Reply to Anonymous Referees #1 and #2

We thank the reviewers for their insightful comments and suggestions. We here answer them both. They mention that our study is a novel/interesting approach to relate dust input to the Mediterranean Sea to surface chlorophyll. We use a state of the art 3D mineral dust transport and deposition model and correlate actual deposition to chlorophyll estimated from the SeaWiFS sensor. We believe our study can make a significant contribution to the scientific community as it will set a geographical framework to test hypothesis about dust fertilization in different areas of the Mediterranean. It needs to be stressed that it is not the intention of this manuscript to provide further clarifications of the fertilizing effect of particular nutrient species in the Mediterranean.

The main concerns of both reviewers stem from the adequacy of the chlorophyll product that we used. After performing some recalculations, in this reply we will argue in favor of the data we use and of the results we derive.

The reviewers mention the inadequacy of standard OC4v4 algorithm for the Mediterranean, although reviewer #2 does not consider this point as crucial. We have recalculated chlorophyll using the equations in Bosc et al. (2004) to get aproximately corrected chlorophyll for the Mediterranean. The resulting correlation maps can hardly be distinguished from the ones used originally without the correction (Figs. 1, 2, 3, 4). Using log transformed chlorophyll (in order to aproximate normality of the distribution) does of course help in reducing the effect of bias of the low chlorophyll values of the original dataset on the correlations. In any case, correlations between dust deposition and chlorophyll are on average similar with respect to the orginal data (2% increase, range from -26% to 68% for the different 1ºX1º areas). The effect is a bit more important for the correlations between seasonally detrended data (15% decrease, range from -197% to 78% for the different areas). In terms of significance of the correlations, only 2 areas previously significantly correlated are now not significant (chl vs dust correlation) or only 4 areas previously significantly correlated are now not significant (seasonally detrended chl vs seasonally detrended dust). In no case do the overall results or interpretation change substantially with respect to the original data. We will use the Bosc et al. (2004) correction in the revised version of our manuscript.

It is true that overall correlations are low (Rev#2) but we would not expect much higher correlations taking into account that the main entrance of nutrients to the upper mixed layer (and thus driver of chlorophyll production) is from the deeper waters, be it owing to the seasonal overturning or to different physical processes that increase vertical diffusion at certain moments. We know from calculations and from experiments that effects owing to dust deposition should be/tend to be small in most situations and we do not argue in favor of African dust deposition to explain a large portion of chorophyl variability. But, ignoring statistical significance (even if explaining a small portion of chlorophyll variability) in a significant number of areas would not be fair to the scientific community.

The reviewers are also concerned about the use of the 8-d averaged product. This product has many advantages actually for many of the reasons the reviewers mention. First, we also use an 8-d averaged dust deposition to make the two data sets comparable so that it is not true that the relationships are not representative of the time interval (Rev#1). Among other advantages are the fact that experiments have shown relatively fast responses of organism activity after deposition but biomass responses tend to lag. Chlorophyll peaks can occur anytime between 1 to a few days after nutrient amendment in classical experiments. Thus, the use of a time interval is more likely to pick up the effect of deposition on biomass. If uptake and recycling of nutrients is channeled to upper trophic levels without increases in phytoplankton biomass, as was the interpretation in the Cyclops experiment, nutrient recycling owing to grazing is nevertheless a must (because of particle elemental stoichiometry), and sooner or later phytoplankton biomass should be able to take advantage. Again, a longer time interval (with respect to hours or one day) should be beneficial to pick up biomass increases, even if ever so slight. All these issues are mentioned in the manuscript to some extent, and we will address them further in a revised version of the manuscript.

Regarding the interference of backscattering of dust with the chlorophyll signal, this is also minimized when using an 8d average since the dust in the water column has more time to settle out. In any case, the corrected chlorophyll (Bosc et al., 2004) that we will use in the revised manuscript takes into account the "greening" of Mediterranean waters. Also, probably the greening of the Mediterranean waters does not have a unique component as large particle loads (2-3 g m^{-2}) are needed in a relatively short time to significantly alter backscattering (Claustre et al., 2002) and this does not tend to be the case with the exception of very large dust deposition events.

