Oxygen data in water column: scientific issues and needs

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Workshop on Interoperability Technologies and Best Practices in Environmental Monitoring - Brest, 10-12 October 2018

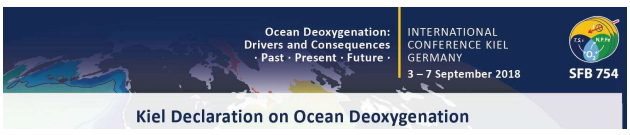
Why are we measuring oxygen ?

Scientific challenges:

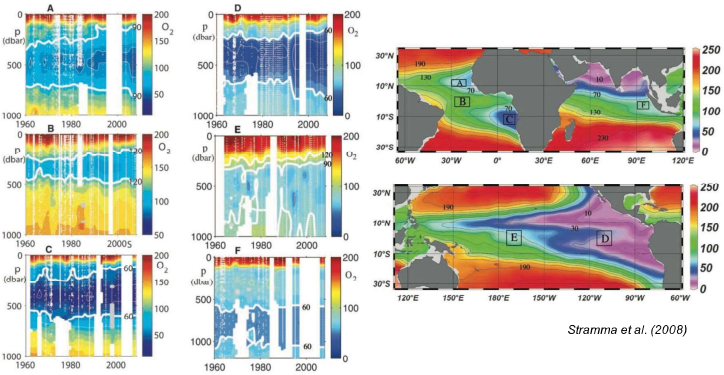
- Detect and documents the ocean's deoxygenation (expansion of OMZ)
- Estimate variability in ocean circulation/mixing (e.g. ventilation)
- Determine seasonal to interannual changes in NCP and export production
- Improve atmospheric O_2/N_2 constraint on the oceanic uptake of anthropogenic CO_2
- Prediction and assessment of anoxic or hypoxic events
- Provide constraints for ocean biogeochemistry models

The ocean is losing its breath

- During the past 50 years oxygen-depleted waters have expanded fourfold and some areas of the ocean have lost up to 40% of their oxygen
- Loss of oxygen is a threat to marine life, the ocean's ecosystems and coastal communities
- Global warming limits the supply of oxygen from the atmosphere (reduce mixing and deep ventilation)
- Inputs of nutrients and organic waste increase oxygen demand (biological production and consumption)
- Deoxygenation can accelerate global warming via enhanced marine production of greenhouse gases under low oxygen conditions



Several O_2-minimum zones have lost O_2 in the recent decades, resulting in a expansion of the regions with hypoxia



Stramma et al. (2008)

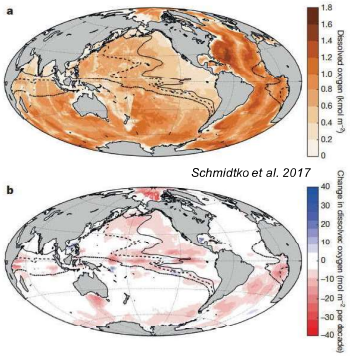
Global oceanic O_2 content since 1960

a- Global O_2 inventory
b- Change in O2 per decade

Table 1 | Oxygen content and change per basin

Basin	Oxygen content (Pmol)	Oxygen change (Tmol per decade)	Change as percentage of global change	Volume as percentage of global ocean volume
Arctic Ocean	4.7±0.2	−73±30	7.6±3.1	1.2
North Atlantic	26.9±0.1	−9±19	0.9±1.9	8.5
Equatorial Atlantic	15.9±0.0	−72±20	7.5±2.1	5.7
South Atlantic	22.4±0.1	−119±27	12.4±2.8	7.8
North Pacific	24.5±0.1	−173±40	18.0±4.2	16.3
Equatorial Pacific	25.5±0.4	−210±125	21.9±13.0	16.3
South Pacific	33.1±0.1	−71±37	7.4±3.9	14.3
Equatorial Indian Ocean	10.7±0.1	−55±49	5.7±5.1	6.6
South Indian Ocean	26.1±0.1	−27±34	2.8±3.5	10.2
Southern Ocean	37.6±0.1	−152±47	15.8±4.9	13.1
Total	**227.4±1.1**	**−961±429**	**100**	**100**

Trends that are more significant than two standard errors are marked in light grey. See Extended Data Table 1 for an extended version of this table.

