A neural based bio-regionalization of the Mediterranean Sea using satellite and Argo-float records

Roy El Hourany, Chris Bowler, Carlos Mejia, Michel Crépon, and Sylvie Thiria

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Bioregionalization :

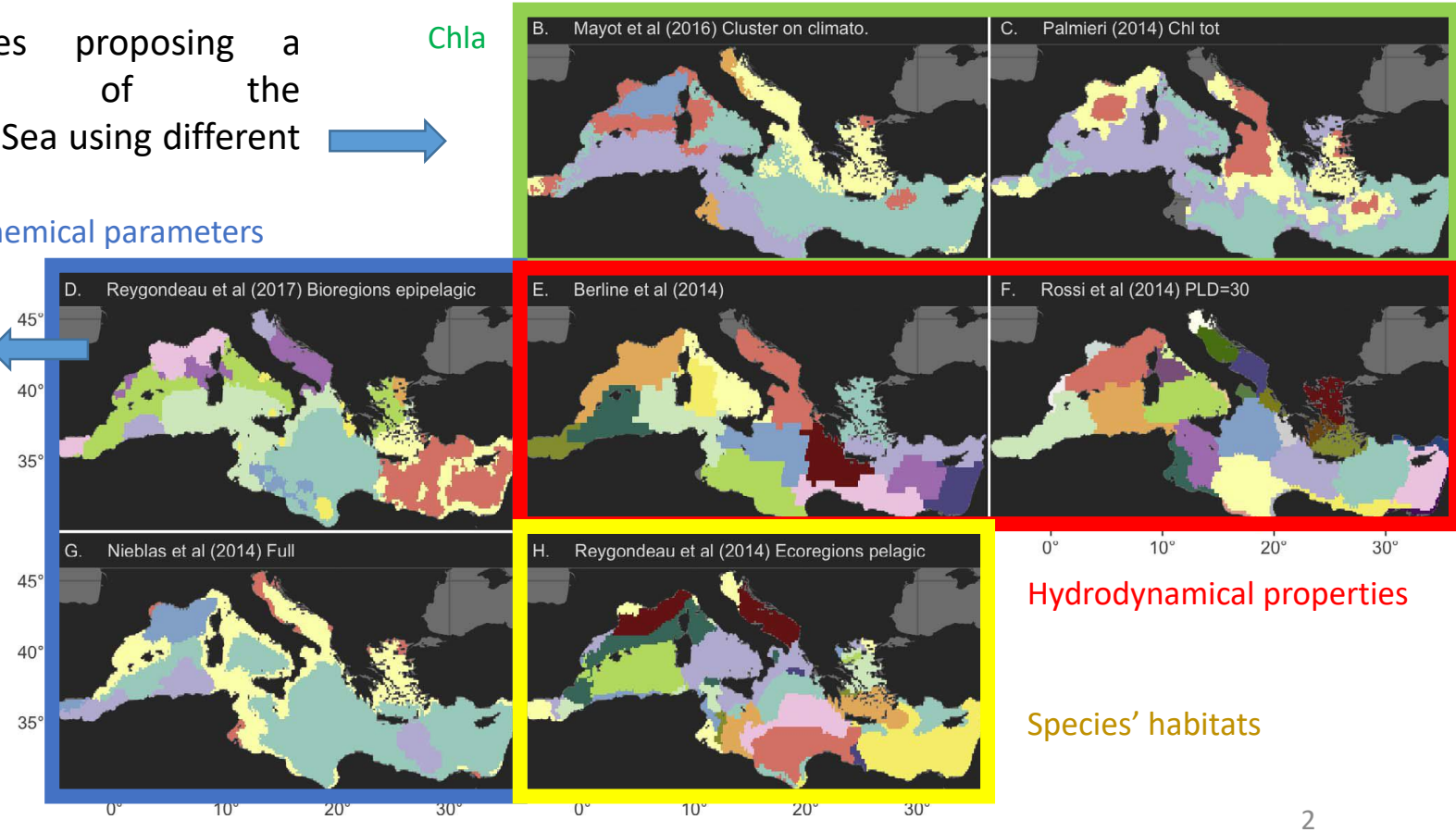
Delimitation of provinces in which physical conditions, geochemical properties and biological communities are homogeneous

Several studies proposing a regionalization of the Mediterranean Sea using different criteria

Chla

Geochemical parameters

Chla, SST and MLD three essential parameter for the regionalization of the Mediterranean surface waters



Hydrodynamical properties

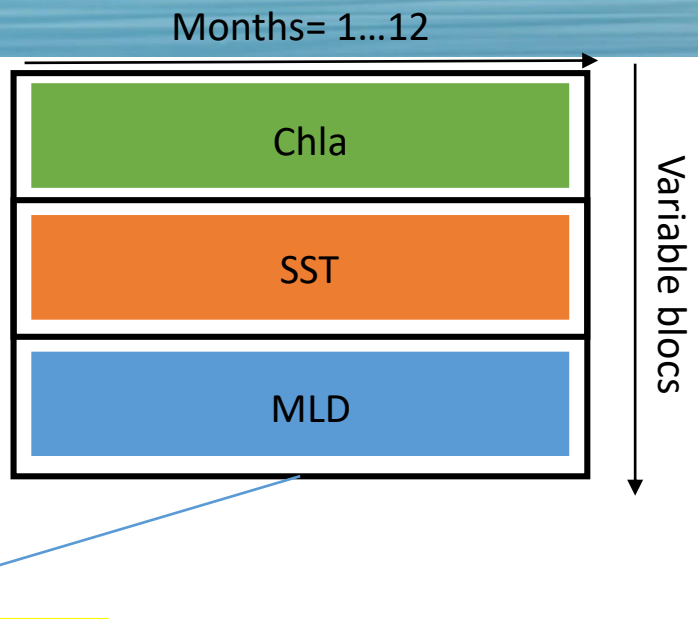
Species' habitats

Data preparation:

1- 12 monthly climatology of Chla MODIS at a 4km spatial resolution between 2002-2018

2- 12 monthly climatology of SST MODIS at a 4km spatial resolution between 2002-2018

3- 12 monthly climatology of MLD (mixed layer depth) from Argo float records at a 1 degree spatial resolution between 2001-2018
(Holte *et al.*, 2017, http://mixedlayer.ucsd.edu/).



Method used:

2S-SOM
50 classes
(10 x 5 neurones)

M **Ouattara** et al., **2014**

Classification and Automatic Weight attribution for each bloc of variable

Main Contribution: Analyzing the weight of the different parameters used to delimit bioregions in the Mediterranean.

