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Seasonal and interannual variability of the pelagic ecosystem and of the organic carbon budget in the Rhodes Gyre (eastern Mediterranean): influence of winter mixing

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Text S1: Equation of OC balance

The variation of the OC inventory in the upper layer of the Rhodes Gyre between times t_1 and t_2 ($\Delta\ OC\ I_{upper}$), in mol C m^{-2}, is equal to the time-integrated sum of all OC fluxes within the Rhodes Gyre area between t_1 and t_2:

$$\Delta\ OC\ I_{upper} = OC\ I_{upper,\ t2} - OC\ I_{upper,t1} = \int_{t_1}^{t_2} \left(F_{OC,lat} + F_{OC,vert} + F_{OC,bgc}\right) dt \qquad \text{(S1)}$$

where $F_{OC,lat}$ and $F_{OC,vert}$ are the lateral and vertical exchange fluxes at the boundaries of the upper layer (150 m to the surface) of the Rhodes Gyre area, and $F_{OC,bgc}$ is the biogeochemical flux inside the Gyre.

$OC\ I_{upper,t}$ was computed from:

$$OC\ I_{upper,t} = \int\int \int_{(x,y)\in\ RG/z\in upper\ layer} OC(x, y, z, t)\ dx\ dy\ dz \qquad \text{(S2)}$$

OC is the sum of organic carbon fast- and slow-sinking detritus, dissolved organic carbon and the carbon biomass of phytoplankton, zooplankton and bacteria.

The lateral exchange flux was computed from:

$$F_{OC,lat} = \int\int_A OC\ *\ (x, y, z, t)\ v_t(x, y, z, t)\ dA \qquad \text{(S3)}$$

where v_t is the current velocity normal to the limit of the Rhodes Gyre area, A is the area of the vertical section limiting the Rhodes Gyre and extending from the base of the upper layer (150 m) to the surface, and where OC* is a function of OC which results from the use of the QUICKEST advection scheme (Leonard, 1979):

$$OC\ *= OC\ -\ \frac{Dx}{2} Cr\ GRAD\ - \frac{1}{3}(1\ -\ Cr^2)\ CURV \qquad \text{(S4)}$$

where Dx is the grid horizontal resolution, CURV and GRAD are given by Leonard (1979) and *Cr* is the Courant number.

$F_{OC,bgc}$ was computed from:

$$F_{OC,bgc} = \int\ \int\ \int_{(x,y)\in\ RG\ /\ z\ \in\ upper\ layer} BGCflux(x, y, z, t)\ dx\ dy\ dz \qquad \text{(S5)}$$

where *BGCflux* is the biogeochemical flux, i.e. GPP - CR (see Table S4 in Supplement Material by Many et al. (2021)).

Finally, the vertical transport flux, $F_{OC,vert}$, was derived from all other terms of Eq. (S1).

The computation of OC balance in the intermediate layer is computed in a similar way between 150 and 400 m

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Table S1: Metrics computed from chlorophyll (Chl) concentration, winter (December-January-February) mixed layer depth (MLD) and surface heat flux for the Rhodes Gyres over the period of 2013-2020. For the mean, the values in parenthesis represent the standard deviation (SD). Winters with strong heat loss and deeper mixed layers are emphasized in bold.

	Units	2013-14	**2014-15**	2015-16	**2016-17**	2017-18	**2018-19**	**2019-20**	Mean (SD)
Mean winter surface heat flux	W m^{-2}	-86	**-139**	-124	**-153**	-119	**-146**	**-142**	-130 (23)
Maximum MLD	m	92	**176**	120	**143**	98	**127**	**124**	126 (28)
Mean winter MLD	m	51	**72**	61	**79**	62	**84**	**65**	68 (11)
Maximum Chl	mg m^{-3}	0.15	**0.33**	0.23	**0.35**	0.22	**0.31**	**0.31**	0.27 (0.07)
Date of maximum Chl	-	12 Feb	**4 Mar**	17 Feb	**11 Feb**	7 Feb	**10 Mar**	**20 Feb**	-

