CES ODATIS CO_2 - pH marin

Integrated observations of oceanic CO_2 in the Northwestern Mediterranean Sea

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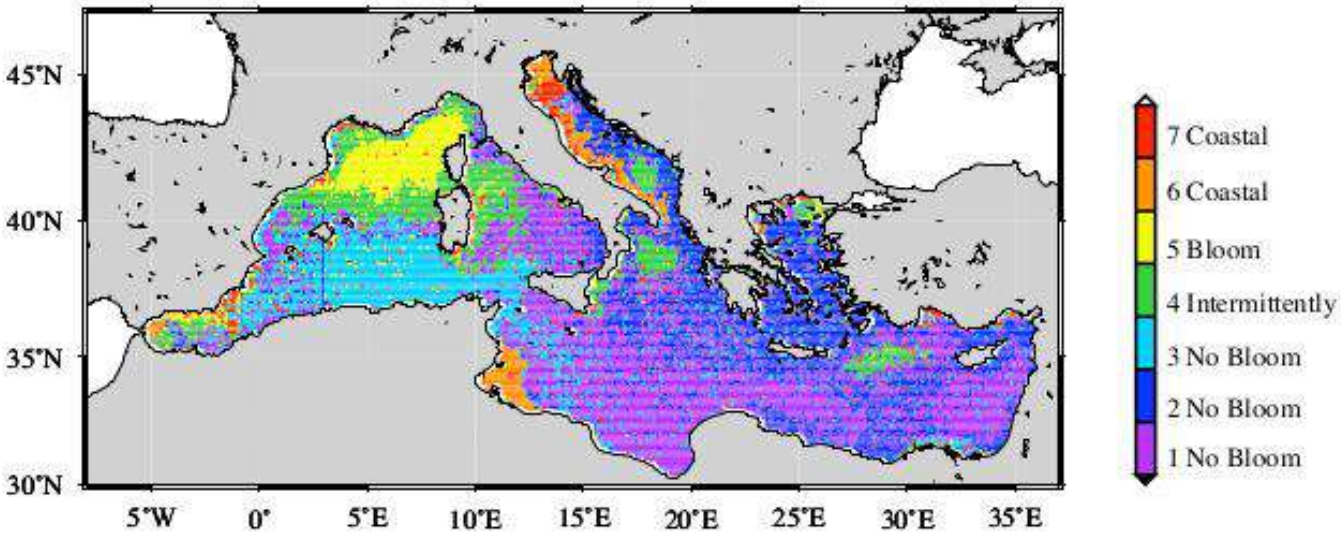
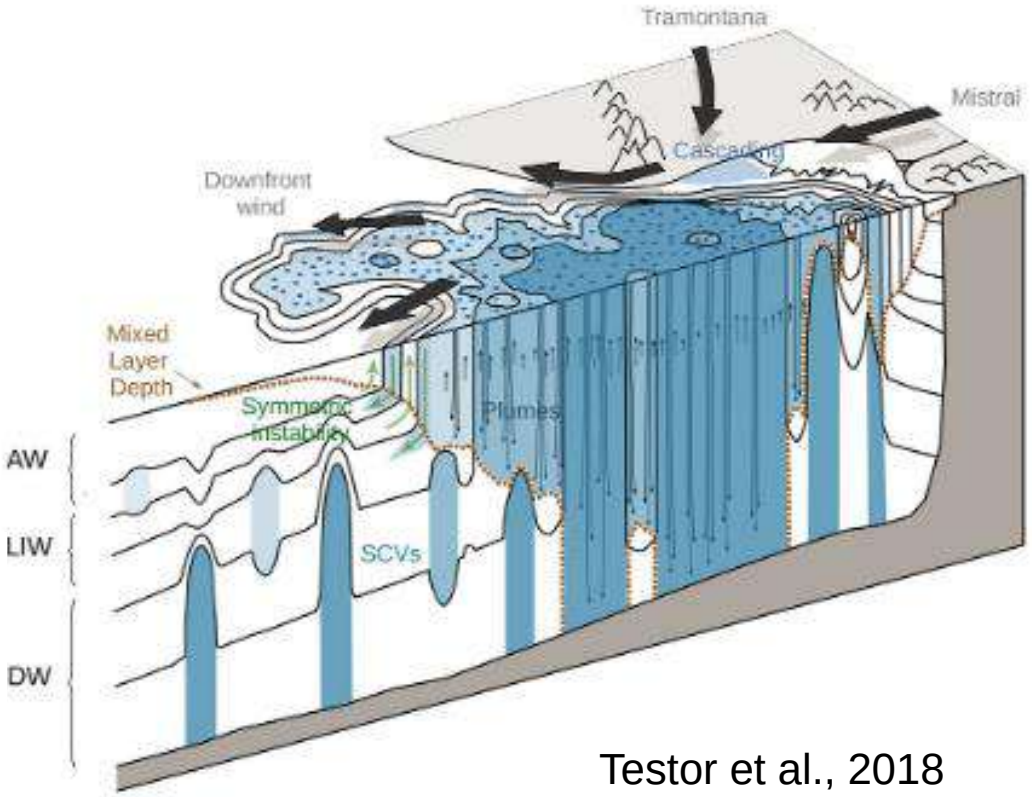
The Northwestern Mediterranean Sea

Dynamic region with intense winter convection and deep ventilation



d'Ortenzio and Ribera d'Alcala, 2009



Testor et al., 2018

An area of intense phytoplankton blooms

Approach with CO_2 time series at fixed stations

Collaboration with Spain and Italy within European initiatives (EMSO, EURO-ARGO, ICOS,…): **the N.W. Med. Sea is one of the most observed area**

The MOOSE observing system

Fixed stations (monthly sampling)

