

Three decades of marine bioregions evolution through analysis of phytoplankton phenology

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Abstract

Ocean biogeochemistry is undergoing significant modification in response to climate change. To better track these evolutions, we present a novel ocean monitoring indicator that follows the temporal evolution of marine bioregions of similar phytoplankton phenologies. Chlorophyll-a concentration observations from remotely sensed ocean color describe seven distinct marine bioregions characterized by their unique patterns of phytoplankton biomass seasonality. The sizes and locations of these bioregions are monitored from 1998 to 2024 using a multi-sensor merged L4 ocean color product. While the bioregions’ extents appear to follow interannual and decadal climate variability, their long term evolution suggests a poleward extension of less seasonal phytoplankton phenology, which is generally characteristic of the tropical and subtropical bands. This innovative approach allows the systematic monitoring of how phytoplankton adapt their seasonal cycle in response to changes in environmental conditions, hence giving valuable insights into the evolution of marine ecosystems over the past three decades and helping advance our understanding of global ocean biological responses to environmental change.

1 Introduction

Phytoplankton, the main primary producers in the ocean, sustain marine food webs (Fenchel, 1988; Kiørboe, 1993) and play a central role in regulating oceanic carbon fluxes (Falkowski *et al.*, 1994). Environmental conditions shape phytoplankton growth and losses through “bottom-up” (e.g., light and nutrients availability) and “top-down” (e.g., grazing) processes. Over the past three decades, satellite ocean color measurements make it possible to estimate phytoplankton biomass (Behrenfeld *et al.*, 2005)

31 proxied by chlorophyll-a concentration (Huot *et al.*, 2007). This, in turn, has enabled the study of
32 phytoplankton phenology (i.e. the temporal succession of main biological events) (Longhurst, 2007;
33 Racault *et al.*, 2012; Sapiano *et al.*, 2012, Boyce *et al.*, 2017). Climate influences the distribution of
34 environmental factors that, in turn, regulate the spatiotemporal dynamics of phytoplankton biomass
35 (Falkowski and Oliver, 2007). Distinct seasonal patterns emerge along latitudinal gradients, from the
36 equator to the poles (Longhurst, 1995). At high latitudes, primary production is mainly light limited,
37 whereas in tropical and subtropical regions, phytoplankton production is essentially nutrient limited
38 (Boyce *et al.*, 2017). Like the marine environment itself, phytoplankton biomass responds to both annual
39 and decadal climate variability (Li *et al.*, 2024).

40 Climate change is altering oceanic ecosystems (ref from OSR #10 chapter 1), with complex impacts on
41 phytoplankton growth. For instance, rising sea temperatures might directly affect metabolism (O'Connor
42 *et al.*, 2009) but also environmental conditions through enhanced water column stratification
43 (Yamaguchi and Suga, 2019), which in turn might further limit growth by hindering upward transport of
44 nutrients to the sunlit layers (Sarmiento *et al.*, 2004; Fernández-González *et al.*, 2022). As for terrestrial
45 plants (Cleland *et al.*, 2007; Inouye, 2022), marine phytoplankton are expected to respond to these
46 environmental changes by adjusting their seasonal cycles (Winder and Sommer, 2012). Most of the
47 documentation effort focused on variations in the onset, duration, and intensity of bloom events (e.g.,
48 Sommer and Lengfellner, 2008; Martinez *et al.*, 2011; Henson *et al.*, 2018; Salgado-Hernanz, 2019). These
49 changes may cause phenological mismatches hence disrupting energy transfer to higher trophic levels
50 (Visser and Both *et al.*, 2005, Asch *et al.*, 2019) and have broader implications for the global carbon cycle
51 (Fisher *et al.*, 2025). Consequently, establishing robust indicators monitoring interannual to decadal
52 changes in phytoplankton phenology is critical to better address the evolution of the marine ecosystem
53 with climate change.

54 With the large amount of remotely sensed ocean color observations, numerical clustering methods
55 emerged as key tools to identify regions with similar seasonal dynamics of phytoplankton (hereafter
56 referred to as bioregions) (International Ocean Color Coordinating Group, IOCCG, 2009). Several studies
57 (e.g. D'Ortenzio and Ribera d'Alcalà, 2009; Lacour *et al.*, 2015; Ardyna *et al.*, 2017; Boyer *et al.*, 2017;
58 Kheireddine *et al.*, 2021; Baudena *et al.*, 2025) have applied such methods to partition oceanic domains
59 into bioregions characterized by similar seasonal patterns of chlorophyll-a concentration, which are
60 often used as a basis for inferring provinces of similar biogeochemical functioning. Similarly to how
61 Mayot *et al.* (2016) extended D'Ortenzio and Ribera d'Alcalà (2009) climatological partitioning of the
62 Mediterranean Sea, this study presents an ocean monitoring approach built on Baudena *et al.* (2025)
63 climatological bioregionalization of the global ocean. This method tracks variations in the extension of
64 the bioregions in respect of time to reveal the trends in geographical changes of phytoplankton
65 phenology. The main idea behind our approach is that tracking these variations may serve as a relevant
66 proxy for assessing changes of phytoplankton dynamics, which, in turn, could inform on main variations

of environmental factors of the marine ecosystem.

