Supplementary Material

Text S1: Equation of OC balance

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

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

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.

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

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

where (x,y) belongs to the upper layer of the Rhodes Gyre area. OC is the sum of organic carbon fast- and slow-sinking detritus, dissolved organic carbon and the 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 (in $m^3\ s^{-1}$), A is the area of the section from the base of the upper layer (150 m) to the surface.

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

$$F_{OC,bgc} = \int \int \int_{(x,y)\in\ RG\ /\ z\ \in\ upper\ layer} BGCflux(x, y, z, t)\ dx\ dy\ dz \qquad \text{(S4)}$$

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, with the inventory variation as the sum of the lateral and vertical exchanges flux at the boundaries, and biogeochemical flux.

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).

	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)
Date of maximum MLD	-	13 Mar	20 Feb	27 Jan	28 Jan	26 Jan	17 Jan	9 Feb	-
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

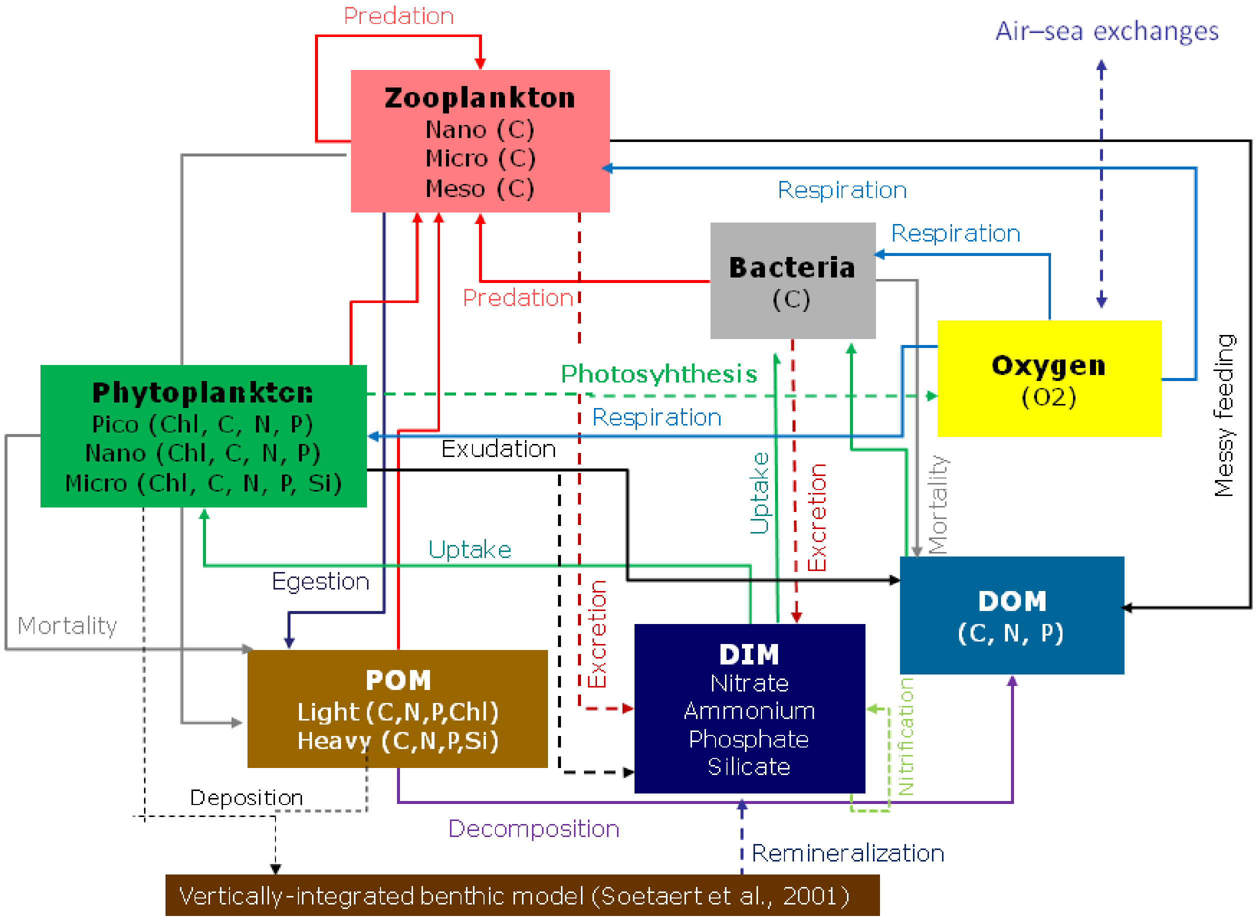

Figure S1: Schematics of the biogeochemical model Eco3M-S (from Ulses et al. 2021).

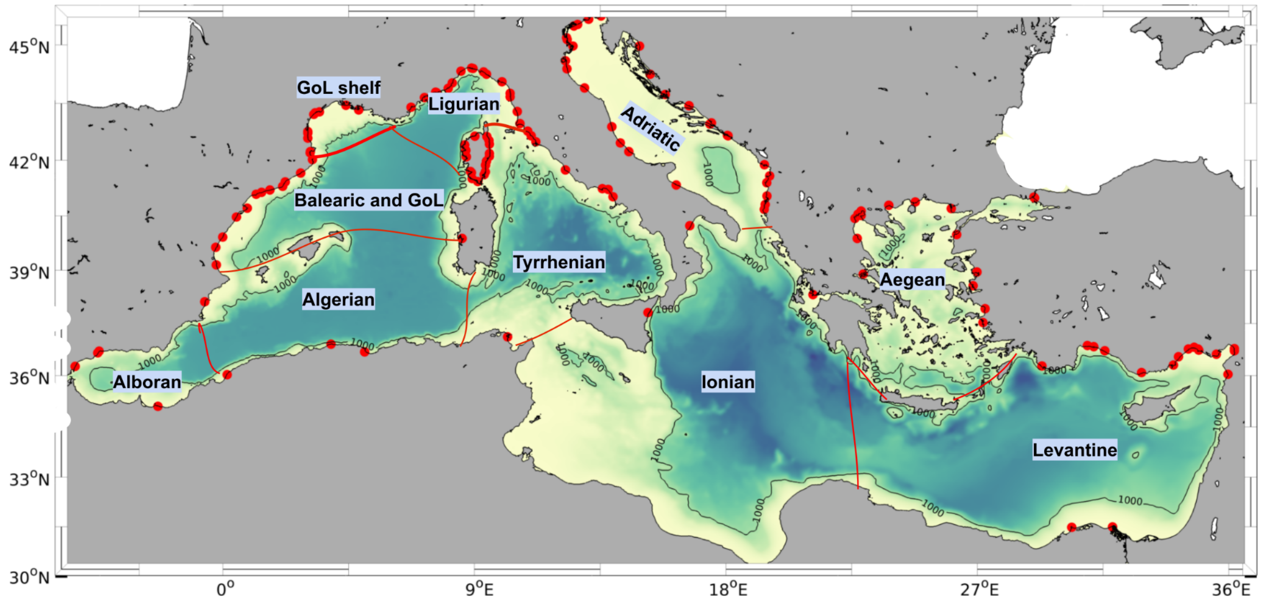

Figure S2: Subregions of the modeled Mediterranean Sea considered for the initialisation of the biogeochemical simulation. Red dots represent the river mouths. GoL: Gulf of Lion. Red dots represent river mouths, red lines indicate the limits of the sub-basin in the model.

