United Nations
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Intergovernmental
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Commission

Workshop Report No. 228

First IODE Workshop on Quality Control of Chemical Oceanographic Data Collections

IOC Project Office for IODE, Oostende, Belgium
8-11 February 2010

UNESCO 2010

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English

Participants from **left to right back row:** Hjalte Parner, Alexander Kuznetsov, David Terhell, Lars Storm, Reiner Schlitzer, Andrew Pascall, Mary Kennedy, Cyndy Chandler, Laure Devine, Bill Burnett; **middle row:** Miriam Solis, Gwenaëlle Moncoiffé; **front row:** Ali Mehdinia, Johan Håkansson, Hernan Garcia, Peter Pissierssens, Sergey Konovalov, Satoshi Yamao, Mutshutshu Tsanwani, Alexander Smirnov.

Abstract:
The IODE workshop on quality control (QC) of chemical oceanographic data collections was held at the IOC Project Office for IODE in Oostende, Belgium between 8 and 11 February 2010. The meeting, proposed and organized by the IODE Group of Experts on Biological and Chemical Data Management and Exchange Practices (GE-BICH), welcomed 19 experts in chemical data management as well as data producers and users from 13 countries. The objective of the workshop was to evaluate existing procedures and define a minimum set of QC tests and criteria for dissolved inorganic nutrients (phosphate, silicate, nitrate+nitrite, nitrate, nitrite, and ammonium) and dissolved oxygen in seawater. The meeting produced several outcomes. First, the meeting identified two proposals to be submitted to the IODE/JCOMM Ocean Data Standards process (1) a quality control flags scheme based on quantifiable and subjective tests; and (2) at a later stage and following consultation with the wider community, a scaled nomenclature for data processing levels for data held at data centers. The meeting also issued a number of recommendations which will be taken forward in post-workshop activities in consultation and in interaction with the wider international community. These included: (1) metadata terminology for reporting measured variables and their units as well as (2) a work plan to recommend a minimum set of numerically defined QC tests that could be adjusted to reflect broad regional to basin scales conditions. These guidelines and recommendations will be assembled on the GE-BICH wiki for peer-review before being published as a technical white paper or guideline document.

For bibliographic purposes this document should be cited as follows:

First IODE Workshop on Quality Control of Chemical Oceanographic Data Collections, IOC Project Office for IODE, Oostende, Belgium, 8-11 February 2010
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1960-2010

The Intergovernmental Oceanographic Commission (IOC) of UNESCO celebrates its 50th anniversary in 2010. Since taking the lead in coordinating the International Indian Ocean Expedition in 1960, the IOC has worked to promote marine research, protection of the ocean, and international cooperation. Today the Commission is also developing marine services and capacity building, and is instrumental in monitoring the ocean through the Global Ocean Observing System (GOOS) and developing marine-hazards warning systems in vulnerable regions. Recognized as the UN focal point and mechanism for global cooperation in the study of the ocean, a key climate driver, IOC is a key player in the study of climate change. Through promoting international cooperation, the IOC assists Member States in their decisions towards improved management, sustainable development, and protection of the marine environment.

1. OPENING OF THE MEETING

1.1 Introduction of participants

The meeting was attended by 19 scientists from 13 countries who were users, managers or producers of chemical oceanographic data (Table 1). The participants were chosen on the basis of their expertise and geographic distribution, with the aim to have a range of contributors from northern and southern hemispheres regions and from Atlantic, Pacific and regional seas areas.

Participants name	Organisation and country	DM	DP	DU
Bill Burnett	NOAA National Data Buoy Center, USA	x		
Cyndy Chandler	Biological and Chemical Oceanography Data Management Office, WHOI, USA	x		
Laure Devine	Institut Maurice-Lamontagne, Canada	x		
Hernan Garcia	US-NODC, World Data Center, Silver Spring, USA	x		x
Johan Håkansson	SMHI Oceanography Laboratory, Sweden	x		
Mary Kennedy	Bedford Institute of Oceanography, Canada	x		
Sergey Konovalov	Marine Hydrophysical Institute, Ukraine		x	
Alexander Kuznetsov	All-Russian Research Institute, World Data Center, Obninsk, Russian Federation	x		
Ali Mehdinia	Iranian Oceanographic Data Center, Iran	x	x	
Gwen Moncoiffé	British Oceanographic Data Centre, UK	x		
Hjalte Parner	International Council for the Exploration of the Sea (ICES)	x		
Andrew Pascall	Council for Scientific and Industrial Research, South Africa		x	
Reiner Schlitzer	Deutsches Ozeanographisches Datenzentrum, Germany	x		x
Alexander Smirnov	Arctic and Antarctic Research Institute, Roshydromet, Russian Federation			x
Miriam Solis	Centro Nacional Patagonico, Argentina		x	
Lars Storm	National Environment Research Institute, Denmark	x		
David Terhell	CSIRO Marine and Atmospheric Research, Australia		x	
Mutshutshu Tsanwani	Department of Environmental Affairs and Tourism, Marine and Coastal Management, South Africa		x	
Satoshi Yamao	Ocean Research Laboratory, Japan Coast Guard, Japan		x	

Table 1. Data managers (DM), data producers (DP), and data users (DU) participants at the IODE workshop on QC of chemical oceanographic data (see also Annex II).

1.2 Adoption of the agenda and presentation of the workshop format.

The format of the meeting was designed to promote discussion on targeted issues. Four issues were targeted:

1- Quality control checks and procedures
2- QC flags schemes
3- Strategy for handling common QC issues
4- Units and minimum metadata requirement for data reporting and exchange

The agenda is provided in Annex I of this report. The workshop started on Monday 8th February 2010 at 09:00 am and ended on Thursday 11 February 12:30 pm. The first two and a half days were reserved for presentations and discussion about the targeted issues. Each session had a designated chair who made an introductory presentation on the subject and led the discussions. Additional presentations were made by workshop participants to inform the meeting on relevant issues. Presentations are available online on the GE-BICH wiki (http://sites.google.com/site/gebichwiki/data-qa-qc/qa-qc-workshop/).

On the third day, a wrap up session was carried out to decide on a set of minimum requirements for the QC of chemical oceanographic data. The last half day was spent deciding on short-term actions and planning the way forward.

A clarification was made at the beginning of the meeting that the workshop was to focus on post-analytical QC procedures and it was not intended to set up guidelines for analytical or sampling procedures. These must remain the responsibility of the data collectors and of the appropriate expert communities. However one of the main outcome of this workshop and of the subsequent activities will be a recommendation on how sampling and analytical procedures should be reported.

1.3 Background to the workshop

Data QA/QC was discussed at the 4th session of the IOC/IODE Group of Experts on Biological and Chemical Data Management and Exchange Practices (GE-BICH), Oostende, Belgium, 27-30 January 2009 (IOC/IODE-BICH-IV/3, 2009). The Group identified a need to develop guidelines for the QC of chemical oceanographic data collections held at data centres. Previous publications and reports showed that there was relatively little work done on agreed standard QC checks for chemical data and no agreed IODE quality assurance strategy (e.g., UNESCO, 1993; Pissierssens, 2007; UNESCO, 2007; IODE/JCOMM, 2008). The GE-BICH group recommended that IODE sponsored a workshop which would bring together experts from oceanographic data centers, universities, and research laboratories who have direct experience in the processing and QC/QA of chemical oceanographic data. In addition, the group recommended and initiated an informal web-based wiki (http://sites.google.com/site/gebichwiki/) to promote open discussion on issues relevant to biological and chemical data management and exchange practices. This wiki served to collate background documents prior to the workshop (e.g., Conkright et al. 1994; Boyer and Levitus, 1994; Boyer et al., 2009; Garcia et al. 2006a,b).

In order to keep the discussions focused, it was decided that in a first instance, the effort will concentrate on the QC/QA of discrete measurements of *in situ* dissolved inorganic nutrients (phosphate, nitrate, nitrite, silicate, and later ammonium) and dissolved oxygen concentrations. These variables were chosen as proof of concept that progress could be made later on with other chemical parameters.

2. OVERVIEW, DISCUSSIONS AND RECOMMENDATIONS

2.1 Quality control checks and procedures

Session chair: Hernan Garcia

The session included presentations by H. Garcia (overview of quality control checks and issues at the data centre level as part of the World Ocean Database and Atlas series), A. Koutzenov (example of using statistical methods to derive data ranges), L. Devine (quality control conducted at the laboratory level), and B. Burnett (QA/QC requirements and strategy for the Integrated Ocean Observing System). Presentations are available from http://sites.google.com/site/gebichwiki/data-qa-qc/qa-qc-workshop/ .

2.1.1 What QC schemes exist at data centers and elsewhere?

A compilation of typical automated and subjective quality control (QC) checks carried out at data centers and research laboratories was prepared by H. Garcia and L. Devine before the meeting and distributed to participants. This list was used as a basis for selecting a minimum set of quantifiable QC checks (see Section 2.1.2).

Outcome: Compilation list of some QC checks (see Annex III)

Annex III contains two types of tests: 1) tests for station headers and 2) tests for variable data values. While tests on variable data values were what the workshop needed to focus on, station metadata QC checks is a pre-requisite to the quality control of the data values.

The group recommended that the QC tests of the sampling location metadata be done in accordance with existing protocols such as GTSPP protocol (IOC manuals and Guides 22 1990, IOC manuals and Guides 22 Second Revised Edition 2009) which includes the following tests:

1.1 Platform Identification
1.2 Impossible Date/Time
1.3 Impossible Location
1.4 Position on Land
1.5 Impossible Speed
1.6 Impossible Sounding (when available)

2.1.2 Do we all agree on minimum and quantifiable QC checks? (e.g., what specific QC tests should be chosen? Can we recommend the adoption of a common global and basin-scale data range limits?)

From the list of tests to be applied to variable data (Annex III), the group recommended the following four quantifiable data QC checks for variables as a minimum:

(1) data range checks;
(2) excessive gradient;
(3) excessive spike;
(4) no gradient.

In this context, quantifiable tests are a mean to assign a metric to qualify measured data quality. These tests need to be applicable to both vertical profiles and time-series/horizontal distributions. The group noted that at present there is no simple way to determine the accuracy of nutrient and oxygen data already available at data centres without independent means (e.g., using certified reference material for nutrients and oxygen data).

2.1.2.1 Range checks

For data range checks, the group discussed the possibility of applying either a fixed data range (global, regional, or local scales), or a statistical range based on a fixed number of standard deviation (SD) from a reference statistical mean (e.g. from a climatology) (Figure 1). Because of data scarcity (in time and/or space) particularly for dissolved inorganic nutrients, the group recommended not to use a statistical SD based range check.

