Ocean Predict

SYMPOSIUM OP'24

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Enhancing Coastal Modeling: Integrating Suspended Particulate Matter effects on Biogeochemical Processes in the Tyrrhenian Sea

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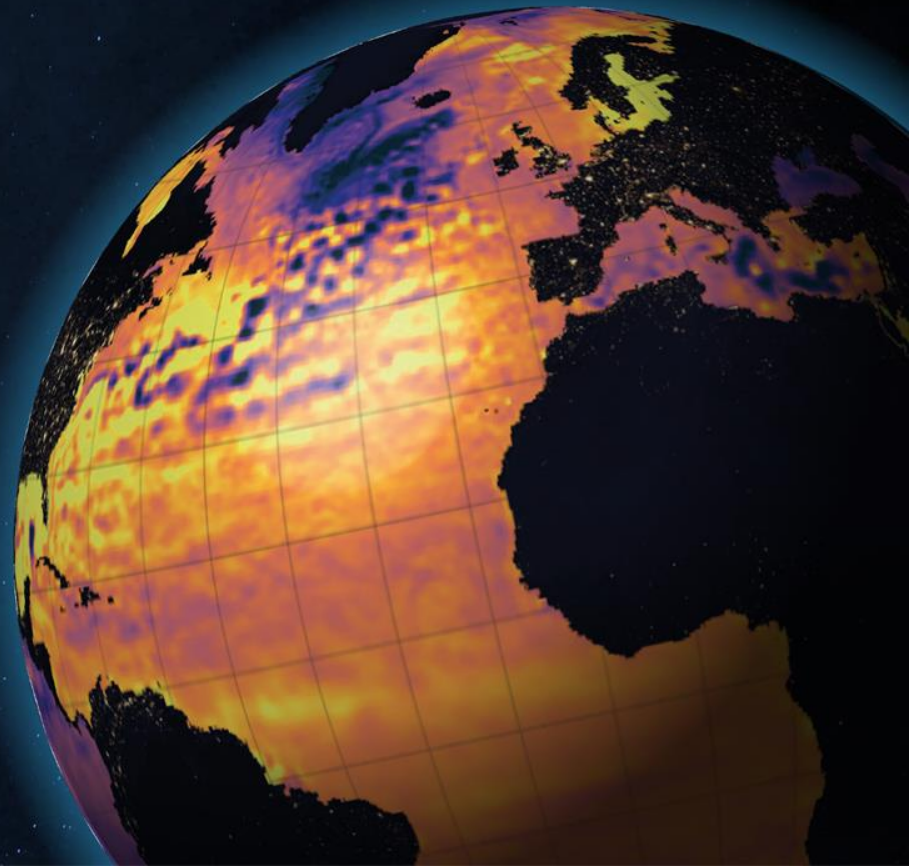

Motivations

- Suspended particulate matter (SPM) plays a critical role in coastal environments, particularly in the attenuation of light, which significantly impacts biogeochemical processes and marine ecosystems.

- The dynamics of SPM, especially its inorganic component, are often overlooked in coastal modeling, leading to gaps in understanding key ecosystem interactions.

- The adoption of SPM models in coastal simulations is invaluable, offering substantial advancements in the management and preservation of coastal ecosystems.

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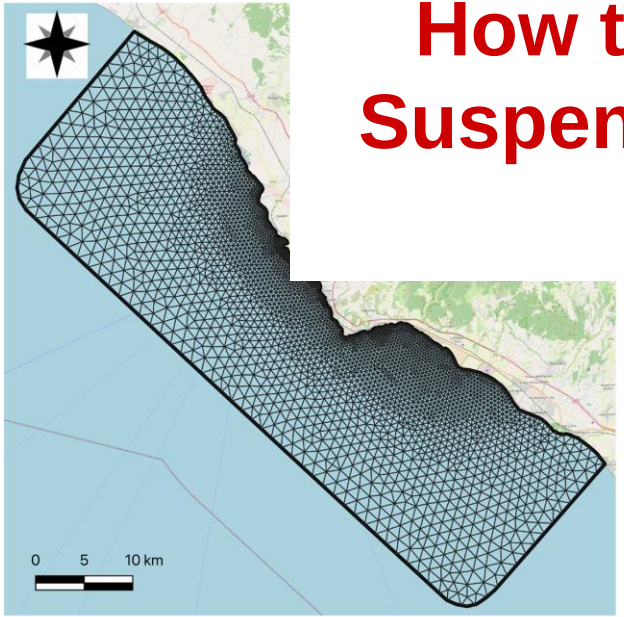
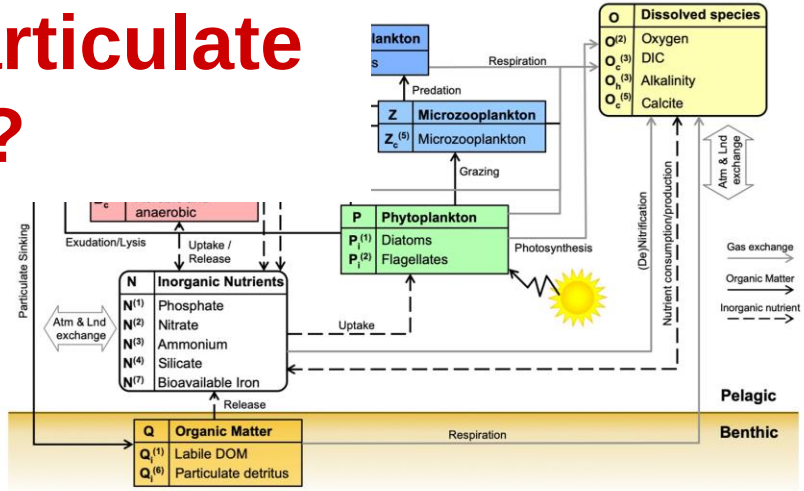
Marine Physical-Biogeochemical modelling system