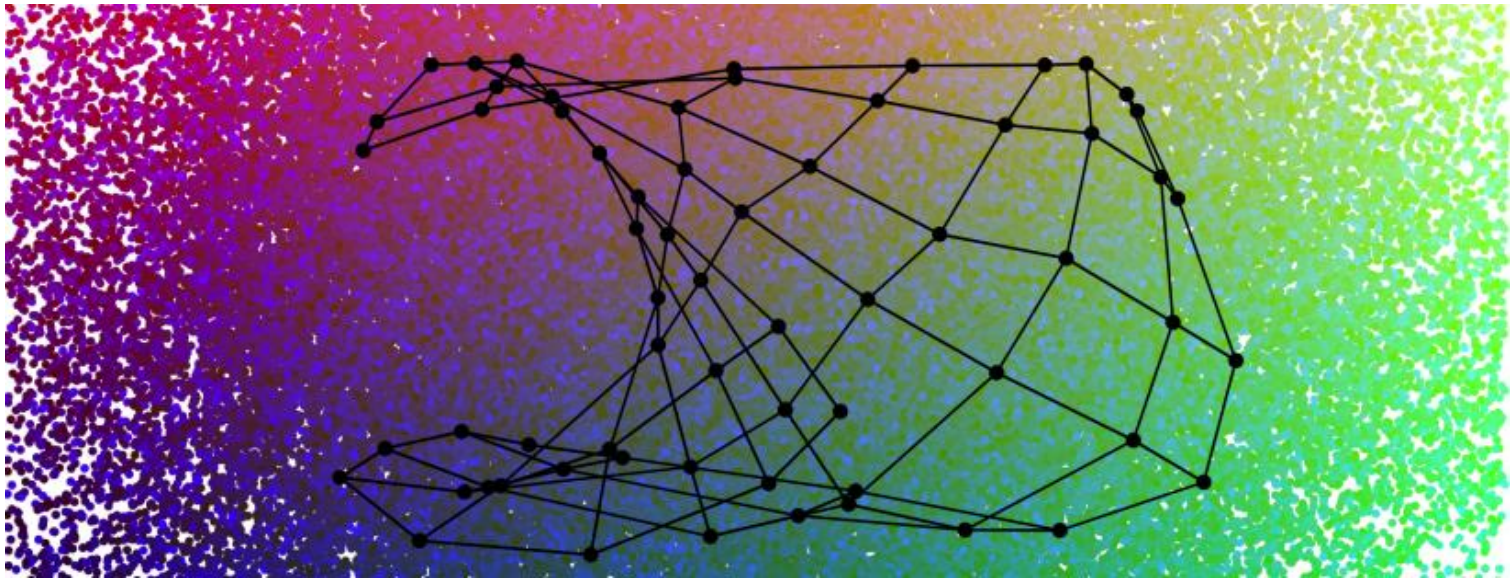
Classification Method:

Self-Organizing Maps

SOM

- unsupervised neural classifier
- Easy Interpretability of the method,
- Project a large multidimensional database on a discreet space of dimension 2.

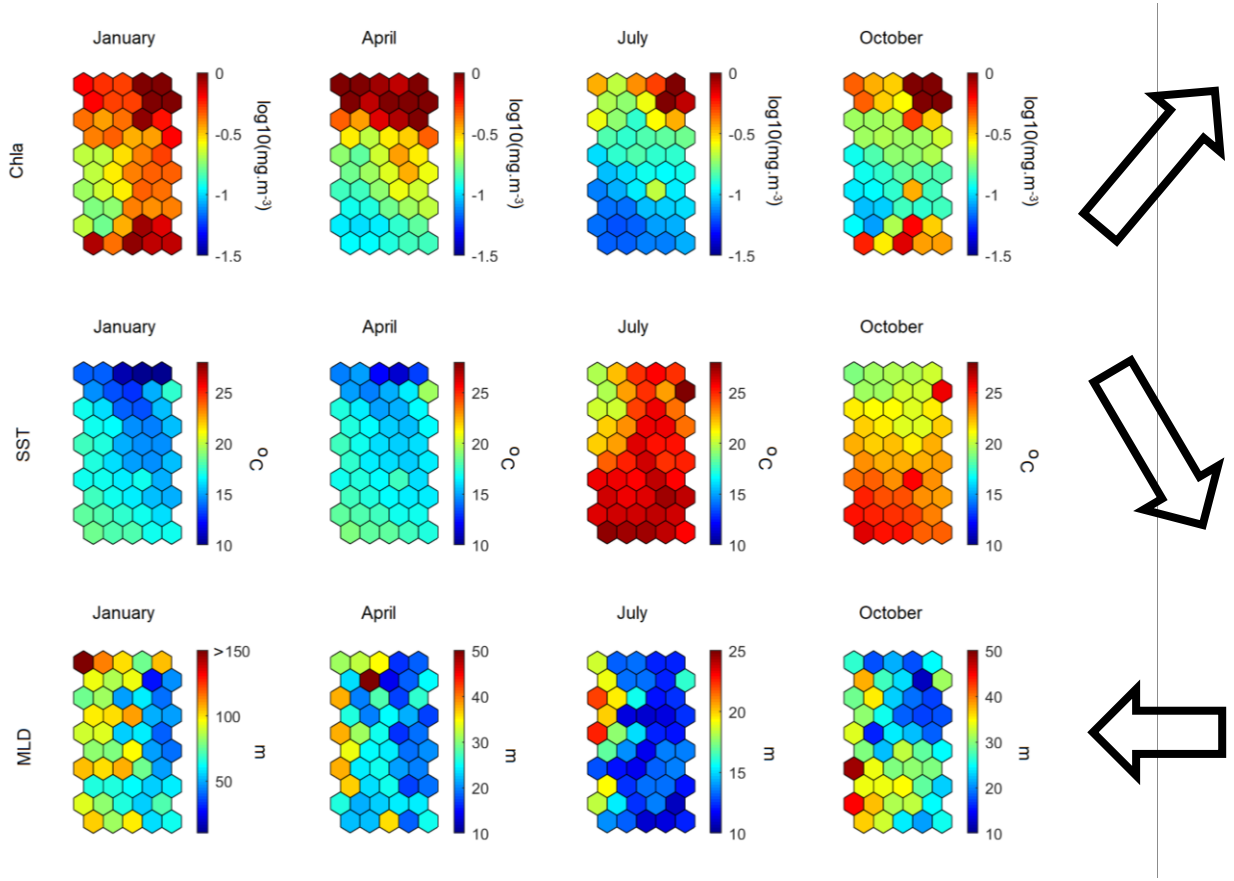
(See Annex for algorithmic details)



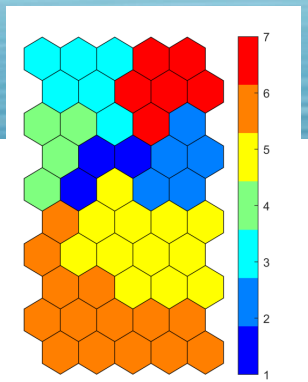
Results: Analysis of the 2S-SOM

Representation of the monthly components for each parameter (Chla, SST and MLD) on the 2S-SOM network

