

The handling editor, Ocean Sciences

Dear Editor:

We appreciate the overall positive appraisal and the detailed and insightful comments of the two reviewers on our manuscript “*DOM and its optical characteristics in the Laptev and East Siberian seas: Spatial distribution and inter-annual variability (2003-2011)*” by Svetlana P. Pugach et al.” (manuscript ID OS-2017-20). Their constructive reviews and suggestions have contributed to further improve the paper during our revisions. All referee comments and our responses, as well as the resulting edits, are detailed below including a point-by-point response to the reviews, a list of all relevant changes made in the manuscript, and a marked-up manuscript version.

Our first intention was to separate “Results” and “Discussion”. However, in the final stage writing this paper we found that is more effective to join that, because of complexity of achieved results: from the role of hydrometeorological situation to the spatial-time variability of the DOC/CDOM and its optical characteristics. In the revised manuscript, the item “Results and Discussion” was significantly modified.

It contains now the following sub-items:

- 4.1 Hydrometeorological situation and CDOM spatial variability
- 4.2 Spatial variability of CDOM spectral characteristics
- 4.3 Optical characteristics of the ESAS biogeochemical provinces
- 4.4 Rapid assessment of dissolved organic carbon based on optical characteristics of dissolved organic matter.

A more comprehensive data analysis and more detailed discussion is now fortified, for instance, by five new figures and associated discussion, a few figures were modified, the fragment related with a goal and objectives, as well as conclusions was rewritten accordingly.

We very hope that the final version of our manuscript fits well to the high standards of the *Ocean Sciences*.

Thank you very much for your consideration,

Svetlana Pugach,
on behalf of all co-authors

Author responses to reviews, and edits to manuscript number OS-2017-20 "DOM and its optical characteristics in the Laptev and East Siberian seas: Spatial distribution and inter-annual variability (2003-2011)" by Svetlana P. Pugach, Irina I. Pipko, Natalia E. Shakhova, Evgeny A. Shirshin, Irina V. Perminova, Örjan Gustafsson, Valery G. Bondur, Alexey S. Ruban, and Igor P. Semiletov.

Anonymous Referee #1

General Comments:

In the manuscript entitled "DOM and its optical characteristics in the Laptev and East Siberian seas: Spatial distribution and inter-annual variability (2003-2011)" the authors describe the dominant factors which control the distribution of dissolved organic matter (DOM) in the Siberian shelf seas. On the basis of a data set of several years the authors also try to explain the reason for the observed year-to-year variability of the DOM distribution. A further focus of the work is on the estimation of the utility of in situ fluorescence measurement.

Basically, the article describes phenomena that have been already investigated and published by other authors, i.e.: - The atmospheric forcing of the Lena freshwater plume - and thus the associated high content of terrestrial DOM (for example: Dmitrenko et al., 2005, Wind-driven surface hydrography of the eastern Siberian shelf, doi:10.1029/2005GL023022).- The geochemical behavior of DOM on the Laptev and East Siberian Seas (for example: Alling et al., 2010, cited in the manuscript) - The usefulness of in situ fluorescence measurements for the investigation of DOM in the East Siberian and Laptev Seas (Belzile et al., 2004; cited in the manuscript). Actually, some of the co-authors of this manuscript were also co-authors of the study published by Belzile. Because both studies are based on samples from the same region and the same year, the question is whether it is the same set of samples? What is the main difference to the work of Belzile et al.?

Thank you for your careful consideration of our results. Indeed, N. Shakhova and I. Semiletov co-authored paper by Belzile et al. (2006) which is based on a very limited data set (14 stations, number of samples = 23) obtained on one single cruise in 2004 in a limited nearshore zone of only the East Siberian Sea (not Laptev Sea). In contrast, the current paper is based on four much longer expeditions, with orders of magnitude more observations over much greater spatial scales, and using more techniques/parameters. The results of the early/pioneering but limited study of Belzile et al. (2006) indeed gave some indications that estimates of dissolved absorption may be obtained from CDOM measured in situ on unfiltered samples, but that work did not at all study the relationship between DOC and CDOM concentrations.