Reviewer #2 suggests using a daily chlorophyll product. Volpe et al. (2012) showed that between 40% and 85% of the pixels had missing information in daily maps for the Mediterranean (1998 to 2006). Thus, the temporal gaps in daily data require a high degree of interpolation, especially at a 1º X 1º spatial resolution, with the obvious drawback for correlation statistics. We understand that increasing the area (Volpe et al., 2009) is a valid approach to study some particular larger synoptic events at a daily frequency. On the contrary, our study (besides using a deposition product rather than an approximation of deposition via AOT) addresses a higher spatial variability, including more local conditions and the fact that we use the whole temporal series, that may give rise to unforseen trends, rather than using selected chunks of the series.

It needs to be stressed that our deposition data is not just a simple transformation of AOT but takes into account the physics of particle transport in the atmosphere in 3D, that is, at different heights. If we correlate seasonally detrended chlorophyll with seasonally detrended AOT (weekly product), that is mostly the effect of events, we find a relatively high correlation in most cases as Volpe et al. (2009) also found. Actually, the correlation is much larger than when using non-seasonally detrended data. As these authors put forward, this may be a spurious correlation because of crossignal contamination, at least partially, and we agree. The fact that the correlation of our seasonally detrended data is lower than for the non-detrended data argues in favor of the cross contamination with deposition (not AOT) to be, to say the least, much less important. Of course, as we mention in our manuscript deposition is not a direct reflection of AOT since dust may be travelling, and does so, at high altitudes without a chance of deposition in many cases. Our results go in the direction of reconciling theoretical calculations and experimental results where dust does have an effect on chlorophyll biomass, albeit necessarily small and not always.

The issue of autocorrelation of the time series for the crosscorrelation analyses is of minor importance in this study, since the highest correlation values are at lag 0 across the board, and we really do not extend into lagged correlations. This does not mean that there is not an obvious autocorrelation in the chlorophyll signal, the annual trend. This is the reason why we perform correlations with and without "climatic"/seasonal detrending. We do find that, especially in the eastern basin, that the non-detrended correlations are relatively high while the correlations with seasonally detrended data are much lower meaning that dust and chlorophyll tend to co-occur on an average basis (albeit correlation does not imply causality) while the eastern med seems less susceptible to response owing to events.

Minor comments:
Rev#1:
L60-61. OK, we will rephrase in the revised version
L142. 10^{-8} Kg m^{-2} d^{-1} represents 3.65 mg m^{-2} y^{-1}, which is a really small amount, so we are hardly overestimating. The reason to set a low threshold is that, as mentioned in the manuscript, computer output can give infinitesimally small values of deposition which are very large local minima spikes in the time series that are no good for statistical analyses. It is an established procedure to add an insignificant amount to a time series that contains 0s and needs to be log transformed. This is no different.
L76, L79, L81, L100, L159, L216, L392. OK, we will correct.

Rev#2
L23 on page 8614. OK we will correct. This is not the place to start a dissertation on the real meaning of production (it actually has units of biomass, contrary to productivity), as it is mostly a semantics issue.
L8 on page 8616. We leave it as is.
L19-21 on page 8622. The reviewer is right. We will amend the text to make it clear. We will try to find an even better color scale, although color bars seem fine to us.

