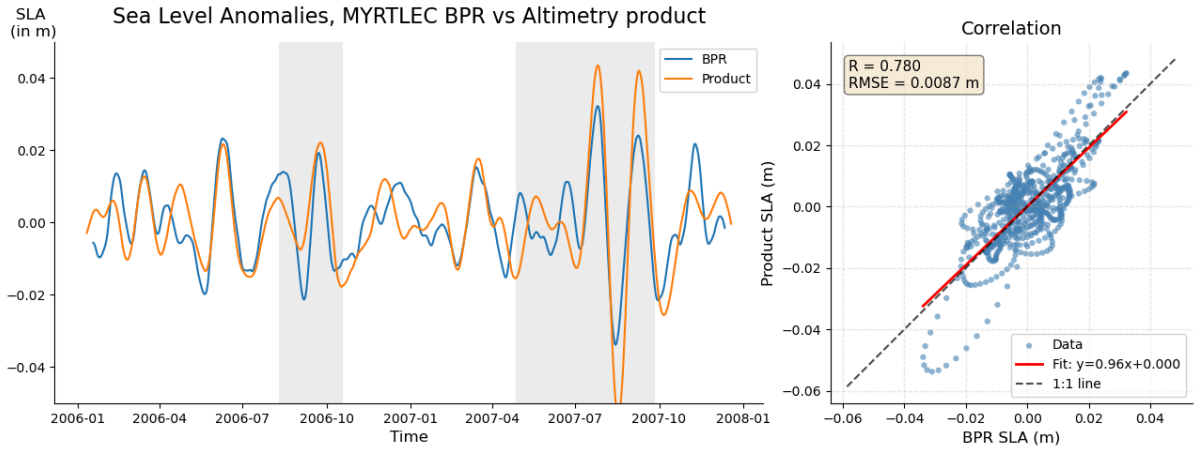

Figure S11 : Same than Fig. S5, but with Bottom Pressure Recorder data, here Myrtle C. A 15-day rolling mean is applied, and the 60-day rolling mean is subtracted to only keep the 15-60 day frequency band.

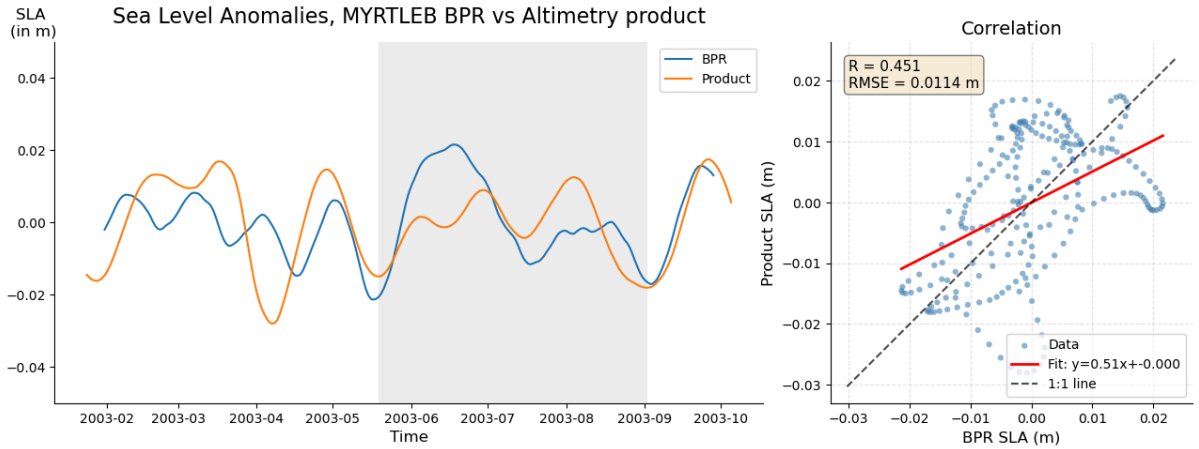

Figure S12 : Same than Fig. S11, but with Myrtle B Bottom Pressure Recorder.

