RESPONSES to the review of the manuscript:

"Patterns of suspended particulate matter across the continental margin in the Canadian Beaufort Sea", Jens K. Ehn, Rick A. Reynolds, Dariusz Stramski, David Doxaran, Bruno Lansard, and Marcel Babin

We greatly appreciate the constructive comments from both reviewers. Here we provide our detailed point-by-point responses and any description of action taken in regards to the comments by Referee #2. The Referees' comments are shown in regular font; our responses follow each comment in blue font.

Response to Referee #2

I was very interested to read this manuscript, whose main goal is to develop a relationship between beam attenuation data collected by transmissometers and suspended particulate matter and particulate organic carbon. Much archived transmissometer data exist for this region so finding such relationships could give valuable historic information on suspended particles. This is a very complex region and others have struggled to find statistically significant relationships between these properties in such complex regions. In general, I think that the authors did a convincing job of showing that there are robust relationships.

It seemed like a secondary goal of this manuscript was to describe the physical forcing responsible for the high or low particulate concentrations. Unfortunately, this is where I think this manuscript fell apart. The interpretation of the physical data was vague and few solid conclusions could be made from the very long discussion. I got the sense that the authors had limited understanding of the physical oceanography of this region.

Perhaps a better approach would be to choose only one physical process that is related to suspended particles. I see the main storyline of the manuscript as a comparison between the attenuation and bottle data. Proof of concept of this relationship could be shown by focusing on only one process, such as the Mackenzie River plume. There is room here for a very thorough study of this process and much new information could be gained on by coming up with concrete conclusions related to one physical process.

REPLY: We would like to thank Referee #2 for insightful comments and suggestions for revisions that we feel have helped improve this manuscript. Specifically, we have followed the Referee's suggestion and used oxygen isotope data to determine freshwater sources. We have also reduced the discussion and focused on the summer season by removing data from the fall 2007.

Regarding choosing only one physical process: As stated by the Referee, the Mackenzie Shelf is a very complex region. We find that it is difficult to interpret SPM distributions in regards to a single physical process, as they respond to multiple and interrelated physical and biological processes occurring at different temporal and spatial scales. The goal is to simply to describe the SPM distributions, and attempt to interpret them within the context of all these processes.

I recommend that this manuscript undergoes major revision before it can be reconsidered for publication. Below are several other concerns and suggestions that I have:

- Page 1, line 6 – Several times throughout the manuscript, the authors state that the surface layer is a mixture of sea ice melt and river runoff. While this may be true, the composition of the surface layer hasn't been quantified so the source of the particles in the freshwater can't be determined. The authors could attempt a freshwater budget as was done by Yamamoto-Kawai et al. (2008, doi:10.1029/2006JC003858) or they can acknowledge that they don't know the source of the freshwater or the particles therein.
REPLY: Thank you for this advice. We have added an analysis of oxygen isotope data to help link the observed particle characteristics to freshwater sources. Furthermore, CDOM fluorescence in Fig. 3 also qualitatively indicates where ice meltwater (low CDOM) vs. river water (high CDOM) dominated the surface layer. We feel that these additions have helped achieve a better focus and improved the manuscript.

- The Introduction is in general quite confusing. I think that a more clear description of the region would greatly help readers not familiar with this area. In addition, a stronger literature review of previous SPM and POC work in this region, and the mechanisms that transport these particles, would set the stage nicely for focusing this manuscript.
REPLY: We have improved the introduction with a broader description of the study area. In particular, we have added the description of the submarine valleys and the effects of wind-forcing on shelf-basin exchange. We have added references for past SPM and POC studies in the region and other relevant studies within the world's ocean.

- Page 2, second paragraph – This paragraph is quite confusing and needs more focus
REPLY: The introduction has been substantially reworked. As a part of this, we expanded paragraph 2 as shown below (with the italic portion representing the original 2nd paragraph) to create on concise paragraph on SPM sources:

"The significance of sediment discharge to the region is underscored by the fact that this sediment load from the Mackenzie River surpasses the combined load of all other major rivers discharging into the Arctic Ocean. Additional sediment sources of minerogenic sediment to the shelf include coastal and bottom erosion, and other rivers, which have been estimated to provide ~9 Tg per year (Macdonald et al., 1998). This makes the Mackenzie Shelf the most turbid shelf sea in the Arctic Ocean. Biological production, *by both marine phytoplankton and sea ice associated algae towards the end of the ice-covered season, is a major authochthonous source of biogenous sediments in the Beaufort Sea during summer (Forest et al., 2007; Forest et al., 2010; Tremblay et al., 2008), although the ice and turbid seawater are thought to greatly limit primary production on the Mackenzie Shelf (Carmack and Macdonald, 2002). The particulate sinking flux therefore comprises highly variable fractions of allochthonous and autochthonous origins (Sallon et al., 2011), making particle characterization in the area a complex task. The vertical export of autochtonous organic material to the deep waters of Canada Basin is found to be surprisingly small, however (Honjo et al., 2010). As the organic material reaching the deep ocean layers is thousands of years old it must be transported there laterally from the shelf or slope reservoirs of highly refractory material (Honjo et al., 2010). This highlights the* *importance of understanding the distribution and lateral transport of particulate material from the shelf.*"

- Page 3, lines 14-15 – Why weren't lines 400 and 500 analyzed in this study?
REPLY: Unfortunately, there was not enough time during the MALINA expedition so that we needed to prioritize some stations and transects over others.

- Page 3, lines 25 -27 – What other depths were sampled in addition to the surface and SCM?
REPLY: There were large variations in other depths and their choice depended on the features seen on the CTD Rosette cast.

- Page 3, line 29 – What is an aliquot?
REPLY: Aliquot is a commonly used term defined as "a portion of a larger whole, especially a sample taken for chemical analysis or other treatment."

- Page 3, line 29 – What is considered a sufficient volume of water? Was this based on the time it took to filter or something else? What determines whether a duplicate or triplicate was sampled?
REPLY: Water from the Niskin bottles were in high demand on the cruise and used for analysis of many variables. We used as much water as was available and appropriate for our analysis. Seawater was passed through the filter to collect sufficient amount of particles but to avoid clogging of the filter. If the first sample filter required, for example, 4 L of water and only 6 L in total were available, then we did not collect a duplicate sample. We think this has been sufficiently described in the text, however, we added the information about "near-clogging" in the text.

- Page 4, lines 10 to 12 – Some other studies sampling SPM rinse the filters with ammonium bicarbonate or ammonium formate. Could the authors please explain why they didn't do this?
REPLY: We chose to rinse our filters with milli-Q to remove as much salt as possible but also avoid potential cell lysis. This is the most common procedure in SPM determination. Milli-Q water was readily available on the ship. We followed the method used in Babin et al. 2003 (as cited in the text), which essentially followed the JGOFS protocol described in Van der Linde, Protocol for determination of total suspended matter in oceans and coastal zones, Tech. Note I.98.182, Joint Res. Cent., Brussels, 1998. We also determined POC using the same sample filters.

- Page 5, line 8 – Please describe the interquartile range method, with a reference if applicable
REPLY: We have described it with the following sentence: "Time series of transmissometer data were also collected at selected depths and processed similarly to above, by taking the average of the interquartile range of the voltage values recorded over the periods when the rosette was stopped for water sampling during upcasts." There are no references for this method.

- Section 2.4 – Comparison of data between different transmissometers is notoriously difficult due to different calibration values and instrument drift. Is the use of dark voltage offset to allow for comparison of tranmissometer data between cruises? If so then could the authors please state the accuracy of this method, with references if applicable.
REPLY: The Vdark and Vref (representing particle-free seawater) are the calibration parameters

supplied with a C-Star and used to obtain beam transmittance and attenuation. The Vdark voltage offset is always done (but mostly directly within the Seabird CTD software). We have cited the Wetlabs C-Star user manual for how these are calculated, and the accuracy is stated by the manufacturer. It is worth noting that manufacturer calibrations are typically done at water temperatures of ~20 °C, but both Vdark and Vref values are sensitive to temperature. In brief, our processing of the C-Star raw voltage data is exactly the same as is typically done in the CTD software. However, as noted, there can be significant drift of the C-Star over time, and the ambient temperature can further affect the readings. To minimize these uncertainties, we have taken the approach to not to rely on the calibrated values (and here we note that the Vdark is of less importance compared to Vref in the relatively clear marine waters) but to determine them ourselves from the raw voltages measured at ambient temperature as described in the manuscript. For determining Vref we have used the clearest waters that we observed in the Arctic Ocean during the field campaigns, rather than pure water in the lab.

- Page 6, line 7 – What depth were the other sensors located at on the mooring?
REPLY: These sensors were all associated with the Aanderaa RCM11 and thus located at the same depth of 178 m.