Figures

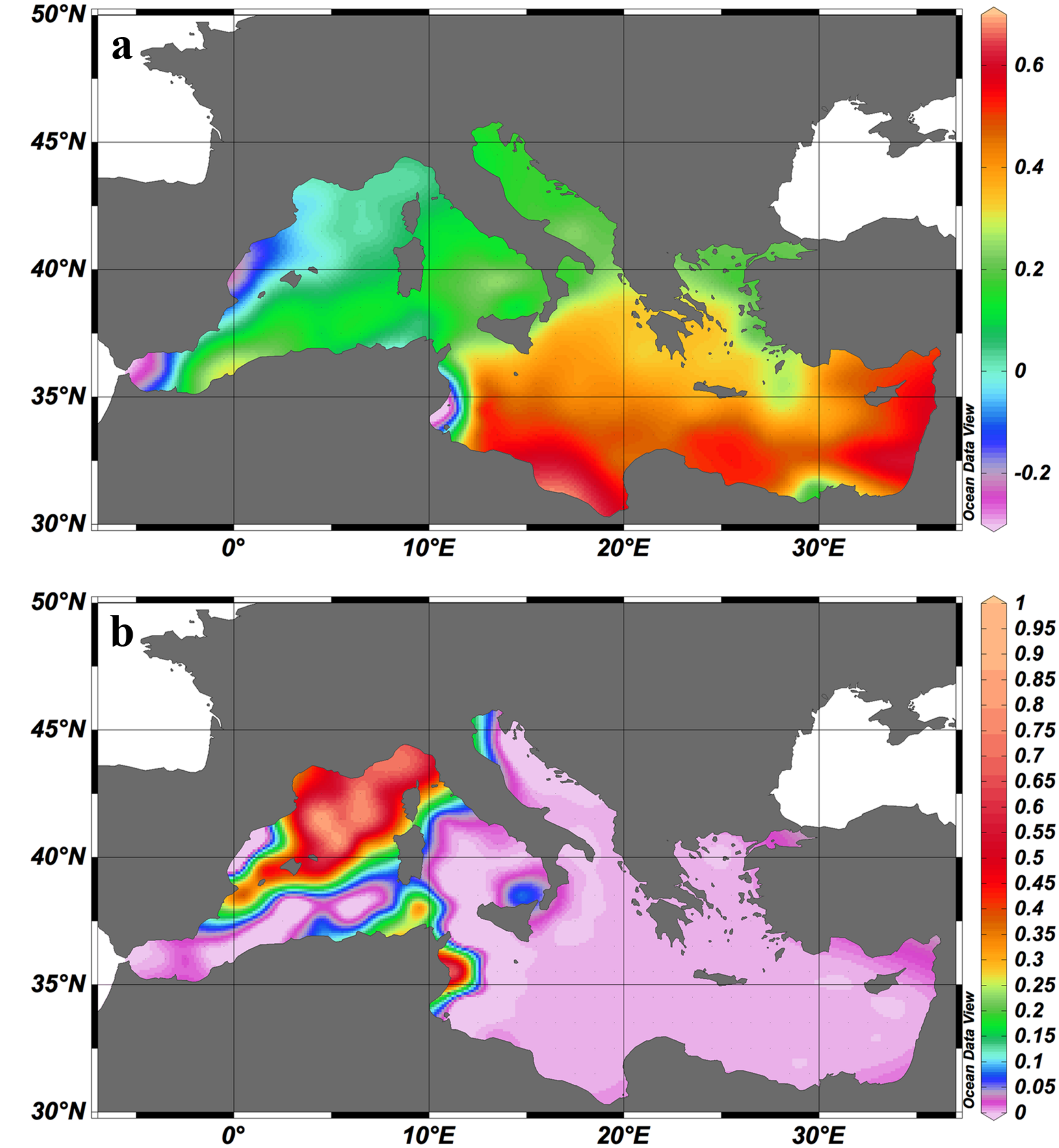

Fig. 1. Chlorophyll and dust deposition correlation at time lag 0 **(a)** and the corresponding p-level statistical significance **(b)**.