Figures

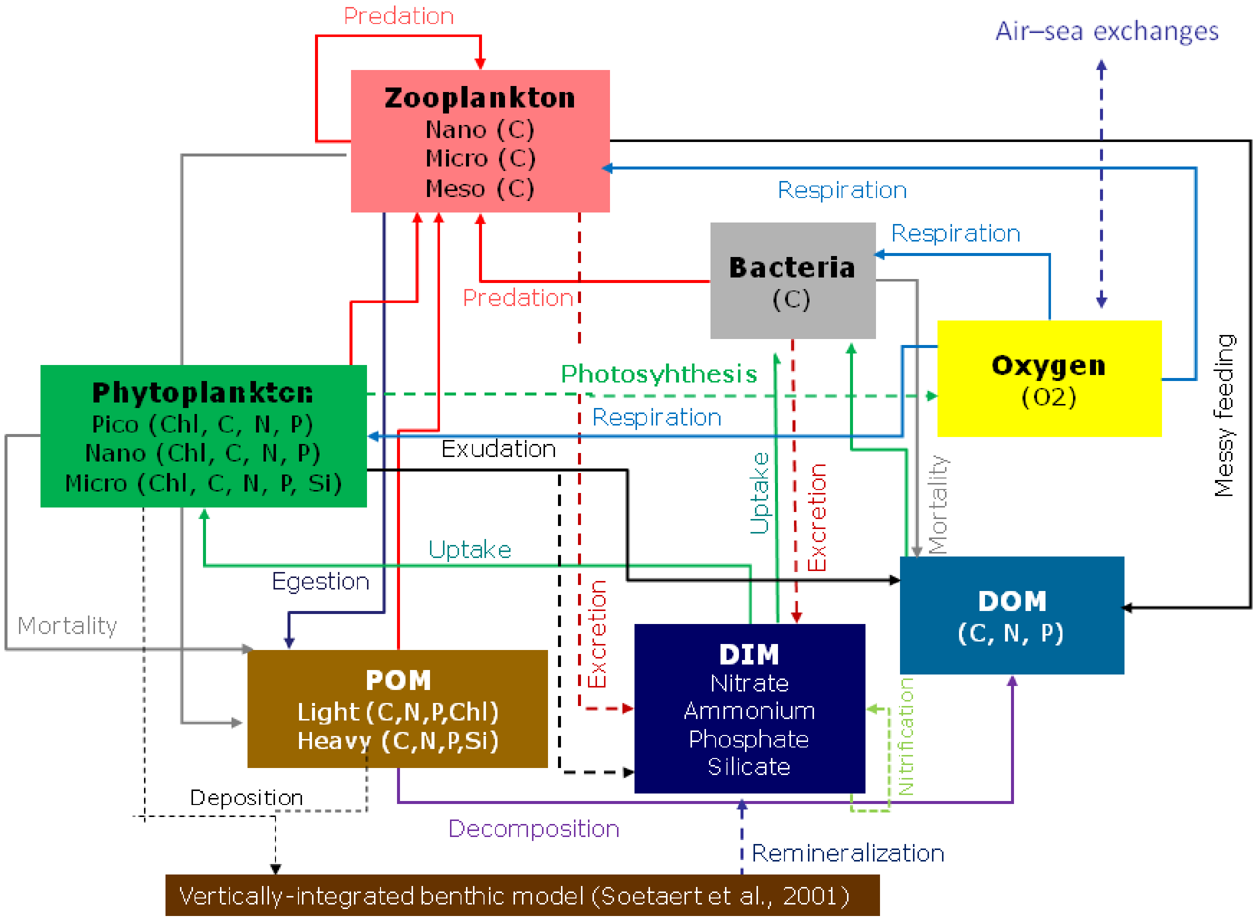

Figure S1: Schematics of the biogeochemical model Eco3M-S (from Ulses et al. 2021).

