

ESA/Contract No. 4000126561/19/I-NB

Consortium Members











ESA Sea Level CCI+

Product Validation and Inter Comparison Report

Reference:

Nomenclature: SLCCI+_PVIR_018_ProductValidation

Issue: 4.0

Date: Nov. 10, 26





Chronology Issues:			
Issue:	Date:	Reason for change:	Author
1.0	02/03/20	Initial Version	NOC, LEGOS, CLS
2.0	30/07/21	Annual update	NOC, LEGOS, CLS
2.1	03/09/21	Improvements after review comments	NOC, LEGOS, CLS
2.2	10/03/22	Update with v2.1 results (sections 2, 3.1)	NOC, LEGOS, CLS
2.3	14/06/23	Validation results of the v2.2 dataset	LEGOS, CLS
3.0	11/12/25	Validation results of the v3.0 dataset	LEGOS, CLS
4.0	9/11/26	Validation results of the v4.0 dataset	LEGOS

People involved in this issue:			
Written by:	A. Cazenave, L Leclercq, L Tolu		
Checked by:	JF Legeais (CLS)		
Approved by:	JF Legeais (CLS)		

Acceptance of this deliverable document:			
Accepted by ESA:	S. Connors (ESA)		Digitally signed by Sarah Connors Date: 2026.11.25 14:23:30 Z

Distribution:		
Company	**Names**	**Contact Details**
ESA	S. Connors, M. Restano	Sarah.Connors@esa.int; Marco.Restano@esa.int
CLS	J.-F. Legeais ; A. Deniau ; A Mangilli ; V Quet	jlegeais@groupcls.com ; adeniau@groupcls.com; amangilli@groupcls.com; vquet@groupcls.com;
LEGOS	A. Cazenave ; L. Leclecrq B. Meyssignac ; F. Birol; F. Nino; F. Leger; L Tolu	anny.cazenave@gmail.com; lancelot.leclercq@univ-tlse3.fr; Benoit.Meyssignac@univ-tlse3.fr; florence.birol@univ-tlse3.fr; fernando.nino@ird.fr; fabien.leger@univ-tlse3.fr; lena.tolu@univ-tlse3.fr;
NOC	S Jevrejeva ; A Wise	sveta@noc.ac.uk; anwise@noc.ac.uk;

Distribution:		
Company	**Names**	**Contact Details**
DGFI-TUM	Marcello Passaro	marcello.passaro@tum.de;

List of Contents

1. Introduction 4

2. Presentation of the V4.0 version 5

3. Validation of the V4.0 version 7

3.1. Datasets used for the v4.0 validation 7

3.1.1. Grided altimetry data 7

3.1.2. IAS 2024 coastal sea level product 7

3.1.3. Tide gauge data 7

3.1.4. GNSS vertical land motions (VLMs) 8

3.2. Comparison between the SL_cci (version v4) SLAs with the C3S DT2024 and IAS data sets 8

3.2.1. Detrended time series 8

3.2.2. Comparison of absolute trends between altimetry-based sea level data from SL_cci with products from C3S (DT2024) and IAS 10

3.3. Comparison of detrended tide gauges records with detrended SL_cci (version v4) SLAs , C3S DT2024 and IAS data (interannual time scale) 10

3.4. Use of SL_cci SLA time series to complete nearby tide gauge records with numerous data gaps 13

4. Relative sea level trends at the virtual stations 15

5. Conclusion 17

6. references 18

6. References 20



1. Introduction

In this report, we present the validation of the latest version v4.0 (November 2026) of the coastal sea level dataset. Different coastal sea level datasets have been produced since the beginning of the project in 2020:

(1) **version 1.1**, consisting of a 16-year-long (June 2002 to May 2018), high-resolution (20-Hz), along-track sea level dataset at monthly interval, together with associated sea level trends computed at 429 coastal sites in six regions (Northeast Atlantic, Mediterranean Sea, West Africa, North Indian Ocean, Southeast Asia and Australia). The validation of this v1.1 data set was presented in Benveniste et al., Coastal sea level anomalies and associated trends from Jason satellite altimetry over 2002-2018, *Nature Scientific Data*, 7, 357, https://doi.org/10.1038/s41597-020-00694-w, 2020.

(2) **version 2.0,** computed during autumn 2021. This is an extension both intime and space of version 1.1. It covers a full 18 year-long time span: January 2002 to December 2019, and in addition to the previous 6 study regions, now covers the whole African continent. This V2.0 product was further extended spatially to include the whole American continent. This geographically extended product is called **v2.1**. It has been published in Cazenave et al., New network of virtual altimetry stations for measuring sea level along the world coastlines, Nature Communications Earth and Environment, 2022.

(3) **version 2.2.** It is an improved version of the v2.1 product with some corrections applied to the dry tropospheric correction (wrong at a few sites) and an optimized calculation of the inter mission bias. The v 2.2 product has been distributed (https://doi.org/10.17882/74354).

(4) **version 2.4.** Produced in November 2024, this new version still covers the 2002-2021time span but differs from the previous v2.3 version by the following improvements: (i) the use of the new GDR-F altimetry standards for Jason-3. The ALES-based waveforms and associated SSB have been recomputed with these new standards for Jason-3; (ii) a new post-processing editing applied to the sea level anomalies time series produced by X-TRACK consisting of a new criteria of at least 50% of valid data over the duration of each Jason mission and an iterative removal of the outliers in the sea level anomalies time series (in addition of the editing criteria previously applied to the sea level trend computation). This product still uses the FES2014 ocean tide model. It consists of 1149 virtual stations.

(5) **version 3.0**. Produced in 2025, this version differs from the previous v2.4 product (released in November 2024) by an important spatial extension. But the time span of analysis remains the same (2002-2021). The v3.0 version uses the new FES22 ocean tide model instead of FES14 model considered in the previous versions. Six new regions have been considered in addition to the 13 previously considered, with the latter sometimes extended spatially to cover new oceanic zones of interest. The newly covered areas include tropical islands of the Pacific and Indian

oceans, the New Zealand area, the Red Sea, the Baltic Sea and the northwest Pacific around Japan.

(6) **version 4.0** presented below is a temporal extension of the v3.0 version. It covers the period January 2002 to December 2024, using altimetry data from the Sentinel-6A Michael Freilich mission. Otherwise, the same 20 regions as for v3.0 are considered and the same geophysical corrections are used (including the FES2022 ocean tide model). A new network of 1653 virtual stations is thus provided. It is presented below as well as the validation of the new data set. The v4.0 version is described in detail in: Leclercq L., Cazenave A., Leger f., Birol F. Passaro M., Nino F. Tolu L., Legeais J.F., Jevrejeva S. and Connors S., Global network of virtual coastal stations from altimetry-based sea level data, submitted, ESSD, 2026.

2. Presentation of the V4.0 version

The location of the 20 study regions is presented in figure 1.

