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Interactive comment on "Phytoplanktonic response to contrasted Saharan dust deposition events during mesocosm experiments in LNLC environment" *by* C. Ridame et al.

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We would like first to thank the reviewers for their relevant comments and suggestions which helped us to improve our manuscript.

The title has been changed into 'Contrasted Saharan dust events in LNLC environment: impact on nutrients dynamics and primary production' to be more representative of the scientific content of the paper. Indeed, the main goal of this study is to explain why different phytoplanktonic responses (stimulation or no change) were observed after contrasted Saharan dust deposition event (wet versus dry; single deposition versus two successive deposition events) through the changes in the atmospheric supply of

new nutrient (N, P, Fe).

SPECIFIC REPLY TO REFEREE 3

GENERAL COMMENTS: In the present study the authors try to elucidate the effect of Saharan dust input on nutrient dynamics, phytoplankton primary production and biomass using an experimental mesocosms approach in an oligotrophic ecosystem. The authors found the dust deposition increased primary production and phytoplankton biomass in LNLC environments, which although has been reported in previous similar studies. Chemical and biological parameters were carefully tested in the study. One of the novelties of this manuscript is to test the different effect of dry and wet deposition and found that the pathway/type of dust is important in determining the phytoplankton response. Below follows a few issues that need to be addressed before publication is warranted.

RESPONSE: We agree that the stimulation of primary production after a Saharan dust addition has already been shown in LNLC environments mainly from bioassays experiments (see review in Guieu et al., 2014). Due to the logistical difficulties of investigating in situ natural dust events, and due to the inherent limitations of microcosm/bioassay experiments, new experimental approaches have been developed in the frame of the DUNE project allowing to perform for the first time realistic dust seedings onto in situ large metal-free mesocosms (52 m3) and follow the impact on chemistry, biology and particles dynamics. Moreover, the duration of the experiment (up to 2 weeks) and the fact that the vertical dimension is taken into account is also original. So to our knowledge, there were not such 'similar studies' before DUNE.

SPECIFIC COMMENTS

In the experiment, the Sahara dust analog was treated with "evapocondensation" to simulate the real wet deposition. And this EC treatment led to higher inorganic N content in the wet deposition and thus resulted in larger increase of Chl and PP compared with dry deposition experiment. However, as far as I know, the dry deposition is not

pure Sahara dust. The dust mobilization process is highly complex, which is a function of many atmospheric, soil, and terrain properties, and associated with winds as well as occurrence of chemical reactions due to aerosol contacting with changing of chemical environment. The dust could also mix with polluted aerosols during the transportation process. So I wonder if the Sahara dust analog used in the experiment can represent the real dry deposition? Why did not the authors use in situ collected atmospheric aerosol and rainwater to represent the dry and wet deposition?

RESPONSE: Indeed, we had to consider during DUNE that wet deposition and dry deposition do not have the same 'history' from the emission to deposition at the sea surface. Most of this has been explained and justified in the methodology paper of Guieu et al, (2010). Indeed, it has been shown that the mixing with anthropogenic components, such as N, is a process that occurs mostly during cloud processes (wet deposition). Our approach to aging dust is based on previous works from Desboeufs et al. (2001), enabling the laboratory simulation of cloud evapocondensation cycling which reproduces the photochemistry and the gradients in pH and ionic strength during cloud processing of dust particles. As described in the review of Formenti et al., (2010), the reactivity of polluted species with dust is determined by several factors: chemical mineralogy of dust, transport pathways, the extent to which dust is transported across polluted sources and meteorology. The internal mixing between dust and other aerosols is favoured in the marine atmosphere where the relative humidity is high (Hanisch and Crowley, 2001) or by in-cloud processing (e.g. Crumeyrolle et al., 2008). Thus, this internal mixing is not systematically observed in the Mediterranean area (Marconi et al., 2014). Moreover, Kandler et al. (2007) show that the mixing is lower to 2% for the transported dust particles larger than 5 μm and to 5% for particles larger than 1 μm, i.e. for the particles preferentially removed by dry deposition. The size distribution and the chemical composition of our untreated dust (non-EC dust) are totally consistent with the characteristics of long-range transported dust (Guieu et al., 2010; Formanti et al., 2011; de Leeuw et al., 2014). From these points, we consider that the untreated dust is representative of dry-deposited dust in Mediterranean Sea.

This information justifying the use of non-EC dust to simulate a dry deposition event has been added in the revised version in section 2.1.

RESPONSE: To simulate a Saharan deposition event (wet or dry), we did not use collected rainwater or collected aerosols but the fine fraction of a Saharan dust analog in order to obtain enough quantity of the same material. The amount of dust per mesocosm required was 41.5 g, which resulted in a total of 125 g of dust for the three replicates for only one seeding experiment (we performed four seeding experiments). Such a large amount of particles could not be collected from airborne dust in the vicinity of the experimental area. Moreover, Saharan dust events are sporadic and collecting rainwater on the field at the time of the mesocosms experiment would have introduced large uncertainties in the feasibility of the project. Thus, our strategy consisted of producing dust from the soil of an appropriate source area, the southern Tunisia. The methodology developed for the DUNE project and in particular the production of large amount of dust analog was one of the objectives of the project. This information has been added in the section 2.1.

