Ocean Surface Topography Science Team Meeting (OSTST)

Steric height contribution to intraseasonal sea surface height in the Southwestern Atlantic

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Introduction

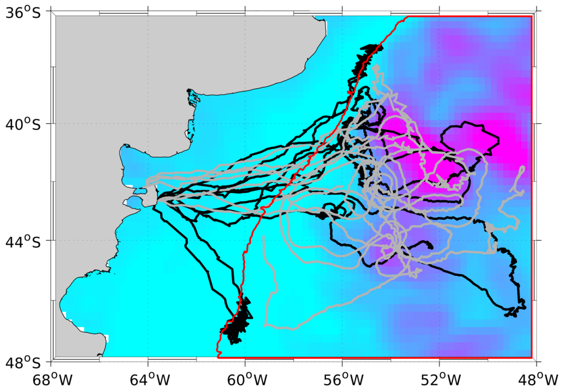


Fig. 1: Map of sea level anomaly (SLA) standard deviation (m) for austral spring-summer 2018 and 2019. The trajectories of 13 elephant seals are shown in black and gray contours for 2018 and 2019 respectively. The red polygon marks the study region.

The sea level varies at diverse spatial and temporal scales due to several physical processes. The main processes are the steric effect, changes in the density of sea water, and the mass changes (e.g. melting ice). In the Southwestern Atlantic, the sea level associated with the steric effect, known as steric height, dominates the seasonal variability and the spatial variation of sea level trends on the Brazil-Malvinas Confluence (BMC) and adjacent area (Ruiz-Etcheverry and Saraceno, 2020). The interannual variability, instead, is important on the mid-latitude of the South Atlantic and negligible over the Southwestern Atlantic continental shelf (Combes and Matano, 2019). Little, however, is known about the intraseasonal sea level variability. Thus, the objective of this work is the understanding of the physical drivers of the sea level variability in the Southwestern Atlantic at temporal scales shorter than seasonal using a combination of high resolution in situ data from CTD attached on elephant seals (ES), altimetry data, and a 3D oceanic model.

Data and methods

- In situ data: Temperature (T), salinity (S) and pressure from CTD attached on elephant seals https://www.meop.net/database/
- Model data: T, S and Sea Surface Height (SSH) from Mercator reanalysis 1/12 degree spatial and daily temporal resolution and Mercator forecast 1/4 degree spatial and daily temporal resolution, https://marine.copernicus.eu
- Satellite data: Absolute Dynamic Topography (ADT) from all-sat gridded altimetry maps ¼ degree spatial and daily temporal resolution, https://marine.copernicus.eu

  The studied periods are from October 2018 to January 2019 and from October to December 2019.

