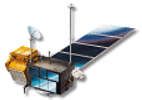
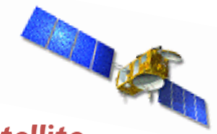
The **MULTI OBSERVATIONS** Thematic Assembly Center of the Copernicus Marine Environnement Monitoring Service

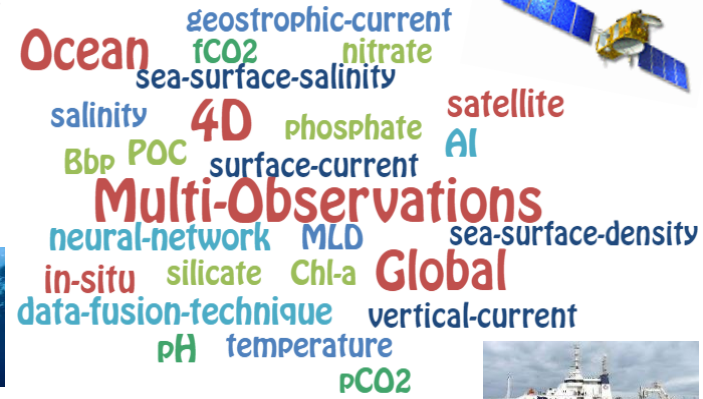
S. Guinehut, B. Buongiorno Nardelli, T. Chau, F. Chevallier, D. Ciani, H. Claustre, H. Etienne, M. Gehlen, E. Greiner, S. Jousset, S. Mulet, R. Sauzède, N. Verbrugge

What is MULTIOBS (MOB TAC)

- The Ocean **Multi Observations** TAC of CMEMS
- Provides **Global 4D qualified** Ocean **Multi Observations** Products
- Products based on **Observations** (satellite & in-situ) and **data fusion techniques**
- Products covering the **blue (4Xphysics)** and **green (1Xcarbon + 2Xbiogeochemical)** ocean
- **Near-Real-Time** & **Multi-Year** products & **Ocean Monitoring Indicators**







- ✓ Taking advantage of the **strengh of the GOOS**
- ✓ Staying **close** to the observations
- ✓ Providing **stable** long timeseries
- ✓ Proving a **complementary approach** to (MFCs)

Sea Surface Salinity & Sea Surface Density

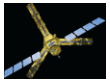
Online since REP-2017 NRT-2018

MULTIOBS_GLO_PHY_S_SURFACE_MYNRT_**015_013**

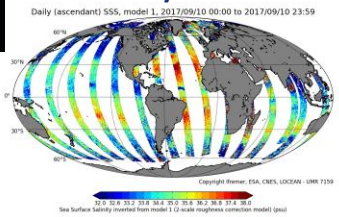
Bruno Buongiorno Nardelli

➔ SSS & SSD NRT & REP time series

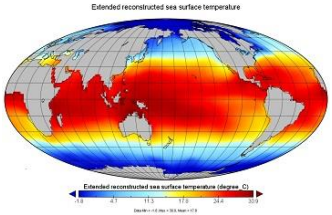
- Based on a **Multivariate Optimal Interpolation** algorithm
- Taking advantage of concurrent SST observations to increase effective space-time resolution up to mesoscale*
- Hypothesis: **SST** and **SSS** variations are correlated at scales smaller than the ones dominating atmospheric variability (in the open ocean)



SSS/SMOS

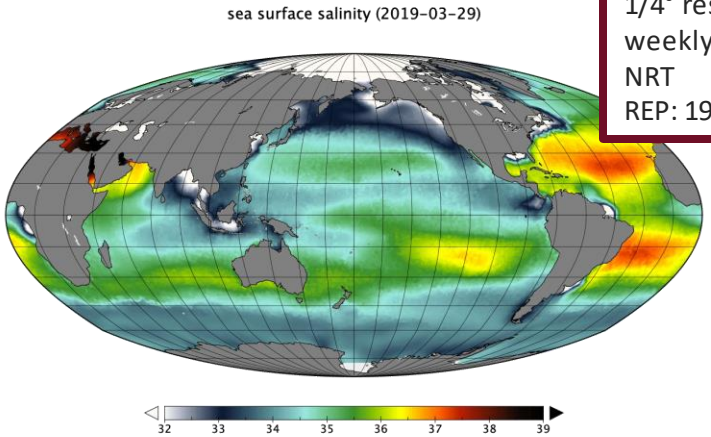


SST/OSTIA



In situ TAC SSS/SSD

Multivariate Optimal Interpolation algorithm



GLOBAL
1/4° resolution
weekly
NRT
REP: 1993-2019

* 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.

