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The effect of water turbidity on the upper-ocean properties and dynamics in the Mediterranean and Black Seas

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Objectives

Evaluate and understand the sensitivity of upper-ocean dynamics to water turbidity as estimated via surface chlorophyll.

- How the Spatio-temporal variations of turbidity affects upper-ocean temperatures?
- How this variability affects air-sea fluxes?
- Should the influence of chlorophyll be considered in climate forecasts?

Model

The model used is a regional configuration of the NEMO ocean model covering the Mediterranean and Black Seas (Fig. 1). The model domain set-up and physics parameterizations are very similar to the one used by [1].

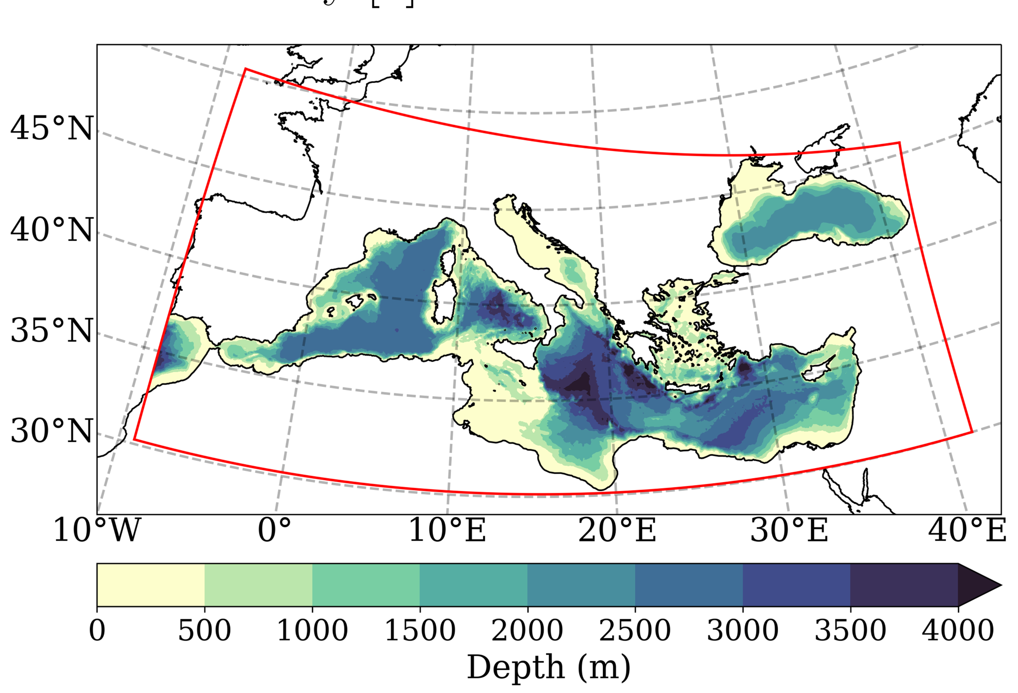


Figure 1:The simulation domain (red line) and its bathymetry in meters.

