Copernicus Marine Service

QUALITY INFORMATION DOCUMENT

IN SITU TAC

INSITU_GLO_BGC_DISCRETE_MY_013_046

Issue: 2.6

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Approval date by the Copernicus Marine Service product quality coordination team: 06/12/2023

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
1.0	17/04/2017	all	First draft version	P. Jaccard, D.Ø. Hjermann, J. Ruohola, S. Marty, T. Kristiansen, K. Sørensen, S. Kaitala, A. Mangin, S. Pouliquen	
	18/04/2018		Reviewed	S. Marty	
	20/04/2018		Reviewed	K. Sørensen	
1.1	31/01/2019	all	New Chl-*a* quality control procedure	Stuart Larsen, Terry Hannant, Vidar S. Lien	
1.1	31/01/2019	all	Reviewed	Henning Wehde	
1.1	02/04/2019	all	Reviewed	Isabel Garcia Hermosa	
1.1b	28/06/2019	all	Revised	Stuart Larsen, Vidar S. Lien	Mercator Ocean
1.2	05/09/2019	all	New O2 quality control procedure	Virginie Racape, Jan Even Øie Nilsen, Håvard Vindenes, Leonidas Perivoliotis, Margarita Bekiari, Eirini Varotsou, Seppo Kaitala, Stuart Larsen, Vidar S. Lien	
2.0	31/03/2020	all	Nutrients quality control procedure;	Håvard Vindenes, Jan Even Øie Nilsen, Kjell Gundersen, Leonidas Perivoliotis, Margarita Bekiari, Maria Sotiropoulou, Seppo Kaitala, Vidar S. Lien, Virginie Racape	

Issue	Date	§	Description of Change	Author	Validated By
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
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

TABLE OF CONTENTS

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 product INSITU_GLO_BGC_REP_OBSERVATIONS_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 the previous year are reprocessed.

This is the In Situ Thematic Assembly Centre (In Situ TAC) Re-Processed Bio-Geo-Chemical product (hereinafter BGC REP) that integrates observation 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) and EMODnet chemistry 2018 and JCOMM global systems (Argo, GOSUD, OceanSITES, GTSPP, DBCP) and the Global telecommunication system (GTS) used by the Met Offices. The BGC REP product integrates updated quality flags from the Near-Real Time (hereinafter NRT) product (INSITU_GLO_NRT_OBSERVATIONS_013_030) history directory files, 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_NRT_OBSERVATIONS_013_030), where the biogeochemical (chlorophyll, oxygen and nutrients (nitrate, phosphate, silicate)) parameters 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 the data of the original files in the dataset mentioned above. Files which do not contain suitable 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 below. These range from laboratory based high pressure liquid chromatography (HPLC) and spectrophotometry to automated fluorometric methods, with the latter becoming increasingly common with the increase in automated platforms. Chlorophyll concentrations are highly spatially variable, especially in coastal waters and upwelling regions where there are higher concentrations of nutrients. On a seasonal basis, they also tend to be higher in spring, again because of increased nutrient availability. As the distribution of nutrients within the ocean is patchy, so too is the chlorophyll concentration as micro-algae rapidly multiply in number to exploit any region with nutrients and light. This patchiness results in small areas with high chlorophyll concentrations, and larger regions with lower values. Sampling such a system typically results in a highly 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 for all data types are milligrams per cubic metre. CPHL data are laboratory analyses using HPLC and spectromophometry 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 earlier periods of the 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 by IMR, Ifremer, HCMR and SYKE. 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», or in µmol/l available in the sub-directory «Data_In_ micromolL», both available on the ftp server[1]. The reprocessed product including oxygen in the original units is available in the sub-directory «OriginalUnit», also on the ftp server.

For nutrients, parameters such as nitrate, provided as 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 by 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. See document CMEMS-INS-QUID-013_030 -036[2] for more information.

[1] ftp://nrt.cmems-du.eu

[2] https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-INS-QUID-013_030-036.pdf

Table 1 : Accuracy numbers for biogeochemical parameter observations for the different platforms. Data are obtained from the In Situ TAC.

Data 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: TRITON/TAO PIRATA/RAMA 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 better than 2% of the full scale. Repeatability: better 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.[3]
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. Note, however, that 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 for chlorophyll or oxygen or nitrate) are included in the corresponding repositories. Due to the diverse sources, the nature of the data, e.g., the frequency in time, the spatial pattern and the depth varies a lot. 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. BGC-Argo data are similar in structure as they also consist of a collection of depth profiles, but here 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. Ferrybox data are collected with a relatively high frequency (typically, one measurement per minute) along a transect, while buoy data are from a single location.

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 (MyOcean, Mersea, MFSTEP, Ferrybox, SEPRISE, etc.) 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 7 oceanographic regions: the global ocean and the 6 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.

3 For information on units for each variable see Product User Manual document.

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 100,000.

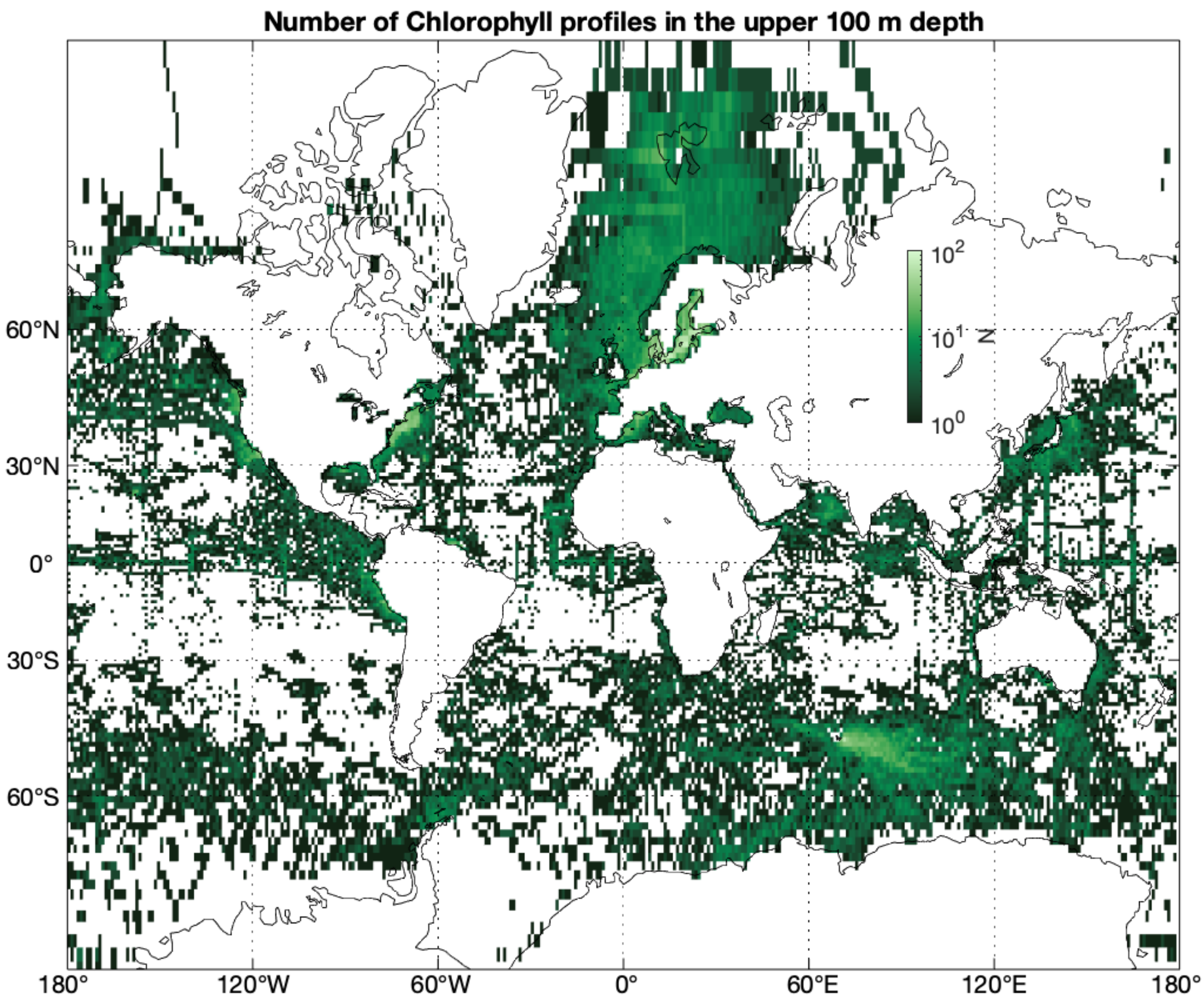

Figure 1: Spatial coverage of chlorophyll, shown as the number (N) of profiles in the upper 100 m water depth in 1°x1° cells. Any profiles in cells outside the map, towards the poles, are summed up onto the northernmost and southernmost row of cells shown. Colour shading is from dark to light, in order to show gaps more clearly.

II.1.2 Global oxygen data

DOXY, DOX1 and DOX2[4] are all oxygen concentrations in different units 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 419,000.

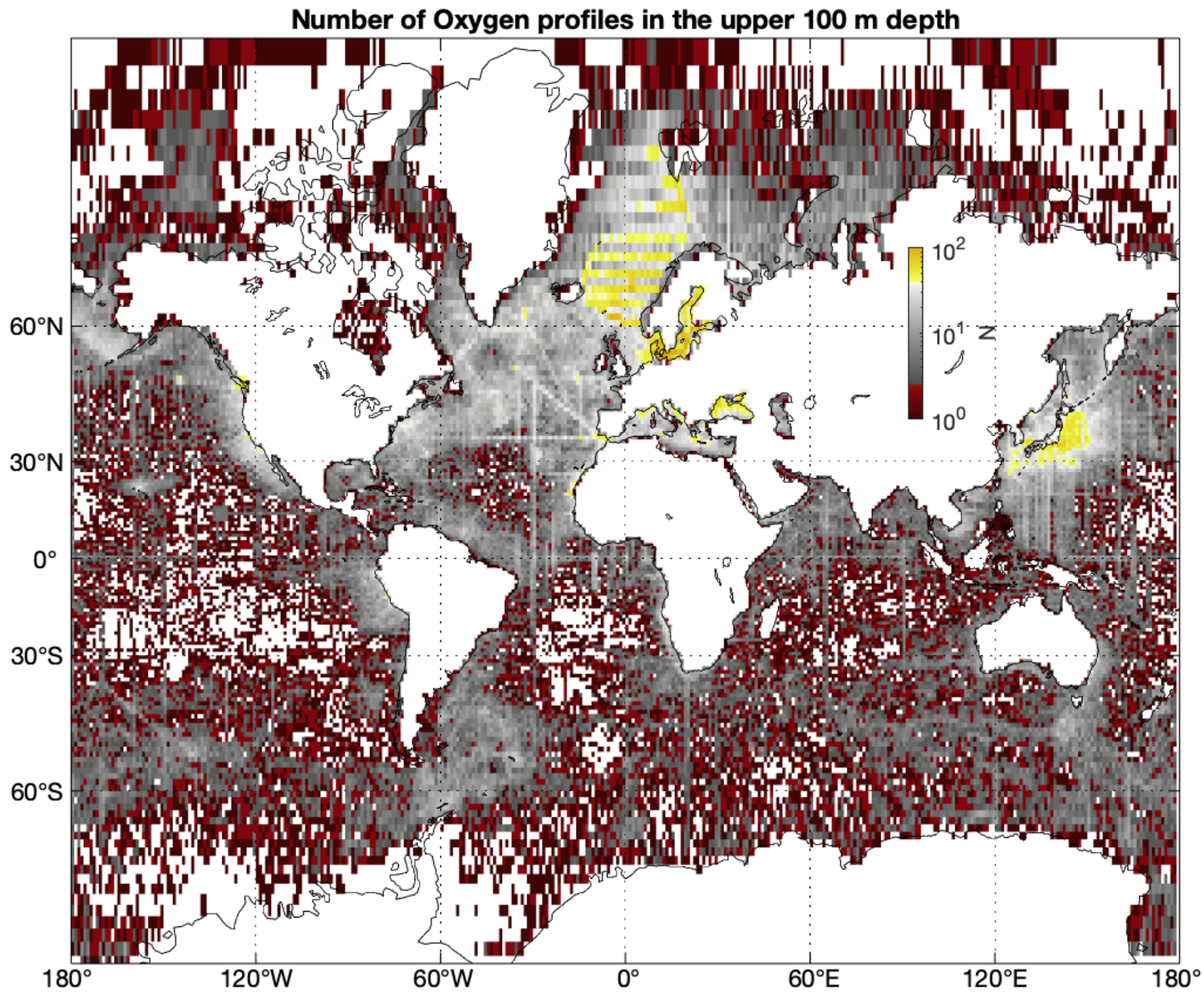

Figure 2: Spatial coverage of oxygen, shown as the number (N) of profiles in the upper 100 m water depth in 1°x1° cells. Any profiles in cells outside the map, towards the poles, are summed up onto the northernmost and southernmost row of cells shown.

4 For additional information about contents and units of each variable see Product User Manual document.

II.1.3 Global nutrient data

Nutrient data use different units for the concentrations depending on which specific nutrient is being referred to. The Nitrate variables are NTAW and NTRA, while Phosphate comes as PHOW and PHOS, and Silicate as SLCW and SLCA, all in µmol kg^{-1} and in mmol m^{-3} , respectively. The spatial distributions of samples of the three different nutrients are shown in Figure 3 through Figure 5. The total number of Nitrate profiles with valid data is 100,000, while valid Phosphate profiles is 191,000 and Silicate profiles 149,000.