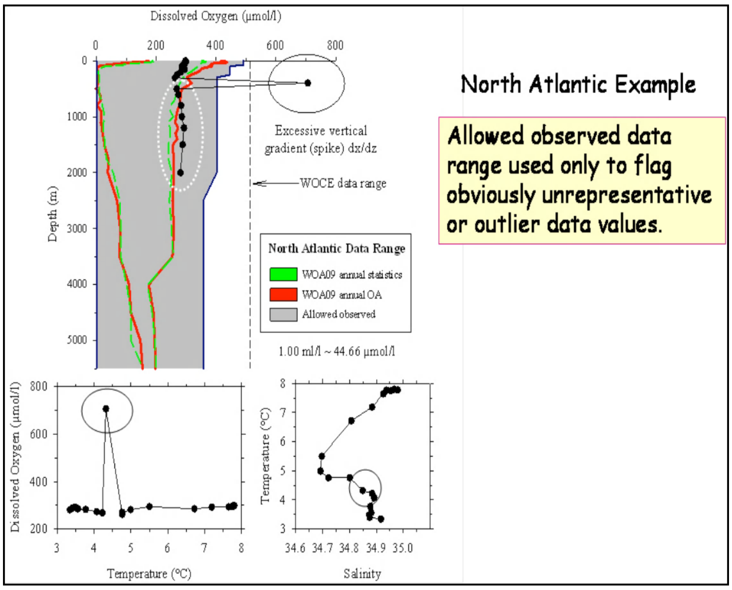

Figure 1. Hypothetical example of using different fixed data ranges and excessive gradients to QC observed data in the North Atlantic.

The group also discussed using density as a reference variable (e.g. QC tests along isopycnals). However, a large number of nutrient and oxygen data at data centres do not include sufficient information to carry out QC tests as a function of density.

The group concluded that currently, the best practical option would be to use a fixed data range as a function of depth as used for example, in the World Ocean Database 2009 (WOD09; Boyer et al. 2009).

As a starting point it was agreed to use the depth-resolved data ranges developed as part of the WOD09 for oxygen, phosphate, silicate, and nitrate (see Annex IV of this report which contains tables 9.3, 9.4, 9.5, and 9.6 extracted from WOD9 Appendix 9, Boyer et al. 2009).

A working group will be formed to further test the suitability of these ranges.

2.1.2.2 Excessive gradients

Excessive gradients checks can be applied to profiles and time-series of nutrients and oxygen. These checks require as a pre-requisite that the depth (or time) channel has passed the increasing depth (or time) test.

For profiles, WOD09 (Boyer et al 2009) includes a check for "excessive decreases and increases in a value over a depth range", or excessive gradients and which is defined as

$$gradient = \frac{v_2 - v_1}{z_2 - z_1} \tag{1}$$

where in Equation (1)

v1 = the value of the variable at the current depth level

v2 = the value of the variable at the next depth level

z1 = the depth (meters) of the current depth level

z2 = the depth (meters) of the next depth level

Maximum gradient and inversion values have been developed for phosphate and nitrate for sampling depths >400 m and <400 m (Table 2). For oxygen, silicate and ammonium, maximum gradient and inversion values need to be proposed.

VARIABLE	Maximum Inversion Value (z<400m)	Maximum Gradient Value (z<400m)	Maximum Inversion Value (z>400m)	Maximum Gradient Value (z>400m)
Oxygen	checks not available			
Phosphate	1.000	1.000	0.500	0.500
Silicate	checks not available			
Nitrate and Nitrate+Nitrite	1.000	1.000	0.500	0.500
Ammonium	checks not available			

Table 2. Maximum gradient and inversion factors used for WOD09. Excessive gradients represent a negative excessive gradient in the value over depth. Excessive inversions represent a positive excessive gradient in value over depth.

The group agreed that these values would be used as a starting point. They will be tested further before being recommended as part of a standard procedure. The group also agreed to develop excessive gradient/inversion checks for oxygen, silicate and ammonium. Similar gradient checks could be applied to time-series measurements.

2.1.2.3 Excessive spike checks

The group identified the need for a spike check.

The formula proposed is the same as that described in WMO/IOC Manuals and Guides #3, and used by GTSPP 2.7 Spike Test and QARTOD:

$$\text{test value} = \left| V_2 - \frac{(V_3 + V_1)}{2} \right| - \left| \frac{(V_3 - V_1)}{2} \right| \qquad (2)$$

Where in Equation (2), V_2 is the measurement being tested as a spike, and V_1 and V_3 are the values previous and next. If test value is greater than a given threshold then V_2 fails the spike test.

The group was not aware of any existing recommended threshold values for nutrients and oxygen, and agreed that a first set of threshold values needed to be defined.

2.1.2.4 Summary

As a summary the meeting proposed the following minimum quantifiable quality control checks based upon WOD09 or more appropriate local climatologies:

1- range checks on observed data based on the depth-resolved acceptable ranges;
2- excessive gradient (vertical and otherwise) based on WOD09 limits. These limits will be checked for suitability by the user community;
3- excessive spike based on threshold values still to be defined;
4- no gradient (constant values).

The criteria associated with these checks will be developed further during post-workshop activities.

Follow-up actions: A subgroup composed of Alexander Kuznetsov, Bill Burnett, Gwen Moncoiffé and Hernan Garcia was formed to further test the suitability of WOD09 data ranges for nitrate+nitrite, phosphate, silicate, and dissolved oxygen, and gradient limits for nitrate+nitrite and phosphate. Gradient limits will be developed for dissolved oxygen and silicate. Spike metric checks will be developed for all nutrients and for oxygen as these do not appear to be readily available. In the case of ammonia, new data ranges, gradient and spike checks will have to be developed, as these do not appear to be readily available neither.

2.1.3 Additional quality control checks and procedures

Session chair: Laure Devine

Discussion in this section focused on criteria and QC tests which were not considered part of the minimum requirement under section 2.1.2 but which would be considered a desirable addition to any QC procedures of nutrients and dissolved oxygen datasets.

The Group recommended the following:

Recommendation 1: to develop data ranges at different spatial scales ranging from basin to regions to improve QC checks (objective tests).

Recommendation 2: to use property-property plots such as nitrate versus phosphate, nitrate vs. temperature, oxygen vs. temperature, depth or time plots as a mean to visually check the data (subjective tests).

Recommendation 3: when available we recommend the use of local climatologies as a quantitative or visual guide.

Recommendation 4: to seek community-wise effort to develop less subjective tests.

Recommendation 5: to compile a list of available statistical and objectively analyzed climatologies available such as Brickman and Petrie 2003, World Ocean Atlas 2009, Hydrobase, GLODAP, Gouretski and Koltermann 2004, the Baltic Atlas of long term inventory and climatology, Oceanographic Atlas for the Black and Azov seas 2009, MEDAR/MEDATLAS, etc.

The group noted that climatologies are useful for the detection of gross data errors but comparison of data with climatologies can also reveal trends, abrupt changes or unusual and extreme conditions. Climatologies are based on limited amount of data and care should be taken when using climatologies in automated QC tests.

2.1.4 Can we adopt an existing documented data product procedure straight away?

Following the discussion of sections 2.1.1 and 2.1.2, the meeting proposed to start with the WOD09 documentation as a working guideline document.

2.2 Common QC issues

Session chair: Hernan Garcia

This session deals with identifying, flagging, correcting, and reporting data offsets as a function of depth.

2.2.1 Lacking universal use of oxygen or nutrient certified reference materials (CRM), can we recommend a nutrient and/or oxygen reference data set to help identify and flag obvious questionable offsets as a function of depth (or density) between measured chemical profiles?

H. Garcia presented a selection of commonly found quality control issues in the historical nutrient and oxygen data (Figure 2). This included near systematic depth offset, which sometimes result from data unit conversion and/or data calibration problems.

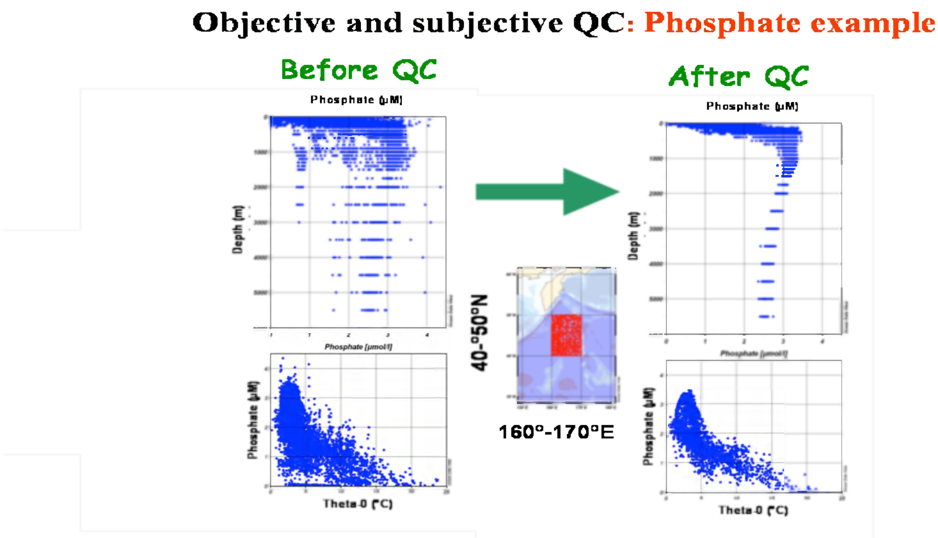

Figure 2. Example of phosphate data before and after objective and subjective QC tests as part of the World Ocean Database 2009

Proposal: the meeting recommended using the WOA09 (to be published in March 2010) as a guidance reference climatology for dissolved nutrients (Nitrate+Nitrite, Nitrate, Phosphate, and Silicate) and oxygen. For example WOA05 is being used as a reference in the International Nutrient Scale System (INSS; see http://www.mri-jma.go.jp/Dep/ge/INSSindex/index.html). More recently, an IOC-ICES Study Group on Nutrient Standards (SGONS; http://www.mri-jma.go.jp/Dep/ge/2010SGONSmeeting/index.html) was established to examine comparability between data sets measured at different times, and by different laboratories using nutrient reference materials.

2.2.2 While original data should be preserved intact, should certain data offsets be corrected as data products? And if so, how should these offset corrections be reported?

