The MULTI OBSERVATIONS Thematic Assembly Centre of the Copernicus Marine Environment Monitoring Service

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COPERNICUS · MARINE ENVIRONMENT MONITORING SERVICE
CMEMS OCEAN MULTI OBSERVATIONS TAC
Contract 83-CMEMS TAC MOB
Until 31 March 2021

CLS

LOV

LSCE

Copernicus Marine Service
Implemented by
MERCATOR OCEAN INTERNATIONAL

The Multi Observations TAC

- ➔ Provides **Global qualified** Ocean **Multi Observation** Products
- ➔ Products based on **Observations** (satellite & in-situ) and **data fusion techniques**
- ➔ Products covering the ocean **Physics** and **BGC**
- ➔ **NRT** & **MY** products & **OMI**

- 4 physical products
- 1 carbon product
- 2 BGC products

- ✓ **Taking advantage of the strength of the GOOS**
- ✓ **Staying close to the observations**
- ✓ **Providing a complementary approaches to model/assimilation**

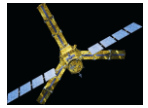
Sea Surface Salinity & Sea Surface Density

MULTIOBS_GLO_PHY_NRT_015_001 / MULTIOBS_GLO_PHY_REP_015_002

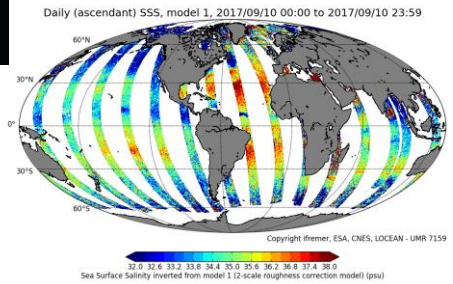
Bruno
Buongiorno Nardelli

➔ SSS & SSD NRT & REP time series

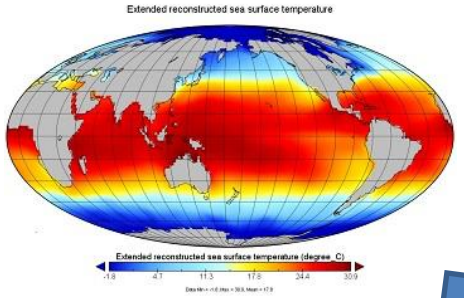
- Based on a **Multivariate Optimal Interpolation** algorithm
- Hypothesis: **SST** and **SSS** variations are correlated at scales smaller than the ones dominating atmospheric variability (in the open ocean)



SSS



SST

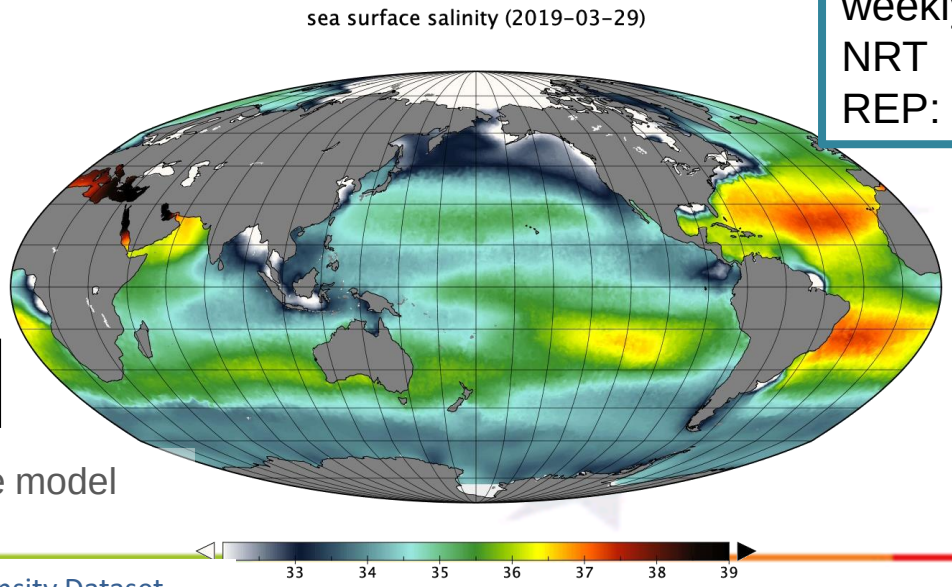


In situ SSS/SSD

$$x_{analysis}=x_{bck}+C(R+C)^{-1}(y_{obs}-x_{bck})$$

$$C(\Delta r,\Delta t,\Delta SST)=e^{\left(-\frac{\Delta t}{\tau}\right)^2}e^{\left(-\frac{\Delta r}{L}\right)^2}e^{\left(-\frac{\Delta SST_{filtered}}{T}\right)^2}$$

*multi-dimensional covariance model



GLOBAL
1/4° resolution
weekly
NRT
REP: 1993-2018

R. Droghei, B. Buongiorno Nardelli, and R. Santoleri (2018), A new Global Sea Surface Salinity and Density Dataset from Multivariate Observations (1993-2016), Front. Mar. Sci., 5(March), 1-13, doi:10,3389/fmars,2018,00084.