- Section 2.5 – Why were data from only CA05 shown? This mooring is at the edge of the Cape Bathurst upwelling region, which is not particularly representative of the region. Several other moorings have been deployed along the Canadian Beaufort during the study period, 2004 to 2009. Why was only this mooring selected to represent the region?
REPLY: This mooring was located on our line 100, at the shelfbreak, so it is representative of our observations. These data also show well the change in the direction of the current at 178 m associated with upwelling.

- Page 6, line 28 – where is the proof that there were strong easterly winds in June 2009?
REPLY: Figure 8a (now Fig. 12a) shows that the wind direction during June was persistently from northeast (along the shelf).

- Section 3.1.1 – Please add some references to the different water mass definitions.
REPLY: We think that Carmack et al (1989) is a pertinent citation for water mass definitions for the study region. We have added the following sentence: "The water mass definitions that ensue follow Carmack et al (1989) and are consistent with descriptions in Lansard et al. (2012) and Matsuoka et al. (2012)." We removed these citations from the next sentence. We have also added a reference to Jackson et al. (2015).

- Page 7, lines 5-6 – Please see Jackson et al (2015, 10.1002/2015JC010812) for information on Pacific winter water in this region
REPLY: Thank you for suggesting this reference. We have included it.

- Page 7, lines 10 – 17 – The c_p values in this paragraph don't appear to match those in Figure 2
REPLY: The range is correct. Note that the higher cp values are represented with white contour lines. The colour bar represents the full range.

- Page 7, line 18 – what does the ‘strong chl-a fluorescence signal mean? Couldn’t they be quantified by discrete chlorophyll samples?
REPLY: In principle, this could be done by ‘calibrating’ the fluorescence sensor with discrete chl-a measurements, but, as far as we know, this calibration has not been done on the data from the MALINA cruise. There are uncertainties associated with this calibration. We simply use the chl-a fluorescence (and CDOM fluorescence) in a qualitative sense to gain a better understanding of particle characteristics and patterns on the shelf. A ‘strong chl-a fluorescence signal’ simply means that the instruments detected higher fluorescence at these depths/locations than elsewhere, which is generally indicative of higher concentration of particles containing chl-a.

- Page 7, line 22 – What is the source of CDOM in Pacific Winter water? Perhaps more information can be added from Guegen et al., 2012 (doi:10.1016/j.dsr2.2011.05.004)
REPLY: The paper by Matsuoka et al (2012) describes the CDOM observations during MALINA. Therefore, we think that the addition of more information overlapping with the Matsuoka et al. study is not necessary in our manuscript. However, the CDOM source is likely associated with the decomposition of organic materials in the Bering and Chukchi Seas.

- Page 8, line 10 – There is no information about the location or methods used for barge sampling
REPLY: Barge sampling is described in Doxaran et al. (2012). We cited that study in that context. We have mentioned that barge stations were in the vicinity of the CCGS Amundsen, and also mentioned the transects to the Mackenzie River mouths.

- Page 8, lines 24 – 26 – Why is it not possible to measure PSD using the Coulter technique in low salinity, turbid waters?
REPLY: The Coulter Counter counts and sizes particles suspended in an electrolyte by aspirating sample through a small aperture and recording the change in the electrical impedance as particles pass through the aperture. In our case, the electrolyte is seawater. Reductions in salinity decrease the conductivity across the aperture and increases the noise associated with the measurement; below a certain threshold of salinity the uncertainties of the measurement become untenable.

Although turbid waters may pose a challenge because of the need for coincidence correction (accounting for multiple particles passing simultaneously through the aperture), this can generally be handled through appropriate dilution of the sample. In the present case, the statement “low salinity, turbid waters” is made simply because the waters near the river mouth were associated with both low salinity and high turbidity, not because of any limitation in the technique associated with turbidity per se.

- Page 8, line 32 – I disagree with this statement. The relationships shown in Figure 4b are not very convincing. Is the relationship statistically significant?
REPLY: We have deleted the first sentence. We did not test the statistical significance.

- Page 9, lines 8-10 – What is the difference between the MALINA and Amundsen data?
REPLY: No difference. It was used to specify the contrast between sampling from Amundsen

and barge during MALINA. For clarity we have changed "CCGS Amundsen" to "ship-based sampling".

- Page 9, lines 18 -20 – Of these three regression analyses, why is only ii) shown in Figure 5?
REPLY: We decided to clarify the results of regression analysis in the revised manuscript by moving details of this analysis to the Supplementary Materials, and keeping only the most essential regression fits actually utilized in the manuscript.

