Ecosystem baseline assessment for an offshore carbon storage site in the North Sea

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Motivation & Objectives

Carbon capture coupled with offshore geological CO_2 storage (GCS) is vital for the UK's decarbonisation goals. The subsurface beneath the UK's shelf waters is rich in stable rock formations like saline aquifers and depleted oil fields –ideal locations for GCS. However, the UK government has not yet provided a comprehensive assessment of the North Sea's GCS capacity and associated environmental risks. Critical concerns involve potential releases of toxic brines and CO_2, which could detrimentally impact the marine ecosystem. Addressing these concerns requires establishing a robust ecological baseline assessment, providing a longer-term view of regional spatiotemporal variability, against which anomalies can be identified. Here, we present a baseline assessment of the ecological indicators of the pelagic ecosystem for the Endurance site —the first of 27 licensed GCS sites in UK waters[1] (**Fig. 1**). Our assessment of 'normal', baseline conditions focuses on phytoplankton phenology metrics, a strategic choice enabling cost-effective satellite monitoring and effectively capturing environmental signatures in the surface ocean ecosystem[2]. This poster showcases various aspects of our baseline assessment: satellite data validation (**Fig. 2**), ecosystem long-term dynamics (**Fig. 3**), 'blue' carbon stocks (**Fig. 4**) and correlation analysis of phenology metrics with potential drivers (**Fig. 5**).

