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NCP AND AIR-SEA CO_2 FLUX FROM GLIDERS IN THE LIGURIAN SEA

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ALSEAMAR ALCEN

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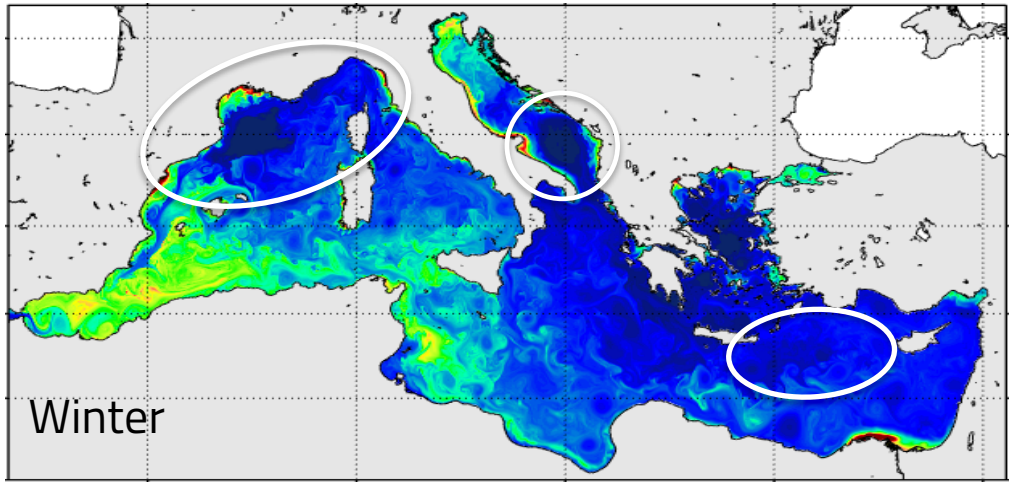
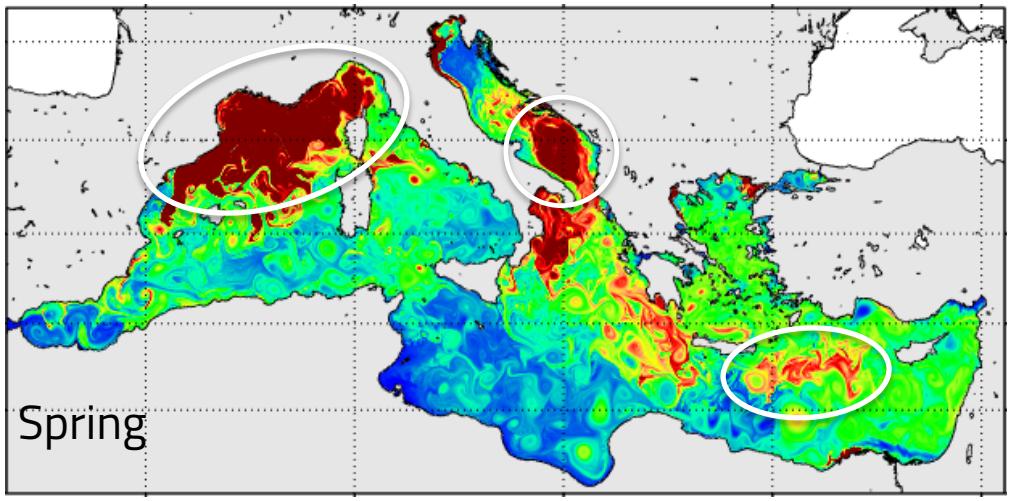
SCIENCES SORBONNE UNIVERSITÉ





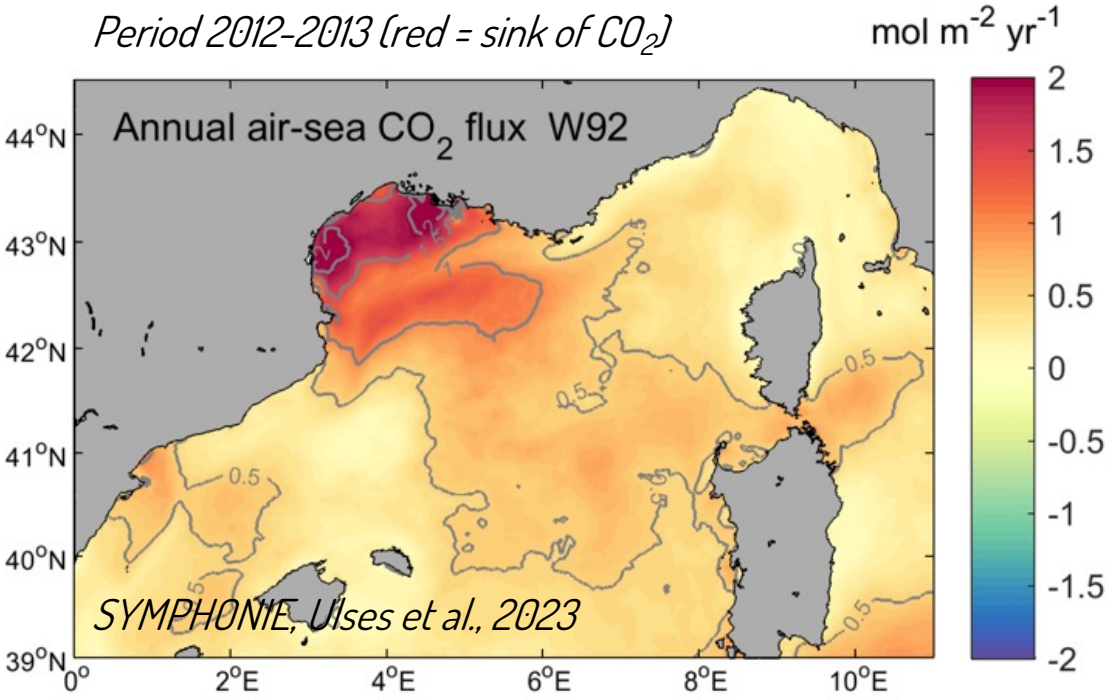
Hot spot sensitive to climate change and anthropogenic pressure.

Deep water formation and rapid circulation (100 years).

Impacts on nutrient inputs, ventilation (O_2, CO_2) and plankton production ("bio-regions")

Impacts on physical carbon pump and BCP ? Need to better observe the evolution of NCP and air-sea CO_2 flux ...

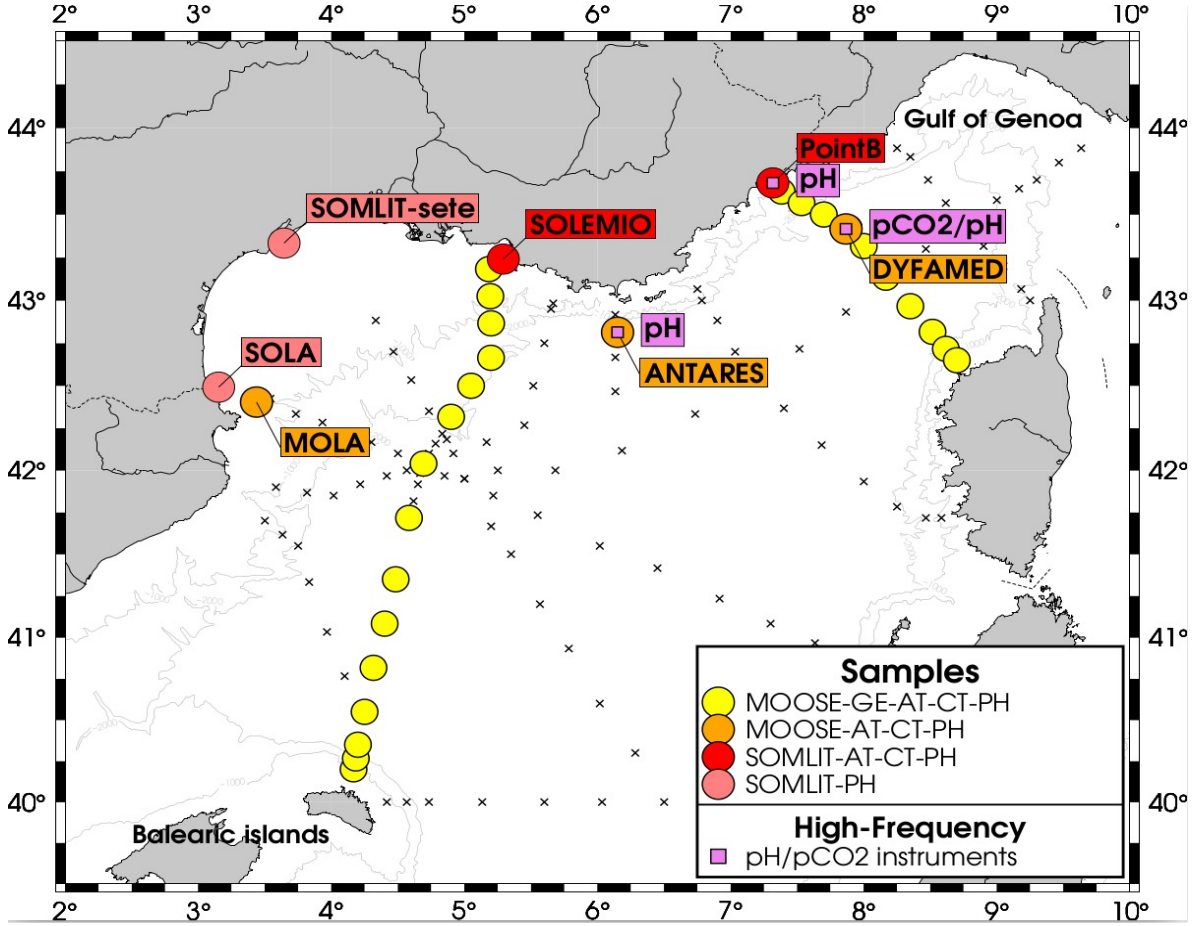
Period 2012-2013 (red = sink of CO_2)



