Point by point response to reviewers for

Ms. Ref. No. essd-2022-140

Title: Hyperspectral reflectance dataset of pristine, weathered and biofouled plastics

Reviewer Hu, Chuanmin:

Comment 1.1 This is a great effort toward remote sensing of marine plastics. The remote sensing capability heavily relies on our understanding of the spectral characteristics of various forms of plastics, and this dataset should be useful for algorithm development.

> **Response:** We thank the reviewer for their kind words.

Comment 1.2 However, I feel that both the experimental settings and end results are poorly described, and I ended up with more questions than answers after I read through the descriptions. I understand it's impossible to present all measured spectra, but to a minimum, some representative spectra of plastic speciemen A, B, C… in their dry, weathered, and submerged conditions should be presented and discussed. In particular, after several recent publications reporting similar datasets of macroplastics, how do these new results compare with those existing? What new information do we gain? Without the knowledge of why they agree or disagree on the same type of plastics, I sense that all we can get are some additional data, but our understanding of plastics reflectance may get worse.

> **Response:** We understand the reviewer's comment and agree that to broaden our understanding of plastic reflectance, it is crucial not only to collect the data but also to give interpretation and discussion on what those data mean. However, the presented manuscript is intended to be a data description paper. Therefore, the aim of drawing conclusions from the presented data is outside of the scope of this work. In fact, as mentioned in the Earth System Science Data (ESSD) guidelines for manuscript types: The "interpretations of data – i.e., detailed analysis as an author might report in a research article – remain outside the scope of this data journal". However, as we fully agree with the reviewer, to provide some examples to the reader illustrating the representativeness of the acquired spectra, we have, we have added in the supplementary material two graphs as examples of pristine, weathered and biofouled plastics. In addition, in the main text we have added a short explanation stating 'From the presented dataset it is possible to visually see the spectral reflectance of different plastic polymers and compare the different conditions experimentally tested (Fig 1S; Fig 2S). For instance, it is possible to derive the effect of weathering and biofouling on the spectral reflectance of a polymer when compared with the same pristine one' (see lines 217-220). Besides the complementary value of the presented dataset, we have two novel assessed parameters when compared to other recent publications (Knaeps et al.,2020, Garaba & Dierssen, 2020 and Garaba & Dierssen, 2018): 1) the artificially weathered and 2) biofouled plastics for which the spectral reflectance was measured.

Comment 1.3 Line 43 – 48: “To date, only a limited number of high-quality datasets consisting of hyperspectral measurements of wet and submerged plastic litter, have been published in open-access repositories (e.g., Garaba and Dierssen, 2019, Garaba and Dierssen, 2020; Knaeps et al., 2021). The dataset described in the current paper aims at complementing the existing datasets by adding new information about the hyperspectral reflectance of pristine plastic items, harvested plastic litter, and artificially weathered and biofouled plastic samples”. This is certainly a good motivation. However, how do these additional data compare, contrast, and complement the existing data? Does this paper measure the same plastic materials (e.g., A, B, C) but measured under different dry/wet or marine conditions? Or does this paper measure different plastic materials (e.g., D, E, F instead of the existing A, B, C) under the same conditions as in the current literature? How do the new spectra compare with the existing spectra? If there is difference, what’s the reason?

> **Response:** The reviewer raised an important concern, and we have now clarified comparability of the acquired data in the main text (Table 1). To make the distinction of which measurements are novel in this study compared to what has been previously published we have added a new Table 1 (line 91) and text stating ‘Table 1 provides an overview of measured plastic types within this study and compared to existing datasets. This dataset adds additional information of plastic spectral reflectance of similar polymers to what is already available in the literature, allowing comparison, but also novel conditions and treatments (Table 1).’ (Lines 86-89). The plastic measured in this study are covering similar ranges of plastic polymers as previous publications such as Garaba et al., 2021 or Knaeps et al., 2020. Even though some of the conditions of the plastics measured in this study are, as for Garaba et al., 2021 or Knaeps et al., 2020, pristine and environmental samples in dry and wet or submerged conditions, we have the addition of artificially weathered and biofouled samples also measured in turbid waters with algae. The artificially weathered and biofouled plastics are an added value to this dataset compared to previous publications. In fact, the measurements of the same plastic when being (i) pristine, (ii) biofouled, and (iii) weathered allows addressing the impact of each specific condition on the spectral reflectance of the plastic when compared with the pristine polymer. Real environmental samples were also included to understand if artificially weathered and biofouled plastics are similar or comparable to weathering and biofouling in natural conditions. Since plastics are extremely diverse there is a need to generate a large database with multiple plastic polymers/types under different experimental and natural conditions.