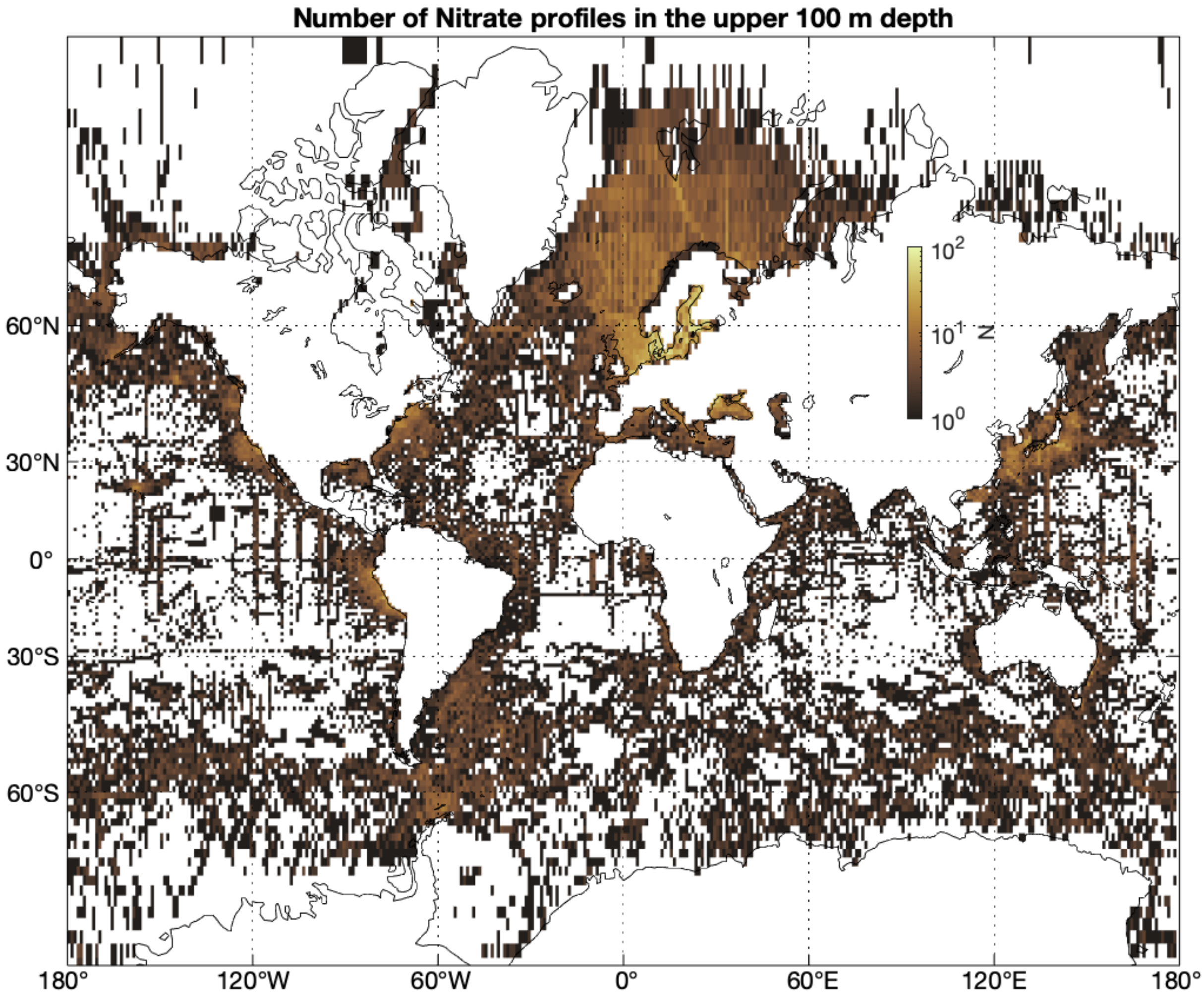

Figure 3 : Spatial coverage of nitrate, shown as the number (N) of profiles in the upper 100 m water depth in 1°x1° cells. Any profiles in cells outside the map, towards the poles, are summed up onto the northernmost and southernmost row of cells shown. Colour shading is from dark to light, in order to show gaps more clearly.

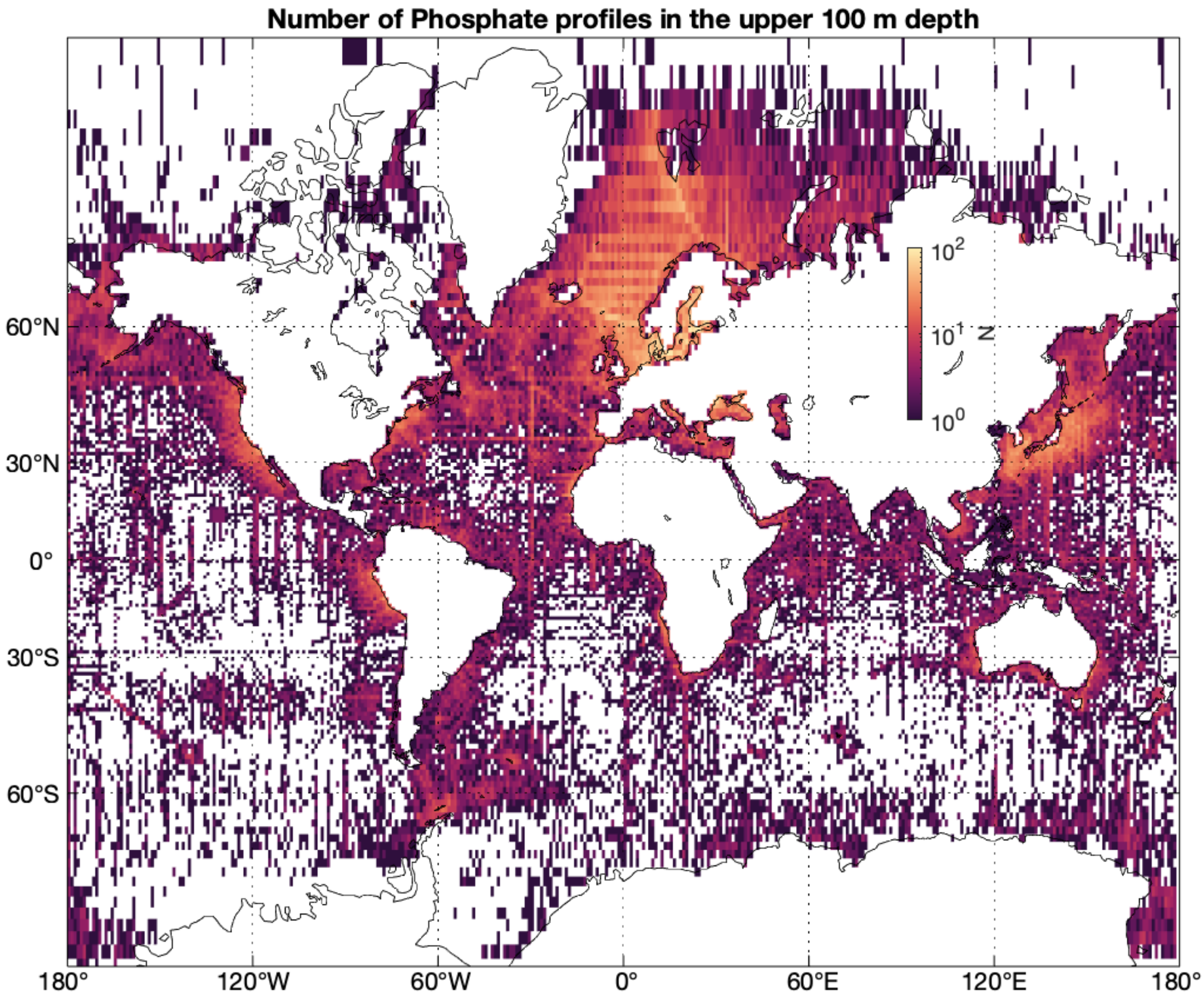

Figure 4 : Spatial coverage of phosphate, shown as the number (N) of profiles in the upper 100 m water depth in 1°x1° cells. Any profiles in cells outside the map, towards the poles, are summed up onto the northernmost and southernmost row of cells shown. Colour shading is from dark to light, in order to show gaps more clearly.

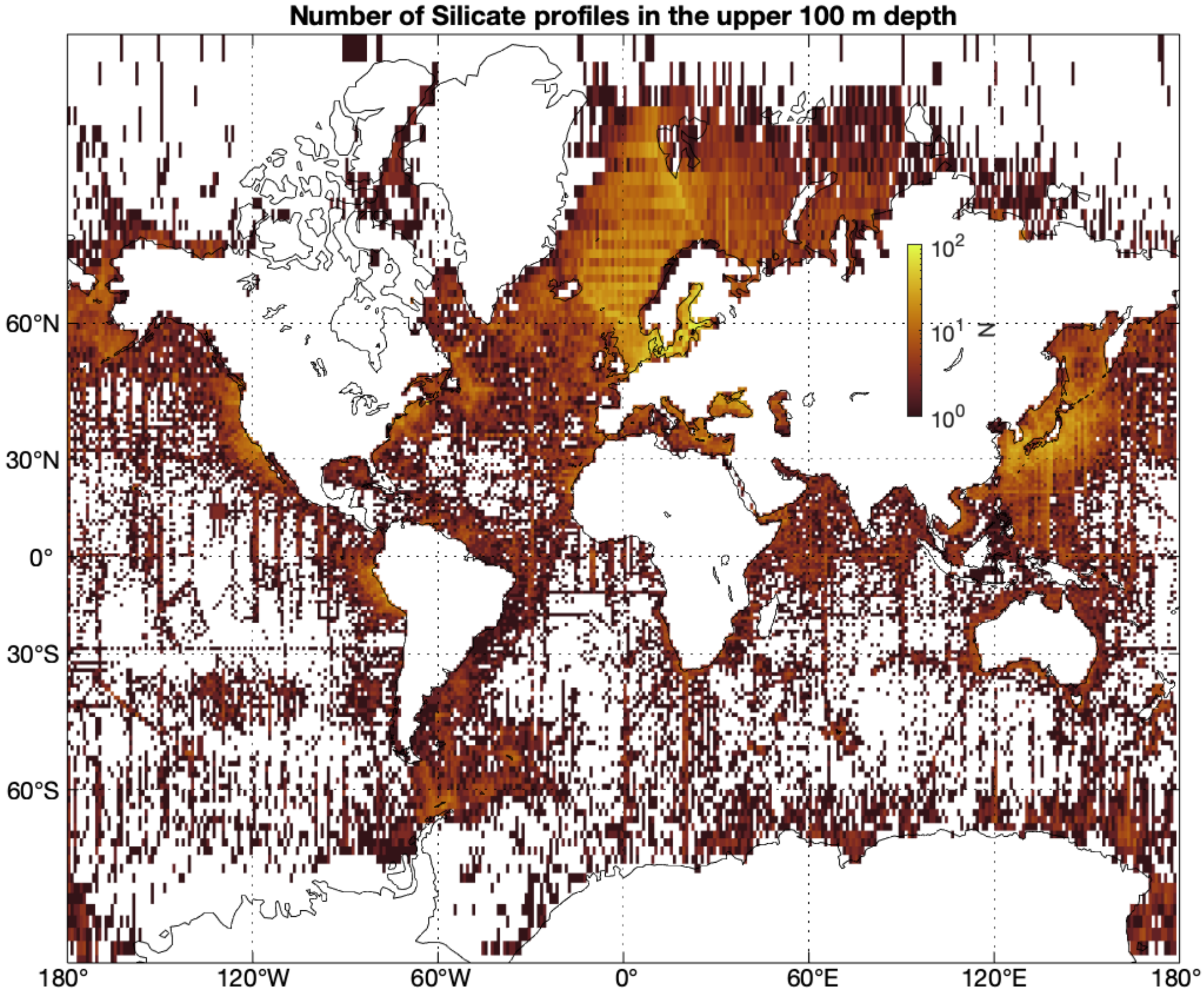

Figure 5 : Spatial coverage of silicate, shown as the number (N) of profiles in the upper 100 m water depth in 1°x1° cells. Any profiles in cells outside the map, towards the poles, are summed up onto the northernmost and southernmost row of cells shown. Colour shading is from dark to light, in order to show gaps more clearly.

II.1.4 Baltic Sea oxygen and nutrient data

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

Ferrybox systems provide a large amount of data, collected in two ways: either a flow through system that measures in intervals, e.g. 20 seconds, or in other cases some ferryboxes which use a sequence sampler collecting bottle samples for a later analysis in the laboratory. These systems typically collect from a nominal depth of around 5 meters.

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 and 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 (23.72%), profiling floats and gliders (27.03%) and moorings (4.05%), bottles (44.14%), and ferrybox (0.45%). The deep ocean part of the Mediterranean Sea is mainly covered by Argo floats and research vessels and the shelf part is mainly covered by fixed stations. Oxygen variables are provided in ml/l, µmol/l and µmol/kg. Considering the averaged potential density of seawater equals to 1.025 kg/l (used for consistency and independent of the availability of temperature and salinity measurements and their quality) and the conversion factor of 44.6596 µmol/ml (SCOR WG 142), units of DOX1 and DOXY variables are converted to µmol/kg (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.