3D T/S/UVg/MLD – ARMOR3D

MULTIOBS_GLO_PHY_NRT_015_001 / MULTIOBS_GLO_PHY_REP_015_002

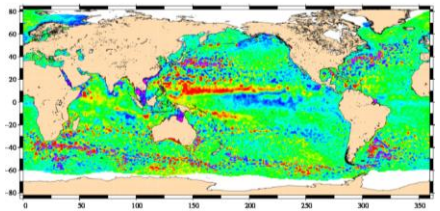
Stéphanie Guinehut
Sandrine Mulet
Nathalie Verbrugge
Eric Greiner

➔ **3D temperature, salinity, geostrophic velocities and MLD NRT & REP time series**

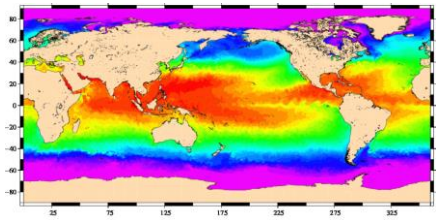
- Based on a 3 steps method starting from a first guess climatology
  (1) Satellite data (SLA + SST + SSS) are projected onto the vertical using a **multiple linear regression** method
  (2) Combination between step 1 fields with T/S in situ profiles using an **optimal interpolation** method
  (3) Use of the **thermal wind equation** to combine the 3D T/S fields with surface geostrophic current fields to generate 3D geostrophic currents