*The current paper contributes much novel data and interpretations/insights relative to Belzile et al., 2006; Dmitrenko et al., 2005 (**no optical data at all**), and Alling et al., 2010 (**very limited optical data used only as ancillary information**). For instance, the utility of high-resolution CDOM (> 1750 measurements made only in 2008) and at 286 different stations for biogeochemical studies is assessed by in situ multi-year data obtained in the two very different regimes of the East Siberian Sea, and the Laptev Sea. The spectral characteristics of CDOM and salinity in different East Siberian Arctic Shelf (ESAS) areas (obtained during the 2004, 2005, and 2011 surveys) were used to separate the ESAS into western and eastern biogeochemical provinces (Table 2). Moreover, based on the approach described by Weishaar et al., (2003), specific UV absorbance (SUVA) - defined as the UV absorbance of a water sample at 254 nm normalized for DOC concentration, was used to estimate the degree of aromaticity in bulk CDOM. For the first time, CDOM/DOC interannual variability in connection with atmospheric pressure fields and dynamics/wind-driven water circulation is considered in our paper. Taken together, the current paper, relative to earlier studies focusing on hydrology and bulk DOC distribution, focuses on DOM dynamics and its optical properties and thereby provides new insight in biogeochemical processes in the ESAS - the broadest and shallowest shelf in the World Ocean.*

In general, it is hard for me to recognize on which data set the analysis is based on. According to Table 1, CDOM (for absorbance measurement) was sampled on 245 stations, but in Table 2 (statistics)

the number of samples (N) is 90. Also Figure 2a and 5 give no explanation because the gridded maps do not show the sampling locations for CDOM. Figure 9 (DOC) only shows ~19 sampling locations. This makes it difficult to follow the study's line of argumentation - at least for me. In my opinion, the presentation of the data has to be revised.

We agree that clarity on these aspects may be improved. The number of samples used in the Table 2 was determined by the number of spectral characteristic measurements (Table 1). The sampling locations for CDOM were given in Figure 2b. In the current Figure 10a we showed only 19 sampling locations because at these sites salinity was < 24.5 psu (the total number of the DOC measurements is 20); it is explained in ms that in areas with higher salinity, the correlation between CDOM and DOC is breaking down.

The authors distinguish a western biogeochemical province from an eastern province and state that the CDOM concentration is high near the Lena Delta and low in the eastern East Siberian Sea, a region that is less influenced by riverine freshwater. They also found a strong negative correlation between the CDOM absorption and the salinity and concluded that the CDOM is mainly of terrestrial origin. For the Arctic Ocean, this is a well-documented hypothesis (see the work of R. Amon, C. Stedmon; M. Granskog and many others). Unfortunately, no figures were presented to show the correlation between salinity and CDOM. In my opinion, we are not dealing here with different biogeochemical regimes but with differences in the hydrography and spatial expansion of the region of freshwater influence (ROFI) driven by atmospheric forcing. The conclusion that "the atmospheric circulation regime is the dominant factor controlling CDOM spatial distribution" is therefore somewhat misleading. Are the geochemical processes fundamentally different within and outside of the ROFI? This point needs to be discussed in much greater detail.

Thank you for this comment, which helps to improve our manuscript. In this paper, we don't pretend to be the first who predicted a strong negative correlation between the CDOM absorption and the salinity and concluded that the CDOM is mainly of terrestrial origin. Our objective is to deliver to scientific community our unique multi-year CDOM data sets obtained in the poorly explored shallow ESAS. As requested, a new (Figure 3) was presented to show the correlation between salinity and CDOM.

Concerning the comment: "we are not dealing here with different biogeochemical regimes but with differences in the hydrography and spatial expansion of the region of freshwater influence (ROFI) driven by atmospheric forcing", we give our explanation showing that there are no contradiction between reviewer's 1 and our understanding for such a matter. We use an approach described by Semiletov et al., 2005 and Pipko et al., 2005, which shows that based on distribution of the hydrological (and hydrochemical data), two biogeochemical provinces (areas) were identified in the shallow ESAS: a western area (heterotrophic biogeochemical province) that is influenced strongly by freshwater flux and particulate material transport of the coastal eroded material enriched by organic carbon, and an eastern area (autotrophic) which is under the influence of highly productive Pacific-derived waters. From year to year, depending from dominated wind-regimes, the longitudinal shift of the boundary between western and eastern areas may reach 10 degrees and more. In this paper, in addition to hydrological and hydrochemical data, the CDOM and its spectral characteristics were applied to identify different biogeochemical provinces in the surveyed area. (New section 4.3).