Examples of data offsets:

- Systematic offsets due to apparent unit conversion errors (most common case)
- Systematic offsets due to analytical methods
- Systematic offsets for no obvious reason

The group discussed if such corrections could be made and if so how to report these.

Workshop participants agreed that no matter what the problem may be, the original data must be preserved as received. It was also highlighted that, if still contactable, data originators needed to be kept informed of QC issues encountered with their data.

With regards to applying correction to the original data, participants agreed that this should not be done at the data centre level. Corrections to measured data should only be applied by the originators or by expert groups involved in the compilation of derived data products. In all cases, corrections must be well documented. The group recognized that there was a need to define a scaled nomenclature to clearly identify the different stages of processing once the data have been submitted to a data centre. It was proposed to adopt a similar nomenclature to that used by WMO's classification for remote sensing data (see Guide on the Global Observing System (Publication WMO N° 488), Part IV, ftp://ftp.wmo.int/Documents/MediaPublic/Publications/WMO488_GOSguide/488_Guide_2007.pdf) but adapted to discrete measurements banked in oceanographic databases:

Data Processing Level	Description
0	Originators data: unmodified originator's processed data which should be permanently archived and preserved intact (e.g., data received at data centers).
1	Data in database (pre-processing may include unit conversion, reformatting, mapping to parameter codes, adding accurate metadata). Any corrections to the data should be done in close collaboration with data originator when possible or a citable reference, and documented. QC data flags may be assigned (e.g. WOD09 at observed depth levels)
2	Changes to observed data values can be done by empirical, non-authoritative factors if any. They need to be documented. Further data QC may be done (e.g., GLODAP, corrected data only at original x, y, z, t). Empirical or non-authoritative corrections can only be made if the data are clearly labeled as level 2 or above.
3	Remapping (gridding)/interpolation in space or time. Further data QC may be done. Empirical corrections may be done
4	Composite product (multisource) or result of model analysis of lower level data.
5	Atlas/ model output. Being at level 5 does not imply that actions of all previous levels were done.

Table 3. Schema for data processing levels for use in oceanographic data management.

Proposal: the meeting recommended that the issue of correcting systematic offsets in datasets whose originators are no longer contactable be carried out in consultation with a group of experts following the example of the GLODAP and CARINA projects. If so, such corrections should be applied at data of level 2 or above.

2.3 QC flags schemes

Session chair : Reiner Schlitzer

The aim of this session was to:

1- discuss and document the pros and cons of some of the existing schemes;
2- recommend a mapping between existing schemes;
3- recommend a strategy for the future.

2.3.1 Pros and cons of existing schemes, building up on the results of the SeaDataNet survey.

Reiner Schlitzer presented an overview of existing data value QC flags schemes (see http://sites.google.com/site/gebichwiki/data-qa-qc/qa-qc-workshop/). These are used to record results of quality control checks and enable users to filter data based on known QC criteria. The meeting was informed that many such schemes already exist in different levels of complexity, ranging from very detailed to very simple schemes. His selection only included representative examples.

Starting from a simple scheme and increasing through multiple levels of complexity, the following examples were provided. More examples can also be viewed on http://odv.awi.de/fileadmin/user_upload/odv/misc/ODV4_QualityFlagSets.pdf

ODV generic quality flags

Code	Description
0	Good
1	Unknown
4	Questionable
8	Bad

QARTOD quality flags – proposed, not yet definitive

Code	Description
0	Quality not evaluated
1	Bad
2	Questionable/suspect
3	Good
9	Missing data

GTSPP quality flags

Code	Description
0	No quality control has been assigned
1	QC was performed; appears to be correct
2	QC was performed; probably good
3	QC was performed; appears doubtful
4	QC was performed; appears erroneous
5	The value was changed as a result of QC
9	The value is missing

BODC

	Description
Blank	Acceptable value
<	Below detection limit
>	In excess of quoted value
A	Taxonomic flag for affinis (aff.)
B	Beginning of CTD down/up cast
C	Taxonomic flag for confer (cf.)
D	Thermometric depth
E	End of CTD down/up cast
H	Extrapolated value
I	Taxonomic flag for single species (sp.)
K	Improbable value, unknown QC source
L	Improbable value, originators QC
M	Improbable source, BODC QC
N	Null value
O	Improbable value, user QC
P	Trace/calm
Q	Indeterminate
R	Replacement value
S	Estimated value
T	Interpolated value
U	Uncalibrated
W	Control value
X	Excessive difference

WOD

Code	Description
0	Accepted value
1	Range outlier
2	Failed inversion check
3	Failed gradient check
4	Observed level “bullseye” flag and zero gradient check
5	Combined gradient and inversion checks
6	Failed range and inversion checks
7	Failed range and gradient checks
8	Failed range and questionable data checks
9	Failed range and combined gradient and inversion checks

The main problem is that all but the simplest (e.g. ODV, QARTOD) and the WOD scheme have flags that describe data history rather than quality (e.g. “interpolated value”). Such values could still be good or bad, and usage of the particular flag basically leaves the value without a quality assessment. This makes it difficult to map objectively between the different schemes.

Also, many QC flags schemes use subjective descriptions of quality (e.g. “probably good”). The WOD scheme is the only example of a scheme which is explicitly based on results from subjective and quantifiable tests.

All schemes surveyed used a single character to record the results of quality control. Is a single character sufficient? Is a single scheme sufficient?

QC flags may be assigned by the data originators as part of their QC routine. Once ingested in a database, data receive further QC and new flags may be applied. WOD does preserve the originators QC flags within the database however most data centres will convert the originators QC flags into their own scheme resulting in possible loss of information.

Usage of QC flags will depend on the user's experience and background as well as his/her knowledge about the source of QC. Trusts and reliability are important factors. Casual users will tend to only select values which have been flagged as good. Others may want more information about why the values were flagged "bad" or "questionable". This raises the question on whether a two-level QC flags scheme should be considered.

Bill Burnett informed the meeting about the SensorML initiative, which uses an XML encoding for describing any process, including the process of measurement by sensors, quality control and instructions for deriving higher-level information from observations.

Proposal: the meeting expressed interest in SensorML and proposed to study it further for the purpose of handling multiple QC flags schemes.

2.3.2 Can we adopt/recommend a QC flag strategy?

The meeting addressed whether a new QF scheme was needed and if so how detailed it should be.

The meeting discussed different options ranging from a completely new scheme to adopting an existing one. Comparison was made between the various options with particular attention to the wording associated with the different flag levels. Consideration was also given to the proposal of adopting a two-level scheme.

The group recognized the importance of adding a quantifiable QF scheme. It was also considered important to have a simple universal scheme, which would only include criteria related to data quality, and could act as a primary QF scheme and easily map to existing schemes or other secondary quantifiable or specialized schemes.

Proposal: The meeting proposed to adopt as a minimum a 5-level QC flags scheme with the following common language (Table 4):

Code	Description
0	Good (= passed all the applied QC tests)
1	Quality not evaluated
4	Questionable/suspect (meaning inconclusive – failed non-critical metric or subjective QC test(s))
8	Bad (= failed critical metric QC test(s))
9	Missing data. Although not a data quality indicator, this flag serves as a place holder.

Table 4. Proposed 5-level quality control flags scheme

The code values are inversely correlated with the quality so that flags on calculated derived values can be easily computed.

Critical and not critical tests might be different for different types of data. For nutrients and oxygen data they would correspond to the tests mentioned in sections 2.1.2. (critical tests) and 2.2.2. (desirable/additional tests).

The group discussed the need to work on operational definitions for objective and subjective QC tests in Table 4.

A QC flags system based on two levels was believed to be the optimum set up. The first level (using the scheme described above) would indicate the quality of the data while the second level would indicate the reason for such QC flag decision. The decision could be based on subjective or objective criteria. The group is aware that further work is necessary to further develop and implement such a QC test system.

Follow up: The meeting agreed that a 2-tier quality level flags system would be optimum. Follow up actions will need to take this into consideration and investigate how this could be implemented with the minimum disruption to existing schema. It is also desirable that when provided, the originator`s data quality flags be preserved, in addition to the data centre`s QC flags.

2.3.3 Can we recommend a mapping between selected QC flags schemes?

Follow-up: the meeting recommended that mapping tables be developed based upon the quality flags scheme proposed under 2.3.2 and using the mapping tables already prepared by Reiner Schlitzer. Bill Burnett suggested that the new scheme (provisionally called "GE-BICH QC") could be adopted by QARTOD. He will inform the IODE Secretariat if and when this decision has been taken.

2.4 Units and metadata requirements for data reporting and exchange

Session chair: Cyndy Chandler

This session included a presentation by Andrew Pascall on ISO17025 general requirements for the competence of testing and calibration laboratories (see http://sites.google.com/site/gebichwiki/data-qa-qc/qa-qc-workshop/). The presentation informed the meeting analytical, quality control and data reporting procedures, which are expected from an analytical laboratory in order to obtain ISO 17025 accreditation. There are other accreditation schemes such as QUASIMENE although cost (e.g. cross laboratory calibrations) can be prohibitive for some countries or laboratories. The group is also aware that many research laboratories often operate outside the accreditation system.

2.4.1 Can we recommend an existing best practice document for data reporting and exchange?

While informal recommendations and guidelines for submitting data do exist in a number of data centers, the group was not aware of the existence of a best practice document dealing specifically with oceanographic chemical data reporting and exchange.

Proposal: the meeting agreed that there is no existing document and that one should be developed.

Meanwhile, it is recommended that at a minimum, the following information be provided in data report prepared by data originators when the data are submitted to the data centers:

- sample preservation/handling/transport protocol (after sampling but before analysis);
- analytical method specification with reference (e.g. published, citable reference used or deviations from reference cited), specifying procedure, equipment, precision, accuracy, method detection limit, significant figures as determined by the measurement precision;
- sampling and sample preparation including filtration, preservation and analysis;
- Certified Reference Material (CRM), or standard availability and use;
- estimation of measurement uncertainty;
- inter-laboratory comparison study availability;

- laboratory analysis duplicate limits (repeatability of analysis);
- use of internal QC with specified precision limits.

If the laboratory is accredited then this should be specified.

2.4.2 Can we agree on a common reporting terminology and unit for each variable?

Data submitted to data centres use non standard and sometimes inaccurate or ambiguous terminology to label chemical parameters and units.

