Interactive comment on “Variability of light transmission through Arctic land-fast sea ice during spring” by M. Nicolaus et al.

Anonymous Referee #2

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Overarching general review/comments

The topic of study is highly relevant to the present day environmental concerns and dynamics related to the energy and mass balance of Arctic sea ice. That said- the data and study does contribute to the large body of work regarding the variability of the transfer of energy through sea ice. However, given that the body of literature and data on the topic is very extensive (as nicely reviewed in the introduction of the current submission) the manuscript, in its present form, does not yet make an overly compelling case that the findings or analyses of the findings are particularly novel. Rather- the findings and analysis, as presented/analyzed, seems to indicate that these measurements are very consistent and repeat what others have found for the past several decades (Namely that snow cover is a major determinant of the transmittance of solar radiation that passes into and through sea ice, the annual dynamics of solar radiation passing through sea ice is very dependent on the season and, in the absence of significant amounts of algal material or colored material, the spectral composition of the under ice irradiances is fairly predictable or known).

We have to highlighted the novel elements more, including 2 more highlight sentences in the abstract:

- The unique intercomparison of seasonal and spatial variability in this study highlights the significance of spatial variability for energy transfer and habitat conditions.
- The under-ice sled approach is new and has a good potential for similar, and extended, applications. While even greater possibilities arise from the use of Remotely Operated Vehices (ROVs), under-ice sleds reduces cost, size, demands on operator skills, and logistics requirements.

We agree that snow is the predominant factor in all these studies during spring(!). In that respect we confirm earlier findings. Amount, spatial distribution, and seasonality of snow on sea ice is (and will be in the next years) one of the key questions and topics in sea-ice and polar research. The presented data and findings are useful since they highlight the significance of spatial variability compared with seasonal change. Data on spatial variability are still sparse while point measurements provide limited information.

The manuscript and data however, likely has greater potential beyond what has been presented. Specifically, the manuscript has at its foundation a good series of measurements collected in a sound manner (for which the authors should be commended) that can quantitatively address spatial variability issues. As presented thus far, the ms presents a rather mundane analysis of the summary statistics (e.g. mean, mode, variance etc..) regarding light transmission along transects and show the transect data. Although this level of analysis does quantify the variation along a small scale (meters) it does not attempt to quantitatively correlate or relate the variability and the spectral (numerically speaking) characteristics of the along-track or horizontal variation. Looking at the data this type of analysis might not be statistically achievable given that the transects did not over many (e.g. 5 or more) wave forms in the along track variations). However, we really don’t know if this is the case based in the data as presented because the data is only presented on a logtransformed scale. After presenting on a different scale and conducting an analysis of spatial variance- they may or may not find spectral (spatial) characteristics that may not be readily evident from their analysis presented thus far. It may turn out they do not have enough data to derive statistics such as autocorrelation lengths etc.. . However, any data that seeks to explain spatial or temporal variations and dynamics should be subject to that type of analyses. Even in the instances where the data may be insufficient to derive such information- the explanation as to why the information could not be obtained could be presented.

As the reviwer points out, spatial variability can be described in a range of ways. Most commonly used methods are calculation of mean and variance, more sophisticated geospatial methods include variograms and spectral (in a numerical sense) analysis. Each method is justified by a particular application: in linear systems, the mean is sufficient for mass or energy budgets. The variance is an important parameter for analysis of non-linear systems, again with respect to mass and energy budgtes. Variograms are used to analyze patch size, which may be highly relevant for biological systems for example, and the mechanisms behind the formation and evolution of the variations. We presented the most fundamental measures to describe and compare the under-ice light environemnt, i.e. mean and variance. We believe that presenting and discussing these measures makes a valuable contribution to scientific knowledge as they can be used to determine energy budgets and to relate our measurements to measurement of previous groups.

We agree that there is greater potential for data analysis, with respect to advanced geo-statistical analyses. However, in order to obtain such results at statistical significance, larger data sets will be needed. From our own (Petrich et al., 2012) and others (Sturm et al., 2002) work on snow measurements it became obvious that the large correlation lengths (around 10m) require transect lengths of the order of hundreds of meters to obtain statistically robust results. As the reviewer suggested, this is much longer than our presented profiles. Hence, we suggest that these aspects could be considered in future measurements. While geospatial analysis cannot be performed on this data set, we included this aspect into the discussion section.

Beyond this, larger data sets, as needed for such geo-statistical analyses, can be obtained from the use of ROVs (Nicolaus et al., 2012, GRL) or AUVs, when grids of several hundred meters can be measured on single measurement days.

Then, once this information (on distance variability etc..) is gathered or summarized, the data should be placed in context of the previous studies- in such a manner that comparisons can be made. For instance, a fundamental attribute that can allow a more readily comparison of information on transmittance and under ice irradiances, is the attenuation coefficient which – although it is apparent optical property- id does allow some comparisons to be made when thicknesses of the overlying snow and or ice become confounding factors in comparing the properties of the ice.

We are not aware of any such study that provides geo-statistics on similar data. But this is certainly a good suggestion for upcoming studies, since we believe that this kind of spatial variability data, e.g. using ROVs, will become more and more state of the art (see also comment above). We agree with the reviewer that attenuation/extinction coefficients can be calculated. We now include this apparent optical property, i.e. the extinction coefficient, in the discussion.

The above discussion and comments are provided in hopes that some of the information and data analysis from this study can be integrated into a revision that will help progress the concepts which will be more useful to include in analyses – of not only current or past data-but data and studies of the future, and thus look forward to seeing the ms in a revised version.

Technical comments:

The presentation of the abbreviations for different irradiance values is not consistent with the standards for hydrologic optics. Specifically Ed(z,lambda) is downwelling irradiance (the d should be subscripted and it denotes a cosine geometry of the collector) and z and lamda denote the depth and the wavelength respectively.

We agree that our abbreviations should be consistent with other publications of the same type of data. Since we had to find good solutions for similar data sets during the last months for under-ice optical measurements (Nicolaus et al, 2012, GRL; Nicolaus and Katlein, 2012, TCD) we decided to use identical abbreviations. Since both, above and under ice measurements are measurements of down-welling solar irradiance (E_D) and since the depth of measurement z is not constant along the measurements, we use the subscripts "S" for surface and "T" for transmitted / under ice. We also need to include that we restrict the wavelength range to PAR in this study. Hence, we use $E_{S,PAR}(l)$ and $E_{T,PAR}(l)$. With regard to the comments and suggestions from reviewer 1, we also summarize statistical summaries of all measurements of each measurement session in a new table.

The references are not consistent and the reference for Nicolaus 2012 is not presented.

We corrected this