IN SITU Global Distribution Production Centre

INSITU_GLO_BGC_DISCRETE_MY_013_046

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CHANGE RECORD

When the quality of the products changes, the QuID is updated and a row is added to this table. The third column specifies which sections or sub-sections have been updated. The fourth column should mention the version of the product to which the change applies.

Issue	Date	§	Description of Change	Author	Validated By
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2.1	04/09/2020	all	Some updates to oxygen quality control procedures; six-month extension of period covered (Jul-Dec 2019)	Jan Even Øie Nilsen, Maria Sotiropoulou, Virginie Racape, Vidar S. Lien	
2.1	21/12/2020	all	Revised version after remarks from Mercator	Vidar S. Lien	S. Tarot
2.2	08/01/2021		Some structural changes in Sections III and IV.	Jan Even Øie Nilsen, Virginie Racape, Vidar S. Lien, Sebastian Ehrhart, Dimitra Denaxa	S. Tarot

Issue	**Date**	**§**	**Description of Change**	**Author**	**Validated By**
2.3	31/08/2021		Updated results, figures and tables; added text on EMODNET inclusion;	Jan Even Øie Nilsen, Virginie Racape, Vidar S. Lien, Sebastian Ehrhart, Margarita Bekiari,	S. Tarot
2.3	30/11/2021		Correction of external links	Stéphane Tarot	S. Tarot
2.4	21/02/2022		Jan – Jun 2021 Extension + added information on update frequency	Jan Even Øie Nilsen, Virginie Racape, Vidar S. Lien, Sebastian Ehrhart, Margarita Bekiari	S. Tarot
2.5	30/08/2022	all	Six-month extension; added river mouth detection algorithm	J. E. Ø. Nilsen, V. Racapé, S. Ehrhart, G. Anastasopoulou	S. Tarot
2.6	18/08/2023	all	Six-month extension; full reprocessing; improved regional ranges	J. E. Ø. Nilsen, V. Racapé, S. Ehrhart, A. Papapostolou	S. Tarot
2.7	04/09/2024	all	Six-month extension; full reprocessing; improved regional ranges (WOA23)	J. E. Ø. Nilsen, V. Racapé, S. Ehrhart, A. Papapostolou	S. Tarot

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I EXECUTIVE SUMMARY

I.1 Products covered by this document

This document gives a detailed picture of the processes and tools used to validate the datasets found in the product INSITU_GLO_BGC_DISCRETE_MY_013_046. The datasets are updated two times per year: in June when the datasets are extended to include all data up until the end of June the previous year, and in November when the full datasets up until the end of December of the previous year are reprocessed.

The present document refers to the In Situ Thematic Assembly Centre (In Situ TAC) Re-Processed Bio-Geo-Chemical product (hereinafter BGC REP) that integrates observations aggregated from the Regional EuroGOOS consortium (Arctic-ROOS, BOOS, NOOS, IBI-ROOS, MONGOOS) and Black Sea GOOS, as well as from SeaDataNet2 National Data Centers (NODCs), EMODnet chemistry 2018 and JCOMM global systems (Argo, GOSUD, OceanSITES, GTSPP, DBCP), together with the Global telecommunication system (GTS) used by the Met Offices.

The BGC REP product integrates updated quality flags from the history directory files of the Near-Real Time (hereinafter NRT) product (INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030), downloaded from the Global Distribution Unit at IFREMER. Quality flags have been reanalysed in delayed mode using updated real-time and delayed mode quality assessment procedures as described in this document.

The product is a subset of the Global Ocean In-Situ Near-Real-Time Observations (INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030), where the biogeochemical parameters (chlorophyll, oxygen and nutrients -nitrate, phosphate, silicate-) have been quality controlled and new quality control flags have been applied. The other parameters present in the files (and their quality control flags) are identical to those in the original files of the INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030 dataset. Files which do not contain chlorophyll, oxygen or nutrients data are not included.

I.2 Summary of the results

This product contains time series and profiles with measurements of chlorophyll, fluorescence, oxygen concentration, nitrate, silicate, and phosphate. Chlorophyll concentration is used as the best available proxy for phytoplankton biomass. It should be noted, though, that it is a proxy, and the actual biomass may vary substantially for a given chlorophyll concentration in response to the environmental conditions in which the phytoplankton grow (Geider, 1987; Geider et al., 1997, 1998; Kruskopf and Flynn, 2006).

Chlorophyll concentration is measured using a range of techniques from many different platforms, as described in section II.1 below. These data sources range from laboratory based high pressure liquid chromatography (HPLC) and spectrophotometry to automated fluorometric methods, with the latter becoming increasingly common with their more frequent use in automated platforms in more recent time.

Chlorophyll concentrations are highly spatially variable, especially in coastal waters and upwelling regions where there are larger concentrations of nutrients. On a seasonal basis, they also tend to be higher in spring, again because of increased nutrient availability. Similar to the distribution of nutrients within the ocean, the chlorophyll concentration is also patchy, as micro-algae rapidly multiply in number to exploit any region where nutrients and light are available. This patchiness results in small areas with high chlorophyll concentrations in contrast to large regions with low values. Sampling such a system typically results in a highly and positively skewed distribution.

Chlorophyll data are sorted into three types: CPHL (chlorophyll-*a*), FLU2 (chlorophyll-*a* fluorescence) and CHPT (total chlorophyll), as described by Jaccard et al. (2018). The units of measurement for all data types are milligrams per cubic metre (mg m^{-3}). CPHL data are obtained from laboratory analyses using HPLC and spectromorphometry and fluorometric data from the BGC-Argo platforms alone. FLU2 data comprise all other in-situ fluorometric-based measurements from gliders, ferrybox, buoys and other platforms. CHPT represents a significant amount of data, but it has been poorly documented. Much of it comes from the first collected records, when instruments did not discriminate between different forms of chlorophyll, and we have not used it in the production of this reprocessed product.

Oxygen data come from various sources and providers. Therefore, dissolved oxygen concentration can be expressed either in ml/l (for DOX1; volume fraction of oxygen), in mmol m^{-3}, equivalent to µmol/l for DOXY (the mole concentration of dissolved molecular oxygen), or in µmol/kg for DOX2 (moles of oxygen per unit mass). Quality control procedures for the oxygen parameters are developed and performed on the original data set in collaboration with the Institute of Marine Research (IMR), Norway, the French Research Institute for Exploitation of the Sea (IFREMER), France, the Hellenic Centre for Marine Research (HCMR), Greece, and the Finnish Environment Institute (SYKE), Finland. In addition, some region-specific quality control procedures are developed and applied for the Baltic Sea (by SYKE) and for the Mediterranean Sea (by HCMR). Additional visual inspection is applied. To increase the user-friendliness, the oxygen product is then converted by the Global In Situ TAC distribution unit (DU) either in µmol/kg, available in the sub-directory “Data_In_ micromolKG”[1], or in µmol/l available in the sub-directory “Data_In_ micromolL”[2], both available on the Marine Data Store. The reprocessed product including oxygen in the original units is also available in the sub-directory “OriginalUnit”[3], also on the Marine Data Store.

For nutrients, parameters such as nitrate, provided either as variable NTRA (mmol m^{-3}) or NTAW (µmol kg^{-1}), phosphate concentration PHOS (mmol m^{-3}), and silicate concentration SLCA (mmol m^{-3}) are included. Quality control procedures for the nutrient parameters have been developed and performed in collaboration with IMR, HCMR and SYKE. In addition, some region-specific QC procedures have been developed and applied for the Baltic Sea (by SYKE) and for the Mediterranean Sea (by HCMR). Additional visual controls have been applied.

I.3 Estimated Accuracy Numbers

Table 1 summarizes the accuracy of biogeochemical measurements that can be expected depending on the platforms and sensors. This is the best accuracy a user can expect for in situ data to which a quality flag “Good data” (QC=1) has been applied after the validation process. Please see the CMEMS-INS-QUID-013-030 -036 document[4] for more information.

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[1] Global Ocean - Delayed Mode Biogeochemical product | Copernicus Marine Service

[2] Global Ocean - Delayed Mode Biogeochemical product | Copernicus Marine Service

[3] Global Ocean - Delayed Mode Biogeochemical product | Copernicus Marine Service

[4] https://doi.org/10.13155/75807

Table 1: Accuracy for the observations of biogeochemical parameters in the different platforms. Data are obtained from the In Situ TAC.

Platform type	**Chlorophyll fluorescence**	**Oxygen**	**Nitrate**	**Silicate**	**Phosphate**
CTD	0.05 mg m^{-3}	8 µmol/kg	Discrete samples	Discrete samples	Discrete samples
PFL (profiling floats)	0.05 mg m^{-3}	2% of saturation	2 µmol/kg or 10% of concentration (whichever is greater)	N/A	N/A
Moored buoy; surface Subsurface	0.05 mg m^{-3}	<8 µmol/kg or 5% of concentration (whichever is greater)	2 µmol/kg or 10% of concentration (whichever is greater)	N/A	N/A
Drifting buoy	0.05 mg m^{-3}		N/A	N/A	N/A
Glider	0.05 mg m^{-3}	2% of saturation	2 µmol/kg or 10% of concentration (whichever is greater)	N/A	N/A
Ferrybox	0.05 mg m^{-3}	8 µmol/kg	Typically lower than 2% of the full scale. Repeatability: lower than 2%	N/A	N/A

II PRODUCTION SYSTEM DESCRIPTION

Production centres name: Global Distribution Unit at IFREMER, France

Production system name: Global reprocessed in situ BGC observations

Table 2: Description of the datasets.

Product code	INSITU_GLO_BGC_DISCRETE_MY_013_046
Datasets	cmems_obs-ins_glo_bgc-chl_my_na_irr cmems_obs-ins_glo_bgc-ox_my_na_irr cmems_obs-ins_glo_bgc-nut_my_na_irr
Geographical coverage	Global
Variables	TIME, DEPH, LATITUDE, LONGITUDE, FLU2, CPHL, DOXY, DOX1, DOX2, NTAW, NTRA, PHOS, SLCA.[5]
Available time series	1990 to December Y-1
Temporal resolution	Hourly/monthly/daily

II.1 Data sources

The data come from a variety of sources (platforms) including manual CTD-O_2 measurements, BGC-Argo profiling floats (delayed mode data), ferrybox systems, gliders and moored buoys. However, as this product gathers global reprocessed in situ BGC observations, only BGC floats with delayed-mode data (i.e., data assessed by a scientist or a specialist in chlorophyll, oxygen and/or nitrate) are included in the corresponding repositories. Due to the diverse sources, the characteristics of the data (e.g., the time frequency for recording, the spatial pattern, the depth) may largely vary. For instance, CTD-O_2 measurements are typically sampled along a transect or a grid, with measurements for a large number of depths (a depth profile) for each point in the grid. In contrast, BGC-Argo data are similar in structure, as they also consist of a collection of depth profiles but in these data, the location of the profiles follows the drift pattern of the float. Ferrybox data and buoy data, on the other hand, are time series collected at a fixed depth. However, while Ferrybox data are collected with a relatively high frequency (typically, one measurement per minute) along a transect, buoy data are from a single location. Moreover, the data coverage is skewed towards the northern hemisphere.

The data are collected through Copernicus Marine In Situ TAC, a distributed system built on the existing activities and services developed previously within the EC supported projects (e.g., MyOcean, Mersea, Ferrybox, among others) and the activities carried out in the EuroGOOS Regional alliances (ROOSes). Copernicus Marine In Situ TAC provides the interface between centres, distributing in situ measurements from national and international observing systems. It is a distributed centre organized around seven oceanographic regions: the global ocean and the six EuroGOOS regional alliances. It involves 15 partners from 10 countries in Europe. It doesn't deploy or operate any observing systems by itself but depends on data obtained by national/regional data providers.

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[5] For information on units for each variable see the Product User Manual document. CMEMS-INS-PUM-013-046.pdf

II.1.1 Global chlorophyll data

The spatial distribution of chlorophyll samples is shown in Figure 1. The total number of Chlorophyll profiles with valid data is approximately 112,000.

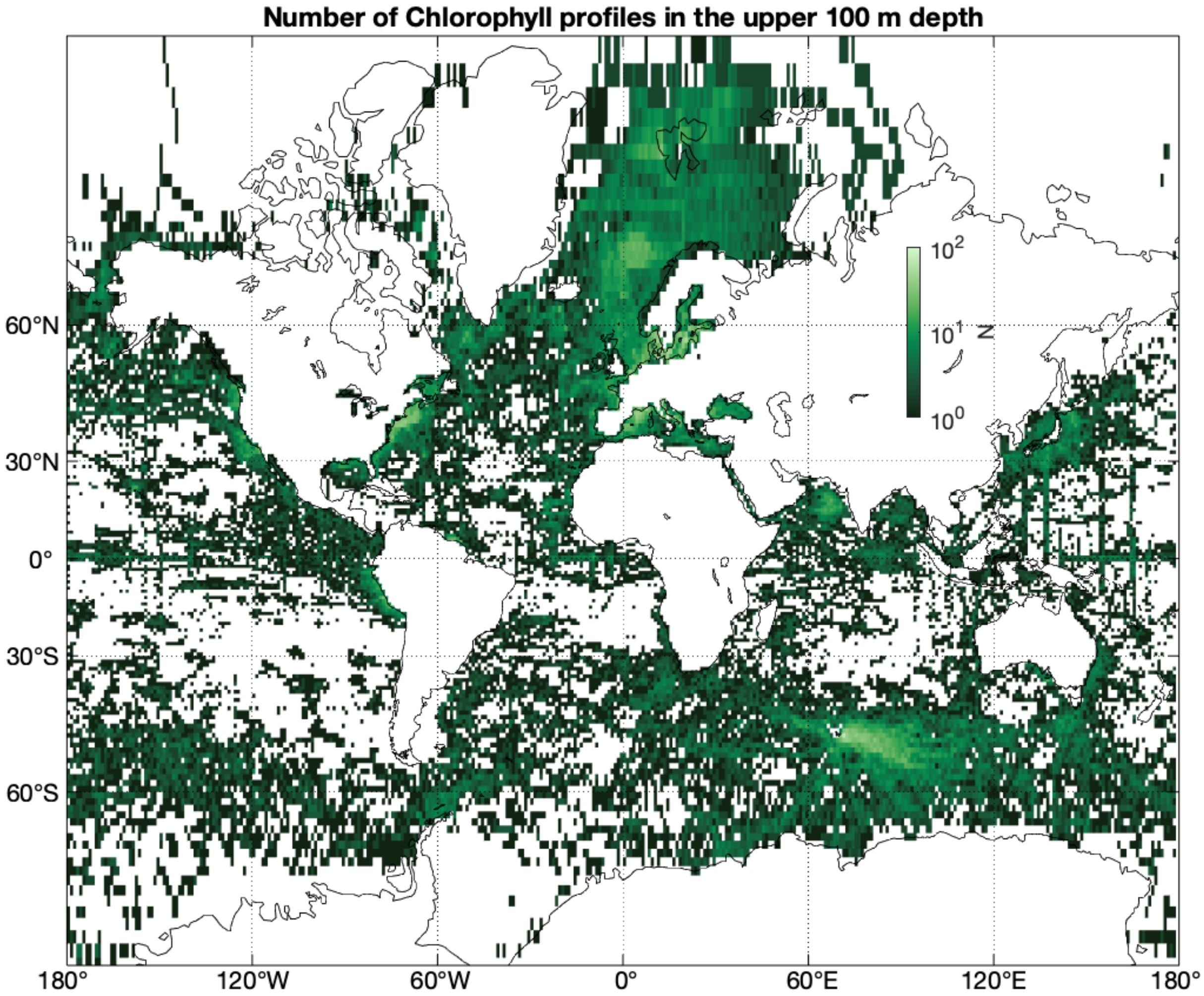

Figure 1: Spatial coverage of chlorophyll data, shown as the number (N) of profiles in the upper 100 m water depth in 1° x 1° cells. Profiles in cells towards the poles not shown in the map are summed up onto the northernmost and southernmost row of cells displayed in the map. An inverse colour ramp is used, thus the darker the colour, the lower the number of profiles, in order to show the gaps in the coverage more clearly.

II.1.2 Global oxygen data

DOXY, DOX1 and DOX2[6] are all oxygen concentrations but measured in different units and available in the “OriginalUnit” product. The spatial distribution of oxygen samples is shown in Figure 2. The total number of oxygen profiles with valid data is 436,000.

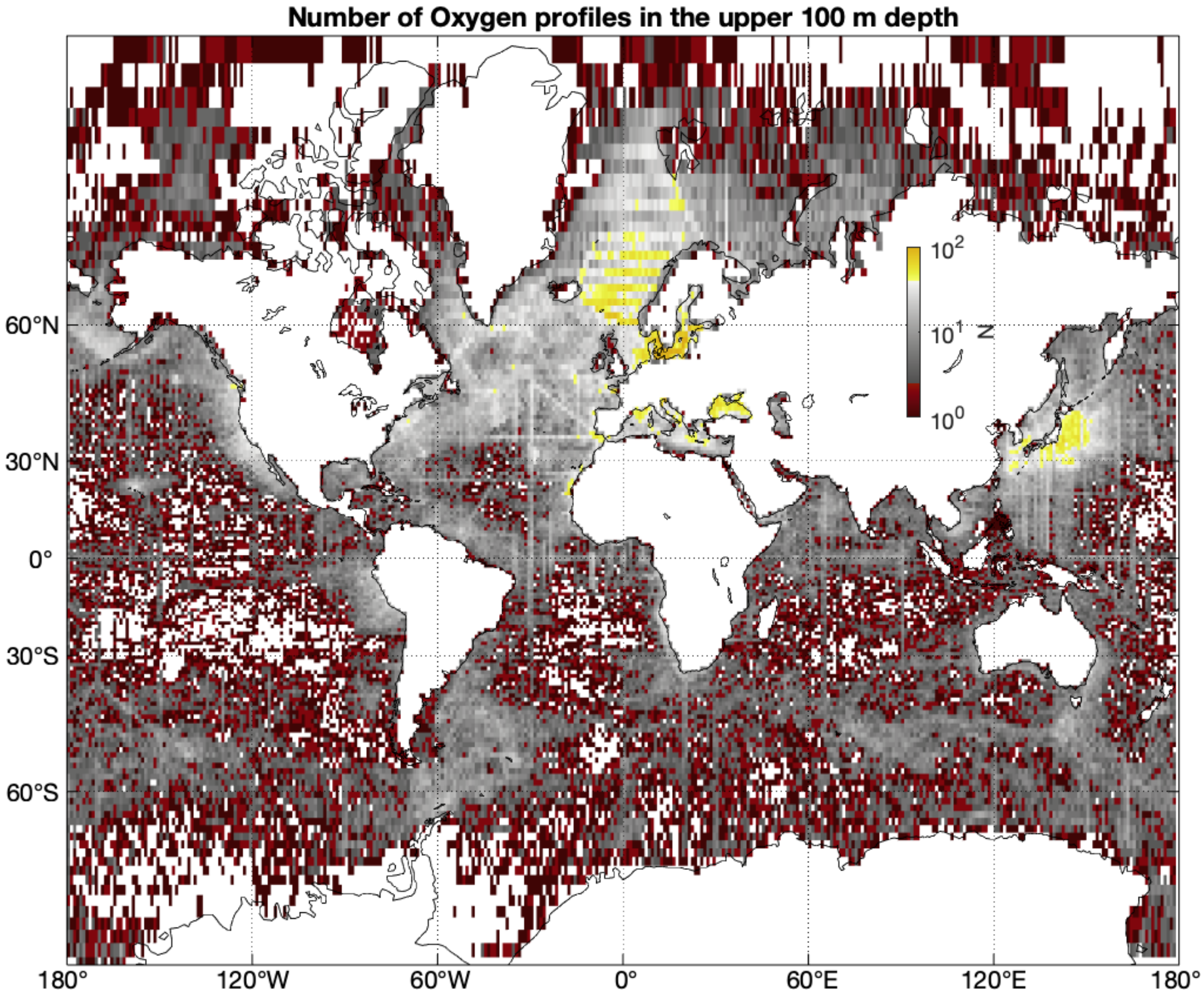

Figure 2: Spatial coverage of oxygen data, shown as the number (N) of profiles in the upper 100 m water depth in 1° x 1° cells. Profiles in cells towards the poles not shown in the map are summed up onto the northernmost and southernmost row of cells displayed in the map. An inverse colour ramp is used, thus the darker the colour, the lower the number of profiles, in order to show the gaps in the coverage more clearly.

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[6] For additional information about contents and units of each variable see Product User Manual document. CMEMS-INS-PUM-013-046.pdf

II.1.3 Global nutrient data

Nutrient data use different units of concentration depending on which specific nutrient is being referred to. The Nitrate variables are moles per unit mass (NTAW) and mole concentration (NTRA), while variables measuring Phosphate are PHOW and PHOS, whereas variables for Silicate are SLCW and SLCA, all in µmol kg^{-1} and in mmol m^{-3}, respectively. The spatial distributions of the samples for the three different nutrients are shown in Figure 3 to Figure 5. The total number of Nitrate profiles with valid data is 111,000, while valid Phosphate profiles are 180,000 and Silicate profiles 149,000.

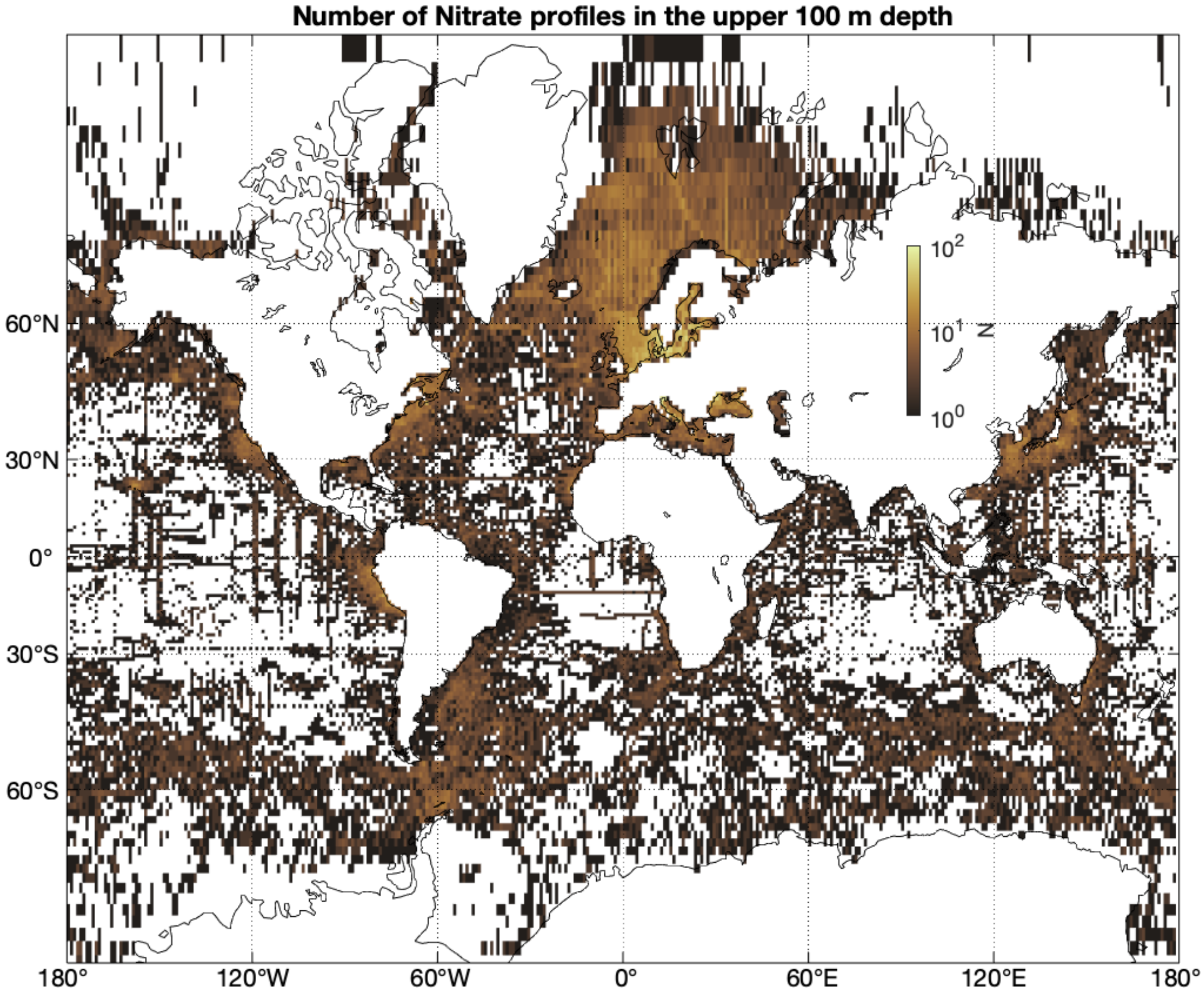

Figure 3: Spatial coverage of nitrate data, shown as the number (N) of profiles in the upper 100 m water depth in 1° x 1° cells. Profiles in cells towards the poles not shown in the map are summed up onto the northernmost and southernmost row of cells displayed in the map. An inverse colour ramp is used, thus the darker the colour, the lower the number of profiles, in order to show the gaps in the coverage more clearly.

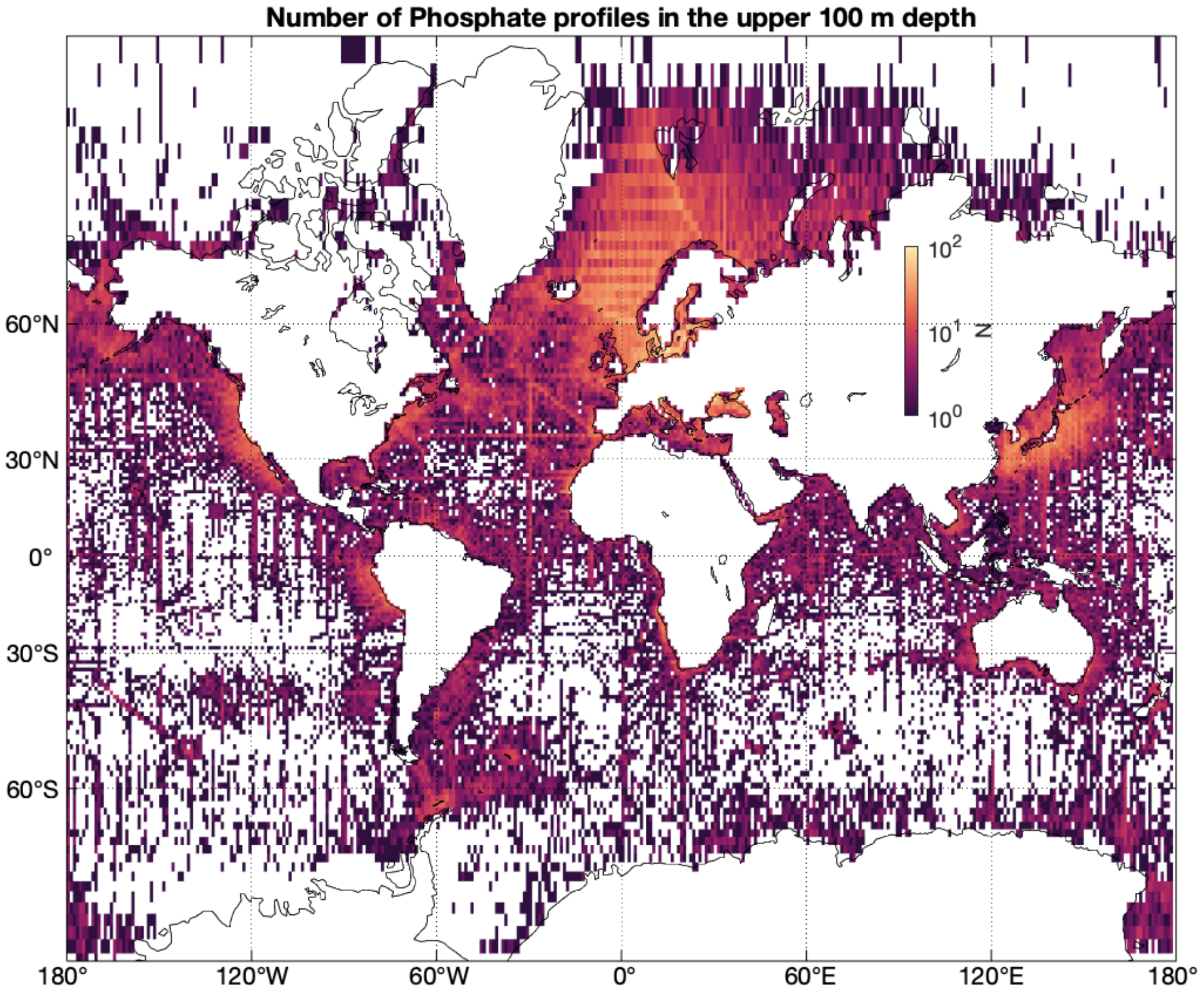

Figure 4: Spatial coverage of phosphate data, shown as the number (N) of profiles in the upper 100 m water depth in 1° x 1° cells. Profiles in cells towards the poles not shown in the map are summed up onto the northernmost and southernmost row of cells displayed in the map. An inverse colour ramp is used, thus the darker the colour, the lower the number of profiles, in order to show the gaps in the coverage more clearly.