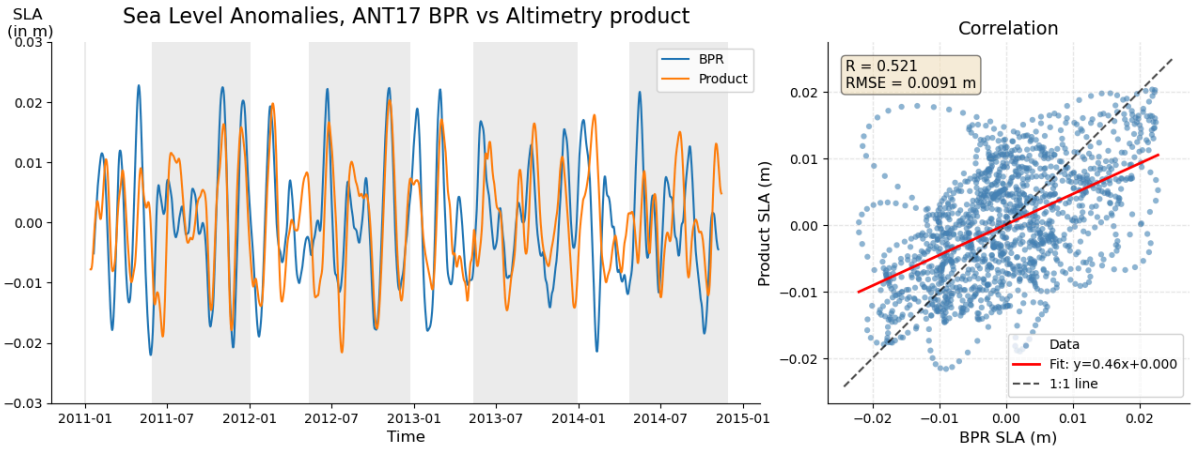

Figure S13 : Same than Fig. S11, but with ANT 17 Bottom Pressure Recorder.

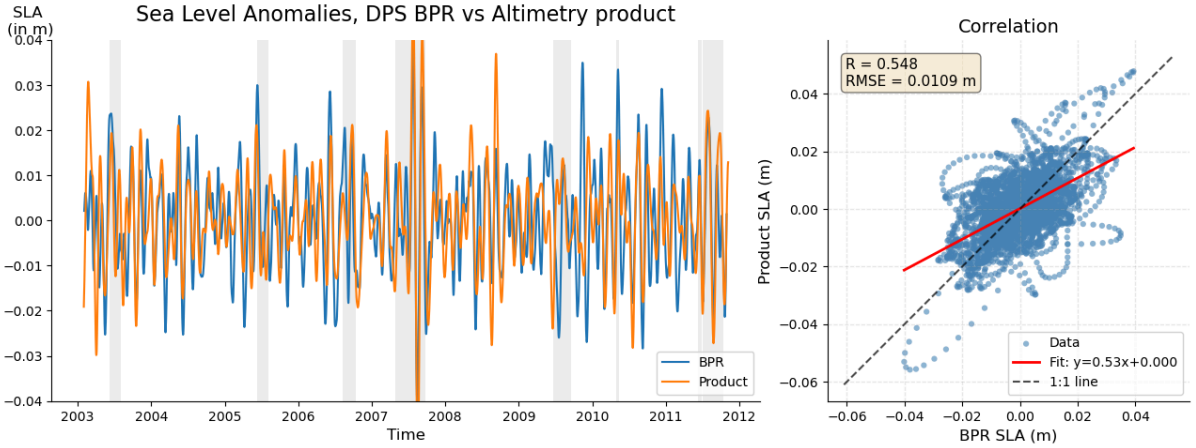

Figure S14 : Same than Fig. S11, but with Drake Passage South Bottom Pressure Recorder.

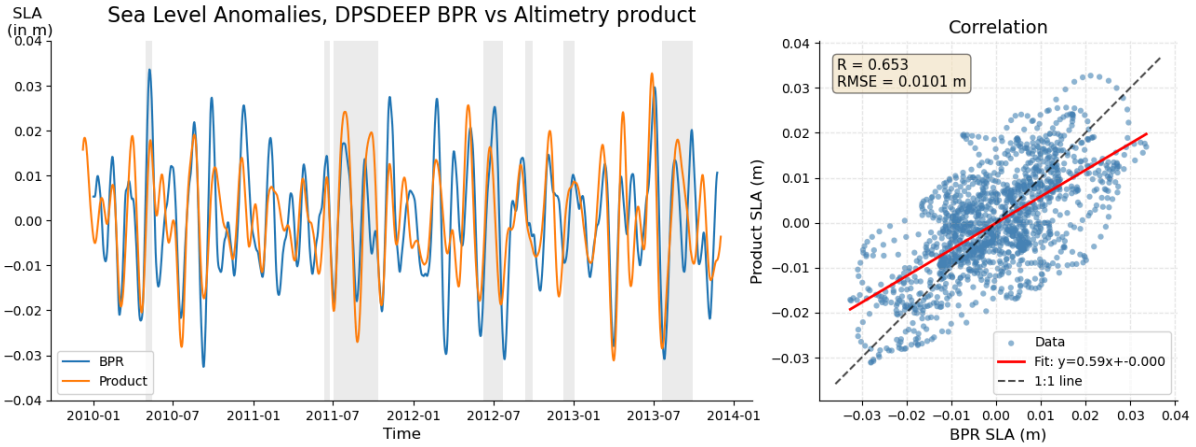

Figure S15 : Same than Fig. S11, but with Drake Passage South Deep Bottom Pressure Recorder.

