Essential Ocean Variable (EOV): Stable Carbon Isotopes

Background and Justification

The utility of carbon-13 isotope (δ13C, the carbon-13 to carbon-12 isotope ratio $^{13}C/^{12}C$) as a tracer of the ocean's carbon cycle is observation limited. By observing the temporal development of the lightening of the oceanic inorganic carbon pool due to the uptake of CO_2 originating from the burning of ^{13}C-depleted fossil fuel carbon, a phenomenon also known as oceanic ^{13}C Suess effect, an estimation of the anthropogenic carbon fraction of DIC is possible. Recent improvements in measuring the concentration of carbon dioxide (CO_2) gas dissolved in seawater using field portable spectrometers open up the possibility of underway $^{13}C/^{12}C$ observations across large portions of the surface ocean. Such data sets would substantially improve $\delta^{13}C$-based estimates of organic matter (OM) export rate and of the air-sea $^{13}CO_2$ flux. The latter term can be compared to depth-integrated $^{13}CO_2$ inventory changes in the water column to provide a separation of anthropogenic CO_2 change due to air-sea CO_2 flux versus change due physical transport by ocean circulation. Recent application of this approach in the North Atlantic indicates that 50% of the anthropogenic CO_2 increase in this ocean basin is a result of transport from the South Atlantic as part of the meridional overturning circulation.

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

Table 1: EOV Information	
Name of EOV	Stable Carbon Isotopes
Sub-Variables	$^{13}C/^{12}C$ isotope ratio of Dissolved Inorganic Carbon (DIC)
Derived Products	Air-sea carbon flux, Anthropogenic CO_2 inventories, Organic matter export flux
Supporting Variables	Surface and subsurface temperature, Surface and subsurface salinity, Inorganic Carbon (DIC, Total Alkalinity (TA), partial pressure of CO_2 (pCO_2))
Responsible GOOS Panel	GOOS Biogeochemistry Panel Contact: ioccp@ioccp.org

Table 2: Requirements Setting				
Societal Drivers	1. The role of ocean biogeochemistry in climate 2. Human impacts on ocean biogeochemistry			
Scientific Application(s)	Q 1.1. How is the ocean carbon content changing? Q 2.2. What are rates and impacts of ocean acidification?			
Readiness Level **(as defined in the FOO)**	Mature			
Phenomena to Capture	**1** **Anthropogenic carbon sequestration**	**2** **Export Fluxes**	**3** **Air-sea fluxes**	
Temporal Scales of the Phenomena	Decadal	Seasonal to decadal		
Spatial Scales of the Phenomena	100-1000 km	100-1000 km		
Magnitudes/Range of the Signal to Capture	2 Pg C $year^{-1}$	0.5 Pg C yr^{-1} $decade^{-1}$ (organic matter)		
Current Uncertainty Relative to the Signal				
Target Uncertainty Relative to the Signal	± 10%	± 20 %		