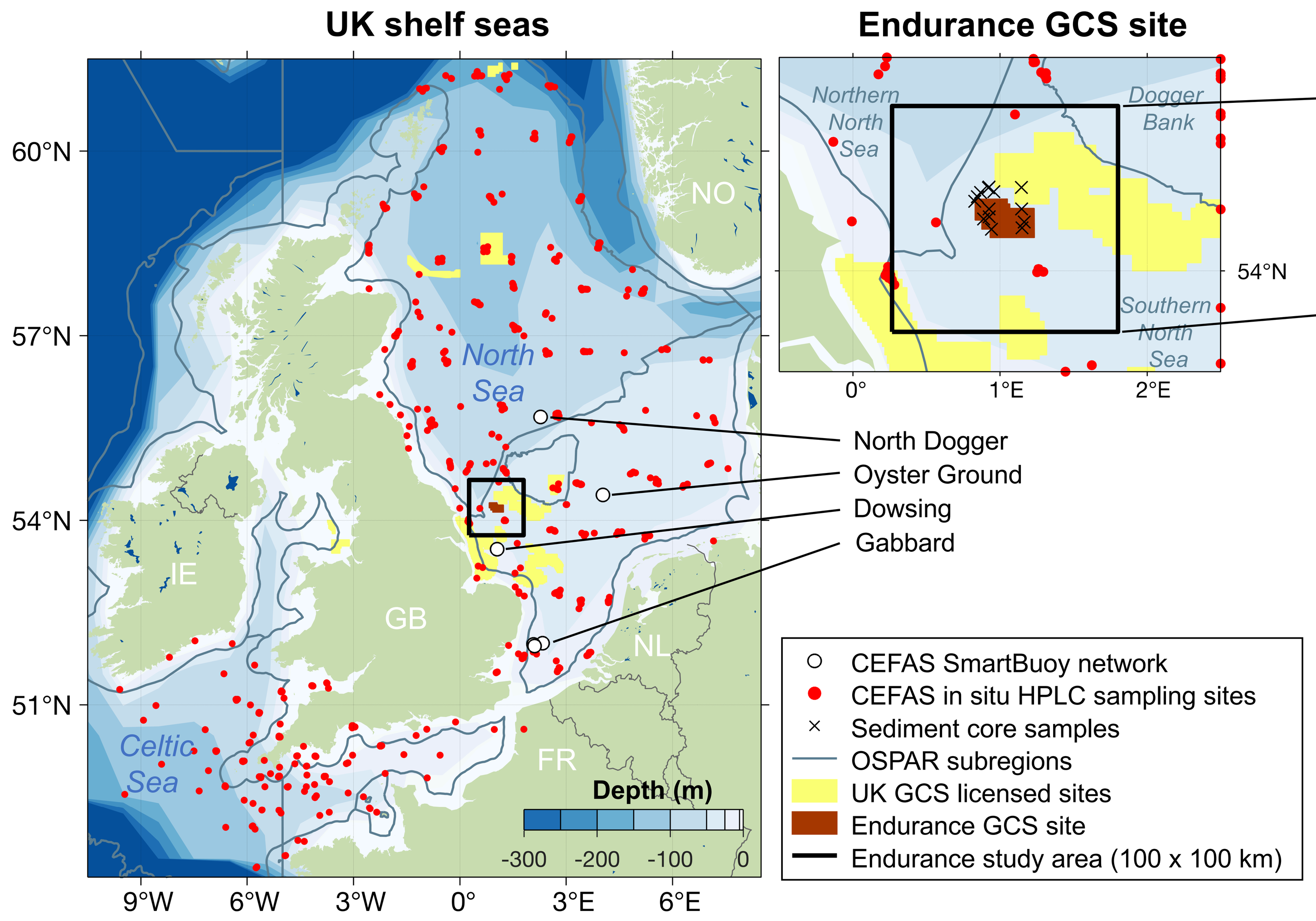


Figure 1. Map showing the location of UK's offshore capture and geological CO_2 storage (GCS) sites (yellow), the Endurance GCS site (brown), marine automated measuring buoys in the vicinity of the Endurance site operated by the UK environmental agency CEFAS (white circles), available *in situ* HPLC data (red scatters) and the boundaries of the 100 x 100 km area for which satellite observations of ocean colour have been obtained (square).