We introduce here a proof of concept for such an approach using the supervised clustering method introduced in Baudena *et al.*, 2025. Annual partition of the global ocean (56°S–56°N) from 1998 to 2024 is obtained by classifying annual time series of remotely sensed chlorophyll-a concentration (Copernicus-GlobColor) into bioregions. After presenting the mean climatological state of the bioregions, we investigate their change in surface area over the last three decades. Then, building on D’Ortenzio *et al.* (2012) and adapting methods from Higgins *et al.* (2016), originally applied to terrestrial biomes, we compare the geographical extension of the bioregions between two decadal periods at the greatest extent of our dataset, (1998-2007 and 2015-2024) to identify the main trends in the reorganization of phytoplankton phenology. Finally, possible correlation with environmental changes and method limitations are evoked in the discussion section.

2 Material and methods

2.1 Data

Chlorophyll-a concentrations data were retrieved from the merged multi-sensor ocean color product ref. no. 1 (see Table 1). This product offers cloud free remotely sensed surface chlorophyll-a concentration at a 4 km spatial resolution and daily intervals. Using such a L4 product (an optimally interpolated, merged satellite dataset), as compared to L3 (merged product) in Baudena *et al.*, (2025), compensates for the lack of observation inherent to satellite ocean color (Stock *et al.*, 2020) and ensures a maximal spatialization of the bioregions at an annual temporal resolution.

Product ref. no.	Product Id & type	Data access	Documentation
1	OCEANCOLOUR_GLO_BGC_L4_MY_009_104, Satellite observations	EU Copernicus Marine Service Product (2024)	Quality Information Document (QUID): Garnesson <i>et al.</i> (2025) Product User Manual (PUM): Colella et al. (2024)

Table 1: Product table

2.2 Supervised Clustering

Annual ensembles of seasonal time series of chlorophyll-a concentration were built from 1998 to 2024. The time series composing them were all processed similarly to allow subsequent classification

according to Baudena *et al.* (2025) supervised clustering method. In short, within each annual ensemble, each individual time series characterizes the seasonal evolution of chlorophyll-a concentration over a $1^{\circ} \times 1^{\circ}$ grid. Following the method detailed in supplementary section S1, the time series were obtained averaging all available observations within each $1 \times 1^{\circ}$ pixel over a 8-day temporal window. To dampen sub-seasonal variations, time series were all smoothed with a 5 weeks centered rolling average method. Finally, all annual time series were normalized by their maximum to ensure that the clustering method focuses on their shape rather than on their magnitude.

Time series associated with pixels in the Arctic and Southern Oceans (respectively above 56°N and below 56°S) were removed from every annual ensemble due to lack of continuous satellite observation through winter in relation to permanent cloud presence and polar night. Coastal pixels located within 111 km ($\sim 1^{\circ}$) from the coast were also discarded due to the uncertainty in chlorophyll-a concentration estimations within optically complex waters (Case 2 waters). As a result 80% of the global ocean area is considered. In the southern hemisphere, time series were all shifted six months backward, to ensure identical sequencing of seasons in the time series of all pixels.

Each annual ensemble was then partitioned into the seven clusters of Baudena *et al.*, 2025 based on their seasonality patterns. These seven clusters were found to optimally partition open ocean seasonal cycles of surface chlorophyll-a concentration in respect of multiple statistical tests discussed in the companion study. The assignment of a given time serie into one of the clusters was done according to its minimal euclidean distance (maximal similarity) with the central time series of Baudena *et al.*, 2025 clusters. To prevent assignment of too dissimilar seasonal patterns, a threshold distance was considered to accept (distance below the threshold) or refuse (distance above the threshold) an assignment. To account for the method's sensitivity to this hyperparameter, we discretized a range of possible values, defined by the minimum and maximum classification distances found among the most deviating elements of any cluster, from 1.33 (cluster 1) to 2.60 (cluster 7), based on the unsupervised clustering of Baudena *et al.*, (2025). Each annual ensemble was partitioned several times from a low (strict definition of the clusters) to high threshold values (lax definition of the clusters) selected within this range with a regular step of 0.05 (see sensitivity analysis in supplementary section 2). At least 88 % of the time series were always successfully sorted within the seven clusters (see Fig. S2b). Unclassified time series, mostly located in regions of low satellite data availability region (see Fig. S2a), were all excluded from ulterior analysis.

2.3 Bioregions

The spatial projection of each pixel's membership over the global ocean forms large coherent spatial domains similarly classified. These oceanic domains correspond to the bioregions as defined by Baudena *et al.* (2025). As a reminder, bioregions share similar seasonal patterns in phytoplankton phenology suggesting a common biogeochemical functioning (Longhurst, 1995). Over time, the spatial definition of the bioregion might change with annual time series characteristic of a given pixel being attributed to

different clusters over different years. A change of phytoplankton phenology is attributed to a pixel when its bioregion changes from one year to another. For a given pixel, the frequency of phenology change is defined as the total sum of these changes over the study period. These changes might present oscillating patterns from annual to decadal period or long term trends.

Three climatological partitions of the global ocean were considered hereafter. They were constructed by keeping, in each pixel, the most frequent bioregion over the selected temporal extent. The three considered periods are: from 1998 to 2024 and two decadal periods from 1998 to 2007 and from 2015 to 2024. The former climatological period supports the documentation of the average bioregion extent while the latter two decadal periods were chosen at the edge of the temporal span to support the documentation of long term changes in the bioregion's extent. The use of decadal bioregions also dampens interannual variability.

