ESA Atlantic Regional Initiative: Primary Production in Upwelling Systems (PRIMUS)

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PML Plymouth Marin Laboratory
CSIC Consejo Superior de Investigaciones Científicas
FCiências.ID Associação para a Investigação e Desenvolvimento de Ciências
IPMA
Universidad de Las Palmas de Gran Canaria
CSIR Touching lives through innovation

PRIMUS

- Started mid September 2021
- Two-year project
- PML lead with key entities working in EBUS regions in:
  - Spain (mainland and Canary Islands)
  - Portugal
  - South Africa
- Builds on several ESA projects presented at LPS, including BICEP & OceanSODA

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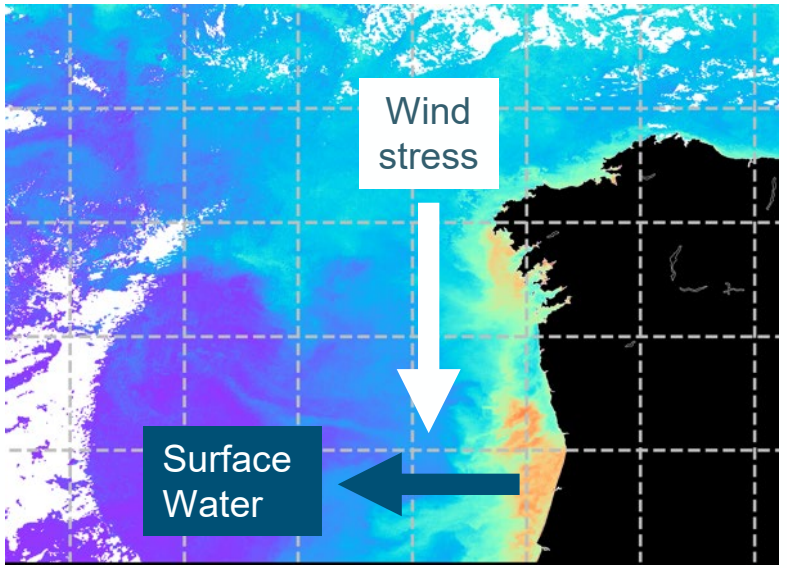
PRIMUS Early-adopters and Collaborators

Region	Scientific partner	Early-adopter
Galician Upwelling, Spain	CSIC-IIM	**ASMECRUZ** – Mussel farmers association
	Spanish Institute of Oceanography (IEO)	**INTECMAR** – Technological Institute for the Monitoring of the Marine Environment in Galicia), regional administration, particularly complementing their weekly in-situ sampling
Iberian Upwelling, Portugal	FC.ID	**IPMA** – Portuguese MSFD and fisheries monitoring institute
		DGRM – Portuguese maritime safety and services, implementation of policies on fisheries, aquaculture
Canary Upwelling, Spain / West Afrika	University of Las Palmas	**PLOCAN** – researching exploitation and management of island marine resources (fisheries and aquaculture)
		Government of the Canary Islands, Vice-Ministry of Climate Change – Interested not only in local fisheries, but also in climate regulation ,aquaculture and coastal tourism
Benguela Upwelling, South Africa, Namibia, Angola	CSIR	**NatMIRC** – Namibia mandated to assess the state of Namibia's marine environments

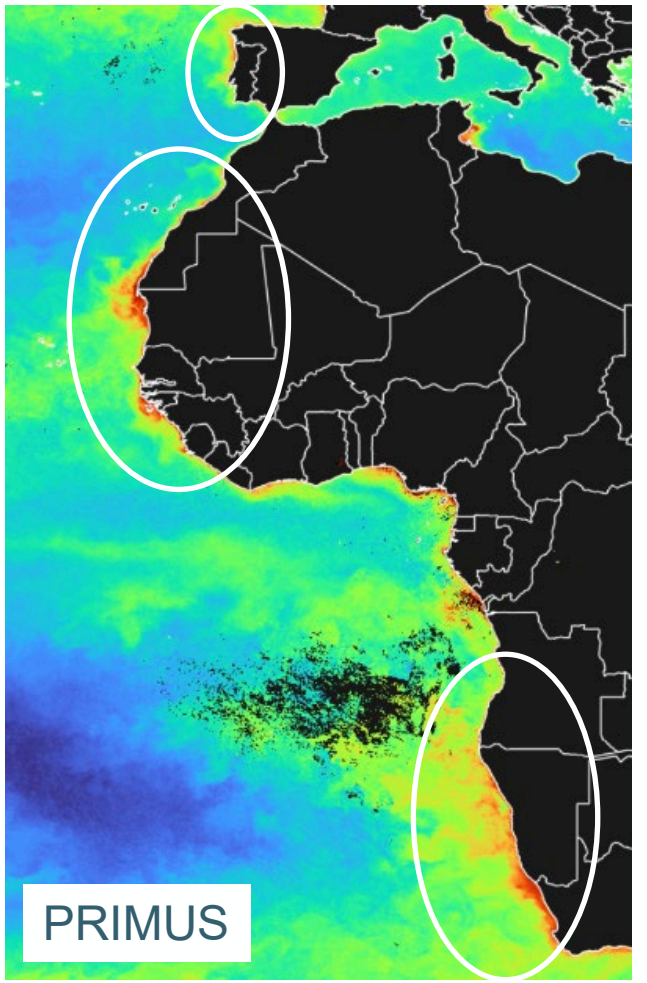
PRIMUS External collaborators
Dr. Mati Kahru UC San Diego, Scripps Institute of Oceanography
Dr. Sebastian Ferse Future Earth Coasts
Prof. Osvaldo Ulloa IMO, Universidad de Concepción
Dr. Jamie Shutler University of Exeter
Dr. Joe Salisbury University of New Hampshire
Dr. Stephanie Dutkiewicz MIT

