Text S1. Details on the numerical solution technique of the biogeochemical model

The system of ODEs is non-linear and hence, quite complex to solve ”in block”. Therefore, each iteration is split into a sequence of fractional time steps to achieve the implicit solution. This method, often known as *splitting by physical processes* is applied in a certain ecological order according to the main food chain (NO_3, NH_4, phytoplankton, zooplankton, detritus).

At each fractional time step, the component that is being consumed is treated in a partial implicit way and its updated concentration is used in the computation of the next component. The term “partial implicit” is used here for non-linear terms to distinguish this method from a fully implicit one, since only the variable that is being discretized is evaluated at the right hand side of the equation at the actual time step. Moreover, if the process that affects the variable to be discretized is non-linear with respect to the same variable, a kind of linearization is applied in such a way that only this linear part is evaluated at the actual time step. In order to illustrate this fact, we consider here the process of phytoplankton grazing by zooplankton (Fennel et al. 2006)

$$\frac{\delta Phy}{\delta t} = -g_{max}\frac{Phy^2}{K_p+Phy}Zoo, \qquad \text{(S1)}$$

with g_{max} and K_p constants.

The application of the partial implicit scheme to (S1) would lead to

$$\frac{Phy(t)-Phy(t-\delta t)}{\delta t} = \frac{g_{max}Phy(t-\delta t)Zoo(t-\delta t)}{K_p+Phy(t-\delta t)}Phy(t), \qquad \text{(S2)}$$

where δt is the time step.

If the consumption process is strictly linear, we are dealing with a simple standard implicit scheme. However, strictly linear processes are treated in the ROMS subroutine fennel.h explicitly and not implicitly, thus losing stability in the solution. This is the case of the mortality of phytoplankton and the excretion due to the basal metabolism of zooplankton. In order to avoid this problem and to ensure positiveness in the solution (another nice property of the implicit scheme), we transformed the previous processes in fennel.h from explicit to implicit. We exemplify this transformation below by considering the phytoplankton mortality (see Fennel et al. 2006) and the incorporation of this term to the small detritus compartment.

$$\frac{\delta Phy}{\delta t} = -m_p Phy, \qquad \text{(S3)}$$

$$\frac{\delta SDet}{\delta t} = m_p Phy, \qquad \text{(S4)}$$

with m_p a constant. By applying the Euler implicit scheme we have

$$Phy(t) = \frac{1}{1+\delta t m_p}Phy(t-\delta t), \qquad \text{(S5)}$$

where δt is the time step. Notice that since the term $\frac{1}{1+\delta t m_p}$ is always positive, the scheme guarantees positive definiteness.

By considering the updated concentration of phytoplankton in equation (S5), the concentration of small detritus is obtained as

$$SDet(t) = SDet(t - \delta t) + \frac{m_p \delta t}{1 + \delta t m_p} Phy(t - \delta t). \quad \text{(S6)}$$

From equations (S5) and (S6) it is easy to prove that $Phy(t) + SDet(t) = Phy(t - \delta t) + SDet(t - \delta t)$, thus ensuring mass conservation.

Text S2. Variability in nutrient supply through the model boundaries in 2006 and 2007

Figure S1 is included to highlight the way in which calculation of the temperature/nitrate relationships in Section 2.1.2 (see Figure 2 and explanatory text) allowed us to reproduce the interannual variability in nutrient supply through the model boundaries. Figures S1 A and B represent the temperature that is imposed at the northern boundary of the domain obtained from MERCATOR for years 2006 and 2007, respectively. By assuming that the lower the temperature, the deeper the mixed Layer, we see that the winter of 2007 was milder than the previous year. Note that the extremely cold and dry winter of 2005 resulted in extreme mixed layer depths reached in 2005 and 2006 (Somavilla et al. 2009). Estimations of the Mixed Layer Depth from Argo profiles in the Bay of Biscay confirm that MLD was twice deeper in the winter 2006 than in 2007 (Hartman et al. 2014). Under these conditions and taking into account Figure 2, we would expect that the input of nutrients in 2006 was higher than in 2007 due to winter convective mixing. Figures S1 C and D, constructed using the temperature/nitrate relationships, do confirm this observation, meaning that the model is properly considering at its boundaries the interannual variability in nutrient supply.