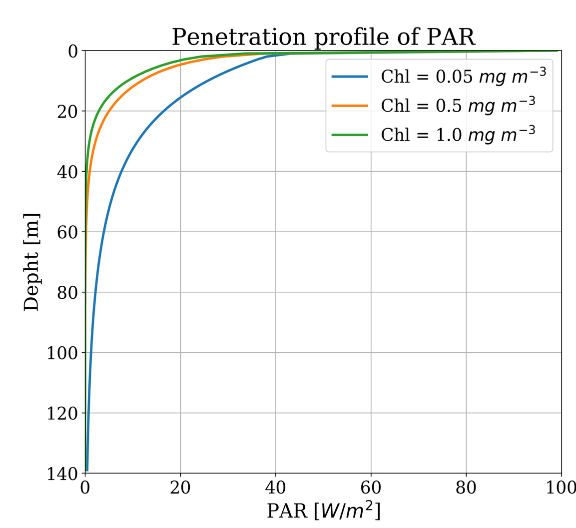
Table 1:Model configuration

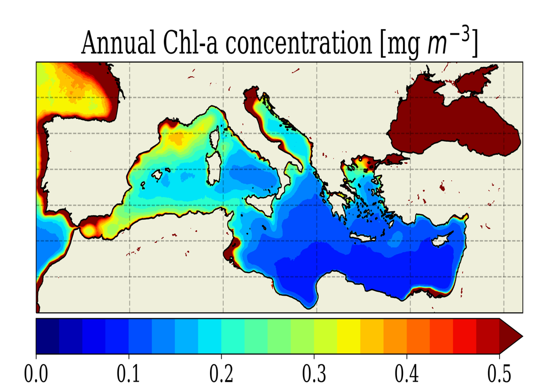
NEMO v4.2.0 ocean model [2]
Δx,y $\sim$ 1/12° [609 × 320]
50 vertical levels, $\Delta t = 360$s
Med and Black Seas explicitly connected
Atm. forcing: 3-hourly ERA5 reanalysis
IC/LC: GLORYS12 daily reanalysis
Tidal potential: On
Period of study: Jan. 2012 → Dec. 2018
Spin-up: 4 yrs starting from Jan. 2008

Experimental design

1. We performed **twin-simulation** experiments that only differ in the spatial and temporal distribution of the chlorophyll concentrations used to estimate water turbidity:
