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Key Points:

- Both regional and seasonal differences exist at the global scale in coastal dissolved organic carbon (DOC) concentrations
- Globally, salinity is the main driver of DOC concentrations and trends, while temperature has a regional impact
- We estimate that coastal waters globally contain between 2.62 and 3.57 Pg DOC (median: 3.15 Pg DOC)

Supporting Information:

Supporting Information may be found in the online version of this article.

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Dissolved Organic Carbon in Coastal Waters: Global Patterns, Stocks and Environmental Physical Controls

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Abstract Dissolved organic carbon (DOC) in coastal waters is integral to biogeochemical cycling, but global and regional drivers of DOC are still uncertain. In this study we explored spatial and temporal differences in DOC concentrations and stocks across the global coastal ocean, and how these relate to temperature and salinity. We estimated a global median coastal DOC stock of 3.15 Pg C (interquartile range (IQR) = 0.85 Pg C), with median DOC concentrations being 2.2 times higher than in open ocean surface waters. Globally and seasonally, salinity was the main driver of DOC with concentrations correlated negatively with salinity, without a clear relationship to temperature. DOC concentrations and stocks varied with region and season and this pattern is likely driven by riverine inputs of DOC and nutrients that stimulate coastal phytoplankton production.

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Temporally, high DOC concentrations occurred mainly in months with high freshwater input, with some exceptions such as in Eastern Boundary Current margins where peaks are related to primary production stimulated by nutrients upwelled from the adjacent ocean. No spatial trend between DOC and temperature was apparent, but many regions (19 out of 25) had aligned peaks of seasonal temperature and DOC, related to increased phytoplankton production and vertical stratification at high temperatures. Links of coastal DOC with salinity and temperature highlight the potential for anthropogenic impacts to alter coastal DOC concentration and composition, and thereby ecosystem status.

1. Introduction

Dissolved organic matter (DOM) is commonly defined as the organic matter capable of passing through a filter with a pore size between 0.2 and 0.7 μm (Lønborg et al., 2020). This pool encompasses a complex mixture of biochemical substances commonly subdivided into dissolved organic carbon (DOC), nitrogen (DON), phosphorus (DOP) and sulfur (DOS) pools, which all play roles in ocean biogeochemical cycles (Carlson & Hansell, 2015; Karl & Björkman, 2015; Ksionzek et al., 2016; Sipler & Bronk, 2015).

Globally, the marine DOC pool is estimated to contain around 662 Pg C (Hansell, 2013), accounting for up to 95% of the organic carbon in the ocean (Hedges, 2002). Most of this DOC is found in the open ocean due to its large volume; however, the concentration and reactivity of DOC is highest in coastal waters (Fichot et al., 2023; Lønborg et al., 2024). Coastal DOC concentrations are the result of multiple inputs (allochthonous and autochthonous), transformations, and losses. Allochthonous inputs to the coastal DOC pool are commonly derived from riverine discharge (Raymond & Spencer, 2015), hydro-meteorological events (e.g., storms; (Osburn et al., 2019)), submarine groundwater discharge (Goodridge, 2018), and atmospheric inputs (Jickells et al., 2013). Of these, the riverine input of DOC is the best quantified being between 0.3 and 0.7 Pg C yr^{-1} (Chaplot & Mutema, 2021; Liu et al., 2024) globally. Autochthonous DOC in coastal waters originates from phytoplankton and macrophyte primary production and exudation, bacterial degradation, physiological processes (e.g., excretion and egestion), sediment fluxes, and viral infections (Carlson & Hansell, 2015; Nagata, 2000). These organic compounds can be recycled and transformed by biotic and abiotic processes in coastal waters, which alter the quantity and composition of DOC. Planktonic microbes are the main biotic engine of marine biogeochemical cycling and the major consumers transforming DOC into energy and carbon dioxide (CO_2) or biotic particulate organic carbon (POC), whereby they can transfer energy to higher trophic levels (Carreira et al., 2021). During microbial DOC degradation, organic molecules are remineralized to their inorganic constituents as well as new labile and recalcitrant organic compounds (Chen et al., 2022; Koch et al., 2014; Lønborg & Álvarez-Salgado, 2012). Microbial DOC processing varies with the affinity of microbes for available substrates, but also with environmental factors, such as temperature and inorganic nutrient availability (Berggren et al., 2015; Lønborg, Álvarez-Salgado, et al., 2018). In coastal waters, photochemical transformation of DOC is also important for mineralization to CO_2 (Fichot & Benner, 2014; Miller & Zepp, 1995; Zhu et al., 2023), release of simpler products (Bushaw et al., 1996; Vähätalo & Wetzel, 2004), or formation of complex compounds (Berto et al., 2016; Carena et al., 2023; Kieber et al., 1997). DOC in coastal waters can be removed by flocculation, for example, in the freshwater-seawater interface of estuaries, or via adsorption to suspended particles and subsequent sinking (Asmala et al., 2014; Sholkovitz, 1976; Uher et al., 2001). Depending on the efficiency of removal by biotic and abiotic processes, part of the coastal DOC pool is transported by currents and mesoscale features (filaments, eddies) away from the shelf to adjacent open ocean regions (Alvarez-Salgado et al., 2007; Chaichana et al., 2019; Hung et al., 2003), where it either can be degraded or potentially persist several global ocean meridional overturns (Hansell & Orellana, 2021), thereby contributing to the continental shelf pump (i.e., transport of carbon from the coastal to the deep ocean) (Tsunogai et al., 1999). However, despite decades of research into the processes controlling the coastal DOC pool, a global perspective on potential drivers is still lacking.

Given the central role of DOC in coastal biogeochemistry and the spatial-temporal complexity in its production and degradation pathways, this study aims to (a) investigate regional and seasonal differences in coastal DOC concentrations and stocks around the globe and (b) determine how temperature and salinity drive DOC concentrations in coastal waters.

2. Methods

2.1. Data Compilation

We used the recently published CoastDOM v.1 database of global coastal DOM measurements (Lønborg et al., 2024), which consists of measured salinity, temperature, concentrations of dissolved organic carbon (DOC) and, where available, dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP). Additionally, other ancillary biogeochemical data, such as chlorophyll a or POC were frequently gathered. In this study we defined coastal waters as those between estuaries (salinity >0.1) and the continental shelf break (water depth <200 m). There are exceptions, such as coastal deep fjords (water depth >200 m), which are nonetheless included (Lønborg et al., 2024). These data were compiled from published studies based on a formal literature search but also included unpublished data submitted by research groups participating in the compilation effort. The data set contains more than 70,250 sampling points. Temperature and salinity were recorded for all samples, but the coverage of ancillary biogeochemical properties varied widely. DOC was measured in 89% of sampling points, whereas the coverage of variables such as dissolved inorganic carbon or total alkalinity was below 10%. Focusing on the sampling points with DOC concentrations, DON and DOP were only available for 18% and 10% of those samples, respectively. Chlorophyll *a* values were recorded at 30% of sampling points, but with variable spatial coverages. In addition, the number of sampling points with more than one parameter besides DOC is lower, limiting the performance of a multivariate global analysis. For these reasons, this study focused on the DOC pool.

The CoastDOM v.1 data set comprises DOC data obtained from 1978 to 2022, but just a small fraction of this data set (<2%) was collected before 1990. Given that this study aims at a global analysis, we restricted our analysis to data collected in the period from 1990 to 2022. Data were collected across a wide range of depths (0–1,300 m) but given the low number and sparseness of data at greater depth, we focused on shallow waters (i.*e*., <200 m; 99% of samples). Finally, after a first exploratory analysis of the data set, we found that DOC had a heavy right-tailed distribution, with some extremely high concentrations. After confirming that these concentrations were not located in a single area, we selected the 99th percentile of DOC (DOC = 870 μmol C L^{-1}) as a benchmark for outliers and restricted our analysis to data with DOC below this concentration. After these data selection procedures, our final data set for the statistical analysis comprises 46,075 DOC measurements collected in surface coastal waters (depth <10 m) since 1990.

The temperature and salinity data used in this study were collected and processed by many laboratories. These data have undergone internal quality control by the contributing laboratories and are routinely measured. Thus these data have a small associated errors relative to the range of values in the database, so we did not attempt further quality control. Nonetheless, DOC concentrations were measured over a long period by many research groups, inevitably leading to some methodological variation. The DOC concentrations were mostly determined using high-temperature catalytic oxidation (HTCO), but 18% of the samples were analyzed using wet-chemical digestion and/or UV digestion. Details of the methodology and quality control for DOC samples and this data set can be found in Álvarez-Salgado et al. (2023) and Lønborg et al. (2024), respectively.