The MOOSE observing system
Fixed stations (monthly sampling)
DYFAMED, since 1998
ANTARES, since 2010
MOLA, since 2010

Network of annual basin scale stations
MOOSE-GE, since 2010

The SOMLIT observing system
Fixed stations (Weekly sampling)
Point B, since 2005
SOLEMIO, since 2016



Carbonate chemistry is estimated from "high quality" measurements of A_T, C_T and pH_T

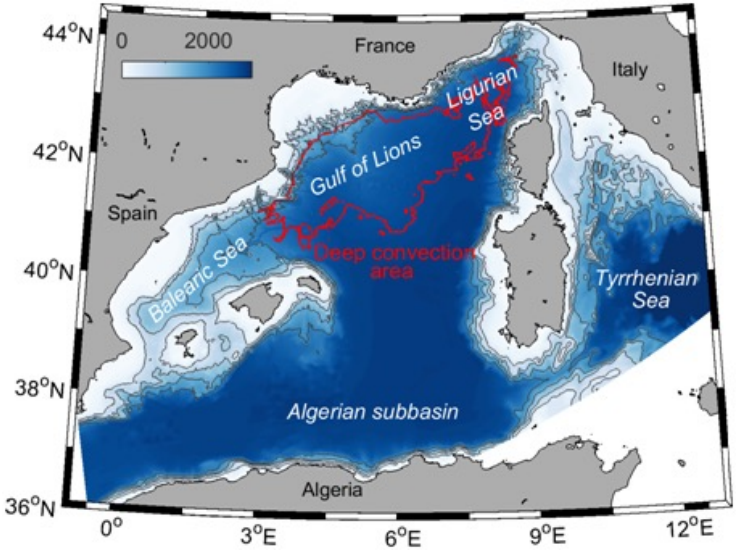
Implementation of a coupled physical/biogeochemical/carbonate system model
to investigate the seasonal cycle and estimate an annual budget of air-sea CO2 fluxes

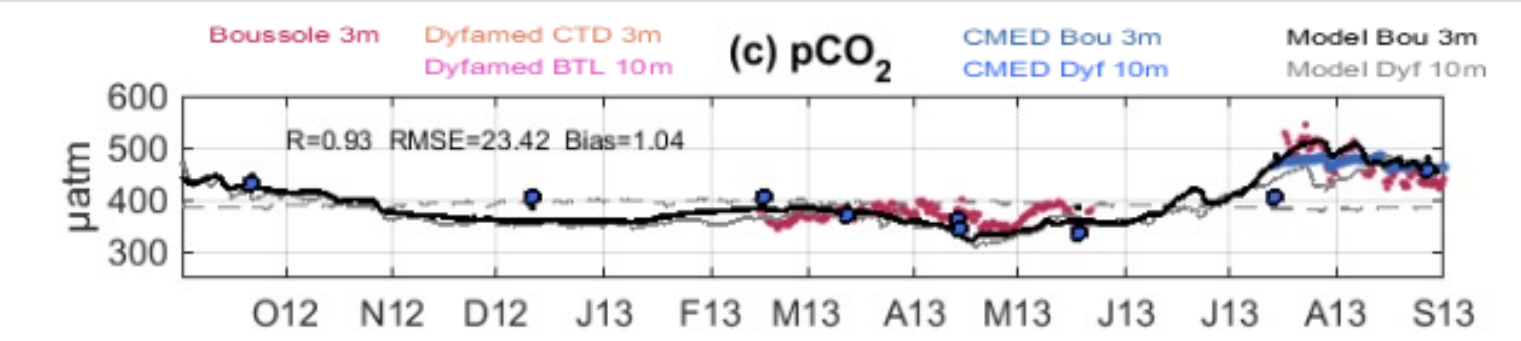
Hydrodynamic model
SYMPHONIE
(Marsaleix et al., 2008)

Biogeochemical model ECO3M-S
(Ulses et al., 2021)

Carbonate system model
(Soetaert et al., 2007)

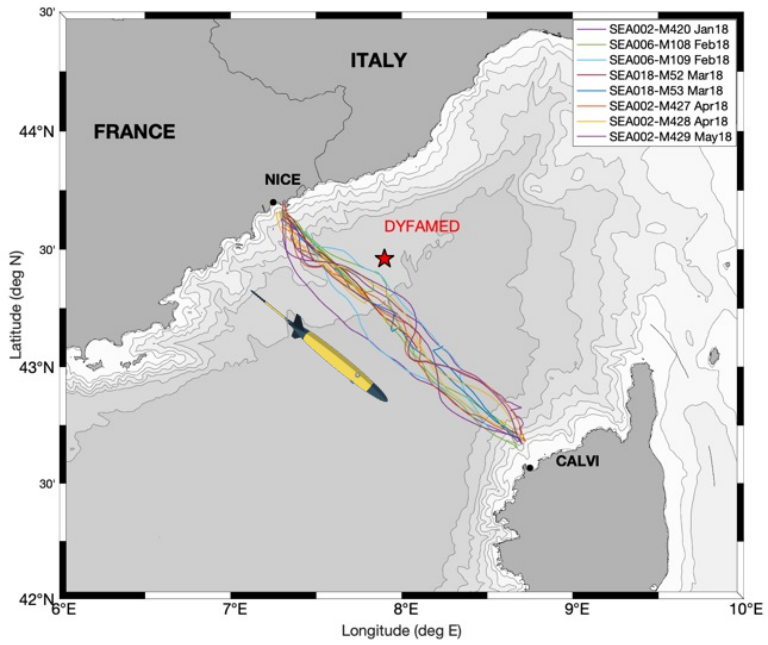
SYMPHONIE ECO3M-S





Assessment of the coupled model: Comparison with in-situ pCO_2 data at the DYFAMED site

Ulses et al., Frontiers 2023

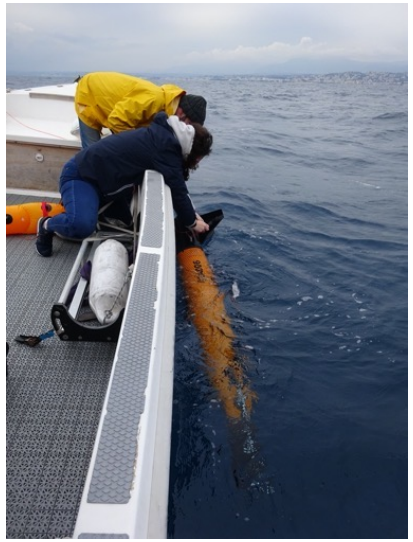


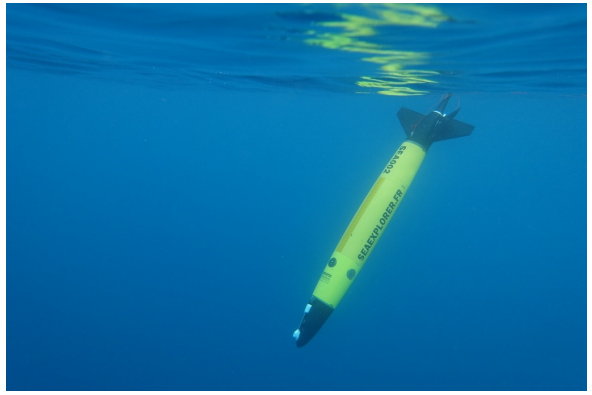
7 Nice-Calvi sections from January 11th to May 23rd 2018

Platforms: SeaExplorer (SEA002, SEA006 and SEA018).

Sensors: Seabird GPCTD (SBE43F), Wetlabs ECO FLBBCD.