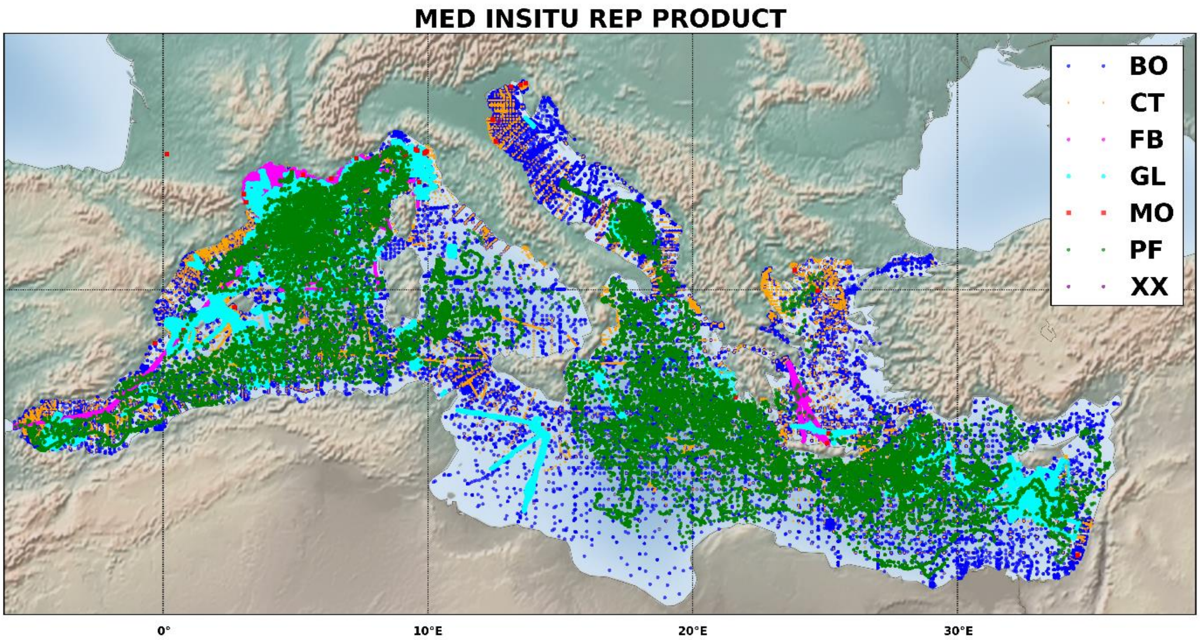

Figure 6 : Map of different platform locations with sampling of biogeochemical data in the MED region available in the history directory of the MED In Situ TAC portal. Green: profiles (PF); red: moorings (MO); blue: bottles (BO); cyan: gliders (GL); orange: vessels (CT); magenta: ferrybox (FB); purple: 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. The framework applied for the chlorophyll data is based on the classical statistical concept known as the Empirical Rule or the "three sigma rule" (99^{th} percentile ≈ 3σ and 95^{th} percentile ≈ 2σ) to provide the upper valid ranges for values of chlorophyll concentration in coastal and pelagic regions. The quality control procedures used to reprocess the quality flags of 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 BGC-REP.

Table 3 : Quality Control (QC) flag scale.

Code	Meaning	Comment
0	No QC performed	-
1	Good data	All QC tests passed
2	Probably good data	-
3	Bad data that are potentially correctable	These data are not to be used without scientific correction
4	Bad data	Data have failed one or more of the tests
5	Value changed	Data may be recovered after transmission error
6	Value below detection/quantification	The level of the measured phenomenon was too small to be quantified/detected by the technique employed to measure it. The accompanying value is the quantification/detection limit for the technique or zero is that value is unknown
7	Nominal value	Data were not observed but reported (e.g., an instrument target depth)
8	Interpolated value	Missing data may be interpolated from neighbouring data in space or time
9	Missing value	The value is missing

III.2 Testing of metadata

In all files metadata, such as date, location, pressure, and existing QC, are reprocessed using the tests described in the following sections.

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 in range -90 to 90
- Longitude in range -180 to 180

If either of the metadata values fails the test by being outside the respective allowed range, the QC flag of the variable is set to 4 “Bad value”.

III.2.2 Metadata QC test

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

III.2.3 Negative pressure test

This test checks whether the observation pressure or depth from the profile data is greater than or equal to 0, both for dbar and meter (depth/pressure is positive downwards). If PRES or DEPH < 0 then also the QC flag of the variable is set to 4 “Bad data”.

III.2.4 Automated test for on-land positions

Erroneous positioning data is not uncommon. In the BGC-REP 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 cells with any GSHHS full resolution coastline inside. The remaining cells are divided into two more masks, one for offshore and one for inland regions, with the aid of ETOPO2 elevation data. Some manual checking and editing of the latter two masks are done to ensure the robustness of these three masks.

For each file, as a first step the offshore mask is used to except lon/lat positions from further testing. Next, the inland mask is used to flag positions clearly 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 cluster is tested for existence of positions within a land polygon (QC=4).

The results are validated by visual checks of random sampled cases of on-land detection (see, e.g., Figure 8a).

Furthermore, flagged positions closer to the coastline than the resolution of the coastline, i.e., nearer than the distance between any of the two nearest coastline segments, are flagged as 'probably good data' (QC=2; Figure 8b). 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.

a) b)

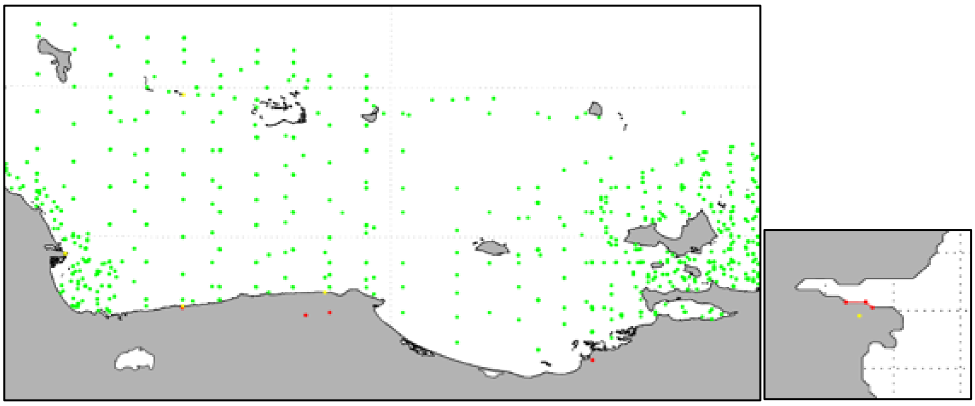

Figure 7: Example of the detection of on-land positions. a) Using GSHHS coast dataset on-land positions (red dots) and near coast 'probably good data' (yellow dots near the coastline) are detected and flagged, while good points (green dots) are good. b) Example showing the detection method for probably 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 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 exact expansion of the river-mouth regions is to include larger bays while limiting the long-shore expansion reasonably. 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). This means that is important to characterise these regions with different upper and lower limits of chlorophyll concentration (if a unique upper limit was used for both regions, then it would be much too high for the pelagic waters). Coastal waters also show greater range of variability in chlorophyll concentration over the year compared to deep ocean areas. 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 shape files of Spalding et al. (2007, 2012), which define coastal and pelagic regions, respectively. These shape files may be downloaded from the web: https://www.worldwildlife.org/publications/marine-ecoregions-of-the-world-a-bioregionalization-of-coastal-and-shelf-areas and http://data.unep-wcmc.org/datasets/38, respectively. 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 9). The "coastal waters" are defined as extending 200 nautical miles (370 km) offshore, or to the 200-metre isobath wherever this lies further offshore. The shape files for the coastal and pelagic provinces overlap in places. In allocating a data point as being either in "coastal" or pelagic waters, the geographical location is checked first to see if it lies within any of the "coastal" shape files, and if not, then to see which pelagic shape file it was associated with. 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 that 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" shape files of Spalding et al. (2007) and so, no pelagic waters are defined for the Mediterranean Sea. Further work is required to define a new shape file specifically for the Mediterranean coastal and pelagic regions.

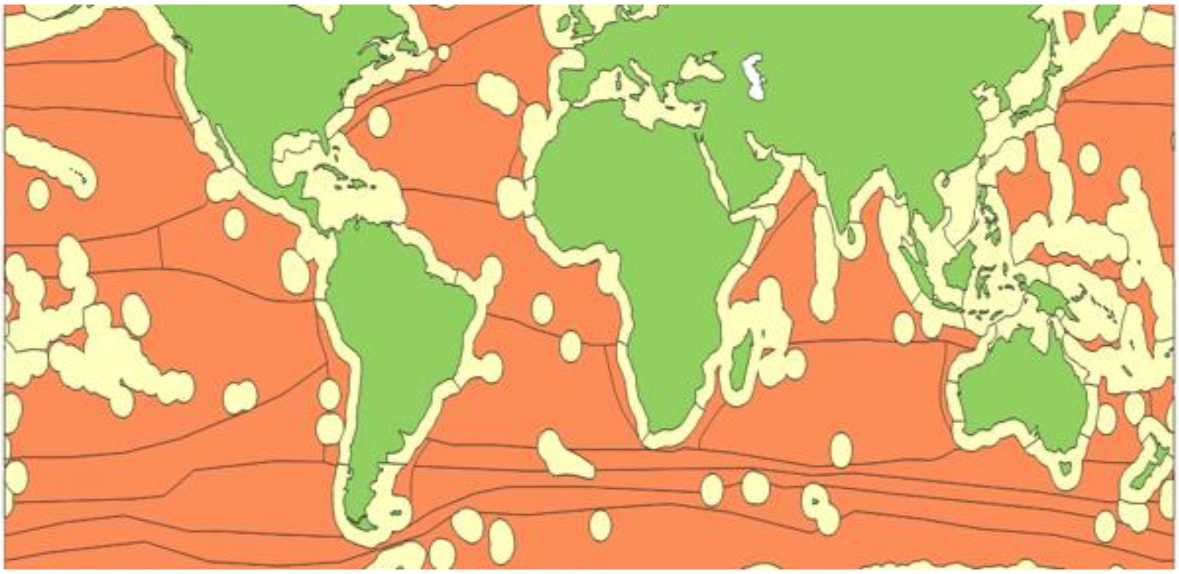

Figure 9 : Ocean provinces based on Spalding et al (2007, 2012). Yellow: coastal areas; orange: pelagic areas. The lines delimit the different provinces.

Using these shapefiles, all available global Chlorophyll data are collated and sorted into each of the respective provinces (Figure 9).

The shape files of Spalding et al. (2007), which define the coastal regions, also extend around the remote islands which lie within the pelagic regions (Figure 9). Those islands lying within the tropics typically have chlorophyll concentrations similar to pelagic waters in which they lie and for these specific coastal provinces a lower maximum chlorophyll concentration value is expected than in the case of proper coastal waters surrounding the continental land masses.

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

In addition to separating the oceans into coastal and pelagic provinces, we also separate 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, for all waters greater than 200 metres in depth, for all 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 check for all chlorophyll data for all waters in this depth range. In Table 10 of Jaccard et al. (2018) the longitudinal limit is set to a minimum of -60°E and a max of 180°E, and latitudinal limits 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 greater than 200 metres in depth will not be available, by definition, as Spalding et al. (2007) use the 200-metre isobath to determine the boundary of the shape files delimiting the coastal waters.

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

$$g = 9.780318(1 + 5.2788 \times 10^{-3} sin^2\varphi + 2.36 \times 10^{-5} sin^4\varphi \qquad (1)$$

Where g is the acceleration due to gravity, corrected for latitude, ϕ, expressed in radians. Depth (z) in metres is then given as a function of pressure (P) in decibars as:

$$z = \frac{C_1P - C_2P + C_3P - C_4P}{g + 1.092 \times 10^{-6} P} \qquad (2)$$

Where C_1= 9.72659, C_2=2.2512*10^{-5}, C_3=2.279*10^{-10}, and C_4=1.82*10^{-15}. An example for the source code in C is included in Appendix 2. This algorithm is also implemented in Python in the Seawater 3.3.4 library (Available from https://pypi.org/project/seawater/) and this 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 varies with season, latitude, water mass and the biological productivity within the water column. We have used 0-200 metres as the maximum limit for this zone. However, chlorophyll concentration is generally much higher in the waters nearer the surface. Therefore, we subdivide the euphotic zone into 0-100 metres and 100-200 metres. The effect of this choice is illustrated for two provinces, the North Central Atlantic Gyre and the more productive Sub-Arctic Atlantic (Figure 10). In this figure the frequency distributions and corresponding 95th (≈2σ) and 99th (≈3σ) percentile values of the data are plotted; the rationale of this approach will be discussed in Section III.3.4. When the whole euphotic zone (0-200 metres) is considered as one water mass, the chlorophyll observations obtained at greater depths have the effect of increasing the number of occurrence of values with low chlorophyll concentration, therefore reducing the 95 and 99 percentile values as shown (top vs. middle panels). Separating the euphotic zone vertically into 0-100 metres and 100-200 metres 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, especially in late spring and summer with a shallower surface mixed layer depth and a highly productive surface layer, the depth of the euphotic zone may be less than 100 metres. We have not been able to correct for this condition on a global basis and the effect may be to bias our percentile values slightly lower in some regions. Although we cannot quantify this effect, it is likely to be small.