Eastern Boundary Upwelling Systems (EBUS)

- Northerly winds along northern hemisphere eastern boundaries of oceans + Coriolis cause surface water advection offshore



S3 OLCI 300m; 13 Sep 2019, Galicia, Spain

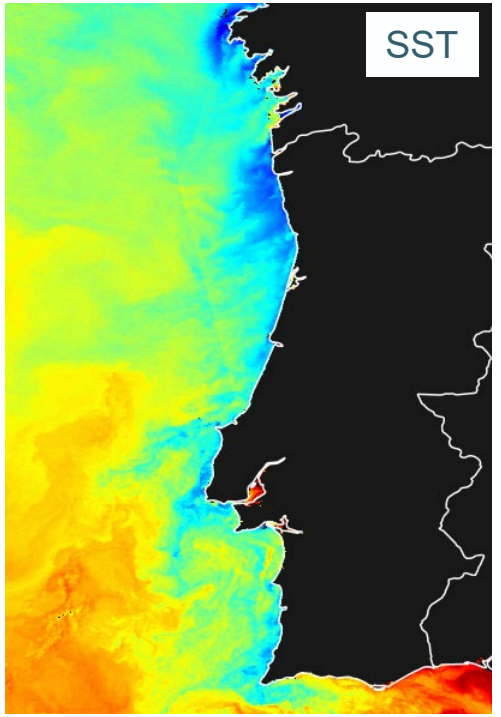


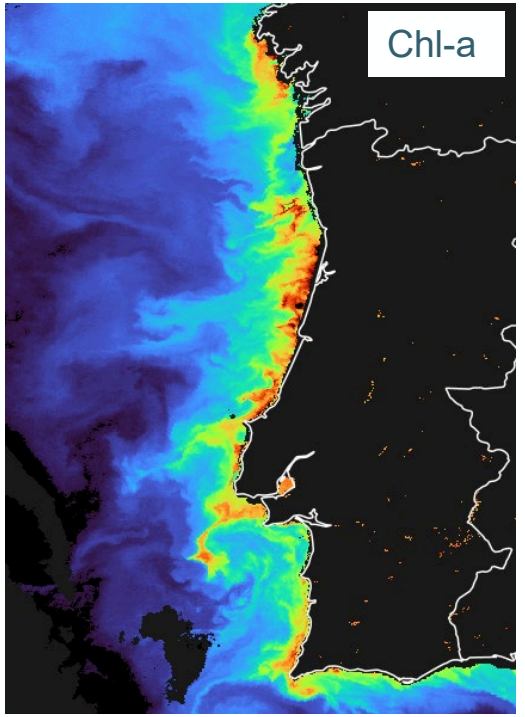
Monthly Chl-a; ESA Ocean Colour CCI

➢ Also known as Ekman pumping

Eastern Boundary Upwelling Systems (EBUS)