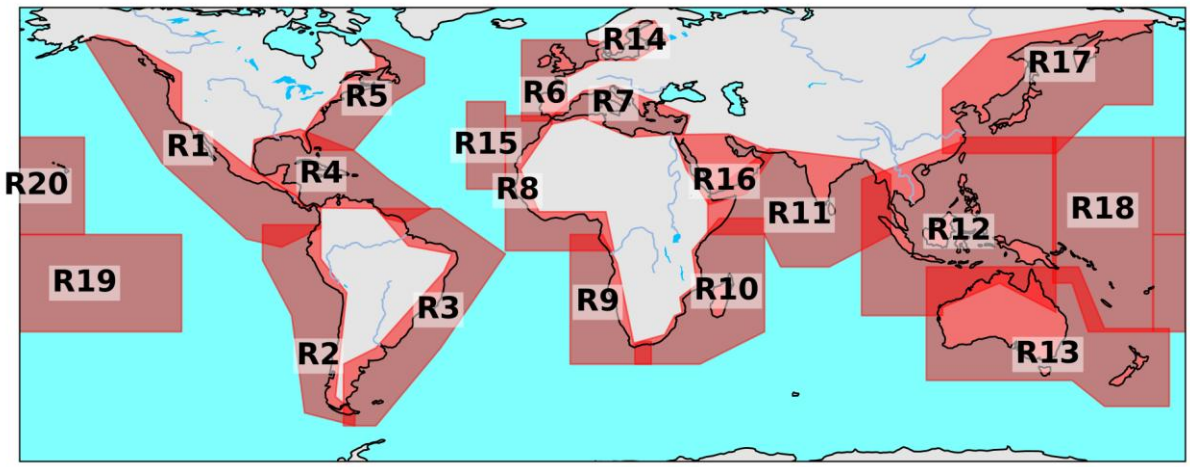

Figure 1: Location of the 20 regions (red shaded areas) considered for the SL_cci coastal altimetry data processing (version v4).

The details about the data processing are described in the ESSD paper (Leclercq et al., 2026). Figure 2 shows the distribution of the 1653 coastal virtual stations along the world coastlines. Associated colors represent the distance of the first along-track valid point, i.e., defined as the distance to the coast of the virtual station.

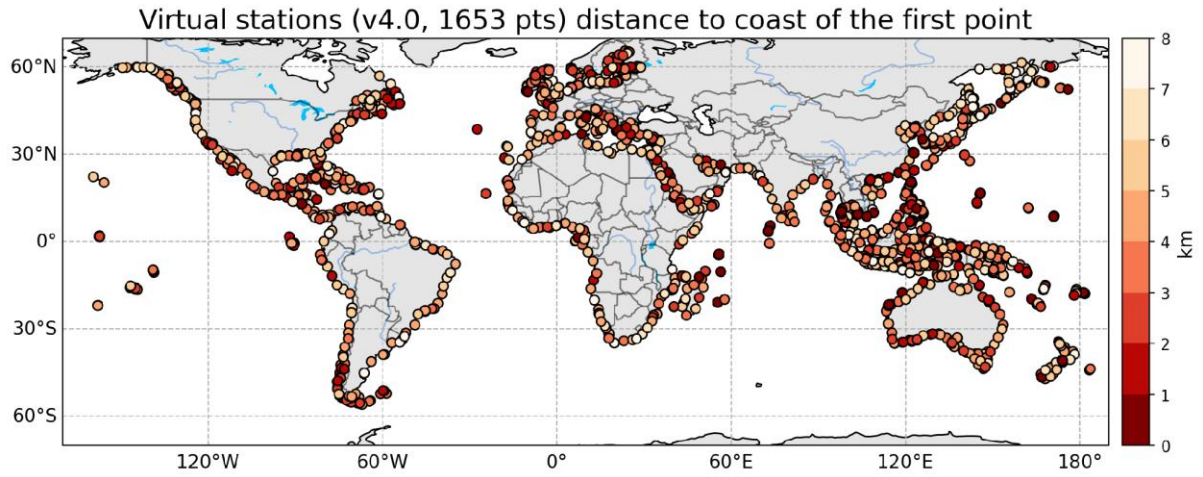

Figure 2. Distribution of the 1653 coastal virtual stations along the world coastlines. The colorbar indicates the distance (in km) of the first along-track valid point to the nearest coastline.

The mean distance value to the coast of these 1653 virtual stations is 3.9 km (see histogram in Figure 3, right panel). Trends and trend errors (from the least-squares fit) are averaged over 2 km from the closest first points to the coast. Figure 3 shows that the averaged trend of the whole dataset amounts to 3.4 mm/yr over the 2002-2024 time span, and the associated standard deviation is 1.39 mm/yr. The mean trend error based on the least-squares fit amounts to 0.7 mm/yr but more realistic trend errors are presented in Tolu et al. (2026).

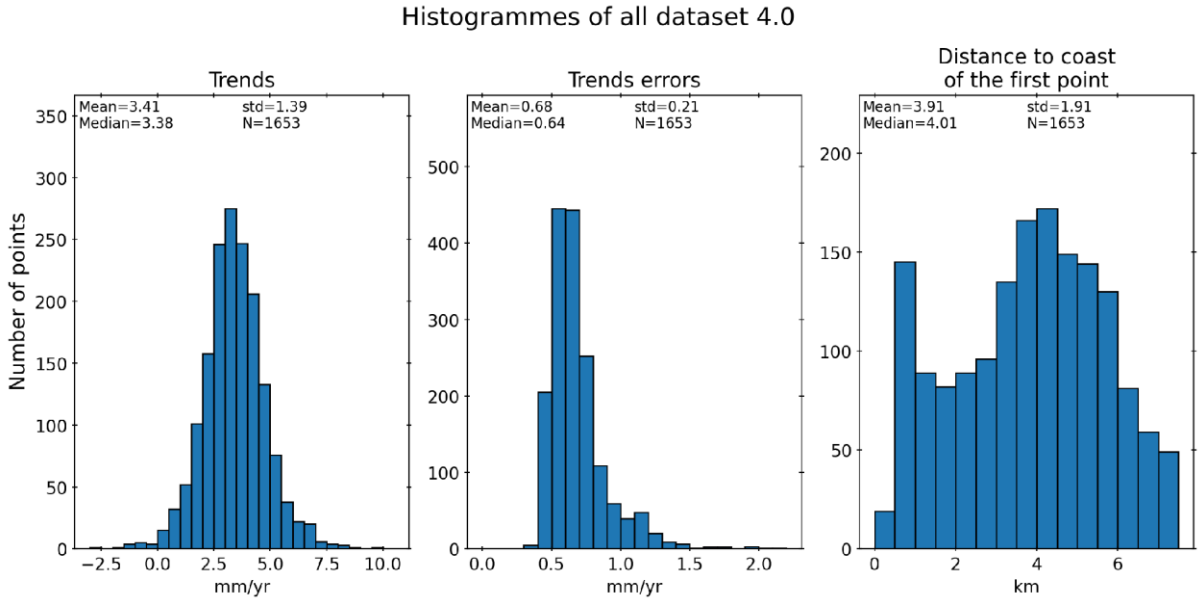

Figure 3: Histograms of the trends (left panel), trend errors (from the least-squares fit; middle panel) and distance of the closest along-track point to the coast (right panel). Trends and trend errors (in mm/yr) are averaged over 2 km from the closest first points to the coast. Distances are in km.



3. Validation of the V4.0 version

In this section the SL_cci v4 solution is compared both in terms of time series and trends with different products: the gridded C3S DT2024 data, the IAS dataset (Peng et al., 2026) and tide gauge records. Two approaches are performed: (1) the DT2024 and IAS data are compared with the SL_cci v4 product using the SL_cci v4 virtual stations positions as reference, and (2) SL_cci v4, DT 2024 and IAS data are compared to tide gauge records at tide gauge sites colocated with the SL_cci v4 virtual stations (within 60 km). For the interannual time scale comparison, all time series are linearly detrended.