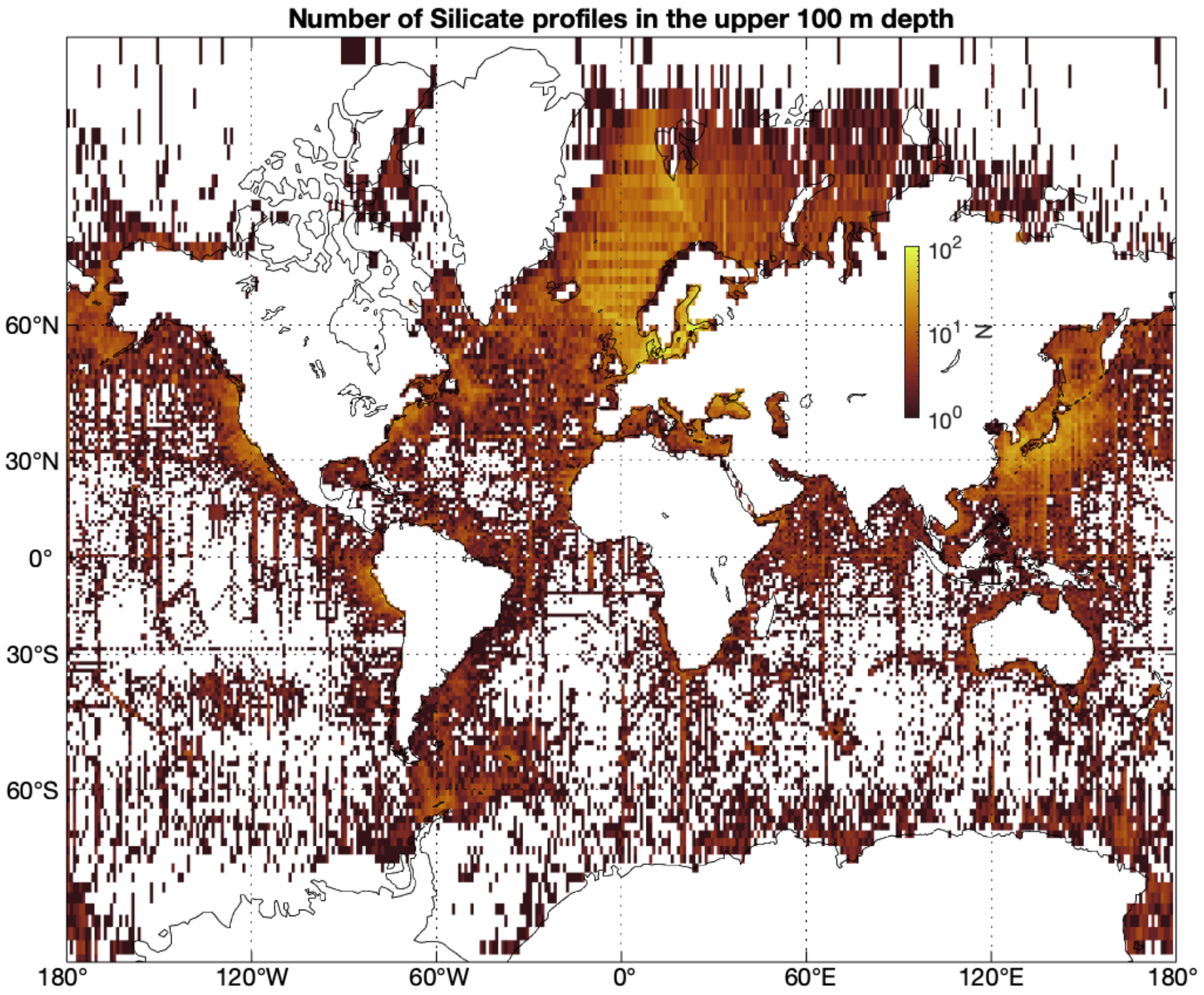

Figure 5: Spatial coverage of silicate data, shown as the number (N) of profiles in the upper 100 m water depth in 1° x 1° cells. Profiles in cells towards the poles not shown in the map are summed up onto the northernmost and southernmost row of cells displayed in the map. An inverse colour ramp is used, thus the darker the colour, the lower the number of profiles, in order to show the gaps in the coverage more clearly.

II.1.4 Baltic Sea oxygen and nutrient data

In the Baltic Sea region oxygen and nutrients data are collected by several research vessels as part of a continuous monitoring effort (see the Manual for Marine Monitoring in the COMBINE Programme; HELCOM, 2017).

Ferrybox systems provide a large amount of data collected in two different ways: (i) either a flow through system that measures at each interval (e.g. every 20 seconds); or (ii) ferryboxes which use a sequence sampler to collect bottle samples that will be later analysed in the laboratory. These systems typically collect data at a nominal depth of around 5 m.

Data from these sources consist of chlorophyll-a fluorescence measurements from ferrybox flow through systems and gliders, Chlorophyll-*a* and nutrient concentrations from ferrybox bottle samples, vertical profiles, and oxygen measurements.

II.1.5 Mediterranean oxygen and nutrient data

The Mediterranean Sea region (5.61° W – 37.0° E, 28.0° N - 41.0° N, and 0.0° E – 20.0° E, 41.0° N – 45.8° N) contains oxygen data collected from vessels (10.6%), profiling floats and gliders (13.5%), moorings (2.5%), bottles (73.3%), and ferryboxes (0.2%). The deep ocean part of the Mediterranean Sea is mainly covered by Argo floats and research vessels, whereas the shelf part is mainly covered by fixed stations. Oxygen variables are provided as ml/l, µmol/l and µmol/kg. For consistency and for independence of the availability and quality of temperature and salinity measurements, it was considered that the averaged potential density of seawater equals to 1.025 kg/l. Applying a conversion factor of 44.6596 µmol/ml (SCOR WG 142), DOX1 and DOXY variables can be converted into µmol/kg (i.e., DOX2). Nutrient data from the Mediterranean region consist of nitrate, nitrite, silicate and phosphate data collected from vessels, bottles, profiling floats and gliders. Figure 6 depicts the location of the aforementioned platform types recording oxygen and nutrient data in the Mediterranean region.

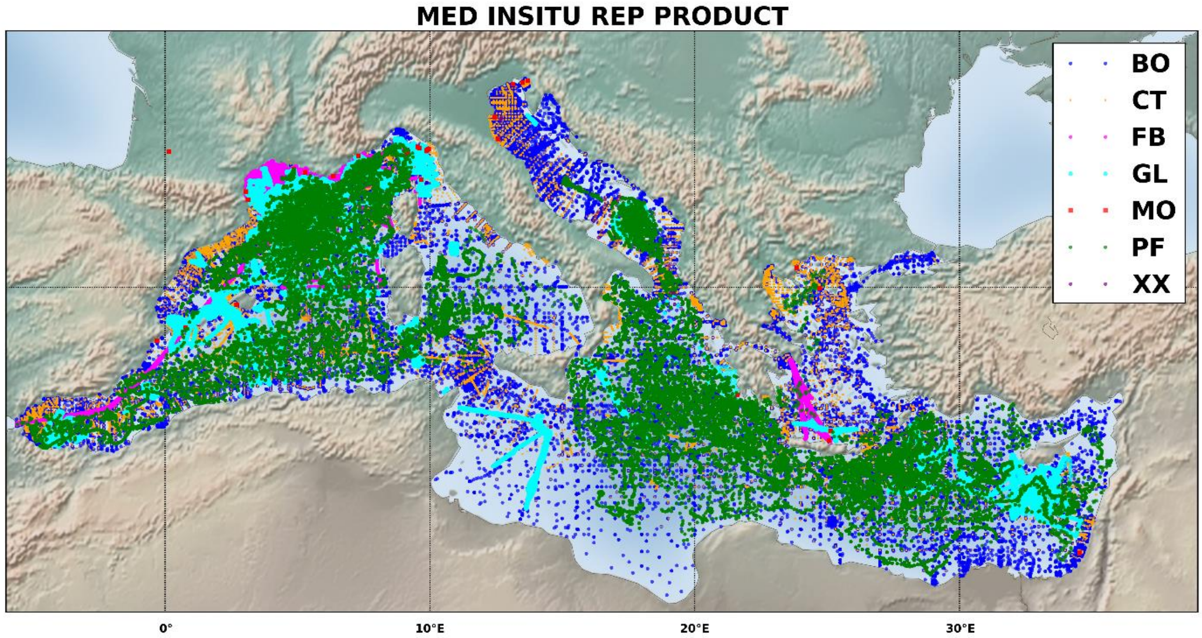

Figure 6: Location of the different platforms where biogeochemical data are sampled in the Mediterranean region. Green: profiles (PF); red: moorings (MO); dark blue: bottles (BO); light blue: gliders (GL); orange: vessels (CT); pink: ferrybox (FB); purple: profiles (XX).

III VALIDATION FRAMEWORK

The validation framework used to assess the validity of the BGC data within this product and its rationale are discussed in this section.

To determine the upper range of valid values for chlorophyll concentration in coastal and pelagic regions, the framework applied to the chlorophyll data is based on a classical statistical concept known as the "Empirical Rule" or the "three sigma rule" (99th percentile ≈ 3σ and 95th percentile ≈ 2σ; σ = one standard deviation). The quality control procedures used to reprocess the quality flags for oxygen and nutrient data are based on a regional range test that flags outliers while allowing for strong climate signals.

III.1 Quality control flags

The quality control (QC) flags and their meaning and application for users are summarized in Table 3. The value QC=6, inherited from the EMODNET chemistry data is included, but is not applied in any test during the reprocessing.

Table 3: Quality Control (QC) flag scale. The flag QC=6, inherited from the EMODNET chemistry data, is not applied in any test during BGC-REP.

Code	Quality level
0	No QC performed
1	Good data
2	Probably good data
3	Bad data that are potentially correctable
4	Bad data
5	Value changed
6	Value below detection/quantification
7	Nominal value
8	Interpolated value
9	Missing value

III.2 Testing of metadata

For all the files metadata, such as date, location, pressure, and existing QC, are reprocessed using the tests described in the following sections to assess the quality of the metadata.

III.2.1 Impossible date and location test

This metadata test checks whether the observation date, time, latitude and longitude from the profile data are within the following allowed ranges:

- Date no greater than today
- Latitude within -90° to 90° range
- Longitude within -180° to 180° range

When the metadata values fail the test (i.e., the metadata are outside the respective allowed range), the QC flag of the variable is set to 4 “Bad data” (Table 3).

III.2.2 Metadata QC test

This test checks that a valid observation (i.e., with a flag that differs from QC = 4, 9 or False Value) is well defined according to x, y, z and t axes, with a valid longitude, latitude, depth (or pressure) and time variable. Thus, when the quality flags for <POSITION_QC>, <TIME_QC>, <PRES_QC> and/or <DEPH_QC> equals 4, the oxygen concentration (DOX2) is marked as bad, QC = 4. This test only applies to DOX2 and NTAW (QC = 4 for DOX2 and NTAW if QC = 4 from the metadata test), as DEPH and PRES are used for the conversion to µmol/kg.

III.2.3 Negative pressure/depth test

This test checks the sign of the observed pressure (PRES; desibar) or depth (DEPH; meter) from the profile data (positive downwards). If PRES or DEPH < 0 then the QC flag of the variable is set to 4 “Bad data” (Table 3).

III.2.4 Automated test for on-land positions

Errors in data position are frequent. In the BGC-REP, data positions are tested against both ETOPO2 elevation data (NOAA, 2006) and the Global Self-consistent Hierarchical High-resolution Shorelines (GSHHS) dataset (Wessel et al., 1996).

A 6 arc-minute global mask for near coast regions was created by detecting all cells encompassing a coastline, using the GSHHS full resolution database. The remaining cells are used to create two additional masks: (i) a mask for offshore and (ii) a mask for inland regions, with the support of ETOPO2 elevation data. Some manual checking and editing of the latter two masks are done to ensure the robustness of the methodology.

For each file, as a first step the offshore mask is used to omit lon/lat positions in further testing. Next, the inland mask is used to flag positions that are clearly positioned on inland from the coastline (QC=4). Then, full resolution GSHHS lon/lat (WGS84) coastline polygons for the geographical region covered by the remaining data are extracted (using the m_map package in Matlab; Pawlowicz, R., 2019). Finally, each polygon is tested for existence of positions within a land polygon, in which case the QC=4.

The results are validated by visual checks of on-land detection random sampled cases (see an example in Figure 7a).

Furthermore, flagged positions within a distance to the coastline closer than the maximum resolution of the coastline (i.e., closer than the distance between any of the two nearest coastline segments), are flagged as ‘probably good data’ (QC=2; Table 3; Figure7b). It is found that the resolution of the coastline vector-data is the best indicator for coastline precision. The possibility of loss of sign or ‘W’ on longitudes or ‘S’ on latitudes, is not investigated.

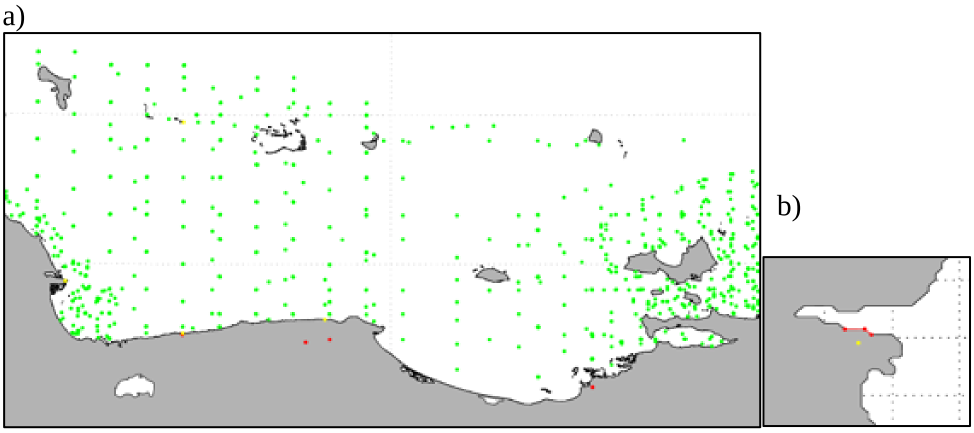

Figure 7: a) Example showing on-land positions (red dots); near coast ‘probably good data’ (yellow dots near the coastline), and good data (green dots). The on-land positions are flagged as ‘bad data’, while the ‘probably good data’ points are detected and manually checked through visual inspection. b) Example showing the detection method for probably good positions (yellow dots), with nearest coastline points and line segments in red.

III.2.5 River-mouth detection

Ocean regions near river mouths are detected using World Vector Shorelines (WVS) and CIA World Data Bank II (WDBII) rivers database as embedded in the *m_map* toolbox (Pawlowicz, R., 2019). Regions where river vector data intercept coastline vector data are found by projecting both datasets onto 6 arc-minute grid cells and then identifying the overlapping cells. These identified river mouth regions are then allowed to expand seven times by one grid cell in all directions, but always limited to a coastal zone defined by the twice expanded shoreline mask. The reason for this expansion of the river-mouth regions is to include larger bays while still limiting the along-shore expansion. This automated approach is only meant to provide a simple indicator of areas where care should be taken with respect to the effect of river discharge.

The river-mouths mask is at this point only used to highlight data points near river-mouths in the visual control of the range tests, and thus has no direct effect on the automated range test or other tests.

III.3 Chlorophyll

III.3.1 Division of the global ocean into biogeochemical regions

Chlorophyll concentration is typically much higher, by a factor of 10 or more, in coastal waters than in pelagic (or deep ocean) waters. Coastal waters also show greater range of variability in chlorophyll concentration over the year compared to deep ocean areas. Therefore, an acceptable range must be set based on that found in a given biogeochemical area. Defining each of these regions separately therefore allows for increased precision in detecting unusual values.

There are several published methods for subdividing the global ocean into biogeochemically similar areas. The system of Longhurst (1998) defines broad biogeographical provinces, with less detail near the coast. Alternatively, the Large Marine Ecosystem approach (Sherman and Duda, 1999; Sherman et al., 2005) defines only coastal provinces. We have chosen to use the system of Spalding et al. (2007, 2012) as it covers the entire globe and allows us to define in detail all coastal and pelagic regions. Using this system, we sub-divide the global ocean to “province”-level using the shapefiles of Spalding et al. (2007, 2012), which define coastal and pelagic regions, respectively. These shapefiles may be downloaded from the web[7] [8]. Globally, these give 62 provinces covering the coastal regions, islands, shallow seas and enclosed seas (for simplicity called “coastal” waters here), and 37 provinces for the pelagic oceans (Figure 8). The “coastal waters” are defined as extending 200 nautical miles (370 km) offshore, or to the 200-meter isobath wherever this lies further offshore. The polygons in the shapefiles for the coastal and pelagic provinces overlap in some areas. When assigning a data point to “coastal” or pelagic waters, the geographical location is checked first to assess whether it lies within any of the “coastal” polygons in the shapefiles. If not, then the geographical location is checked to determine which pelagic polygon in the shapefile is associated with that particular data point. It is important to search and sort the data, in this order, to avoid coastal chlorophyll data being associated with pelagic waters.

This approach works everywhere except for the Mediterranean Sea, where the above definition of the “coastal” waters essentially covers the entire sea, and no pelagic water mass is defined. This occurs as the shapefiles of Spalding et al. (2007) take precedence over those of Spalding et al. (2012) which do have a pelagic province covering the whole Mediterranean that extends right to the coast. In this re-processing we therefore use these “coastal” shapefiles of Spalding et al. (2007) and therefore, no pelagic waters are defined for the Mediterranean Sea. Further work is required to define a new shapefile specifically for the Mediterranean coastal and pelagic regions.

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[7] https://www.worldwildlife.org/publications/marine-ecoregions-of-the-world-a-bioregionalization-of-coastal-and-shelf-areas

[8] http://data.unep-wcmc.org/datasets/38

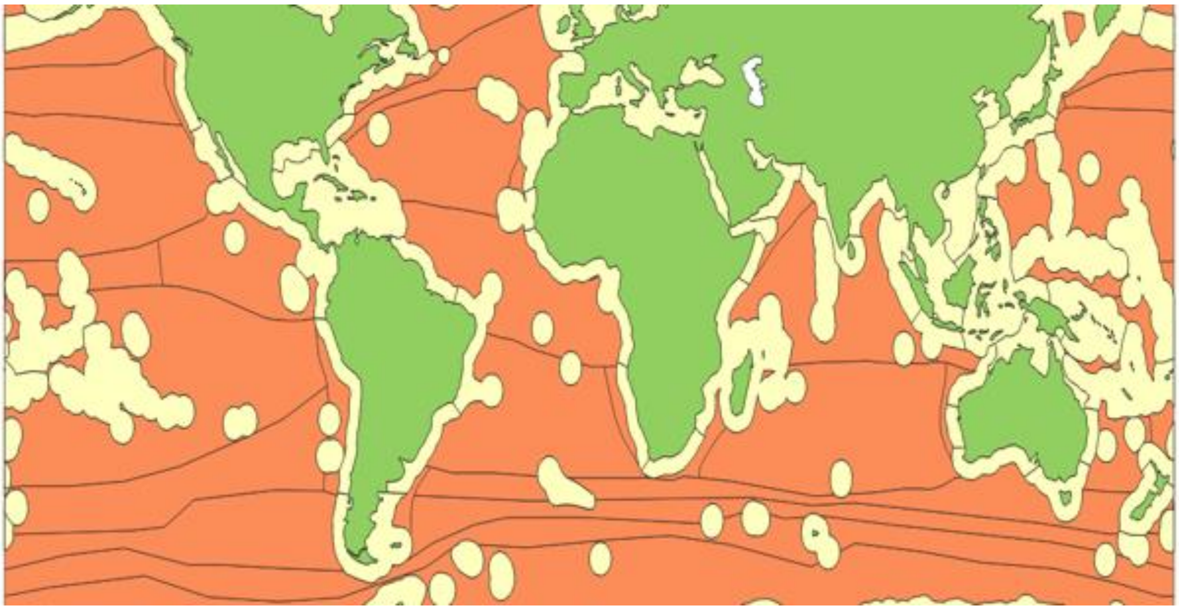

Figure 8: Ocean provinces based on Spalding et al (2007, 2012). Yellow: coastal areas; orange: pelagic areas. The lines delimit the different provinces.

Using these shapefiles, all available global Chlorophyll data are collated and sorted into each of the respective provinces (Figure 8).

The polygons in the shapefiles of Spalding et al. (2007), which define the coastal regions, also cover areas around the remote islands which lie within the pelagic regions (Figure 8). Those islands lying within the tropics typically have chlorophyll concentrations similar to pelagic waters in which they lie. Therefore, for these specific coastal provinces a lower maximum chlorophyll concentration value is expected than in the case of coastal waters surrounding the continental land masses.

III.3.2 Division of the oceans in terms of depth for chlorophyll

After following the steps described in the previous section, to separate the oceans into coastal and pelagic provinces, we also divide the global ocean into three depth ranges: two for the “euphotic” zone and one for deep waters (below 200 metres) which have very low chlorophyll values due to the absence of light.

III.3.2.1 All waters 200 - 10,000 m deep

Jaccard et al. (2018) recommends a range of acceptable values of between -0.1 to 0.5 mg m^{-3} for both CPHL and FLU2 variables, in all waters larger than 200 metres in depth, and over all the months of the year (Tables 9 and 10 in Jaccard et al., 2018). We adopt these values in our analysis, and they are applied as a range for checking any chlorophyll data in all waters within this depth range. In Table 10 of Jaccard et al. (2018) the longitudinal limit is set to a minimum of -60°E and a maximum of 180°E, whereas latitudinal limits are set from 90°S to 30°S. This appears to be a typographical mistake, and we apply the range values in the same way as in Table 9 of Jaccard et al. (2018), which spans all longitudes and all latitudes.

It should be noted that for most of the “coastal” regions, except for the inland and enclosed seas, data for waters deeper than 200 metres will not be available, by definition, as Spalding et al. (2007) use the 200-metre isobath to determine the boundary of the polygons delimiting the coastal waters in the shapefiles.

Data for processing may measure pressure in decibars rather than depth in metres. One decibar is approximately equivalent to one metre depth of seawater, but for depths larger than 200 metres this simple assumption leads to errors of a few metres. In order to convert these values to a linear measure, the methods of Fofonoff and Millard (1983) and of Leroy and Parthiot (1998) are used:

$$g = 9.780318(1 + 5.2788\times10^{-3}\sin^{2}\phi + 2.36\times10^{-5}\sin^{4}\phi \quad \text{Eq. (1)}$$

Where g is the acceleration due to gravity, corrected for latitude, being ϕ the latitude expressed in radians.

Depth (z) in metres is then given as a function of pressure (P) in decibars as:

$$z = \frac{C_1P - C_2P + C_3P - C_4P}{g + 1.092\times10^{-6}P} \quad \text{Eq. (2)}$$

Where C_1, C_2, C_3 and C_4 are constants (C_1= 9.72659, C_2=2.2512*10^{-5}, C_3=2.279*10^{-10}, and C_4=1.82*10^{-15}).

This algorithm is implemented in Python using the *Seawater* library[9] (version 3.3.4), which is used for the main re-processing stage of the analysis.

III.3.2.2 The “Euphotic zone” 0-200 metres deep

The euphotic zone is considered to be the region where there is sufficient light to enable photosynthesis. The actual depth of this zone therefore varies with season, latitude, water mass and the biological productivity within the water column. We have used 0-200 m as the maximum limit for this zone to include all latitudes and seasons. However, chlorophyll concentration is generally much higher in the waters nearer the surface. Therefore, we subdivide the euphotic zone into 0-100 m and 100-200 m. The effect of this choice is illustrated for two provinces, the North Central Atlantic Gyre and the more productive Sub-Arctic Atlantic (Figure 9). In Figure 9, the frequency distributions and corresponding 95th (≈2σ) and 99th (≈3σ) percentile values of the data are plotted. The rationale for this approach is further discussed in Section III.3.4 below. When the whole euphotic zone (0-200 m) is considered as one water mass, the chlorophyll observations obtained at larger depths present higher occurrence of values with low chlorophyll concentration, therefore reducing the 95 and 99 percentile values (as shown in the Figure 9, see top vs. middle panels). Separating the euphotic zone vertically into 0-100 m and 100-200 m serves to isolate the lower values of the deep euphotic zone from the surface waters, which allows an increased representativeness when calculating the percentile values. It should be noted, though, that in some regions, particularly those with a shallower surface mixed layer depth and a highly productive surface layer, and especially in late spring and summer, the depth of the euphotic zone may be less than 100 m. We have not been able to correct for this condition on a global basis and the effect may be to slightly bias our percentiles towards the lower values in some regions. However, although we cannot quantify the magnitude of this effect, it is likely to be small.

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[9] https://pypi.org/project/seawater/

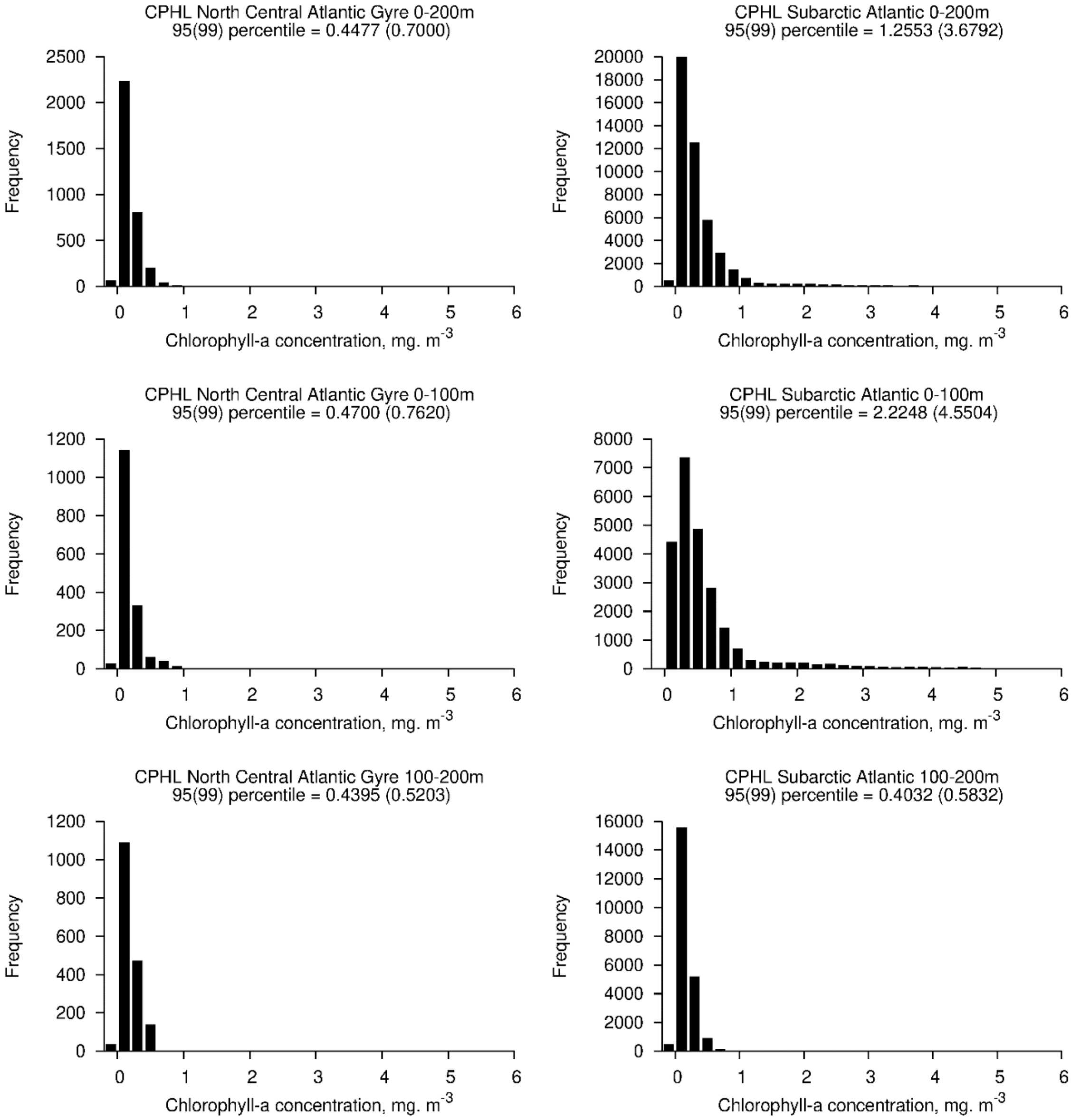

Figure 9: Frequency plot for CPHL in the North Atlantic Gyre (left) and Subarctic Atlantic (right) provinces, calculated for 0-200-m (top), 0-100-m (middle) and 100-200-m (bottom) depth ranges. Note the different scales on the vertical axes.

III.3.3 Seasonality in chlorophyll

Neither the coastal nor the pelagic data are sorted by season, as the latitudinal limits of the polygons in the shapefiles defining each province are in part a result of the present climatic regime. Climate change and natural variability (which may occur on several temporal scales -season, interannual, decadal, etc--) may shift the boundaries of “seasons” thus applying too strict definitions of seasons may result in rejecting future data that should be accepted due to climate change.

The largest seasonal effects are most likely to occur during spring-bloom events, and these are much more pronounced in the “coastal” waters described above, which have higher maximum ranges set accordingly. In contrast, seasonal variability in the pelagic waters is much lower and lies within the range of acceptable values as defined.

We inspect the effect of partitioning the data by season (discussed in Section IV). However, the data available for the reprocessing are not equally distributed in all seasons, and for some provinces there are as of yet, too few data points to adequately represent the spatial or seasonal variability.

III.3.4 Calculation of the acceptable upper and lower limits for chlorophyll concentration

Antoine et al. (1996) calculated a global mean value for near surface chlorophyll concentration of 0.19 mg m^{-3} based on data for all the oceans between 50°N - 50°S, with more than 95% of the waters in this region having a chlorophyll concentration lower than 1.0 mg m^{-3} (see Figure 1b in Antoine et al., 1996). Those regions with a chlorophyll concentration of more than 10.0 mg m^{-3} cover less than 0.05% of the total area between 50°N and 50°S (Figure 1a in Antoine et al., 1996).

Jaccard et al. (2018) adopted maximum values of either 10 or 20 mg m^{-3} for the global oceans (Tables 9 and 10 in Jaccard et al., 2018). In the light of Antoine et al (1996), these are one to two orders of magnitude larger than measures in most of the ocean regions, although in some coastal regions such values may occur. Setting the maximum to values like those for all regions means that the precision is lost when performing any quality control on the vast majority of the data.

In this reprocessing, we adopt a different strategy: to use the 99th percentile value of a given province to determine the acceptable maximum value. We use the percentile value, rather than the 99% confidence interval to define the maximum acceptable limiting value because the data are highly positively skewed. Calculation of the 99% confidence interval requires that the data be normalised first. We experimented with various methods for doing this, but none proved itself to be consistent for all data sets. Calculation of the 95th or 99th percentile provides an objective method for excluding erroneous data. It should be noted that using this approach, we will reject a few very high values that should have been accepted, but the trade-off is to greatly increase the precision when accepting or rejecting the vast majority of the data values observed.

For each set of data (CPHL and FLU2), in each pelagic and coastal province and for each depth range (0-100 m and 100-200 m) in the euphotic zone, the 95 and 99 percentile values are calculated using only data with quality control flags of 0 (no quality control performed), 1 (good data) and 2 (probably good data); see Table 3 for a description of the QC flags. Quality control flag 0 data are used as they include both good and bad data, thus providing some noise. In these data, some chlorophyll data have extremely high values with magnitudes of the order of 100-1000 mg m^{-3}. To prevent these observations from biasing the data distribution, the data are pre-screened and any value from the input data set used to calculate the 95th and 99th percentiles greater than 20 mg m^{-3} is discarded.

Precision for chlorophyll measurements is 0.05 mg m^{-3} (

Table 1). Note, however, that different instruments vary in the precision that they provide. In using the data of this reprocessing, precision to two significant decimal places should be assumed (Table 1).

Where no data exists in any given province, no attempt is made to assign a value, as this would be meaningless in a re-processed product.

Table 18 in Appendix 1 lists the 99th percentile values for coastal and pelagic provinces for the two depth ranges used to define the euphotic zone. For the minimum acceptable value (i.e., "zero" value) we use –0.1 mg m^{-3} following Jaccard et al. (2018) to allow for some instrumental error around zero. Therefore, any value in the reprocessed data between -0.1 and 0 should be treated as 0. With this assumption we do not specifically calculate a lower limit (such as the 1st percentile). It should be noted that for some provinces the percentile value is based on a small number of data points (see Table 23 through Table 32 in appendix 1), which will reduce the precision. In these cases, the data are also often restricted to one season and while the calculated 99th percentile may be representative for that season in that province, it may not be representative for the year as a whole.