GLOBAL
1/4° resolution
weekly
NRT
REP: 1993-2018

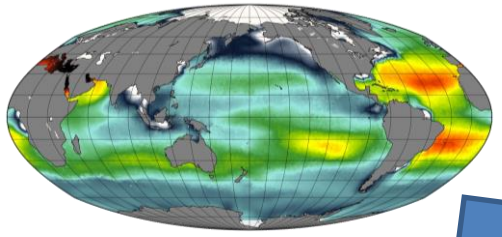
SLA



SST

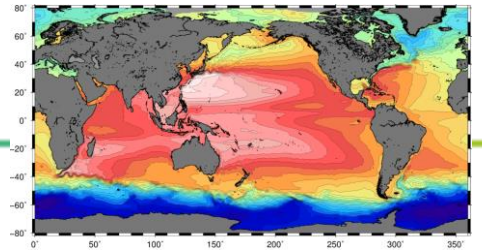


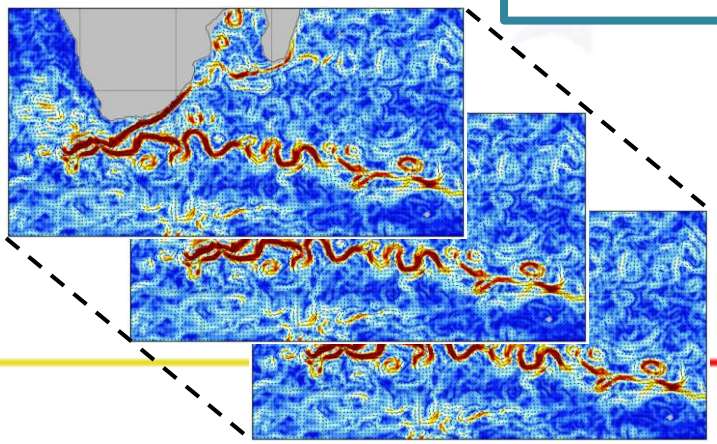
SSS



In situ T/S

MDT



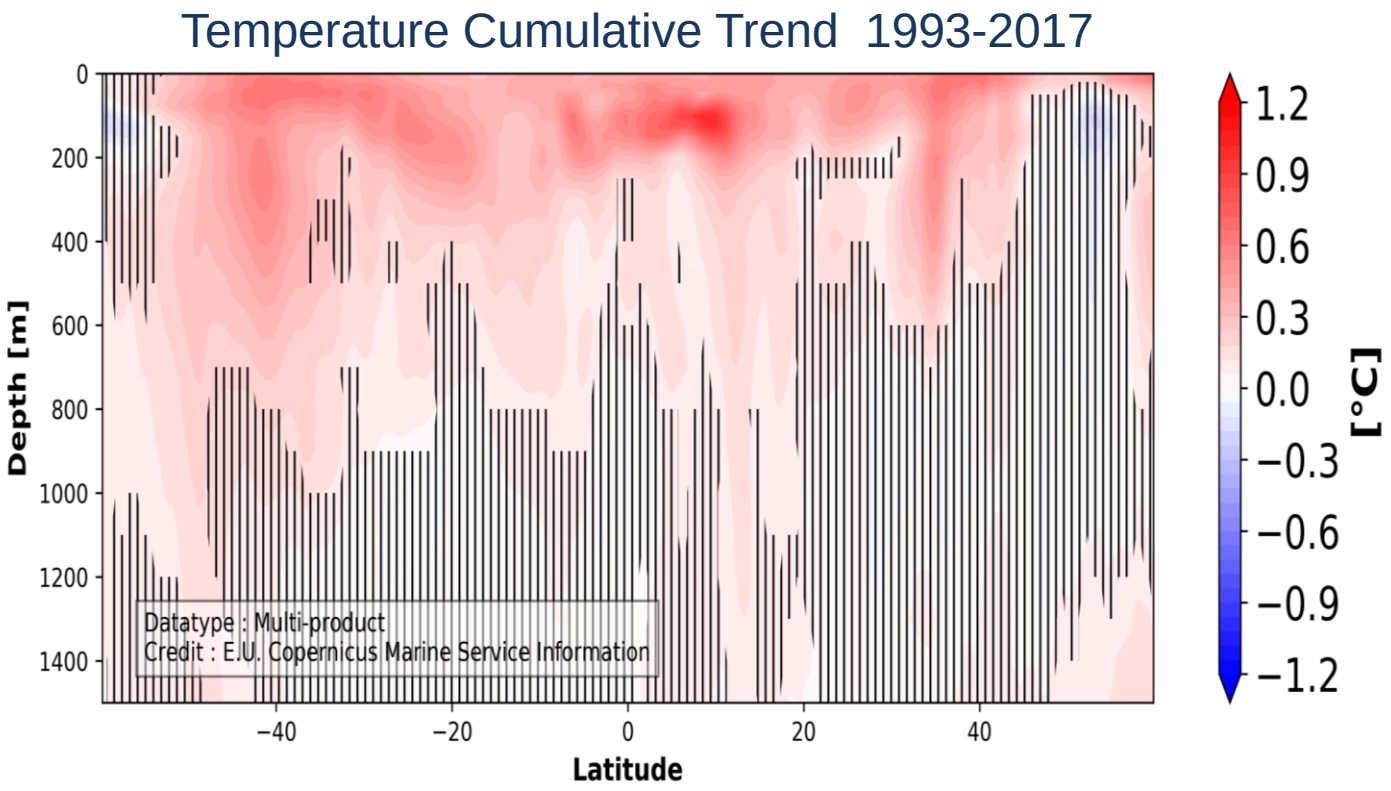


- Guinehut, Dhomps, Larnicol & Le Traon (2012)
- Mulet, Rio, Mignot, Guinehut & Morrow (2012)

3D T/S/UVg/MLD – ARMOR3D

➔ **3D temperature, salinity, geostrophic velocities and MLD** NRT & REP time series

➔ **OMI**: Cumulative trend of Subsurface Temperature



Multi-product approach
Shaded = not significant

Vertical velocities

New in Nov 2019

➔ **OMEGA3D-Global 3D Vertical Velocities (+horizontal ageostrophic velocity)** based on the application of the **diabatic QG Omega equation** to ARMOR3D observation-based fields

Bruno Buongiorno Nardelli

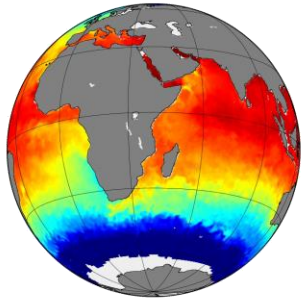
$$\nabla^2{}_h(N^2 w) + f^2 \frac{\partial^2 w}{\partial z^2} = \nabla_h \cdot Q$$

$$Q = 2Q_{twg} + (Q_{th} + Q_{dm}) \rightarrow \begin{cases} Q_{twg} = \frac{g}{\rho_0}\left(\frac{\partial u_g}{\partial x}\frac{\partial \rho}{\partial x} + \frac{\partial v_g}{\partial x}\frac{\partial \rho}{\partial y}, \frac{\partial u_g}{\partial y}\frac{\partial \rho}{\partial x} + \frac{\partial v_g}{\partial y}\frac{\partial \rho}{\partial y}\right) \\ Q_{dm} = \frac{f}{\rho_0}\left(-\frac{\partial^2}{\partial z^2}\left[\rho K_m\left(\frac{\partial u}{\partial z} - \gamma_u\right)\right], \frac{\partial^2}{\partial z^2}\rho\left[K_m\left(\frac{\partial v}{\partial z} - \gamma_v\right)\right]\right) \\ Q_{th} = -\frac{g}{\rho_0}\nabla_h\left(\frac{\partial}{\partial z}\left[K_\rho\left(\frac{\partial \rho}{\partial z} - \gamma_\rho\right)\right]\right) = \nabla_h\left(\frac{\partial}{\partial z}\left[K_\rho\left(N^2 + \frac{g}{\rho_0}\gamma_\rho\right)\right]\right) \end{cases}$$

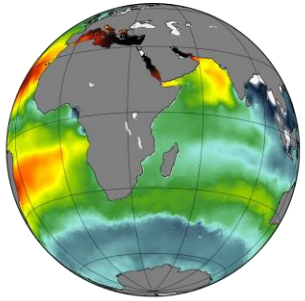
forcing (Q) and solution (w) include adiabatic (*twg*) and turbulent flux components (momentum, *dm*, and heat, *th*)

ARMOR3D

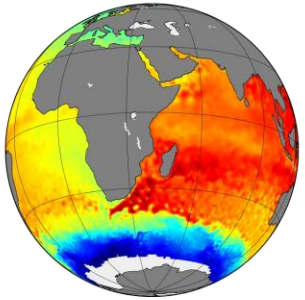
Temperature



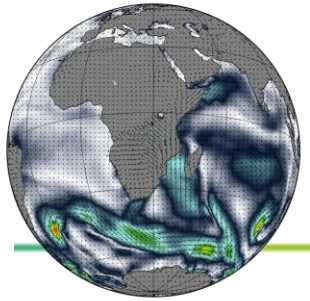
Salinity

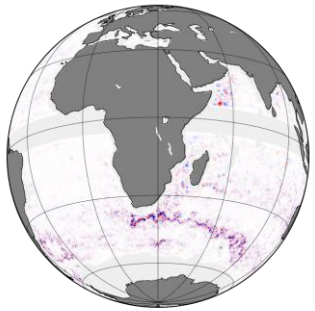


ADT

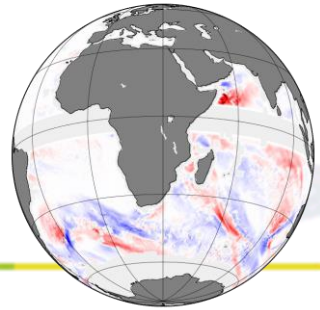


ERA-interim
Atmospheric fluxes





Vertical velocities driven by kinematic deformation $2Q_{twg}$



Vertical velocities driven by turbulent fluxes $(Q_{th}+Q_{dm})$

targeted for Open ocean not applicable in equatorial band/coastal areas

B. Buongiorno Nardelli, S. Mulet, and D. Iudicone (2018), Three-Dimensional Ageostrophic Motion and Water Mass Subduction in the Southern Ocean, *J. Geophys. Res. Ocean.*, 1–30, doi:10.1002/2017JC013316.

