Sea Level Budget Closure - Climate Change Initiative +

Product Specification Document

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1. Introduction

1.1. Purpose of document

This document is the Product Specification Document (PSD) for the ESA SLBC_cci+ project ([AD-1] and [AD-2]). It aims at specifying datasets of individual sea level budget components that will be generated as an input to the sea level budget assessments. The document also presents the input data product catalogue. Figure 1 summarises the content and scope of the Product Specification Document (PSD), Data Access Requirement Document (DARD) and Algorithm Theoretical Baseline Document (ATBD).

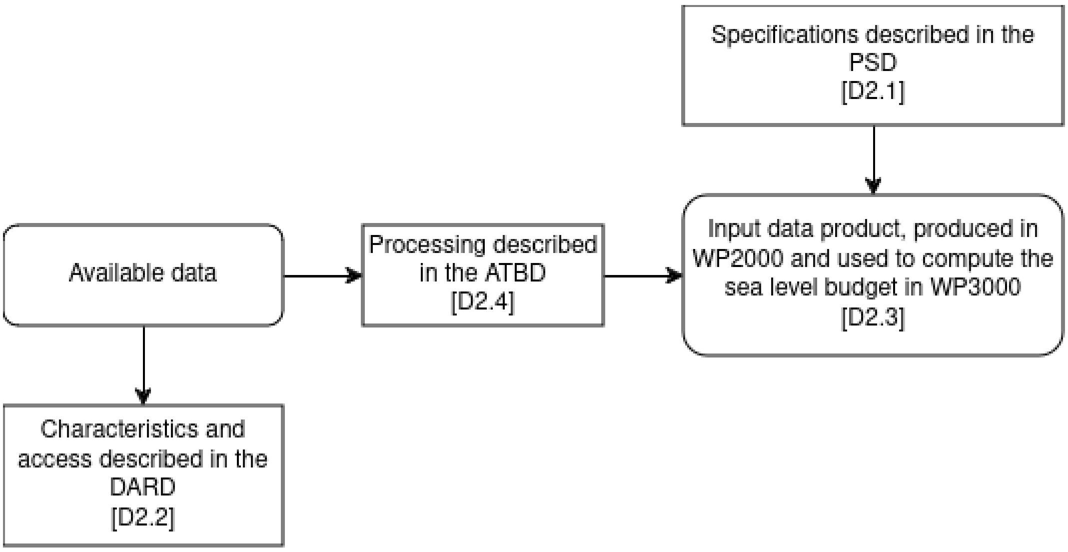

Figure 1: Scope of the Product Specification Document (PSD), Data Access Requirement Document (DARD) and Algorithm Theoretical Baseline Document (ATBD).

1.2. Document structure

In addition to this introduction, this document includes the following sections: Section 2 explains the logic behind the definition of products. Section 3 specifies all individual products. Section 4 details product formats, if not included in Section 3. Section 5 provides the input data products catalogue.

1.3. Related documents

1.3.1. Applicable documents

Id.	Ref.	Description
[AD-1]	ESA AO/1-11340/22/I-NB	Call to tender "SEA LEVEL BUDGET CLOSURE_CCI+ (SLBC_CCI+)"
[AD-2]	MAG-22-PTF-060_DetailedProposal_V2	Detailed proposal in response to ESA/ESRIN Request for Quotation "SEA LEVEL BUDGET CLOSURE_CCI+ (SLBC_CCI+)" ESA AO/1-11340/22/I-NB [AD-1]
[AD-3]	SLBC_CCI-DT-008-MAG_SRD_D1-1	SEA LEVEL BUDGET CLOSURE_CCI+ Science Requirements Document Version 1.2, 07/06/2024
[AD-4]	SLBC_CCI-DT-040-MAG_DARD_D2-2	SEA LEVEL BUDGET CLOSURE_CCI+ Data Access Requirement Document (DARD)

Table 1: List of applicable documents.

1.3.2. Reference documents

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1.4. Terminology

The list of acronyms that are used in the document is presented in the following table (Table 2).

Acronym	Description
AD	Applicable Document
AIS	Antarctic Ice Sheet
ATBD	Algorithm Theoretical Basis Document
C3S	Copernicus Climate Change Service

CCI	The ESA Climate Change Initiative
DARD	Data Access Requirement Document
ECV	Essential Climate Variable
ESA	European Space Agency
GEWEX	Global Energy and Water Cycle Exchanges project
GIA	Glacial Isostatic Adjustment
GIC	Glaciers and ice caps
GIS	Greenland Ice Sheet
GMC	Gravimetric Mass Change
GRACE	Gravity Recovery and Climate Experiment
GRACE-FO	GRACE Follow-On
GRD	Earth Gravity, Earth Rotation and viscoelastic solid-Earth Deformation
G-VAP	GEWEX water vapour assessment project
IB	Inverse Barometer
ISAS	In Situ Analysis System
LWS	Land Water Storage
OCCIPUT	OceaniC Chaos—ImPacts, strUcture, predictabiliTy
OI	Optimal Interpolation
PSD	Product Specification Document
SLBC	Sea level budget closure
SLBC_cci	Sea Level Budget Closure of the ESA Climate Change Initiative (first phase)
SLBC_cci+	Sea Level Budget Closure of the ESA Climate Change Initiative (second phase, this activity)
SL_cci	The Sea Level component of the ESA Climate Change Initiative
SLE	Sea Level Equation

TWS	Terrestrial Water Storage
WP	Work Package

Table 2: List of acronyms.

