Supplementary Material

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Guerreiro, C.V. et al. Seasonal upwelling–dust controls on export production in the Canary Current System revealed by Lagrangian particle tracking

Correspondence to: Catarina V. Guerreiro (cataguerreiro@fc.ul.pt)

Abstract. The Canary Current System (CCS) is a major eastern boundary upwelling system where intense nearshore productivity, dynamic offshore transport, and Saharan dust deposition jointly shape biogeochemical cycling. Understanding how these physical and atmospheric forcings regulate particulate export is crucial for assessing the biological carbon pump under ongoing North Atlantic warming. Here we combine Lagrangian backtracking of satellite-derived chlorophyll-a (Chl-a), particulate inorganic carbon (PIC), and primary production (PP) with one year of sediment trap fluxes from Cape Blanc (CB) and M1, integrating lithogenic, organic, and coccolith species export with satellite-based upwelling, sea surface height (SSH), aerosol optical depth (AOD), and in situ water-column observations.

The results reveal strong seasonal connectivity between coastal upwelling, offshore transport, and deep export. Late winter–spring intensification of mixing, upwelling, and filament/eddy activity sustained elevated Chl-a, PP, PIC, and high $CaCO_3$ fluxes, with sinking assemblages dominated by fast-blooming placolith-bearing coccolithophores –especially at CB. Lagrangian trajectories further show that this connectivity weakens offshore, with strong coast-to-open-ocean declines in Chl-a, PP, and PIC – particularly along pathways to M1 – highlighting reduced cross-shelf transfer and a stronger yearlong influence of stratified tropical waters at that site.

During summer–autumn, weakened upwelling and intrusions of warm Mauritanian Current waters reduced surface productivity at both traps, yet deep organic matter export remained high – most prominently at CB and even at the persistently oligotrophic M1. Across this period, elevated Saharan dust deposition coincided with enhanced particle fluxes. Multivariate statistical analyses show strong negative correlations between dust and all upper photic zone (UPZ) productivity indicators, and positive associations with warm, stratified conditions dominated by tropical, non-blooming lower photic zone (LPZ) taxa typical – suggesting that mineral ballasting was as the dominant seasonal dust effect. At CB, where summer cross-shelf transfer weakened, the persistence of high export under low surface Chl-a suggests that lateral and subsurface supply of previously produced organic matter played a major role, with Saharan dust further enhancing its downward transfer through mineral ballasting.

Nonetheless, several dust-associated export pulses also displayed increases in coccolith UPZ/LPZ ratios, suggesting episodic fertilisation responses by fast-blooming taxa superimposed on a predominantly ballasting-driven regime. Importantly, dust contributed under both windy, high-productivity late winter–spring conditions and during the stratified summer–autumn phase, sustaining downward particle flux even when local surface productivity was low. The weak relationship between AOD and measured dust flux reflects cloud-induced suppression of satellite AOD retrievals during wet deposition rather than reduced dust deposition.

Altogether, these results demonstrate a dual physical–atmospheric control on export in the central–southern CCS. Upwelling and cross-shelf transport fuel the winter–spring $CaCO_3$-rich export regime, whereas Saharan dust plays a particularly important role in maintaining organic-matter fluxes under summer–autumn stratification through ballasting, with secondary episodic fertilisation. These findings contribute to refine the mechanistic understanding of coast-to-ocean and vertical export pathways and help constrain how dust–upwelling interactions will shape the biological carbon pump under future climate forcing.

Table S1 – Sources of satellite-driven Earth Observation time-series data processed for the sediment-trap deployment period at CB and M1 and for the Lagrangian analysis.

