Reply to comments, Referee 1

'Ocean Colour remote sensing in the Southern Laptev Sea: Evaluation and Applications' by Heim et al.

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REFEREE 1: The manuscript presents new in situ measurements of optical parameters (CDOM, Chla, TSM) that are used to evaluate the quality of MERIS C2R algorithms products in the Laptev Sea. Due to the strong cloud cover in the area, the manuscript focuses not on the normal matchup of in situ data with remote sensing images but on a general evaluation of data quality. The manuscript also presents a series of images to discuss the applicability of these to the study of specific hydrodynamic process. In general, my opinion is that the manuscript contains enough material of sufficient interest to be published as the Laptev Sea is not well studied overall. Use of remote sensing is clearly indicated in that remote location. However, the manuscript is seriously hampered by a lack of clarity as indicated by the numerous question marks I wrote on my paper copy. I thus recommend a serious revision of the manuscript to deal with this problem. There are many places where there is too much information while some other lacks information.

I believe the manuscript would gain in quality if the results were presented in a clearer manner. I suggest to the authors to reorganise section 4.3 with subsections devoted to each of the dynamical process they want to address. This manuscript cannot deal with temporal variability or with the intensity of features but it can certainly present case studies showing the interesting process visible on the images. I would also suggest that the Results and Discussion sections for C2R evaluation be merged together. This would generate a more concise manuscript. The discussion should focus on the capacity to detect significant bio-physical process in the Laptev Sea using remote sensing.

I thus conclude by saying that the manuscript has good content but its presentation is awful. This manuscript should be revised and resubmitted.

We thank Referee 1 for providing helpful comments to improve and clarify the text: the text was generally revised and restructured. The chapters 'methods', 'results' and 'discussions' were structured into more subchapters to improve the readability of the text.

main points made by Referee 1 and main editorial changes made by the authors:

the Results and Discussion sections for C2R evaluation be merged together

done, the C2R evaluation discussion chapter has been moved and merged within 'results'. Also, the methods of the C2R evaluation, such as how the in-situ data have been handled [e.g. which depths, depth of the upper mixing layer, time delay between match-ups etc.] have been moved out of the chapter 'results' to a new subchapter C2R evaluation in 'methods' because several comments of referees 1 and 2 had asked for this information that had been in the manuscript text already in 'results' but obviously was not well readable and detectable. In detail:

i) moved to 'methods', new subchapter: 3.3. Match-up analyses with MERIS C2R parameters

The MERIS acquisitions on Jul 31, Aug 3-6, and Aug 10, 2010 show low cloud coverage and are close in time to the L10 ship expedition in Buor Khaya Bay that took place from Jul 29 to Aug 7, 2010. A MERIS acquisition on Sep 7, 2010 is the cloud-free acquisition closest in time to the TRANSDRIFT-XVII expedition that took part from Sep 9-20, 2010. The next usable MERIS acquisitions on Sep 18 and 20, 2010, have higher cloud coverage.

The in-situ data taken for the evaluation of the MERIS C2R parameters are averaged over the first 2 m water layer for transmissivity, cDOM, SPM and Chl-a. CTD data from L10 and the TRANSDRIFT-XVII expedition show a homogenous, mixed layer in any case within this depth. Stratification due to the riverine freshwater occurred in the Buor Khaya Bay with a sharp halocline below 5 to 8 meter in August 2010 during L10 (Kraberg et al., this volume), and below 10 m in September 2010 during TRANSDRIFT-XVII (Kassens et al. 2010).

Exact match-up analyses take the remote sensing value from the pixel location on the same day of the ship-based in-situ measurement. For the Laptev Sea region this is not feasible due to frequent cloud coverage. Match-up analyses using spatial averages of pixels could be a technical solution. However, for the Laptev Sea, the high-spatial and high-temporal horizontal heterogeneity confounds the spatially averaged match-up analyses.

Figures 2 a-c show the high spatial- and temporal variability of MERIS C2R_Z90 on Aug 3, 4, 5, 2010. For example, the L10 sampling stations 1 to 3 and 25 are of the turbid water-type with values of C2R_Z90 ~1 m on Aug 3, 2010, changing to more transparency with values of C2R_Z90 ~2 m only within 1 to 2 days due to frontal changes. The best matching coordinate pairs in time from L10 (table 2) and the TRANSDRIFT-XVII expedition (table 3) were selected for the match-up analyses.

ii) text was moved from 'discussion' to 'results', into subchapter 4.2. Evaluation of MERIS C2R parameters. The new subchapter 4.2 with the merged text sections:

The analyses of matching pairs of cloud-free pixels and L10 data covered a range of values of the optical parameters connected to turbidity within the Buor Khaya Bay, but no types of highly transparent waters such as the water types of the outer shelf system. The matching of pairs of cloud-free pixels and TRANSDRIFT-XVII expedition data cover a larger variety of optical surface water types including transparent water types of the outer shelf. The match-up analyses using SPM data show a close relationship between the optical C2R parameters connected to suspended matter (e.g., $C2R\_k_{min}$, C2R_b_tsm (scattering of TSM), C2R_Z90, C2R_TSM) although there is a temporal difference of 2 to 11 days between the in-situ sampling and the MERIS acquisition on Sep 7, 2010. Fig. 5 shows the relationship TRANSDRIFT-XVII SPM versus C2R_TSM (Sep 7, 2010).