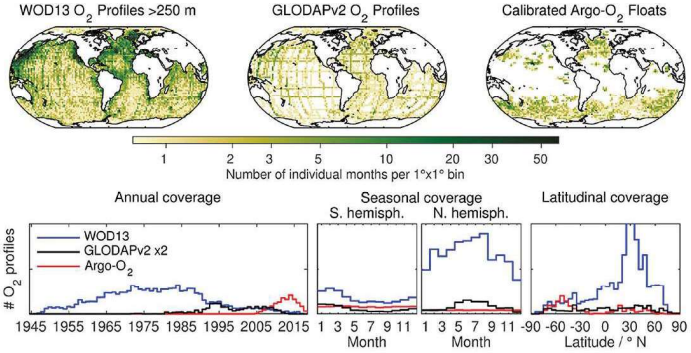


Schmidtko et al. 2017

Expanded observation is immediately required for accurate documentation and prediction of ocean oxygen changes

→ To meet these objectives we are dependent on the quality of the O_2 measurements performed

O_2 is the most measured oceanic biogeochemical variable



Bittig et al. (Frontiers 2018)

Essential Ocean Variable (EOV) for oxygen

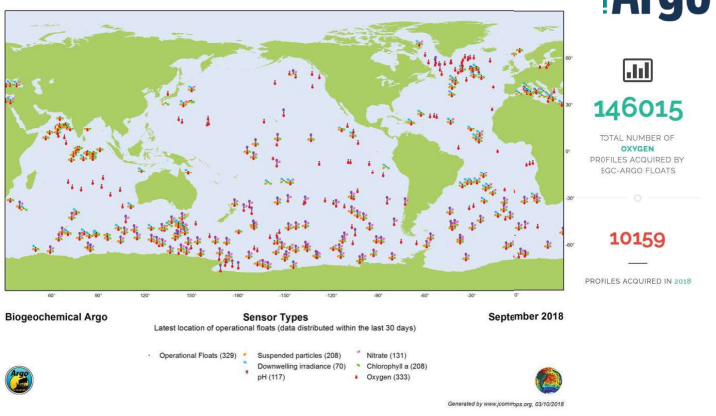
The Global Ocean Observing System

Approach	Profiling floats	Ship sections	Fixed mooring	Gliders	Ship fixed point
OS Network	BGC Argo	GO-SHIP	OceanSites	OceanGliders	
Spatial scales	Global	Global Regional	Global	Regional Coastal	Regional Coastal
Observing frequency	Bi-weekly to annual	Annual Decadal	Hourly	Hourly	Monthly
Technique	Optical	Winkler Polyrographic	Optical	Optical Polyrographic	Winkler Polyrographic
Accuracy (µmol/kg)	± 2.0	± 0.5	± 2.0	± 2.0	± 0.5

Objective: achieve an accuracy of 1 µmol/kg with an accuracy of 0.5 µmol/kg (Gruber et al., 2010)

Where are the O_2 data archived ?