With regards to parameter names:

Proposal: the meeting recommended the following terminology for dissolved inorganic nutrients and dissolved oxygen in seawater:

- Recommended term: SILICATE [Silicic acid is the dominant form of reactive silicate in seawater (e.g., Gordon et al., 1993; Isshiki et al., 1991)]
- Recommended term: NITRATE+NITRITE should be reported if this is what was measured.
- Recommended term: NITRATE (specify whether it was measured directly or if reported as subtracted from measurements of NITRATE+NITRITE minus NITRITE; if the latter then NITRITE should also be reported)
- Recommended term: NITRITE
- Recommended term: PHOSPHATE
- Recommended term: OXYGEN
- Recommended term: AMMONIUM

For accuracy, abbreviations of measured variables and concentration units should be spelled out completely as part of the metadata.

The issue of units usage and conversion was then discussed in depth. Units should follow the international standards and be as close to the measurement unit as possible.

Proposal: it was recommended to use units of micromole per liter (µmol / l) which complies with the SI recommendation (NIST Special Publication 330, 2008) for both dissolved nutrients and dissolved oxygen.

However while the group agreed that concentrations should be reported on a mole per volume basis, it was recognized that a large part of the oceanographic community required concentration of substance in sea water to be reported in units of moles per kilogram.

It is therefore recommended that data producers provide sufficient information to enable values to be converted to/from per volume/per mass for both nutrient and oxygen data. The meeting recognized the difficulty in the conversion between per volume and per mass units, for the reason that the exact temperature and salinity which were used (for the conversion) are not always reported. In order to do an accurate conversion from units of moles per mass to units of moles per volume, the originator of the data needs to provide at a minimum the seawater density conversion factor and the equation of state used in the conversion. In order to convert units of moles per volume into units of moles per mass the originator needs to provide the appropriate temperature, which is, for nutrients, laboratory temperature at the time the sample was analyzed, and for oxygen, water temperature at the sample was drawn.

As a conclusion the group recommended that:

- if submitting data in units per mass, originators supply sufficient information to enable future conversion from per mass to per volume units (and vice versa) to be done

accurately. At a minimum this requires the density conversion factor, the equation of state and the temperature used in the calculation of the density;
- if submitting data in units per volume, originators should also supply the temperature of oxygen sample fixation if measured or, for nutrients, the temperature of the analysed sample (i.e. laboratory temperature), and in situ salinity if not already held at the data center.

Reference was also made to the OceanTeacher page: http://www.oceanteacher.org/oceanteacher/index.php/Conversion_Formulas_for_Chemistry_Measurement_Units . The group recommended that the guidelines for unit conversion be revised according to the previous paragraph.

3. THE WAY FORWARD

Chair(s): Gwen Moncoiffé and Hernan Garcia

3.1 List of issues, knowledge gaps or needs to be addressed in the future

3.1.1 Climatologies

A compilation of available global and regional climatologies could be started as a special section of the web-based GE-BICH wiki page (http://sites.google.com/site/gebichwiki/). As a start and in addition to the Word Ocean Database 2009, the following four references were provided:

For the Black Sea:

1. National Atlas of Ukraine. Electronic Version. (http://isgeo.com.ua/en/products/atlases/elnau) The Atlas smoothly combines six thematic blocks: general characteristics, history, natural environment and natural resources, population and human development, economy, ecological state of the environment.

2. Oceanographic Atlas of the Black Sea and Sea of Azov. 2009, 356pp.

For the Baltic Sea:

State and Evolution of the Baltic Sea, 1952 - 2005 (http://www.io-warnemuende.de/baltic2008/index.html) A Detailed 50-Year Survey of Meteorology and Climate, Physics, Chemistry, Biology, and Marine Environment edited by R. Feistel, G. Nausch and N. Wasmund Wiley 2008.

For the Mediterranean Sea:

MEDAR/MEDATLAS database and climatology (http://www.ifremer.fr/medar/)

Action: Gwen Moncoiffé to create a section on Climatologies on the GE-BICH wiki.

It was also recommended that a section on creating climatologies be developed in OceanTeacher.

Action: Peter Pissierssens to inform Murray Brown

3.1.2 Development of a white technical paper

A white technical paper describing in detail the recommended steps in chemical oceanographic data quality control could be started on the GE-BICH wiki and later published either as an IOC publication, via OceanTeacher or in a peer-reviewed journal. Elements of the recommended procedure could be submitted to the peer-reviewed JCOMM/IODE Ocean Data Standard process (ODS).

GE-BICH wiki (http://sites.google.com/site/gebichwiki/home)

The GE-BICH wiki is a publicly available web site which is simple to use and maintain. The main objective of the wiki is to provide us with a "window" to the outside world and obtain quick feedback on work in progress. In order to optimize our effort we need to invite input from the wider community of analytical scientists, oceanographers and data managers. The wiki is currently administered by 3 "owners" (G. Moncoiffé, H. Garcia and M. Kennedy). In order to contribute, people must first be registered as collaborators by the site owners. Only owners can register new collaborators. Collaborators can post comments and attachments, and make changes to pages and attachments.

The wiki could be advertised to the targeted wider community via listservs/mailing lists (e.g. Ocean Carbon and Biogeochemistry OCB), international programs newsletters (e.g. GEOTRACES, SOLAS, IMBER), and through oral or poster presentations to relevant conferences (see below).

Ocean Data Standards (http://www.oceandatastandards.org/):

The peer-review process was thought to be important in particular with regards to proposals for standardization. It was proposed that the IODE's Ocean Data Standard process be used as a mean to present the case for what we feel should be adopted as a standard, and obtain community feedback on the proposal.

Journal article:

For issues which were not felt suitable for submission as standards, publication in peer-reviewed journals or in the grey literature could be considered. Possible journals include:

- **Earth Science Informatics** (http://www.springer.com/earth+sciences+%26+geography/computer+%26+mathematical+applications/journal/12145)
- **International Journal of Digital Earth** (http://www.informaworld.com/smpp/title~db=all~content=g793145301~tab=summary)
- **Earth System Science Data** (http://www.earth-system-science-data.net/)

The importance of publishing is that it enables recommended QC procedures to be cited. It was noted that this could also be done through the grey literature wither via the IOC or via other organizations (e.g., NOAA, ICES, etc.).

3.1.3 Collaborations with other initiatives elsewhere

OceanSITES (http://www.oceansites.org/)

OceanSITES is deploying chemical sensors on buoys and moorings. They have also started compiling a list of protocol documents for data collection and processing. There is a share interest between the work started through this workshop and their initiative. OceanSITES data management web pages and GE-BICH wiki are already cross-referencing each others. Bill Burnett is co-chair of the OceanSITES data management team.

QARTOD (http://qartod.org)

QARTOD (Quality Assurance of Real Time Oceanographic Data) is a US multi-agency effort to address the quality assurance and quality control issues of the Integrated Ocean Observing System (IOOS) community, including data from chemical sensors. Bill Burnett will be our contact with QARTOD.

GO-SHIP (http://www.go-ship.org/)

GO-SHIP aims to develop a globally coordinated network of sustained hydrographic sections as part of the global ocean/climate observing system. They are or will be recommending best practice protocols for the sampling and processing of some chemical variables (see their Hydro Manual). We need to be aware of the protocols they adopt.

INSS (http://www.mri-jma.go.jp/Dep/ge/INSSindex/index.html)

The International Nutrient Scale System aims to improve the comparability and traceability of nutrients data in the world's oceans by developing Certified Reference Materials and organising interlaboratory comparison exercises. They had an international workshop in February 2009, Paris (http://www.mri-jma.go.jp/Dep/ge/2009INSSworkshop/2009inss_workshop_index.html). The group is chaired by Michio Aoyama from Japan. Hernan Garcia and Gwen Moncoiffé will contact the chair of INSS.

MMI (http://marinemetadata.org/)

Marine Metadata Interoperability (MMI) is a good way to publicize vocabularies and ontologies. Cyndy Chandler will post the abstract from the workshop report to the MMI website.

EMODNET Chemical lot (http://www.emodnet-chemistry.eu/portal/portal/)

This is one of the EMODNET pilot projects which is being implemented by SeaDataNet. Reiner Schlitzer is a member of this group. Next meeting in on 2nd April at UNESCO HQ contact Allessandra Giorgetti. Reiner will report to them about the workshop.

MyOcean (http://www.myocean.eu.org/)

A European-funded project (2009-11) which will lead the setting up of a pan-European service delivering ocean-related monitoring and forecasting data and information, based on in situ and remote sensing observations, assimilated in 3D simulation models, covering global and regional scales (European Seas). The project will include biological and chemical parameters, and intends to develop Quality Control procedures for in situ sensors.

3.1.4 Revision of outdated nutrient and oxygen data ranges and units in IOC Manual 26 (Manual of quality control procedures for validation of oceanographic data. IOC, Manuals and Guides 26. UNESCO 1993, 352 pp.)

This is a task alreay scheduled under the GE-BICH group and is due for completion in time for the next GE-BICH session in January 2011.

3.1.5 Extension to other variables

Guidelines for QC of other variables are also needed e.g. chlorophyll, freons, isotopes, etc. Should we take a similar approach in the future for these variables?

The group agreed that it was best to concentrate on nutrients and oxygen data for the time being. It may be that we could later join up with other groups to develop QC procedures for other types of chemical data. It was noted that for some parameters, other communities were already doing some ground work.

For isotopes and radionuclides for example, GEOTRACES is putting effort on doing this. It might be necessary to liaise more directly with them at a later stage to have for example some of their recommendations submitted as standards to the ODS process.

It was noted that if a similar approach was taken with other chemical variables then it would benefit the whole process to have an introductory overview presentation on the sampling and analytical methods specific to the chemical species under study.

3.2 Dissemination of results from this workshop

3.2.1 Submission to Ocean Data Standard

3.2.1.1 QC flags scheme

Participants agreed that the proposed QC flags scheme including the scale and associated definitions should be submitted to the IODE/JCOMM Ocean Data Standard (ODS) process. The following milestones were agreed (all to be completed in 2010 prior to the fifth session of GE-BICH on 17-20 January 2011):

- drafting group to further develop the schema proposal: Hernan Garcia, Gwen Moncoiffé, Laure Devine, Reiner Schlitzer, Cyndy Chandler, and Sergey Konovalov;
- submit to participants of the workshop;
- present the schema at IMDIS2010 as part of the presentation about the outcome of the workshop by Gwen Moncoiffé and seek feedback from IMDIS participants and SeaDataNet members;
- go back to the group based upon received feedback and make decision on submission;
- submit to ODS.

3.2.1.2 Nomenclature for processing levels

The nomenclature for the five data processing levels could be prepared for the Ocean Data Standard process following consultation with the wider community. At the time of the meeting, the official status of the NASA/WMO processing levels for remote sensing data was unknown. The meeting decided that this needed to be established first before going forward with the proposal. Other schemes may also exist.