The match-up analyses for cDOM and SPM versus C2R_kmin and C2R_Z90 show for near-coast on-shore waters that the major direct relationship exists between transmissivity and SPM. This optimal relationship (e.g., Fig. 4a, C2R_Z90 versus SPM) indicates that the turbidity/particulate matter is the dominating Ocean Colour producing aquatic component in the water-leaving spectral reflectances. The relationship C2R_Z90 versus cDOM (e.g., Fig. 4b) shows that cDOM influences the transparency parameters (C2R_kmin, C2R_Z90), but is not as dominating as SPM (Fig. 4a).

C2R_Chl-a values show a minimum of ten-fold overestimation that is the order of one magnitude. In general, calculated C2R_Chl-a concentrations in Buor Khaya Bay during the ice-free season show up to 20 to 30 $\mu g\ l^{-1}$ C2R_Chl-a for all the years 2006 to 2011. A minimum of ten-fold Chl-a overestimation that represents the order of one magnitude is also characteristic to the global standard NASA SeaWiFS and MODIS Chl-a products. As an example, we also included the match-ups of the MODIS Level3 binned Chl-a averaged product for September 2010 (9 km spatial pixel resolution) versus the TRANSDRIFT-XVII Chl-a data (Fig. 6). Fig. 7 indicates how the magnitude of cDOM concentration correspondingly influences the calculated values of MERIS C2R_Chl-a.

cDOM is underestimated as C2R_a_gelbstoff. (new figure) but we know from L8, L10 and TRANSDRIFT-XVII expedition data that high cDOM concentrations are widespread in coastal waters and on the inner shelf (table 1). The strong absorption in the visible wavelength range that occurs due to the high cDOM concentrations is operationally attributed towards high Chl-a concentration. The over-estimation of Chl-a occurs with all standard NASA and ESA processing algorithms because the standard assumption in all operational Ocean Colour algorithms contributes the main share of absorption towards the phytoplankton absorption.

iii) Referee 1 suggested adding more discussion about the Chl-a overestimation in Arctic coastal waters, therefore we merged the final general discussion statements on the evaluation and the discussion on Chl-a evaluation to a new subchapter in 'discussions': 5.1. Value and validity of Ocean Colour applications for the Siberian shelf

Ocean Colour remote sensing provides new hydrodynamic information for the shallow Siberian inner shelf waters and coastal waters. The synoptic information on re-suspension events, meandering and filamenting cannot be made visible from sampling from shipborne platforms because high-sea Arctic ship expeditions are forced to stay in deeper waters due to their draft. Even with grid sampling from shallow-water going ships it would be difficult to capture these spatial features as sampling cannot logistically be done on a small enough spatial scale. Deployment of drifting sensors could provide measurements on fronts, meanders, eddies, and filaments, but it would need several weeks for them to map the area of the Southern Laptev Sea. The highly dynamically changing spatial patterns could also not be mapped as temporal snapshots such as it is the case for successful cloud-free satellite acquisitions.

The first evaluation experiments show that the optical C2R parameters such as C2R_Z90 and concentration parameters such as C2R_TSM can be used reliably to trace the surface hydrodynamics of the Laptev Sea region. However, care must be taken when using operational Chl-a products for the Siberian inner shelf regions, the Laptev Sea and the Siberian Sea. Bio-optical measurements from Örek et al., (submitted, this volume) in the organic-rich Lena River waters in 2011 show that the specific phytoplankton absorption coefficient is around 3 times higher and more effective than the global mean. The authors discuss the difficulty of the calculation of phytoplankton from the water-leaving reflectances because phytoplankton absorption contributed < 10 % to the overall absorption. We incorporated the enhanced phytoplankton absorption capacity in the C2R processing (equation 1), however the elevated cDOM background concentrations of the innershelf still lead to a ten-fold Chl-a overestimation, We assume that due to elevated cDOM background concentrations and a very effective phytoplankton absorption due to dark waters all global ESA and NASA Chl-a products show Chl-a concentrations that are overestimated by at least a factor of 10. This regional overestimation is the hightest reported to date for Arctic coastal waters, but also the cDOM background concentrations are the highest reported for Arctic coastal waters.

Vetrov et al. (2008) reported an overestimation factor of around 5 for the Laptev Sea, however described large difficulties of match-ups in the inner-shelf due to cloudiness. It remains unclear how many and which samples were used to estimate the factor. Matsuoka et al. (2007, 2012) report that Ocean Colour Chl-a retrievals for the western Beaufort and Chukchi seas were within 25% and 30% accuracy, Wang and Cota (2003) report an overestimation factor of 1.5 for this region. For the southeastern Beaufort Sea cDOM background concentrations are higher on the inner shelf, Mustapha et al. (212) evaluated operational Chl-a products of various Ocean Colour sensors with the large in-situ data set of the Canadian Arctic Shelf Exchange Study (CASES) reporting an overestimation by a factor of three to five, the highest overestimation based on match-up analyses they found for coastal waters under a freshwater influence. Hessen et al. (2010) describe Chl-concentrations of an order of magnitude too high for Levenberg-Marquadt based processed MODIS products from summer 2003 (Pozdnyakov et al., 2005) covering the southern Kara Sea with the Ob estuary. That may technically also be due to the high concentrations of dissolved organic matter for the coastal Kara Sea waters with reported in-situ concentrations of > 5 mg l^{-1} DOC. Mustapha et al. (2012) in their study of the south-eastern Beaufort Sea also assume that the widespread higher particle background in Beaufort Sea coastal waters increase the backscattering and potentially contributes to the large overestimation of operational Chl-a products.