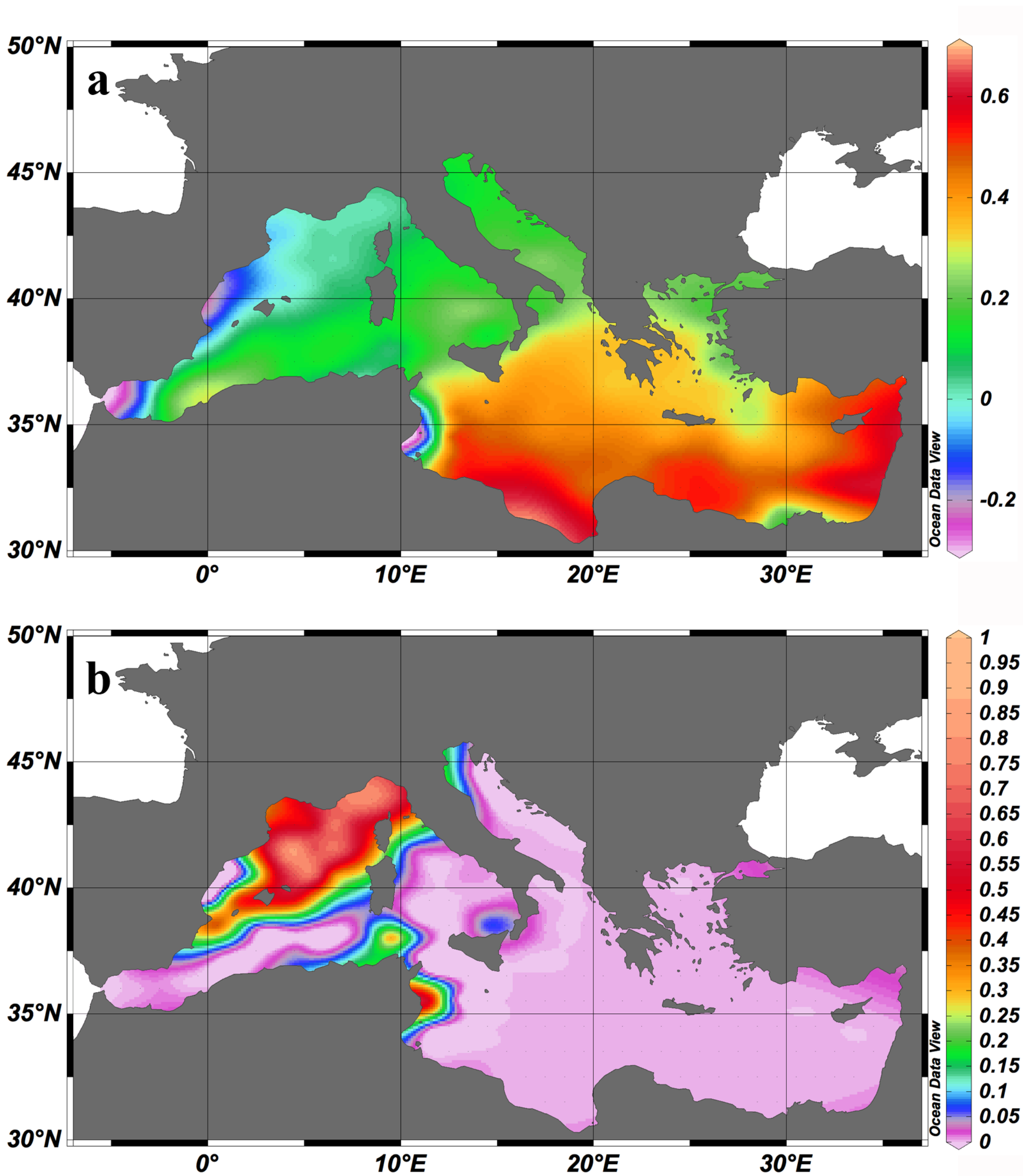

Fig. 2. Chlorophyll and dust deposition correlation, with the application of Bosc et al. (2004) equation, at time lag 0 **(a)** and the corresponding p-level statistical significance **(b)**.