2. Product logic

The product specification is guided by the project requirements [AD3], that is, by the "downstream" work in WP3000 and WP4000 which use the data products as input (highlighted by red arrows in Figure 2).

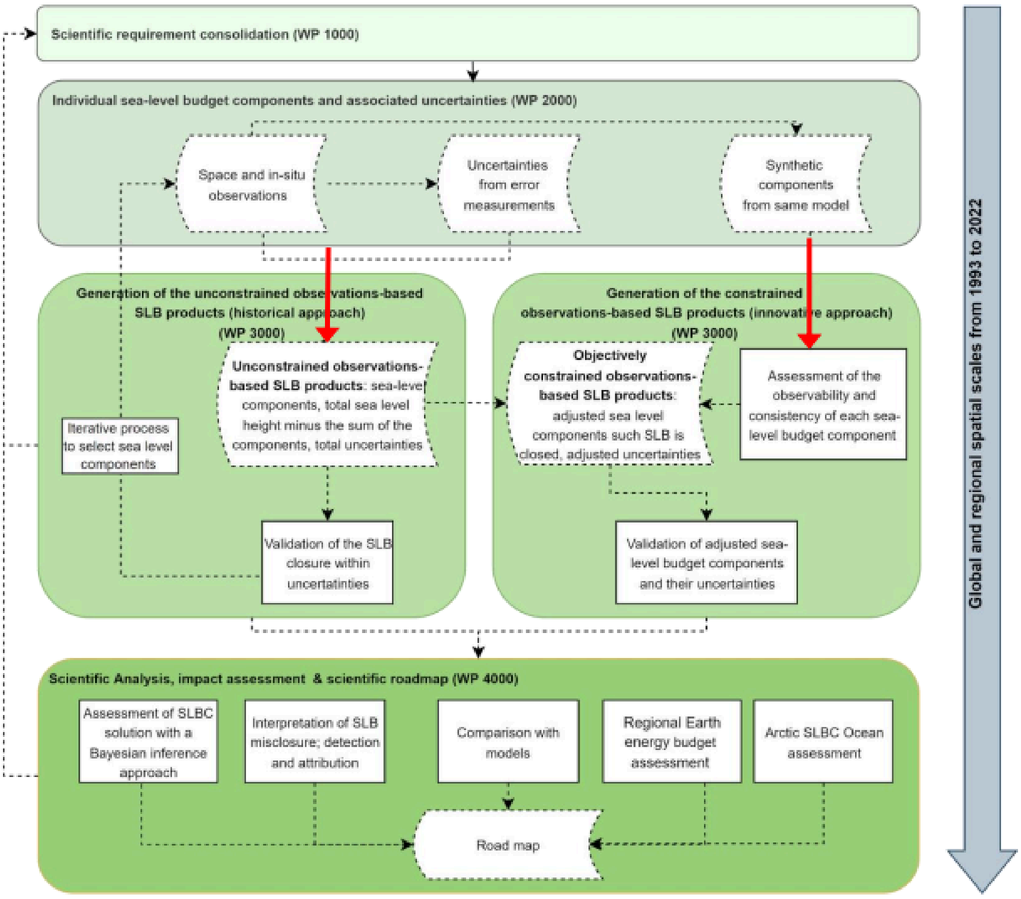

Figure 2: Work logic of the SLBC_cci+ proposal. Red arrows remind the usage, and thereby purpose, of the products described in this document. Figure adapted from [AD2].

Based on this logic, we specify the following roles of datasets:

- **Data product** or (synonymously) **Input Data Product:** a product generated by SLBC_cci+ within WP2000 to serve as input for the SLB analyses in WP3000 and WP4000.

Note that WP3000 and WP4000 will additionally rely on datasets that are available from other sources and not generated (i.e. not a "product") by SLBC_cci+. They may be mentioned for completeness but are not specified in detail.

- **Data:** anything used to generate the "Data products". Data are addressed in the DARD [AD-4]. The way from “data” to “data products” is described in the ATBD.
- **Intermediate data products:** something between "data" and "data products". They may be mentioned (e.g. in the DARD) for the purpose of explanation. They are not addressed in this document.

3. Product Specifications

This section explains the specifications of the different components that will be used to realise the budget. A more synthetic summary is given in section 5. Unless specified otherwise, the components will be provided as monthly gridded files with a 1°x1° spatial resolution. This spatial resolution, higher than the effective resolution of in situ data (about 4°x4°) and satellite gravimetric (about 3°x3°) signals, will ensure not to miss any physical signal in the assessment of the sea level budget. For all components, the product will provide sea level changes with respect to the reference period 01/2005-12/2015 over which all the datasets are available.