SHYFEM-MPI (Micaletto et al., 2021) is the MPI implementation of the three-dimensional finite element model SHYFEM (Umgiesser, 2010).

The Biogeochemical Flux Model (**BFM**, Vichi et al., 2020) relies on the stoichiometrically variables representation of living and non-living Functional Groups to simulate the main pelagic nical cycles.

How to fit Inorganic Suspended Particulate Matter?





Inorganic Suspended Particulate Matter Composition

Suspended Particulate Matter

Organic Particulate Matter (oSPM) is handled by the core biogeochemical model

Inorganic Suspended Matter (iSPM) (Particulated 2-2000 µm)

Sediments are classified by grain size dimension

Cohesive (d<63 micron)

Non-Cohesive (d>63 micron)

		Clast name	Diameter Range
Non-Cohesive	Coarse-grained	Boulder	Larger than 256 mm
		Cobble	64 mm - 256 mm
		Pebble	2 mm - 64 mm
	Medium-grained	Sand	63 µm - 2 mm
		coarse	500 µm - 2 mm
		medium	250 µm - 500 µm
Cohesive		fine	63 µm - 250 µm
	Fine-grained	Silt	2 µm - 63 µm
		Clay	Smaller than 2 µm

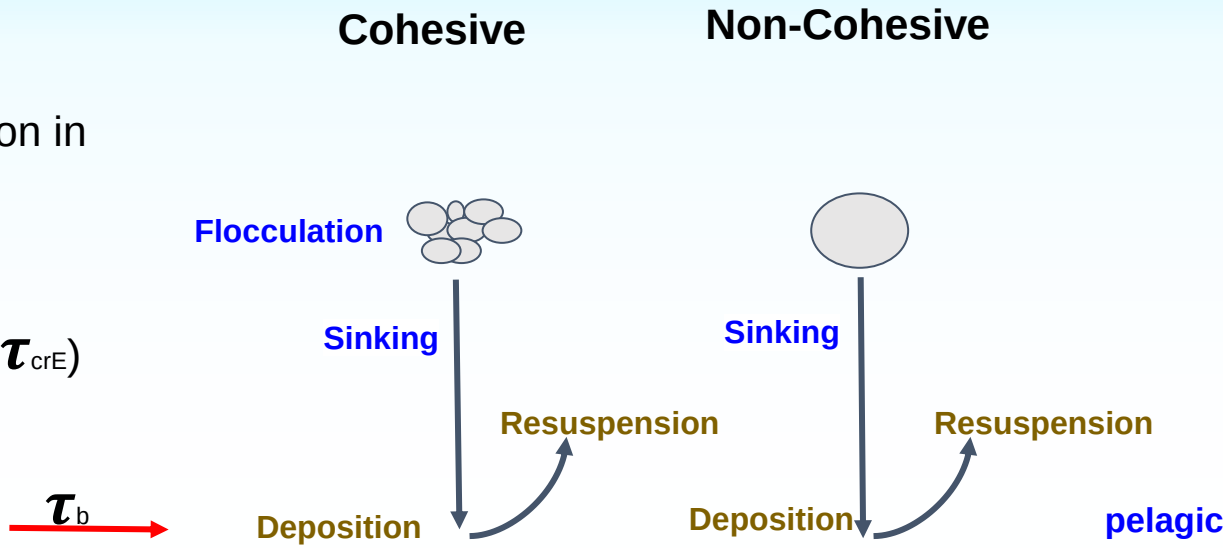
Table. Classification based on grain size. Wentworth (1922).