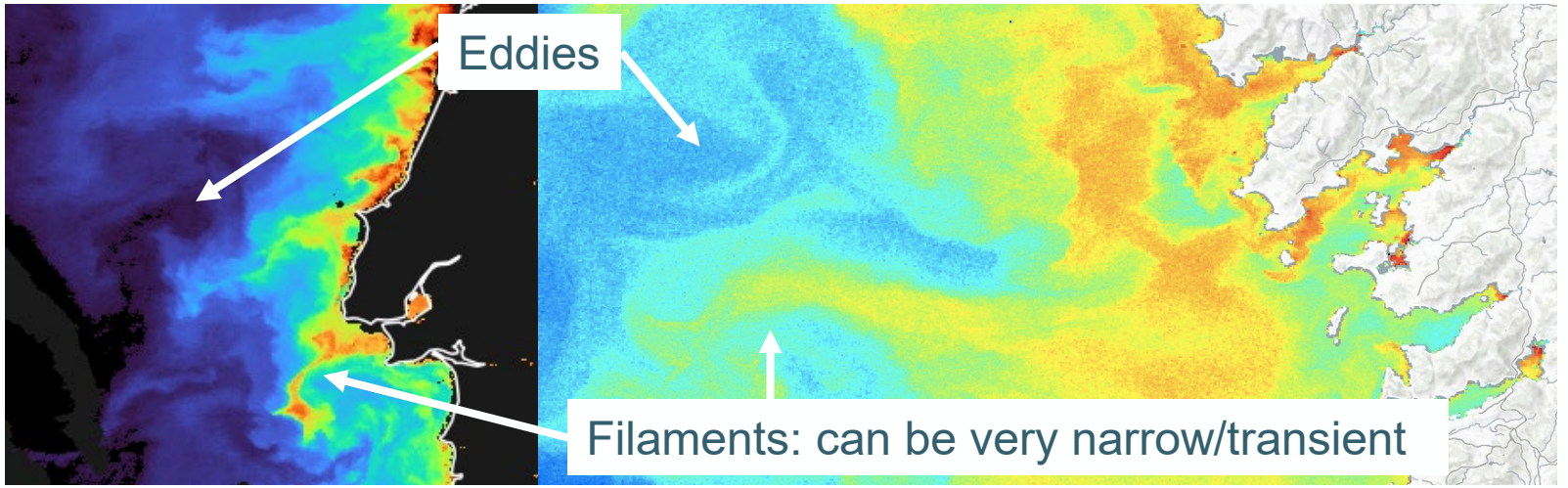
- Upwelling brings cooler/deeper waters to the surface with high nutrients
  - Supports higher phytoplankton primary production (PP)
  - Very important for many global fisheries



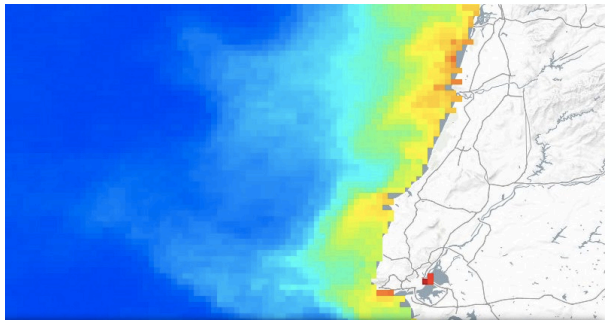
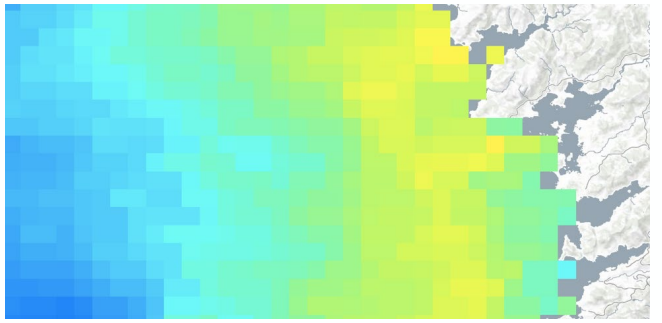
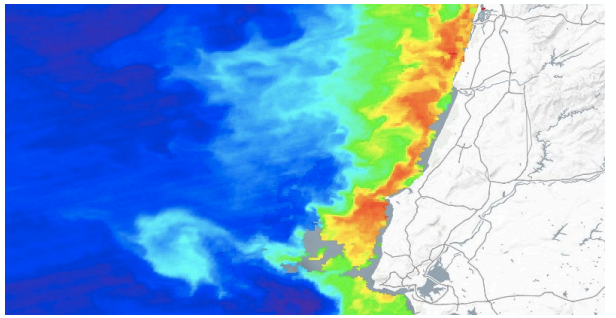
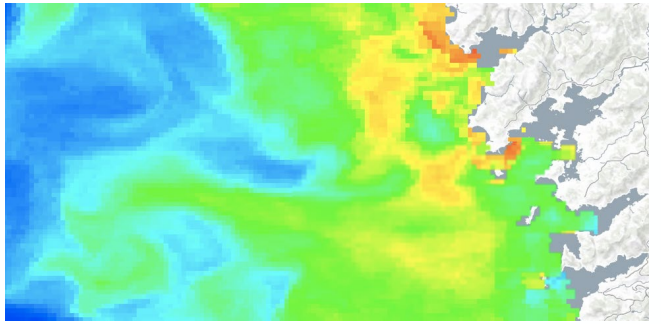
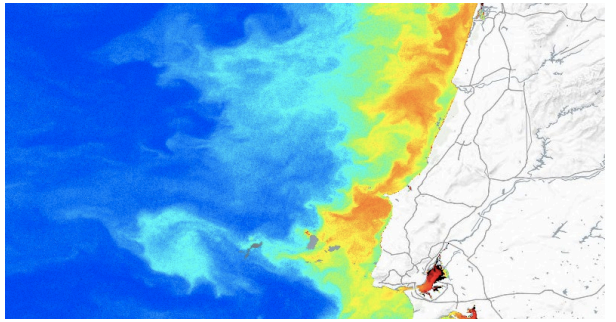
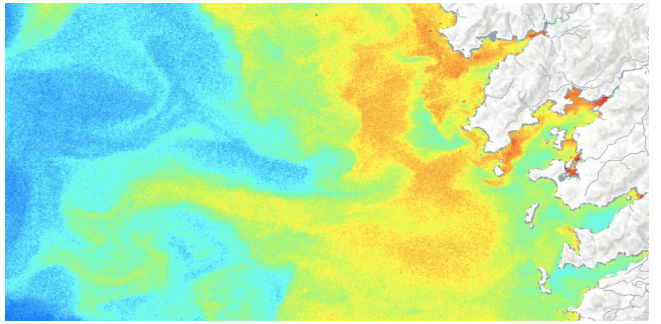