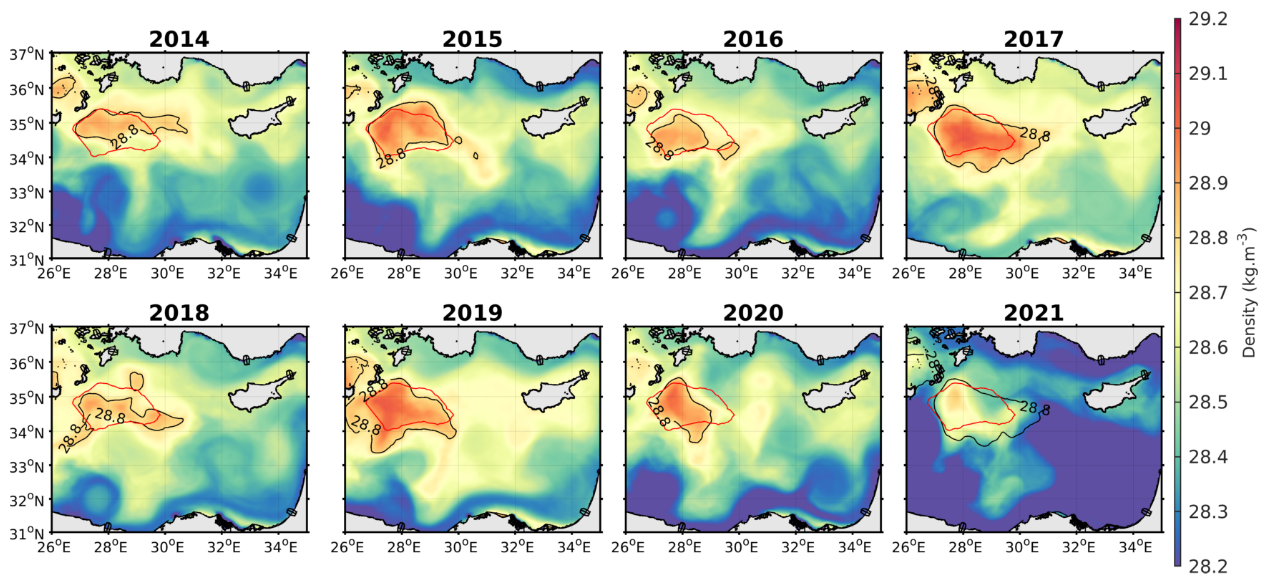

Figure S3: Surface density anomaly (kg m^{-3}) averaged over the mixing period (January-February-mid-March) from year 2014 to year 2021. The red line indicates the limit of the defined Rhodes Gyre area.

