SAGSA

BARYSTATIC AND MANOMETRIC SEA LEVEL DATASETS
PRODUCT USER MANUAL

	Name	Organisation	Date	Visa
Written by:	Alexandre Boughanemi, Marie Bouih, Julia Pfeffer	Magellium	07/07/2026	
Checked by:	Frédéric Thoumieux Alejandro Blazquez	CNES	16/07/2026	AB FT: Lu
Approved by:	Gerald Dibarboure Cyril Germineaud	CNES	16/07/2026	GD:Lu CG: Lu

Document reference:	SAGSA-DT-27-MAG_PUM_Produits_Océan
Edition.Revision:	V1.6
Date Issued:	07/07/2026
Customer:	CNES
Ref. Market, consultation:	MARCHÉ N° 241698/00

Document evolution sheet

Ed.	Rev.	Date	Purpose evolution	Comments
1	0	01/02/2023	Creation of document	
1	2	15/02/2023	Release of first product version (v1-0)	Calculation of barystatic and manometric sea level changes using an ensemble of GRACE solutions with 240 solutions, including: - 5 processing centers (CSR, JPL, GFZ, ITSG CNES), - 4 geocenter models (Lemoine and Reinquin, 2017, Dahle et al., 2012, Uebbing et al., 2019, Sun et al., 2016), - 3 oblateness (C20) models (Lemoine and Reinquin, 2017 updated with combined SLR and GRACE measurements) - 2 GIA models (Peltier et al., 2018; Caron et al., 2018)) - 2 filters (DDK6 and DDK3 applied on all ensemble members except CNES) Calculation of barystatic and manometric sea level changes using the combination of altimetry product (C3S) and steric products (EN4, Ishii, IAP)
1	3	27/04/2023	Release of new product version (v2-0)	Use of a new ensemble of GRACE solutions with 120 solutions, including: - 5 processing centers (unchanged), - 2 geocenter models (***Lemoine and Reinquin, 2017 updated using a 7-month lowpass filter*** ; Sun et al., 2016 unchanged) - 3 oblateness (C20) models (***Lemoine and Reinquin, 2017 updated with combined SLR and GRACE measurements***) - 2 GIA models (***same models recalculated using correct Love numbers***) - 2 filters (DDK6 and DDK3 applied on all ensemble members ***including*** CNES) Use of an ***updated mask*** to compute the barystatic component with the sea level budget approach.

				Application of the ***correction for deep ocean*** to the thermosteric component in the sea level budget approach. No changes to the SLB manometric product.
1	4	28/05/2024	Release of new product version (v4-0)	**The barystatic and manometric datasets V4.0 are calculated based on the GRACE ensemble L3 V2.0 produced by Magellium and the CNES**. • The GRACE ensemble L3 was generated using a new Python code, PANIS, owned by the CNES and developed by the CNES and Magellium. • The GRACE ensemble L3 V2.0 was corrected for errors in the low-degree coefficients and the conversion of Stokes coefficients to gridded equivalent water heights. • The GRACE ensemble L3 V2.0 was extended until September 2023. No changes to the SLB barystatic and manometric products.
1	5	27/11/2025	Release of new product version (GRACE V5-0 and SLB/OMB V3-0)	**The barystatic and manometric datasets V5.0 are calculated based on the GRACE ensemble L3 V2.1 produced by Magellium and the CNES**. • The GRACE ensemble L3 was generated using PANIS v1.1.0, owned by the CNES and developed by the CNES and Magellium. • The GRACE ensemble L3 V2.1 was generated without an apriori. • The degree-1 coefficients were corrected using three estimates based on the TN13a, b and c. • The GRACE ensemble L3 V2.1 was extended until August 2025. **The SLB/OMB barystatic dataset V3.0 is calculated based on the SLBC CCI+ dataset produced in the scope of the ESA SLBC CCI+ project.**
1	6	18/06/2026	Release of new product version (GRACE V6-0)	**The barystatic and manometric datasets V6.0 are calculated based on the GRACE ensemble L3 V2.2 produced by Magellium and the CNES**. • The GRACE ensemble L3 V2.2 was generated using PANIS v1.2.0.

				• Leakage was corrected zonally using the mean_mass_model method. • The C00 coefficient of GAA was set to zero. • The GRACE ensemble L3 V2.2 was extended until February 2026. No changes to the SLB and OMB barystatic products.