ARMOR3D – 3D T/S/UVg/MLD

Online since REP-2010 NRT-2010

MULTIOBS_GLO_PHY_TSUV_3D_MYNRT_**015_012**

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

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

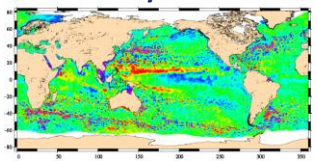
➔ **Mesoscale structures** at the right place thanks to satellite input & **Stable climate signal**

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

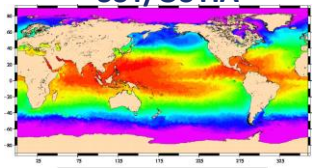
Stéphanie Guinehut
Sandrine Mulet
Nathalie Verbrugge
Eric Greiner

GLOBAL
1/4° resolution
50 levels, weekly
NRT
REP: 1993-2019

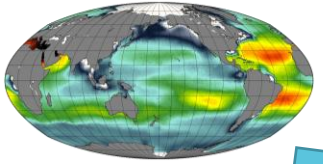
SLA/SL TAC



SST/OSTIA

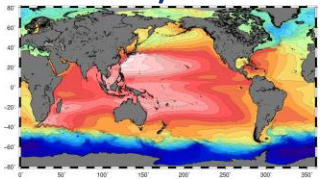


SSS/MOB

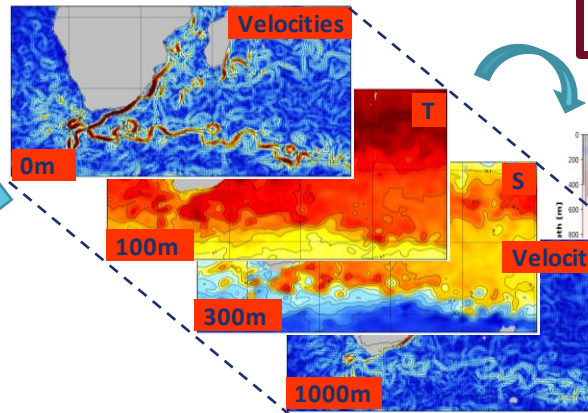


In situ TAC T/S

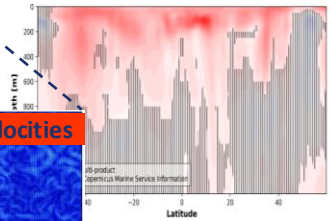
MDT/SL TAC



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



T cumulated trend



OMEGA3D - 3D Quasi-geostrophic currents

Online since REP-2020

MULTIOBS_GLO_PHY_W_3D_REP_**015_007**

➔ **3D Quasi-geostrophic currents (Vertical & Horizontal) REP** based on the application of the **diabatic QG Omega equation** to ARMOR3D observation-based fields & ERA-interim fluxes

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

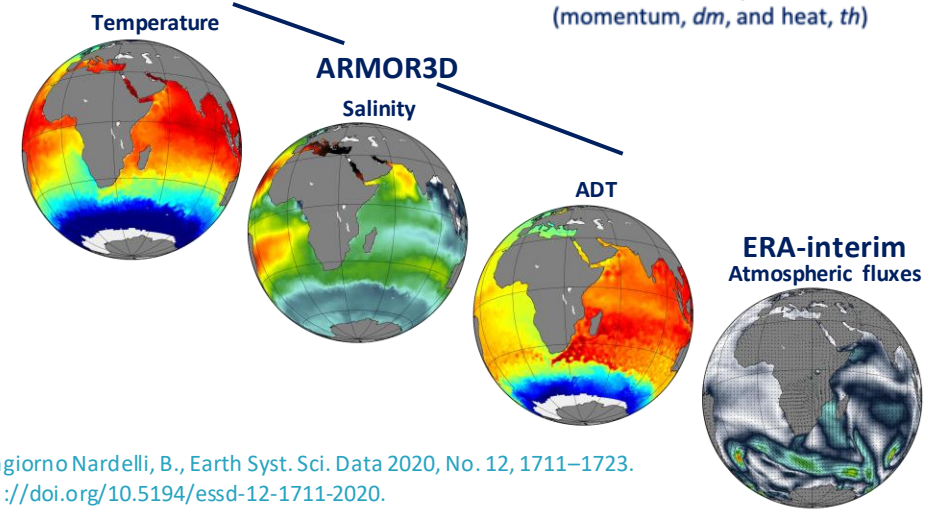
$$\boldsymbol{Q} = 2\boldsymbol{Q_{twg}} + (\boldsymbol{Q_{th}} + \boldsymbol{Q_{dm}}) \rightarrow$$