Surface and near-surface currents

MULTIOBS_GLO_PHY_NRT_015_003 / MULTIOBS_GLO_PHY_REP_015_004

➔ Altimetry derived **Geostrophic** Currents + **Ekman** Currents

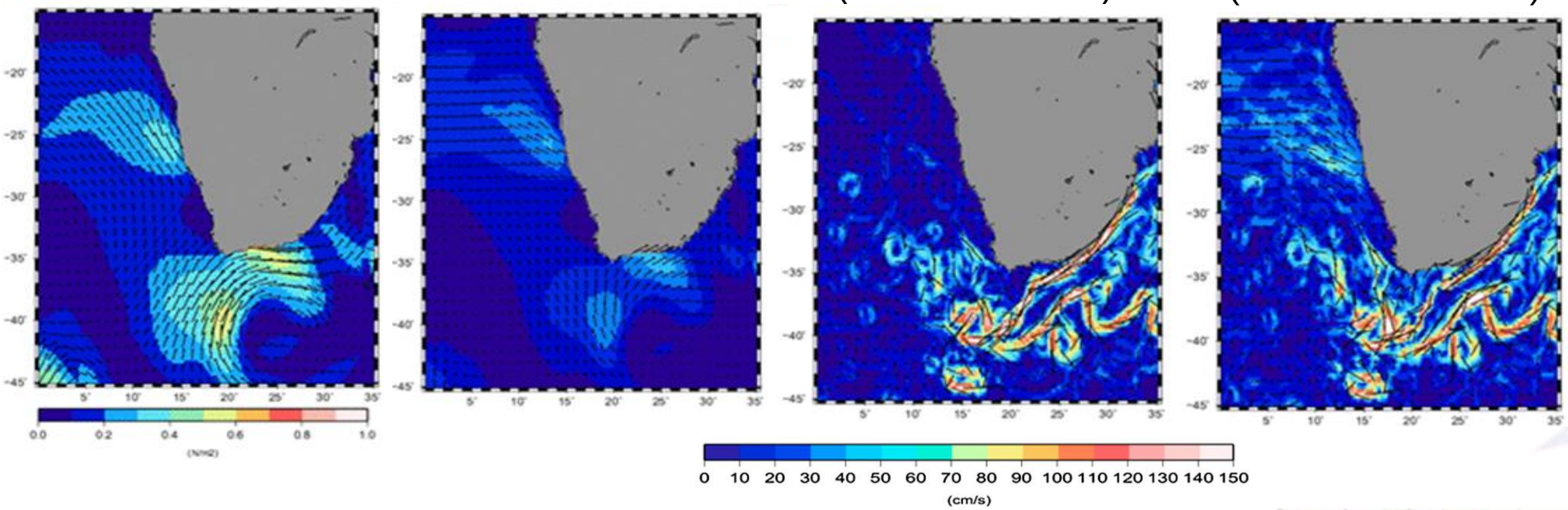
Hélène Etienne
Marie-Hélène Rio (ESA)

Wind stress (ECMWF)

Ekman current at 0m (Empirical model)

Geostrophic current + CNES-CLS13 MDT (CMEMS SL TAC)

Total current at 0m (CMEMS MOB TAC)



GLOBAL
surface/15m
1/4° resolution
NRT: 6-hourly
REP: 3-hourly
(1993-2018)

http://www.globcurrent.org/

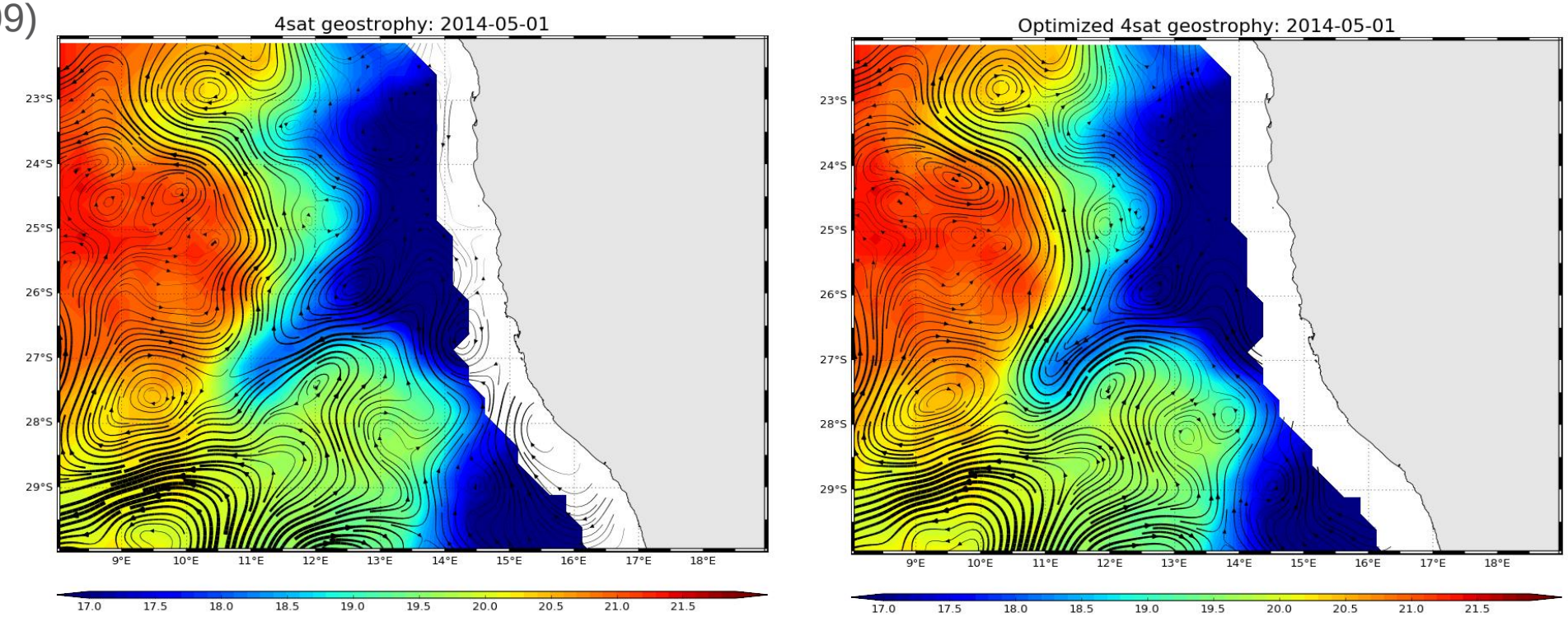
M.-H. Rio, S. Mulet, and N. Picot (2014): Beyond GOCE for the ocean circulation estimate: Synergetic use of altimetry, gravimetry, and in situ data provides new insight into geostrophic and Ekman currents. Geophys. Res. Lett., 41, doi:10.1002/2014GL061773.