EBUS scales of variability

- Upwelling in some regions (like western Iberia) is episodic,
  i.e. upwelling/downwelling can change over days
- Many upwelling related processes are short in duration, like filaments
- Production is non-linear function of Chl-a
- Hence, need for data at weekly or daily frequency to characterise EBUS PP



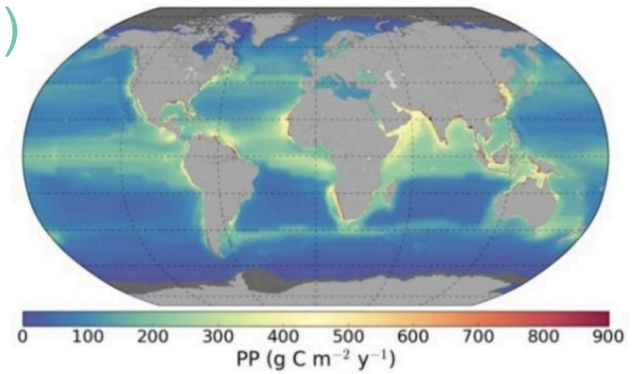
PRIMUS dataset spatio-temporal requirements

	Portuguese coast	NW Spain
OC-CCI 4km Monthly Sep 2019		
OC-CCI 1km Daily 13 Sep 2019		
S3 OLCI FR 300m daily 13 Sep 2019		

PRIMUS Primary Production Dataset

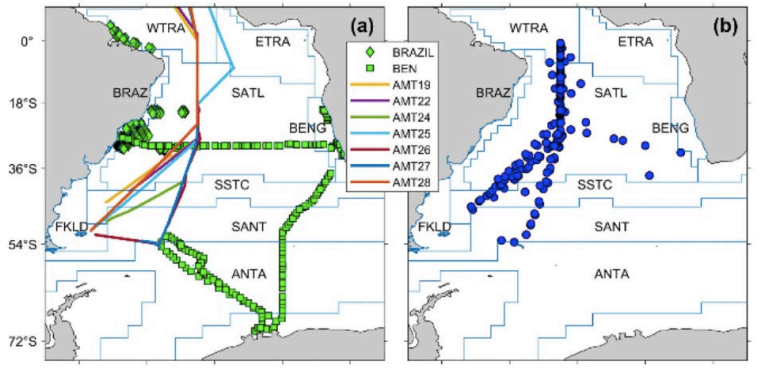
- PRIMUS will compute net PP using two wavelength-resolving models:
  1) Platt & Sathyendranath (1988) model used in ESA-BICEP: Kulk *et al.* (2020)
  2) Smyth *et al.* (2005) / Morel (1991) used in recent Atlantic studies: Ford *et al.* (2021)
- Satellite data: Chl-a, PAR and SST
- Validation with *in situ* PP data and via uncertainty analysis

1)



Kulk et al. 2020, 2021

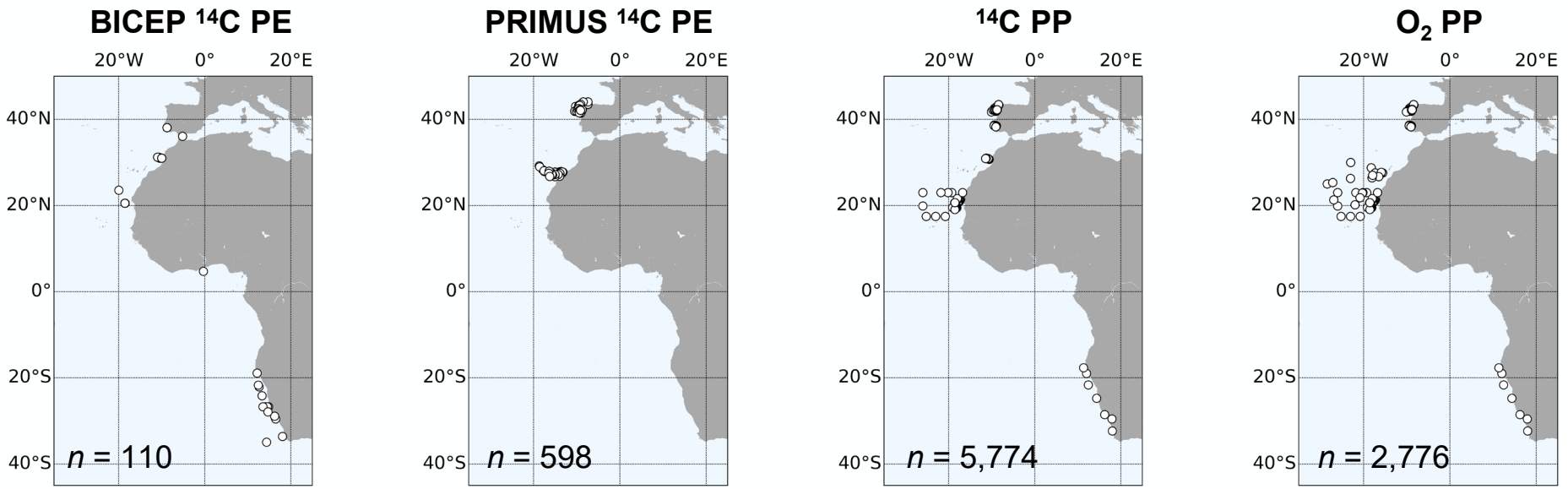
2)



