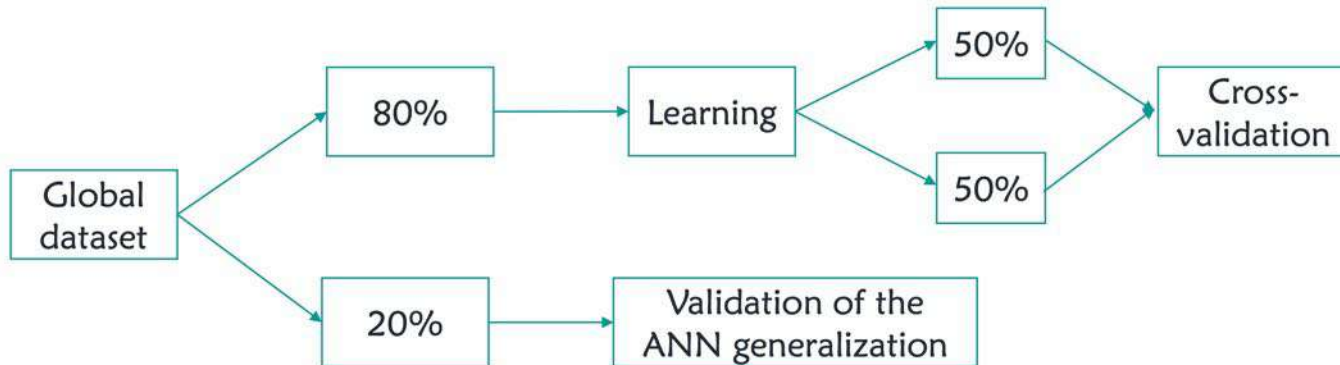
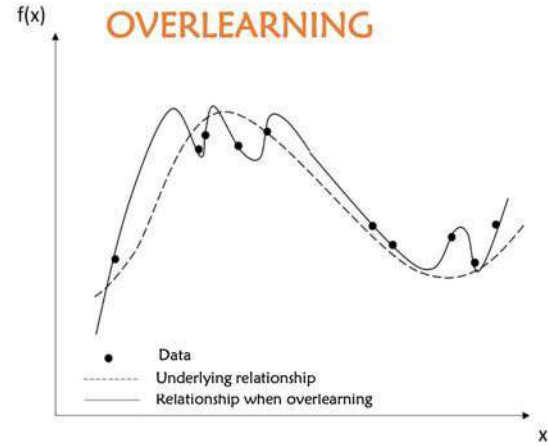
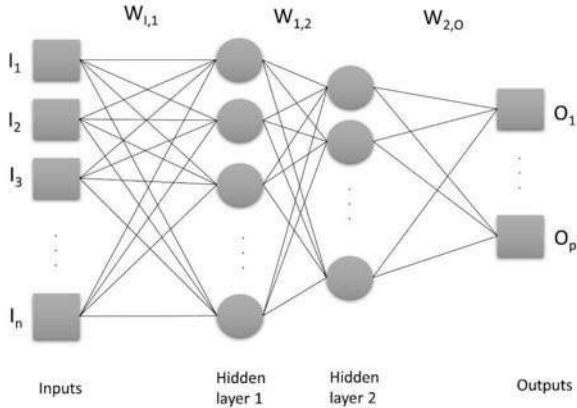


CANYON-MED : UN OUTIL POUR LA PRÉDICTION DE VARIABLES BIOGÉOCHIMIQUES

M.Fourrier, R.Sauzède, L.Coppola et al.

Artificial Neural Networks (ANN)



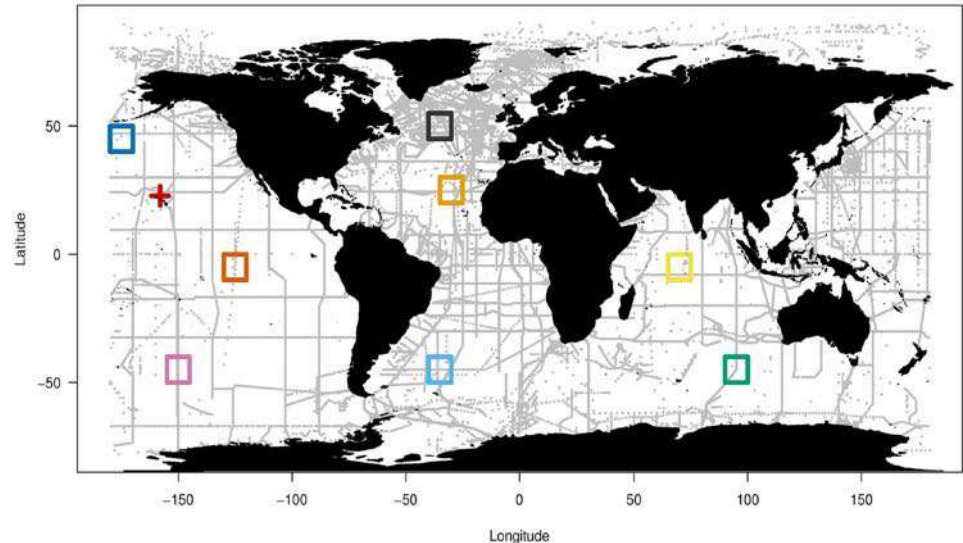
Estimates of Water-Column Nutrient Concentrations and Carbonate System Parameters in the Global Ocean: A Novel Approach Based on Neural Networks

Raphaëlle Sauzède^{1,2*}, Henry C. Bittig¹, Hervé Claustre¹, Orens Pasqueron de Fommervault^{1,3}, Jean-Pierre Gattuso^{1,4}, Louis Legendre¹ and Kenneth S. Johnson⁵

CANYON METHODS

Use of GLODAPv2 (Olsen et al., 2016) to develop the global CANYON method to estimate nutrients and carbonate system variables.