DYFAMED, since 1998

ANTARES, since 2010

MOLA, since 2010

Network of annual basin scale stations

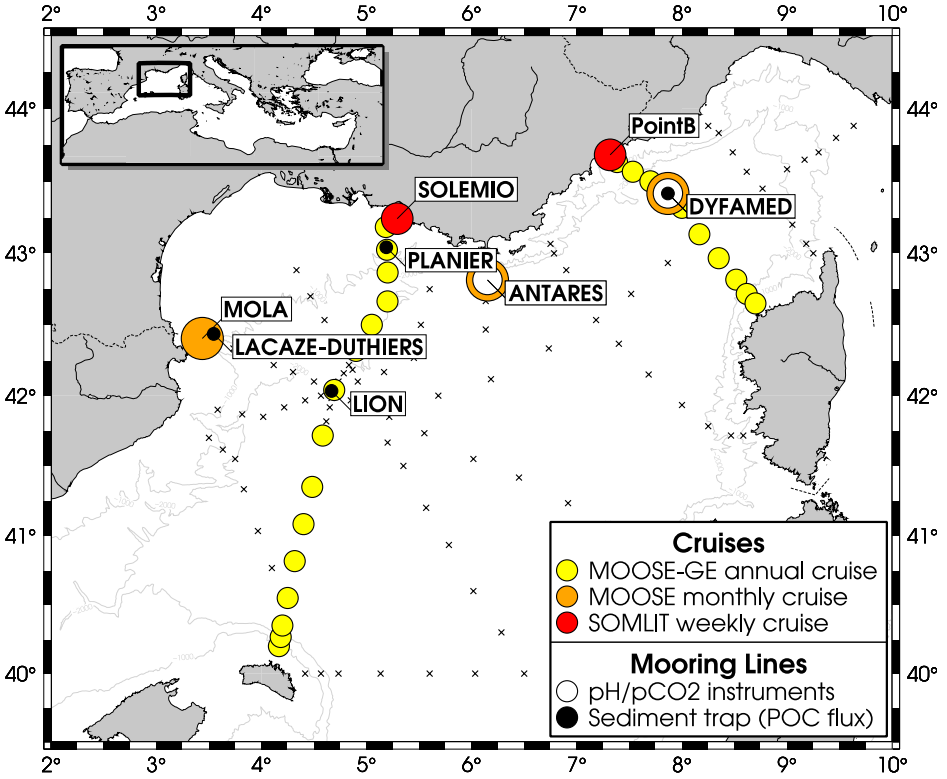
MOOSE-GE, since 2010

The SOMLIT observing system

Fixed stations (Weekly sampling)

Point B, since 2005

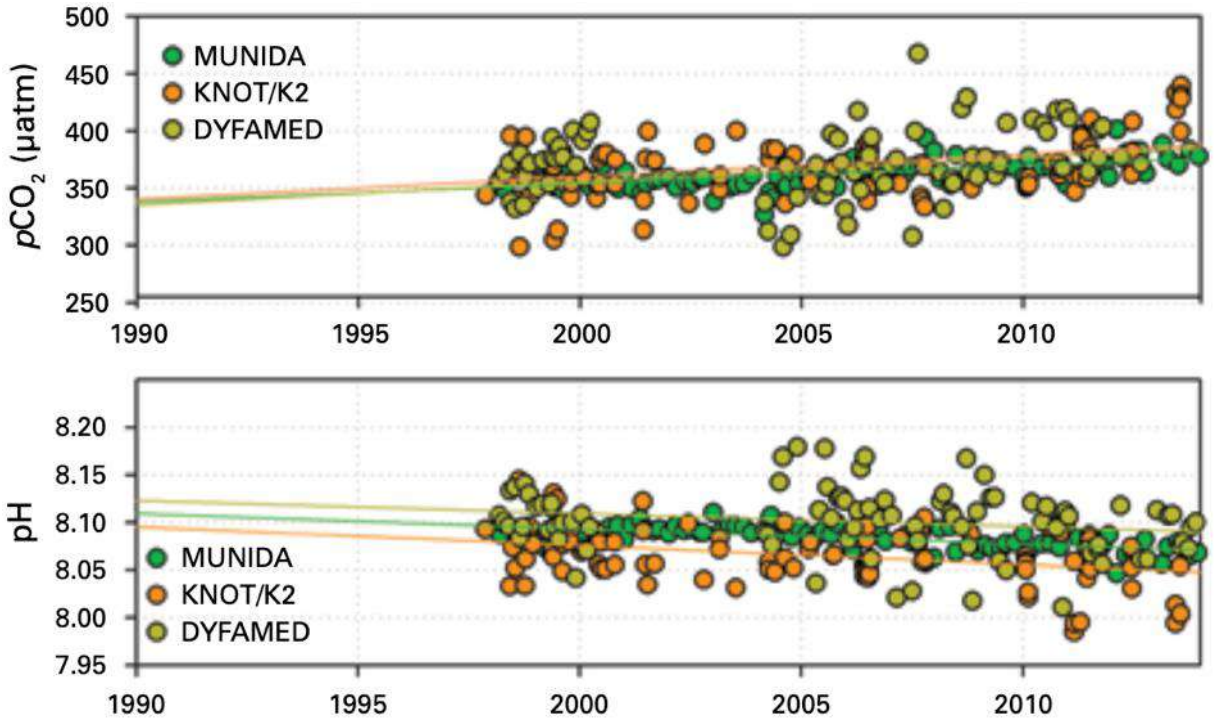
SOLEMIO, since 2016



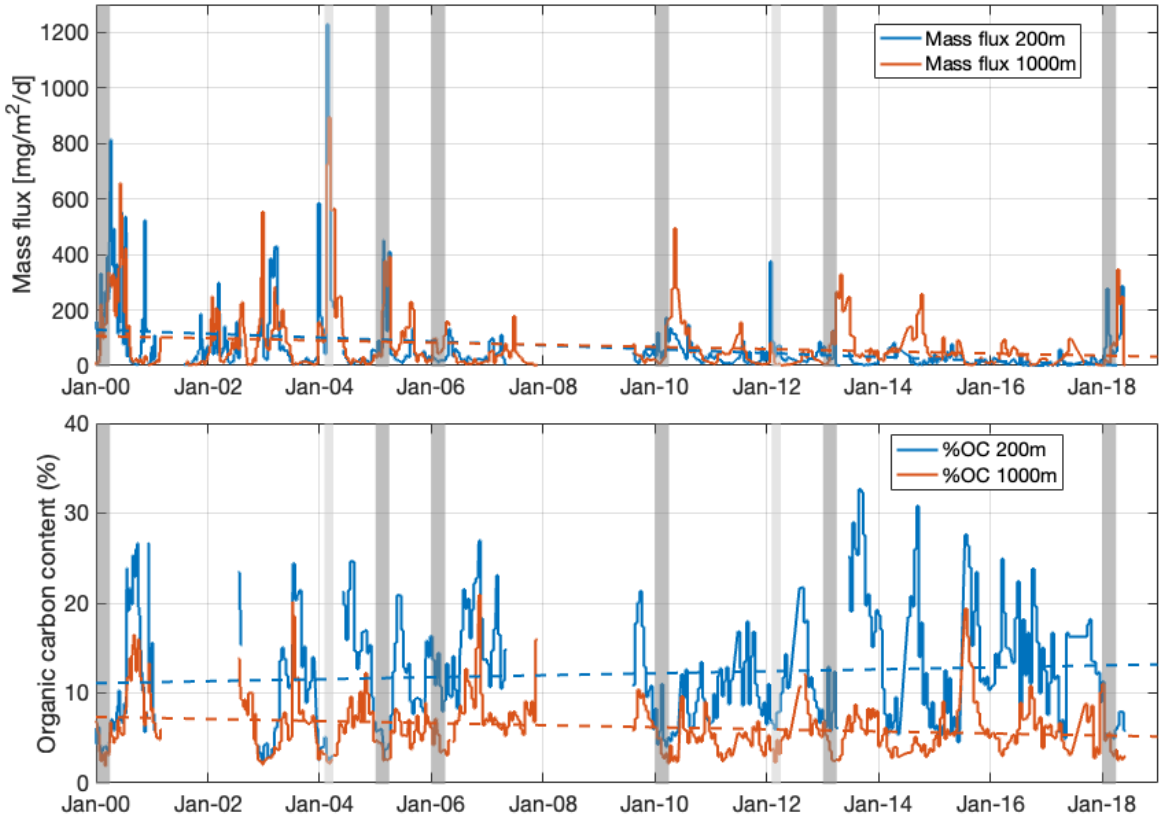
Carbonate chemistry is estimated from "high quality" measurements of A_T, C_T and pH_T

Example with a long time series (DYFAMED)

More than two decades of data …



From AT-CT in surface waters (WMO bulletin No 10, 2014)



Sediment trap fluxes at 200 & 1000m (Coppola, pers. com.)