Action: P. Pissierssens to obtain the official reference to the NASA/WMO processing levels scale from WMO. This will then be taken forward by G. Moncoiffé.

3.2.1.3 QC tests

Minimum QC checks for nutrients and oxygen need to be defined in plain text, and defined with regards to the mathematical formula and reference limits checks used.

A document detailing the minimum QC checks will be compiled and posted on the GE-BICH wiki for all to test and comment on. Once fully tested, decision will be made on whether to submit it to the IODE/JCOMM Ocean Data Standard process or whether it becomes a working document for GE-BICH V. GE-BICH can then decide to publish as a new IOC Manuals and Guides or go forward with the submission process to ODS.

The drafting team will be composed of: Hernan Garcia, Bill Burnett, David Terhell, Gwen Moncoiffé, Laure Devine.

Timeline: working document to be prepared for GE-BICH in Jan 2011 (week of 17 January). First draft to be started in April 2010 and posted on GE-BICH wiki by the end of April.

3.2.2 GE-BICH Wiki

The wiki will be used to disseminate results and ideas from this workshop as mentioned above, and to invite community-wide interactions.

New sections will be added as required. In a first instance the following new sections will be added by Gwen Moncoiffé:

1. a section for the compilation of references to useful climatologies to help with the QC of nutrients and oxygen data.
2. a section to help with the compilation of secondary quantifiable QC flags schemes. In a first instance this section will be populated with schemes provided by Hernan Garcia and Andrew Pascall.

3.2.3 Conferences

The IMDIS conference, Paris, 29-31 March 2010, will be attended by a number of workshop participants. A presentation will be made in Session 1 ("Data Quality Issues in Ocean Science") summarizing the outcome of the workshop (G. Moncoiffé and H. Garcia).

The AGU meeting in December 2010 and the IMBER IMBIZO, Greece will be attended by Cyndy Chandler.

4. CLOSING OF THE WORKSHOP

The meeting was closed on Thursday 11 February 2010 at 12h30.

ANNEX I

AGENDA OF THE MEETING

1. OPENING OF THE MEETING

1.1. Introduction of participants
1.2. Adoption of the agenda
1.3. Introduction of working documents

2. OVERVIEW AND DISCUSSION SESSIONS: TOWARDS DEFINING A MINIMUM SET OF QA/QC PROCEDURES AND CRITERIA: EVALUATION OF EXISTING PROCEDURES AND CRITERIA

2.1. Quality control checks and procedures (Part 1)
2.2. Quality control checks and procedures (Part 2)
2.3. Common QC issues
2.4. QC flags schemes
2.5. Units and metadata requirements for data reporting and exchange

3. WRAP-UP SESSION: RECOMMENDATION OF A MINIMUM SET OF QC CRITERIA AND PROCEDURES

3.1. Quality control recommended checks and procedure
3.2. QC flags recommended scheme
3.3. Agreed strategy for common QC issues
3.4. Recommended units and minimum metadata requirement for data reporting and exchange

4. THE WAY FORWARD

4.1. List of issues, knowledge gaps or needs to be addressed in the future
4.2. Dissemination of results from this workshop

5. CLOSING OF THE WORKSHOP

ANNEX II

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ANNEX III

QUALITY CONTROL TESTS

A comparison of typical automated and subjective quality control tests for station header metadata as described at NODC (Johnson et al. 2009) and Institut Maurice-Lamontagne (Devine and Lafleur, 2008). Tests marked with an asterisk are automated tests.

NODC/WOD	**Institut Maurice-Lamontagne**
Date check (day, month, year, time) [*]	GTSPP Impossible Date/Time [*]
Position on land (1° land/sea mask) [*]	GTSPP Position on Land (Gulf of St. Lawrence, Hudson Bay, eastern Canadian coast only) [*]
Station position (-90/90/-180/180) [*]	GTSPP Impossible location [*]
Country check (ISO) [*]	
Data collecting Institute [*]	
Data submitting institute [*]	
Principal investigator [*]	
Speed check between casts [*]	GTSPP Impossible Speed [*]
Platform check [*]	GTSPP Platform identification [*]
Cruise track inspection	Cruise track visual inspection

A comparison of typical automated and subjective quality control tests for variable (measured or derived) data at NODC (Johnson *et al.* 2009) and Institut Maurice-Lamontagne (Devine and Lafleur, 2008). Tests marked with an asterisk are automated tests. Additional tests may be performed.

NODC/WOD	Institut Maurice-Lamontagne
Duplicate cast [*]	
Near duplicate [*]	
Depth (pressure) inversions [*]	
Depth (pressure) duplication check[*]	
High-resolution pair check [*]	
	Bottle versus CTD Measurements [*]
Global data range check as a function of depth [*]	Profile Envelope (depth intervals) (based on WOD05) [*]
	Global Impossible Parameter Range Values (based on WOD05) [*]
Basin-scale data range check as a function of depth (e.g., N. Atlantic, Coastal N. Atlantic, Equatorial Atlantic) [*]	
	Regional impossible parameter value (based on WOD05) [*]
Sub-basin data range check as a function of depth (e.g, Labrador Sea) [*]	
Excessive vertical gradient check (spike) [*]	Excessive Gradient or Inversion (based on WOD01) [*]
Zero vertical gradient [*]	Constant profile [*]
Depth offset deviation (station) [*]	Ratio and Profile Visual Inspection (station data)
Depth offset deviation (cruise)	Ratio and Profile Visual Inspection (cruise data)
Monthly WOD (1° and 5°) climatology statistical test (variance) [*]	
Seasonal WOD (1° and 5°) climatology statistical test (variance) [*]	
All data WOD (1° and 5°) climatology statistical test (variance) [*]	
Decadal or composite WOD (1° and 5°) climatology statistical test (variance) [*]	
Monthly WOA (1°) climatology objective analysis test (variance) [*]	
Seasonal WOA (1°) climatology objective analysis test (anomaly) [*]	
Al data WOA (1°) climatology objective analysis test (anomaly) [*]	
Decadal or composite WOA (1°) climatology objective analysis test (anomaly) [*]	
Originator flag value	
	Surface O_2 Data versus Percent Saturation [*]
	Petrie et al. (1996) for the Gulf of St. Lawrence (T, S, sigma-t)
	Brickman and Petrie (2003) for the Gulf of St. Lawrence Monthly Climatology [*]
	Replicates Visual inspection (whole cruise data)
	Bottle Versus CTD Measurements Visual Inspection (whole cruise data)
	Variable patterns with time (whole cruise data)
Apparent O_2 utilization checks	
O_2 Percent Saturation check	Surface O_2 Percent Saturation data range check [*]
Density inversion	

ANNEX IV

PARAMETER RANGE LIMITS USED FOR WOD09

Oxygen
Standard unit or scale: ml·l^{-1}

Depth (m)	North Atlantic		Coastal N. Atlantic		Equatorial Atlantic		Coastal Eq. Atlantic		South Atlantic		Coastal S. Atlantic		North Pacific		Coastal N. Pacific		Equatorial Pacific		Coastal Eq. Pacific	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
0	0.00	11.00	0.00	10.00	0.00	7.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00	10.00	0.00	10.00	0.00	8.00	0.00	7.00
10	0.00	11.00	0.00	10.00	0.00	7.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00	10.00	0.00	10.00	0.00	8.00	0.00	7.00
20	0.00	11.00	0.00	10.00	0.00	7.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00	10.00	0.00	10.00	0.00	8.00	0.00	7.00
30	0.00	11.00	0.00	10.00	0.00	7.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00	10.00	0.00	10.00	0.00	8.00	0.00	7.00
50	0.00	11.00	0.00	9.00	0.00	6.00	0.00	9.00	0.00	9.00	0.00	8.00	0.00	10.00	0.00	8.00	0.00	8.00	0.00	6.00
75	0.00	11.00	0.00	9.00	0.00	6.00	0.00	6.00	0.00	9.00	0.00	8.00	0.00	9.00	0.00	8.00	0.00	8.00	0.00	6.00
100	0.00	10.00	0.00	9.00	0.00	6.00	0.00	6.00	0.00	8.00	0.00	8.00	0.00	9.00	0.00	8.00	0.00	6.00	0.00	6.00
125	0.00	10.00	0.00	9.00	0.00	6.00	0.00	6.00	0.00	8.00	0.00	8.00	0.00	9.00	0.00	8.00	0.00	6.00	0.00	6.00
150	0.00	10.00	0.00	9.00	0.00	6.00	0.00	6.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	6.00	0.00	5.00
200	0.00	10.00	0.00	9.00	0.00	6.00	0.00	6.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	5.00	0.00	5.00
250	0.00	10.00	0.00	8.00	0.00	6.00	0.00	6.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	5.00	0.00	5.00
300	0.00	9.00	0.00	8.00	0.00	5.00	0.00	6.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	8.00	0.00	5.00	0.00	5.00
400	0.00	9.00	0.00	8.00	0.00	5.00	0.00	6.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	8.00	0.00	5.00	0.00	5.00
500	0.00	9.00	0.00	8.00	0.00	5.00	0.00	6.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	8.00	0.00	5.00	0.00	5.00
600	0.00	9.00	0.00	8.00	0.00	5.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	5.00	0.00	5.00
700	0.00	9.00	0.00	8.00	0.00	5.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
800	0.00	9.00	0.00	8.00	0.00	5.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
900	0.00	9.00	0.00	8.00	0.00	5.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
1000	0.00	9.00	0.00	8.00	0.00	6.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
1100	0.00	9.00	0.00	8.00	0.00	6.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
1200	0.00	9.00	0.00	8.00	0.00	6.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
1300	0.00	9.00	0.00	8.00	0.00	6.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
1400	0.00	9.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
1500	3.00	9.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
1750	3.00	9.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
2000	3.00	9.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
2500	3.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	5.00
3000	3.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	4.00
3500	3.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	5.00	0.00	4.00
4000	3.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	6.00	0.00	5.00	0.00	5.00	0.00	4.00
4500	3.00	8.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	6.00	0.00	5.00	0.00	5.00	0.00	4.00
5000	3.00	8.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	6.00	0.00	5.00	0.00	5.00	0.00	4.00
5500+	3.00	8.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	6.00	0.00	7.00	0.00	6.00	0.00	5.00	0.00	5.00	0.00	4.00