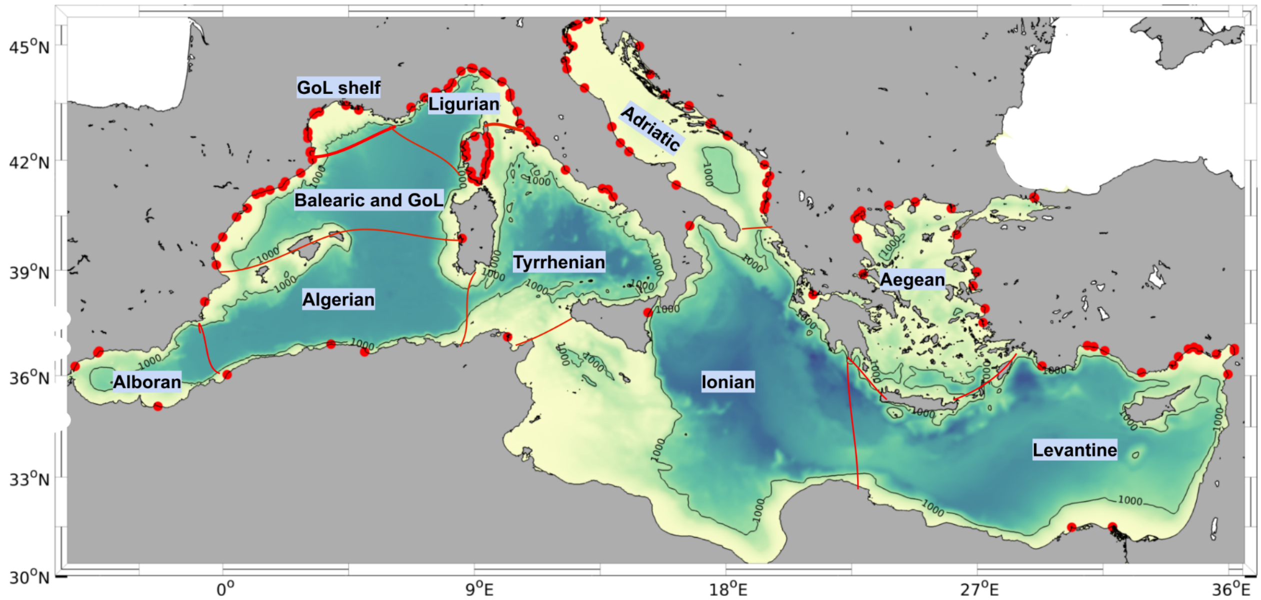

Figure S2: Subregions of the modeled Mediterranean Sea considered for the initialisation of the biogeochemical simulation. GoL: Gulf of Lion. Red dots represent river mouths, red lines indicate the limits of the sub-basins in the model.

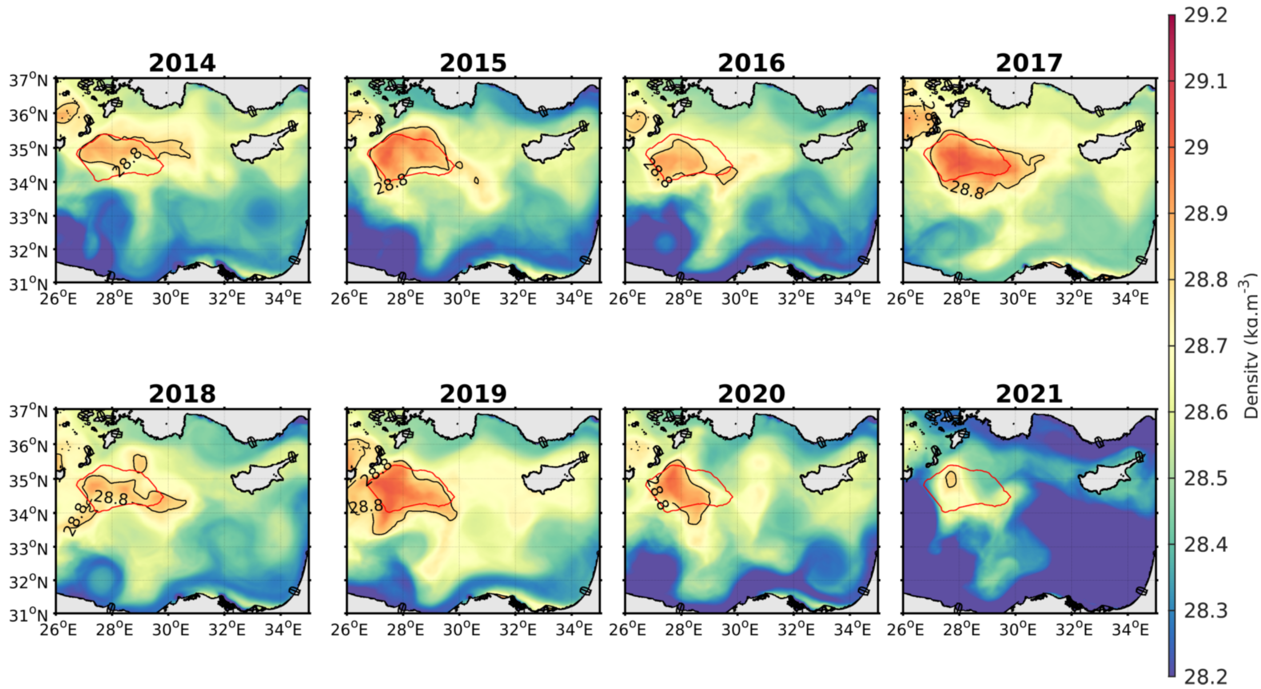

Figure S3: Surface density anomaly (kg m^{-3}) averaged over the mixing period (January-February-mid-March) from year 2014 to year 2021. The red line indicates the limit of the defined Rhodes Gyre area.