Improved near-surface currents using SST

New in 2020

- ➔ Based on the **inversion of the heat conservation equation** for the horizontal velocities
- ➔ Using the **altimeter geostrophic velocities** as background and prescribing source and sinks terms a priori values and associated errors, **+ successive SST fields** (Piterbarg, 2009)

Hélène Etienne
Marie-Hélène Rio (ESA)
Daniele Ciani



M.-H. Rio, and R. Santoleri, 2018: Improved global surface currents from the merging of altimetry and Sea Surface Temperature data, Remote Sensing of Environment, https://doi.org/10.1016/j.rse.2018.06.003.

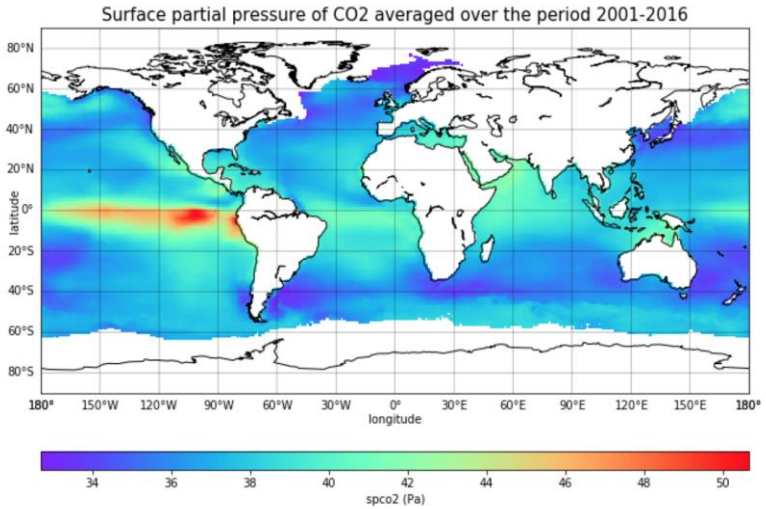
2D Surface Carbon

MULTIOBS_GLO_BIO_REP_015_005

LSCE
Trang Chau
Frédéric Chevallier
Marion Gehlen
Anna Conchon (MOI)

- **Global surface pCO_2, FCO_2, and pH** monthly mean fields (2001-2017)
  - **Surface ocean pCO_2**
    - Based on a **neural-network method (Denvil-Sommer et al., 2019)**
      $pCO_2^{oc} = g$ (SSS, SST, SSH, MLD, Chl, pCO_2^{atm}, lon, lat)
    - Trained on high quality in situ observations of pCO_2^{oc} from the **SOCAT Atlas** (Bakker et al., 2016)
  - **Air-sea flux of CO_2**: gradient of pCO_2 at air-sea interface, wind speed
  - **pH**
    - Based on the **speciation software CO2sys** (van Heuven et al, 2011, Lewis & Wallace, 1998) applied on pCO_2^{oc} and ALK
    - ALK = **LIAR model** (SSS, SST, nutrients) (Carter et al., 2016, 2018)

GLOBAL
1° resolution
monthly
REP: 2001-2017



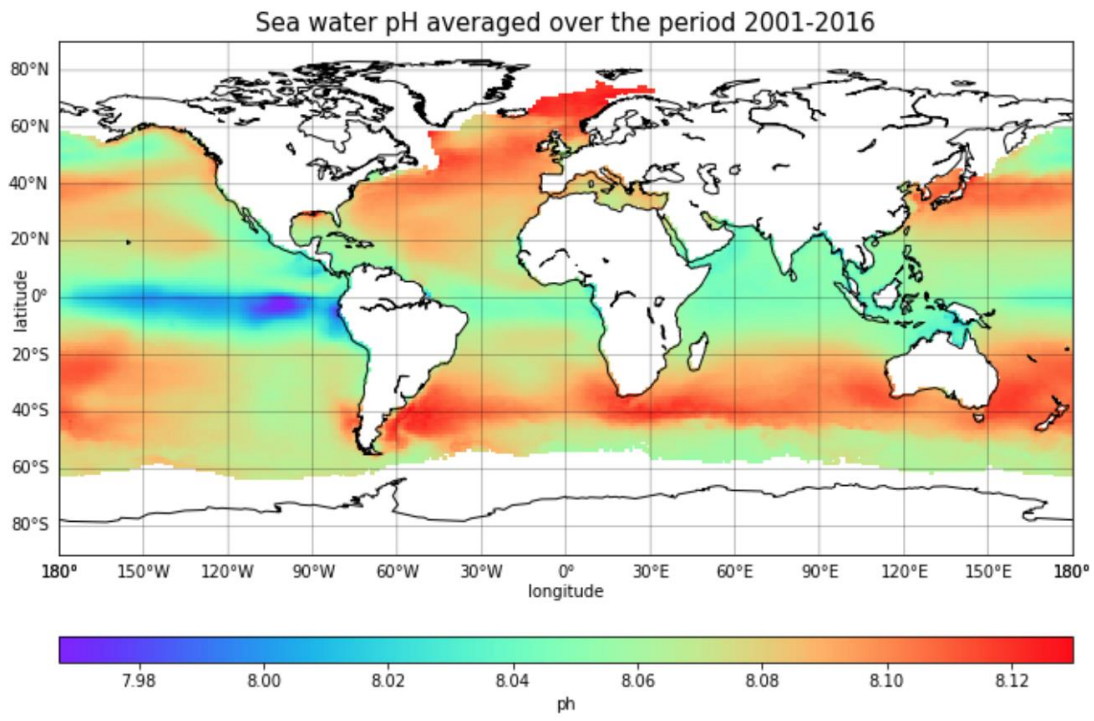
Global accuracies
pCO_2^{oc} : 1.82 Pa
pH : 0.03 pH total scale