Specific and technical comments:

- Are the DOM data accessible? - Please indicate the sampling locations in the figures.

The sampling locations were shown in Figure 2. DOM and all data will be made publicly available at the open-access Stockholm University Bolin Centre Database (<http://bolin.su.se/data/>), once the manuscript is published.

- I guess you used the DIVA tool (ODV) for the spatial gridding. I believe the interpretation of data can be misleading if a spatial interpolation that is based on 17 sampling locations covers an area of approx. 500.000 square kilometers (Figure 9.). The DIVA interpolation gives DOC and CDOM

concentrations ~400 km north of the last sampling location. I would like to suggest to redraw all figures and to show the original data (e.g. as colored dots) instead of the interpolated data.

To avoid any misinterpretation, the Figure 9 was redrawn as shown below. In the upper row-left, original DOC data are presented as colored dots, in the upper row-right, calculated DOC values are shown as colored dots. In the lower row, the same values, but used ODV for the spatial gridding, are presented. We can find a good visual agreement between interpolated original and calculated DOC distribution. So, we slightly changed the Figure 9 (Figure 10 in the revised ms).

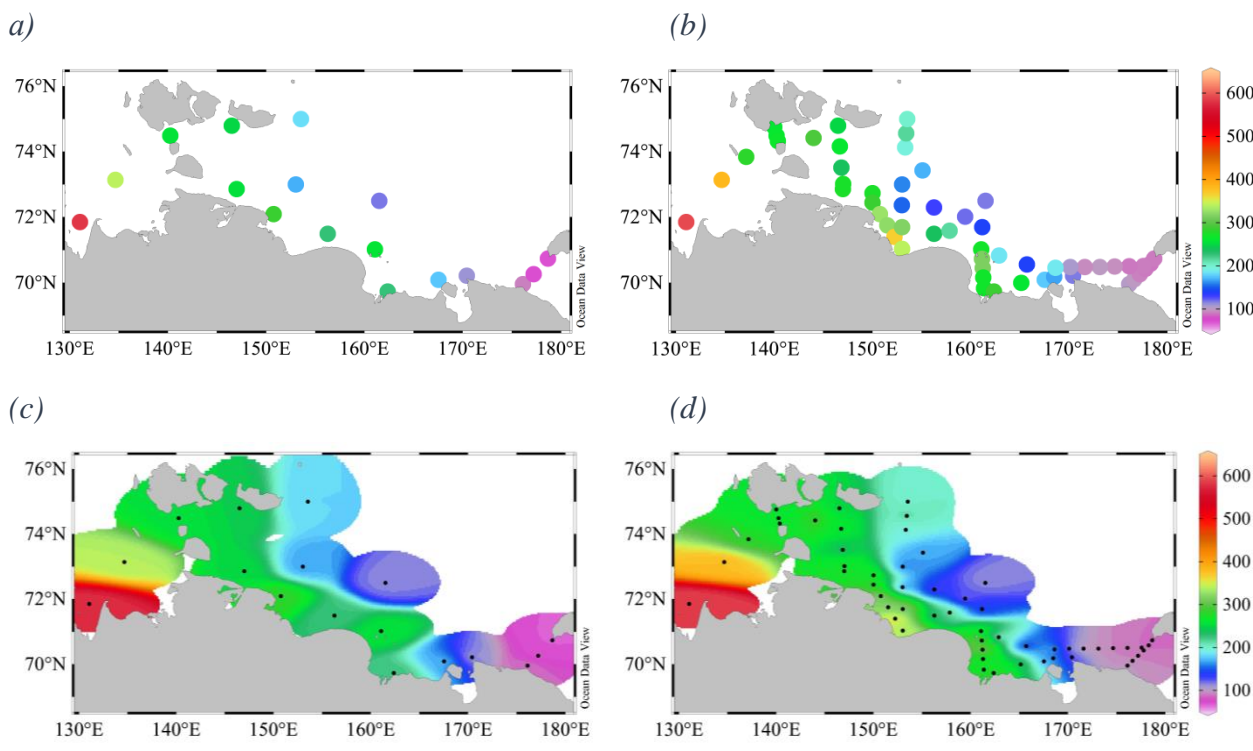


Figure 9. DOC distribution in the ESAS surface waters in September 2004. Upper panels, data presented as colored dots: (a) measured DOC data, (b) DOC data, calculated from CDOM. Low panels, interpolated data: (c) measured DOC data, (d) DOC data, calculated from CDOM.

- Samples were taken from a “seawater intake system” that pumped the water into a 300 l barrel. Have you measured the salinity directly in the sample, or did you use the salinity data from the Seabird CTD?

The inlet of the ship was at 4m water depth. If you have taken the salinity data from the CTD, which depth have you chosen?

We have measured the salinity directly in the barrel using a secondary CTD Seabird 19+ equipped with the WetStar CDOM sensor and fully immersed in the barrel. “In-barrel” salinity data agreed well with the salinity data measured at stations at depth ~4m using the regular NISKIN Rosette CTD. This information was explicitly added to the revised ms (Lines 120-125).

- Please do not use acronyms in the heading of the manuscript

Agree. Fixed.

- Page 3 line 147: I guess 0.7 μm is the correct nominal pore size of the filters.

Thank you. It was our typo. This sentence was rewritten as following: “Water samples underwent filtration through acid-washed Whatman glass fiber filters (GF/F, nominal pore size 0.7 μm)” (Lines 138-139).

- Is figure 3 really necessary? What does it tell about the CDOM distribution?