After this analysis, we compared the 99th percentile values of Table 23 through Table 32 with a combination of peer-reviewed literature, ship-based and satellite data (e.g., Antoine et al., 1996; Gregg and Conkright, 2001) and chose to use the 99th percentile values rather than the 95th percentiles to define the acceptable upper limit of the chlorophyll concentration. This allows more data to pass the quality control test thus that the considered values for the 99th percentile better reflect the range of variability in chlorophyll concentration, as seen in satellite and ship-based data.

In order to produce the new reprocessed product these threshold values are applied to the global data set for the CPHL and FLU2 variables, according to the respective depth interval and province. Data within the range -0.1 and the relevant 99th percentile are flagged as quality control level 1 (good data), while those exceeding it are flagged as quality control 4 (bad data; see Table 3).

Note that the regional range tests do not take river mouths or other special regions into consideration, so care is required when using data in such regions.

III.4 Oxygen

III.4.1 Division of the oceans into regions for the global oxygen range test

This test is built to eliminate outliers in different geographical regions. The regions and limits are based on 1° x 1° by standard depths gridded dataset from WOA23 (Garcia et al., 2024a; Figure 10). These data are provided with sample mean, standard deviation (σ), and sample size (N) for each bin. Thus, a realistic test range for measurements inside a specific bin can be estimated by the confidence interval (set at 99.9%) calculated using the inverse of the Student's T test on the degrees of freedom given by N. ($N<5$ is not accepted.) This approach results in realistic estimations of the ranges for the individual bins. However, they largely vary between neighbouring bins as to be used individually on a 1° x 1° basis. Instead, larger regions encompassing some typical behaviour in the ranges is created.

Dissolved oxygen is measured using different units (DOXY, DOX1 and DOX2) depending on the sensor technology used or the laboratory analysis performed to obtain the data. In principle it is possible to convert from one to the other measure, but this requires knowledge of auxiliary parameters such as water density. For this reprocessing activity, these parameters have been handled independently one from each other.

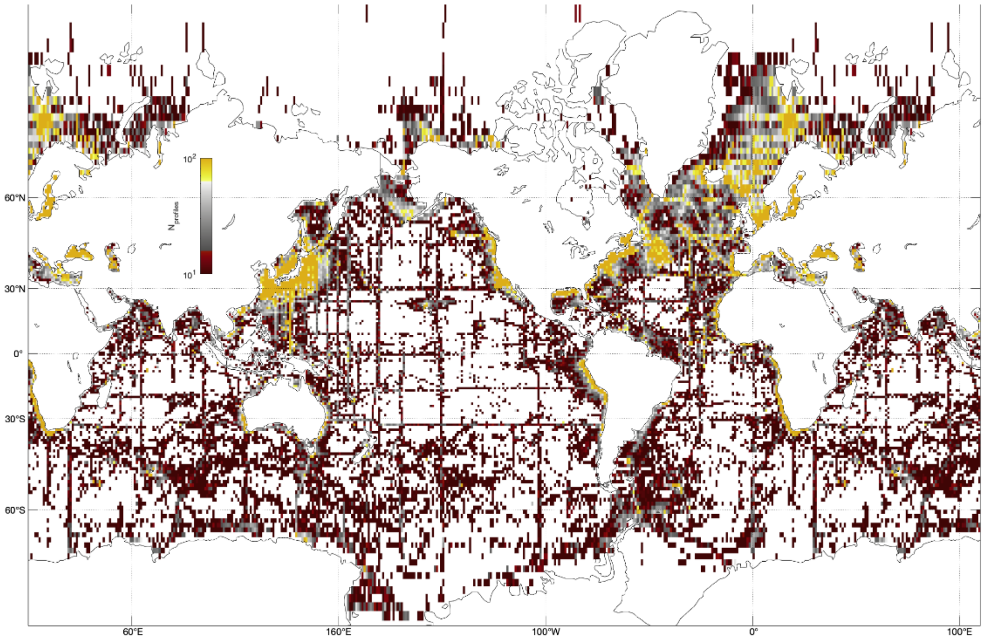

Figure 10: Number of oxygen profiles on which the WOA23 gridded data set is based, for each of the inherent 1° x 1° geographical bins. The colour scale is logarithmic.

For the oxygen test we choose 28 regions (Figure 11) split in two or three layers (Table 19, Appendix 1) which have been defined considering the following aspects:

- Geography, including known hydrographic regions.
- Latitude.
- As far as possible, homogeneous regions in terms of O_2 level and variability.
- Unimodal distribution of bin-mean values within each region and layer, i.e., capturing one type of O_2 domain.
- A study of the vertical distribution of the bins' means and confidence intervals.
- Knowledge regarding other BGC parameters and biological processes that bind them.
- Knowledge regarding marginal seas which are not well characterized in WOA23.

Note as a reminder that the depths and limits are developed subjectively by these aspects to create ranges that will detect a manageable amount of suspicious data to be visually judged by the operator. They must not to be considered absolute ranges as would be applicable in automatic testing.

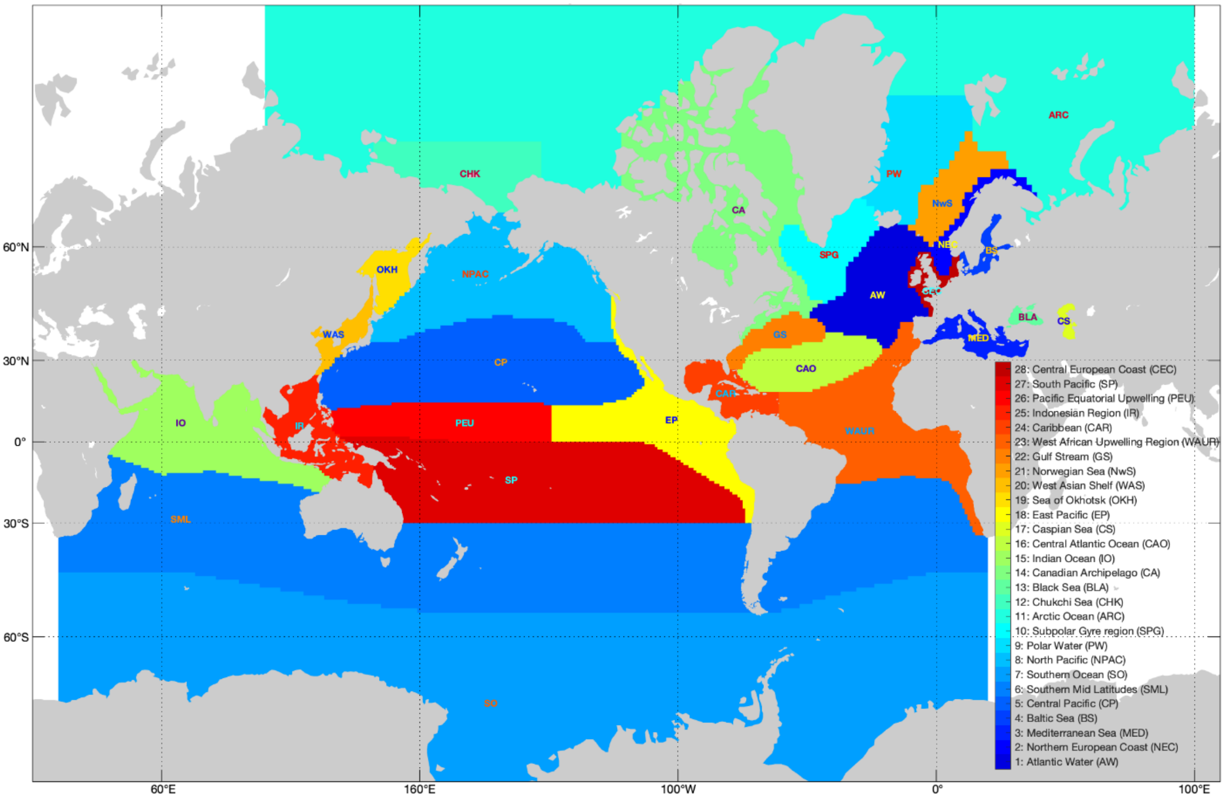

Figure 11: Current geographical regions used in the oxygen range test. The regions are also divided into two layers, with individual separation depths (see Table 19 in Appendix 1).

The range for each region is initially objectively sets between the 0.1 percentile of all the region's lower ranges and the 99.9 percentile of its upper ranges. Then, a visual inspection of the boxplots of the vertical profiles of the ranges of the individual bins is performed, as well as selection of the best vertical separation of the depth layers, since the boxplots show the common spread of observations at different depths. In addition, a double check against GLODAP bottle data (Olsen et al., 2016) is done. Minimum and maximum values for the range test are common with the global range test of the NRT quality control, except for two well-known areas for supersaturation events: the Chukchi Sea shelf in the Arctic Ocean (Copdispoti and Richards, 1971; Lowry et al., 2015) and the Baltic Sea. The default lowest value is set to zero. Ranges for all regions and layers are listed in Table 19 in Appendix 1. In addition, where base data are scarce, or also when the knowledge or the visual inspection of tested data dictate so, ranges are changed manually.

III.4.2 Quality control of global oxygen data

The global historical oxygen data are reprocessed following the quality control procedures listed in both Section III.2 (tests related to metadata) and the tests described in this section. The Baltic and Mediterranean regions have been treated separately (see sections III.4.3 and III.4.4).

III.4.2.1 Regional range test of oxygen values

As described in Section III.4.1, realistic ranges of oxygen values vary among regions of the world oceans. Depending on the region and depth layer, all oxygen values are checked against the ranges in Table 19 (Appendix 1) regardless of the units the oxygen was measured (DOXY, DOX1, or DOX2). Values with no or bad depth/pressure data are tested against the region's widest ranges. Oxygen values outside the given thresholds are considered outliers and flagged as bad data (QC=4). In order to avoid any obvious wrong flagging, a visual check is performed by inspection of the graphical representation of the data. An example of the range test applied for oxygen is shown in Figure 12. When the automated test has applied flags, the data are plotted for the region from where the data was obtained. Note that, even though the visual check includes consideration about the influence from river mouths, care is required using data in such regions.

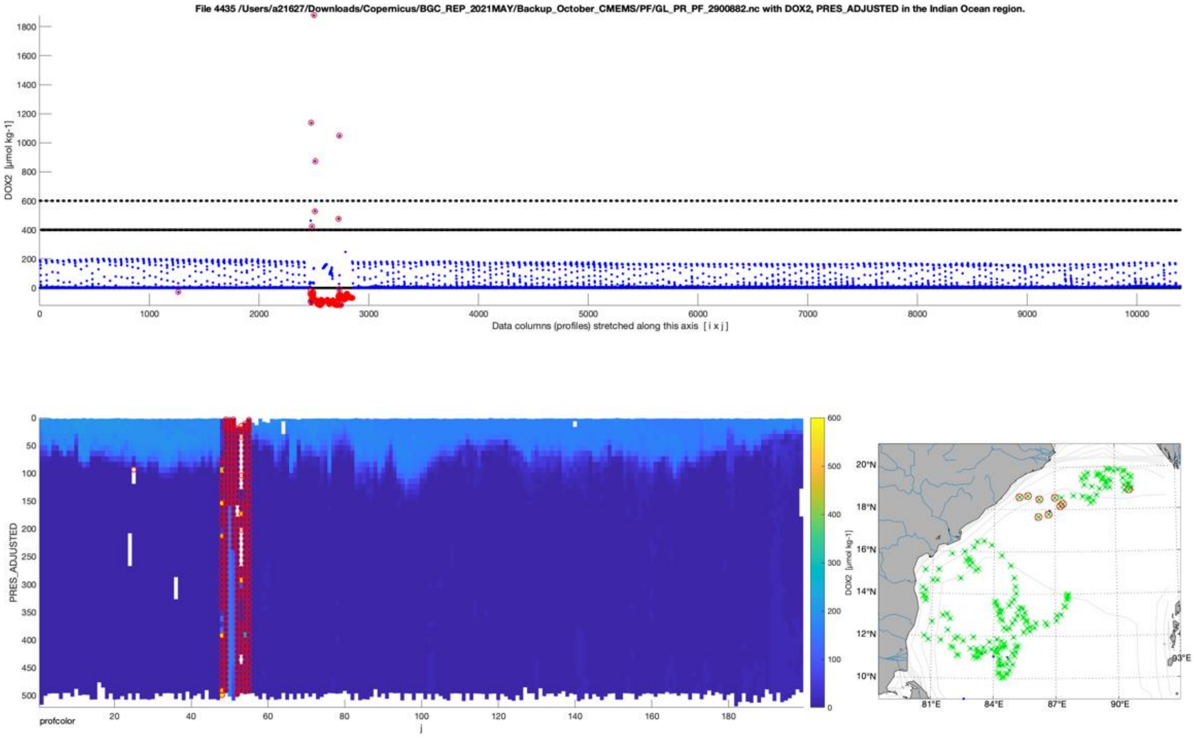

Figure 12: Upper panel: all data in the file stretched out along the horizontal axis, with observations in blue, outlier ranges in black (steps in the plot are caused by the different limits applied in different layers).Lower left panel: profiles shown vertically in a colour shading plot. Data flagged as "bad data" are marked by red circles in both panels. The vertical axis is given in depth (m) and the oxygen (as colour) is DOX1 (ml/l). Lower right panel: map showing all positions in the file marked in blue, positions with oxygen data within the region marked as green 'x', positions with data flagged as "bad data" shown as red circles.

III.4.3 Quality control of oxygen data in the Baltic Sea

III.4.3.1 Range test

Valid ranges for values of DOX1, DOXY and DOX2 are 0–13.8 ml/l, 0–615 µmol/l, and 0–600 µmol/kg, respectively. Values outside these ranges are flagged as bad data (QC = 4).

III.4.3.2 Frozen Instrument test

The frozen instrument test, which checks for repeated identical values, is applied to all DOX1, DOXY and DOX2 measurements except for bottle data. The test is performed only when at least 100 data points were present. Following the recommendation by Jaccard et al. (2018), this test is applied to all vertical profiles along the vertical axis and timeseries along the time axis.

III.4.3.3 Spike Test

As with the frozen instrument test, the spike test, which checks for unrealistic gradients, is applied to all DOX1, DOXY and DOX2 measurements and only applied if 100 data points were present.

III.4.3.4 Vessel data

All the sampling and analytical procedures for nutrients and chlorophyll-a carried of onboard R/V *Aranda* and ferrybox onboard the *Finnmaid* ferry are described in the Manual for Marine Monitoring in the COMBINE Programme of HELCOM[10].

The sample analysis is carried out on R/V Aranda and in ferrybox bottle samples in the Marine Ecology Research Laboratory, Finnish Environment Institute SYKE, Finland. Theses laboratories are FINAS certificated. FINAS is the national accreditation body in Finland[11].

III.4.3.5 Frozen Value Test

This test checks for frozen instrument value in timeseries with a minimum sample size of N=100.

III.4.4 Quality control of oxygen data in the Mediterranean

Reprocessing of oxygen data in the Mediterranean region is performed on the variables: DOX1, DOXY, DOX2 as well as the corresponding adjusted parameters, DOX1_ADJUSTED, DOXY_ADJUSTED and DOX2_ADJUSTED (when available). The reprocessing procedure is applied on top of the quality control already applied at NRT level on these variables. It consists of two additional tests, as described in sections III.4.4.1 and III.4.4.2.

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[10] https://helcom.fi/wp-content/uploads/2020/02/Manual-for-Marine-Monitoring-in-the-COMBINE-Programme-of-HELCOM.pdf

[11] https://www.finas.fi/sites/en/Pages/default.aspx

III.4.4.1 Maximum potential oxygen concentration test (Test 1)

In the maximum oxygen concentration test, dissolved oxygen measurements that have QC flags 1, 2 and 6 (from the NRT quality control) are selected. Then, in situ temperature and salinity values with QC flags 1, 2, 5, 6, 7, or 8 are used. The maximum dissolved oxygen concentration is then calculated following the algorithm by Benson and Krause (1984), using potential temperature calculated from the in situ temperature (conversion made using the CSIRO Seawater_ver3_3.1 software package *sw_ptmp*). The theoretical value of the dissolved oxygen concentration based on the salinity and the potential temperature is computed by using the Matlab algorithm *gsw_O2sol_SP_pt*, as provided by the *TEOS-10*[12] software package. The theoretical value of the dissolved oxygen is in µmol/kg unit. For this reason, DOX1 and DOXY variables have been converted to µmol/kg, in order to get reliable results by the comparison of the theoretical value with the observed value of the dissolved oxygen. Moreover, a further validation procedure of the dissolved oxygen concentration is based on the computation of the percentage of the oxygen saturation. The reason is that in the near surface waters, oxygen concentrations may be greater than the maximum value calculated due to photosynthetic activity and wave entrainment of air and surface mixing. For these surface waters (range from 0 to 200 m) the acceptable maximum saturation is set at 115%.

The percentage of the oxygen saturation *O* in the sea water is calculated from the equation (3) at temperatures between 0–40°C and salinity between 0–40:

$$\%O = \frac{O_2}{O_2^{'}} \times 100 \quad \text{Eq. (3)}$$

Where O_2 is the oxygen concentration in the sample, and O_2' is the oxygen solubility in seawater at the temperature and salinity of the water sample, calculated according to Benson and Krause (1984).

A comparison between the theoretical values and the observed values of the dissolved oxygen is used to change the QC flags from 1 (good data) or 2 (probably good data) to 4 (bad data) when the following criteria are met:

- The observed oxygen concentration exceeds the theoretical maximum
- The observed oxygen concentration is less than zero
- The oxygen saturation in the surface waters (0-200 m) is greater than 115 %

Data for processing may use pressure in decibars rather than depth in metres. For this reason, the variable *PRES* (pressure; desibar) has been converted (conversion by using the CSIRO Seawater_ver3_3.1 software package *sw_dpth*) to the variable DEPH (depth; meter) to apply the set of criteria.

III.4.4.2 Comparison with climatology (Test 2)

In addition to the maximum potential oxygen concentration test, the Mediterranean Sea oxygen measurements are validated through a statistical approach based on climatological, monthly values from the World Ocean Atlas (WOA; WOD23, Garcia et al., 2023). The WOA provides objectively-analysed oxygen data on a global grid at 1° spatial resolution and interpolated onto 33 vertical layers from the surface to the abyssal seafloor at 5500 m depth. Available parameters include dissolved oxygen,

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[12] http://www.teos-10.org

apparent oxygen utilisation, and percent oxygen saturation. The parameters are provided in each grid cell and include the climatological monthly mean and associated standard deviation.

In order to perform the comparison with climatology for Mediterranean region, we converted the units of DOX1 (ml/l) and DOXY (µmol/l) parameters into µmol/kg, which is the standard unit that WOA uses for the oxygen parameter. The climatic characteristics (mean and mean standard deviation – σ -) for different squares of the Mediterranean Sea in each month were calculated at 57 standard hydrographic depth levels (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, 1000, 1050, 1100, 1150, 1200, 1250, 1300, 1350, 1400, 1450, 1500 m).

The comparison is applied to good data (i.e., data with the QC flag 1, 2, 5, 6, 7, or 8). Data are flagged as probably good data (QC flag 2) if the measurement value falls outside the predefined statistical threshold of 1 standard deviation from the climatological mean.

Note that all oxygen variables are treated independently, i.e. an updated DOX2_QC value may be different than the corresponding DOX2_ADJUSTED_QC value.

III.4.5 Easy Oxygen

Easy oxygen is an additional product, based on the original reprocessed data set, in which oxygen is available in an easy format meaning that the unit of dissolved oxygen as well as the unit of the vertical reference are standardized by the Global In Situ TAC DU.

In the easy oxygen format, all oxygen observations are provided either in µmol/l (DOXY, useful for modellers) or in µmol/kg (DOX2, useful for oceanic application and observing systems). The oxygen conversion follows the recommendation of the SCOR WG 142 (Bittig et al., 2016) and uses the conversion factor of 44.6596 µmol/ml and the corresponding potential temperature and salinity to calculate the potential density of seawater (i.e., referenced to a hydrostatic pressure of 0 dbar). If two oxygen variables are available with different units from the conversion result for one profile, the variable with the largest percentage of data classified as “good data” (QC 126578) is chosen. If the score is equal, priority is given to data in ml/l for conversion into µmol/l and to data in µmol/l for conversion into µmol/kg.

The vertical reference is available in both dbar and m, according to algorithms from UNESCO, (1983). Details for each conversion are stored in the new variable PARAM_CONVERSION_METHOD as unique codes. These codes are listed in the Copernicus in situ Reference Table 3.1 for vertical reference and 3.2 for dissolved oxygen.

In the easy oxygen format, the QC flag values attributed to the conversion results are equal to the worst QC flag value of all variables used for conversion according to the QC order (from the best to the worst 1-4, where QC values 5-8 are interpreted as QC2). Moreover, easy oxygen conversion is not done if pressure, temperature or salinity have a QC flag value of ‘0’ or ‘4’. Finally, the variable name PARAM_ADJUSTED will be reduced to the variable name PARAM as well. Data mode of the parameter is always available with the attribute PARAM.data_mode or the variable PARAM_DM, see section 3.2 in the Copernicus Marine In Situ NetCDF Format Manual[13].

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[13] https://doi.org/10.13155/59938

III.5 Nutrients

III.5.1 Division of the oceans into regions and depth layers for global nutrient range test

In the same way as for oxygen (Section III.4.1), we use ranges with lower and upper limits for outlier elimination within regions.

The procedure for defining regions, layer depths, and ranges is the same used for Oxygen (Section III.4.1) based on gridded WOA23 data (Garcia et al, 2024b). For the nutrients tested, that is Nitrate, Phosphate, and Silicate, regions are initially based on Spalding domains (Spalding et al., 2007; 2012). More regions are added as needed, and all regions are changed and developed by the same iterative method as for oxygen until acceptance. Figure 13 shows the resulting regions. The same geographical regions are found and used for all three nutrients but the layer thicknesses may vary.

The resulting ranges are listed in Table 20 to Table 22 (Appendix 1). In addition, where base data are scarce, or knowledge or visual inspection of tested data dictates, ranges are set manually.

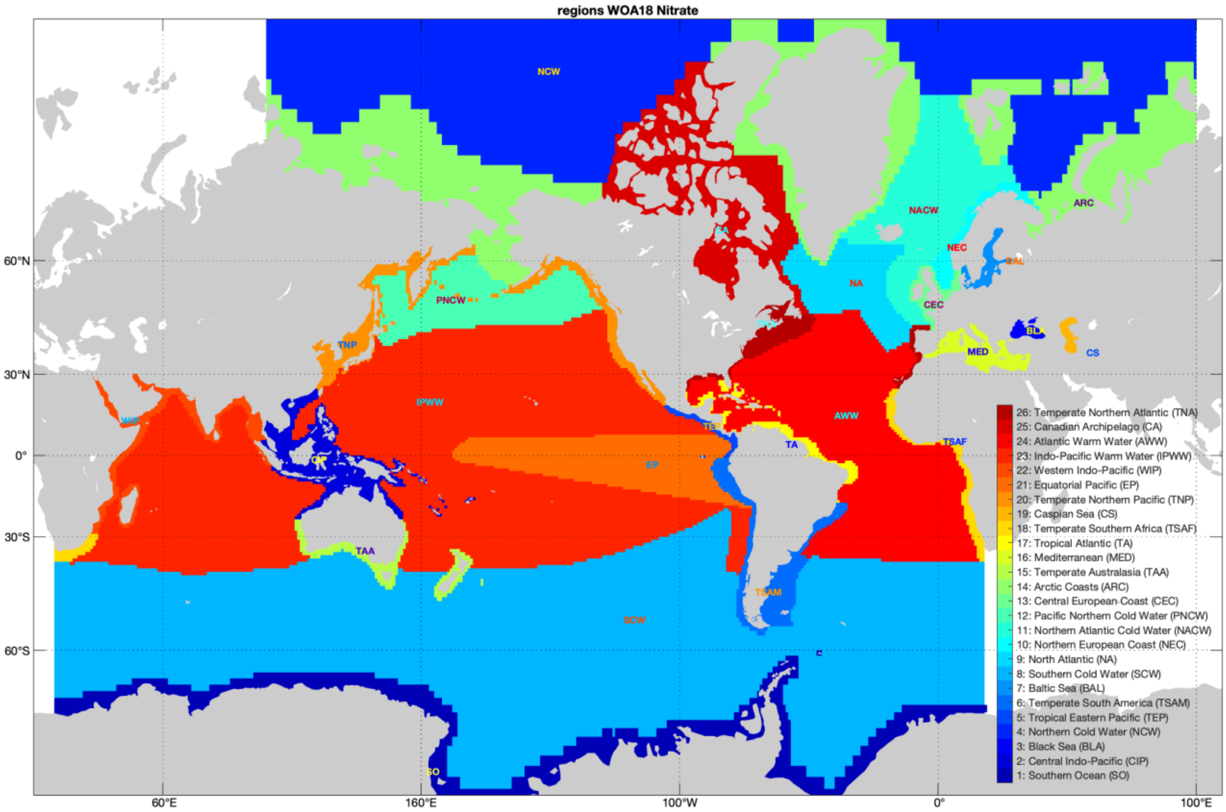

Figure 13: Geographical regions for the nutrient range-testing. The colour bar lists names and abbreviations for regions. For readability the colours of the labels on the map are complementary to their region's colour.

III.5.2 Quality control of global nutrient data

The global historical nitrate, phosphate, and silicate data are reprocessed following the quality control procedures listed in both Section III.2 (tests related to metadata) and the tests described in this section. The Baltic and Mediterranean regions have also been treated separately (see sections III.5.3 and III.5.4).

III.5.2.1 Regional range test of nutrient values

As described in Section III.5.1, the realistic ranges of nutrients values vary between regions of the World oceans. Depending on the region and depth, all nutrient values, regardless of type (NTAW, NTRA, PHOS, PHOW, SLCW or SLCA), are checked against the ranges in Table 20 through Table 22 (Appendix 1). After visual inspection with a procedure similar to the one described in section III.4.2.1, nutrient values outside the ranges are considered outliers and therefore are flagged as bad data (QC=4). Note that, even though the visual check includes consideration of influence from river months, care is required when using data in such regions.

III.5.2.2 Profile test

The nutrient profile test checks nitrate (NTRA, NTAW), phosphate (PHOS, PHOW), and silicate (SLCA, SLCW) variables for values near the surface with higher values than the assumed maximum in the deeper ocean. High nutrient values near the surface are of course not uncommon, especially where there is influence from runoff from land, however we assume that nutrient values in the photic zone of the open ocean, are lower than in the deeper ocean due to consumption. We do not apply the profile test in areas influenced by freshwater runoff from land, where our assumption is not valid. Therefore, we only apply the profile test where the bottom depth is greater than 1000 m. Following these criteria, including the objective considerations about the world's main river runoff regions, as described in section III.2.5, a geographical mask for locating which profiles to test (Figure 14) was made. Furthermore, profiles measured in locations of high latitudes (greater than 80° north, or 75° south) have also been excluded from testing, due to the potential influence of melting sea ice on the nutrient levels.

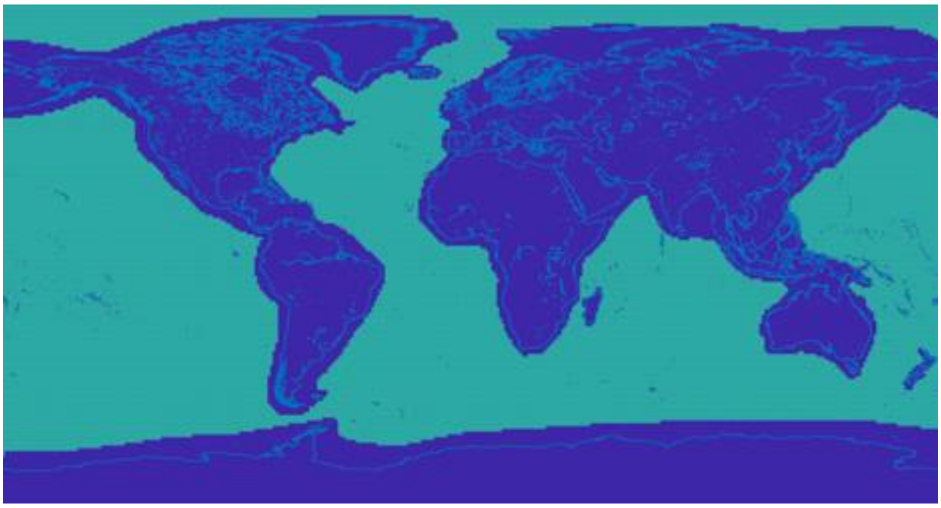

Figure 14: Mask used to identify offshore regions where apply the nutrient profile test in (1° x 1° resolution). Blue: regions with water depth < 1000 m. Green: regions with water depth > 1000 m.

We assume a photic zone depth of 100 m to divide the upper layer from the lower layer. All data above this depth that have a value higher than the maximum value found below 100 m depth are flagged as "bad data" (QC = 4), because the lower layer is the replenishing source for the upper layer, hence, the values in the upper layer cannot exceed the maximum values in the lower layer. The nutrient profiles containing data that were marked during the test are then visually inspected. The profiles are plotted side by side with the two neighbouring profiles and salinity profiles (where possible) to help us determine whether the high nutrient values near the surface are also found in nearby profiles and are therefore part of a pattern. Also to determine whether the salinity profile shows a clear water mass separation. Figure 15 shows an example of datapoints marked by the profile test, while Figure 16 shows a detected anomaly that was cleared after visual inspection, since both neighbouring profiles show a similar increase near the surface, and the salinity profiles show a sharp gradient in the upper 100 m.