Oxygen seawater spatial coverage from Argo



biogeochemical Argo

146015

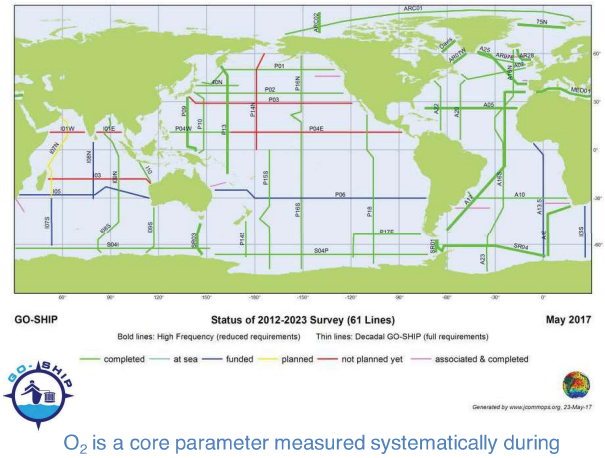
TOTAL NUMBER OF OXYGEN PROFILES ACQUIRED BY EGC-ARGO FLOATS

10159

PROFILES ACQUIRED IN 2018

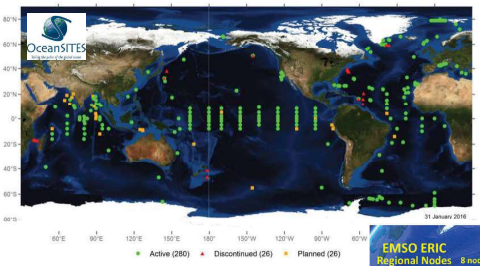
333 Argo-O_2 floats acquisition in real-time

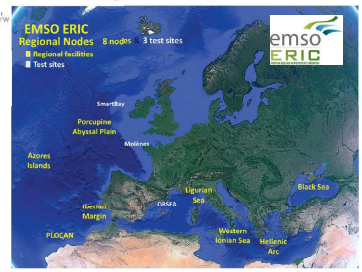
Oxygen seawater spatial coverage from GO-SHIP



O_2 is a core parameter measured systematically during GO-SHIP cruises (full cruise every 10 years)

Oxygen seawater spatial coverage from OceanSites/EMSO



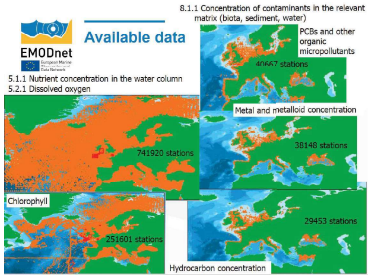


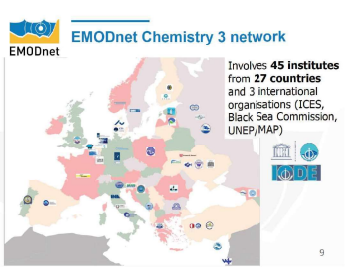
Oxygen is not measured everywhere (RT & DM)

Distributed from surface (pCO2) to deep waters (mixing, ventilation, biological activity) and seafloor (Azores)

Oxygen seawater data archive

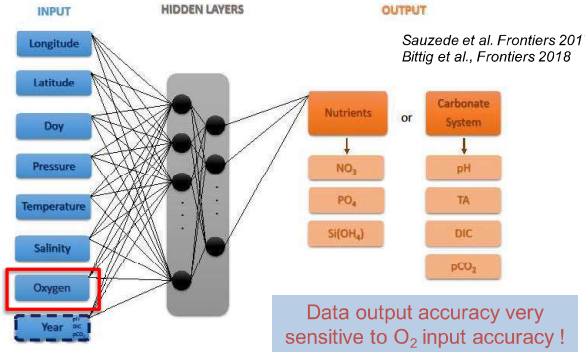
Oceanographic Data





but not all the archived O_2 data are adjusted !

Neural Network principle CANYON



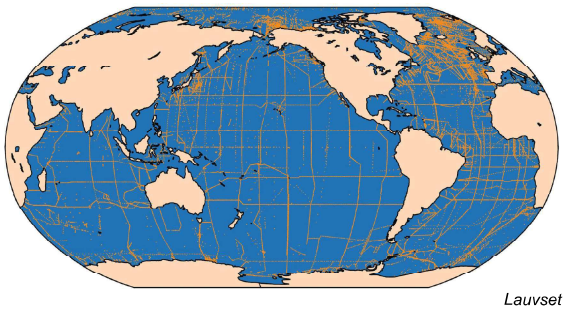
Sauzede et al. Frontiers 2017
Bittig et al., Frontiers 2018

Data output accuracy very sensitive to O_2 input accuracy !