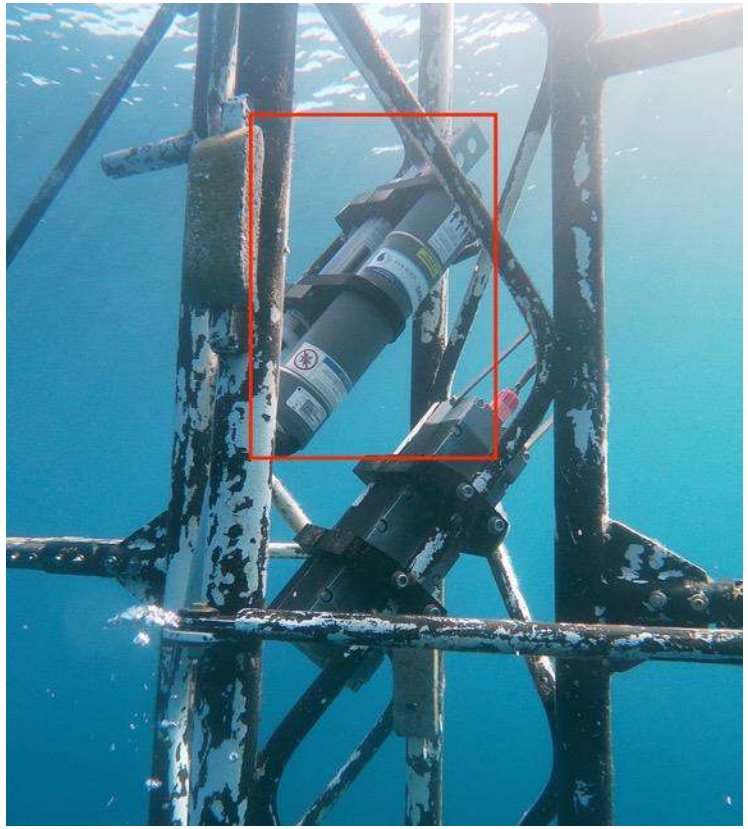
It is important to estimate the fraction of organic carbon **exported and sequestered**.

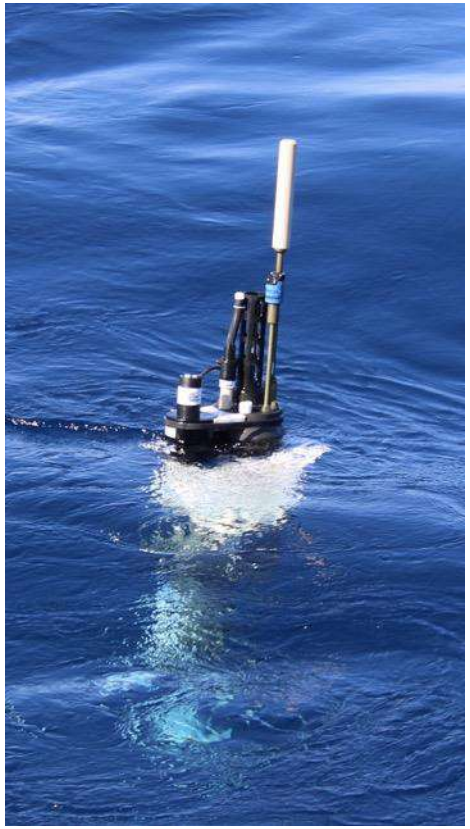
Surface pCO2 observations are essential but not enough to understand the impacts of global warming on CO_2 cycle: **need to observe the carbon into the ocean interior !**

Approach with high frequency measurements

Deployment of pCO_2^{SW} and pH sensors

- **Surface buoy**: pCO_2^{SW} surface measurements with CARIOCA at DYFAMED (1995-1997, 2013 - present)
- **Mooring**: pH measurements at DYFAMED and ANTARES (2021-….)
- 2 **BGC-Argo floats** deployments with pH sensor
- *Planned: pH on **gliders** and pCO2 surface with **Ferrybox** (RV Thalassa) during MOOSE-GE*





emso ERIC
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biogeochemical Argo

Ocean Gliders

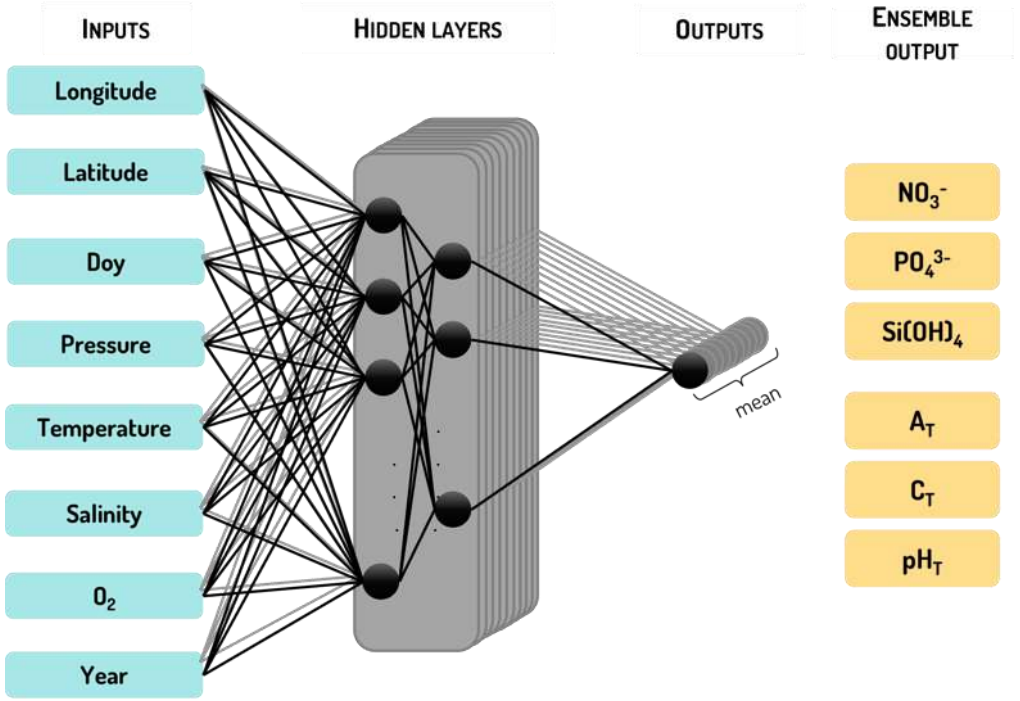
High frequency for oceanic CO_2 measurements **from various platforms with real-time or delayed mode**