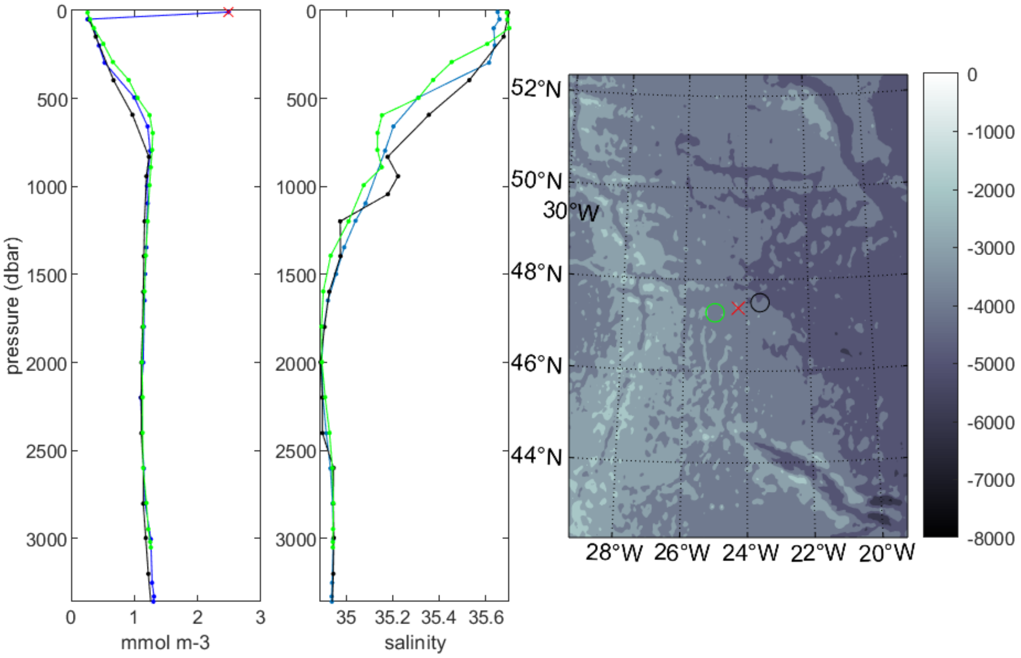

Figure 15: Example of a profile with phosphate data marked with QC=4 by the profile test (surface values exceed the maximum value at depth). Panels show, from left to right: Phosphate profile in blue with the marked datapoint as a red x. The black and green profiles are the previous and next profiles in the variable, respectively. The middle panel shows the salinity profiles, with the same colour-scheme for the tested, the previous, and the next profile in blue, black, and green. The third panel is a plot of the position of the three profiles, with the red x marking the tested profile, with black and green circle representing the previous and next profile.

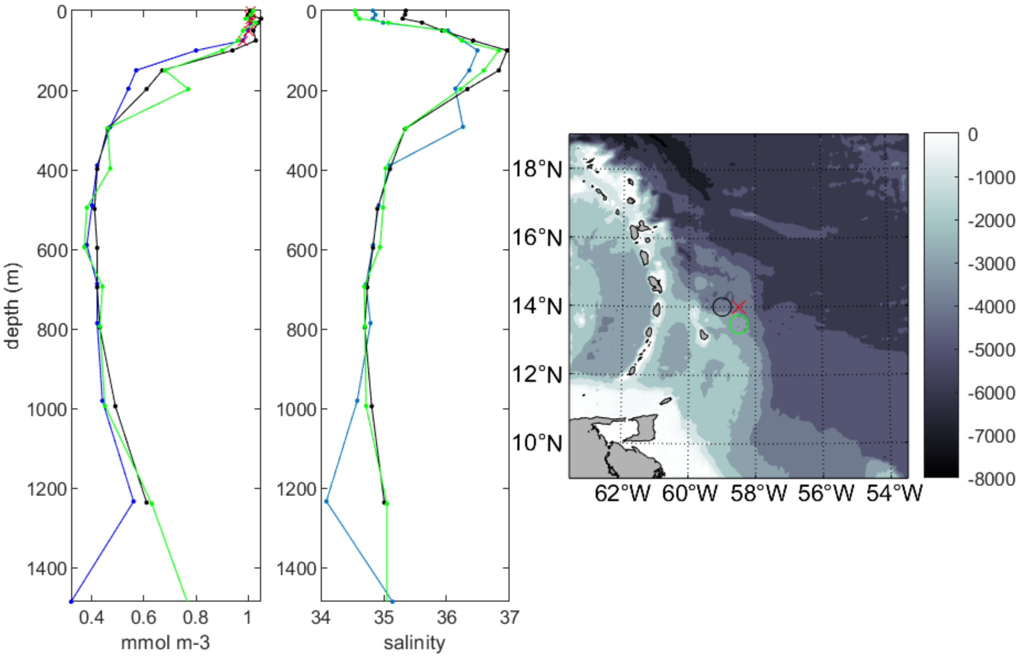

Figure 16: Same type of figure as Figure 15. Example of a profile with phosphate data marked with QC=4 by the profile test (surface values exceed the maximum value at depth). Panels show, from left to right: Phosphate profile in blue with the marked datapoint as a red x. The black and green profiles are the previous and next profiles in the variable, respectively. The middle panel shows the salinity profiles, with the same colour-scheme for the tested, the previous, and the next profile in blue, black, and green. The third panel is a plot of the position of the three profiles, with the red x marking the tested profile, with black and green circle representing the previous and next profile.

III.5.3 Quality control of nutrient data in the Baltic Sea

Baltic sea nutrient data are quality controlled in the same way as oxygen data (Section III.4.3). Upper limits for the range test in upper-lower layers are 16-19 mmol m^{-3} for Nitrate, 3-20 mmol m^{-3} for Phosphate, and 72-250 mmol m^{-3} for Silicate. The lower limit is always zero. Layers are defined as upper (above 50 m depth) and lower (below 50 m depth).

Frozen value and spike tests were conducted only if more than 100 data points were present, following the descriptions given in Sections III.4.3.5 and III.4.3.3, respectively.

III.5.4 Quality control of nutrient data in the Mediterranean Sea

The reprocessing of the nutrients data in the Mediterranean Sea is performed on data from any platform in that region containing nitrate, nitrite, phosphate or silicate measurements. Specifically, reprocessed variable names are the following: NTRA, NTAW, NTRZ, NTRI, PHOS, PHOW, SLCA and SLCW, whereas the corresponding "adjusted" ones, when available, are (NTRA_ADJUSTED, NTAW_ADJUSTED, NTRZ_ADJUSTED, NTRI_ADJUSTED, PHOS_ADJUSTED, PHOW_ADJUSTED, SLCA_ADJUSTED and SLCW_ADJUSTED. The reprocessing of this data is performed on top of the quality control already applied at NRT-level and it consists of two tests (a regional range test and a profile test), as described in sections III.5.4.1 and III.5.4.2 below.

III.5.4.1 Regional range test of nutrients values

In order to perform the regional range test of nitrate (including nitrite), phosphate, and silicate for the Mediterranean Sea, a division of the area into five different sub-areas is performed. In this way, the most suitable ranges for each parameter are applied depending on which is the region where each platform is located.

In the case of nutrient data, the WOA23 climatology was not used due to its lack of data in the Mediterranean region. For this reason, in this case the division of the area is based on a wide literature research on the Mediterranean Sea. The geographical regions for the range tests for silicate, nitrate (including nitrite) and phosphate concentrations as defined by Tables 4, 5 and 6 are presented in Figure 17.

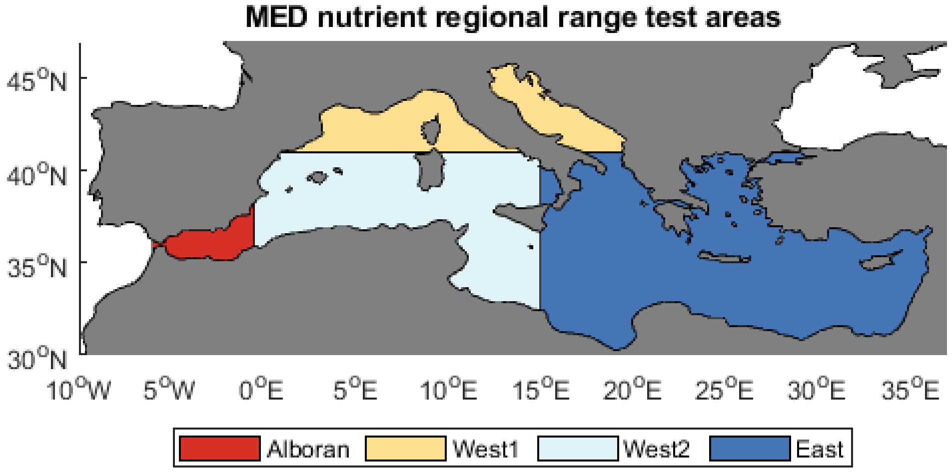

Figure 17: Mediterranean geographical regions for the nutrients regional range test (see also Tables 4, 5 and 6).

The comparison is applied to ”good data” (i.e., data with the QC flag 1, 2 and 6). Data are flagged as “bad data that are potentially correctable” (QC flag 3) if the measurement value is outside the predefined thresholds.

Table 4: Range of Silicate (Si) concentration (µmol/l) applied in the Mediterranean geographical regions (see Figure 17).

Area	**Lon**	**Lon**	**Lat**	**Lat**	**Bottom Depth**		**Sampling Depth**		**Si**	**Si**
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Coastal	-6.0	36.3	30.0	45.8	0	100	0	100	0.0	25
Alboran	-6.0	-0.5	34.5	38.5	100	5200	0	1000	0.0	11
	-6.0	-0.5	34.5	38.5	100	5200	1001	5200	8.0	28
West1	-0.6	20.0	41.0	45.8	100	5200	0	1000	0.0	15
	-0.6	20.0	41.0	45.8	100	5200	1001	5200	1.0	13
West2	-0.6	15.0	30.0	41.0	100	5200	0	1000	0.0	15
	-0.6	15.0	30.0	41.0	100	5200	1001	5200	1.0	13
East	15.0	36.3	30.0	41.0	100	5200	0	1000	0.0	15
	15.0	36.3	30.0	41.0	100	5200	1001	5200	0.0	16

Table 5: Range of Nitrate (NO_x) concentration (µmol/l) applied in the Mediterranean geographical regions (see Figure 17).

Area	**Lon**	**Lon**	**Lat**	**Lat**	**Bottom Depth**		**Sampling Depth**		**NO_x**	**NO_x**
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Coastal	-6.0	36.3	30.0	45.8	0	100	0	100	0.0	20
Alboran	-6.0	-0.5	34.5	38.5	100	5200	0	500	0.0	15
	-6.0	-0.5	34.5	38.5	100	5200	501	5200	10	25
West1	-0.6	20.0	41.0	45.8	100	5200	0	5200	0.0	15
West2	-0.6	15.0	30.0	41.0	100	5200	0	5200	0.0	15
East	15.0	36.3	30.0	41.0	100	5200	0	5200	0.0	11

Table 6: Range of Phosphate (PO_4) concentration (µmol/l) applied in the Mediterranean geographical regions (see Figure 17).

Area	**Lon**	**Lon**	**Lat**	**Lat**	**Bottom Depth**		**Sampling Depth**		**PO_4**	**PO_4**
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Coastal	-6.0	36.3	30.0	45.8	0	100	0	100	0.0	1.60
Alboran	-6.0	-0.5	34.5	38.5	100	5200	0	500	0.0	0.80
	-6.0	-0.5	34.5	38.5	100	5200	501	5200	0.5	1.50
West1	-0.6	20.0	41.0	45.8	100	5200	0	1100	0.0	0.80
	-0.6	20.0	41.0	45.8	100	5200	1101	5200	0.1	0.65
West2	-0.6	15.00	30.0	41.0	100	5200	0	1100	0.0	0.80
	-0.6	15.00	30.0	41.0	100	5200	1101	5200	0.1	0.65
East	15.0	36.3	30.0	41.0	100	5200	0	5200	0.0	0.60

III.5.4.2 Profile test

The depth of the nutricline (i.e., the depth of the largest vertical gradient in nutrients) depends on the degree of water column stratification and the magnitude of momentum transfer associated with wind stress. When physical mixing increases, the upper mixed layer penetrates the nutricline, thereby providing a source of nutrients to the euphotic zone and nutrient concentration increase throughout the upper water column. Conversely, when thermal stratification increases, the upper water column is deprived of nutrients, leading to a progressive deepening of the nutricline that closely tracks the depth of the euphotic layer. In the Profile test, nutrients should increase from surface layers to deep layers. Thus, values that are being reduced below the depth of 200 meters are marked as “bad data” (QC flag 4).

IV VALIDATION RESULTS

IV.1 Metadata

IV.1.1 Changes in QC flags for positions

From the total 45 million original positions, the land test resulted in 1 million positions (2.3%) being flagged as "bad data" (QC=4) and 572 thousand positions (1.3%) as "probably good data" (QC=2).

Note that none of the data with positions flagged QC ≥ 4 enters the subsequent tests of the reprocessing procedure as those require positioning.

IV.2 Chlorophyll

IV.2.1 Validation results for chlorophyll data

IV.2.1.1 Changes in flags for global chlorophyll data

In producing the reprocessed product, a total of 312 million chlorophyll data values with valid depth and positions (see position test, Section III.2.4), and no previous flags above QC=3, were examined. Chlorophyll values outside the ranges were flagged QC=4 (about 0.3% of the examined data). See Table 18 (Appendix 1) for range test criteria and Table 3 for a QC flag description.

IV.2.1.2 Changes in flags for chlorophyll data in the Baltic Sea

Range tests for variables *CPHL* and *FLU2* are applied to all Baltic data. Spike tests and frozen values test are applied only for non-bottle data and datasets with more than 100 entries along DEPTH or TIME axis. Minimum and maximum values for range tests are set to 0 and 60 mg/m^3, respectively, for all layers. The upper limit is larger than the globally accepted range due to the seasonally high algae concentration. The percentage change of values for each test is given in Table 7. Empty values indicate no data present in the directory while integer 0 indicates no change and 0.0 indicates changes below 0.01%.

Table 7: Percentage of chlorophyll values flagged as "bad data" in the Baltic region before and after testing.

Directory	**Variable**	**Percentage labelled as "bad data"**	
		before (%)	after (%)
Bottle	FLU2	25.9	25.9
Bottle	CPHL	0.0	0.2
CTD	FLU2	0.1	1.5
CTD	CPHL	0.0	0.1
Glider	CPHL	0.4	0.4
Ferrybox	FLU2	9.0	11.6
Mooring	FLU2	8.6	12.5
Profile	CPHL	3.2	3.8
Timeseries	FLU2	24.4	24.6

IV.2.2 Potential errors and means of improvement – validation synthesis

IV.2.2.1 Data

The method used here is dependent on sufficient QC level 1 and 2 data being available for each province, and this is not yet the case for all of them, or for all seasons. The percentile value calculated, derived for example from only a range of winter observations, may correctly define the winter season in a given province, but cannot be used to describe summer. The influence of seasonal bias may decrease as more data become available, but note should be made of the number of observations available in each province and where there are few, of the season in which they were collected.

IV.2.2.2 Seasonality

The method used for the pelagic oceans is robust, but it is possible that the 99th percentile limit may be too low in some highly seasonal waters when annual data are considered. For example, the highly productive period in the Southern Ocean is in spring, with less activity for the remainder of the year. This means that there are, for example, nine months of lower chlorophyll values and three months of higher values. When averaging over a year, this may bias the 99th percentiles down. This bias could be reduced by calculating seasonal values, but this solution would require more data than are currently available in many provinces.

IV.2.2.3 CHLT variable

The CHLT data (total chlorophyll) are not analysed here due to insufficient documentation (i.e., they only retain their NRT QC flag). This value may encompass the total sum of chlorophyll types *a*, *b*, and *c*, and these three types are found to varying extents in different microalgae (though not all). Such data are most likely to have been obtained from spectrophotometric methods or early fluorimetry. Nevertheless, CHLT represents a significant amount of data, and in future reprocessing should be investigated further to determine how analysis similar to that performed here can be applied.

IV.2.2.4 Baltic Sea

The Baltic Sea is currently grouped into the Northern European Seas province with 99th percentile values of 17.5 and 16.38 mg m^{-3} for the CPHL and FLU2 variables, respectively. This sea may have surface cyanobacterial blooms with extremely high chlorophyll concentrations, while lower values occur in the waters below. The 99th percentile values used here will reject some of these surface chlorophyll data. However, for the Baltic as a whole, the 99th percentile values encompass the chlorophyll concentrations reported in the literature, see, e.g., Kahru et al. (1990), Nakonieczny and Renk (1991), Wasmund and Uhig (2003), Kudryavtseva et al. (2011), Pitarch et al. (2016).

Two improvements can be made. The first is to define the Baltic Sea as a separate province from the Northern European Seas. The second is to introduce a third depth layer (0-10 metres) to define the euphotic zone, in order to capture these surface bloom concentrations.

The first of these improvements is made in this version. Being a region of the province, the Baltic Sea now has its own chlorophyll range.

IV.2.2.5 Mediterranean region

As noted earlier, the shape files of Spalding et al. (2007) overlay those of Spalding et al (2012), with the result that a true pelagic region for the Mediterranean is not defined, and observations from the more oligotrophic waters will act to bias the 99th percentile downward. The current 99th percentile values (1.99 and 2.03 mg m^{-3} for CPHL and FLU2, respectively) suggest that these will be valid for most of the Mediterranean Sea, as mentioned in section III.3.1, with the exception of near shore waters along the eastern coast of Italy, the Nile Delta and the Tunisian coast (Lavigne et al., 2015; Colella et al., 2016). Greater precision for both coastal and pelagic regions of the sea will be obtainable if these regions are further divided into smaller regions providing polygons with further spatial detail.

IV.2.2.6 Day/night and fluorescence data

In Figure 9 of Jaccard et al. (2018), the large variation between day and night values in fluorescence-based chlorophyll measurements is shown, a phenomenon well known from laboratory studies (see for example Fisher et al. (1996). We recommend that users of the BGC-REP data consider using the time stamp information to determine whether the observations were made in the day or at night as this will improve the precision of the data.

IV.2.2.7 Instrument type flags

Currently, the data are described only as CPHL (which includes BGC-Argo fluorescence, HPLC, and spectrophotometry data) and FLU2 (which includes all other fluorometric based data), and CHLT (total chlorophyll). In entering the data, it is currently optional to include the instrumental method used to collect it. We recommend that this becomes a mandatory flag in future data inputs.

IV.3 Oxygen

IV.3.1 Validation results for oxygen data

IV.3.1.1 Changes in flags for global oxygen data

In producing the BGC-REP product, a total of 133 million oxygen data values with valid depth and positions (see position test, Section III.2.4), and no previous flags above QC=3, are examined. Oxygen values outside the ranges are flagged QC=4, which encompass 0.4% of the examined data. See Table 19 for range test criteria and Table 3 for QC flag description.

IV.3.1.2 Changes in flags for oxygen data in the Baltic region

Changes in QC flags in the Baltic region are reported in Table 8. Very few values fail the range test and frozen values appear to be mostly a Ferrybox issue. Generally, Ferrybox data see the largest changes, likely due to the large amount of data, high sampling frequency and automated nature of the measurements.

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Table 8: Percentage of oxygen values flagged as “bad data” in the Baltic region before and after testing.

Directory	**Variable**	**Percentage labelled as “bad data”**	
		before (%)	after (%)
Bottle	DOX1	0.3	0.3
	DOX2	0.1	0.1
	DOXY	0.1	0.1
CTD	DOX1	9.7	11.1
	DOX2	3.0	7.2
	DOXY	84.9	85.0
Ferrybox	DOXY	13.5	16.5
	DOX1	26.6	26.7
Mooring	DOX1	10.4	10.4
	DOXY	0.0	0.2
Profile	DOX2	28.0	28.9

IV.3.1.3 Changes in flags for oxygen data in the Mediterranean region

During the validation procedure for dissolved oxygen by applying Test 1 and Test 2 to the Mediterranean oxygen data set (sections III.4.4.1 and III.4.4.2), the number of QC flags changes (from 1, 2 or 6 to 4; and from 1 to 2, respectively), is presented as percentages with respect to the total values entering each routine test (Table 9 and Table 10), and after the whole REP procedure (Table 11). Table 12 presents the absolute number of oxygen values passing through the tests and the resulting number of modified flag values, for every platform type. The output data quality information given by the MED In Situ TAC is a high percentage (exceeding 90%) of good data quality for all platforms on average.

Table 9: Percentages of the flags that have been changed through validation procedure during Test 1.

Platform type	***QC flags changed (%)***
CTD	0.17
Bottle	0.02
Ferrybox	0.00
Mooring	0.01
Profile	0.01
Glider	0.00

Table 10: Percentages of the flags that have been changed through validation procedure during Test 2.

Platform type	***QC flags changed (%)***
CTD	0.17
Bottle	0.39
Ferrybox	15.31
Mooring	0.70
Profile	5.66
Glider	0.01

Table 11: Percentages of the flags that have been changed through validation procedure by using Test 1 and Test 2.

Platform type	***QC flags changed (%)***
CTD	0.34
Bottle	0.41
Ferrybox	15.31
Mooring	0.71
Profile	5.67
Glider	0.01

Table 12: Changes on QC flags for the data used to produce the reprocessed product of the dissolved oxygen in the Mediterranean Sea. Changes performed using the methods in Test 1 and Test 2, as described in sections III.4.4.1 and III.4.4.2.

Platform type	***Total Oxygen values tested***	***Modified flag values (%)***
CTD	600731795	0.34
Bottle	21360958	0.42
Ferrybox	747748	15.31
Mooring	38662888	0.71
Profile	45368508	5.66
Glider	392583288	0.01

IV.3.1.4 General overview of results for oxygen data in the Mediterranean region

An overview of the number of profiles and time series per type of platform until 31/12/2023 is shown in Figure 18 for the different oxygen variables DOX1, DOXY and DOX2. During the last decade we saw a noticeable increase in the number of of Argo floats, which is a remarkable source of oceanographic observations, as well as the most important source of oxygen observations for the last 10 years. Oxygen observations derived from moorings are significantly increased after 2010. For the same variables, the percentages of good quality values for all platform types in the Mediterranean region are presented in the bar graph of Figure 19.

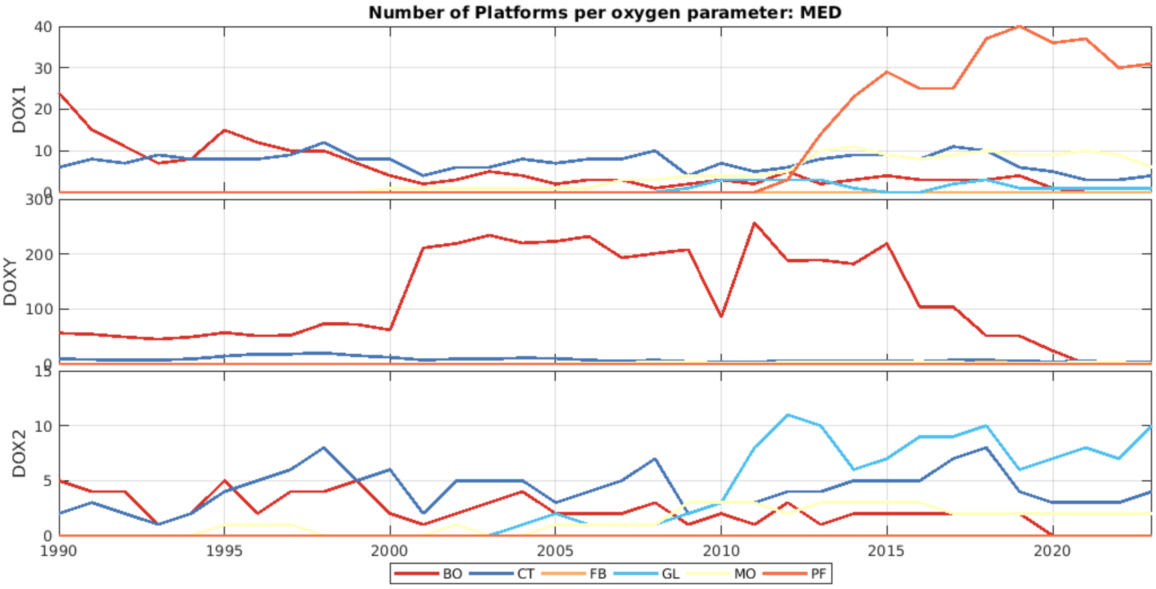

Figure 18: Evolution of the number of platforms by type in the Mediterranean Sea containing all dissolved oxygen variables (y-axis): DOX1 (upper); DOX (middle); DOX2 (lower) from the beginning of dataset up to now (years in x-axis).

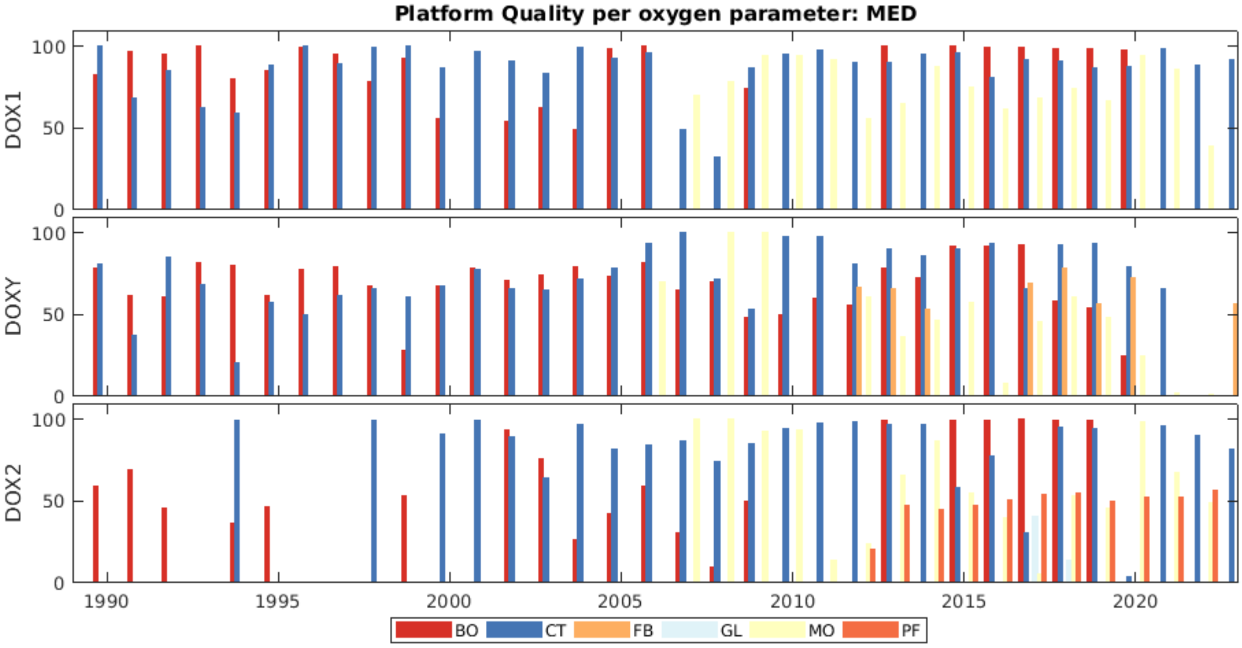

Figure 19: Data quality for DOX1, DOXY and DOX2 oxygen parameters in the Mediterranean region, from the beginning of the dataset up to now. Bars correspond to the percentage of good quality data (QC =1), while different colours represent the platform type.

Figure 20 shows an example of how the quality controls in the reprocessed BGC product are applied to the oxygen (DOX1) data. The time series in black colour in both panels of Figure 20 are retrieved from the reprocessed product, while the red time series are the original data.

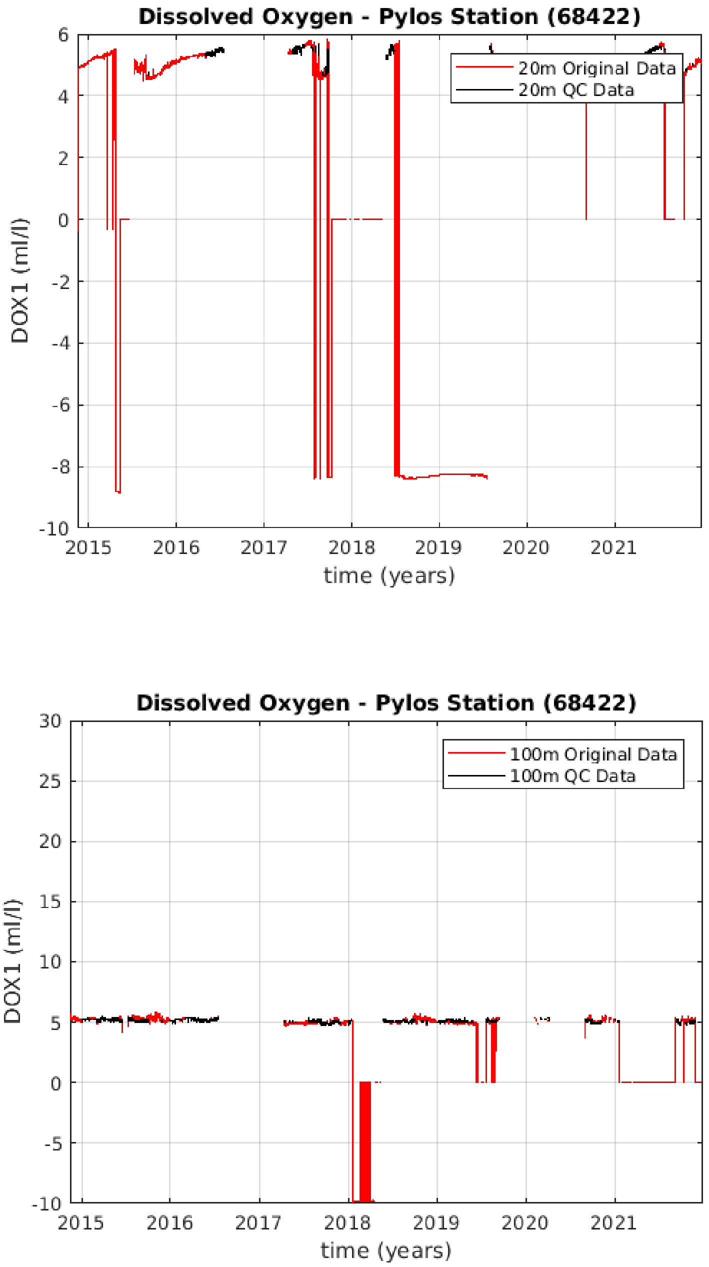

Figure 20: Dissolved oxygen data from Pylos station (68422) in the Mediterranean Sea at 20 m (top) and 100 m depth (bottom) from the beginning of data set up to now. Black: good quality (QC = 1) data after the application of the REP QC procedures; Red: rejected data.

IV.4 Nutrients

IV.4.1 Validation results for nutrient data

IV.4.1.1 Changes in flags for the global nutrient data

When producing the reprocessed product, only data with valid depth and positions (see position test, Section III.2.4), and no previous flags above QC=3 were examined. See Table 20 to Table 22 in Appendix 1 for range test limits and Table 3 for QC flag descriptions. The tests performed on the global nutrient data, resulted in the following changes in the quality control flags.

The range test (Section III.5.2.1) resulted in (QC=4) flagging of 2.5% of the 7.1 million valid Nitrate values, 0.01% of the 4.9 million valid Phosphate values, and 0.01% of the 3.9 million valid Silicate values.

There was one profile detected by the nutrient profile test, but in a region where nutrients could come laterally, so no flagging was done. No further profiles were detected by the nutrient profile test.

IV.4.1.2 Changes in flags for nutrient data in the Baltic region

As with the Baltic oxygen measurements (section IV.3.1.2), the nutrients are summarised in Table 13. Range tests are responsible for most of the flagged data. While there is practically no flagging due to frozen instruments or spike tests.