When comparing the decadal bioregions' extent between the 1998-2007 and the 2015-2024, we attribute a stable phenology change to a given pixel when its classification changed between the two periods and if this assignment remained identical for more than six years in each of the two decades. This temporal criterion was chosen strictly above half a decade to grant a reasonable and robust indicator of the bioregion persistence while remaining permissive in respect of inter annual climate variability.

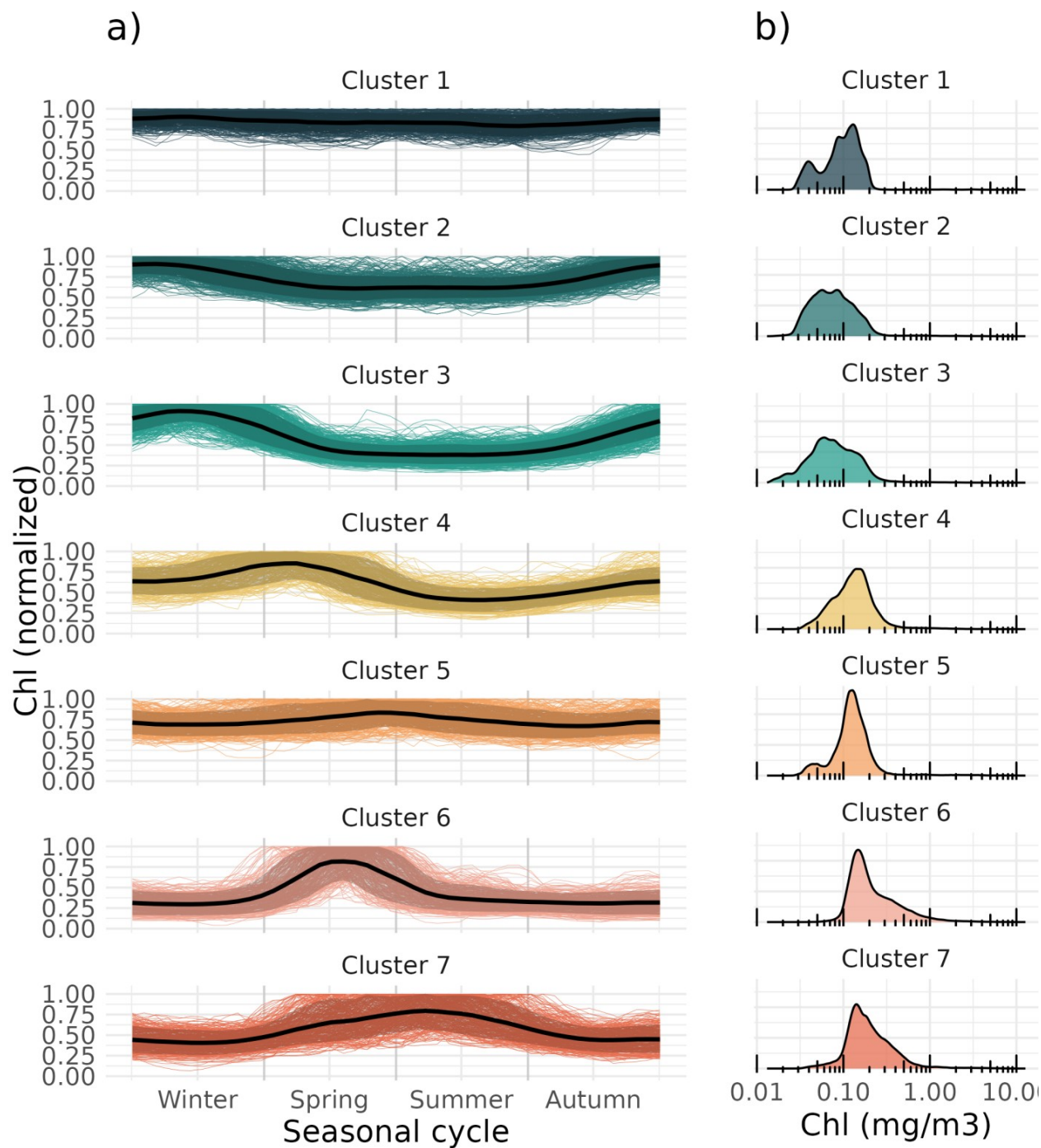
To assess phytoplanktonic biomass across the bioregions, we analyzed their chlorophyll-a concentrations, presented as probability distribution functions in Fig. 1b. The distribution for bioregion 1 is notably bimodal, showing a minor peak near 0.03 mg.m^{-3} and a dominant one just above 0.1 mg.m^{-3} . This finding prompted us to subdivide bioregion 1, after the clustering, based on a threshold of 0.06 mg.m^{-3} for yearly average chlorophyll-a, creating an oligotrophic group (below the threshold) and a mesotrophic group (above the threshold). Although both sub-regions exhibit a similar non-seasonal pattern, this subdivision reveals distinct phenologies, suggesting they are controlled by different environmental forcings that either sustain or inhibit year-round phytoplankton growth.