-CST Fixed turbidity (i.e. a constant Chl value everywhere at 0.05 mg/m^3) representative of clear waters.
-CHL.clim Monthly satellite Chlorophyll-a climatology used to estimate turbidity and SWR penetration.

2. The solar radiation penetration is computed using a three-waveband RGB formulation [3] considering the surface Chl concentration (Copernicus GlobColour product [4]).





SST changes

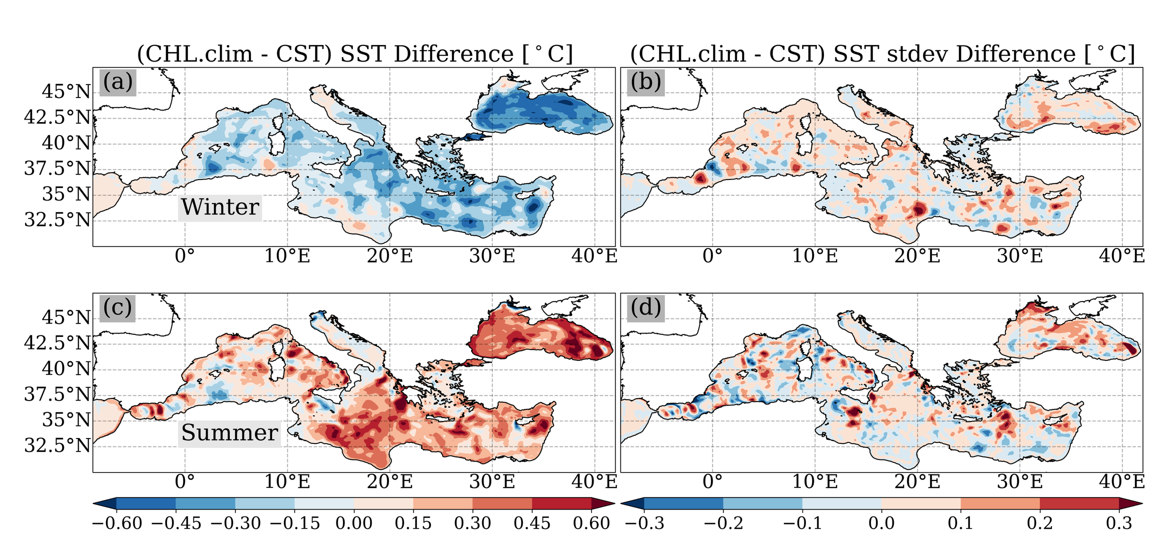
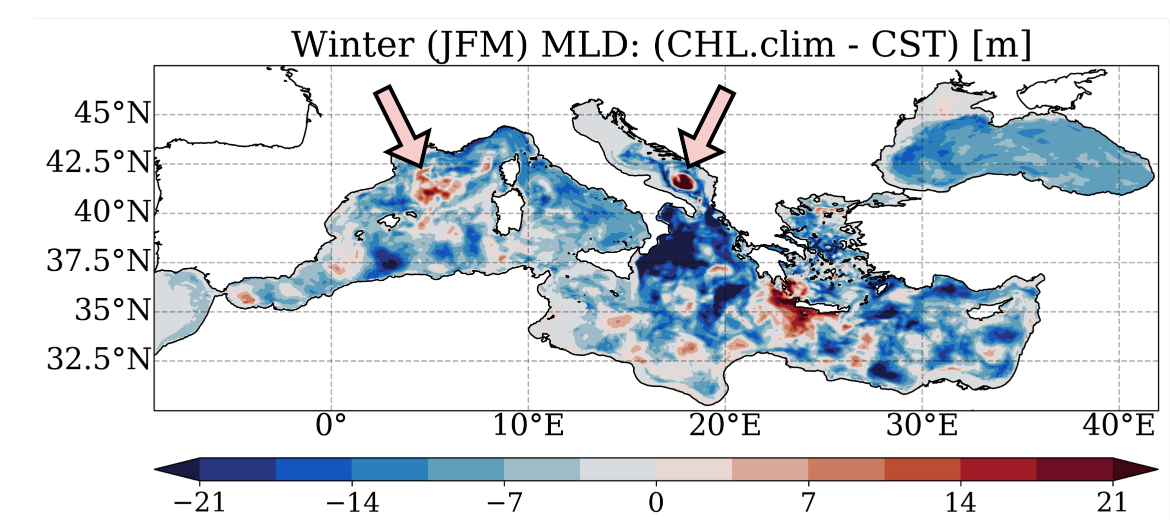