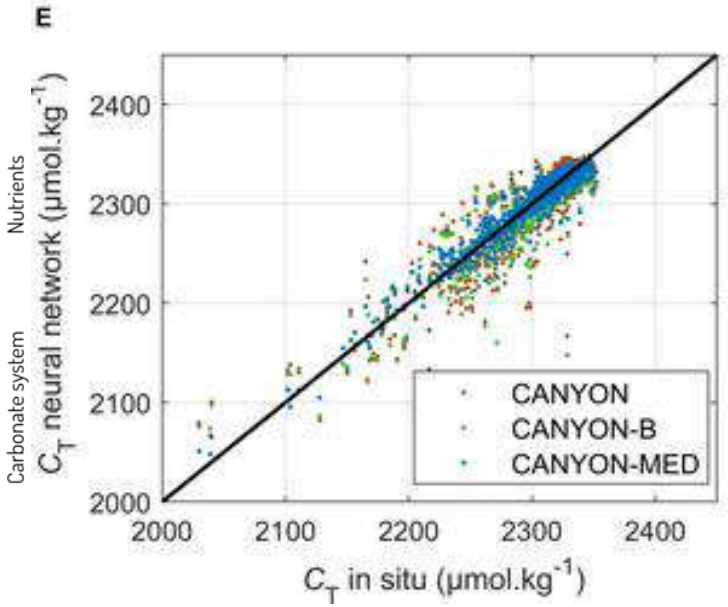
Approach with a regional neural network

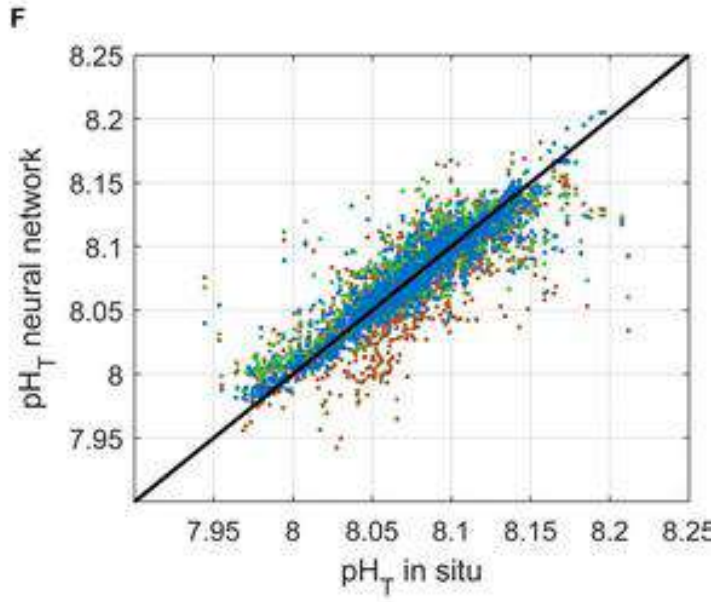
Carbonate chemistry variable can be inferred from cost-effective « predictors » thanks to machine learning

CANYON-MED a regional method for the MedSea (Fourrier et al., 2020)
- Tuned for a specific use in the Med. Sea
- Trained using quality-controlled dataset for the Med. Sea.

CANYON for the global ocean : « CArbonate system and Nutrients concentration from hYdrological properties and Oxygen using a Neural-network » (Sauzède et al. 2017)

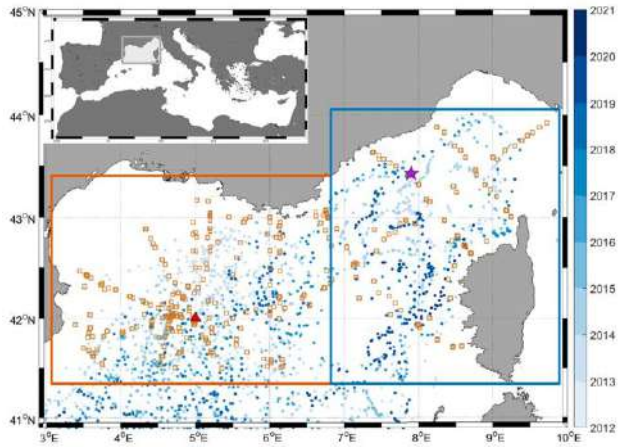




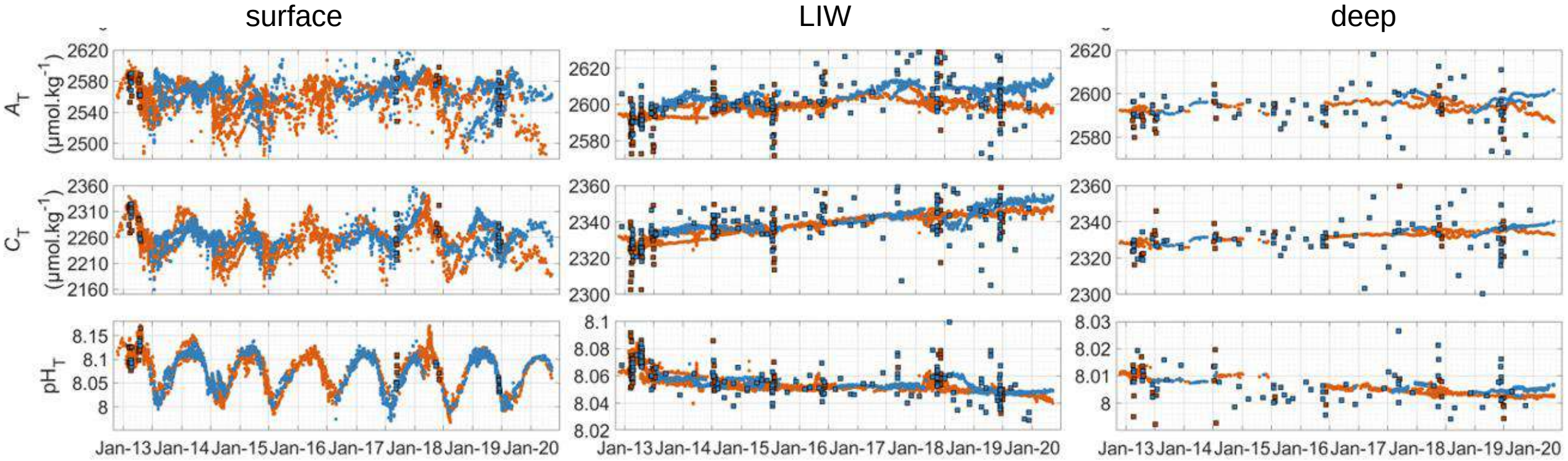


Fourrier et al., 2020/2021

Example with CANYON-MED



- Based on **« high-quality » oxygen measurements** from BGC-Argo floats deployed in the North-Western Med. during the last decade.
- Total carbon and alkalinity increase from 2013-2020 in the entire water column
- Deep winter mixing: deeper penetration of atmospheric CO2 and lower pH
- Biological pump: release CO2 during remineralization of sinking particles



