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Interactive comment on "Main drivers of transparent exopolymer particle distribution across the surface Atlantic Ocean" *by* Marina Zamanillo et al.

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We thank the reviewer for his valuable comments on our manuscript. We answer below to each comment and question. (a more edited version is submitted in pdf)

R: This is a good manuscript that provides excellent summary of TEP information. A good synthesis of data at hand despite the limitations of coverage in space (data collected only at 4m and at times the discussion is based on 1 sample to represent a hydrographic domain, say CU).

A: We thank the reviewer for his supportive comments. We were not trying to repre-

sent a hydrographic domain with a single sample, but we just treated the CU as an independent sample (i.e. removing it when calculating TEP averages and regression analyses between TEP and other environmental and biological parameters) due to its particularity, as indicated in the objectives section (end of the introduction). We are aware that some sentences could have given that impression and we will fix this in the revised version of the MS. For example we will change the following sentences:

Line 45: "with the maximum concentrations in the SWAS and in a station located at the edge of the Canary Coastal Upwelling (CU)"

Line 223: "and presented the minimum concentrations in the CU station and surroundings"

Line 322: "namely in the station located in the CU and within the SWAS"

Line 392: "with the maximum value in the station located in the CU"

Line 401: "The highest TEP:Chl a ratio of the entire transect observed in the station located in the CU was probably associated with the high relative abundance of diatoms and dinoflagellates."

R: The authors made the point that TEP contributes majorly to POC than phytos and HP based on the quantification of TEP, phytos and HP carbon pools estimated from available conversion factors. That the authors are well aware of limitations/approximations of these conversion factors, semi-quantitative nature estimations of TEP, phytos and HP pools (the last two are based on cell numbers) one would have expected the authors to critically evaluate their % contributions keeping the associated overall errors (methodology+conversion). This may not alter their conclusions but convinces the readers with appropriate comparisons having taken errors into account. I recommend minor revision of this manuscript before it is accepted for publication.

A: We will add information in the manuscript regarding the errors associated to the methodology and conversion factors. More specifics are given in the responses below.

R: 1. Lines 65-66: ‘Enhancing particle sinking’ – The authors may want to see open ocean TEP information from North Indian Ocean (Kumar et al., 1998)

A: We will add the suggested reference in the revised version of the MS.

R: 2. Line 67: ‘can also ascent’ gives a meaning that TEP float by themselves but these are mainly transported to surface microlayer by rising bubbles through scavenging

A: We will change the sentence to: “On their way to aggregation, and due to their low density, TEP and TEP–rich microaggregates formed near the surface may ascend and accumulate in the sea surface microlayer (SML) (Engel and Galgani, 2016), a process that is largely enhanced by bubble-associated scavenging (Azetsu-Scott and Passow, 2004; Wurl et al., 2009; Wurl et al., 2011b).”

R: 3. Lines 109-110: “in situ studies of TEP distributions in the ocean are scarce, particularly in the open ocean (Table 2)”. But Table 2 specifies TEP in surface layers. Kumar et al. (1998) and Ramaiah et al. (2000) provided the first TEP open ocean data from the Indian Ocean (see below for references).

A: We thank the reviewer for drawing our attention to these references. We will specify in the text and figure legend that we are referring to surface measurements. Note that, for the sake of direct comparison with our study, Table 2 only listed TEP measurements conducted with the spectrophotometric method and Xanthan Gum calibration. However, in order to be more inclusive, we will add the indicated references.

We will add the following information to Table 2: [see Figure 1 attached]

R: 4. Line 115: ‘entire POC’ will also include non-living non-TEP organic carbon fraction. This was not addressed in the manuscript.

A: We are aware that POC also includes other organic particle fractions such as non-living non-TEP organic carbon (for instance, cell fragments and proteinaceous - Coomassie stainable particles). In the present work we decided to compare our target variable, TEP, with the two pools of POC that are considered most abundant in sea

water, namely phytoplankton and heterotrophic prokaryotes. We will add the following sentence in the results to clarify it: “To better explore the importance of TEP–C with respect to other major quantifiable POC pools, we estimated phytoplankton biomass (phyto–C) and HP biomass (HP–C) throughout the whole cruise (Fig. 2). It is worth mentioning that POC also includes other fractions of non-living non-TEP organic carbon (e.g., cell fragments and Coomassie stainable particles), but phytoplankton and heterotrophic prokaryotes are generally considered the most abundant in open sea water (Ortega-Retuerta et al., 2009b; Yamada et al., 2015). TEP–C contributed the most to the POC pool in the OAO, where it represented twice the share of phyto-C and HP-C. In the SWAS, conversely, TEP-C was not significantly different than phyto-C, and three times higher than HP-C (Fig. 3).”