Table 13: Percentage of nutrients values flagged as “bad data” in the Baltic region before and after testing.

Directory	**Variable**	**Percentage labelled as “bad data”**	
		before (%)	after (%)
Bottle	NTRA	2.8	3.7
	PHOS	0.1	5.1
	SLCA	0.2	1.8
CTD	PHOS	5.7	6.1
Profile (XX)	PHOS	0.0	0.0
	SLCA	0.0	0.0

IV.4.1.3 Changes in flags for nutrient data in the Mediterranean region

During the validation procedure for nutrient data, after applying the Regional Test and the Profile Test to the Mediterranean data set (sections III.5.4.1 and III.5.4.2), the number of QC flag changed from 1, 2 or 6 to 3; and from 1, 2 or 6 to 4, respectively. The percentages of these changes with respect to the total number of values for each of these two tests, and after the whole reprocessing procedure, are presented in Table 14 to Table 16. Table 17 shows the absolute number of nutrient values reprocessed and the corresponding number of values that changes flag during the REP procedure, for every platform type.

Table 14: Percentages of the flags that have been changed through validation procedure during Regional Test.

Platform type	***Nitrate/nitrite (%)***	***Silicate (%)***	***Phosphate (%)***
CTD	0.0	0.0	0.0
Bottle	0.2	0.9	0.6
Ferrybox	-	-	-
Mooring	-	-	-
Profile	0.0	-	-
Glider	0.0	-	-

Table 15: Percentages of the flags that have been changed through validation procedure during Profile Test.

Platform type	***Nitrate/nitrite (%)***	***Silicate (%)***	***Phosphate (%)***
CTD	0.0	0.0	0.0
Bottle	1.9	0.1	1.2
Ferrybox	-	-	-
Mooring	-	-	-
Profile	0.0	-	-
Glider	0.0	-	-

Table 16: Percentages of the flags that have been changed through validation procedure by using Regional Test and Profile Test.

Platform type	***Nitrate/nitrite (%)***	***Silicate (%)***	***Phosphate (%)***
CTD	0.0	0.0	0.0
Bottle	2.1	0.9	1.7
Ferrybox	-	-	-
Mooring	-	-	-
Profile	0.0	-	-
Glider	0.0	-	-

Table 17: Changes on QC flags for the data used to produce the reprocessed product of the nutrient data in the Mediterranean Sea. Changes performed using Regional Test and Profile Test as described in sections III.5.2.1 and III.5.2.2.

Platform type	***Total Nutrient values tested***	***Marked values (%)***
CTD	87054	0.0
Bottle	2210635	1.6
Ferrybox	-	-
Mooring	-	-
Profile	631236	4.3
Glider	90654	0.0

IV.4.1.4 General overview of results for Nutrient data in the Mediterranean region

The quality of all silicate and phosphate measurements from CTD casts from vessels (CT) and bottles (BO) in the Mediterranean is shown in Figure 21. For both parameters and platform types, the percentage of good quality data exceeds 90% in most years.

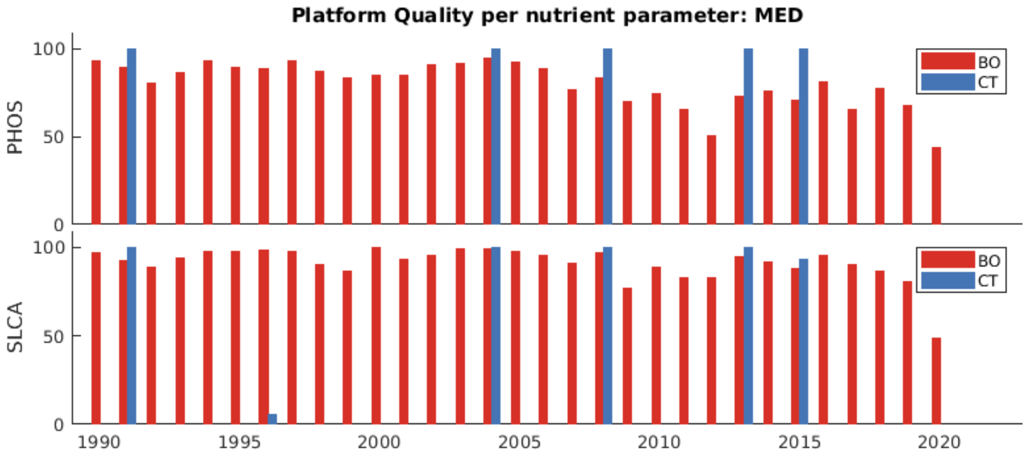

Figure 21: Data quality for parameters PHOS (top) and SLCA (bottom) from the beginning of the dataset until now (years: x-axis). Percentage of good quality data from CTD casts from vessels (red) and from bottles (blue) in the Mediterranean Sea (y-axis).

V SYSTEM’S NOTICEABLE EVENTS, OUTAGES OR CHANGES

Date	Change/Event description	System version	Other
31/08/2021	Inclusion of EMODnet Chemistry data		

VI QUALITY CHANGES SINCE PREVIOUS VERSION

VI.1.1 Changes in Version 1.1 from Version 1.0

Limits for chlorophyll concentration cannot be calculated directly from physical variables. Therefore, an acceptable range must be set based on that found in a given biogeochemical area. In the previous reprocessing, coarse values were used to determine the upper acceptable limit. These are too high levels for most of the global ocean, especially the pelagic regions, i.e., the open ocean. In contrast to the previous version, where unrealistically wide global range tests with additional spike tests were applied, in the present approach of the reprocessed product, the ocean is divided into a higher-resolution set of regions/provinces where upper limits are set based on the 99th percentile for a given set of chlorophyll observations. Dividing the ocean into coastal and pelagic provinces (following the definitions by Spalding et al., 2007, 2012, also see section III.3.1) we are better able to characterise the chlorophyll concentrations in each province. We have also split the ocean vertically into three levels (two for the euphotic zone rather than one) and that also gives us better precision in the surface waters where the highest variability in chlorophyll concentrations occurs. The higher precision available with the method we have used in this reprocessing has resulted in a change in the quality control flags for 73% of the observations, 67% of the data being reclassified as QC level 1 (“good data”). This is discussed in detail in Section III.3.

VI.1.2 Changes in Version 1.2 from Version 1.1

In Version 1.2 an updated quality control procedure for oxygen data has been implemented, while some region-specific quality control procedures for the Baltic Sea have been retained. Moreover, additional tests at metadata level have been implemented as described in Section III.2. New features of the oxygen quality control procedure include a new land-test checking the position of the measurement, and a regional range test at regional resolution.

VI.1.3 Changes in Version 2.0 from Version 1.2

As the third and final fundamental step in the evolution of the biogeochemical re-processed product, in version 2 nutrient data have been included (nitrate: NTAW, NTRA; silicate: SLCA; and phosphate: PHOS) and associated quality control procedures for these nutrient data have been implemented. In addition to the globally applied quality control procedures, the quality control also includes some region-specific procedures for the Baltic and Mediterranean seas, as shown in subsequent sections.

VI.1.4 Changes in Version 2.1 from Version 2.0

Updates to the quality control procedure for the oxygen data have been implemented. In addition, some changes have been made in the implementation of the ranges in the quality control procedures for the chlorophyll data. But more importantly, the chlorophyll re-processed dataset no longer contains quality control flags that have been changed from ‘4’ (“bad data”) to ‘1’ (“good data”) during the re-processing. In contrast, in the NRT quality control procedure all data that got quality flag values ‘4’ (“bad data”) are kept at ‘4’.

VI.1.5 Changes in Version 2.2 from Version 2.1

Minor changes to some of the regions.

VI.1.6 Changes in Version 2.3 from Version 2.2

The EMODnet chemistry 2018 dataset was included, and thereby the use of QC flag ‘6’ was inherited. Minor changes in the ranges of some regions, based on visual checks, were implemented.

VI.1.7 Changes in Version 2.4 from Version 2.3

None.

VI.1.8 Changes in Version 2.5 from Version 2.4

This version adds a river mouth detection algorithm to be used in the visual inspection of the ranges for the test results. This resulted in a more thorough visual check and less low quality flags in such regions.

VI.1.9 Changes in Version 2.6 from Version 2.5

Including seasonality in the upper layer in the range tests. The use of three depth layers has been implemented in most regions. The parameters PHOW and SLCW were included in the testing.

VI.1.10 Changes in Version 2.7 from Version 2.6

Recalculating ranges for oxygen and nutrients based on the new WOA23 data. In addition, some layer depths were adjusted in the range tests based on the new results. The new results did not warrant any changes to the geographical regions as the geographical regions, which are data driven, remain unchanged, despite the change from WOA18 to WOA23 as the underlying dataset.

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VIII APPENDIX

VIII.1 Auxiliary tables

Table 18: Ranges for the global range testing of chlorophyll in the pelagic and coastal provinces for the three layers. The upper range is the 99th percentile. Note that pelagic and coastal provinces may overlap, but the test uses the range for the coastal province when available. NaN means no range available. Lower end of all ranges and upper end in the lower layer are fixed values but displayed for completeness. Note that for the Baltic Sea region of the Northern European province the range is set manually to -0.1–60 mg m^{-3} at all depths in order to not interfere with the regional tests and are thus not used in practice (continues in next page).

Province	CPHL(_ADJUSTED) (mg m-3)			FLU2(_ADJUSTED) (mg m-3)		
	Upper layer (0–100 m)	Second layer (100–200 m)	Lower layer (>200 m)	Upper layer (0–100 m)	Second layer (100–200 m)	Lower layer (>200 m)
Coastal – Agulhas	-0.1–2.18	-0.1–0.45	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Amsterdam-St Paul	-0.1–2.50	-0.1–0.42	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal – Andaman	-0.1–1.63	-0.1–0.44	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal – Arctic	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–16.61	-0.1–1.59	-0.1–0.5
Coastal - Bay of Bengal	-0.1–1.56	-0.1–0.42	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Black Sea	-0.1–1.91	-0.1–0.20	-0.1–0.5	-0.1–8.67	-0.1–0.13	-0.1–0.5
Coastal - Central Indian Ocean Islands	-0.1–1.49	-0.1–0.53	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Central Polynesia	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–0.62	-0.1–0.69	-0.1–0.5
Coastal - Cold Temperate NE Pacific	-0.1–7.37	-0.1–0.48	-0.1–0.5	-0.1–9.23	-0.1–0.38	-0.1–0.5
Coastal - Cold Temperate NW Atlantic	-0.1–8.23	-0.1–1.05	-0.1–0.5	-0.1–9.54	-0.1–0.21	-0.1–0.5
Coastal - Cold Temperate NW Pacific	-0.1–2.60	-0.1–0.10	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Continental High Antarctic	-0.1–4.23	-0.1–1.50	-0.1–0.5	-0.1–1.20	-0.1–0.75	-0.1–0.5
Coastal - East Central Australian Shelf	-0.1–1.43	-0.1–0.76	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Eastern Coral Triangle	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–0.67	-0.1–0.42	-0.1–0.5
Coastal - Gulf of Guinea	-0.1–1.62	-0.1–0.18	-0.1–0.5	-0.1–12.76	-0.1–0.64	-0.1–0.5
Coastal - Lord Howe and Norfolk Islands	-0.1–1.54	-0.1–0.51	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal – Lusitanian	-0.1–2.16	-0.1–0.55	-0.1–0.5	-0.1–19.70	-0.1–1.15	-0.1–0.5
Coastal – Magellanic	-0.1–0.64	-0.1–0.61	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Marshall, Gilbert and Ellis Isl.	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–0.93	-0.1–0.46	-0.1–0.5
Coastal - Mediterranean Sea	-0.1–1.99	-0.1–0.64	-0.1–0.5	-0.1–2.03	-0.1–1.85	-0.1–0.5
Coastal - North Brazil Shelf	-0.1–3.17	-0.1–0.97	-0.1–0.5	-0.1–6.48	-0.1–0.22	-0.1–0.5
Coastal - Northern European Seas	-0.1–17.50	-0.1–0.51	-0.1–0.5	-0.1–16.38	-0.1–0.76	-0.1–0.5
Coastal - NW Australian Shelf	-0.1–1.40	-0.1–0.45	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Red Sea and Gulf of Aden	-0.1–0.86	-0.1–0.60	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - SE Australian Shelf	-0.1–3.17	-0.1–0.80	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - SE Polynesia	-0.1–0.21	-0.1–0.75	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - SW Australian Shelf	-0.1–1.80	-0.1–0.76	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Subantarctic Islands	-0.1–6.00	-0.1–3.56	-0.1–0.5	-0.1–2.86	-0.1–1.79	-0.1–0.5
Coastal - Subantarctic New Zealand	-0.1–1.50	-0.1–0.86	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Tristan Gough	-0.1–0.56	-0.1–0.49	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Tropical East Pacific	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–5.69	-0.1–0.14	-0.1–0.5
Coastal - Tropical NW Atlantic	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–0.55	-0.1–0.33	-0.1–0.5
Coastal - Tropical NW Pacific	-0.1–0.87	-0.1–0.38	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Tropical SW Atlantic	-0.1–2.67	-0.1– NaN	-0.1–0.5	-0.1–1.03	-0.1–1.10	-0.1–0.5
Coastal - Tropical SW Pacific	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–2.60	-0.1–1.49	-0.1–0.5
Coastal - Warm Temperate NW Pacific	-0.1–0.89	-0.1–0.95	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Warm Temperate SE Pacific	-0.1–7.64	-0.1–0.28	-0.1–0.5	-0.1–10.71	-0.1–0.37	-0.1–0.5
Coastal - Warm Temperate SW Atlantic	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–0.79	-0.1–0.50	-0.1–0.5
Coastal - West African Transition	-0.1–2.20	-0.1–0.17	-0.1–0.5	-0.1–5.42	-0.1–0.14	-0.1–0.5
Coastal - West Central Australian Shelf	-0.1–0.47	-0.1–0.52	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - West and South Indian Shelf	-0.1–2.29	-0.1–0.36	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Western Coral Triangle	-0.1–1.74	-0.1–0.51	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Coastal - Western Indian Ocean	-0.1–10.51	-0.1–11.45	-0.1–0.5	-0.1–3.09	-0.1–1.70	-0.1–0.5
Pelagic - Agulhas Current	-0.1–1.43	-0.1–0.67	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic – Antarctic	-0.1–4.03	-0.1–2.56	-0.1–0.5	-0.1–1.57	-0.1–1.13	-0.1–0.5
Pelagic - Antarctic Polar Front	-0.1–6.10	-0.1–2.60	-0.1–0.5	-0.1–7.11	-0.1–0.89	-0.1–0.5

Province	CPHL(_ADJUSTED) (mg m-3)			FLU2(_ADJUSTED) (mg m-3)		
	Upper layer (0–100 m)	Second layer (100–200 m)	Lower layer (>200 m)	Upper layer (0–100 m)	Second layer (100–200 m)	Lower layer (>200 m)
Pelagic – Arctic	-0.1–4.98	-0.1–4.00	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - California Current	-0.1–1.30	-0.1–0.73	-0.1–0.5	-0.1–1.46	-0.1–0.10	-0.1–0.5
Pelagic - Eastern Tropical Pacific	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–2.79	-0.1–0.26	-0.1–0.5
Pelagic - Equatorial Atlantic	-0.1–1.49	-0.1–0.88	-0.1–0.5	-0.1–5.29	-0.1–0.98	-0.1–0.5
Pelagic - Equatorial Pacific	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–0.60	-0.1–0.25	-0.1–0.5
Pelagic - Guinea Current	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–0.55	-0.1–0.05	-0.1–0.5
Pelagic - Gulf Stream	-0.1–3.92	-0.1–0.63	-0.1–0.5	-0.1–1.85	-0.1–0.10	-0.1–0.5
Pelagic - Humboldt Current	-0.1–1.45	-0.1–0.75	-0.1–0.5	-0.1–2.55	-0.1–0.53	-0.1–0.5
Pelagic - Indian Ocean Gyre	-0.1–1.90	-0.1–0.97	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - Indian Ocean Monsoon Gyre	-0.1–2.42	-0.1–0.69	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - Indonesian Through-Flow	-0.1–1.80	-0.1–0.22	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic – Kuroshio	-0.1–0.96	-0.1–0.61	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - Leeuwin Current	-0.1–0.38	-0.1–0.41	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - Malvinas Current	-0.1– NaN	-0.1– NaN	-0.1–0.5	-0.1–3.25	-0.1–0.46	-0.1–0.5
Pelagic - Non-gyral SW Pacific	-0.1–1.34	-0.1–0.68	-0.1–0.5	-0.1–0.94	-0.1–0.52	-0.1–0.5
Pelagic - North Atlantic Transitional	-0.1–3.00	-0.1–0.20	-0.1–0.5	-0.1–1.86	-0.1–0.53	-0.1–0.5
Pelagic - North Central Atlantic Gyre	-0.1–0.76	-0.1–0.52	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - North Central Pacific Gyre	-0.1–1.54	-0.1–0.78	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - North Pacific Transitional	-0.1–4.91	-0.1–4.94	-0.1–0.5	-0.1–0.96	-0.1–0.14	-0.1–0.5
Pelagic - Somali Current	-0.1–2.46	-0.1–0.39	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - South Central Atlantic Gyre	-0.1–2.47	-0.1–0.69	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - South Central Pacific Gyre	-0.1–1.61	-0.1–0.92	-0.1–0.5	-0.1–1.98	-0.1–0.82	-0.1–0.5
Pelagic – Subantarctic	-0.1–10.61	-0.1–4.09	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - Subarctic Atlantic	-0.1–4.55	-0.1–0.58	-0.1–0.5	-0.1–9.48	-0.1–1.09	-0.1–0.5
Pelagic - Subarctic Pacific	-0.1–2.78	-0.1–0.41	-0.1–0.5	-0.1– NaN	-0.1– NaN	-0.1–0.5
Pelagic - Subtropical Convergence	-0.1–3.64	-0.1–0.97	-0.1–0.5	-0.1–1.43	-0.1–0.83	-0.1–0.5

Table 19: Ranges for the global range testing of oxygen in different regions and layers. The table contains the individual layer depths for the geographical regions detailed in Figure 11. Missing Layer 2 indicates that there are only two layers. Seasonality in the limits (Layer 1 only) is indicated with the seasonal span of the limit. Mediterranean and Baltic Seas limits are set high in order to not interfere with the regional tests and are thus not in effect (continues in next page.)

Region	Layer (layer bottom depth)	DOX1 (ml/l)		DOXY (µmol/l)		DOX2 (µmol/kg)	
		low	high	low	high	low	high
Atlantic Water	Layer 1 (100 m)	0.0-2.5	10.1-11.2	0-113	451-502	0-110	440-490
	Layer 2 (1500 m)	0.0	9.0	0	400	0	390
	Layer 3	3.9	8.5	174	379	170	370
Northern European Coast	Layer 1 (50 m)	0.0-3.7	9.9-11.0	0-164	441-492	0-160	430-480
	Layer 2 (800 m)	3.7	9.2	164	410	160	400
	Layer 3	4.6	8.0	205	359	200	350
Mediterranean Sea	Layer 1 (100 m)	0.0-0.0	23.0-23.0	0-0	1025-1025	0-0	1000-1000
	Layer 3	0.0	23.0	0	1025	0	1000
Baltic Sea	Layer 1 (100 m)	0.0-0.0	23.0-23.0	0-0	1025-1025	0-0	1000-1000
	Layer 3	0.0	23.0	0	1025	0	1000
Central Pacific	Layer 1 (100 m)	0.0-0.0	9.2-10.5	0-0	410-471	0-0	400-460
	Layer 2 (800 m)	0.0	10.3	0	461	0	450
	Layer 3	0.0	4.6	0	205	0	200
Southern Mid Latitudes	Layer 1 (100 m)	0.0-0.0	11.2-12.6	0-0	502-564	0-0	490-550
	Layer 2 (1500 m)	0.0	10.1	0	451	0	440
	Layer 3	2.1	6.9	92	308	90	300

Region	Layer (layer bottom depth)	DOX1 (ml/l)		DOXY (µmol/l)		DOX2 (µmol/kg)	
		low	high	low	high	low	high
Southern Ocean	Layer 1 (100 m)	0.0-0.0	13.8-13.8	0-0	615-615	0-0	600-600
	Layer 2 (1000 m)	0.0	13.5	0	605	0	590
	Layer 3	2.5	7.3	113	328	110	320
North Pacific	Layer 1 (100 m)	0.0-0.0	13.8-13.8	0-0	615-615	0-0	600-600
	Layer 2 (800 m)	0.0	13.8	0	615	0	600
	Layer 3	0.0	4.8	0	215	0	210
Polar Water	Layer 1 (100 m)	2.5-4.4	10.8-13.8	113-195	482-615	110-190	470-600
	Layer 3	4.6	9.6	205	430	200	420
Subpolar Gyre region	Layer 1 (100 m)	0.0-0.0	11.9-13.8	0-0	533-615	0-0	520-600
	Layer 2 (800 m)	1.8	9.6	82	430	80	420
	Layer 3	4.1	8.5	184	379	180	370
Arctic Ocean	Layer 1 (100 m)	2.3-2.3	11.2-16.7	102-102	502-748	100-100	490-730
	Layer 2 (800 m)	0.0	11.9	0	533	0	520
	Layer 3	4.1	9.2	184	410	180	400
Chukchi Sea	Layer 1 (100 m)	0.0-0.0	13.8-13.8	0-0	615-615	0-0	600-600
	Layer 2 (800 m)	2.3	10.1	102	451	100	440
	Layer 3	3.9	9.0	174	400	170	390
Black Sea	Layer 1 (40 m)	0.0-0.0	11.5-13.8	0-0	513-615	0-0	500-600
	Layer 2 (100 m)	0.0	11.9	0	533	0	520
	Layer 3	0.0	6.7	0	297	0	290
Canadian Archipelago	Layer 1 (50 m)	0.0-0.0	12.4-13.8	0-0	554-615	0-0	540-600
	Layer 2 (800 m)	0.0	11.9	0	533	0	520
	Layer 3	0.0	7.8	0	349	0	340
Indian Ocean	Layer 1 (100 m)	0.0-0.0	12.6-13.8	0-0	564-615	0-0	550-600
	Layer 2 (800 m)	0.0	8.7	0	390	0	380
	Layer 3	0.0	5.3	0	236	0	230
Central Atlantic Ocean	Layer 1 (100 m)	2.1-2.5	8.0-8.7	92-113	359-390	90-110	350-380
	Layer 2 (1600 m)	0.0	7.8	0	349	0	340
	Layer 3	3.0	7.6	133	338	130	330
Caspian Sea	Layer 1 (100 m)	0.0-0.0	12.9-13.8	0-0	574-615	0-0	560-600
	Layer 2 (400 m)	0.0	13.3	0	595	0	580
	Layer 3	0.0	8.0	0	359	0	350
East Pacific	Layer 1 (200 m)	0.0-0.0	13.8-13.8	0-0	615-615	0-0	600-600
	Layer 2 (1500 m)	0.0	6.2	0	277	0	270
	Layer 3	0.0	4.8	0	215	0	210
Sea of Okhotsk	Layer 1 (50 m)	0.0-0.0	13.8-13.8	0-0	615-615	0-0	600-600
	Layer 2 (1000 m)	0.0	13.3	0	595	0	580
	Layer 3	0.0	3.2	0	144	0	140
West Asian Shelf	Layer 1 (50 m)	0.0-2.8	11.0-13.1	0-123	492-584	0-120	480-570
	Layer 2 (1000 m)	0.0	9.9	0	441	0	430
	Layer 3	2.8	7.6	123	338	120	330
Norwegian Sea	Layer 1 (100 m)	2.3-4.1	9.0-11.7	103-185	400-523	100-180	390-510
	Layer 2 (1000 m)	5.1	8.7	226	390	220	380
	Layer 3	4.8	9.2	215	410	210	400
Gulf Stream	Layer 1 (100 m)	0.0-0.0	12.4-13.8	0-0	554-615	0-0	540-600
	Layer 2 (1500 m)	0.0	10.3	0	461	0	450
	Layer 3	2.8	8.5	123	379	120	370
West African Upwelling Region	Layer 1 (50 m)	0.0-0.0	11.5-12.6	0-0	513-564	0-0	500-550
	Layer 2 (1500 m)	0.0	10.6	0	472	0	460
	Layer 3	3.7	6.9	164	308	160	300
Caribbean	Layer 1 (100 m)	0.0-0.0	9.2-11.5	0-0	410-513	0-0	400-500
	Layer 2 (1500 m)	0.0	7.6	0	338	0	330

Region	Layer (layer bottom depth)	DOX1 (ml/l)		DOXY (µmol/l)		DOX2 (µmol/kg)	
		low	high	low	high	low	high
	Layer 3	0.0	7.8	0	349	0	340
Indonesian Region	Layer 1 (100 m)	0.0-0.0	7.8-9.2	0-0	349-410	0-0	340-400
	Layer 2 (800 m)	0.0	6.9	0	308	0	300
	Layer 3	0.0	3.9	0	174	0	170
Pacific Equatorial Upwelling	Layer 1 (100 m)	0.0-0.0	7.6-9.0	0-0	338-400	0-0	330-390
	Layer 2 (1000 m)	0.0	8.5	0	379	0	370
	Layer 3	0.0	4.8	0	215	0	210
South Pacific	Layer 1 (100 m)	0.0-0.0	9.0-10.8	0-0	400-482	0-0	390-470
	Layer 2 (1500 m)	0.0	9.4	0	420	0	410
	Layer 3	0.0	5.3	0	236	0	230
Central European Coast	Layer 1 (50 m)	0.0-0.0	9.7-13.1	0-0	431-584	0-0	420-570
	Layer 2 (1000 m)	2.5	9.0	113	400	110	390
	Layer 3	2.3	8.0	102	359	100	350

Table 20: Ranges for the global range testing of nitrate in different regions and layers. The table contains the individual layer depths for the geographical regions detailed in Figure 13. Missing Layer 2 indicates there are only two layers. Seasonality in the limits (Layer 1 only) is indicated with the seasonal span of the limit. Mediterranean and Baltic Seas limits are set high in order to not interfere with the regional tests and are thus not in effect (continues in next page).

Region	Layer (layer bottom depth)	NTRA (µmol/l)		NTAW (µmol/kg)	
		low	high	low	high
Southern Ocean	Layer 1 (50 m)	0-29	34-64	0-28	33-62
	Layer 2 (800 m)	0	56	0	55
	Layer 3	26	41	25	40
Central Indo-Pacific	Layer 1 (100 m)	0-0	21-57	0-0	20-56
	Layer 2 (1500 m)	0	82	0	80
	Layer 3	26	45	25	44
Black Sea	Layer 1 (50 m)	0-0	21-24	0-0	20-23
	Layer 3	0	26	0	25
Northern Cold Water	Layer 1 (50 m)	0-0	33-42	0-0	32-41
	Layer 2 (300 m)	0	52	0	51
	Layer 3	0	25	0	24
Tropical Eastern Pacific	Layer 1 (50 m)	0-0	38-59	0-0	37-58
	Layer 2 (2000 m)	0	67	0	65
	Layer 3	31	51	30	50
Temperate South America	Layer 1 (50 m)	0-0	64-74	0-0	62-72
	Layer 2 (1000 m)	0	82	0	80
	Layer 3	0	77	0	75
Baltic Sea	Layer 1 (50 m)	0-0	1024-1024	0-0	999-999
	Layer 3	0	1024	0	999
Southern Cold Water	Layer 1 (100 m)	0-13	35-70	0-13	34-68
	Layer 2 (1000 m)	0	59	0	58
	Layer 3	12	46	12	45
North Atlantic	Layer 1 (50 m)	0-0	23-37	0-0	22-36
	Layer 2 (4000 m)	0	33	0	32
	Layer 3	16	29	16	28
Northern European Coast	Layer 1 (50 m)	0-0	24-36	0-0	23-35
	Layer 2 (800 m)	0	32	0	31

Region	Layer (layer bottom depth)	NTRA (µmol/l)		NTAW (µmol/kg)	
		low	high	low	high
	Layer 3	10	21	10	20
Northern Atlantic Cold Water	Layer 1 (50 m)	0-0	32-48	0-0	31-47
	Layer 2 (4000 m)	0	39	0	38
	Layer 3	19	26	19	25
Pacific Northern Cold Water	Layer 1 (50 m)	0-0	53-79	0-0	52-77
	Layer 2 (1000 m)	0	82	0	80
	Layer 3	0	82	0	80
Central European Coast	Layer 1 (50 m)	0-0	21-62	0-0	20-60
	Layer 2 (1000 m)	0	26	0	25
	Layer 3	10	21	10	20
Arctic Coasts	Layer 1 (50 m)	0-0	41-62	0-0	40-60
	Layer 2 (800 m)	0	65	0	63
	Layer 3	11	21	11	20
Temperate Australasia	Layer 1 (50 m)	0-0	13-28	0-0	13-27
	Layer 2 (800 m)	0	54	0	53
	Layer 3	0	77	0	75
Mediterranean	Layer 1 (100 m)	0-0	1024-1024	0-0	999-999
	Layer 3	0	1024	0	999
Tropical Atlantic	Layer 1 (100 m)	0-0	8-40	0-0	8-39
	Layer 2 (1500 m)	0	67	0	65
	Layer 3	14	29	14	28
Temperate Southern Africa	Layer 1 (50 m)	0-0	62-72	0-0	60-70
	Layer 2 (1000 m)	0	69	0	67
	Layer 3	13	42	13	41
Caspian Sea	Layer 1 (50 m)	0-0	1-4	0-0	1-4
	Layer 3	0	2	0	2
Temperate Northern Pacific	Layer 1 (100 m)	0-0	60-82	0-0	59-80
	Layer 2 (1000 m)	0	82	0	80
	Layer 3	0	68	0	66
Equatorial Pacific	Layer 1 (100 m)	0-0	28-75	0-0	27-73
	Layer 2 (1000 m)	0	78	0	76
	Layer 3	27	54	26	53
Western Indo-Pacific	Layer 1 (100 m)	0-0	46-73	0-0	45-71
	Layer 2 (1000 m)	0	55	0	54
	Layer 3	26	44	25	43
Indo-Pacific Warm Water	Layer 1 (50 m)	0-0	35-39	0-0	34-38
	Layer 2 (1000 m)	0	81	0	79
	Layer 3	19	56	19	55
Atlantic Warm Water	Layer 1 (100 m)	0-0	53-82	0-0	52-80
	Layer 2 (1500 m)	0	68	0	66
	Layer 3	0	44	0	43
Canadian Archipelago	Layer 1 (100 m)	0-0	18-31	0-0	18-30
	Layer 3	0	36	0	35
Temperate Northern Atlantic	Layer 1 (100 m)	0-0	34-57	0-0	33-56
	Layer 2 (800 m)	0	82	0	80
	Layer 3	0	39	0	38

Table 21: Ranges for the global range testing of phosphate in different regions and layers. The table contains the individual layer depths for the geographical regions detailed in Figure 13. Missing Layer 2 indicates there are only two layers. Seasonality in the limits (Layer 1 only) is indicated with the seasonal span of the limit. Mediterranean and Baltic Seas limits are set high in order to not interfere with the regional tests and are thus not in effect (continues in the next page).