***Oxygen* (continued 1)**
Standard unit or scale: ml·l^{-1}

Depth (m)	**South Pacific**		**Coastal S. Pacific**		**North Indian**		**Coastal N. Indian**		**Equatorial Indian**		**Coastal Eq. Indian**		**South Indian**		**Coastal S. Indian**		**Antarctic**		**Arctic**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
0	0.00	8.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	10.00	0.00	6.00	0.00	10.00	0.00	9.00	5.25	11.00	0.00	11.00
10	0.00	8.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	10.00	0.00	6.00	0.00	10.00	0.00	9.00	5.25	10.50	0.00	11.00
20	0.00	8.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	10.00	0.00	6.00	0.00	10.00	0.00	9.00	5.25	10.00	0.00	11.00
30	0.00	8.00	0.00	8.00	0.00	7.00	0.00	7.00	0.00	10.00	0.00	6.00	0.00	10.00	0.00	9.00	5.00	10.00	0.00	11.00
50	0.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	10.00	0.00	6.00	0.00	10.00	0.00	9.00	4.00	10.00	0.00	11.00
75	0.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	10.00	0.00	6.00	0.00	8.00	0.00	9.00	3.75	9.50	0.00	10.00
100	0.00	8.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	7.00	0.00	6.00	0.00	8.00	0.00	9.00	3.50	9.25	0.00	10.00
125	0.00	8.00	0.00	7.00	0.00	5.00	0.00	5.00	0.00	7.00	0.00	5.00	0.00	8.00	0.00	9.00	3.50	9.00	0.00	10.00
150	0.00	8.00	0.00	7.00	0.00	5.00	0.00	5.00	0.00	7.00	0.00	5.00	0.00	8.00	0.00	9.00	3.50	8.75	0.00	10.00
200	0.00	7.00	0.00	7.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00	8.00	0.00	9.00	3.50	8.50	0.00	10.00
250	0.00	7.00	0.00	7.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00	8.00	0.00	7.00	3.50	8.50	0.00	10.00
300	0.00	7.00	0.00	7.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	7.00	0.00	7.00	3.50	8.25	0.00	10.00
400	0.00	7.00	0.00	7.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	7.00	0.00	7.00	3.50	8.00	0.00	10.00
500	0.00	7.00	0.00	7.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	7.00	0.00	7.00	3.50	8.00	0.00	10.00
600	0.00	7.00	0.00	7.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	7.00	0.00	6.00	3.50	7.75	0.00	9.00
700	0.00	7.00	0.00	6.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	7.00	0.00	6.00	3.50	7.75	0.00	9.00
800	0.00	7.00	0.00	6.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	3.00	0.00	6.00	0.00	6.00	3.50	7.75	0.00	9.00
900	0.00	7.00	0.00	6.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	3.00	0.00	6.00	0.00	6.00	3.50	7.50	0.00	9.00
1000	0.00	6.00	0.00	6.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	3.00	0.00	6.00	0.00	6.00	3.50	7.50	0.00	9.00
1100	0.00	6.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	3.00	0.00	6.00	0.00	6.00	3.25	7.50	0.00	9.00
1200	0.00	6.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	3.00	0.00	6.00	0.00	6.00	3.25	7.50	0.00	9.00
1300	0.00	6.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	3.00	0.00	6.00	0.00	6.00	3.00	7.50	0.00	9.00
1400	0.00	6.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	3.00	7.50	0.00	9.00
1500	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	3.00	7.25	0.00	9.00
1750	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	3.00	7.25	0.00	9.00
2000	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	3.00	7.25	0.00	9.00
2500	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	3.25	7.25	0.00	9.00
3000	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	3.50	7.25	0.00	9.00
3500	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	3.75	7.00	0.00	9.00
4000	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	4.00	6.50	0.00	9.00
4500	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	4.00	6.50	0.00	9.00
5000	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	4.25	6.50	0.00	9.00
5500+	0.00	5.00	0.00	5.00	0.00	5.00	0.00	4.00	0.00	5.00	0.00	5.00	0.00	6.00	0.00	6.00	4.50	6.50	0.00	9.00

Oxygen (continued 2)
Standard unit or scale: ml·l^{-1}

Depth (m)	Mediterranean		Black Sea		Baltic Sea		Persian Gulf		Red Sea		Sulu Sea	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0.00	8.00	0.00	10.00	0.00	12.00	0.00	12.00	0.00	12.00	0.00	5.00
10	0.00	8.00	0.00	10.00	0.00	12.00	0.00	12.00	0.00	12.00	0.00	5.00
20	0.00	8.00	0.00	10.00	0.00	12.00	0.00	12.00	0.00	12.00	0.00	5.00
30	0.00	8.00	0.00	10.00	0.00	12.00	0.00	12.00	0.00	12.00	0.00	5.00
50	0.00	8.00	0.00	10.00	0.00	12.00	0.00	12.00	0.00	12.00	0.00	5.00
75	0.00	7.00	0.00	8.00	0.00	9.50	0.00	9.50	0.00	9.50	0.00	5.00
100	0.00	7.00	0.00	8.00	0.00	9.50	0.00	9.50	0.00	9.50	0.00	4.00
125	0.00	7.00	0.00	8.00	0.00	9.50	0.00	9.50	0.00	9.50	0.00	4.00
150	0.00	7.00	0.00	8.00	0.00	9.50	0.00	9.50	0.00	9.50	0.00	4.00
200	0.00	7.00	0.00	5.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00	3.00
250	0.00	7.00	0.00	5.00	0.00	9.00	0.00	9.00	0.00	9.00	0.00	3.00
300	0.00	7.00	0.00	5.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	3.00
400	0.00	7.00	0.00	2.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	3.00
500	0.00	7.00	0.00	2.00	0.00	8.00	0.00	8.00	0.00	8.00	0.00	3.00
600	0.00	7.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	3.00
700	0.00	7.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	3.00
800	0.00	7.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	3.00
900	0.00	7.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	3.00
1000	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	3.00
1100	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	3.00
1200	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
1300	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
1400	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
1500	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
1750	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
2000	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
2500	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
3000	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
3500	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
4000	0.00	6.00	0.00	2.00	0.00	7.10	0.00	7.10	0.00	7.10	0.00	2.00
4500	0.00	6.00	0.00	2.00	0.00	6.00	0.00	6.00	0.00	6.00	0.00	2.00
5000	0.00	6.00	0.00	2.00	0.00	6.00	0.00	6.00	0.00	6.00	0.00	2.00
5500+	0.00	6.00	0.00	2.00	0.00	6.00	0.00	6.00	0.00	6.00	0.00	2.00

Phosphate
Standard unit or scale: µM

Depth (m)	North Atlantic		Coastal N. Atlantic		Equatorial Atlantic		Coastal Eq. Atlantic		South Atlantic		Coastal S. Atlantic		North Pacific		Coastal N. Pacific		Equatorial Pacific		Coastal Eq. Pacific	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
0	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
10	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
20	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
30	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
75	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
100	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
125	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
150	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
200	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
250	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
300	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
400	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
500	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
600	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
700	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
800	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
900	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1100	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1200	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1300	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1400	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1500	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1750	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
2000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
2500	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
3000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
3500	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
4000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
4500	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
5000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
5500+	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50

Phosphate (continued 1)
Standard unit or scale: µM

Depth (m)	South Pacific		Coastal S. Pacific		North Indian		Coastal N. Indian		Equatorial Indian		Coastal Eq. Indian		South Indian		Coastal S. Indian		Antarctic		Arctic	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
10	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
20	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
30	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
75	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
100	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
125	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
150	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
200	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
250	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
300	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
400	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
500	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50	0.00	4.50
600	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
700	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
800	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
900	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1100	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1200	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1300	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1400	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1500	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
1750	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
2000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
2500	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
3000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
3500	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
4000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
4500	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
5000	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50
5500+	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50	0.01	4.50

Phosphate (continued 2)
Standard unit or scale: µM

Depth (m)	Mediterranean		Black Sea		Baltic Sea		Persian Gulf		Red Sea		Sulu Sea	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0.00	30.00	0.00	30.00	0.00	60.00	0.00	1.50	0.00	4.50	0.00	2.75
10	0.00	30.00	0.00	30.00	0.00	60.00	0.00	1.50	0.00	4.50	0.00	2.75
20	0.00	30.00	0.00	30.00	0.00	60.00	0.00	1.50	0.00	4.50	0.00	2.75
30	0.00	30.00	0.00	30.00	0.00	60.00	0.00	1.50	0.00	4.50	0.00	2.75
50	0.00	30.00	0.00	30.00	0.00	60.00	0.00	1.50	0.00	4.50	0.00	2.75
75	0.00	5.00	0.00	15.00	0.00	60.00	0.02	1.50	0.00	4.50	0.00	2.75
100	0.00	5.00	0.00	15.00	0.00	20.00	0.02	1.50	0.00	4.50	0.00	2.75
125	0.00	5.00	0.00	15.00	0.00	20.00	0.02	1.50	0.00	4.50	0.00	2.75
150	0.00	5.00	0.00	15.00	0.00	20.00	0.02	1.50	0.00	4.50	0.00	2.75
200	0.00	5.00	0.00	15.00	0.00	20.00	0.02	1.50	0.00	4.50	0.00	2.75
250	0.00	2.50	0.00	15.00	0.00	20.00	0.02	1.50	0.00	4.50	0.50	2.75
300	0.00	2.50	0.00	15.00	0.00	20.00	0.02	1.50	0.00	4.50	0.50	2.75
400	0.00	2.50	0.00	15.00	0.00	20.00	0.02	1.50	0.00	4.50	0.50	2.75
500	0.00	2.50	0.00	15.00	0.00	20.00	0.02	1.50	0.10	4.50	0.50	2.75
600	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
700	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
800	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
900	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
1000	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
1100	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
1200	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
1300	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
1400	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
1500	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
1750	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
2000	0.01	2.50	0.01	15.00	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
2500	0.01	2.50	0.01	4.50	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
3000	0.01	2.50	0.01	4.50	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
3500	0.01	2.50	0.01	4.50	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
4000	0.01	2.50	0.01	4.50	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
4500	0.01	2.50	0.01	4.50	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
5000	0.01	2.50	0.01	4.50	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75
5500+	0.01	2.50	0.01	4.50	0.01	20.00	0.02	1.50	0.10	4.50	0.50	2.75