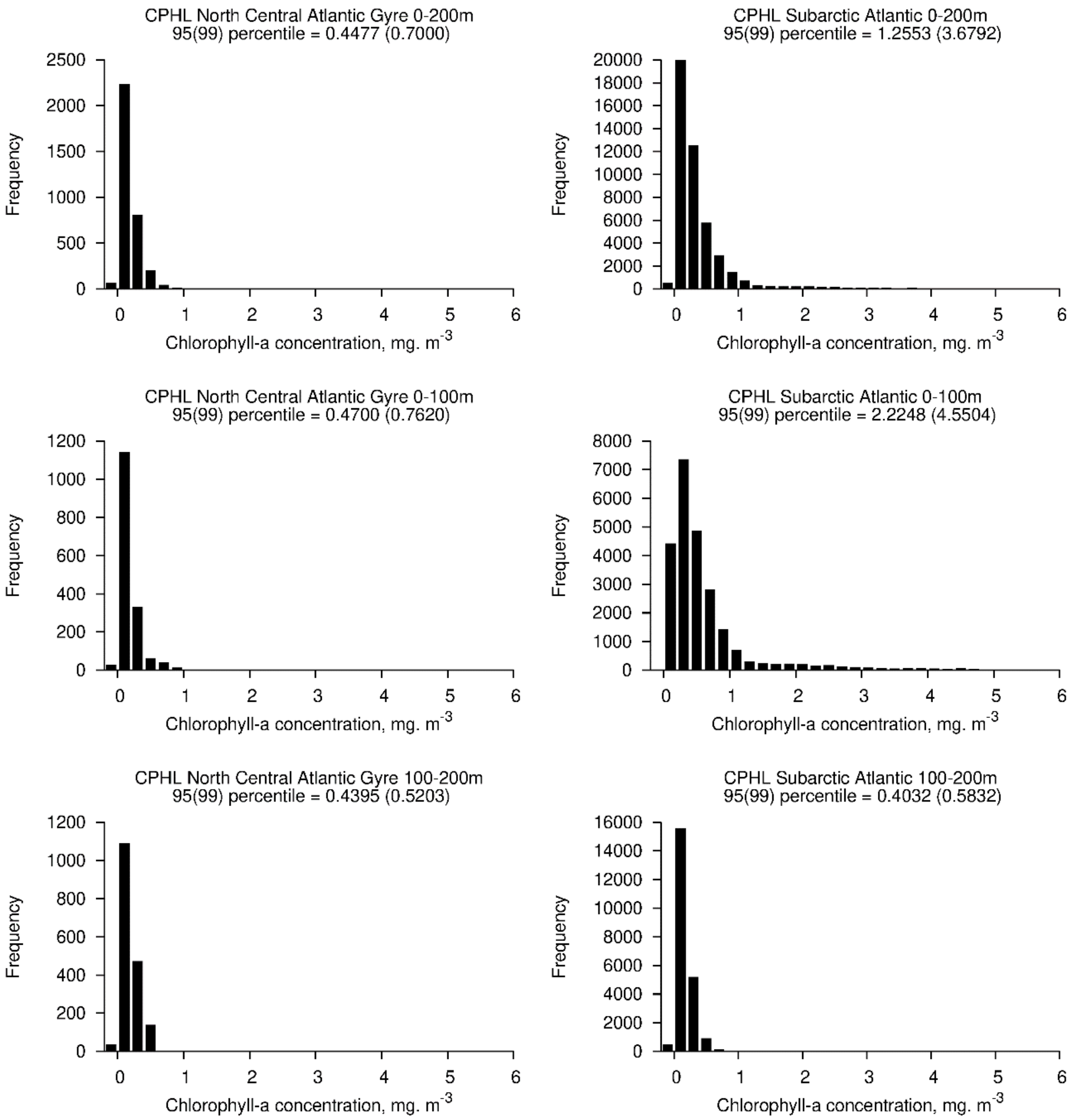

Figure 10: Frequency plot for CPHL in the provinces North Atlantic Gyre (left) and Subarctic Atlantic (right), calculated for 0-200-metre (top), 0-100-metre (middle) and 100-200-metre (bottom) depth ranges. Note the different scales on the vertical axes.

III.3.3 Seasonality in chlorophyll

Neither the coastal nor the pelagic data are sorted by season as the latitudinal limits of the shape files defining each province are in part a result of the present climatic regime. Climate change (and natural variability) may shift the boundaries of "seasons" and being too precise may result in rejecting data that should in the future be accepted.

The largest seasonal effects are most likely to be seen during spring-bloom events, and these are much more pronounced in the "coastal" waters described above, which have higher maximum threshold limits set accordingly. Seasonal variability in the pelagic waters is much smaller and lies within the range of acceptable values as defined.

We have looked at 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 less 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} occupy 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 too high for most of the ocean, although in some coastal regions such values do occur. Setting the maximum to values like those for all regions means precision is lost when performing any quality control on the vast majority of data.

In this reprocessing we adopt a different strategy which is 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 for choosing to accept or reject the vast majority of data values observed.

For each set of data (CPHL and FLU2), for each pelagic and coastal province and for each depth range (0-100 and 100-200 metres) 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, so providing some noise. In the level 0 data, some chlorophyll data have extremely high values with magnitudes of the order of 100-1000 mg m^{-3}. To prevent these from biasing the data distribution, the data are pre-screened and any value greater than 20 mg m^{-3} are rejected from the input data set used to calculate the 95th and 99th percentiles.

Precision for chlorophyll measurements is 0.05 mg m^{-3} (Table 1). Note, however, that different instruments vary in the precision obtainable. In using the data of this reprocessing, precision to two significant decimal places should be assumed.

Where no data exist in any given province, no attempt is made to assign a value as this would be meaningless in a re-processed product. However, this process of determining the 99th percentile should be be iterative. Each year as it is repeated, the increasing amount of data available to each re-processing will both start to provide limit values for provinces which currently do not have them, and also increase the precision of the acceptable upper limit values in those provinces which do. A comparison of the threshold values from one reprocessing to the next may also provide a means of detecting any systematic change occurring in the chlorophyll concentrations of a given province.

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 case, 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, so 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 1 (good data; see Table 3), while those exceeding it are flagged as quality control 4 (bad data).

Note that the regional range tests do not take river mouths or other special regions into consideration, so care is required hen 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° by 1° by standard depths gridded dataset from WOA18 (Garcia et al., 2018; Figure 11). These data are provided with sample mean, standard deviation (std), 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 (chosen at 99.9%) calculated using the inverse of the Student's T test at the degrees of freedom given by N. (N<5 is not accepted.) This approach results in realistic ranges estimations for the individual bins. However, they vary too much between neighbouring bins to be used individually on a 1° by 1° basis. Instead, larger regions encompassing some typical behaviour of ranges is sought.

DOXY, DOX1 and DOX2 are all oxygen concentrations in different units. Dissolved oxygen will occur in one of these flavours according to the sensor technology used or the laboratory analysis performed. In principle it is possible to convert from one to the other, but this requires knowledge of auxiliary parameters such as water density. For this reprocessing activity, these parameters have been handled independently from each other.

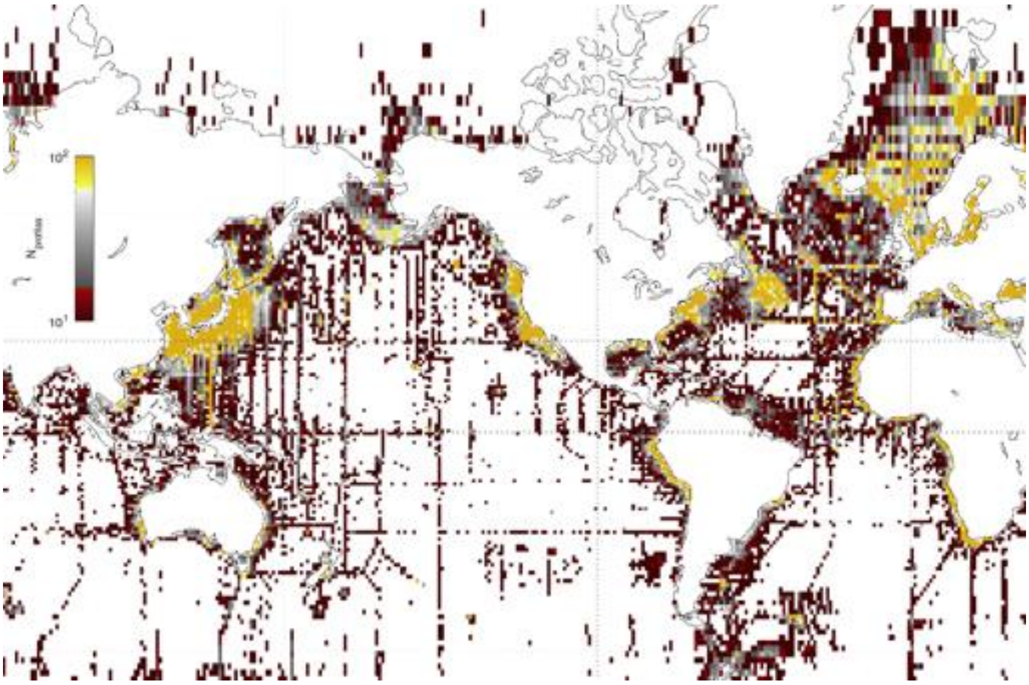

Figure 11 : The number of oxygen profiles on which the WOA18 gridded data set is based, for each of the inherent 1° x 1° geographical bins. The colour scale is logarithmic.

For the oxygen test we choose 28 regions (Figure 12) each separated into 2 or 3 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 O2 level and variability.
- Unimodal distribution of bin-mean values within each region and layer, i.e., capturing one type of O2 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 WOA18.

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

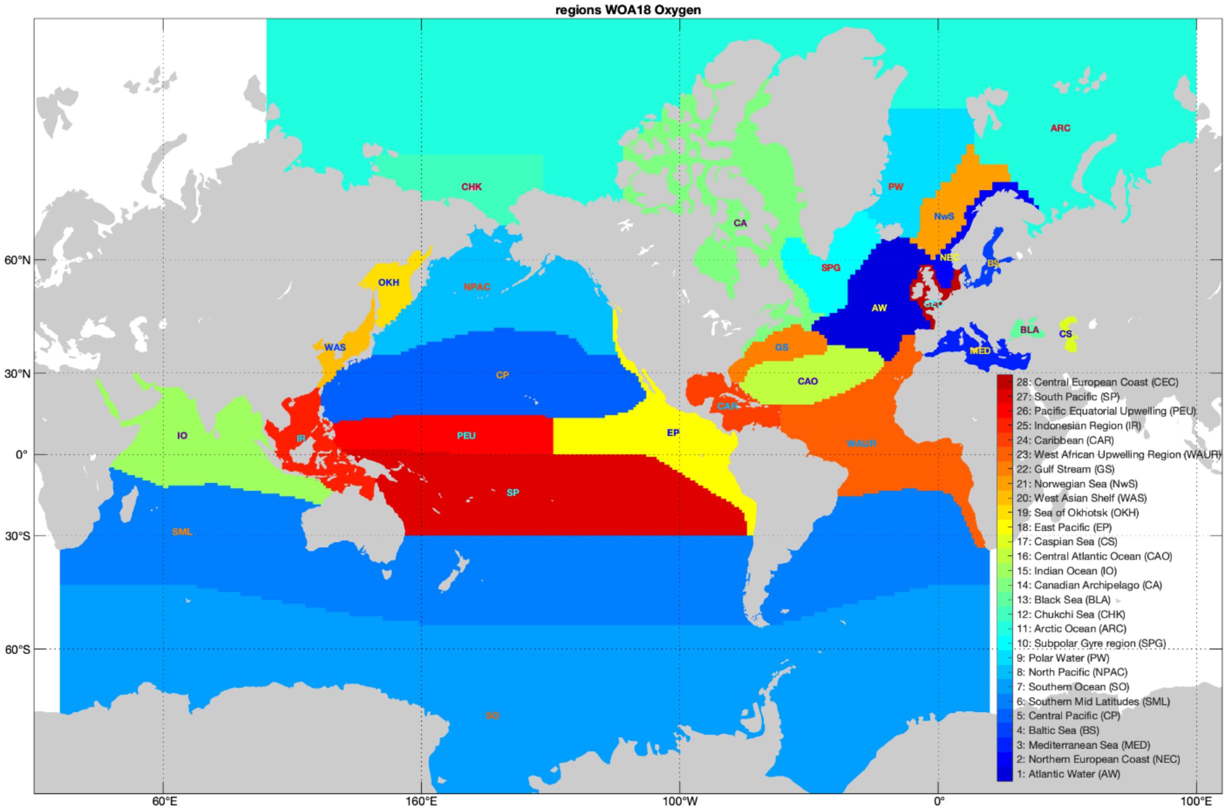

Figure 12: The current geographical regions used in the oxygen range test. The regions are also divided into 2 layers, with individual separation depths (see Table 19 in appendix 1).

The initial selection of range for a region is objectively set as between the 0.1 percentile of all the region's lower ranges and the 99.9 percentile of its upper ranges. Thereafter, a visual inspection of vertical profiles of boxplots of the ranges of individual bins and allows for some adjustment, 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: Chukchi Sea (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 knowledge or visual inspection of tested data dictates 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 0 (tests related to metadata) and the tests described in this section. The Baltic and Mediterranean regions have also 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 type (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 graphs of the data (Figure 13). Note that, even though the visual check includes consideration of the influence from river mouths, care is required when using data in such regions.

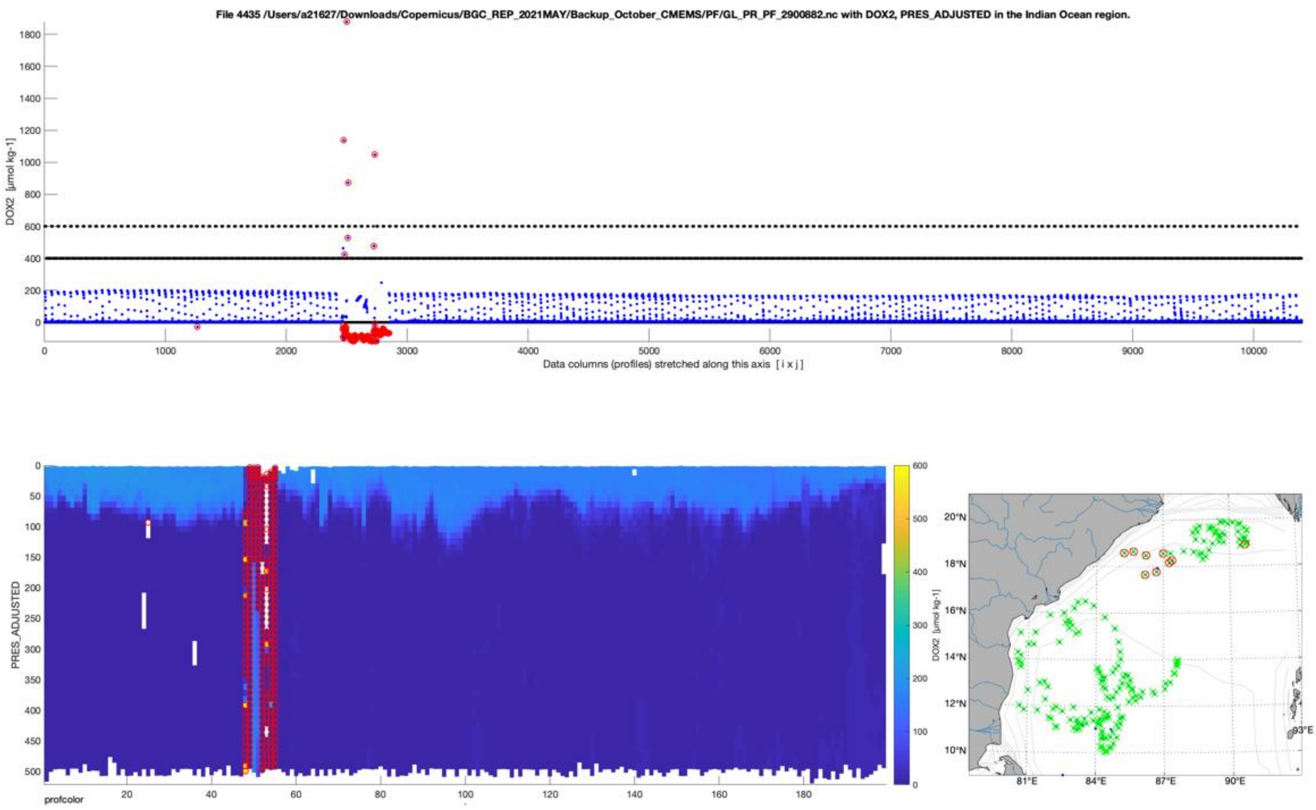

Figure 13: Example of range testing of Oxygen. When flags are set, a plot of data from the file and the region it occurred in, is made (see title of graph). In the upper panel all data are stretched out along the horizontal axis, with observations in blue, outlier ranges in black (steps are due to the different limits in different layers). In this file there are several profiles, as can be seen by the repeated signatures of oxygen values, and repeated steps in the ranges. In the lower left panel, the profiles are shown vertically in a colour shading plot. The flagged data are marked by red circles in both panels. In this example the vertical axis is given in depth (m) and the oxygen (as colour) is DOX1 (ml/l). A map is added where all positions in file are marked in blue, positions with oxygen data within the region as green 'x', and positions of flagged data 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 to bottle data in the BO subdirectory. The test is performed only when at least 100 data points were present. Following the recommendation by to 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 Finnmaid Ferry are described in the Manual for Marine Monitoring in the COMBINE Programme of HELCOM (https://helcom.fi/wp-content/uploads/2020/02/Manual-for-Marine-Monitoring-in-the-COMBINE-Programme-of-HELCOM.pdf).