Figure 2: Schematic overview of the CANYON MLP-based algorithm that retrieves the vertical distribution of nutrients (NO_3, PO_4 and $Si(OH)_4$) and parameters of the carbonate system in seawater (pH, TA, DIC and pCO_2) from temperature, salinity, oxygen and pressure associated with the geolocation and time of sampling of the considered inputs. The year is used as input only for retrieving pH, DIC and pCO_2 parameters

Oxygen seawater data available
GLODAP v2 = GLODAP v1 + CARINA + PACIFICA

glodapv2

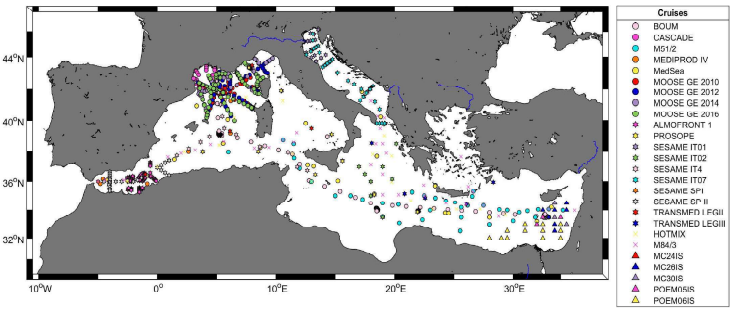


Lauvset et al., Earth Syst. Sci. Data 2016
Olsen et al., Earth Syst. Sci. Data 2016

722 oxygen cruises data with accuracy better than 1%:

- 378 accurate with no adjustment necessary
- 207 adjusted (secondary QC flag)
- 127 good quality but have not been subjected to full secondary QC

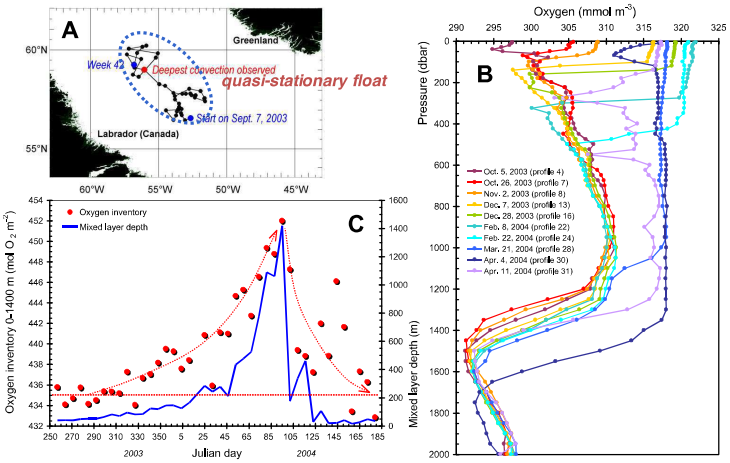
CARIMED: 26 cruises with QC2 (1981-2016)



All of them with O_2 data with QC 2 *(Alvarez et al., CIESM 2016)*

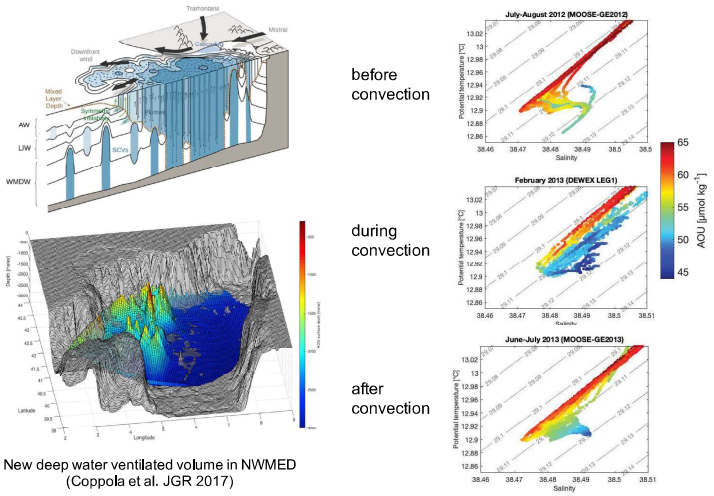
Some applications with O_2 adjusted data