Fourrier et al., JGR Oceans in

Approach with a regional PHY-BGC model

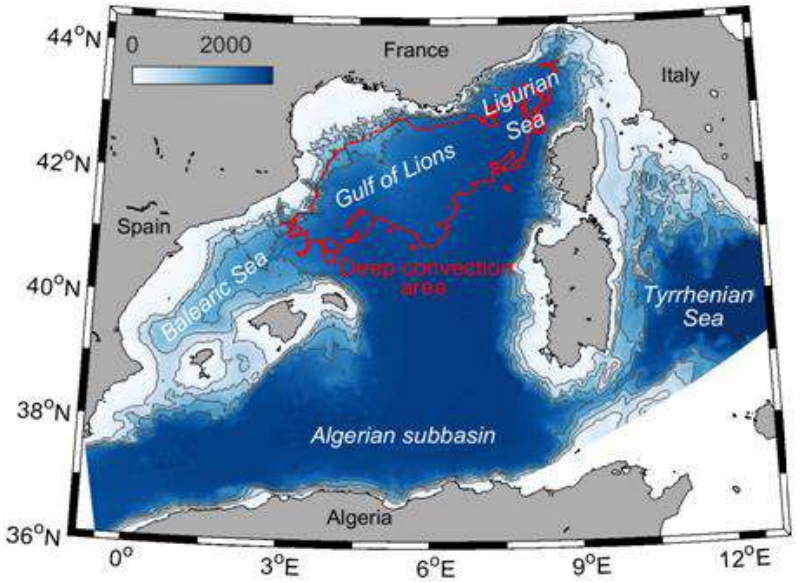
Implementation of a coupled physical/biogeochemical/carbonate system model
to investigate the **seasonal cycle** and estimate an **annual budget of air-sea CO2 fluxes**

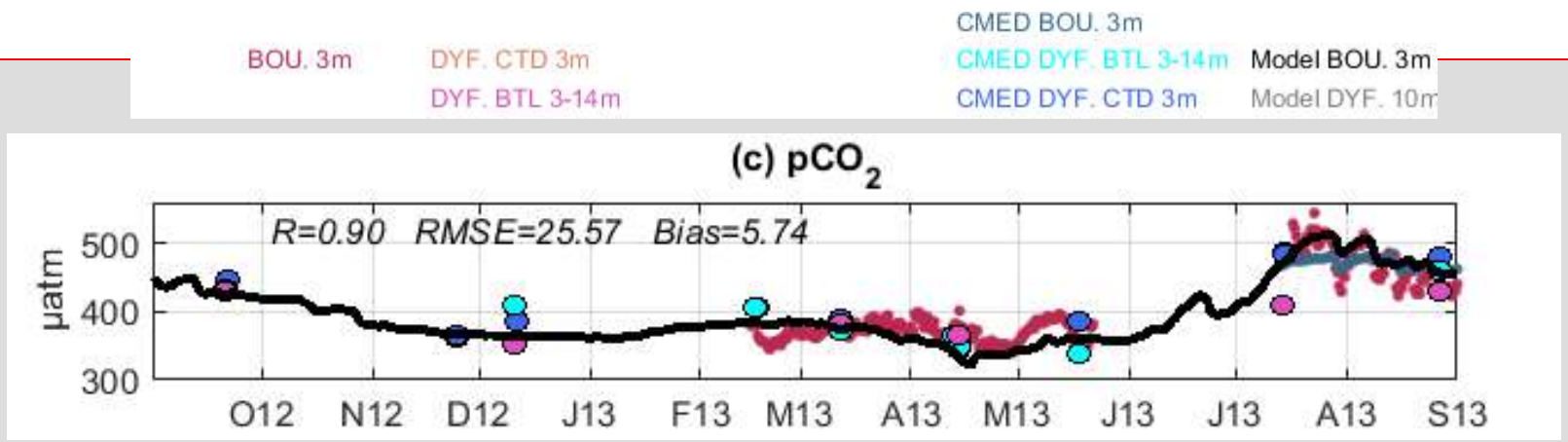
Hydrodynamic model
SYMPHONIE
(Marsaleix et al., 2008)

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

Carbonate system model
(Soetaert et al., 2007)