Comment 1.4 Line 53 – 54. Not really, unless ALL possible scenarios in natural conditions are considered and measured here. Presenting certain examples of reflectance under different depths or under different algae or sediment concentration doesn’t mean much, because this is already known based on radiative transfer principles. What is more useful is to perform a numerical simulation to see whether the measured reflectance can be reproduced. If the answer is yes, then reflectance under different measurement scenarios can simply be generated using simulations without involving more experimental settings.

> **Response:** The reviewer has raised an interesting topic. We recognize that not all possible scenarios are and can be checked with the experimental measurements performed in our study. The acquired data can however contribute to the understanding of the spectral reflectance of plastics in real conditions and for numerical simulations (to

verify data reproducibility). Radiative transfer simulations could potentially not cover the entire environmental plastic complexity. Furthermore, weathering and biofouling are hard to simulate. However, we acknowledge this good suggestion from the reviewer, i.e., to compare the spectra with numerical simulations in a future study. In the revised version of the manuscript, we have added this topic in the text by mentioning: 'As plastics in our environment are so diverse in polymer type, colour, transparency, thickness, state (pristine, bio fouled, weathered, wrinkled) and wetness (dry, wet, submerged), it is critical to generate, within the scientific community, substantiated data sets which represents plastics in many different facets. The collected spectra can serve as reference or endmember spectra in future Remote Sensing plastic detection techniques and help to understand the complexity of plastic detection through spectral analysis. It is recognized that not all possible scenarios can be measured in an experimental way, therefore the dataset can further be used to compare with and complement numerical simulations' (lines 45-52).

Comment 1.5 Line 54 – 56. This is great – at least the community can use this data for a variety of purposes.

Response: We thank the reviewer for the kind comment.

Comment 1.6 Section 2.1. How do these 6 types of polymers compare with those of Garaba, Knaeps, and their coworkers?

Response: This is a pertinent suggestion, which we have also addressed above in comment 1.3. The plastic specimens used in this study cover different polymer types and conditions of plastics. The experiments performed by Knaeps et al., 2020 were pristine and environmental plastics. The plastics used by Garaba & Dierssen 2018 and Garaba 2021 were also pristine plastic and marine plastic washed ashore. The novelty of the samples used in this study is that we tested not only environmental plastics or pristine plastics as Knaeps, Garaba, and colleagues did, but we also artificially weathered or biofouled plastics for which all the conditions were controlled. To better visualize the comparison and added value of the presented dataset we have included Table 1 (line 91) to the manuscript. This table shows the comparison of polymers and conditions in which these polymers are tested (e.g., dry, wet) between the presented dataset and the literature.

Comment 1.7 Table 1. It's good to include photos, but all photos have poor quality. The first 5 photos actually show nothing except some blurred features. The rest of the photos are also very vague. They all need to be improved in quality, and a length scale bar is needed for every photo. For a bright target, a dark background is required to show the appearance of the target.

Response: This is a very relevant concern. The first 5 photos on the table represent the pristine plastics used during the experiments. In the original version of the manuscript, with those images, we intended to illustrate if the plastics are opaque or translucent. The

'blur' is because the reader can actually see the background behind the plastic because of it being transparent and opaque. However, we understand that this might not be immediately clear. Therefore, we have retaken the first five pictures of the table. As for the plastic dimensions, within the table, the size of each plastic is reported in cm. There are a couple of items for which the size was not stated (e.g., plastic bag) because these are off-the-shelf items for which the dimensions are commonly known or are plastics coming from the environment (e.g., grey buoy, wrinkled bags) for which the complete dimensions are less relevant. Moreover, FOV of the instrument is small and only a small part of the sample is actually measured. Lastly, these pictures are useful to inform the reader on the weathering status of the used plastic items. For instance, it is possible to notice the discoloration from the weathering or how the biofilm looks like.