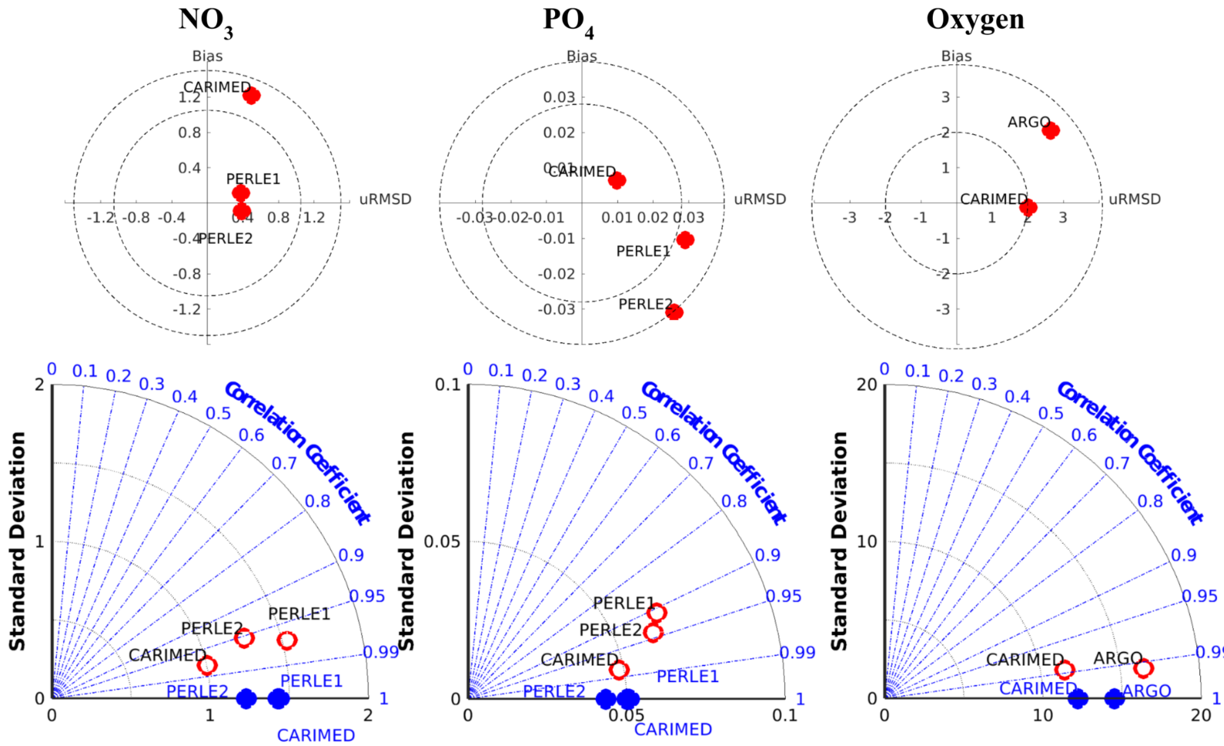

Figure S4: Statistical parameters of the modeled and observed nitrate (mmol N m^{-3}), phosphate (mmol P m^{-3}) and dissolved oxygen (µmol O_2 kg^{-1}) concentrations in the Levantine Basin: Top: target diagram of the bias and the centered RMSD, bottom: Taylor diagram with the correlation coefficient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