- Page 9, line 26 – do the authors mean 'nonlinear power function' instead of 'nonlinear least squares regression'?
REPLY: Firstly, the description containing this sentence has been deleted and moved to the Supplementary Materials. Secondly, in the Supplementary Materials, we have now written: "Therefore, we selected the SPM vs. $c_p(660)$ relationship obtained from the power function fit using nonlinear least squares regression to ordinary (non-transformed) variables as the algorithm for estimating SPM in [g m^{-3}] from $c_p(660)$ in [m^{-1}] in the rest of this study".

- Page 12, lines 20 – 26 – Figure 8 is very unclear and possibly incorrect. I can't see the statements in this paragraph supported in Figure 8
REPLY: In our opinion, progressive vector plots are the best way to display the overall wind and current regimes. We have improved the clarity of the figure and we see no problems that could make it incorrect. We have marked the timing of the expeditions on all plots, removed the fall 2007 period, and removed the observations from 54 m depth in an effort to clarify the figure.

- Page 12, line 28 – I can't see the wind speeds in Figure 8a
REPLY: The colour of the progressive vector plot indicates wind speed.

- Page 12, lines 31-35 – Don't these lines contradict lines 11-13 on page 12?
REPLY: Yes, indeed. We did not mention the one week period of southeasterly winds during the last week of July. We have added the sentence "Winds turned to southwesterly for the last week of July with wind speed > 8 m s^{-1}".

- Section 3.3.3. This section need much more work. How was cross-shelf defined? What depths were influenced by cross shelf currents? How do we know that the currents observed at CA05 were representative of the rest of the region? How was a cross-shelf episode defined? I'm not entirely sure how this section is giving evidence of upwelling and relaxation
REPLY: As indicated cross-shelf current was defined by the direction of 300 degrees as indicated by the change in direction in the progressive vector current plot (original Fig. 8b, now Fig. 12b). We have not tried to expand this analysis of currents to cover the full Mackenzie Shelf region. This is beyond the scope of our study. More information on modelled currents can be found, for example, in Mol et al. (2018) which is cited. The increase in salinity and temperature during upwelling episodes are an indication of upwelling of deeper waters that are more salty and warm. The upwelling shelfbreak flow is also linked with seaward Ekman transport of surface waters during which the plume extends further north and northwest. This reverses during downwelling inducing winds or relaxation of upwelling. We show that the SPM patterns on the shelf reflect this circulation.

- Section 3.3.4 – I don't see the point of this section. What new information does it tell us about SPM and POC in the Canadian Beaufort Sea?
REPLY: Section 3.3.4 describes the geostrophic currents which were used to detect the shelf break jet and the overall circulation on the shelf. This information clearly has bearing on SPM distributions on the shelf. Beam attenuation values were noticeably elevated at the shelf break jet, so the jet plays a role in resuspending particles and/or keeping particles in suspension. The occurrence of the shelf break jet is an indication for downwelling flow (e.g. Dmitrenko et al. 2016; Forest et al. 2015). We argue that this plays a role in SPM patterns on the shelf.

- Page 13, line 29 – Could the authors please be more clear with where the current intensification is observed? I refer the authors to Forest et al (2015, http://dx.doi.org/10.1016/j.csr.2015.03.009) for discussion of other strong shelfbreak currents in the region
REPLY: We have rewritten this section and it is now incorporated in section 3.1 (page 8). We have included a reference to Forest et al 2015. We have been more specific by saying "along the Makenzie Shelf shelfbreak" instead of "at this location".

- Page 14, lines 10- 11 – What causes this clear water extension onto the shelf?
REPLY: The particles originate from the river and shelf bottom. Therefore, the absence of particles in the clear water layer reflects the water column structure and dynamics, with the river plume in a stratified surface layer from which particle settling is limited, and bottom resuspension reaching only a certain level. This leaves a clear layer in between. We have described this in the text on page 12 (4^{th} paragraph).

- Page 14, lines 24-25 – Is there proof of downwelling return flow and after upwelling?
REPLY: Yes, the mooring record, its link to wind speed and direction, the geostrophic current sections, and SPM patterns are all evidence for Ekman upwelling/downwelling.

- Section 4 – I am unclear exactly how the physical observations described in section 3 lead to the listed conclusions in section 4. Much more work needs to be done to understand the physical processes before they can be related to the particle concentrations
REPLY: We feel that the addition to the revised manuscript of freshwater source analysis has strengthened this link. We have also removed data from the fall 2007, rearranged and tried to better focus the text in order to address this issue.