Inorganic Suspended Particulate Matter Processes

A) Individual sediment classes concentration in the water column

B) Temperature and salinity profiles (for τ_{crE})

C) Bottom stress (τ_b)



Mass of each sediment class in seabed

Case study: Civitavecchia (Italy, Tyrrhenian Sea)

Location: Tyrrhenian Sea, Civitavecchia (Italy), (extension is 20 km offshore, 65 km alongshore)

Horizontal Resolution: from 100m near the coast up to ~1.5Km in the open ocean

Vertical Resolution: 43 levels from 1m to 220m

Initial Conditions:

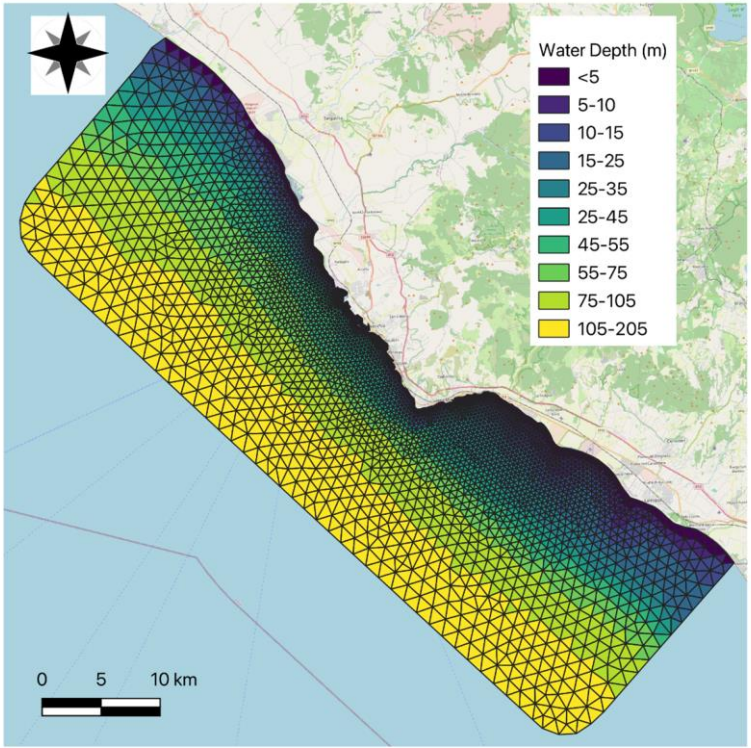
CMEMS MED Reanalysis	(Physics)
NEMO-BFM hindcast simulation	(Biogeochemistry)
EMODnet Seabed-habitats	(Bottom Sediments)

Boundary Conditions:

CMEMS MED Reanalysis	(Physics)
NEMO-BFM hindcast simulation	(Biogeochemistry)
CMEMS MED L3 SPM	(iSPM)

Forcing: ERA5 reanalysis

Period: 2 years, 2020-2021



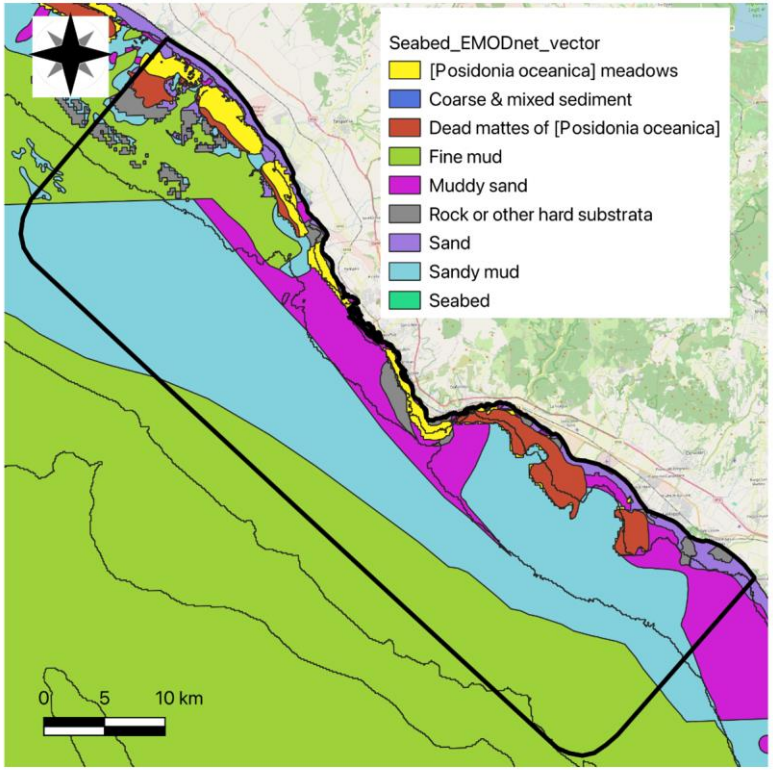
Sediment classes definition and Seabed types