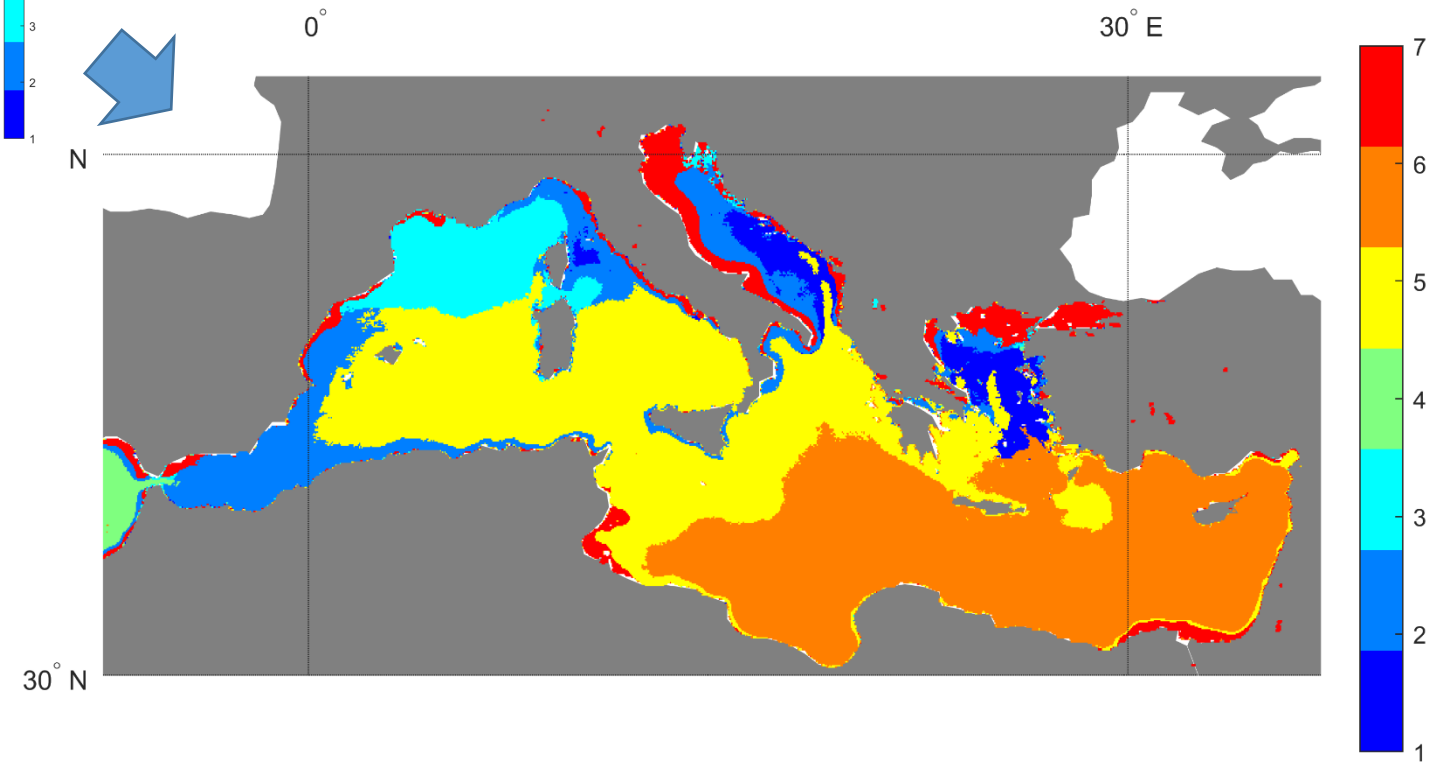
Direction of the positive gradient



Representation of the Bioregions on the geographic space of the Mediterranean



Result of the classification of 2S-SOM neurons into 7 classes by Ascending Hierarchical Clustering (CAH)



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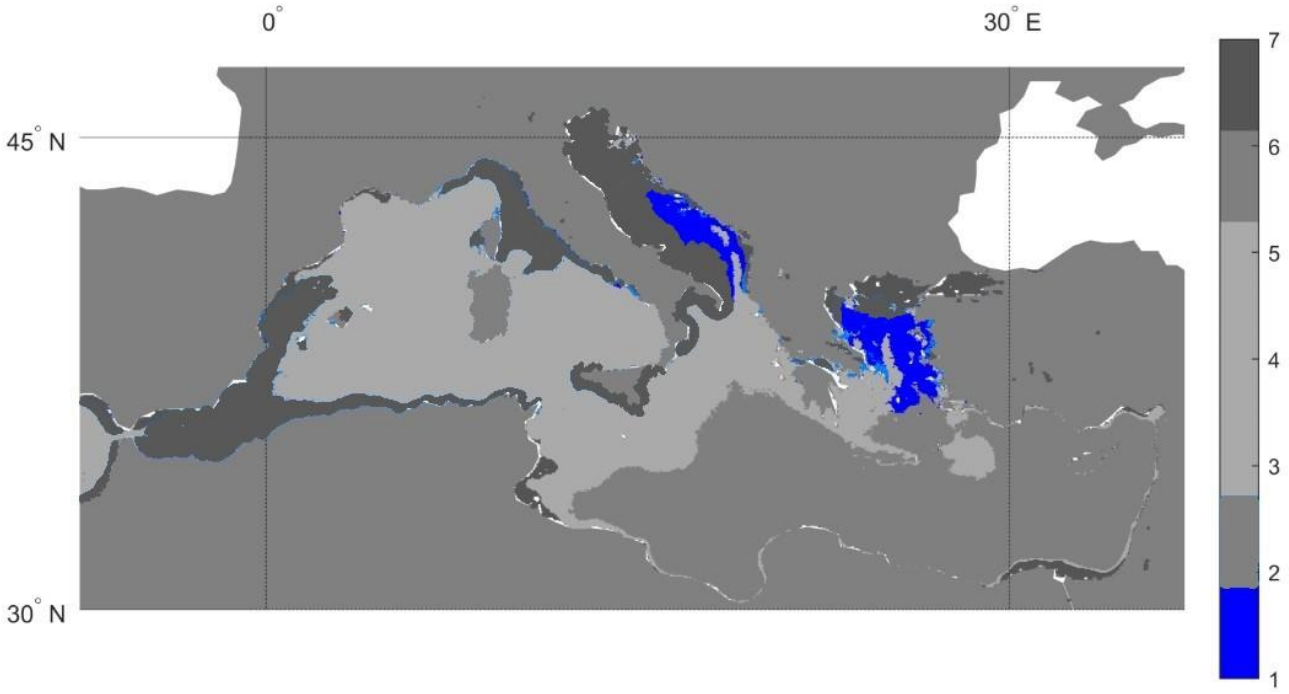
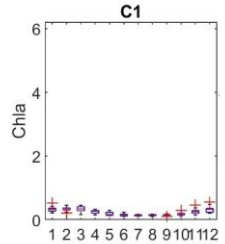
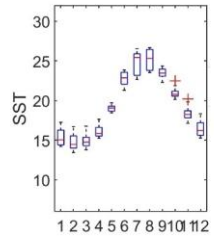
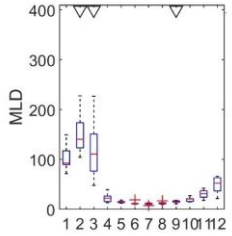