3.1. Total sea level

The total sea level component is observed by altimetry satellite measurements. Multi-mission gridded products are available (see DARD [AD-4]). The total sea level component will include instrumental corrections as needed, in particular the TOPEX-A altimeter drift correction and the Jason-3 wet troposphere correction drift. However, it will not be corrected for any changes in Earth Gravity, Earth Rotation and viscoelastic solid-Earth Deformation (GRD) (defined by Gregory et al., 2019) because glacial isostatic adjustment (GIA) and fingerprints due to the contemporary GRD changes will be provided as a separate component (see section 3.5).

The total sea level product will be provided as a monthly 1°x1° gridded file.

Uncertainties are fully documented in the literature in global mean (Ablain et al., 2019; Guérou et al., 2023) and at local scale (Prandi et al., 2021). The authors identify the various sources of uncertainties (geophysical corrections, precise orbit determination, etc.), provide a description of the uncertainty model used (drift, correlated errors, etc…), estimates of their values based on the literature and estimate the covariance matrix associated with the mean sea level and global mean sea level resulting from altimetric data.

3.2. Steric sea level

The steric sea level component will be provided over the period 1993-2023. This period will be covered with different datasets.

The steric sea level components will be computed with the gridded fields of temperature and salinity interpolated with the In Situ Analysis System (ISAS, Gaillard et al., 2016). These fields preserve as much as possible the time and space sampling capabilities of the Argo network. The ISAS product is based on Optimal Interpolation (OI) methods (Bretherton et al., 1976). This is a state of the art method widely used in the community to grid T/S fields, estimate error and derive indicators such as Steric Sea Level.

More precisely, we will use ISAS20 release (Kolodziejczyk et al., 2023) where the monthly data is interpolated on 183 standard depth levels between 0-5500 m depth and about 0.5°x0.5° global horizontal grid between the period 2002-2023, which is higher than the effective resolution of the Argo network which is about 4°x4°.

In OI systems, a priori statistics are a main source of uncertainty (Gaillard et al., 2016). As a consequence, accurate estimates of a priori statistics is mandatory to accurately analyze the in situ dataset and compute the steric sea level components. In order to estimate and reduce the uncertainties, we will use synthetic profiles extracted from model outputs and compare them with the original model outputs that represent a “true” ocean state (Allison et al., 2019; Llovel et al., 2022). This will provide a controlled approach to test the sensitivity of a priori OI statistics in order to adjust them and, finally, reduce the uncertainties.

In complement, the new ISAS estimates of global mean sea level will be compared with several *in situ* interpolated products: the RG-Argo product developed by the SCRIPPS Institution of Oceanography (Roemmich and Gilson, 2009), the IPRC product developed by the Asia-Pacific Data-Research Center, the EN.4.2.2 products developed by the Met Office Hadley Centre (Good et al., 2013), the MOAA GPV product developed by JAMSTEC (Hosoda et al., 2008), the STASA product developed by the National Center for Atmospheric Research (Ishii et al., 2017) and the WOA23 product developed by the Nation Centers for Environmental Information (Reagan et al., 2024). The EN.4.2.2, STASA and WOA23 products will cover the 1993-2023 period while all the other products (including ISAS) will be used to cover the 2005-2023 period.

To compute the steric sea level components among the different data products, we will consider data in the top 2000 meters of the water column and located between 60°N–60°S where the Argo network sampled optimally the global ocean. The anomalies of the steric sea level components will be computed by removing the monthly climatology (over the longer time period if possible, i.e. 2005-2023). The land-ocean mask applied to the data is the original ISAS mask. The gridded steric sea level components will be provided in meters at a monthly 1°x1° resolution.

3.3. Ocean mass from space gravimetry missions

The GRACE (2002-2017, Tapley et al., 2019) and GRACE-FO (launched 2018, Landerer et al., 2020) satellite gravity missions allow to observe temporal changes of Earth's gravitational field at a temporal resolution of 1 month and a spatial resolution of 200-500 km. The temporal gravity variations are caused by mass redistributions within the solid Earth (mainly GIA and tectonics) and at the Earth surface (water, ice, atmosphere). If the gravity effects of solid-Earth processes are known and subtracted, the remaining temporal gravity field variations can be converted into temporal variations of the surface mass distribution (in units of mass per surface area). Integration over predefined regions (such as the global ocean) leads to temporal variations of surface mass in this region.

Accordingly, two types of gravimetric mass change (GMC) products will be generated from GRACE and GRACE-FO spheical harmonic gravity field solutions.

Gridded gravimetric mass change product

They represent anomalies of surface mass distribution, expressed as areal density in units of kg/m^2. By "anomalies" we refer to the difference between the mass distribution in the particular month and the mean mass distribution over a reference period.

