Interactive comment on "Sea–ice and water dynamics and moonlight impact the acoustic backscatter diurnal signal over the eastern Beaufort Sea continental slope" by Igor A. Dmitrenko et al. by Jørgen Berge (Referee)

We highly appreciate helpful comments and suggestions by Prof. Jørgen Berge (Reviewer #1). In the following, the comments by Reviewer #1 are underlined and our responses to the comments are in normal characters. Modifications to the text are shown in quotation marks with bold characters indicating newly added text, and normal characters indicating text that was already present in the previous version. The line numbering is referenced to the marked-up manuscript version.

Referee #1:

1. Abstract: To which degree will the ADCP "see" suspended particles? Is it really true that suspended particles can mask the backscatter signal from zooplankton? I think this should be included in the discussion as a separate topic

There is a large number of papers demonstrating that the sound wave is scattered off the particles, and the backscatter intensity is related to suspended sediment concentration. Over the past few decades, the implication of ADCPs for detection of suspended sediment became commonly accepted (e.g., see overview by Thorne and Hurther, 2014: An overview on the use of backscattered sound for measuring suspended particle size and concentration profiles in non-cohesive inorganic sediment transport studies, doi:10.1016/j.csr.2013.10.017). Nowadays ADCPs (including those operating at 300 KHz) are extensively used for suspended sediment transport monitoring (e.g., Venditti et al., 2016, doi:10.1002/2015WR017348; Dwinovantyo et al., 2017, doi:10.1155/2017/4890421; etc. etc.). Moreover, in 2007, RDI published a technical note providing information on commercially available software packages converting ADCP backscatter data into total suspended sediment concentration as follows: http://www.teledynemarine.com/Documents/Brand%20Support/RD%20INSTRUMENTS/Technical%20Resources/Technical%20Notes/WorkHorse%20-%20ADCP%20Special%20Applications%20and%20Modes/FST017.pdf. Therefore, there is no doubt that ADCPs "see" suspended particles. So, we do not think that discussion on this point is appropriate in the context of our manuscript. Discussion on how the backscatter signal from zooplankton is impacted by suspended particles is already provided in the last paragraph of section 6.1 (lines 590-604). Figures 7d-7f clearly show enhanced MVBS 24 h a day, which is consistent with an acoustic signature of suspended particles. The light attenuation enhanced by suspended particles likely impacts DVM during summer 2005. We agree that term "mask" seems to be inappropriate in this context. DVM can also be impacted by light attenuation generated by enhanced concentration of suspended particles in water column. So, following this comment we changed "*masked*" to "***impacted***" (lines 20, 282, and 590).

2. Introduction: Line 45: Zooplankton samples taken 13 years after the mooring was deployed? I would suggest that the part on zooplankton samples is taken out, as it in reality have very little added value. This applies throughout the manuscript

The part on zooplankton samples was removed, lines 135-149.

3. Line 46: "The environmental factors controlling DVM in the seasonally ice-covered Arctic areas,..., remains poorly assessed". There have been numerous studies documenting that it is light that is

proximate cue for DVM, both in the Arctic and elsewhere. So if you mean that proximate cues are poorly studied, I would disagree. However, if you are referring to other environmental factor and their effect on DVM, then this is a topic not merely poorly studied in the Arctic, but in general. The effect of upwelling/downwelling is also a novel and important contribution to the understanding of DVM in general! I would recommend rewriting this so that it becomes clearer?

Reviewer #1 is correct. To make our statement clearer, we modified this sentence in line 46 as follows: "*The* ***oceanographic*** *factors controlling DVM in the seasonally ice-covered Arctic areas... remains poorly assessed*".

4. Line 48: To avoid confusion, I would refer to Cohen et al 2020 (table 3.1) with definition of polar night...since you are discussing light levels, the most correct term is actually "civil twilight" which occur during polar twilight when the sun is less than 6 degrees below the horizon. The same applies for the other locations mentioned in the sentences below (need to separate between the definition of types of twilight and polar night periods)

Following this comment, we modified text in lines 48-54 as follows: "***At t****his latitude* ***no actual daylight is experienced during short winter daylight hours with the exception of the civil twilight*** *when solar illumination is still sufficient for the human eye to distinguish terrestrial objects. This geographical position makes our DVM observational site vastly different from those at Svalbard (****astronomical twilight, the Sun is between 12 and 18° below the horizon****, ~80°N; e.g., Grenvald et al., 2016; Darnis et al., 2017), Canada Basin (nautical twilight, the Sun is between 6 and 12° below the horizon, ~77.5°N; La et al., 2018), and Northeast Greenland (nautical twilight, ~74.5°N, Petrusevich et al., 2016)*".

