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▶ **To cite this version:**

Marine Fourrier, Laurent Coppola, Fabrizio d'Ortenzio, Hervé Claustre, Raphaëlle Sauzède, et al.. A neural network approach to estimate water-column nutrient concentrations and carbonate system variables in the Mediterranean Sea: CANYON-MED. EGU General Assembly 2019, Apr 2019, Vienne, Austria. hal-02552409

HAL Id: hal-02552409
https://hal.science/hal-02552409

Submitted on 23 Apr 2020

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A neural network approach to estimate water-column nutrient concentrations and carbonate system variables in the Mediterranean Sea: CANYON-MED

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1– Introduction and objectives

The Mediterranean Sea is characterized by a short residence time (Somot et al., 2006), an elevated **salinity** and is one of the largest oceanic nutrient-depleted area (Ignatiades, 2005) exhibiting an eastward-increasing **oligotrophy** gradient (Pujo-Pay et al., 2011).

In the context of a critically undersampled ocean, the development and intensive use of instrumented *in situ* **autonomous platforms** allows to densify the measurements of some biogeochemical variables (remaining however far from exhaustive).

Recently, deep learning techniques have been developed for the global ocean. The **CANYON** (for Carbonate system and Nutrients concentration from hYdrological properties and Oxygen using a Neural-network; Sauzède et al., 2017) neural network-based method provides estimations of nutrients (i.e. nitrates, phosphates and silicates) and carbonate system parameters (i.e. total alkalinity, dissolved inorganic carbon, pH_T, pCO_2) from systematically measured oceanographic variables. The CANYON method produces **limited results in the Mediterranean** Sea.

Objectives of this study:

- Adapt the existing CANYON method to the Mediterranean Sea: **CANYON-MED neural networks**.
- Verify its accuracy on a **BGC-Argo float equipped with a nitrate sensor**.

3– Neural network method

3.1– Training

These Multi-Layered Perceptrons provide estimations of **nutrients** and **carbonate system variables** from systematically measured oceanographic variables such as *in situ* measurements of pressure, temperature, salinity, and oxygen together with geolocation (latitude, longitude) and date of sampling (day of year (doy), year).

Neural network ensembles comprising the 10 best topologies were created for each retrieved variable to reduce the uncertainties in the outputs.

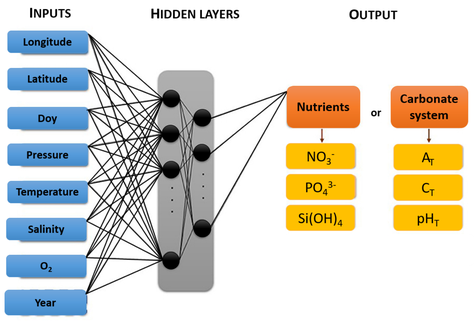

***Figure 2**: Schematic representation of the CANYON-MED neural networks.*
Adapted from Sauzède et al., 2017.

3.2– CANYON-MED improvement

The regional CANYON-MED highly **outperforms** the global CANYON method in the Mediterranean Sea. The difference stems from the difference in salinity, as well as the oligotrophic nutrient concentrations and low pH_T values found in the Mediterranean Sea.

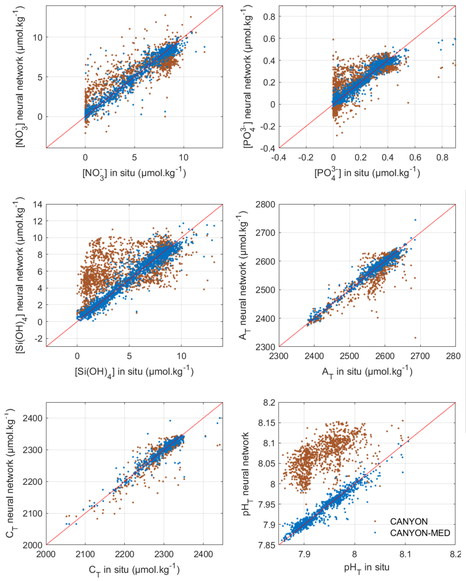

***Figure 3**: Comparison of the **CANYON** and **CANYON-MED** retrieved values for the Mediterranean Sea with the corresponding* in situ *measurements for: NO_3^- (top left), PO_4^{3-}(top right), Si $(OH)_4$ (middle left), A_T (middle right), C_T (bottom left), pH_T (bottom right). The 1:1 line is shown.*