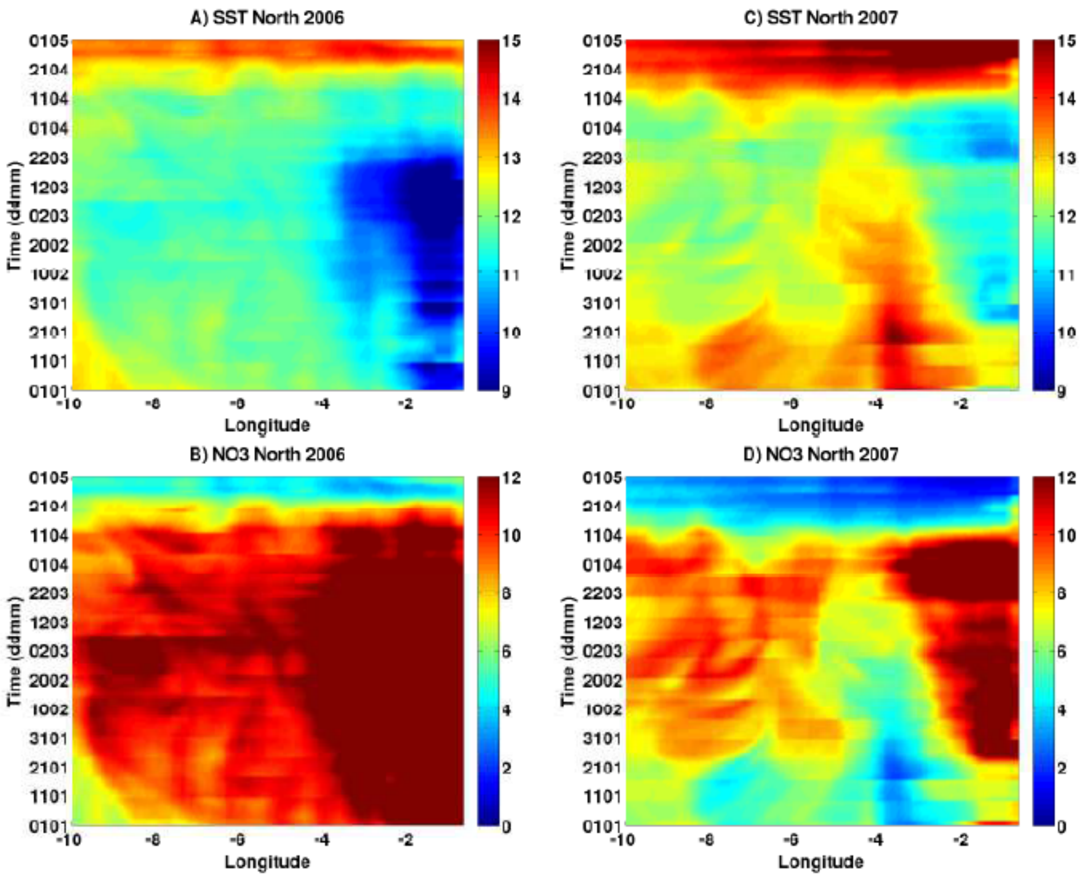

Figure S1. Minimum surface temperatures from MERCATOR: A) 2006 and B) 2007. Maximum nitrate concentration obtained from the temperature fields: C) 2006 and D) 2007. Notice that the discontinuities are due to the shock of assimilating in situ data every week

Text S3. Model spin up considerations

Figure S2 shows the domain averaged Eddy Kinetic Energy (EKE) for the 2006 and 2007 simulations. We can see that in both cases the results seem to be in equilibrium and show similar patterns of variability.

