Spatial and temporal patterns of sea surface chlorophyll concentration and environmental forcing in the southern European Atlantic

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Introduction

Phytoplankton dynamics is possibly the single parameter that better resumes the general characteristics of the pelagic ecosystem. In one hand, its magnitude and the spatial and temporal patterns at different scales reflect the dynamics of physical processes (Mann and Lazier, 1996). In the other hand, phytoplankton dynamics have a large impact on the rest of the food web (e.g. Razzoulzagegan and Legendre, 1995; Pauly and Christensen, 1996).
Although the ocean does not have apparent physical barriers, gradients exist in ecosystem characteristics, often presenting strong clines. Regionalization of marine ecosystems is a fundamental scientific and management objective in Oceanology (e.g. Longurst, 1998, ICES areas, Marine Strategy Framework Directive).

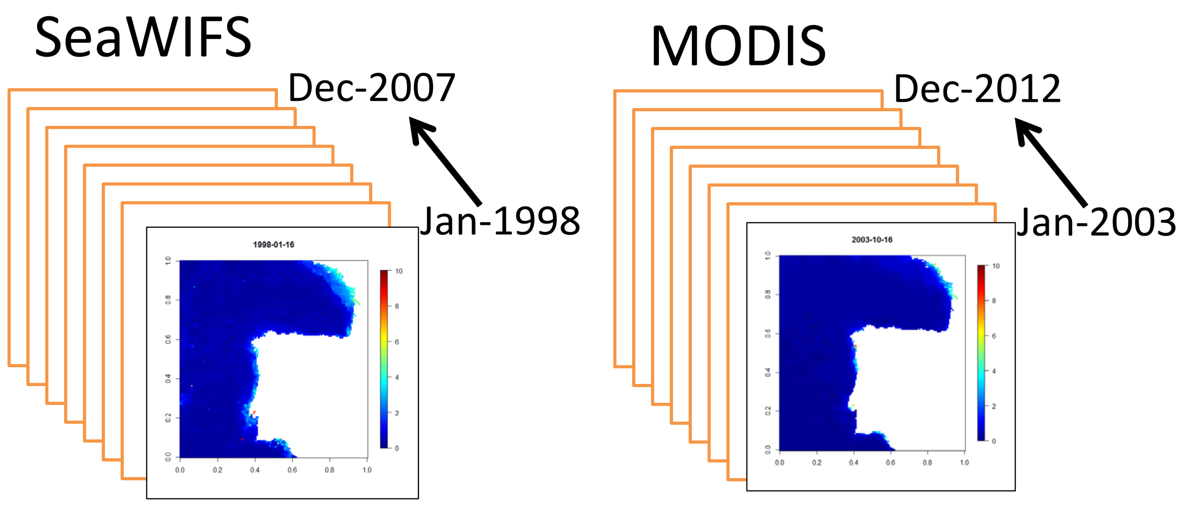
Objectives

The objectives in this study were: (1) to accomplish a regionalization of the southern European Atlantic, (2) identify the main spatial and temporal patterns of this variability and (3) infer the forcing processes that force different dynamics across regions.

General Methodology

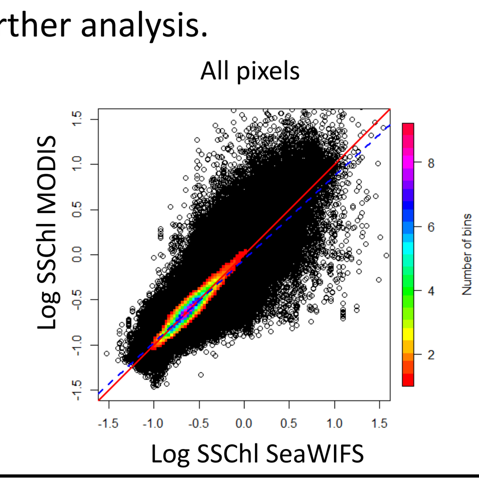
Regionalization was performed with an objective analysis (Empirical Orthogonal Funtions; EOFs) of monthly Sea Surface Chlorophyll concentration (SSChl) from satellite imagery. This variable allowed us to integrate the most relevant spatial and temporal scales in the study area. Its spatial resolution allowed a precise determination of gradients and it also resolved seasonality (the main mode of temporal variability in temperate regions) and its consistency during a long enough period (1998 – 2012).