Ford et al.2021

PRIMUS *in situ* PP dataset

- Types of PP measurements
  - *In situ* incubations
  - Simulated *in* situ, on-deck incubations
  - Photosynthesis-irradiance (PE) curves
  - ➢ Based on ^{14}C and O_2 methods



PP uncertainty estimates

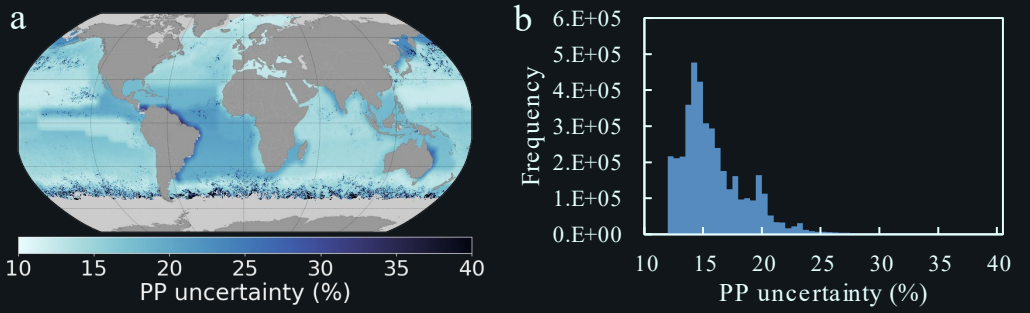
- Uncertainty estimates following GUM approach
  - Formulate model with input and output quantities
  - Calculate standard error of the mean of input quantities
  - Propagate errors through model to obtain combined uncertainty

Model for total water-column primary production (P):

$$P = f(P_m^B, B, D, K, I) = \frac{P_m^B BD}{K} f(I_*^m),$$

Error propagation to evaluate combined uncertainty:

$$u_c(P) = \sqrt{u_{P_m^B}^2 + u_{B/K}^2 + u_{f(I_*^m)}^2},$$

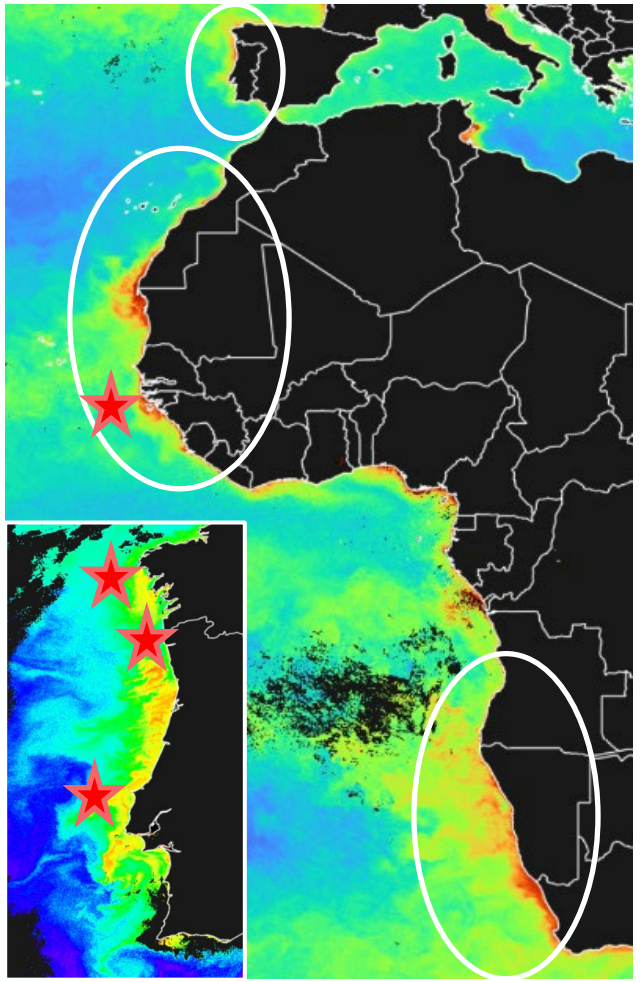


First results of the error propagation for $f(P)$ with a a) map and b) histogram of the combined PP uncertainty for May 2010.

