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Interactive comment on "Quantification of the lithogenic carbon pump following a dust deposition event" *by* M. Bressac et al.

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Please find below our reply after the review of our paper initially entitled "Quantification of the lithogenic carbon pump following a dust deposition event". We would like to thank the second reviewer for their relevant comments on the manuscript. We agree with the comments and have taken the suggestions of the reviewers into account. Some sections have been re-written based on these comments.

General Comments: This is an interesting paper by Bressac et al., which focuses on the importance of lithogenic ballast minerals in enhancing the flux of organic carbon into the ocean interior. Efforts on this subject have mainly focused on the role of calcite and/or opal as ballast agent, however, lithogenic material and its ability to enhance carbon export is understudied. Because of the importance of the carbon pump and

the atmospheric dust fluxes in the global carbon cycle, this study is very well within the scope of Biogeosciences. The authors examine the distribution of larges particles, the primary productivity and the downward export of carbon in two artificial seedings performed in mesocosms. Methods and results are clearly presented or refer to companion papers of the special issue if not fully described. The paper diagnoses the biotic (fertilization) and abiotic (aggregation catalyst and ballast) effects of seeding of POC fluxes and particles dynamic. However, it is not clear how the authors come to their main conclusion (namely: "the lithogenic carbon pump could be considered as a pathway by which DOM could reenter the biological pump") as the DOM data are not presented and not considered in the discussion. The authors base their argument on literature rather than actual data. Therefore, moderate revision is needed before publication.

Specific comments: 1) The title needs to reflect the "artificial" nature of the study (artificial seeding in mesocosms).

RESPONSE: The title has been changed in order to appropriately describe our study, as follows: "Quantification of the lithogenic carbon pump following a simulated dust deposition event in large mesocosms".

2) Introduction: P12642-L8: Please add [Hedges et al., 2000], key paper of the protection effect and [Engel et al., 2009] that demonstrate it in lab-controlled experiments.

RESPONSE: We apologize for not having used these references before, which are definitely relevant for our explanations. These references have been added and the sentence has been changed, as follows: "Although little evidence for a direct protective mechanism has emerged from in situ observations (Ingalls et al., 2006; Ploug et al., 2008; Iversen and Ploug, 2010), laboratory controlled experiments have demonstrated the potential for minerals to inhibit the microbial degradation of OM (Arnarson and Keil, 2005; Engel et al., 2009a; Le Moigne et al., 2013)".

3) Material Methods: P13645-L5: How does that compare with a natural deposition

event?

RESPONSE: Several aspects have to be taken into account in order to compare the artificial seeding with a natural dust deposition event: the resemblance between actual dust and the analog. As requested by the first reviewer, a new paragraph (2.2. The dust analog and the seeding) in the methodology section has been added: "The finest dust fraction (<20 μm) was separated from the bulk soil samples, dominated by quartz (40%), calcite (30%) and clays (25%), by grinding and dry-sieving. Then the dust analogs were processed to simulate cloud evapocondensation cycles. The physico-chemical characteristics of the dust analog are reported in Desboeufs et al. (2013). The resulting dust population presented a volume median diameter around 6.5 μm and a peak at $\sim$10 μm, while the particle number size distribution peaked at 0.1 μm (Guieu et al., 2010a). The DUNE-2 experiment lasted 14 days, from 26 June to 09 July 2010. Two artificial seedings were successively conducted seven days apart within the same mesocosm and consisted of mimicking realistic wet deposition events with a dust flux of 10 g m-2. Such a flux corresponds to 41.5 g of evapocondensed dust diluted in 2 L of ultrapure water and sprayed onto the surface of each of the mesocosms for a total duration of $\sim$40 minutes. In the Mediterranean basin, dust is mainly derived from the Sahara desert in the form of strong pulses (Loÿe-Pilot et al., 1986; Bergametti et al., 1989; Guerzoni et al. 1999). Between 1984 and 1994, Loÿe-Pilot and Martin (1996) reported a mean annual flux in Corsica of 12.5 g m-2 yr-1, mainly attributed to pulses > 1 g m-2. According to the same authors, this deposition is mainly wet deposition and may occur only with few drops of rain meaning that high amount of dust can be deposited in time scales of minutes. Similar strong and sudden (few hours) events have been recorded over the past decade with African dust deposition fluxes as high as 22 g m$-$2 (Bonnet and Guieu, 2006; Guieu et al., 2010b; Ternon et al., 2010). Our simulation, which allows to seed on a quasi-synoptic way all the +dust mesocosms, is thus realistic in term of flux and duration (Guieu et al., 2013a)".

4) Results: How did the PP evolved after both seedings? The PP is presented in an "in

prep" paper but not available to the reader yet. PP data is presented vs POC flux in fig 5 but the paper would benefit of presenting a figure similar to fig 1 but for the PP data.

RESPONSE: Indeed, primary production data will be presented in a companion paper not available to the reader yet. However, the figure of the evolution of primary production in control and +dust mesocosms is presented in the reply to the reviewer #1. As requested by the reviewer #1, the evolution and variability in PP of replicate mesocosms are now explained in the text: "Since optical data was limited to the first 48 hours of experiments, sediment trap data and primary production (PP) were used to determine the biological and lithogenic contributions in POC export over experiments. Similar increases in PP (by a factor of 2.3-2.4) were observed within +dust mesocosms following both seedings, while PP remained constant within control mesocosms (Ridame et al., 2013a). Both data sets remained significantly different (p-values < 0.05) throughout the experiment".