Comment 1.8 Some of the targets in Table 1 appear spatially heterogenous. With 1-degree or 8-degree FOV, the ASD fiber probe may only see a small facet of the target, and reflectance can be strongly dependent on the location of the facet. For example, for "Bag dog food", completely different spectra may result from the blue and yellow parts of the target. Then how are these spectra used as "endmembers" for remote sensing purpose where the footprint of a remote sensing pixel is way larger than the target itself?

Response: The reviewer is right to point out that some of the targets measured in this study are heterogeneous. This is because in our study, the goal was to provide an overview of the highly heterogeneous nature of plastics, and to go beyond the measurement of only homogeneous targets, as representative proxies of environmental plastic litter items. These spectra, combined with the other datasets in the literature, will provide us with a better overview of the variability of the plastic endmember. The very interesting question is whether it is possible to define one plastic endmember, as reflectance, particularly in the VNIR is highly variable, and research on plastic litter is still in its infancy. To clarify this topic with the readers, concerning the heterogeneity of plastic samples, we have highlighted this in the revised version of the manuscript (see lines 134-135).

Comment 1.9 Table 2. It's better to add a photo showing the experimental setting. Also, it's better to show the before/after comparison of the same samples. Finally, can these UV exposures really simulate the weathering process in nature, where plastic materials are in marine water under different chemical, physical, and biological conditions?

Response: Table 2 shows the reader the experimental settings used in the Sun chamber. As recommended by Gewert et al., 2018, performing experiments for the weathering process in a UV chamber such as the one we used in the experiments can mimic the solar exposure of plastic in the environment. We agree with the reviewer that UV exposures in laboratory settings might not mimic the exact conditions that might happen in the environment. However, UV light exposure causes degradation of plastic polymers, and this procedure allows comparability and reproducibility. To add some level of complexity and obtain results as close as possible to 'real-life conditions', we weathered the plastic under two treatments, with and without seawater. To clarify this point, we have adapted the text in the revised version of the manuscript (see lines 112-114). These experiments

are crucial to unraveling the spectral reflectance of plastics when weathering because it is possible to control the conditions in which each plastic is weathered. By only measuring the spectral reflectance of plastics collected from the environment we might not really know under which condition that particular object has been and, therefore, what the measured reflectance means. We believe that experiments with biofilm and artificial weathering of plastics are crucial to better understand how these conditions can modify the reflectance of plastics. As for a comparison of before and after of the same polymer is shown in the imaged of Table 1S, now in the supplementary material.

Reference: Gewert, B., Plassmann, M., Sandblom, O., and Macleod, M.: Identi fi cation of Chain Scission Products Released to Water by Plastic Exposed to Ultraviolet Light, https://doi.org/10.1021/acs.estlett.8b00119, 2018.

Comment 1.10 Figure 1. Please annotate each part of the photo – which is what. Also, it's better to show a before/after photo comparison of the same specimen.

Response: We agree with the reviewer, and we have now annotated, in the revised version of the manuscript, each part of the photo. In Table S1 we have provided images of the pristine polymer items and of weathered or biofouled polymers for comparison.

Comment 1.11 Figure 2. See comment above about spatial heterogeneity.

Response: In Figure 2 we illustrate the type of environmental plastics. As explained in comment 1.10, the plastic collected from the field is not spatially homogeneous and the figure intends to show this. To clarify the message, we have now deleted this image, and provided an additional explanation on the heterogeneity of plastics in the text: 'and are naturally exposed to weathering and biofouling and are, compare to pristine polymers, non-homogeneous' (see lines 134-135).

Comment 1.12 Section 3. Where is the experimental setting (i.e., how is the sample illuminated, how far is the fiber optic probe, does the lamp produce collimated beam, etc)? What's the footprint size of the fiber optic probe under the experimental setting, and does the footprint fall on different colors of the same plastic target? A photo or at least an illustration chart is required, including the illumination, ASD probe, water tank, placement of the plastic target, and placement of the 99% reference.