Table of contents

1 Introduction **5**
2 Methodology **6**
2.1 GRACE and GRACE-FO Datasets 6
2.1.1 Manometric sea level changes 6
2.1.2 Barystatic sea level changes from GRACE data 9
2.2 Sea Level And Ocean Mass Budget Datasets 10
2.2.1 Sea level budget approach 10
2.2.2 Ocean mass budget approach 11
3 PRODUCT DESCRIPTION **13**
3.1 Spatial information 13
3.2 Temporal information 13
3.3 File format 13
3.4 File naming convention 13
3.5 Product content 14
3.5.1 Dimensions 14
3.5.2 Variables 14
3.5.3 Metadata 16
4 REFERENCES **17**

1 Introduction

The Product User Manual (PUM) provides estimates of the mass contributions to sea level change, along with their associated uncertainties, over the satellite gravimetry period (April 2002 – February 2026) and the satellite altimetry period (January 1993 – June 2023). Following Gregory et al. (2019), we define local and global mass contributions to sea level change as the manometric and barystatic components, respectively.

Manometric sea level changes are available online as fully documented, ready-to-use three-dimensional grids (time, latitude, longitude) interpolated to a monthly, one-degree resolution. It should be noted that the effective resolution of satellite gravity-based products is on the order of a few hundred kilometers (~300 km). Both manometric and barystatic sea level changes are expressed as anomalies relative to the temporal average over the period covered by the product.

2 Methodology

2.1 GRACE and GRACE-FO Datasets

The GRACE and GRACE Follow-On missions have monitored the time variations in the gravity field almost continuously since 2002. Numerous centers distribute time-lapse solutions of the Earth's gravitational potential, delivered as Stokes coefficients, known as Level 2 solutions. The Level 2 solutions need to be corrected for several geophysical effects and instrumental errors, converted into surface mass anomalies, and projected onto the Earth's surface modelled either as a sphere or an ellipsoïd. The resulting gridded surface mass anomalies with appropriate corrections applied are referred to as Level 3 solutions. Several sources of errors affect the solutions of Level 2 and 3, imposed by the satellite configuration, instrumental errors, and uncertainties in the geophysical corrections used to process the measurements. We use the ensemble approach of Blazquez et al., (2018), to robustly estimate the manometric and barystatic sea level changes and their uncertainties. The GRACE ensemble L3 V2.2 was used to generate the barystatic and manometric datasets V6.0. The L3 V2.2 equivalent water height anomalies and the barystatic and manometric sea level anomalies are referenced to the temporal mean over the period January 2005 to December 2014.

2.1.1 Manometric sea level changes

The GRACE Legos - Magellium Manometric Level 3 V6.0 product provides manometric sea level anomalies and their uncertainties from April 2002 to February 2026 at a monthly timescale and with a spatial resolution of 1 degree. Monthly manometric sea level changes are estimated from an ensemble of 180 GRACE and GRACE-FO solutions corrected for GIA (Glacial Isostatic Adjustment), mass displacements associated with large earthquakes (co-seismic deformations only), and atmosphere loading. The ensemble is based on L2 spherical harmonic solutions from five different centers: CNES RL5.0, CSR RL06.3, GFZ RL06.3, JPL RL06.3, and TUGRAZ ITSG2018. The ocean dealiasing model (GAB) is restored using AOD1B RL06 (Dobslaw et al., 2017). The C00 coefficient of the GAA is set to zero in order to avoid the dry mass drift over GRACE-FO period. A large variety of post-processing corrections is applied in the ensemble, including three geocentre motions using the Sun et al., 2016 methodology, three oblateness values of the Earth (Cheng et al., 2013; Lemoine and Reinquin, 2017; Loomis et al., 2019), and two GIA corrections (Peltier et al., 2018, Caron et al., 2018). To reduce the anisotropic noise, DDK filters are applied to the L2 solutions, including DDK3 and DDK6 (Kusche et al., 2009). Solid Earth displacement due to the largest earthquakes (Sumatra 2004 and 2012, Tohoku 2010, and Chile 2010) is corrected following Tang et al., (2020).

The parameters used for the generation of the L3 SAGSA Ensemble V2.2 are reminded in Table 1.

Parameter	Value chosen
Product	Ensemble L3 V2.2
Software	PANIS v1.2.0
Production Date	13/05/2026
Data Period Coverage	April 2002 – February 2026
PC (Processing Centers)	CSR RL06.3, GFZ RL06.3, JPL RL06.3, TUGRAZ 2018, CNES TSVD RL05
Geocentre	Sun JPL, CSR, GFZ
C20	Cheng, Lemoine, Loomis
Leakage Correction	Zonal with the mean_mass_model method
GIA (Glacial Isostatic Adjustment)	ICE-6G-D, Caron 2018
Filter	DDK3, DDK6
Dealiasing	GFZ GAA/GAB RL06, C00 GAA is set to 0
C30	Loomis
Earthquake	Coseismic only
A Priori	None used
Miscellaneous	Spherical projection with mass conservation enforced, new geomask

Table 1**:** *Parameters chosen to produce the SAGSA GRACE Ensemble V2.2*

The GRACE Legos – Magellium Manometric V6.0 product provides the ensemble mean and one-standard-deviation spread of the L3 SAGSA Ensemble V2.2 product. Uncertainties are calculated as the square root of the diagonal elements of the covariance matrix of the full ensemble at each grid point. Grid cells excluded by the ocean mask (i.e., cells over land) are set to NaN, and the used mask is provided with the dataset. No additional processing is performed.