5. Data: Line 83-100: Wallace et al 2010 and later Hobbs et al 2018 used and published a procedure on how to infer ice-cover from an upward-looking ADCP. This would provide a good and in situ data source for ice cover at the mooring site

We estimate the sea-ice cover concentration from AMSR-E. Following comment #8 by Reviewer #2, we changed sea ice concentrations, spatially-averaged over a 200-km rectangle, to that for the single pixel, closest to the mooring position (please see revised text in lines 91-94). The sea-ice thickness, however, remained uncertain. A procedure on how to infer ice-cover thickness from an upward-looking ADCP suggested by Wallace et al. (2010) and later by Hobbs et al. (2018) is based on the algorithm published by Hyatt et al. (2008, doi: 10.1016/j.dsr2.2007.11.004). According to that algorithm, the ADCP bin that samples the sea surface or sea-ice bottom is identified as the bin above the bin with maximum backscatter intensity (Hyatt et al, 2008). For CA13, the velocity and acoustic backscatter data were obtained at 8-m depth intervals, so the last sampled bin #13 was at 4 m depth. This level corresponds to the maximum backscatter intensity (as shown in the figure presented below). Thus, there is no bin above the one with the maximum backscatter intensity, which does not allow to apply this algorithm. To resolve this issue, we followed a recommendation provided by Reviewer #2 (his/her comment #2) to derive sea-ice thickness from the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS) and Hybrid Coordinate Ocean Model (HYCOM) + Community Ice Code (CICE) coupled ocean and sea ice system. Instead of the mean seasonal cycle, we used grid daily data from PIOMAS and HYCOM+CICE for the grid node closest to the mooring position (please see revised text in lines 103-119).

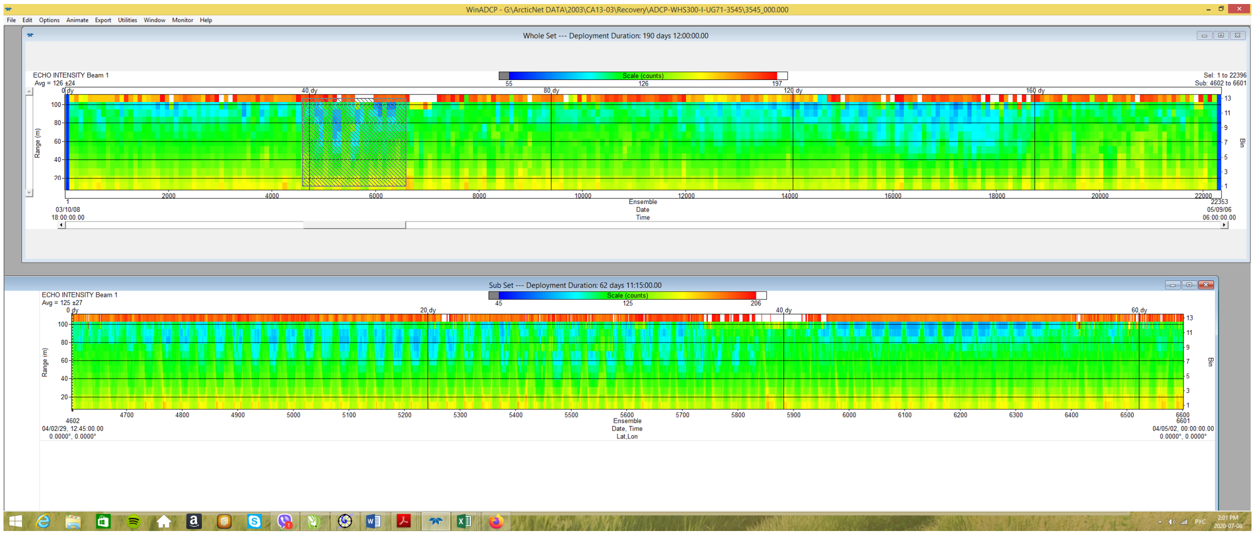

Figure shows acoustic backscatter data from a 300 kHz upward-looking Workhorse Sentinel ADCP by RDI deployed at CA13

6. Lines 101-115: I would argue that this part should be deleted. The samples were collected no less than 13 years after the mooring was deployed, and actually relatively far away from the mooring site. There need to be some seriously strong arguments (that are not provided) for using these samples as a reference point for which scatterers were present 11-13 year earlier. The strength of the manuscript is NOT decreased by omitting these data (quite the opposite, I would argue) - much of the discussion is still valid without referring to zooplankton nets taken in September 2016.

