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The Cryosphere Discussions

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.

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Thank you very much for your comments, and the opportunity to discuss our study with you. As you know, brief communications have a maximum of 3 figures and/or tables, a maximum of 20 references, a maximum of 4 pages, and no supplementary material; therefore, the space is very limited. For this reason, we have changed the article category to a research article, and we have included additional information to further clarify your comments.

Regarding the sample contamination, all the materials used (metal, steel and glass) were previously cleaned with MilliQ water, wrapped in aluminum foil and heated up to 300 °C for 4 hours in order to remove all possible rests of organic matter. The use of any plastic material was avoided. Furthermore, possible contamination due to clothing was controlled throughout the whole process by comparing clothes fibres and fragments with our samples. Moreover, it should be noted that the types of plastics found in our study are not typically associated with clothing, or any of our sampling tools. In fact, some of them (e.g. EPS) are not even allowed in the scientific bases and were not part of any of our sampling gear. Given their size, plastics found in this study were detected by the naked eye and their traceability was easily maintained during quantification and identification of the samples. We have incorporated this in our manuscript, as follows (lines: 153 -161): "2.5 Prevention of procedural contamination. To avoid sample contamination, all materials used were previously cleaned with MilliQ water, wrapped in aluminum foil, and heated to 300 °C for 4 h to remove organic matter. The use of any plastic material during sampling was avoided. Furthermore, possible contamination from our clothes was controlled throughout the sampling, by checking fibers and fragments extracted from the clothes against the MPs and MePs found in the samples, and by positioning us against the wind during sampling. Given their size, plastics found in this study were detected by the naked eye and their traceability could be easily maintained during quantification and identification of the samples."

About the hypothesis of our research. Given the fact that plastics have already been found in other parts of the cryosphere (alpine glaciers, snow and sea ice) and in Antarctica (seawater, freshwater, sediments and organisms), our research question was: could plastic be found on Antarctic glaciers? and, does dry deposition (i.e. by wind) play a role in its transport from areas with human activities?. Following these research questions, the hypothesis in our original manuscript was "Our hypothesis is that plastics have also reached freshwater glaciers in Antarctica and that the dry deposition could be playing a crucial role in this process". To assess this, we chose two ice surfaces areas (an area around Uruguay lake and another around Ionosferico

lake) that constitute part of the ablation zone of Collins Glacier (King George Island, Antarctica). The reason for this choice is that we could easily access from BCAA to both areas on foot as often as the experiment required. Uruguay lake is located ∼300 m from Antarctic Scientific Base and Ionosferico lake is located ∼600 m from Artigas Base (see section 2.1 in material and methods). These relative differences in human pressure and distance from Artigas Beach could be evaluated in future studies to test the effect of distance to human plastic source in their atmospheric dry deposition of plastics in Antarctica. However, our goal in this pilot study was not to test this. In fact, plastics collected in our study are not enough to perform a robust statistical test in order to test this. Furthermore, we believe that other factors such as topography and a more detailed sampling gradient would have been necessary if that was our goal. Therefore, we have written: "So far, plastics have been found in specific parts of the cryosphere (mountain glacier, snow, and sea ice) and Antarctica (seawater, freshwater, sediments, and organisms). We hypothesize that plastics have also reached freshwater glaciers in Antarctica and that atmospheric dry deposition plays a crucial role in this process. To test this hypothesis, we carried out a pilot study to investigate the presence of plastics on two ice surfaces (one area close to Uruguay lake and another one close to Ionosferico lake) that constitute part of the ablation zone of Collins Glacier in Maxwell Bay in King George Island (Antarctica). Furthermore, the daily changes in the presence of plastics in these ice surfaces was evaluated in the absence of rainfall, to clarify the role of wind in their transport."

According your request, we have added another graph showing the temporal trend over the 48 hours in each squares of both ice surface (an area around Uruguay lake and another around Ionosferico lake) that constitute part of the ablation zone of Collins Glacier in Maxwell Bay in King George Island (Antarctica).

Figure 3. Changes in the presence of plastics into the squares marked on ice surface close to Uruguay lake (A) and close to Ionosferico lake (B) that constitute part of the ablation zone of Collins Glacier in Maxwell Bay in King George Island (Antarctica).