The spatial coverage is global. The spatial resolution is 1° x 1°. A land-ocean mask is provided in addition. For inferences on ocean mass change it is important to use the land-ocean mask associated with the gridded product (rather than any different land-ocean mask).

The temporal resolution is quasi-monthly, representing averages of calendar months. The temporal coverage is from 2002-04 to 2023-12. However, some months are missing due to the gap between the end of GRACE mission and the launch of GRACE Follow-On: 11 consecutive months from 2017-07 to 2018-05 and an additional number of single months.

Integrated gravimetric mass change products

They represent estimates of anomalies of the total mass (in Gt) over a predefined region. "Anomalies" are defined the same way as for the gridded products. Addressed regions include

- the global ocean
- the global ocean between 66° North and 66° South (The TOPEX/Jason limits)
- sub-regions of the global ocean according to the requirements of WP3000 and WP4000.

The temporal resolution and coverage is the same as for the gridded GMC product.

Geophysical data content

The involvement of background models on tidal and non-tidal oceanic and atmospheric mass variations in the generation of GRACE L2 products and their (partial) readdition in the subsequent analysis (to be described in the ATBD) leads to the following geophysical data content:

For the gridded product in the ocean domain, the areal densities, divided by seawater density, represent manometric sea level changes as defined by Gregory et al. (2019). The Inverse Barometer (IB) effect is not included. In other words, the areal densities, if multiplied by the gravity acceleration, represent anomalies of ocean bottom pressure, where anomalies of the global-ocean mean atmospheric pressure are subtracted.

The integrated GMC over the global ocean, if divided by freshwater density, represents barystatic sea level change as defined by Gregory et al. (2019).

The effect of GIA is not included in the GMC products. GIA effects are subtracted at the gravity field level (prior to converting gravity field changes to mass changes) based on products described in Section 3.5. Alternative GMC products may be generated based on alternative GIA models used for GIA correction. Here is an example to illustrate this point: GIA causes relative sea-level fall in the Hudson Bay. This effect is not represented in the GMC products. It is represented separately in the products described in Section 3.5 and can be added to the GMC products in later analyses by WP3000 and WP4000 depending on how they want to handle GIA..

Despite the formal resolution at 1°x1°, the inherent resolution of GRACE on the order of 300km implies that the gridded product generally represents a smoothed version of the actual mass redistribution. The effect of this smoothing is called leakage. Leakage mitigation strategies (involving the distinction between land and ocean domains) heavily reduce leakage across coastlines. However, inevitably there are residual leakage effects, that is, gravity effects of land-water or land-ice change may be mis-attributed to ocean-mass change, or vice versa.

Uncertainty characterisation

The uncertainties of integrated GMC will be characterised by full temporal error covariance matrices. They will include effects of noise in the GRACE solutions, errors in the low-degree components (including temporal correlations), leakage (temporally correlated), and errors in corrections (such as for GIA, temporally correlated). The format will be similar to the one presented by Ablain et al. (2019), to be homogeneous with the formalism used for the altimetry data. Individual error components (GRACE solution noise, leakage, etc.) may be provided as individual error covariance matrices.

3.4. Ocean mass from land and atmosphere components

3.4.1. Greenland ice sheet

Ice sheet mass changes are the combined effect of surface mass balance, basal mass balance, and discharge of ice into the ocean by glacier flow.

The Greenland Ice Sheet (GIS) products (see DARD [AD-4]) represent time series of anomalies of ice sheet mass (unit Gt). By "anomalies" we refer to the difference between the mass at the particular time and the mean value over a reference period. By mass change, we refer, precisely speaking, to the part of ice mass change that contributes to barystatic sea-level change (cf. Bamber et al., 2018).

The envisaged temporal resolution is monthly. Note that some input data will not have a truly monthly resolution, so that the monthly sampling will just be the result of interpolation or of adding an additional seasonal cycle.

For each product it will be specified whether it excludes or includes peripheral glaciers. Inclusion of peripheral glaciers may be unavoidable for the case of GRACE-based estimates.

The uncertainty characterisation will consist in the uncertainties of mass anomalies per epoch. They will ideally include effects of systematic errors, which tend to increase with increasing distance to the center of the reference interval to which the anomalies refer. This is why specifying the reference interval may be important.

For the purpose of fingerprint computations (see Section 3.5), an intermediate product of spatially resolved monthly ice mass changes will be provided.

3.4.2. Antarctica ice sheet

The Antarctic Ice Sheet (AIS) product specification is identical to that for the Greenland Ice Sheet.

3.4.3. Glaciers and ice caps

Glacier and Ice Cap (GIC) mass balance time series will be obtained from a time series developed by WGMS, University of Zurich and hosted by Copernicus Climate Services (Copernicus Climate Change Service, 2023; Dussaillant et al., 2023). This provides mass change on a 0.5 degree grid from 1976-present with annual time resolution. A modified version of this has been developed by WGMS that incorporates a realistic seasonal cycle with monthly resolution and this is the version that we will provide. It combines in-situ observations of winter/summer mass balance with a geodetic data set of volume change over 20 years which has glacier level spatial resolution but approximately decadal temporal resolution. The data set is broadly consistent with the ESA GLAMBIE time series (to within +- 0.1 mm/yr SLE) which is of limited temporal duration. Peripheral GIC around Greenland and Antarctica will be included along with uncertainty estimates.