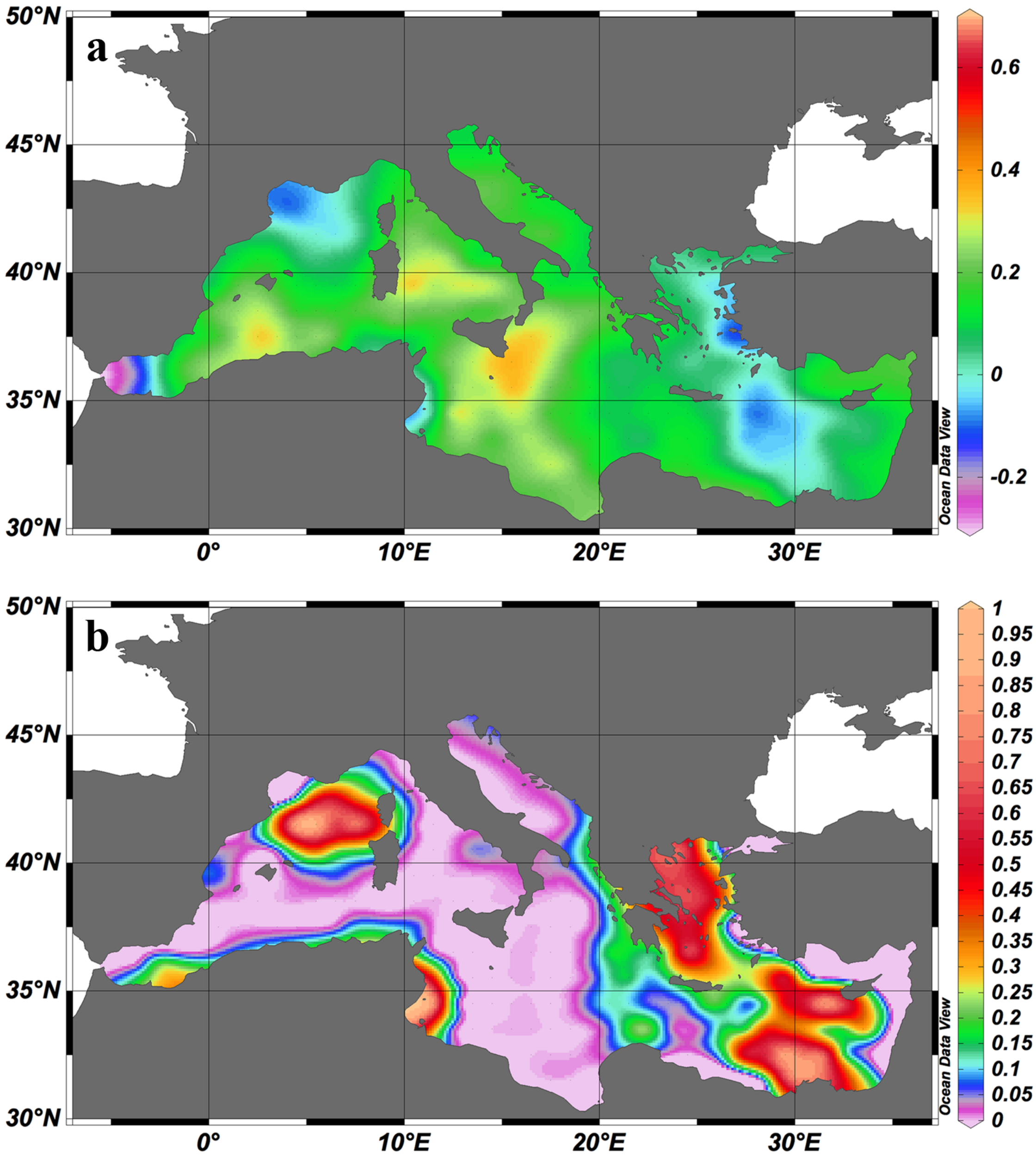

Fig 3. Same as Fig. 1 but for the correlation between seasonally detrended chlorophyll and seasonally detrended deposition