Response: The explanation of the experimental set-up is quite an important topic and is available in section 3. To illustrate the lab and silo set-up, we have now added a new figure as Figure 2 (lines 160-161). This figure illustrates the lamp, the ASD probe, and the placement of the plastic samples. To answer the question 'does the footprint fall on different colors of the same plastic target' we used a laser pen attached to the ASD pistol grip, which allowed us to know exactly where the ASD was measuring the sample and we have now included the explanation in the revised version of the manuscript stating: 'In both laboratory and silo tank set-ups (Fig. 2), we have attached a laser pen to the ASD

pistol grip to ensure that, at all times, the fibre optics of the ASD were pointing at the plastic samples.' (lines 157-159). Finally, the footprint of the fiber optic was calculated during the experimental design by measuring the distance of the sample to the FOV and the type of FOV used (i.e., 8 degrees, 1 degree).

Comment 1.13 Figure 3. Does the splice correction simply lower the reflectance < 1000 nm to remove the spike? Then it doesn't appear correct because after the correction reflectance between 600 and 700 nm is 0 or even negative. How come plastic materials have near-0 reflectance?

Response: We have removed the figure and left the option of performing a spice correction to the reader via lines 221-222

Comment 1.14 Figure 3. What type of polypropylene is this? Please insert a photo. In Table 1, there are several "PP" photos with yellowish or whitish colors. Then why does this reflectance show a spike around 540 nm (greenish)?

Response: We agree with the reviewer have now clarified this issue. As stated in the citation, the PP is from environmental plastic and the reason why there is a spike around 540 nm (green) is that the plastic is green. In fact, this is the spectra of a green buoy. However, following the previous comment (see comment 1.13), we have, in the revised version of the manuscript, removed the figure and kept the statement about the possibility of performing a spice correction in the main text.

Comment 1.15 Figure 4. What field sample? Those in Figure 2? There is no way all these replicates show the same spike around 540 nm from those plastic materials of Figure 2.

Response: We understand the comment raised by the reviewer who is right in mentioning that Figure 4 does not represent replicates of plastics depicted in Figure 2. As the reviewer raised an important concern, we have now clarified the figure by adding a picture representing the object from which the measurements were taken. We have also modified the caption accordingly: 'and figure of the object from which the spectra were obtained (a)' (see line 232). In addition, following the concerns of comment 1.14, in the revised version of the manuscript we present the graphs without splice correction. The spectral reflectance shown originally in Figure 4 were not replicates of different plastic items (e.g., coming from Figure 2), but pseudoreplicates. Therefore, as described in lines 70-71, they are the spectral reflectance of the same exact plastic item that has been slightly moved (a few millimeters) and for which the spectral reflectance has been measured. Since the plastic was from an environmental sample, therefore not homogenous, the spectral reflectance has been collected at a different point within the same item. Figure 4a, in the original version of the manuscript, represents the different pseudo-replicates of one plastic item. Since these measurements are coming from the same item the spike around 540 nm, as well as the other features, are very similar, but not the exact same because the plastic is

not completely homogenous. Figure 4b (in the original version of the manuscript) represents the spectrum created by calculating the mean of all the ten pseudoreplicates.

Reviewer #2:

Comment 2.1 This study is a thorough investigation of plastic examples under conditions which have been under-investigated in previous research. The conditions which each of the plastic samples were investigated under is well documented and described, and assists in studying plastics under conditions like they are found in after weathering and natural processes have taken their toll on them. That the data was released as open access in the same format as the referenced previous studies is progress towards a more complete picture of the spectral properties of plastic litter under differing physical and observational conditions.

Response: We thank the reviewer for these kind words, and we are hopeful that the presented dataset will be useful to depict a clearer picture of the spectral properties of plastic debris.

Comment 2.2 I feel that there are a few issues with how the setup to this experiment is presented in this paper, which makes it difficult to understand fully. There could also be more discussion of how the measurements made in this study compare to those from other studies given the additional conditions considered for this experiment. The studies referenced in the introduction (eg, Garaba et al., 2020) provide notes on how the plastic and measurement properties change the appearance of the spectra in each case. A similar approach could be employed here for the novel aspects of the measurements made in this study, for the case of the biofouling and the UV exposure spectra for each type of plastic. See the notes below for more detailed comments.