SYMPHONIE ECO3M-S



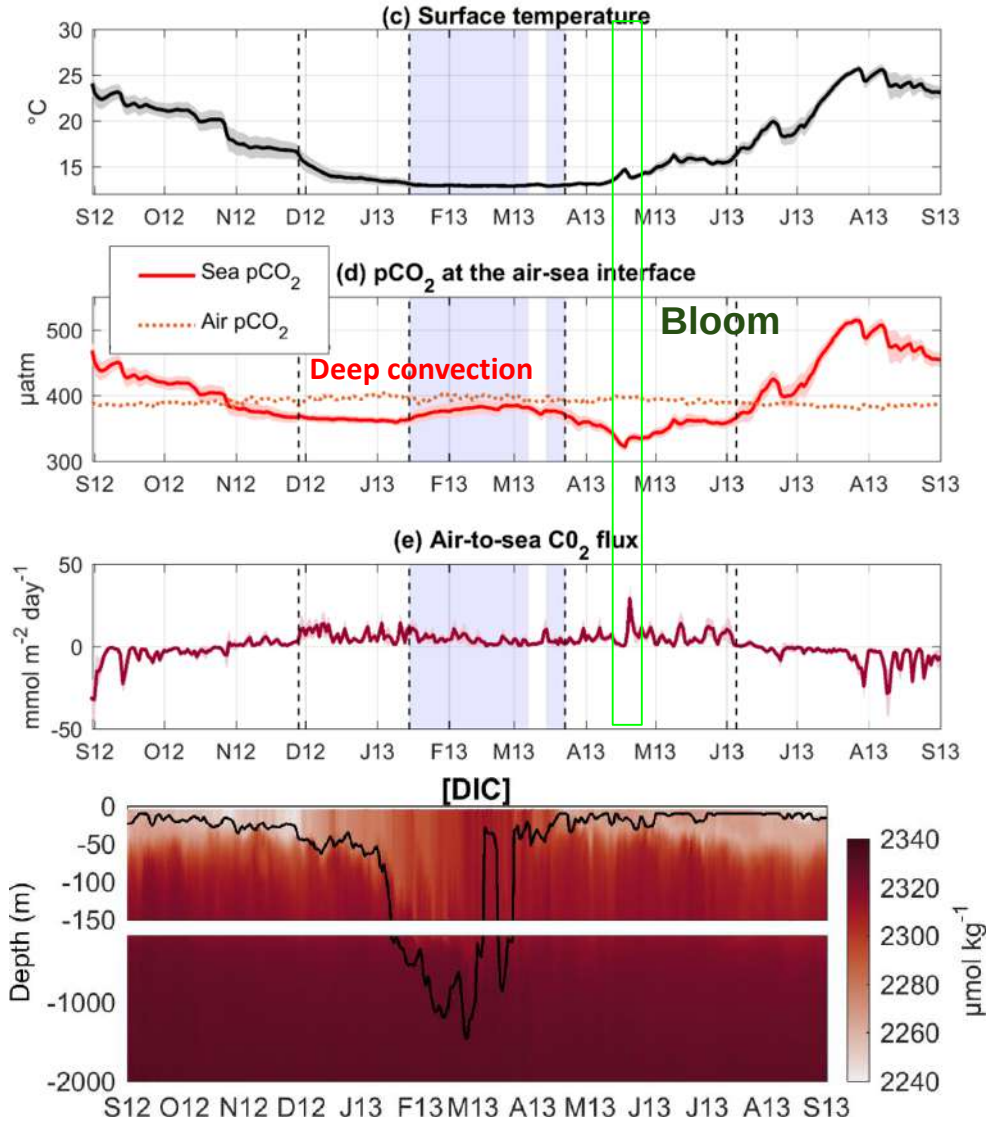


Assessment of the coupled model:
Comparison with *in-situ* pCO_2 data at the DYFAMED site

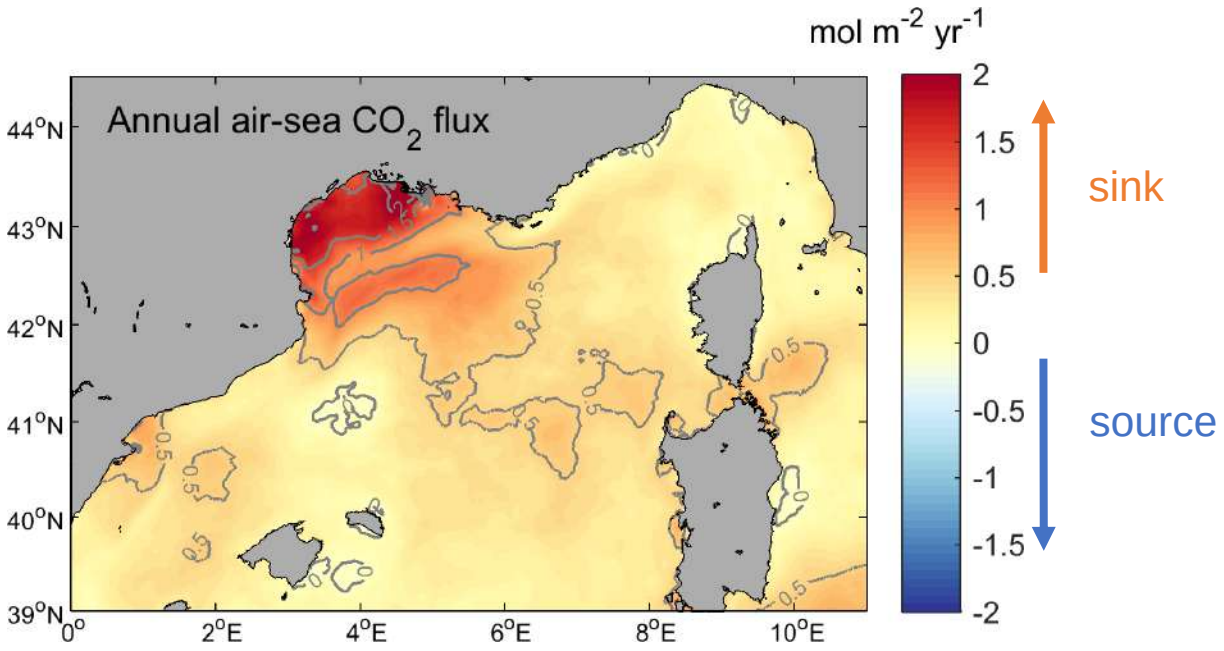
Ulses et al., in prep.

Example: first model estimations of air-sea CO_2 fluxes

Seasonal cycle



Annual budget: The NW Med. Sea is a moderate sink for atmospheric CO_2 (annual flux of +0.5 mol/m^2/yr for convection zone during 2012/13) mostly driven by the coastal area of the Gulf of Lion (+1.5 mol/m^2/yr)