- Figure 1 – Please make the CA05 mark larger and easier to see o It is difficult to distinguish between the different colored stars
REPLY: We added a green arrow pointing to the CA05 mark. We have furthermore added a list of station locations in the Supplementary Materials.

- Figure 2 – Why is the very freshest water on the western shelf away from the Mackenzie River? It doesn't appear that this very fresh water is correlated with the highest attenuation o It would help the reader understand the text if the stations could be marked on these figures o What does the grey area mean?
REPLY: The grey area is below the bottom so no data at the depth exists. The wind direction in 2009 was such that the Mackenzie River plume was pushed eastward. This was also linked to upwelling, as can be seen from the current data. Attenuation values were elevated in the plume,

however, seasonal timing play a role here as, for example, the SPM values in July 2004 (Fig. 7g) were an order of magnitude higher than in August 2009 (Fig. 7h). In August 2009, the highest cp(660) on the shelf are indeed not in the freshest part of the plume, but towards the east. Interestingly, this is also linked to higher salinity. Thus, we draw the conclusion that the wind, the upwelling and tides (which are not discussed in detail) caused resuspension of sediment in the shallow eastern portion of the shelf. Note also that prior to MALINA, during the first part of July, there was a period of northerly winds that pushed the river plume along the shore towards east. Some of the suspended particles may have been remnants from the earlier eastward-moving alongshore plume.

- Figure 3 – Why are the error bars backwards?

REPLY: Figure 3 does not include error bars. If the reviewer is referring to the color bar scale, we have reversed the direction (lowest to highest values going from left to right) in the revised manuscript.

- Figure 4 – It would help the reader interpret this if boundaries were drawn around the 3 different defined areas o Figure 4b – I don't see very strong, statistically significant relationships here. Also, is the salinity from the same depth that the water was sampled from?

REPLY: We have redone this figure to show the POC/SPM boundaries of 0.06 and 0.25 between mixed and organic-dominated particle assemblages. 4b: We agree that there is not a strong statistical relationship here. The point of the figure is to show the range of PSDs. However, there is a strong relationship between the river runoff fraction and POC/SPM (as shown in new Fig. 5b).

- Figure 6 – It is difficult to see the writing of the different cruises

o The data look smoothed. Can the authors please state how they smoothed the data?

REPLY: We have increased the size of the figure. The data has not been smoothed by us. What is plotted is the data downloaded from Environment Canada (http://wateroffice.ec.gc.ca/) and the Canadian Ice Service.

- Figure 8 – I really struggled with this figure. It is difficult to interpret, has very small writing, and has a huge amount of information.

o The wind and current data in particular were difficult to distinguish. It was near impossible to see upwelling or downwelling as this figure was laid out

o I think that the depths in the temperature and salinity plots were mislabeled – the shallower water shouldn't be saltier

o There should be some explanation as to why such salty water was observed in figure 8d. Water of this salinity would have to be upwelled from several hundred meters depth, and a significant upwelling event would need to be evident in the wind data.

o I don't understand what the different colours mean in 8c

REPLY: We are sorry about the figure presentation and agree it is a complex figure with lots of information. In the revised manuscript, we have inserted a larger figure which is intended as a full page width figure. When the paper is prepared in final form for publication we will make additional improvements, if needed, to ensure that all details are clear. We have also simplified this figure by removing the extra depth of 57 m and the turbidity, to just focus on the 178 m data..

- It was not mislabeled. However, the plots were on different scales. This is no longer an issue.
- The timing of upwelling inducing winds (a) and upwelling events (b-d) are consistent. Same is true for downwelling events.
- Colours are current direction which is more easily seen in (b).

- Figure 9 – Please mark the mooring location on line 100 (CA05)

REPLY: Done

o I couldn't distinguish between the different contour lines

REPLY: Figure is now larger which hopefully helps.

o Please include the station locations

REPLY: We have not included station locations, however, the small black dots indicate the profiles taken at the station locations.

o The current values don't make sense to me. General definitions in oceanography are that northward and eastward currents are positive and southward and westward currents are negative. Having different definitions makes this figure very confusing

REPLY: Geostrophic current calculations can only give speeds that are perpendicular to the transect line. We could divide this speed up in U and V components, however, since our transect lines are nearly perpendicular to the shelf break, the calculated geostrophic currents represent along-shelf current magnitude. Note that this is consistent with what has been done in other studies (e.g., Forest et al., 2015).