2 classes for pelagic and benthic systems:
Mud [10 μm] - cohesive
Fine Sand [80 μm] - non-cohesive

1 class only for benthic system:
ROCKS [0.1m]
(NO Erosion and Deposition)

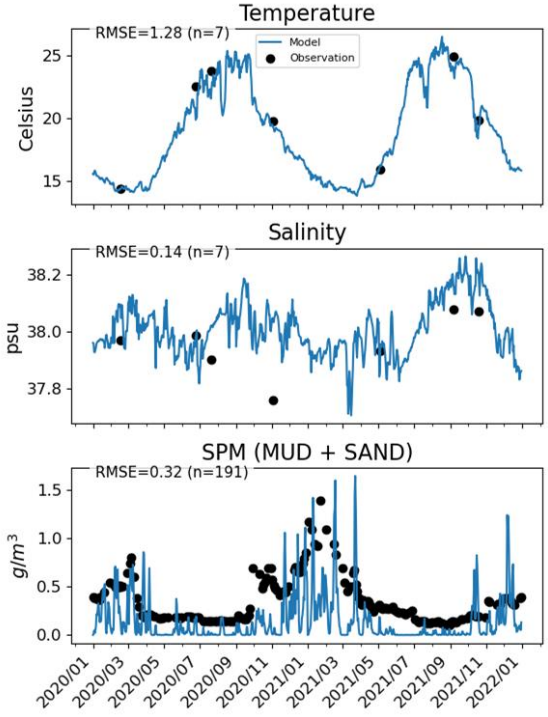
Pelagic sediment initial concentrations in the water column are set to zero.

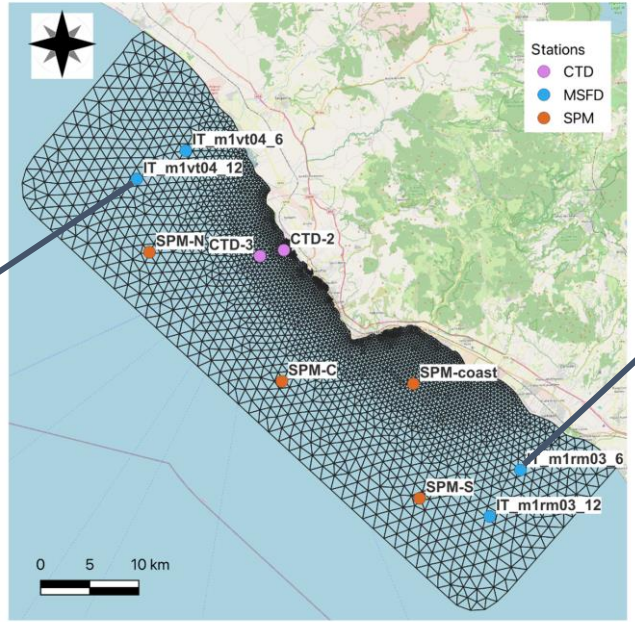
Seabed Habitats dataset from EMODnet was used to identify sediment classes and create initial spatial distribution of each sediment class.

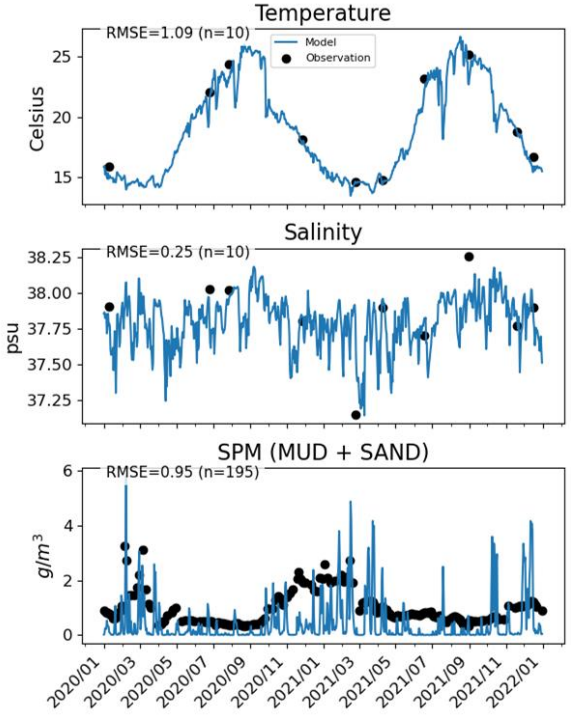


iSPM module verification

The 2 year physical simulation starts after 3 years of spin up and the pelagic SPM classes are initialized at zero. Different monitoring points were selected to evaluate the model dynamics.