We think that for the scientific community and further investigations it would be useful to represent in Figure 3 (Figure 5 in the revised ms) the surface CDOM absorption coefficient spectra a_λ obtained for three distinct sites located in contrasting hydrological and biogeochemical conditions.

- Figure 4: Wouldn't it be better to show the relation between aromaticity and salinity instead of longitude?

The relation between aromaticity and salinity is now presented in a new Figure 6.

- English is not my first language, but I believe the text needs a linguistic revision.

The final version of our manuscript was edited by a professional English native editor.

Anonymous Referee #2

Review of Svetlana et al DOM and its optical characteristics in the Laptev and East Siberian seas: Spatial distribution and inter-annual variability (2003-2011). The manuscript has the aims of reporting on the inter-annual variability in CDOM and DOC in the Laptev and East Siberian sea. It reads very much like a cruise report and would benefit from a more comprehensive data analysis and discussion of the results obtained.

Thank you for all your comments, which helped us to improve our manuscript further.

While we respectfully disagree that our manuscript is “like a cruise report”, we recognize there is indeed several aspects that we can improve. A more comprehensive data analysis and more detailed discussion is now fortified, for instance, by five new figures and associated discussion:

*- **Figure 3.** The relationship between the salinity and CDOM (QSU) in the ESAS surface water in August-September 2003, 2004, 2005, 2008, and 2011 (blue circles – salinity < 24.5, red - > 24.5);*

*- **Figure 4.** Depth profiles of salinity (a) and CDOM (b) measured at two stations on the ESAS, and (c) relationship between CDOM and salinity;*

*- **Figure 6.** The relationship between CDOM absorption coefficient at the 350 nm wavelength (a_{350} , m^{-1}), S_R and the aromatic carbon content (C_{Ar} , %) and salinity in the ESAS surface waters, September 2004 (a), 2005 (b), and 2011 (c);*

*- **Figure 7.** The relationship between the dissolved lignin concentrations ($TDLP_9$, $nmol L^{-1}$) and salinity in the ESAS surface waters, September 2004 (a), 2005 (b), and 2011 (c), where r_W , r_E represent correlation coefficients between $TDLP_9$ and salinity for western and eastern parts of the ESAS, respectively, for these three years combined;*

*- **Figure 8.** Correlation between CDOM (QSU) and absorption coefficient at 350 nm (a_{350} , m^{-1}) in ESAS surface water (a) and relationship between CDOM (QSU) and absorption coefficient at 370 nm (a_{370} , m^{-1}) (b), September 2004. Grey – our data in the Laptev Sea ($N = 23$), green – our data in the East Siberian Sea ($N = 69$), and red – data from Belzile et al., 2006 ($N = 23$).*

Additionally, a few figures were modified (Figures 1, 2, 9 in the revised ms). The structure of the revised manuscript was significantly modified.