2.2. Dividing Coastal Waters Into Segments

To characterize the spatial and temporal distributions of the variables and estimate DOC stocks at global and local scales, we followed the division of (Laruelle et al., 2013), in which coastal waters globally are divided into 8 major Continental Shelf Typologies (referred as shelves hereafter), which are further divided into 45 MARgin and CATchment Segmentation units (MARCATS) (Figure 1, Table 1 and Table S1 in Supporting Information S1). The 45 MARCATS segment regions (referred as segments hereafter) are then finally divided into 145 COastal Segmentation and related CATchment (COSCATS) segments (Figure S1, Table S1 in Supporting Information S1). The major Continental Shelf Typologies have well-defined thermal and/or geographical definitions for all segments except for the Marginal seas, which comprises coastal waters with a wide range of contrasting physical characteristics. Our database contains samples from 7 of the 8 major Continental Shelf Typologies, namely: EBC—eastern boundary current margins; WBC—western boundary current margins; Marginal seas—internal marginal seas; Monsoonal—margins under monsoonal influence; Polar margins; Subpolar margins; and Tropical margins. Our data did not include the "Endorheic Water" shelf typology, since these water bodies are landlocked without surface outlets and therefore, we do not consider this part of coastal waters. It should be noted that in our analysis two of the original COSCAT subsets were reassigned as described in the Supporting Information S1. Also, in the data set there is a particularly high number of data points in the EBC and Subpolar regions.

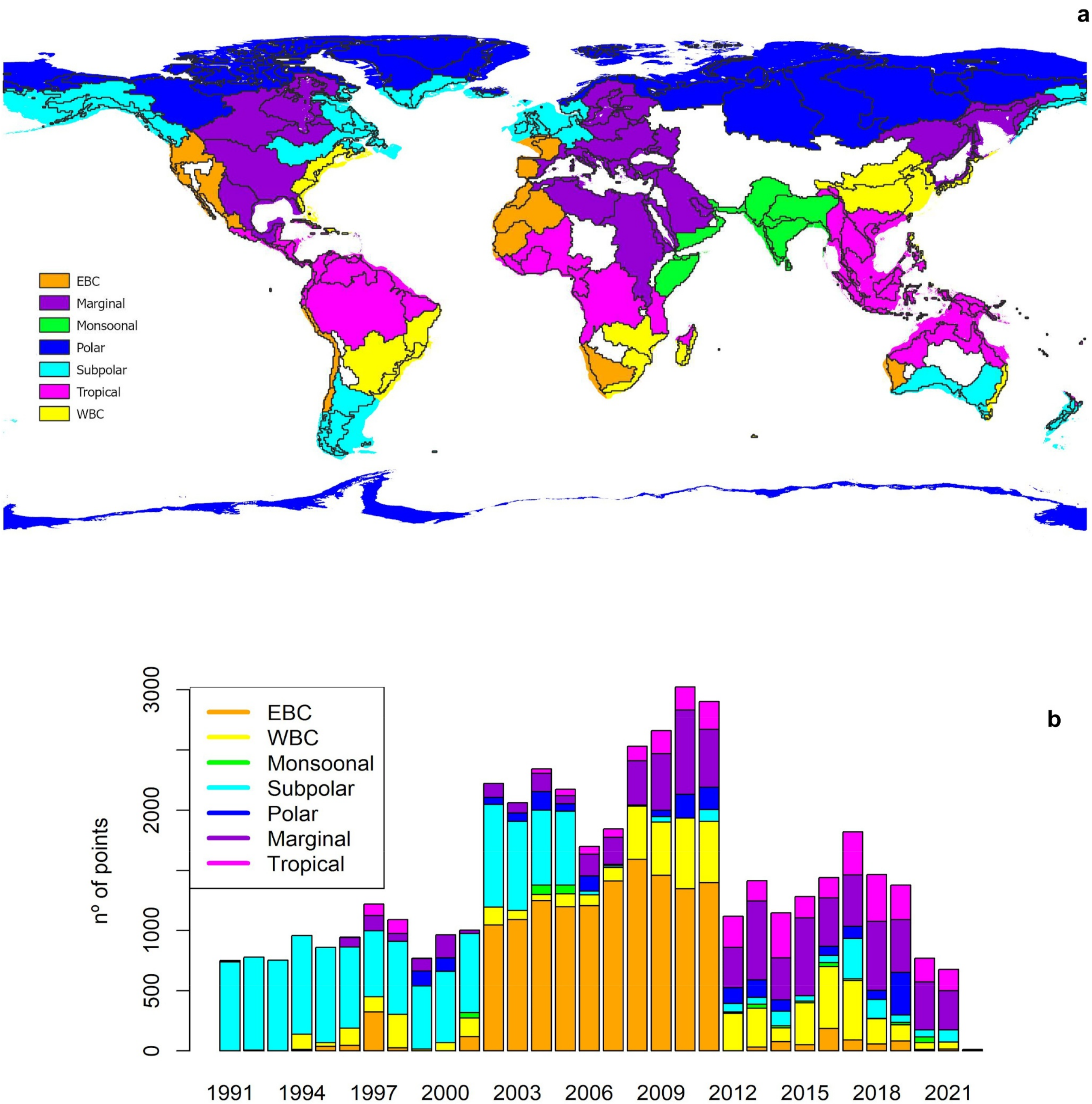

Figure 1. Showing (a) the distribution of the 45 MARgin and CATchments Segmentation (MARCATS) segments (Laruelle et al., 2013), which are divided into 7 major shelf typologies: Eastern boundary current margins (EBC), Western boundary current margins (WBC), Monsoonal, Subpolar, Polar, Marginal Sea and Tropical margins. Please note that some of the original segments were reassigned in this study, further details on this can be found in the methods section. (b) Shows the number of samples by year and segment.

There are likely several reasons for this. One could be that some of these areas are coastal waters of countries with high technical and economic resources (Carreira et al., 2024), as is the case for the North Sea. Another could be that some of these areas are of high interest and importance from a biogeochemical viewpoint, as is the case of the Iberian Peninsula, where upwelling is a known characteristic impacting the coastal DOM biogeochemistry (Álvarez-Salgado et al., 2001).

Table 1
List of MARgin and CATchement Segmentation Units (MARCATS), the MARCATS Regions and the Corresponding System Names

MARCAT segment	MARCAT region	System name
EBC	2-CAL	California Current
	4-HUM	Peruvian Upwelling Current
	19-IBE	Iberian Upwelling
	22-MOR	Moroccan Upwelling
	24-SWA	South-western Africa
	33-LEE	Leeuwin Current
WBC	6-BRA	Brazilian Current
	10-FLO	Florida Upwelling
	25-AGU	Agulhas Current
	35-EAC	Eastern Australian Current
	39-CSK	China Sea and Kuroshio
Monsoonal	27-WAS	Western Arabian Sea
	30-EAS	Eastern Arabian Sea
	31-BEN	Bay of Bengal
Subpolar	1-NEP	North-eastern Pacific
	5-SAM	South America
	11-LAB	Sea of Labrador
	15-SGR	Southern Greenland
	17-NEA	North-eastern Atlantic
	34-SAU	Southern Australia
	36-NWZ	New Zealand
	42-NWP	North-western Pacific
Polar	13-CAN	Canadian Archipelagos
	14-NGR	Northern Greenland
	16-NOR	Norwegian Basin
	43-SIB	Siberian Shelves
	44-BKS	Barents and Kara Seas
	45-ANT	Antarctic Shelves
Marginal	9-MEX	Gulf of Mexico
	12-HUD	Hudson Bay
	18-BAL	Baltic Sea
	20-MED	Mediterranean Sea
	21-BLA	Black Sea
	28-RED	Red Sea
	29-PER	Persian Gulf
	40-JAP	Sea of Japan
	41-OKH	Sea of Okhotsk
Tropical	3-TEP	Tropical Eastern Pacific
	7-TWA	Tropical Western Atlantic
	8-CAR	Caribbean Sea
	23-TEA	Tropical Eastern Atlantic
	26-TWI	Tropical Western Indian
	32-TEI	Tropical Eastern Indian
	37-NAU	Northern Australia
	38-SEA	South–East Asia

2.3. Calculation of Global Dissolved Organic Carbon Stocks

In upscaling our data and calculating DOC stocks in each MARCATS segments, in order to avoid the influence of single very high concentrations, we first used the 99th percentile of DOC concentrations down to 200 m water depth (Table S2 in Supporting Information S1). Therefore, we did not restrict our calculation to shallower depths (<10 m) as for the statistical analysis. In order to extrapolate the DOC data to missing MARCATS regions, we applied the composite area-weighted average of other MARCATS of the same shelf typology as also done previously for global coastal CO_2 fluxes (Dai et al., 2022). Our DOC data set was dominated by surface samples (Figure S2 in Supporting Information S1) which naturally have higher concentrations than those found in deeper waters. Therefore in order to provide a likely upper and lower limit and associated uncertainties of the calculated DOC stocks we used four different approaches to calculate these in each MARCATS segment: (a) DOC stocks were calculated using median instead of mean values, as the former are less affected by extreme values; (b) DOC stocks were estimated using median values after excluding the highest and lowest 25% of DOC concentrations from the entire data set (referred to as "25% cut-off total"), and then dividing the data set into the MARCATS; (c) DOC stocks were estimated using median values, with the data set divided into the MARCATS, and then excluding the highest and lowest 25% of DOC concentrations (referred to as "25% cut-off shelf"); and (d) depth-integrated DOC median concentrations were used. For our global DOC stock estimate we included water depths <200 m which resulted in a total of 59,203 DOC measurements (1% trimmed) included in calculation for method 1, 29,588 for method 2, 29,330 for method 3 and 59,203 for method 4. Once we had those median DOC concentrations in each MARCATS segment and the shelf volumes, we calculated the total DOC stocks per MARCATS segment, shelf typology, and globally, by multiplying these concentrations by the shelf water volume. In these calculations, it should be noted that shelf volumes were recalculated to water depths <200 m (using information provided in Laruelle et al. (2013)), and accounting for the previous errors and above-mentioned changes to the original assignments. Determining an error associated with the shelf volumes used in our calculation of the DOC stock is challenging since the size and volume and associated errors of different shelves will vary depending on the physical boundaries chosen (e.g., outer shelf limit defined by a varying shelf break depth vs. a fixed isobath of 200 m). However, comparing four fairly well studied MARCATS units (the North Sea, Baltic Sea, Hudson Bay and Persian Gulf) with other published surface and volume values for the same regions suggests an approximate relative error of 2.5% for surface areas and 8% for volumes (G. G. Laruelle pers. Comm).