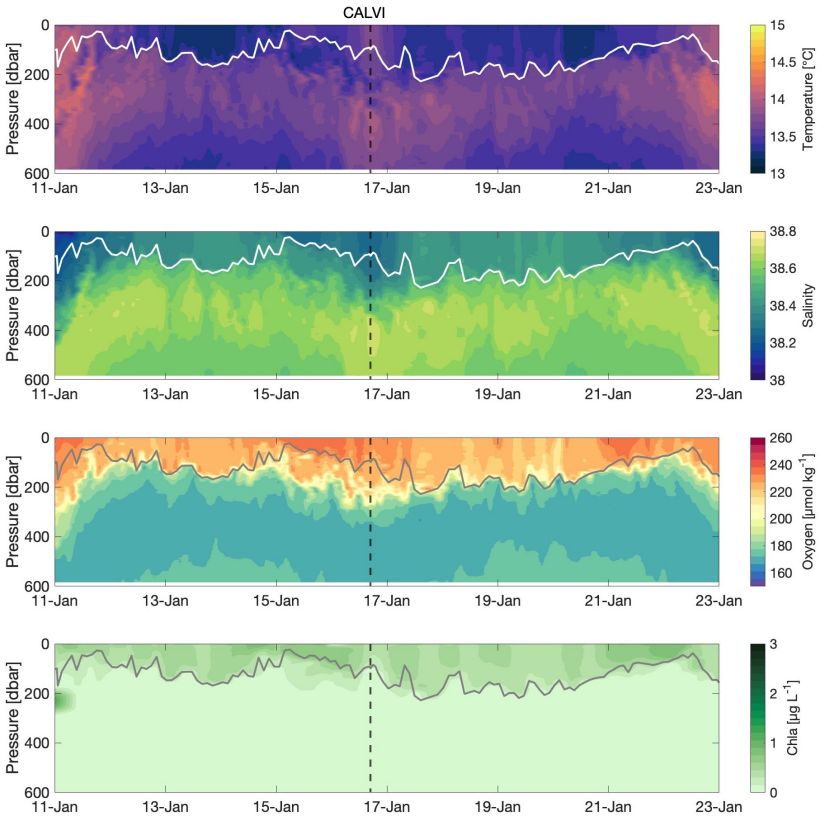
Figures	Section	Gliders	Starting date	Ending date	Total dives	Total days	GPCTD	FLBBCD	SBE43	Period observed
A	M420	SEA002	11/01/2018	24/01/2018	165	13	sn0013	sn1999	sn0247	pre-convection
B	M108	SEA006	02/02/2018	15/02/2018	114	13	sn0117	sn3542	sn2905	mixing starting
C	M109	SEA006	20/02/2018	05/03/2018	159	13	sn0117	sn3542	sn2905	deep mixing
D	M53	SEA018	17/03/2018	27/03/2018	80	10	sn0117	sn3544	sn2905	mixing ending
E	M427	SEA002	27/03/2018	10/04/2018	164	14	sn0013	sn1999	sn0247	bloom starting
F	M428	SEA002	16/04/2018	03/05/2018	182	17	sn0013	sn1999	sn0247	maximum bloom
G	M429	SEA002	07/05/2018	23/05/2018	171	16	sn0013	sn1999	sn0247	stratification

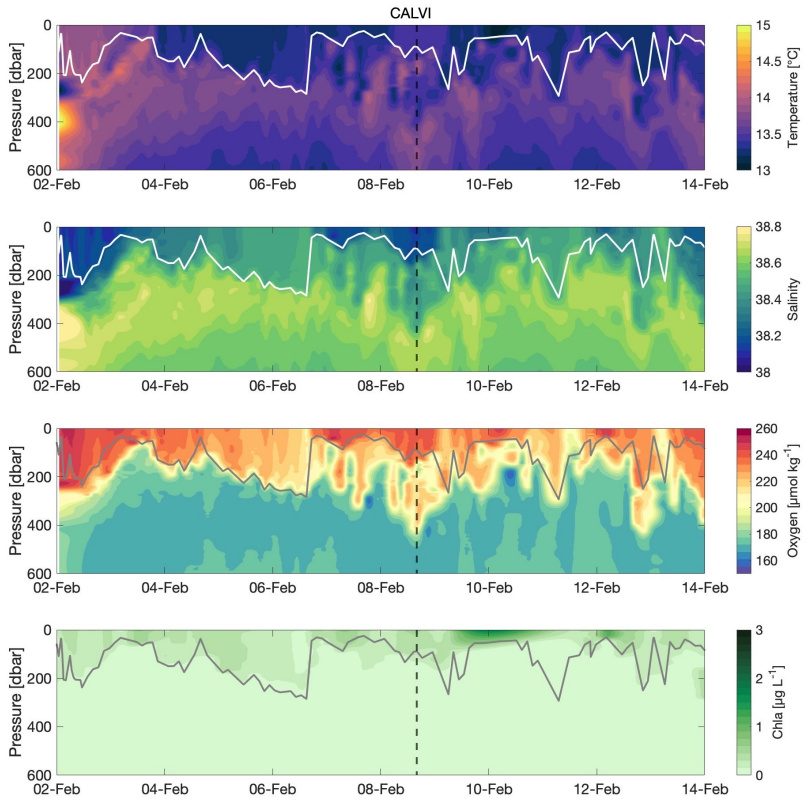


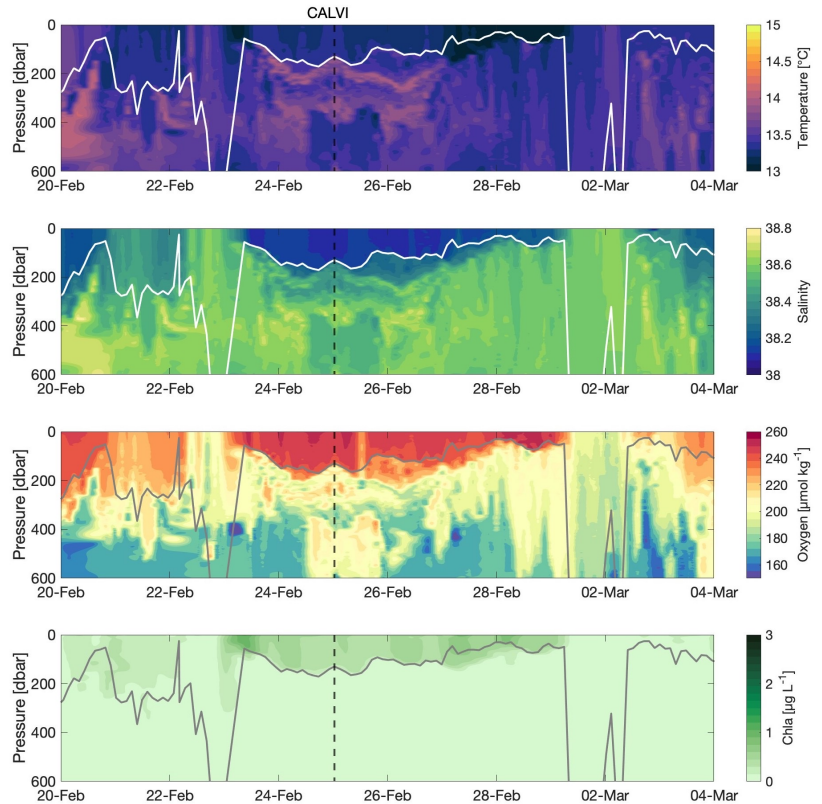


- Profiles: 650/700m.
- Resolution: 3km (about 3 hours).
- Data acquisition during descents and ascents.
- Adjustment with DYFAMED series.

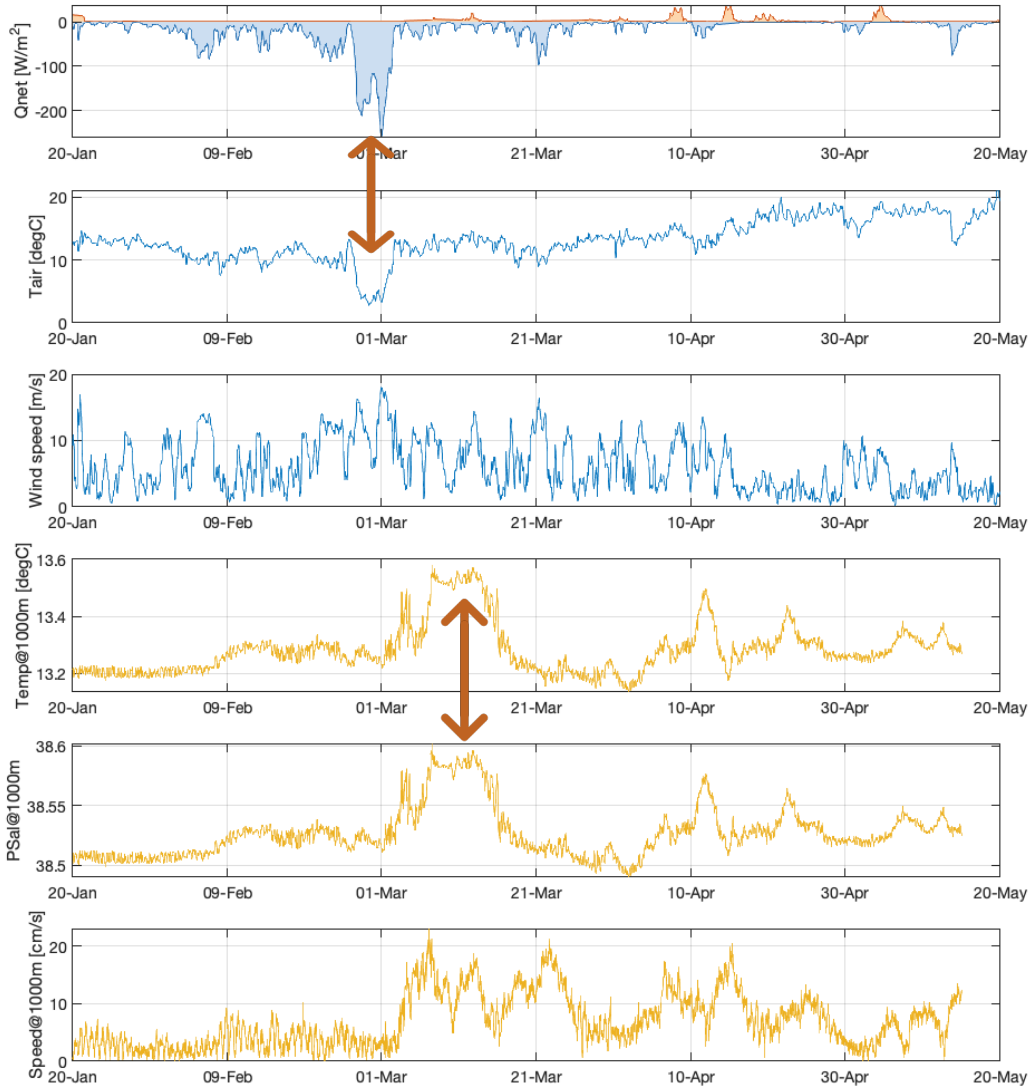
- Correction of S by linear fitting (slope & offset).
- Correction of DOXY with least squares fitting using Winkler *in situ* measurements (calibration adjustment of coefficients).
- Use here downcast and interpolation.