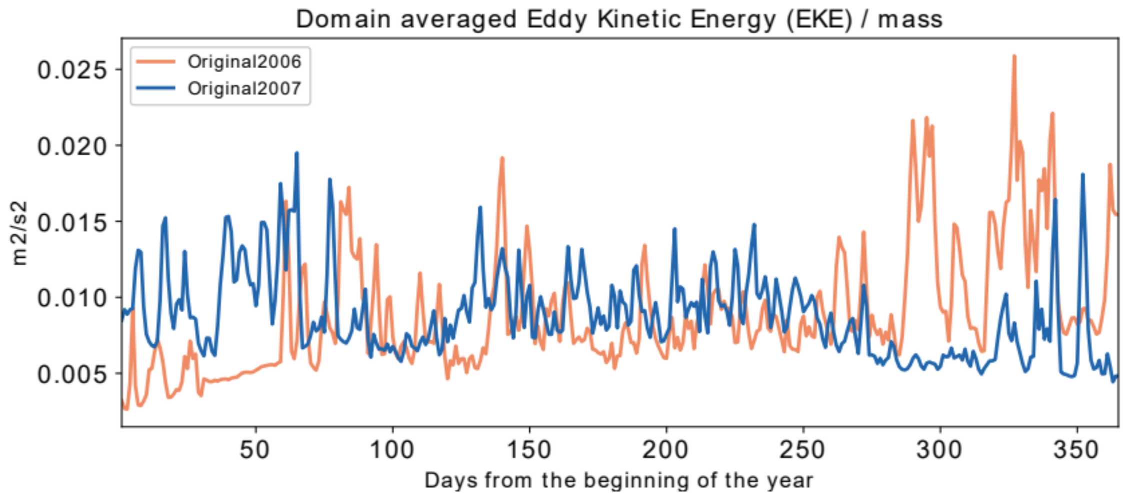

Figure S2. Domain averaged EKE/mass at the model surface layer for the simulations of years 2006 and 2007

Figure S3 shows the results of the two additional tests that were performed to investigate the effect of the initial conditions: test A followed Fraysse et al. (2003) and consisted of initializing the simulation for 2006 with the initial conditions from the 2007 run, and test B in which the 2007 year run was also initialized from the results of the large scale model in the same way the original 2006 simulation was initialized (2007 coldstart). In this way, we could compare the results for a year (2007) with and without a spinup peroid.

For test A (red line in Figure S3), we see that the initial conditions were quite different from the original ones (salmon line), especially for temperature, nitrate and ammonium. The temperature differences were negligible after 60 to 80 days of simulation. Nitrate shows that the differences at initialization remained constant up to approximately 60 days after. This is reflecting the fact that nitrate, which is not consumed in winter, acts like a passive tracer, which only experiences passive transport. This changes in the spring bloom, when growth starts, and nitrate is consumed by phytoplankton. The differences in peak chlorophyll show the differences in the initial concentration of nitrate (the more nitrate in the winter, the higher the peak of chlorophyll in spring). This test proves that the model behaves reasonably well, with no instabilities, with independence of the initial condition, and that the chlorophyll in spring is the result of the nitrate in winter, which is further demonstrated by the fact that the peak concentration of chlorophyll in 2007 (blue line) is almost the same as the peak concentration of chlorophyll in 2006 using the initial conditions of 2007 (red line).

Test B shows that the initial conditions in terms of temperature and salinity were very similar in both model runs, meaning that we started from very similar physics (blue and black lines). Nitrate was slightly lower in the 2007 run with no spin up (black line), which implied a lower chlorophyll peak in spring, but the same dynamics. The higher nitrate values in winter in the model with spin-up most likely result from the previous model history (accumulation from the 2006 simulation, for which nutrients were higher). This effect is expected to occur, and the results after two or more years spin up would be different from those after one year spin up. In this sense, only small variations in the absolute value of chlorophyll in spring are expected. This means that, if the 2006 simulation have had a one year spin up, this would probably have resulted in higher concentrations of nutrients in winter (2005 was characterized by a high concentration of nutrients) and a higher spring peak of chlorophyll.