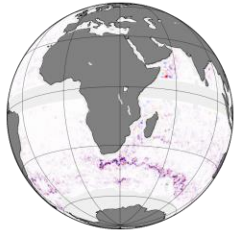
$$\begin{cases} \mathbf{Q}_{twg} = \frac{g}{\rho_0}\left(\frac{\partial u_g}{\partial x}\frac{\partial \rho}{\partial x} + \frac{\partial v_g}{\partial x}\frac{\partial \rho}{\partial y}, \frac{\partial u_g}{\partial y}\frac{\partial \rho}{\partial x} + \frac{\partial v_g}{\partial y}\frac{\partial \rho}{\partial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

forcing ($\boldsymbol{Q}$) and solution (w) include adiabatic (twg) and turbulent flux components (momentum, dm, and heat, th)

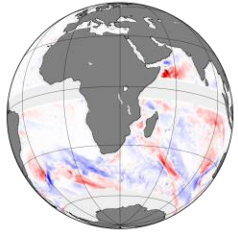
Bruno Buongiorno Nardelli

GLOBAL
1/4° resolution
75 levels, weekly
REP: 1993-2018





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



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

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

Buongiorno Nardelli, B., Earth Syst. Sci. Data 2020, No. 12, 1711–1723. https://doi.org/10.5194/essd-12-1711-2020.

Surface and near-surface currents

Online since REP-2018 NRT-2018

MULTIOBS_GLO_PHY_NRT_**015_003** / MULTIOBS_GLO_PHY_REP_**015_004**

➔ 2D surface and near-surface currents NRT & REP time series (Copernicus-Globcurrent)

- Altimetry derived **Geostrophic** Currents + **Ekman** Currents
- Wind driven Ekman model constructed using **in situ observations** of **Argo** surface drift and 15 m depth **SVP drifters** together with **wind stress** from ECMWF (ERA5 & Oper)

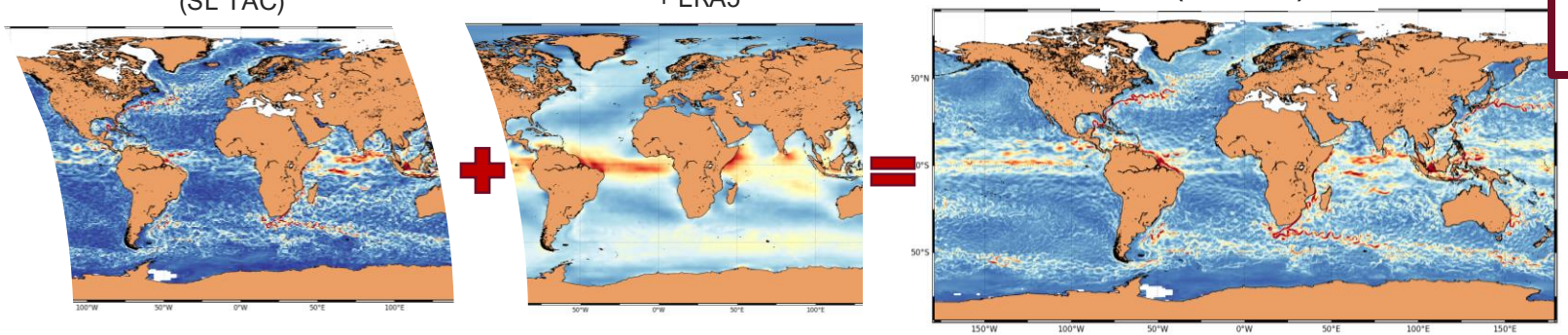
CLS
Hélène Etienne
Solène Jousset

GLOBAL
surface/15m
1/4° resolution
NRT: 6-hourly
REP: 3-hourly
(1993-2020)

Geostrophy
CNES-CLS18 MDT + DUACS18 SLA (SL TAC)

Wind driven
Empirical model (0, 15m) + ERA5

Total current (0, 15m)



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.