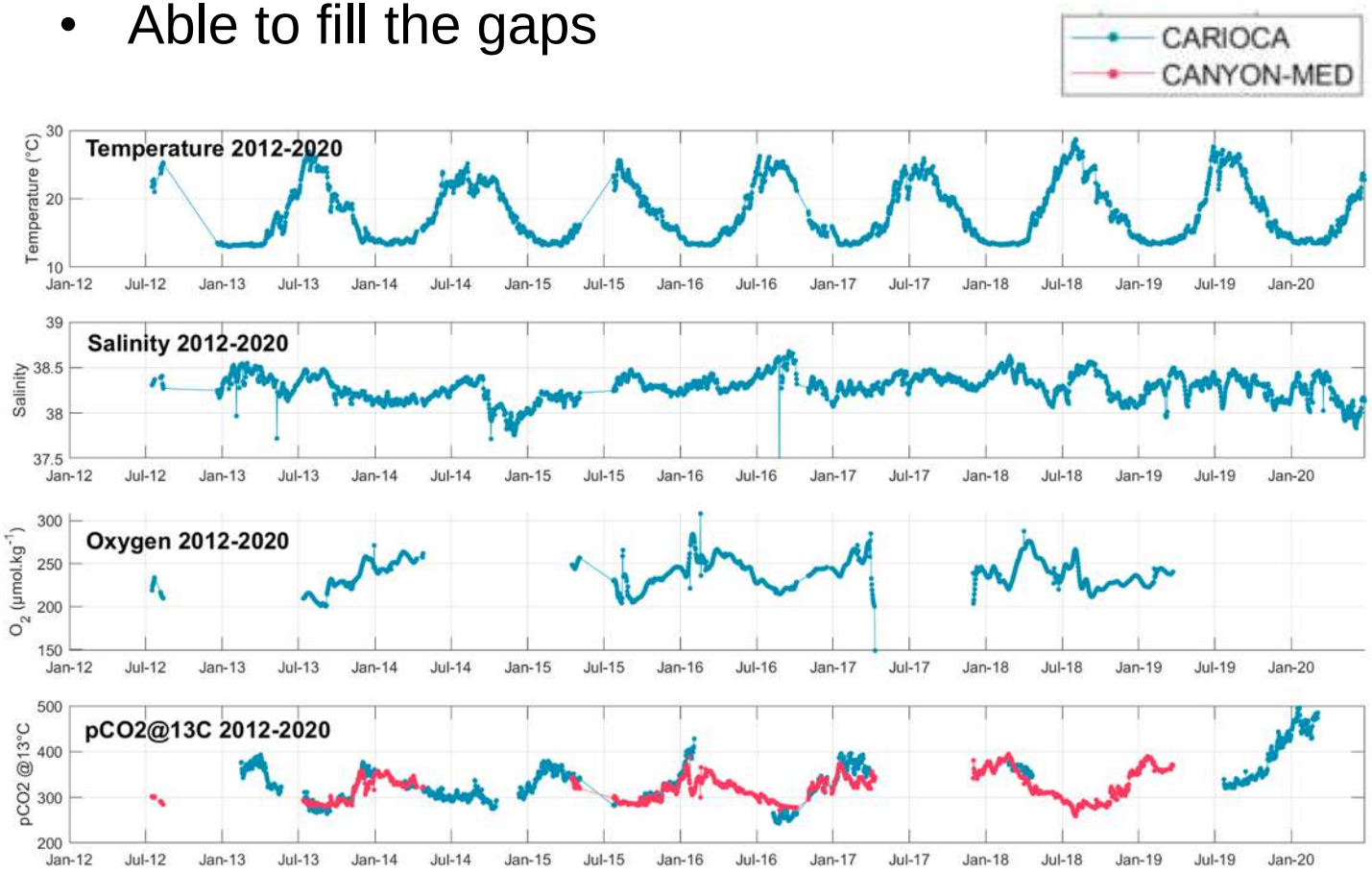


Ulses et al., in prep.

Future applications in the NW MedSea

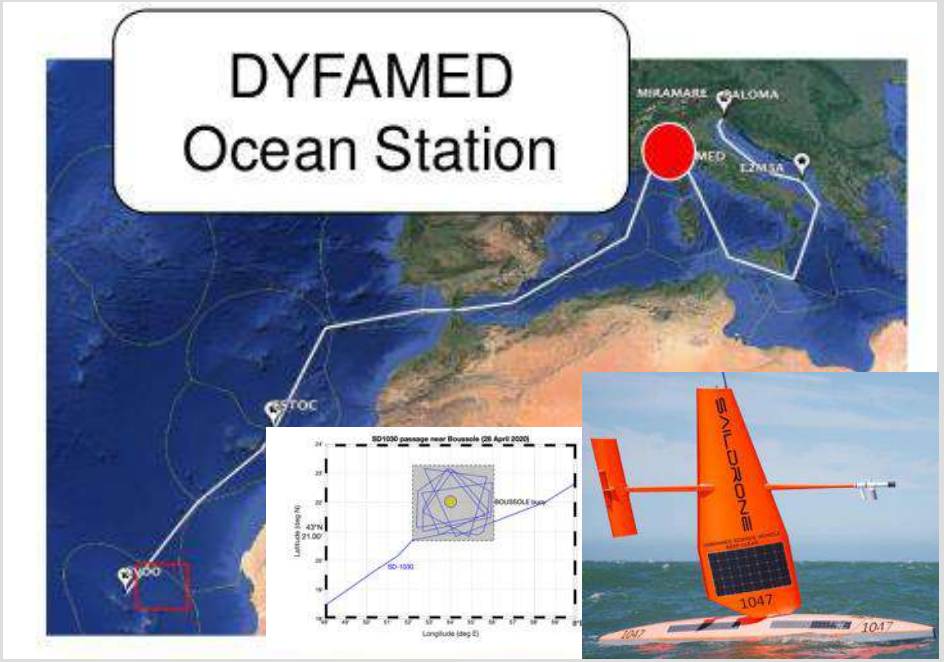
The combination “virtual” / *in-situ* data allows:

- “Internal consistency” test
- Able to fill the gaps



Fourrier and Coppola, personal communication.

Use of these «augmented mooring line» observations for match-up with autonomous moving platforms.