The referencing of previous literature is suboptimal and at times inappropriate. In my opinion there is a missed opportunity for a solid analysis on the linkage between CDOM absorption, fluorescence and DOC across several years.

The referencing of previous literature has now been carefully reconsidered and complemented by several additional references.

The linkage between CDOM absorption, fluorescence and DOC was considered in detail only for summer 2004, because only this year all these parameters were investigated simultaneously.

Why not take more inspiration from the Belzile paper cited and include a comparison of your data with theirs from the East Siberian sea? Does the same FDOM to CDOM relationship exist?

In the revised ms, we have now compared the relationship between FDOM and absorption coefficient at 370 nm (a_{370}), which quantify CDOM, using the 2004 East Siberian Sea' data reported by Belzile et al. (2006) and our data obtained in both the Laptev and East Siberian seas. Figure 8 demonstrates a good agreement between Belzile's and our data. Correlation coefficient between FDOM and CDOM - in terms of a_{370} , have been found the same in the ESAS ($r=0.97$, $N=92$) and Belzile's samples (Boothbay Harbor, West Harbor Pond, Beaufort Sea and East Siberian Sea): ($r=0.98$, $N=74$).

Highest values of FDOM and a_{370} can be seen in the Laptev Sea (marked as grey circles) which is strongly impacted by the Lena River runoff.

The section on the inter-annual variability is difficult for the reader to follow as is. It would likely

be easier if figure 5 and 6 were combined so that the sea level pressure maps could be compared with the CDOM and salinity distribution maps. Alternatively, the authors could just compare the maps of both salinity and SLP, then in a separate figure reveal how robust the salinity CDOM relationship was. In this form the manuscript is not suitable for publication and I recommend re-submission after revising the data analysis.

As espoused above and further below, the ms is significantly revised to further the data analysis and interpretations. We combined Figures 5 and 6 according to the comment (Figure 2 in the revised ms).

Whilst doing this you should consider splitting the results and discussion sections to allow for a better separation between your results and reflections on how your findings link to other studies.

Our first intention was to separate “Results” and “Discussion”. However, in the final stage writing this paper we found that is more effective to join that, because of complexity of achieved results: from the role of hydrometeorological situation to the spatial-time variability of the DOC/CDOM and its optical characteristics.

Other points to address:

Line 8. “amount” rather than “volume”.

Corrected.

Line 21. Replace “were” with “was”

Try to avoid use of “e.g.” in referencing and citing very many studies. Find the most relevant and limit it to 3-4.

Agree. Corrected/adjusted throughout the ms.

Line 46. Replace “gives input” with “supplies”.

Corrected.

Line 50-51. I suggest you specify this more. Many rivers and streams have high or higher DOC but few large rivers have concentrations this high at their mouth.

This part of the Introduction was rewritten as:

“Annually, the Arctic rivers transport 25-36 Tg of DOC to the Arctic Ocean, which is ~10 % of the global riverine DOC discharge (Raymond et al., 2007). Siberian rivers are high in DOC, with a mean concentration of more than 500 μM (Gordeev et al., 1996; McClelland et al., 2012; Amon et al., 2012). These concentrations are an order of magnitude higher than in the inflowing Atlantic (60 μM) and Pacific (70 μM) waters, but the volume flux of the two oceans is about 60 times larger than that of continental runoff (Anderson and Amon, 2015). Furthermore, Arctic and subarctic regions contain approximately 50 % of the global terrestrial OC in their frozen soils (Hugelius et al., 2011). Warming and intensification of the hydrologic cycle is leading to an increased rate of water and dissolved organic matter (DOM) discharge from the Siberian rivers (Savelieva et al., 2000; Semiletov et al., 2000; Stein and Macdonald, 2004).” (Lines 62-69).