Region	Layer (layer bottom depth)	PHOS (µmol/l)		PHOW (µmol/kg)	
		low	high	low	high
Southern Ocean	Layer 1 (100 m)	0.0-1.3	3.0-4.6	0.0-1.3	2.9-4.5
	Layer 2 (1000 m)	0.0	4.4	0.0	4.3
	Layer 3	1.4	3.2	1.4	3.1
Central Indo-Pacific	Layer 1 (100 m)	0.0-0.0	3.7-4.8	0.0-0.0	3.6-4.7
	Layer 2 (1500 m)	0.0	7.4	0.0	7.2
	Layer 3	1.7	3.6	1.7	3.5
Black Sea	Layer 1 (100 m)	0.0-0.0	7.7-10.1	0.0-0.0	7.5-9.9
	Layer 3	0.0	14.4	0.0	14.0
Northern Cold Water	Layer 1 (50 m)	0.0-0.0	2.0-3.7	0.0-0.0	2.0-3.6
	Layer 2 (300 m)	0.0	5.0	0.0	4.9
	Layer 3	0.0	2.3	0.0	2.2
Tropical Eastern Pacific	Layer 1 (50 m)	0.0-0.0	2.7-5.2	0.0-0.0	2.6-5.1
	Layer 2 (1500 m)	0.0	7.0	0.0	6.8
	Layer 3	1.0	5.1	1.0	5.0
Temperate South America	Layer 1 (50 m)	0.0-0.0	7.3-8.8	0.0-0.0	7.1-8.6
	Layer 2 (1000 m)	0.0	6.5	0.0	6.3
	Layer 3	0.0	6.4	0.0	6.2
Baltic Sea	Layer 1 (50 m)	0.0-0.0	1024.0-1024.0	0.0-0.0	999.0-999.0
	Layer 3	0.0	1024.0	0.0	999.0
Southern Cold Water	Layer 1 (200 m)	0.0-0.0	3.8-5.7	0.0-0.0	3.7-5.6
	Layer 2 (1000 m)	0.0	5.3	0.0	5.2
	Layer 3	0.0	3.7	0.0	3.6
North Atlantic	Layer 1 (50 m)	0.0-0.0	2.0-2.8	0.0-0.0	2.0-2.7
	Layer 2 (4000 m)	0.0	2.7	0.0	2.6
	Layer 3	0.0	2.5	0.0	2.4
Northern European Coast	Layer 1 (50 m)	0.0-0.0	2.0-2.6	0.0-0.0	2.0-2.5
	Layer 2 (800 m)	0.0	2.4	0.0	2.3
	Layer 3	0.0	1.4	0.0	1.4
Northern Atlantic Cold Water	Layer 1 (50 m)	0.0-0.0	2.2-3.1	0.0-0.0	2.1-3.0
	Layer 2 (4000 m)	0.0	2.5	0.0	2.4
	Layer 3	1.0	2.0	1.0	2.0
Pacific Northern Cold Water	Layer 1 (100 m)	0.0-0.0	4.8-6.9	0.0-0.0	4.7-6.7
	Layer 2 (1000 m)	0.0	6.6	0.0	6.4
	Layer 3	1.1	5.3	1.1	5.2
Central European Coast	Layer 1 (50 m)	0.0-0.0	2.7-4.3	0.0-0.0	2.6-4.2
	Layer 2 (1000 m)	0.0	1.8	0.0	1.8
	Layer 3	0.0	2.0	0.0	2.0
Arctic Coasts	Layer 1 (50 m)	0.0-0.0	4.1-8.9	0.0-0.0	4.0-8.7
	Layer 2 (800 m)	0.0	5.6	0.0	5.5
	Layer 3	0.0	1.9	0.0	1.9
Temperate Australasia	Layer 1 (50 m)	0.0-0.0	1.8-3.9	0.0-0.0	1.8-3.8
	Layer 2 (800 m)	0.0	3.8	0.0	3.7
	Layer 3	0.0	4.4	0.0	4.3
Mediterranean	Layer 1 (100 m)	0.0-0.0	1024.0-1024.0	0.0-0.0	999.0-999.0
	Layer 3	0.0	1024.0	0.0	999.0
Tropical Atlantic	Layer 1 (100 m)	0.0-0.0	1.7-3.1	0.0-0.0	1.7-3.0
	Layer 2 (1500 m)	0.0	5.4	0.0	5.3

Region	Layer (layer bottom depth)	PHOS (µmol/l)		PHOW (µmol/kg)	
		low	high	low	high
	Layer 3	0.0	2.0	0.0	2.0
Temperate Southern Africa	Layer 1 (50 m)	0.0-0.0	5.3-6.3	0.0-0.0	5.2-6.1
	Layer 2 (1500 m)	0.0	5.5	0.0	5.4
	Layer 3	0.0	3.3	0.0	3.2
Caspian Sea	Layer 1 (100 m)	0.0-0.0	1.7-3.8	0.0-0.0	1.7-3.7
	Layer 3	0.0	2.5	0.0	2.4
Temperate Northern Pacific	Layer 1 (100 m)	0.0-0.0	6.7-7.8	0.0-0.0	6.5-7.6
	Layer 2 (1500 m)	0.0	6.0	0.0	5.9
	Layer 3	0.0	3.7	0.0	3.6
Equatorial Pacific	Layer 1 (100 m)	0.0-0.0	4.0-6.2	0.0-0.0	3.9-6.0
	Layer 2 (1000 m)	0.0	5.8	0.0	5.7
	Layer 3	1.9	3.7	1.9	3.6
Western Indo-Pacific	Layer 1 (100 m)	0.0-0.0	4.7-6.2	0.0-0.0	4.6-6.0
	Layer 2 (1500 m)	0.0	6.3	0.0	6.1
	Layer 3	1.7	3.4	1.7	3.3
Indo-Pacific Warm Water	Layer 1 (50 m)	0.0-0.0	2.7-4.8	0.0-0.0	2.6-4.7
	Layer 2 (1500 m)	0.0	6.0	0.0	5.9
	Layer 3	1.2	4.1	1.2	4.0
Atlantic Warm Water	Layer 1 (100 m)	0.0-0.0	3.2-4.8	0.0-0.0	3.1-4.7
	Layer 2 (1500 m)	0.0	4.5	0.0	4.4
	Layer 3	0.0	3.4	0.0	3.3
Canadian Archipelago	Layer 1 (100 m)	0.0-0.0	2.3-4.5	0.0-0.0	2.2-4.4
	Layer 3	0.0	3.2	0.0	3.1
Temperate Northern Atlantic	Layer 1 (100 m)	0.0-0.0	2.8-4.1	0.0-0.0	2.7-4.0
	Layer 2 (800 m)	0.0	4.5	0.0	4.4
	Layer 3	0.0	2.8	0.0	2.7

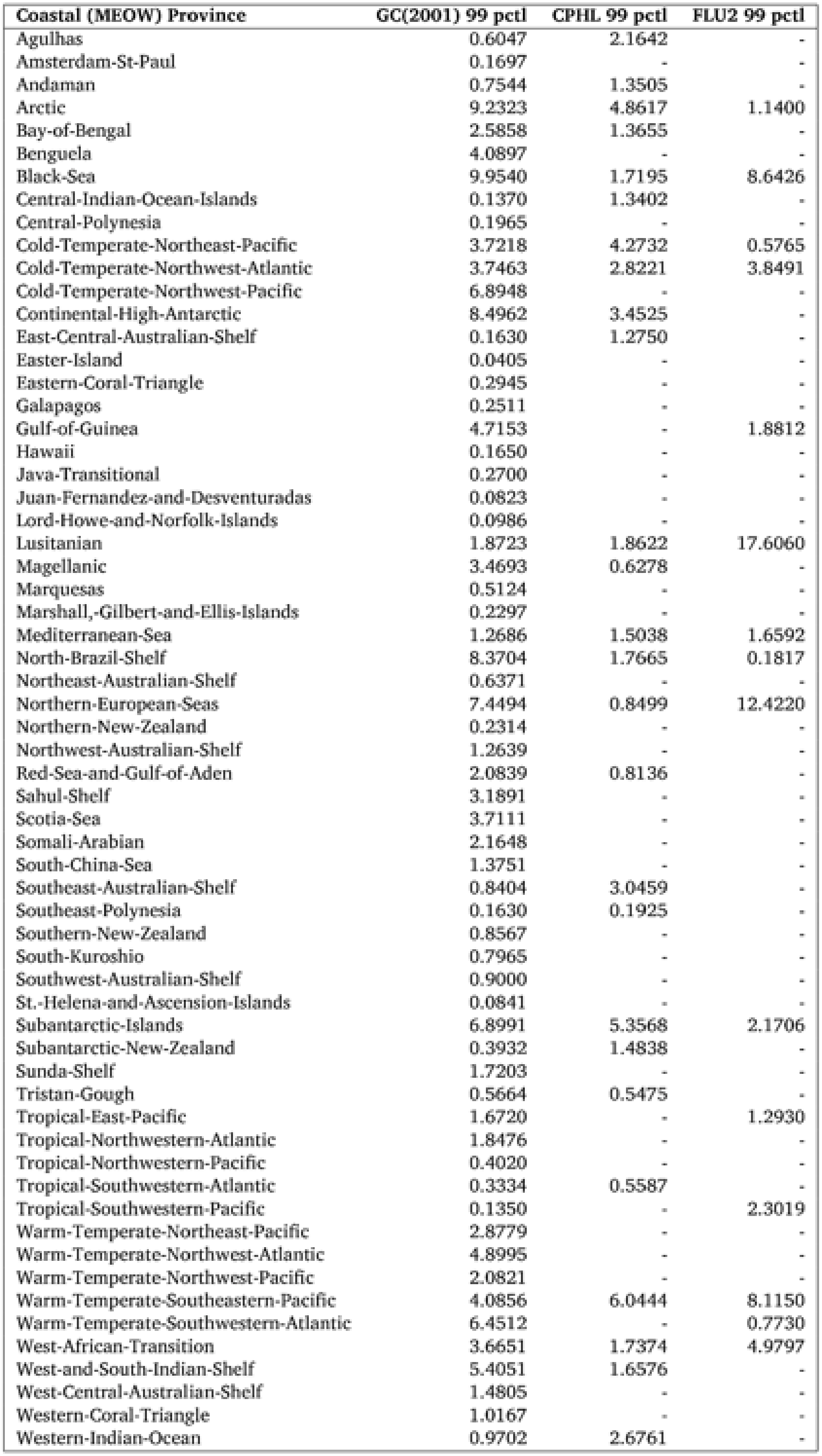
Table 22: Ranges for the global range testing of silicate in different regions and layers. The table contains the individual layer depths for the geographical regions detailed in Figure 13. Missing Layer 2 indicates there are only two layers. Seasonality in the limits (Layer 1 only) is indicated with the seasonal span of the limit. Mediterranean and Baltic Seas limits are set high in order to not interfere with the regional tests and are thus not in effect (continues in next page).

Region	Layer (layer bottom depth)	SLCA (µmol/l)		SLCW (µmol/kg)	
		low	high	low	high
Southern Ocean	Layer 1 (50 m)	0-31	123-195	0-30	120-190
	Layer 2 (1000 m)	0	205	0	200
	Layer 3	0	205	0	200
Central Indo-Pacific	Layer 1 (100 m)	0-0	72-103	0-0	70-100
	Layer 2 (1500 m)	0	205	0	200
	Layer 3	72	174	70	170
Black Sea	Layer 1 (100 m)	0-0	174-174	0-0	170-170
	Layer 3	0	256	0	250
Northern Cold Water	Layer 1 (300 m)	0-0	21-123	0-0	20-120
	Layer 3	0	41	0	40
Tropical Eastern Pacific	Layer 1 (100 m)	0-0	82-82	0-0	80-80
	Layer 2 (1500 m)	0	154	0	150
	Layer 3	82	185	80	180
Temperate South America	Layer 1 (100 m)	0-0	72-113	0-0	70-110
	Layer 2 (1000 m)	0	133	0	130
	Layer 3	0	215	0	210

Region	Layer (layer bottom depth)	SLCA (µmol/l)		SLCW (µmol/kg)	
		low	high	low	high
Baltic Sea	Layer 1 (50 m)	0-0	1025-1025	0-0	1000-1000
	Layer 3	0	1025	0	1000
Southern Cold Water	Layer 1 (200 m)	0-0	174-226	0-0	170-220
	Layer 2 (1500 m)	0	205	0	200
	Layer 3	0	205	0	200
North Atlantic	Layer 1 (800 m)	0-0	21-31	0-0	20-30
	Layer 2 (4000 m)	0	72	0	70
	Layer 3	21	62	20	60
Northern European Coast	Layer 1 (50 m)	0-0	21-21	0-0	20-20
	Layer 2 (100 m)	0	21	0	20
	Layer 3	0	21	0	20
Northern Atlantic Cold Water	Layer 1 (800 m)	0-0	31-41	0-0	30-40
	Layer 2 (4000 m)	0	62	0	60
	Layer 3	21	72	20	70
Pacific Northern Cold Water	Layer 1 (100 m)	0-0	103-246	0-0	100-240
	Layer 2 (1000 m)	0	256	0	250
	Layer 3	51	256	50	250
Central European Coast	Layer 1 (50 m)	0-0	72-92	0-0	70-90
	Layer 2 (1000 m)	0	21	0	20
	Layer 3	0	31	0	30
Arctic Coasts	Layer 1 (50 m)	0-0	51-256	0-0	50-250
	Layer 2 (800 m)	0	226	0	220
	Layer 3	0	21	0	20
Temperate Australasia	Layer 1 (500 m)	0-0	21-41	0-0	20-40
	Layer 2 (2000 m)	0	154	0	150
	Layer 3	41	164	40	160
Mediterranean	Layer 1 (100 m)	0-0	1025-1025	0-0	1000-1000
	Layer 3	0	1025	0	1000
Tropical Atlantic	Layer 1 (100 m)	0-0	31-72	0-0	30-70
	Layer 2 (1500 m)	0	92	0	90
	Layer 3	0	82	0	80
Temperate Southern Africa	Layer 1 (100 m)	0-0	72-123	0-0	70-120
	Layer 2 (500 m)	0	72	0	70
	Layer 3	0	185	0	180
Caspian Sea	Layer 1 (100 m)	0-0	51-103	0-0	50-100
	Layer 3	0	72	0	70
Temperate Northern Pacific	Layer 1 (100 m)	0-0	154-205	0-0	150-200
	Layer 2 (1500 m)	0	256	0	250
	Layer 3	0	246	0	240
Equatorial Pacific	Layer 1 (200 m)	0-0	62-92	0-0	60-90
	Layer 2 (1500 m)	0	154	0	150
	Layer 3	92	195	90	190
Western Indo-Pacific	Layer 1 (100 m)	0-0	82-103	0-0	80-100
	Layer 2 (1500 m)	0	144	0	140
	Layer 3	61	195	60	190
Indo-Pacific Warm Water	Layer 1 (100 m)	0-0	72-113	0-0	70-110
	Layer 2 (1500 m)	0	256	0	250
	Layer 3	31	236	30	230
Atlantic Warm Water	Layer 1 (100 m)	0-0	31-72	0-0	30-70
	Layer 2 (800 m)	0	62	0	60
	Layer 3	0	174	0	170
Canadian Archipelago	Layer 1 (200 m)	0-0	31-62	0-0	30-60
	Layer 2 (600 m)	0	62	0	60

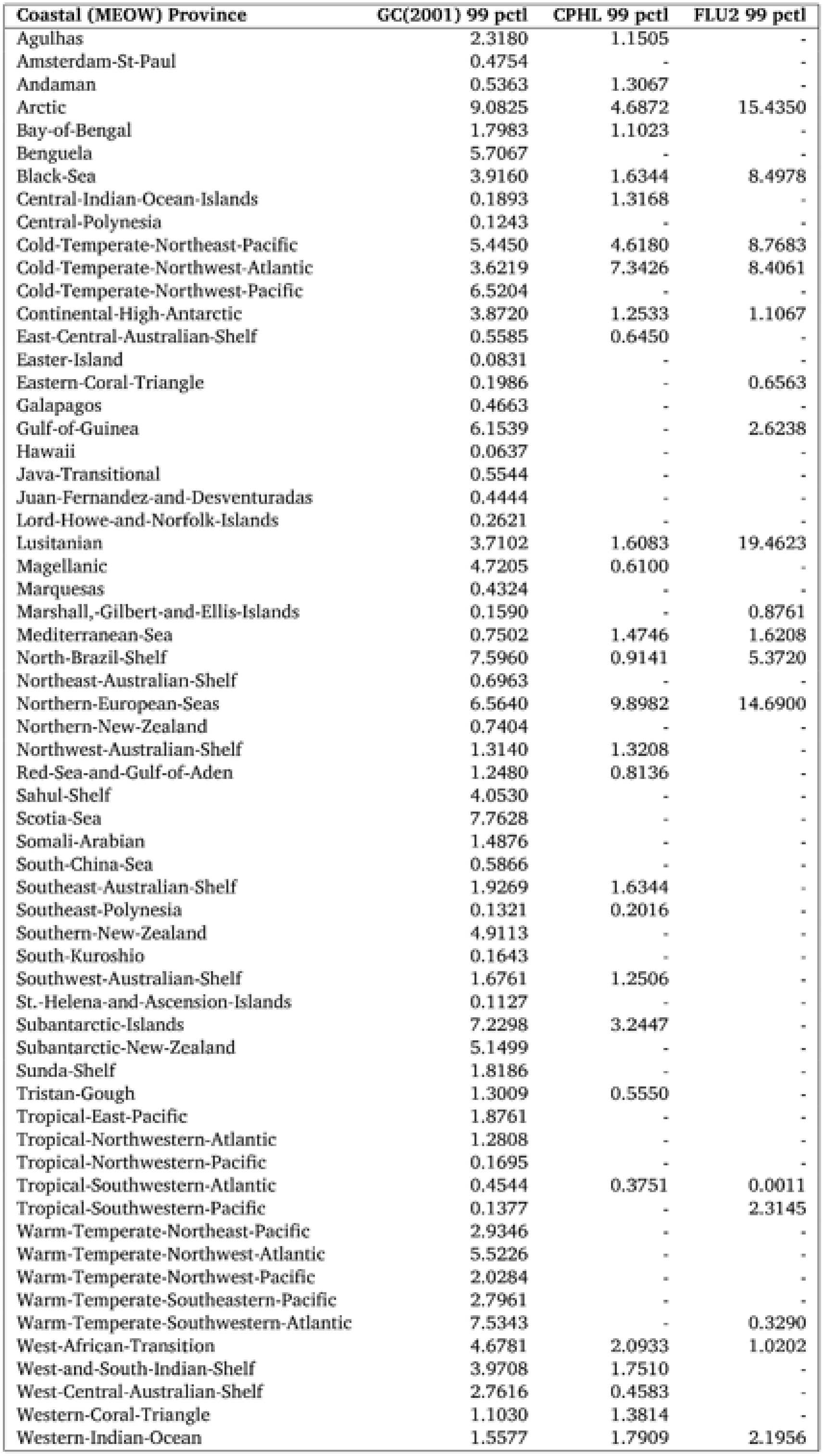
Region	Layer (layer bottom depth)	SLCA (µmol/l)		SLCW (µmol/kg)	
		low	high	low	high
	Layer 3	0	154	0	150
Temperate Northern Atlantic	Layer 1 (100 m)	0-0	51-72	0-0	50-70
	Layer 2 (800 m)	0	144	0	140
	Layer 3	0	62	0	60

Table 23: Percentile 99th values calculated for the coastal Marine Ecoregions of the World (MEOW) provinces based on a subset of data from the Gregg and Conkright (2001) (only data in January-March and data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.



Coastal (MEOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas	0.6047	2.1642	-
Amsterdam-St-Paul	0.1697	-	-
Andaman	0.7544	1.3505	-
Arctic	9.2323	4.8617	1.1400
Bay-of-Bengal	2.5858	1.3655	-
Benguela	4.0897	-	-
Black-Sea	9.9540	1.7195	8.6426
Central-Indian-Ocean-Islands	0.1370	1.3402	-
Central-Polynesia	0.1965	-	-
Cold-Temperate-Northeast-Pacific	3.7218	4.2732	0.5765
Cold-Temperate-Northwest-Atlantic	3.7463	2.8221	3.8491
Cold-Temperate-Northwest-Pacific	6.8948	-	-
Continental-High-Antarctic	8.4962	3.4525	-
East-Central-Australian-Shelf	0.1630	1.2750	-
Easter-Island	0.0405	-	-
Eastern-Coral-Triangle	0.2945	-	-
Galapagos	0.2511	-	-
Gulf-of-Guinea	4.7153	-	1.8812
Hawaii	0.1650	-	-
Java-Transitional	0.2700	-	-
Juan-Fernandez-and-Desventuradas	0.0823	-	-
Lord-Howe-and-Norfolk-Islands	0.0986	-	-
Lusitanian	1.8723	1.8622	17.6060
Magellanic	3.4693	0.6278	-
Marquesas	0.5124	-	-
Marshall,-Gilbert-and-Ellis-Islands	0.2297	-	-
Mediterranean-Sea	1.2686	1.5038	1.6592
North-Brazil-Shelf	8.3704	1.7665	0.1817
Northeast-Australian-Shelf	0.6371	-	-
Northern-European-Seas	7.4494	0.8499	12.4220
Northern-New-Zealand	0.2314	-	-
Northwest-Australian-Shelf	1.2639	-	-
Red-Sea-and-Gulf-of-Aden	2.0839	0.8136	-
Sahul-Shelf	3.1891	-	-
Scotia-Sea	3.7111	-	-
Somali-Arabian	2.1648	-	-
South-China-Sea	1.3751	-	-
Southeast-Australian-Shelf	0.8404	3.0459	-
Southeast-Polynesia	0.1630	0.1925	-
Southern-New-Zealand	0.8567	-	-
South-Kuroshio	0.7965	-	-
Southwest-Australian-Shelf	0.9000	-	-
St.-Helena-and-Ascension-Islands	0.0841	-	-
Subantarctic-Islands	6.8991	5.3568	2.1706
Subantarctic-New-Zealand	0.3932	1.4838	-
Sunda-Shelf	1.7203	-	-
Tristan-Gough	0.5664	0.5475	-
Tropical-East-Pacific	1.6720	-	1.2930
Tropical-Northwestern-Atlantic	1.8476	-	-
Tropical-Northwestern-Pacific	0.4020	-	-
Tropical-Southwestern-Atlantic	0.3334	0.5587	-
Tropical-Southwestern-Pacific	0.1350	-	2.3019
Warm-Temperate-Northeast-Pacific	2.8779	-	-
Warm-Temperate-Northwest-Atlantic	4.8995	-	-
Warm-Temperate-Northwest-Pacific	2.0821	-	-
Warm-Temperate-Southeastern-Pacific	4.0856	6.0444	8.1150
Warm-Temperate-Southwestern-Atlantic	6.4512	-	0.7730
West-African-Transition	3.6651	1.7374	4.9797
West-and-South-Indian-Shelf	5.4051	1.6576	-
West-Central-Australian-Shelf	1.4805	-	-
Western-Coral-Triangle	1.0167	-	-
Western-Indian-Ocean	0.9702	2.6761	-

Table 24: Percentile 99th values calculated for the coastal Marine Ecoregions of the World (MEOW) provinces based on a subset of data from the Gregg and Conkright (2001) (only data in April-June and data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.

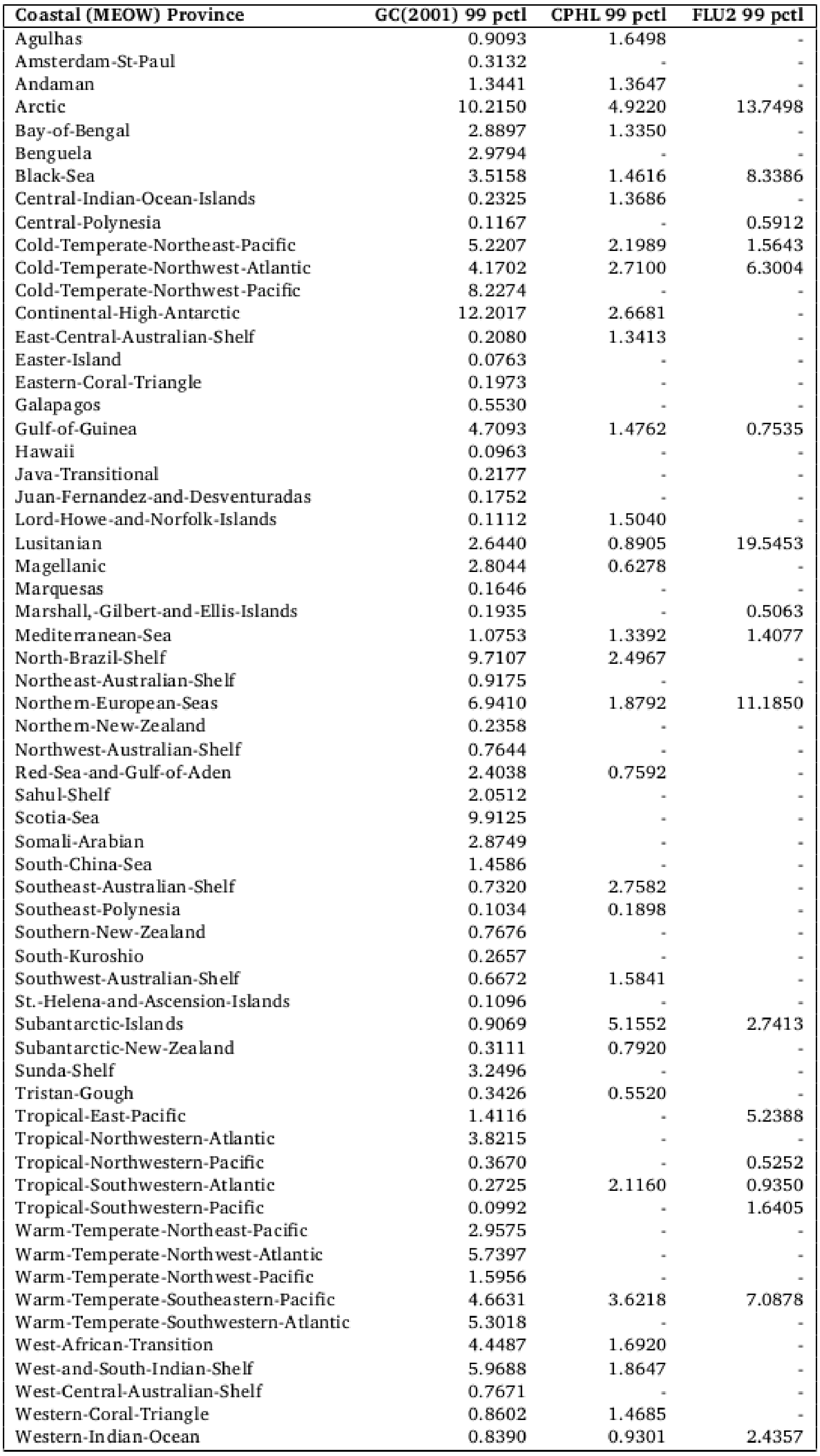


Coastal (MEOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas	2.3180	1.1505	-
Amsterdam-St-Paul	0.4754	-	-
Andaman	0.5363	1.3067	-
Arctic	9.0825	4.6872	15.4350
Bay-of-Bengal	1.7983	1.1023	-
Benguela	5.7067	-	-
Black-Sea	3.9160	1.6344	8.4978
Central-Indian-Ocean-Islands	0.1893	1.3168	-
Central-Polynesia	0.1243	-	-
Cold-Temperate-Northeast-Pacific	5.4450	4.6180	8.7683
Cold-Temperate-Northwest-Atlantic	3.6219	7.3426	8.4061
Cold-Temperate-Northwest-Pacific	6.5204	-	-
Continental-High-Antarctic	3.8720	1.2533	1.1067
East-Central-Australian-Shelf	0.5585	0.6450	-
Easter-Island	0.0831	-	-
Eastern-Coral-Triangle	0.1986	-	0.6563
Galapagos	0.4663	-	-
Gulf-of-Guinea	6.1539	-	2.6238
Hawaii	0.0637	-	-
Java-Transitional	0.5544	-	-
Juan-Fernandez-and-Desventuradas	0.4444	-	-
Lord-Howe-and-Norfolk-Islands	0.2621	-	-
Lusitanian	3.7102	1.6083	19.4623
Magellanic	4.7205	0.6100	-
Marquesas	0.4324	-	-
Marshall,-Gilbert-and-Ellis-Islands	0.1590	-	0.8761
Mediterranean-Sea	0.7502	1.4746	1.6208
North-Brazil-Shelf	7.5960	0.9141	5.3720
Northeast-Australian-Shelf	0.6963	-	-
Northern-European-Seas	6.5640	9.8982	14.6900
Northern-New-Zealand	0.7404	-	-
Northwest-Australian-Shelf	1.3140	1.3208	-
Red-Sea-and-Gulf-of-Aden	1.2480	0.8136	-
Sahul-Shelf	4.0530	-	-
Scotia-Sea	7.7628	-	-
Somali-Arabian	1.4876	-	-
South-China-Sea	0.5866	-	-
Southeast-Australian-Shelf	1.9269	1.6344	-
Southeast-Polynesia	0.1321	0.2016	-
Southern-New-Zealand	4.9113	-	-
South-Kuroshio	0.1643	-	-
Southwest-Australian-Shelf	1.6761	1.2506	-
St.-Helena-and-Ascension-Islands	0.1127	-	-
Subantarctic-Islands	7.2298	3.2447	-
Subantarctic-New-Zealand	5.1499	-	-
Sunda-Shelf	1.8186	-	-
Tristan-Gough	1.3009	0.5550	-
Tropical-East-Pacific	1.8761	-	-
Tropical-Northwestern-Atlantic	1.2808	-	-
Tropical-Northwestern-Pacific	0.1695	-	-
Tropical-Southwestern-Atlantic	0.4544	0.3751	0.0011
Tropical-Southwestern-Pacific	0.1377	-	2.3145
Warm-Temperate-Northeast-Pacific	2.9346	-	-
Warm-Temperate-Northwest-Atlantic	5.5226	-	-
Warm-Temperate-Northwest-Pacific	2.0284	-	-
Warm-Temperate-Southeastern-Pacific	2.7961	-	-
Warm-Temperate-Southwestern-Atlantic	7.5343	-	0.3290
West-African-Transition	4.6781	2.0933	1.0202
West-and-South-Indian-Shelf	3.9708	1.7510	-
West-Central-Australian-Shelf	2.7616	0.4583	-
Western-Coral-Triangle	1.1030	1.3814	-
Western-Indian-Ocean	1.5577	1.7909	2.1956

Table 25: Percentile 99th values calculated for the coastal Marine Ecoregions of the World (MEOW) provinces based on a subset of data from the Gregg and Conkright (2001) (only data in July-September and data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.