3.4.4. Land water storage

Land water storage (LWS) variations are due to variations of water content in snow, canopy, soil moisture, groundwater, lakes, reservoirs, wetland and rivers. Terrestrial water storage (TWS) variations are defined as the budget over land between precipitation, evapotranspiration and runoff, hence includes LWS and land glaciers contributions. As the contribution of glaciers and ice caps is estimated as a separate component (see previous section), this section deals with the LWS component.

The LWS product will be provided as a monthly time series of global mean LWS integrated over land, in Gt.

For the purpose of fingerprint computations (see section 3.5), an intermediate product of monthly 1°x1° gridded LWS over land will be provided, in kg/m².

3.4.5. Atmosphere water vapour content

The atmosphere water vapour content variations contribute to the sea level and ocean mass budget. This component is estimated from total column water vapour data, also called precipitable water. Datasets provide water vapour data either globally, over land only or over oceans only (see DARD [AD-4]).

The product will consist of a monthly time series of global mean atmosphere water vapour data, integrated over both land and oceans, in Gt. No gridded dataset will be provided.

Uncertainties will be estimated from the comparison between several datasets and from the literature, including the outputs of the water vapour CCI project and of the Global Energy and Water Cycle Exchanges project (GEWEX) water vapour assessment (G-VAP) from Schröder et al. (2016).

3.5. Fingerprints and GIA

Product background summary

Fingerprints. The fingerprints represent the response of the Earth to surface mass redistribution associated with either ice thickness or water storage variations. An elastic behaviour for the Earth is assumed since the time scale of evolution of the surface mass is short (a few decades) compared with the Maxwell time scale (~1ka) on which inelastic relaxation occurs. The fingerprints computed here have been obtained by numerically solving a gravitationally and rotationally self-consistent Sea Level Equation (SLE) in the purely elastic approximation. The discretization of the SLE has been accomplished on a global icosahedral-shaped geodesic grid with about 141,000 nodes, with each node corresponding to a disc-shaped load element of ~70 km diameter. The solution scheme is based on an iterative approach in which contributions to solid earth deformation and geoid height change from individual disc elements are combined and subsequently used to update the load applied on each point. The elastic structure of the Earth, used to obtain the Green's Functions associated with the response to the elementary load, is taken from the seismic model STW105 of Kustowski et al. (2008). Rotational feedback has been accounted for according to the "revised rotational theory" by Mitrovica and Wahr (2011).

Glacial isostatic Adjustment (GIA). GIA represents the delayed deformational, gravitational and rotational response of the Earth to the melting of the late Pleistocene ice sheets in terms of sea level variations and solid Earth deformations. GIA is a long term process that is generally modelled assuming a spherically symmetric Earth with a Maxwell (linear) rheological behaviour for the mantle and an elastic lithosphere. The GIA solutions considered here have been obtained by numerically solving the full self-consistent SLE with the open-source SELEN4 solver by Spada and Melini (2019). The solution has been obtained on a global geodesic grid with a spatial resolution of ~40 km and including harmonic terms up to degree 512, which corresponds to a minimum wavelength of ~80 km on the Earth's surface. Horizontal migration of coastlines has been accounted for, and the present-day global topography has been prescribed according to the ETOPO1 elevation model, integrated with the Bedmap2 relief south of 60°S latitude. Spatio-temporal evolution of ice sheets has been assumed as a realisation on the geodesic grid of the ICE-7G model by Roy and Peltier (2015, 2017), and the Earth rheological profile has been consistently defined according to the VM7 viscosity model (Roy and Peltier, 2017). Rotational feedback has been accounted for following the revised rotational theory by Mitrovica and Wahr (2011).