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 (https://www.finas.fi/sites/en/Pages/default.aspx).

III.4.3.5 Frozen Value Test

A number of samples (*N)* larger than the one for the global test ~~was~~ is needed, since the test is currently applied to already rounded data. This is generally a poor practice, but is currently used due to legacy data acquisition software. A value of *N*=100 for data points is used, which appears to correctly detect possible frozen instrument values.

III.4.4 Quality control of oxygen data in the Mediterranean

Reprocessing of oxygen data of 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 and it consists of two additional tests, as described in sections III.4.4.1 and III.4.4.2.

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 by 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 (http://www.teos-10.org) 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 calculated maximum 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 ºC and salinity between 0–40:

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

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 of pressure has been converted (conversion by using the CSIRO Seawater_ver3_3.1 software package (sw_dpth)) to the variable of depth 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; WOD18, Garcia et al., 2018). 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, apparent oxygen utilisation, and percent oxygen saturation. The parameters are provided at each gridpoint 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 MED Sea for 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, available in both sub-directories Data_In_micromolKG and Data_In_micromolL, 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 1234, QC 5678 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[5].

[5] https://archimer.ifremer.fr/doc/00488/59938/101776.pdf

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 WOA18 data. For the nutrients tested, that is Nitrate, Phosphate, and Silicate, regions are initially based on Spalding domains. More regions are added as needed, and all regions are changed and developed by the same iterative method as for oxygen, until acceptance. Figure 14 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 through Table 22 (appendix 1). In addition, where base data are scarce, or knowledge or visual inspection of tested data dictates, ranges are set manually.

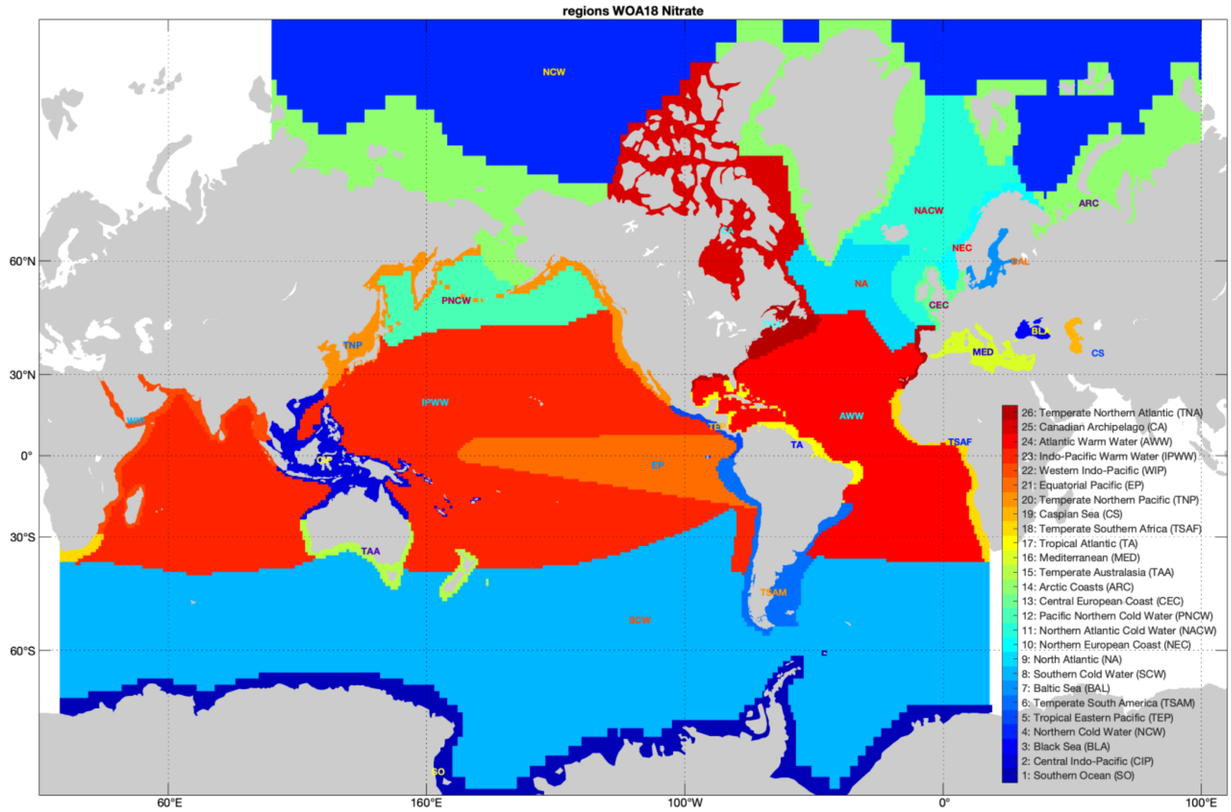

Figure 14: Geographical regions for the nutrient range-testing. The colourbar lists names and abbreviations for regions. For readability the colours of the labels on the map are complementary to their region's colour.

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 0 (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 in the open ocean nutrient values in the photic zone, due to consumption, are lower than in the deeper ocean. We do not apply the profile test in areas of influence from 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 15) was made. Furthermore, profiles measured in locations of high latitudes (greater than 80 degrees north, or 75 degrees south) have also been excluded from testing, due to the potential influence of melting sea ice on the nutrient levels.

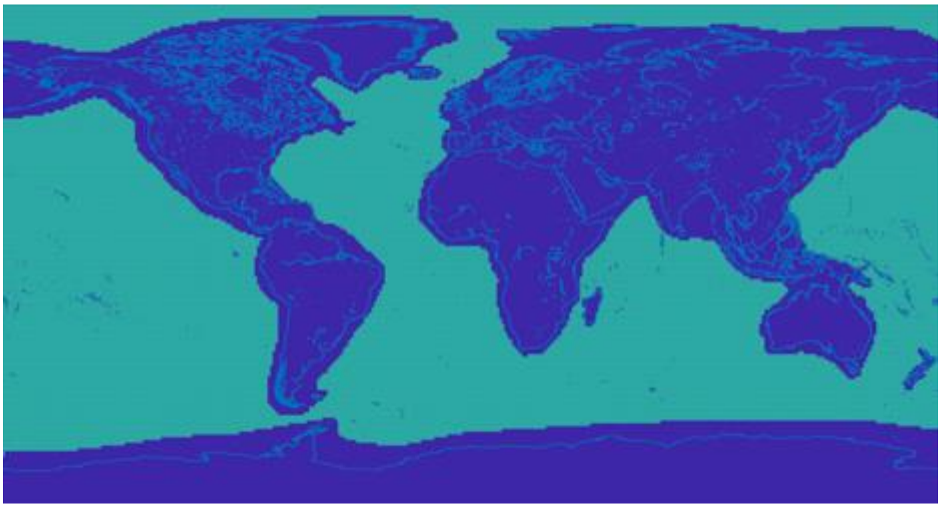

Figure 15: The 1° x 1° mask used to identify offshore regions to apply the nutrient profile test in. Blue: regions with water depth less than 1000 m. Green: regions with water depth larger than 1000 m.

We assume a photic zone depth of 100 m and mark as bad data (QC = 4) all data above this depth that ~~has~~ have a value higher than the maximum value below 100 m.-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 part of a pattern, and whether the salinity profile shows a clear water mass separation. Figure 16 shows an example of datapoints marked by the profile test, while Figure 17 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.

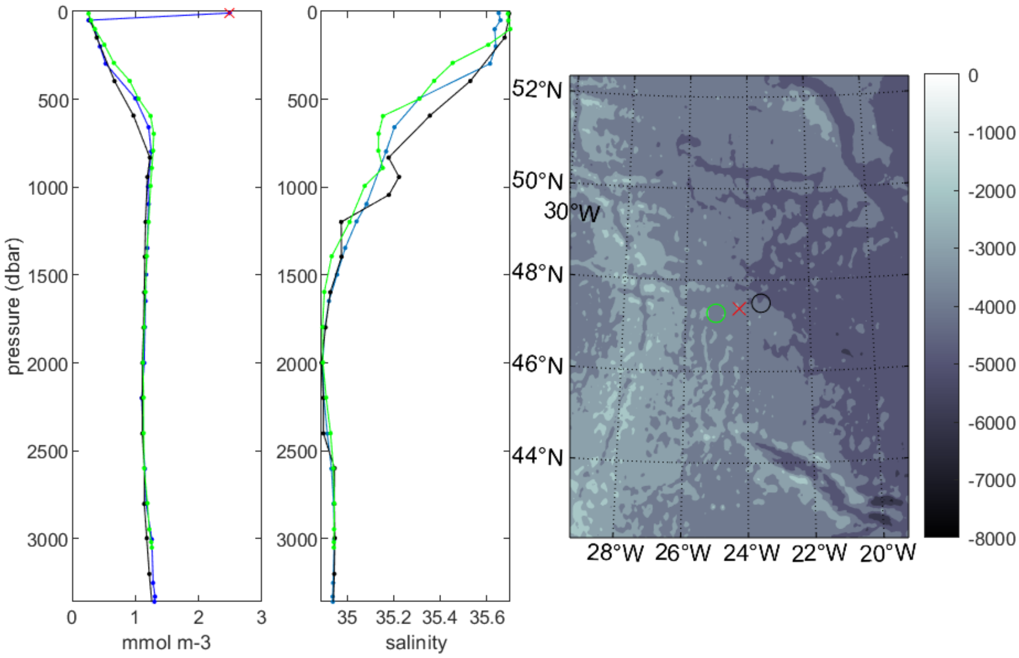

Figure 16: Example of a profile with marked phosphate data. Panels show, from left to right: Phosphate profile in blue with the marked datapoint as a red x. The black and green profiles are the previous and next profiles in the variable, respectively. The middle panel shows the salinity profiles, with 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.

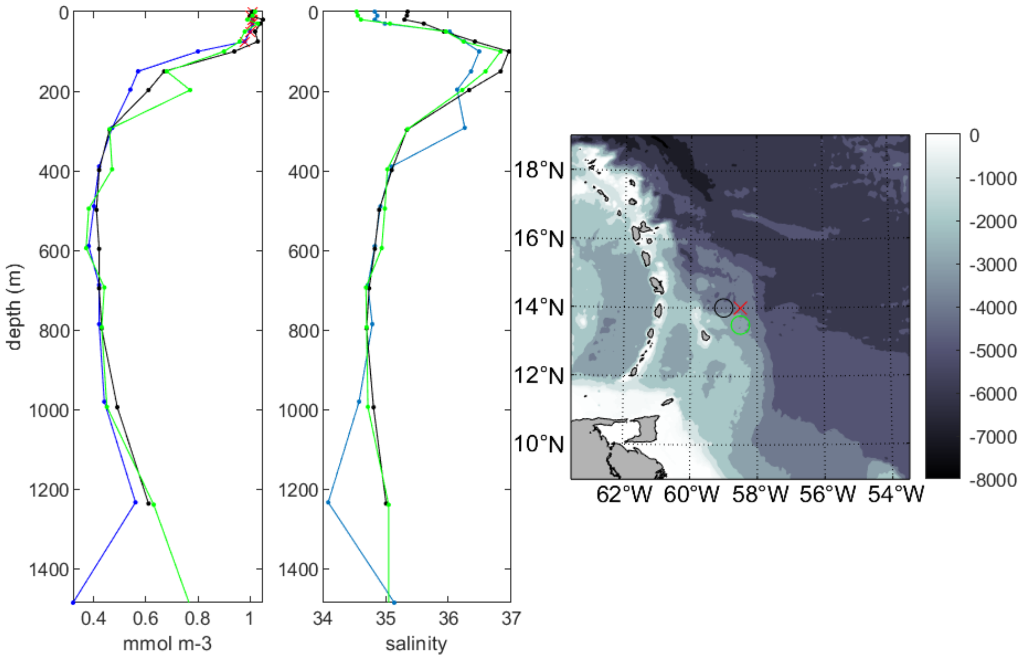

Figure 17: Same type of figure as Figure 16, but with an example of profile with marked phosphate data that was cleared after visual inspection.

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. 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

Reprocessing of nutrients data in the Mediterranean is performed on data from any platform in the Mediterranean 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 below:

III.5.4.1 Regional range test of nutrients values

In order to perform the regional range test of nitrate (incl. nitrite), phosphate, and silicate for the Mediterranean Sea, a division of the area into five different sub-areas is performed so to use the appropriate ranges for each parameter separately, depending on where each platform is located.

