Assessment of the TOPEX GMSL stability by analysing the global mean sea level closure using the AVISO L2P-2024 products.

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For more information, visit https://climate.esa.int/en/projects/sea-level-budget-closure/about/.

Why do we want to close the SLB?

Assessing the sea level budget is a robust method to cross-validate the observing systems involved. As examples, sea level budget studies have highlighted errors linked to altimetry measurements such as the TOPEX-A altimeter drift (Dieng et al., 2017) and the Jason-3 wet troposphere correction drift (Barnoud et al., 2023), but also errors linked to Argo in situ data such as salinity drift since 2015 (Barnoud et al., 2021).

The sea level budget equation

$$\Delta SL_{relative} = \Delta SL_{mass} - \Delta SL_{steric}$$

$\Delta SL_{relative}$: Altimetry measurements
ΔSL_{mass}: Gravimetry measurements (GRACE/FO)
$\Delta SL_{steric} = \Delta SL_{thermosteric} + \Delta SL_{halosteric}$: In situ temperature and salinity measurements (Argo network)

Global mean SLB using L2P 2024

The official dataset from ESA SLBC CCI+ project is used in this study (see Table 1). There are two independent ways to estimate the barystatic sea level: using satellite gravimetry data (GRACE/FO data from 2002 to 2025) or summing all individuals mass contributions to the ocean mass (from 1993 to 2023).

Table 1: *Description of all datasets used in this study.*

	Relative sea level	Thermosteric sea level	Barystatic sea level
Dataset	**C3S 2021** (10.24381/cds.4c328c78 Copernicus Climate Change Service, 2018) corrected for the empirical correction of the TPA drift obtained using the altimeter/tide gauge method. (Ablain et al. 2018)	EN4 temperature profiles mapped using ISAS (ESA SLBC CCI+ dataset)	GRACE/GRACE-FO dataset from ESA SLBC CCI+ dataset
	L2P DT 2024 (Kocha et al. 2023) GDR-F over the TOPEX period		Sum of individual mass contributions from ESA SLBC CCI+ dataset

Figure 1 shows the Global Mean Sea Level (GMSL) budget which is computed using the L2P vDT 2024 altimetry data and the ESA SLBC CCI+ components.

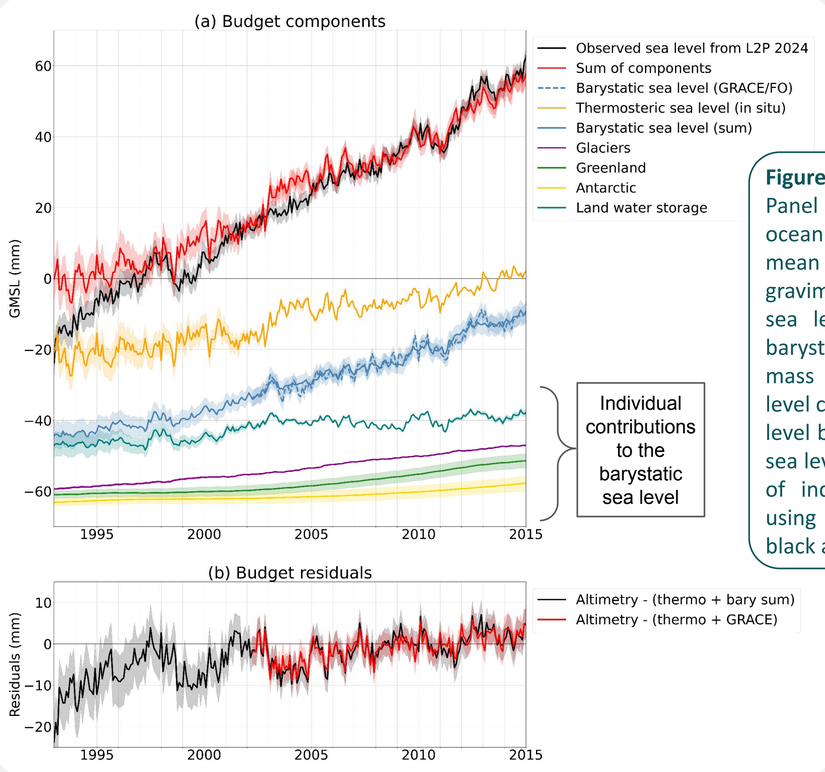


Figure 1: Panel a: Global mean sea level and ocean mass budgets. Solid lines: Global mean sea level budget using altimetry, gravimetry and in situ data for panel a sea level budget residuals using the barystatic sea level based on individual mass contributions to barystatic sea level change. Dotted lines: barystatic sea level based on GRACE/FO data. Panel b: sea level budget residuals using the sum of individual mass contributions and using barystatic from GRACE/FO, resp. black and red lines.

- ➔ Over the **GRACE period**, there is a **good agreement** between the **sum of individual mass contributions** (Greenland, Antarctica, glaciers, land water storage) and the **GRACE-based ocean mass estimate**.
- ➔ Before GRACE (TOPEX-A period), the **barystatic sea level** is reconstructed from the **sum of individual mass contributions**.
- ➔ Over **1993–2002 (TOPEX)**, the SLB **residuals shows variations significantly higher than over the 2002-2015 period.**
- ➔ A potential **drift over the TOPEX-A period is observed**.

Drift assessment

A **Key Performance Indicator** was developed within the framework of the ESA ASELSU project (https://www.aselsu.org/) as a **general approach to detect potential drifts in measurement time series**.