2.4 Uncertainties estimation

Following the set of threshold distance, each annual ensemble is partitioned twenty six times (see section 2.2). In each of these partitions, the distribution of the bioregion surface area relative to the set of threshold distances is characterised hereafter by its central value (the median) within its interquartile range (Q1–Q3). The interquartile range of surface area estimates accounts for the bioregionalization method uncertainty. All surface areas are reported relative to the total global ocean area. To identify long-term changes, we fitted a linear model to the central surface area estimates in respect of time. The statistical significance of these linear trends was determined using a Spearman rank correlation, with a trend considered significant at $p < 0.1$.

158 **3 Results**

159 Our analysis is presented in three parts. First, we recall the phytoplankton phenology and climatological
160 repartition of the seven marine bioregions (described in more details in Baudena *et al.*, 2025). Second, we
161 assess the interannual variability and long-term trends in the surface area evolution of each bioregion
162 from 1998 to 2024. Finally, we identify the locations of stable phenological changes by comparing two
163 distinct decades at the edges of the period.



165

166 Figure 1: Clusters resulting from the supervised clustering of the ensemble of year 2024 from product ref. no.

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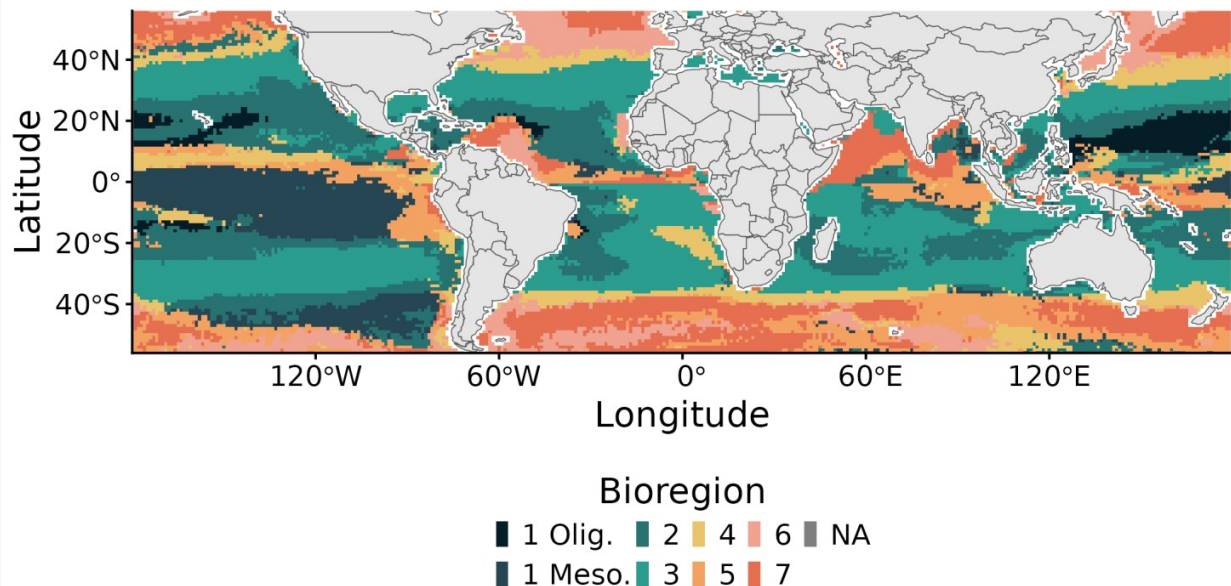
167 1 according to the strictest threshold. The left panel (a), shows the mean normalized seasonal cycles within
168 each cluster (thick continuous black line) within its 10% and 90% percentiles (transparent black bands). In the
169 background, examples of time series within that cluster are represented. The right panel (b), displays the
170 distribution of chlorophyll concentration within each cluster.

171 For each year, the supervised clustering method subdivides the ensemble into the seven clusters
172 identified in Baudena *et al.* (2025). These clusters outline specific phenological patterns inferred from the
173 mean seasonal cycle of chlorophyll-a concentration (Fig. 1a). These patterns, corresponding to the
174 bioregions in Fig. 2a, range from no clear seasonality (bioregion 1) to those with pronounced single or
175 double peak events (bioregions 7-6-4), which are typical of blooms in temperate and high-latitude
176 systems, as we found in Fig. 2a.