CALVI
Pressure [dbar]
Temperature [°C]
Salinity
Oxygen [µmol kg⁻¹]
Chla [µg L⁻¹]
11-Jan
13-Jan
15-Jan
17-Jan
19-Jan
21-Jan
23-Jan


CALVI
Pressure [dbar]
Temperature [°C]
Salinity
Oxygen [µmol kg⁻¹]
Chla [µg L⁻¹]
02-Feb
04-Feb
06-Feb
08-Feb
10-Feb
12-Feb
14-Feb

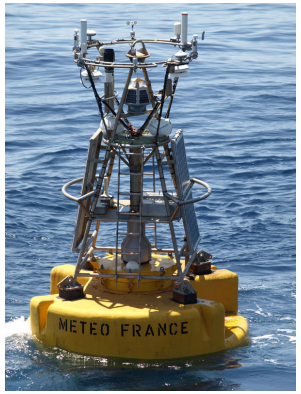

CALVI
Pressure [dbar]
Temperature [°C]
Salinity
Oxygen [µmol kg⁻¹]
Chla [µg L⁻¹]
20-Feb
22-Feb
24-Feb
26-Feb
28-Feb
02-Mar
04-Mar

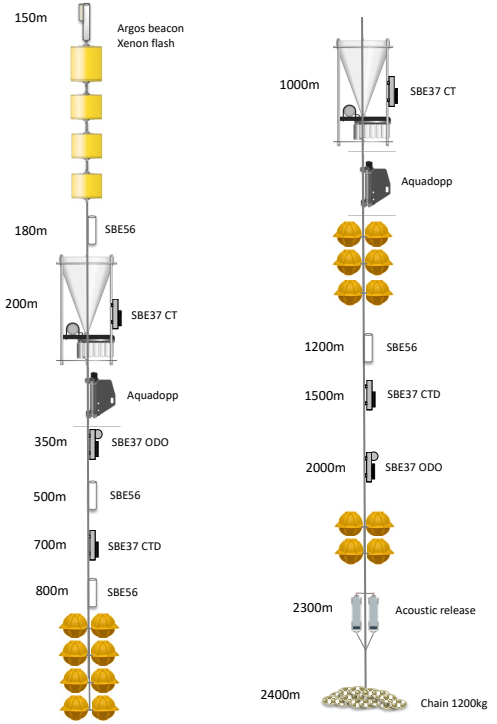
INTENSE MIXING AND COLD WINTER IN 2018



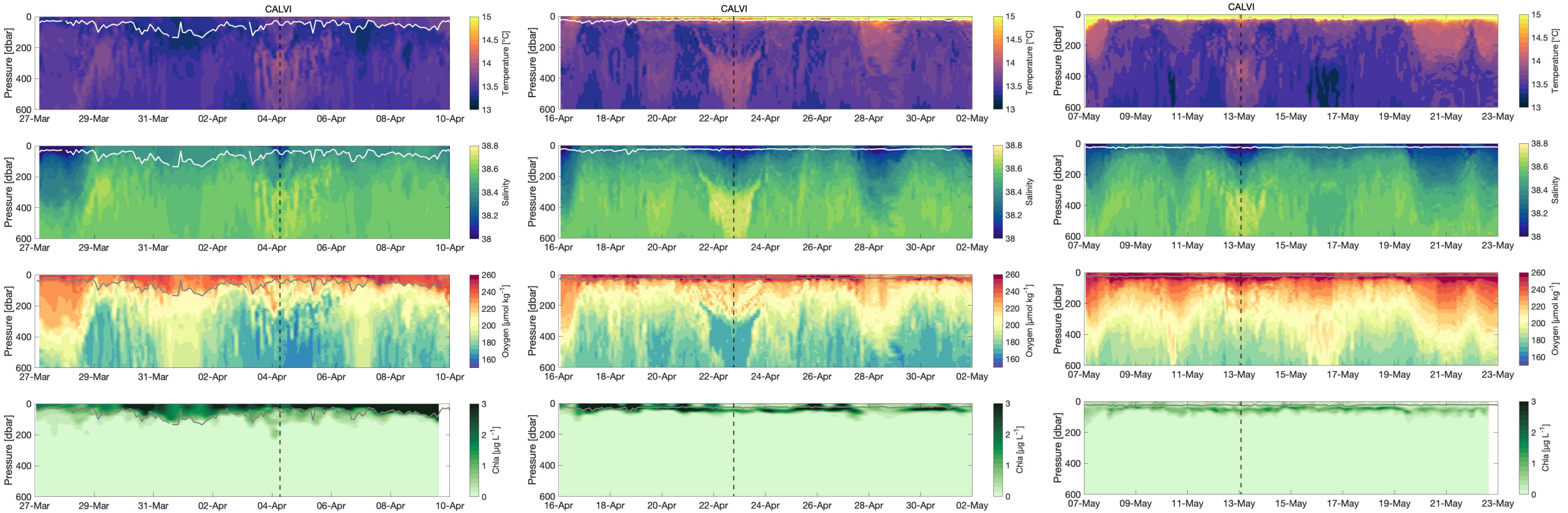
DYFAMED mooring @1000m and ODAS buoy in 2018

