

## ***Interactive comment on “Brief communication: Atmospheric dry deposition of microplastics and mesoplastics in an Antarctic glacier: The case of the expanded polystyrene” by Miguel González-Pleiter et al.***

**Melanie Bergmann (Referee)**

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Received and published: 10 December 2020

1. General points: I recommend publication of this interesting MS in the journal Cryosphere since it is based on rare data from a remote area (Antarctica). In addition, it covers atmospheric microplastic pollution, an emerging issue that we do not know so much about until now. I also like the fact that larger plastic, mesoplastic, is addressed, for which we don't have so much data, especially in terms of atmospheric MP pollution. However, there are a few concerns that have to be tackled before this can be published in my opinion. Since you deal with microplastic, please provide a few lines

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on how you dealt with contamination (e.g. from yourselves). Did you do take a control? If you did not, this should at least be critically be discussed. The standard in microplastic research is nowadays to take blanks and give details on contamination prevention. Both of which is currently not mentioned at all. Based on this many reviewers would (rightly) reject the MS. However, since it is from such a remote place and deals with large micro- and mesoplastic, I think it merits publication. Still, this drawback needs to be communicated clearly. Please, make goals of this research clearer by formulating hypotheses or research questions: why you studied the two lake glaciers (e.g. test effect of distance to human plastic source). In addition, I strongly recommend that you then test your hypothesis on the data that you collected in both the sampling and experiment via statistical testing of abundance and polymer composition. Please add another graph, which shows the temporal trend over the 48-h experiment. Now this is hardly mentioned at all in the MS, which is a shame given all the work done. Please, also describe the trend in a separate section in results and consider statistical testing. Please, present all data as per m<sup>2</sup>, refrain from using numbers without a unit, which are meaningless.

2. Specific points Abstract -L. 31: Some readers may only be able to read the abstract. Therefore, please present the most important data here: the range of mean plastic pollution as well as microplastic that you recorded at the two sites in m<sup>-2</sup>, that polystyrene was the main polymer type found and also present the size range.

Introduction -L. 60: “The concentration of MP in snow is generally higher (0 to 1.5 x 10<sup>5</sup> MP L<sup>-1</sup> of melted snow) near urban areas (Bergmann et al., 2019), than in sea ice (up to 12000 MP L<sup>-1</sup> of melted ice), although there are large differences between studies even from the same region (Peeken et al., 2018; Von Friesen et al., 2020).” This is not a good comparison if you want to infer that plastic concentrations are higher in snow vs sea ice, as you compare snow concentrations from an urban (Bavarian Alps) area with sea ice concentrations from a remote area (Arctic). Please use the Arctic snow concentrations given in the paper, not the Bavarian ones! If you do so, the concentrations

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are similar. In addition, snow and sea ice are not so comparable as sea ice concentrates (microplastic) particles during ice formation. -L.65: Should it not rather be 'ice weight'? Because we are not really talking about sediments here but of ice?! -L.73: Other studies very likely found more small MP because they used methodology that can detect smaller particle sizes (e.g. u-FTIR imaging), this should be mentioned. Otherwise, it sounds as if MP in the Central Arctic were of larger size, which is likely only a detection bias. Please, add sth. like "due to the analytical methods used, which can capture smaller- sized plastic" -L74: "In general, the presence of plastics > 5mm are not reported in compartments of the cryosphere, probably due to the difficulty of large plastic items to reach the remote areas where these are located. I do not think that this is assumption is likely. Why should larger plastic not make it to the same places in the ocean as microplastic? I think the reason why they have not been reported in the marine cryosphere is that their concentrations are lower compared with MP. The likelihood of catching them by sampling gear is therefore also smaller, especially when analysing only small sample volumes. I would add sth. like: "In general, the presence of plastics > 5mm are not reported in compartments of the cryosphere, probably because they occur at lower concentrations and therefore often evade our detection." -L. 96: Please rephrase the strange term 'occurrence dynamics' -Please, add research questions/hypotheses in the end of the Introduction. Why the two lakes? Why did you do the experiment? Material & methods: I am missing any mention of fibres. Many (atmospheric) studies find that they predominate (possibly contamination). You do not refer to them at all except from the introduction. Did you exclude them (describe this)? If you did not find any, please also discuss this. Absher et al. reported fibres from Antarctic waters (Absher, T.M., Ferreira, S.L., Kern, Y., Ferreira, A.L., Christo, S.W., Ando, R.A., 2019. Incidence and identification of microfibers in ocean waters in Admiralty Bay, Antarctica. Environmental Science and Pollution Research 26, 292-298.)