Monthly climatology

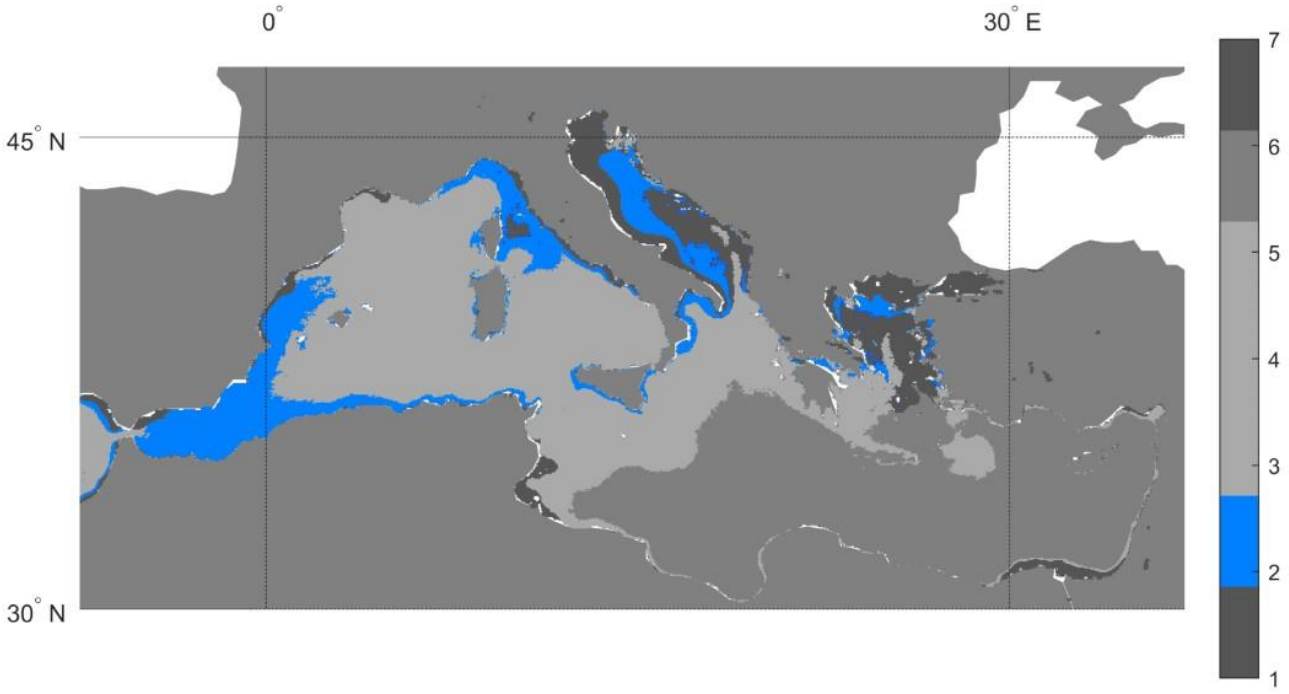






C1 waters are mainly found in the central Adriatic Sea and the Aegean Sea. These areas are subject to winter convection leading to Adriatic water formation on the one hand and Ligurian Intermediate Water (LIW) on the other hand.

Representation of the Bioregions on the geographic space of the Mediterranean



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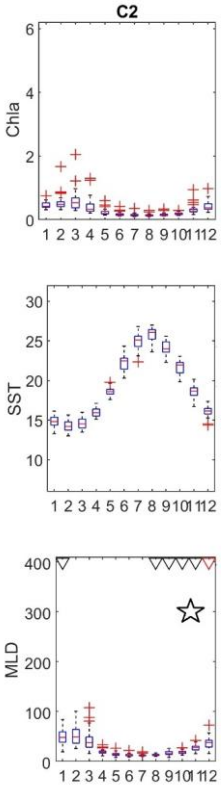
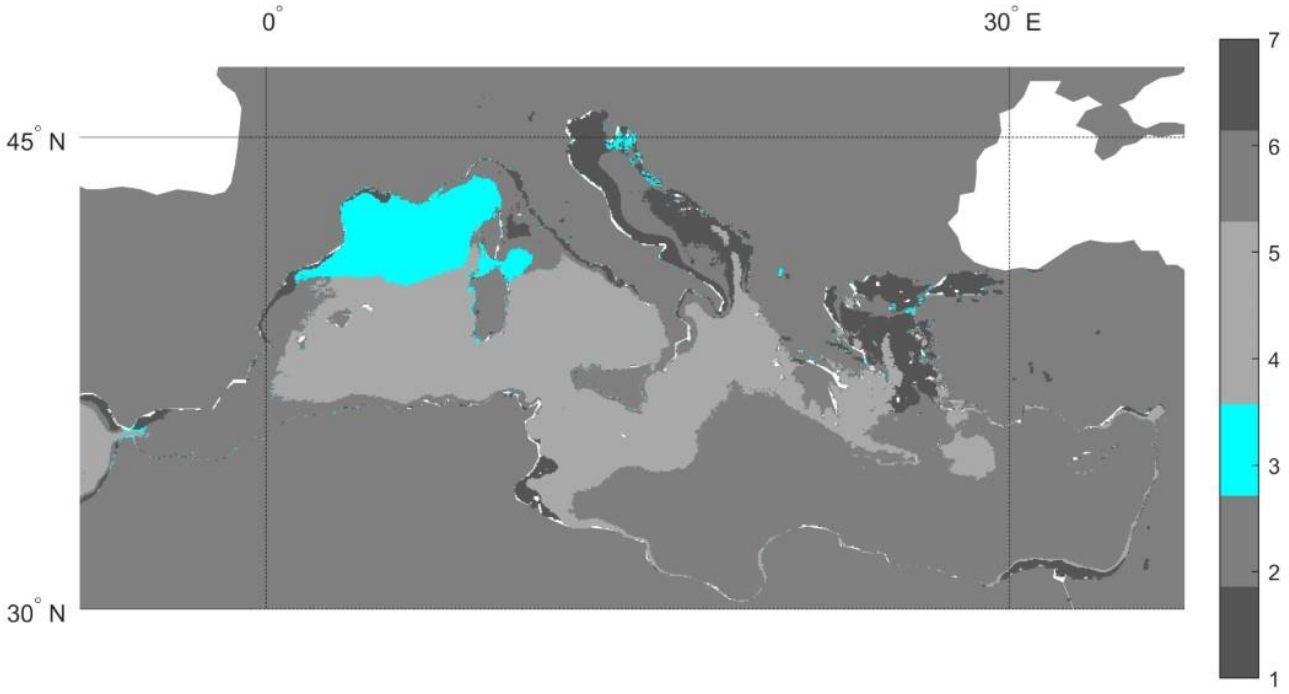
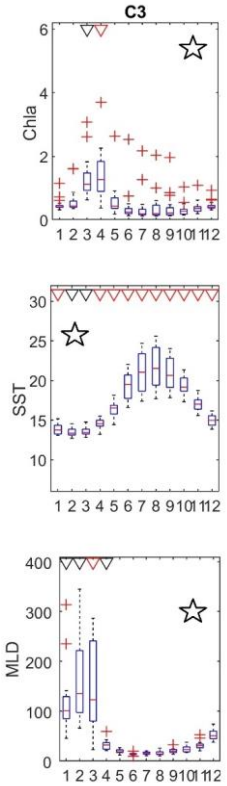


C2 is present in several disconnected regions and are associated with currents responsible for important and permanent advections. Along the northern shores of the western basin, the advection is linked to the northward current of modified Atlantic water.