The GRACE Legos – Magellium Manometric V6.0 product is directly comparable with sea level anomalies derived from satellite altimetry or steric sea level anomalies from Argo. All necessary corrections were applied during the generation of the L3 SAGSA Ensemble V2.2 product.

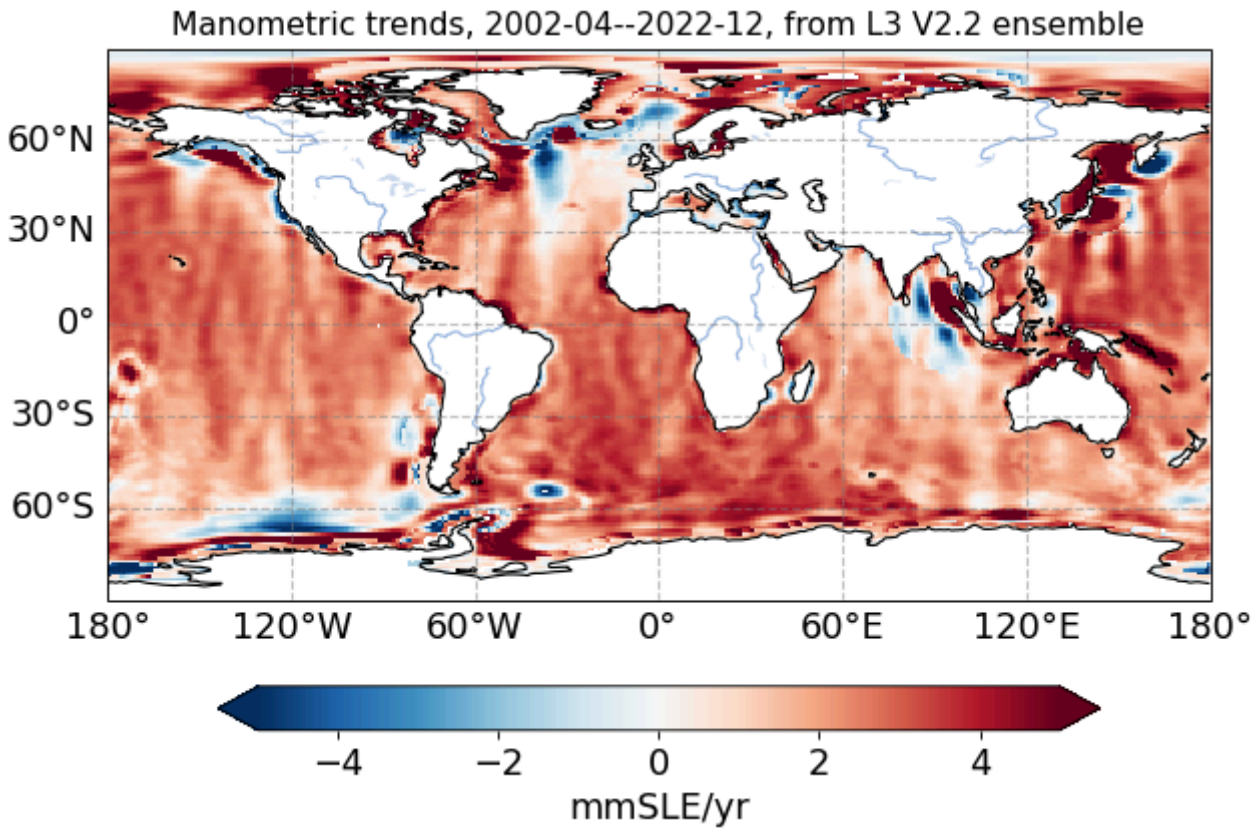

Figure 1: Manometric sea level trends estimated from April 2002 until December 2022 with GRACE and GRACE-FO ensemble V2.2. The data are available until February 2026, but the period used to compute the trend was restricted to April 2002 - December 2022 to be comparable with the SLB V2.0 approach.