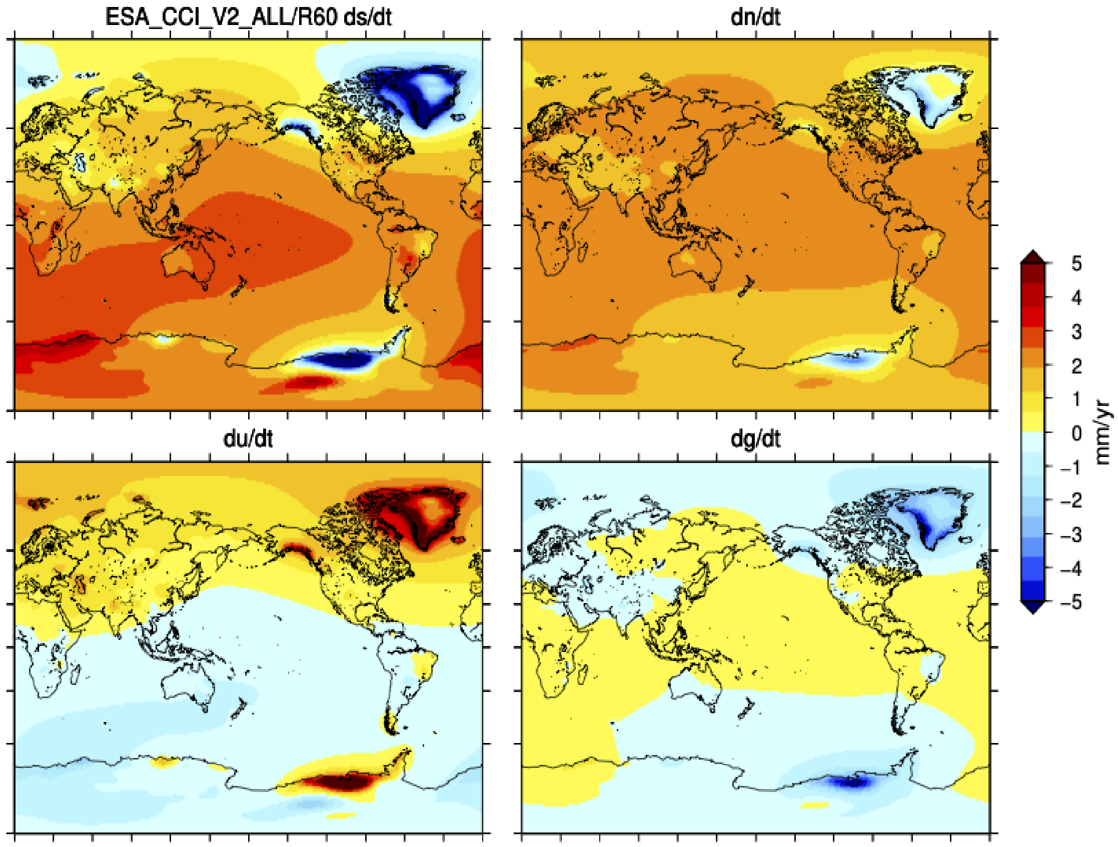

Figure 3: Elastic fingerprints due to trends of present-day mass redistribution on sea-level change (dS/dt), sea surface height change (dN/dt), vertical land motion (dU/dt) and geoid height change (dG/dt). Rates are obtained as a least-squares linear fit of the monthly time series for each field.

Product geophysical data content

The products contain various geophysical data associated with the elastic fingerprints and the visco-elastic GIA. These include relative sea level (S), absolute sea level (N), the vertical displacement of the solid Earth (U), and geoid height change (G). Elastic fingerprints have been evaluated taking into account the cumulated cryospheric and Land Water storage components. Individual contributions associated with the three major cryospheric sources (GRiS, AiS and Glaciers) have also been separately estimated. Monthly anomalies are expressed as the deflection in metres (m) of the reference surface associated with each field (the radius of the solid earth for U, the geoid for G and the sea surface for N), while S is defined as S=N-U. For GIA, rates in mm/yr are given for each field. Monthly variations of the Stokes coefficients of the gravity field are also estimated, as well as their background rates of change due to GIA. Stokes coefficients are given in the GRACE convention up to harmonic degree 256.

Space and time coverage and resolution

Both elastic and GIA fingerprints have a global spatial coverage on a 1° global regular grid. Elastic fingerprints are computed for each time step of the input mass balance model, i.e. on 213 monthly time steps from April 2002 to December 2019. The response to GIA can be assumed stationary on the decadal timescale and therefore GIA fingerprints are expressed as constant rates (mm/yr) over the considered time window.

Way of uncertainty characterisation

The uncertainties on the fingerprints have two sources. The first is related with the finite discretization of the Sea Level Equation, the second with the assumption of a specific 1D structure of the elastic Earth model. These do not exceed the +/- 5% level on the computed fingerprints. For GIA, the uncertainty is comparable to that obtained for the mini-ensemble approach of Melini and Spada (2019).

3.6. Synthetic observations:

For the synthetic data, we exploit the the OceaniC Chaos—ImPacts, strUcture, predictabiliTy (OCCIPUT) ensemble of 1/4◦ ocean/sea-ice simulations (Penduff et al., 2014). These simulations are based on the NEMO3.5 model (Bessières et al., 2017) and cover the period 1960-2015. Each simulation (member) was initialised on January 1st, 1960 where a slight stochastic perturbation in the seawater equation (Brankart, 2013) was applied during the first year. This perturbation was switched off at the end of 1960 producing 50 members with different oceanic states. Each ensemble member was integrated from January 1st 1961 until the end of 2015 with the same atmospheric forcing based on Drakkar Forcing Set 5.2 (Dussin et al., 2016).

3.6.1. Altimetric synthetic data

From ocean simulations, a synthetic altimetric total sea level component will be provided, with the same specifications as in Section 3.1.