Deep convection in the Labrador Sea using Argo-O_2 float



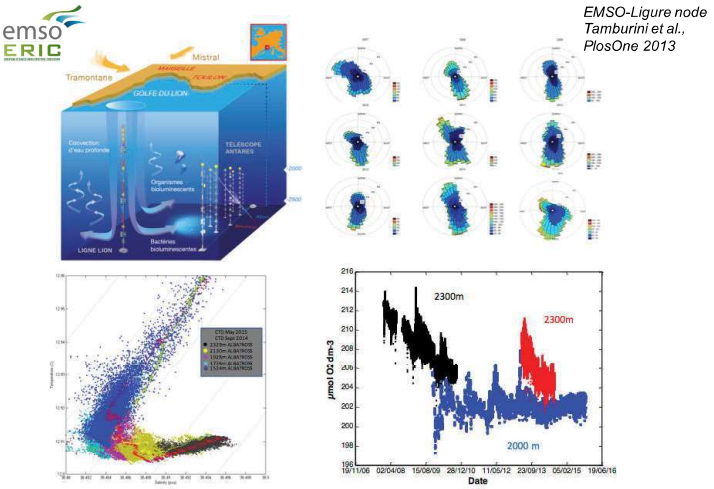
Körtzinger *et al.* (2004). The ocean takes a deep breath. *Science*, **306**, 1337.

Deep ventilated volume using combined Argo-O_2 fleet and ship



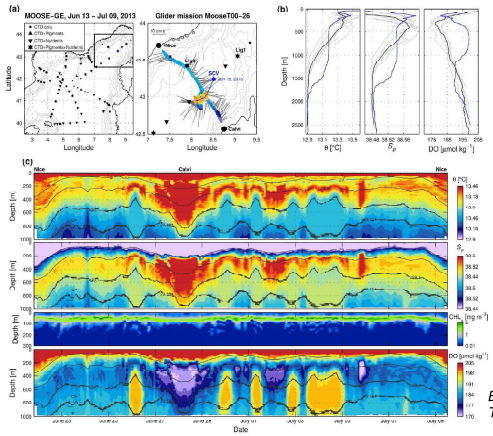
New deep water ventilated volume in NWMED (Coppola et al. JGR 2017)

Convection and deep biological activity – O_2 mooring



EMSO-Ligure node
Tamburini et al., PlosOne 2013

Submesoscale eddies, fronts – O_2 gliders

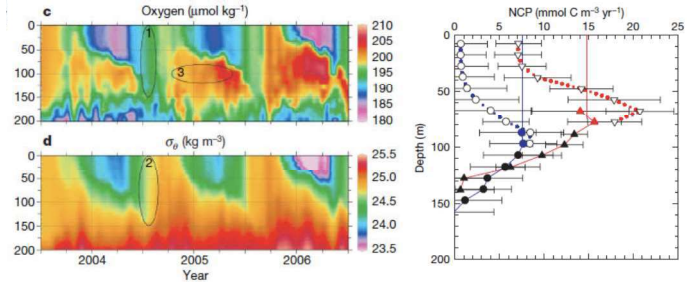


Bosse et al. JGR 2017
Testor et al., JGR 2018

Figure 2. Same as Figure 1 but for the MOOSE-GE 2013 summer cruise and the MOOSE T00-25 glider mission carried out in June–July 2013. In Figure 2a, the colored dots along the glider trajectory represents the dissolved oxygen concentration with the same scale as in Figure 2c. Note that total carbon was measured at the same stations as phytoplankton pigments. In Figure 2d, the light gray profiles correspond to those carried out in the Ligurian sea (defined by the black box drawn in Figure 2d), the black profile is the average of all the gray profiles. The blue profile was carried out within the core of a deep eddy that was further sampled by a glider shortly afterward.

Net community production – O_2 ARGO floats

Convert O_2 production to carbon uptake with the modified Redfield ratio (150:106) + extrapolate to an annual value by multiplying the daily increase by 365



ARGO floats near Hawaii.
Riser & Johnson. 2008. Nature 451: 323