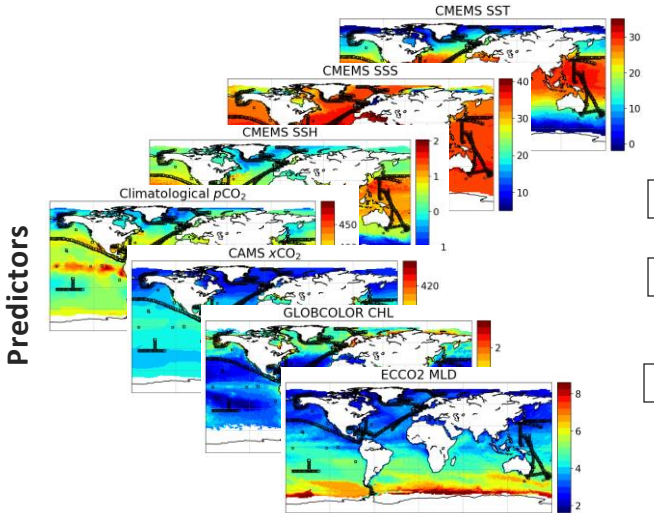
CMEMS-FFNN 2D Surface Carbon

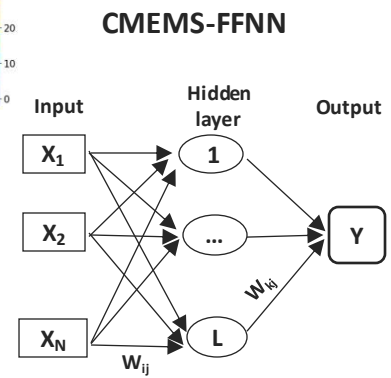
Online since REP-2018

MULTIOBS_GLO_BIO_CARBON_SURFACE_REP_**015_008**

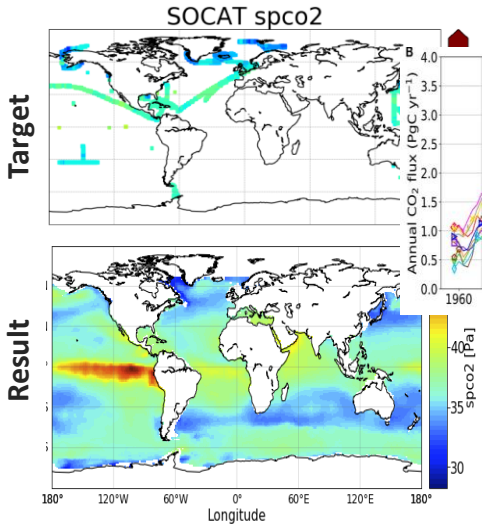
LSCE
Trang Chau
Frédéric Chevallier
Marion Gehlen

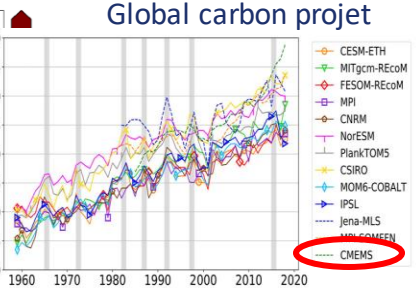
- **Global surface pCO_2, FCO_2, and pH** monthly mean fields (1985-2019)
  - **Surface ocean pCO_2 (spco2) => Air-sea flux of CO_2 (fgco2) => pH**
    - Based on an ensemble of **100** feed forward **neural-network models (CMEMS-FFNN)**
      $pCO_2^{oc} = g$ (SSS, SST, SSH, MLD, Chl, xCO_2, $pCO_2^{oc,clim}$, lon, lat)
    - Trained on high quality in situ observations of pCO_2^{oc} from the **SOCATv2020 Atlas** (Bakker et al., 2016)
- **OMIs:** global yearly **pH** time series, global yearly **ocean carbon sink**