3.6.2. Steric synthetic data

The steric sea level data contain various geophysical data such as latitude (LATITUDE), longitude (LONGITUDE), time (JULD), depth (DEPTH), potential temperature (POTM_OBS), practical salinity (PSAL_OBS) and in situ temperature (TEMP). For our work we will use the potential temperature and the practical salinity data.

OCCIPUT synthetic data are on an irregular grid but cover the global ocean and the maximum depth reached by the profiles is 2000 metres. On a temporal scale, we focus on the period 2005-2015 because our interpolation tool (ISAS) has been designed to only map data during this period. The synthetic data have a monthly resolution.

3.6.3. Gravimetric synthetic data

Gravimetric synthetic data are the sum of ocean bottom pressure generated from the OCCIPUT synthetic data with a sea-level fingerprint effect evaluated taking for the cryospheric and land water storage components. The synthetic cryospheric part is composed of the three major cryospheric sources (GIS, AIS and GIC) based on real observations (Groh and Horwath, 2021; Hugonnet et al., 2021) and the land water storage component is based on GRACE products. Due to the use of GRACE products, gravimetric synthetic data have a monthly resolution and cover the period 2002-2015 with a spatial resolution of 1°x1°.

4. Product formats

4.1. Data resolution

The expected resolution of the data is as follows:

- Spatial resolution: Its spatial resolution must be of 1°x1°
- Temporal resolution: Its temporal resolution must be monthly.

4.2. File format

The data files must be provided in netCDF format, respecting at maximum the Climate Forecast (currently CF1.11) netCDF file format.

4.3. Time dimension

The dimension which refers to the time must be named “time” and must be in CNES Julian Days (i.e.: **`days since 1950-1-1 0:0:0`**), it is explained in the Julian Calendar where a Julian-year is 365.25 days.
Each value must represent the mean value for the entire month and the time must be stamped at the 15th of the corresponding month.

4.4. Latitude and longitude dimension

When applicable, the dimension relative to the latitude and longitude must be named “latitude” and “longitude” and must range respectively from -90° to 90° and 0° to 360°.
Each value must represent the variable estimate in a cell, the latitude and longitude coordinates indicating the centre of the corresponding cell.

4.5. Variable and global attributes

Possible attributes for each variable **`xxx`** include:

```
xxx:long_name = " …" ;
xxx:standard_name = "..." ;    # if any
xxx:units = "..." ;
xxx:comment = "..." ;
xxx:scale_factor = ... ;
```

```
xxx:add_offset = ... ;
xxx:missing_value = ... ;
```

Each netCDF may have the following global attributes:

```
:title = "..." ;
:institution = "..." ;
:references = "..." ;
:Conventions = "CF-1.11" ;
:contact = "..." ;
:version = "...";
:comment = "..." ;
:source = "..." ;
```

5. Input data product catalogue

Data product name	**Total sea level**
Physical quantity [units]	Sea level anomaly [m]
Short description	Sea-level anomaly, multi-mission gridded product
Spatial resolution	1°x1°
Spatial coverage	Global ocean
Temporal resolution	Monthly
Temporal coverage	01/01/1993-07/06/2023
Comments	No correction for changes in Earth Gravity, Earth Rotation and viscoelastic solid-Earth Deformation (GRD) because glacial isostatic adjustment (GIA) and fingerprints due to the contemporary GRD changes will be provided as a separate component.

Data product name	**Steric sea level**
Physical quantity [units]	Steric sea level anomaly [m]
Short description	Steric Sea-level anomaly
Spatial resolution	1°x1°
Spatial coverage	Global ocean
Temporal resolution	Monthly
Temporal coverage	1993 - 2023
Comments	

Data product name	**Ocean mass from space gravimetry missions**
Physical quantity [units]	Anomalies of surface mass distribution [kg/m²] Anomalies of surface mass integrated over defined regions [Gt]
Short description	Anomalies of the global distribution of water and ice masses.
Spatial resolution	1°x1°
Spatial coverage	Global (land and ocean) Land-ocean mask will be provided to separate ocean mass change
Temporal resolution	Monthly
Temporal coverage	2002-04 to 2023-12. Some months are missing: 11 consecutive months from 2017-07 to 2018-05 and an additional number of single months.
Comments	Irrespective of the formal spatial resolution, the inherent resolution of the space gravimetry missions GRACE and GRACE-FO is on the order of 300 km. Effects of Glacial Isostatic Adjustment (GIA) are corrected. They are not included in this product (except for effects of errors in the correction models)

Data product name	**Greenland Ice Sheet mass change**
Physical quantity [units]	Anomalies of ice mass [Gt]
Short description	Greenland Ice Sheet mass anomalies
Spatial resolution	None
Spatial coverage	A single time series for Greenland
Temporal resolution	Monthly
Temporal coverage	1993-01 – 2022-12 2002-04 – 2023-12 (space gravimetry based, with a number of months missing)
Comments	It will be specified whether the product excludes or includes peripheral glaciers. Inclusion of peripheral glaciers may be unavoidable for the case of GRACE-based estimates. Some input data will not have a truly monthly resolution, so that the monthly sampling will just be the result of interpolation or of adding an additional seasonal cycle.