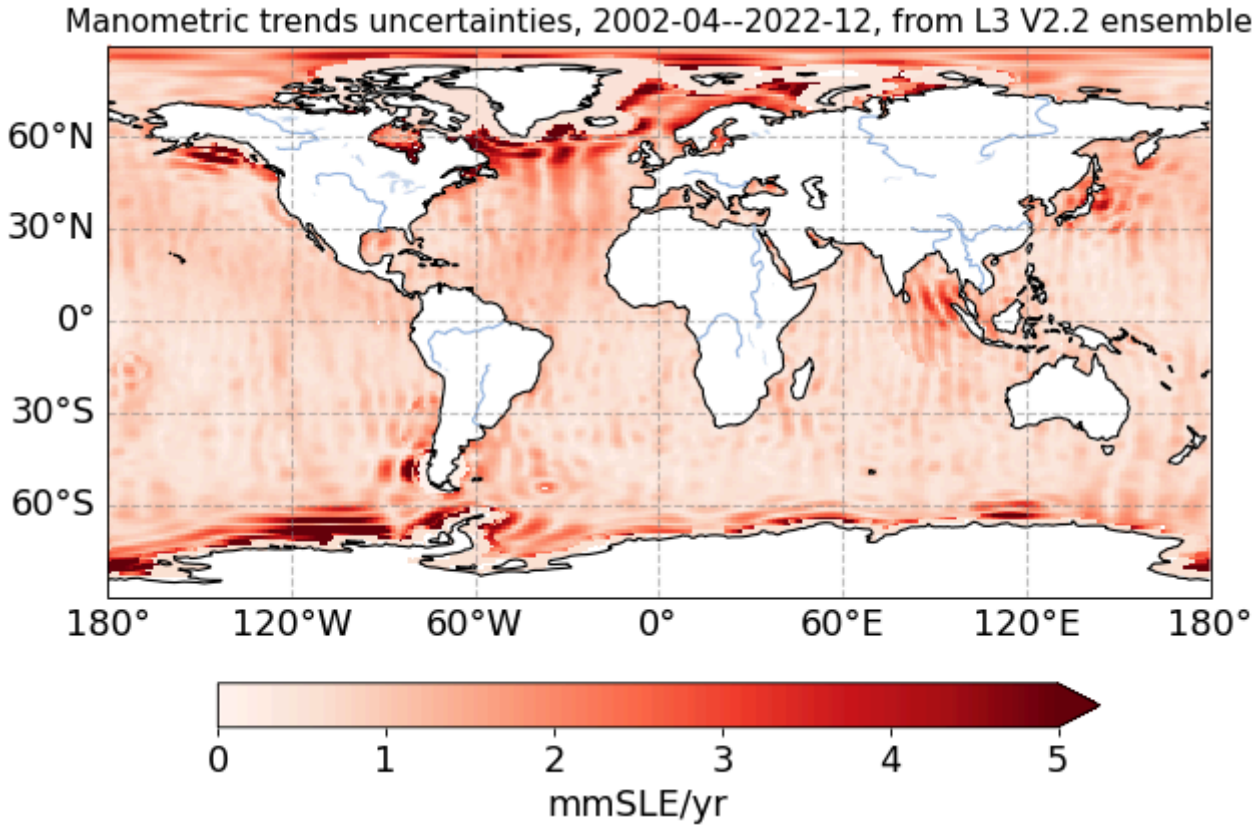

Figure 2: Uncertainty on manometric sea level trends estimated from April 2002 until December 2022 with GRACE and GRACE-FO ensemble V2.2.

2.1.2 Barystatic sea level changes from GRACE data

The GRACE Legos - Magellium Barystatic Level 3 V6.0 product contains the monthly barystatic sea level changes and their uncertainties from April 2002 to February 2026.

The barystatic sea level changes are calculated as the global average of the manometric sea level anomalies weighted according to the surface area of each grid cell. The GRACE Legos - Magellium Barystatic V6.0 product contains the ensemble mean of the 180 barystatic solutions and their uncertainties estimated as the square root of the diagonal terms of the covariance matrix of the full ensemble, also provided.

Two estimates of the barystatic sea level changes are provided corresponding to two different geographical masks, including (i) the ocean surface covered by GRACE and GRACE-FO, (ii) the ocean surface covered by satellite altimetry and in situ measurements of the seawater temperature and salinity. The barystatic sea level changes calculated with the second mask can directly be compared with the barystatic estimates derived from the sea level budget approach. Both masks are included in the NetCDF file.

2.2 Sea Level And Ocean Mass Budget Datasets

The SLB LEGOS MAGELLIUM BARYSTATIC V3.0 product provides monthly barystatic sea level changes and associated uncertainties over the period January 1993 to June 2023. Compared to previous versions of the product, this new release introduces two independent approaches to estimate the barystatic sea level: a first method based on the Sea Level Budget (SLB), a second method based on the ocean mass balance (OMB) approach.

Both barystatic sea level estimates rely on datasets produced within the framework of the ESA SLBC CCI+ project. A summary of the input datasets and applied corrections is provided in Table 1, while a detailed description of the processing strategy is available on the ESA SLBC CCI+ project website : https://climate.esa.int/en/projects/sea-level-budget-closure/.

2.2.1 Sea level budget approach

The estimation of barystatic sea level anomalies is extended over the full altimetry era from January 1993 to June 2023 using the sea level budget (SLB) approach. This method takes advantage of the redundancy of the global ocean observing system, which independently measures (i) geocentric sea level changes from satellite radar altimetry, (ii) barystatic sea level changes from satellite gravimetry, and (iii) steric sea level changes from in situ temperature and salinity observations. Any component of the sea level budget can thus be derived from the two others. In this framework, barystatic sea level changes can be estimated as the difference between altimetry-based geocentric sea level changes and in situ estimates of steric sea level changes.