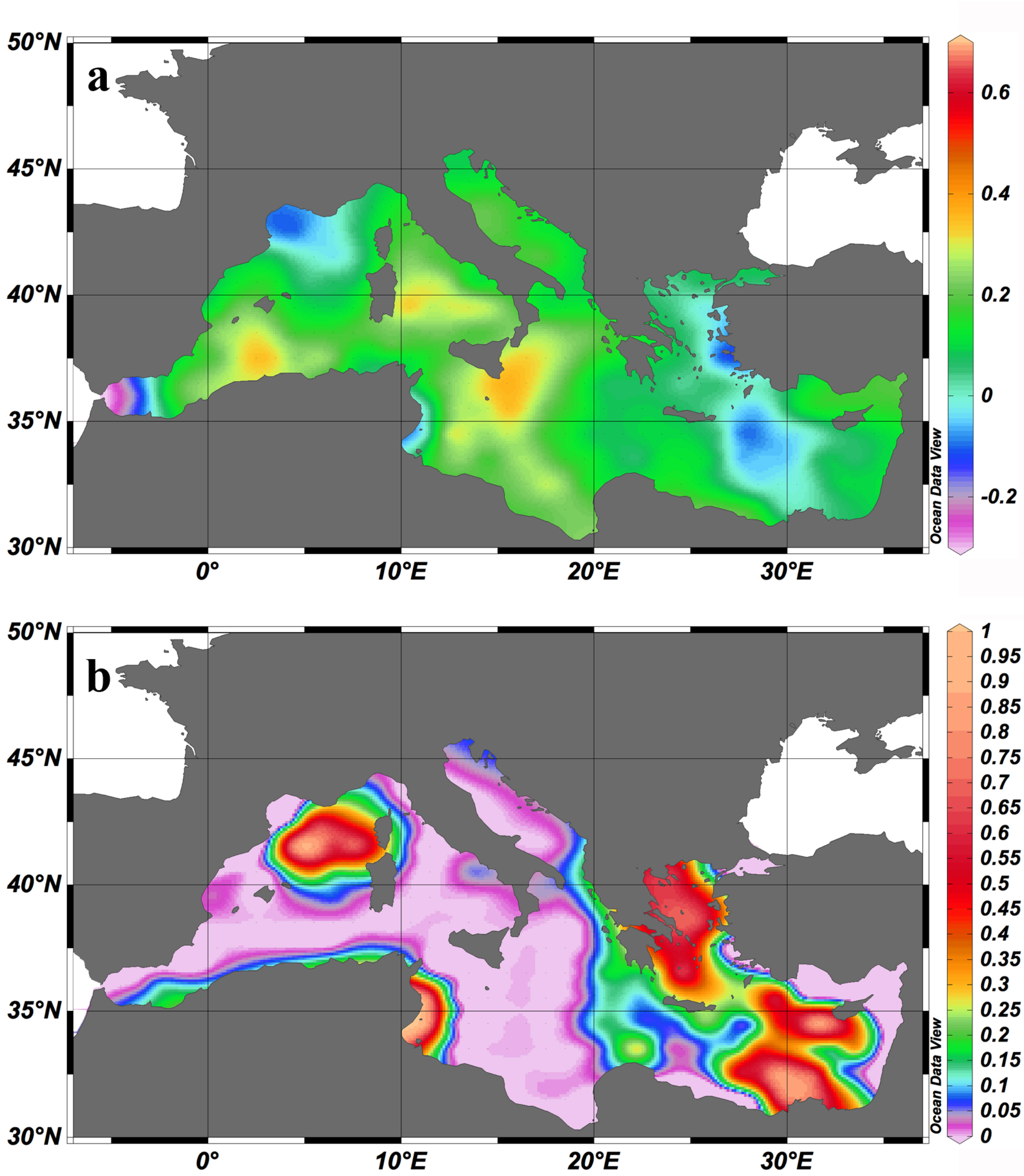

Fig 4. Same as Fig. 2 but for the correlation between seasonally detrended chlorophyll and seasonally detrended deposition

References

Bosc, E., Bricaud, A., and Antoine, D.: Seasonal and interannual variability in algal biomass and primary production in the Mediterranean Sea, as derived from 4 years of SeaWiFS observations, Global Biogeochemical Cycles, 18, GB1005, doi:10.1029/2003GB002034, 2004.

Claustre, H., Morel, A., Hooker, S. B., Babin, M., Antoine, D., Oubelkheir, K., Bricaud, A., Leblanc, K., Queguiner, B., and Maritorena, S.: Is desert dust making oligotrophic waters greener?, Geophysical Research Letters, 29, doi:10.1029/2001gl014056, 2002.

Volpe, G., Banzon, V. F., Evans, R. H., Santoleri, R., Mariano, A. J., and Sciarra, R.: Satellite observations of the impact of dust in a low-nutrient, lowchlorophyll region: Fertilization or artifact?, Global Biogeochemical Cycles, 23, GB3007, doi:10.1029/2008GB003216, 2009.

Volpe, G., Nardelli, B. B., Cipollini, P., Santoleri, R., and Robinson, I. S.: Seasonal to interannual phytoplankton response to physical processes in the Mediterranean Sea from satellite observations, Remote Sensing of Environment, 117, 223-235, 10.1016/j.rse.2011.09.020, 2012.