Replies to reviewer comments

Please find our answers to the reviewer's overall minor comments in blue font under the respective comments.
We thank you very much for the constructive reviews and the interest in publishing our work in The Cryosphere.

Anonymous Referee #1

This manuscript describes the development and implementation of a novel sensor system for the measurement of shortwave radiation within ice. The "light chain" is a simple, inexpensive, easy-to-deploy instrument that collects optical propagation data within a 5 cm diameter bore hole autonomously. The demonstration deployment was in~2m thick sea ice in the vicinity of the North Pole. This tool is novel and, I expect, will be very useful for understanding the propagation of light through ice, a topic which is highly relevant to current climate research. Beyond development and implementation, the manuscript offers insights regarding the transport of light within the ice in ways that could fundamentally streamline many routine measurements. I find this paper to be very nicely written, easy to read, appropriately referenced, and supported by clear illustrations and informative figures.
We thank you very much for the positive evaluation of our manuscript and are happy that we could convince you of the usefulness of our approach.

Overall, the manuscript gives a great overview of the motivation, methods, and materials of this new system. I am pleased to see the conclusion regarding the proportionality that exists between the side-welling planar irradiance and the spherical irradiance. This seems to be a very useful result. I have only a few minor questions and a few technical points:
We thank you very much for your careful evaluation and appreciate your constructive comments.

The title is fine, and it is completely acceptable to leave as is. However, I suggest a modification: 'New insights into radiative transfer within sea ice derived from autonomous optical propagation measurements' might be slightly more informative?
We revised the title accordingly.

It appears the data from this system were perhaps downloaded locally (during the 4weeks the ship was on station)?, but then telemetered (past September), but this is never explicitly stated. It would be helpful to know what the telemetry requirements look like.
We added the following sentence to section 2.1: "Measured data were sent via an Iridium SBD satellite link requiring data transfer of around 65kB per day for the hourly sampling schedule."

Line 15: shortwave shouldn't be hyphenated
Corrected accordingly

Line 115: "The ice was homogeneously grown,..."? Please clarify what is meant by this statement.

We removed this ambiguity and it now reads “The level ice was covered by a 10-15cm thick surface scattering layer.”

Line 155: “in the clear”? does this refer to the broadband channel on the sensor? It’s not obvious.
We added the word “channel” for clarity.

157: delete “both,”
deleted

Fig 6 caption: “attenuation coefficients”, color bar label: “apparent extinction”. It would be helpful if the terminology was consistent.
We changed the Figure caption to “apparent extinction coefficients” also for figure 7

Fig 7: I am assuming that the borehole did not immediately re-freeze, given the August deployment, but it would be helpful to know what that process looked like? I wonder if some of the features shown in Fig. 7 are associated with the refreezing process? In particular, I would not expect the surface scattering layer to re-form within the bore hole after drilling and installation. Why does a highly scattering surface layer appear to increase so quickly between 31 Aug and 14 Sept maybe that is a SSL reestablishing? It is interesting that the attenuation in the uppermost 5 cm of the ice drops so dramatically when snow began to accumulate. I suppose that happens because the uppermost portion of the ice is no longer at the top boundary, and the new snow above is now attenuating light strongly. Should one be surprised that this attenuation drops so much?
To arrive at realistic observations of the topmost cm, the top of the hole was backfilled with cuttings and the surface scattering layer restored. While this is not exactly the natural configuration, it is extremely close to it. This backfilling also avoids any light leaking through the top of the hole, such that influence of the hole during refreezing is minimal due to the large sensor footprint.
To specify this, we added “The topmost part of the hole was backfilled with cuttings and the surface scattering layer restored.” to the description of the deployment in section 2.3.
Thus features visible in Figure 7 are not related to the refreezing of the hole, but only the deposition of snow, where a few mm have dramatic effects on the optics increasing light extinction e.g. between 31 Aug and Sep 14. (See section 3.3). We added a statement “Spectrally integrated attenuation in the layer directly beneath the surface is largest even when the interface location changes.” To refer to the “drop” in attenuation which we are not surprised about (e.g. Grenfell & Maykut 1977). In general it should be noted that data at the surface can’t be overinterpreted, as the spatial resolution with 5cm sensor spacing is too crude as we mention already in section 4.2 “While the sensor spacing of 5 cm seems to excellently resolve the vertical decay of light within sea ice, this vertical resolution is not high enough to decipher detailed optical properties of the snow pack and surface scattering layer. Also the precise detection of the vertical position of interfaces between water, ice, snow and air is limited.”

Fig 8b shows values increasing 1.7 to 2.1m-1. Is this really an ice-evolution time series? Or a refreezing bore hole time series?

As we see these increases in all depth layers, we do not suspect this to be a result of hole refreezing and are confident that this is really an ice evolution time series as stated.

247: not “identical”, but “proportional”!
Corrected accordingly

Fig11: I need a bit more info to know how to look at this RGB rendering. I don’t see obvious colors, but perhaps some guidance could help?
As both reviewers did not seem to understand this figure and we did not manage to generate a clearer representation, we deleted this figure and rephrase the respective section accordingly: “The four spectral bands of the light sensor chain also allow a simple assessment of light color and spectral changes over time. Our first results suggest that there is potential to detect at least transient high concentrations of in-ice algae by this light sensor chain, either in RGB plots or simple band ratios similar to remote sensing algorithms.”

Fig 12 (and line 286): looks like the Trios transmittance data are picking up some chla absorption (strong dip wavelengths < 470 nm)? Is this detectable in the light chaindata?
As the strength of this dip doesn’t seem to change much over time, there is also no clearly evident chlorophyll signal in this light chain dataset. From recent deployments this year (not to be described here) we however know that we can detect chlorophyll signals. Due to the limited spectral accuracy it is easier to detect transient chlorophyll signals by the light chain. We added this to the respective section.

315-316: significantly reducing? Please quantify!
We deleted the word significantly and provided a rough quantificantion of this effect from the measurements: “This effect is currently mostly unaccounted for in simple exponential radiative transfer parameterizations, but is reducing light levels at the ice bottom, by up to a factor of 2-3” Some exponential models might have been tuned to use ‘inaccurate’ extinction coefficients yielding correct results in turn.

361: data suggest (not suggests); also...why only summer?
Corrected accordingly and removed the word summer.