Geocentric sea level changes are derived from the vDT2021 global mean sea level product operationally generated by the Copernicus Climate Change Service (C3S) for climate applications (Legeais et al., 2021). These data are corrected for the TOPEX-A instrumental drift (Ablain, 2017) and for the Jason-3 wet tropospheric correction drift (Barnoud et al., 2023). Additional corrections include Glacial Isostatic Adjustment (GIA) using the ensemble mean of 27 GIA models centered on ICE6G-D (Prandi et al., 2021; Peltier et al., 2015), and the elastic deformation of the solid Earth induced by present-day ice mass redistribution (Spada and Melini, 2019). The uncertainties associated with geocentric sea level changes are computed following the error budget methodology described in Ablain et al. (2019).

Thermosteric sea level changes are computed from gridded temperature and salinity fields derived from EN4 in situ profiles (Good et al., 2013), mapped using the ISAS optimal interpolation algorithm (Kolodziejczyk et al., 2023). Thermosteric sea level changes are calculated for the 0–2000 m depth layer. To account for the contribution of the deep ocean below 2000 m, a linear trend of 0.1 ± 0.1 mm/yr is added, based on the estimate of Johnson and Purkey (2019). Steric sea level changes are estimated as the ensemble mean of six

independent solutions, and their uncertainty is derived from the covariance matrix of the ensemble after removing the temporal mean of each member. The thermosteric uncertainty ensemble includes datasets from EN4 (Good et al., 2013), IAP (Cheng et al., 2017, 2020), and Ishii et al. (2017).

2.2.2 Ocean mass budget approach

In this new version of the product, an independent estimate of the barystatic sea level based on the ocean mass balance approach is also provided, in addition to the SLB-based method.

In this approach, the barystatic sea level change is estimated as the sum of all individual mass contributions entering the ocean from land and atmosphere, namely:

- Greenland Ice Sheet mass balance (GIS),
- Antarctic Ice Sheet mass balance (AIS),
- Glaciers and Ice Caps (GIC),
- Land Water Storage (LWS),
- Atmospheric Water Vapour contribution (AWV).

The barystatic sea level change from the sum of individual mass contributions is defined as:

$$BSL_sum = LWS + GIS + AIS + GIC + AWV$$

This formulation corresponds to the ocean mass budget, where the barystatic sea level is directly reconstructed from physical mass exchanges between the continents, atmosphere, cryosphere, and the ocean.

Table 2 *: Table describing the input dataset and corrections used to estimate barystatic sea level using SLB method and ocean mass budget.*

Component	Standard	Corrections	Uncertainty
Relative sea level	C3S (vDT2021)	- Jason-3 wet troposphere correction (WTC) Brown et al. 2023 - TOPEX-A drift correction - GIA: ICE-6G_D (VM5a) by Peltier et al. 2018 - PDIM: Spada et al. SLBC_cci+ fingerprints	Update of Guerou et al. 2023
Thermosteric sea level	EN4 Argo profiles interpolated over ISAS	Deep ocean contribution: - Johnson and Purkey (0.1	- Standard deviation of EN4 products

	projection	mm/yr)	
Greenland Ice Sheet	IMBIE-2_R2 dataset (1992-2020) CCI GRACE Mass Balanced (2020-2023)	None	IMBIE uncertainty: 16Gt/an (trend)
Antarctica Ice Sheet		None	IMBIE uncertainty: 18Gt/an (trend)
Land glaciers and ice caps	Dussaillant et al. 2024	None	- 1993/2000: 0.3 mm (white noise) - 2000/2023: 0.1 mm (white noise)
Land Water Storage	(WaterGAP) Hydrological Model (WGHM) version 22e	None	- Short-term time-correlated effects at 6 months 0.13 mm - Long-term time-correlated effects at 3 years 0.13 mm - Drift 0.3 mm/yr (1993/2003) - Anthropogenic contribution: 0.11 m/yr (Caceres et al. 2020)
Atmospheric Water Vapor	ERA5 Total Column Water Vapor	None	Standard deviation from ensemble (ERA5+HOAPS-CCI)

3 PRODUCT DESCRIPTION

3.1 Spatial information

The GRACE manometric & SLB/OMB manometric products are provided on a regular 1x1° grid projected on a sphere. GRACE data are defined on the global ocean (Fig. 1 and 2), and SLB data are defined on the global ocean except for marginal seas and high latitudes ($\gtrsim 60°$).

3.2 Temporal information

All GRACE based products are provided at each mid-month time step between April 2002 and February 2026. SLB data are given at the first of each month but actually correspond to the 15th of each month, between January 1993 to December 2022. Data gaps are filled with non-defined values (NaN).