Response: We understand the comment posed by the reviewer and agree that a discussion on how the presented dataset compares with the existing literature as well as what results can be extracted by this dataset is crucial. For this reason, and to clarify the point raised by the reviewer, we have included in the revised version of the manuscript, Table 1, which aims at illustrating a comparison between the presented dataset and studies referenced in the introduction. However, as this manuscript is intended as a data description paper, we have explicitly avoided a detailed result section or interpretation of the dataset in this specific manuscript.

Comment 2.3 Line 64 – Data Collection – For the pseudo-replicates, how much are you moving the plastic samples each time in between each of the measurements? Looking at the samples chosen in Table 1, some of the spectra will more significantly change with a small movement, as stated, but for some of the food packaging items with prominent logos there will be a significant change as the sensor is over the logo/non-logo parts of the plastic.

Response: The question asked by the reviewer raises an important point. The samples were slightly moved in between each measurement of a few millimeters. It was not our intention to measure a label or a different color within the sample, but to capture the heterogeneity of a polymer. We do understand the point raised by the reviewer with

respect to the food packaging for instance, as these items might indeed have logos or different colors. This change was taken to obtain a more realistic overall reflectance (i.e., mean of the pseudoreplicates) of the environmentally or artificially weathered and biofouled polymer within the same portion of the sample.

Comment 2.4 Line 81 – Table 1 – The size of the table is substantial due to the image sizes. This table could be moved to an annex section to preserve the flow of the paper, or the types and conditions of plastics could be summarised into a more concise format with the images removed to keep the table as a summary of the plastics used.

Response: We agree with the reviewer; the size of the table is substantial. Therefore, in the revised version of the manuscript we have moved Table 1 from the original version of the manuscript into the supplementary material.

Comment 2.5 Line 81 – Table 1 – Some of the images are not too clear on the type of plastic they are showing. Specifically, the plastic sheets and pristine plastics look like white squares in the images. Whilst this is likely the case in person for these items, the picture does not add to the table in a meaningful way. A wider-angle image would provide some better context on the appearance of the piece of plastic being tested.

Response: This is a very relevant concern. To clarify we have retaken the pictures of the pristine plastic sheets.

Comment 2.6 Line 88 – Pristine Plastic specimens – The mention of additives here could form a point of analysis later in the paper, as the pristine plastics are compared to the non-pristine plastics. It is good that pristine plastics are provided alongside the packaging samples, but a follow-up description of how they are different would be good to include.

Response: We thank the reviewer for this relevant comment. The use and effect of additives in plastics and how they could modify plastics' optical features is indeed an interesting and important point of discussion. However, we intentionally did not include any discussion on the type of samples selected for the experiments, but merely describe them.

Comment 2.7 Line 98 – Weathered plastics – Good that UV weathering of plastic litter is being spectrally measured under lab conditions.

Response: We thank the reviewer for this comment and we agree that the use of reproducible methods to weather plastics are critical for comparability purposes.

Comment 2.8 Line 128 – Figure 2 – The image could more clearly show the selection of plastic collected. If the items were spread onto a flat surface and categorised by type then it would provide a clearer impression of what was collected during this survey collection.

> **Response:** The comment posed by the reviewer is extremely valid. It is true that if the items were spread onto a flat surface and categorized by type the Figure would provide a better overview. Because the overview of the samples is already present in Table 1S, this picture has been removed from the revised version of the manuscript.

Comment 2.9 Line 128 – Figure 2 - From the way the collection of plastic items is being referenced in the main body of text, the figure may not be necessary. Just mentioning that items were collected during 2020 from the Port of Antwerp would be enough, and the figure could be removed.

> **Response:** As mentioned in the comment above (comment 2.8), we agree with the reviewer. Figure 2 is indeed not necessary and has been removed from the revised version of the manuscript.

Comment 2.10 Line 143 – Experimental Setup – To accompany this description, a labelled diagram or clear labelled image of the experimental setup would be useful to visualise how all the components fit together.