The focus of our application is therefore not to use the absolute parameter values but to analyse the Ocean Colour data qualitatively. In the following sections we discuss the value of the Ocean Colour visualization for several applications: i) the hydrographic pattern of meanders, eddies and filaments that indicate a wide-spread lateral advection in the sea-ice free season and ii) re-suspension zones that potentially indicate vertical transport pathways of nutrients, carbon, sediments and heat.

The new discussion sub-chapters follow: '5.2 Widespread lateral surface advection in the sea ice-free season'. The text here has not been changed and is the same as in the original manuscript, only being put separately as sub-chapter.

Wegner et al. (this volume) discuss how the freshwater from the Lena River and other Siberian rivers is wide-spread on the Laptev Sea shelf. The authors describe a SPM-enriched fresh water surface layer up to latitude of 76.8° N north of the Lena River Delta and 77.8° N on the eastern shelf due to dominating offshore winds, in September 2008, a non-normal year of anti-cyclonic atmospheric circulation pattern. Even in September 2007, in a quasi-normal year of cyclonic atmospheric circulation pattern, with dominating onshore winds and eastward, non cross-shelf transport of the riverine freshwater, the authors describe that SPM-enriched fresh water was measured up to latitude of 75° N. The authors showed that this contrasting fresh-water transport could also be made visible in the mapped MERIS C2R-parameters: In 2008, the outer shelf areas showed less transmissivity (higher C2R_k_{min}, lower C2R_Z90) compared to more transparent waters on the outer shelf in 2007 (Wegner et al., this volume).

We did not observe a well-defined Lena River plume in the distribution of C2R_a_gelbstoff and C2R_TSM ore related turbidity parameters (C2R_k_{min}, C2r_Z90). Multi-year expedition data show that the southern Laptev Sea is characterised by a wide-spread high freshwater signal and background cDOM concentrations (e.g., $a443_{cDOM}$ range in Buor Khaya Bay is 2 to 2.5 m^{-1}) and that the cDOM concentration of the Lena River in August is of the same magnitude as in the surface waters around the Lena River Delta and in Buor Khaya Bay in the August and September months. That the magnitude of concentrations is of the same order or higher in Buor Khaya Bay is also a finding related to POC, nutrients (NO3, PO4) pCO2 and oxygen saturation from multi-year expedition data (Semiletov et al., this volume, submitted).

Due to continuous cloud coverage north of 75° N at a longitude of 130° E and westwards of it, the most transparent, lowest cDOM and SPM-water type is only visible within a few small cloud-free patches in the MERIS time series. Regularly, the high gradient between high-cDOM freshwater-influenced surface waters to low-cDOM marine-background waters seems to lie northwards of the cloud-free mapped areas. However, what is still visible even under these limited conditions is that the MERIS snapshots of the outer shelf system indicate that the spatial pattern of the transparent waters and the different types of less transparent waters do outline a coastal turbid meandering zone of several 100 km. Only in the year of prevailing anti-cyclonic atmospheric circulation in 2008, this spatial pattern was partly hidden due to higher diffuse turbidity of surface waters on the outer shelf.

The horizontal meander fields and filament-fields in the Southern Laptev Sea suggest that a high frontal instability is continuously being generated. The frontal instability may be shed from the Lena River inflow and from unstable coastal currents. Meanders, filaments and eddies horizontally transport material in the surface water layer due to hydrodynamical equilibrium forces. Hydrodynamical model simulations and mooring current measurements show that these horizontal structures also provide vertical motion and indicate the vertical mixing of a surface layer (e.g., Chao and Shaw, 2002, Ralph 2002, Sutherland et al., 2011, Fong et al., 2002). Kraberg et al. (this volume) show a well-mixed fresh-water influenced upper layer of 5 to 8 m depth in the Buor Khaya Bay. The rich hydrographic spatio-temporal pattern of filament fields, meander fields and eddies suggests that they carry chemical and biological fields and could trigger a high patchiness of phytoplankton and zooplankton in the Laptev See region. Kraberg et al (this volume) discuss a high spatial heterogeneity in phytoplankton composition in August 2010 in the Buor Khaya Bay probably resulting from the out-flushing from the Lena River.

'5.3 Resuspension zones above shallows'. The text here has not been changed and is the same as in the original manuscript, only being put separately as sub-chapter.

The visualisation of resuspension events in the mapped MERIS C2R parameters highlights vertical mixing events down to the sea bottom of shallow banks in the southern Laptev Sea region. A turbidity belt around the Lena River delta is always visible. Reimnitz (2000) describes the high-latitudinal specific shallow bank around the Lena River Delta and other Arctic deltas that is most probably generated by bottom-fast ice cover. Eicken et al. (2005) describe that the presence of the wide shallow bank around the Lena River Delta is in line with the mostly extensional sea-ice regime in this area.

Several shallow banks are delineated by the 5 m, 10 m and 15 m isobaths (State Geological Map of Russian Federation, 1999) on the Laptev Sea shelf and in the western part of the East Siberian Sea shelf. Gavrilov et al. (2003) discuss that the present-day shallow banks represent former Ice-Complex islands that have been destroyed by coastal thermal erosion and thermal abrasion during the last thousand years. Gavrilov et al. (2003) cite observations made on Russian seismic expeditions during the summer months that described the local turbidity on these shallow banks (in Lisitsin et al., 2000; Dmitrenko et al., 2001).