Representation of the Bioregions on the geographic space of the Mediterranean

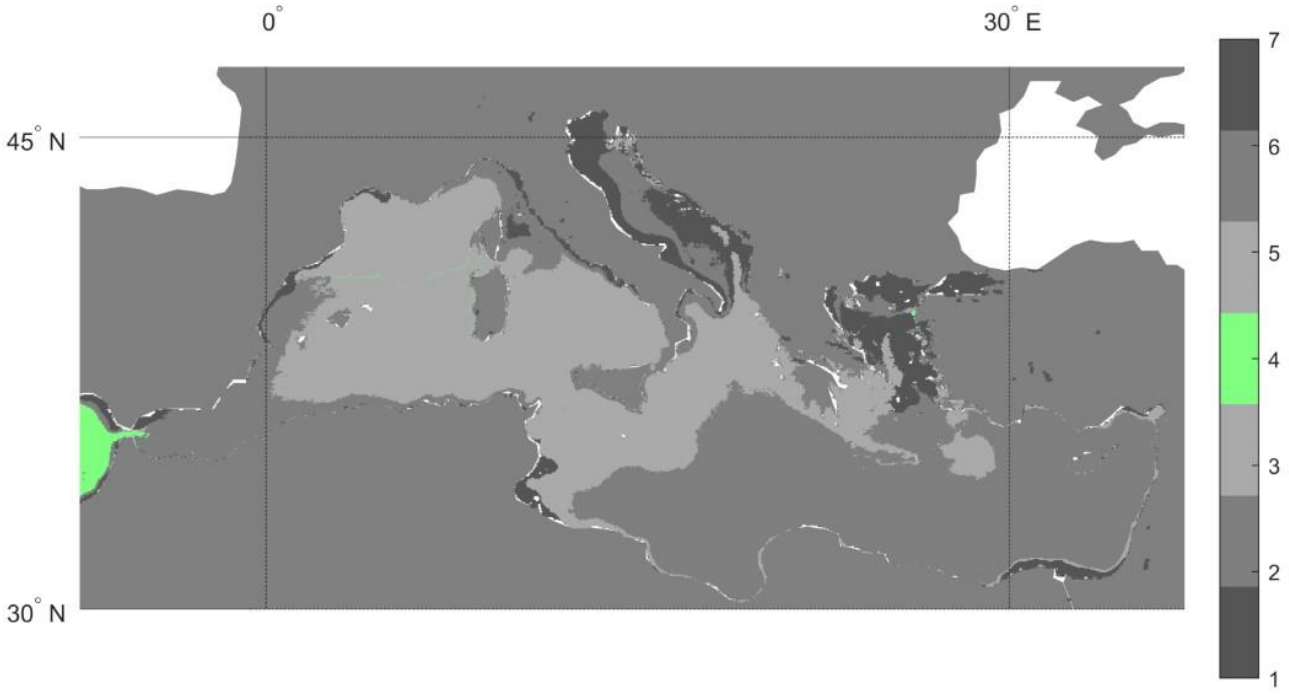


Monthly climatology



C3 characterizes the Liguro Provençal basin and the adjacent Balearic Sea. These zones of convection, which form the western Mediterranean deep waters (WMDW), are the engines of the Mediterranean thermohaline circulation

Representation of the Bioregions on the geographic space of the Mediterranean



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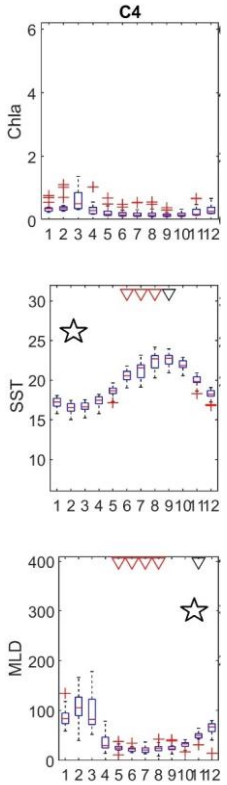
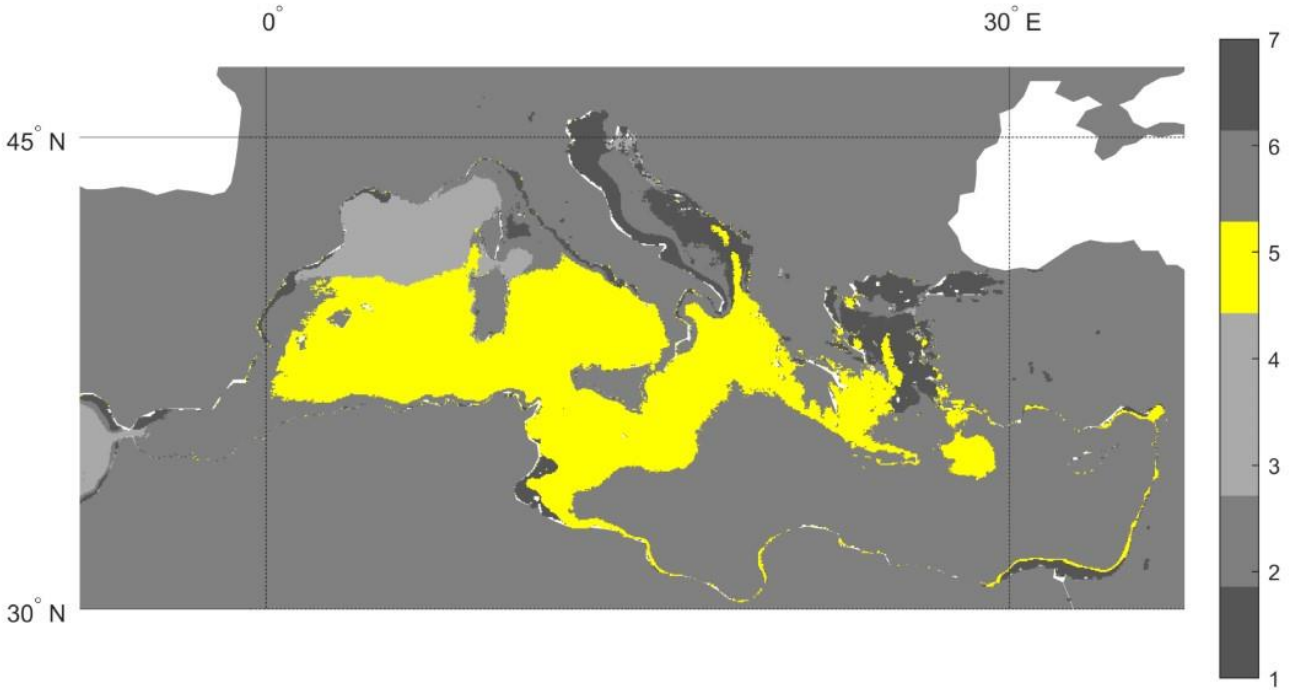
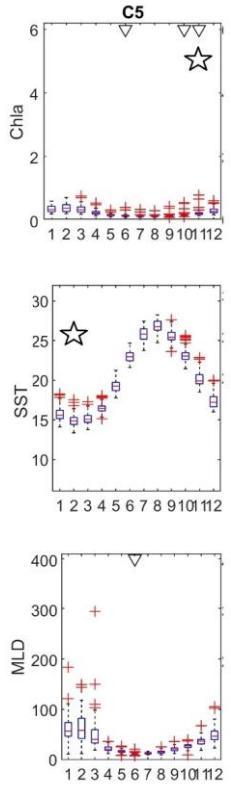


C4 characterizes the Atlantic surface water of the Gulf of Cadiz and is observed in the Strait of Gibraltar forming a small tongue entering the Mediterranean.