Vertical light extinction experiments

Vertical Light Extinction (ε) formulations analysed

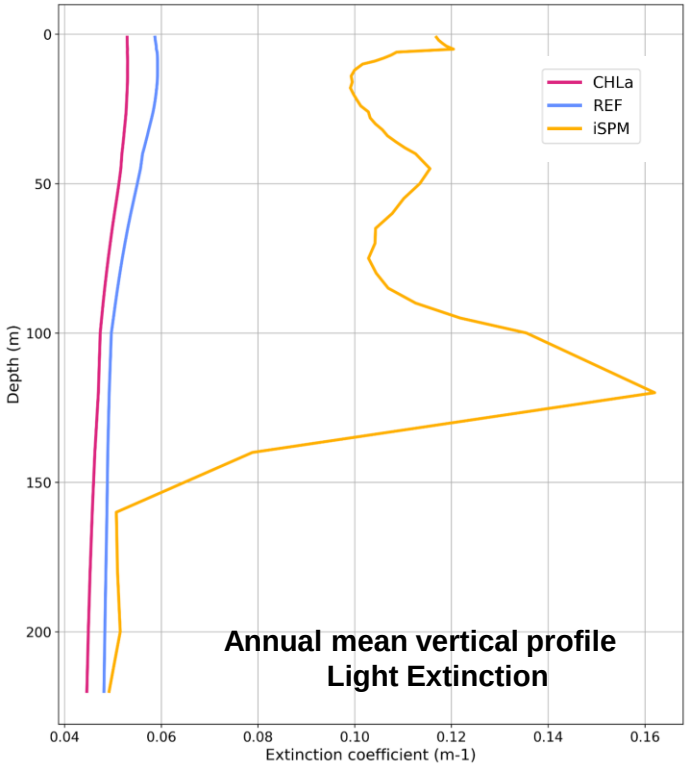
$$\varepsilon = \varepsilon_0 + \varepsilon_{chla} \cdot Chla + \varepsilon_{r6} \cdot R6 + \varepsilon_{ess} \cdot ESS$$

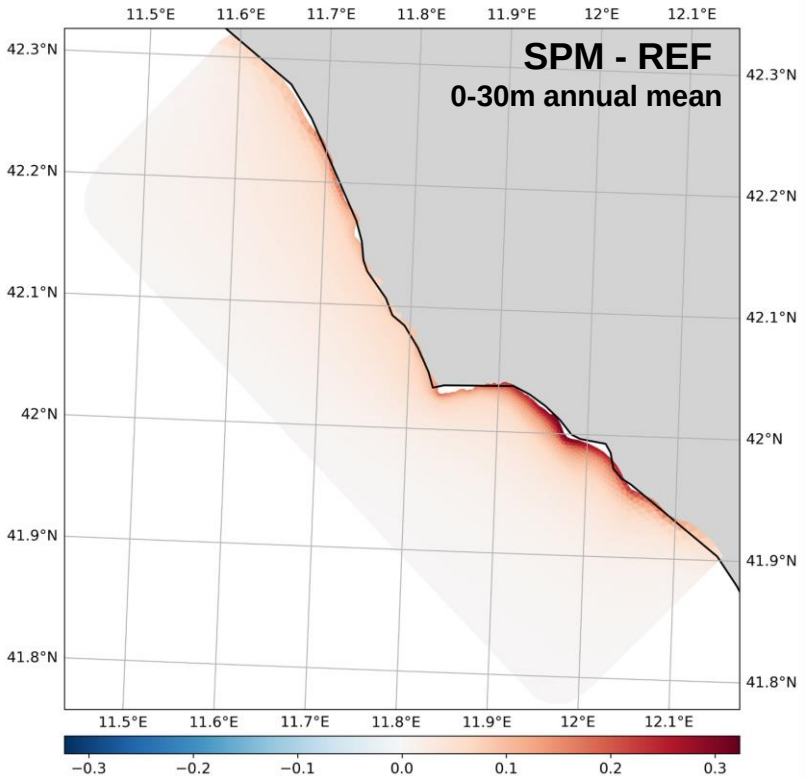
CHLA REF iSPM

Where:

- ε: Total extinction coefficient
- ε_0: Background attenuation
- ε_{r6}: POC-specific attenuation
- R6: POC concentration
- ε_{ess}: SPM-specific attenuation
- ESS: Suspended sediments concentration
- ε_{chla}: Chlorophyll-specific attenuation
- Chla: Chlorophyll concentration

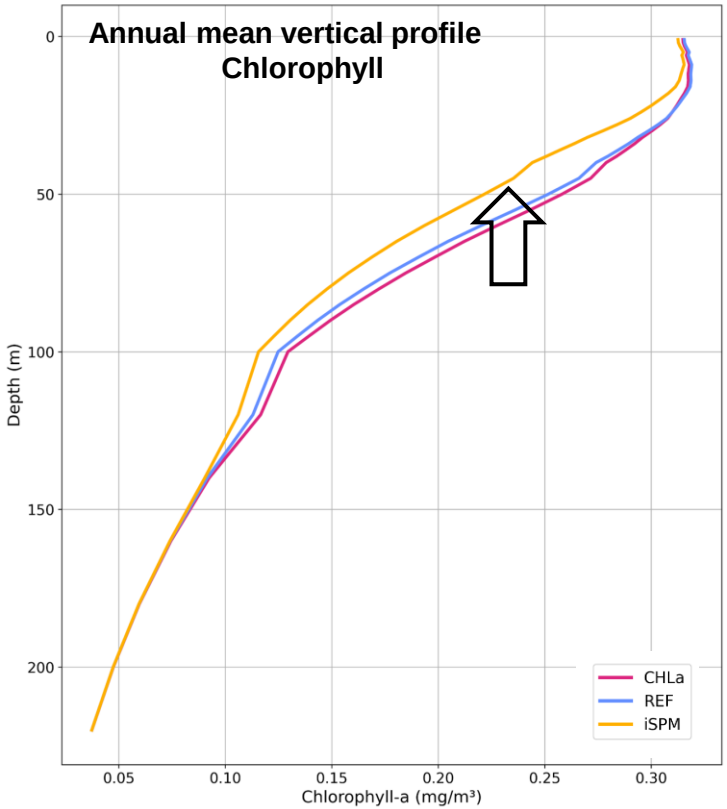
Light Extinction in the water column

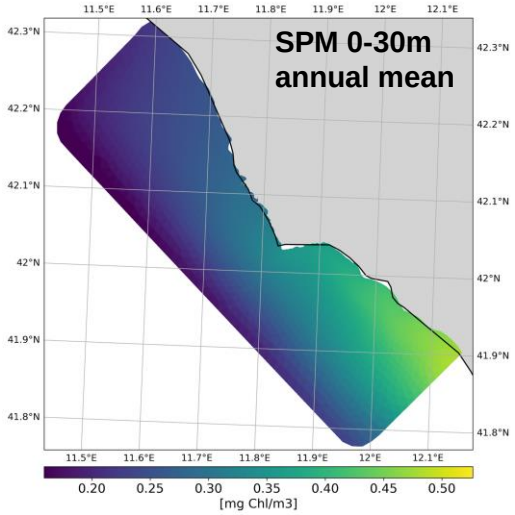


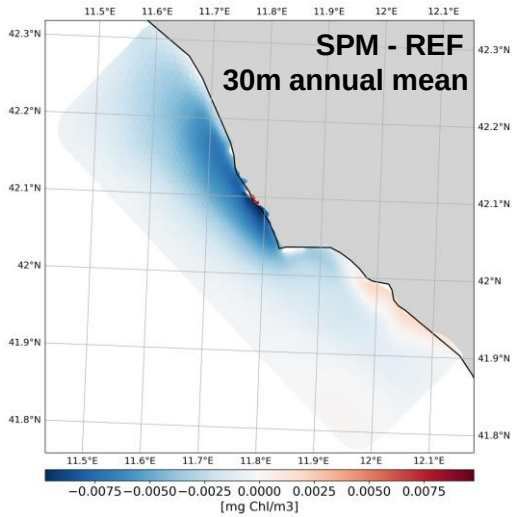


Light Extinction is higher in SPM experiment over all the domain → due to suspended sediments in the water column