Charkin et al. (2011) discuss that for the shallow Laptev Sea, the impacted zone by resuspension events should be on average down to the 10 m bathymetry (with an estimation of average wave height of 1 m), accounting for the only short durability of strong waves. They describe how the dominating sand to sandy silt fraction that they found on the shallows and on the shallow bank around the Lena River Delta supports the theory of vertical mixing events that bring velocity currents down to these bathymetric depths.

Vonk et al. (2012) confine a potential sedimentational regime to the shelf areas below 30 m depth, thereby excluding half of the shelf area of the Laptev Sea and Eastern Siberian shelf. Wegner et al. (this volume, submitted) discuss that sediment entrainment due to resuspension at depths around 30 m take place mainly after storm events. Their data are based on current speeds of the ANABAR mooring station (74° 30' N, 127° 20' E) in the Laptev Sea.

With minor text changes relating to specific comment # 26 of referee 1 (see below): These findings on the depth of the mixing events should be revisited and analysed in the context what resuspension events made be visible by Ocean Colour remote sensing show in terms of the depth of the mixing layer. Analysing the resuspension events related to wind strength and directions may allow to spatially distinguishing between the submarine depths of regular submarine seabed erosion and entrainment and the submarine depths where abrasion occurs only caused by strong storm events.

Referee#1

Specific comments:

1. P3850: lines 18-27: paragraph needs to be rewritten.

Abstract subchapter rewritten:

The mapped optical parameters show that the Laptev Sea is dominated by frontal meanders with amplitudes up to 30 km and eddies and filaments with diameters up to 100 km that prevail throughout the sea ice-free season. The meander crests, filaments and eddy-like structures that become visible through the mapped MERIS C2R parameters indicate enhanced horizontal transport energy for lateral advection of terrigenous and living biological matter. The mapped calculated optical parameters, such as the first attenuation depth, Z_{90}, the attenuation coefficient, k, and Suspended Particulate Matter, SPM, visualize resuspension events that occur in shallow coastal and shelf waters indicating vertical mixing events down to the sea bottom that may vertically transport nutrients and heat.

2. P3851: lines 17-18: replace sophisticated by specific. **done**

3. P3852: lines 1-10: paragraph needs to be rewritten. Too much information. C2R is well known.

We agree that the information given is detailed. However, the part of the Ocean Colour remote sensing community that is not familiar with processing on MERIS satellite data is not familiar with C2R processing either and experts from other fields are not familiar with Ocean Colour processing. We deleted too much detail:

removed: Brockmann Consult (DE), in cooperation with the Norwegian Institute for Water Research and the Canadian Institute of Ocean Sciences)

4. P3853: lines 19-20: That phrase (Elevated...) is not in the right paragraph.

removed: Elevated Pleistocene terraces without an active drainage system build up the north-western part of the Lena River Delta.

5. Replace Transdrift-XVII by T17. The same way, Lena2008-2010 could be replaced by L08 and L10.

Transdrift-XVII is replaced in diagrams by T17. Lena2008-2010 is replaced by L08 and L10 within the text and diagrams.

6. P3854: line 24: please provide a reference for the 3.5x overestimation factor.

Reference added: TRANSDRIFT report (Kassens et al.).

7. P3855: lines 1-14: Please provide more details on the analytical protocols. It seems that 2 different protocols were used for TSM. Why use 0.7 um filters for CDOM instead of the standard 0.2 um? Use of brown bottles is not prescribed by the optics protocols that prefer clear bottles. Need more detail for the Chla analysis. Was there a baseline correction for CDOM? At such high absorption values, there must be a residual signal at 650-700 nm where normally there is no absorption at all.

SPM Yes, 2 slightly different SPM protocols were used on the LENA08 expedition in 2008 and on the TRANSDRIFT expedition in 2010. It is reported in more detail.

cDOM - questions on operational filter sizes and baseline correction of absorbance spectra: Investigations of other authors (Laanen et al., Journ European Optical Society-Rapid publications, Vol 6, 2011) comparing laboratory cuvette absorption measurements with absorption measurements in a calibrated Point-Source integrating-Cavity Absorption Meter (PSICAM) found that filtration over 0.7 µm caused a systematic 8% overestimation of CDOM measured in the cuvette caused by residual scattering. By filtering over 0.2 µm CDOM cuvette values were 6% underestimated because also a significant fraction of absorption was removed from the sample. With a sample size of N = 10 we tested different filtration methods (e.g. filter sizes: 0.2, 0.45 and 0.7) with duplicates of LENA2008 samples. The magnitude of deviations between filtrates from these different filters came out to be not relevant for this study. Because dissolved and particulate phases are operationally defined and our marine DOC measurement protocols are based on 0.7 mm GF/F filtrates, we consistently use in our programs 0.7 mm GF/F filters both for DOC and cDOM to relate the same operationally defined cDOM to DOC within other projects.

No, no baseline correction using the NIR wavelength region was applied. There exists different views on baseline correction of absorbance spectra, specifically for cDOM-loaden waters where the NIR is still caused by cDOM and much less by other factors. Due to high cDOM concentrations in the Laptev Sea waters, there is still cDOM-related absorption in the NIR wavelength region and it would be wrong to assume $a_{715} = 0$ for high cDOM-loaden waters (e.g., Downing et al., Limnology and Oceanography: Methods, 7, 119-131, 2009). Although baseline offsets are assumed to be wavelength-independent, baseline corrections seem to be not yet verified, and may result in spectral changes, e.g., of the spectral slopes (e.g., Floge et al., Limnology and Oceanography: Methods, 7, 260-268, 2009).