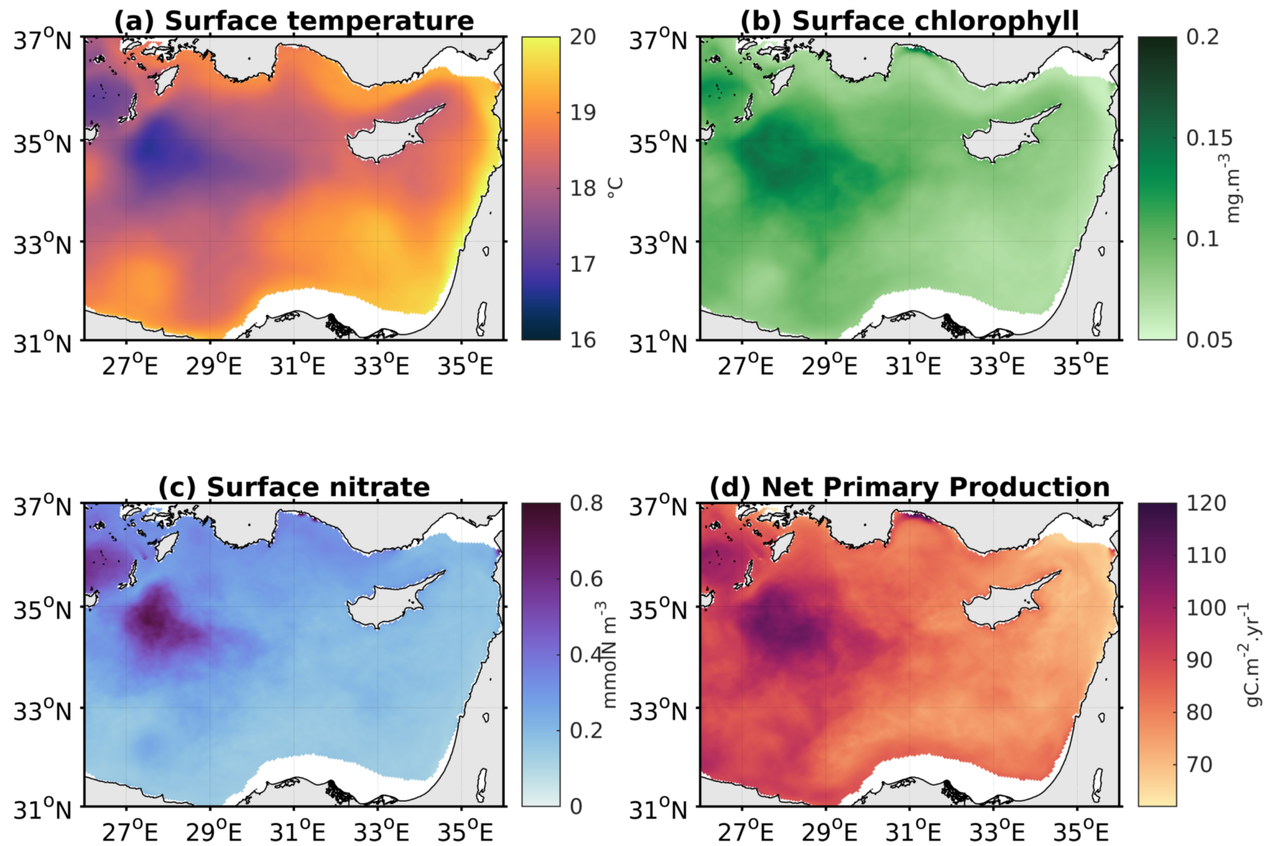

Figure S5: Modeled surface temperature (°C), chlorophyll (mg m^{-3}), nitrate (mmol N m^{-3}) concentrations and net primary production integrated over the surface (0-150 m) layer (g C m^{-2} yr^{-1}), averaged over the 2013-2020 winters (December-January-February).

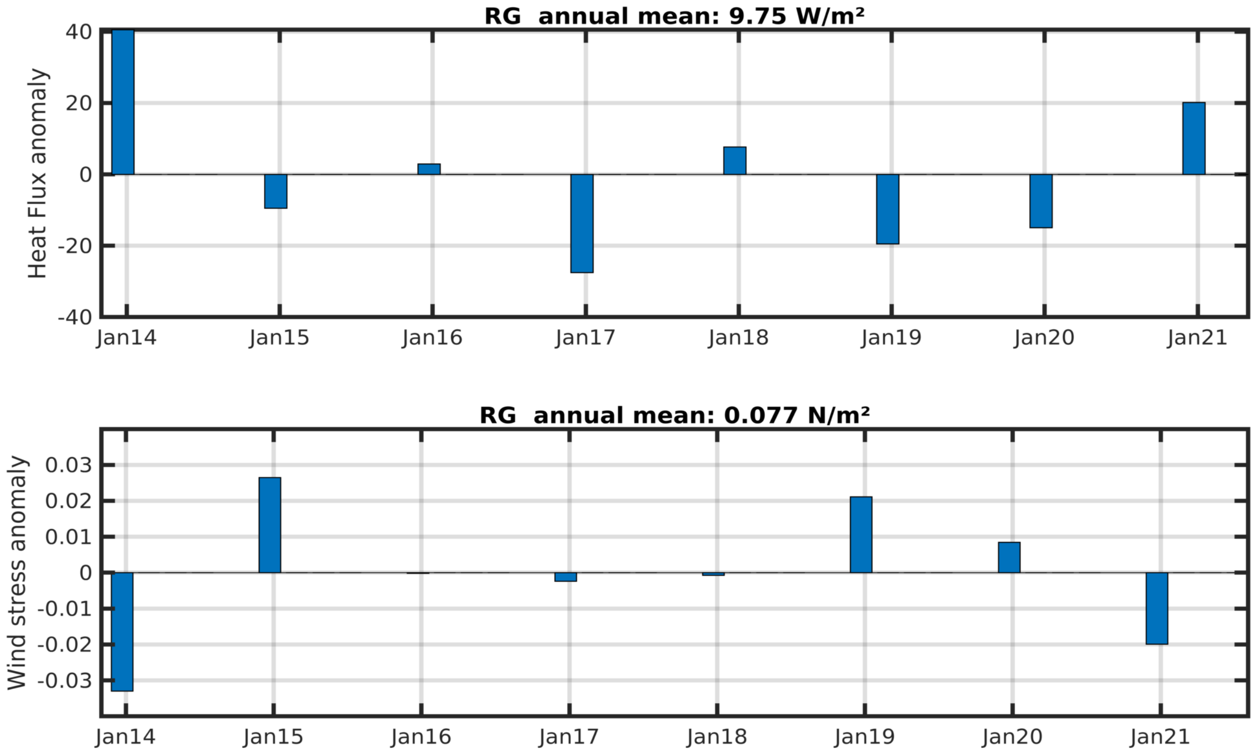

Figure S6: The seasonal surface heat flux (W m^{-2}) and wind stress (N m^{-2}) anomalies for the Rhodes Gyre (winter: December to February, spring: March to May, summer: June to August, fall: September to November).