CANYON: CARbonate system and Nutrients concentration from hYdrological properties and Oxygen using a Neural-network.



Estimates of Water-Column Nutrient Concentrations and Carbonate System Parameters in the Global Ocean: A Novel Approach Based on Neural Networks

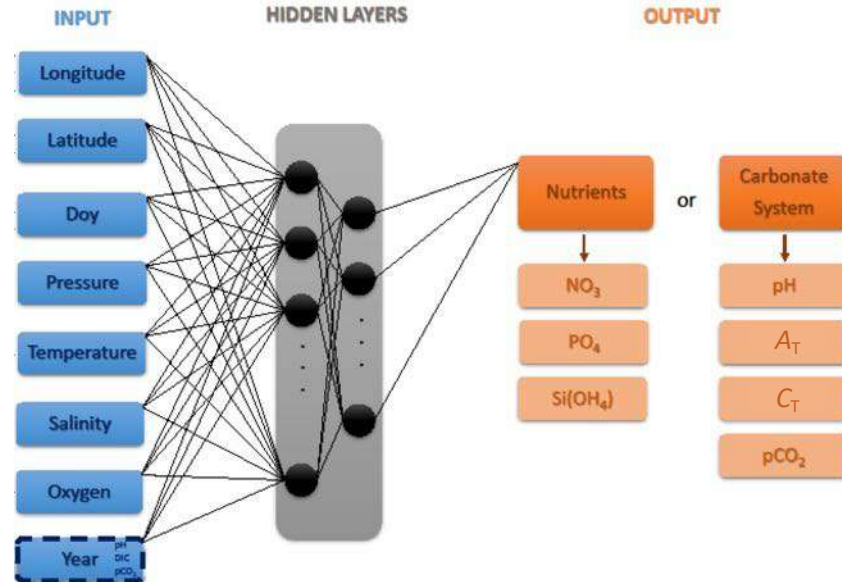
Raphaëlle Sauzède^{1,2*}, Henry C. Bittig¹, Hervé Claustre¹, Orens Pasqueron de Fommervault^{1,3}, Jean-Pierre Gattuso^{1,4}, Louis Legendre¹ and Kenneth S. Johnson⁵

An Alternative to Static Climatologies: Robust Estimation of Open Ocean CO₂ Variables and Nutrient Concentrations From T, S, and O₂ Data Using Bayesian Neural Networks

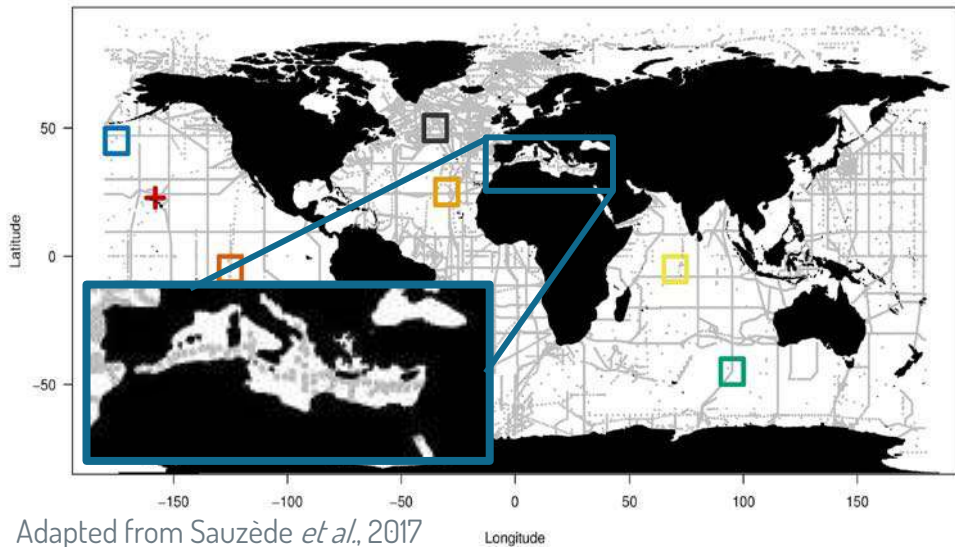
Henry C. Bittig^{1*}, Tobias Steinhoff², Hervé Claustre¹, Björn Fiedler¹, Nancy L. Williams^{3,4}, Raphaëlle Sauzède¹, Arne Körtzinger^{2,6} and Jean-Pierre Gattuso^{1,7}