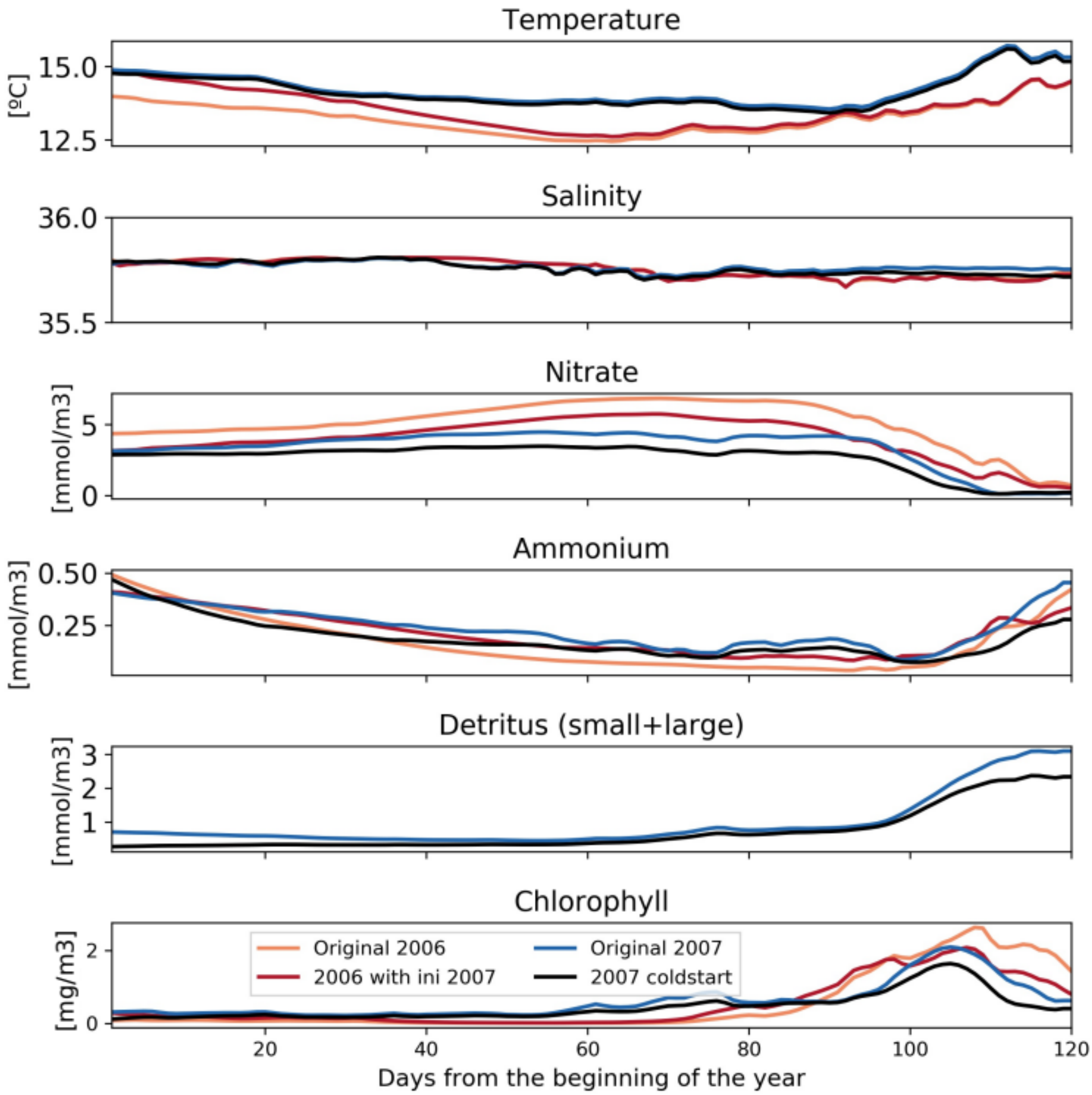

Figure S3. Spin up analysis for some hydrodynamic and biogeochemical variables at the model surface layer: domain average.

Text S4. Further details on model validation

This section is devoted to provide additional information on the quantitative validation of the model results against observations. Figure S4 shows the Taylor diagrams for the statistical comparison of the temperature and salinity observations during the Pelacus cruises 2006 and 2007 against model results displayed in Figure 5.