Representation of the Bioregions on the geographic space of the Mediterranean

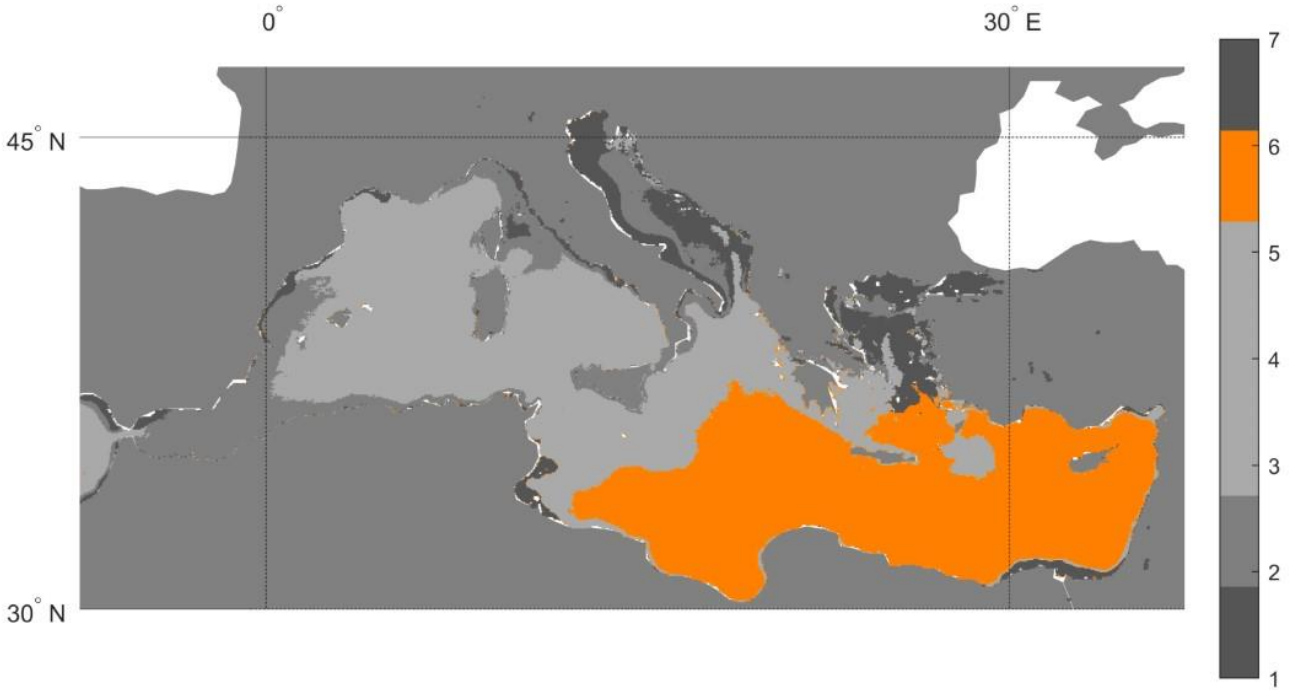
Monthly climatology



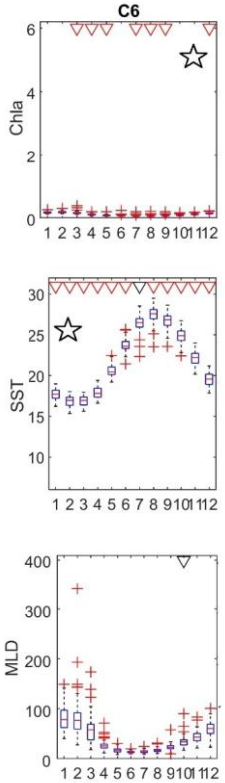


C5 and C6 characterize the central waters of the western basin (C5) and the eastern basin waters (C6). C5, which covers the center of the western basin, has a lower SST and a higher chl-*a* concentration than that of C6. The western basin is strongly influenced by the fresh and warm Atlantic waters which inflow through the strait of Gibraltar and generate a large-scale cyclonic circulation. C6 occupies the eastern basin which is very oligotrophic with a strong summer stratification and a shallow MLD.

Representation of the Bioregions on the geographic space of the Mediterranean



Monthly climatology



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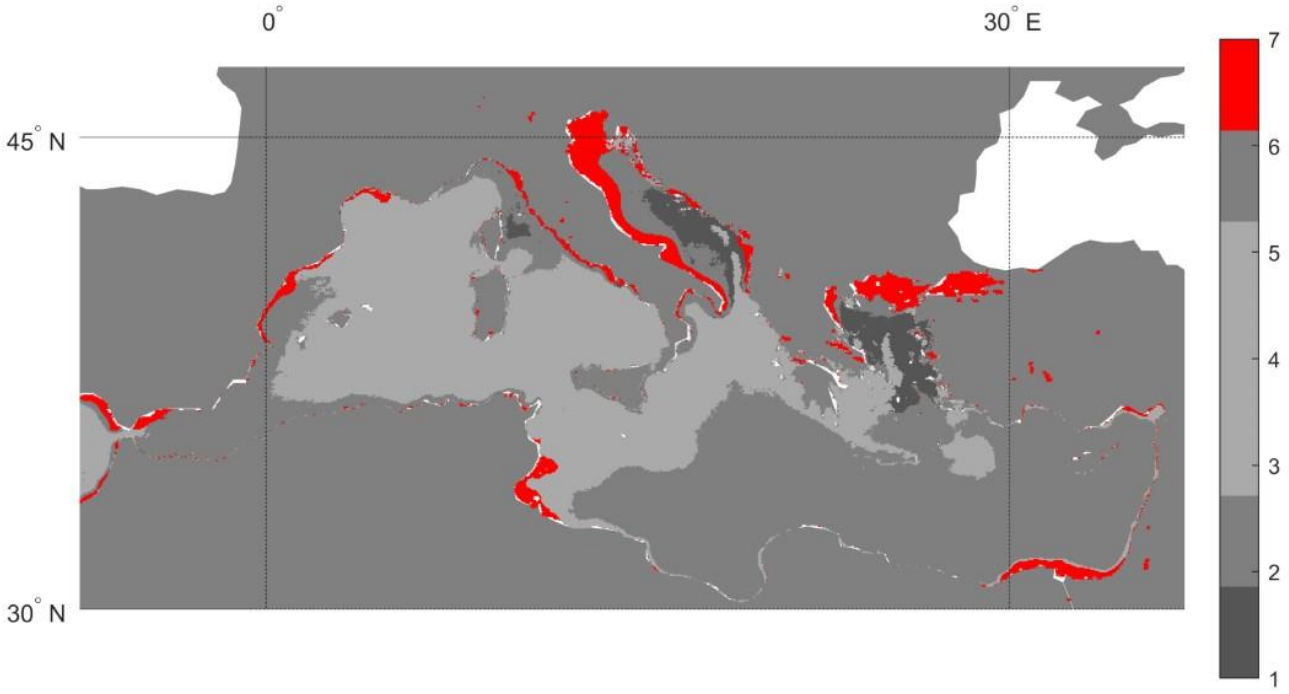
Representation of the Bioregions on the geographic space of the Mediterranean