Plastics were monitored every 12 hours for two days (18/2/2020 and 20/2/2020) in the absence of rainfall. Asterisks indicate squares different from those used to the assessment of plastic concentration.

Following your request, we have structured the MS including in the results and material and methods new subtitles.

Besides, we agree with the reviewer about the importance of showing data as per m2. In this sense, all data have been also presented as plastics per m2 throughout the MS (. In fact, we have included two tables to clarify the results of both experiments (the assessment of plastic concentration and the assessment of atmospheric dry deposition of plastics). Furthermore, we considered relevant to include the total number of items identify as plastics with respect the total items collected as well as their characterization (see section 3.1 Characterization and identification of the plastics) in order to show the importance of the item identification using appropriate techniques (e.g. FTIR, RAMAN, HPLC-MS/MS).

Table S1. Characteristics of plastics found into the squares used for the assessment of plastic concentration on ice surface close to Uruguay lake and close to Ionosferico lake that constitute part of the ablation zone of Collins Glacier in Maxwell Bay in King George Island (Antarctica).

Area ID Square Polymer Color Size 1 (μm) Size 2 (μm) Type Uruguay 1 EPS White 4100 4022 Microplastic Uruguay 1 Polyester Red 4822 2544 Microplastic Uruguay 2 Polyester Red 6662 3747 Macroplastic Uruguay 3 not detected - - - - Uruguay 4 not detected - - - - Uruguay 5 EPS White 12628 11334 Macroplastic Uruguay 6 not detected - - - - Uruguay 7 not detected - - - - Uruguay 8 not detected - - - - Uruguay 9 not detected - - - - Uruguay 10 not detected - - - - Uruguay 11 not detected - - - - Uruguay 12 Polyester Red 2292 1356 Microplastic Uruguay Mean 0.17 EPS/m2 and 0.25 Polyester/m2 Ionosferico 1 EPS White 7583 5591 Macroplastic Ionosferico 2 not detected - - - - Ionosferico 3 not detected - - - - Ionosferico 4 not detected - - - - Ionos-

ferico 5 EPS White 3817 3318 Microplastic Ionosferico 6 not detected - - - - Ionosferico Mean 0.33 EPS/m2

Table S2. Characteristics of plastics found at the end of the experiment into the squares used for the assessment of atmospheric dry deposition of plastics on ice surfaces that constitute part of the ablation zone of Collins Glacier (King George Island, Antarctica).

Area ID Square Polymer Color Size 1 (μm) Size 2 (μm) Type Uruguay 1 EPS White 4100 4022 Microplastic Uruguay 1 Polyester Red 4822 2544 Microplastic Uruguay 2* Polyurethane Brown > 5000 > 5000 Macroplastic Uruguay 3* EPS White 9301 8265 Macroplastic Uruguay 4* Polyester Red 6989 6834 Macroplastic Uruguay 4* Polyester Red 6168 5891 Macroplastic Uruguay 4* Polyester Red 5909 501 Macroplastic Uruguay 4* Polyester White > 5000 > 5000 Macroplastic Uruguay 5 EPS White 12628 11334 Macroplastic Uruguay 6* EPS White 9720 7963 Macroplastic Uruguay 6* EPS White 6292 5567 Macroplastic Uruguay 6* EPS White 9192 9023 Macroplastic Uruguay 6* EPS White 5595 4574 Macroplastic Uruguay 6* EPS White 7847 3640 Macroplastic Ionosferico 1 EPS White 7583 5591 Macroplastic Ionosferico 2* EPS White 6437 5220 Macroplastic Ionosferico 2* EPS White 10932 7572 Macroplastic Ionosferico 2* EPS White 5278 4726 Macroplastic Ionosferico 2* EPS White 9363 9186 Macroplastic Ionosferico 3* EPS White 9209 7932 Macroplastic Ionosferico 3* EPS White 7946 3834 Macroplastic Ionosferico 3* EPS White 13155 7925 Macroplastic Ionosferico 4* EPS White 7007 6905 Macroplastic Ionosferico 4* EPS White 7094 5112 Macroplastic Ionosferico 4* EPS White 16737 16085 Macroplastic Ionosferico 5 EPS White 3817 3318 Microplastic Ionosferico 6* EPS White 11576 11105 Macroplastic

Asterisks indicate squares different from those used for the assessment of plastic concentration.