DYFAMED

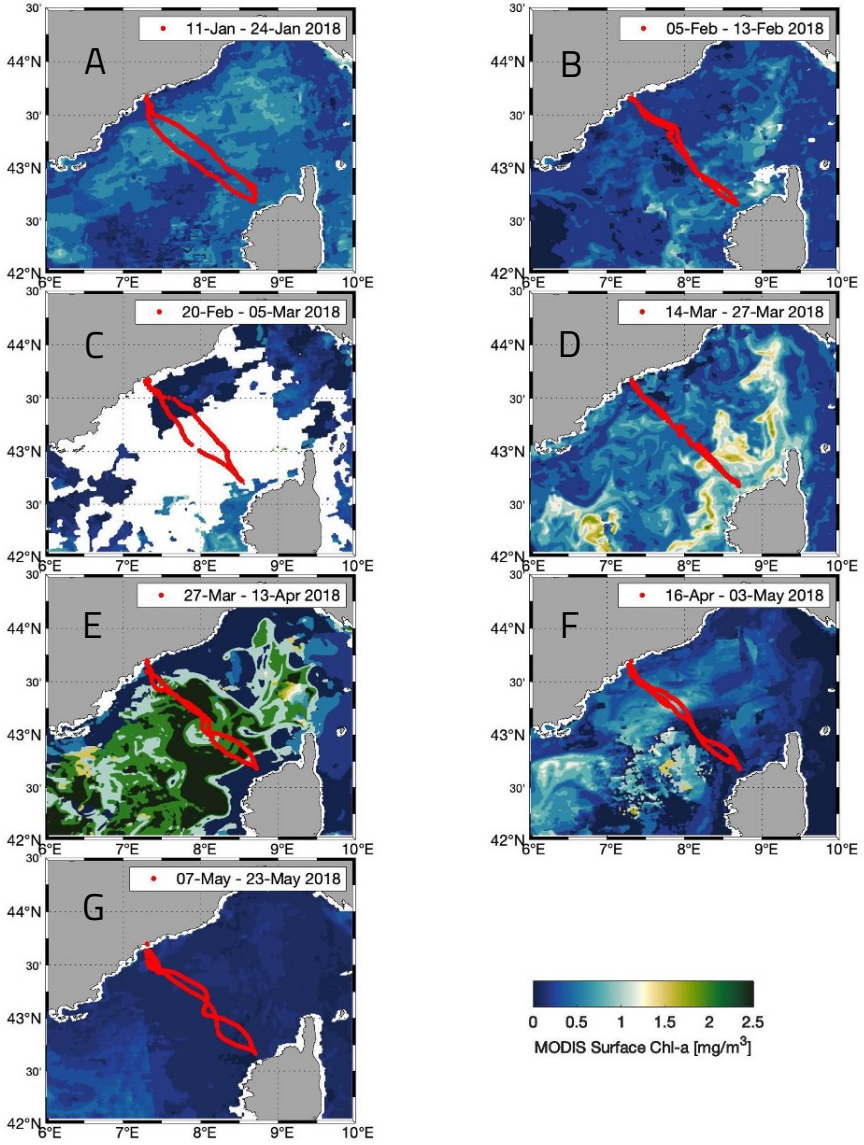


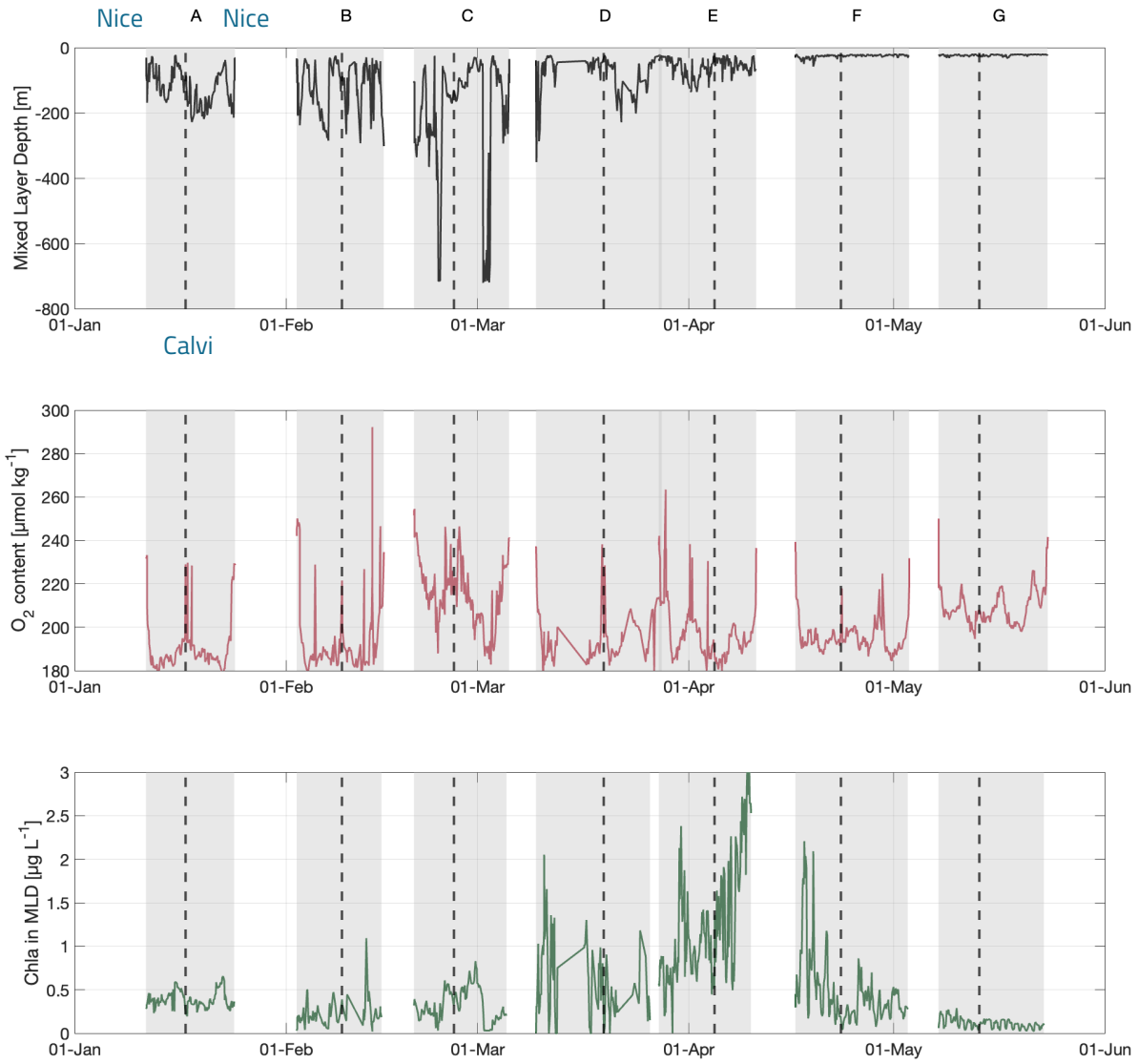


- Situation consistent with intense air-sea fluxes (high heat loss in early March 2018).
- Very cold situation : air temperature near 2-3°C for 4-5 days. Intense wind forcing at DYFAMED station (up to 20 m/s).
- Mixed Layer Depth observed at 1000m at DYFAMED.


CALVI
CALVI
CALVI
Pressure [dbar]
Temperature [°C]
Salinity
Oxygen [µmol kg⁻¹]
Chla [µg L⁻¹]
27-Mar
29-Mar
31-Mar
02-Apr
04-Apr
06-Apr
08-Apr
10-Apr
16-Apr
18-Apr
20-Apr
22-Apr
24-Apr
26-Apr
28-Apr
30-Apr
02-May
07-May
09-May
11-May
13-May
15-May
17-May
19-May
21-May
23-May

MLD, DO CONTENT AND CHLA VARIABILITY





GlobColour daily merged MODIS/VIIRSN product) from ACRI-ST

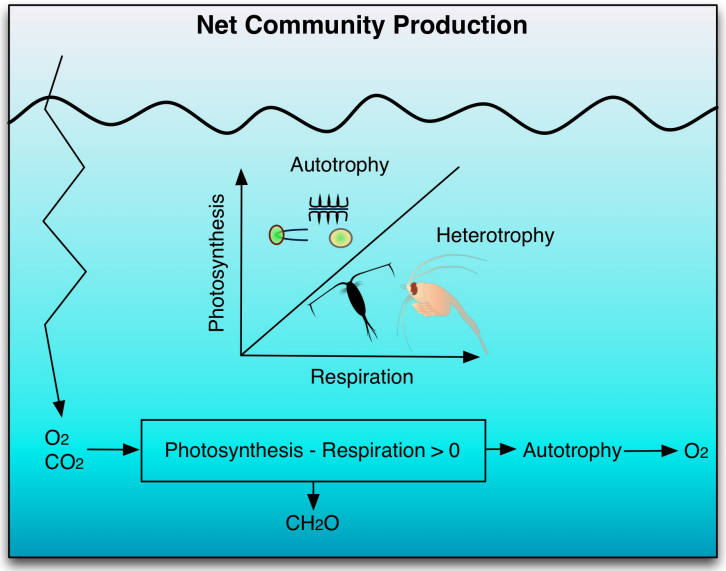
NCP = NET COMMUNITY PRODUCTION

NCP = gross primary production (by phytoplankton) minus total respiration (by phytoplankton, zooplankton and bacteria) (Alkire et al., 2012) = NCP measures the net amount of carbon removed from the atmosphere by the biological pump (autotrophic = NCP>0, heterotrophic = NCP<0)

Direct measurements with ^{14}C (new prod) and stoichiometric ratio (Marty et al., 2002)

O_2 – DIC budget = production vs. saturation (Copin-Montégut 2000; Coppola et al., 2018).

High frequency O_2/Ar measurements by mass spectrometry (Tortell, 2005; Cassar et al., 2009; Hamme et al. 2012...).

