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Biogeosciences Discussions

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Interactive Comment

Interactive comment on "Particle fluxes in the deep Eastern Mediterranean basins: the role of ocean vertical velocities" *by* L. Patara et al.

L. Patara et al.

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We would like to thank all Referees for the time devoted to this manuscript and for the constructive comments. We deeply apologize for the inconvenience caused by the second submission occurred at the end of August. We respond below to general and specific comments indicated by Referees. We give a collective reply to all three Referee Comments, as several of the raised issues are common to all of them. To make the revisions clearer, we produced new figures which are available on the website: http://www.bo.ingv.it/˜tonani/ (where ˜ = tilde).

GENERAL SCIENTIFIC ISSUES RAISED BY REFEREES:

1. IMPACT OF HORIZONTAL ADVECTION ON OBSERVED PARTICLE FLUXES: Anonymous Referee #1 suggests a more thorough analysis of the impact of horizontal

advection on the investigated particle flux time series. Ocean horizontal velocities could in fact affect the 'distribution of upwelled nutrients, then the primary producers distribution and finally the fluxes resulting from aggregation, food web pathway, and others mechanisms' (Anonymous Referee #1, page S1909, paragraph 2), as well as sediment trap collecting efficiency. Anonymous Referee #1 argues that 'there are obvious temporal and spatial issues in the present study that need to be clarified' and that at the moment 'the spatial issue remains unaddressed' (page S1909, paragraph 2). Moreover in the manuscript we hypothesize that spatial variability of horizontal advection could account for some the correlation differences between the Urania and Bannock sites, as well as between the 500 m and 2800 m depth traps. Referee L. Vandenbulcke suggests that 'the OGCM could be used to check whether there is anything particular with the horizontal advection at the specified location during that period' (page S1838, paragraph 2).

AUTHOR RESPONSE: We analyze horizontal currents, temporally averaged over the sediment trap rotation intervals, at 90 m depth - i.e. approximately at the base of the euphotic layer - and at 500 m and 2800 m depth - i.e. at the depth of the sediment trap moorings. Results for our study period, at the Urania and Bannock sites, are shown in Figure 10. Horizontal currents at the Urania site have a mean of 7,5 - 2,8 - 0,6 cm sec-1 at 90 - 500 - 2800 m depth, whereas at the Bannock site they have a mean of 4,1 - 2,0 - 0,2 cm sec-1 at 90 - 500 - 2800 m depth. At 90 m depth, horizontal currents are higher at the Urania with respect to the Bannock site, and a rather pronounced seasonality is evident at the Urania site, with strongest currents (>15 cm sec-1) occurring in autumn 1999. On the other hand, at 500 m and 2800 m depth mean currents are lower in amplitude and almost stationary with greater variability again at the Urania site.

Sediment trap collecting efficiency is expected to be biased in the presence of strong horizontal currents; however in our study area horizontal velocities are well below 5 cm sec-1 at 500 m and 2800 m depth and thus we do not expect a significant impact on particle collection efficiency (Buesseler et al., 2007), at both the Urania and Bannock

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sites. On the contrary, lateral advection in the upper ocean is relevant and it may modify the source regions of the particles collected by deep sediment traps (Siegel et al., 2008). Horizontal velocities between 10 and 15 cm sec-1 would cause in fact horizontal transport of primary producers and/or nutrients of about 100-200 km during a 10-15 day period. We may then argue that the Bannock site, where near surface currents are normally below 5 cm sec-1, will be more representative of local production conditions than the Urania site, where currents are overall higher.

To address the 'spatial issue' at the Urania site we use two different approaches: (a) we perform a sensitivity analysis on the horizontal integration area of current vertical velocities. This is done in order to assess how the spatial heterogeneity of the vertical velocity field will affect correlations with particle flux data. (b) We compare zonal and meridional current velocities at 90 m depth at the Urania site with zonal and meridional chlorophyll concentration gradients over a 200 km spatial scale. This is done in order to verify in which periods horizontal gradients of chlorophyll and current velocities at the Urania site are significantly different from zero and to assess the qualitative aspects of horizontal advection of primary producers in the area.