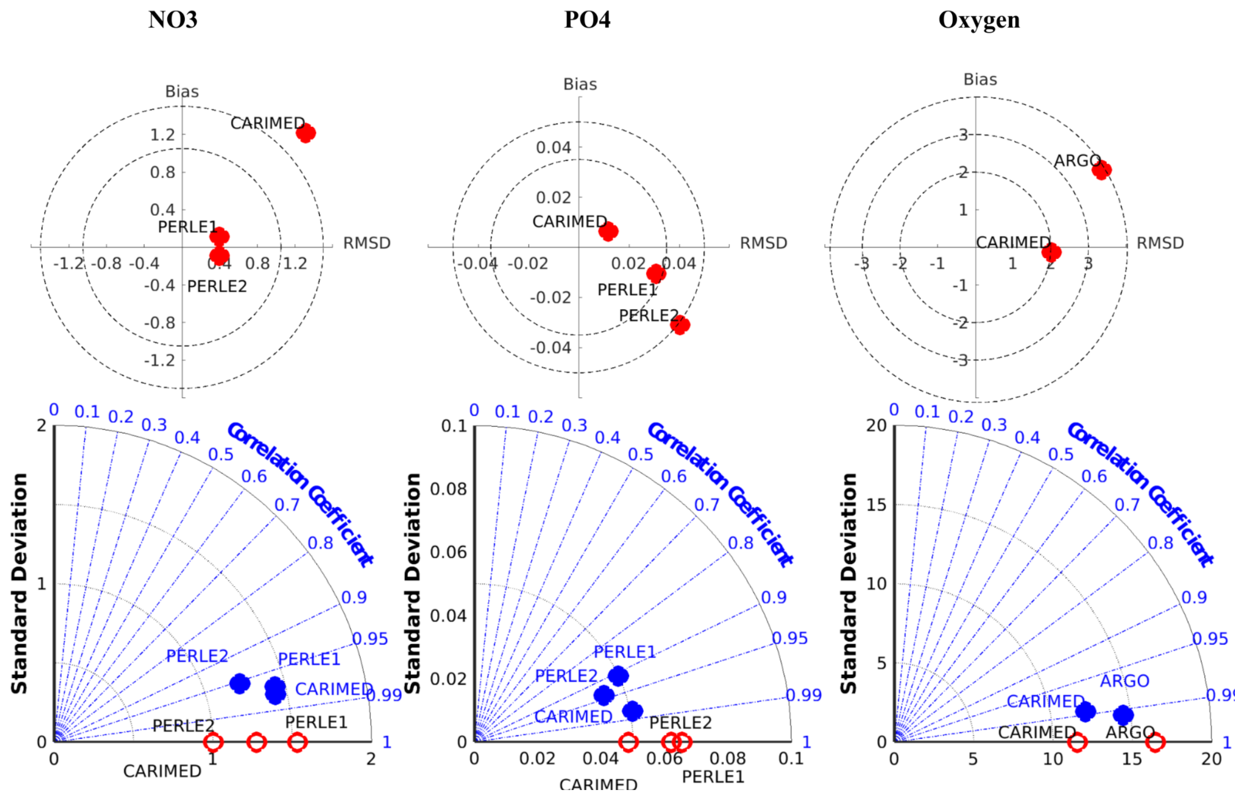

Figure S4: Statistical parameters of the modeled and observed nitrate (mmol N m^{-3}), phosphate (mmol P m^{-3}) and dissolved oxygen (µmol O_2 kg^{-1}) concentrations in the Levantine Basin: Top: target diagram of the bias and the ~~centered~~ RMSD, bottom: Taylor diagram with the correlation coefficient and the standard deviation. Blue dots indicate model outputs and red circles and dots observations. The angle represents the correlation coefficient.

