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 13C/12C) 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 CO2 originating from the burning of 13C-depleted fossil fuel carbon, a phenomenon also known as oceanic 13C Suess effect, an estimation of the anthropogenic carbon fraction of DIC is possible. Recent improvements in measuring the and 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.

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
Supporting Variables	Temperature (T), Salinity (S), Dissolved Inorganic Carbon (DIC), Total Alkalinity (TA), Fugacity of carbon dioxide (fCO_2)
Contact/Lead Expert(s)	Contact: IOCCP Lead Experts: Arne Körtzinger (GEOMAR, Germany), Paul Quay (University of Washington, USA)

Table 2: Requirements Setting				
Responsible GOOS Panel	Biogeochemistry Panel			
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	Mature			
Phenomena to Capture	**1** **Interior ocean anthropogenic CO_2 storage**	**2** **Organic carbon export from euphotic zone**		
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	2 Pg C $year^{-1}$	0.5 Pg C yr^{-1} $decade^{-1}$?		
Desired Detection Limit Relative to the Signal	± 10%	± 20 %		

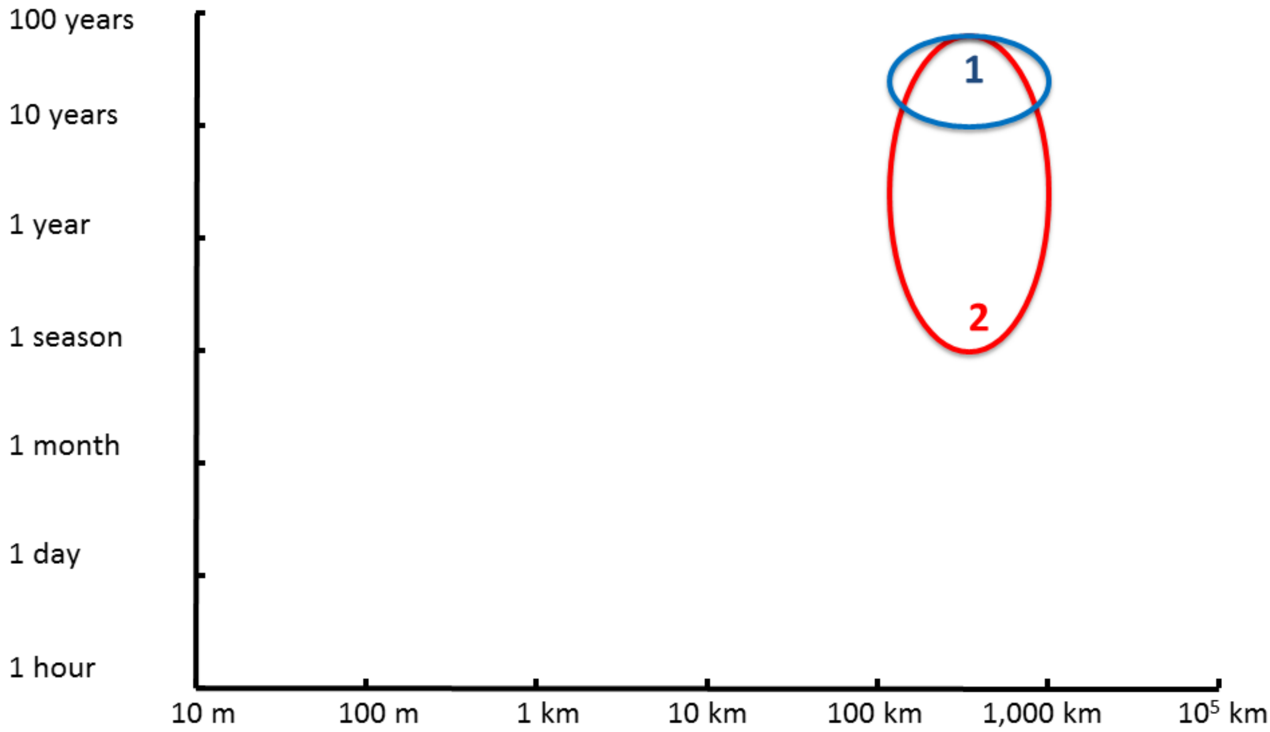

Figure 1: Spatial and temporal scales of phenomena (as color-coded and listed in Table 2 above) to be addressed.