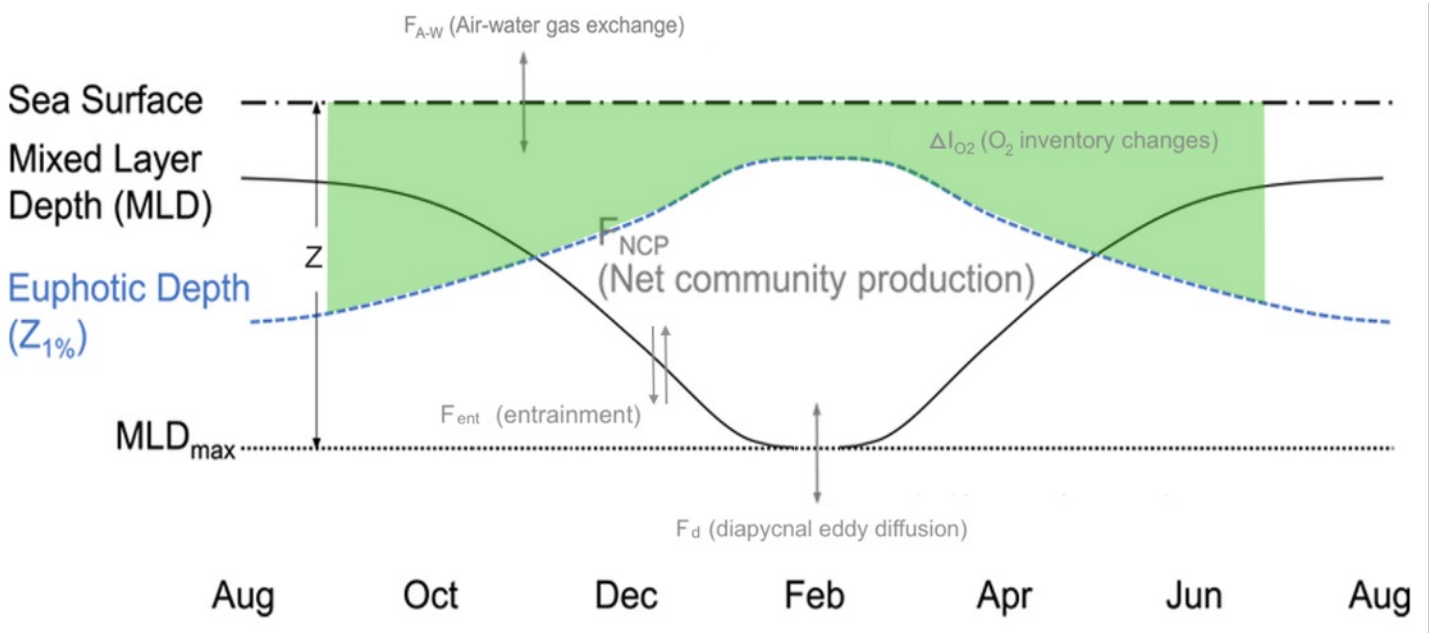


History and intensity of bloom differ each year = time of bloom varies from year to year (between March and April)

Objectives: to map the spatial and temporal variations of the NCP and air-sea CO_2 flux in the Ligurian Sea

Using DO content to calculate the fluxes and estimate the NCP

Biological processes (respiration, photosynthesis) + Physical processes (dissolution of air, bubble injection, changes in water temperature and air pressure)



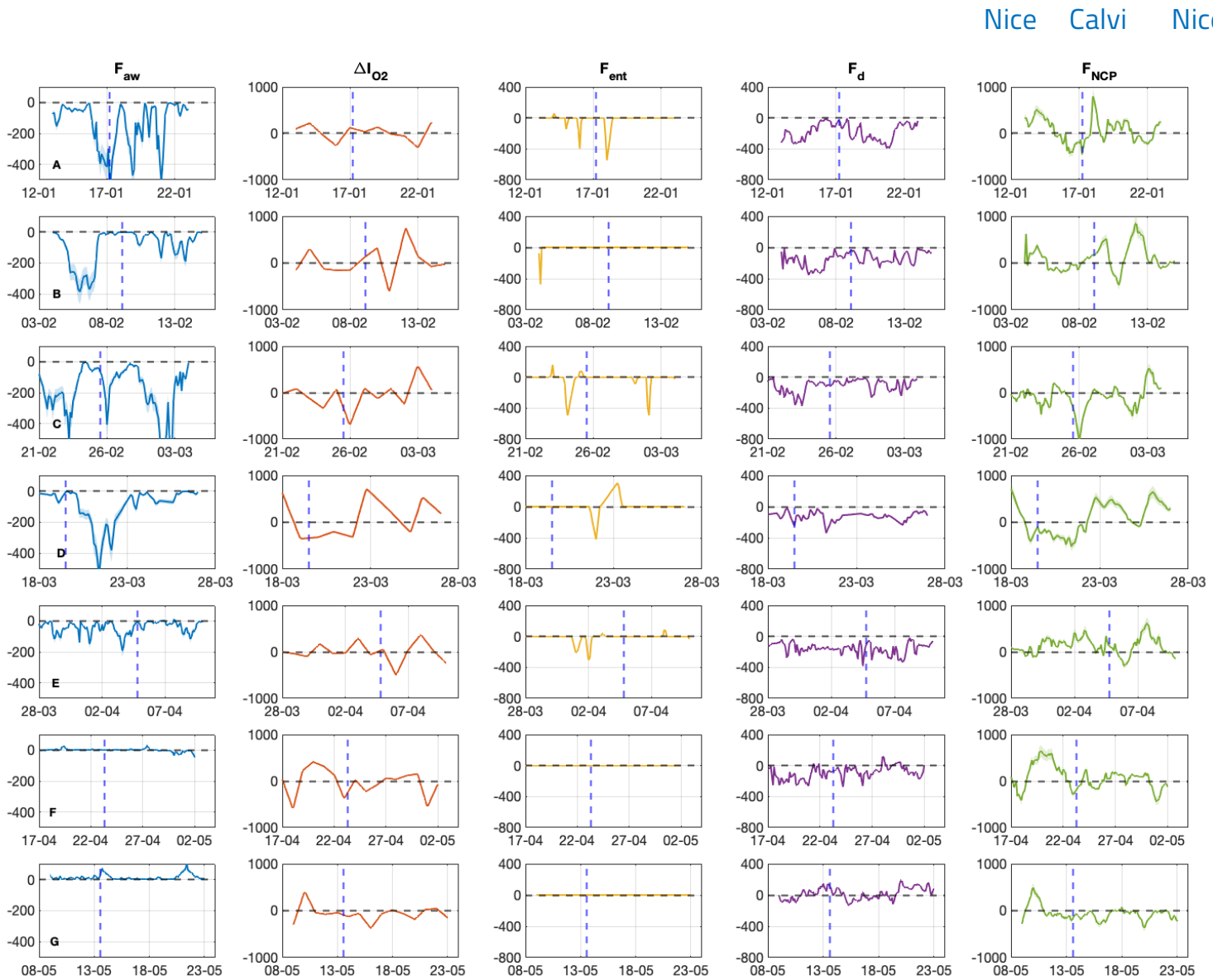
$NCP\ [mmol/m^2/d] = InvO_2 + F_{aw} - F_{ent} - F_d$

$InvO_2$ = change of O_2 inventory between consecutive profiles (above Zeu).

F_{aw} = method of bubble injection from Woolf and Thorpe (1991).

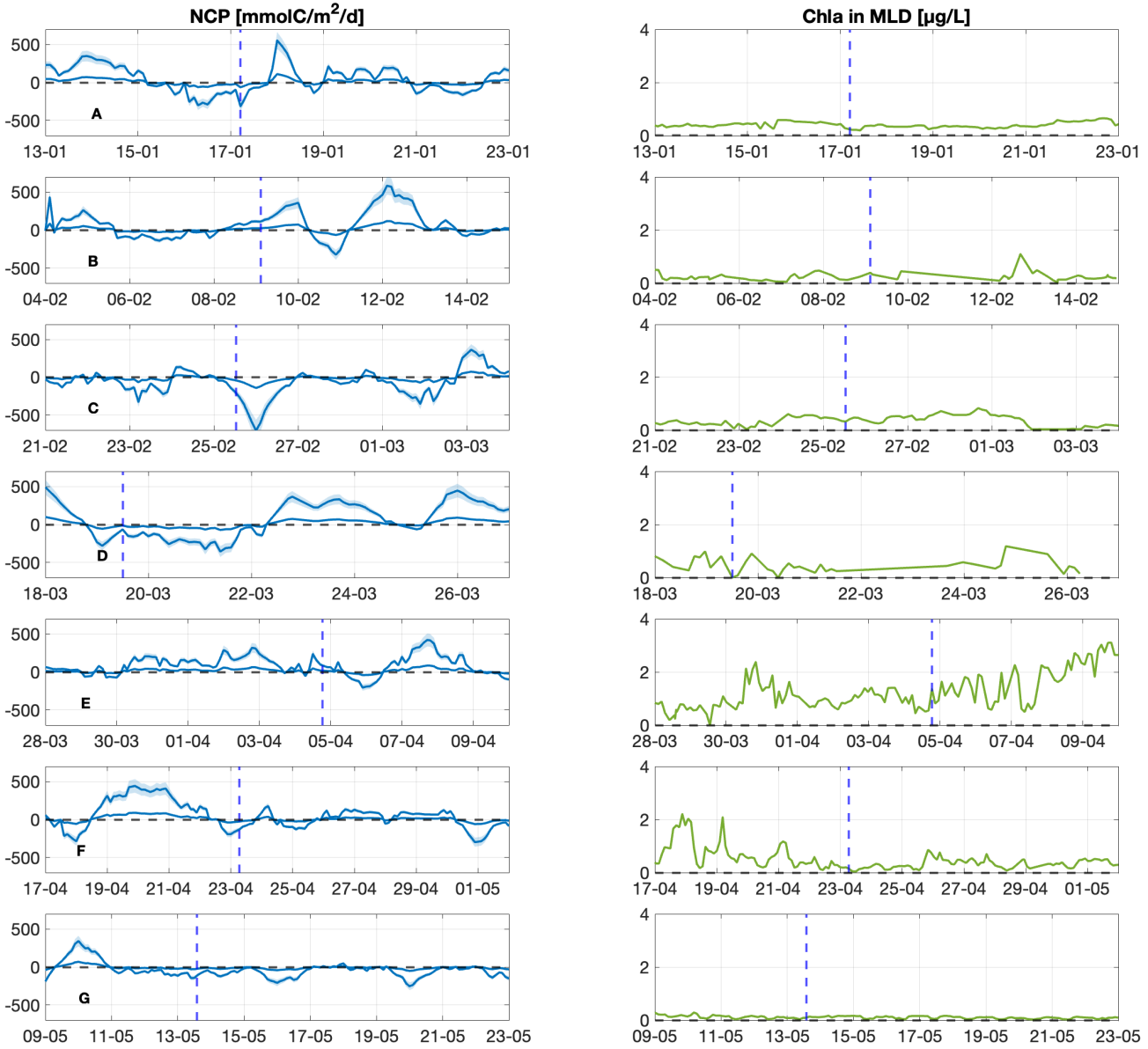
F_{ent} = change of O_2 concentrations when MLD deepens (Z_{MLD} below Z_{eu}). If $F_{ent} > 0$: increase of O_2 inventory.

