Essential Ocean Variable (EOV): Nutrients

Background and Justification

The availability of inorganic macronutrients (nitrate (NO_3), phosphate (PO_4), silicic acid ($Si(OH)_4$), ammonium (NH_4), nitrite (NO_2)) in the upper ocean frequently limits and regulates the amount of organic carbon fixed by phytoplankton, thereby constituting a key control mechanism of carbon and biogeochemical cycling. There is a number of biogeographic regions in the open ocean characterized by different macronutrient regimes, either permanently or seasonally limiting the growth of phytoplankton. Measuring changes in macronutrient concentrations is essential to constraining net biological production and export fluxes, detecting shifts in biogeographic regimes, but also monitoring eutrophication phenomena.

For the glossary of terms and list of abbreviations please see the back of the document.

Table 1: EOV Information	
Name of EOV	Nutrients
Sub-Variables	Nitrate (NO_3^-), Nitrite (NO_2^-), Ammonium (NH_4), Phosphate (PO_4), Silicic acid ($Si(OH)_4$)
Derived Products	Quasi-conservative tracers such as preformed nitrate (N*) and NO etc.,
Supporting Variables	Surface and subsurface temperature, Surface and subsurface Salinity, Oxygen, Transient Tracers
Responsible GOOS Panel	GOOS Biogeochemistry Panel Contact: ioccp@ioccp.org

Table 2a: Requirements Setting				
Societal Drivers	1. The role of ocean biogeochemistry in climate 2. Human impacts on ocean biogeochemistry 3. Ocean ecosystem health			
Scientific Application(s)	Q 1.1. How is the ocean carbon content changing? Q 2.1. How large are the ocean's "dead zones" and how fast are they changing? Q 3.1. Is the biomass of the ocean changing? Q 3.2. How do the eutrophication and pollution impact ocean productivity and water quality?			
Readiness Level *[as defined in the FOO]*	Mature			
Phenomena to Capture	**1 Ventilation**	**2 Remineralization**	**3 Primary production**	**4 Eutrophication**
Temporal Scales of the Phenomena	Annual to decadal		Seasonal to decadal	Sub-weekly to decadal
Spatial Scales of the Phenomena	1000-3000 km		Coastal 0.1-100 km Open Ocean 100-1000 km	Coastal 0.1-100 km
Magnitudes/Range of the Signal to Capture			0.5 Pg C $year^{-1}$ $decade^{-1}$ (net community production)	a few %
Current Uncertainty Relative to the Signal				
Target Uncertainty Relative to the Signal				

Table 2b: Requirements Setting (continued)			
Phenomena to Capture	**5 Deoxygenation**	**6 Land-sea fluxes**	**7 Benthic fluxes**
Temporal Scales of the Phenomena			
Spatial Scales of the Phenomena			
Magnitudes/Range of the Signal to Capture			
Current Uncertainty Relative to the Signal			
Target Uncertainty Relative to the Signal			