	R^2	RMSE
NO_3^- (µmol.kg^{-1})	0.77 0.96	1.57 0.64
PO_4^{3-}(µmol.kg^{-1})	0.65 0.94	0.097 0.037
$Si(OH)_4$ (µmol.kg^{-1})	0.4 0.96	2.9 0.6
A_T (µmol.kg^{-1})	0.74 0.96	32.4 11.4
C_T (µmol.kg^{-1})	0.78 0.95	24.8 10.8
pH_T	0.30 0.92	0.138 0.012

***Table 1**: Statistics (coefficient of determination (R^2) and RMSE (Root Mean Squared Error)) of the regressions between the **CANYON** and **CANYON-MED** retrieved values with the corresponding* in situ *measurements.*

2– Mediterranean Sea database

We compiled a **homogeneous quality-controlled** dataset of *in situ* measurements from 1981 to 2017, including samples of **core** variables such as dissolved oxygen (O_2), temperature (T), salinity (S) as well as **macronutrients** (nitrates: NO_3^-, phosphates: PO_4^{3-}, silicates: $Si(OH)_4$) and **carbonate system variables** (total alkalinity: A_T, total carbon: C_T, and pH on the total scale: pH_T) .

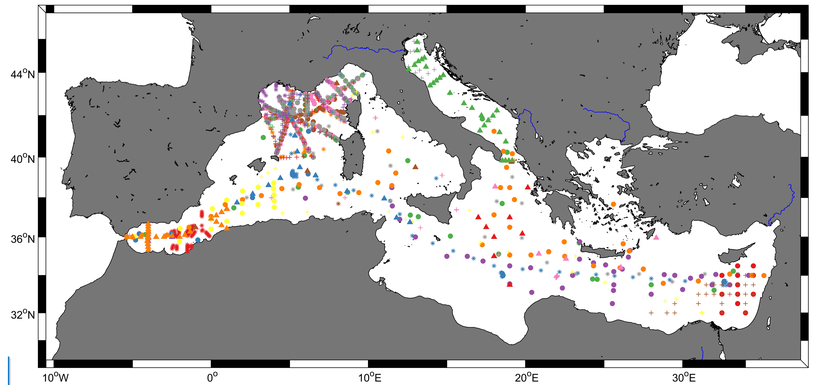

***Figure 1**: Map of the 34 cruises and the time-series used for the training and validation of the CANYON-MED neural networks. (~7 000 values for NO_3^-, ~10 000 for PO_4^{3-} and $Si(OH)_4$; and ~5 000 for A_T and pH_T, ~3 500 values for C_T).*

Cruises

ALMOFRONT	METEOR_51_2	POEMXXIS
BOUM	METEOR_84_3	PROSOPE
CARBOGIB	MILLERO	SESAME_IT01
CASCADE	MOOSE_GE_2010	SESAME_IT_02
DEWEX	MOOSE_GE_2011	SESAME_IT_04
DYFAMED	MOOSE_GE_2012	SESAME_IT_07
GEOSECS_LEG_3	MOOSE_GE_2013	SESAME_SPI
GIFT	MOOSE_GE_2014	SESAME_SPII
HOTMIX	MOOSE_GE_2015	SOMBA
MCXXIS	MOOSE_GE_2016	TRANSMED_LEGII
MEDIPROD IV	OTRANTO	TRANSMED_LEGIII
MEDSEA_2013	PACIFIC_CELEBES	

3.3– CANYON-MED application

CANYON-MED was applied on a BGC-Argo float, deployed in 2014 in the northwestern Mediterranean Sea, measuring T, S, O_2 as well as NO_3^-.

- **Deep and surface** NO_3^- values globally agree.
- Main **trends** are adequately predicted: *e.g.* water column mixing and **nutrients replenishment** in surface during the convection in the winter 2014-2015. ⇓
- Float and CANYON-MED derived **nitraclines** are in agreement with values established by Kessouri *et al.*, 2017 (~60 m average for stratified periods).