Figure 2:Spatial differences for SST (left column) and its standard deviation (stdev; right column) during winter (a-b) and summer (c-d) period.

- **Summer**: warmer SSTs in CHL.clim (shallow MLD & low Chl values); **Winter**: SSTs become cool instead of warm despite high Chl values.
- Stronger SST variability in CHL.clim; The difference in stdev locally exceeds 0.3° C.
- SST changes lead to an increase in annual heat loss in the Med Sea by about 1.5 W/m^2.

Winter MLD differences



Turbidity decreases the mixed layer depth (MLD) over the entire domain during winter, except for the main deep convection areas in the Med Sea.

Subsurface ocean changes

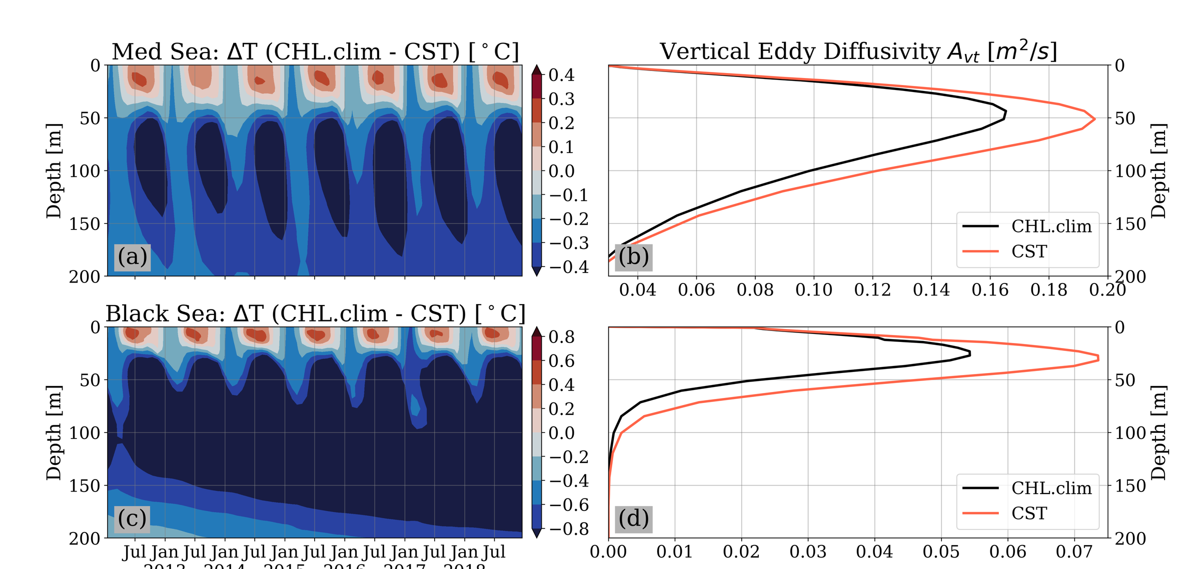
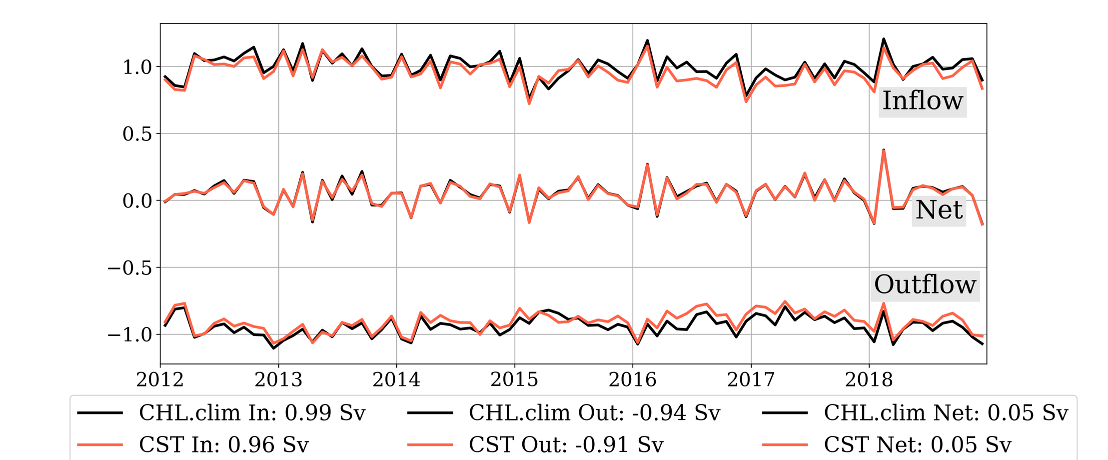


Figure 3:Time-depth evolution of temperature difference between the two experiments (left column) and eddy vertical diffusivity during winter (right column) for the Mediterranean (a-b) and Black Sea (c-d) respectively.

- In the surface layer (0-20 m): more intense warming in summer than cooling in winter; Basin scale cooling below the mixed layer.
- Weaker vertical mixing in CHL.clim is associated with shallower MLD and surface cooling during winter.

Transport at Gibraltar



Slightly stronger transport in both directions when considering turbidity.

Messages and future steps

- Upper-ocean temperature changes depend not only on water turbidity variation, but also on dynamical processes such as vertical mixing.
- **Ongoing work** is currently being undertaken to estimate the indirect atmospheric feedback due to turbidity changes, using a fully-coupled ocean-atmosphere system (NEMO-WRF).

References

[1] G. Varlas, V. Vervatis, C. Spyrou, E. Papadopoulou, A. Papadopoulos, and P. Katsafados. Investigating the impact of atmosphere–wave–ocean interactions on a mediterranean tropical-like cyclone. *Ocean Modelling*, 153:101675, 2020.

[2] `https://www.nemo-ocean.eu/` (Accessed: 2023-03-15).

[3] Matthieu Lengaigne, Christophe Menkes, Olivier Aumont, Thomas Gorgues, Laurent Bopp, Jean Michel André, and Gurvan Madec. Influence of the oceanic biology on the tropical pacific climate in a coupled general circulation model. *Climate Dynamics*, 28:503–516, 4 2007.

[4] https://doi.org/10.48670/moi-00281.

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