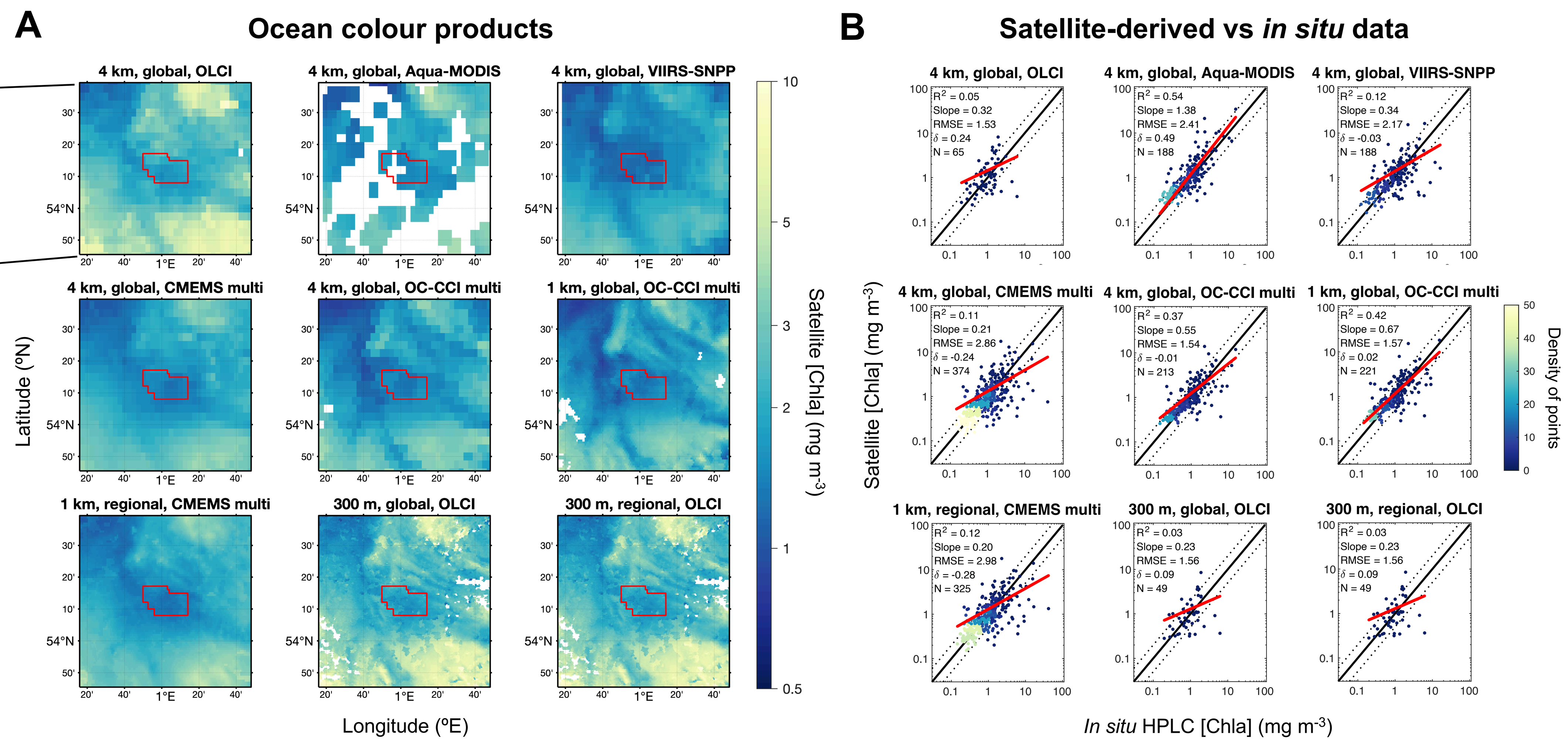