PRIMUS Science Cases and Science into Impact Demos

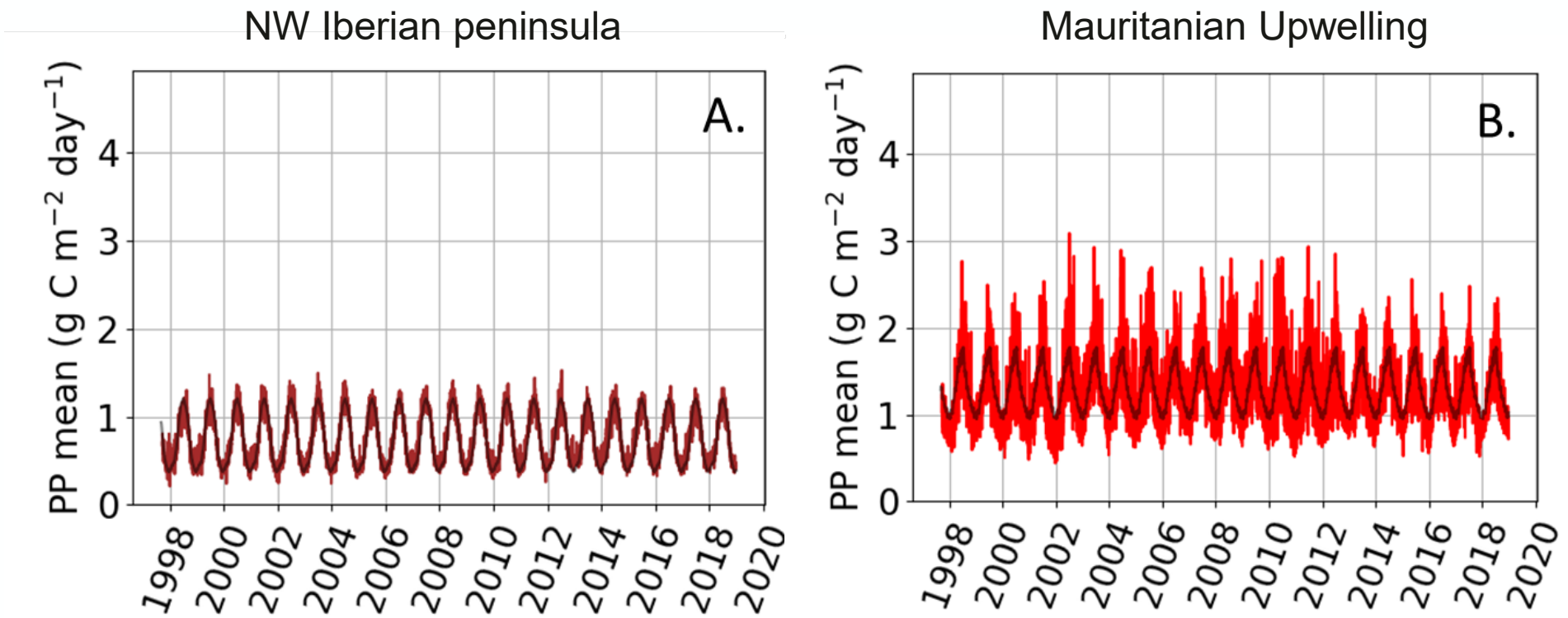
Science Cases
1) PP in relation to upwelling and climate indices for EBUS
2) High-resolution (300m) PP in Galician Rias
3) Lagrangian estimation of PP for EBUS
4) CO_2 flux and ocean acidification impacts for EBUS (ESA-OceanSODA)
5) Carbon pools for EBUS (ESA-BICEP)
6) Eutrophication in Iberian Upwelling
7) Fisheries in Iberian Upwelling
8) Particle flux in Canary Upwelling
9) AI for PP in EBUS

Science to Impact Demonstrations
1) PP and aquaculture in Galicia Upwelling System
2) EBUS and fisheries
3) Portuguese coastal upwelling and eutrophication
4) EBUS data operationalisation