Table 3: Current Observing Networks*						
Observing Network	**Ship Of Opportunity (SOO)**	**Repeat Hydrography (RH)**	**Ship-based Time-Series (STS)**			
Phenomena Addressed	**2**	**1,2**	**1,2**			
Readiness Level of the Observing Network (as defined in the FOO)	Pilot	Mature	Mature			
Spatial Scales Currently Captured by the Observing Network	30-60 nm	30-60 nm	Local			
Typical Observing Frequency	Seasonal to decadal	Annual to decadal	Seasonal to decadal			
Supporting Variables Measured	Atmospheric /Oceanic CO_2, T, S, fCO_2, DIC, TA	T, S, DIC, TA	T, S, DIC, TA			
Sensor(s)/ Technique	Isotope ratio mass spectrometry, Cavity ring down spectrometry	Isotope ratio mass spectrometry	Isotope ratio mass spectrometry, Cavity ring down spectrometry			
Accuracy/Uncertainty Estimate (units)	± 0.07 ‰	± 0.05 ‰	± 0.05 ‰			
Reporting Mechanism(s)	GOOS Implementation Plan IOCCP Report GO-SHIP					

*By an Observing Network we understand a number of reasonably well coordinated observing platforms equipped with technology allowing measurements of this particular EOV.

Table 4: Future Observing Networks					
Observing Network					
Phenomena Addressed					
Readiness Level of the Observing Network (as defined in the FOO)					
Spatial Scales Captured by the Observing Network					
Typical Observing Frequency					
Time-scale until Part of Observing System					
Supporting Variables Measured					
Sensor(s)/Technique					
Accuracy/Uncertainty Estimate (units)					