CANYON METHODS

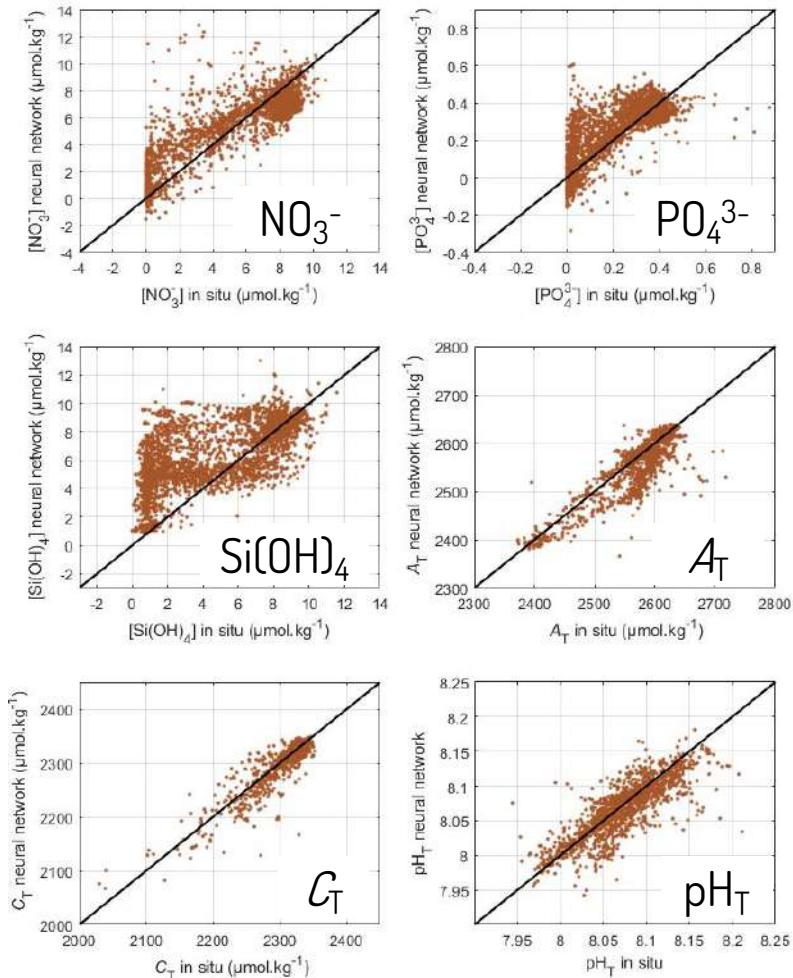
- **CANYON** (Sauzède *et al.*, 2017).
 - Original neural network.
 - Global uncertainties.
- **CANYON-B** (Bittig *et al.*, 2018).
 - Bayesian neural network mapping.
 - Robust uncertainty estimate incorporating information from the **local** conditions.
- **CONTENT** (Bittig *et al.*, 2018).
 - Combines and refines the four carbonate system variables to be consistent with **carbonate chemistry**.
 - Robust uncertainty estimate incorporating information from the **local** conditions.