Yes, use of brown glass bottles is not prescribed by the optics protocols. The reference of the optics protocols is not linked to this sentence. Use of brown glass bottles is reported by a variety of authors, in most of these studies this is due to samples being not processed within 1-2 days but within few weeks after the expeditions. We tested the potentially leakage of dissolved organic matter by these type of bottles in long-term laboratory experiments and this factor proved to be not relevant.

More Details on the analytical protocols were added for SPM, cDOM and Chl-a.:

The water samples on L8, L10, and TRANSDRIFT-XVII were filtered on low vacuum and prepared at site. On TRANSDRIFT-XVII 0.5 litre was filtered for SPM through preweighed 0.45 µm pore size MILLIPORE Durapore membrane filters, with the elutable portion of the used filters <0.3 mg l^{-1}. On L08, 1 litre was filtered through 0.45 µm-pore size preweighed cellulose-acetate (CA) filters for SPM. On L08 and TRANSDRIFT-XVII the filters used were oven-dried and pre-weighed (in mg). In the laboratory, SPM filters were re-dried prior to weighting under a dry atmosphere.

On L08 and L10 water was filtered through 0.7 µm-pore size glass-fibre (GF) filters with syringes for DOC and cDOM. On TRANSDRIFT-XVII a filtering device was used to filter through 0.7 µm-pore size glass-fibre (GF) filters. For cDOM and DOC filtrations on TRANSDRIFT-XVII and L08, L10, care was taken that the first 200 ml of the filtrate was discarded. Because dissolved and particulate phases are highly operationally defined and marine DOC measurement protocols are commonly based on 0.7 mm GF/F filtrates, we consistently used 0.7 mm GF/F filters both for DOC and cDOM in this study. cDOM filtrates were stored in brown quartz glass bottles cooled and in the dark and measured immediately following each expedition at the Russian-German Otto-Schmidt Laboratory (OSL) in St. Petersburg using a Specord200 (Jena Analytik). Optical Density (OD) spectra of the filtrates were measured from 300 nm to 750 nm in 1 nm steps using 5 cm and 10 cm acid cleaned quartz cuvettes on dual beam mode s, according to the absorption capacity of the samples (Ocean Optic Protocols, 2000). OD of each sample was measured 3 times against ultra-pure water that was changed every sample to not overheat the reference sample that needs the same temperature then the room-warmed sample. Absorption per m was calculated based on the averaged OD value of each sample using $2.303 \times OD/ 0.1$ for the 10 cm-cuvette, and $2.303 \times OD/ 0.05$ for the 5 cm-cuvette, respectively.

The spectrophotometrically measured cDOM absorption correlated well with the in-situ cDOM fluorescence (Quinine Sulphate Dihydrate units) measured with WETSTAR (R^2=0,94), demonstrating the instrument's good performance in the waters of the Laptev Sea. Because the spectro-photometrically measured cDOM absorption values covered more sampling stations, the data analyses presented in this paper used the spectrophotometrical cDOM data. The vertical fluorescence-based cDOM profiles could be used to assess the shape of the vertical distribution and confirm the mixing depth of constituents within the upper mixed layer.

Detailed Chl-a protocol and also explanations referring to

15. P3859: lines 20-29: There is no comparison between fluorimetry and fluorescence data to show if they are similar. The authors use a mix of both without proving they carry the same information. No real discussion about the vertical structure.

On TRANSDRIFT-XVII 1 l water was filtrated for Chl-a through 0.7 µm pore size Whatman GF filters with a pressure of not more than 0.2 bar. The Chl-a filters were immediately frozen on site. Chl-a from the filters was measured at the OSL in St. Petersburg (RU) using a TD-700 fluorimeter using the U.S. Environmental Protection Agency Method 445.0 (Rev. 1.2) for determination of Chl-a by fluorescence. As we focus on the Chl-a concentration the non-acidification technique for extracted Chl-a analysis was used. According to previous work (Kassens et al., 2010) the WETlabs in-situ Chl-a fluorescence (mg m^{-3}) shows an overestimation of a factor of 3.5 compared to in-situ Chl-a by direct sampling and is accordingly corrected by this factor. The Chl-a data analyses carried out within this study are based on the fluorimetric Chl-a analyses, the Chla-fluorescence profile data were used to assess the shape of the vertical profile.

8. Tables 1 and 2 are not useful. **Rows that did not contain match-up data were removed. The tables now give optically a better overview on the data used**.

9. P3855: lines 17-19: that phrase about MODIS is not useful.

The MODIS missions are the currently most important Ocean Colour colour missions, also MODIS Chl-a is discussed and presented in this paper. We included 'the most important'

The two Moderate Resolution Imaging Spectroradiometer (MODIS) missions on the platforms TERRA and AQUA are currently **the most important** operating Ocean Colour missions (http://modis.gsfc.nasa.gov/).

10. P3856: lines 11-23: C2R products are well known. That paragraph is way too long for nothing.

removed: The three optical components calculated for the MERIS band 2 (central wavelength at 443 nm): absorption of phytoplankton pigments (C2R a pig); scattering of all particles b tsm, (C2R TSM); and absorption of dissolved organic material (C2R a gelbstoff) form the basis for calculating the concentrations. Chl *a* concentration is determined from an empirically derived relationship between absorption (a pig) and Chl *a* concentration, and the dry weight of TSM from its empirically derived relationship with b tsm, equals the operational parameter SPM with mgL−1 a gelbstoff, absorption of gelbstoff at 442.5nm equals cDOM absorption (Doerffer and Schiller, 2007, 2008).