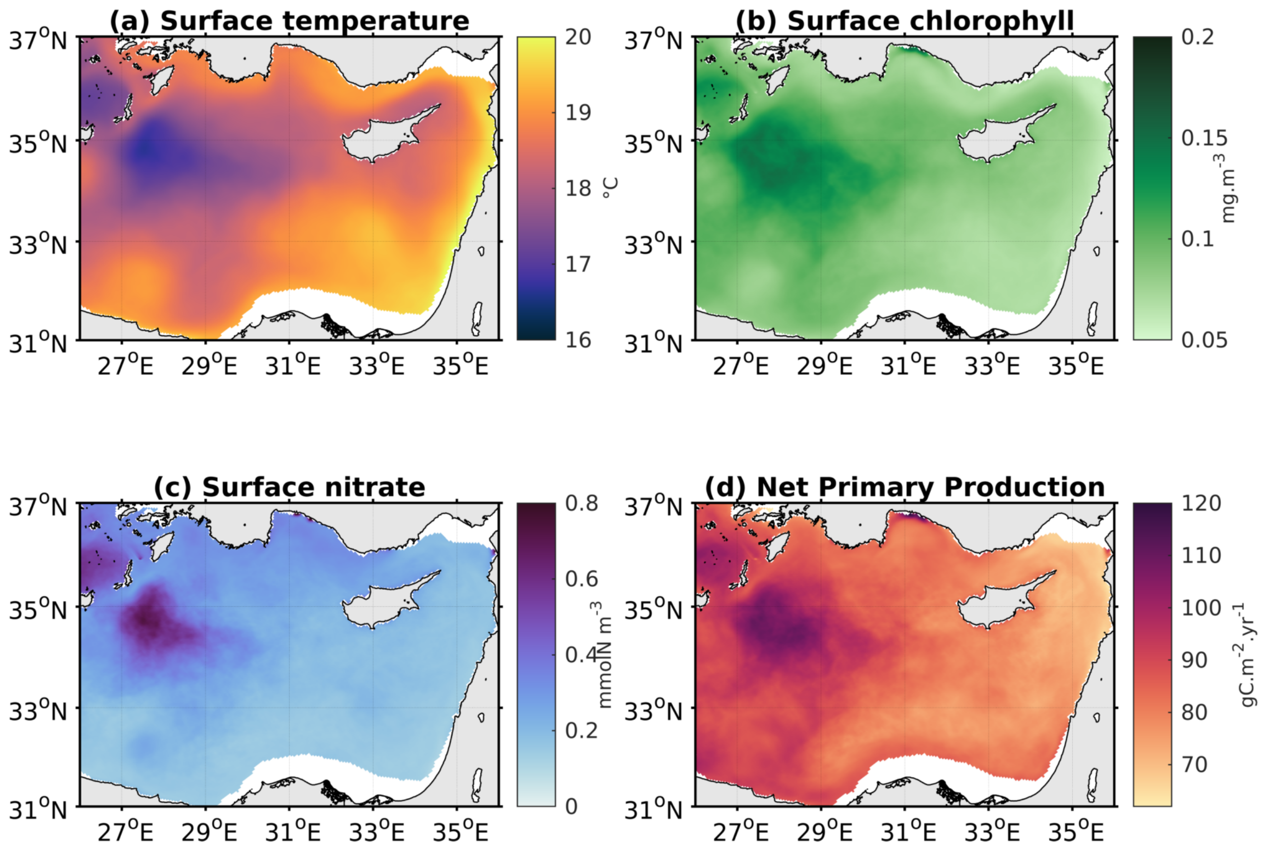

Figure S5: Modeled surface temperature (°C), chlorophyll (mg m^{-3}), nitrate (mmol N m^{-3}) concentrations and net primary production integrated over the surface (0-150 m) layer (g C m^{-2} yr^{-1}), averaged over the 2013-2020 winters (December-January-February).