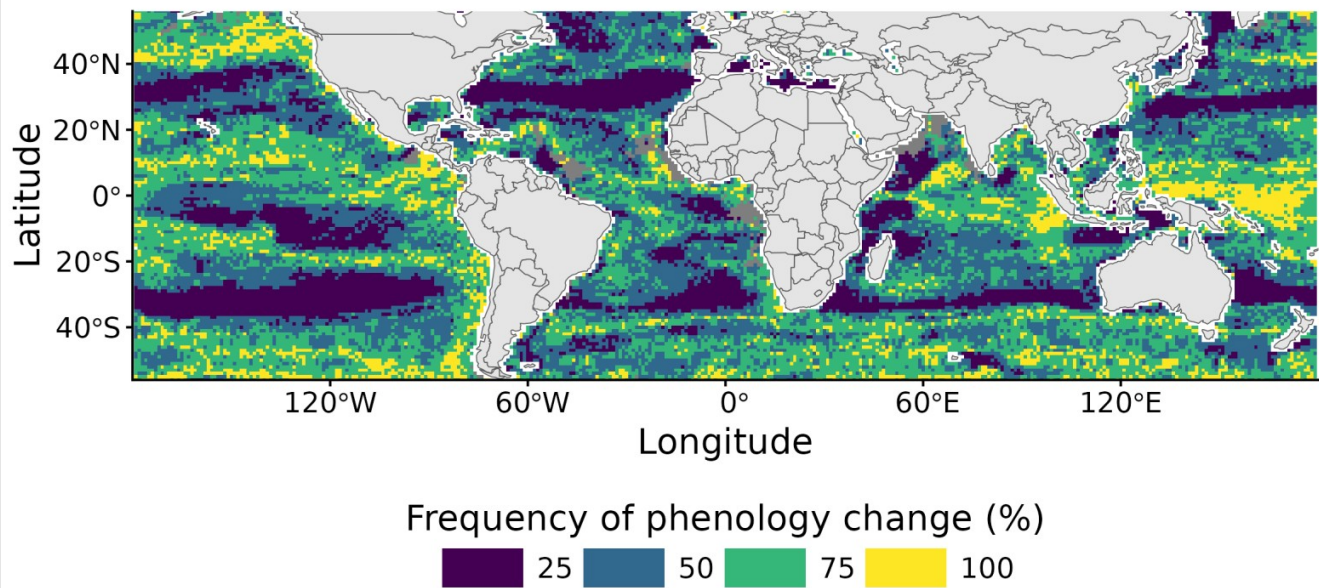
177 In agreement with Baudena *et al.* (2025), the climatological distribution of the related bioregions over the
178 1998-2024 period (Fig. 2a) follows a meridional distribution sketching coherent, large-scale structures
179 corresponding to major oceanic domains, such as the subtropical gyres (bioregions 1 Olig., 2 and 3) and
180 convergences zones (bioregion 4). The biogeochemical relevance of this partitioning is reinforced by the
181 distribution of chlorophyll-a concentrations within each bioregion (Fig. 1b). A clear poleward
182 productivity gradient emerges, with the lowest surface biomass in the perpetually stratified regimes of
183 the subtropical band and the highest in the high-latitude bloom regions (bioregion 6-7). This aligns with
184 established knowledge of global ocean productivity patterns (Behrenfeld *et al.*, 2005).

185 Baudena *et al.* (2025) offered a biogeochemical interpretation of the bioregions, summarized as follows.
186 Bioregions 6 and 7 correspond to Longhurst's (1995) model 1 (*polar, irradiance-limited*). Bioregion 5
187 exhibits features of both model 1 and model 2 (*mid-latitude, nutrient-limited spring production peak*).
188 Bioregion 4 closely aligns with the Bloom bioregion identified by D'Ortenzio *et al.* (2012). Bioregion 3
189 matches Longhurst's (1995) model 3 (*subtropical, winter nutrient-limited*), whereas Bioregion 2 closely
190 resembles the Tropical bioregion described by D'Ortenzio *et al.* (2012). Finally, Bioregion 1 corresponds
191 to Longhurst's model 4 (*tropical*). Its additional subdivision, introduced here, produces spatially coherent
192 domains that distinguish between oligotrophic regions in the centers of subtropical gyres and
193 mesotrophic regions primarily distributed around the equator.

(a) 1998-2024



(b) 1998-2024



194

195 Figure 2: (a) Climatological distribution of the bioregions in the 1998-2024 period. (b) Amount of phenology
196 change per pixel over the 1998-2024 period given in % of the total number of considered years. Both panels
197 display the results obtained using the least strict clustering criteria on the ensemble processed from product
198 ref. no. 1. Pixels designated as NA (in grey) refer to the position of the time series that were not successfully
199 classified.

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200 **3.1 Temporal evolution of the bioregions**

201 The boundaries of bioregions in Fig. 2a are not static. Fig. 2b displays the frequency of changes in each
202 pixel bioregion's affiliation, interpreted as changes in phytoplankton phenology, over the 1998–2024
203 period. These changes occur most frequently in transitional areas in-between major bioregions, as well
204 as in coastal zones, over the equatorial band, and over high-latitude regions of the northern Pacific and
205 Southern Ocean (Fig. 2b). Bioregion 3, centered at 30° in both hemispheres, appears as the most stable
206 bioregion.

207 A visual analysis of the temporal evolution of each bioregion's surface area (Fig. 3) reveals strong
208 interannual variabilities (time evolution of black dots) in all bioregions. Bioregions 1, 2, 3 and 6 also
209 display high decadal variability (black lines). Linear trend analysis ($p < 0.1$) indicates a significant
210 reduction in the global surface area of bioregion 3 and bioregion 4. Conversely, the mesotrophic
211 bioregion 1 shows a significant expansion. While surface areas of bioregions 6 and 7 exhibit large
212 changes from one year to the other, their surface area estimates are associated with large method
213 uncertainties (~50%), precluding the consideration of the trend significance.