(a) Current vertical velocities (CVV) are horizontally averaged on six different horizontal areas of increasing dimensions, from the smallest area F of 70 km side, to the largest area A of 145 km side. Current vertical velocities are then correlated with particle fluxes in the three cases '0 lag', '1 lag' and '2 lags'. Spearman rank correlation coefficients are plotted in Fig. 11 as a function of the horizontal integration area. Note: the correlation coefficients shown in Table 2 of the discussion paper are obtained by using area E of 90 km side. We would like to mention that the use of Pearson correlation coefficients instead of Spearman rank correlation coefficients does not change our results significantly. Correlation coefficients exhibit some heterogeneity with respect to the horizontal integration areas but in most cases they appear to be higher when the horizontal average is performed in the smallest area around the station coordinates. This result strengthens our hypothesis of increased particle fluxes triggered by upward

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currents. Our results appear however to be robust with respect to the spatial integration area of ocean vertical velocities. We could then argue that surface horizontal transport due to lateral advection should not be causing major changes in the distribution of upwelled nutrients at the Urania site, where horizontal surface velocities are of the order of 10-15 cm sec-1.

(b) We use SeaWiFS satellite chlorophyll monthly values available from the JRC Ocean Color Portal (http://oceancolour.jrc.ec.europa.eu/) for the years 1999-2004 to compute zonal and meridional chlorophyll concentration gradients. The data have a horizontal resolution of approximately 2 km in our study area. In Fig. 12 we show, for the Urania site, zonal and meridional chlorophyll gradients computed over an area of 200 km side and local values of zonal and meridional currents at 90 m depth. With arrows we indicate the direction of ocean velocities (in grey) and of positive chlorophyll gradients (in white), during periods when these simultaneously exceed 5 cm sec-1 (i.e. 4.3 km day-1) and 0.01 mg m-3/200 km respectively. The choice of these threshold values is not based on quantitative arguments: our aim here is only to make our qualitative description clearer. A simplified equation accounting for the local rate of change of chlorophyll due to horizontal advection can be written as: Chlt= - u Chlx - v Chly (4), where Chlt, Chlx and Chly are the partial derivatives of chlorophyll concentration in time, in the zonal direction and in the meridional direction respectively.

When horizontal velocity and chlorophyll gradients have opposite sign, we expect an enhancement of local chlorophyll values by horizontal advection as shown in equation 4. This process might be occurring at the Urania site in December 1999, in March 2000 and in May 2000. When horizontal velocity and chlorophyll gradients have the same direction, we expect lateral advection to cause instead a reduction of local chlorophyll values. This process might be occurring at the Urania site in November 1999 and in January-February 2001. We may then speculate that part of the particle flux increase occurring in December 1999 and March-May 2000 at the Urania site may be due to lateral advection from more productive regions near the site. On the other hand, parti-

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cle fluxes at the Urania site in January-February 2001 may be particularly low because of lateral divergence of chlorophyll away from the station. However these calculations should be taken with caution: we might in fact question whether satellite measurements are able to capture algal biomass up to the deep euphotic layer, even if evidence exists that this might be possible in open ocean conditions (McGillicuddy et al., 2001a).

Figures 10, 11 and 12 and the above discussion will be added to the revised version of the manuscript.

2. RELATIONSHIP BETWEEN CURRENT VERTICAL VELOCITIES, CHLOROPHYLL SATELLITE DATA AND PARTICLE FLUXES: we discuss here three reviewer comments.

Referees A. Calafat and A. Sanchez-Vidal suggest including 'SeaWiFS-derived chlorophyll-a concentration to support discussion related to enhanced primary production' (page S1902, paragraph 8).

Anonymous Referee #1 suggests that 'chlorophyll satellite data could be correlated to the CVV field with and without time lags and also spatially and temporarily correlated to the 500 and 2800 m sediment traps fluxes data' (page S1910, paragraph 1).

'The coagulation of primary producers ... could also generate large marine snow particles with fast sinking rates (100s m day-1) that would highly contribute to the total flux' (Anonymous Referee #1, page S1911, paragraph 3).

AUTHOR RESPONSE: We use SeaWiFS chlorophyll monthly means available from the JRC Ocean Color Portal (http://oceancolour.jrc.ec.europa.eu/) for the years 1999-2004 to compute average chlorophyll concentrations around the Urania and Bannock sites. We analyze total chlorophyll values (CHL-T) and chlorophyll anomalies with respect to the long-term seasonal mean (CHL-A). In Figs. 13 and 14 we depict, at the Urania and Bannock sites respectively, CHL-T and CHL-A together with simulated current vertical velocity (CVV) and total particle flux (TPF). CVV, CHL-T and CHL-A are horizontally averaged over an area of 70 km side around the station coordinates.