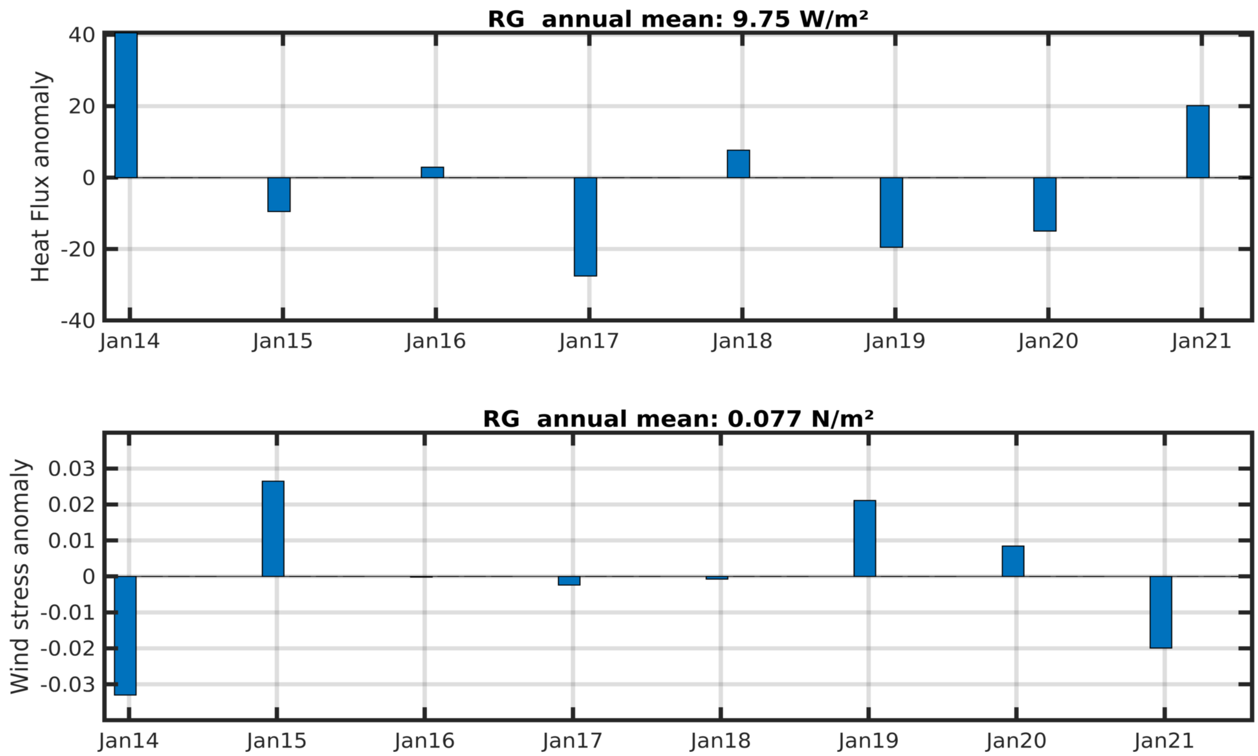

Figure S6: The modeled winter surface heat flux (W m^{-2}) and wind stress (N m^{-2}) anomalies for the Rhodes Gyre (winter: December to February).