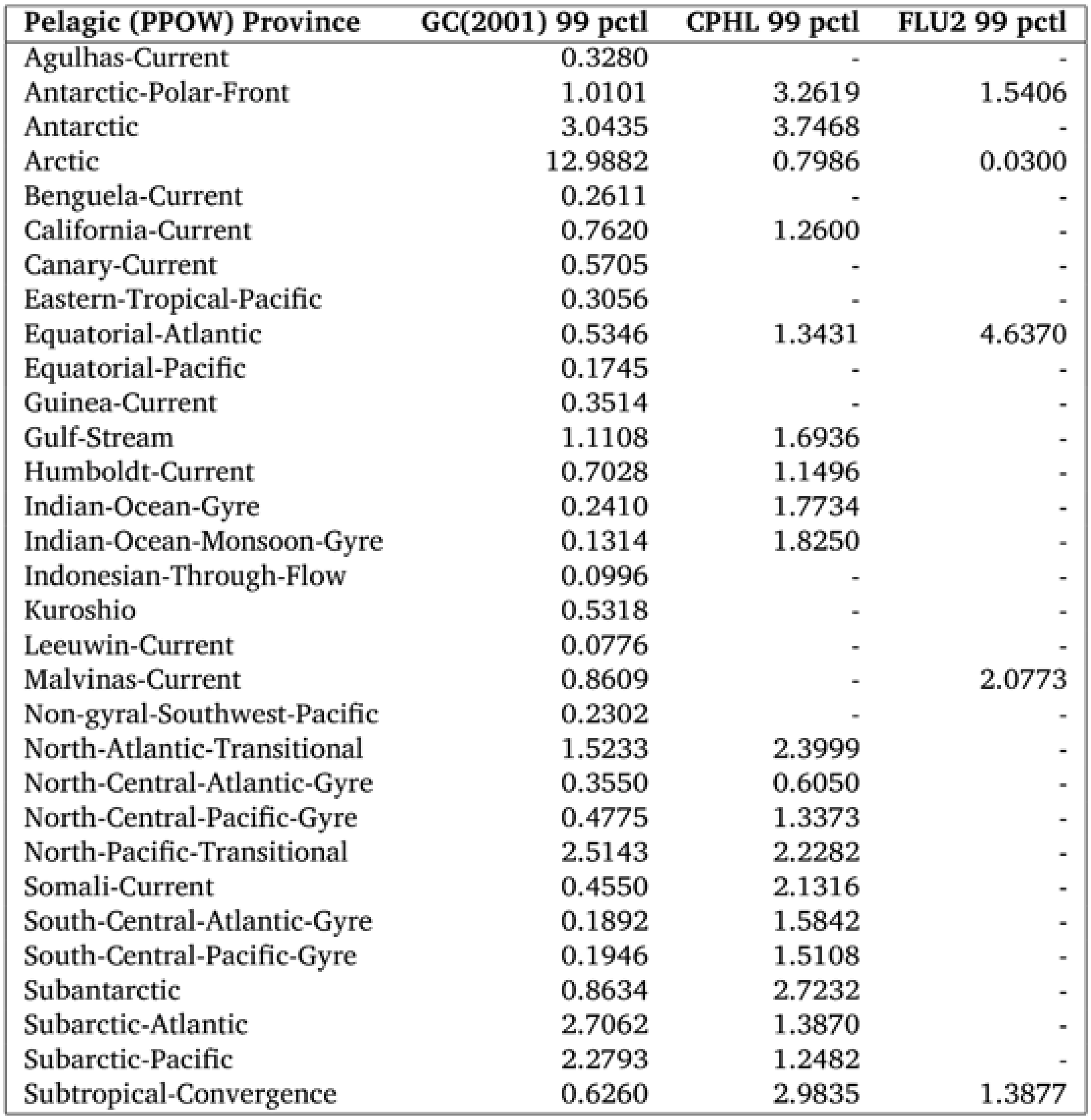
Coastal (MEOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas	0.9093	1.6498	-
Amsterdam-St-Paul	0.3132	-	-
Andaman	1.3441	1.3647	-
Arctic	10.2150	4.9220	13.7498
Bay-of-Bengal	2.8897	1.3350	-
Benguela	2.9794	-	-
Black-Sea	3.5158	1.4616	8.3386
Central-Indian-Ocean-Islands	0.2325	1.3686	-
Central-Polynesia	0.1167	-	0.5912
Cold-Temperate-Northeast-Pacific	5.2207	2.1989	1.5643
Cold-Temperate-Northwest-Atlantic	4.1702	2.7100	6.3004
Cold-Temperate-Northwest-Pacific	8.2274	-	-
Continental-High-Antarctic	12.2017	2.6681	-
East-Central-Australian-Shelf	0.2080	1.3413	-
Easter-Island	0.0763	-	-
Eastern-Coral-Triangle	0.1973	-	-
Galapagos	0.5530	-	-
Gulf-of-Guinea	4.7093	1.4762	0.7535
Hawaii	0.0963	-	-
Java-Transitional	0.2177	-	-
Juan-Fernandez-and-Desventuradas	0.1752	-	-
Lord-Howe-and-Norfolk-Islands	0.1112	1.5040	-
Lusitanian	2.6440	0.8905	19.5453
Magellanic	2.8044	0.6278	-
Marquesas	0.1646	-	-
Marshall,-Gilbert-and-Ellis-Islands	0.1935	-	0.5063
Mediterranean-Sea	1.0753	1.3392	1.4077
North-Brazil-Shelf	9.7107	2.4967	-
Northeast-Australian-Shelf	0.9175	-	-
Northern-European-Seas	6.9410	1.8792	11.1850
Northern-New-Zealand	0.2358	-	-
Northwest-Australian-Shelf	0.7644	-	-
Red-Sea-and-Gulf-of-Aden	2.4038	0.7592	-
Sahul-Shelf	2.0512	-	-
Scotia-Sea	9.9125	-	-
Somali-Arabian	2.8749	-	-
South-China-Sea	1.4586	-	-
Southeast-Australian-Shelf	0.7320	2.7582	-
Southeast-Polynesia	0.1034	0.1898	-
Southern-New-Zealand	0.7676	-	-
South-Kuroshio	0.2657	-	-
Southwest-Australian-Shelf	0.6672	1.5841	-
St.-Helena-and-Ascension-Islands	0.1096	-	-
Subantarctic-Islands	0.9069	5.1552	2.7413
Subantarctic-New-Zealand	0.3111	0.7920	-
Sunda-Shelf	3.2496	-	-
Tristan-Gough	0.3426	0.5520	-
Tropical-East-Pacific	1.4116	-	5.2388
Tropical-Northwestern-Atlantic	3.8215	-	-
Tropical-Northwestern-Pacific	0.3670	-	0.5252
Tropical-Southwestern-Atlantic	0.2725	2.1160	0.9350
Tropical-Southwestern-Pacific	0.0992	-	1.6405
Warm-Temperate-Northeast-Pacific	2.9575	-	-
Warm-Temperate-Northwest-Atlantic	5.7397	-	-
Warm-Temperate-Northwest-Pacific	1.5956	-	-
Warm-Temperate-Southeastern-Pacific	4.6631	3.6218	7.0878
Warm-Temperate-Southwestern-Atlantic	5.3018	-	-
West-African-Transition	4.4487	1.6920	-
West-and-South-Indian-Shelf	5.9688	1.8647	-
West-Central-Australian-Shelf	0.7671	-	-
Western-Coral-Triangle	0.8602	1.4685	-
Western-Indian-Ocean	0.8390	0.9301	2.4357

Table 26: Percentile 99th values calculated for the coastal Marine Ecoregions of the World (MEOW) provinces based on a subset of data from the Gregg and Conkright (2001) (only data in October-December and data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.



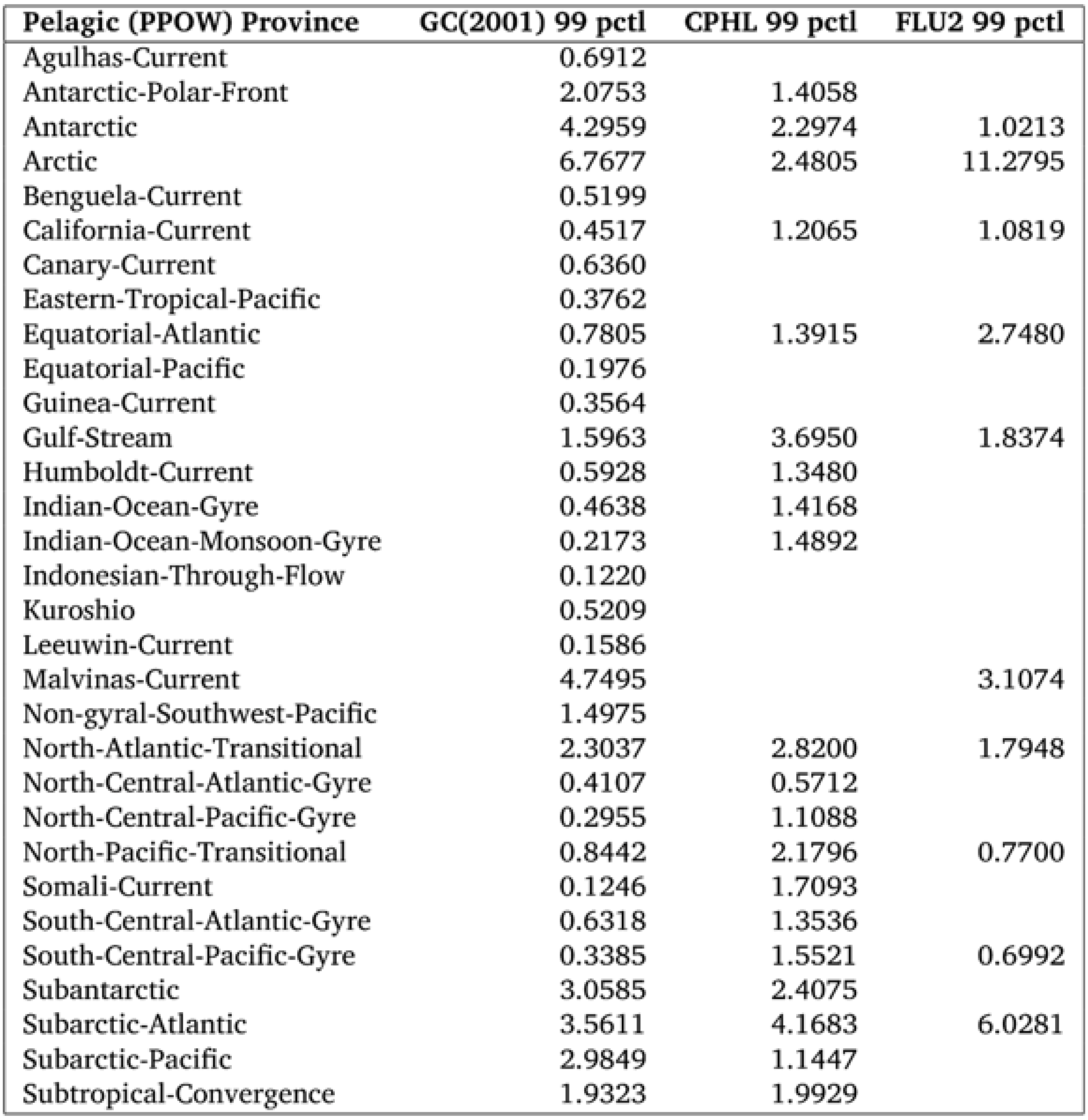
Coastal (MEOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas	0.9093	1.6498	-
Amsterdam-St-Paul	0.3132	-	-
Andaman	1.3441	1.3647	-
Arctic	10.2150	4.9220	13.7498
Bay-of-Bengal	2.8897	1.3350	-
Benguela	2.9794	-	-
Black-Sea	3.5158	1.4616	8.3386
Central-Indian-Ocean-Islands	0.2325	1.3686	-
Central-Polynesia	0.1167	-	0.5912
Cold-Temperate-Northeast-Pacific	5.2207	2.1989	1.5643
Cold-Temperate-Northwest-Atlantic	4.1702	2.7100	6.3004
Cold-Temperate-Northwest-Pacific	8.2274	-	-
Continental-High-Antarctic	12.2017	2.6681	-
East-Central-Australian-Shelf	0.2080	1.3413	-
Easter-Island	0.0763	-	-
Eastern-Coral-Triangle	0.1973	-	-
Galapagos	0.5530	-	-
Gulf-of-Guinea	4.7093	1.4762	0.7535
Hawaii	0.0963	-	-
Java-Transitional	0.2177	-	-
Juan-Fernandez-and-Desventuradas	0.1752	-	-
Lord-Howe-and-Norfolk-Islands	0.1112	1.5040	-
Lusitanian	2.6440	0.8905	19.5453
Magellanic	2.8044	0.6278	-
Marquesas	0.1646	-	-
Marshall,-Gilbert-and-Ellis-Islands	0.1935	-	0.5063
Mediterranean-Sea	1.0753	1.3392	1.4077
North-Brazil-Shelf	9.7107	2.4967	-
Northeast-Australian-Shelf	0.9175	-	-
Northern-European-Seas	6.9410	1.8792	11.1850
Northern-New-Zealand	0.2358	-	-
Northwest-Australian-Shelf	0.7644	-	-
Red-Sea-and-Gulf-of-Aden	2.4038	0.7592	-
Sahul-Shelf	2.0512	-	-
Scotia-Sea	9.9125	-	-
Somali-Arabian	2.8749	-	-
South-China-Sea	1.4586	-	-
Southeast-Australian-Shelf	0.7320	2.7582	-
Southeast-Polynesia	0.1034	0.1898	-
Southern-New-Zealand	0.7676	-	-
South-Kuroshio	0.2657	-	-
Southwest-Australian-Shelf	0.6672	1.5841	-
St.-Helena-and-Ascension-Islands	0.1096	-	-
Subantarctic-Islands	0.9069	5.1552	2.7413
Subantarctic-New-Zealand	0.3111	0.7920	-
Sunda-Shelf	3.2496	-	-
Tristan-Gough	0.3426	0.5520	-
Tropical-East-Pacific	1.4116	-	5.2388
Tropical-Northwestern-Atlantic	3.8215	-	-
Tropical-Northwestern-Pacific	0.3670	-	0.5252
Tropical-Southwestern-Atlantic	0.2725	2.1160	0.9350
Tropical-Southwestern-Pacific	0.0992	-	1.6405
Warm-Temperate-Northeast-Pacific	2.9575	-	-
Warm-Temperate-Northwest-Atlantic	5.7397	-	-
Warm-Temperate-Northwest-Pacific	1.5956	-	-
Warm-Temperate-Southeastern-Pacific	4.6631	3.6218	7.0878
Warm-Temperate-Southwestern-Atlantic	5.3018	-	-
West-African-Transition	4.4487	1.6920	-
West-and-South-Indian-Shelf	5.9688	1.8647	-
West-Central-Australian-Shelf	0.7671	-	-
Western-Coral-Triangle	0.8602	1.4685	-
Western-Indian-Ocean	0.8390	0.9301	2.4357

Table 27: Percentile 99th values calculated for the Pelagic Provinces of the World (PPOW) provinces based on a subset of data from the Gregg and Conkright (2001) (only data in January-March and data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.



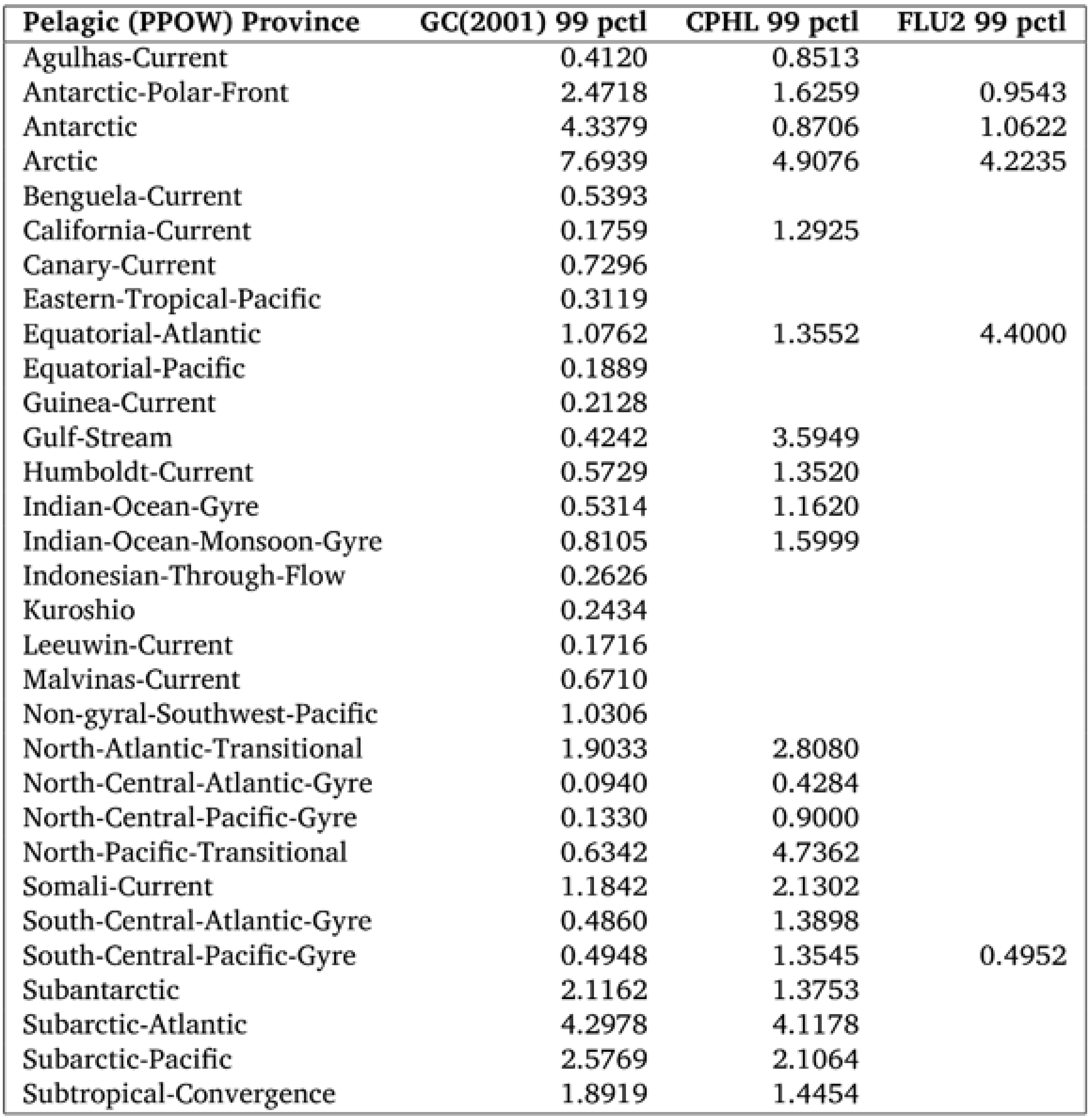
Pelagic (PPOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas-Current	0.3280	-	-
Antarctic-Polar-Front	1.0101	3.2619	1.5406
Antarctic	3.0435	3.7468	-
Arctic	12.9882	0.7986	0.0300
Benguela-Current	0.2611	-	-
California-Current	0.7620	1.2600	-
Canary-Current	0.5705	-	-
Eastern-Tropical-Pacific	0.3056	-	-
Equatorial-Atlantic	0.5346	1.3431	4.6370
Equatorial-Pacific	0.1745	-	-
Guinea-Current	0.3514	-	-
Gulf-Stream	1.1108	1.6936	-
Humboldt-Current	0.7028	1.1496	-
Indian-Ocean-Gyre	0.2410	1.7734	-
Indian-Ocean-Monsoon-Gyre	0.1314	1.8250	-
Indonesian-Through-Flow	0.0996	-	-
Kuroshio	0.5318	-	-
Leeuwin-Current	0.0776	-	-
Malvinas-Current	0.8609	-	2.0773
Non-gyral-Southwest-Pacific	0.2302	-	-
North-Atlantic-Transitional	1.5233	2.3999	-
North-Central-Atlantic-Gyre	0.3550	0.6050	-
North-Central-Pacific-Gyre	0.4775	1.3373	-
North-Pacific-Transitional	2.5143	2.2282	-
Somali-Current	0.4550	2.1316	-
South-Central-Atlantic-Gyre	0.1892	1.5842	-
South-Central-Pacific-Gyre	0.1946	1.5108	-
Subantarctic	0.8634	2.7232	-
Subarctic-Atlantic	2.7062	1.3870	-
Subarctic-Pacific	2.2793	1.2482	-
Subtropical-Convergence	0.6260	2.9835	1.3877

Table 28: Percentile 99th values calculated for the Pelagic Provinces of the World (PPOW) provinces based on a subset of data from the Gregg and Conkright (2001) (only data in April-June and data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.



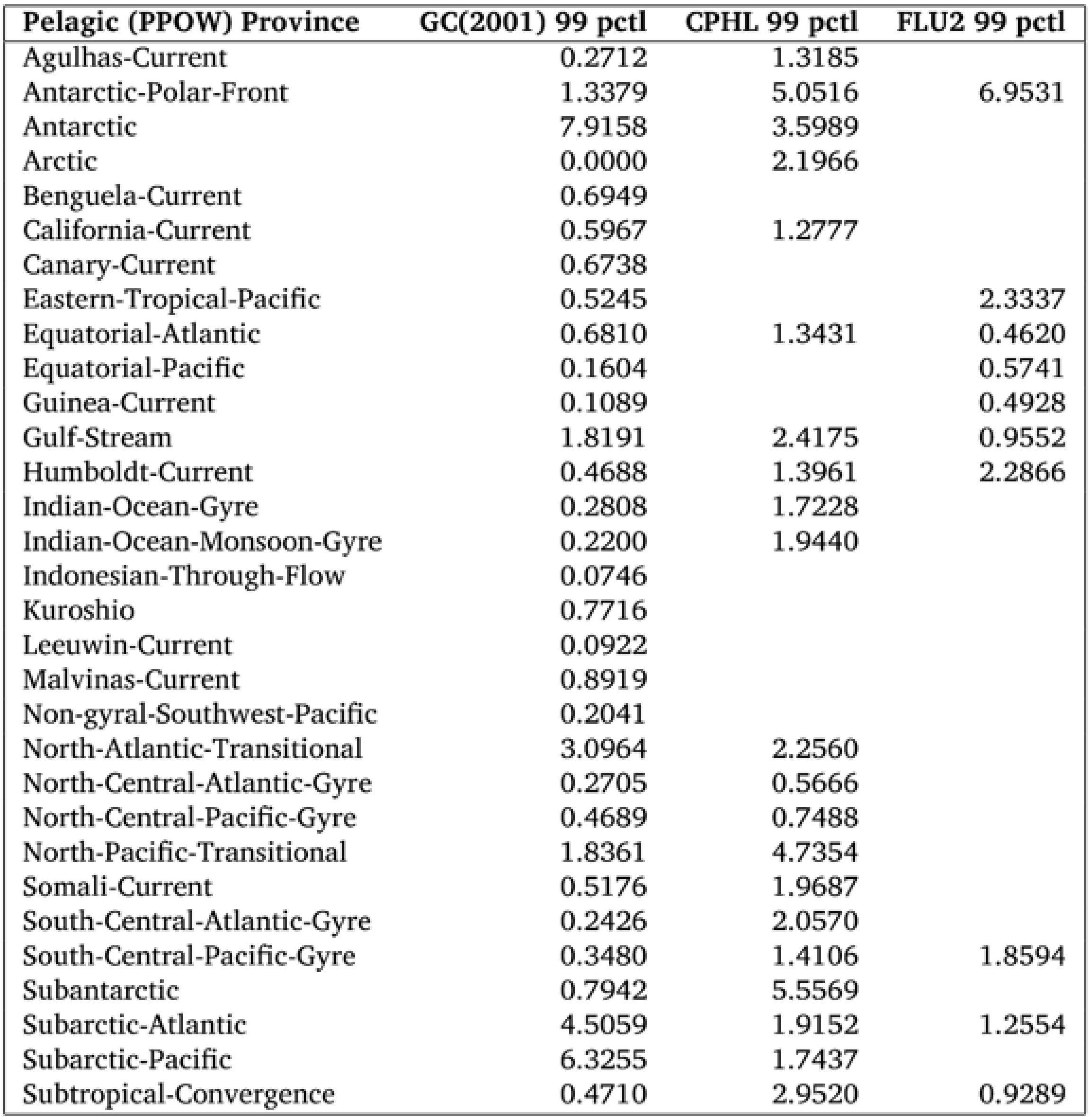
Pelagic (PPOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas-Current	0.6912		
Antarctic-Polar-Front	2.0753	1.4058	
Antarctic	4.2959	2.2974	1.0213
Arctic	6.7677	2.4805	11.2795
Benguela-Current	0.5199		
California-Current	0.4517	1.2065	1.0819
Canary-Current	0.6360		
Eastern-Tropical-Pacific	0.3762		
Equatorial-Atlantic	0.7805	1.3915	2.7480
Equatorial-Pacific	0.1976		
Guinea-Current	0.3564		
Gulf-Stream	1.5963	3.6950	1.8374
Humboldt-Current	0.5928	1.3480	
Indian-Ocean-Gyre	0.4638	1.4168	
Indian-Ocean-Monsoon-Gyre	0.2173	1.4892	
Indonesian-Through-Flow	0.1220		
Kuroshio	0.5209		
Leeuwin-Current	0.1586		
Malvinas-Current	4.7495		3.1074
Non-gyral-Southwest-Pacific	1.4975		
North-Atlantic-Transitional	2.3037	2.8200	1.7948
North-Central-Atlantic-Gyre	0.4107	0.5712	
North-Central-Pacific-Gyre	0.2955	1.1088	
North-Pacific-Transitional	0.8442	2.1796	0.7700
Somali-Current	0.1246	1.7093	
South-Central-Atlantic-Gyre	0.6318	1.3536	
South-Central-Pacific-Gyre	0.3385	1.5521	0.6992
Subantarctic	3.0585	2.4075	
Subarctic-Atlantic	3.5611	4.1683	6.0281
Subarctic-Pacific	2.9849	1.1447	
Subtropical-Convergence	1.9323	1.9929	

Table 29 : Percentile 99th values calculated for the Pelagic Provinces of the World (PPOW) provinces based on a subset of data from the Gregg and Conkright (2001) (only data in July-September and data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.



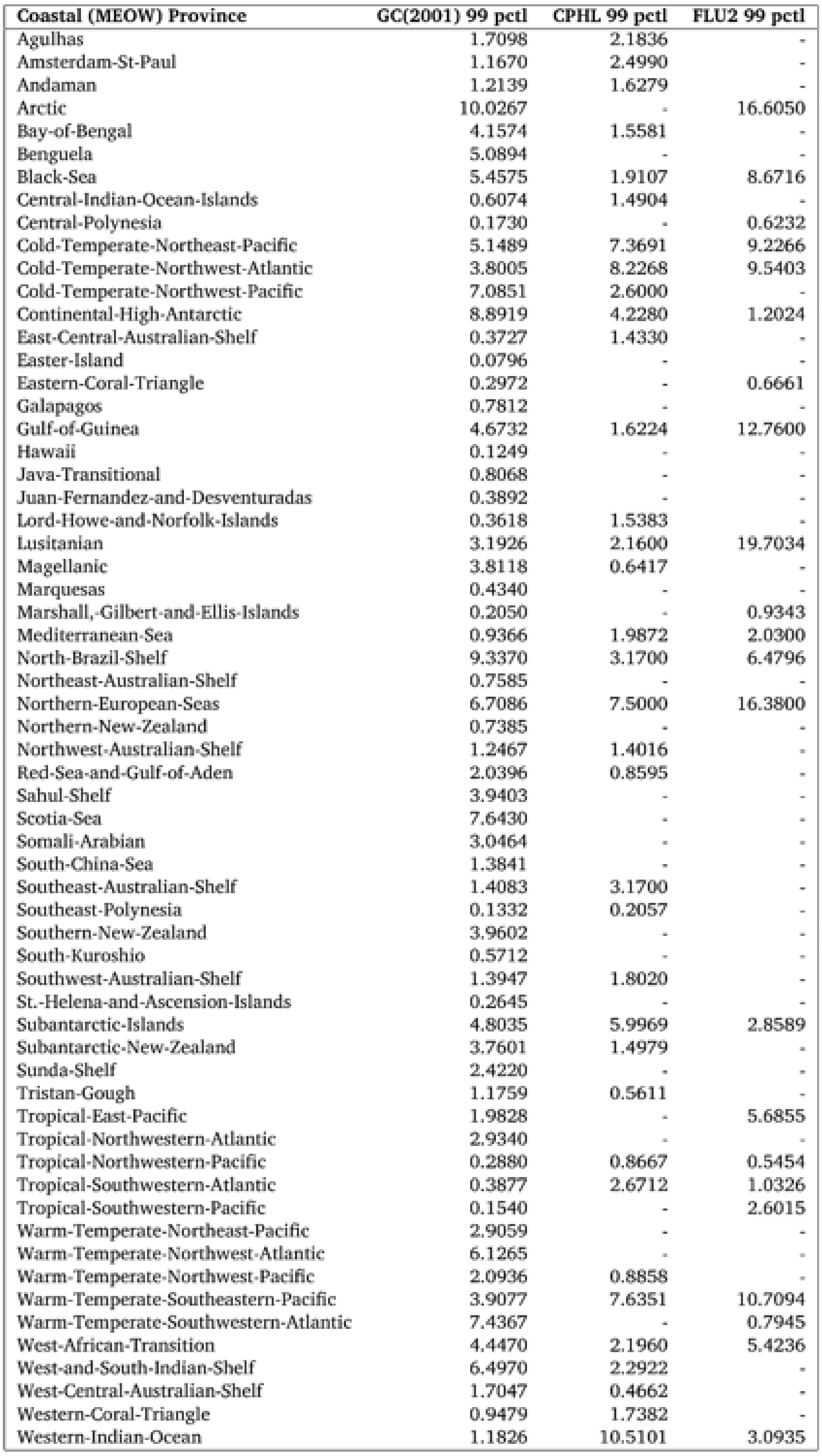
Pelagic (PPOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas-Current	0.4120	0.8513	
Antarctic-Polar-Front	2.4718	1.6259	0.9543
Antarctic	4.3379	0.8706	1.0622
Arctic	7.6939	4.9076	4.2235
Benguela-Current	0.5393		
California-Current	0.1759	1.2925	
Canary-Current	0.7296		
Eastern-Tropical-Pacific	0.3119		
Equatorial-Atlantic	1.0762	1.3552	4.4000
Equatorial-Pacific	0.1889		
Guinea-Current	0.2128		
Gulf-Stream	0.4242	3.5949	
Humboldt-Current	0.5729	1.3520	
Indian-Ocean-Gyre	0.5314	1.1620	
Indian-Ocean-Monsoon-Gyre	0.8105	1.5999	
Indonesian-Through-Flow	0.2626		
Kuroshio	0.2434		
Leeuwin-Current	0.1716		
Malvinas-Current	0.6710		
Non-gyral-Southwest-Pacific	1.0306		
North-Atlantic-Transitional	1.9033	2.8080	
North-Central-Atlantic-Gyre	0.0940	0.4284	
North-Central-Pacific-Gyre	0.1330	0.9000	
North-Pacific-Transitional	0.6342	4.7362	
Somali-Current	1.1842	2.1302	
South-Central-Atlantic-Gyre	0.4860	1.3898	
South-Central-Pacific-Gyre	0.4948	1.3545	0.4952
Subantarctic	2.1162	1.3753	
Subarctic-Atlantic	4.2978	4.1178	
Subarctic-Pacific	2.5769	2.1064	
Subtropical-Convergence	1.8919	1.4454	

Table 30: Percentile 99th values calculated for the Pelagic Provinces of the World (PPOW) provinces based on a subset of data from the Gregg and Conkright (2001) (only data in October-December and data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.