In the manuscript, the authors made some conclusive statements that "wet and dry deposition events induced contrasted responses to the phytoplankton community", "dry deposition event was shown to be a negligible source of NO3". Considering the dust used in the experiment was not real in situ dry deposition, the authors should be cautious making such statement. I suggested using term "direct addition of Saharan dust" instead of "dry deposition".

RESPONSE: As said in the preceding reply (see above), we consider that the untreated dust is representative of dry-deposited dust in the Mediterranean Sea.

Besides, many other studies using non-EC dust (dry deposition) observed significant chl increase (e.g., Paytan et al., 2009; Lekunberri et al., 2010, etc). I suggested the authors comparing the results of this study with others and adding more discussions.

RESPONSE: We have added in the discussion section a new paragraph about the

comparison of our results after a simulated dry deposition (non-EC dust) event with results based on non-EC dust addition in bioassay experiments in the Mediterranean Sea (Ridame, 2001; Bonnet et al., 2005). To our knowledge, only these two studies were performed in the Mediterranean Sea, during stratification period, and with 'pure' untreated Saharan dust. The results of both studies show no chla increase after simulated dry deposition event (2.5-12.5 g.m-2) which is in good agreement with our observations.

We consider that it was tricky to compare our results with those obtained by Paytan et al., (2009) because in addition to difference in the incubation strategy: -the study site of Paytan et al., (2009) is the Red Sea, not the Mediterranean Sea -Paytan et al., (2009) did not use 'pure' Saharan dust but African aerosols locally collected which have been mixed with anthropogenic/local particles -The initial macro-nutrients conditions are quite different: 0.2 μM of nitrates (< 30 nM in our study), 20 nM of DIP (2-5 nM in our study). In the study of Lekunberri et al., (2010), the authors have used the particulate phase of a Saharan rain. So, addition of these aerosols did not simulate a dry deposition event. Besides, the authors have simulated unrealistic Saharan dust wet deposition events of 500 and 5000 g.m-2 which is much higher than those observed in the field (0.1 - 20 g m-2 event-1, see review in Guieu et al., 2014).

In the result and discussion part, the authors included too many descriptive details on the nutrient dynamics in response to dust deposition (especially in section 3.1 and 4.2). The two parts lack focus and take home messages. Since the title of the manuscript is "phytoplanktonic response to contrasted: : :", it would be better if the authors link the pathways of nutrients to phytoplankton changes.

RESPONSE: The main part of the Discussion is focused on the impact of contrasted (wet and dry) Saharan dust events on the nutrient dynamics (N, P, Fe) as it is directly linked with the response of the phytoplanktonic community in term of biomass and CO2 fixation. For this reason, we have decided to change the title of our manuscript into 'Contrasted Saharan dust events in LNLC environment: impact on nutrients dynamics

and primary production' which is more representative of the scientific content of the paper. Besides, this study is complementary to the companion paper of Giovagnetti et al. (2013) focusing on changes in the structure and composition of the phytoplanktonic community as well as in the ecophysiological state of the phytoplanktonic cells after a wet deposition event.

P758 Line 20: it is not clear why the authors added a concentration of 41 g of mineral dust mimicking a realistic flux of 10 g m-2.

RESPONSE: the surface of each mesocosm was 4.15 m2 and we added 41.5 g of dust per mesocosm leading to a dust deposition event of 10 g.m-2.

Fig.8 Please add some explanations on how those lines were drawn.

RESPONSE: We did not use a modeling method to perform figure 8. These lines represented the general trend of the temporal variations of nitrates and DIP concentrations. For a better understanding, this figure has been changed by using the calculated variation (DUST-CONTROL) of the DIP and nitrate stocks (see below).

The legends of axes in Fig 2-5 and Fig 7 are too small.

RESPONSE: This has been changed in the revised version

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Interactive comment on Biogeosciences Discuss., 11, 753, 2014.

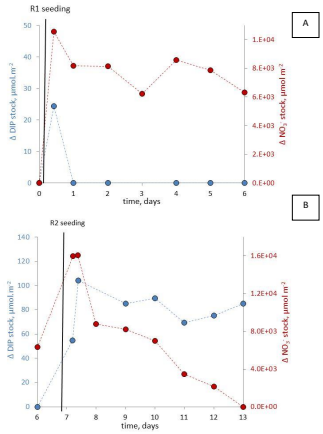

Fig.8: Averaged temporal changes in the variation (Dust-Control) of NO_3^- (red line) and DIP stock (blue line) (A) after the DUNE-2-R1 seeding and (B) after the DUNE-2-R2 seeding.

Fig. 1.