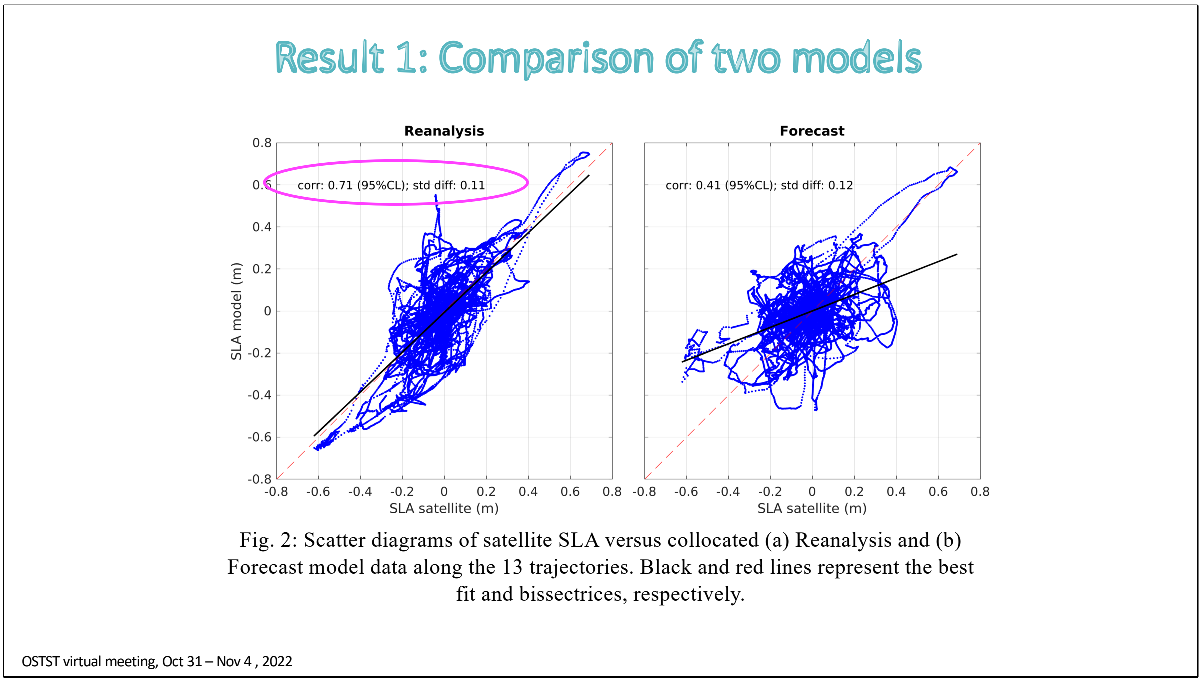
❑ Steric height (SH) equation

$$SH = -\frac{1}{\rho_0}\int_{-H}^{0}(\rho - \rho)\,dz = -\frac{1}{\rho_0}\int_{-H}^{0}\left(\rho(n,z,t) - \overline{\rho(z)}\right)dz \quad (1)$$

Average along the trajectory

❑ Fraction of the variance:

$$Fvar = 100\% * \left(1 - \frac{var(y-x)}{var(y)}\right) \quad (2)$$



- SLA from Reanalysis model is selected to compute SH since showed a higher correlation and lower standar deviation of the difference with satellite data than Forecast product.

Result 2: Does the reanalysis model resolve SH?

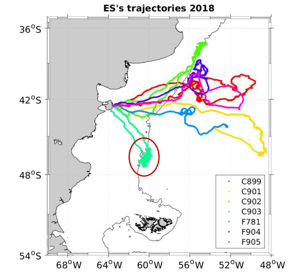


Fig. 3: trajectories of seven Elephant Seals during October 27th 2018 - January 1st 2019.

Table 1: correlation coeficients (95%CL) between SH derived from in situ and model data along the trajectories during 2018.

ES's name	C899	C901	C902	C903	F781	F904	F905
corr	0.57	0.47	0.49	0.31	0.51	0.52	0.94

Table 2: correlation coeficients (95%CL) between SH derived from in situ and model data along the trajectories during 2019.

ES's name	051	053	054	875	878	F905
corr	0.77	0.62	0.55	0.74	0.58	0.87

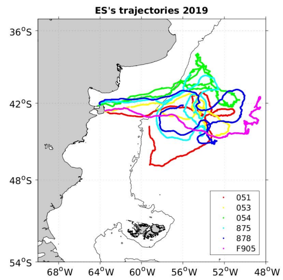


Fig. 4: trajectories of six Elephant Seals during October 23th – December 24th 2019

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The temperature and salinity from reanalysis model are interpolated on the position and depth of the trajectories of the elephant seals. Using Gibbs SeaWater (GSW) Oceanographic Toolbox (McDougall & Barker, 2011) that considers the Thermodynamic Equation of Seawater 2010 (TEOS-2010), we calculated the in situ and model potential density for all the trajectories. Then, we estimated the SH (equation 1) and the correlation coefficients with a confident level of 95%.

The results show that the model SH represents adequately the SH in situ, obtaining correlations > 0.45 in 12 cases out of 13 (Table 1, 2). The low correlation on the C903 trajectory might be related with the spatial resolution of the model. This ES C903 (Fig. 3) did 4268 dives in a small portion of the shelf-break (~208.59 km) which is approximately 20 dives per kilometer.