2.4. Statistical Analysis

We provide an analysis of DOC in coastal waters globally using the MARCATS detailed above, with a descriptive analysis of the variables (temperature, salinity, and DOC) at segment and shelf levels. This descriptive analysis includes summary statistics and an estimate of the distribution of each variable. The latter was obtained by kernel density estimation with 2-stages plug-in bandwidth (Sheather & Jones, 1991; Silverman, 2018). The descriptive measures reported include mean, median, variance and the interquartile range (IQR). The IQR was calculated as the difference in the upper (under which 75% of data points are found) and lower (under which 25% of the data is found) quartile values of the data set and thereby provides a measure of the data spread.

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Table 2
The Number of Samples (N), Period Where Samples Were Collected, Mean, Median, and Interquartile Range (IQR) for Temperature (°C), Salinity and Dissolved Organic Carbon (DOC in μmol C L^{-1}) in the 7 MARgin and CATchments Segmentation (MARCATS) Shelf Typologies: EBC, Eastern Boundary Current Margins; WBC, Western Boundary Current Margins; Monsoonal, Margins Under Monsoonal Influence, Subpolar Margins; Polar Margins, Marginal Seas, Internal Marginal Seas, and Tropical Margins

		Period		Temperature (°C)			Salinity			DOC (μmol C L^{-1})		
MARCATS	N	Start year	End year	Mean	Median	IQR	Mean	Median	IQR	Mean	Median	IQR
EBC	14,165	1994	2021	15.5	15.2	3.7	33.8	35.0	1.8	95	91	22
WBC	6,079	1992	2021	19.9	20.9	10.9	24.5	30.4	18.5	228	130	207
Monsoonal	397	2001	2020	29.4	29.3	3.1	22.2	25.9	17.1	236	208	125
Subpolar	11,573	1991	2022	12.0	12.2	9.5	27.4	30.3	8.8	203	159	134
Polar	2151	1991	2019	3.5	2.1	4.5	25.4	30.8	12.9	176	80	189
Marginal	7,987	1994	2021	12.9	12.8	12.1	15.4	7.1	31.6	295	325	246
Tropical	3,723	1996	2021	26.7	27.3	4.7	31.4	34.2	3.5	116	83	38

Note. A more detailed statistical summary is provided in Table S4 of Supporting Information S1.

We estimated the seasonal patterns of the target variables for regions with sufficient seasonal resolution (see below). For this purpose, we applied a generalized additive model (GAM) (Wood, 2017) with circular cubic splines using month as an explanatory variable; we used the Gaussian distribution family ("gaussian") for temperature; while we used the scaled *t* family ("scat") distribution for salinity and DOC due to the heavy-tailed distribution. The goodness-of-fit of each estimate was evaluated by the deviance explained and adjusted R^2. The criteria for including data in the seasonal analysis were:

- The region should have at least 1 year of data with monthly sampling.
- For each region, only the years with monthly samplings were included.
- Differences between regions within segments were tested, when applicable (see Figures S3–S8 in Supporting Information S1 and associated text in the Supporting Information S1 for further details).

To estimate the relationship between salinity and temperature with DOC concentrations, we first applied the nonparametric regression test (Bowman & Azzalini, 1997). When significant relationships were found ($p < 0.05$), we fitted them using GAM fits with a scat family to deal with the heavy-tailed distribution of DOC, and low-rank tensor product splines to model interactions between the explanatory variables (Wood, 2017). Statistical analyses were conducted using the statistical Software R.4.1.3 (R Core Team, 2022); the "sm" package (Bowman & Azzalini, 2021) was used to conduct the regression test; the "mgcv" package (Wood, 2017) was used for GAM fits; and the "forecast" (Hyndman & Athanasopoulos, 2018) and "npsp" (Fernandez-Casal & Fernandez-Casal, 2016) packages were used to model the spatial and temporal structure of residuals when required.

3. Results

The location of sampling points in the different shelves and MARCATS segments, and number of datapoints by segment and period are shown in Figure 1 and Table 2 and Table S3 of Supporting Information S1. Please note that a detailed description of the data used in this study is provided in the Figures S3–S8 of Supporting Information S1. The number of datapoints varied widely over time and between coastal regions (Figure 1). As examples, in the EBC and Subpolar shelves, the greatest number of measurements (>90%) were collected in the Iberian Upwelling Current (19-IBE) and the North–East Atlantic (17-NEA) segments respectively. In contrast, some segments in the Polar, Tropical and mainly Monsoonal shelves were underrepresented (Figure 1 and Table 2).

3.1. Geographical Patterns and Seasonal Variability

Table 2 provides a summary description of temperature, salinity, and DOC for the MARCATS to provide a global perspective on the common conditions found in the coastal waters studied (see Table S4 in Supporting

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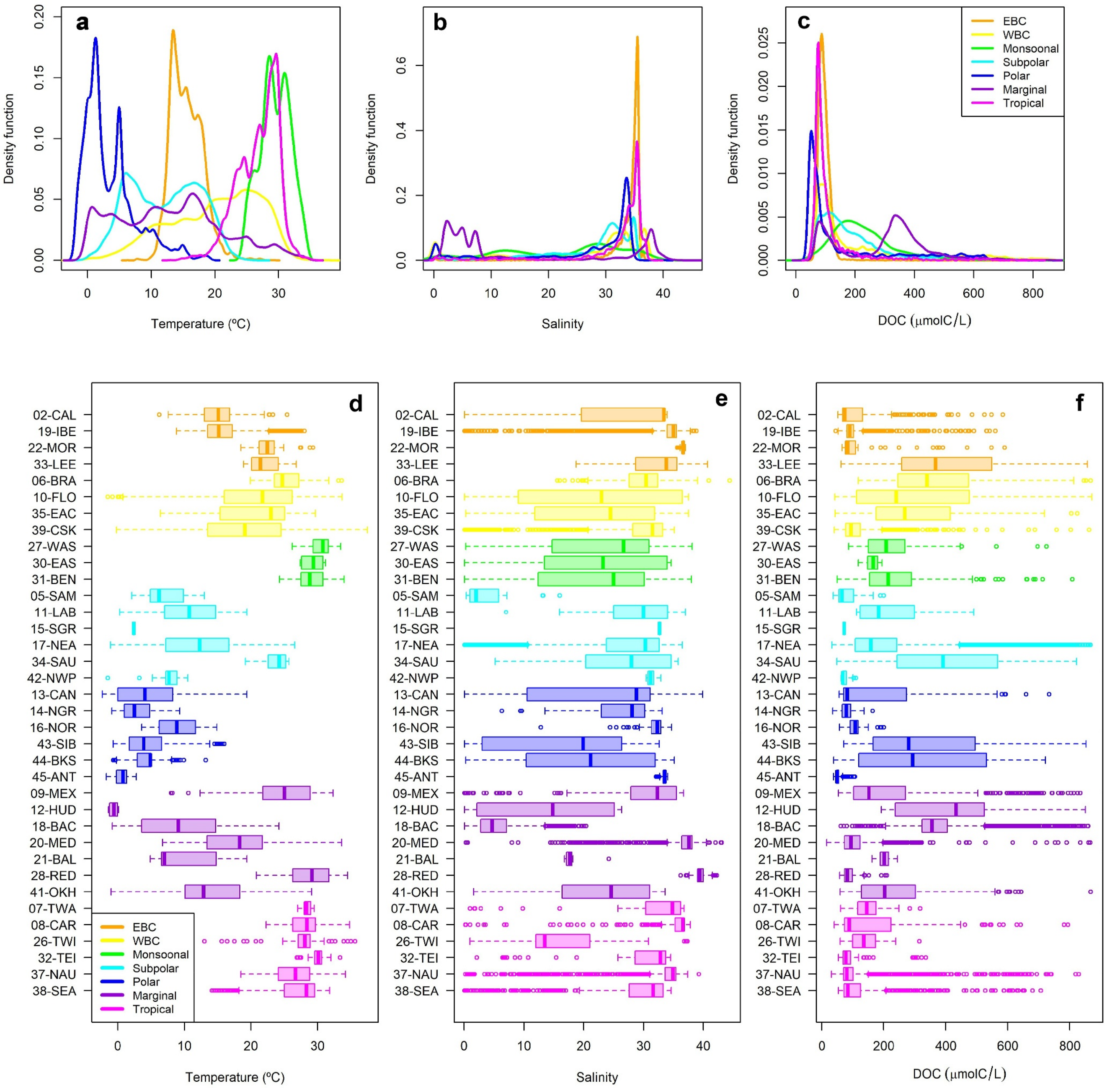