In the case of nutrient data, the WOA 2018 climatology was not used due to the lack of data in the Mediterranean region. The division of the area is based on a large literature research for the Mediterranean Sea. The ranges of silicate, nitrate (incl. nitrite) and phosphate concentrations as defined by Tables 4, 5 and 6 are presented in Figure 17.

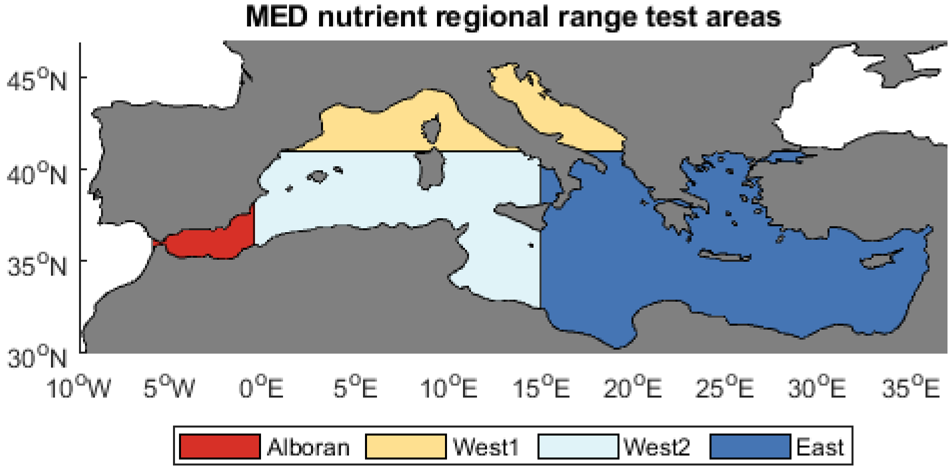

Figure 18 : Mediterranean geographical regions for the nutrients regional range test (see also Tables 4,5 and 6).

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 concentration (µmol/l) in Mediterranean subdivisions.

Area	Lon	Lon	Lat	Lat	Bottom Depth	Bottom Depth	Sampling 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	15.00	30.0	41.0	100	5200	0	1000	0.0	15
	-0.6	15.00	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 concentration (µmol/l) in Mediterranean subdivisions

Area	Lon	Lon	Lat	Lat	Bottom Depth	Bottom Depth	Sampling 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	15.00	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 concentration (µmol/l) in Mediterranean subdivisions

Area	Lon	Lon	Lat	Lat	Bottom Depth	Bottom Depth	Sampling 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 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 increases 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. So, values that are being reduced below the depth of 200 meters are marked as bad values (QC flag 4).

IV VALIDATION RESULTS

IV.1 Metadata

IV.1.1 Changes in QC flags for positions

Out of the total 60 million original positions, the land test resulted in 1.6 million positions (3%) being flagged as bad positions (QC=4) and 374 thousand positions (0.6%) as 'probably good data' (QC=2).

Note that none of the data with positions flagged QC=4 or worse enters the subsequent tests of the REP 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 344 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, and this amounted to 1.8% of the examined data. See Table 18 (appendix 1) for range test criteria and Table 3 for QC flag meaning.

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

Range tests for 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 in the Baltic region before and after testing.

Directory	Variable	percentage labelled bad data	
		before / %	after / %
Bottle	FLU2	25.9	25.9
Bottle	CPHL	<0.01	0.16
CTD	FLU2	0.08	1.5
CTD	CPHL	0.02	0.06
Glider	CPHL	0.35	0.4
Ferrybox	FLU2	9	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 depends on sufficient QC level 1 and 2 data being available for each province. However, this is not yet the case for all provinces, 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 a 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 limits may be biased 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, 9 months of lower chlorophyll values and 3 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 sum total of chlorophyll types *a*,*b*, and *c*, which are found to varying extents in different microalgae (though not all). Such data are most likely to have been obtained from spectrophometric methods or early fluorimetry. Nevertheless, CHLT represents a significant amount of data, and in future reprocessing should be investigated to see 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 encompasses 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

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, 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 separate shape files are defined for these regions.

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

DOXY, DOX1 and DOX2 are all oxygen concentrations in different units. Dissolved oxygen will occur in one of these flavours according to the sensor technology used or the laboratory analysis performed (see section III.4.1). In principle it is possible to convert from one to the other, but this requires knowledge of auxiliary parameters such as water density. In the scope of this reprocessing activity, these parameters have been handled independently from each other.

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 113 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, and this amounts to 0.4% of the examined data. See Table 19 for range test criteria and Table 3 for QC flag meaning.

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

Changes in QC flags in the Baltic for BGC are reported for each of the subdirectories 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 in the Baltic region before and after testing.

Directory	**Variable**	**Percentage labelled bad data**	
		before / %	after / %
Bottle	DOX1	0.27	0.27
	DOX2	0.1	0.1
	DOXY	0.07	0.07
CTD	DOX1	9.74	11.06
	DOX2	2.99	7.16
	DOXY	84.86	85
Ferrybox	DOXY	13.54	16.5
	DOX1	26.6	26.7
Mooring	DOX1	10.4	10.4
	DOXY	<0.01	0.16
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 or 2 or 6 to 4 and from 1 to 2, respectively, is presented in terms of percentages with respect to the total values entering each test routine (Table 9 and

Table 10) as well as 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 on Dissolved Oxygen (%)* *REP test 1*
CTD	0.0186
Bottle	0.1717
Ferrybox	29.4340
Mooring	0.00112
Profile	0.0032
Glider	0.0000
Profile (XX)	21.1031

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

Platform type	QC flags changed on Dissolved Oxygen (%) REP test 2
CTD	0.0126
Bottle	2.1280
Ferrybox	17.8249
Mooring	0.1142
Profile	1.1977
Glider	0.0151
Profile (XX)	15.6746

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 on Dissolved Oxygen (%) (Test 1 & Test 2)
CTD	0.0312
Bottle	2.2997
Ferrybox	47.25
Mooring	0.1153
Profile	1.2009
Glider	0.0151
Profile (XX)	36.7777

Table 12 : The effect on the QC flags of the data used to produce the reprocessed product of the dissolved oxygen in the Mediterranean Sea by using the methods 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 (Test 1 & Test 2)
CTD	552970189	172092
Bottle	2737433	62927
Ferrybox	405073	191433
Mooring	111117863	129182
Profile	74411508	866032
Glider	21148692	31890
Profile (XX)	504	255

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 31/12/2022 is shown in Figure 19 for the different oxygen variables DOX1, DOXY and DOX2.. During the last decade we saw a noticeable increase 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 20.

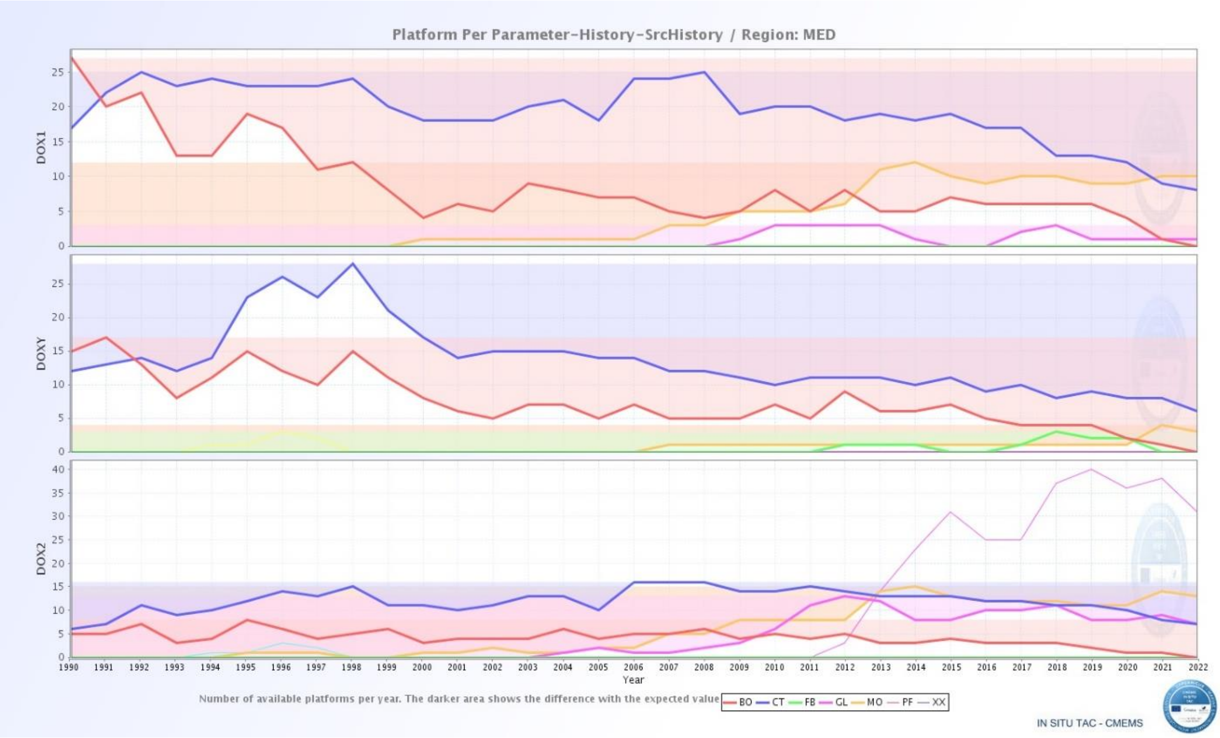

Figure 19 Number of platforms by type in the Mediterranean Sea containing all dissolved oxygen types (Y-axis, DOX1-upper panel, DOXY-middle panel and DOX2-lower panel) from the beginning of dataset up to now (time X-axis). Red: bottles (BO), blue CTD from vessels (CT), green: ferrybox (FB), magenta: gliders (GL), orange: moorings (MO), purple: profiles (PF) and light blue: profiles (XX).

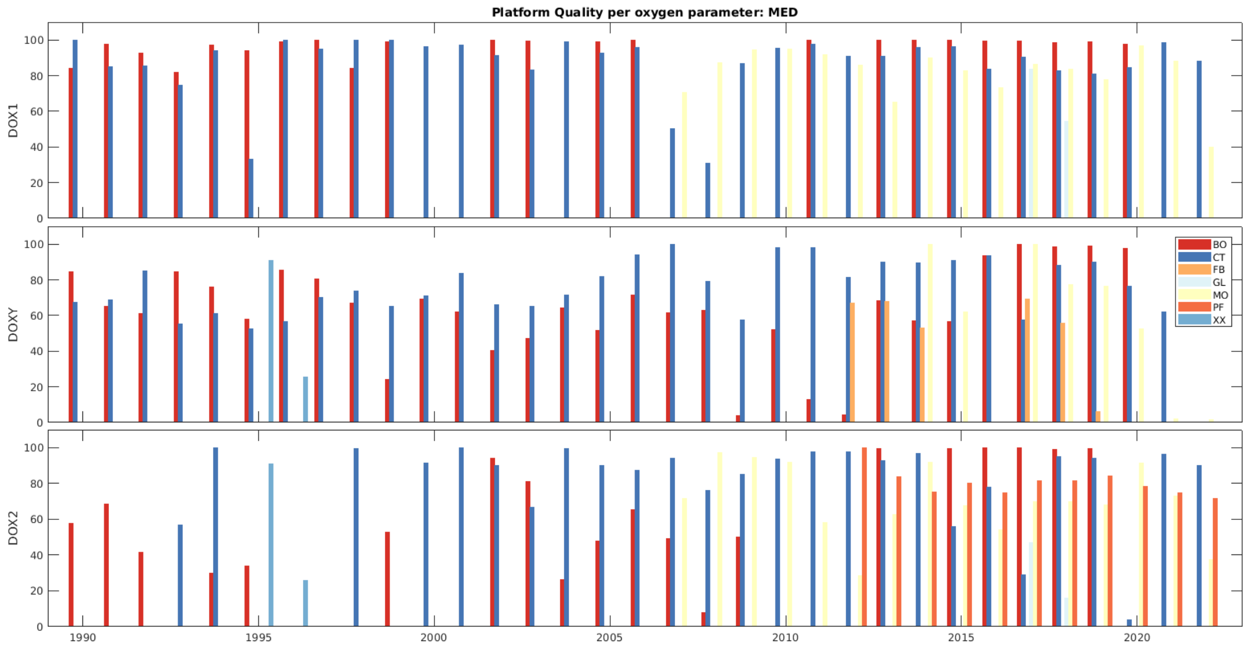

Figure 20: Data quality for DOX1, DOXY and DOX2 oxygen parameters in the Mediterranean region, from the beginning of the dataset up to now. Bars correspond to the percentage of good quality data (QC =1), while different colours represent the platform type:

Figure 21 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 21 are retrieved from the reprocessed product, while the red time series are the original data.