Science Case 1: PP time series

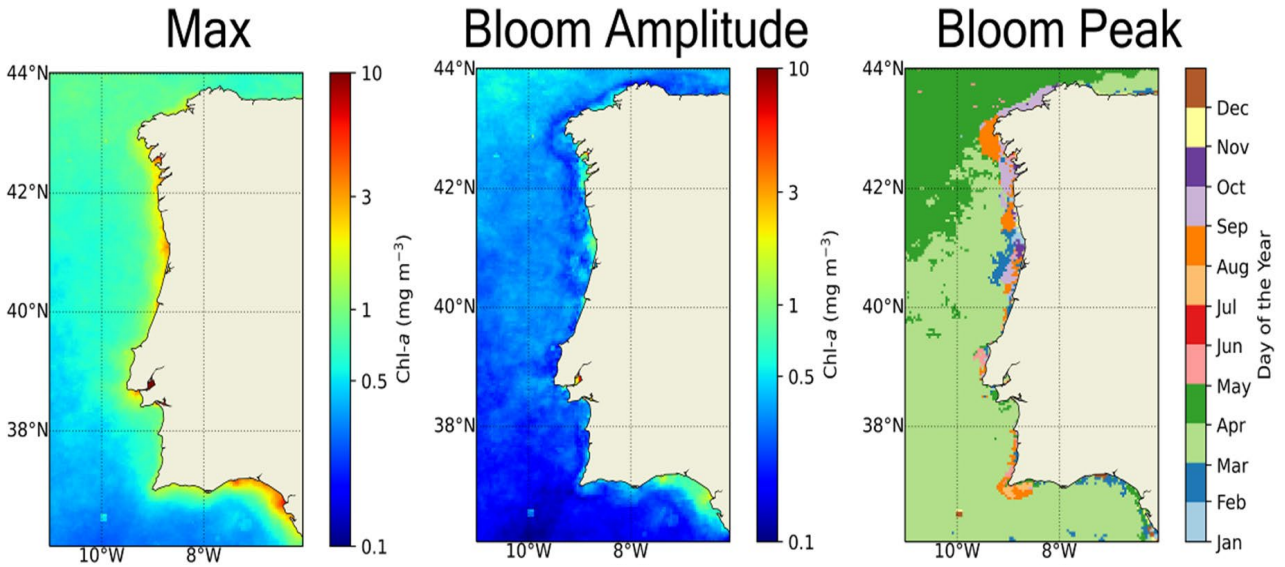
- Comparison of 25-year time series of PP between Atlantic EBUS
- Investigate relationships to climate and other indices

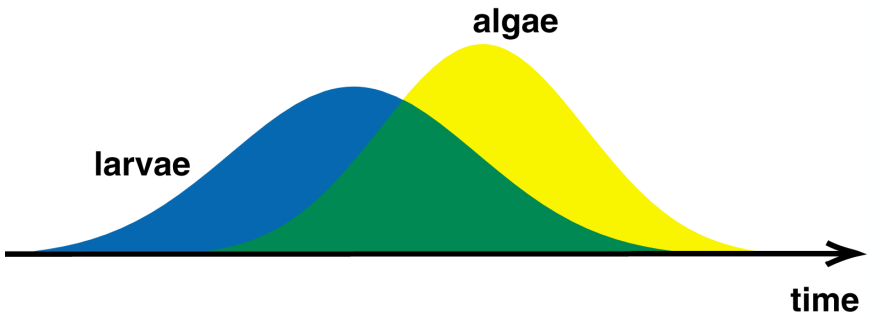


Science Case 7: Relating EBUS PP to fisheries

- Investigate links between PP phenology and recruitment of *Sardina pilchardus*, the most important of the pelagic fish of Iberian fisheries
- PP as proxies for food availability for fish larval development, influencing recruitment (the Hjort–Cushing hypothesis: Platt *et al.* 2003)