5) Discussion: P13653-L5: Add [Honda and Watanabe, 2010] for justification of considering an additional non-lithogenic associated fraction of the total POC flux.

RESPONSE: This reference has been added.

6) P13653-L5: Please provide equation, it will help understanding how you've worked out the carrying coefficients.

RESPONSE: The following equation has been added to the text: "POCdust flux = a $\times$ lithogenic flux + b where a is defined as the carrying coefficient (Klaas and Archer, 2002) and b corresponds to the unassociated POC flux".

7) P13654-L1: Specify by increasing particle sinking speeds or aggregating cells after ballasting.

RESPONSE: This correction has been done.

8) P13656 - section 4.3.1. I found this section a bit weak, as it is currently not supported by DOM data. The authors mentioned that "Dissolved ..... subsequent POC export" and

then conclude "While dust deposition .... In this sense, the lithogenic carbon pump could be considered as a pathway by which DOM could reenter the biological pump". It is one of the main outcomes of this paper. It therefore needs fully supported by data and requires more consideration in the discussion section.

RESPONSE: We totally agree with this comment. In order to scale down the certainty with which we discuss this aspect (as this study is not supported by DOM data), several changes have been performed in the revised manuscript.

(i) In the abstract, we initially stated: "At the scale of a dust deposition event, we estimated that 42-50% of POC fluxes were strictly associated with lithogenic particles through an aggregation process". The last part of this sentence has been changed, as follows: ". . . were strictly associated with lithogenic particles (through aggregation and most probably sorption processes)".

(ii) We now specify that DOM and TEP concentrations have not been measured in this study: "Although DOM and TEP concentrations were not measured during this experiment, the abundance of such organic material prior to the second seeding was likely higher within the +dust than within the control mesocosms, contributing to the larger difference in POC fluxes observed following the second seeding".

(iii) As requested by the reviewer #1, sorption of DOM onto minerals is discussed with more details. In particular, POC fluxes observed in the +dust mesocosms are compared with results from a complementary abiotic experiment (Bressac and Guieu, 2013) that used the same dust analog and flux in filtered seawater: "Sorption of dissolved organic matter (DOM) from solution onto mineral surfaces could reach equilibrium very rapidly (within ∼1 hour; Arnarson and Keil, 2000, 2005). This process likely contributed to the downward POC export in the first 24 h following the seedings. By using the same dust analog and flux in 0.2 μm filtered seawater, Bressac and Guieu (2013) quantified this abiotically driven organic carbon export and its variation as a function of the composition and abundance of DOM. During this abiotic experiment,

the amount of organic carbon adsorbed onto dust particles and exported downward was of the same order of magnitude as the POC fluxes observed in the +dust mesocosms".

(iiii) In the conclusion, we initially stated: "While dust deposition generally induces the production of labile OM, the adsorption of DOM onto lithogenic particles and subsequent lithogenic ballasting could constitute a pathway by which DOM could escape from being remineralized within the upper ocean. In this sense, the lithogenic carbon pump could be considered as a pathway by which DOM could reenter the biological pump". In the revised manuscript, sorption of DOM onto dust particles is only addressed in the section 4.3.1, and this sentence has been changed, as follows: "While dust deposition can have a fertilization effect on the phytoplankton compartment by bringing new nutrients, the labile OM produced could escape from being remineralized within the upper ocean through the physical associations (i.e. aggregation and adsorption processes) with dust particles and subsequent lithogenic ballasting".

9) P13654-L28. Please add [Le Moigne et al., 2012] and P13656-L28: Please add [Buesseler, 1998].

RESPONSE: These references have been added.

References cited: Bressac, M., Guieu, C., Doxaran, D., Bourrin, F., Obolensky, G., and Grisoni J.-M.: A mesocosm experiment coupled with optical measurements to assess the fate and sinking of atmospheric particles in clear oligotrophic waters, Geo-Mar. Lett., 32, 153-164, doi:10.1007/s00367-011-0269-4, 2012. Bressac, M., and Guieu, C.: Post-depositional processes: What really happens to new atmospheric iron in the ocean's surface? Global Biogeochem. Cycles, 27, 859-870, doi:10.1002/gbc.20076, 2013. Giovagnetti, V., Brunet, C., Conversano, F., Tramontano, F., Obernosterer, I., Ridame, C., and Guieu, C.: Assessing the role of dust deposition on phytoplankton ecophysiology and succession in a low-nutrient low-chlorophyll ecosystem: a mesocosm experiment in the Mediterranean Sea, Biogeosciences, 10, 2973-2991, doi:10.5194/bg-10-2973-2013, 2013. Guieu, C., Dulac, F., Ridame, C., and Pondaven, P.: Introduction to the project DUNE, a DUst experiment in a low Nutrient, low chlorophyll Ecosystem, Biogeosciences Discuss., 10, 12491-12527, doi:10.5194/bgd-10-12491-2013, 2013. Ridame, C., Dekaezemacker, J., Guieu, C., Bonnet, S., and L'Helguen, S.: Phytoplanktonic responses to contrasted Saharan dust events: results from dust seeding in large mesocosms, Biogeosciences, in preparation, 2013.

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