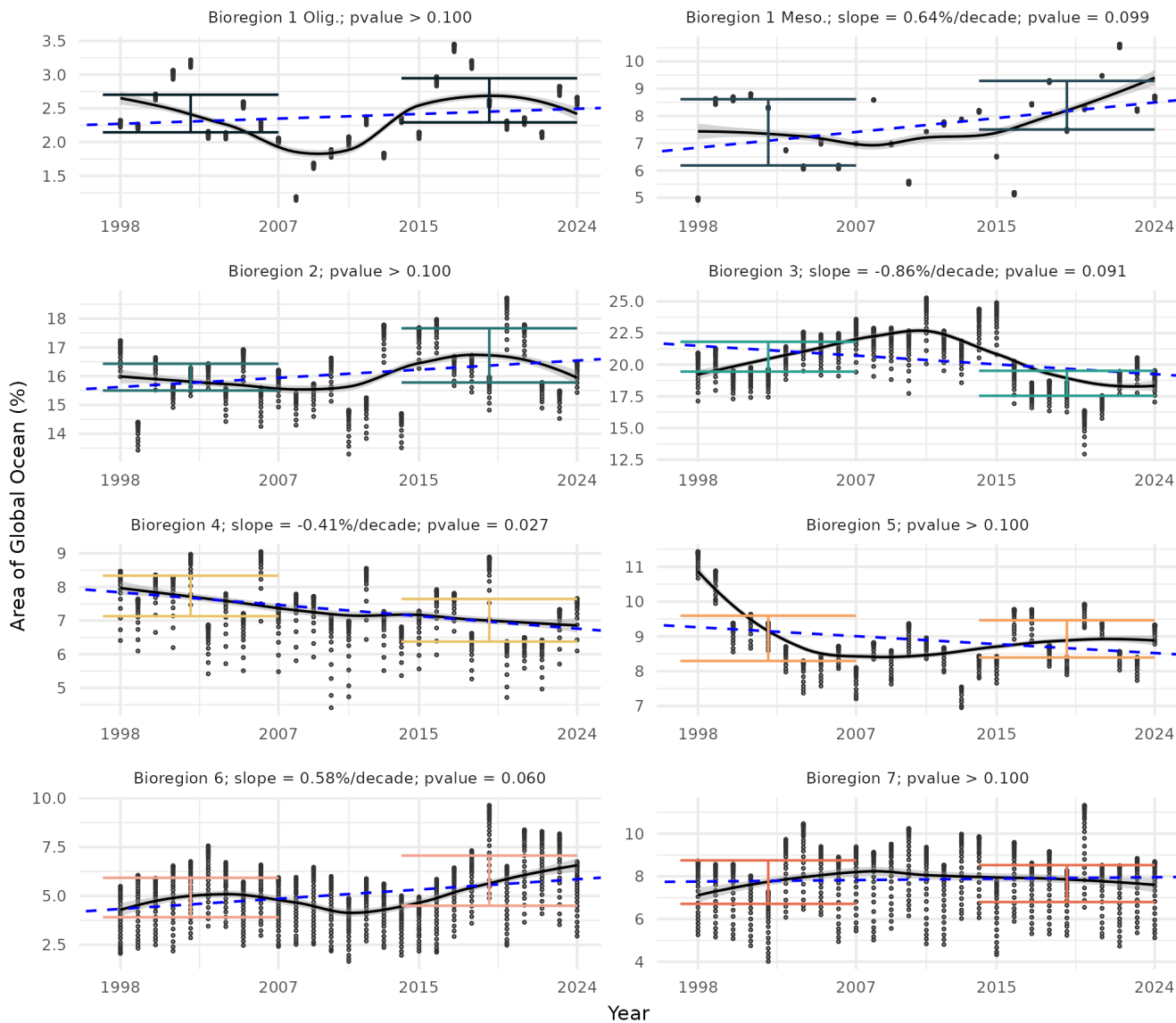
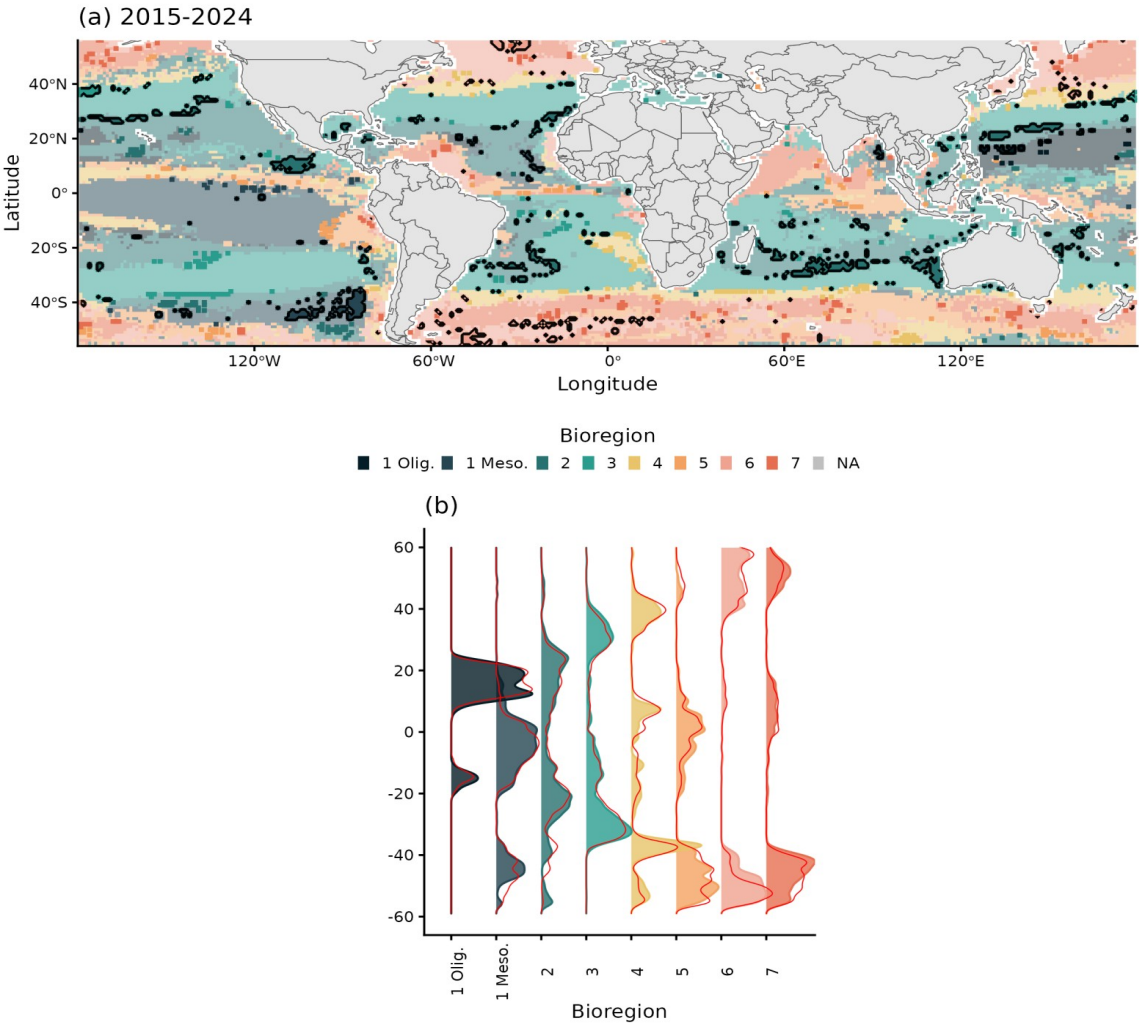