At both the Urania and Bannock sites, CHL-T exhibits a well developed seasonal cycle with maximum values in the late winter months (up to 0.1 mg Chl m-3) and minimum values in the summer months (below 0.04 mg Chl m-3). The Urania and Bannock chlorophyll concentration values are characterized by equivalent mean values (i.e. approximately 0.05 mg m-3) and seasonality (i.e. seasonal maximum in February-March). This chlorophyll concentration pattern is typical of a subtropical oligotrophic setting where light is never limiting and nutrients are conveyed seasonally in the eutrophic layer by means of winter mixing. CHL-A values, i.e. the interannual chlorophyll fluctuations around the seasonal mean, are less than 0.03 mg Chl m-3 in absolute value at both the Urania and Bannock sites.

CVV does not exhibit any synchronous correspondence with CHL-T, whereas it appears to be more synchronously correlated with CHL-A values, as it may be seen at Urania site in autumn 1999 and 2000 (positive CHL-A, upward currents) and in winter 2000 and 2001 (negative CHL-As, downward currents) and at the Bannock site in March 2000 (positive CHL-As, upward currents) and in late winter 2001 (negative CHL-As, downward currents). We may attribute the lack of correlation between CVV and CHL-T to the predominant role played by vertical mixing - rather than water column upward displacement - in causing the winter increase in chlorophyll concentration. Vertical isopycnal displacements at the base of the euphotic layer (McGillicuddy et al., 2001a) appear instead to affect interannual variability of chlorophyll concentration values, even though in this area also other processes, such as Saharan dust fertilization (e.g. spring 2000 at the Urania site), are certainly relevant in determining chlorophyll interannual fluctuations.

When comparing CHL-T and TPF fields, we notice that a direct correspondence between the two fields is not readily observed. The Urania and Bannock sites, even though characterized by equivalent upper ocean chlorophyll patterns, exhibit however very dissimilar export regimes (TPFs at the Bannock site are generally an order of

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magnitude lower than at the Urania site). In addition, the seasonality of algal biomass magnitude does not appear to directly determine particle flux variability. On the contrary, TPFs appear to respond with a similar magnitude to the winter chlorophyll concentration maximum (peaks in late winter 2000 and 2001 at the Urania site) and to its interannual anomalies: higher than average TPFs often concur with positive CHL-A values (autumn 1999 and 2000 and late spring 2000 at the Urania site; spring 2000 at the Bannock site), whereas lower than average TPFs are often associated with negative CHL-A values (late summer 2000 and winter 2000 and 2001 at the Urania site; winter 2001 at the Bannock site).

These results suggest a non-linear relationship between upper ocean algal biomass and deep sedimentary fluxes, with an amplification of the summer-autumn response of particle fluxes to upper chlorophyll amount with respect to winter and early spring. The weak coupling between primary producers and deep particle fluxes supports the hypothesis that particle export depends, in addition to primary production, also on the biological pump efficiency. Other studies (Buesseler, 1998; Francois et al., 2002; Dunne et al., 2007; Lutz et al., 2002; Conte et al., 2001) have shown that in oligotrophic areas primary production and particle fluxes are often decoupled, and argue for a relevant role of the food web structure, sedimentation pathways and particle properties in affecting deep particle fluxes. From our data it is possible to speculate on three possible factors affecting the biological pump: 1) grazer community composition and activity; 2) phytoplankton coagulation processes; 3) particle properties connected to Saharan dust events.

1) The pulsed-like behavior of particle flux maxima in early autumn 1999 and 2000 could be linked to the occurrence of macrozooplankton swarms (Conte et al., 2003) which would efficiently feed on the positive chlorophyll anomalies generated by upward current velocities. To our knowledge, measures of gelatinous zooplankton in the Ionian Sea are scarce: Greze (1963) observe the presence in the Ionian Sea of doiliolids and salps with maximum occurrence in summer; Mazzocchi et al. (2003)

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detect an eastward increase of appendicularia species. Observations in coastal areas of the Mediterranean Sea show that warm-dwelling species of gelatinous zooplankton, such as O. dioica, D. nationalis and T. democratica, exhibit their seasonal maximum in spring-summer and autumn (Avancini et al., 2006). We could then speculate that gelatinous zooplankton organisms in this area would be mostly abundant during the summer and autumn months whereas they would be lower in winter. If this is the case, deep particle flux pulses occurring during the summer and autumn months might be related to a higher abundance of macrozooplankton organisms. It is possible that the differences between Urania and Bannock particle fluxes could be associated with differences in macro-zooplankton populations at the two sites.