11. The next paragraph is also too complex for nothing. Please just state the parameters used in you study. and 12. P3857: lines 20-24. Not really useful

Here paragraphs were removed:

removed: 'The properties of Beer's Law describe that each dimensionless unit of optical depth corresponds exponentially to a reduction of the intensity to e^{-1} or ~37 % of its initial value. The vertical attenuation of sun light with depth can be described by the exponential equation, where the coefficient k is called the attenuation coefficient and is measured in m^{-1}. The vertical downwelling diffuse attenuation coefficient is an apparent optical property depending on the irradiance distribution at the time and point of measurement.'

…' $Z_{90}(\lambda) = \frac{2.3}{2K_d(\lambda)}$,m'

all described parameters were used in this study: C2R k_min, Z_{90}, Z_{Eu}

13. P3858: Section 4.1 results should be presented in a table and possibly with maps. The description of the spatial variability is very hard to understand. The whole section is hard to read with the presentation of the results moving from place to place and between the different cruises. It is really hard to get a sense of the parameters variability. I suggest the use of sub-sections for CDOM, chla and TSM and figures to show the results. Also, I don't understand why the authors speak about the data from the CDOM sensor. This is not important at all and should be discarded.

The chapter 'results' was structured into sub-sections. Care was taken to follow a more similar and consistent description for the different parameters. For most of parameters we could distinguish near-shore, on-shore, offshore waters – Buor Khaya Bay, mid- to outershelf offshore waters (description in the text). We do not show spatially extrapolated maps of field parameters because the spatial extrapolation based on samples aligned in transects cannot capture and visualize the high spatial heterogeneity of fronts and meanders and local points of anomalies that exist and are made visible in the Ocean Colour satellite data. A new table 1 was added with ranges of optically visible water constituents for near-shore, on-shore and offshore waters. Figures 1 a and b provide an overview on the transects and station numbers.

The vertical Chl-a and cDOM profiles could be used to assess the shape of the vertical distribution in high resolution and confirm the mixing depth of constituents within the upper mixed layer. Respective explanations were added in the text in the chapter 'methods'.

Newly structured text with more details and the same text content as in the original manuscript:

4.1.1 Transparency

The investigated near shore and onshore water types (up to 2 to ~8 m water depth) around the Lena river delta and in the Buor Khaya Bay were characterized by low transparencies (table 1). Lena river and near shore waters in 2008 and 2010 had high turbidity, with in-situ Secchi depths of less than 0.5 m. Onshore waters in the Buor Khaya Bay showed in-situ Secchi depths of 1 to 1.5 meters in 2008, and measured transmissivity ranging from 60 to 75 % in 2010. Offshore waters (>8 m water depth) had in-situ Secchi depths of up to 2 meters in 2008.

4.1.2 cDOM

In summary, cDOM background concentrations were high, including in the surface water layer of the stratified off-shore waters and connected to the freshwater signal. The cDOM concentration of the Lena River in August 2008, and August 2010 was of the same magnitude as the cDOM concentrations of the coastal waters y in August 2008, August 2010, and September 2010. Measured cDOM values in riverine waters and in the surface waters of the Buor Khaya Bay on L08 and L10 were of high magnitudes during the summers 2008 and 2010. Ranges for the absorption of cDOM at 443 nm, $a443_{cDOM}$, were: Lena River, $a443_{cDOM}$: 1.3-3.5 m^{-1}; mixed onshore waters, $a443_{cDOM}$: 2.5-4 m^{-1}; offshore waters (stratified waters, >8 m water depth), $a443_{cDOM}$: 2-3 m^{-1}, coastal waters close to melt water outflows of the permafrost coast showed the highest $a443_{cDOM}$ values: 3-7 m^{-1} (table 1).

The TRANSDRIFT-XVII samples in Sep 2010 also show the elevated surface water cDOM concentrations in onshore and offshore inner shelf waters. The range of cDOM concentrations of the TRANSDRIFT-XVII transect going northwards through the Buor Khaya Bay were 2.2 m^{-1} and 1.5 m^{-1} (samples 1-3, 5- 6). More than 100 km north of the Lena River Delta along the east-west transect, high cDOM concentrations of 1.2 m^{-1} were still encountered (samples 8-17). The mid-shelf to outer-shelf transects had background concentrations of 0.4-0.6 m^{-1}. A cDOM maximum of 1.7 m^{-1} occurred north of the New Siberian Islands (sample 19) (table 1).

The cDOM results, both spectrometrically measured and by fluorescence, showed a nearly conservative mixing within a wide salinity range (0-32) (Loginova et al. 2011). **Fig. new shows the largely conservative distribution of the spectroradiometrically measured cDOM along the salinity gradient. A conservative mixing of riverine DOC for the Laptev Sea has been reported e.g., in Kattner et al. (1999), Lobbes et al. (2000), Semiletov et al. (2011), Semiletov et al. (this volume, submitted). This new figure displaying the relationship cDOM versus salinity and text was added referring to**

14. P3858: line 25. The authors should present the mixing relationship and compare it with other published results on the subject.