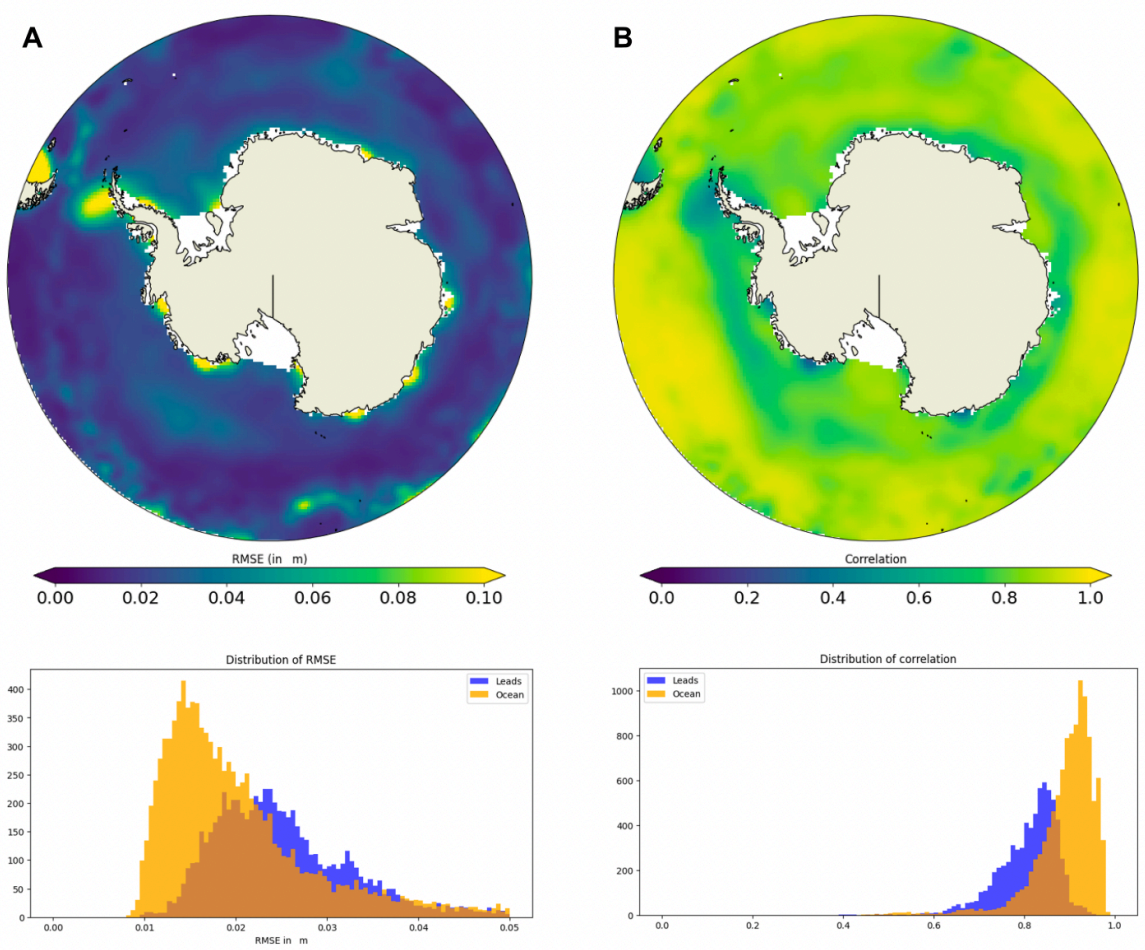

Figure S16 : Comparison between the SSH product presented in Cocks et al. 2025 and the SLA product presented here. (A) RMSE map and distribution. For the distribution, lead data correspond to the subpolar Southern Ocean, defined by the MDT contour shown in Fig. 8. Ocean data corresponds to the Southern Ocean north of this contour. (B) Same figures but for correlation.