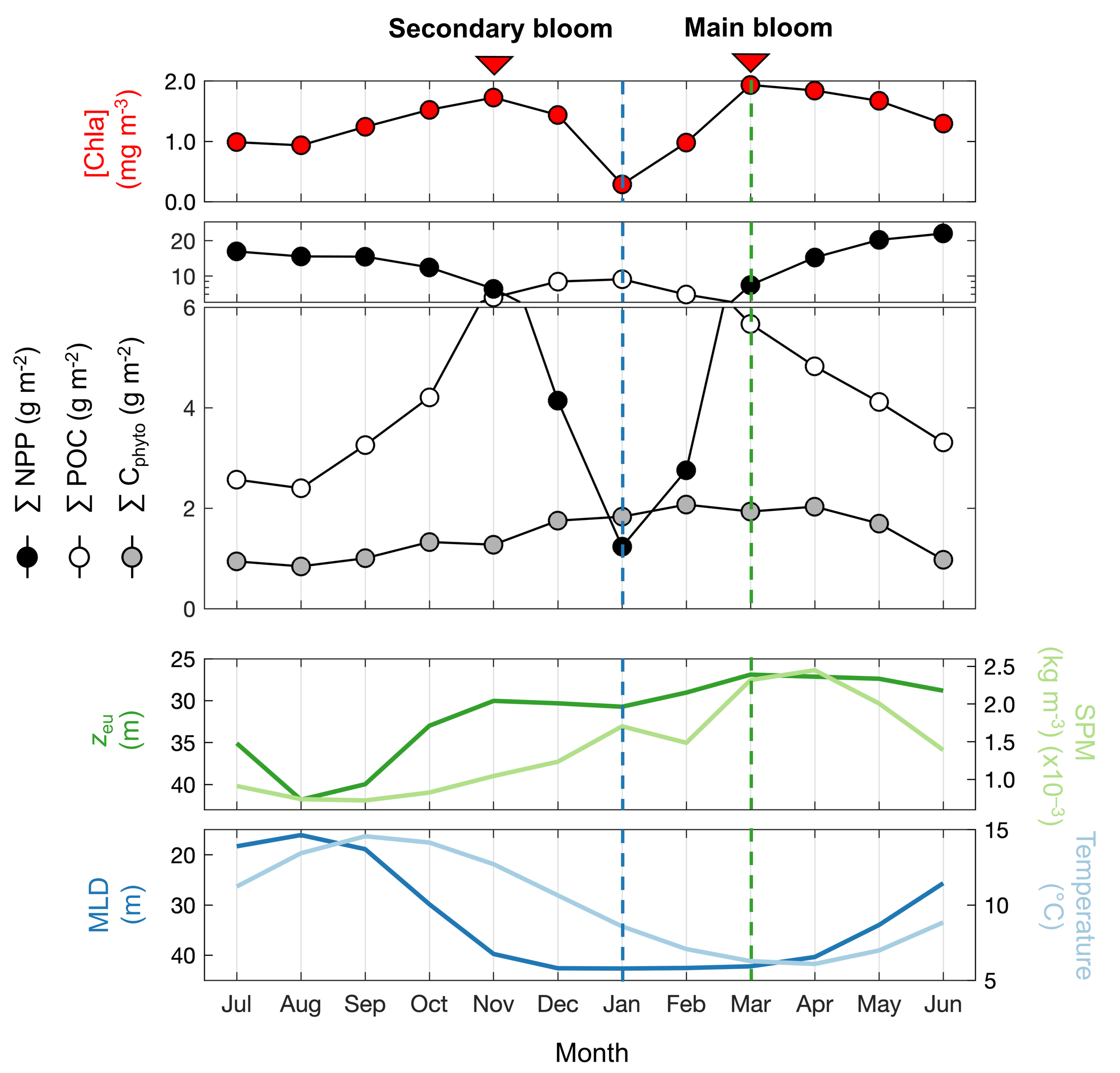