2) The exudation by phytoplankton organisms - including coccolithophores - of transparent exopolymer particles (TEP) may be playing a relevant role in promoting phytoplankton aggregation and export at depth (Engel et al., 2004). Beauvais et al. (2003) observe, in an off-shore site of the western Mediterranean Sea, an increase in TEP volume after the spring bloom and throughout the summer months, and they relate this feature to increases in carbon excretion by phytoplankton and to thermally stratified conditions. Thus it is possible that during summer there may be more favorable conditions for TEP-enhanced phytoplankton aggregation mechanisms followed by higher particle fluxes.

3) The higher frequency of Saharan dust events in summer (Kubilay et al., 2002) may lead to an increase of lithogenic material availability which would act as ballast for biogenic particles thus enhancing particle flux at depth (Thunell et al., 2007). We believe this process responsible for the high particle flux event in May 2000.

Note: We did not compute correlation coefficients between CVV/TPF and chlorophyll concentration data because of the different spatial and temporal resolution.

Note: The analysis performed in point 1b (analysis of lateral advection and chlorophyll gradients) was done using both CHL-T and CHL-A values. The results are very similar

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in the two cases, indicating that lateral chlorophyll gradients remain virtually unchanged when the seasonal cycle is removed from the CHL-T field.

Figures 13 and 14 and the above discussion will be added to the revised version of the manuscript.

3. LAGGED DYNAMICS BETWEEN CURRENT VERTICAL VELOCITIES AND PARTICLE FLUXES: Anonymous Referee #1 demands a more careful explanation of the temporal dynamics involved in the upwelling-enhanced deep particle fluxes, and in particular of the fact that 'all processes leading to fluxes events (production of settling material by primary production, then aggregation/ degradation of primary production/repackaging via the food web/remineralization etc... would happen in less than 10 days concerning mooring 2 and mooring 1 regarding the none lag correlation, or could take up to 20 days regarding the 2 lags correlation (only mooring 1 at 2800 m)' (page S1910, paragraph 1).

AUTHOR RESPONSE: We believe that highest correlations observed at 500 m depth with '1 lag' for Mooring 1 and with '0 lag' for Mooring 2 are not necessarily inconsistent, as the temporal resolution is of 10 days for Mooring 1 and of 15 days for Mooring 2. The fact that the 2800 m depth trap exhibits highest correlations could be due to the fact that the 500 m depth trap may be more affected by upper ocean biological dynamics (e.g., vertical migrating organisms, higher abundance of zooplanktonic 'swimmers' in the sediment traps). However we agree with Anonymous Referee # 1 that, due to the shortness of the time series, the robustness of temporally lagged correlation results might be questioned and that one must be cautious in drawing conclusions. What our results appear to tell is that various time scales are involved in the sedimentation of particle pulses from the ocean surface. We may speculate that this is due to different particle sinking regimes. However we cannot strengthen our hypotheses with information on the 'flux composition' and 'on the size/composition of aggregates in the sediment traps', as suggested by Anonymous Referee #1 (page S1911, paragraph 2), as these data are not available at the moment.

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The above discussion will be added to the revised version of the manuscript.

4. THE POLARITY OF VERTICAL VELOCITIES: Referees A. Calafat and A. Sanchez-Vidal ask for an interpretation of 'the seasonal polarity of current vertical velocity' peaks (i.e. increased upward vertical velocity during the autumn months), mostly visible at the Urania site (page S1902, paragraph 10).

AUTHOR RESPONSE: Ocean vertical velocities are seasonally modulated by the wind stress curl field, with positive/negative wind stress curl values inducing cyclonic/anticyclonic vorticity in the ocean (Pinardi and Masetti, 2000). In Figure 15 we show time series at the Urania and Bannock sites of Ekman vertical velocities (EVV) computed from the wind stress curl, and simulated current vertical velocities (CVV) vertically averaged between 100 and 600 m depth. EVVs are horizontally averaged over a 145 km side area (area A); due to the large spatial scale of the wind stress field, horizontal averages over smaller areas yield nearly the same results. CVVs are horizontally averaged over areas of 145 km side (area A) and of 90 km side (area E). At the Urania site, peaks of positive (i.e. upward) EVVs and CVVs are observed in autumn 1999 and 2000, suggesting a major role of the wind stress curl field in modulating the seasonal polarity of ocean vertical velocity. However, CVVs averaged over the smaller area F are much larger in amplitude with respect to EVVs and to CVVs averaged on the larger area A: this indicates that ocean dynamics amplifies the atmospheric forcing and translates it into smaller scale motions.