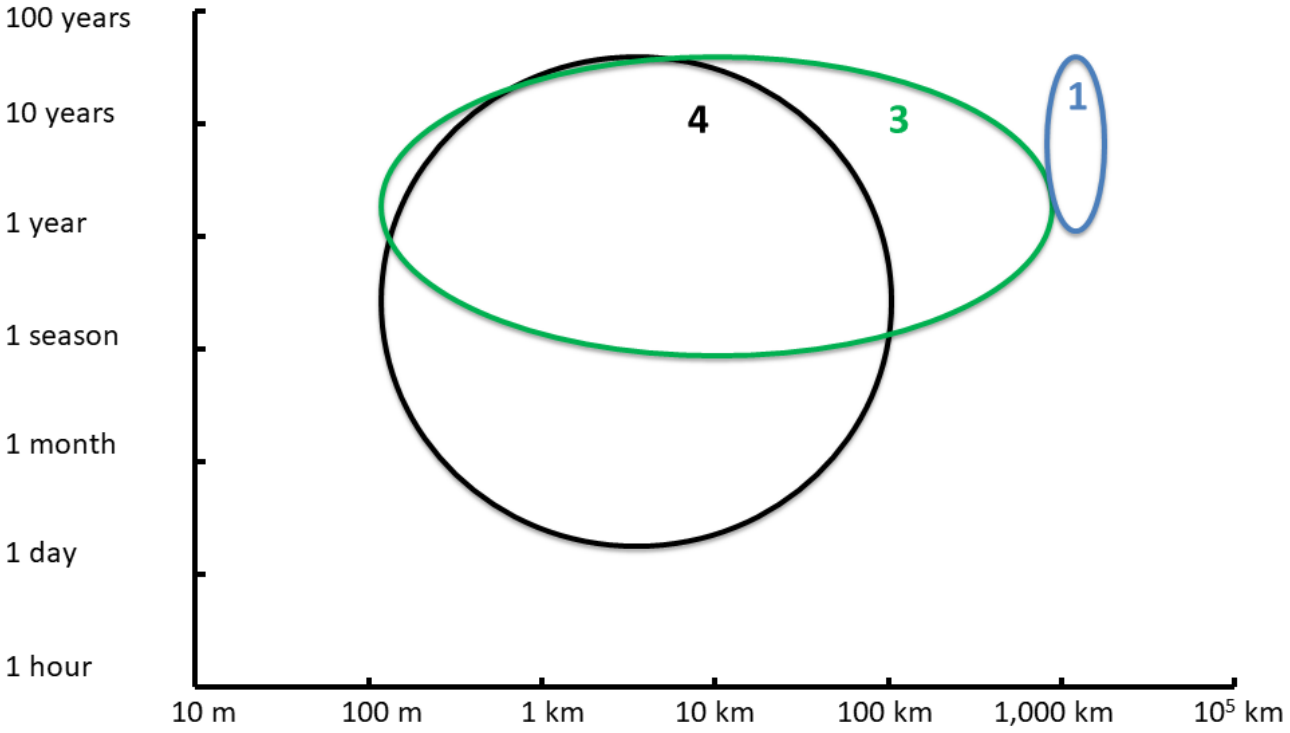

Figure 1: Spatial and temporal scales of phenomena (as color-coded and listed in Table 2 above) to be addressed. Some phenomena from Table 2 are missing due to lack of characteristic scales provided.

Table 3: Current Observing Networks						
Observing Approach	**Ship-based Underway Observations**	**Ship-based Repeat Hydrography**	**Ship-based Fixed-point Observatories**	**Profiling Floats**		
Readiness Level of the Observing Approach for this EOV	Pilot	Mature	Mature	Pilot		
Leading Observing Network	SOOP-CO_2	GO-SHIP		Biogeochemical (BGC) Argo		
Readiness Level of the Observing Network	Concept	Mature		Pilot		
Phenomena Addressed	3,5	1,2,3,4,5	1,2,3,4,5	1,2,3,5		
Spatial Scales Currently Captured by the Observing Network	Horizontal coverage: global, every 1°, denser in the coastal domain Vertical coverage: surface Footprint: *[to be defined for various oceanographic regimes]*	Horizontal coverage: global, very 1°, denser in the boundary current domain Vertical coverage: full depth Footprint: *[to be defined for various oceanographic regimes]*	Horizontal coverage: local Vertical coverage: Footprint: *[to be defined for various oceanographic regimes]*	Horizontal coverage: global Vertical coverage: Footprint: *[to be defined for various oceanographic regimes]*		
Typical Observing Frequency	Weekly to decadal	Decadal	Weekly to decadal			
Supporting Variables Measured	Surface and subsurface temperature and salinity	Surface and subsurface temperature and salinity	Surface and subsurface temperature and salinity			

Sensor(s)/ Technique	Bottle sampling, continuous flow	Bottle sampling, continuous flow	Bottle sampling, continuous flow	UV spectro-photometry		
Accuracy/Uncertainty Estimate (units)	PO_4: ±0.05 NO_3: ±0.03 Si: ±0.1 (µmol kg^{-1})	PO_4: ±0.05 NO_3: ±0.03 Si: ±0.1 (µmol kg^{-1})	PO_4: ±0.05 NO_3: ±0.03 Si: ±0.1 (µmol kg^{-1})	$\underline{NO_3}$ ~0.5-3 µM		
Reporting Mechanism(s)	Individual Networks Annual Reports IOCCP Annual Report					

Table 4: Future Observing Capacity			
Observing Approach	**Gliders**	**Moored Fixed-Point Observatories**	
What is the novel aspect of this observing approach?	Novel observing network (OceanGliders)	Resolving water column measurements of nutrients.	
How does this novel aspect impact our observing capacity?			
Readiness Level of the Observing Network	NO_3 Pilot Other Concept	NO_3 Pilot Other Concept	
Spatial Scales Captured by the Observing Network	Surface: 1 km Subsurface: 10-1000 km	1-100 km	
Typical Observing Frequency	Surface: Daily to annual Subsurface: daily to monthly	Daily to annual	
Time-scale Until Part of Observing System			
Sensor(s)/ Technique	UV spectro-photometry	UV spectro-photometry	
Accuracy/Uncertainty Estimate (units)	NO_3 ~0.5-3 µM	NO_3 ~0.5-3 µM	