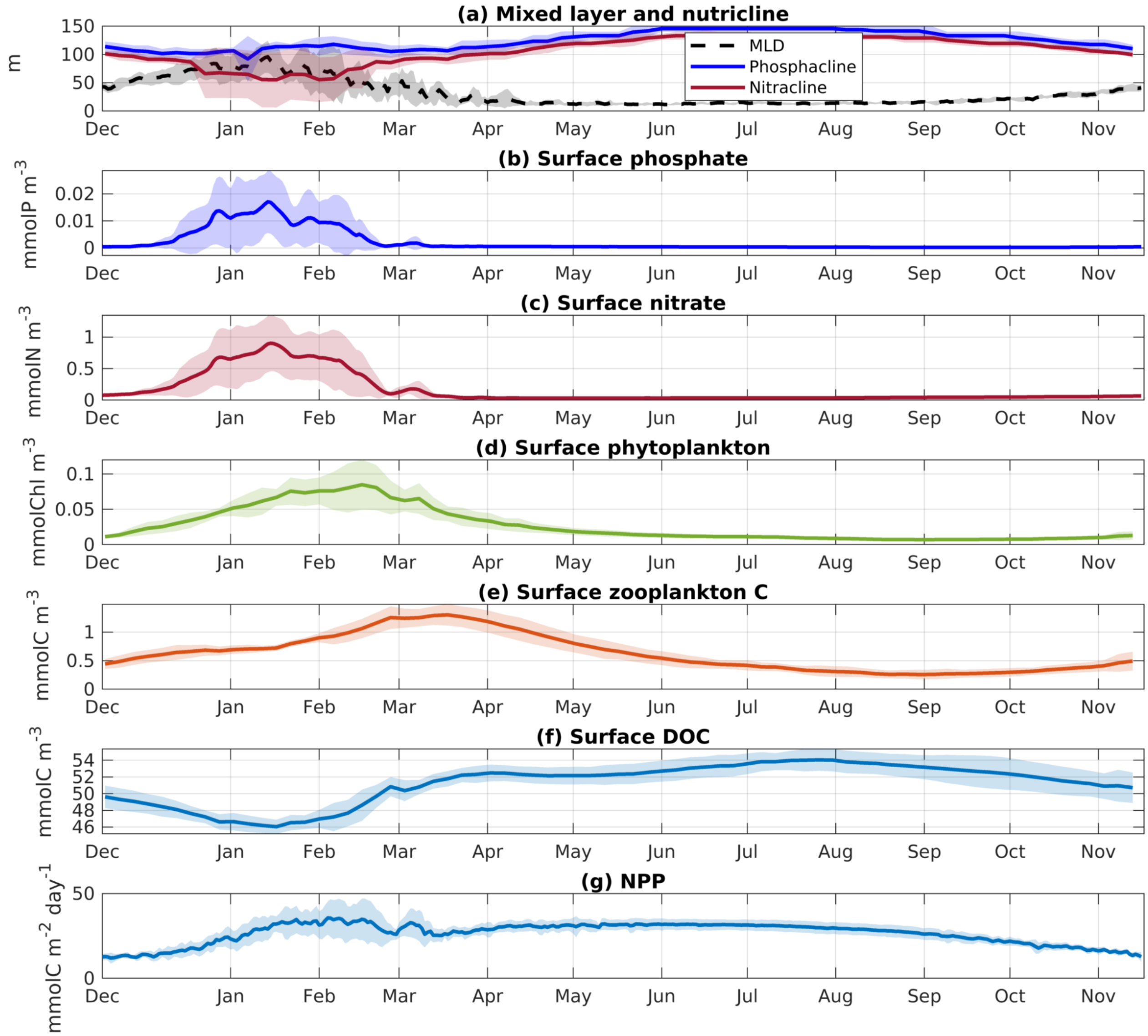

Figure S7: sSeasonal cycle of the modeled (a) mixed layer and nutricline depths, (b) surface phosphate, (c) nitrate, (d) phytoplankton, (e) zooplankton carbon, (f) DOC concentrations and (g) NPP, in the Rhodes Gyre averaged over the period 2013-20 (solid line for mean daily value, shaded areas for standard deviation).