Chl-a bloom phenology metrics for Iberian Peninsula

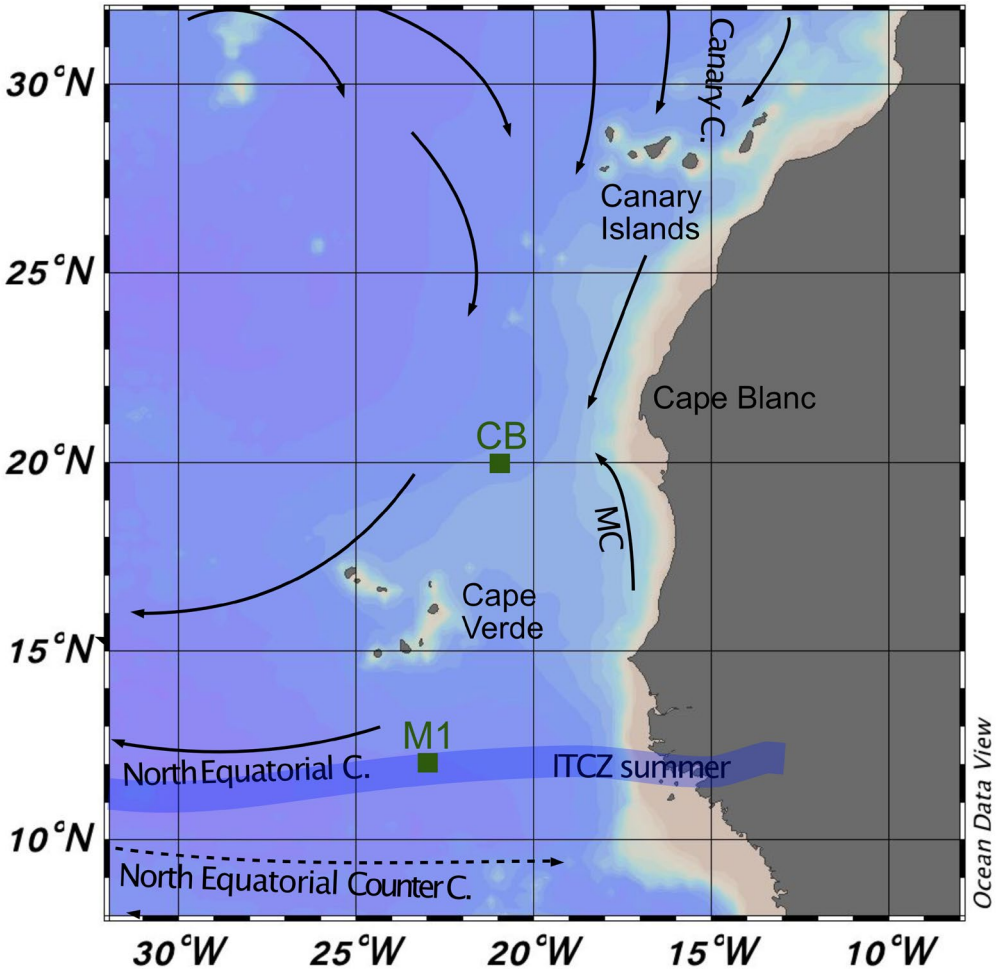




Ferreira et al. (2021)

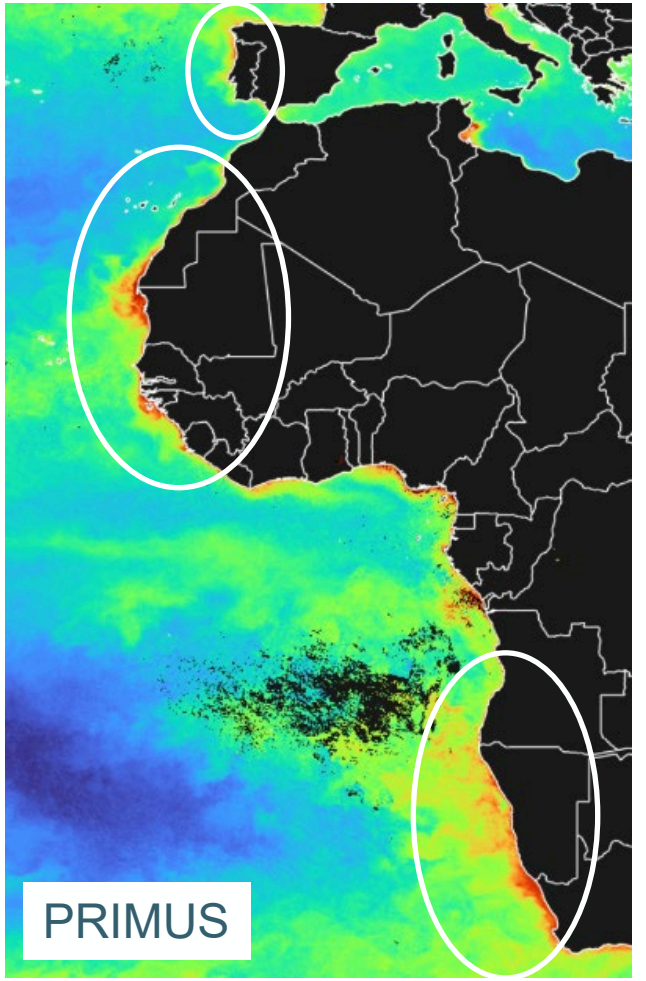
Science Case 8: Particle flux

- Builds on Guerreiro *et al.* (2019, 2021), using an area-average approach to compare satellite Chl-a and PIC with particle flux data collected at two trap moorings at 1200 m
- Good match between *in situ* observations of seasonally resolved fluxes and satellite RS in some cases
- Will use both standard estimates of PP and a Lagrangian approach to follow particles from the upwelling zone in 3D



ESA PRIMUS Summary

- Primary production products
  - 25-year, 1-km PP time-series in Iberian, Canary and Benguela upwelling systems based on OC-CCI
  - Experimental 300-m PP from unique capabilities of MERIS/OLCI in Galician upwelling, Spain
- 9 Science Cases
  - PP interannual variability; Carbon pools; Lagrangian PP; Fisheries; Particle export
- 4 Science into Impact Demonstrations
  - MSFD monitoring; Fisheries; Aquaculture; links with Future Earth Coasts
- Future R&D roadmap



Monthly Chl-a; ESA Ocean Colour CCI

Thank you

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