Figure 2. Distribution of temperature (°C), salinity, and dissolved organic carbon (DOC in µmol C L^{-1}) concentrations among shelf types and regions. Top graph (a, b, and c) shows the kernel density estimators of the distribution of temperatures, salinity, and DOC concentrations for the MARgin and CATchments Segmentation (MARCATS) shelf typologies: Eastern boundary current margins (EBC), Western boundary current margins (WBC), Monsoonal, Subpolar, Polar, Marginal Sea and Tropical margins. The bottom box-and-whiskers plots (d, e, and f) show temperatures, salinity, and DOC concentrations by shelf and region. Boxes include the 1st to 3rd quantile range, the solid line is the median, and the whiskers indicate data included within 1.5IQR distance of each quantile. Please see Table 1 for the name of each region mentioned in the label of the box-and-whiskers plots.

Information S1 for a summary statistic at MARCATS segment level) and Figure 2 shows the distribution of the target variables along the segments.

As expected, the highest median annual temperatures were recorded close to the Equator in the Monsoonal (29.3°C) and Tropical (27.3°C) shelves, while the Polar shelf (2.1°C) had the lowest temperatures. These shelves also showed lower variability (IQR < 5°C; Table 2). Overall, there were small differences between segments within each shelf (Figure 2), with the exception of the Marginal seas, where the median temperatures of

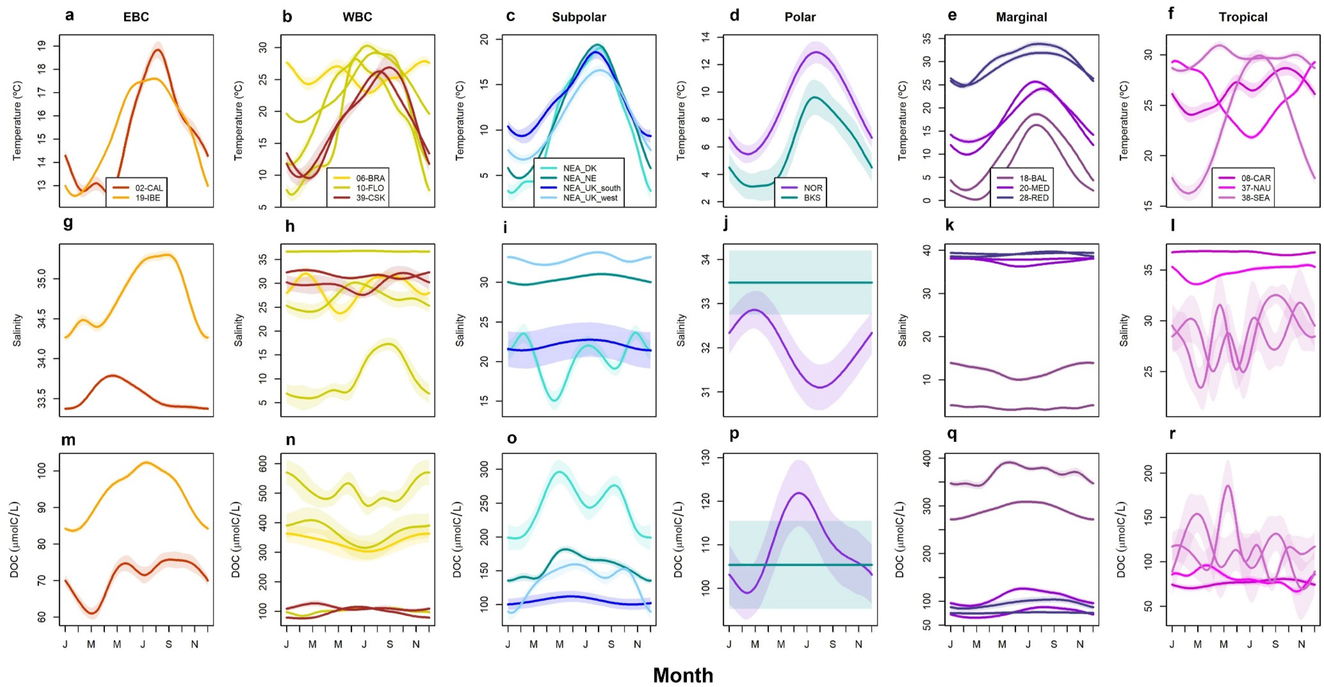

Figure 3. Fitted seasonal trends of temperature (°C) (a–f), salinity (g–l) and dissolved organic carbon (DOC in μmol C L^{-1}) concentrations (m–r) for regions within the 6 MARgin and CATchments Segmentation (MARCATS) shelf typologies (EBC, Eastern boundary current margins; WBC, Western boundary current margins; Subpolar margins; Polar margins; Marginal Sea, internal marginal seas; and Tropical margins). Lines in each graph represent the seasonal trend in temperature, salinity and DOC using a generalized additive model (GAM) fit with shaded areas defining 95% confidence intervals of those trends. Please note the difference in scale of the *y*-axis and that segments were divided into subregions due to differences in the annual trends (i.e., several lines are visible per segment; see text for further details).

MARCATS segments range from −0.6°C in the Hudson Bay to 29°C in the Red Sea (Figure 2 and Table S4 in Supporting Information S1).

Salinity had a heavy left-tailed distribution in most segments, with medians close to 30.5 in the WBC, Subpolar and Polar shelves, and values reaching around 34–35 in the EBC and Tropical shelves, with minimum values close to 0 in most shelves (Figure 2, Table 2 and Table S4 in Supporting Information S1). Salinity also showed high variability in the Marginal seas (IQR = 31.6) where it had a bimodal distribution due to the high variability between segments, with median salinities ranging from 4.7 in the Baltic Sea to 37.9 and 39.4 in the Mediterranean and Red Seas. We also observe large variability in the WBC (IQR = 18.5), which in this case reflects large salinity ranges within segments (Figure 2 and Table 2 and Table S4 in Supporting Information S1). In contrast, EBC (IQR = 1.8) and Tropical shelves reported low variability in salinity (IQR = 3.5).

The DOC concentrations had a heavy right-tailed distribution (Figure 2), with high median concentration in the Marginal seas (325 μmol C L^{-1}) and lowest concentrations in the Polar (80 μmol C L^{-1}), Tropical (83 μmol C L^{-1}) and EBC (91 μmol C L^{-1}) shelves (Figure 2). As observed for salinity, DOC had large variability in Marginal seas (IQR = 246 μmol C L^{-1}), which had a bimodal distribution accounting for differences between segments, with the DOC concentrations ranging from 83 to 95 μmol C L^{-1} in the Red and Mediterranean Seas to 356 and 433 μmol C L^{-1} in the Baltic Sea and Hudson Bay. The large variability observed in the WBC (IQR = 207 μmol C L^{-1}) accounts for internal variability within segments (Figures 2 and 3).

3.2. Seasonal Trends of Dissolved Organic Carbon

Following the selection criteria detailed in Section 2.4, we fitted the annual cycles of temperature, salinity and DOC concentrations, except in the Monsoonal shelf, which had very few data points. Therefore, the seasonal analysis was only conducted in areas with high seasonal coverage and overall, in areas with large data coverage (e.g., IBE, NEA_NE) there was a clear seasonal pattern for temperature while this was weaker for salinity (Table S5 in Supporting Information S1). Considering the large variability observed in temperature, salinity and DOC concentrations and the geographical dispersion of the sampling points within some MARCATS, we divided these

MARCATS into regions in case of large internal variability (see details in Figures S3–S8 of Supporting Information S1).

The results of the seasonal GAM fits for each region for temperature, salinity, and DOC concentrations are presented in Figure 3, and Table S5 of Supporting Information S1. Significant seasonality was observed in most cases, with GAM fits explaining between 32% and 95% of the variability in temperature, 1%–81% of the variability in salinity, and 1%–60% of the variability in DOC concentrations (Table S5 in Supporting Information S1). Temperature (Figure 3 top) generally had maximum values in summer (July/August in the northern hemisphere and December/January in the southern hemisphere) and minima in winter (February/March in the northern hemisphere and July/August in the southern hemisphere), although the seasonal pattern was more irregular in two tropical segments, 38-SEA and 8-CAR, where the annual temperature range was small (<5°C).