CANYON RESULTS IN THE MEDITERRANEAN

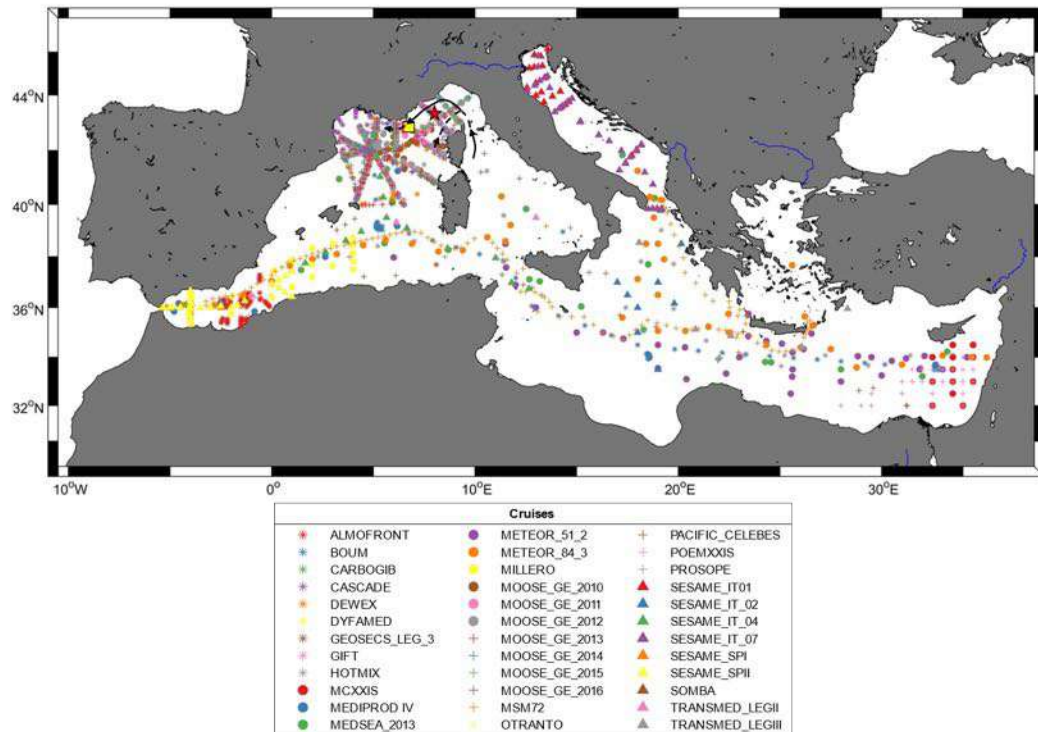


Adapted from Sauzède *et al.*, 2017



DATABASE GATHERING

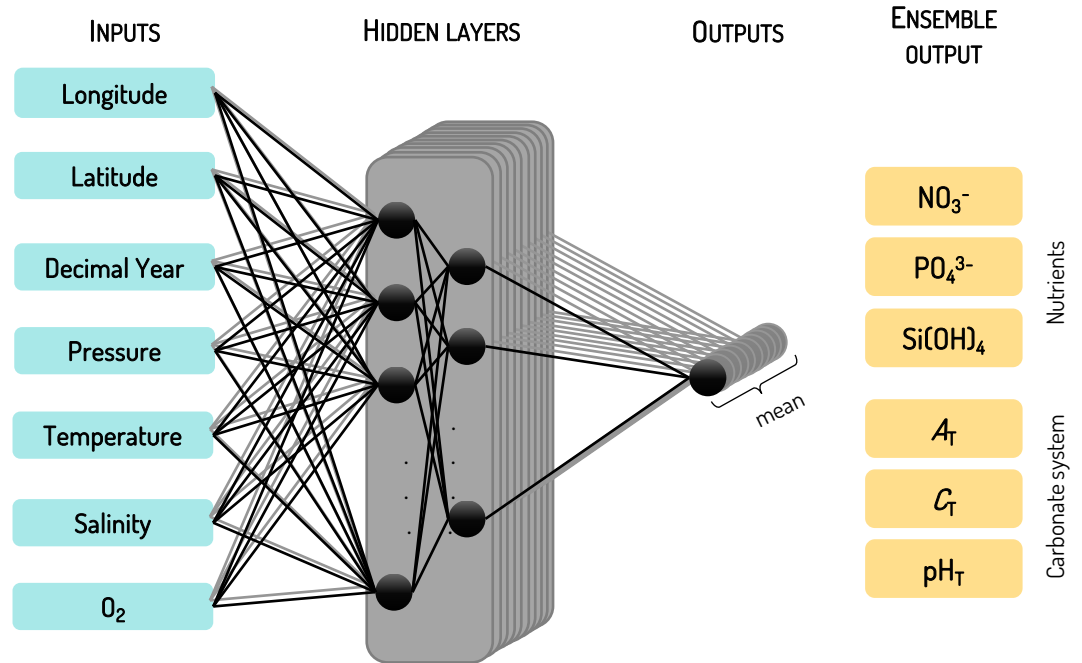
- 35 cruises (based on CARIMED, M. Álvarez, personal communication) and 1 time series: DYFAMED.
- 1981-2018.
- Quality-controlled bottle data.
- Homogenization and quality control.
- Cruises: ~1,500 profiles.
- DYFAMED: ~200 profiles.



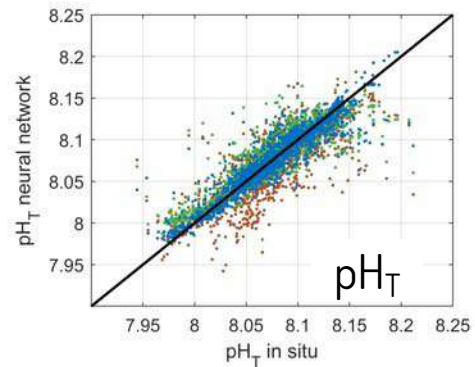
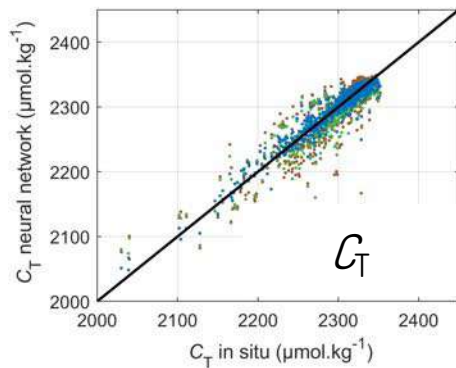
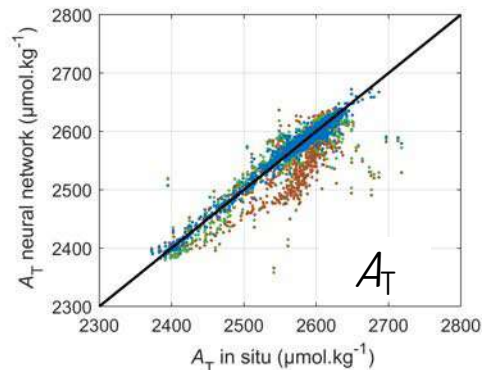
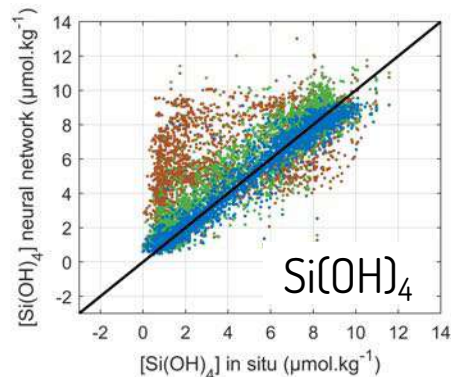
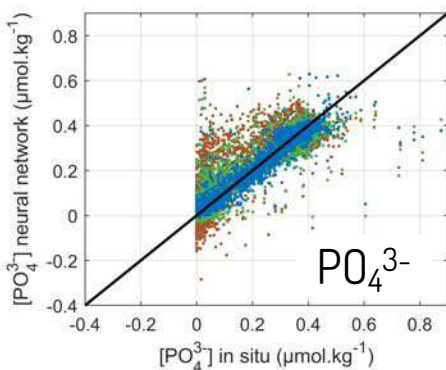
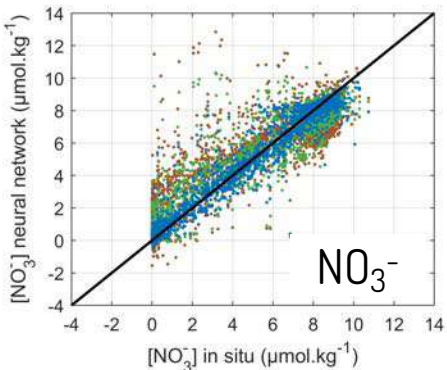
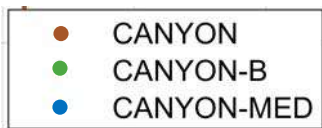
TECHNICAL MODIFICATIONS

From CANYON-B

- Neural network ensemble.
- Doy + year → Decimal Year.
- Bayesian regularization.
- One neural network ensemble for each output.