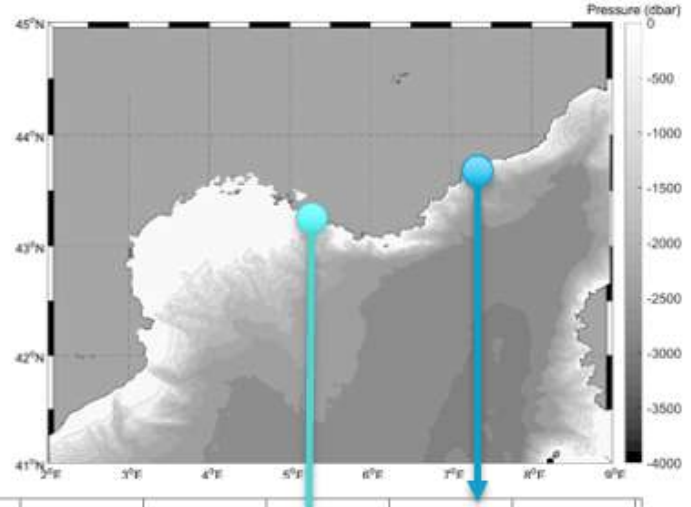


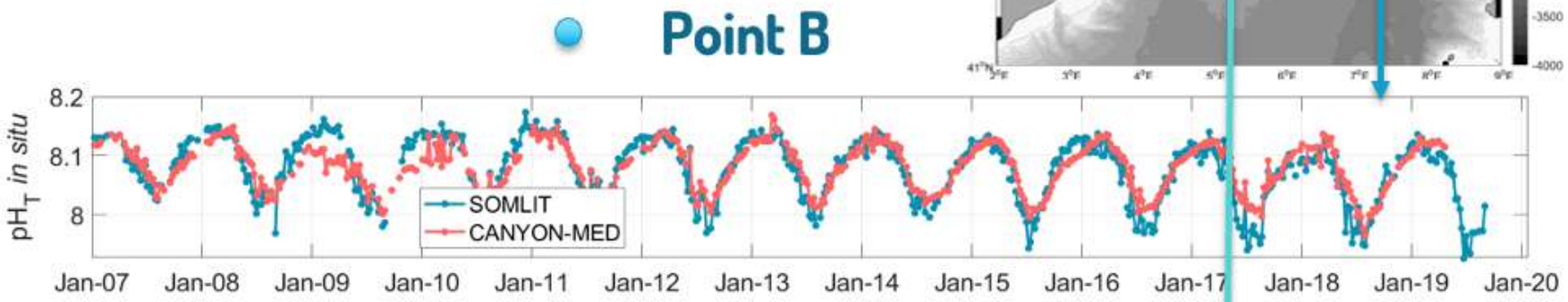
The ATL2MED Saildrone mission

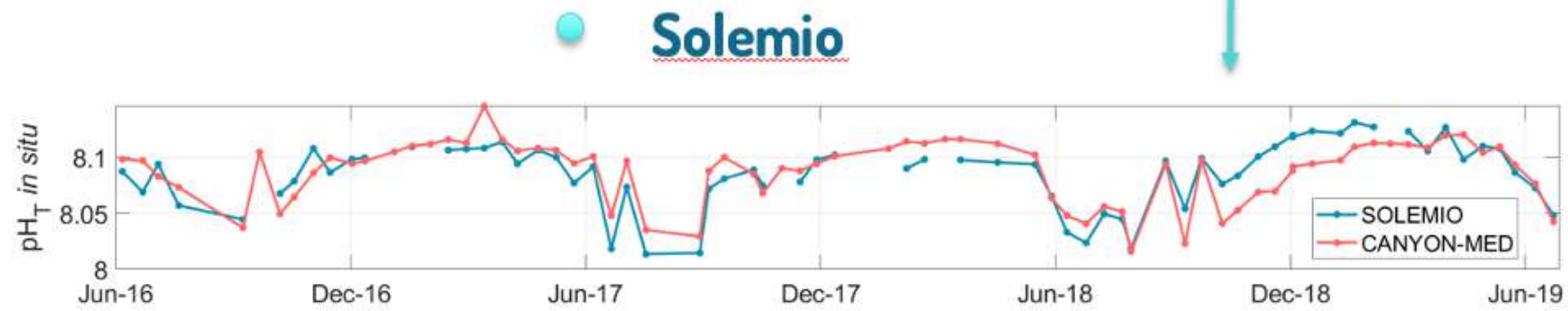
Applications in coastal waters

COASTAL TIMESERIES

- Poorly constrained biogeochemistry of coastal domain.
- Influence of rivers (Rhône).
- Evolution of anthropogenic input (N, P in fertilizers and detergents) (Ludwig *et al.*, 2009).
- Networks with QCed, adjusted and sustainable monitoring (Coast-HF, SOMLIT).







Thèse M.Fourrier, Sorbonne Univ. 2021

Data management: QC procedures & databases

- MOOSE CO_2 data (AT-CT-pH) available in SISMER (monthly and annual cruises) with DOI and QC procedures from experts (T.Wagener, N.Metzl, L.Coppola)
- SOMLIT pH only available on SOMLIT database
- pCO2 from DYFAMED available on SOCAT after qualification with in situ TA, TC (L.Beaumont)

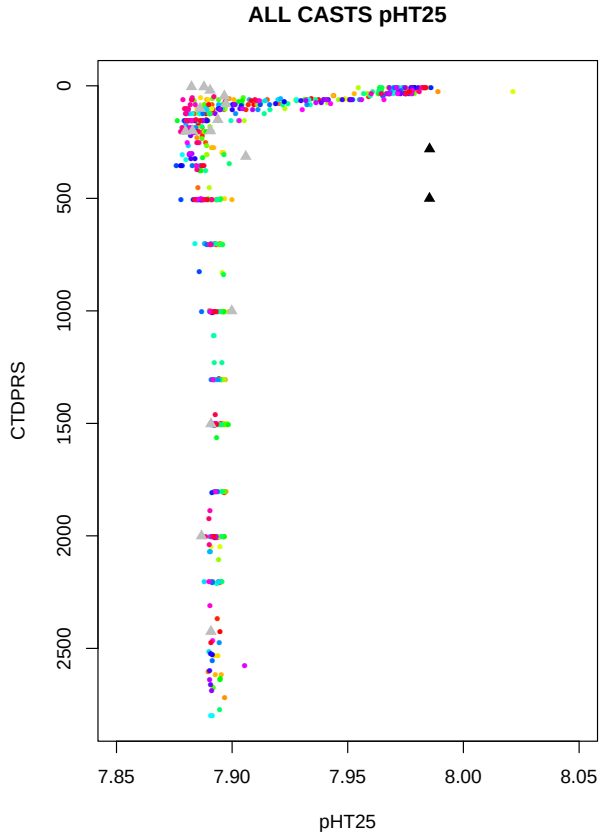
1- For TA, TC in duplicate: difference < 10 µmol/kg

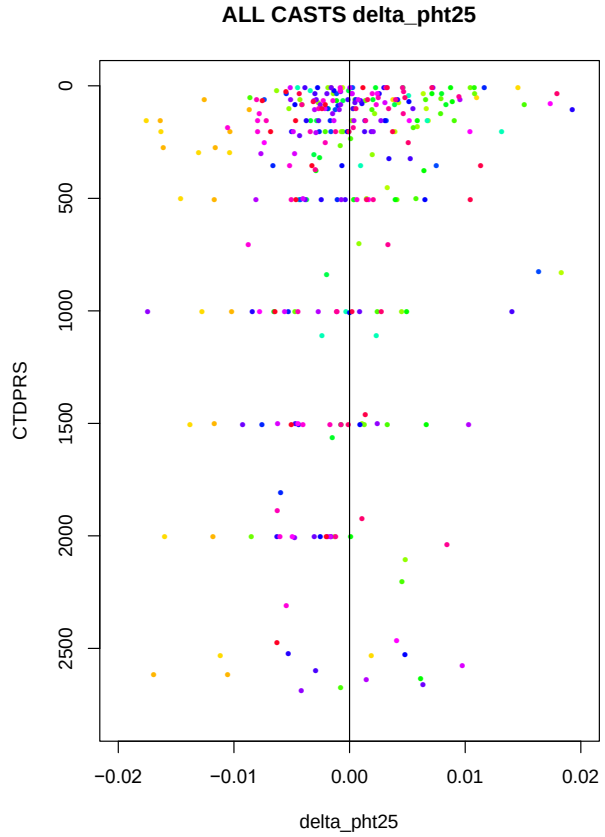
2- For TA, CT in deep waters : values < mean +/- 2 x stdev

3- Measurement of a third parameter (pH) during MOOSE-GE

Comparison of pH measured values (in duplicate) and calculated pH values (measurements carried out on board, no conservation of samples, low cost)

pH QC good when diff. pH < 0.02





Conclusion

Estimation of long term trends

- Trends of pCO_2^{Sw} and acidification from the longest time-series of oceanic CO_2 is **unique but not enough**
- "Virtual" measurements can "extend in space and time" oceanic CO_2 measurements BUT need **high quality S & O2 data with easy access** (FAIR procedures)

Estimation of air-sea CO_2 fluxes

- **Coordinated observations** from the coast to the open Med. Sea is needed.
- **High resolution regional models** to estimate air-sea CO_2 fluxes at the scale of the N.W. Med. Sea are under development and promising
- **New technologies** are also promising but need more tests & validation (gliders, surface drones…)

NW Med Sea: a case study for integrated CO_2 oceanic observations (ICOS, EURO-ARGO, EMSO)

Combination of *in-situ* data + "virtual" data + regional models : a tool to better understand CO_2 dynamic in the face of climate change