R: 5. Lines 147-148: Given the 18.7% difference in concentrations between TEP duplicates specify the errors in TEP-C estimation to compare with other org C-reservoirs.

A: We will specify the errors of TEP-C estimations in the material and methods of the revised version of the MS:

Line 146: “We estimated the TEP carbon content (TEP–C) using the conversion factor of 0.51 μg TEP–C L-1 per μg XG eq L-1 (Engel and Passow, 2001). Errors in TEP-C estimations averaged 8.4 μg C L-1 (0.2- 70.3 μg C L-1).”

R: 6. Lines 175 to 202 and Lines 283-287: How accurate is the cell abundances counting of the respective biological groups? Please specify uncertainties involved. This is particularly important because each of subgroups will carry uncertainties in carbon per cell and that will be additive. Total uncertainties involved assume significance since a comparison is being made with TEP-C, where TEP estimation itself is semi-quantitative! For example, line 232-233 show phytoplankton biomass estimation carries nearly 50% of uncertainties in cell counts and cell C estimations! Authors discussion (Lines 343-353) on uncertainties in TEP-C contribution to POC arising from cell-C conversion and analytical artifacts is well appreciated. But the authors should

help the readers by providing a comparative evaluation including errors in estimated carbon pools in a Table.

A: Replicates for the prokaryotic abundance measurement with flow cytometry were not done because the standard errors obtained are usually very low (i.e around 1.5 % in Pernice et al. 2015).

Line 199: "Only one replicate was analysed since standard errors of duplicates are usually very low (around 1.5 % in Pernice et al., 2015)."

Microscopic observations must be interpreted with caution due to the following (Kozlowski et al., 2011; Cassar et al., 2015): - They are biased towards relatively large forms (> 5 μm) of phytoplankton groups with identifiable morphological characteristics - Problems associated with biovolume estimates - Problems with the microscopic identification of naked and small-celled groups

Line 175: "Uncertainty sources for micro-phytoplankton biomass estimates are the conversion factors, biovolume estimates, and proper identification based on morphological characteristics, harder for naked cells and those at the lower size edge (5-10 μm) (Kozlowski et al., 2011; Cassar et al., 2015)."

Regarding the phytoplankton biovolume-to-carbon conversion factors, we show the 95 % confidence intervals obtained by Menden-Deuer and Lessard (2000) for phytoplankton biomass estimation: log pg C cell-1=log a (95 % C.I.) + b (95 % C.I.) x log V (μm3), where log a is the y-intercept, b is the slope and 95% C.I. is the 95 % confidence intervals:

Protist plankton: log pg C cell-1=log -0.665 (0.132) + 0.939 (0.041) x log V (μm3) Diatoms: log pg C cell-1=log -0.541 (0.099) + 0.811 (0.028) x log V (μm3)

Line 173: "Cell C content was calculated using conversion equations of Menden-Deuer and Lessard (2000) log pg C cell-1=log a (95 % confidence intervals) + b (95 % confidence intervals) x log V (μm3): one for diatoms (log pg C cell-1=log -0.541 (0.099)

+ 0.811 (0.028) x log volume (μm3)) and one for the other algae groups (log pg C cell-1=log -0.665 (0.132) + 0.939 (0.041) x log volume (μm3))."

As for the bacterial cell-to-carbon conversion factor, we will add the following explanation: Line 202: "Ducklow (2000) summarized the carbon contents of free-living marine bacteria reported in the literature for a number of oceanic regions, bays and estuaries. The average $\pm$ standard deviation for open ocean regions was 12.3 $\pm$ 2.5 fg C cell-1. A factor of 12 fg C cell-1 is equivalent to use the empirical equation proposed by Norland (1993), fgC cell-1 = 0.12 (μm3 cell vol)0.72, for an average bacterial biovolume of 0.04 μm3."