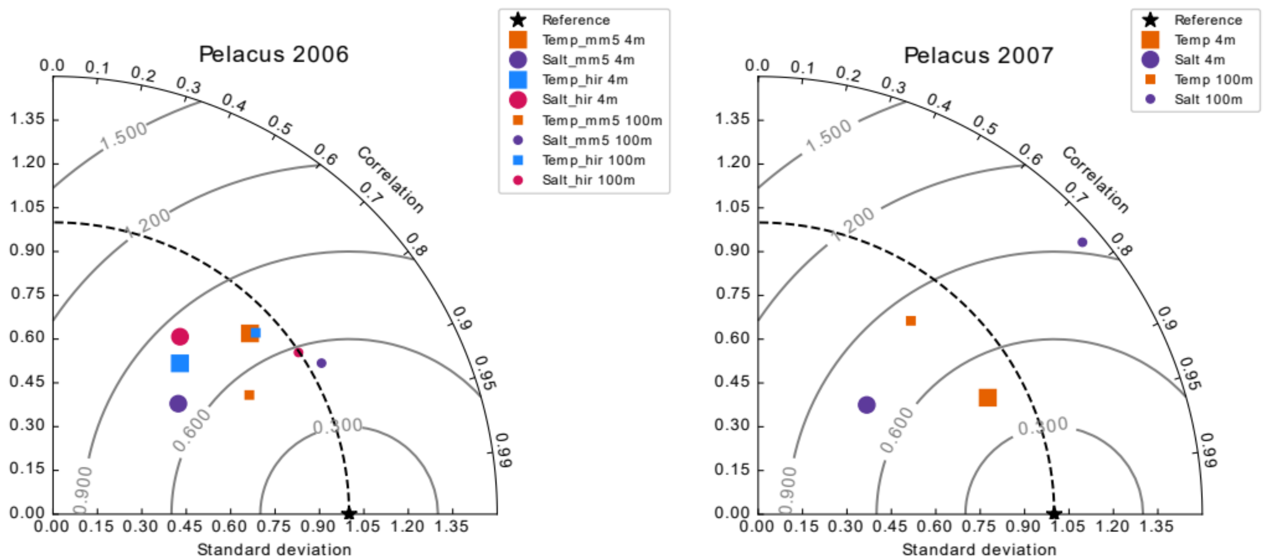

Figure S4. Taylor diagram of the model against observations of Temperature and Salinity at 4m and 100m depth during Pelacus 2006 (left panel) and Pelacus 2007 (right panel). Notice that for Pelacus 2006 we provide statistics for the model considering different meteorological forcing: WRF/MM5 and HIRLAM.

Figures S5 and S6 show the quantitative comparison of the model results against observations during the Pelacus 2006 and Pelacus 2007 cruises. The figures provide the average of the satellite and model chlorophyll in the period considered, as well as the correlation coefficient and percentage bias, calculated as the sum of the differences between the model results and satellite observations divided by the sum of the observations.

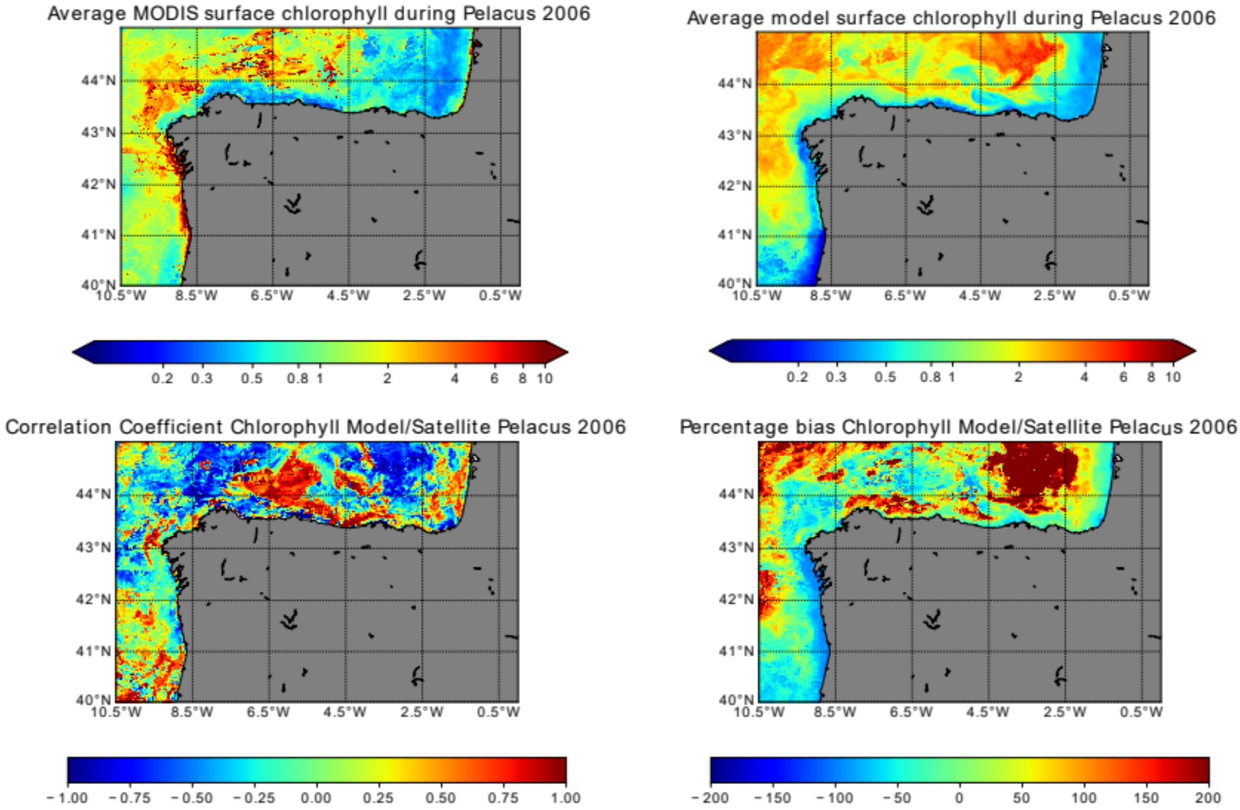

Figure S5. Statistics for the comparison of satellite and model (forced with HIRLAM) chlorophyll concentration during the Pelacus 2006 period. Top left panel: satellite chlorophyll average; Top right panel: model averaged chlorophyll; Bottom left panel: Model/satellite correlation coefficient. Bottom right panel: Model/satellite percentage bias. Units are mg/m³.