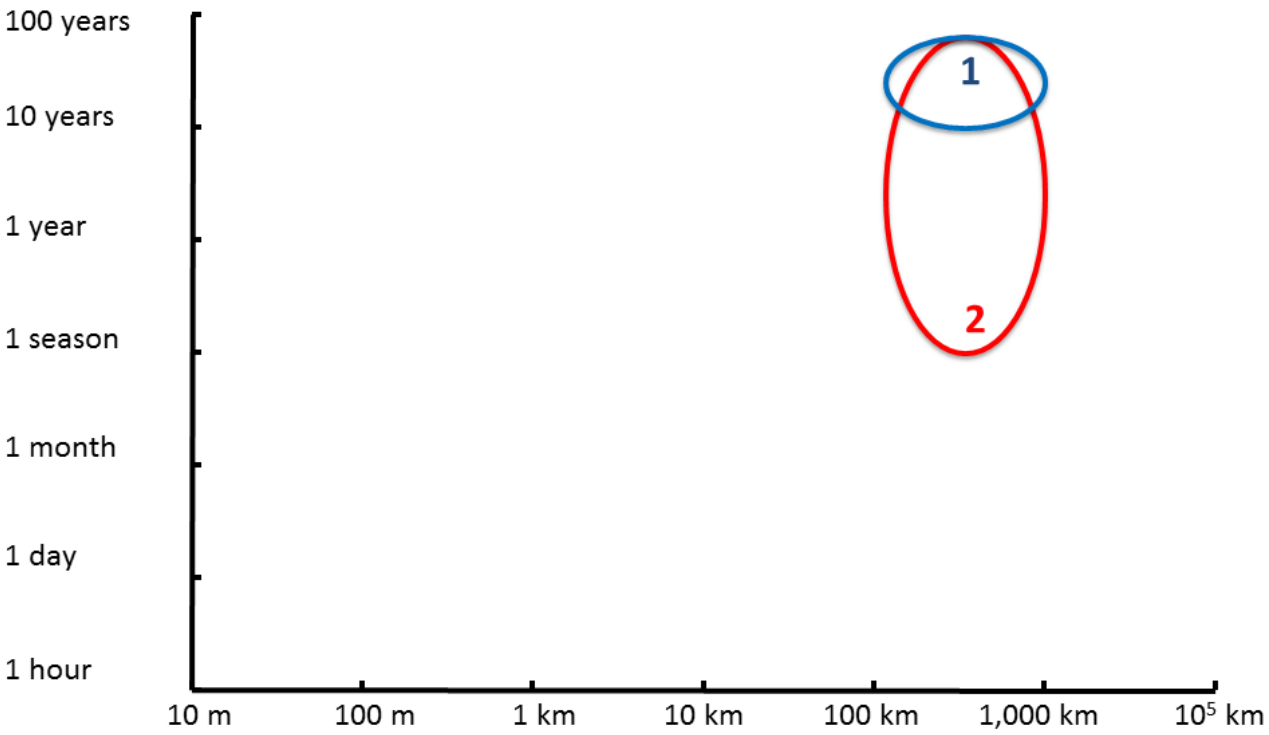

Figure 1: Spatial and temporal scales of phenomena (as color-coded and listed in Table 2 above) to be addressed.

Table 3: Current Observing Networks			
Observing Approach	**Ship-based Repeat Hydrography**	**Ship-based Fixed-point Observatories**	**Ship-based Underway Observations**
Readiness Level of the Observing Approach for this EOV	Mature	Mature	Pilot
Leading Observing Network	GO-SHIP		SOOP-CO_2
Readiness Level of the Observing Network	Mature	Concept	Concept
Phenomena Addressed	**1,2,3**	**1,2,3**	**2,3**
Spatial Scales Currently Captured by the Observing Network	Horizontal coverage: every 30-60 nm Vertical coverage: Footprint: *[to be defined for various oceanographic regimes]*	Horizontal coverage: Vertical coverage: Footprint: *[to be defined for various oceanographic regimes]*	Horizontal coverage: every 30-60 nm Vertical coverage: Footprint: *[to be defined for various oceanographic regimes]*
Typical Observing Frequency	Annual to decadal	Seasonal to decadal	Seasonal to decadal
Supporting Variables Measured	Surface and subsurface temperature, Surface and subsurface salinity, DIC, TA	Surface and subsurface temperature, Surface and subsurface salinity, DIC, TA	Atmospheric /Oceanic CO_2, Surface and subsurface temperature, Surface and subsurface salinity, fCO_2, DIC, TA
Sensor(s)/ Technique	Isotope ratio mass spectrometry	Isotope ratio mass spectrometry, Cavity ring down spectrometry	Isotope ratio mass spectrometry, Cavity ring down spectrometry
Accuracy/Uncertainty Estimate (units)	± 0.05 ‰	± 0.05 ‰	± 0.07 ‰
Reporting Mechanism(s)	Individual Networks Annual Reports		

Table 4: Future Observing Capacity	
Observing approach	
What is the novel aspect of this observing approach?	*none at this time*
How does this novel aspect impact our observing capacity?	