The part on zooplankton samples was omitted in lines 135-149, 458-466, and 489-515. Figure 1 was modified accordingly, and Figure 10 was removed.

7. Lines 201-206: Check values...disregarding atmospheric refraction, the polar day and polar night are symmetrical. Atmospheric refraction will prolong the observed polar day, but hardly as much as presented here (20 days longer polar day compared to the polar night).

The duration of polar night and polar day (the Sun 24 h a day below and above the horizon, respectively) for CA13 position (71°21.356’N, 228°38.176’E) was taken from https://nrc.canada.ca/en/research-development/products-services/software-applications/sun-calculator/. The NOAA calculator at https://www.esrl.noaa.gov/gmd/grad/solcalc/sunrise.html provides similar results. For the North Pole location, this calculator gives results on the duration of the Polar Night and the midnight sun that are similar to those in your Figure 1.5 caption, page 12, POLAR NIGHT Marine Ecology: Life and Light in the Dead of Night, 2020. Following comment #17 by Reviewer #2, this text was shortened and moved to lines 54-57.

8. Discussion Line 438-440: DVM during the polar night is most likely not "diurnal movement of zooplankton towards the surface at dusk", but rather the opposite (movement away for the surface during the short period of increased illumination at around noon). Suttle, but important distinction in order to understand the process of DVM during the polar night (see recent literature on polar night zooplankton and dvm)

The text in lines 517-525 discusses results on DVM at CA13 with respect to the illuminance threshold. During the polar night, these results clearly show the diurnal movement of zooplankton toward the surface at dusk (higher MVBS highlighted by green color in Figure 7d), and descends back the next morning before the short period of increased illumination at around noon (lower MVBS highlighted by dark blue color in Figure 7d). With respect to the reversed DVM (movement away for the surface during the short period of increased illumination at around noon during the Polar Night), Reviewer #1 likely referenced observations taken during the astronomical twilight at 79-80°N (e.g., Berge et al., 2008; Wallace et al., 2010), where during the civil polar night the Sun is between 12° and 18° below the horizon. In contrast, we used observations taken during the civil twilight, when the Sun was between 0 and <6° below the horizon. We pointed out this important difference in lines 51-54: "*This geographical position makes our DVM observational site vastly different from those at Svalbard (**astronomical twilight, the Sun is between 12 and 18° below the horizon**, ~80°N; e.g., Grenvald et al., 2016; Darnis et al., 2017), Canada Basin (**nautical twilight, the Sun is between 6 and 12° below the horizon**, ~77.5°N; La et al., 2018), and Northeast Greenland (**nautical twilight**, ~74.5°N, Petrusevich et al., 2016)*".

9. Section 7.4: How does this study deviate from previous studies (e.g. from Svalbard) that have aimed at studying the effect of water masses, halo- and pycnoclines, etc?

The previous studies from the Svalbard area were focused on the relationship between zooplankton community structure and the local hydrography (e.g. Willis et al., 2008, 2011; Kwasniewski et al., 2012; Berge et al., 2014). In contrast, Section 6.3 (former section 7.4) is focused on the DVM modifications related to water dynamics. Effects of water masses and stratification were not discussed because only limited CTD information is available at CA13.

10. General comment: I find the results in relation to an absolute threshold of light (lux=1) interesting, but I think the authors have a lot to gain from presenting a more thorough discussion on the importance of light intensity vs rate of change. Most published papers emphasise the rate of change as the important cue. Also, the use of lux is not very common in studies of DVM - is it possible to relate lux to absolute quantas of photons? This would enhance comparison with previous studies.

"Our results on the light threshold are consistent with the preferendum (isolume) hypothesis (e.g., Cohen and Forward, 2009). A variant of the preferendum hypothesis, the absolute intensity threshold hypothesis, suggests that an ascent at sunset is initiated once the light intensity decreases below a particular threshold level and a descent at sunrise occurs when the light intensity increases above the threshold intensity (e.g., Cohen and Forward, 2019). This is in line with our findings on an absolute 0.1-lux threshold of light, which corresponds to the moonlight illuminance at the gibbous moon during clear sky (Gaston et al., 2014)". We added this statement in lines 525-530. We introduced an artificial visual boundary on the illuminance colour scheme at 1 lux (gray to orange), which corresponds to illuminance during the deep twilight – lines 177-179. For the sunlight, 1 lux corresponds to about 0.019 micromoles photons per square meter per second (µmole photons m^{-2} s^{-1}). Following this comment, we introduced this unit for the color scale of the under-ice illuminance in Figures 3c-3e.