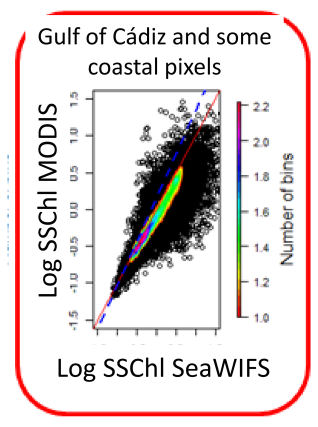
The data source

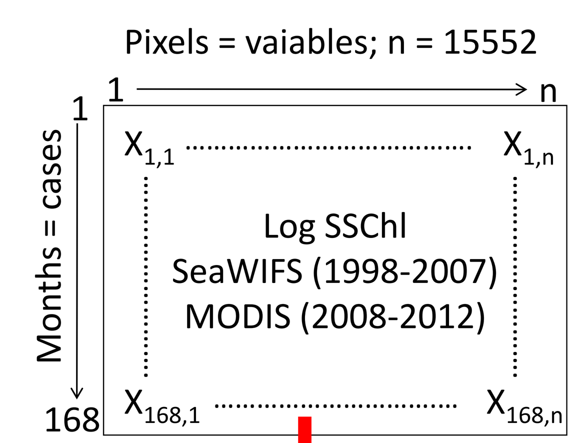


Merging onto a single data base

Preliminary analysis identified several areas (Gulf of Cádiz shelf and certain costal pixels along the Western Iberian and French shelves) that presented SeaWIFS/MODIS SSChl ratios differing from 1:1. This inconsistency between satellites is possibly related with the interference of yellow substances with the chlorophyll signal. These areas were excluded from further analysis.



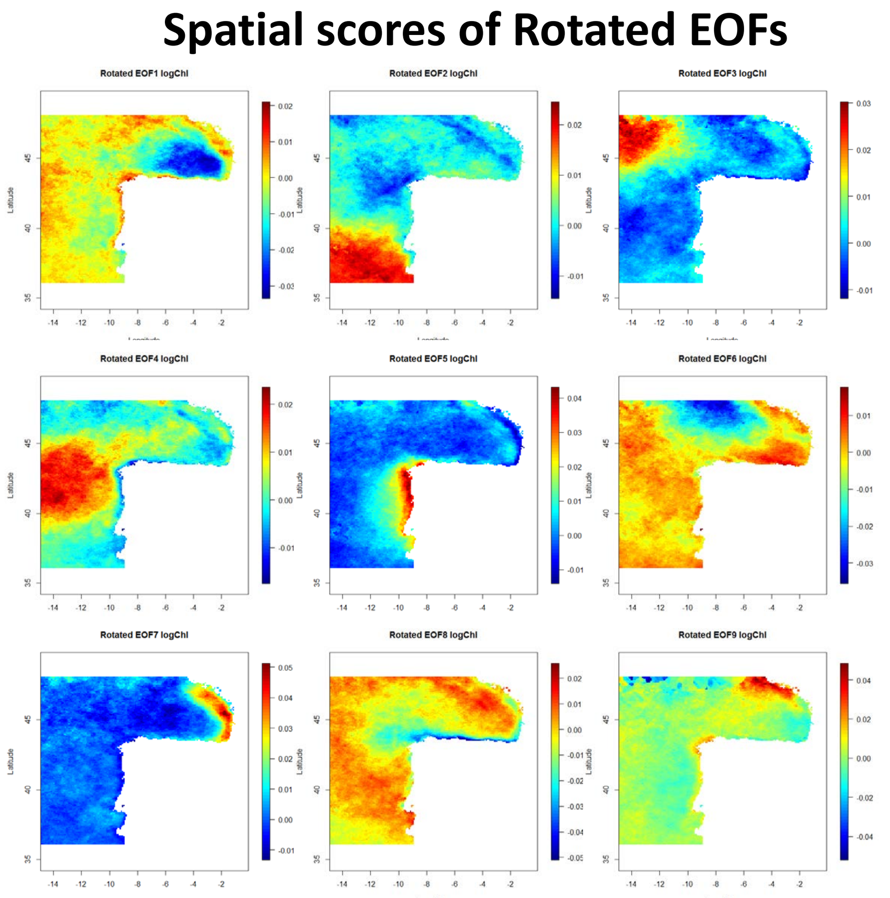




The EOF analysis.