CANYON- METHODS



| | RMSE | Mediterranean range |
|--|-------|---------------------|
| NO_3^- ($\mu\text{mol}/\text{kg}$) | 0,73 | 0 – 12 |
| PO_4^{3-} ($\mu\text{mol}/\text{kg}$) | 0,045 | 0 – 0,9 |
| $\text{Si}(\text{OH})_4$ ($\mu\text{mol}/\text{kg}$) | 0,70 | 0 – 14 |
| A_T ($\mu\text{mol}/\text{kg}$) | 11 | 2350 – 2750 |
| C_T ($\mu\text{mol}/\text{kg}$) | 10 | 2000 – 2400 |
| pH_T | 0,016 | 7,95 – 8,22 |



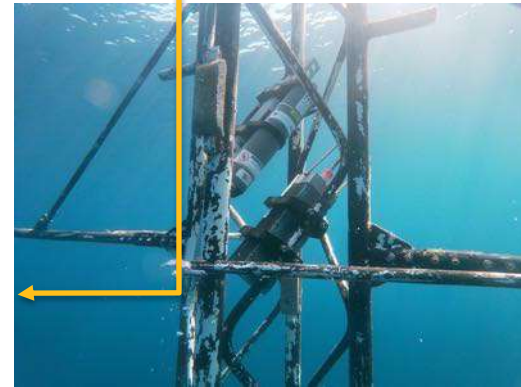
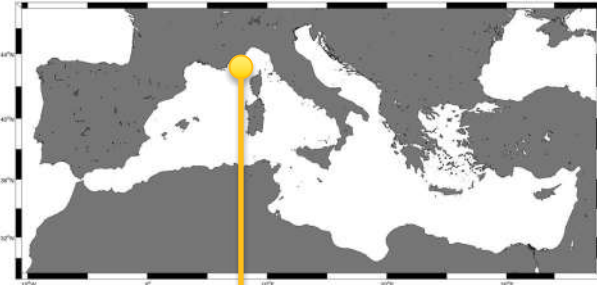
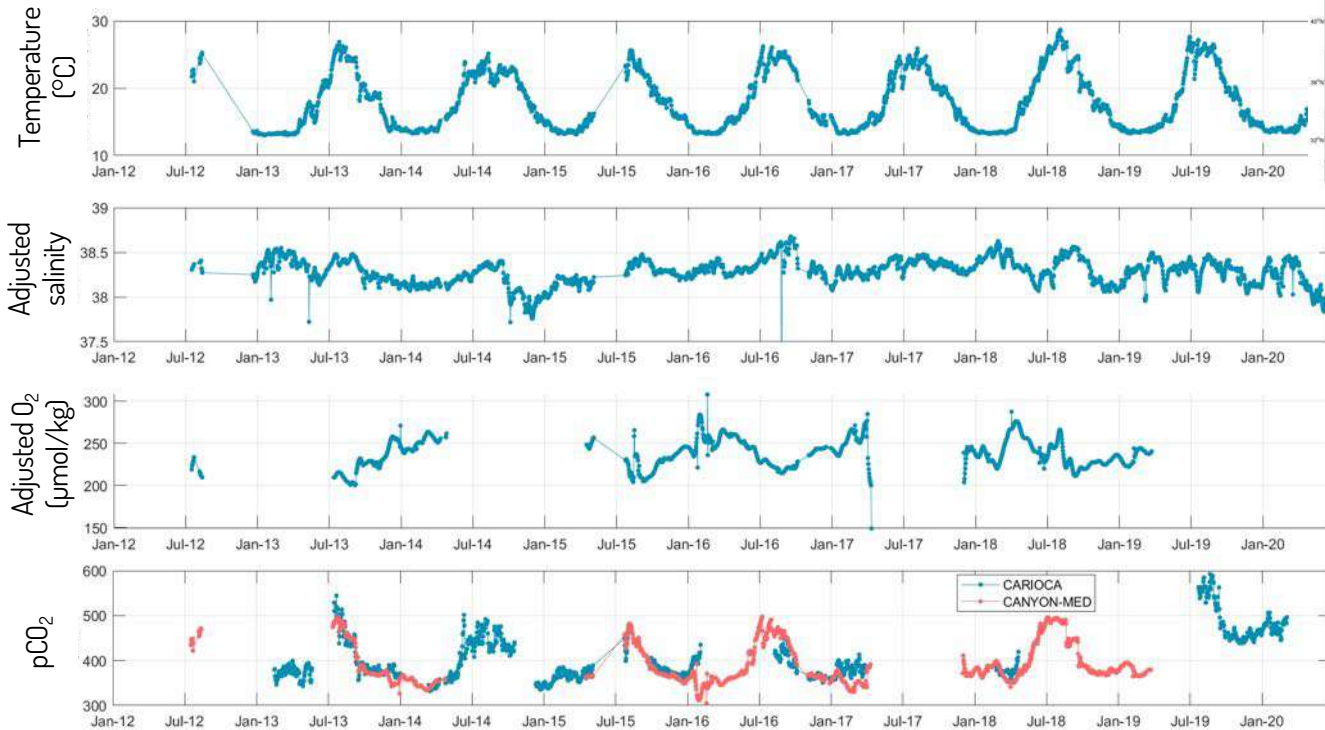
A Regional Neural Network Approach to Estimate Water-Column Nutrient Concentrations and Carbonate System Variables in the Mediterranean Sea: CANYON-MED