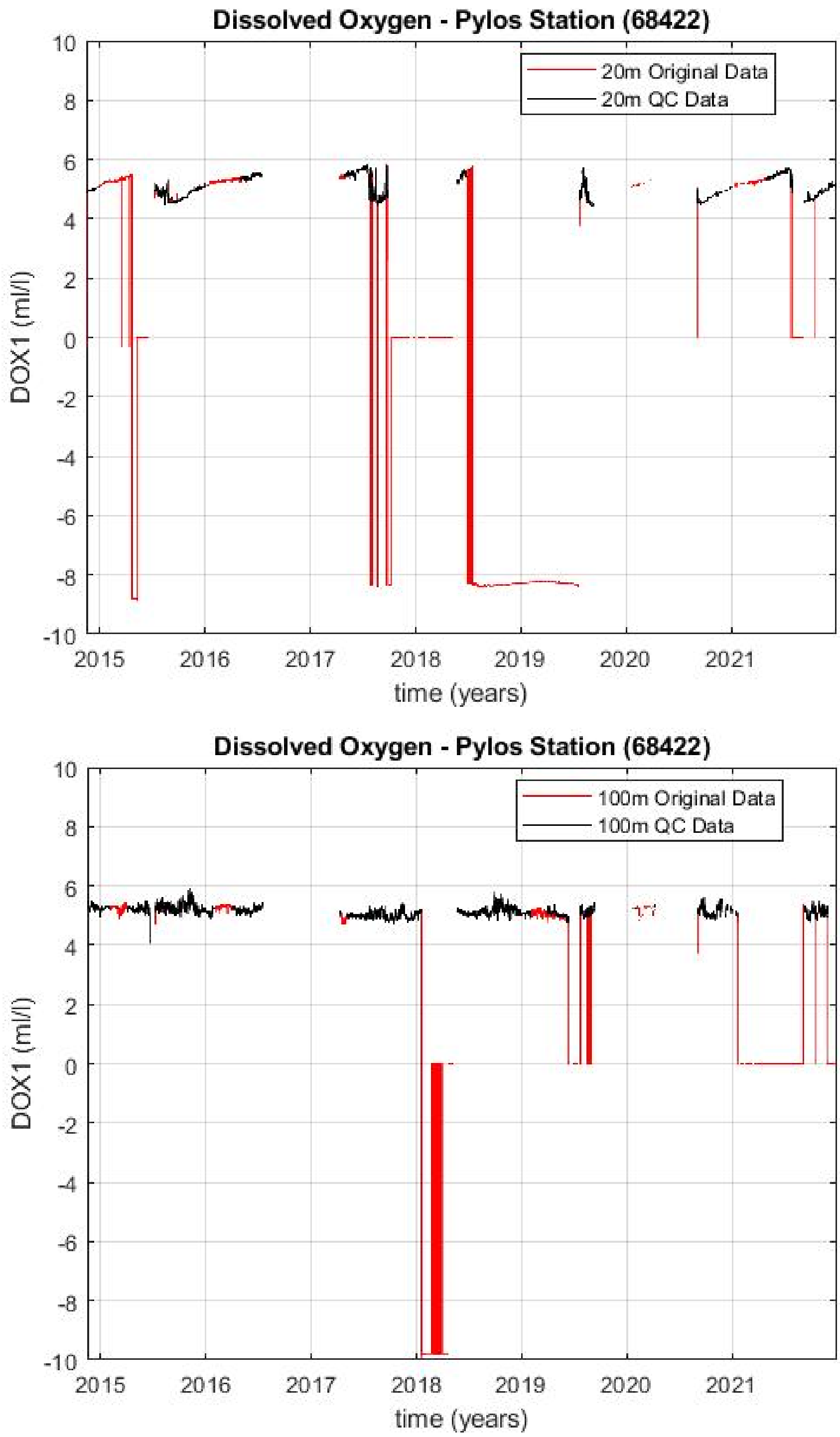

Figure 21: Dissolved oxygen data from Pylos station (68422) in the Mediterranean at 20m (top) and 100 m depth (bottom) from the beginning of data set up to now. Black colour represents the good quality (QC = 1) values after the application of the REP QC procedures, while red colour represents the rejected ones.

IV.4 Nutrients

IV.4.1 Validation results for nutrient data

IV.4.1.1 Changes in flags for the global nutrient data

In 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 through Table 22 in appendix 1 for range test limits and Table 3 for QC flag meanings. The tests performed on the global nutrient data, resulted in the following amounts of changes of quality control flags.

The range test (Section III.5.2.1) resulted in (QC=4) flagging of 1.1% of the 5.7 million valid Nitrate values, 0.01% of the 5.4 million valid Phosphate values, and 0.02% of the 4.0 million valid Silicate values.

No further profiles were detected by the nutrient profile test.

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

Similar to 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 in the Baltic region before and after testing.

Directory	**Variable**	**Percentage of data flagged bad**	
		before	after
Bottle	NTRA	2.8	3.67
	PHOS	0.1	5.08
	SLCA	0.19	1.75
CTD	PHOS	5.7	6.12
Profile (XX)	PHOS	0	0.01
	SLCA	0	0.04

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

During the validation procedure for nutrient data by 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 changes 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 entering each of these two tests as well as after the whole REP procedure are presented in Table 14 through 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	QC flags changed on Nitrate (incl. nitrite) data (%)	QC flags changed on Silicate data (%)	QC flags changed on Phosphate data (%)
CTD	0.0	0.0	0.0
Bottle	0.22	0.41	0.53
Ferrybox	-	-	-
Mooring	-	-	-
Profile	4.26	-	-
Glider	0.0	-	-
Profile (XX)	0.0	0.0	1.3

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

Platform type	QC flags changed on Nitrate (incl. nitrite) data (%)	QC flags changed on Silicate data (%)	QC flags changed on Phosphate data (%)
CTD	0.18	0.21	0.00
Bottle	2.53	0.91	1.41
Ferrybox	-	-	-
Mooring	-	-	-
Profile	9.49	-	-
Glider	0.0	-	-
Profile (XX)	7.88	6.85	10.13

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

Platform type	QC flags changed on Nitrate (incl. nitrite) data (%)	QC flags changed on Silicate data (%)	QC flags changed on Phosphate data (%)
CTD	0.18	0.21	0.00
Bottle	2.75	1.32	1.94
Ferrybox	-	-	-
Mooring	-	-	-
Profile	13.75	-	-
Glider	0.0	-	-
Profile (XX)	7.88	6.85	11.43

Table 17 : The effect on the QC flags of the data used to produce the reprocessed product of the nutrient data in the Mediterranean Sea by using Regional Test and Profile Test as described in previous sections.

Platform type	Total Nutrient values tested	Marked values (Test 1 & Test 2)
CTD	2099	3
Bottle	1819633	38533
Ferrybox	-	-
Mooring	-	-
Profile	612765	58128
Glider	90654	0
Profile (XX)	1363	115

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 22. For both parameters and platform types, the percentage of good quality data exceeds 90% in most years.

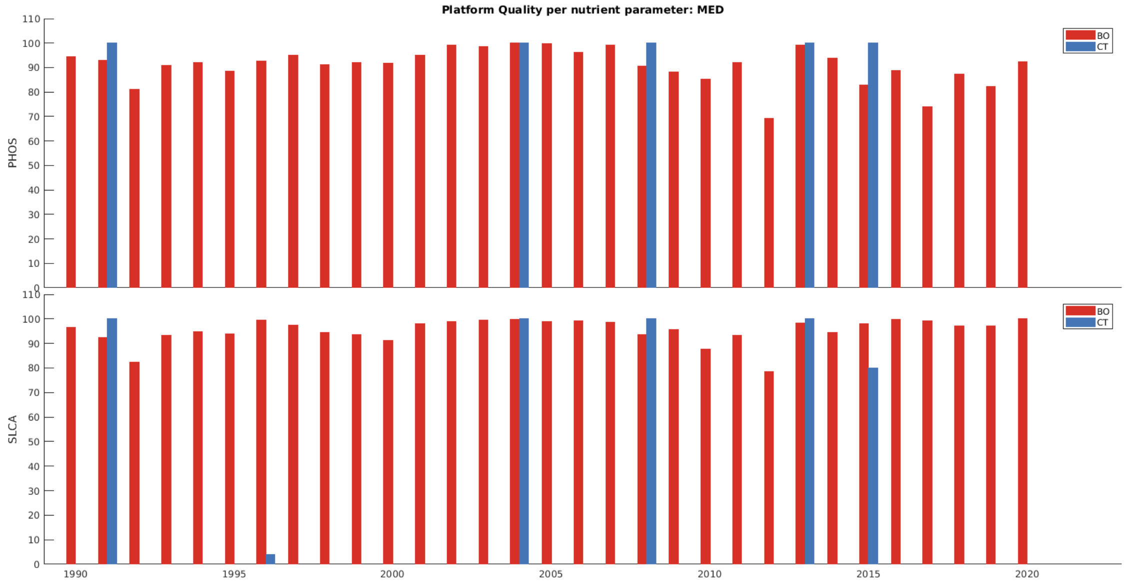

Figure 22: Data quality for PHOS (top) and SLCA (bottom) from the beginning of the dataset until now. Bars correspond to the percentage of good quality data, from CTD casts from vessels (red) and bottles (blue) in the Mediterranean Sea. For both parameters and platform types, the percentage of good quality data exceeds 90%.

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 from Version 1.0

Unlike physical variables, limits for chlorophyll concentration cannot be calculated directly from other physical values and an acceptable range must be set based on that found in a given biogeochemical area. In the previous reprocessing, coarse values were used for the upper acceptable limit, and these are too high for most of the global ocean, especially the pelagic regions, i.e., the open ocean. The approach taken here differs from the previous version of the reprocessed product, in that 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, as opposed to applying unrealistically wide global range tests with additional spike tests. In 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 this also gives us better precision in the surface waters where the highest variability in chlorophyll concentrations occur. 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% being to re-classify the data as QC level 1 ("good" data). This is discussed in detail in Section 0.

VI.1.2 Changes 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 on metadata level have been implemented as described in Section 0. 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 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 (in separate sub-folders) and associated quality control procedures for nutrient data have been implemented. Three nutrient parameters have been included: nitrate (NTAW, NTRA), silicate (SLCA), and phosphate (PHOS). 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 from Version 2.0

Updates to the quality control procedure for the oxygen data have been implemented. In addition, some changes to 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 – all data that got quality flag values '4' (bad data) by the NRT quality control procedure are kept at '4'.

VI.1.5 Changes from Version 2.1

Minor changes of the area of two of the regions, as well as minor changes to depth and range of some regions, based on the visual checks.

VI.1.6 Changes from Version 2.2

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

VI.1.7 Changes from Version 2.3

None.

VI.1.8 Changes from Version 2.4

Added river mouth detection algorithm for use in assessment during visual check of range of test results. This resulted in a more thorough visual check and less bad flags in such regions.

VI.1.9 Changes from Version 2.5

Included 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.

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VII.1 Auxiliary tables

Table 18 : The 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 not to 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
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

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 - 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: The ranges for the global range testing of oxygen in different regions and layers. The geographical regions are shown in Figure 12 and individual layer depths are indicated in the table. Missing Layer 2 indicates there are only two layers. Seasonality of limits (Layer 1 only) is indicated with the seasonal span of the limit. Mediterranean and Baltic Seas limits are set high not to interfere with the regional tests and are thus not in effect. (Table continues 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)	0.0-2.8	10.3-11.7	0-123	461-523	0-120	450-510
	Layer 2 (1500 m)	0.0	9.2	0	410	0	400
	Layer 3	3.9	8.5	174	379	170	370
Northern European Coast	Layer 1 (50 m)	0.0-3.9	9.9-11.5	0-174	441-513	0-170	430-500
	Layer 2 (800 m)	2.1	10.6	92	472	90	460
	Layer 3	4.6	8.0	205	359	200	350
Mediterranean Sea		0.0	23.0	0	1025	0	1000
Baltic Sea		0.0	23.0	0	1025	0	1000
Central Pacific	Layer 1 (100 m)	0.0-0.0	9.2-11.2	0-0	410-502	0-0	400-490
	Layer 2 (800 m)	0.0	10.1	0	451	0	440
	Layer 3	0.0	5.0	0	225	0	220
Southern Mid Latitudes	Layer 1 (100 m)	0.0-0.0	10.5-13.8	0-0	471-615	0-0	460-600
	Layer 2 (1500 m)	0.0	11.2	0	502	0	490
	Layer 3	1.8	7.3	82	328	80	320
Southern Ocean	Layer 1 (100 m)	0.0-4.8	10.5-13.8	0-215	471-615	0-210	460-600
	Layer 2 (1000 m)	0.0	13.3	0	595	0	580
	Layer 3	2.3	7.6	102	338	100	330
North Pacific	Layer 1 (100 m)	0.0-0.0	13.1-13.8	0-0	584-615	0-0	570-600
	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)	0.0-4.6	10.3-13.8	0-205	461-615	0-200	450-600
	Layer 3	4.6	9.6	205	430	200	420
Subpolar Gyre region	Layer 1 (100 m)	0.0-0.0	11.5-13.8	0-0	513-615	0-0	500-600
	Layer 2 (800 m)	0.0	11.7	0	523	0	510
	Layer 3	4.1	8.7	184	389	180	380

Region	Layer (layer bottom depth)	DOX1 (ml/l)		DOXY (µmol/l)		DOX2 (µmol/kg)	
		low	high	low	high	low	high
Arctic Ocean	Layer 1 (100 m)	2.3-2.3	11.2-18.1	102-102	502-810	100-100	490-790
	Layer 2 (800 m)	0.0	12.4	0	554	0	540
	Layer 3	5.5	8.5	246	379	240	370
Chukchi Sea	Layer 1 (100 m)	0.0-3.0	12.2-13.8	0-133	543-615	0-130	530-600
	Layer 2 (800 m)	3.7	9.0	164	400	160	390
	Layer 3	6.0	7.3	267	328	260	320
Black Sea	Layer 1 (40 m)	0.0-0.0	11.7-13.8	0-0	523-615	0-0	510-600
	Layer 2 (100 m)	0.0	11.9	0	533	0	520
	Layer 3	0.0	6.9	0	308	0	300
Canadian Archipelago	Layer 1 (50 m)	0.0-1.8	11.7-13.8	0-82	523-615	0-80	510-600
	Layer 2 (800 m)	0.0	12.9	0	574	0	560
	Layer 3	0.0	7.6	0	338	0	330
Indian Ocean	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	9.7	0	431	0	420
	Layer 3	0.0	5.5	0	246	0	240
Central Atlantic Ocean	Layer 1 (100 m)	2.3-2.5	7.6-8.0	103-113	338-359	100-110	330-350
	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	6.9	0	308	0	300
	Layer 3	0.0	4.8	0	215	0	210
Sea of Okhotsk	Layer 1 (50 m)	0.0-6.0	10.6-13.8	0-267	472-615	0-260	460-600
	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)	0.0-3.0	11.0-13.8	0-133	492-615	0-130	480-600
	Layer 2 (1000 m)	0.0	11.0	0	492	0	480
	Layer 3	3.0	7.3	133	328	130	320
Norwegian Sea	Layer 1 (100 m)	2.8-4.4	9.0-12.4	123-195	400-554	120-190	390-540
	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	11.7-13.8	0-0	523-615	0-0	510-600
	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	11.7-13.8	0-0	523-615	0-0	510-600
	Layer 2 (1500 m)	0.0	11.2	0	502	0	490
	Layer 3	3.4	7.1	154	318	150	310
Caribbean	Layer 1 (100 m)	0.0-0.0	8.7-11.5	0-0	390-513	0-0	380-500
	Layer 2 (1500 m)	0.0	8.0	0	359	0	350
	Layer 3	2.8	9.0	123	400	120	390
Indonesian Region	Layer 1 (100 m)	0.0-0.0	8.3-9.2	0-0	369-410	0-0	360-400
	Layer 2 (800 m)	0.0	7.3	0	328	0	320
	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	9.4	0	420	0	410
	Layer 3	0.0	4.8	0	215	0	210
South Pacific	Layer 1 (100 m)	0.0-0.0	7.8-11.5	0-0	349-513	0-0	340-500
	Layer 2 (1500 m)	0.0	11.2	0	502	0	490
	Layer 3	0.0	5.5	0	246	0	240

Region	Layer (layer bottom depth)	DOX1 (ml/l)		DOXY (µmol/l)		DOX2 (µmol/kg)	
		low	high	low	high	low	high
Central European Coast	Layer 1 (50 m)	0.0-0.0	9.7-13.3	0-0	431-595	0-0	420-580
	Layer 2 (1000 m)	1.8	9.7	82	431	80	420
	Layer 3	2.3	8.0	102	359	100	350

Table 20: The ranges for the global range testing of nitrate in different regions and layers. The geographical regions are shown in Figure 14 and individual layer depths are indicated in the table. Missing Layer 2 indicates there are only two layers. Seasonality of limits (Layer 1 only) is indicated with the seasonal span of the limit. Mediterranean and Baltic Seas limits are set high not to interfere with the regional tests and are thus not in effect. (Table continues next page.)