- GRACE data are provided from April 2002 until February 2026, with several data gaps including a gap of 12 months between the last data from GRACE (June 2017) and the first from GRACE-FO (June 2018).
- SLB & OMB data are provided from January 1993 to June 2023.

3.3 File format

The product is delivered as a set of Network Common Data Form version 4 (netCDF4) files. Metadata attributes are compliant with version 1.7 of the Climate & Forecast conventions (https://cfconventions.org/Data/cf-conventions/cf-conventions-1.7/cf-conventions.html)

3.4 File naming convention

The product follows the naming standard:

<METHOD>_<CENTERS>_<VARIABLE>_<VERSION><_OPT>.nc

where:

- <METHOD> indicates the method used to generate the products. Here, we provide two different methods GRACE and SLB.
- <CENTERS> indicates the centers that generated the data. Here, both the LEGOS and MAGELLIUM were involved in the generation of the data.
- <VARIABLE> indicates the variable estimated in the product. Here we provide estimates of the manometric and barystatic sea level changes.
- <VERSION> is the version number, here 'V1-0' for the first major version. The first digit changes each time a major version is released ('V2-0', 'V3-0'), while changes in the second digit indicate reprocessing versions or minor versions ('V1-2', 'V1-3').
- <_OPT> is optionally included to add information. Covariance matrices are provided in option.
- .nc: standard NetCDF filename extension.

Example: GRACE_LEGOS_MAGELLIUM_MANOMETRIC_V5-0.nc

3.5 Product content

3.5.1 Dimensions

There are 3 dimensions present in every netCDF:

- latitude: size 180, dimension corresponding to degrees north
- longitude: size 360, dimension corresponding to degrees east
- time: size 366 for the SLB/OMB products, 238 for the manometric and barystatic products, dimension corresponding to hours since the first date of the product, using the gregorian proleptic calendar

3.5.2 Variables

The variables defined in the files referring to manometric measurements are the following:

Table 3 **:** *Description of GRACE_LEGOS_MAGELLIUM_MANOMETRIC_V6-0.nc file variables*

Variables(dimensions)	Description	Units	Data Type
time (time)	Time	hours since 2002-04-16	datetime64
Latitude (latitude)	Latitude	degrees_north	float
Longitude (longitude)	Longitude	degrees_east	float
Manometric (time, latitude, longitude)	Manometric sea level anomalies	millimeters	float
Manometric_std (time, latitude, longitude)	One sigma uncertainty on manometric sea level anomalies	millimeters	float
Manometric_trend (time, latitude, longitude)	Manometric sea level trends	millimeters/year	float
Manometric_trend_std (time, latitude, longitude)	One sigma uncertainty on manometric sea level trends	millimeters/year	float

The variables defined in the files referring to GRACE barystatic measurements are the following:

Table 4 *: Description of GRACE_LEGOS_MAGELLIUM_BARYSTATIC_V6-0.nc file variables*

Variables (dimensions)	Description	Units	Data Type

time (time)	Time	hours since 2002-04-16	datetime 64
latitude (latitude)	Latitude	degrees_north	float
longitude (longitude)	Longitude	degrees_east	float
barystatic_full_ocean (time)	Barystatic sea level anomalies calculated with the global ocean	millimeters	float
barystatic_full_ocean_std (time)	One sigma uncertainty on barystatic sea level anomalies calculated with the global ocean	millimeters	float
barystatic_slb_mask (time)	Barystatic sea level anomalies calculated with the SLB mask	millimeters	float
barystatic_slb_std (time)	One sigma uncertainty on barystatic sea level anomalies calculated with the SLB mask	millimeters	float
barystatic_full_ocean_trend	Barystatic sea level anomalies trend calculated with the global ocean	millimeters/year	float
barystatic_full_ocean_trend_std	One sigma uncertainty on barystatic sea level anomalies trend calculated with the global ocean	millimeters/year	float
barystatic_slb_trend	Barystatic sea level anomalies trend calculated with the SLB mask	millimeters/year	float
barystatic_slb_trend_std	One sigma uncertainty on barystatic sea level anomalies trend calculated with the SLB mask	millimeters/year	float
Ocean_mask (latitude, longitude)	Mask of the global ocean used to compute the barystatic sea level.	no unit	boolean
Slb_mask (latitude, longitude)	Mask of the zones covered by the altimetry and in situ data used for the Sea Level Budget approach.	no unit	boolean

The variables defined in the files referring to SLB & OMB barystatic measurements are the following:

Table 5 *: Description of SLB-OMB_ESA_SLBC_CCI+_MAGELLUM_BARYSTATIC_V3-0.nc file variables*