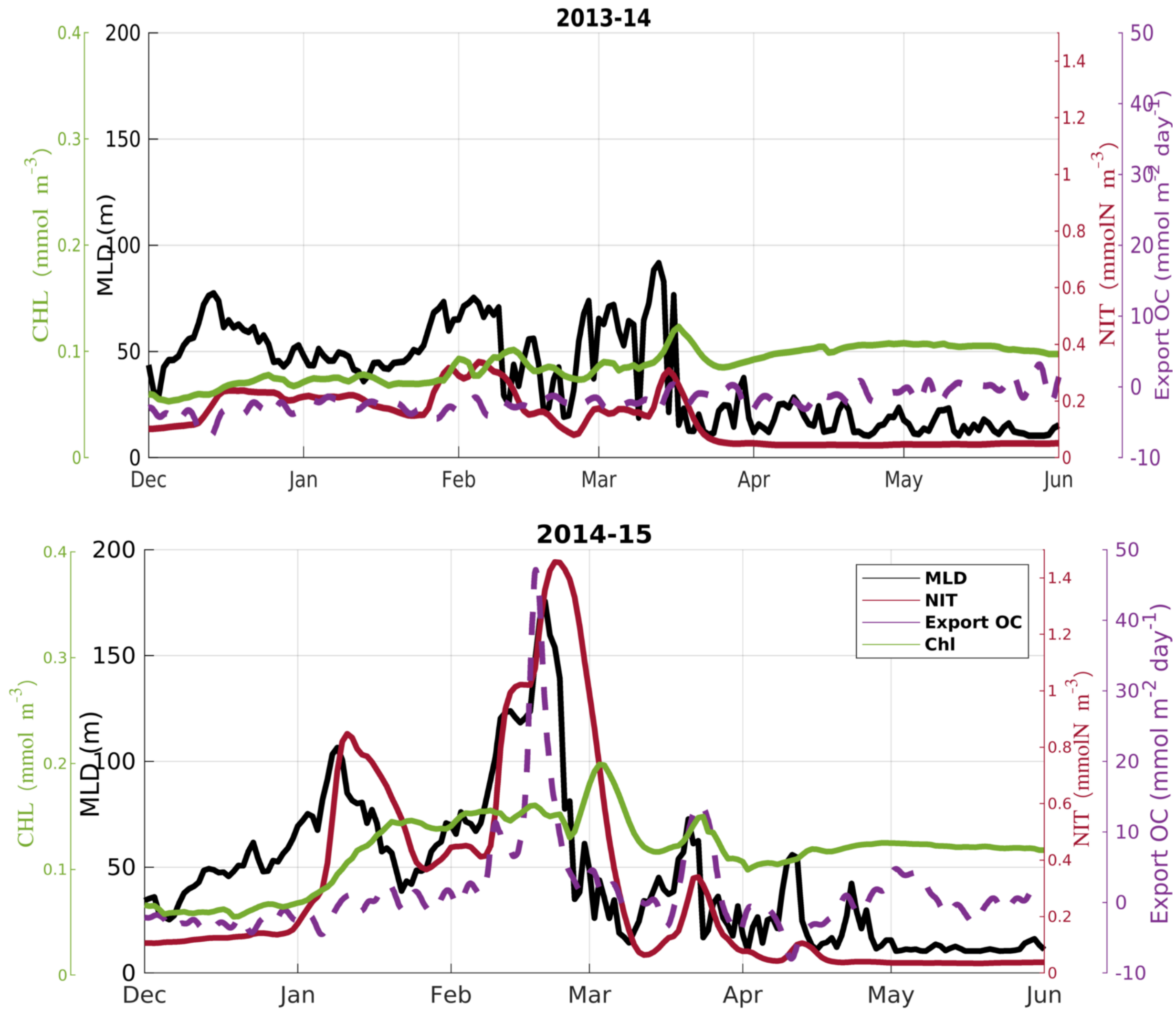

Figure S8: Annual cycle of the modeled Mixed Layer Depth (MLD, m) (black), surface chlorophyll (CHL, mg m^{-3}) (green), nitrate (NIT, mmol N m^{-3}) (red) concentration, and the organic carbon export (mmol C m^{-2} day^{-1}) at 150 m depth (purple), for years 2013-14, and 2014-15.

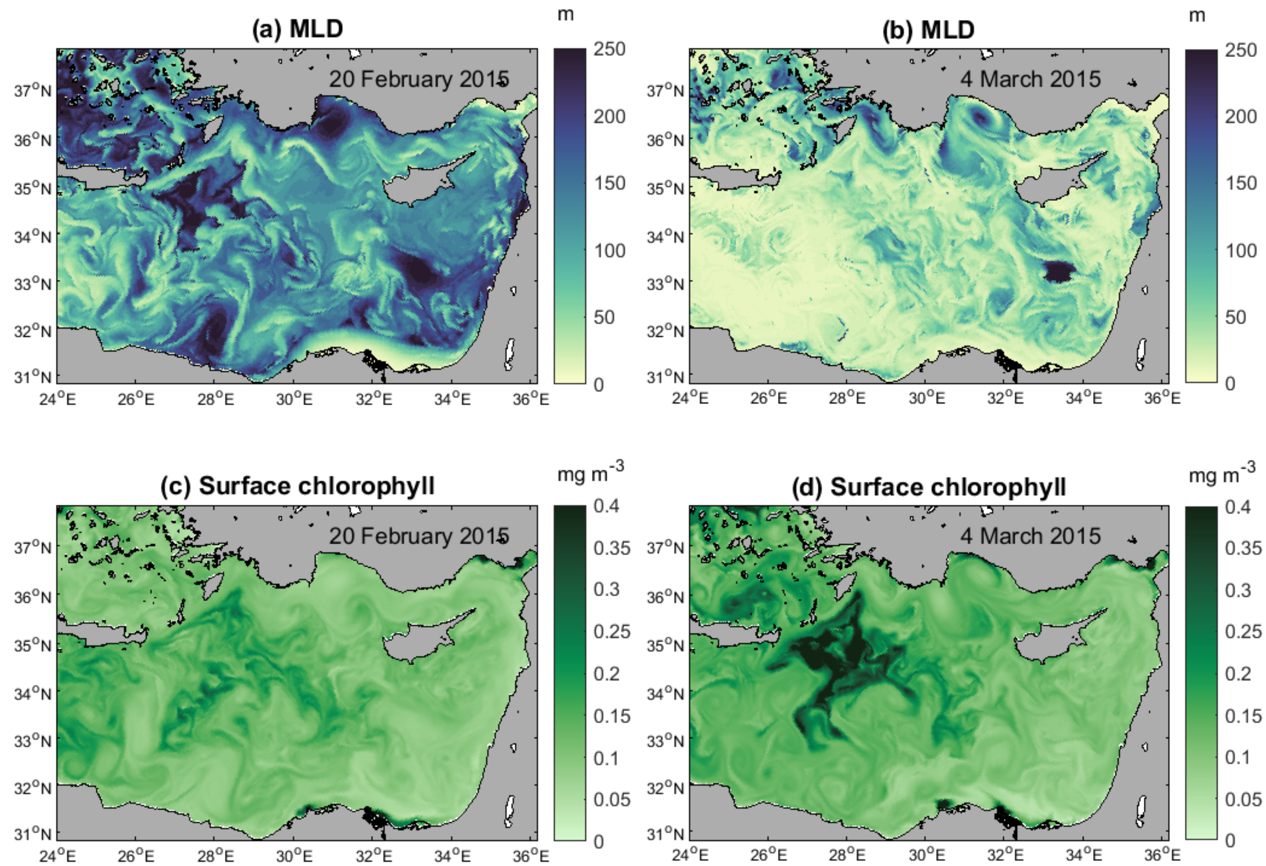

Figure S9: (a,b) Mixed layer depth (MLD, m) and (c,d) surface chlorophyll concentration (mg Chl m^{-3}), modeled for 20 February 2015 and 4 March 2015, respectively.