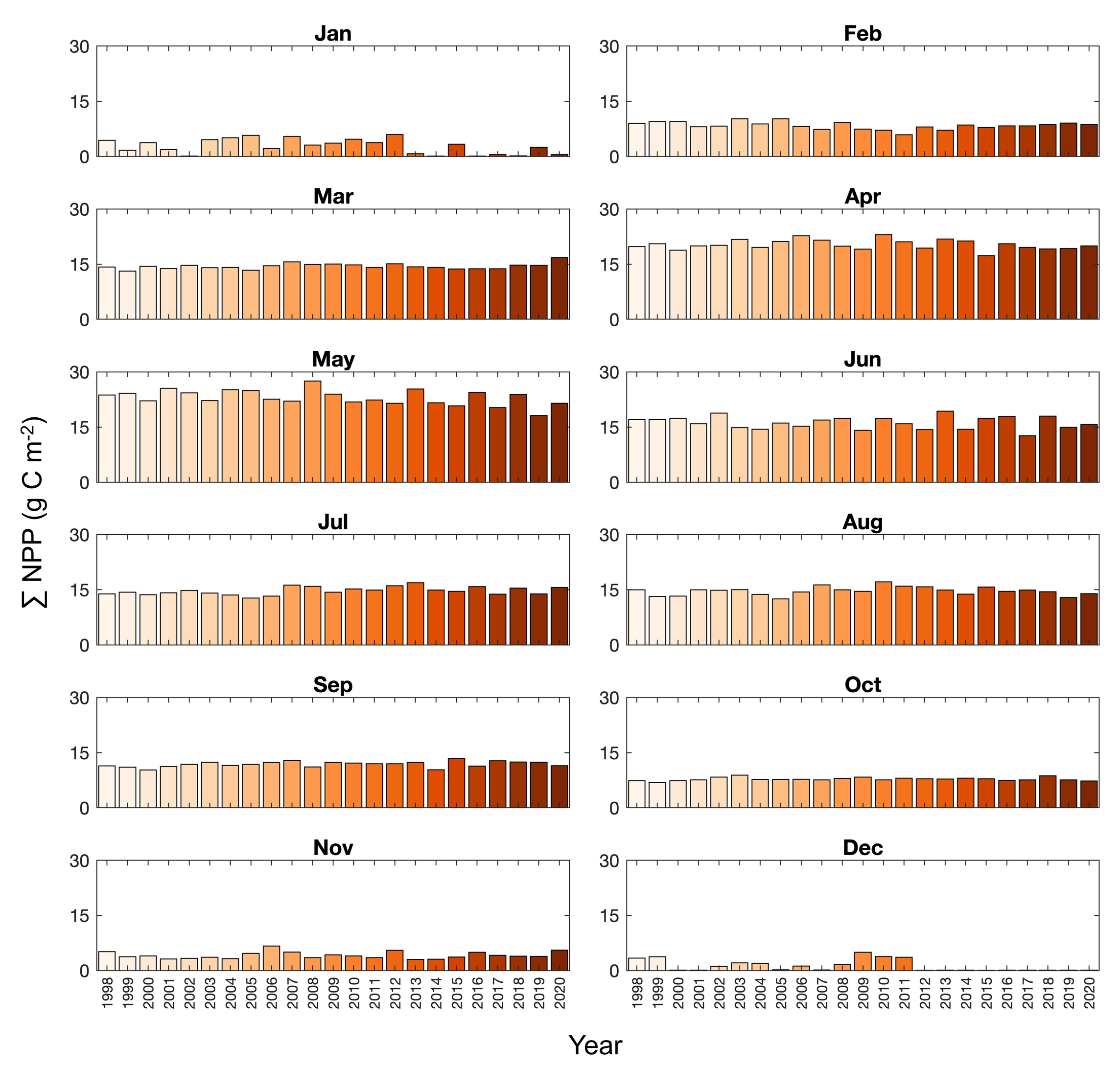