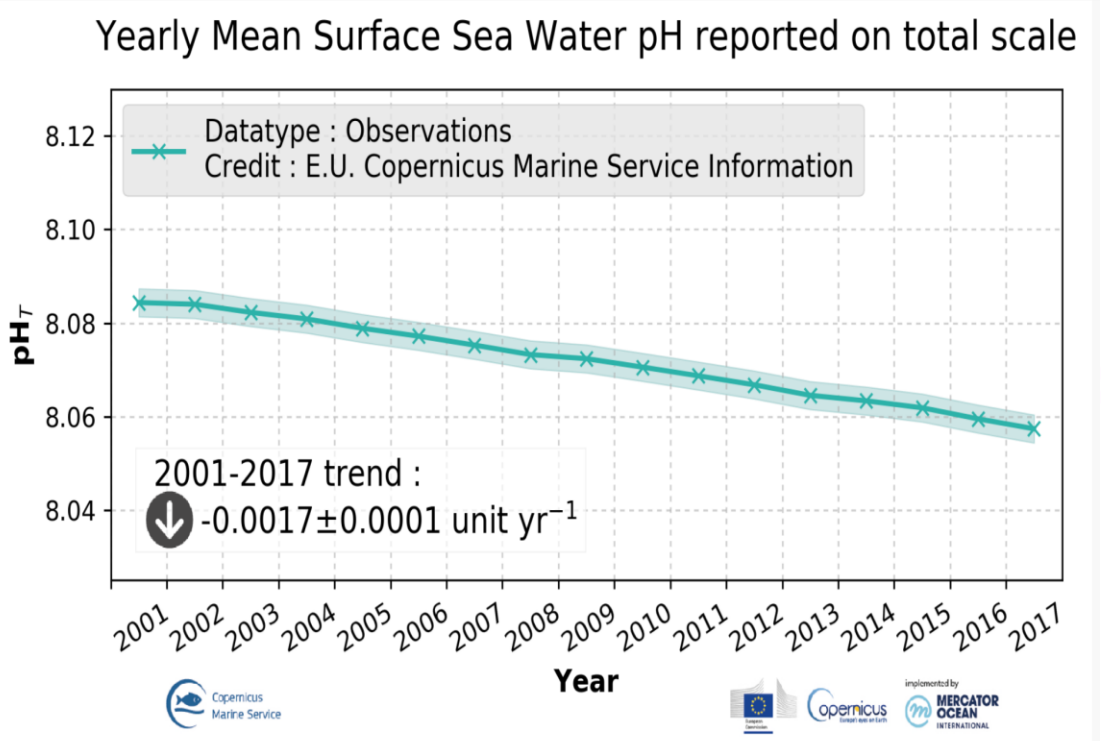
Denvil-Sommer, A., Gehlen, M., Vrac, M., and Mejia, C. (2018) FFNN-LSCE: A two-step neural network model for the reconstruction of surface ocean pCO2 over the Global Ocean, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2018-247, in review, 2018.

2D Surface Carbon

- **Global surface pCO_2, FCO_2, and pH** monthly mean fields (2001-2017)

  ➔ **OMI**: global yearly **pH** time series (,global yearly **ocean carbon sink**)



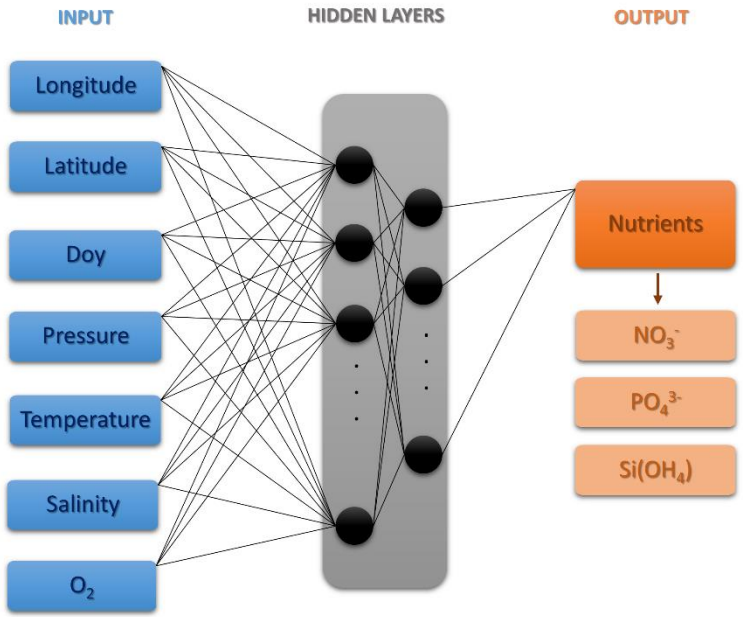


3D BGC

➔ Nutrient vertical profiles from BGC-Argo P/T/S/O_2 profiles

- Based on a **neural-network method** trained on high quality nutrient data collected over the last 30 years (**GLODAPv2** database)