Denvil-Sommer, A., Gehlen, M., et al. (2019) LSCE-FFNN





GLOBAL
1° resolution
monthly
REP: 1985-2019

CANYON - Nutrient vertical profiles

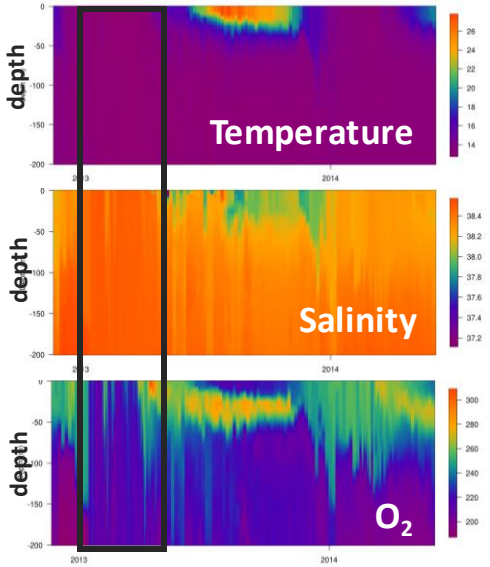
Online since REP-2019

MULTIOBS_GLO_BIO_NUTRIENTS_PROFILES_REP_**015_009**

➔ **Nutrient (nitrate, phosphate and silicate) vertical profiles derived from BGC-Argo P/T/S/O_2 profiles**

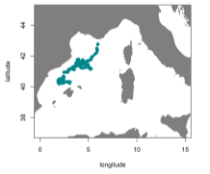
- Based on the **neural-network method CANYON** trained on high quality nutrient data collected over the last 30 years (**GLODAPv2** database)

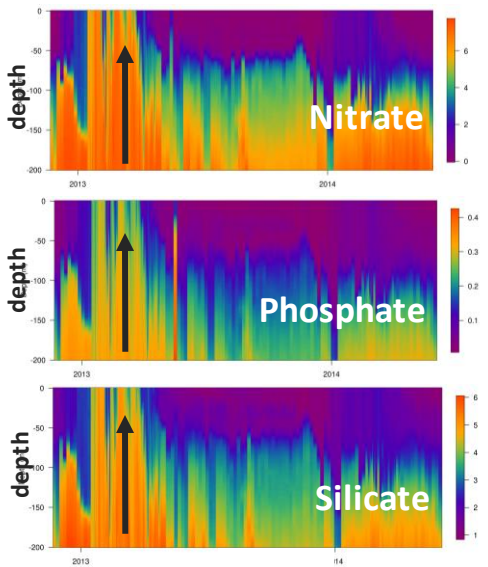
Raphaëlle Sauzède
Hervé Claustre



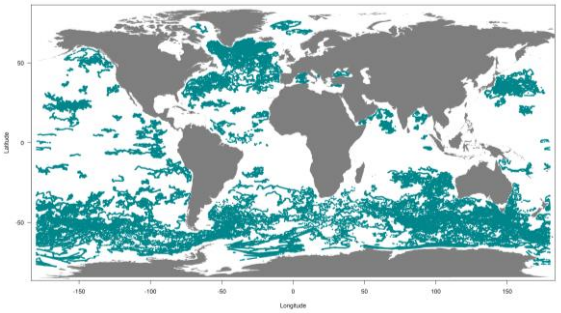
CANYON-B
CANYON-MED

+ geolocation





98 789 profiles
(June 2004 – December 2020)



CANYON-B: CArbonate system and Nutrients concentration from hYdrological properties and Oxygen using a Neural-network. Sauzède et al., 2017, Front. Mar. Sci. 4:128.doi: 10.3389/fmars.2017.00128; Bittig et al., 2018. **CANYON-MED**: Fourrier et al., 2020