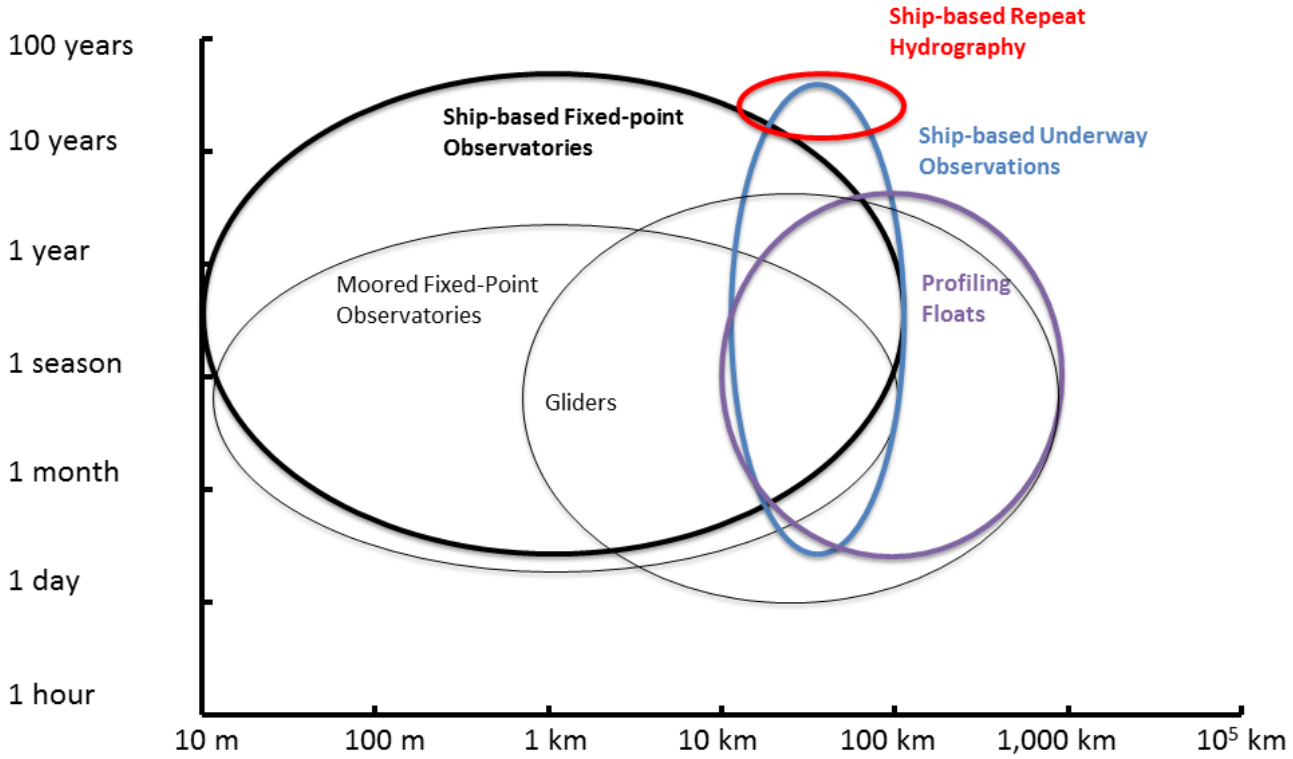

Figure 2. Spatial and temporal observation scales of component networks listed in Table 3 (thick coloured circles) and in Table 4 (thin black circles).

Table 5: Data & Information Creation					
Observing Approach	**Oversight & Coordination**	**Data Quality Control**	**Near Real-Time Data Stream Delivery**	**Data Repository**	**Data Products**
Ship-based Underway Observations	SOOP-CO_2			NCEI OCADS	GLODAPv2 World Ocean Atlas nutrient climatologies
	concept				
Ship-based Repeat Hydrography	GO-SHIP			CCHDO NCEI OCADS	
	mature				
Ship-based Fixed-Point Observatories				NCEI OCADS	
Profiling floats	BGC Argo	At the DAC level	Argo GDACs	Argo GDACs	
	pilot				