If R > 1, significant drift is detected

If R ≤ 1, stability assessed within the uncertainty of the validation method

$$R(t, \Delta t) = \frac{|\delta(t, \Delta t)|}{u_\delta(t, \Delta t)}$$

Drift detected by the validation method at t over a period Δt

The KPI depends of the time (t) and the length of the period analyzed (Δt)

*Uncertainty on the trend at t over a period Δt **(1-sigma)***

The method is applied here (Figure 2) to the sea level budget residuals to detect potential observational drifts.

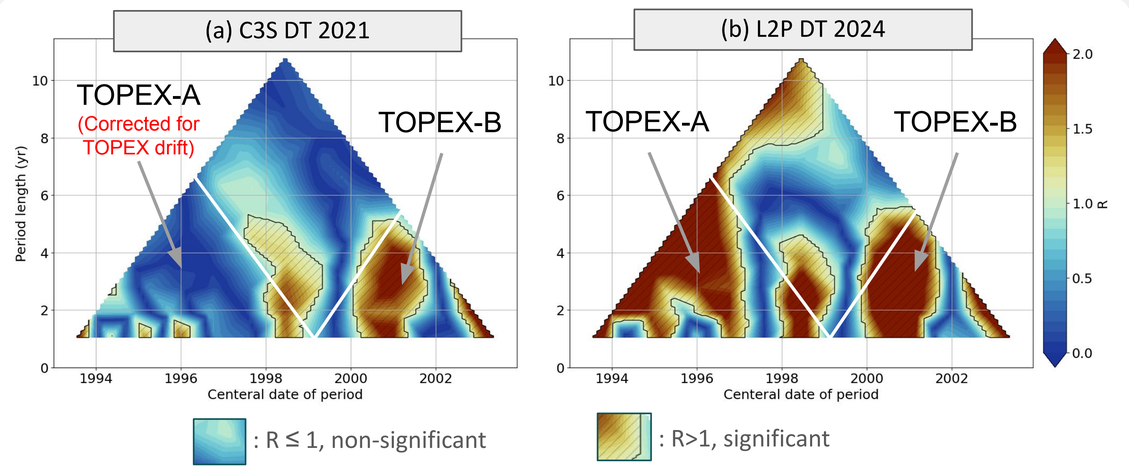
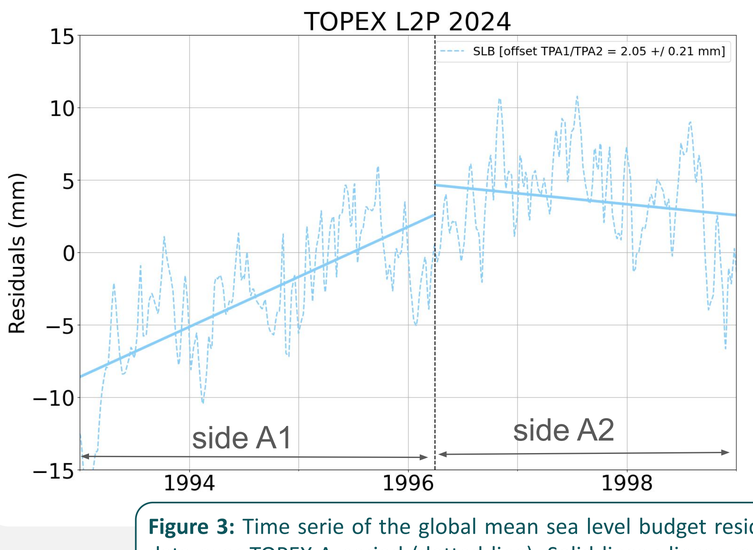


Figure 2: Pyramid trend diagrams of the derivation of KPI R for the global mean sea level budget method for any period and at any time over the TOPEX era (1993-2003). The hatched areas are plotted for R >1 and highlight the periods when SLB residuals trend is significant compared to the uncertainties. Panel a: global mean SLB using C3S 2021. Panel b: global mean SLB using L2P DT 2024.

- ➔ Over the TOPEX-A period, SLB residuals KPI shows a **significant drift in the SLB residuals using DT2024 altimetry data** not present in DT2021 corrected data : **this very likely indicate a drift in TOPEX-A GMSL DT2024.**
- ➔ Over the TOPEX-B period, a significant drift is also detected. Since this drift is observed in both DT 2021 and DT 2024 datasets, it is not yet possible to determine which component of the sea level budget is responsible for it.

Topex-A drift quantification



Latest estimates of drift over Topex-A period with SLB method:

TPA = 1.9 ± 0.9 mm/yr
(vs 1.5 ± 0.5 mm/yr from Dieng et al. 2017)

TPA1 = 3.2 ± 1.3 mm/y

TPA2 = -1.1 ± 1.4 mm/yr
(non-significant)

Figure 3: Time serie of the global mean sea level budget residuals using L2P DT 2024 data over TOPEX-A period (dotted line). Solid lines : linear regression estimated over side A1 and side A2. Uncertainties provided are estimated at 1-sigma confidence level.

- ➔ This drift over the entire TOPEX-A period is estimated at **1.9 mm/yr ± 0.9 mm/yr** (1 sigma), consistent with other studies on L2P 2021 (Dieng et al. 2017).
- ➔ The drift modelling needs to be refined as it is subject to several choices

Conclusions and outlook

- The significant drift detected on the SLB residuals over the TOPEX A period (1.9 ± 0.9 mm/yr) can be attributed to the TOPEX A measurements (GDRF).
- This drift is especially detected over the TOPEX A side A1 period : 3.2 ± 1.3 mm/yr
- Results over TOPEX-B period are under investigation to identify the origin of the potential drift detected in the SLB residuals. It could be due to other sea level components
- This work could be strengthened by better characterizing the temporal correlation structure of the errors in the steric sea-level component and the land water storage component

References

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