3.1. Datasets used for the v4.0 validation

3.1.1. Grided altimetry data

We used the monthly mean 0.25°×0.25° gridded altimetry-based sea level anomaly (SLA) data, version DT2024, downloaded from the Copernicus Climate Change Service (C3S) (https://cds.climate.copernicus.eu/; Climate Data Store, 2018; 10.24381/cds.4c328c78) and based on the 2024 version of Level-2P input data (Kocha et al., 2026). The data set is based on a steady two-satellite merged constellation at all time steps: one satellite ensures the long-term stability of the data record (i.e., Topex/Poseidon/Jason series, Sentinel-6A MF) and the other satellite is used to improve accuracy, sample mesoscale processes and provide coverage at high latitudes. The DT2024 data set is not corrected for the absolute Glacial Isostatic Adjustment (GIA) effect. Hence, in this work, we further applied the absolute GIA correction of the ICE6G-D model from Peltier et al. (2018) to the C3S gridded SLAs. This data set is used over the January 2002 to December 2024 time span.

3.1.2. IAS 2024 coastal sea level product

This high-resolution along-track sea level dataset has been produced by the International Altimetry Service team (Peng et al., 2023, 2024, 2025). Only Jason-1, Jason-2 and Jason-3 missions are considered, covering the January 2002 to April 2022 time span. The data consists of 1548 virtual stations but for the comparison with the SL_cci v4 data, only the common 1122 virtual stations are considered.

3.1.3. Tide gauge data

Monthly values of tide gauges records from the Permanent Service for Mean Sea Level (PSMSL, https://www.psmsl.org, Holgate et al., 2013) are used. Only tide gauge records with at least 80 % of valid data over the January-2002-December 2024 time



span are considered. To be consistent with altimetry data, tide gauges data are corrected for atmospheric loading, using the same correction applied to altimetry data (see section 3.3). Finally, outlier removal is performed by suppressing values outside the 3 times z-score envelope where $z = \frac{x-\mu}{\sigma}$, is the z-score, x the series values, μ the mean of the series and σ the standard deviation of the series.

Monthly averages are computed for all sea level data sets. In the case of the SL_cci v4 and IAS products, this means that the monthly averages of the original 10-day data are based on at most 4 orbital cycles. The seasonal (annual and semi annual) cycles are further removed by simple least-squares fit of 6- and 12-month sinusoids to the altimetry and tide gauge data.

3.1.4. GNSS vertical land motions (VLMs)

For the GNSS-based vertical land motions (VLMs), we use data available from the Système d'Observation du Niveau des Eaux Littorales (SONEL) database (https://www.sonel.org/-GPS-24-.html?lang=fr). GNSS solutions from four processing centers are provided : University of La Rochelle (ULR), Nevada Geodetic Laboratory (NGL), Jet Propulsion Laboratory (JPL) and the German Research Centre for Geosciences (GFZ). For this study, we only consider the ULR20 and NGL20 solutions because at the time of this study, only these solutions are expressed in the ITRF (International Terrestrial Reference Frame) 2020 reference frame (Altamimi et al., 2023). These consist of monthly time series covering short time spans of a few years only. We selected solutions showing quasi linear variations over time in order to be able to extrapolate the VLMs over the 2002-2024 time span considered in this study.

3.2. Comparison between the SL_cci (version v4) SLAs with the C3S DT2024 and IAS data sets

For this comparison, the DT2024 grids are interpolated over each SL_cci v4 virtual station track; 1403 sites are retained, where both gridded data and CCI along-track data are available. We also select IAS virtual stations colocated with the SL_cci v4 virtual stations and, in this case, only IAS product along-track points common with those of the SL_cci virtual station are considered. In the end, there are 1122 common sites for the comparison between IAS and SL_cci v4 products.

3.2.1. Detrended time series

Figure 4 shows histograms (left panels) and geographical maps (right panels) of RMSE (root mean squares error) of differences between the detrended SL_cci SLAs time series over 2002-2024 and interpolated time series from the gridded product (upper panels) and along-track IAS data (lower panels). **Figure 4a, b indicates that the**

difference time series between SL_cci v4 and DT2024 data interpolated at 1403 sites of the virtual station network have a mean of RMSE of 39.92 mm. On the other hand, the RMSE of the SL_cci v4 minus IAS time series amounts to 69.33 mm (1122 common sites, Figure 4 c,d). In the latter case, the largest differences between the two along-track products are seen in the North Sea, Baltic Sea, Red Sea and Southeast Asian seas and north of Australia.

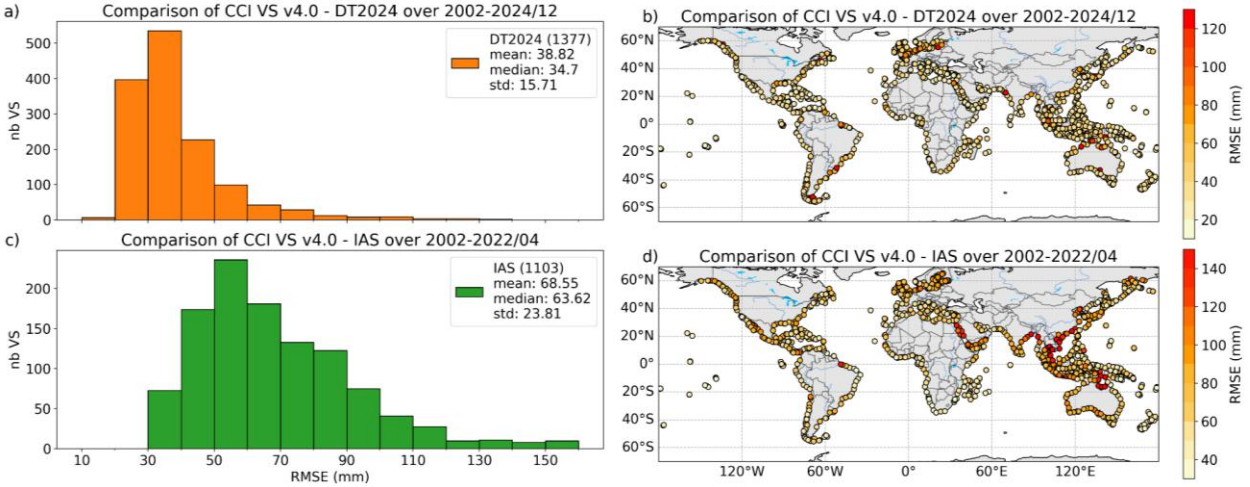

Figure 4: RMSE (mm) of the differences between SL_cci v4 data and gridded DT2024 altimetry data (a,b), and IAS data (c,d), at their common virtual station sites. Left panels : histograms. Right panels: geographical maps.

In Figure 5 are presented correlations between the detrended time series for the three data sets. Histograms (left panels) and the geographical maps (right panels) of the correlations between SL_cci v4 and DT2024 time series (Figure 5a, b) and IAS time series (Figure 5 c,d) are shown at their common virtual station sites. **A slightly higher mean correlation is noted with the DT2024 gridded product than with the IAS data (0.7 versus 0.6). But although the gridded product shows the highest mean correlation, the dispersion is higher, and at some sites the correlation is very low.**