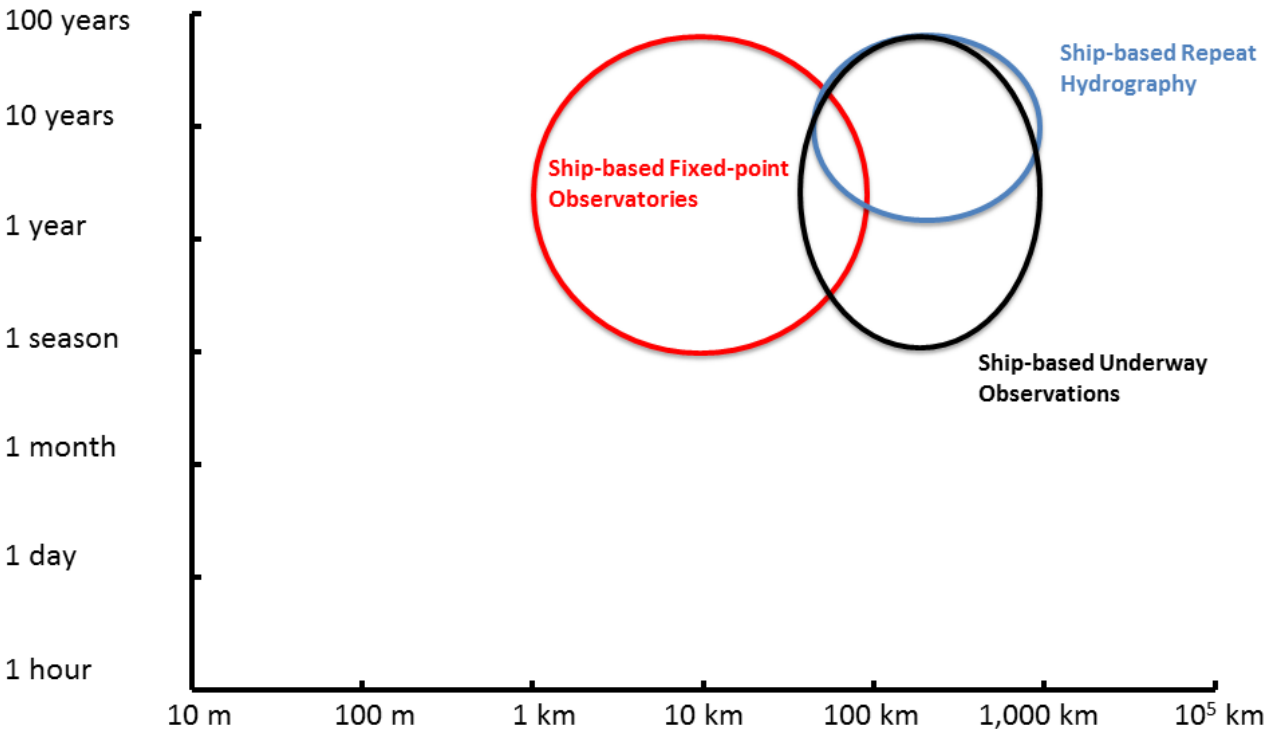

Figure 2. Spatial and temporal observation scales of component networks listed in Table 3 (thick coloured circles) and in Table 4 (thin black circles).

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				NCEI OCADS	GLODAPv2 An internally consistent dataset of d13C-DIC in the North Atlantic Ocean – NAC13v1 Global compilation of Carbon-13 measurements during 1990-2005 in dissolved inorganic carbon (δ13C_DIC)
Ship-based Repeat Hydrography	GO-SHIP	CCHDO		CCHDO NCEI OCADS	
Ship-based Fixed-Point Observatories					

Table 6: Links & References	
Best Practices, Guides and Other Background Documentation	A. P. McNichol et al. (2010). Collection and measurement of carbon isotopes in seawater DIC. 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.
Links for Contributing Networks	GO-SHIP: http://www.go-ship.org/index.html
Links for Near-Real Time Data Stream Delivery	CCHDO: http://cchdo.ucsd.edu/
Links to Data Repositories	CCHDO: http://cchdo.ucsd.edu/ NCEI OCADS: https://www.nodc.noaa.gov/ocads/
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. An internally consistent dataset of d13C-DIC in the North Atlantic Ocean – NAC13v1 Becker, M., Andersen, N., Erlenkeuser, H., Humphreys, M. P., Tanhua, T., and Körtzinger, A. (2016). An internally consistent dataset of δ13C-DIC in the North Atlantic Ocean – NAC13v1, Earth Syst. Sci. Data, 8, 559-570, doi:10.5194/essd-8-559-2016. Global compilation of Carbon-13 measurements during 1990-2005 in dissolved inorganic carbon (δ13C_DIC) Schmittner, A., Gruber, N., Mix, A. C., Key, R. M., Tagliabue, A., and Westberry, T. K. (2013). Biology and air–sea gas exchange controls on the distribution of carbon isotope ratios (δ13C) in the ocean, Biogeosciences, 10, 5793-5816, doi:10.5194/bg-10-5793-2013.

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
$\delta^{13}C$ – Carbon-13 isotope
CO_2 – Carbon dioxide
fCO_2 – Fugacity of carbon dioxide
DIC – Dissolved Inorganic Carbon
TA – Total Alkalinity
nm – nautical mile = 1.852 km
GO-SHIP – The Global Ocean Ship-Based Hydrographic Investigations Program
NCEI OCADS – National Centers for Environmental Information Ocean CArbon Data System
CCHDO – The Clivar & Carbon Hydrographic Data Office
GLODAP – Global Ocean Data Analysis Project

List of References

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Quay, P. D., R. Sonnerup, T. Westby, J. Stutsman, and A. McNichol. 2003. Changes in the $^{13}C/^{12}C$ of dissolved inorganic carbon in the ocean as a tracer of anthropogenic CO_2 uptake. Global Biogeochemical Cycles 17:1-20 [doi:10.1029/ 2001GB001817].

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