4.1.3 SPM

TRANSDRIFT-XVII SPM ranges in 2010 showed SPM concentrations within the first 2 meters between 0.5 and 1 mg l^{-1}. on the mid- and outer shelf together with marine salinities of 32. and 1.5 to 2 mg l^{-1} in Buor Khaya Bay (samples 1-3) with peaks of SPM concentrations of 5 to 6 mg l^{-1} further north (samples 4, 10, 16). L08 SPM ranges showed a value range of 5 to 12 mg l^{-1} for near-shore and onshore waters.

The Lena freshwater influence is found widespread in coastal waters and on the inner shelf: low salinites with a wide value range of SPM occur (Lena river waters, near-shore and on-shore waters of Buorkhaya Bay (table 1). Within the turbid surface water layer the SPM concentrations varied between 1 mg l^{-1} at the front between the river-dominated and shelf waters and up to 18 mg l^{-1} near the Lena Delta.

4.1.4 Phytoplankton

Investigations on phytoplankton (filter and in-situ fluorescence-derived Chl-a) of multi-year TRANSDRIFT expedition data always report low to medium Chl-a concentrations in surface waters from onshore to offshore waters. In 2010, the concentrations of TRANSDRIFT-XVII Chl-a were from 1.9 µg l^{-1} to 2.5 µg l^{-1} Chl-a in the Buor Khaya Bay (samples 1-3) and strongly connected to the freshwater signal. The thickness of the mixed layer in the Buor Khaya Bay at the time of sampling was about 12 m with a temperature of 7.8° C. The east-west transect north of the Lena River Delta (samples 8-17) showed transitional hydrological values with temperatures around 3° C, an averaged salinity of 22.6 and about 1 µg l^{-1} Chl-a at most stations. An exceptionally high Chl-a concentration occurred at station 12 (128° E, 74.20° N) with a maximum value of 8 µg l^{-1}. In the outer shelf waters Chl-a concentrations of the surface layer fluctuated around 0.5 µg l^{-1} Chl-a. An area of elevated Chl-a concentrations in surface waters of the outer shelf had concentrations of 1.5 to 2 µg l^{-1} Chl-a (samples 30-34) in marine waters of 32 salinity (table 1).

15 P3859: lines 20-29: There is no comparison between fluorimetry and fluorescence data to show if they are similar. The authors use a mix of both without proving they carry the same information. No real discussion about the vertical structure.

Explanation is included in reply to specific comment 7 (see above)

16. P3861: line 29: The exact overestimation is easy to calculate and should be provided instead of the 'one order of magnitude' estimate.

We added within the text in the respective sentences: ‘a minimum of a ten-fold overestimation of Chl a, that is of the order of one magnitude’ **and also** ‘a Chl-a overestimation of the factor 10 that is of the order of one magnitude’.

17. Captions for figure 1a and 1b should be merged together. 18. Idem for captions of figure 4a and b. **done**

19. What does represent the line on figure 6? **line removed**

20. Figures 2 and 8 are too small to be useful. **We assessed the readability of the figures with colleagues and got positive feedback for Figures 2 and 8. We can enlarge the number figure of the sampling stations in Figure 2.**

21. Page 3865: line 20: It is surprising that C2R does not produce better results than empirical algorithms. This should be discussed. and 22. Discussion: the discussion of C2R evaluation lacks comparisons with other environments to better represent the Laptev Sea particularities.

There are no such dark coastal and inner shelf waters elsewhere where the C2R algorithm has been applied. C2R has been trained on neuronal networks based on bio-optical coefficients from coastal waters of the North Sea that do not include these extreme absorption values, these dark absorbing coastal and inner-shelf waters of the Laptev Sea are not comparable to the North Sea Trained neuronal networks. Currently new training of neuronal networks incorporating the new coefficients derived from the LENA2011 expedition (Örek et al., submitted, this volume) is on the way, but is not yet part of the official C2R processing installed within BEAM VISAT.

Örek et al., (submitted, this volume) are discussing the technical limitations of deriving Chl-a if phytoplankton is only contributing to 10 % of the total absorption they measured. This has been referred to in the original text and discussion on it is expanded in the subchapter 'discussions: 5.1. Value and validity of Ocean Colour applications for the Siberian shelf'

with new references to several bio-optical investigations in Arctic coastal and shelf waters (Western Beaufort Sea, Chukchi Sea, Eastern Beaufort Sea). See new references below, also from the newly released Special BG - Special Issue 'How changes in ice cover, permafrost and UV radiation impact on biodiversity and biogeochemical fluxes in the Arctic Ocean–The Malina project.' Editor(s): M. Babin, S. Belanger, W. Li, W. Miller, P. Wassmann, and E. Boss.

23. Page 3866, lines 4-10: I do not see the utility to present the results from the Kara Sea. The whole paragraph needs to be rewritten to present the overestimation problem in arctic coastal seas.

The whole paragraph has been rewritten and restructured in the subchapter 'discussions: 5.1. Value and validity of Ocean Colour applications for the Siberian shelf' (see above).

24. There are mistakes with the years of some references. **checked**

25. Page 3869: line 4. Is it 'bench' or 'bank' or 'beach'? **we homogenized all related sentences with choosing 'bank', also the term 'shallows' is used. The term 'bank' is specifically used to describe the surrounding shallow area around the Lena River Delta that is referred to in literature as 'bench'. The term 'beach' was never mentioned in the original text because we are referring to submarine banks, 'shallows'.**

26. Page 3869: I am not sure last 2 paragraphs are necessary. They should at least be modified to be smaller in length.

removed (last paragraph): 'To further understand the processes of deposition of terrestrial material on the Laptev Sea and Eastern Siberian shelf regions the Ocean Colour remote sensing may provide the information on hydrodynamic structures during the ice-free season.'