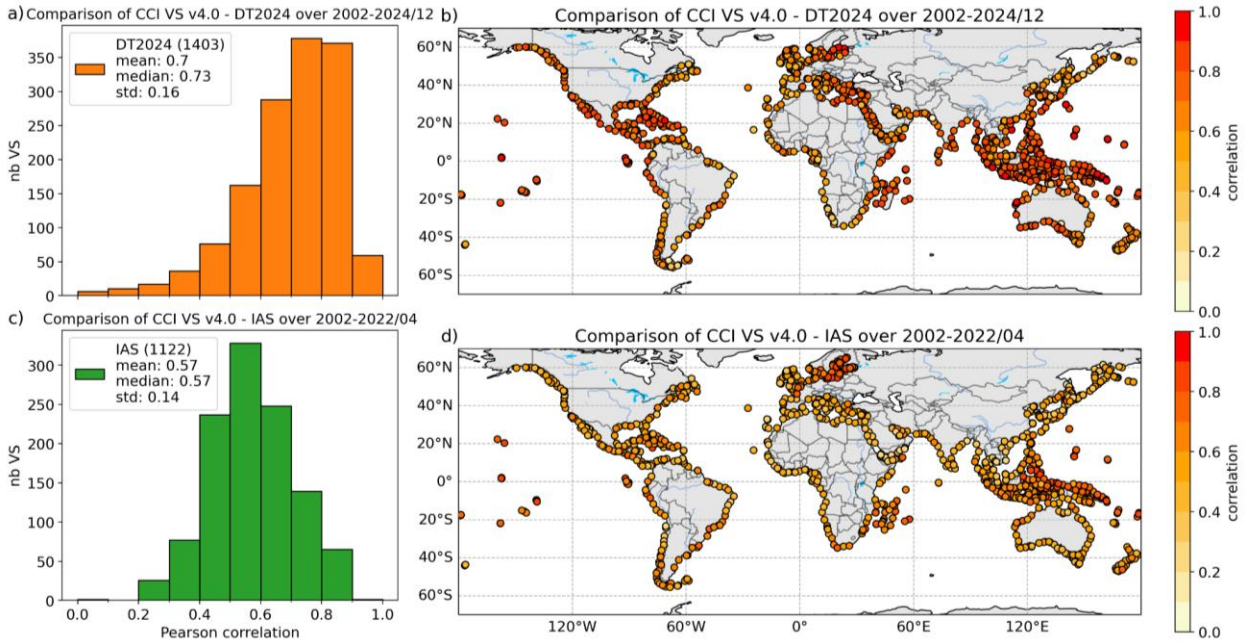

Figure 5: Correlation of the gridded DT2024 altimetry and IAS data with SL_cci v4 data at their common virtual stations. Left panels : histograms. Right panels: geographical maps.

3.2.2. Comparison of absolute trends between altimetry-based sea level data from SL_cci with products from C3S (DT2024) and IAS

Absolute trends of the SL_cciCCI v4 product are compared with trends estimated with gridded DT2024 and IAS data. Figure 6 shows histograms of the trend differences between the datasets (Figure 6a, c) and maps of the trend differences (Figure 6b, d). **Figure 6a indicates that the SL_cci v4 data and the gridded altimetry product have a small mean trend difference of -1.1 mm/yr. On the other hand, the mean trend difference with IAS data is 0.3 mm/yr, although the standard deviation is much higher, amounting 2.33 mm/yr (Figure 6c).**

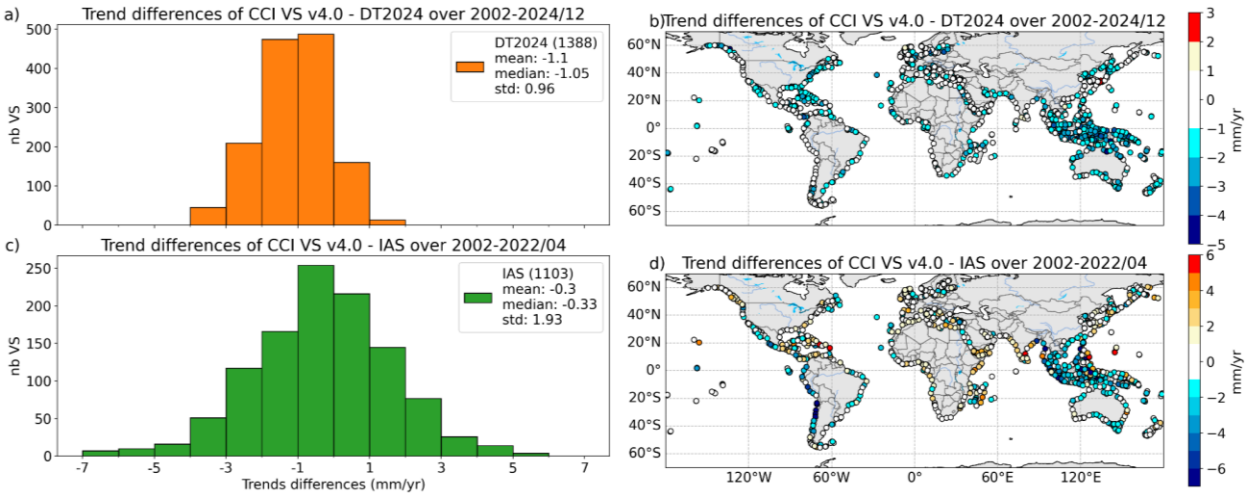

Figure 6: Trend differences (mm/yr) between the gridded C3S DT2024 altimetry product, IAS product and the SL_cci v4 product. Left panels : histograms. Right panels: geographical maps.

3.3. Comparison of detrended tide gauges records with detrended SL_cci (version v4) SLAs , C3S DT2024 and IAS data (interannual time scale)

Here we compare detrended SL_cci v4, DT 2024 and IAS SLAs time series with detrended tide gauges data. Tide gauges located at less than 60 km from a SL_cci virtual station and with more than 80% of valid data over January 2002 to December 2024 are selected. The IAS virtual stations considered here are located at the same position as the SL_cci virtual stations. For the IAS dataset the time span of comparison ends in April 2022.

DT2024 grids are interpolated along the SL_cci track segment for each virtual station colocated with a tide gauge. **Figure 7a, b, c shows that the C3S DT2024 product has the smallest RMSE with the tide gauge data, with an averaged value of 31.9. mm and the smallest standard deviation (16.4 mm). For the along-track products, the SL_cci v4 and the IAS products have an averaged RMSE of respectively 55.7 mm and 82.9 mm. The standard deviations of the RMSE values are respectively 23 mm and 24.5 mm.**