Figure 15 and the commenting text will be added to the revised version of the manuscript.

5. NON-LINEAR EKMAN PUMPING; Anonymous Referee #1 asks to provide more information over non-linear Ekman pumping that 'could generate vertical velocities of 10s m day-1 at sub-mesocale' and asks whether in this study 'total, linear or non linear Ekman vertical velocities' were calculated (S1910, paragraph 2).

AUTHOR RESPONSE: Large vertical velocities associated with non-linear Ekman

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pumping are thought to arise in cases of large Rossby numbers and of non-negligible non-linearity (Pedlosky, 2008), as it may occur in small scale oceanic phenomena of the order of <1 km. Such sub-mesoscale structures, which commonly occur in correspondence of narrow geostrophic jets and strong shears (Mahadevan, 2006), result from the non-linear interaction of mesoscale eddies, these latter having a spatial scale of the order of the internal Rossby radius of deformation, and wind forcing by Ekman pumping processes. In a modeling study, Lévy et al. (2001) show that vertical velocities of the order of 10s m day-1 associated with sub-mesoscale features efficiently inject nutrients in the upper layer and may therefore have an important effect on new production. The OGCM used in present study has a horizontal resolution of approximately 6 km, which is eddy permitting but too coarse to resolve sub-mesoscale features. Thus high sub-mesoscale vertical velocities cannot be captured by our model simulations. However, enhanced density gradients and velocity shears leading to the formation of sub-mesoscale structures are not a predominant feature of our study area and we do not expect this to be a substantial mechanism in the Ionian Sea.

The above comment will be added to the revised version of the manuscript.

SPECIFIC COMMENTS RAISED BY REFEREES:

1. Referees A. Calafat and A. Sanchez-Vidal and Anonymous Referee #1 ask to provide more information over 'the sediment trap (type, sampling area, collecting cups, etc.' and 'some basic technical details of the sampling procedures. In addition, explain the units of coccoliths flux' (Referees A. Calafat and A. Sanchez-Vidal, page S1902, paragraphs 2 and 3). AUTHOR RESPONSE: in this study we use conical Technicap PPS5/2 sediment traps in glass reinforced polyester equipped with 24 polypropylene bottles. Traps have a 1 m2 collection area, measure 2,3 m height and have an aspect ratio equal to 6,25. Upon recovery of the traps, swimmers were removed from the samples by hand picking under a stereoscope with fine tweezers and samples were then splitted into eight equal fractions using a pneumatic splitter. For coccolith analysis, samples were further splitted and one fraction was processed following the method of

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Bairbakhish et al. (1999) in order to remove organic matter and disaggregate particles. As a consequence, coccolith data represent the contribution from both loose coccoliths and coccospheres disaggregated during sample preparation. Samples were then filtered onto a millipore cellulose acetate filter (0.45 micrometer pore size, 47 mm diameter), oven dried at 40°C and stored in plastic petri dishes. A portion of each filter was mounted on a glass slide and analyzed along radial transects from the centre to the edge using a polarized light optical Olympus microscope (LM) at 1250 magnification. Coccolith count of major species was performed on areas of about 0.2 to 5 mm2, depending on coccolith concentration on the filter, whereas minor and rare species were counted on areas of about 1 to 10 mm2. Coccolith flux was calculated according to the following equation: F = N x Af x S / af x Ast x T, where F = coccolith flux (nC m-2 day-1), N = number of counted specimens (nC), Af = filter area (mm2), S = split factor, af = investigated filter area (mm2), Ast = sediment trap aperture area (m2) and T = sample collecting interval (days). The above description will be added to the revised version of the manuscript.

2. Section 3.1 on surface circulation in the Ionian Sea 'is part of the introduction to the study area as any result is shown' (Referees A. Calafat and A. Sanchez-Vidal, page S1902, paragraph 4). AUTHOR RESPONSE: we agree with Referees that this section might seem more suitable to the introduction to the study area. However we decided to include it in the results section as, to our knowledge, surface circulation in the Ionian Sea simulated with OPA 8.1 at a 1/16 of a degree has not yet been published and discussed. We believe that this is an important part of the understanding of the physical dynamics at the two studied sites.

3. Referees A. Calafat and A. Sanchez-Vidal ask why we chose the values of 25 mg m-2 day-1 (for TPF) and of 5 x 10ˆ8 nC m-2 day-1 (for TCF) as threshold values in highlighting the flux peaks (page S1902, paragraphs 5 and 6). AUTHOR RESPONSE: we admit that there was no quantitative argument for choosing those values. To avoid any confusion, we will remove this additional information from the revised version of

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the manuscript, as the particle flux peaks can be easily seen by readers.