The last sentence (last paragraph) **was edited so that the purpose of describing the different literature sources dealing with the mixing depth in the Laptev Sea is now clearer:** 'These findings on the depth of the mixing events should be revisited and analysed in the context what resuspension events made be visible by Ocean Colour remote sensing show in terms of the depth of the mixing layer. Analysing the resuspension events related to wind strength and directions may allow to spatially distinguish between the submarine depths of regular submarine seabed erosion and entrainment and the submarine depths where abrasion occurs only caused by strong storm events.'

27. Page 3870: lines 15-18. Is it really necessary to speak about bottom transport?

The main known transport pathways of terrestrial material in the Laptev Sea system are the bottom transport and the transport via sea ice.

in Conclusions: 'The spatio-temporal patterns of the Ocean Colour parameters indicate a strong potential for lateral advection of terrestrial (dissolved and fine particulates) and living biological material during the ice-free season. This is a new finding that strong lateral advections may occur in summer in the surface layer. Up to today, the recognized horizontal transport pathways in the Laptev Sea are known to function by transport within and on the sea-ice (Eicken et al., 1997, 2000) and via the bottom nepheolid layer (Wegner et al., 2003, 2005).'

28. Page 3871: The conclusion should be rewritten to concentrate on results and future work that would be needed to improve the results.

The conclusions have been rewritten to improve the readability and are more precise. Future work needed to improve the results would need to come from large bio-optical campaigns in the coastal and inner shelf waters of the Laptev Sea and Siberian sea comparable to the MALINA program in the Beaufort Sea (CA) or the Norwegian bio-optical ship-based expedition programs. A technical limitation is also the very shallow depth of the Siberian shelf system that limits the use of ocean-going expedition vessels.

7 Conclusions

During the ice-free season, the Lena River flows out in coastal and shelf waters of similar or even higher concentrations of SPM and cDOM. For SPM this is due to re-suspension events of the shallow bank around the Lena River delta and on the numerous shallows of the shallow Laptev Sea bathymetry. The expedition data show that high cDOM concentrations are distributed throughout Buor Khaya Bay and in the coastal and inner shelf waters northeast of the Lena River Delta. Care must be taken when using Ocean-Colour derived Chl-a concentrations that are highly overestimated by a factor of ten due to the elevated cDOM, resulting in the highest Chl-a overestimation reported for Arctic coastal waters.

The spatio-temporal patterns of the Ocean Colour parameters indicate a strong potential for lateral advection of terrestrial (dissolved and fine particulates) and living biological material during the ice-free season. This is a new finding that strong lateral advection may occur in the surface layer in summer. To date, the recognized horizontal transport pathways in the Laptev Sea are known to function by transport within and on the sea-ice (Eicken et al., 1997, 2000) and via the bottom nepheloid layer (Wegner et al., 2003, 2005). The frontal meanders, filaments and eddies revealed by the Ocean Colour parameters may also explain the high heterogeneity of coastal phytoplankton communities (e.g. Kraberg et al., this volume).

The frontal meanders, filaments and eddies indicate frontal instabilities, and enhanced vertical mixing forces. This is an important result as it shows potential vertical pathways for downward and upward transport of material. Resuspension events that were made visible in the Ocean Colour parameters show that the shallow regions, specifically the shallow bank around the Lena River, but also the wide-spread submarine shallows are regularly influenced by resuspension that indicates vertical mixing.

29. I am not sure the results really explain the heterogeneity of zooplankton.

Frontal zones are blockades for the lateral transport of living material.

30. Page 3872: line 15: The Envisat project is acknowledged twice. **removed**

New references, revised manuscript:

Kattner, G., Lobbes, J.M., Fitznar, H.P., Engbroth, R., Nöthig, E.-M., Lara, R.J., 1999. Tracing dissolved organic substances and nutrients from the Lena River through the Laptev Sea, Arctic. Mar. Chem. 65, 25-39.

Matsuoka, A., Huot, Y., Shimada, K., Saitoh, S., and Babin, M., 2007. Bio-optical characteristics of the Western Arctic Ocean: implications for ocean color algorithms, Can. J. Remote Sen., 33, 503–518.

Matsuoka, A., Bricaud, A., Benner, R., Para, J., Sempere, R., Prieur, L., Belanger, S., and Babin, M., 2012. Tracing the transport of colored dissolved organic matter in water masses of the Southern Beaufort Sea: relationship with hydrographic characteristics, Biogeosciences, 9, 925–940.

Matsuoka, A., Huot, Y., Shimada, K., Saitoh, S., and Babin, M. 2012. Bio-optical characteristics of the Western Arctic Ocean: Implications for ocean color algorithms, Can. J. Remote Sen., 33, 503–518.

Mustapha, S.B., Belanger, S. and Larouche, P., 2012. Evaluation of ocean color algorithms in the southeastern Beaufort Sea, Canadian Arctic: New parameterization using SeaWiFS, MODIS, and MERIS spectral bands. Can. J. Remote Sen., 38, 5, 535- 556.

Vetrov, E.A., Romankevich, E.A., and Belyaev, N.A., 2008. Chlorophyll, primary production, fluxes, and balance of organic carbon in the Laptev Sea. Geochemistry International, 46, 1055- 1063.

Wang, J. and G.F. Cota, 2003. Remote sensing reflectance in the Beaufort and Chukchi Seas: Observations and models. Appl. Optics, 42, 2754-2765.