Parameter	Acronym	Units	Sensor	Product	Resolution	Source	Reference
Chlorophyll	Chl-*a*	mg m^{-3}	OC-CCI	V6-daily	4 km	https://www.oceancolour.org	Sathyendranath et al. (2019)
Primary Production	PP	mg C m^{-2} d^{-1}	Multisensor	daily	4km	https://primus.eofrom.space/	Smyth et al. 2005
Particle Inorganic Carbon	PIC	mol m^{-3}	MODIS-Aqua	L3-daily	4km	https://oceancolor.gsfc.nasa.gov/cgi/l3	Gordon et al., 2001; Balch et al., 2005 ; Hopkins et al., 2015
Sea Surface Temperature	SST	ºC	OSTIA	L4-daily	0.05º	https://doi.org/10.48670/moi-00168	Good et al. (2020), Worsfold et al. (2024)
Daily Precipitation	DPP	mm day^{-1}	multiple	L3-daily	0.25º	https://disc.gsfc.nasa.gov/datasets/TRMM_3B42RT_Daily_7/summary	Goddard Earth Sciences Data and Information Services Center (2016); Huffman et al. (2007); Xie and Arkin (1997)
Mixed Layer Depth	MLD	m	NOBM (model)	daily	0.67x1.25°	https://catalog.data.gov/dataset/nasa-ocean-biogeochemical-model-assimilating-satellite-chlorophyll-data-global-monthly-vr2-5b906	Gregg and Rousseaux, (2017)
Aeorosol Optical Depth (865)	AOD	unitless	Multisensor	daily	4km	GlobColour - Home	Gordon, 1997
Upwelling Index	UI	K	OSTIA SST	daily	0.051º	https://primus.eofrom.space/	N/A
Sea Surface Height	SSH	m	Multiple	daily	0.125 x 0.125º	https://doi.org/10.48670/moi-00148	Global Ocean Gridded L 4 Sea Surface Heights And Derived Variables Reprocessed 1993 Ongoing. E.U. Copernicus Marine Service Information (CMEMS). Marine Data Store (MDS). DOI: 10.48670/ moi-00148

Table S2. Annual means and ranges of fluxes and relative contributions of major coccolith taxa, $CaCO_3$, organic matter, $bSiO_2$, and lithogenic fractions measured in situ from sediment traps M1 and CB along with environmental time-series data from satellite remote sensing at both trap mooring sites (particle flux data from Korte et al., 2017; Guerreiro et al., 2019, 2021).

	M1 (12ºN/23ºW)				CB (21ºN/20ºW)			
Coccolith Sinking Taxa	**Fluxes (coccoliths m^{-2} d^{-1} $*10^7$)**		**Percentages (%)**		**Fluxes (coccoliths m^{-2} d^{-1} $*10^7$)**		**Percentages (%)**	
	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max
Emiliania huxleyi	8	3 - 16	16	8 - 21	29	2 - 99	34	15 - 51
Gephyrocapsa spp.	4	1 - 8	9	5 - 19	7	3 - 16	13	4 - 29
Calcisdicus leptoporus	1	0.1 - 8	1	0.4 - 3	3	0.4 - 12	4	2 - 8
Helicosphaera spp.	4	1 - 8	8	6 - 12	2	0.2 - 8	2	1 - 4
Rhabdosphaera spp. & *Umbellosphaera* spp.	3	0.3 - 8	6	1 - 10	4	0.3 - 20	5	2 - 14
Florisphaera profunda & *Gladiolithus flabellatus*	23	10 - 42	48	39 - 56	19	5 - 50	26	14 - 35
Umbillicosphaera spp.	2	0.6 - 6	5	1 - 8	4	1 - 12	5	3 - 8
Other taxa	4	2 - 9	8	5 - 14	10	1 - 33	12	6 - 21
Total	50	21 - 91			79	15 - 215		
Sediment Bulk Composition	**Fluxes (mg m^{-2} d^{-1} $*10^7$)**		**Percentages (%)**		**Fluxes (mg m^{-2} d^{-1} $*10^7$)**		**Percentages (%)**	
	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max
$CaCO_3$	38	23 - 85	34	21 - 45	92	3 - 297	57	27 - 83
Organic matter	15	10 - 28	10	8 - 13	17	2 - 35	13	6 - 29
$bSiO_2$	11	6 - 17	14	11 - 17	5	0.1 - 20	4	1 - 12
Lithogenic flyx (unspecified*)	48	33 - 71	43	30 - 58	38	1 - 114	27	5 - 58
Total Mass	112	77 - 200			150	6 - 423		
Satellite-driven Parameters	Mean	Min-Max			Mean	Min-Max		
Aerosol Optical Depth (AOD 865, unitless)	0.17	0.1 - 0.2			0.14	0.1 - 25		
Daily Precipitation (mm/d)	2.6	0 - 11			0.2	0 - 2		
Sea Surface Temperature (SST, ºC)	26	24 - 29			22	18 - 26		
Mixed Layer Depth (MLD, m)	23	11 - 35			45	20 - 73		
Chlorophyll-a (Chl-*a* , µg/L)	0.16	0.13 - 0.2			0.62	0.3 - 1.5		
Particulate Inorganic Carbon (PIC, mol/L$*10^{-8}$)	2	1.2 - 6			8	0 - 32		
Primary Production (PP, mg C/m^2 /d)	722	603 - 885			1145	674 - 2335		

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