Silicate
Standard unit or scale: μM

Depth (m)	North Atlantic		Coastal N. Atlantic		Equatorial Atlantic		Coastal Eq. Atlantic		South Atlantic		Coastal S. Atlantic		North Pacific		Coastal N. Pacific		Equatorial Pacific		Coastal Eq. Pacific	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
0	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	100.00	0.00	250.00	0.00	150.00	0.00	250.00
10	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	100.00	0.00	250.00	0.00	150.00	0.00	250.00
20	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	100.00	0.00	250.00	0.00	150.00	0.00	250.00
30	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	100.00	0.00	250.00	0.00	150.00	0.00	250.00
50	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	100.00	0.00	250.00	0.00	150.00	0.00	250.00
75	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	100.00	0.00	250.00	0.00	150.00	0.00	250.00
100	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	100.00	0.00	250.00	0.00	150.00	0.00	250.00
125	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	100.00	0.00	250.00	0.00	150.00	0.00	250.00
150	0.00	150.00	0.00	250.00	0.00	80.00	0.00	250.00	0.00	150.00	0.00	250.00	0.00	110.00	0.00	250.00	0.00	150.00	0.00	250.00
200	0.01	150.00	0.01	250.00	0.01	80.00	0.01	250.00	0.01	150.00	0.01	250.00	0.01	120.00	0.01	250.00	0.00	150.00	0.01	250.00
250	0.01	150.00	0.01	250.00	0.01	80.00	0.01	250.00	0.01	150.00	0.01	250.00	0.01	125.00	0.01	250.00	0.01	150.00	0.01	250.00
300	0.01	150.00	0.01	250.00	0.01	80.00	0.01	250.00	0.01	150.00	0.01	250.00	0.01	130.00	0.01	250.00	0.01	150.00	0.01	250.00
400	0.01	150.00	0.01	250.00	0.01	80.00	0.01	250.00	0.01	150.00	0.01	250.00	0.01	140.00	0.01	250.00	0.01	150.00	0.01	250.00
500	0.01	150.00	0.01	250.00	0.50	80.00	0.01	250.00	0.50	150.00	0.01	250.00	0.50	150.00	0.01	250.00	0.50	150.00	0.01	250.00
600	0.01	150.00	0.01	250.00	1.00	80.00	0.01	250.00	2.50	150.00	0.01	250.00	5.00	160.00	0.01	250.00	2.00	150.00	0.01	250.00
700	0.01	150.00	0.01	250.00	2.00	80.00	0.01	250.00	5.00	150.00	0.01	250.00	5.00	165.00	0.01	250.00	5.00	150.00	0.01	250.00
800	0.01	150.00	0.01	250.00	2.00	80.00	0.01	250.00	5.00	150.00	0.01	250.00	5.00	170.00	0.01	250.00	5.00	155.00	0.01	250.00
900	0.01	150.00	0.01	250.00	5.00	80.00	0.01	250.00	10.00	150.00	0.01	250.00	10.00	175.00	0.01	250.00	5.00	160.00	0.01	250.00
1000	2.50	150.00	1.00	250.00	5.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	10.00	180.00	1.00	250.00	5.00	165.00	1.00	250.00
1100	2.50	150.00	1.00	250.00	5.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	10.00	190.00	1.00	250.00	10.00	165.00	1.00	250.00
1200	2.50	150.00	1.00	250.00	5.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	200.00	1.00	250.00	10.00	170.00	1.00	250.00
1300	2.50	150.00	1.00	250.00	5.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	200.00	1.00	250.00	10.00	170.00	1.00	250.00
1400	2.50	150.00	1.00	250.00	5.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	200.00	1.00	250.00	10.00	170.00	1.00	250.00
1500	5.00	150.00	1.00	250.00	5.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	225.00	1.00	250.00	10.00	175.00	1.00	250.00
1750	5.00	150.00	1.00	250.00	5.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	225.00	1.00	250.00	10.00	180.00	1.00	250.00
2000	5.00	150.00	1.00	250.00	10.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	250.00	1.00	250.00	10.00	200.00	1.00	250.00
2500	5.00	150.00	1.00	250.00	10.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	250.00	1.00	250.00	10.00	200.00	1.00	250.00
3000	5.00	150.00	1.00	250.00	10.00	80.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	250.00	1.00	250.00	10.00	200.00	1.00	250.00
3500	5.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	250.00	1.00	250.00	10.00	200.00	1.00	250.00
4000	5.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	200.00	1.00	250.00	10.00	200.00	1.00	250.00
4500	10.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	200.00	1.00	250.00	10.00	200.00	1.00	250.00
5000	10.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	190.00	1.00	250.00	10.00	200.00	1.00	250.00
5500+	15.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	10.00	150.00	1.00	250.00	20.00	180.00	1.00	250.00	10.00	200.00	1.00	250.00

Silicate (continued 1)

Standard unit or scale: µM

Depth (m)	**South Pacific**		**Coastal S. Pacific**		**North Indian**		**Coastal N. Indian**		**Equatorial Indian**		**Coastal Eq. Indian**		**South Indian**		**Coastal S. Indian**		**Antarctic**		**Arctic**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
0	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
10	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
20	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
30	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
50	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
75	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
100	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
125	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
150	0.00	140.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	250.00	0.00	180.00	0.00	250.00	0.00	200.00	0.00	200.00
200	0.01	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	200.00
250	0.01	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	200.00
300	0.01	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	200.00
400	0.50	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	200.00
500	2.00	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	200.00
600	3.00	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	200.00
700	4.00	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	200.00
800	5.00	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	1.00	200.00	0.01	200.00
900	7.00	140.00	0.01	250.00	0.01	180.00	0.01	250.00	0.01	200.00	0.01	250.00	0.01	180.00	0.01	250.00	1.00	200.00	0.01	200.00
1000	10.00	150.00	1.00	250.00	1.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	1.00	180.00	1.00	250.00	1.00	200.00	0.01	200.00
1100	20.00	150.00	1.00	250.00	1.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	1.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
1200	25.00	150.00	1.00	250.00	1.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	1.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
1300	30.00	155.00	1.00	250.00	1.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
1400	35.00	160.00	1.00	250.00	5.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
1500	40.00	165.00	1.00	250.00	5.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
1750	50.00	165.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
2000	60.00	170.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
2500	65.00	170.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
3000	75.00	170.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
3500	80.00	170.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
4000	85.00	170.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
4500	90.00	170.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
5000	100.00	170.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00
5500+	100.00	170.00	1.00	250.00	10.00	180.00	1.00	250.00	1.00	200.00	1.00	250.00	5.00	180.00	1.00	250.00	10.00	200.00	0.01	200.00

Silicate (continued 2)
Standard unit or scale: µM

Depth (m)	Mediterranean		Black Sea		Baltic Sea		Persian Gulf		Red Sea		Sulu Sea	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
10	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
20	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
30	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
50	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
75	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
100	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
125	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
150	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00	0.00	200.00
200	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
250	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
300	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
400	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
500	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
600	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
700	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
800	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
900	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00	0.01	200.00
1000	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
1100	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
1200	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
1300	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
1400	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
1500	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
1750	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
2000	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
2500	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
3000	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
3500	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
4000	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
4500	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
5000	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00
5500+	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00	1.00	200.00

Note: A slightly different set of Silicate ranges were used in creating the World Ocean Atlas 2009 for the following basins: Mediterranean, Black, Baltic, Persian Gulf, Red and Sulu Seas.

Nitrate
Standard unit or scale: µM

Depth (m)	North Atlantic		Coastal N. Atlantic		Equatorial Atlantic		Coastal Eq. Atlantic		South Atlantic		Coastal S. Atlantic		North Pacific		Coastal N. Pacific		Equatorial Pacific		Coastal Eq. Pacific	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0.00	18.00	0.00	500.00	0.00	18.00	0.00	30.00	0.00	22.00	0.00	60.00	0.00	26.00	0.00	50.00	0.00	22.00	0.00	100.00
10	0.00	18.00	0.00	500.00	0.00	18.00	0.00	30.00	0.00	26.00	0.00	60.00	0.00	26.00	0.00	50.00	0.00	22.00	0.00	100.00
20	0.00	18.00	0.00	500.00	0.00	18.00	0.00	30.00	0.00	26.00	0.00	60.00	0.00	26.00	0.00	50.00	0.00	22.00	0.00	100.00
30	0.00	18.00	0.00	500.00	0.00	18.00	0.00	30.00	0.00	30.00	0.00	60.00	0.00	30.00	0.00	50.00	0.00	26.00	0.00	100.00
50	0.00	26.00	0.00	500.00	0.00	26.00	0.00	30.00	0.00	30.00	0.00	60.00	0.00	30.00	0.00	50.00	0.00	34.00	0.00	100.00
75	0.00	30.00	0.00	500.00	0.00	30.00	0.00	30.00	0.00	34.00	0.00	60.00	0.00	34.00	0.00	50.00	0.00	34.00	0.00	100.00
100	0.00	30.00	0.00	500.00	0.00	30.00	0.00	30.00	0.00	34.00	0.00	60.00	0.00	34.00	0.00	50.00	0.00	34.00	0.00	100.00
125	0.00	30.00	0.00	500.00	0.00	30.00	0.00	40.00	0.00	34.00	0.00	60.00	0.00	42.00	0.00	50.00	0.00	34.00	0.00	100.00
150	0.00	30.00	0.00	500.00	0.00	30.00	0.00	40.00	0.00	34.00	0.00	60.00	0.00	42.00	0.00	50.00	0.00	38.00	0.00	100.00
200	0.00	30.00	0.00	500.00	0.00	30.00	0.00	40.00	0.00	38.00	0.00	60.00	0.00	46.00	0.00	50.00	0.00	38.00	0.00	100.00
250	0.00	34.00	0.00	500.00	0.00	34.00	0.00	45.00	0.00	38.00	0.00	60.00	0.00	46.00	0.00	75.00	0.00	42.00	0.00	100.00
300	0.00	34.00	0.00	500.00	0.00	34.00	0.00	45.00	0.00	38.00	0.00	60.00	0.00	46.00	0.00	75.00	0.00	42.00	0.00	100.00
400	0.00	42.00	0.00	500.00	0.00	42.00	0.00	45.00	2.00	42.00	0.00	60.00	2.00	46.00	0.00	75.00	2.00	42.00	0.00	100.00
500	0.00	42.00	0.00	500.00	0.00	42.00	0.00	45.00	2.00	46.00	0.00	60.00	2.00	46.00	0.00	75.00	2.00	46.00	0.00	100.00
600	0.00	42.00	0.00	500.00	0.00	42.00	0.00	45.00	2.00	46.00	0.00	60.00	2.00	50.00	0.00	75.00	2.00	46.00	0.00	100.00
700	6.00	46.00	0.00	500.00	0.00	46.00	0.00	45.00	2.00	46.00	0.00	60.00	2.00	50.00	0.00	75.00	2.00	50.00	0.00	75.00
800	6.00	46.00	0.00	500.00	0.00	46.00	0.00	45.00	2.00	46.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	56.00	0.00	75.00
900	6.00	46.00	0.00	500.00	0.00	46.00	0.00	45.00	2.00	46.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	56.00	0.00	75.00
1000	6.00	46.00	0.00	500.00	0.00	46.00	0.00	40.00	2.00	46.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	56.00	0.00	75.00
1100	6.00	46.00	0.00	500.00	0.00	46.00	0.00	40.00	2.00	46.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	56.00	0.00	75.00
1200	6.00	48.00	0.00	500.00	0.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	56.00	0.00	75.00
1300	6.00	48.00	0.00	500.00	0.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	50.00	0.00	75.00
1400	6.00	48.00	0.00	500.00	6.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	50.00	0.00	75.00
1500	6.00	48.00	0.00	500.00	6.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	50.00	0.00	75.00
1750	6.00	48.00	0.00	500.00	6.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	50.00	0.00	75.00
2000	6.00	48.00	0.00	500.00	6.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	50.00	0.00	75.00
2500	6.00	48.00	0.00	500.00	6.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	54.00	0.00	75.00	2.00	50.00	0.00	75.00
3000	6.00	48.00	0.00	500.00	6.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	50.00	0.00	75.00	2.00	46.00	0.00	75.00
3500	10.00	48.00	0.00	500.00	10.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	46.00	0.00	75.00	2.00	46.00	0.00	75.00
4000	10.00	48.00	0.00	500.00	10.00	48.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	46.00	0.00	75.00	2.00	46.00	0.00	75.00
4500	10.00	46.00	0.00	500.00	10.00	46.00	0.00	40.00	6.00	42.00	0.00	60.00	2.00	42.00	0.00	75.00	2.00	46.00	0.00	75.00
5000	10.00	44.00	0.00	500.00	10.00	44.00	0.00	40.00	10.00	42.00	0.00	60.00	10.00	42.00	0.00	75.00	2.00	46.00	0.00	75.00
5500+	14.00	42.00	0.00	500.00	14.00	42.00	0.00	40.00	14.00	34.00	0.00	60.00	14.00	42.00	0.00	75.00	2.00	46.00	0.00	75.00