In relation to line 232-233: "The phytoplankton biomass was generally dominated by Prochlorococcus, with an average of 233 1.68 $\times$ 105 $\pm$ 0.81 $\times$ 105 cells mL-1, which corresponded to a biomass of 8.58 $\pm$ 4.16 μg C L-1.", the standard deviation of biomass is not the uncertainty of the estimate, but the variability (standard deviation) of biomass along the Northeastern Subtropical Gyre.

R: 7. Line 310: 'we present the first inventory of surface TEP concentration' – can the seawater samples collected from 4 m depth be treated as representative of surface layer to make an inventory? Here seems to be an incompatibility that needs to be clarified.

A: We agree with the reviewer that 4 m may at times not be representative of surface waters. Relatively high variability within the top surface meters has sometimes been observed (Wurl et al., 2009). However, 4 meters is usually considered as surface in most oceanographic studies, where sampling is mostly conducted either with the CTD rosette or with an underway pumping system. Nonetheless, the word 'inventory' may induce misunderstanding, and we will change it to 'distribution'. We will modify line 310-311 of the manuscript as follows:

"We present the first distribution of surface (4 m) TEP concentration along a latitudinal gradient in the Atlantic Ocean, covering both open sea and shelf waters. It is worth

mentioning that vertical variability within the top surface meters (< 4 m) has sometimes been observed (Wurl et al., 2009), but 4 m is usually considered "surface ocean" in studies where samples are collected with either an oceanographic rosette or an underway pumping system."

R: 8. Lines 360-364: Given the large uncertainties involved statements such as 'Only in one station of the SWAS phyto–C dominated the TEP–C (line 360-1)' and 'with the maximum concentrations in the edge of the Canary Coastal Upwelling (CU, n = 1) (lines 45-46)' may be avoided as these oversimplify a complex reality of spatial variability in horizontal and vertical (see line 310 comment above) dimensions.

A: As explained above, we were not trying to represent a hydrographic domain with a single sample, so we will make the appropriate changes in the text to clarify that we are just referring to our dataset without any purpose to generalise. E.g.: Line 45-6: "with the maximum concentrations in the station located in the edge of the Canary Coastal Upwelling (CU) and the SWAS"

R: 10. Line 448: Please show the negative relation in a diagram.

A: We will add this plot to the supplementary section. [see figure 2 attached]

Figure S1. Relationship between the accumulated (previous 24 hours-average) solar irradiance (W m-2) and TEP (μg XGeq. L-1) in the OAO. The linear regression line is plotted and the equation indicated.

R: 11. Lines 462-463: Figure 3 suggests that in spite of higher (nearly double) contribution of phytos to %POC in SWAS than in OAO, TEP and HP contributions to %POC are nearly the same. It appears that HP is more important in regulating TEP concentrations in the Atlantic, in general. This is slightly different from what has been said in lines 472-473 (The drivers of TEP distribution were primarily phytoplankton and, to a lesser extent, heterotrophic prokaryotes)

A: The identification of drivers of TEP distribution is based on regression analyses of

covariation (Table 3). In OAO, the largest share of TEP variance is explained by Chl a (R2=0.56) and phytoplankton biomass (0.47), particularly Synechococcus biomass (0.72), and in the SWAS it is phytoplankton biomass (0.62) followed by High nucleic acid containing prokaryotic heterotrophs (0.46). The fact that phytoplankton mainly drive TEP variability despite very different contribution to total POC is further exemplified by the large difference in the TEP:Chl a ratio between the two regions. In other words, the two regions are characterized by phytoplankton differently prone to TEP production, but in both phytoplankton are the main TEP drivers.

REFERENCES

Cassar, N., Wright, S. W., Thomson, P. G., Trull, T. W., Westwood, K. J., de Salas, M., Davidson, A., Pearce, I., Davies, D. M., and Matear, R. J.: The relation of mixed-layer net community production to phytoplankton community composition in the Southern Ocean, Global Biogeochemical Cycles, 29, 446-462, 10.1002/2014gb004936, 2015.

Ducklow, H.: Bacterial production and biomass in the oceans, in: Microbial Ecology of the Oceans, edited by: Kirchman, D. L., 2000.

Kozlowski, W. A., Deutschman, D., Garibotti, I., Trees, C., and Vernet, M.: An evaluation of the application of CHEMTAX to Antarctic coastal pigment data, Deep Sea Research Part I: Oceanographic Research Papers, 58, 350-364, 10.1016/j.dsr.2011.01.008, 2011.