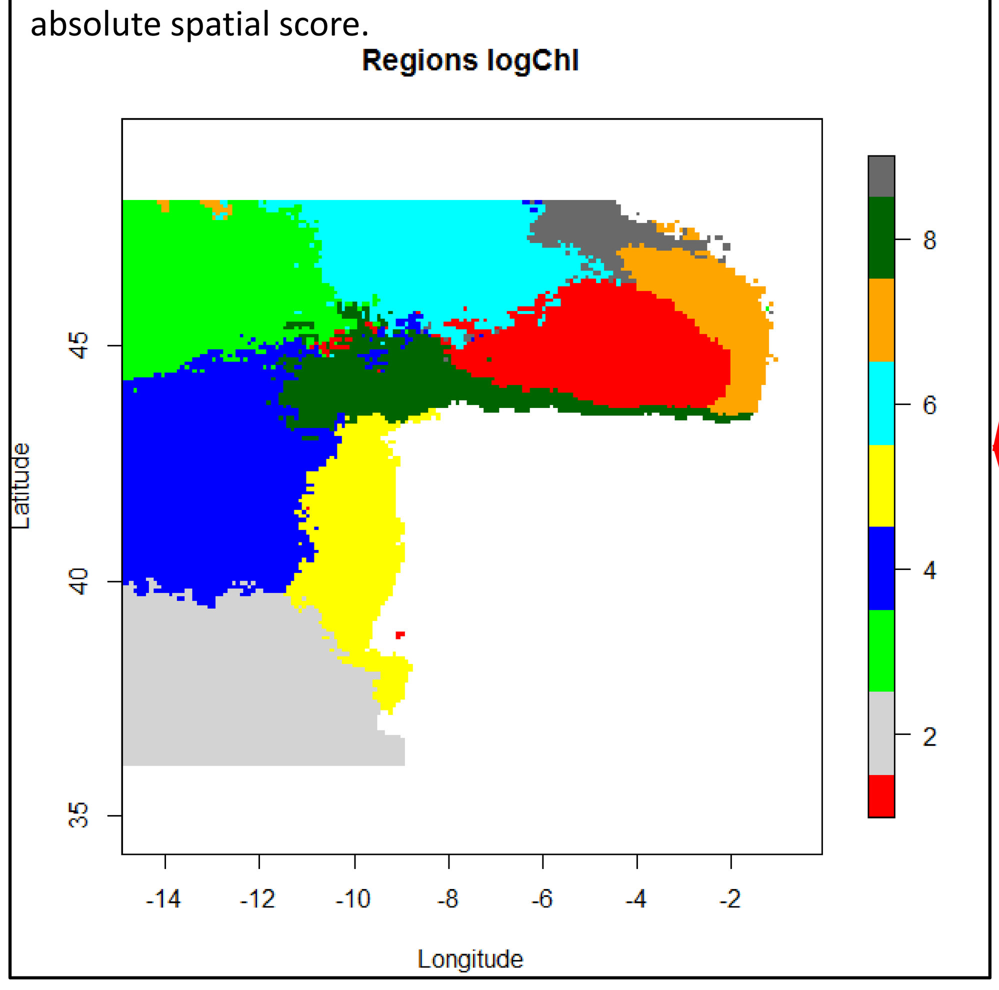
1) A first EOF analysis identified 9 "significant" EOFs.
2) We performed a varimax rotation on these 9 EOFs only.

Spatial scores of Rotated EOFs



Regionalization.

Each pixel was asigned to the EOF number (and its corresponding color below) for which it presented the highest absolute spatial score.