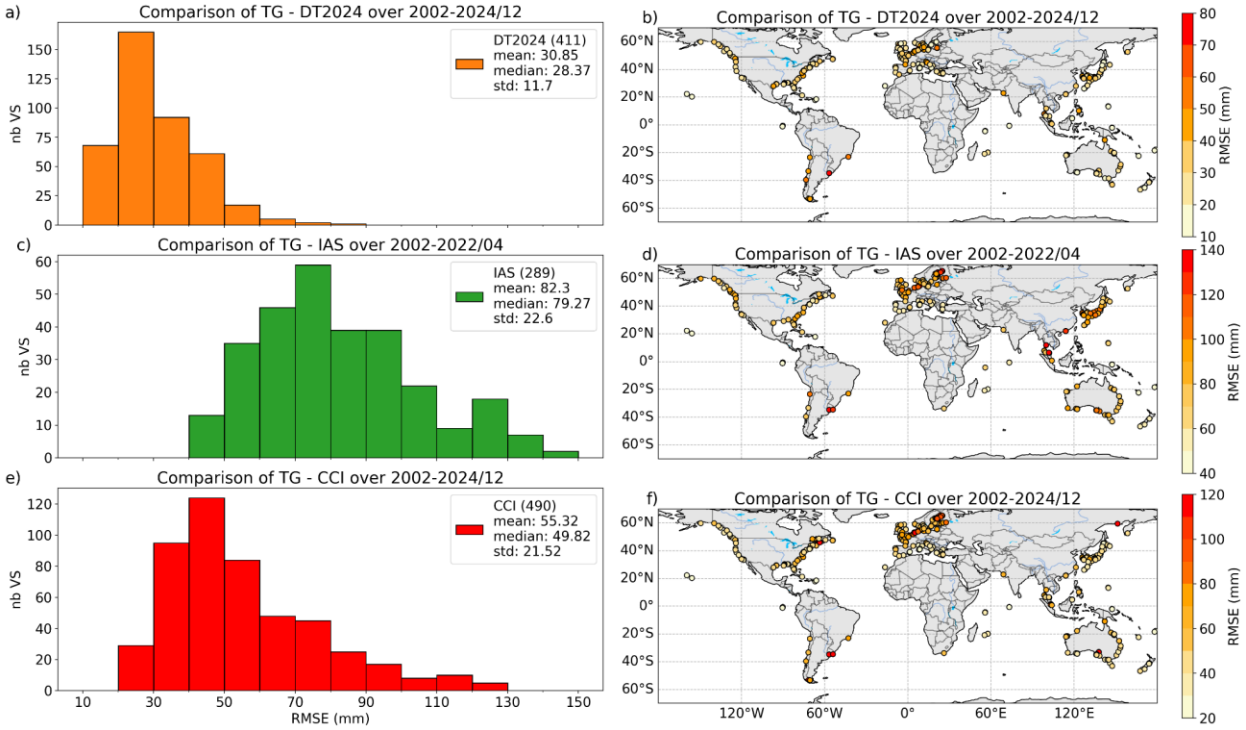

Figure 7: RMSE (mm) of the gridded DT2024 altimetry product, IAS and SL_cci v4 along-track virtual stations, compared to tide gauge records. Left panels: histograms. Right panels: geographical maps.

Figure 8 shows the correlations between the three detrended SLA time series and detrended tide gauge records. **We note that the C3S DT2024 altimetry product displays the highest correlations with the tide gauge data, with an averaged value of 0.75.** For the along-track data sets, the SL_cci v4 and the IAS products have an averaged correlation with the tide gauge data of 0.58 and 0.46 respectively.

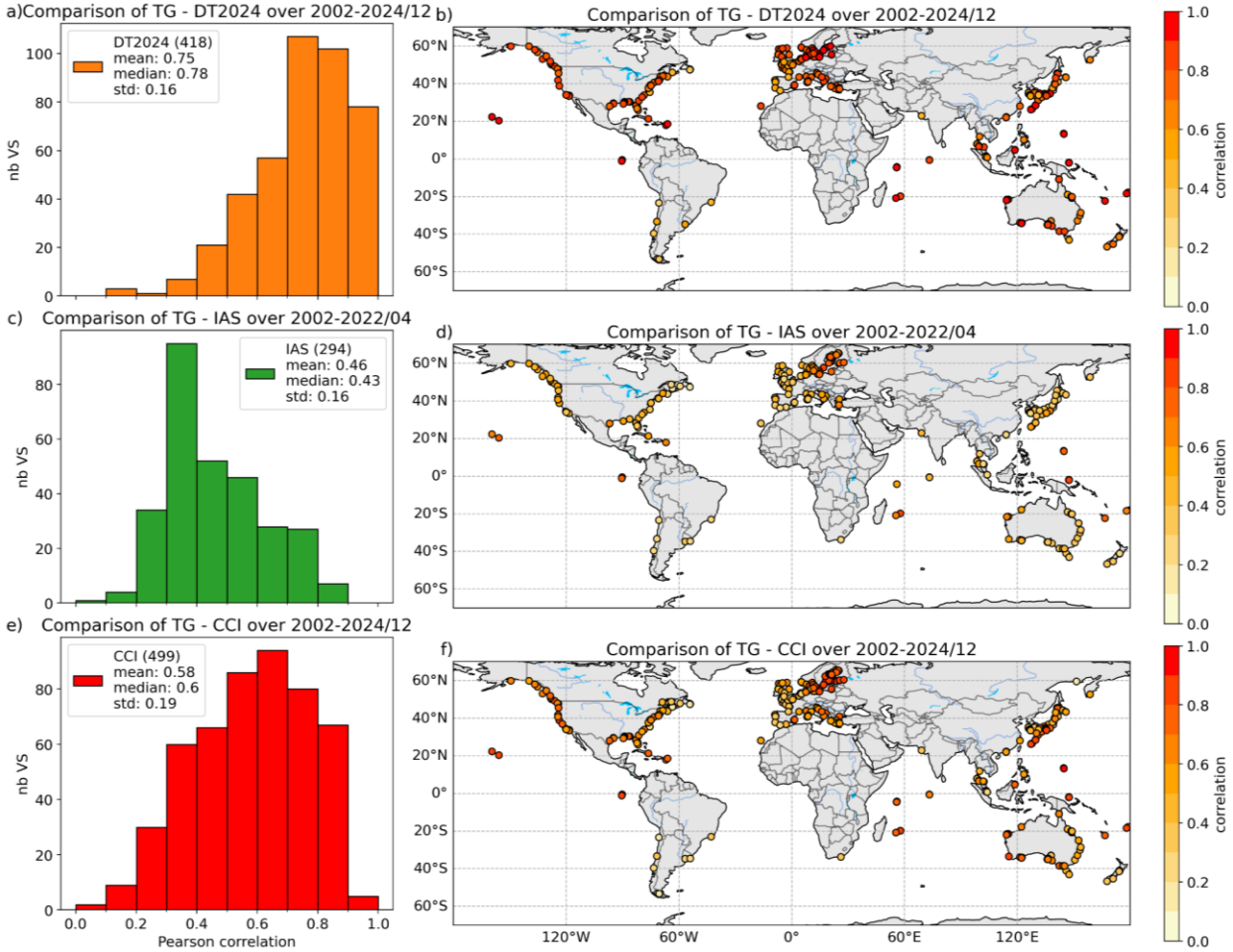

Figure 8: Correlation at their common sites between detrended gridded DT2024 altimetry product, IAS and SL_cci v4 along-track coastal virtual stations with detrended tide gauge records. Note that the number of common sites is different from one case to another. Left panels : histograms. Right panels: geographical maps.

It is worth noting that the apparent better agreement between the gridded C3S DT2024 and tide gauge data, compared to the along-track products can be explained by the different temporal sampling of the data sets: (1) monthly tide gauge data are based on averages of hourly (or higher frequency) data, (2) monthly C3S DT2024 data result from daily interpolated data, (3) the monthly SL_cci v4 and IAS averages are based on at most four orbital cycles of 10-day duration, hence at most four values for the averaging, but most of the time only two and three. Thus, these monthly averages do not capture the same sea level dynamics, with the SL_cci v4 and IAS monthly data displaying more temporal variability, with a broad range of timescales (Cazenave et al., 2026). Sea level variability along the coastline

is impacted by several near-coastal processes and ocean adjustment mechanisms in shelf seas (Cipollini et al., 2018; Durand et al., 2019; Woodworth et al., 2019; Cazenave et al., 2026), including ocean tides, local atmospheric effects or coastal trapped waves, coastal currents, and freshwater transport in estuaries. In addition, remote steric changes and open ocean mass transport contribute to the changes in near coastal sea level variability (Cazenave et al., 2026).

3.4. Use of SL_cci SLA time series to complete nearby tide gauge records with numerous data gaps

Here we show that the SL_cci v4 SLA time series can be used to complete tide gauge records that display many data gaps. To perform the completion of the tide gauge time series, we consider tide gauge records with at least 20% of valid data over the study period. Figure 9 shows that, among the 715 tide gauges located at less than 60 km from a virtual station, 485 have more than 80% of valid data. 230 tide gauges have more than 20% of data and less than 80%.