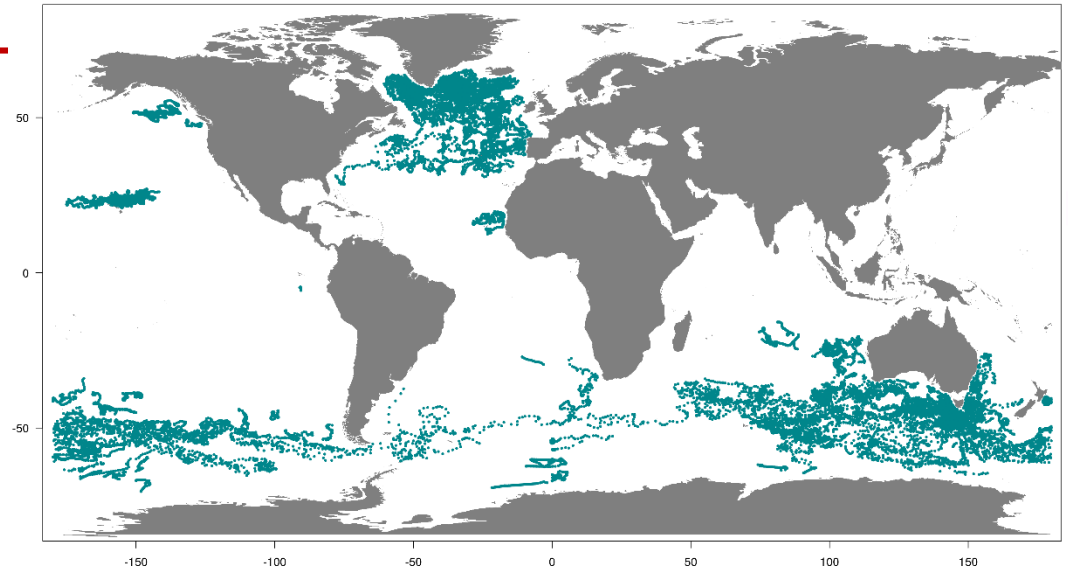
LOV
Raphaëlle Sauzède
Hervé Claustre



Global accuracies
(µmol kg^{-1}):
NO_3^- : 0.7
PO_4^{3-} : 0.05
$Si(OH)_4$: 2.3

CANYON-B (CArbonate system and Nutrients concentration from hYdrological properties and Oxygen using a Neural-network)

30 338 profiles (June 2004 – Nov 2018)



Bittig et al., 2018; Sauzède R, Bittig HC, Claustre H, Pasqueron de Fommervault O, Gattuso J-P, Legendre L and Johnson KS (2017) Estimates of Water-Column Nutrient Concentrations and Carbonate System Parameters in the Global Ocean: A Novel Approach Based on Neural Networks. Front. Mar. Sci. 4:128.doi: 10.3389/fmars.2017.00128