Fd = diapycnal eddy diffusion flux

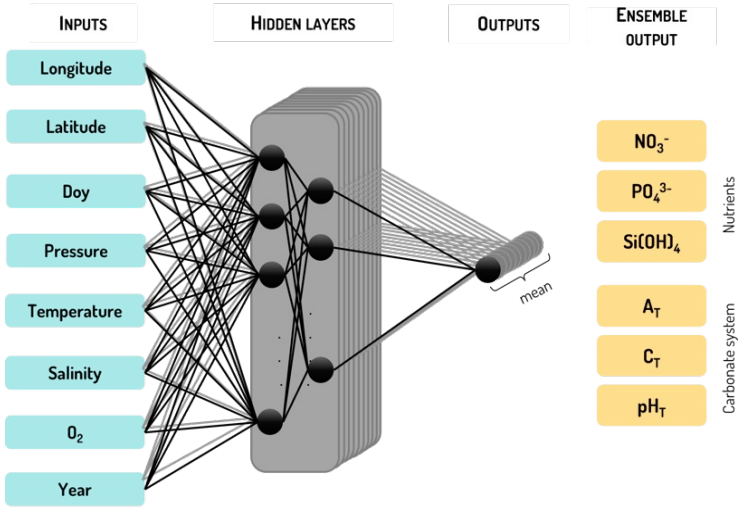


- **Intense F_{aw}** in center of the Ligurian Sea **until mid-March** (negative = DO influx, undersaturation).
- **InvO_2 high and variable in Feb-March** when MLD deepens.
- **F_{ent} important during deep MLD** (DO content increased).
- **NCP related first on O2 inventory change and air-sea O2 flux !**

EVOLUTION OF NCP FROM JANUARY TO MAY 2018



- Heterotrophic situation : NCP<0 (on average) in winter when Chl-a was low.
- Autotrophic situation: NCP>0 or close to 0 in spring when bloom started and Chl-a increased.
- High variability between coastal vs. open sea waters and dynamic conditions in winter.
- DYFAMED = 300-500 mmol/m²/d in April during bloom (200-400 mmol/m²/d end of March 2016, Hemming et al., 2022).



ORIGINAL RESEARCH article
Front. Mar. Sci., 06 August 2020
Sec. Ocean Observation
Volume 7 - 2020 | https://doi.org/10.3389/fmars.2020.00620

frontiers

A Regional Neural Network Approach to Estimate Water-Column Nutrient Concentrations and Carbonate System Variables in the Mediterranean Sea: CANYON-MED

Marine Fourrier[1*] Laurent Coppola[1,2] Hervé Claustre[1] Fabrizio D'Ortenzio[1] Raphaëlle Sauzède[2] Jean-Pierre Gattuso[1,3]

JGR Oceans
RESEARCH ARTICLE
10.1029/2022JC018615

Key Points:

- In the absence of deep convection events, the O_2-depleted layer spreads vertically and intensifies more in the Ligurian than Gulf of Lion
- Nutrients increase in deep and to a lesser extent in intermediate waters with a decoupling between nitrate and phosphate trends

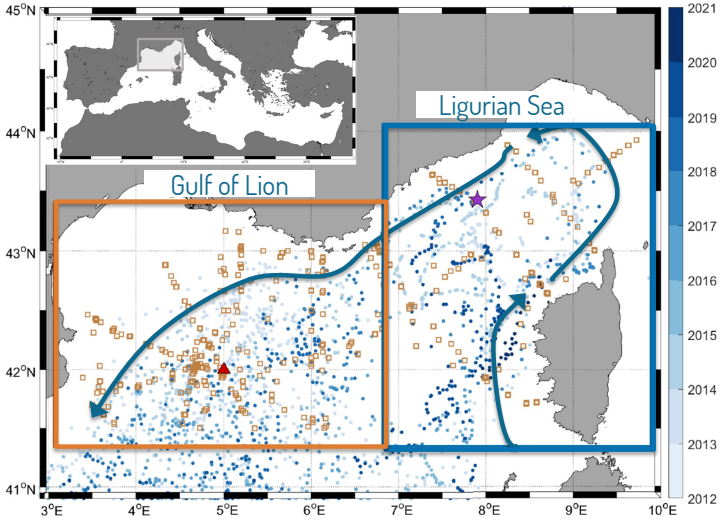
Impact of Intermittent Convection in the Northwestern Mediterranean Sea on Oxygen Content, Nutrients, and the Carbonate System

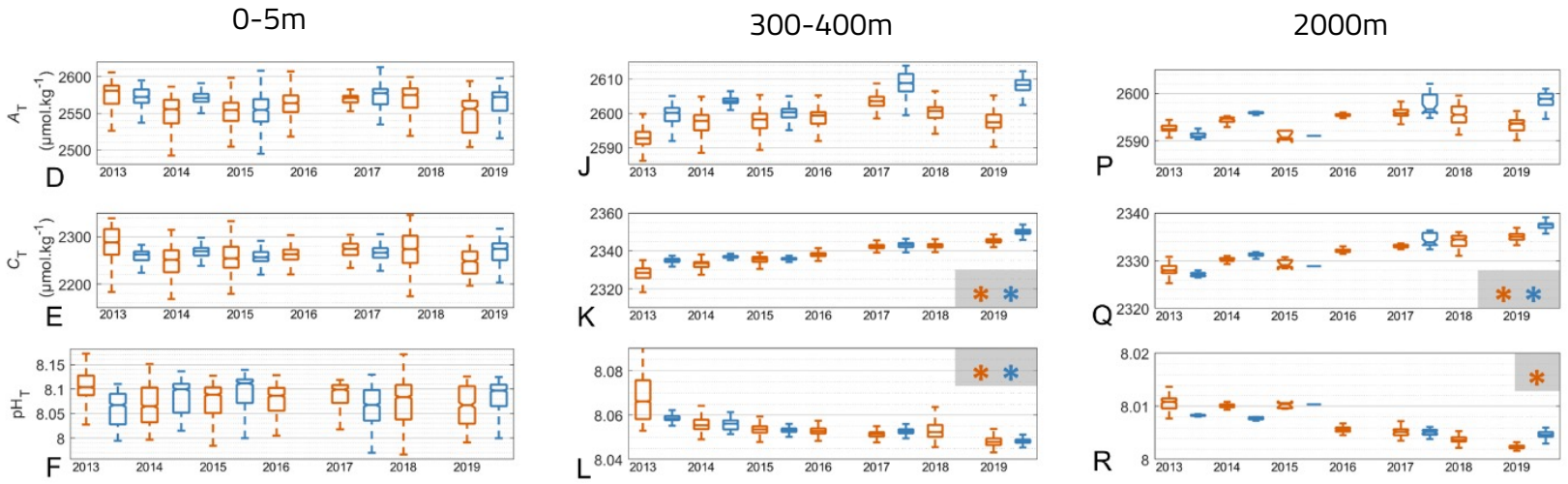
Marine Fourrier[1], Laurent Coppola[2], Fabrizio D'Ortenzio[1], Christophe Migon[1], and Jean-Pierre Gattuso[1,3]

[1]Laboratoire d'Océanographie de Villefranche, CNRS, Sorbonne Université, Villefranche-sur-Mer, France, [2]CNRS, OSU STAMAR, UAR2017, Sorbonne Université, Paris, France, [3]Institute for Sustainable Development and International Relations, Sciences Po, Paris, France

Application of a artificial neural network for biogeochemistry in MedSea (CANYON-MED)

→ estimates trends in increasing inorganic carbon and acidification in the NW Mediterranean (Fourrier et al., 2020; 2022)