Figure 2. Validation matchup analysis of satellite-derived ocean colour (OC) products. (**A**) Seven-day composite images of chlorophyll *a* concentration [Chla] (1–7 April 2022) for nine Level-3 daily OC products. (**B**) Comparisons of these products with *in situ* [Chla] from CEFAS cruises, analysed using high performance liquid chromatography (HPLC). Solid black lines indicate a 1:1 relationship, scatter dots are colour-coded by matchup density. We show five matchup metrics: coefficient of determination (R^2), slope of the regression, root mean squared error (RMSE), bias (δ) and number of matchups (N). We had available a total of 674 *in situ* data points.

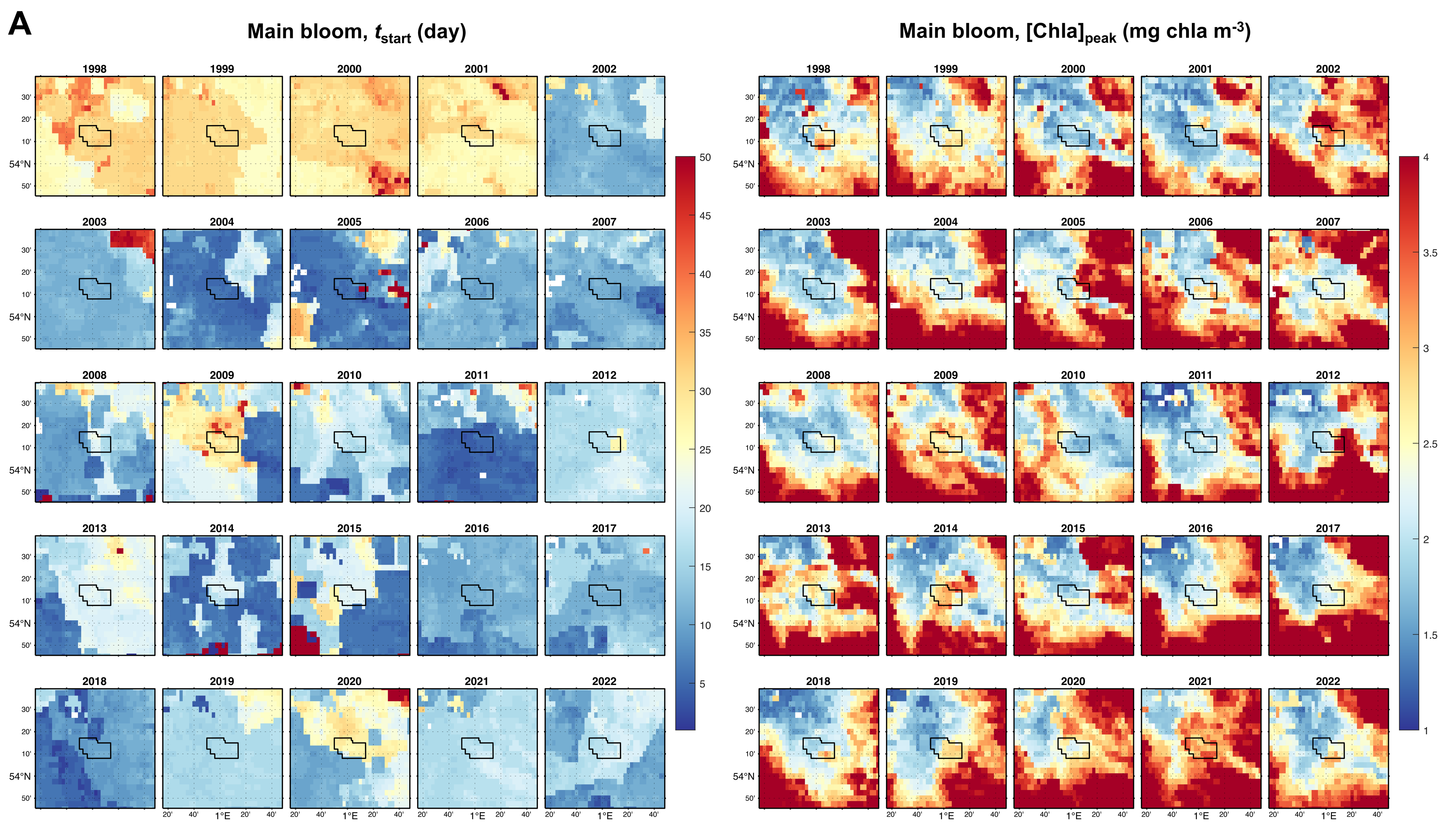


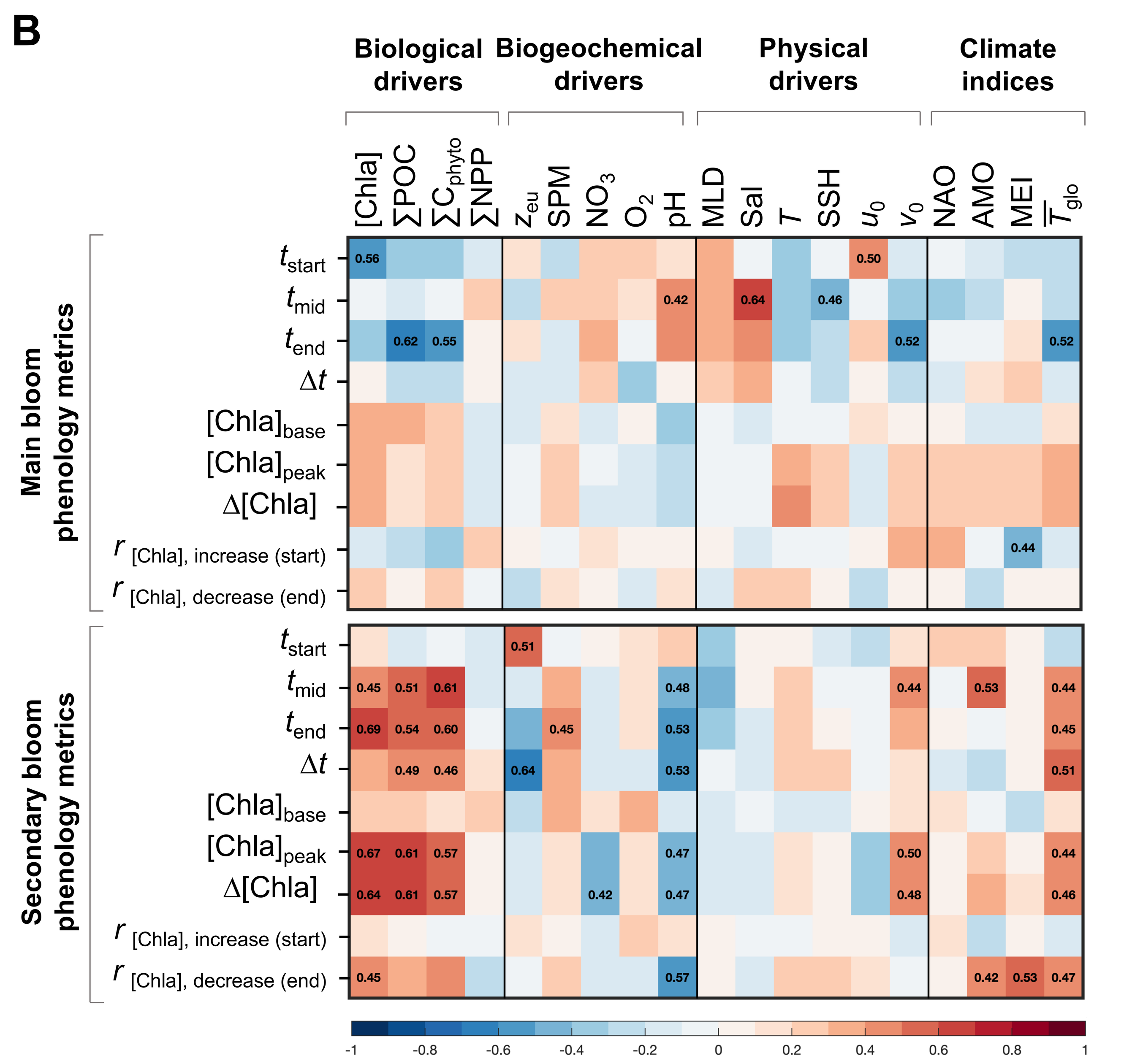


(*Left*) **Figure 3**. Satellite monthly mean (1998–2023) [Chla] from ESA's OC-CCI 4 km, global product (https://www.oceancolour.org) compared with three satellite-derived 'blue' carbon indicators from ESA's BICEP (https://bicep-project.org/Deliverables)[3]: depth-integrated carbon stocks of net primary production (NPP), particulate organic carbon (POC) and phytoplankton carbon (C_{phyto}). These four OC products presented alongside period means of environmental variables impacting satellite signal quality: euphotic layer depth (z_{eu}), suspended particulate matter concentration (SPM), mixed layer depth (MLD) and temperature, all obtained from the CMEMS regional model reanalysis product for the NW European Shelf (https://data.marine.copernicus.eu/products). Secondary and main phytoplankton blooms are highlighted, as well as their co-location with the max. MLD and min. z_{eu}.