It should be noted that in our new version of the manuscript we have also added more information and further discussed the role of wind intensity and direction in the area, in

order to give more insight into the possible influence of this environmental variable.

Specific points Line 31 (lines: 29 - 41): Thank you for your comment, we have included the most important data in the abstract: “Plastics have been found in several compartments in Antarctica. However, there is currently no evidence of their presence in Antarctic glaciers. Our pilot study investigated plastic occurrence on two ice surfaces (one area close to Uruguay lake and another one close to Ionosferico lake) that constitute part of the ablation zone of Collins Glacier (King George Island, Antarctica). Our results showed that expanded polystyrene (EPS) was ubiquitous ranging from 0.17 to 0.33 items m-2 whereas polyester was found only on the ice surface close to Uruguay lake (0.25 items m-2). Furthermore, we evaluated the daily changes in the presence of plastics in these areas in the absence of rainfall to clarify the role of the wind in their transport. We registered an atmospheric dry deposition rate between 0.08 items m-2 day-1 on the ice surface close to Uruguay lake and 0.17 items m-2 day-1 on the ice surface close to Ionosferico lake. Our pilot study is the first report of plastic pollution presence in an Antarctic glacier, possibly originated from local current and past activities, and the first to assess the effect of wind in its transport.”

Line 60: We have written (lines: 60 – 65): “The occurrence of MPs in snow ranged from 0 to 1.5 x 105 MP L-1 of melted snow (Bergmann et al., 2019), although it should be noted that a part of this study was conducted near urban areas. Regarding sea ice, concentrations of up to 1.2 x 104 MP L-1 have been reported, although there are large differences between studies even from the same region (Peeken et al., 2018; von Friesen et al., 2020).”

Line 65: Ambrosini et al 2019 reported the occurrence of plastics as “items kg$-$1 of sediment (dry weight)”. Checking section 2.2. Sample collection of their article we found the following description: “collected two cryoconite samples and four samples of sparse and fine (<2âĂŕmm) supraglacial debris from the ablation area of Forni Glacier”. We have modified our manuscript to reflect this as: We have written (lines: 66 – 67): “[. . .] of ice weight (78.3 $\pm$ 30.2 MPs Kg-1 of sparse and fine supraglacial debris; Am-

brosini et al., 2019) and mass [. . .]" instead of "[. . .] of sediment weight (78.3 $\pm$ 30.2 MPs Kg-1 of sediments; Ambrosini et al., 2019) and mass [. . .]"

Line 73: We have written: "The differences between these studies may be due to the different analytical methods used, particularly methodologies such as micro Fourier transform infrared spectroscopy (μFTIR, which can identify smaller sized MPs)."

Line 74: We have written (line 76 – 79): "In general, the presence of plastics > 5mm are not reported in discrete parts of the cryosphere, probably because they occur at lower concentrations and therefore often evade our detection" inside of "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."

Line 96: Please, see lines: 94 -103.

In general, we excluded fibers from our study, since they were non detectable with the naked eye, and would have required ice extraction, melting and posterior water analysis, impacting our sampling strategy (i.e ice extraction from sampling squares). We have now added this information in the materials and methods section 2.2 (lines: 127 - 130): "It should be noted that our sampling strategy excluded the plastics non-detectable by the naked eye (i.e. small plastics such as fibers). Thus, we probably underestimated the concentration of small plastics on the ice surface."

Regarding the distance of each lake to the Artigas Scientific Base, we have now added this information in the new version of the manuscript (lines: 112 – 115).

Figure S. Distance between Artigas Scientific base and Ionosferico lake $\sim$600 m (A). Distance between Artigas station and Uruguay lake $\sim$300 m (B).

Line 104: Following your request, we have modified geographical positions as follows: "(S 62° 11' 6.54", O 58° 54' 42.23")" and "(62° 11' 59.41", O 58° 57' 44.17")"

According our request, we have added a paragraph on data analysis (see section 2.4)

Following your request, we have structured the MS including in the results and material and methods new subtitles.