Salinity (Figure 3 center) generally had low seasonal variability (salinity annual amplitude <2, Table S5 in Supporting Information S1) for most of the segments (17 of 25 segments), and the majority of the shelf typologies, including EBC, Subpolar, Polar, Marginal seas, and two Tropical segments. However, more than half of the segments in WBC presented wider annual amplitudes in salinity (4 of 6 segments). Other clear exceptions were the following segments: NEA_DK in the Subpolar shelf, BAL_DE in the Marginal seas, and the two Tropical regions in Southeast Asia (SEA_north and SEA_south), where salinity varied significantly with season, but with different patterns. It should be noted that in this study we cannot directly determine if the different seasonal patterns in salinity are due to for example, changing river flow or other processes.

The GAM fits detected seasonal variability in DOC concentrations in all shelves except one WBC segment (FLO_SAB), one tropical segment (RED_Reef), and a Polar segment (BKS) (Figure 3, Table S5 in Supporting Information S1). In most cases, two distinct seasonal patterns were observed (Figure 3). The less common DOC seasonal pattern had two peaks synchronised with the salinity minimum in the Tropical Southeast Asia region (SEA_north and SEA_south), one Subpolar area (NEA_DK in the Northeast Atlantic) and one WBC area (FLO_MAB). In these areas DOC was thus inversely related to salinity across the annual cycle, likely reflecting differences in riverine inputs. The most common seasonal DOC pattern consists of an annual cycle with a maximum and a minimum, but with differences between segments in the timing of the maximum and minimum concentrations. This seasonal pattern was evident in the two EBC regions (CAL and IBE), in 3 of the 4 Subpolar regions (NEA_NE, UK_south, UK_west), in one Polar region (NOR), in four of the six Marginal segments (BAL-DE and BAL-DK, MED_Adiatic and MED_Blanes, and RED_Harbor), and in the Brazilian (BRA) and Caribbean (CAR) Tropical segments. Maximum DOC concentrations were present in summer (between mid-May and mid-August in the Northern and during December–January in the Southern Hemisphere), while minimum concentrations were found in winter (January–February in the Northern, and June–July in the Southern Hemisphere) coinciding with the highest and lowest seasonal temperatures, respectively.

3.3. Environmental Physical Controls of Dissolved Organic Carbon

As detailed in Section 2.4, we tested the effect of temperature and salinity on DOC concentrations and estimated GAM fits when significant relationships were found in regions with sufficient data coverage. Figures 4 and 5 and Table S6 in Supporting Information S1 provide a summary of the fitted GAM models for all the MARCATS segments, regions and subregions under study.

In the EBC, WBC, Subpolar, and Marginal seas, both temperature and salinity had a significant effect on DOC variability (regression test, p-value < 0.005). In the Subpolar Northeastern Atlantic (17-NEA) we found a significant contribution of both physical parameters in all areas except the Western United Kingdom coast (NEA_UK_west; p-value $= 0.98$), where significant interactions between the effects of temperature and salinity were found (Figures 4 and 5). Within the Polar segment, we found a significant correlation between DOC and salinity (p-value < 0.001) but no evidence of significant correlation with temperature (p-value > 0.01) were found in the Arctic Polar regions (16-NOR and 44-BKS). In contrast, temperature had a significant correlation with DOC (p-value < 0.0001) in the Antarctic coast (45-ANT), while no significant correlation between salinity and DOC were found (p-value $= 0.35$). In the Tropical shelf, significant correlations of DOC with temperature and salinity (p-value < 0.05) were found in all regions except for the Caribbean Sea (08-CAR), where no significant correlation between DOC and salinity was found (p-value $= 0.34$). We found interactions between salinity and temperature, that is, the relationship between salinity and DOC varied with temperature and vice-versa, in all

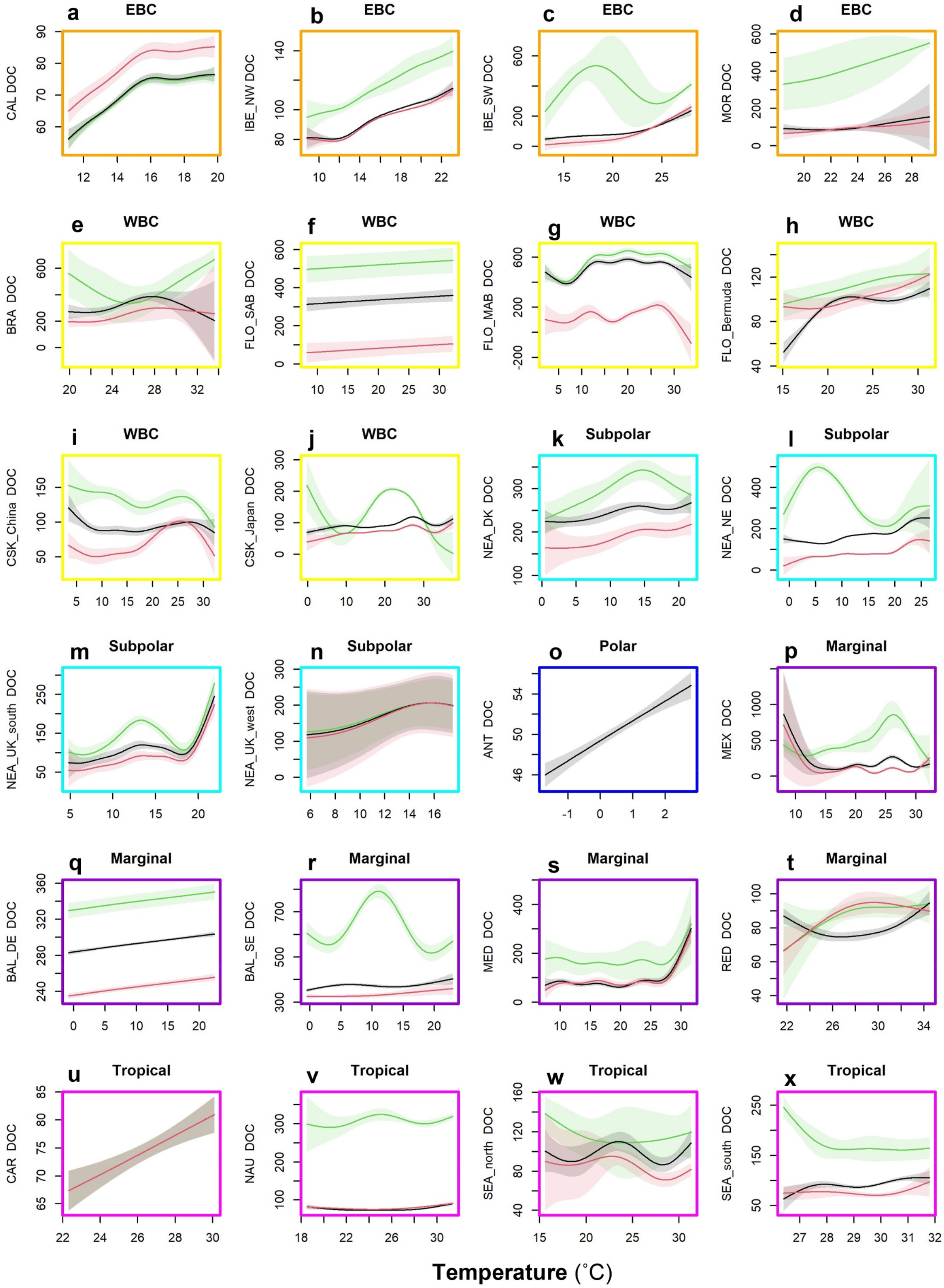

Figure 4. Estimated dissolved organic carbon (DOC) concentrations (in μmol C L^{-1}) as a function of low (2.5th percentile (P2.5), green), median (black) and high (97.5th percentile (P97.5), red) temperature (°C) for all regions in the six segments under study: (a–d), EBC; (e–i), WBC; (j–n), Subpolar; (o–p), Polar; (q–u), marginal; and (v–x) tropical (see temperature percentile values in Table S4 of Supporting Information S1). Please note: no significant contribution of temperature was detected in the two Arctic Polar regions and difference in scale of the axis values. See Table 1 for names of the regions and please note that some regions were divided into subregions due to differences in trends.