-Please, provide distance (m) of each lake to the research station. -L.104: Is this the correct journal format for positions? If not please convert as appropriate with °N/°W etc.

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-Please, add a paragraph on data analysis (s. below).

-Throughout the MS, please structure into 1. Assessment of glacial plastic pollution 2. Experimental assessment of atmospheric plastic deposition

Results/Discussion

-L.145-157: It is not clear which particles these numbers refer to. To the time zero (before experiment started)? Or do the figure refer to all items recorded? Please make this clear (s. above re structure). Also, please refer to number of items per m<sup>2</sup> rather than presenting (meaningless) numbers throughout the text/tables/Figures.

-Please, add a headline referring to before Experiment and Dry-deposition experiment or similar, which makes it easier for the reader to follow (s. above).

-Please, present both total plastic abundance and microplastic abundance (in m<sup>-2</sup>) only, because other MP researchers may only want to compare their microplastic data with yours.

-L. 182: please add figures from your own research (mean or range in m<sup>-2</sup>) and provide figures from the papers that you cite for comparison.

-L. 184: How does this support " the notion that freshwaters could play a role in the life cycle of plastics in this region"? I do not understand? I don't think this conclusion can be drawn from the data, especially when consensus is building that the atmosphere is an important pathway/source of microplastic not vice versa? It could be concluded that it comes from the same source. However, you state elsewhere that your pollution may actually come from the research base, so this would be quite a different source compared to that of plastic in the ocean Please delete this or rephrase.

-L. 187: You can only make this statement if you have tested this. Because by looking at Fig. 2 B I could not be sure if there is actually a significant difference in the abundance of plastics at the two sites. But it would be interesting if you could: So, I suggest, you do some t-testing or similar (see also below).

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-L.190: Please honor this statement of growing tourism with a citation.

-L. 193: please provide some examples/citations of long-range transport of small particles (e.g. dust, pollen, algae) by winds.

-In addition, it needs to be stated that when comparing your data with those of others: you looked employed quite a different methodology, which is better suited at capturing larger items compared with the many microplastic studies and that the data are not comparable strictly speaking. By saying so, I do not mean that you should not compare. It just needs to be mentioned.

-L.195: These are good statements but please beef them up with your own findings and those of other workers. Please also refer to other papers, which deal with research-based plastic pollution in Antarctica, to strengthen your line of argument. You could also argue that more needs to be done on microplastic pollution, given that it seems widespread in the southern Ocean. Along the lines of:

99 “Our research indicates that our research in sensitive remote areas such as Antarctica leaves a footprint, namely plastic pollution. While reports of research-based litter pollution on the seafloor and beaches date back as early as the 1970’s (Dayton & Robillard 1971; Lenihan et al., 1990; Sander et al. 2009) the handling of waste has improved through the Antarctic Treaty System , Annex III ‘Waste Disposal and Waste Management’. It requires treaty states to remove all plastic from Antarctica, with the only exception 100 being those plastics that can be incinerated without producing harmful emissions 101 (Antarctic Treaty Secretariat, 1998). However, once plastics are broken down into small 102 fractions and dispersed throughout the continent and nearby waters, management 103 measures become very difficult to address, as indicated by our data. Sander et al. (2009) also report ongoing pollution from research debris, which had not been removed. A more rigorous management of macro- and microplastics is therefore essential for preserving the integrity of sensitive polar environments.”