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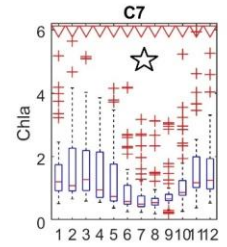
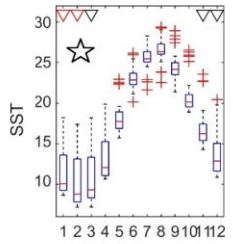
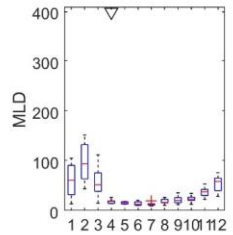


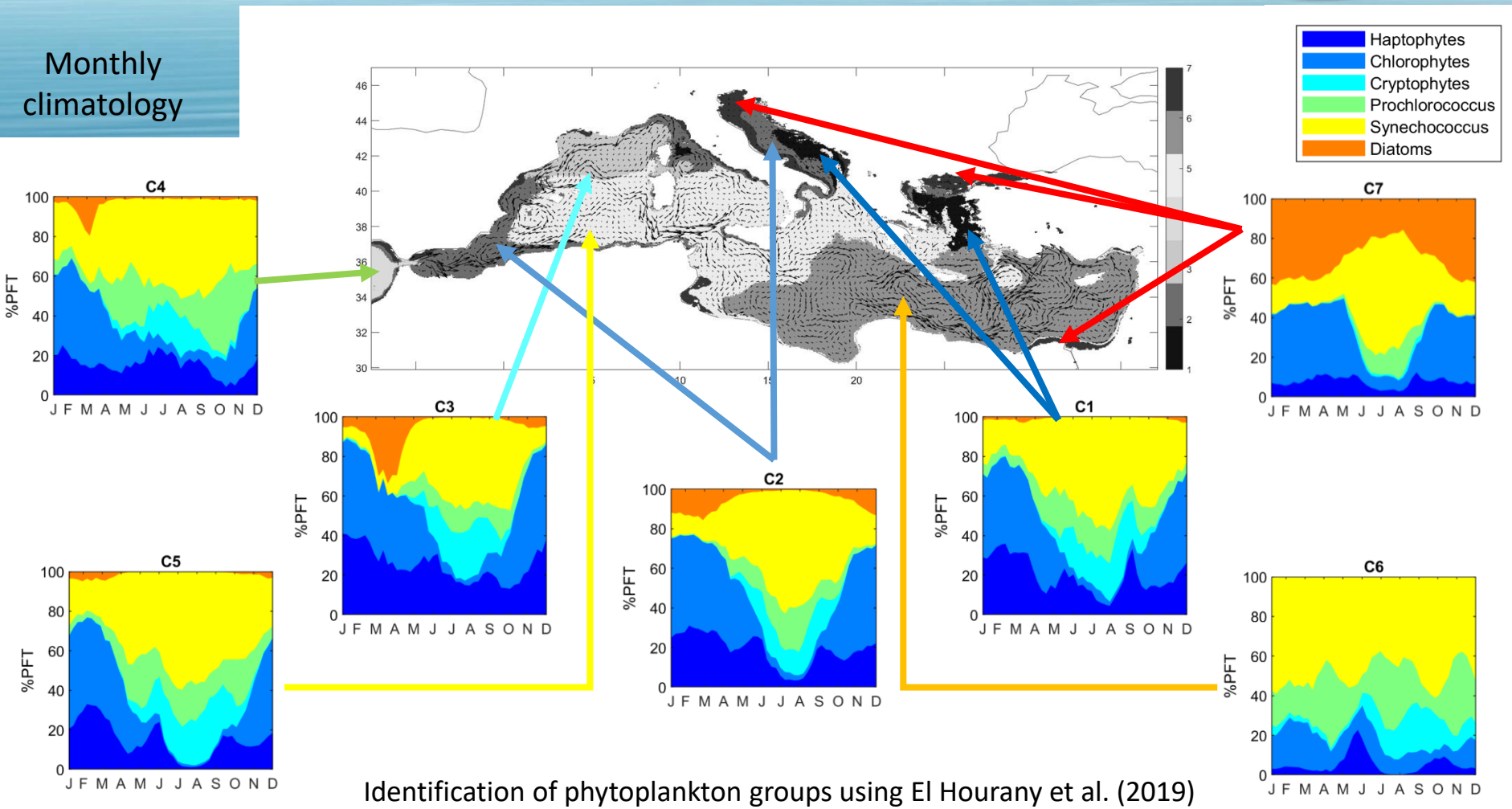




C7 includes coastal areas, such as those along the east coast (Adriatic) and west of Italy (Tyrrhenian), part of the coast of the Gulf of Lion, and the coasts of Egypt and Lebanon. C7 waters are strongly influenced by river discharge and by human activities. C7 waters are also found in shallow areas where the tidal activity is intense.

Characterization of the Bioregions in the light of the phytoplankton dynamic

Monthly climatology



Identification of phytoplankton groups using El Hourany et al. (2019) method (*Phytoplankton Diversity in the Mediterranean Sea From Satellite Data Using Self-Organizing Maps*, JGR Oceans)

Conclusion

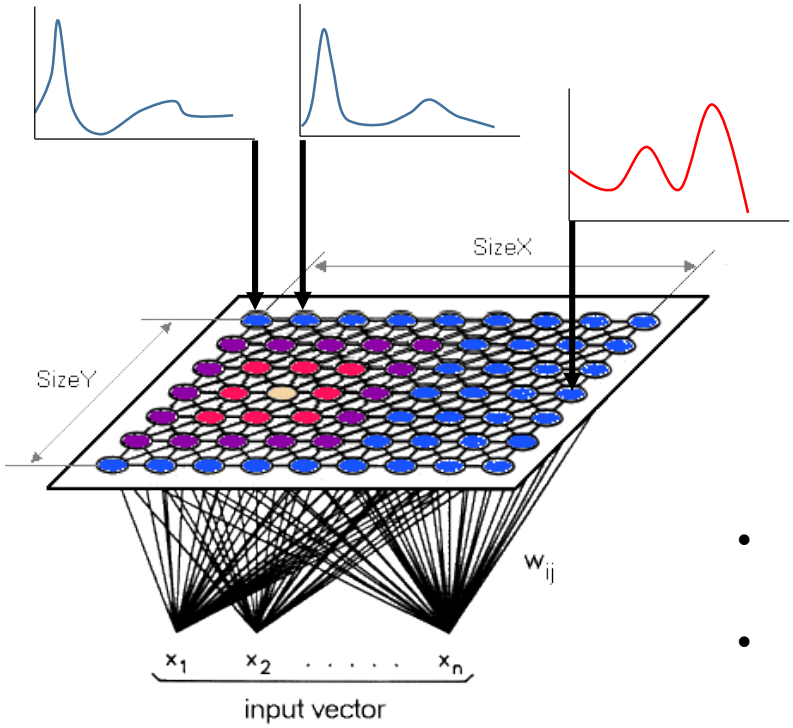
SOM, an efficient tool for studying the dynamics of an ecosystem