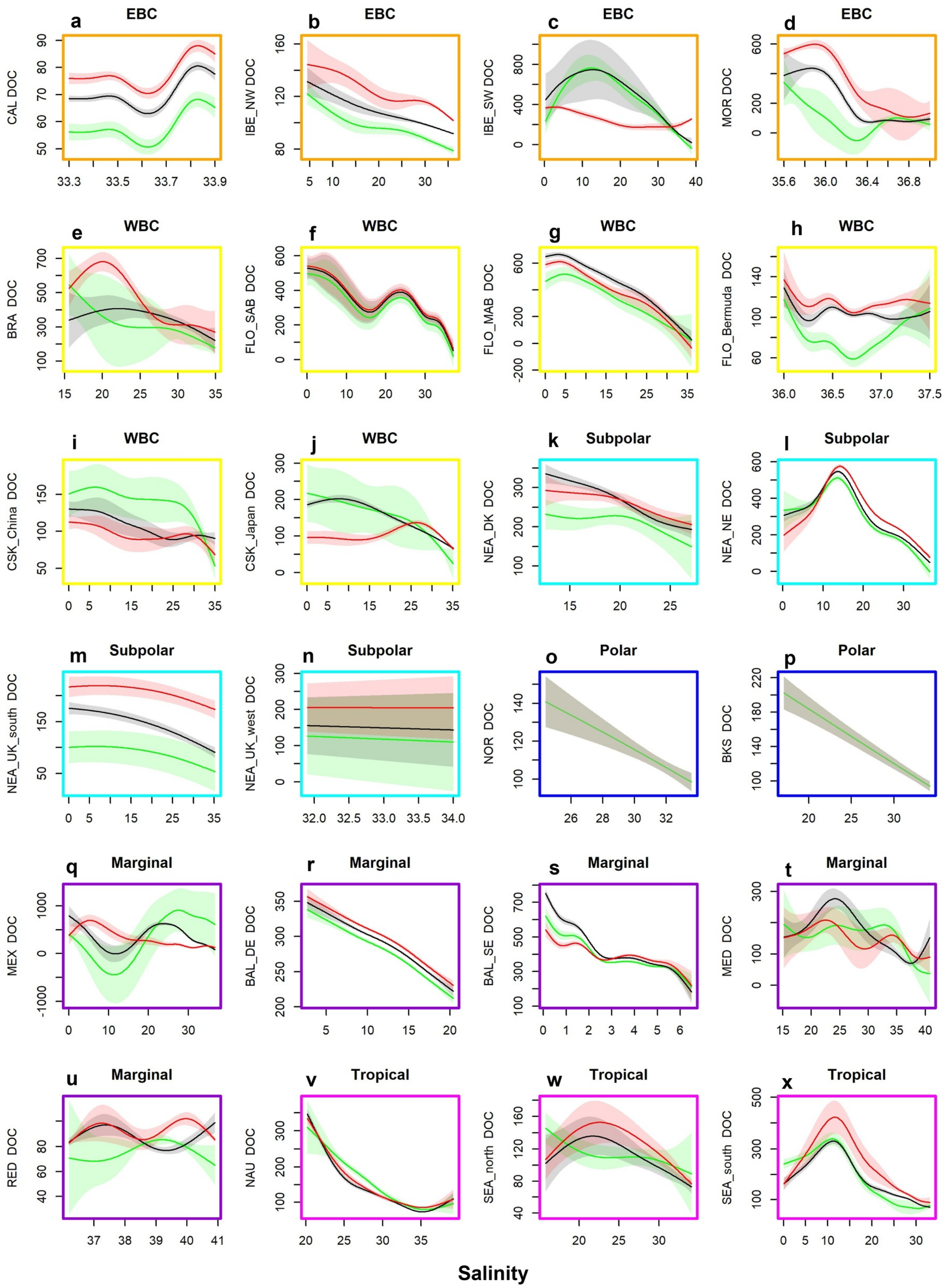

Figure 5. Estimated dissolved organic carbon (DOC) concentrations (in μmol C L^{-1}) as a function of low (2.5th percentile (P2.5), green), median (black) and high (97.5th percentile (P97.5), red) salinity for all regions in the six segments under study: (a–d), EBC; (e–i), WBC; (j–n), Subpolar; (o–p), Polar; (q–u), marginal; and (v–x) tropical (see salinity percentile values in Table S4 in Supporting Information S1). Notice that no significant contribution of salinity was detected in Antarctic Shelf (45-ANT) and Caribbean Sea (08-CAR). Please also note differences in scale of the axis values. See Table 1 for names of the regions and please note that some regions were divided into subregions due to differences in trends.

Table 3

The Shelf Volume (km^3), Percentage Contribution to the Total Volume, Dissolved Organic Carbon (DOC) Standing Stocks (Pg C; <200 m) and Median Annual Freshwater Discharge Into the Region (km^3 yr^{-1}) for the 7 MARgin and CATchments Segmentation (MARCATS) Shelf Typologies (EBC, Eastern Boundary Current Margins; WBC, Western Boundary Current Margins; Monsoonal, Margins Under Monsoonal Influence; Subpolar Margins; Polar Margins; Marginal Seas; Internal Marginal Seas; and Tropical Margins; Laruelle et al., 2013)

Shelf type	Shelf vol. (km^3)	% Of total shelf vol.	Fresh water discharge (km^3 yr^{-1})	Pg C DOC (Median)	Pg C DOC (25% cut-off of whole)	Pg C DOC (25% cut-off by shelf)	Pg C DOC (Depth integrated)
EBC	90.3	5	900	0.21	0.14	0.21	0.18
WBC	208.4	12	3,966	0.53	0.36	0.53	0.30
Monsoonal	58.9	3	1,959	0.15	0.12	0.15	0.15
Subpolar	402.3	23	3,529	0.66	0.60	0.67	0.60
Polar	384	22	3,033	0.77	0.56	0.77	0.48
Marginal	294.3	17	4,019	0.92	0.54	0.92	0.65
Tropical	338.5	19	20,342	0.32	0.40	0.32	0.28
Total	**1,776.6**	**100**	**37,748**	**3.56**	**2.74**	**3.57**	**2.62**

Note. The DOC standing stocks were calculated using: (a) median DOC concentrations, (b) median values after excluding the highest and lowest 25% of values from the entire data set (referred to as "25% cut-off total"), (c) median values with the 25% highest and lowest values in each shelf typology removed (25% cut-off by shelf), and (d) depth integrated median concentrations.

segments except in the California Current (02-CAL) and the South Atlantic Bight (18-FLO_SAB; Figures 4 and 5, and Table S6 in Supporting Information S1).

Although the relationship between temperature and DOC was not linear in most cases, we found some exceptions at lower salinities, where DOC concentrations increased with temperature in the WBC (FLO_SAB and FLO_-Bermuda), Subpolar (17-NEA), the Baltic German coast (BAL_DE), the Mediterranean Sea (20-MED) and for $T > 20°C$ in the Marginal seas (Figure 4). We also observed an increasing trend in DOC with temperature in the Antarctic Polar region (45-ANT) and the Tropical Caribbean Sea (08-CAR), although weak (explained deviance <15%).

Figure 5 shows that DOC concentrations generally decreased with increasing salinity. Whereas in some regions, such as the Netherlands coast (NEA_SEA) and some warm Marginal seas (28-RED) and Tropical (39-SEA) regions, DOC concentration increased reaching its maximum at mid-salinity (10–20) and decreased thereafter. Finally, we observed a decrease in DOC concentrations as salinity increased in the two Arctic Polar regions.

3.4. Dissolved Organic Carbon Stocks in Coastal Waters

The total shelf volume, used to calculate DOC stocks in the different MARCATS segments, was updated from those previously reported (Laruelle et al., 2013), because we reassigned some of the included coastal regions (see Section 2.2). As shown in Table 3, the shelf volumes varied considerably, with the Monsoonal segment having the lowest (58.9 km^3; 3% of total volume; Table 3 and Table S2 in Supporting Information S1) and the Subpolar shelf having the highest volume and overall contribution to global coastal waters (402.3 km^3; 23% of total volume; Table 3). Our estimate of the total global coastal DOC stock ranged from 2.62 to 3.57 Pg C (median: 3.15 Pg C; IQR = 0.85 Pg C) depending on the approach used. This variability in the estimates suggests that this should be seen as a first approximation which needs to be refined in the future when more data becomes available. Overall, the highest DOC stocks were found in the Marginal Sea (0.54–0.92 Pg C) and lowest in the Monsoonal segment (0.12–0.15 Pg C; Table 3). The high stock in the Marginal Seas was mainly due to the high median DOC concentrations, while the low stock in the Monsoonal region was due to its smaller volume. Overall, DOC stocks increased with the calculated freshwater inputs; however, it should be noted that the Tropical segment did not follow this trend (Figure 6).