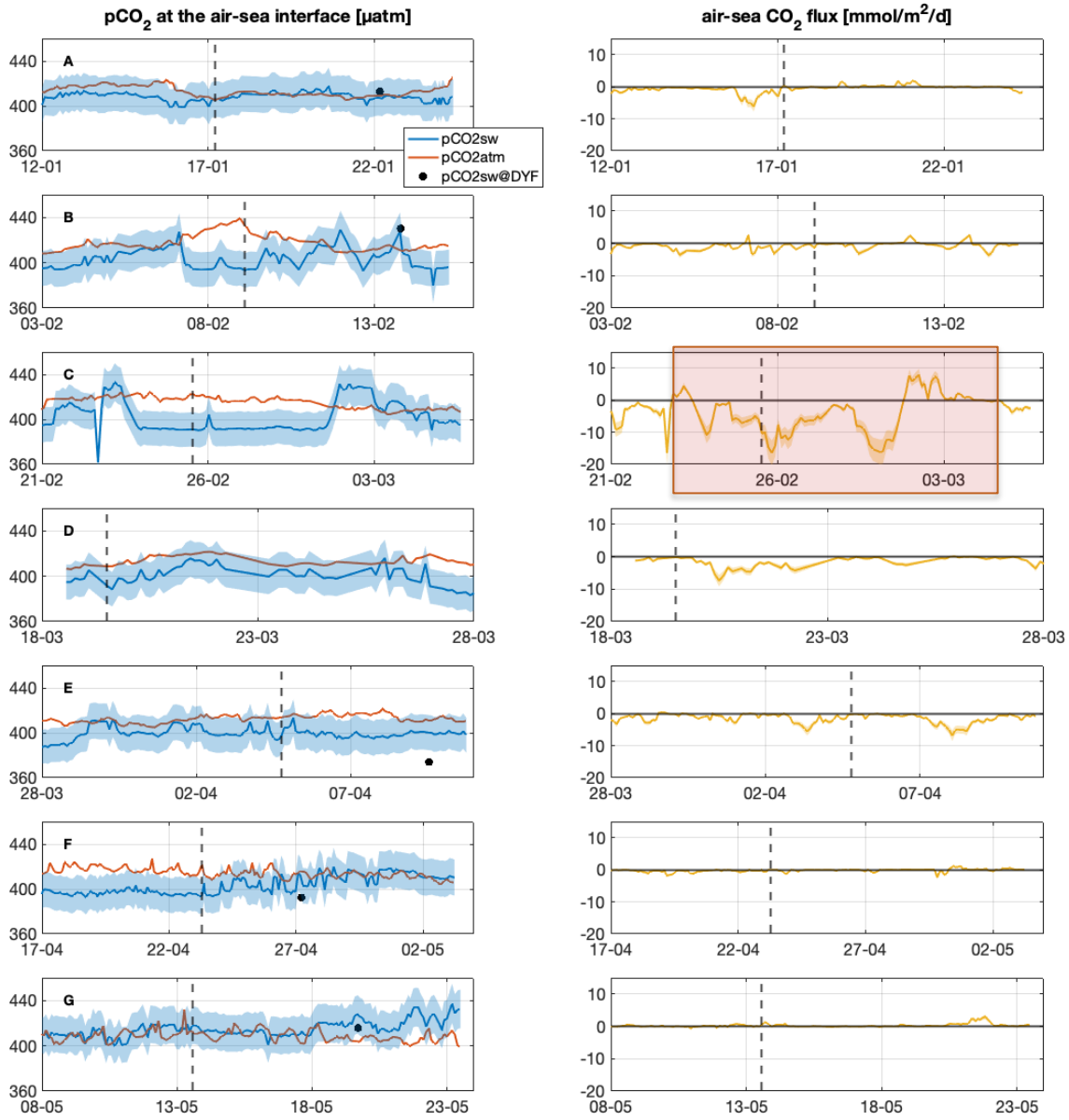


THE AIR-SEA CO2 FLUX IN THE LIGURIAN SEA

$$F_{CO2} = k \times \alpha \times (pCO_{2SW} - pCO_{2atm})$$

k depends on wind speed (Wanninkholf, 2014)
pCO2sw estimated from TC and pH with COSYS toolbox
TC is predicted from TSO2 gliders with CANYON-MED (surface only !)

- pCO2 sw is consistent with measured pCO2sw (sensor @DYF) and CO2 flux is consistent with SYMPHONIE model: -0.4 TgC/yr for all NW MedSea in 2012-2013 convective year
- **CO2 flux is negative and high in winter** : strong winds and undersaturation of DIC in surface
- **CO2 flux 10-20 times lower than NCP** : heterotrophic conditions (NCP< 0) during CO2 sink (opposite to the theory) due to large T gradients
- Estimates of air-sea CO_2 fluxes show that during the **convection episode the central zone of the Ligurian Sea is a marked sink for CO_2**



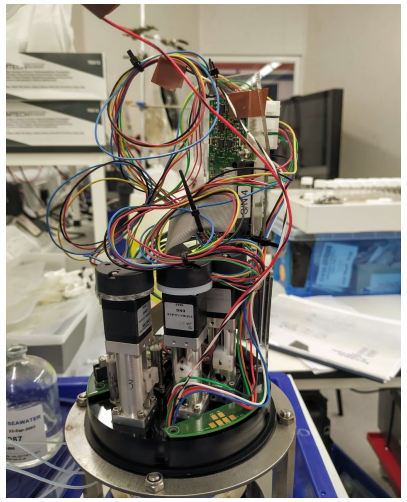
GEORGE PROJECT: IMPROVE OCEANIC CO2 MEASUREMENTS

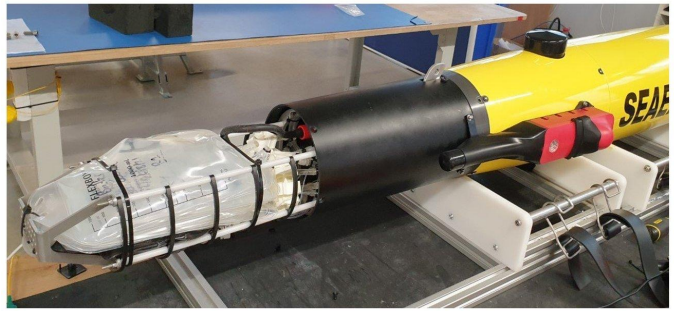
- **HORIZON Infra-Technology project 2023-2027** ("next GEneration multiplatform Ocean obseRvinG tEchnologies for research infrastructures")
- Involves three ERICs (EMSO, EURO-ARGO, ICOS) to improve capacities for CO_2 observations
- Develop and validate new AT-DIC LoC sensor (NOC), fast pH sensor (CWS) and pCO2 (Mini-Pro) on Sea-Explorer gliders + acoustic sensor to estimate the wind speed
- Multiple demonstrations of innovation on the platforms. Large demonstration in 2026 in the NW Mediterranean Sea

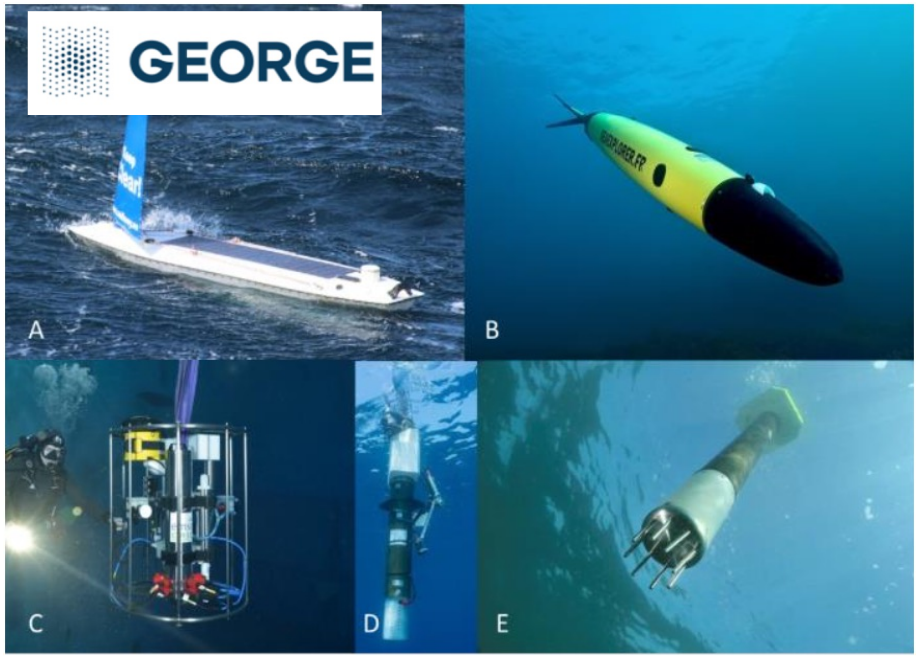
ICOS Integrated Carbon Observation System

emso ERIC EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIUM

Euro Argo







ORIGINAL RESEARCH article
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frontiers

High-resolution study of the air-sea CO_2 flux and net community oxygen production in the Ligurian Sea by a fleet of gliders

Laurent Coppola[1,2*] Marine Fourrier[1] Orens Pasqueron de Fommervault[3] Antoine Poteau[1]
Emilie Diamond Riquier[4] Laurent Béguery[3]

MERCI / THANKS

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