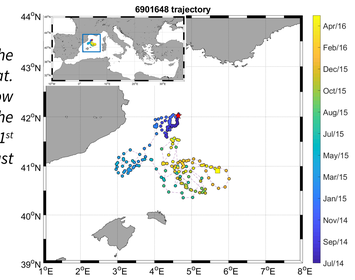

***Figure 4**: Location of the 6901648 BGC-Argo float. The red star and yellow square represent the location of the 1st (07/07/2014) and last profile (26/05/2016).*

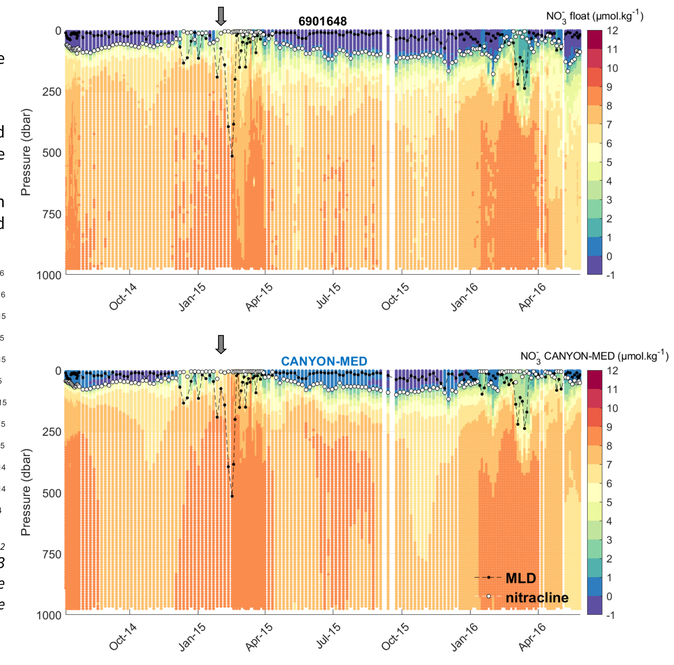

***Figure 5**: Timeseries of NO_3^--float data (top) and CANYON-MED corrected-O_2 based NO_3^- estimate (bottom), mixed-layer depth (MLD) (black) using the 0.03 criteria (de Boyer Montégut* et al., *2004) and nitracline depth (white) using the 1µM isoline according to Lavigne (2013). NO_3^- float data was corrected using the reference deployment profile's deep NO_3^- value.*

4 – Conclusion

The regional CANYON-MED neural networks constitute a **good downscaling** of CANYON, and satisfactory results are obtained: accuracies of **0.73**, **0.043**, and **0.63 µmol.kg^{-1}** for **NO_3^-**, **PO_4^{3-}** and **$Si(OH)_4$** respectively, and **0.014**, **17 µmol.kg^{-1}** and **12 µmol.kg^{-1}** for **pH_T**, **A_T** and **C_T** respectively. It can successfully be applied on **autonomous platforms**, such as profiling floats, gliders or moorings measuring T, S, O_2 to increase the amount of biogeochemical data in the Mediterranean Sea.

References: de Boyer Montégut, C. (2004). Mixed layer depth over the global ocean: An examination of profile data and a profile-based climatology. Journal of Geophysical Research, 109(C12). https://doi.org/10.1029/2004JC002378 // Ignatiades, L. (2005). Scaling the trophic status of the Aegean Sea, eastern Mediterranean. Journal of Sea Research, 54(1), 51–57. https://doi.org/10.1016/j.seares.2005.02.010 // Kessouri, F., Ulses, C., Estournel, C., Marsaleix, P., Severin, T., Pujo-Pay, M., et al. (2017). Nitrogen and Phosphorus Budgets in the Northwestern Mediterranean Deep Convection Region. Journal of Geophysical Research: Oceans, 122(12), 9429–9454. https://doi.org/10.1002/2016JC012665 // Lavigne, H. (2013). Impact of mixed layer depth seasonal variations on the phytoplankton phenology in the Mediterranean Sea. // Pujo-Pay, M., Conan, P., Oriol, L., Cornet-Barthaux, V., Falco, C., Ghiglione, J.-F., et al. (2011). Integrated survey of elemental stoichiometry (C, N, P) from the western to eastern Mediterranean Sea. Biogeosciences, 8(4), 883–899. https://doi.org/10.5194/bg-8-883-2011 // Sauzède, R., Bittig, H. C., Claustre, H., Pasqueron de Fommervault, O., Gattuso, J.-P., Legendre, L., & Johnson, K. S. (2017). Estimates of Water-Column Nutrient Concentrations and Carbonate System Parameters in the Global Ocean: A Novel Approach Based on Neural Networks. Frontiers in Marine Science, 4. https://doi.org/10.3389/fmars.2017.00128 // Somot, S., Sevault, F., & Déqué, M. (2006). Transient climate change scenario simulation of the Mediterranean Sea for the twenty-first century using a high-resolution ocean circulation model. Climate Dynamics, 27(7–8), 851–879. https://doi.org/10.1007/s00382-006-0167-z