Figure 3 : Evolution of bioregions' surface area from 1998 to 2024. The time evolution of black dots represent estimates of the areas following the varying acceptance thresholds. The black trend line displays the smoothed centered 10-year rolling average, the blue dotted line corresponds to the linear tendency of the annual median area estimate. Panel's titles show the linear trends on the condition that it was found significant ($p < 0.1$). First and third quartiles of the decadal bioregions (1998-2007 and 2015-2024) are indicated as colored error bars. Note the varying y-scale across panels.



222

223 **Figure 4: (a) Bioregions in the 2015-2024 decadal period with stable changes identified by black contours. (b)**
224 **Latitudinal distribution of bioregions for the 2015-2024 decadal period (filled), compared with the 1998-2007**
225 **decadal period (red line).**

226 To isolate long-term trends from interannual variability, we identified areas with stable phenological
227 changes between the 1998–2007 and 2015–2024 decadal periods. As highlighted in Fig. 4a, these regions
228 are mostly located within the tropical and subtropical band. Overall 4.93% [4.56%, 5.06%] of the global
229 ocean is affected suggesting slow transitions in essentially steady conditions. The dominant pathways in
230 phenology transition are summarized in Table 2. The most prominent change (1.82% of the global ocean)

is the transition from bioregion 3 to the less seasonal bioregion 2, occurring primarily in the subtropical Pacific and Indian Oceans. Other significant shifts include the expansions at lower latitude of bioregion 1 at the expense of bioregion 2 (0.62%) and of bioregion 3 at the expense of bioregion 4 (0.27%). In the North Atlantic's temperate band, a notable net transition from bioregion 7 to 6 also occurred (0.09%). As summarized by Fig.4b, the most prominent trend is a poleward expansion of bioregions of weaker seasonality. These spatial patterns of change correspond to the surface area trends observed over the full time series (Fig. 3).

		Oceanic Basins					Total
		Indian Ocean	North Pacific Ocean	South Pacific Ocean	North Atlantic Ocean	South Atlantic Ocean	
Pathways of stable phenology changes	2 to 1 Olig.	-	0.12 % [0.12, 0.12]	0.01% [0.01, 0.01]	0.03 % [0.03, 0.03]	-	0.16 % [0.16, 0.16]
	2 to 1 Meso.	0.03 % [0.03, 0.03]	-	0.36 % [0.36, 0.36]	0.07% [0.07, 0.07]	-	0.46 % [0.46, 0.46]
	3 to 2	0.67% [0.66, 0.67]	0.55% [0.52, 0.55]	0.15 % [0.15, 0.15]	0.19 % [0.18, 0.19]	0.21 % [0.21, 0.21]	1.82 % [1.78, 1.83]
	4 to 3	0.01 % [0.01, 0.01]	0.16 % [0.14, 0.16]	0.02 % [0.01, 0.02]	0.02 % [0.02, 0.02]	0.06 % [0.06, 0.06]	0.27 % [0.24, 0.27]
	6 to 7	-	0.03 % [0.02, 0.06]	0.02 % [0.01, 0.02]	0.08 % [0.03, 0.10]	0.01 % [0.001, 0.10]	0.13 % [0.06, 0.19]
	7 to 6	0.01% [0.01, 0.01]	0.01% [0.01, 0.02]	-	0.17 % [0.13, 0.19]	0.23 % [0.19, 0.24]	0.43 % [0.33, 0.47]

Table 2: Major pathways among stable phenology changes. Changes in surface area from one bioregion to another are given relatively to the global ocean. Estimates are given within their first and third quartiles and grouped by oceanographic basins. Minor changes, associated with an area inferior to 0.01% of the global ocean, are not represented. Estimates highlighted in bold indicate values greater than 0.1 % of the global ocean.