Region	Layer (layer bottom depth)	NTRA (µmol/l)		NTAW (µmol/kg)	
		low	high	low	high
Southern Ocean	Layer 1 (50 m)	0-22	38-69	0-21	37-67
	Layer 2 (800 m)	0	63	0	61
	Layer 3	25	41	24	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	15-23	0-0	15-22
	Layer 3	0	26	0	25
Northern Cold Water	Layer 1 (50 m)	0-0	26-37	0-0	25-36
	Layer 2 (300 m)	0	56	0	55
	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	70	0	68
Baltic Sea		0	1024	0	999
Southern Cold Water	Layer 1 (100 m)	0-0	42-71	0-0	41-69
	Layer 2 (1000 m)	0	58	0	57
	Layer 3	12	46	12	45
North Atlantic	Layer 1 (50 m)	0-0	23-40	0-0	22-39
	Layer 2 (4000 m)	0	34	0	33
	Layer 3	16	29	16	28
Northern European Coast	Layer 1 (50 m)	0-0	24-34	0-0	23-33
	Layer 2 (800 m)	0	34	0	33
	Layer 3	10	21	10	20
Northern Atlantic Cold Water	Layer 1 (50 m)	0-0	32-46	0-0	31-45
	Layer 2 (4000 m)	0	39	0	38
	Layer 3	19	26	19	25
Pacific Northern Cold Water	Layer 1 (50 m)	0-0	41-74	0-0	40-72
	Layer 2 (1000 m)	0	82	0	80
	Layer 3	23	63	22	61
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

Region	Layer (layer bottom depth)	NTRA (µmol/l)		NTAW (µmol/kg)	
		low	high	low	high
Arctic Coasts	Layer 1 (50 m)	0-0	41-62	0-0	40-60
	Layer 2 (800 m)	0	81	0	79
	Layer 3	11	19	11	19
Temperate Australasia	Layer 1 (50 m)	0-0	17-29	0-0	17-28
	Layer 2 (800 m)	0	53	0	52
	Layer 3	13	53	13	52
Mediterranean		0	1024	0	999
Tropical Atlantic	Layer 1 (100 m)	0-0	9-40	0-0	9-39
	Layer 2 (1500 m)	0	67	0	65
	Layer 3	12	29	12	28
Temperate Southern Africa	Layer 1 (50 m)	0-0	62-72	0-0	60-70
	Layer 2 (1000 m)	0	67	0	65
	Layer 3	13	42	13	41
Caspian Sea	Layer 1 (50 m)	0-0	3-11	0-0	3-11
	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	55	26	54
Western Indo-Pacific	Layer 1 (100 m)	0-0	46-72	0-0	45-70
	Layer 2 (1000 m)	0	55	0	54
	Layer 3	25	51	24	50
Indo-Pacific Warm Water	Layer 1 (50 m)	0-0	28-39	0-0	27-38
	Layer 2 (1000 m)	0	81	0	79
	Layer 3	19	58	19	57
Atlantic Warm Water	Layer 1 (100 m)	0-0	53-72	0-0	52-70
	Layer 2 (1500 m)	0	69	0	67
	Layer 3	0	45	0	44
Canadian Archipelago	Layer 1 (100 m)	0-0	21-31	0-0	20-30
	Layer 3	0	42	0	41
Temperate Northern Atlantic	Layer 1 (100 m)	0-0	35-41	0-0	34-40
	Layer 2 (800 m)	0	72	0	70
	Layer 3	0	38	0	37

Table 21: The ranges for the global range testing of phosphate in different regions and layers. The geographical regions are shown in Figure 14 and individual layer depths are indicated in the table. Missing Layer 2 indicates there are only two layers. Seasonality of limits (Layer 1 only) is indicated with the seasonal span of the limit. Mediterranean and Baltic Seas limits are set high not to interfere with the regional tests and are thus not in effect. (Table continues 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	4.6	0.0	4.5
	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	6.5	0.0	6.3
	Layer 3	1.4	4.5	1.4	4.4
Black Sea	Layer 1 (100 m)	0.0-0.0	7.1-9.7	0.0-0.0	6.9-9.5
	Layer 3	0.0	14.3	0.0	14.0
Northern Cold Water	Layer 1 (50 m)	0.0-0.0	2.4-4.2	0.0-0.0	2.3-4.1
	Layer 2 (300 m)	0.0	6.9	0.0	6.7
	Layer 3	0.0	2.8	0.0	2.7
Tropical Eastern Pacific	Layer 1 (50 m)	0.0-0.0	3.1-4.7	0.0-0.0	3.0-4.6
	Layer 2 (1500 m)	0.0	5.7	0.0	5.6
	Layer 3	1.0	5.1	1.0	5.0
Temperate South America	Layer 1 (50 m)	0.0-0.0	6.0-7.5	0.0-0.0	5.9-7.3
	Layer 2 (1000 m)	0.0	6.3	0.0	6.1
	Layer 3	0.0	5.5	0.0	5.4
Baltic Sea		0.0	1024	0	999
Southern Cold Water	Layer 1 (200 m)	0.0-0.0	4.6-5.8	0.0-0.0	4.5-5.7
	Layer 2 (1000 m)	0.0	5.3	0.0	5.2
	Layer 3	0.0	3.9	0.0	3.8
North Atlantic	Layer 1 (50 m)	0.0-0.0	2.0-4.1	0.0-0.0	2.0-4.0
	Layer 2 (4000 m)	0.0	2.7	0.0	2.6
	Layer 3	0.0	2.4	0.0	2.3
Northern European Coast	Layer 1 (50 m)	0.0-0.0	2.0-2.3	0.0-0.0	2.0-2.2
	Layer 2 (800 m)	0.0	2.4	0.0	2.3
	Layer 3	0.0	1.6	0.0	1.6
Northern Atlantic Cold Water	Layer 1 (50 m)	0.0-0.0	2.4-2.9	0.0-0.0	2.3-2.8
	Layer 2 (4000 m)	0.0	2.6	0.0	2.5
	Layer 3	1.0	2.0	1.0	2.0
Pacific Northern Cold Water	Layer 1 (100 m)	0.0-0.0	5.4-6.3	0.0-0.0	5.3-6.1
	Layer 2 (1000 m)	0.0	7.1	0.0	6.9
	Layer 3	0.0	5.7	0.0	5.6
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	4.1-8.7	0.0-0.0	4.0-8.5
	Layer 2 (800 m)	0.0	5.8	0.0	5.7
	Layer 3	0.0	1.8	0.0	1.8
Temperate Australasia	Layer 1 (50 m)	0.0-0.0	2.5-3.9	0.0-0.0	2.4-3.8
	Layer 2 (800 m)	0.0	3.8	0.0	3.7
	Layer 3	0.0	4.5	0.0	4.4
Mediterranean		0.0	1024	0	999
Tropical Atlantic	Layer 1 (100 m)	0.0-0.0	1.7-2.4	0.0-0.0	1.7-2.3
	Layer 2 (1500 m)	0.0	4.5	0.0	4.4
	Layer 3	0.0	2.0	0.0	2.0
Temperate Southern Africa	Layer 1 (50 m)	0.0-0.0	5.0-5.8	0.0-0.0	4.9-5.7
	Layer 2 (1500 m)	0.0	5.3	0.0	5.2

Region	Layer (layer bottom depth)	PHOS (µmol/l)		PHOW (µmol/kg)	
		low	high	low	high
	Layer 3	0.0	3.6	0.0	3.5
Caspian Sea	Layer 1 (100 m)	0.0-0.0	1.2-3.8	0.0-0.0	1.2-3.7
	Layer 3	0.0	2.3	0.0	2.2
Temperate Northern Pacific	Layer 1 (100 m)	0.0-0.0	6.0-6.9	0.0-0.0	5.9-6.7
	Layer 2 (1500 m)	0.0	6.8	0.0	6.6
	Layer 3	0.0	4.3	0.0	4.2
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	6.7	0.0	6.5
	Layer 3	1.9	3.8	1.9	3.7
Western Indo-Pacific	Layer 1 (100 m)	0.0-0.0	4.8-6.2	0.0-0.0	4.7-6.0
	Layer 2 (1500 m)	0.0	5.8	0.0	5.7
	Layer 3	1.1	3.9	1.1	3.8
Indo-Pacific Warm Water	Layer 1 (50 m)	0.0-0.0	3.0-4.8	0.0-0.0	2.9-4.7
	Layer 2 (1500 m)	0.0	6.2	0.0	6.0
	Layer 3	0.0	4.3	0.0	4.2
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	5.0	0.0	4.9
	Layer 3	0.0	3.4	0.0	3.3
Canadian Archipelago	Layer 1 (100 m)	0.0-0.0	1.8-3.9	0.0-0.0	1.8-3.8
	Layer 3	0.0	2.9	0.0	2.8
Temperate Northern Atlantic	Layer 1 (100 m)	0.0-0.0	2.7-4.1	0.0-0.0	2.6-4.0
	Layer 2 (800 m)	0.0	4.7	0.0	4.6
	Layer 3	0.0	2.6	0.0	2.5

Table 22: The ranges for the global range testing of silicate in different regions and layers. The geographical regions are shown in Figure 14 and individual layer depths are indicated in the table. Missing Layer 2 indicates there are only two layers. Seasonality of limits (Layer 1 only) is indicated with the seasonal span of the limit. Mediterranean and Baltic Seas limits are set high not to interfere with the regional tests and are thus not in effect. (Table continues 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	31-103	0-0	30-100
	Layer 3	0	31	0	30
Tropical Eastern Pacific	Layer 1 (100 m)	0-0	82-82	0-0	80-80
	Layer 2 (1500 m)	0	144	0	140
	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	164	0	160
	Layer 3	0	215	0	210
Baltic Sea		0	1025	0	1000

Region	Layer (layer bottom depth)	SLCA (µmol/l)		SLCW (µmol/kg)	
		low	high	low	high
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	31	62	30	60
Northern European Coast	Layer 1 (50 m)	0-0	21-31	0-0	20-30
	Layer 2 (100 m)	0	21	0	20
	Layer 3	0	31	0	30
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	103-215	0-0	100-210
	Layer 2 (1000 m)	0	256	0	250
	Layer 3	51	256	50	250
Central European Coast	Layer 1 (50 m)	0-0	31-72	0-0	30-70
	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	195	0	190
	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		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 3	0	185	0	180
Caspian Sea	Layer 1 (100 m)	0-0	51-103	0-0	50-100
	Layer 3	0	92	0	90
Temperate Northern Pacific	Layer 1 (100 m)	0-0	154-195	0-0	150-190
	Layer 2 (1500 m)	0	256	0	250
	Layer 3	0	256	0	250
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	164	0	160
	Layer 3	51	195	50	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	41	236	40	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	82-82	0-0	80-80
	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 : The 99th percentile values calculated for the coastal Marine Ecoregions of the World (MEOW) provinces using data only for Jan-Mar from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the coastal (MEOW) provinces using data only for Apr-Jun from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the coastal (MEOW) provinces using data only for Jul-Sep from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the coastal (MEOW) provinces using data only for Oct-Dec from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the Pelagic Provinces of the World (PPOW) provinces using data only for Jan-Mar from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the pelagic (PPOW) provinces using data only for Apr-Jun from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the pelagic (PPOW) provinces using data only for Jul-Sep from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the pelagic (PPOW) provinces using data only for Oct-Dec from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the Coastal (MEOW) provinces using data for Jan-Dec from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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 : The 99th percentile values calculated for the pelagic (PPOW) provinces using data for Jan-Dec from the Gregg and Conkright (2001) data set, and QC level 0,1 and 2 data for CPHL and FLU2 for 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) for the Large Marine Ecosystem provinces (LME) of 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. The number given in brackets is that of the LME. Also shown are the 99th percentile values for the 0-100 m CPHL and FLU2 data (where available) calculated here and the closest corresponding province from the Spalding et al. (2007) classification to that of the LME classification

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 : The area of each province in square kilometres, and the percentage expressed relative to the total global ocean area.

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%

VII.2 Example source code to convert pressure to depth

```
/* Example C code to convert pressure measurment 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);
}
```