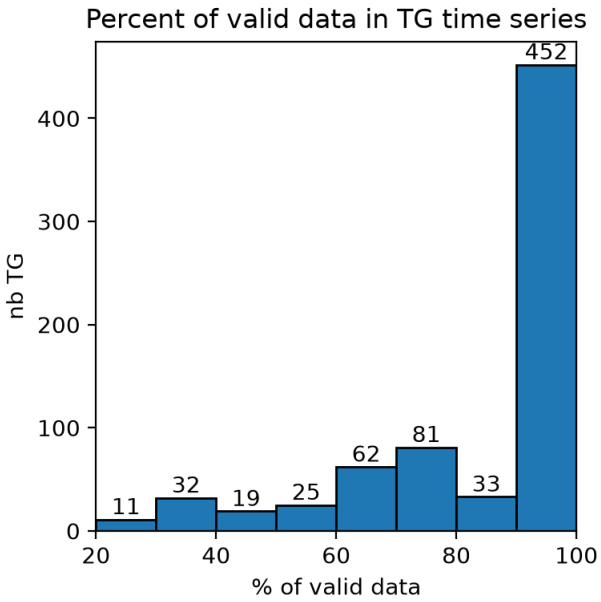

Figure 9: Histogram of the percentage of valid data in the tide gauges (TG) time series from January 2002 to December 2024.

Figure 10a, b presents two examples of tide gauge records completed with SL_cci v4 SLA time series: Kiribati Islands in the equatorial Pacific and along the coast of Denmark in the North Sea.

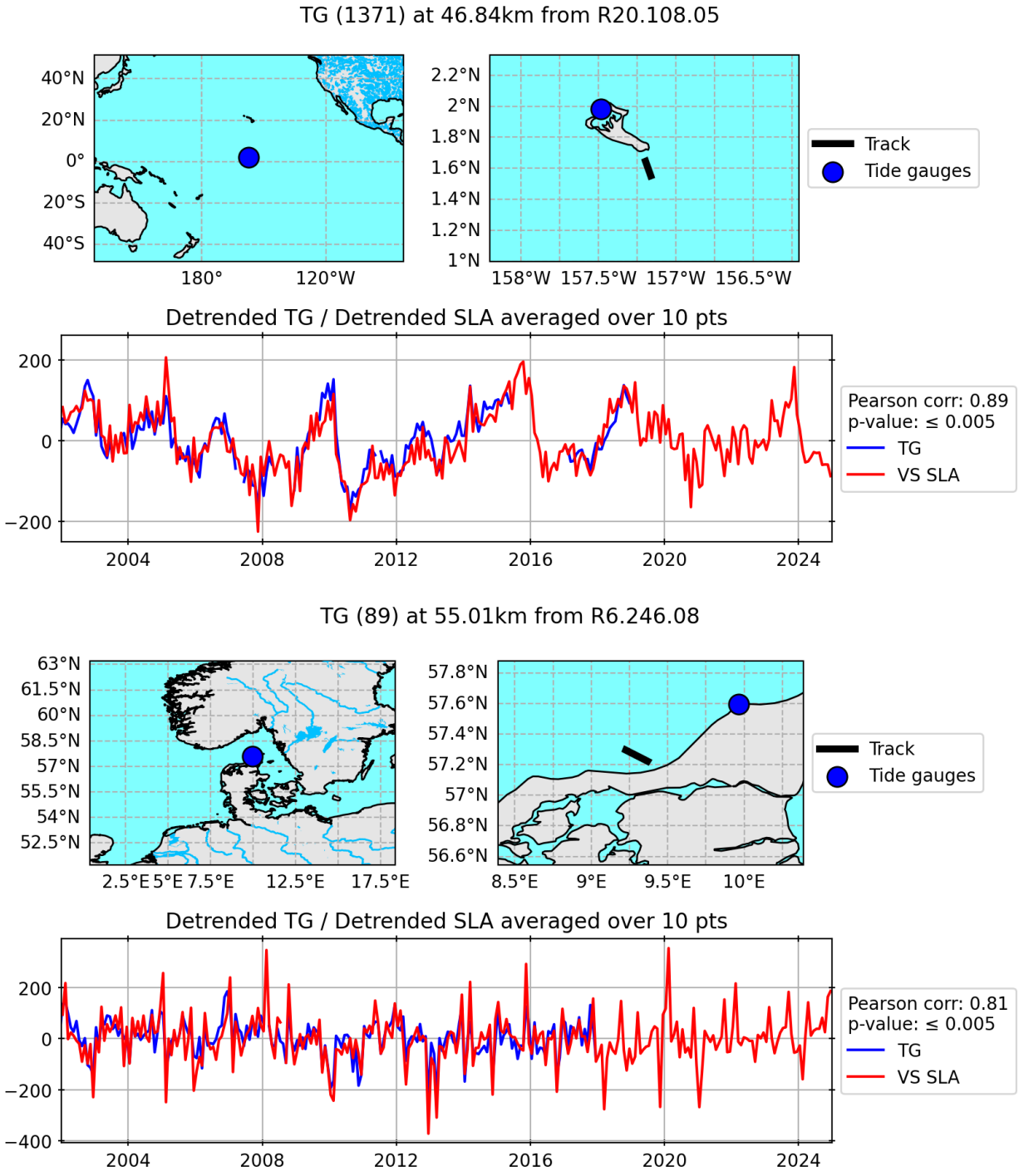

Figure 10: Detrended SL_cci SLA time series (red curve) and detrended tide gauge record (blue curve) over 2002-2024, at the Kiribati Islands, equatorial Pacific (a) and along the coast of Denmark, North Sea (b). The correlation between the two time series over their overlapping time span is indicated.

The above examples demonstrate that gaps in the tide gauge records can be filled with the coastal altimetry data with great confidence, improving the availability of sea level information for decision about adaptation strategies in regions already

impacted by present-day sea level rise, in particular in low-laying small islands with limited instrumental records. Improved and extended tide gauge data will provide crucial information for calibration and validation numerical models, commonly used for simulation of future coastal sea level changes.

4. Relative sea level trends at the virtual stations

In this section, we estimate relative sea level trends at the virtual stations located nearby tide gauges colocated with GNSS stations. As explained in section 2, for correcting the altimetry-based sea level trends for the VLMs, here we only consider the GNSS solutions from the ULR and NGL centers, as available from the SONEL database (https://www.sonel.org).

For computing the relative sea level trends at the virtual stations and further comparing with tide gauge trends, two conditions are imposed :

(1) the tide gauge- and virtual station-based sea level time series are both almost complete (with at least 80% of data) over the 2002-2024 time span

(2) the GNSS time series display quasi linear trends, no gap, and at least 5 years of data

The second condition is based on the meticulous visual examination of the GNSS-based VLM time series. In the case of complex temporal behavior, large gaps or too short record length, the estimated VLMs are considered non reliable for correcting altimetry-based absolute sea levels.

Applying the above two constraints, we have selected a list of 70 tide gauge-virtual station sites. The absolute sea level trends at the virtual stations are corrected for the VLM trends considering both the ULR and NGL GNSS trend solutions. The corresponding 'relative' trends are further compared to the tide gauge trends. Results are gathered in Table S1 of the Supplementary Information. They include the differences between VLM-corrected trends at the virtual stations for the two GNSS solutions, as well as tide gauge trends.