Menden-Deuer, S., and Lessard, E. J.: Carbon to volume relationships for dinoflagellates, diatoms, and other protist plankton, Limnology and Oceanography, 45, 569-579, 2000.

Norland, S.: The relationship between biomass and volume of bacteria, in: Handbook of methods in aquatic microbial ecology, edited by: Publishers, L., 303-307, 1993.

Ortega-Retuerta, E., Reche, I., Pulido-Villena, E., Agustí, S., and Duarte, C. M.: Uncoupled distributions of transparent exopolymer particles (TEP) and dis-

solved carbohydrates in the Southern Ocean, Marine Chemistry, 115, 59-65, 10.1016/j.marchem.2009.06.004, 2009.

Pernice, M. C., Forn, I., Gomes, A., Lara, E., Alonso-Saez, L., Arrieta, J. M., del Carmen Garcia, F., Hernando-Morales, V., MacKenzie, R., Mestre, M., Sintes, E., Teira, E., Valencia, J., Varela, M. M., Vaque, D., Duarte, C. M., Gasol, J. M., and Massana, R.: Global abundance of planktonic heterotrophic protists in the deep ocean, ISME J, 9, 782-792, 10.1038/ismej.2014.168, 2015.

Wurl, O., Miller, L., Röttgers, R., and Vagle, S.: The distribution and fate of surface-active substances in the sea-surface microlayer and water column, Marine Chemistry, 115, 1-9, 10.1016/j.marchem.2009.04.007, 2009.

Yamada, Y., Fukuda, H., Uchimiya, M., Motegi, C., Nishino, S., Kikuchi, T., and Nagata, T.: Localized accumulation and a shelf-basin gradient of particles in the Chukchi Sea and Canada Basin, western Arctic, Journal of Geophysical Research: Oceans, 120, 4638-4653, 10.1002/2015jc010794, 2015.

Please also note the supplement to this comment:
https://www.biogeosciences-discuss.net/bg-2018-359/bg-2018-359-AC1-supplement.pdf

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Sargasso Sea	Oligotrophic	Spring, summer, autumn 2012 and spring 2013	0–100	21 ± 2– 57 ± 3	0.05–1 [c]		Cisternas–Novoa et al. (2015)
North Indian Ocean -Arabian Sea -Bay of Bengal	-Eutrophic	-August 1996 -September 1996	0–1000	-60[j,k] (<5–102[j]) -7–13[c,j]			Kumar et al., (1998), Ramaiah et al., (2000)

j: TEP concentrations were given in milligram equivalent of alginic acid L^{-1} and absorbance was measured at 745 nm instead of 787 nm

k: 0–50 m

Fig. 1.

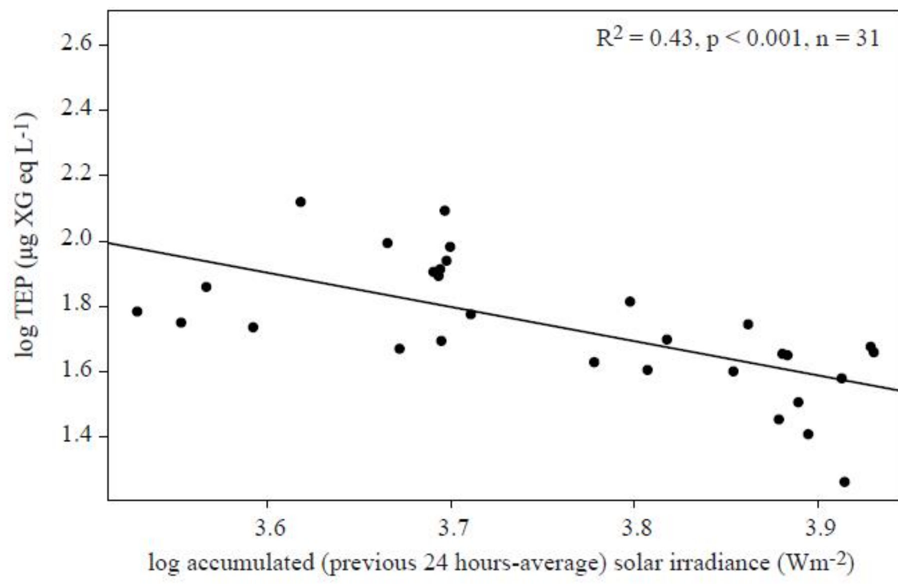

Fig. 2.