Marine Fourier^{1*}, Laurent Coppola^{1,2}, Hervé Claustre¹, Fabrizio D'Ortenzio¹, Raphaëlle Sauzède² and Jean-Pierre Gattuso^{1,3}

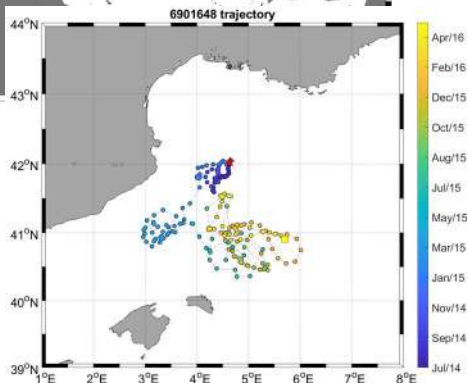
¹ Sorbonne Université, CNRS, Laboratoire d'Océanographie de Villefranche, Villefranche-sur-Mer, France, ² Sorbonne Université, CNRS, Institut de la Mer de Villefranche, Villefranche-sur-Mer, France, ³ Institute for Sustainable Development and International Relations, Sciences Po, Paris, France

OPEN ACCESS

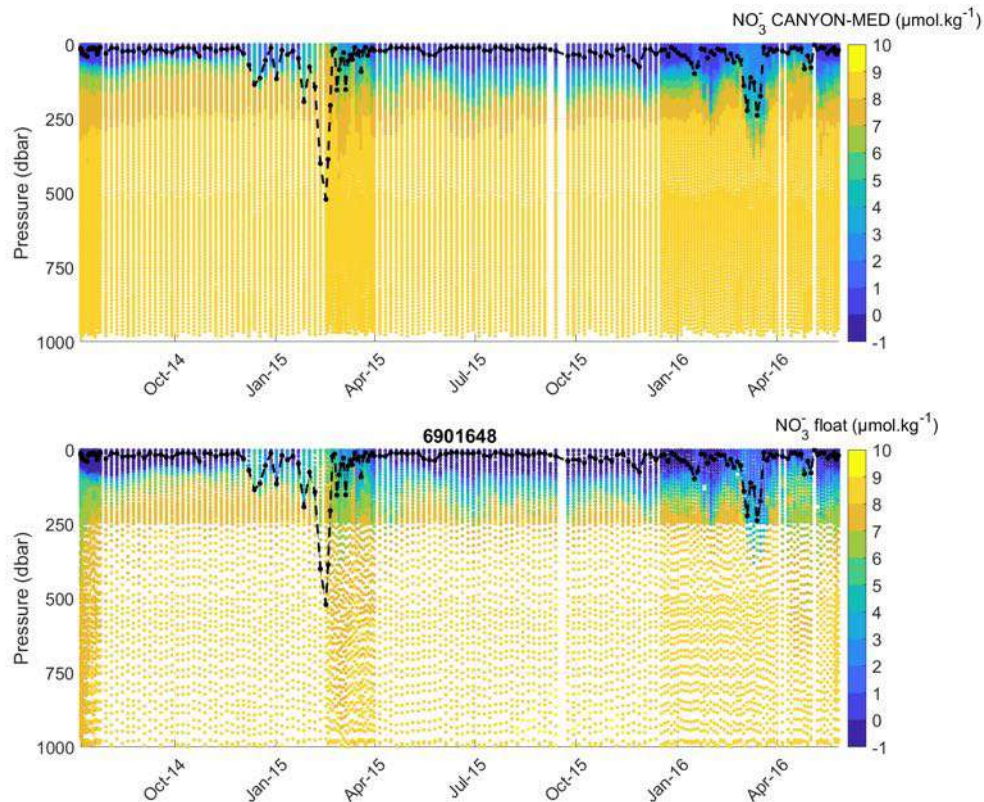
<https://github.com/MarineFou/CANYON-MED/> in R, Matlab and Python