4. Discussion

DOC in coastal waters is integral to all major biogeochemical cycles and is strongly impacted by both global and regional environmental pressures, such as ocean warming, acidification, eutrophication, and changes in the hydrology of adjacent watersheds (Ward et al., 2023). However, the complex chemical composition of DOC and the

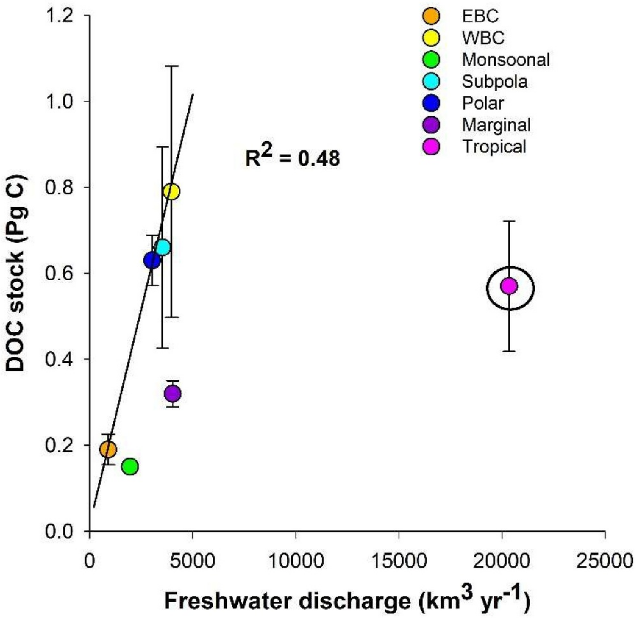

Figure 6. Plot of the calculated median freshwater discharge (km^3 yr^{-1}) versus median dissolved organic carbon (DOC) stocks (in Pg C) for the MARgin and CATchments Segmentation (MARCATS) coastal segments (EBC, Eastern boundary current margins; WBC, Western boundary current margins; Monsoonal—margins under monsoonal influence, Subpolar margins, Polar margins, Marginal Sea—internal marginal seas, and Tropical margins). Linear regression line and coefficient of determination (R^2) are shown, please note that the datapoint from the Tropical Margin (encircled datapoint) was omitted from the regression analysis. The freshwater discharge estimates were obtained from a previous study (Laruelle et al., 2013). Error bars for the DOC stocks represent the interquartile range (IQR) and were based on the values obtained in this manuscript using four different approaches.

myriads of processes involved in its cycling, make it difficult to determine which factors are most important for regulating DOC concentrations at global and regional scales. In this study, we used a recently published global DOC data set (Lønborg et al., 2024) to explore spatial and temporal differences in DOC concentrations and stocks, and to conduct detailed statistical analysis to establish impacts of temperature and salinity. A more detailed analysis of how global and regional differences in for example, how microbial processes impact the measured DOC concentrations would be a logical next step, and we suggest that large scale ecosystem models should be used for this. Such modeling exercises would provide a more detailed understanding of how different processes impact the DOC pool in coastal waters.

4.1. Global and Regional Patterns in Coastal Dissolved Organic Carbon

Rivers deliver high concentrations of DOC (on the order of hundreds of μmoles C L^{-1}) to coastal waters (Cauwet & Salot, 1994) and supply inorganic nutrients that fuel primary production, adding more DOC to coastal water stocks (Hill & Wheeler, 2002). The concentrations and distribution of DOC in coastal waters largely depend on the physical mixing between distinct volumes of freshwater and seawater, which commonly results in negative relationships between DOC concentrations and salinity (Figure 5), dominated by the conservative mixing of these water bodies (Abril et al., 2002; Voss et al., 2021). However, non-conservative relationships between salinity and DOC have been identified in several studies, which can result from processes such as anthropogenic pollution, wetland inputs (Arellano et al., 2019; Santos et al., 2021), sediment resuspension, and removal processes such as photodegradation and flocculation (Fichot & Benner, 2014; Guo et al., 2021; He et al., 2010; Sun et al., 2022).

The prominence of freshwater inputs is one characteristic used to categorize coastal seas. Our statistical analysis showed distinct DOC and salinity signatures for each coastal MARCATS shelf (Figure 5). Previous studies have divided coastal seas into river-dominated ocean margins (RiOMars), which have a major river impact, and ocean-dominated margins (OceMars) with minimal direct influence from rivers (Dai et al., 2013; McKee et al., 2004). Lowest DOC concentrations and highest salinity observed in our study were found in the EBC, due to minimal direct impact from land and a strong influence of upwelled deeper waters, characteristic of the extensive arid coastal upwelling regions associated with the Canary, Benguela, Humboldt and California Currents. The EBC is, therefore, an OceMars where coastal upwelling periodically injects high nutrient concentrations that trigger primary production, which can elevate DOC concentrations (Álvarez-Salgado et al., 2006; Wetz & Wheeler, 2003). Two exceptions to this were Southwestern (33-LEE) and Southern (34-SAU) Australian Coast regions, which showed elevated DOC concentrations at median salinities. These regions generally do not have high primary productivity or large riverine inputs (Robertson et al., 1999). However, given that these are small data sets ($n < 20$) with limited spatial and temporal coverage, the elevated DOC concentrations are hard to explain relative to salinity.

In contrast to the EBC, highest DOC concentrations and lowest salinities were found in the Marginal seas. Here the compilation was dominated (65%) by data from the Baltic Sea, which is a region highly affected by river runoff and large anthropogenic nutrient inputs (Lønborg & Markager, 2021). Therefore, in general, the Marginal seas should be considered a river-dominated RiOMars system. However, the Marginal seas also showed one of the highest variabilities in DOC, reflecting the very distinct regions included in this shelf type. In the Marginal seas, some of the lowest salinities and highest DOC concentrations were driven by discharge of the Amur River into the Sea of Okhotsk (41-OKH) (Nakatsuka et al., 2004), and discharge of multiple rivers into Hudson Bay (12-HUD), some of which contain thawing permafrost (Godin et al., 2017). The highest salinities in the Marginal Sea were measured in the Red Sea (28-RED) and the Mediterranean Sea (20-MED), which have high evaporation rates and low nutrient concentrations (Calleja et al., 2019; Santinelli, 2015). The Red Sea also lacks substantial river inputs, which leads to low DOC concentrations (Calleja et al., 2019).

In the Tropical shelves, elevated temperatures and salinities and low DOC concentrations were common (Table 2 and Table S4 in Supporting Information S1), suggesting that this segment is either less affected by land than other shelves and should be considered an OceMars region, and/or that terrestrial inputs are being rapidly degraded in the Tropics due to for example, higher temperatures and elevated UV levels. The former hypothesis fits well with the fact that tropical coastal waters generally have relatively stable environmental conditions (e.g., temperature) and are commonly oligotrophic. River discharge into these regions is typically driven by distinct wet and dry seasonality. In the case of monsoonal settings, short-lived pulses of river inputs occur following seasonal rainfall events and episodic floods due to tropical storms (Lønborg et al., 2021; McKinnon et al., 2017). However, in our data set the tropical western Indian Ocean (26-TWI) segment, which contained data originating from Kenya, had large variability in both salinity and DOC relative to salinity, which is different from the rest of the Tropical shelf. This signature might be due to variable contributions of the Kidogoweni and Mkurumuji Rivers, which have elevated DOC concentrations (Bouillon et al., 2007). In major river systems such as the Amazon and Congo River plumes, consistently high discharge occurs, delivering terrestrial DOC to the coastal ocean (Spencer et al., 2012; Ward et al., 2015). This terrestrially derived DOC is rapidly remineralized and photo-oxidized along the lower river reaches and coastal ocean (Seidel et al., 2016; Spencer et al., 2009), meaning only a recalcitrant fraction of the terrestrially derived DOC is entrained into the coastal DOC pool (Medeiros et al., 2015).

Polar and Subpolar shelves had intermediate DOC concentrations and variable salinities (Table 2 and Table S4 in Supporting Information S1). In some parts of the Polar shelf, DOC concentrations were relatively high and salinity was low, largely due to the influence of Siberian and Canadian rivers, which are known for their elevated DOC and nutrient concentrations (Anderson & Amon, 2015; Cauwet, 2002). In the Canadian zone, permafrost melting might add DOC and freshwater to the coast (Connolly et al., 2020). On the other hand, low DOC concentrations near the Antarctic Peninsula suggest a more marine-like nature of DOC in this region (Doval et al., 2002). In the Subpolar shelf, highest DOC concentrations were found in more enclosed shelves, such as the Labrador Sea (11-LAB). The lowest mean salinity and DOC concentration of any coastal region in our data set was in the Subpolar Patagonian fjords (05-SAM), which could be due to high amounts of glacier meltwater since it is generally DOC-depleted, with concentrations sometimes below the detection limit of the HTCO method (Marshall et al., 2021).

The WBC shelf had a wide range of DOC concentrations and salinity (Table 2 and Table S4 in Supporting Information S1). In this shelf, most samples were collected along the east coast of the United States (10-FLO) and in the China Sea (39-CSK), both of which are impacted to varying degrees by anthropogenic and river-derived sources of DOC (e.g., Changjiang River, James River; (Sharp et al., 2009; Wang et al., 2012)). One exception to this general trend was the Brazilian Current (06-BRA), which had high salinity and DOC concentrations (around 371 μmol L^{-1}), likely because the data from this region were obtained in an eutrophic coastal embayment which receives large amounts of domestic effluents and is dominated by large phytoplankton blooms (Cotovicz et al., 2018), therefore caution should be taken in generalizing the observed pattern to the whole region.