4. 'The dissolution of coccolithophore and coccoliths can be controlled by microscope' (Referees A. Calafat and A. Sanchez-Vidal, page S1902, paragraph 7). AUTHOR RESPONSE: microscope visual inspection has revealed no evidence of coccolith dissolution (Malinverno et al., in preparation). This information will be added to the revised version of the manuscript.

5. 'Give details regarding the settling velocities calculations. I'm afraid authors have used the peak of May 2000, which is an overestimated value at both depths. Otherwise, I'm not able to find which TCF peak is recorded at the same time at both depths' (Referees A. Calafat and A. Sanchez-Vidal, page S1902, paragraph 9). AUTHOR RESPONSE: The peak of May 2000 is being removed from computations for both TCF and TPF. In particular for TCF, the correlation between the 500 m and 2800 m depth traps is performed on the first 14 samples, as the remaining part of the time series exhibits a few missing samples. Correlation coefficients are significant at 95% for both TPF and TCF, even though flux peak simultaneousness is not always clearly visible. These significant correlations led us to envisage a rapid coupling between upper and deep traps. Particle settling velocities were then calculated by dividing the distance between the two traps (in meters) by the sediment trap temporal resolution (in days). This clarification will be added to the revised version of the manuscript.

6. Referees A. Calafat and A. Sanchez-Vidal and Anonymous Referee #1 argue that without any additional information (i.e. organic matter, calcium carbonate or lithogenic concentrations) the common sinking mechanism between biogenic and lithogenic material cannot be seen (page S1902, paragraph 8). Moreover Referees A. Calafat and A. Sanchez-Vidal suggest controlling the 'relationship between the relative abundance of coccolith per sample (number/mg) and total mass flux' (page S1902, paragraph 8). AUTHOR RESPONSE: Additional information over the composition of the flux is unfortunately not available at the moment, and the percentage of TCF to TPF does not give any clear signal. We agree that the issue of common sinking mechanisms and

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composition of the flux cannot so easily be deduced from correlation coefficients and we will therefore remove this speculation from the revised version of the manuscript.

7. Referees A. Calafat and A. Sanchez-Vidal 'suggest to include percentages of organic matter, calcium carbonate etc. as found in the literature for the study area' (page S1903, paragraph 1). AUTHOR RESPONSE: To our knowledge, information over organic matter and calcium carbonate percentages are lacking in the open areas of the Ionian Sea. However data are available for other oligotrophic sites of the Mediterranean Sea. Zuñiga et al. (2008) measure in the open Algero-Balearic basin biogenic and lithogenic fluxes by means sediment traps. Biogenic fluxes contribute to about half of the total particle flux and show a seasonal increase in the winter months. Calcium carbonate is a major contributor to biogenic material (around 25% of total particle flux, with a maximum of 60% during winter). Organic matter is highest in the upper ocean (around 25% of total particle flux) whereas it decreases down to 10% at depth. The above information will be added to the revised version of the manuscript.

8. Referees A. Calafat and A. Sanchez-Vidal suggest to 'see Zuñiga et al (2008) for a direct effect of Saharan dust on the particle fluxes measured with sediment traps in Western Mediterranean' (page S1903, paragraph 2). AUTHOR RESPONSE: Zuñiga et al. (2008) investigate, by means of satellite and in situ data, Saharan dust events and dust deposition in the Algero-Balearic Basin and find a higher frequency of dust events in the summer and autumn months. These dust pulses are associated with an increase of the lithogenic fraction in their sediment trap particle fluxes. This result, also obtained for an oligotrophic site of the Mediterranean Sea, is in agreement with our hypothesis of dust-enhanced particle fluxes during the summer period. The above information will be added to the revised version of the manuscript.

9. Referees A. Calafat and A. Sanchez-Vidal notice that 'Reference Volpe et al. (submitted)' is missing (page S1903, paragraph 3). AUTHOR RESPONSE: The cited reference is 'Satellite observations of the impact of dust in a low nutrient low chlorophyll region: fertilization or artifact?' by Volpe, G., Banzon, V. F., Evans, R.H., Mariano, A.J.,

Santoleri, R., Sciarra, R., submitted, and it will be added to the revised version of the manuscript.

REFERENCES: References included in the response to Referee Comments are given in a separate Author Comment.

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