The location of the tide gauge sites colocated with a GNSS station selected for this analysis is presented in Figure 11 (with colors indicating the differences between VLM-corrected trend at the virtual stations and the tide gauge trends). Most tide gauges colocated with a GNSS station are located in the northern hemisphere. Figure 12 shows the histogram of the differences in the computed relative sea level trends for the two GNSS solutions. **From figures 11 and 12, we note that most relative trend differences are within -1 and +2 mm/yr, with a peak between 0 and + 1 mm/yr.**

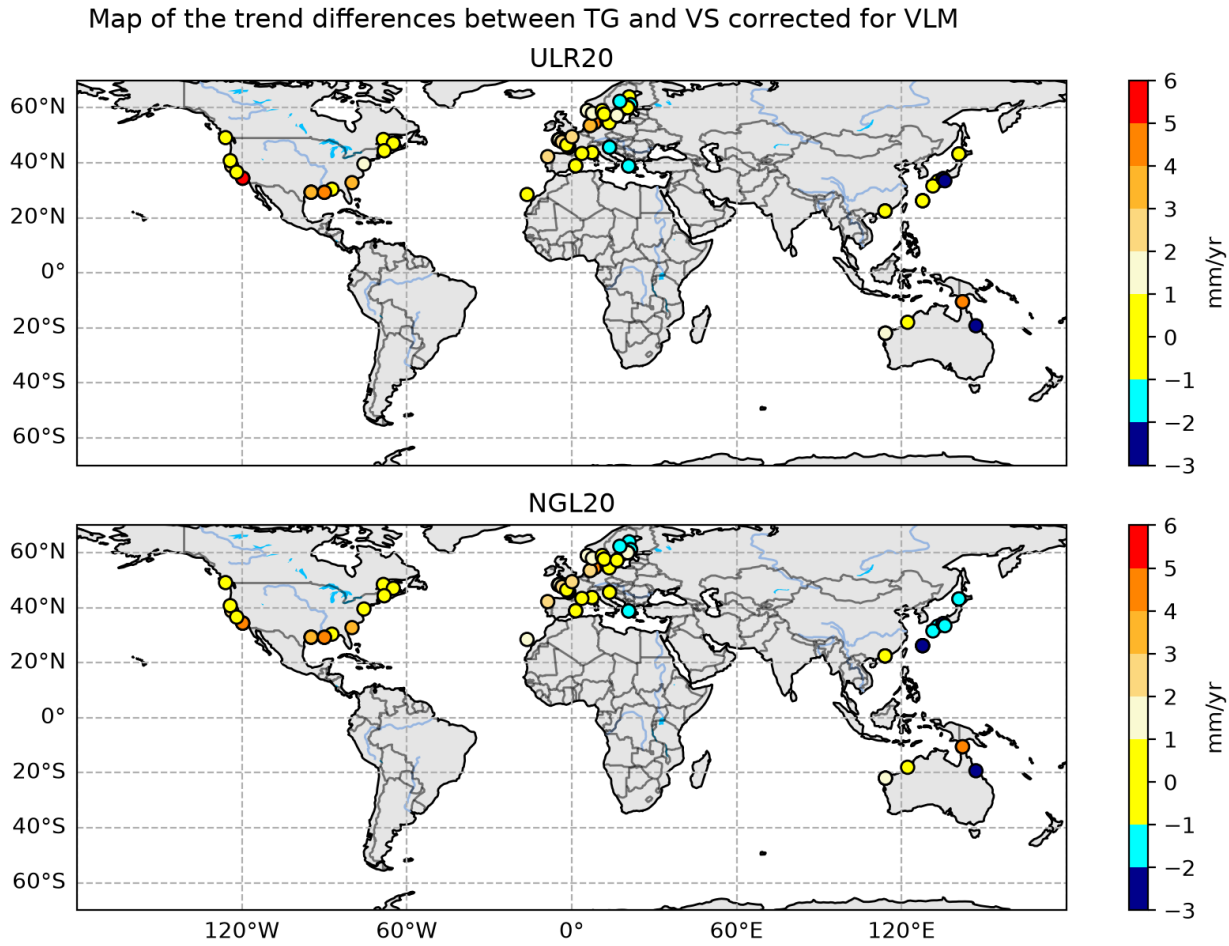

Figure 11: Map showing the location of the tide gauge sites colocated with a GNSS station selected for this analysis (70 sites among the 485 tide gauge sites located at less than 60 km from a virtual station). The colored circles represent the differences in mm/yr between the tide gauge trends and the relative trends at the virtual stations over 2002 and 2024 (SL_cci v4 absolute trends corrected for the GNSS-based VLMs (upper panel: URL20 solution; lower panel: NGL20 solution).

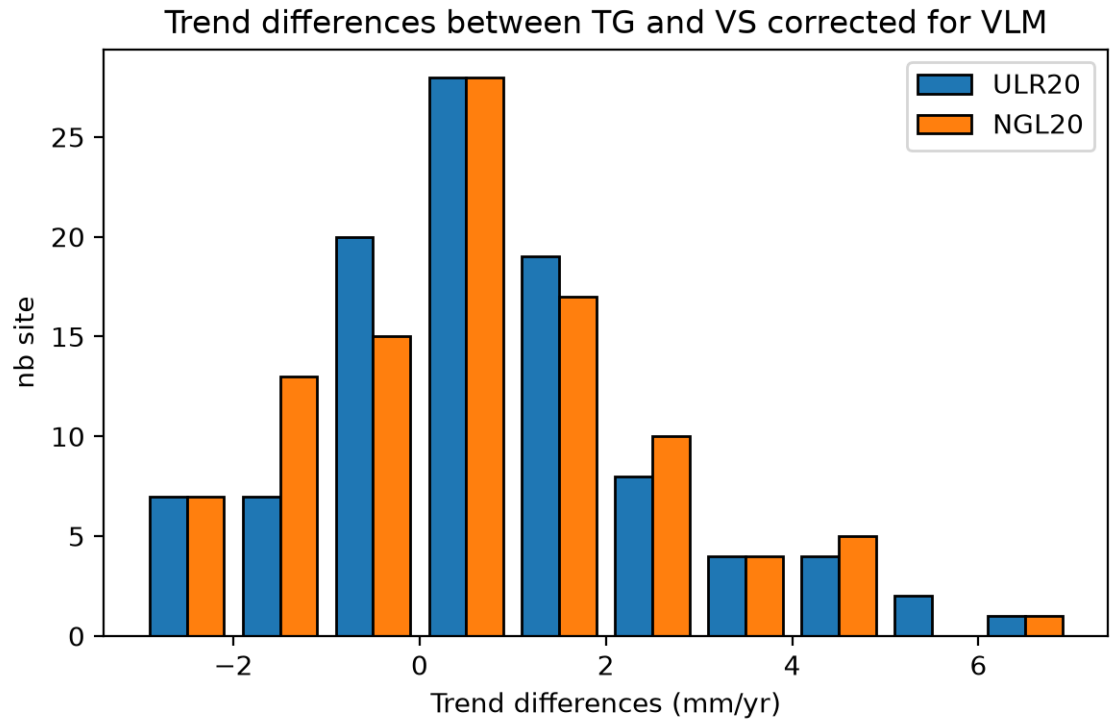

Figure 12: Histogram of the differences between VLM-corrected sea level trends at the virtual stations and TG trends estimated over 2002-2024.

5. Conclusion

We have described the latest version (v4) of the SL_cci coastal sea level product, based on the reprocessing of the Jason-1, 2, 3 and Sentinel-6A MF altimetry data in the world coastal zones, as well as its validation.

This v4.0 version differs from the early published versions (e.g., Benveniste et al., 2020, Cazenave et al., 2022) by a spatio-temporal extension of the data (additional regions and temporal extension using the data from the Sentinel-6A MF mission, as well as by a number of improvements in the geophysical corrections and data processing. Sea level time series over January 2002 to December 2024 and estimated sea level trends over the study time span are provided along 1653 satellite track segments from 20 km offshore to the coast, with an along-track resolution of about 350m. The corresponding 1653 virtual coastal stations are located at an average distance of 4 km from the coastline, sometimes at less than 1 km. Such a data set usefully completes the international tide gauge network that suffers from incomplete spatial coverage, in particular in the southern hemisphere, as well as from temporal gaps in many records.