Line 145-157: To clarify , we have added Figure 3 and a new Table S2 showing the temporal trend over the 48 hours in each squares of both ice surface (an area around Uruguay lake and another around Ionosferico lake) that constitute part of the ablation zone of Collins Glacier in Maxwell Bay in King George Island (Antarctica).

Lines 182: Following your request, we have compared our results in m-2 with the papers that we cited (lines: 251 -262)

Line 184: We have deleted this.

Line 187: These relative differences in human pressure and distance from Artigas Beach could be evaluated in future studies to test the effect of distance to human plastic source in their atmospheric dry deposition of plastics in Antarctica. However, our goal in this pilot study was not to test this. In fact, plastics collected in our study are not enough to perform a robust statistical test to test this.

Line 190: We have incorporated this in our manuscript (see discussion). Line 193: Here, we have mentioned: "Our results show that the atmospheric deposition of plastics on glaciers is very low being between two and four orders of magnitude lower than what is generally found in the rest of the continents (Dris et al. 2016; Cai et al 2017; Klein and Fischer, 2019; Brahney et al 2020). This could be due to the fact that we have used a different methodology that those used in previous studies and that probably underestimated the concentration of plastics, especially small fractions. Nevertheless, further research is necessary to elucidate the distribution, sources, pathways and trajectories, and impacts on this ecosystem of the plastics".

Line 195: We have modified our discussion

Figure 2 and Table 1: To clarify , we have added a new Figure 3 and a new Table S2 showing the temporal trend over the 48 hours in each squares of both ice surface (an

area around Uruguay lake and another around Ionosferico lake) that constitute part of the ablation zone of Collins Glacier in Max

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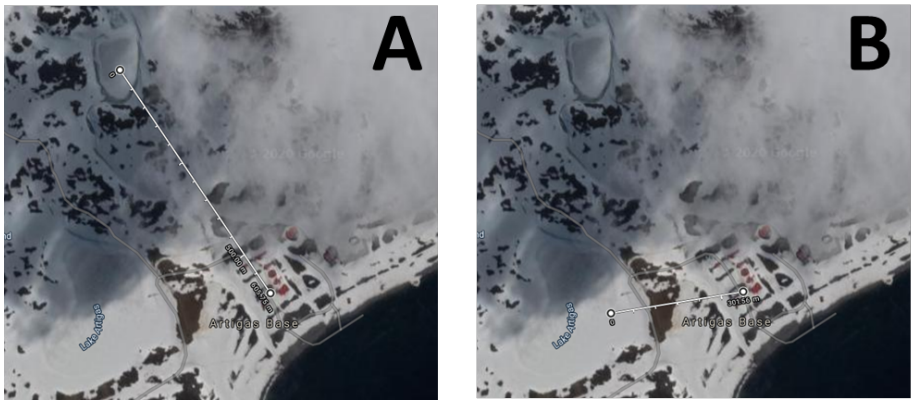

Fig. 1.

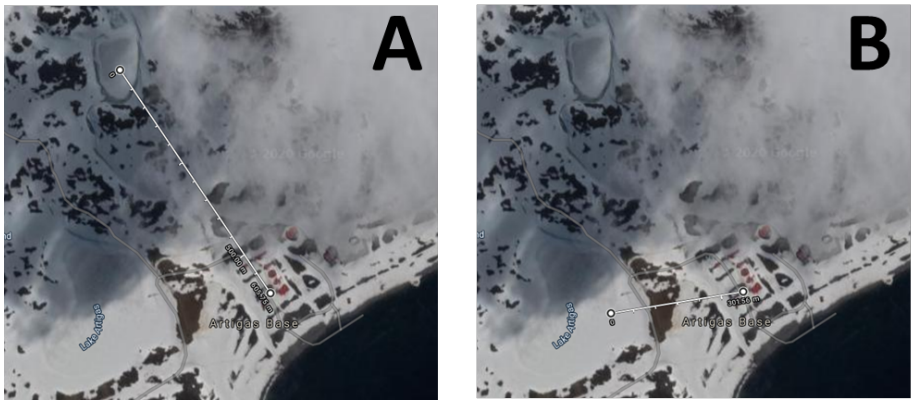

Fig. 2.