Chlorophyll

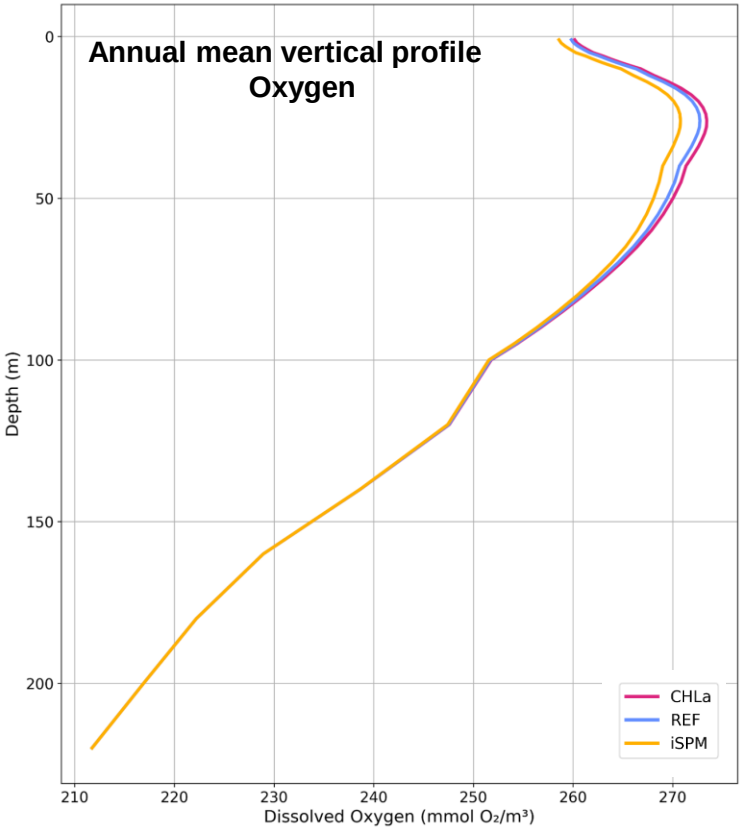


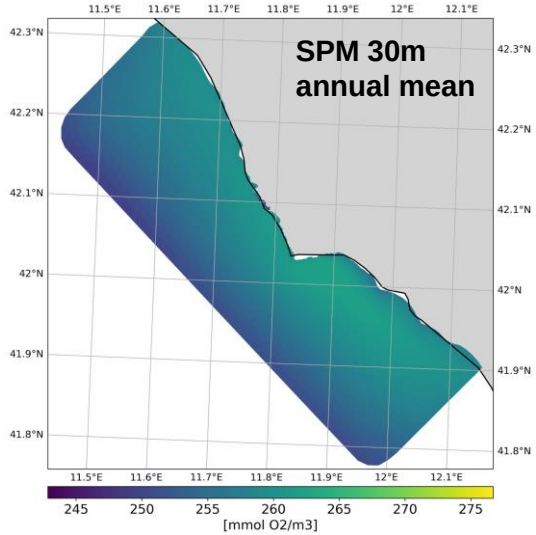


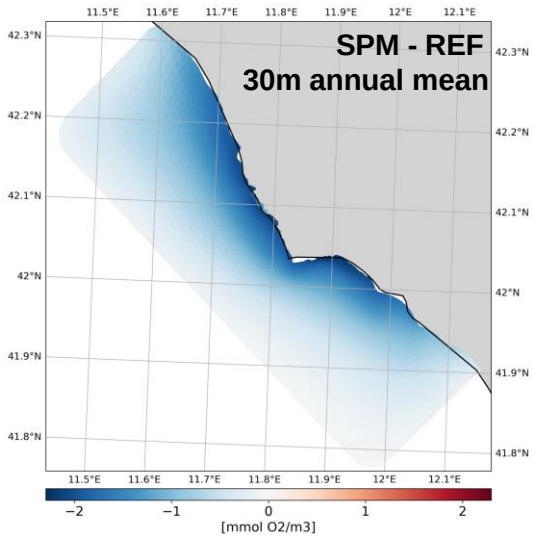


- Highest Chlorophyll concentrations in the first 20-30m
- Between 40m-100m, chlorophyll decreases rapidly in all configurations
- The SPM configuration shows lower chlorophyll concentrations between 0-100m due to limited availability of light
- The inclusion of SPM causes an upward shift of Chlorophyll likely linked to the shift of the optimal growth conditions for phytoplankton