Result 3: Analysis of the SH

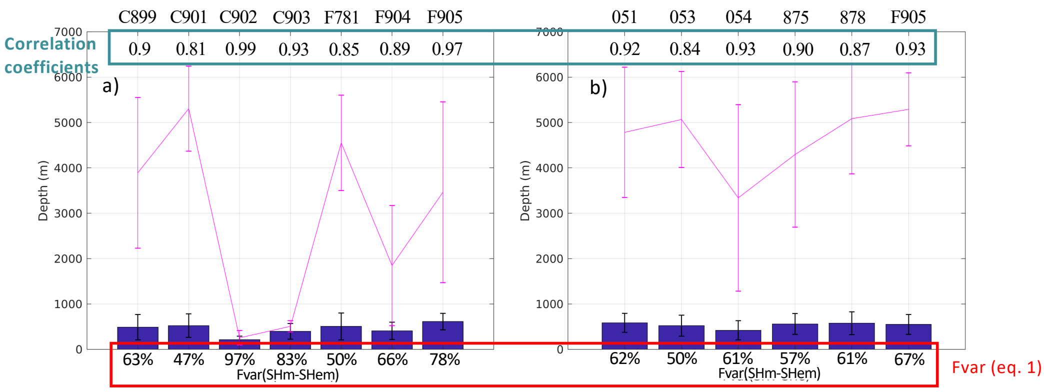

Fig. 5: Mean depth along the trajectories of the ES derived from CTD (dark blue bars) and GEBCO 2020 (magenta line) as a function of the fraction of variance between model SH integrating the entire column (SHm) and integrating the depth of the elephant seals's dives (SHem) for a) 2018 and b) 2019. The error is one standar deviation.

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The results from previous slide show that the model represent adequately the SH along most of the ES's trajectories. Next question to be answered is: can we resolve the SH signal by only integrating the depth of the ES's dives? To answer, we calculate the % of the total SH variance explained by model SH integrating the depth of the dives (SHem), the fraction of the variance (Fvar). The total SH (SHm) is defined as the model SH integrating the entire water column. The Fvar analysis (x axis Fig. 5) indicates that the SHem explains more than 47% of the SHm in the 13 ES's trajectories. The Fvar increases when the depth of the dives is closer to the actual bathymetry. In general, the ESs dived at depth < 1000m in regions where the bathymetry varies between 2000 and 5000m. The SHem correlates very well with SHm, obtaining correlation coefficients > 0.8 (95%CL, Fig. 5, 6).

Result 3: Analysis of the SH

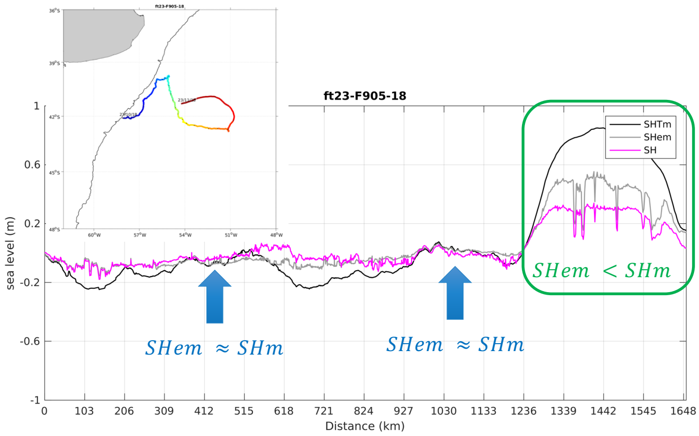

Fig. 6: In situ SH (magenta line), model SH integrating the entire column (SHm, black line) and model SH integrating up to the elephant seal's depth (SHem, gray line) F905. X axis represents the distance of the trajectory of the ES from the isobaths 200 meters

Can we resolve a great % of the SH integrating the depth of the SE's dives?