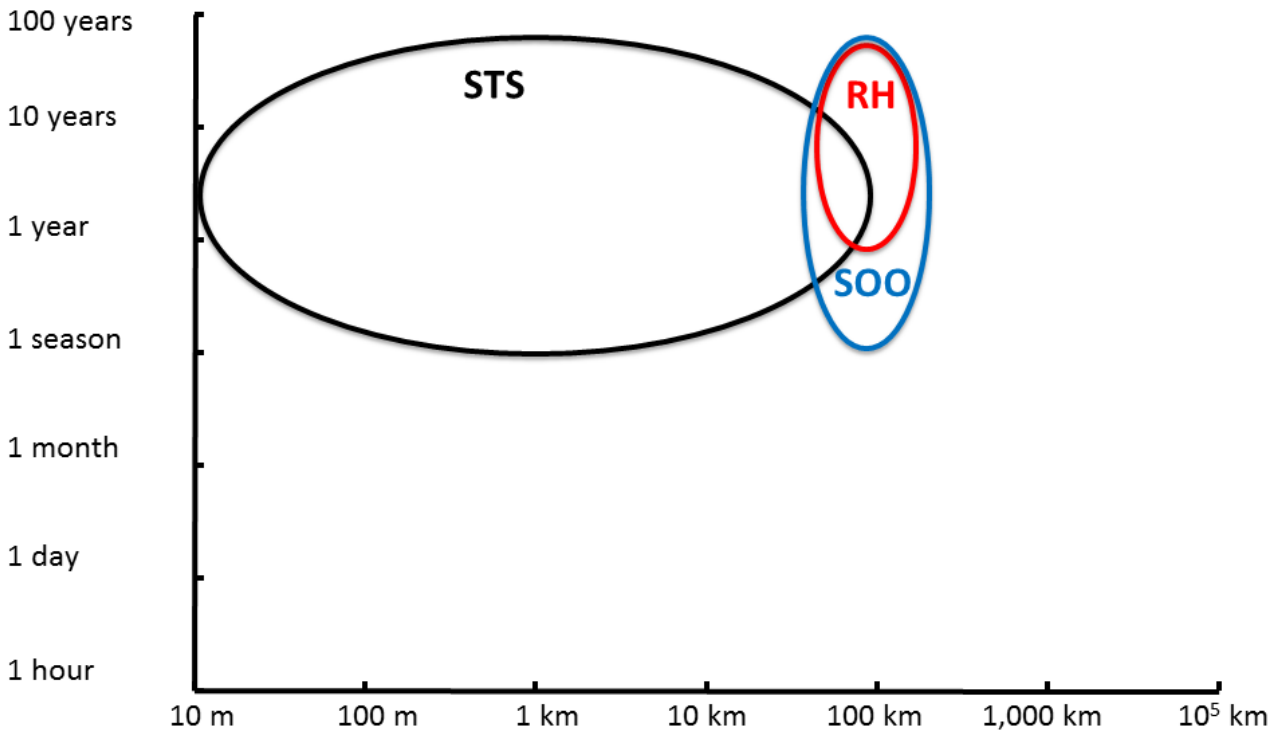

Figure 2. Spatial and temporal observation scales of component networks listed in Table 3 (thick coloured circles) and in Table 4 (thin black circles).

Table 5: Data & Information Creation					
Responsible entity and readiness level in each category per observing network	**Oversight & Coordination**	**Data Quality Control**	**Near Real-Time Data Stream Delivery**	**Data Repository**	**Data Product**
Ship of Opportunity	no formal group for surface underway measurements				
	?				
Repeat Hydrography	Ocean section coordination through IOCCP/GO-SHIP	CCHDO	CCHDO	CDIAC CCHDO for repeat hydrography	GLODAPv2
	?				
Ship-based Time-Series					

Table 6: Links & References	
Links (especially regarding Background and Justification)	Becker N., N. Andersen, B. Fiedler, P. Fietzek, A. Körtzinger, T. Steinhoff, and G. Friedrichs. 2012. Using cavity ringdown spectroscopy for continuous monitoring of $\delta^{13}C(CO_2)$ and fCO_2 in the surface ocean. Limnology and Oceanography: Methods 10: 752-766 [doi:10.4319/lom.2012.10.752]. Quay, P., J. Stutsman, R. A. Feely, and L.W. Juranek. 2009. Net community production rates across the subtropical and equatorial Pacific Ocean estimated from air-sea $\delta^{13}C$ disequilibrium. Global Biogeochemical Cycles 23:1-15 [doi:10.1029/2008GB003193]. 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]. Schmittner, A., N. Gruber, A.C. Mix, R.M. Key, A. Tagliabueand T.K. Westberry. 2013. Biology and air–sea gas exchange controls on the distribution of carbon isotope ratios ($\delta^{13}C$) in the ocean, Biogeosciences, 10, 5793-5816 [doi:10.5194/bg-10-5793-2013].
Links for Contributing Networks	http://www.go-ship.org/index.html http://www.locean-ipsl.upmc.fr/~oceans13c/indexAng.htm
Data References	http://cchdo.ucsd.edu/ CDIAC

List of abbreviations

EOV – Essential Ocean Variable
GOOS – Global Ocean Observing System
IOCCP – International Ocean Carbon Coordination Project
FOO – Framework for Ocean Observing
GEOMAR – GEOMAR Helmholtz Centre for Ocean Research
$\delta^{13}C$ – Carbon-13 isotope
CO_2 – Carbon dioxide
T – Temperature
S – Salinity
fCO_2 – Fugacity of carbon dioxide
DIC – Dissolved Inorganic Carbon
TA – Total Alkalinity
SOO – Ships Of Opportunity
RH – Repeat Hydrography
STS – Ship-based Time-Series
nm – nautical mile = 1.852 km

GO-SHIP – The Global Ocean Ship-Based Hydrographic Investigations Program
CDIAC – Carbon Dioxide Information Data Analysis Center
CCHDO – The Clivar & Carbon Hydrographic Data Office
GLODAP – Global Ocean Data Analysis Project