Bioregionalization of the Mediterranean into bioregions

- Use and evaluation of an effective weighting system: 2S-SOM
- Evaluation of the contributions of the different biophysical parameters used: Chla, SST and MLD
- 7 bioregions identified with their characteristics
- Coherence with physical and biogeochemical dynamics

Submitted to RSE journal; El Hourany et al., *A neural based bio-regionalization of the Mediterranean Sea using satellite and Argo-float records*

Unsupervised classification: SOM



Neighboring Kernel Function

$$J_{SOM}^{T}(\chi, W) = \sum_{xi \in D} \sum_{c \in SOM} K^{T}\left(\delta\left(c, \chi(x_i)\right)\right) \|x_i - w_c\|^2$$

Kohonen, 2013

- Each class will be represented by a reference vector (neuron) of the same nature as the initial data
- 2 neighboring classes on the map represent similar data

2S-SOM Algorithm: The difference with SOM

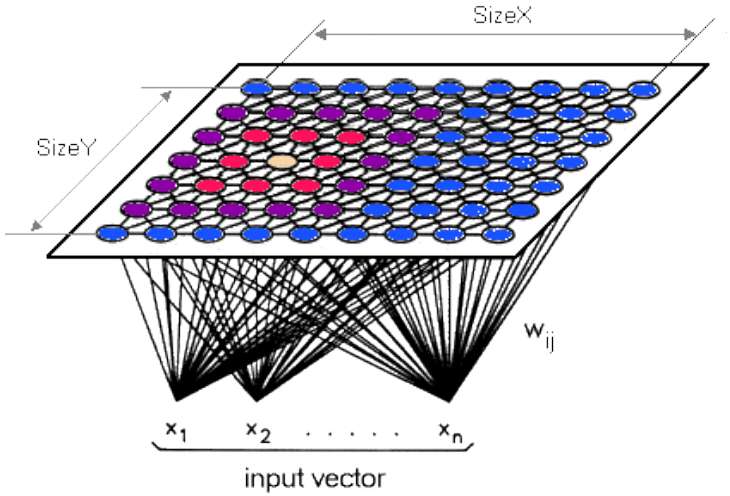
$$J_{2S-SOM}^{T}(\chi, W, \alpha, \beta)$$

Weights on blocs

Entropy

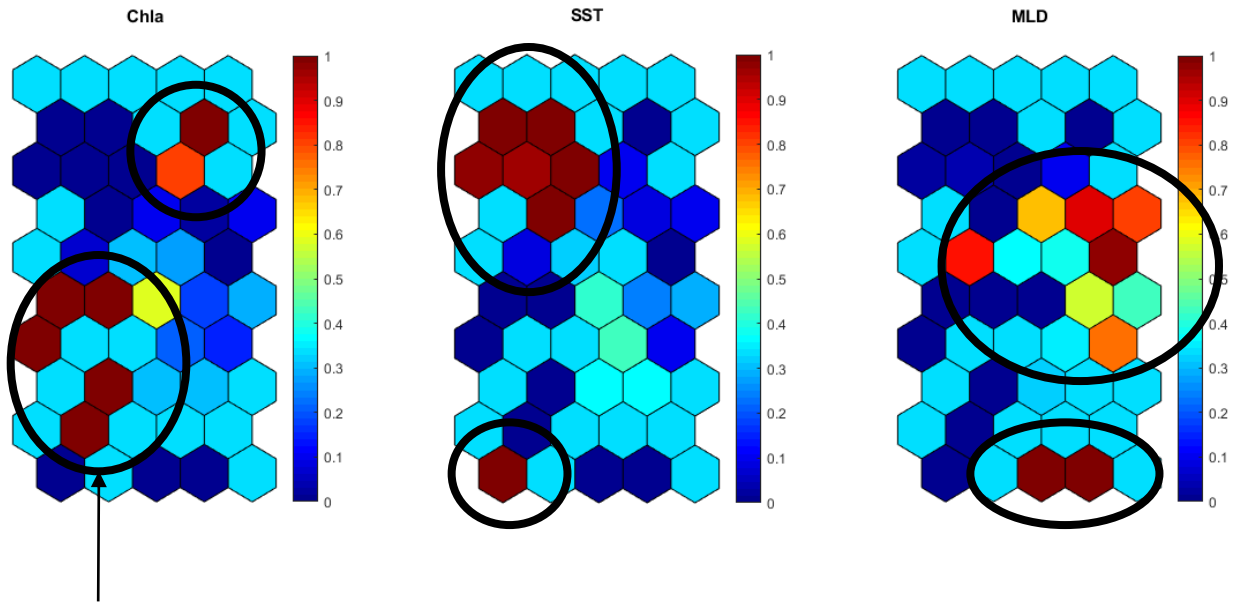
M **Ouattara** et al., **2014**

- Useful for the classification of blocks of variables of different nature



- Allows to weight the variables during learning and therefore to differentiate their importance in the classification
- Each neuron is a class and has a weight for each block

Distribution of block weights on 2S-SOM neurons

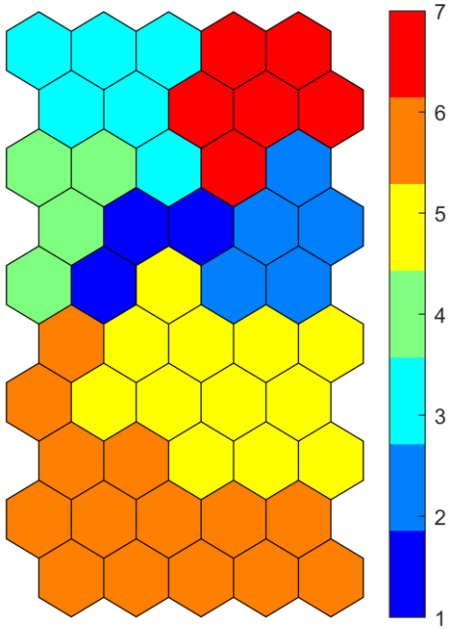


Neurons attributed with high weights for a certain bloc of variables

The sum of the 3 bloc weights on each neuron is equal to 1

Ascending Hierarchical Clustering (CAH)

Result of the classification of 2S-SOM neurons into 7 classes by Ascending Hierarchical Clustering (CAH)



Distribution of block weights over the 7 classes

	Chla	SST	MLD
C1	0.06	0.44	0.51
C2	0.15	0.17	0.68
C3	0.17	0.67	0.17
C4	0.17	0.65	0.18
C5	0.36	0.29	0.35
C6	0.45	0.24	0.31
C7	0.52	0.24	0.24

Light blue/red denotes which block (Chla, SST and MLD) is the most weighted in each cluster, and therefore contributed the most to the construction of the neurons of this cluster