4 Discussion and conclusion

Our analysis introduces a novel ocean indicator approach that distinguishes between intermittent, year-to-year variability and persistent, long-term shifts in phytoplankton phenology. While boundary regions exhibit frequent intermittent changes (Fig. 2b), our decadal analysis finds that nearly 5% (see Table 2) of the global ocean experienced a displacement of phytoplankton phenology suggesting persistent ecosystem reorganization over the past three decades. The cascading changes (i.e., transitions from bioregion 4 to 3, bioregion 3 to 2, and 2 to 1) identified above, are possibly driven by an intensification of

upper-ocean stratification in relation to climate warming (Capotondi *et al.*, 2012). At these low latitudes (30°S-30°N), a shallower vertical mixing prevents entrainment of deeper nutrients (Vereshchaka and Shatrabvin, 2025) therefore hindering biomass accumulation of surface waters (Sarmiento *et al.*, 2004; Polovina *et al.*, 2008). The robustness of our ocean indicator approach is further validated in the temperate North Atlantic, where despite high method uncertainties, the documented shift from a double to a single bloom phenology (bioregion 7 to 6) linked to delayed autumnal mixing in Martinez *et al.* (2011) is successfully captured. The documented changes also echo the variations of micronekton habitats provinces monitored from sea surface temperature, stratification index and net primary production evolution in Albernhe *et al.* (2025).

The proposed ocean monitoring approach is nevertheless subject to several limitations. First, satellite ocean color observations are sparse at high latitudes inducing increasing method uncertainties poleward and the exclusion of the subpolar and polar domains (above 60°). In these domains significant and rapid phenological changes are already documented (Kahru *et al.*, 2011; Thomalla *et al.*, 2023; Manizza *et al.*, 2023), with potential propagating effects on higher trophic levels (Fossheim *et al.*, 2015). Second, because satellites only measure the ocean surface, our analysis cannot capture changes in subsurface productivity patterns, such as the deepening of the deep chlorophyll maximum (Mignot *et al.* 2014, Cornec *et al.*, 2021). Finally, while the twenty seven year long time series is substantial, it remains challenging to definitively disentangle long-term climate-driven trends from the influence of natural decadal-scale climate modes (e.g., D'Ortenzio *et al.*, 2012; Zhai *et al.*, 2013; Li *et al.*, 2024).

Despite these limitations, the ocean indicator approach presented here provides a powerful and pragmatic tool to effectively map the locations of potential long-term ecosystem shifts. This makes it a crucial complement to established indicators, such as the ocean indicator method for chlorophyll-a concentration (10.48670/moi-00230). While such concentration-based indicators quantify how much biomass is present, our phenology-based approach reveals how the ecosystem's seasonal dynamics are unfolding. It can therefore detect critical shifts in ecosystem structure and function even when the total annual biomass remains unchanged. Furthermore, identifying long term trends in the distribution of chlorophyll-a concentration was shown to be dependent on the type of ocean color product (Zhai *et al.*, 2024, Pauthenet *et al.*, 2024). Investigating the presence and variability of the bioregions based on ESA's Ocean Color Climate Change Initiative (Sathyendranath *et al.*, 2019) would further consolidate (invalidate) the highlighted trends. In this paper, we mainly propose an approach, a proof-of-concept, that could be further applied to other ocean colors time-series

Future work could integrate Global ocean hindcast, to overcome the limitations of remotely sensed ocean color and extend monitoring to regions with poor satellite coverage (10.48670/moi-00019) and other four dimensional products (10.48670/moi-00046) to account for in-depth process. Earth system models can also help predict future states according to climatic projections (Yamaguchi *et al.*, 2022; Fisher *et al.*,

286 2025). The partitioning could also be refined by incorporating additional variables (e.g., the particulate
287 backscattering coefficient) to better delineate bioregions. However, the current method's simplicity
288 remains its main asset, ensuring a broad application range, ease of use, and making it an ideal candidate
289 for immediate operational implementation.

290 **Code and Data availability**

291 Ocean color data were collected from the OCEANCOLOUR_GLO_BGC_L4_MY_009_104 product, provided
292 by the Copernicus Marine Environment Monitoring Service (CMEMS, <http://marine.copernicus.eu/>).
293 Cluster centroids resulting from Baudena *et al.* (2025) were obtained directly from the author. Code is
294 available upon request from the corresponding author

295 **Author Contribution CRediT**

296 **WR:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Visualization,
297 Writing – Original Draft Preparation. **NM:** Conceptualization, Investigation, Methodology, Writing –
298 Original Draft Preparation, Visualization, Writing – Review & Editing. **AM:** Conceptualization, Formal
299 Analysis, Visualization, Writing – Review & Editing. **VT:** Conceptualization, Supervision, Writing – Review
300 & Editing. **FDO:** Conceptualization, Funding Acquisition, Supervision, Writing – Review & Editing.

301 **Competing Interests**

302 The authors declare that they have no known competing financial interests or personal relationships that
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