Data product name	**Antarctic Ice Sheet mass change**
Physical quantity [units]	Anomalies of ice mass [Gt]
Short description	Antarctic Ice Sheet mass anomalies
Spatial resolution	None
Spatial coverage	A single time series for Antarctica
Temporal resolution	Monthly

Temporal coverage	1993-01 – 2022-12 2002-04 – 2023-12 (space gravimetry based, with a number of months missing)
Comments	It will be specified whether the product excludes or includes peripheral glaciers. Inclusion of peripheral glaciers may be unavoidable for the case of GRACE-based estimates. Some input data will not have a truly monthly resolution, so that the monthly sampling will just be the result of interpolation or of adding an additional seasonal cycle.

Data product name	**Glaciers and ice caps mass change**
Physical quantity [units]	Anomalies of ice mass [Gt]
Short description	Glaciers and ice caps (GIC) mass anomalies
Spatial resolution	None
Spatial coverage	A single time series for Glaciers and ice caps outside Greenland and Antarctica Additional time series for GIC in Antarctica and GIC in Greenland
Temporal resolution	Monthly
Temporal coverage	1993-01 – 2022-12
Comments	Some input data will not have a truly monthly resolution, so that the monthly sampling will just be the result of interpolation or of adding an additional seasonal cycle.

Data product name	**Land water storage change**
Physical quantity [units]	Anomalies of global integrated land water storage [Gt]
Short description	Anomalies of global integrated land water storage, not including glaciers and ice caps
Spatial resolution	None
Spatial coverage	A single time series for global mean land water storage
Temporal resolution	Monthly
Temporal coverage	1993-01 – 2022-12
Comments	

Data product name	**Changes of atmosphere water content**
Physical quantity [units]	Anomalies of water vapour mass [Gt]
Short description	Anomalies of global integrated atmospheric water vapour
Spatial resolution	None
Spatial coverage	A single time series for global integral mass

Temporal resolution	Monthly
Temporal coverage	1993-01 – 2022-12
Comments	

Data product name	**Changes of atmosphere water content**
Physical quantity [units]	Anomalies of water vapour mass [Gt]
Short description	Anomalies of global integrated atmospheric water vapour
Spatial resolution	None
Spatial coverage	A single time series for global integral mass
Temporal resolution	Monthly
Temporal coverage	1993-01 – 2022-12
Comments	

Data product name	**Elastic and GIA Fingerprints**
Physical quantity [units]	Relative sea level (S), absolute sea level (N), vertical displacement of the solid Earth (U), and geoid height change (G) [mm] for the elastic component; S, N, U and G [mm/yr] for the GIA component
Short description	Elastic Fingerprints associated with land sources and GIA fingerprints associated with the ICE-7G(VM7) GIA model
Spatial resolution	1 degree by 1 degree
Spatial coverage	Global
Temporal resolution	Monthly
Temporal coverage	Apr 2002 - Dec 2019
Comments	

Data product name	**Elastic and GIA fingerprints: gravity field effect represented by Stokes coefficients**
Physical quantity [units]	Variation of Stokes coefficients Clm and Slm due to the elastic response and rates of change for the Stokes Coefficients [1/yr] for the GIA response
Short description	Elastic variation of the Stokes coefficients associated with land sources and present-day rate of change of Stokes Coefficients due to GIA according to the ICE-7G(VM7) model. Coefficients are given for harmonic degrees up to Lmax=256.
Spatial resolution	N/A

Spatial coverage	Global
Temporal resolution	Monthly
Temporal coverage	Apr 2002 - Dec 2019
Comments	

Data product name	**Synthetic observations: altimetric synthetic data**
Physical quantity [units]	Sea level anomaly [m]
Short description	Synthetic sea-level anomaly
Spatial resolution	1°x1°
Spatial coverage	Global ocean
Temporal resolution	Monthly
Temporal coverage	1993-2015 (TBC)
Comments	

Data product name	**Synthetic observations: steric synthetic data**
Physical quantity [units]	Steric sea level anomaly [m]
Short description	Steric Sea-level anomaly
Spatial resolution	1°x1°
Spatial coverage	Global ocean
Temporal resolution	Monthly
Temporal coverage	1993-2015 (TBC)
Comments	

Data product name	**Synthetic observations: gravimetric synthetic data**
Physical quantity [units]	Anomalies of surface mass distribution [kg/m²] Anomalies of surface mass integrated over defined regions [Gt]
Short description	Anomalies of the global distribution of water and ice masses, based on synthetic datasets of the different components and their treatment in a manner that mimics the process of GRACE gravity field determination and subsequent analysis.

Spatial resolution	1°x1°
Spatial coverage	Global (land and ocean) Land-ocean mask will be provided to separate ocean mass change
Temporal resolution	Monthly
Temporal coverage	2002-04 to 2015-12
Comments	