Variables (dimensions)	Description	Units	Data Type
time (time)	Time	CNES julian days	datetime64
time_covar (time_covar)	Time used for expressing the covariance matrix	CNES julian days	datetime64
time_covar_1 (time_covar_1)	Time used for expressing the covariance matrix	CNES julian days	datetime64
latitude (latitude)	Latitude	degrees_north	float
longitude (longitude)	Longitude	degrees_east	float
barystatic_omb (time)	Barystatic Sea Level from the sum of individual components (barystatic_omb = global_mean_land_water_storage + global_mean_glaciers_ice_cap + global_mean_greenland_ice_sheet + global_mean_antarctic_ice_sheet + global_mean_atmospheric_water_vapor)	millimeters	float
barystatic_slb (time)	Barystatic Sea Level from the difference between relative sea level from altimetry and thermosteric sea level from argo in situ data	millimeters	float
Barystatic_omb_covar (time_covar, time_covar_1)	Covariance matrix for barystatic sea level from the sum of individual components	millimeters	float
barystatic_slb_covar (time_covar, time_covar_1)	Covariance matrix for barystatic sea level from the ocean mass budget	millimeters	float
slb_mask (latitude, longitude)	Mask of the zones covered by the altimetry and in situ data used for the Sea Level Budget approach.	no unit	boolean

3.5.3 Metadata

Users will find a number of metadata attributes in the NetCDF file, at the file level, at the layer level, and at the level of the dimension variables.

4 REFERENCES

Ablain, M.: The TOPEX-A Drift and Impacts on GMSL Time Series, available at: https://meetings.aviso.altimetry.fr/fileadmin/user_upload/tx_ausyclsseminar/files/Poster_OSTST17_GMSL_Drift_TOPEX-A.pdf, Miami, US (October, 2017), available at: https://meetings.aviso.altimetry.fr/fileadmin/user_upload/tx_ausyclsseminar/files/Poster_OSTST17_GMSL_Drift_TOPEX-A.pdf (last access: 15 February 2023.), 2017.

Barnoud, A., Pfeffer, J., Cazenave, A., and Ablain, M.: Revisiting the global mean ocean mass budget over 2005–2020, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2022-716, 2022.

Blazquez, A., Meyssignac, B., Lemoine, J.-M., Berthier, E., Ribes, A., Cazenave, A., Exploring the uncertainty in GRACE estimates of the mass redistributions at the Earth surface: implications for the global water and sea level budgets, Geophysical Journal International, 215 (1), 415–430,https://doi.org/10.1093/gji/ggy293, 2018.

Caron, L., Ivins, E. R., Larour, E., Adhikari, S., Nilsson, J., and Blewitt, G.: GIA Model Statistics for GRACE Hydrology, Cryosphere, and Ocean Science, Geophys. Res. Lett., 45, 2203–2212, https://doi.org/10.1002/2017GL076644, 2018.

Chang, L., Tang, H., Wang, Q., and Sun, W.: Global thermosteric sea level change contributed by the deep ocean below 2000 m estimated by Argo and CTD data, Earth and Planetary Science Letters, 524, 115 727, https://doi.org/10.1016/j.epsl.2019.115727, 2019.

Chen, J., Tapley, B., Seo, K.-W., Wilson, C., and Ries, J.: Improved Quantification of Global Mean Ocean Mass Change Using GRACE Satellite Gravimetry Measurements, Geophys. Res. Lett., 46, 13984–13991, https://doi.org/10.1029/2019GL085519, 2019.

Cheng, M., Tapley, B. D., and Ries, J. C.: Deceleration in the Earth's oblateness, J. Geophys. Res.-Sol. Ea., 118, 740–747, https://doi.org/10.1002/jgrb.50058, 2013.

Cheng, L., Trenberth, K. E., Fasullo, J., Boyer, T., Abraham, J., and Zhu, J.: Improved estimates of ocean heat content from 1960 to 2015, Science Advances, 3, https://doi.org/10.1126/sciadv.1601545, 2017.

Cheng, L., Trenberth, K. E., Gruber, N., Abraham, J. P., Fasullo, J. T., Li, G., Mann, M. E., Zhao, X., and Zhu, J.: Improved Estimates of Changes in Upper Ocean Salinity and the Hydrological Cycle, Journal of Climate, 33, 10 357–10 381, https://doi.org/10.1175/jcli-d-20- 315 0366.1, 2020.

Crétaux, J.-F., Abarca-del-Río, R., Bergé-Nguyen, M., Arsen, A., Drolon, V., Clos, G., and Maisongrande, P.: Lake Volume Monitoring from Space, Surv. Geophys., 37, 269–305, https://doi.org/10.1007/s10712-016-9362-6, 2016.

Dahle, C., Flechtner, F., Gruber, C., K¨onig, R., Michalak, G., & Neumayer, K.-H.. GFZ GRACE Level-2 Processing Standards Document for Level-2 Product Release 0005 : revised edition, January 2013. Scientific Tech364 nical Report STR - Data, Potsdam : Deutsches GeoForschungsZentrum GFZ,21 p.. doi: 10.2312/GFZ.b103-1202-25, 2012.