Nitrate (continued 1)
Standard unit or scale: μM

Depth (m)	South Pacific		Coastal S. Pacific		North Indian		Coastal N. Indian		Equatorial Indian		Coastal Eq. Indian		South Indian		Coastal S. Indian		Antarctic		Arctic	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0.00	18.00	0.00	40.00	0.00	14.00	0.00	30.00	0.00	4.00	0.00	35.00	0.00	18.00	0.00	50.00	0.00	46.00	0.00	18.00
10	0.00	18.00	0.00	40.00	0.00	18.00	0.00	30.00	0.00	6.00	0.00	35.00	0.00	18.00	0.00	50.00	0.00	46.00	0.00	18.00
20	0.00	18.00	0.00	40.00	0.00	18.00	0.00	30.00	0.00	6.00	0.00	35.00	0.00	18.00	0.00	50.00	0.00	46.00	0.00	18.00
30	0.00	22.00	0.00	40.00	0.00	18.00	0.00	30.00	0.00	14.00	0.00	35.00	0.00	18.00	0.00	50.00	0.00	46.00	0.00	18.00
50	0.00	26.00	0.00	40.00	0.00	30.00	0.00	30.00	0.00	18.00	0.00	35.00	0.00	18.00	0.00	50.00	0.00	46.00	0.00	18.00
75	0.00	30.00	0.00	40.00	0.00	30.00	0.00	40.00	0.00	26.00	0.00	35.00	0.00	22.00	0.00	50.00	0.00	46.00	0.00	18.00
100	0.00	30.00	0.00	40.00	0.00	30.00	0.00	40.00	0.00	30.00	0.00	45.00	0.00	22.00	0.00	50.00	0.00	46.00	0.00	22.00
125	0.00	30.00	0.00	40.00	0.00	42.00	0.00	40.00	0.00	34.00	0.00	45.00	0.00	26.00	0.00	50.00	0.00	46.00	0.00	22.00
150	0.00	30.00	0.00	40.00	0.00	42.00	0.00	40.00	0.00	34.00	0.00	45.00	0.00	30.00	0.00	50.00	0.00	46.00	0.00	22.00
200	0.00	38.00	0.00	40.00	0.00	42.00	0.00	40.00	0.00	38.00	0.00	45.00	0.00	30.00	0.00	50.00	0.00	46.00	0.00	26.00
250	0.00	38.00	0.00	40.00	2.00	42.00	0.00	40.00	2.00	38.00	0.00	50.00	0.00	30.00	0.00	50.00	0.00	46.00	0.00	26.00
300	0.00	38.00	0.00	60.00	2.00	50.00	0.00	40.00	2.00	46.00	0.00	50.00	0.00	30.00	0.00	50.00	0.00	46.00	0.00	26.00
400	4.00	42.00	0.00	60.00	2.00	50.00	0.00	40.00	2.00	46.00	0.00	50.00	0.00	34.00	0.00	50.00	4.00	46.00	0.00	28.00
500	6.00	46.00	0.00	60.00	2.00	50.00	0.00	40.00	2.00	46.00	0.00	50.00	0.00	34.00	0.00	50.00	6.00	46.00	0.00	28.00
600	6.00	50.00	0.00	60.00	2.00	50.00	0.00	40.00	2.00	46.00	0.00	50.00	0.00	38.00	0.00	50.00	6.00	46.00	0.00	32.00
700	6.00	50.00	0.00	60.00	2.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	0.00	46.00	0.00	50.00	6.00	46.00	0.00	32.00
800	10.00	50.00	0.00	60.00	2.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	0.00	46.00	0.00	50.00	14.00	46.00	0.00	42.00
900	10.00	50.00	0.00	60.00	2.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	0.00	46.00	0.00	50.00	14.00	46.00	0.00	42.00
1000	10.00	50.00	0.00	60.00	2.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	0.00	46.00	0.00	50.00	14.00	50.00	0.00	46.00
1100	10.00	50.00	0.00	60.00	2.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	0.00	46.00	0.00	50.00	14.00	50.00	0.00	46.00
1200	10.00	54.00	0.00	60.00	2.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	0.00	46.00	0.00	50.00	14.00	50.00	0.00	46.00
1300	10.00	54.00	0.00	60.00	2.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	0.00	46.00	0.00	50.00	14.00	50.00	0.00	50.00
1400	10.00	54.00	0.00	60.00	2.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	0.00	46.00	0.00	50.00	14.00	50.00	0.00	50.00
1500	10.00	54.00	0.00	60.00	20.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	50.00	0.00	50.00
1750	10.00	54.00	0.00	60.00	20.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	50.00	0.00	50.00
2000	10.00	54.00	0.00	60.00	20.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	50.00	0.00	54.00
2500	10.00	54.00	0.00	60.00	20.00	54.00	0.00	40.00	2.00	54.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	50.00	0.00	54.00
3000	10.00	54.00	0.00	60.00	20.00	54.00	0.00	40.00	2.00	46.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	50.00	0.00	54.00
3500	10.00	54.00	0.00	60.00	20.00	46.00	0.00	40.00	2.00	46.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	46.00	2.00	54.00
4000	10.00	54.00	0.00	60.00	20.00	46.00	0.00	40.00	2.00	46.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	46.00	2.00	46.00
4500	10.00	42.00	0.00	60.00	20.00	46.00	0.00	40.00	2.00	46.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	42.00	2.00	46.00
5000	10.00	38.00	0.00	60.00	20.00	46.00	0.00	40.00	2.00	46.00	0.00	50.00	2.00	46.00	0.00	50.00	14.00	42.00	2.00	46.00
5500+	14.00	38.00	0.00	60.00	20.00	46.00	0.00	40.00	2.00	46.00	0.00	50.00	10.00	46.00	0.00	50.00	18.00	42.00	2.00	46.00

Nitrate (continued 2)

Standard unit or scale: µM

Depth (m)	Mediterranean		Black Sea		Baltic Sea		Persian Gulf		Red Sea		Sulu Sea	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
0	0.00	30.00	0.00	125.00	0.00	50.00	0.00	10.00	0.00	35.00	0.00	45.00
10	0.00	30.00	0.00	125.00	0.00	50.00	0.00	10.00	0.00	35.00	0.00	45.00
20	0.00	30.00	0.00	75.00	0.00	50.00	0.00	10.00	0.00	35.00	0.00	45.00
30	0.00	30.00	0.00	75.00	0.00	50.00	0.00	10.00	0.00	35.00	0.00	45.00
50	0.00	30.00	0.00	50.00	0.00	50.00	0.00	10.00	0.00	35.00	0.00	45.00
75	0.00	30.00	0.00	35.00	0.00	30.00	0.00	10.00	0.00	35.00	0.00	45.00
100	0.00	30.00	0.00	35.00	0.00	30.00	0.00	10.00	0.00	35.00	0.00	45.00
125	0.00	20.00	0.00	35.00	0.01	20.00	0.00	10.00	0.00	35.00	0.00	45.00
150	0.00	20.00	0.00	35.00	0.01	20.00	0.00	10.00	0.00	35.00	0.00	45.00
200	0.00	20.00	0.00	30.00	0.01	20.00	0.00	10.00	0.00	35.00	0.00	45.00
250	0.00	20.00	0.00	15.00	0.01	20.00	0.00	10.00	0.01	35.00	0.00	45.00
300	0.00	20.00	0.00	15.00	0.01	20.00	0.00	10.00	0.01	35.00	0.00	45.00
400	0.00	20.00	0.00	5.00	0.01	20.00	0.00	10.00	0.01	35.00	0.00	45.00
500	0.00	20.00	0.00	5.00	0.01	20.00	0.00	10.00	0.01	35.00	0.00	45.00
600	0.00	20.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	45.00
700	0.00	20.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	45.00
800	0.00	20.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	45.00
900	0.00	20.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	45.00
1000	0.00	20.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	45.00
1100	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
1200	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
1300	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
1400	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
1500	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
1750	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
2000	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
2500	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
3000	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
3500	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
4000	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
4500	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
5000	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00
5500+	0.01	15.00	0.00	2.50	0.01	15.00	0.00	10.00	0.01	40.00	5.00	40.00

ANNEX V

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