In the Arctic, I also found evidence of increasing research vessel activities correlated to

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increasing litter on the seafloor (Bergmann, M., Klages, M., 2012. Increase of litter at the Arctic deep-sea observatory HAUSGARTEN. *Marine Pollution Bulletin* 64, 2734–2741).“ e.g. Lenihan, H.S., Oliver, J.S., Oakden, J.M., Stephenson, M.D., 1990. Intense and localized benthic marine pollution around McMurdo Station, Antarctica. *Marine Pollution Bulletin* 21, 422-430.

-In the discussion, you could discuss that Polystyrene particles, which you detected, have been shown to affect Antarctic biota, e.g. sea urchin *Sterechinus neumayeri* (Bergami, E., Krupinski Emerenciano, A., González-Aravena, M., Cárdenas, C.A., Hernández, P., Silva, J.R.M.C., Corsi, I., 2019. Polystyrene nanoparticles affect the innate immune system of the Antarctic sea urchin *Sterechinus neumayeri*. *Polar Biology* 42, 743-757.). Nanoplastic also affect Antarctic krill: Bergami, E., Manno, C., Cappello, S., Vannuccini, M.L., Corsi, I., 2020. Nanoplastics affect moulting and faecal pellet sinking in Antarctic krill (*Euphausia superba*) juveniles. *Environment International* 143, 105999.

Figure 2 / Data analysis

-Please indicate if the data presented are from the Time-0 or the deposition experiment. 2A: I would be more interested to see the size frequency of all microplastics, not necessarily ordered by polymer type or width/length. I would either rely on the widest dimension only (as do many MP researchers) or calculate the surface area of particles (width x length = area) and present a size frequency of this surface area. The first suggestion may produce data that are more comparable with those of other researchers, though. You can still provide a supplement where length and width are presented. In addition, you could test for significant differences between sizes of particles from the two lakes. Maybe the more distant lake harbours smaller particles as the larger items are not transported over longer distances?

-2B: You should present the means per m2 and give error bars in B as well, pertaining to Stdev, SEM or another metric of data dispersion. These numbers are meaningless

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without an area reference. You have 6 replicates if I did not misread the methods, so error bars should be possible. Please present all numbers in the whole text as means plus/minus SEM or similar in m<sup>-2</sup>.

-In addition, I strongly suggest carrying out t-test or similar on the number of microplastics recorded from the two lakes to test your assumption that the closer proximity to the research base caused a greater MP load on one lake. The abundances look similar to me, actually, as is. You could also test for significant differences in the polymer composition between the two lakes using multivariate data analyses such as PERMANOVA or ANOSIM (e.g. in PRIMER-e or r)

-Please do the same test for the experiment. Also, please provide a graph to show the temporal trend in mean plastic abundance per m<sup>2</sup> over the 48-h period in addition to data given the table (which could go into the supplement)

Table 1 -Please provide only data on confirmed plastic in this table and get rid of the column 'Total Plastics confirmed by FTIR', otherwise it is confusing to the reader. You can show other particles in a supplementary. -How come some abundances are negative or positive?! -Please define: what is 'U' or replace by Plot 1, 2, . . . , 6, . . . , 12 -Please convert and present all data as per m<sup>2</sup> or write in legend that data are presented as m<sup>-2</sup>. -Underneath the polymer types add a row with 'Total plastic'

References:

-Please replace Bergmann et al. 2017 by this article, which deals with MP in snow, which you refer to in you MS, instead of sediments: Bergmann, M., Mützel, S., Primpke, S., Tekman, M.B., Trachsel, J., Gerdtz, G., 2019. White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. *Science Advances* 5, eaax1157.

-There are quite a few references missing pertaining to (small) plastic pollution in Antarctica. I have highlighted where these should be added in the MS.