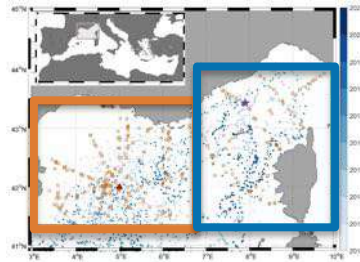
BGC-ARGO FLOAT IN THE MEDITERRANEAN



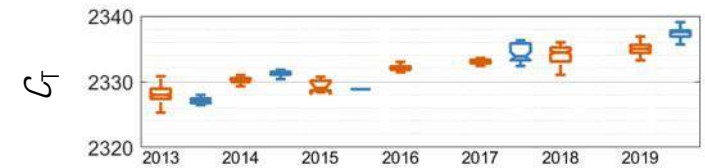
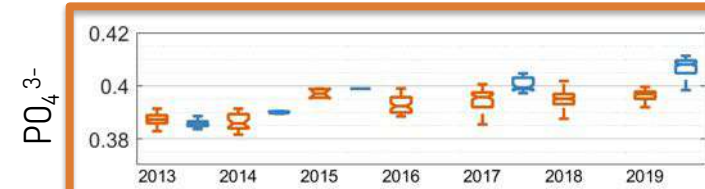
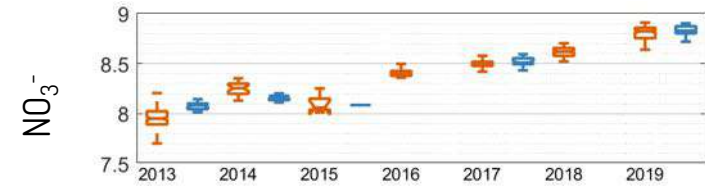
SUNA NO_3^- sensor accuracy: $1 \mu\text{mol/kg}$



DEEP WATERS



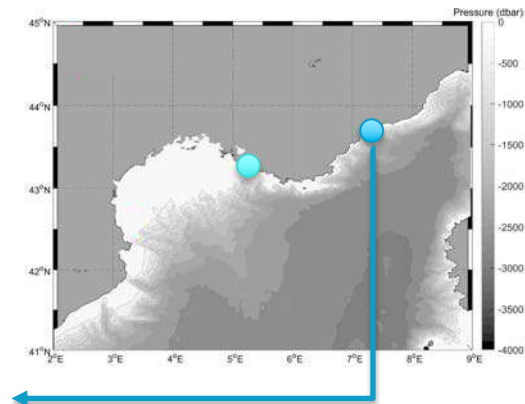
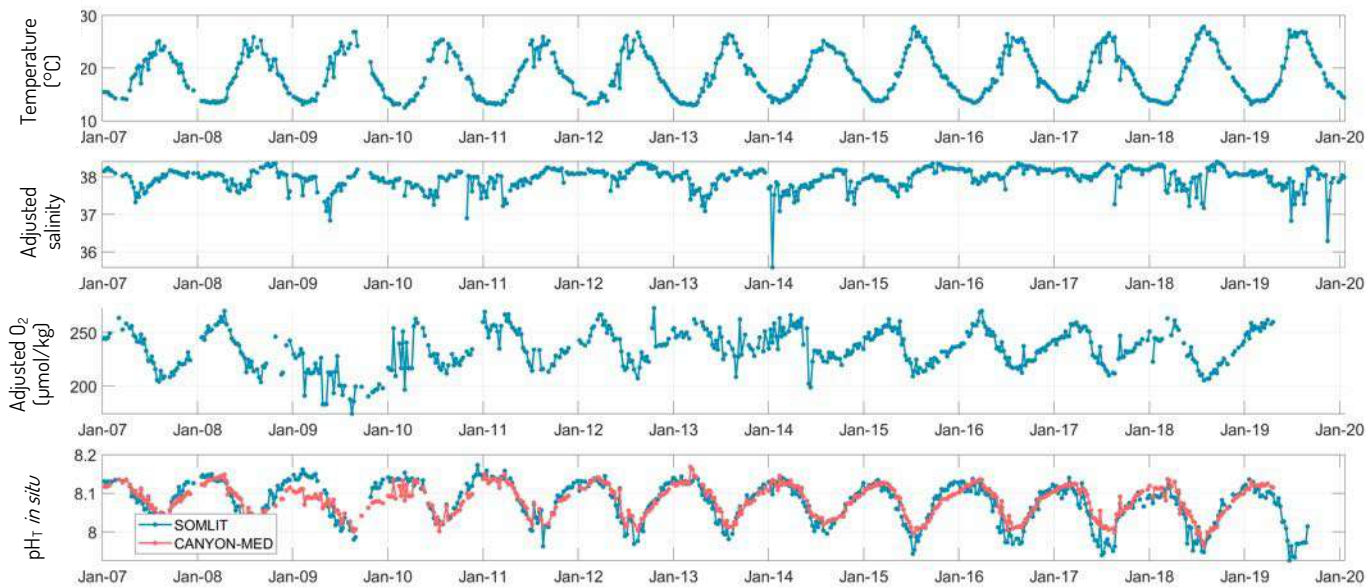
- Significant trends for NO_3^- , PO_4^{3-} , Si(OH)_4 , G_T and pH_T .
- NO_3^-
 - GOL: +0,135 $\mu\text{mol/kg/y}$
 - LIG : +0,129 $\mu\text{mol/kg/y}$ (+0,23%; 1991–2011; Pasqueron de Fommervault *et al.*, 2015)
- PO_4^{3-}
 - GOL: +0,0016 $\mu\text{mol/kg/y}$
- Si(OH)_4
 - GOL: +0,18 $\mu\text{mol/kg/y}$
 - LIG : +0,19 $\mu\text{mol/kg/y}$ (+0,60%; 1991–2011; Pasqueron de Fommervault *et al.*, 2015)
- G_T
 - GOL: + 1,21 $\mu\text{mol/kg/y}$
 - LIG: + 1,60 $\mu\text{mol/kg/y}$ (+1,36; 1998–2016; Coppola *et al.*, 2020)
- pH_T
 - GOL: -0,0016 /y [-0,12 to -0,11 [Preind-2011]; Touratier *et al.*, 2016)
[-0,006 to -0,005 [Preind-2001]; Palmiéri *et al.*, 2015)



- Nombreuses plates-formes d'observation équipées d'O₂.
- Contrôle de qualité et ajustement des données O₂.
- Réseau neuronal pour dériver les variables biogéochimiques (NO₃⁻, PO₄³⁻, Si(OH)₄, AT, CT et pHT) dans la mer Méditerranée.
- Dépend beaucoup de la trajectoire des flotteurs Argo
- Besoin d'étendre le concept en milieu côtier...