Table 6: Links & References	
Best Practices, Guides and Other Background Documentation	D. J. Hydes et al. (2010). Determination of dissolved nutrients (N, P, SI) in seawater with high precision and inter-comparability using gas-segmented continuous flow analysers. The GO-SHIP Repeat Hydrography Manual: A collection of Expert Reports and Guidelines, IOCCP Report No. 14, ICPO Publication Series No. 134, Version 1, 2010. K. Johnson, Pasqueron De Fommervault Orens, Serra Romain, D'Ortenzio Fabrizio, Schmechtig Catherine, Claustre Hervé, Poteau Antoine (2016). Processing Bio-Argo nitrate concentration at the DAC Level. Argo data management. http://doi.org/10.13155/46121 M. Aoyama, K. Bakker, J. van Ooijen, S. Ossebaar, E.M.S. Woodward (2015), Report from an International Nutrient Workshop focusing on Phosphate Analysis, Yang Yang Publisher, Fukushima, Japan. M. Aoyama et al. (2016). IOCCP-JAMSTEC 2015 Inter-laboratory Calibration Exercise of a Certified Reference Material for Nutrients in Seawater. IOCCP Report No. 1/2016. Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan. Certified Reference Materials (CRMs): SCOR JAMSTEC CRMs available from: http://www.jamstec.go.jp/scor/
Links for Contributing Networks	GO-SHIP: http://www.go-ship.org/ BGC Argo: http://biogeochemical-argo.org/index.php
Links for Near-Real Time Data Stream Delivery	BGC Argo: http://biogeochemical-argo.org/data-access.php
Links to Data Repositories	CCHDO: http://cchdo.ucsd.edu/ NCEI OCADS: https://www.nodc.noaa.gov/ocads/ BGC Argo: http://biogeochemical-argo.org/data-access.php
Data Product Links and References	GLODAPv2: http://glodap.info/ Olsen, A., Key, R. M., van Heuven, S., Lauvset, S. K., Velo, A., Lin, X., Schirnick, C., Kozyr, A., Tanhua, T., Hoppema, M., Jutterström, S., Steinfeldt, R., Jeansson, E., Ishii, M., Pérez, F. F., and Suzuki, T.: The Global Ocean Data Analysis Project version 2 (GLODAPv2) – an internally consistent data product for the world ocean, Earth Syst. Sci. Data, 8, 297-323, doi:10.5194/essd-8-297-2016, 2016. World Ocean Atlas 2013 (WOA13): https://climatedataguide.ucar.edu/climate-data/world-ocean-atlas-2013-woa13 Mishonov, Alexey & National Center for Atmospheric Research Staff (Eds). Last modified 13 Oct 2016. "The Climate Data Guide: World Ocean Atlas 2013 (WOA13)." Retrieved from https://climatedataguide.ucar.edu/climate-data/world-ocean-atlas-2013-woa13.

Glossary of terms

A **Framework for Ocean Observing (FOO)** is a guide for the ocean observing community to establish an integrated and sustained global observing system that addresses the variables to be measured, the approach to measuring them, and how their data and products will be managed and made widely available. FOO is available from: http://www.ioccp.org/index.php/foo

A **GOOS Essential Ocean Variable** is a sustained measurement or a group of measurements necessary to assess state and change at a global level, and to increase societal benefits from the ocean *[on scales from global to regional].*

Sub-variables are components of the EOV that may be measured, derived or inferred from other elements of the observing system and used to estimate the desired EOV.

Supporting variables are other EOVs or other measurements from the observing system that may be needed to deliver the sub-variables and/or derived products of the EOV.

Derived products are calculated from the EOV and other relevant information, in response to user needs.

A **phenomenon** is an observed process, event, or property, with characteristic spatial and time scale(s), measured or derived from one or a combination of EOVs, and needed to answer at least one of the GOOS Scientific Questions.

A **footprint** is here defined as the area over which given EOV measurements performed by a single observing element (as a transect, station, track, etc.) are representative of a broader region.

List of abbreviations

EOV – Essential Ocean Variable
GOOS – Global Ocean Observing System
IOCCP – International Ocean Carbon Coordination Project
FOO – Framework for Ocean Observing
UV – Ultraviolet
GO-SHIP – The Global Ocean Ship-Based Hydrographic Investigations Program
BGC - Biogeochemical
CCHDO – Clivar & Carbon Hydrographic Data Office
NCEI OCADS – National Centers for Environmental Information Ocean CArbon Data System
GDAC – Global Data Assembly Centre