Barnes, D.K.A., Walters, A., Goncalves, L., 2010. Macroplastics at sea around Antarc-

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tica. *Marine Environmental Research* 70, 250-252.

Cabrera, M., Valencia, B.G., Lucas-Solis, O., Calero, J.L., Maisincho, L., Conicelli, B., Massaine Moulatlet, G., and Capparelli, M.V. (2020). A new method for microplastic sampling and isolation in mountain glaciers: A case study of one artisanal glacier, Ecuadorian Andes. *Case Studies in Chemical and Environmental Engineering* 2, 100051. <https://doi.org/10.1016/j.csee.2020.100051>

Convey, P., Barnes, D., Morton, A., 2002. Debris accumulation on oceanic island shores of the Scotia Arc, Antarctica. *Polar Biology* 25, 612-617.

Cunningham, E.M., Ehlers, S.M., Dick, J.T.A., Sigwart, J.D., Linse, K., Dick, J.J., Kiriakoulakis, K., 2020. High Abundances of Microplastic Pollution in Deep-Sea Sediments: Evidence from Antarctica and the Southern Ocean. *Environmental Science & Technology*.

Creet, S., Van Franeker, J.A., Van Spanje, T.M., Wolff, W.J., 1994. Diet of the Pintado Petrel Daption Capense at King George Island, Antarctica, 1990/91. *Marine Ornithology* 22, 221-229. Dayton, P.K., Robilliard, G.A., 1971. Implications of pollution to the McMurdo Sound benthos. *Antarctic Journal*, 53-56.

Fijn, R.C., Franeker, J.A., Trathan, P.N., 2012. Dietary variation in chick-feeding and self-provisioning Cape Petrel Daption capense and Snow Petrel Pagodroma nivea at Signy Island, South Orkney Islands, Antarctica. *Marine Ornithology* 40, 81-87.

Geilfus, N.X., Munson, K.M., Sousa, J., Germanov, Y., Bhugaloo, S., Babb, D., and Wang, F. (2019). Distribution and impacts of microplastic incorporation within sea ice. *Marine Pollution Bulletin* 145, 463-473.

Huntington, A., Corcoran, P.L., Jantunen, L., Thaysen, C., Bernstein, S., Stern, G.A., Rochman, C.M., 2020. A first assessment of microplastics and other anthropogenic particles in Hudson Bay and the surrounding eastern Canadian Arctic waters of Nunavut. *FACETS* 5, 432-454.

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Ibañez, A.E., Morales, L.M., Torres, D.S., Borghello, P., Haidr, N.S., Montalti, D., 2020. Plastic ingestion risk is related to the anthropogenic activity and breeding stage in an Antarctic top predator seabird species. *Marine Pollution Bulletin* 157, 111351.

Isobe, A., Uchiyama-Matsumoto, K., Uchida, K., Tokai, T., 2017. Microplastics in the Southern Ocean. *Marine Pollution Bulletin* 114, 623-626. Le Guen, C., Suaria, G., Sherley, R.B., Ryan, P.G., Aliani, S., Boehme, L., Brierley, A.S., 2020. Microplastic study reveals the presence of natural and synthetic fibres in the diet of King Penguins (*Aptenodytes patagonicus*) foraging from South Georgia. *Environment International* 134, 105303. Lacerda, A.L.d.F., Rodrigues, L.d.S., van Sebille, E., Rodrigues, F.L., Ribeiro, L., Secchi, E.R., Kessler, F., Proietti, M.C., 2019. Plastics in sea surface waters around the Antarctic Peninsula. *Scientific Reports* 9, 3977. Laganà, P., Caruso, G., Corsi, I., Bergami, E., Venuti, V., Majolino, D., La Ferla, R., Azzaro, M., Cappello, S., 2019. Do plastics serve as a possible vector for the spread of antibiotic resistance? First insights from bacteria associated to a polystyrene piece from King George Island (Antarctica). *International Journal of Hygiene and Environmental Health* 222, 89-100. Sander, M., Costa, E.S., Balbao, T.C., Carneiro, A.P.B., Santos, C.R., 2009. Debris recorded in ice free areas of an Antarctic Specially Managed Area (ASMA): Admiralty Bay, King Georgia Island, Antarctic Peninsula. *Neotropical Biology and Conservation* 4, 36-39.