> **Response:** We thank the reviewer for raising this concern. To clarify the experimental set-up, we have added a new Figure 2 (see lines 160-161) describing both experimental set-ups (i.e., tank and lab).

Comment 2.11 Line 200 – Data description – A comparison of this dataset with the datasets you referenced in the introduction would be beneficial to this paper, highlighting specifically in the spectral plot the differences from biofouling or UV degradation occur. Whilst presenting the dataset as an addition to the community is valuable, a discussion of initial findings from this dataset compared to contemporaries would improve it further, especially as the introduction references these alternative plastic and observation conditions as being the main motivation for collecting these measurements.

> **Response:** We thank the reviewer for this comment, which we fully understand. A comparison of this dataset to the work referenced in the introduction has been added to the revised version of the manuscript as Table 1. In addition, as a visual representation of how the spectral reflectance of artificially biofouled and weathered plastics look like in comparison with the same pristine polymer would indeed be beneficial to the paper, we have added two graphs in the supplementary material.

Comment 2.12 Line 218 – Figure 3 – The plots after the correction has been applied (right) show negative reflectance for the plastic in the < 700nm range. Is the correction applied to a larger range of data than just the discontinuity highlighted in the image on the left? This may need fixing if so.

> **Response:** We understand the concern raised by the reviewer and, as we agree, the plot with the splice correction is removed from the revised version of the manuscript. We have left the suggestion to the reader of using a splice correction.

Comment 2.13 Line 232 – Conclusions – Additional comparisons of how the unique features measured as part of this dataset contribute to the measured spectra against samples without those features would be good to include here, or in a separate discussion section. Specifically, the biofouling, UV, and sediment measurements provide opportunities to make observations on these effects.

> **Response:** We agree with the reviewer's suggestion, we have added two graphs (Fig 1S& Fig 2S) on the contribution of examples of spectral reflectance of UV and biofouled samples. As the description of the outcomes that can be generated by the described dataset is outside of the scope of this data journal, we have purposely not added interpretations or discussion.

Comment 2.14 Line 59 – Data collection – Grammar, “Data collection consisted in measuring…. “-> “Data collection consisted of measuring….”

Response: We thank the reviewer for bringing this issue to our attention. We have changed this in the revised version of the manuscript.

Comment 2.15 Line 157 – Silo tank setup – How the measurements of the tank are displayed (2 top diameter x 3 depth m) is not immediately clear by the way this is written. Diameter 2m, Depth 3m is clearer. This is another chance to include a setup diagram to supplement the description.

> **Response:** We agree with the reviewer; the way the measurements initially written were clear. Therefore, we have changed this in the revised version of the manuscript.

Comment 2.16 Line 209 – Data description – Typo, ensures -> ensure.

> **Response:** We thank the reviewer and corrected the typo.

Editor:

Comment 1.1 Reviewers will undoubtedly ask about differences or advances in this data from those already presented by some co-authors (Knaeps et al, https://doi.org/10.5194/essd-13-713-2021). If reviewers fail to ask, I will ask. Think of users! What do they learn from this data set not available from prior work? Biofouling? What else. You talk about sample numbering consistency, but what should a user find where? More clarity about advantages, knowledge gained, how users should select or react?

> **Response:** The comment posed by the Editor raises important questions. In fact, similar points of concern were raised by the reviewers. To compare our dataset with the previously published work we have added, in the revised version of the manuscript, Table 1 (see line 91). This Table clarifies what readers can learn from previous work and what is novel in the presented dataset. In the revised version of the manuscript, we have now written 'In addition, from the data presented it is possible to investigate the effects that biofouling and weathering have on the detection of different polymers. Lastly, the conditions in which a plastic item is (i.e., dry, wet or submerged with different turbidity) are also described and assessed in the presented dataset.'

Notification to the authors:

Comment 1.1 For the next revision, please note that each DOI, no matter where, must be accompanied by a citation. Thereby, add a citation to a DOI in section "Introduction" etc.

> **Response:** We thank the editorial staff for bringing this to our attention. We have added a citation to each DOI.