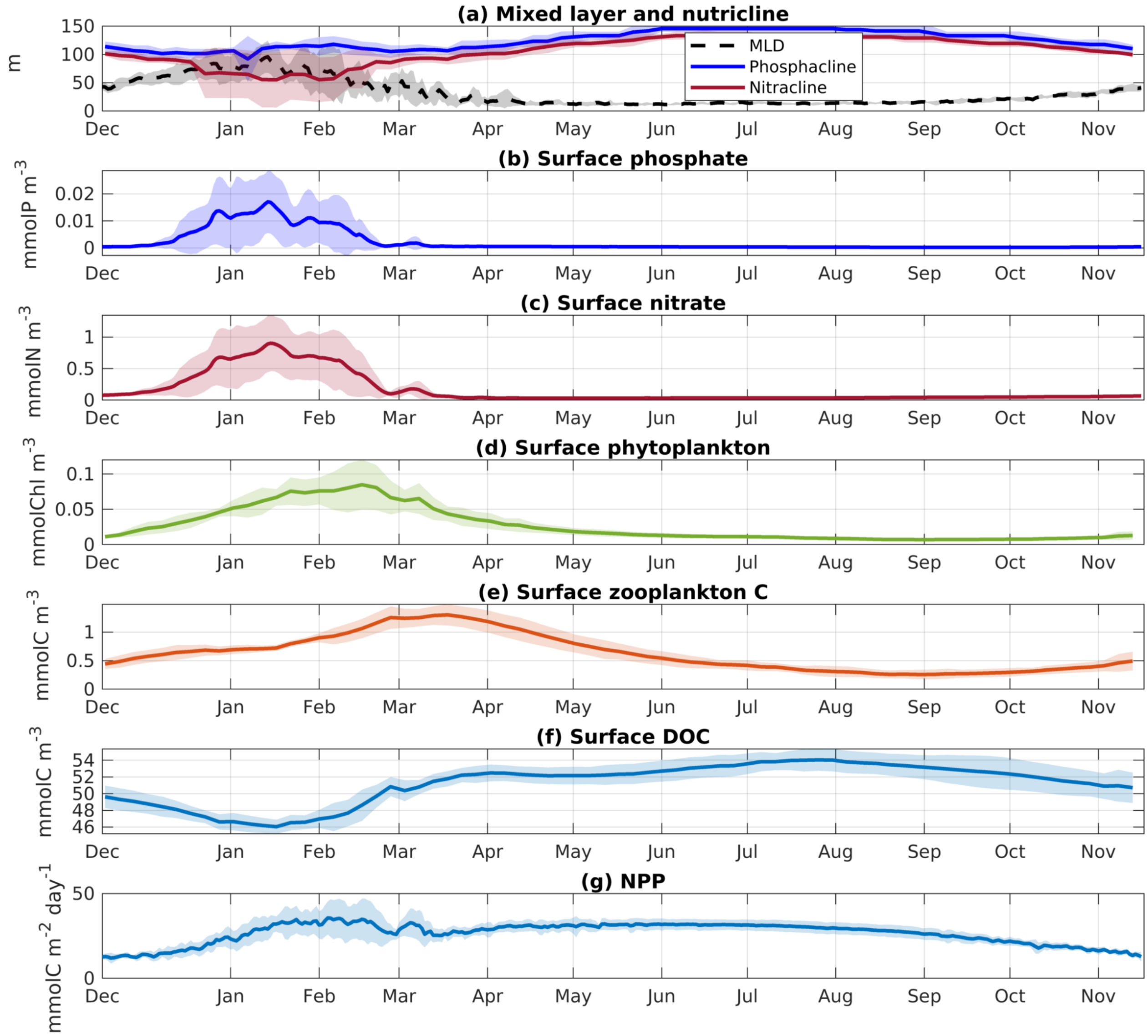

Figure S7: Seasonal cycle of (a) the mixed layer and nutricline depths, (b) surface phosphate, (c) nitrate, (d) phytoplankton, (e) zooplankton, (f) DOC concentrations and (g) NPP in the Rhodes Gyre averaged over the period 2013-20 (solid line for mean daily value, shaded areas for standard deviation).