As an example, trajectory of SE F905

Here we show the SH derived from model along the trajectory of the ES F905. This is an example where the Fvar and correlation are high, 78% and 0.9 (95%CL) repectively (Fig. 5a). However, the SHem subestimates the amplitude of the SHm between 1339 and 1648 km (Fig. 6), where a strong anticyclonic eddy was detected (Fig. 7). Considering that the study region is characterized by presence of eddies, it is better to integrate the entire water column to reproduce the SH signal.

Result 4: the role of SH in the SLA

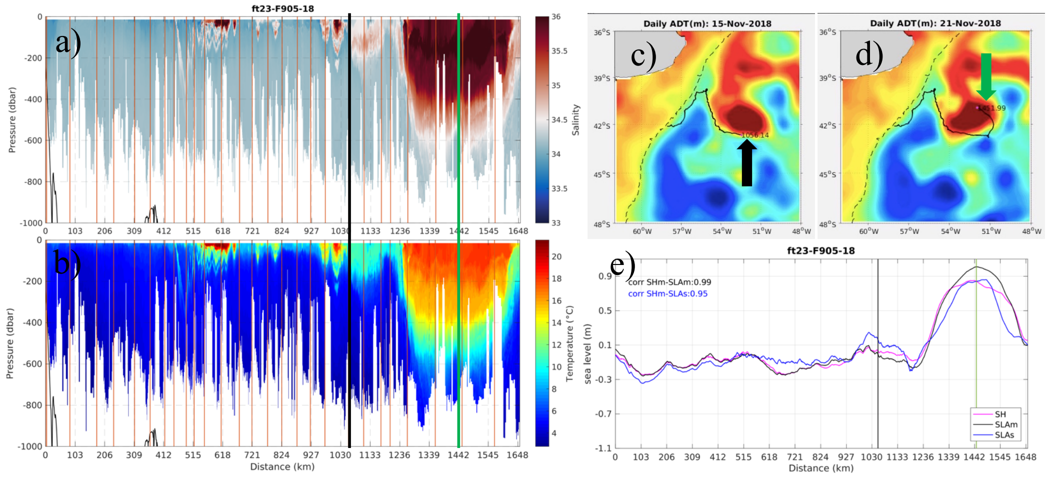

Fig. 7: Vertical sections of a) salinity and b) temperature along the trajectory of the ES F905. The dark-orange vertical lines indicate the beginning of the day . c) and d) are two maps of satellite SLA superimposed with the portion of the trajectory swam by the ES 905. The black and green arrows match with the black and green lines in panels a) and b). e) model SH (magenta line), satellite SLA and model SLA along the ES F905's trajectory. X axis represents the distance of the trajectory of the ES from the isobaths 200 meters.

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Fig. 7 ilustrates an example of the good coherence between satellite, model and in-situ data. The ES swam along the edge and across strong anticyclonic eddy. This anomaly is captured by satellite and model SLA. It also observed that SH dominates the SLA, explaining 97% (model) and 88% (satellite).

Note: Model SLA and satellite SLA are computed as ADT – mean(ADT along trajectory)

Result 4: the role of SH in the SLA

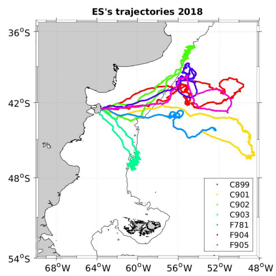

Table 3: Percentage of the SLA (model and satellite) variance explaind by the model SH for trajectories during 2018.

Fvar (%)	C899	C901	C902	C903	F781	F904	F905
SLAm-SHm	81	22	58	45	79	91	97
SLAs-SHm	77	29	43	28	20	29	88

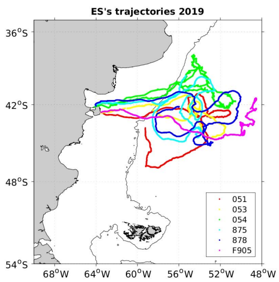

Table 4: Percentage of the SLA (model and satellite) variance explaind by the model SH for trajectories during 2019.