Suaría, G., Perold, V., Lee, J.R., Lebouard, F., Aliani, S., Ryan, P.G., 2020. Floating macro- and microplastics around the Southern Ocean: Results from the Antarctic Circumnavigation Expedition. *Environment International* 136, 105494.

Please also note the supplement to this comment:

<https://tc.copernicus.org/preprints/tc-2020-261/tc-2020-261-RC4-supplement.pdf>

Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2020-261>, 2020.

C9

Review report on "Atmospheric dry deposition of microplastics and mesoplastics in an Antarctic glacier: The case of the expanded polystyrene."

#### 1. General points:

I recommend publication of this interesting MS in the journal *Cryosphere* since it is based on rare data from a remote area (Antarctica). In addition, it covers atmospheric microplastic pollution, an emerging issue that we do not know so much about until now. I also like the fact that larger plastic, mesoplastic, is addressed, for which we don't have so much data, especially in terms of atmospheric MP pollution.

However, there are a few concerns that have to be tackled before this can be published in my opinion. Since you deal with microplastic, please provide a few lines on how you dealt with contamination (e.g. from yourself). Did you do take a control? If you did not, this should at least be critically be discussed. The standard in microplastic research is nowadays to take blanks and give details on contamination prevention. Both of which is currently not mentioned at all. Based on this many reviewers would (rightly) reject the MS. However, since it is from such a remote place and deals with large micro- and mesoplastic, I think it merits publication. Still, this drawback needs to be communicated clearly.

Please, make goals of this research clearer by formulating hypotheses or research questions: why you studied the two lake glaciers (e.g. both effect of distance to human plastic source). In addition, I strongly recommend that you then test your hypothesis on the data that you collected in both the sampling and experiment via statistical testing of abundance and polymer composition.

Please add another graph, which shows the temporal trend over the 48-h experiment. Now this is hardly mentioned at all in the MS, which is a shame given all the work done. Please, also describe the trend in a separate section in results and consider statistical testing.

Please, present all data as per m<sup>2</sup>, refrain from using numbers without a unit, which are meaningless.

#### 2. Specific points

##### Abstract

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##### Introduction

L. 62: "The concentration of MP in snow is generally higher (0 to 1.5 x 10<sup>5</sup> MP L<sup>-1</sup> of melted snow) near urban areas (Bergmann et al., 2019), than in sea ice (up to 12000 MP L<sup>-1</sup> of melted ice), although there are large differences between studies even from the same region (Peeken et al., 2018; Von Hesse et al., 2020)".

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Fig. 1. Referee's report

1 **Brief communication:**  
2 **Atmospheric dry deposition of microplastics and mesoplastics in an**  
3 **Antarctic glacier: The case of the expanded polystyrene.**  
4  
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26  
27 **Abstract**  
28 Plastics have been found in marine water and sediments, sea ice, marine invertebrates,  
29 and penguins in Antarctica, ~~generally~~ there is increasing evidence of their presence in Antarctic  
30 glaciers. Our pilot study investigated plastic occurrence on two ice surfaces that constitute part of  
31 the ablation zone of Caldes Glacier (King George Island, Antarctica).  
32 Our results showed concentrations of expanded polystyrene (EPS) in the 0.17-0.33 items m<sup>-2</sup> range.  
33 We registered an atmospheric dry deposition between 0.08 and 0.17 items m<sup>-2</sup> day<sup>-1</sup> (February  
34 2019). This is the first report of plastic ~~equivalent in Antarctic~~ glaciers.  
35 glaciers, to which it was probably transported by wind, possibly from local research activities.  
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Fig. 2. Annotated changes in provided document