(*Right*) **Figure 4.** Monthly stocks of net primary production (NPP) for the Endurance GCS area over the years, derived from ESA's BICEP project (scene averaged, depth-integrated and monthly integrated).

(*Bottom*) **Figure 5. (A)** Two phenology metrics for the Endurance GCS area over the years, focusing on the main bloom, calculated using TIMESAT[4] software. **(B)** Spearman's rank correlation coefficients between the annual mean of nine phenology metrics and potential drivers. Metrics are shown in red (positive correlation) or blue (negative correlation) and only statistically significant correlation coefficients (p < 0.05) are displayed. Metric abbreviations: t_{start}, bloom start day; t_{mid}, bloom mid-season day; t_{end}, blom end day; Δt, bloom duration; $[Chla]_{base}$, base level; $[Chla]_{peak}$, peak intensity; $\Delta[Chla]$ = amplitude of the bloom; $r_{[Chla],\ increase\ (start)}$, rate of increase at the start of the season; $r_{[Chla],\ decrease\ (end)}$, rate of decrease at the end of the season.





References

1 North Sea Transition Authority (2023). UKCS Carbon Storage Licenses (ED50), from https://arcq.is/0KOura.

2 Blackford, et al. (2021). Efficient Marine Environmental Characterisation to Support Monitoring of Geological CO_2 Storage. *Int J. Greenh. Gas Con.*, 109.

3 BICEP's products DOI: NPP (10.5285/69b2c9c6c4714517ba10dab3515e4ee6), C_{phyto} (10.5285/6a6ccbb8ef2645308a60dc47e9b8b5fb), POC (10.5285/5006f2c553cd4f26a6af0af2ee6d7c94).

4 Timesat – A program for analyzing time-series of satellite sensor data. *Comput. Geosci.*, 30.

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