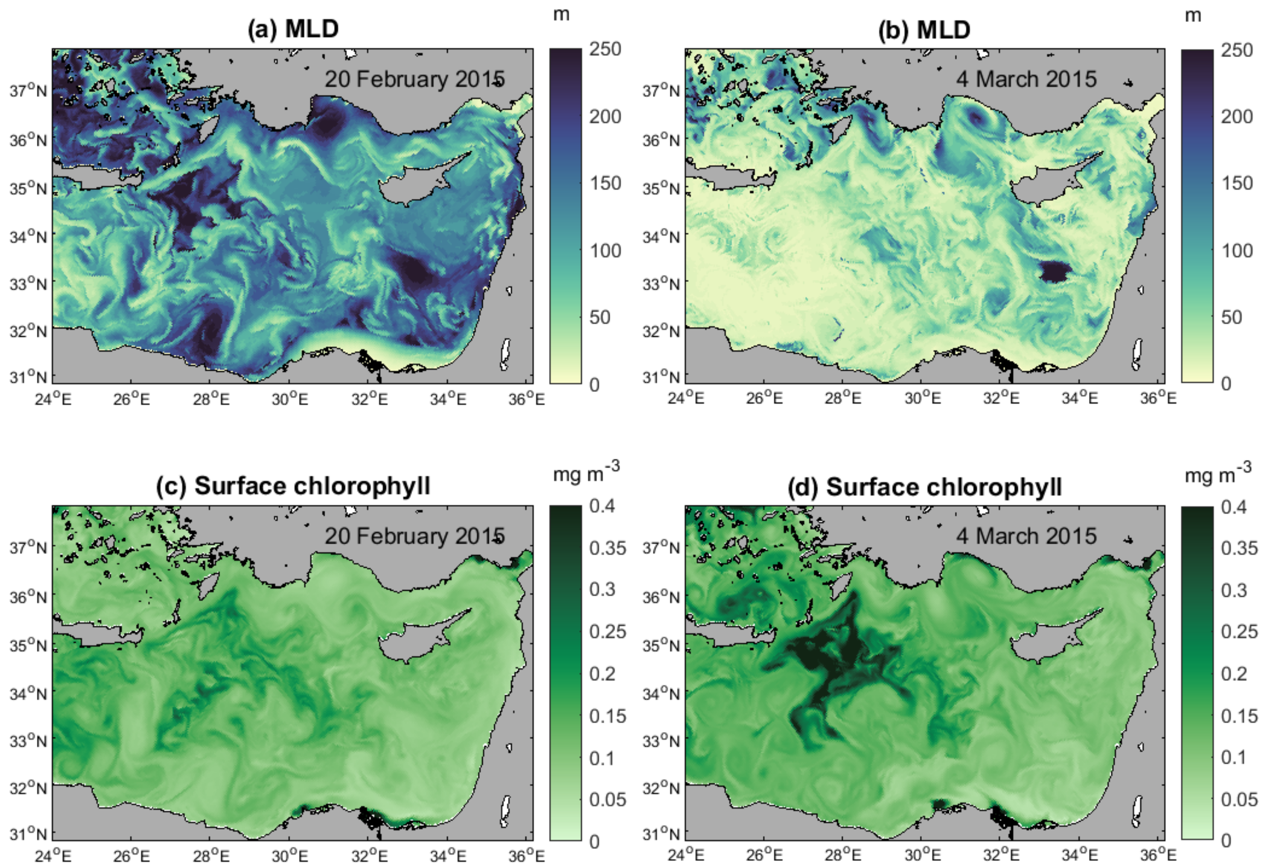

Figure S8: (a,b) Mixed layer depth (MLD, m) and (c,d) surface chlorophyll concentration (mg Chl m^{-3}), modeled for 20 February 2015 and 4 March 2015, respectively.