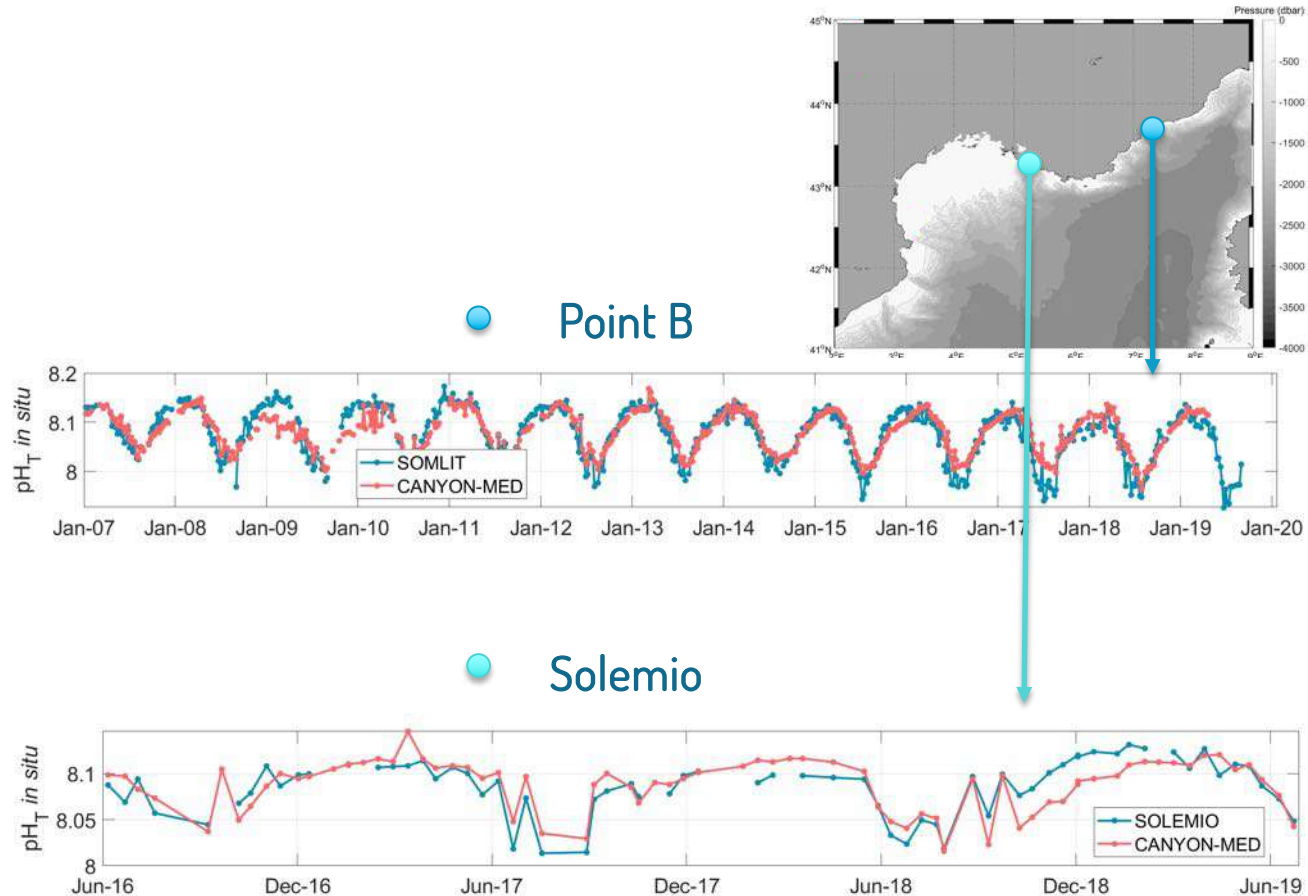
COASTAL TIMESERIES

● Point B



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).



- Pour la Méditerranée NO, forte variabilité spatiale des positions des flotteurs. Seulement 10 ans avec deux grands événements de mélange. Difficile de conclure sur les tendances à long terme.
- Limitation en zone côtière: **besoin d'adapter les données d'entrée** (ex. CO2 drivers = SST, SSS, MLD, Chla, pCO2 atm)
- **Besoin de données historiques** pour l'entraînement (entrée et sortie) et corrigées : T, S, O2, lat/lon, doy, AT-CT, pH, (pCO2) – **référencer les campagnes en mer**
- **Besoin de données d'entrée corrigées pour les prédictions:** T, S, O2, lat/lon, doy + autres selon le type de réseau de neurones qui sera développé
- Estimations en MedSea à partir des flotteurs O2 disponibles de manière opérationnelle dans le produit CMEMS à l'aide de CANYON-MED (global: CANYON-B/CONTENT):

https://data.marine.copernicus.eu/product/MULTIOBS_GLO_BGC_NUTRIENTS_CARBOON_PROFILES_MYNRT_015_009/description

MERCI / THANKS