SOCA - 3D Chla / POC / b_{bp}

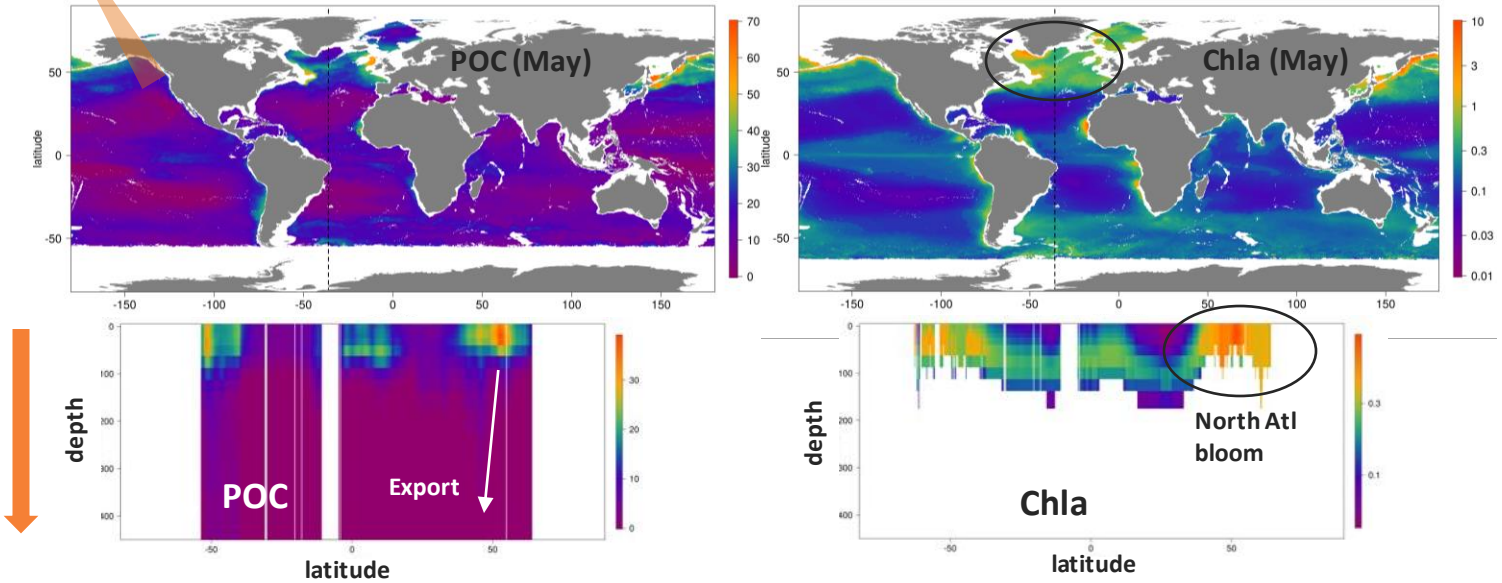
Online since REP-2020

MULTIOBS_GLO_BIO_BGC_3D_REP_**015_010**

➔ Global 3D POC/b_{bp} and Chla from satellite products

- Based on the **neural-network method SOCA** 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 and applied on satellite products

Raphaëlle Sauzède
Hervé Claustre

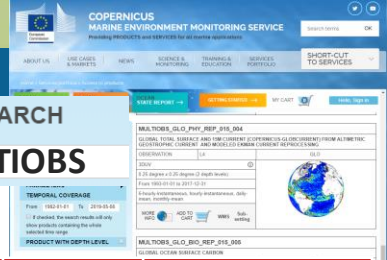


GLOBAL
1/4° resolution
36 levels
weekly + clim
REP: 1998-2019

SOCA: Satellite Ocean-Color merged with Argo. Sauzède, R., H. Claustre, J. Uitz et al. (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

Questions =>
sguinehut@groupcls.com



U: Update, N: New

	Produc id MULTIOBS_015_*	Variables	Horizontal, Vertical, Temporal resolution	NRT	MYP	OMI	Partners
SSS/SSD	015_**013**	SSS/SSD	1/4°, 1Z [surface], weekly, 1993-(Day-7)	N	U	N	
3D T/S/UVg/MLD	015_**012**	T/S/UVg/H/MLD	1/4°, 50Z [0-bottom], weekly, 1993-(Day-7)	U	U	N	CLS
3D Vertical currents	015_**007**	W	1/4°, 75Z [0-bottom], weekly, 1993-2018		N		
Surface currents	015_**003** 015_**004**	U/V	1/4°, 2Z [0m,15m], 6(3)-hourly, 1993-(Day-1)	N	N		CLS
Surface carbon	015_**008**	FCO2, pCO2, pH	1°, 1Z [surface], monthly, 1985-(Year-1)		N	N	LSCE
Nutrient profiles	015_**009**	NO_3^-, PO_4^{3-}, $Si(OH)_4$	Discrete June 2004-(Year-1)		N		LOV
3D POC/Chl-a	015_**010**	POC, b_{bp}, Chla	1/4°, 36Z [0-1000m], weekly, 1998-(Year-1)		N		LOV