Fvar (%)	051	053	054	875	878	F905
SLAm-SHm	72	83	86	89	91	66
SLAs-SHm	65	77	28	65	64	74

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SHm explains more than 58% of the SLAm in 11 trajectories out of 13 (Tables 3, 4). The number of cases with high % decreases when satellite SLA is analyzed. Futher analisys is necessary to understand if the origin of the discrepancy is due to the spatial esolution of the altimetry product or due to the model performance.

Result 4: the role of SH in the SLA

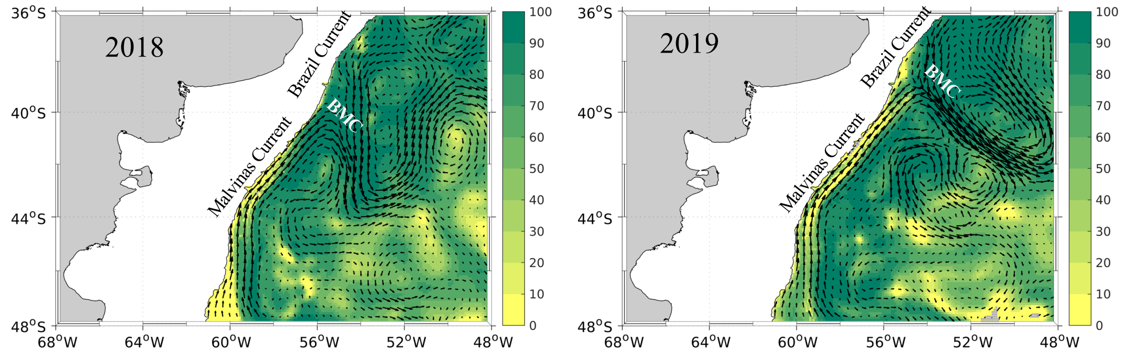

Fig. 8: Map of percentage of variance of SLA explained by the SH for spring-summer 2018 and spring-summer 2019. The black arrows represent the geostrophic currents derived from ADT. Gray dots indicate the percentage higher than 100%.

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The % of SLA variance explained by SH along the trajectories is a Lagrangean analysis, involving space and time. The ESs swam crossing different regimes that might impact the role of SH in SLA. Therefore, we estimated the % of SLA variance explained by SH on the model grid (Fig. 8). The results indicate that the SH explains more than 60% of the SLA in the study area, except on the Malvinas Current (MC) and small areas. The MC presents an approximately barotropic structure and its flow is strongly constrained by potential vorticity. In addition, the temperature and salinity of the MC water have not change significantly in the last decades (e.g. Artana et al., 2019; Franco et al., 2022). Thus, it is not expected an intense SH signal. On the contrary, the Brazil Current (BC) is a baroclinic current, and there are evidences of temperature and salinity variation (e.g Artana et al., 2019; Leyba et al., 2019; Franco et al., 2022) that impact on SLA (Ruiz-Etcheverry and Saraceno, 2020). The submesoscale and mesoscale activities generated by the BMC create changes in salinity and temperature, and, thus, a strong SH signal.

Conclusions

- The Mercator Reanalysis model represents adequately the SLA in the study region.
- Singnificant correlations > 0.45 were obtained between model SH and in situ SH.
- The SH integrated on the ES's depth explains more than 47% of the signal.
- The data collected by the ES F905 during 2018 allows to detect an anticyclonic eddy which is observed on satellite and model SLA. Here, the SH explains more than 88% of SLA.
- The SH plays an important role in the SLA in most of the ES's trajectories, especially in 2019.
- The SH dominates the SLA in region influenced by mesoescale activity, such as BMC.
- On the Malvinas Current, the SLA is not highly explained by the SH.

Thank you for your attention

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