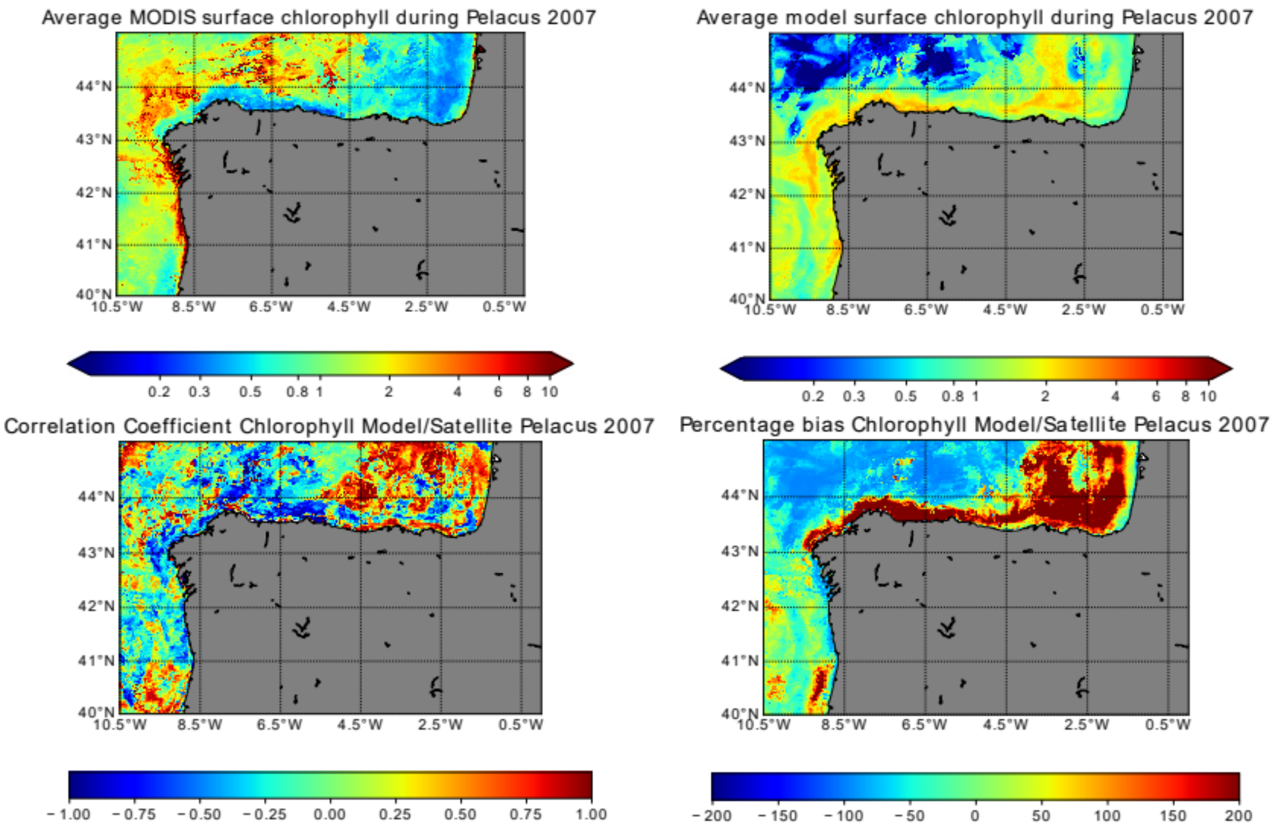

Figure S6. Statistics for the comparison of satellite and model (forced with MM5) chlorophyll concentration during the Pelacus 2007 period. Top left panel: satellite chlorophyll average; Top right panel: model averaged chlorophyll; Bottom left panel: Model/satellite correlation coefficient. Bottom right panel: Model/satellite percentage bias. Units are mg/m³.

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