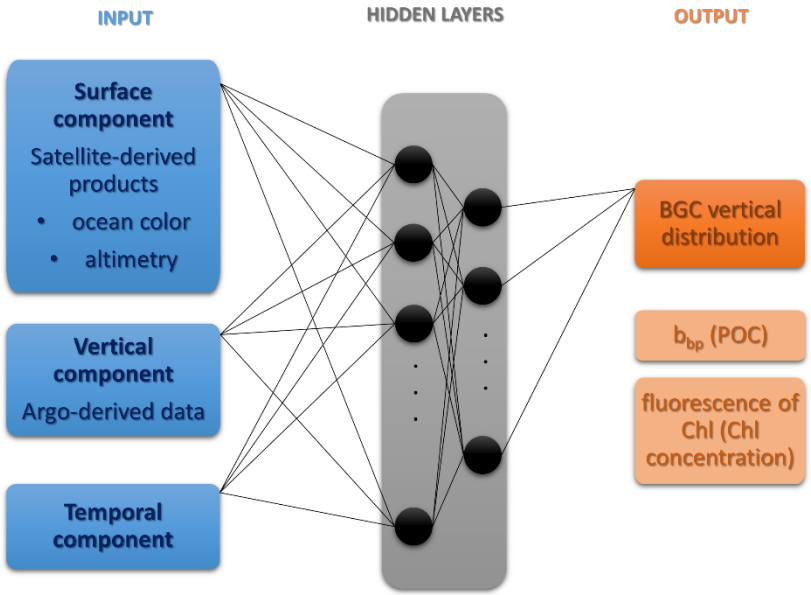
3D BGC

New in 2020

➔ Global 3D POC and Chla from satellite products

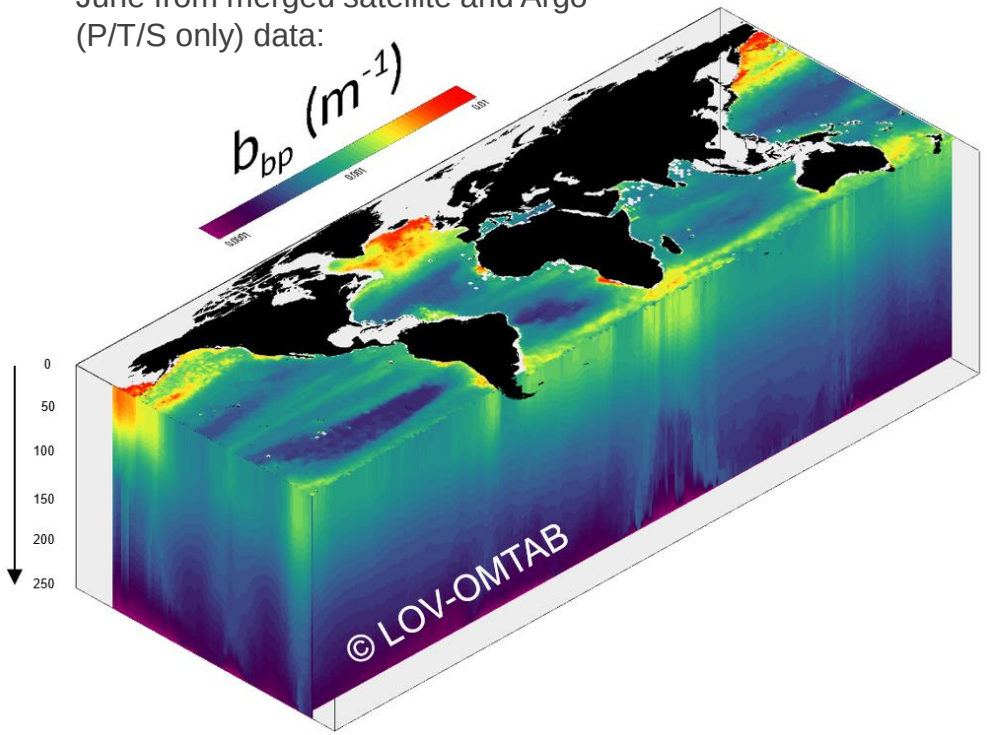
- Based on a **neural-network method** trained on high quality b_{bp} (bio-optical proxy of POC) and fluorescence of Chl (bio-optical proxy of Chla concentration) data collected from **BGC-Argo** floats

Raphaëlle Sauzède
Hervé Claustre



Global error
~20 % on b_{bp}
~50 % on Chla

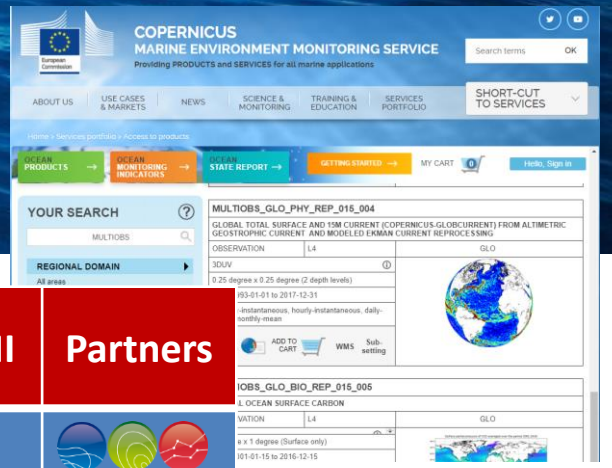
Example of the climatological vertical distribution of b_{bp} for the month of June from merged satellite and Argo (P/T/S only) data:



SOCA (Satellite Ocean-Color merged with Argo)

Sauzède, R., H. Claustre, J. Uitz, C. Jamet, G. Dall'Olmo, F. D'Ortenzio, B. Gentili, A. Poteau, and C. Schmechtig (2016), A neural network-based method for merging ocean color and Argo data to extend surface bio-optical properties to depth: Retrieval of the particulate backscattering coefficient, J. Geophys. Res. Oceans, 121, doi:10.1002/2015JC011408.

Summary



	Status	Parameters	Horizontal/Vertical/ Temporal resolution	NRT	REP	OMI	Partners
3D PHYS	**ARMOR3D** MULTIOBS_GLO_PHY_NRT_**015_001** MULTIOBS_GLO_PHY_REP_**015_002**	**T/S/UVg/H/ MLD**	1/4°, 33Z, W+M, 1993-(D-7)	U	U	N	CLS
SSS/SSD	**SSS/SSD** MULTIOBS_GLO_PHY_NRT_**015_001** MULTIOBS_GLO_PHY_REP_**015_002**	**SSS/SSD**	1/4°, 1Z [surface], W+M, 1993-(D-7)	N	U	N	
Surface currents	**New – inherited from CNES/CLS & ESA GlobCurrent projects** MULTIOBS_GLO_PHY_NRT_**015_003** MULTIOBS_GLO_PHY_REP_**015_004**	**U/V**	1/4°, 2Z [surface,15m], 6-hourly (3)+D+M, 1993-(D-1)	N	N		CLS
Vertical velocities	**New – inherited from MESCLA (MyOcean) & ACCUA (it) projects** MULTIOBS_GLO_PHY_REP_**015_007**	**W**	1/4°, 24Z [0-1500], W+M, 1993-(Y-1)		N		
Surface carbon	**New – inherited from H2020 AtlantOS project** MULTIOBS_GLO_BIO_REP_**015_005**	**FCO2, pCO2, pH**	1°, 1Z [surface], M, 2001-(Y-1)		N	N	LSCE
3D BGC	**New – inherited from H2020 AtlantOS project & RSauzède PHD thesis** MULTIOBS_GLO_BIO_REP_**015_006**	**NO_3^-, PO_4^{3-}, $Si(OH)_4$, POC, Chla**	discrete tbd, Z=first 300m, M, 2013-2015		N		LOV

+ Product User Manual / Quality Information Document

U: Update, N: New