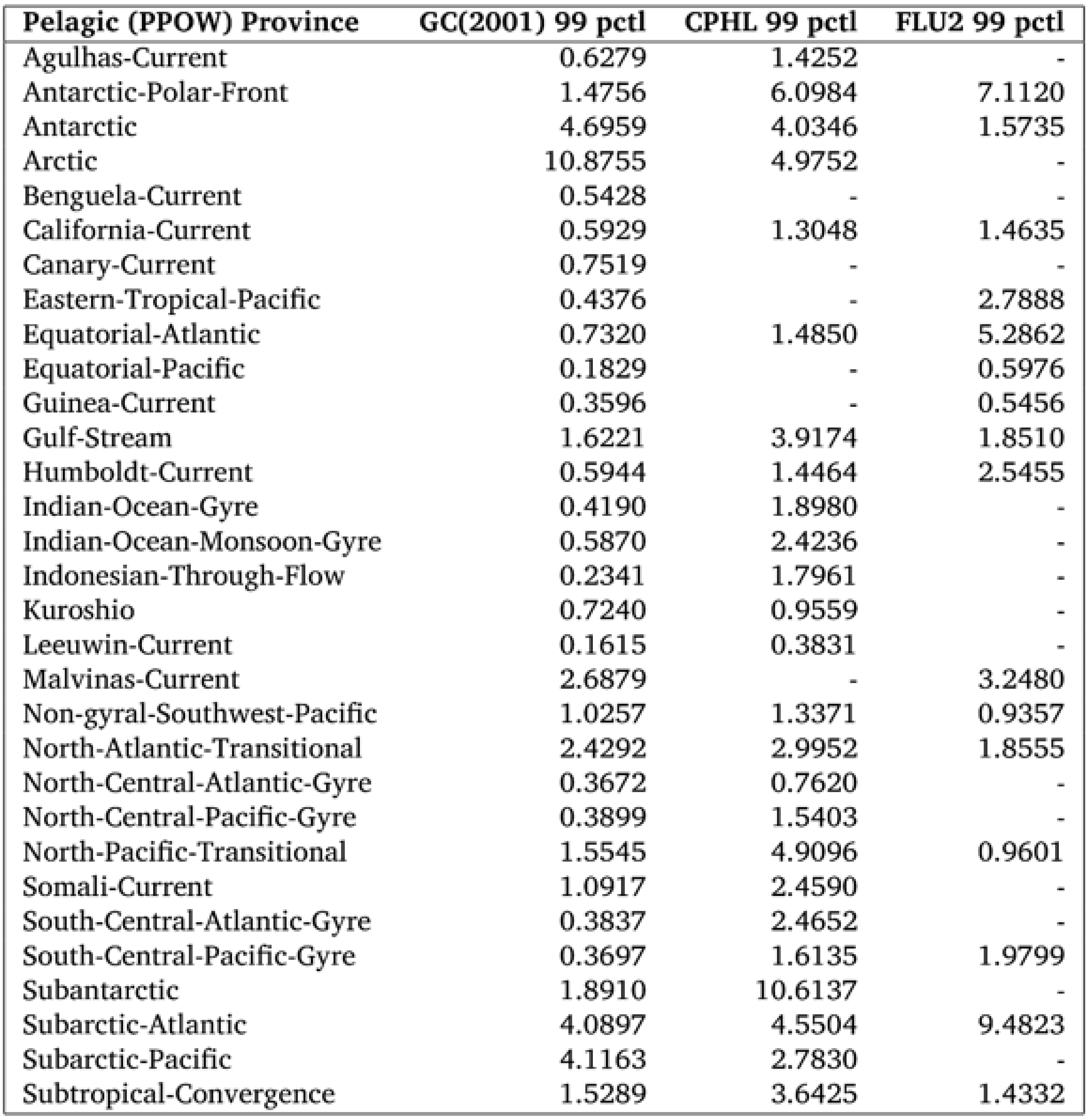
Pelagic (PPOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas-Current	0.2712	1.3185	
Antarctic-Polar-Front	1.3379	5.0516	6.9531
Antarctic	7.9158	3.5989	
Arctic	0.0000	2.1966	
Benguela-Current	0.6949		
California-Current	0.5967	1.2777	
Canary-Current	0.6738		
Eastern-Tropical-Pacific	0.5245		2.3337
Equatorial-Atlantic	0.6810	1.3431	0.4620
Equatorial-Pacific	0.1604		0.5741
Guinea-Current	0.1089		0.4928
Gulf-Stream	1.8191	2.4175	0.9552
Humboldt-Current	0.4688	1.3961	2.2866
Indian-Ocean-Gyre	0.2808	1.7228	
Indian-Ocean-Monsoon-Gyre	0.2200	1.9440	
Indonesian-Through-Flow	0.0746		
Kuroshio	0.7716		
Leeuwin-Current	0.0922		
Malvinas-Current	0.8919		
Non-gyral-Southwest-Pacific	0.2041		
North-Atlantic-Transitional	3.0964	2.2560	
North-Central-Atlantic-Gyre	0.2705	0.5666	
North-Central-Pacific-Gyre	0.4689	0.7488	
North-Pacific-Transitional	1.8361	4.7354	
Somali-Current	0.5176	1.9687	
South-Central-Atlantic-Gyre	0.2426	2.0570	
South-Central-Pacific-Gyre	0.3480	1.4106	1.8594
Subantarctic	0.7942	5.5569	
Subarctic-Atlantic	4.5059	1.9152	1.2554
Subarctic-Pacific	6.3255	1.7437	
Subtropical-Convergence	0.4710	2.9520	0.9289

Table 31: Percentile 99th values calculated for the coastal Marine Ecoregions of the World (MEOW) provinces based on a subset of data from the Gregg and Conkright (2001) (data in January-December and only data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.



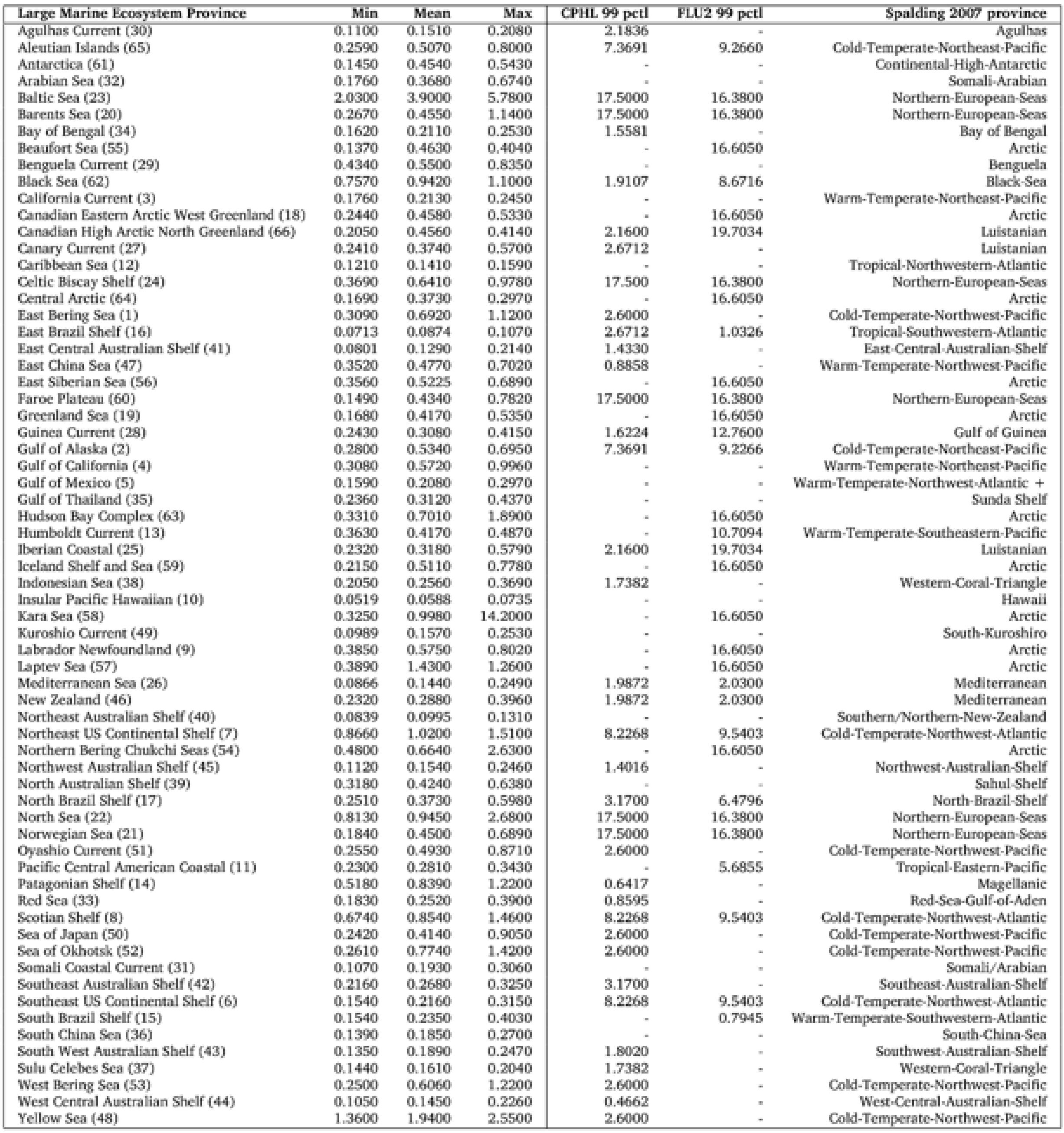
Coastal (MEOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas	1.7098	2.1836	-
Amsterdam-St-Paul	1.1670	2.4990	-
Andaman	1.2139	1.6279	-
Arctic	10.0267	-	16.6050
Bay-of-Bengal	4.1574	1.5581	-
Benguela	5.0894	-	-
Black-Sea	5.4575	1.9107	8.6716
Central-Indian-Ocean-Islands	0.6074	1.4904	-
Central-Polynesia	0.1730	-	0.6232
Cold-Temperate-Northeast-Pacific	5.1489	7.3691	9.2266
Cold-Temperate-Northwest-Atlantic	3.8005	8.2268	9.5403
Cold-Temperate-Northwest-Pacific	7.0851	2.6000	-
Continental-High-Antarctic	8.8919	4.2280	1.2024
East-Central-Australian-Shelf	0.3727	1.4330	-
Easter-Island	0.0796	-	-
Eastern-Coral-Triangle	0.2972	-	0.6661
Galapagos	0.7812	-	-
Gulf-of-Guinea	4.6732	1.6224	12.7600
Hawaii	0.1249	-	-
Java-Transitional	0.8068	-	-
Juan-Fernandez-and-Desventuradas	0.3892	-	-
Lord-Howe-and-Norfolk-Islands	0.3618	1.5383	-
Lusitanian	3.1926	2.1600	19.7034
Magellanic	3.8118	0.6417	-
Marquesas	0.4340	-	-
Marshall,-Gilbert-and-Ellis-Islands	0.2050	-	0.9343
Mediterranean-Sea	0.9366	1.9872	2.0300
North-Brazil-Shelf	9.3370	3.1700	6.4796
Northeast-Australian-Shelf	0.7585	-	-
Northern-European-Seas	6.7086	7.5000	16.3800
Northern-New-Zealand	0.7385	-	-
Northwest-Australian-Shelf	1.2467	1.4016	-
Red-Sea-and-Gulf-of-Aden	2.0396	0.8595	-
Sahul-Shelf	3.9403	-	-
Scotia-Sea	7.6430	-	-
Somali-Arabian	3.0464	-	-
South-China-Sea	1.3841	-	-
Southeast-Australian-Shelf	1.4083	3.1700	-
Southeast-Polynesia	0.1332	0.2057	-
Southern-New-Zealand	3.9602	-	-
South-Kuroshio	0.5712	-	-
Southwest-Australian-Shelf	1.3947	1.8020	-
St.-Helena-and-Ascension-Islands	0.2645	-	-
Subantarctic-Islands	4.8035	5.9969	2.8589
Subantarctic-New-Zealand	3.7601	1.4979	-
Sunda-Shelf	2.4220	-	-
Tristan-Gough	1.1759	0.5611	-
Tropical-East-Pacific	1.9828	-	5.6855
Tropical-Northwestern-Atlantic	2.9340	-	-
Tropical-Northwestern-Pacific	0.2880	0.8667	0.5454
Tropical-Southwestern-Atlantic	0.3877	2.6712	1.0326
Tropical-Southwestern-Pacific	0.1540	-	2.6015
Warm-Temperate-Northeast-Pacific	2.9059	-	-
Warm-Temperate-Northwest-Atlantic	6.1265	-	-
Warm-Temperate-Northwest-Pacific	2.0936	0.8858	-
Warm-Temperate-Southeastern-Pacific	3.9077	7.6351	10.7094
Warm-Temperate-Southwestern-Atlantic	7.4367	-	0.7945
West-African-Transition	4.4470	2.1960	5.4236
West-and-South-Indian-Shelf	6.4970	2.2922	-
West-Central-Australian-Shelf	1.7047	0.4662	-
Western-Coral-Triangle	0.9479	1.7382	-
Western-Indian-Ocean	1.1826	10.5101	3.0935

Table 32: Percentile 99th values calculated for the pelagic (PPOW) provinces based on a subset of data from the Gregg and Conkright (2001) (data in January-December and only data classified as QC level 0,1 and 2) for CPHL and FLU2 along the 0-100 m depth range.



Pelagic (PPOW) Province	GC(2001) 99 pctl	CPHL 99 pctl	FLU2 99 pctl
Agulhas-Current	0.6279	1.4252	-
Antarctic-Polar-Front	1.4756	6.0984	7.1120
Antarctic	4.6959	4.0346	1.5735
Arctic	10.8755	4.9752	-
Benguela-Current	0.5428	-	-
California-Current	0.5929	1.3048	1.4635
Canary-Current	0.7519	-	-
Eastern-Tropical-Pacific	0.4376	-	2.7888
Equatorial-Atlantic	0.7320	1.4850	5.2862
Equatorial-Pacific	0.1829	-	0.5976
Guinea-Current	0.3596	-	0.5456
Gulf-Stream	1.6221	3.9174	1.8510
Humboldt-Current	0.5944	1.4464	2.5455
Indian-Ocean-Gyre	0.4190	1.8980	-
Indian-Ocean-Monsoon-Gyre	0.5870	2.4236	-
Indonesian-Through-Flow	0.2341	1.7961	-
Kuroshio	0.7240	0.9559	-
Leeuwin-Current	0.1615	0.3831	-
Malvinas-Current	2.6879	-	3.2480
Non-gyral-Southwest-Pacific	1.0257	1.3371	0.9357
North-Atlantic-Transitional	2.4292	2.9952	1.8555
North-Central-Atlantic-Gyre	0.3672	0.7620	-
North-Central-Pacific-Gyre	0.3899	1.5403	-
North-Pacific-Transitional	1.5545	4.9096	0.9601
Somali-Current	1.0917	2.4590	-
South-Central-Atlantic-Gyre	0.3837	2.4652	-
South-Central-Pacific-Gyre	0.3697	1.6135	1.9799
Subantarctic	1.8910	10.6137	-
Subarctic-Atlantic	4.0897	4.5504	9.4823
Subarctic-Pacific	4.1163	2.7830	-
Subtropical-Convergence	1.5289	3.6425	1.4332

Table 33: Annual minimum, mean, and maximum chlorophyll concentrations (mg m-3) in the Large Marine Ecosystem provinces (LME) delimited by Sherman et al. (2005) as calculated by O´Reilly (2017). The mean value for the East Siberian Sea has been changed to 0.1280, see text for details. LME provided in brackets. Also displayed percentile 99th values for the 0-100 m CPHL and FLU2 data (where available) calculated in the present validation. To the far right the closest corresponding province from the Spalding et al. (2007) classification to that of the LME classification is listed



Large Marine Ecosystem Province	Min	Mean	Max	CPHL 99 pctl	FLU2 99 pctl	Spalding 2007 province
Agulhas Current (30)	0.1100	0.1510	0.2080	2.1836	-	Agulhas
Aleutian Islands (65)	0.2590	0.5070	0.8000	7.3691	9.2660	Cold-Temperate-Northeast-Pacific
Antarctica (61)	0.1450	0.4540	0.5430	-	-	Continental-High-Antarctic
Arabian Sea (32)	0.1760	0.3680	0.6740	-	-	Somali-Arabian
Baltic Sea (23)	2.0300	3.9000	5.7800	17.5000	16.3800	Northern-European-Seas
Barents Sea (20)	0.2670	0.4550	1.1400	17.5000	16.3800	Northern-European-Seas
Bay of Bengal (34)	0.1620	0.2110	0.2530	1.5581	-	Bay of Bengal
Beaufort Sea (55)	0.1370	0.4630	0.4040	-	16.6050	Arctic
Benguela Current (29)	0.4340	0.5500	0.8350	-	-	Benguela
Black Sea (62)	0.7570	0.9420	1.1000	1.9107	8.6716	Black-Sea
California Current (3)	0.1760	0.2130	0.2450	-	-	Warm-Temperate-Northeast-Pacific
Canadian Eastern Arctic West Greenland (18)	0.2440	0.4580	0.5330	-	16.6050	Arctic
Canadian High Arctic North Greenland (66)	0.2050	0.4560	0.4140	2.1600	19.7034	Luistanian
Canary Current (27)	0.2410	0.3740	0.5700	2.6712	-	Luistanian
Caribbean Sea (12)	0.1210	0.1410	0.1590	-	-	Tropical-Northwestern-Atlantic
Celtic Biscay Shelf (24)	0.3690	0.6410	0.9780	17.500	16.3800	Northern-European-Seas
Central Arctic (64)	0.1690	0.3730	0.2970	-	16.6050	Arctic
East Bering Sea (1)	0.3090	0.6920	1.1200	2.6000	-	Cold-Temperate-Northwest-Pacific
East Brazil Shelf (16)	0.0713	0.0874	0.1070	2.6712	1.0326	Tropical-Southwestern-Atlantic
East Central Australian Shelf (41)	0.0801	0.1290	0.2140	1.4330	-	East-Central-Australian-Shelf
East China Sea (47)	0.3520	0.4770	0.7020	0.8858	-	Warm-Temperate-Northwest-Pacific
East Siberian Sea (56)	0.3560	0.5225	0.6890	-	16.6050	Arctic
Faroe Plateau (60)	0.1490	0.4340	0.7820	17.5000	16.3800	Northern-European-Seas
Greenland Sea (19)	0.1680	0.4170	0.5350	-	16.6050	Arctic
Guinea Current (28)	0.2430	0.3080	0.4150	1.6224	12.7600	Gulf of Guinea
Gulf of Alaska (2)	0.2800	0.5340	0.6950	7.3691	9.2266	Cold-Temperate-Northeast-Pacific
Gulf of California (4)	0.3080	0.5720	0.9960	-	-	Warm-Temperate-Northeast-Pacific
Gulf of Mexico (5)	0.1590	0.2080	0.2970	-	-	Warm-Temperate-Northwest-Atlantic +
Gulf of Thailand (35)	0.2360	0.3120	0.4370	-	-	Sunda Shelf
Hudson Bay Complex (63)	0.3310	0.7010	1.8900	-	16.6050	Arctic
Humboldt Current (13)	0.3630	0.4170	0.4870	-	10.7094	Warm-Temperate-Southeastern-Pacific
Iberian Coastal (25)	0.2320	0.3180	0.5790	2.1600	19.7034	Luistanian
Iceland Shelf and Sea (59)	0.2150	0.5110	0.7780	-	16.6050	Arctic
Indonesian Sea (38)	0.2050	0.2560	0.3690	1.7382	-	Western-Coral-Triangle
Insular Pacific Hawaiian (10)	0.0519	0.0588	0.0735	-	-	Hawaii
Kara Sea (58)	0.3250	0.9980	14.2000	-	16.6050	Arctic
Kuroshio Current (49)	0.0989	0.1570	0.2530	-	-	South-Kuroshiro
Labrador Newfoundland (9)	0.3850	0.5750	0.8020	-	16.6050	Arctic
Laptev Sea (57)	0.3890	1.4300	1.2600	-	16.6050	Arctic
Mediterranean Sea (26)	0.0866	0.1440	0.2490	1.9872	2.0300	Mediterranean
New Zealand (46)	0.2320	0.2880	0.3960	1.9872	2.0300	Mediterranean
Northeast Australian Shelf (40)	0.0839	0.0995	0.1310	-	-	Southern/Northern-New-Zealand
Northeast US Continental Shelf (7)	0.8660	1.0200	1.5100	8.2268	9.5403	Cold-Temperate-Northwest-Atlantic
Northern Bering Chukchi Seas (54)	0.4800	0.6640	2.6300	-	16.6050	Arctic
Northwest Australian Shelf (45)	0.1120	0.1540	0.2460	1.4016	-	Northwest-Australian-Shelf
North Australian Shelf (39)	0.3180	0.4240	0.6380	-	-	Sahul-Shelf
North Brazil Shelf (17)	0.2510	0.3730	0.5980	3.1700	6.4796	North-Brazil-Shelf
North Sea (22)	0.8130	0.9450	2.6800	17.5000	16.3800	Northern-European-Seas
Norwegian Sea (21)	0.1840	0.4500	0.6890	17.5000	16.3800	Northern-European-Seas
Oyashio Current (51)	0.2550	0.4930	0.8710	2.6000	-	Cold-Temperate-Northwest-Pacific
Pacific Central American Coastal (11)	0.2300	0.2810	0.3430	-	5.6855	Tropical-Eastern-Pacific
Patagonian Shelf (14)	0.5180	0.8390	1.2200	0.6417	-	Magellanic
Red Sea (33)	0.1830	0.2520	0.3900	0.8595	-	Red-Sea-Gulf-of-Aden
Scotian Shelf (8)	0.6740	0.8540	1.4600	8.2268	9.5403	Cold-Temperate-Northwest-Atlantic
Sea of Japan (50)	0.2420	0.4140	0.9050	2.6000	-	Cold-Temperate-Northwest-Pacific
Sea of Okhotsk (52)	0.2610	0.7740	1.4200	2.6000	-	Cold-Temperate-Northwest-Pacific
Somali Coastal Current (31)	0.1070	0.1930	0.3060	-	-	Somali/Arabian
Southeast Australian Shelf (42)	0.2160	0.2680	0.3250	3.1700	-	Southeast-Australian-Shelf
Southeast US Continental Shelf (6)	0.1540	0.2160	0.3150	8.2268	9.5403	Cold-Temperate-Northwest-Atlantic
South Brazil Shelf (15)	0.1540	0.2350	0.4030	-	0.7945	Warm-Temperate-Southwestern-Atlantic
South China Sea (36)	0.1390	0.1850	0.2700	-	-	South-China-Sea
South West Australian Shelf (43)	0.1350	0.1890	0.2470	1.8020	-	Southwest-Australian-Shelf
Sulu Celebes Sea (37)	0.1440	0.1610	0.2040	1.7382	-	Western-Coral-Triangle
West Bering Sea (53)	0.2500	0.6060	1.2200	2.6000	-	Cold-Temperate-Northwest-Pacific
West Central Australian Shelf (44)	0.1050	0.1450	0.2260	0.4662	-	West-Central-Australian-Shelf
Yellow Sea (48)	1.3600	1.9400	2.5500	2.6000	-	Cold-Temperate-Northwest-Pacific

Table 34: Absolute area of each province (in km²), as well as relative area of the provinces (as percentage) in relation to the total global ocean surface.

Coastal Province	Area	%	Pelagic Province	Area	%
Agulhas	699434	0.19	Agulhas-Current	705593	0.19
Cold-Temperate-Northeast-Pacific	3107084	0.86	Antarctic	22469177	6.20
North-Brazil-Shelf	1000720	0.28	Antarctic-Polar-Front	12671074	3.50
Amsterdam-St-Paul	395362	0.11	Arctic	4565012	1.26
Continental-High-Antarctic	6701880	1.85	Benguela-Current	648637	0.18
Andaman	1788468	0.49	California-Current	370723	0.10
Scotia-Sea	1919718	0.53	Canary-Current	284440	0.08
Somali-Arabian	1478057	0.41	Eastern-Tropical-Pacific	7749595	2.14
Warm-Temperate-Southeastern-Pacific	1546864	0.43	Equatorial-Atlantic	11958202	3.30
Sahul-Shelf	1386348	0.38	Equatorial-Pacific	4367007	1.21
Subantarctic-New-Zealand	778105	0.21	Guinea-Current	9588	0.00
Lusitanian	2841249	0.78	Gulf-Stream	445235	0.12
Arctic	11884353	3.28	Humboldt-Current	1145719	0.32
Tropical-Northwestern-Atlantic	5760609	1.59	Indian-Ocean-Gyre	16335383	4.51
Northern-European-Seas	2952146	0.82	Indian-Ocean-Monsoon-Gyre	10518481	2.90
Western-Coral-Triangle	4786475	1.32	Indonesian-Through-Flow	506070	0.14
Southeast-Australian-Shelf	1012654	0.28	Kuroshio	52225	0.01
Eastern-Coral-Triangle	3251209	0.90	Leeuwin-Current	527122	0.15
Black-Sea	448644	0.12	Malvinas-Current	407812	0.11
Subantarctic-Islands	2053288	0.57	Non-gyral-Southwest-Pacific	1984748	0.55
West-African-Transition	1092499	0.30	North-Atlantic-Transitional	4730955	1.31
Western-Indian-Ocean	6001512	1.66	North-Central-Atlantic-Gyre	9850017	2.72
Warm-Temperate-Northwest-Atlantic	923243	0.25	North-Central-Pacific-Gyre	26099460	7.21
Warm-Temperate-Northwest-Pacific	1250734	0.35	North-Pacific-Transitional	7387276	2.04
Southern-New-Zealand	1438389	0.40	Somali-Current	864287	0.24
Central-Indian-Ocean-Islands	1931687	0.53	South-Central-Atlantic-Gyre	12567723	3.47
Magellanic	1873507	0.52	South-Central-Pacific-Gyre	25095919	6.93
Tropical-East-Pacific	3503880	0.97	Subantarctic	15404983	4.25
Java-Transitional	1427402	0.39	Subarctic-Atlantic	2552276	0.70
Tropical-Southwestern-Pacific	4919624	1.36	Subarctic-Pacific	4325905	1.19
Warm-Temperate-Northeast-Pacific	957090	0.26	Subtropical-Convergence	18663311	5.15
Tropical-Northwestern-Pacific	5320363	1.47			
Easter-Island	662129	0.18			
Tropical-Southwestern-Atlantic	2436016	0.67			
Galapagos	849153	0.23			
Bay-of-Bengal	911303	0.25			
Northwest-Australian-Shelf	738035	0.20			
Marshall-Gilbert-and-Ellis-Islands	4444671	1.23			
Southwest-Australian-Shelf	1032922	0.29			
Red-Sea-and-Gulf-of-Aden	1012899	0.28			
Gulf-of-Guinea	2359710	0.65			
Cold-Temperate-Northwest-Atlantic	1489746	0.41			
Sunda-Shelf	1986560	0.55			
South-China-Sea	1834493	0.51			
Hawaii	2649273	0.73			
West-Central-Australian-Shelf	370715	0.10			
Juan-Fernandez-and-Desventuradas	886732	0.24			
Cold-Temperate-Northwest-Pacific	4422132	1.22			
Northern-New-Zealand	1143820	0.32			
Central-Polynesia	4757581	1.31			
Lord-Howe-and-Norfolk-Islands	741400	0.20			
East-Central-Australian-Shelf	434251	0.12			
Southeast-Polynesia	5744699	1.59			
Benguela	823732	0.23			
Warm-Temperate-Southwestern-Atlantic	1017477	0.28			
West-and-South-Indian-Shelf	1284348	0.35			
South-Kuroshio	1011072	0.28			
St-Helena-and-Ascension-Islands	858375	0.24			
Tristan-Gough	961644	0.27			
Marquesas	738719	0.20			
Northeast-Australian-Shelf	388882	0.11			
Mediterranean-Sea	2493210	0.69			
TOTAL	136918297 km^2	37.8%		225263955 km^2	62.2%

VIII.2 Example of source code to convert pressure to depth

```
/* Example C code to convert pressure measurements in the ocean to
*  a depth measurement using the method of:
*
*  Fofonoff and Millard (1983) "Algorithms for the computation of
*  fundamental properties of seawater" UNESCO Technical Papers in
*  Marine Sciences 44.
*
*  A standard ocean of temperature  = 0, salinity = 35 is assumed.
*  pressure is in decibars, depth  is in metres, latitude is in decimal
*  degrees (converted to radians in program).
*
*  Check value = 9712.65 for lat = 30 and press = 10000
*/

#include <stdio.h>
#include <math.h>

float  p, z, g, lat;
float  c1=9.72659, c2=2.2512e-5, c3=2.279e-10, c4=1.82e-15;
int main()
{
printf("Enter latitude (decimal degrees\n");
scanf("%f", &lat);
printf("Enter pressure level in sea (decibars)\n");
scanf("%f", &p);

// Convert latitude to radians

lat=lat/57.29578;

// Correct the acceleration due to gravity for latitude

g=9.780318*(1.0+0.0052788*(pow(sin(lat),2.0))+0.0000236*(pow(sin(lat),4.0)));

// Calculate the depth (m)

z=(c1*p-c2*(pow(p,2.0))+c3*(pow(p,3.0))-c4*(pow(p,4.0)))/(g+p*1.092e-6);

printf("%10.8f %10.3f %5.0f\n",g,z,p);
}
```