Dobslaw, H., Bergmann-Wolf, I., Dill, R., Poropat, L., Thomas, M., Dahle, C., Esselborn, S. , König, R., Flechtner, F., A new high-resolution model of non-tidal atmosphere and ocean mass variability for de-aliasing of satellite gravity observations: AOD1B RL06, Geophysical Journal International, 211 (1) 263–269. https://doi.org/10.1093/gji/ggx302, 2017.

Frederikse, T., Riva, R. E. M., and King, M. A.: Ocean Bottom Deformation Due To Present-Day Mass Redistribution and Its Impact on Sea Level Observations, Geophys. Res. Lett., 44, 12306–12314, https://doi.org/10.1002/2017GL075419, 2017.

Good, S. A., Martin, M. J., and Rayner, N. A.: EN4: Quality controlled ocean temperature and salinity profiles and monthly objective analyses with uncertainty estimates, Journal of Geophysical Research: Oceans, 118, 6704–6716, https://doi.org/10.1002/2013jc009067, 2013.

Gregory, J.M., Griffies, S.M., Hughes, C.W. et al. Concepts and Terminology for Sea Level: Mean, Variability and Change, Both Local and Global. Surv Geophys 40, 1251–1289. https://doi.org/10.1007/s10712-019-09525-z. 2019.

Hugonnet, R., McNabb, R., Berthier, E., Menounos, B., Nuth, C., Girod, L., Farinotti, D., Huss, M., Dussaillant, I., Brun, F., and Kääb, A.: Accelerated global glacier mass loss in the early twenty-first century, Nature, 592, 726–731, https://doi.org/10.1038/s41586-021-03436-z, 2021.

Ishii, M., Fukuda, Y., Hirahara, S., Yasui, S., Suzuki, T., and Sato, K.: Accuracy of Global Upper Ocean Heat Content Estimation Expected from Present Observational Data Sets, SOLA, 13, 163–167, https://doi.org/10.2151/sola.2017-030, 2017.

Kusche, J., Schmidt, R., Petrovic, S., and Rietbroek, R.: Decorrelated GRACE time-variable gravity solutions by GFZ, and their validation using a hydrological model, J. Geodesy, 83, 903–913, https://doi.org/10.1007/s00190-009-0308-3, 2009.

Legeais, J.-F., Meyssignac, B., Faugère, Y., Guerou, A., Ablain, M., Pujol, M.-I., Dufau, C., and Dibarboure, G.: Copernicus sea level space observations: a basis for assessing mitigation and developing adaptation strategies to sea level rises, Front. Mar. Sci., 8, 704721, https://doi.org/10.3389/fmars.2021.704721, 2021.

Lemoine, J.-M., Bourgogne, S., Biancale, R., Bruinsma, S., and Gégout, P.: CNES/GRGS solutions Focus on the inversion process, in Paper presented at the GRACE Science Team Meeting, A1-02, Berlin, Germany, 2016.
Lemoine J.-M., Reinquin F.,Processing of SLR observations at CNES, *Newsletter EGSIEM*, October, Page 3. 2017.

Loomis, B. D., Rachlin, K. E., and Luthcke, S. B.: Improved Earth Oblateness Rate Reveals Increased Ice Sheet Losses and Mass-Driven Sea Level Rise, Geophys. Res. Lett., 46, 6910–6917, https://doi.org/10.1029/2019GL082929, 2019.

Peltier, W. R., 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.-Sol. Ea., 123, 2019–2028, https://doi.org/10.1002/2016JB013844, 2018.

Prandi, P., Meyssignac, B., Ablain, M., Spada, G., Ribes, A., and Benveniste, J.: Local sea level trends, accelerations and uncertainties over 1993–2019, Sci. Data, 8, 1, https://doi.org/10.1038/s41597-020-00786-7, 2021.

Sun, Y., Riva, R., and Ditmar, P.: Optimizing estimates of annual variations and trends in geocenter motion and J2 from a combination of GRACE data and geophysical models, J. Geophys. Res.-Sol. Ea., 121, 8352–8370, https://doi.org/10.1002/2016JB013073, 2016.

Tang, L., Li, J., Chen, J., Wang, S.-Y., Wang, R., and Hu, X.: Seismic Impact of Large Earthquakes on Estimating Global Mean Ocean Mass Change from GRACE, Remote Sens., 12, 935, https://doi.org/10.3390/rs12060935, 2020.

Uebbing, B., Kusche, J., Rietbroek, R., and Landerer, F. W.: Processing Choices Affect Ocean Mass Estimates From GRACE, J. Geophys. Res.-Oceans, 124, 1029–1044, https://doi.org/10.1029/2018JC014341, 2019.