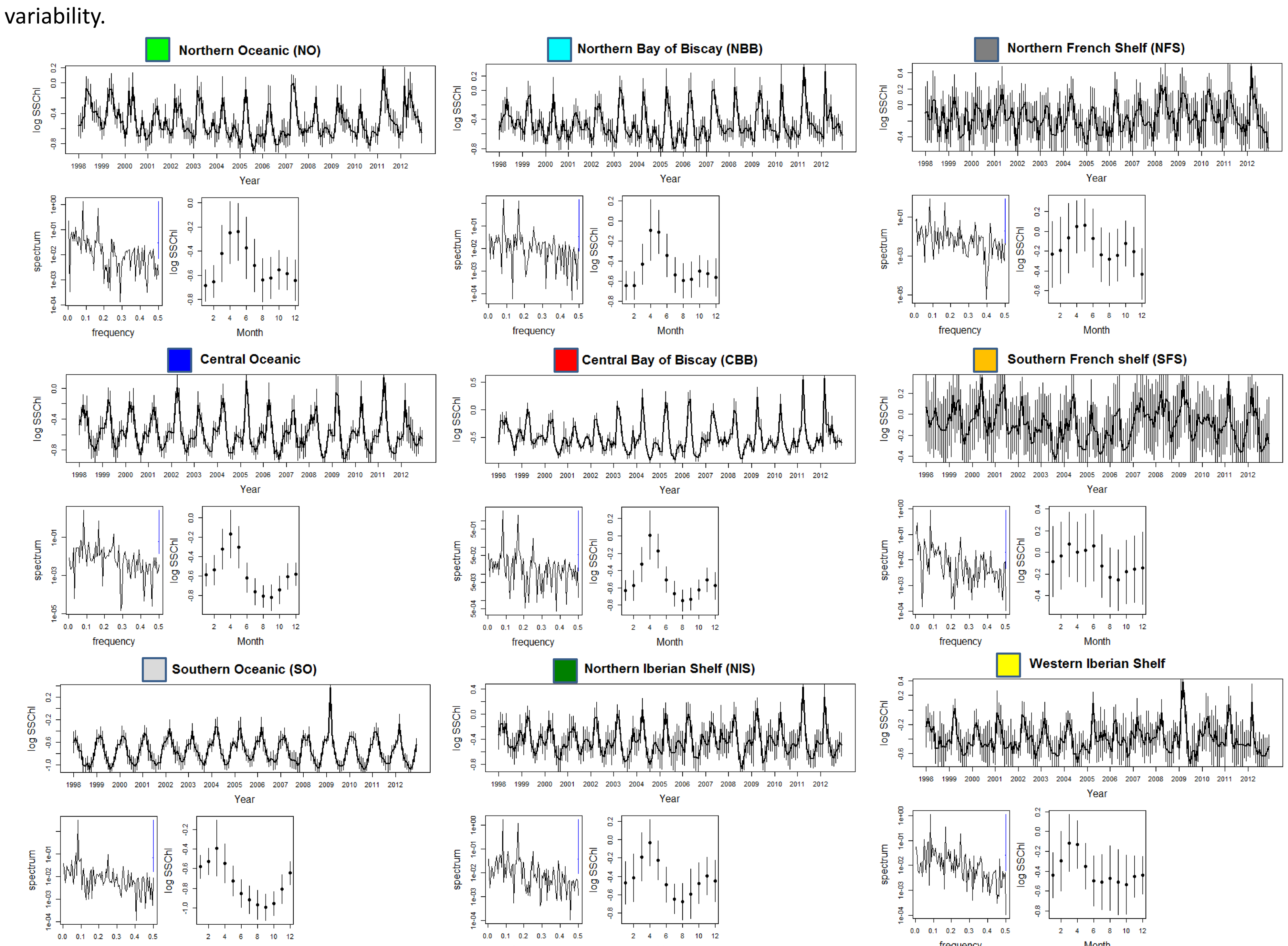


Regional temporal patterns.

For each region, figures below show the time series mean and estándard deviation of LogSSChl, the spectrum of the mean and the monthly mean and standard deviation.

Main features:

1) Oceanic regions (NO, CO, SO, NBB and CBB) present lower Chl concentrations, lower variability and more apparent seasonal patterns than shelf regions (NFS, SFS, NIS and WIS).
2) The timing of the spring bloom follows a latitudinal gradient in western oceanic regions (NO, CO, SO). Within the Bay of Biscay it occurs slightly earlier than it would correspond to their latitude, due to the "stagnation" effect of the Bay on hternal stratification (not shown).
3) NIS presents intermediate patterns between Oceanic and Shelf regions.
4) Possibly, more intense mesoscale processes occuring in shelf regions (upwelling, river inputs…) contribute to higher SSChl levels and variability.



Temporal and spatial models.

The following categories models were fitted in each region: 1) T = Log SSChl ~ Trend (lineal, cuadratic or cubic funtion). 2) T+Se = Log SSChl ~ Trend + Seasonality (*f* month). 3) T+Se+Sp = Log SSChl ~ Trend + Seasonality + Spatial (*s*(Latitude, Longitude)).

Main features (The table below shows the % of variance explained by the best model of each category):

1) Seasonality explains most of the variability in Oceanic regions.
2) Spatial patterns associated with mesoscale processes account for most of the variability in shelf regions.
3) NIS region presents an intermediate pattern, due to lower intensity of mesoscale processes than in other shelf regions.

Model	**NO**	**CO**	**SO**	**NBB**	**CBB**	**NIS**	**NFS**	**SFS**	**WIS**
T	5.9	1.5	1.5	0.3	<0.0	1.5	0.3	0.4	1.8
T+Se	46.0	60.9	58.4	49.1	56.8	34.6	12.8	16.3	11.8
T+Se+Sp	46.3	64.3	68.3	55.4	58.7	49.5	74.3	60.9	49.5
Mesoscale processes									
Coastal Upwelling	-	-	-	-	-	Medium	Low	Low	Very High
River runoff	-	-	-	Medium	Medium	Low	Very High	Very High	High
Others	Low	Low	Low	High	Medium	Medium	Medium	Medium	Low

Conclusions

1) SSChl obtained from satellite imagery combined with EOF analysis constitutes an objective methodology for pelagic ecosystem regionalization.
2) Regions match *a priori* knowledge of the study area.
3) Regional SSChlTemporal and spatial patterns vary according to the dynamics of physical forcing

References.

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Longurst, A. (1998) Ecological geography of the sea. Academic Press, San Diego. 398pp.

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