Oxygen

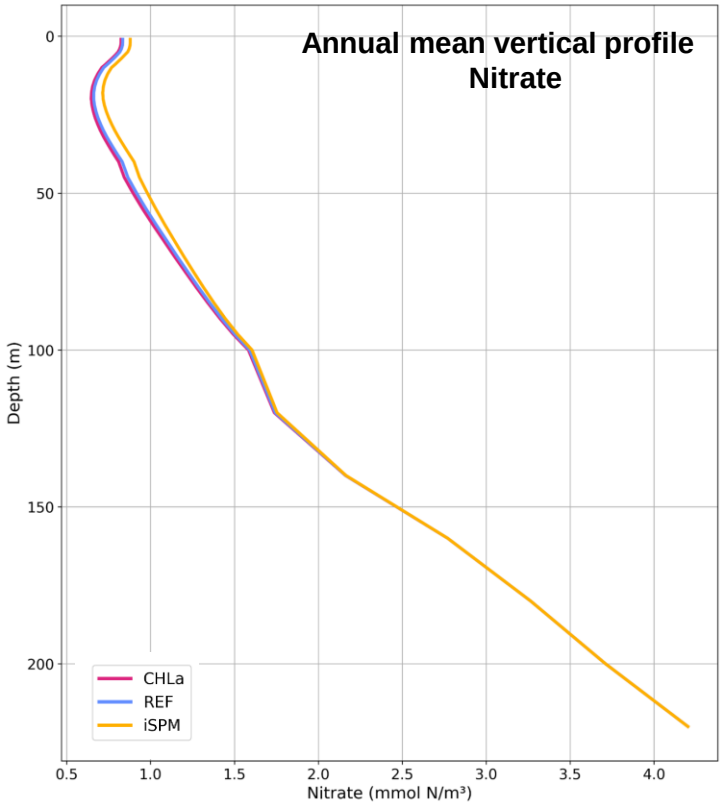


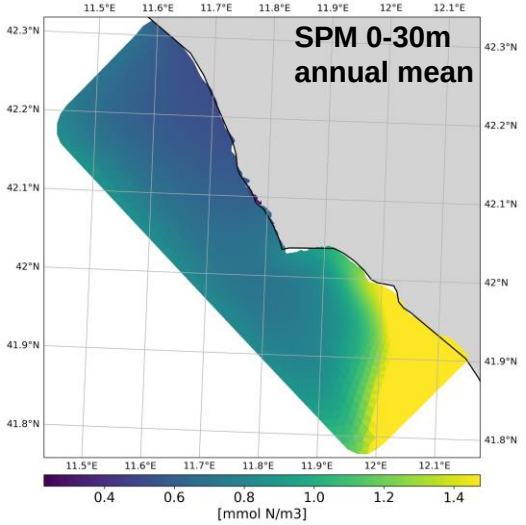


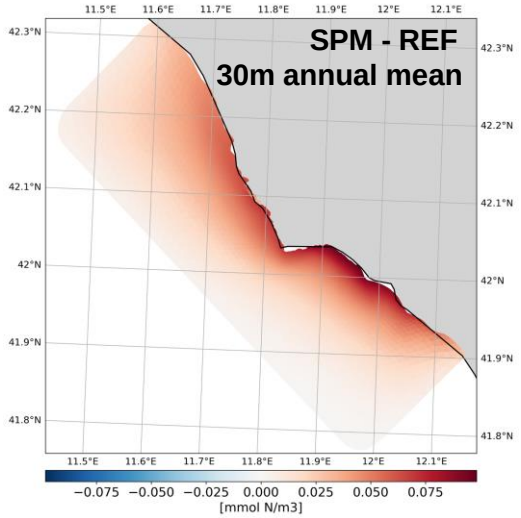


- All configurations show a maximum around 30-40m depth
- Below 100m, oxygen decreases gradually
- The profile with SPM shows lower oxygen concentrations in the upper layer: the addition of SPM increases light attenuation slightly reduced photosynthesis and therefore slightly lower oxygen production at the surface

Nitrate







- Low surface concentrations at surface
- Clear nutricline starting around 50m depth
- Increasing concentrations with depth
- Small differences between experiments: slightly higher values with SPM in upper layers likely due to reduced nutrient uptake from lower phytoplankton activity

Key findings

- Insignificant differences between CHLa and REF experiments, suggesting that REF addition does not substantially modify the biogeochemical dynamics.
- iSPM has significant impact in the upper-middle layers (0-100m):
  - Most notable effects are observed in the euphotic zone where light plays a crucial role
  - Modifies the underwater light field through increased attenuation which leads to:
    - Decreased chlorophyll concentrations throughout the water column due to reduced light availability for photosynthesis
    - Reduced oxygen production as a direct consequence of lower photosynthetic activity
    - Slightly higher nutrient concentrations in surface waters due to reduced uptake from lower phytoplankton activity
- Despite the high difference in light extinction, biogeochemical patterns remain stable:
  - Nutrient profiles maintain their characteristic shape
  - Oxygen distributions show only minor modifications while preserving typical vertical structure
  - The fundamental biogeochemical functioning of the system persists across configurations, indicating model robustness

NEXT STEPS: study seasonal variations, phytoplankton structure modifications, effects on the biological pump efficiency

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