In the Monsoonal shelf type, lower variability and generally high DOC concentrations and moderate salinity were found, though mainly OceMars regions were included (Table 2 and Table S4 in Supporting Information S1). The data set for this shelf was dominated by samples collected in the Bay of Bengal (31-BEN), where DOC concentrations were higher in comparison to the Arabian Sea (30-EAS), likely due to larger riverine discharge to the former and the potential influence of coastal upwelling in the latter (Krishna et al., 2015). Some of the included data in the Bay of Bengal were also collected in mangrove creeks, which have elevated DOC concentrations (Sanyal et al., 2020).

4.2. Seasonal Changes in Dissolved Organic Carbon

In most of the analyzed regions (19 out of 25), seasonal patterns of temperature and DOC had similar peak timing (Figure 3). Among these 19 regions, eight had a clear coupling between seasonal temperature and DOC concentrations. These regions include the Iberian Upwelling (19-IBE-NW), Bermuda (10-FLO-Bermuda), Southern part of the British coast (17-NEA-UK-South), the Mediterranean Sea (20-MED), the Red Sea (28-RED) and the Caribbean Sea (8-CAR). The increase in temperature and vertical stratification, linked to changes in productivity, is one factor influencing DOC, which increases during the spring months and subsequently accumulates during summer months in most of these regions (Santinelli et al., 2013). In addition, the direct influence of temperature may result in higher DOC production from processes like plankton production, grazing, excretion, and viral-mediated release, all of which increase with warming temperatures (Engel et al., 2011; Zhao et al., 2023).

Increased carbohydrate exudation during periods of nutrient limitation, for example, due to long term stratification, may also increase DOC production (Søndergaard et al., 2000). The Caribbean Sea (8-CAR) is an exception, as this area is generally controlled by both physical and biological drivers, with maximum DOC concentrations in surface waters related to the rainy season in September-October, and minima during the upwelling season in April, as surface DOC is diluted with colder deeper DOC-poor waters (Lorenzoni et al., 2013). Overall, understanding the specific similarities among the eight regions where there was a coupling between seasonal temperature and DOC levels is challenging. Their latitudes ranged from 10 to 50° and in some regions, the seasonal cycle of salinity mirrors that of DOC, while in others, it exhibits an inverse pattern. Additionally, some regions experience upwelling, while others do not. One common characteristic among these eight regions is that the amplitude of the salinity seasonal cycle tends to be smaller than in other regions (Table S5 in Supporting Information S1). In contrast, regions with higher seasonal salinity amplitudes usually also had higher seasonal amplitudes of DOC and temperature (Table S5 in Supporting Information S1).

Among the 25 regions analyzed for seasonal change, 18 exhibited inverse seasonal peaks between salinity and DOC, emphasizing the impact of riverine inputs. This pattern was particularly notable in regions close to major river systems, such as the Baltic Sea (18-BAL-DE and 18-BAL-DK), the Danish part of the Northeast Atlantic (17-NEA-DK), the southern part of Southeast Asia (38-SEA-south), and Northern Australia (37-NAU). Thus, in these regions, high DOC concentrations were pronounced during the months characterized by a large proportion of freshwater inputs (Hoikkala et al., 2015; McKinnon et al., 2017; Zhou et al., 2021) and likely also storm events, while lower concentrations were likely related to the input of deep waters that tend to dilute surface DOC.

4.3. Dissolved Organic Carbon Standing Stock in Coastal Waters

The ocean DOC pool contains around 662 Pg C (Hansell, 2013); our upper estimate of 3.57 Pg C for coastal waters therefore only represents 0.5% of that total ocean pool. However, it is here important to notice that our global estimate ranged from 2.62 to 3.57 Pg C depending on the approach used, suggesting that our estimate should be seen as a first approximation which needs to be refined in the future when more DOC data and accurate estimates of water volumes become available. The much larger DOC pool in the open ocean is due to its disproportionately larger volume (133×10^6 vs. 1,777 km^3), while the median DOC concentrations in the different MARCATS segments were only 1.1 to 4.6 times (mean: 2.2 times) higher than those found in surface waters of the open ocean (assuming an average of 70 μmol C L^{-1}; (Hansell et al., 2021)). The coastal DOC pool is however a much more dynamic pool. Assuming that the refractory DOC fraction in the surface open ocean and in coastal waters is the same at around 40 μmol C L^{-1}, 47% of the surface open ocean DOC, but only 21% in coastal waters would be refractory (Letscher et al., 2013; Lønborg & Álvarez-Salgado, 2012; Lønborg et al., 2024). Globally, the riverine input of DOC into coastal waters is estimated between 0.3 and 0.7 Pg C yr^{-1} (Chaplot & Mutema, 2021; Liu et al., 2024) of which up to 90% is chemically transformed or degraded on the inner shelf as a result of photo-chemical and microbial degradation (Raymond & Spencer, 2015). Considering that the net DOC export from coastal waters to the adjacent ocean is 0.15–0.35 Pg C y^{-1} (Fichot et al., 2023), riverine DOC would constitute less than 20%–50% of this export flux, with the remaining being autochthonous coastal DOC. This also fits well with previous studies which have found that other sources such as phytoplankton, macrophytes, salt marshes, sediments, submarine groundwater and the atmosphere (Burdige, 2001; Egea et al., 2019; Maher & Eyre, 2010; Thornton, 2014) make substantial contributions to this net export flux.

The median DOC stock in the different segments varied considerably, being highest in the Marginal seas and lowest in the Monsoonal shelf, due to differences in the DOC concentrations and their total volume. Previous work has demonstrated large regional variability in riverine DOC inputs, with the largest found in the western ocean boundaries (~96 Tg C yr^{-1}), followed by the polar ocean boundaries (~46 Tg C yr^{-1}), the semi-enclosed seas, islands and Australia (~33 Tg C yr^{-1}), and the eastern ocean boundaries (~32 Tg C yr^{-1}) (Dai et al., 2012). The DOC stock generally increased with the calculated freshwater inputs (Figure 6), suggesting that higher contents are located in segments with larger riverine inputs, due to both direct and indirect impacts, with the latter being due to nutrients that stimulate autochthonous DOC production. An exception to this was the Tropical shelf type where DOC content was lower compared with the freshwater discharge. As Tropical rivers contribute 62% of the total global riverine DOC input (Dai et al., 2012) and 55%–64% of the global total N and P export to coastal waters (Mayorga et al., 2010), this difference was not due to limited direct river influx or lack of nutrients, which can stimulate DOC production. Lower DOC content could instead reflect the combination of a short residence time on the shelf near the Equator due to a reduced Coriolis force, combined with high temperatures and irradiance, ensuring efficient DOC export and degradation in the tropics (Lønborg, Álvarez–Salgado, et al., 2018; Lønborg et al., 2021; Zhou et al., 2021) though there are exemption to this efficient cycling (Chu et al., 2025).

4.4. Ways Forward in Rapidly Changing Coastal Waters

Climatic and anthropogenic disturbances, such as acidification, ocean warming, coastal eutrophication, and the subsequent expansion of coastal hypoxia/anoxia, have both persistent and acute effects on DOC biogeochemistry and associated biological responses in coastal waters (Breitburg et al., 2018; Lønborg et al., 2020; Morán et al., 2024). The effects of warming, changing hydrology, and increased stratification on DOC dynamics have been studied, while ocean acidification, deoxygenation, and sea level rise have received less attention in terms of impacts on coastal DOC composition and biogeochemical cycling (Lønborg et al., 2020). Furthermore, river dams impact the concentration and composition of DOC by disconnecting the rivers and changing the flow regime, ultimately impacting coastal waters receiving these waters (e.g., Oliver et al., 2016; Zhuang et al., 2023). These anthropogenic impacts may have synergistic or antagonistic effects, both direct and indirect, on the concentrations and composition of coastal DOC that is strongly related to regional hydrology and physicochemical parameters. It remains unclear how these positive and negative feedback will impact future DOC cycling and consequently influence the ecosystem state. However, due to the general close connection between salinity and DOC found in this study changes on land and in rivers could likely have large impacts on the future DOC pool in coastal waters. But whether future changes on land would have a larger impact on the DOC pool then changes in coastal environments themselves are difficult to resolve. This is because both river-derived and marine sources as well as their sinks are influenced by multiple interacting anthropogenic (e.g., dredging, land reclamation), climatic (e.g., sea level rise, warming) and food web (e.g., seagrass loss) elements.

5. Conclusion

In conclusion: (a) both seasonal and spatial differences exist in the DOC concentrations of coastal waters; (b) on a global scale, salinity was the main driver of DOC concentrations and temporal trends, while temperature also played a major role at a regional scale; and (c) globally, coastal waters contain between 2.62 and 3.57 Pg DOC (median: 3.15 Pg C). In this study we provided one possibility of how global coastal data products, such as CoastDOMV.1, can be utilized to investigate global patterns. We strongly encourage others to establish and utilize such data sets to provide a better understanding of coastal waters patterns both globally and regionally.

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Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The data set used in this manuscript can be downloaded from the PANGEA database (https://doi.org/10.1594/PANGAEA.964012; Lønborg et al., 2023).

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