Although limited to along-track measurements, this altimetry-based coastal sea level data set might be much useful to decision makers in charge of developing adaptation



and mitigation strategies to face the many environmental risks affecting coastal regions because of climate change, geohazards and human activities, especially in populated world's coastal zones. In effect, in addition to completing the limited tide gauge network, such coastal data provide additional information on sea level variations very close to the coast that current gridded products do not carry due to their lower resolution. Besides, such novel coastal data might be highly useful to validate high-resolution hydrodynamical models. Although still very few of such high-resolution models are currently available, once validated with altimetry-based coastal data, will contribute to improved small-scale process understanding. In effect, coastal sea level changes result from the combination of the global mean rise, regional variations and small-scale coastal processes, the latter being in general very poorly known and may vary from one virtual station to another. The models may also be run in forecast mode to predict how coastal sea level will evolve in the future, again a critical information to adaptation purposes.

As final remarks, it should be noted however that altimetry-based measurements only inform on absolute (climate-related) sea level change while for adaptation to sea level rise impacts, the quantity of interest is relative sea level, i.e., the combined effects of absolute sea level change and VLMs. This means that for some applications, virtual stations need to be colocated with GNSS stations, as are some tide gauge sites. The largest limitation of the along-track coastal altimetry data set presented here is the large intertrack distance (300 km in equatorial regions), hence large along-coast gaps between successive virtual stations. Use of additional satellite altimetry missions on different orbits may improve the coastline coverage. The most promising perspective here is the use of data from the SWOT (Surface Waters Ocean Topography; Fu et al., 2024). SWOT, launched in 2022, embarks novel altimetry technology (a radar interferometer, Rodriguez et al., 2018), allowing 2 km resolution over two 50 km wide swaths on each side of the satellite track, thus providing unprecedented 2-dimensional coverage of the oceanic domain, including of the coastal zones (Morrow et al., 2019). Hence, SWOT provides much higher cross-track resolution and sea level measurements much closer to the coast than traditional nadir altimeters. SWOT observations along the coast will thus allow data continuity between adjacent satellite tracks, hence between virtual stations. Although the SWOT data record is still short, it will provide unprecedented information on the coherence (or lack of it) of along-coast sea level variations on a few years' time scale, and even on longer-term changes as the SWOT record length increases.

6. references

Altamimi, Z., Rebischung, P., Collilieux, X., Métivier, L., & Chanard, K., ITRF2020: An augmented reference frame refining the modeling of nonlinear station motions.



Journal of Geodynamics, 97(47), 47. https://doi.org/10.1007/s00190-023-01738-w, 2023.

Benveniste, J., Birol, F., Calafat, F., Cazenave, A., Dieng, H., Gouzenes, Y., Legeais, J. F., Léger, F., Niño, F., Passaro, M., Schwatke, C., and Shaw, A.: Coastal sea level anomalies and associated trends from Jason satellite altimetry over 2002–2018, Sci Data, 7, 357, https://doi.org/10.1038/s41597-020-00694-w, 2020.

Cazenave, A., Gouzenes, Y., Birol, F., Leger, F., Passaro, M., Calafat, F. M., Shaw, A., Nino, F., Legeais, J. F., Oelsmann, J., Restano, M., and Benveniste, J.: Sea level along the world's coastlines can be measured by a network of virtual altimetry stations, *Commun Earth Environ*, 3, 117, https://doi.org/10.1038/s43247-022-00448-z, 2022.

Cazenave A., Almar, R., Almeida, P. et al., Present-day sea level variations in coastal areas from daily to multi decadal time scales; Observations and causes, *Surveys in Geophysics*, https://doi.org/10.1007/s10712-026-09956-5, 2026.

Cipollini, P.; Benveniste, J.; Birol, F.; Fernandes, M.J.; Obligis, E.; Passaro, M.; Strub, P.T.; Valladeau, G.; Vignudelli, S.; Wilkin, J. Satellite altimetry in coastal regions. In Satellite Altimetry Over the Oceans and Land Surfaces; Stammer, D., Cazenave, A., Eds.; CRC Press: Boca Raton, FL, USA; London, UK; New York, NY, USA; pp. 343–373, 2018.

Copernicus Climate Change Service, Climate Data Store: Sea level gridded data from satellite observations for the global ocean from 1993 to present, https://doi.org/10.24381/cds.4c328c78, 2018.

Durand, F., Piecuch, C.G., Becker, M., Papa, F., Raju, S.V., Khan, J.U., Ponte, R.M., Impact of Continental Freshwater Runoff on Coastal Sea Level. *Surv Geophys* 40, 1437–1466. https://doi.org/10.1007/s10712-019-09536-w, 2019 .

Fu, L.-L., Pavelsky, T., Cretaux, J.-F.,Morrow, R., Farrar, J. T., Vaze, P., et al., The Surface Water and Ocean Topography Mission: A breakthrough in radar remote sensing of the ocean and landsurface water. *Geophysical Research Letters*, 51, e2023GL107652. https://doi.org/10.1029/2023GL107652, 2024.

Holgate, S.J., Matthews, A., Woodworth, P.L., Rickards, L.J., Tamisiea, M.E., Bradshaw, E., Foden, P.R., Gordon, K.M., Jevrejeva, S., Pugh. New Data Systems and Products at the Permanent Service for Mean Sea Level. *Coastal Research.*, 29, 493–504. https://doi.org/10.2112/JCOASTRES-D-12-00175.1, 2013.

Kocha, C., Liévin, M., Pageot, Y., Rubin, C., Quet, V., Octau, F., et al., Three decades of sea level multi-mission satellite data reprocessed to improve mesoscale quality while ensuring climate scale consistency. *Earth System Science Data Discussions*, 1–40. https://doi.org/10.5194/essd-2025-604, 2026.



Leclercq L., Cazenave A., Leger f., Birol F. Passaro M., Nino F. Tolu L., Legeais J.F., Jevrejeva S. and Connors S., Global network of virtual coastal stations from altimetry-based sea level data, submitted, ESSD, 2026.

Morrow R. et al.. Global Observations of Fine-Scale Ocean Surface Topography With the Surface Water and Ocean Topography (SWOT) Mission, *Frontiers in Marine Science*, 6, 2019.

Peltier, R. W., Argus, D. F., and Drummond, R.: Comment on "An assessment of the ICE-6G_C(VM5a) glacial isostatic adjustment model" by Purcell et al., *J. Geophys. Res.-Solid Earth*, 123, 2019-2028, 2018.

Peng, F. K., Deng, X. L., Jiang, M. F., Dinardo, S., and Shen, Y. Z.: A new method to combine coastal sea surface height estimates from multiple retrackers by using the Dijkstra algorithm, Remote Sens., 15, 2329, https://doi.org/10.3390/rs15092329, 2023.

Peng, F., Deng, X., Shen, Y., and Cheng, X.: IAS2024 coastal sea level dataset, , https://doi.org/10.5281/ZENODO.13208305, 2024.

Peng, F., Deng, X., Shen, Y., and Cheng, X., The International Altimetry Service 2024 (IAS2024) coastal sea level dataset and first evaluations, *Earth System Science Data*, 17, 1441–1460, https://doi.org/10.5194/essd-17-1441-2025, 2025.

Tolu et al., Quantifying uncertainties in coastal sea level trends estimates using Jason altimetry observations (2002-2021), submitted, *Scientific Data*, 2026.

Woodworth, P.L. et al., Forcing Factors Affecting Sea Level Changes at the Coast. *Surveys in Geophysics*, 40, 1351–1397, https://doi.org/10.1007/s10712-019-09531-1, 2019.



End of the document