Line 54. Replace “lead” with “is leading to”

Corrected.

Line 56-68. This section should be rephrased and better references found. If you do not want to have too many references I recommend you pick either the original papers or first to demonstrate this in the Arctic. Currently there is a bizarre selection of studies cited and not all directly relevant.

This section was deleted.

Line 78-79. Several of these references are not even Arctic.

This part was rewritten as:

“Empirical relationships between the optical properties of DOM and DOC have already been the subject of investigation in the Arctic Ocean (Stedmon et al., 2011; Guéguen et al., 2005, 2007; Fichot and Benner, 2011; Gonçalves-Araujo et al., 2015; Kaiser et al., 2017). The present study synthesizes the authors’ multi-year observations on the remote ESAS with the focus on exploring the extent and dynamics of riverine DOC, using CDOM as a proxy.” (Lines 83-86).

Line 80. Were there not any additional scientific aims or hypotheses? Possibly developed during the data analysis for this study? Try to mention them here. As stated now the aim reads very much as a data report.

It was edited to the following:

“This paper aims (1) to study the spatial and inter-annual dynamics of DOM optical characteristics in shelf waters of the Eastern Arctic seas on the basis of multi-year summertime (August–September) expedition data (2003, 2004, 2005, 2008, 2011); (2) to examine the relationship between CDOM fluorescence and DOC in order to validate a useful method for accurately predicting DOC concentration from CDOM properties in the ESAS; and (3) to demonstrate the feasibility, using DOM optical characteristics, of determining the terrigenous DOM distribution and identifying different biogeochemical provinces in the shelf water.” (Lines 87-92).

Delete line 83-86. This has been established in the Introduction.

We wanted to highlight these two seas of the ESAS because here the influence of river discharge and the biogeochemical signal of permafrost degradation are the most prominent. The introduction referred to the entire ESAS.

Line 95. Check your phrasing of “would be oxidised”.

This sentence was replaced by:

“Moreover, it has been found that in the past the Lena River played a dominant role in sediment discharge, flushing out soil OM from its vast watershed (Tesi et al., 2016); a significant fraction of “fresh” terrestrial OM contributes to the DOM pool (Vonk et al., 2013; Karlsson et al., 2016).” (Lines 103-105).

Line 133-134. Delete this. It is a standard fluorometer which is readily available. No need for this.

Also the description of the interior optics can be removed. Not really necessary and appears to be copy pasted word for word from Belize et al 2006 paper, which is a little alarming.

It was edited as following:

“CDOM fluorescence was measured with a WETStar DOM fluorometer, which is suitable for in situ measurements without prior filtration of water (Belzile et al., 2006). The raw voltage from the fluorometer was converted to quinine sulfate units (QSU) (Belzile et al., 2006).” (Lines 176-178).

Line 146. What ranges? I do not understand.

It was a typo. This sentence is replaced by: “Water samples underwent filtration through acid-washed Whatman glass fiber filters (GF/F, nominal pore size 0.7 μm)” (Lines 138-139).

Line 150. It is not valid to apply the fit across this range. The spectrum does not behave exponentially and in many samples there will be a shoulder at 280. Additionally the absorption below 240 will be mainly due to other constituents.

This section was rewritten (Lines 136-178 in the revised ms).

Line 156. Sr is not explained, and the whole this part if poorly written.

We explained Sr and rewrote this part of the ms (Lines 136-178)

Line 157. SUVA is not that recent and include a citation of the original paper for this (Weishaar).

Fixed (Lines 162-165).

Line 158. I do not agree with this sentence. Starting “The last parameter. . .”

The sentence was deleted.

Line 161. I do not agree with this extrapolation. The relationship demonstrates the expected link between MW and SUVA but not does not mean that the relationship is fixed and one can use it to determine MW in other systems.

This text was clarified (Line 168 in the revised ms).

Line 168. “The value of S increases with the decrease of the CDOM absorption coefficient”. This is not true. It depends on the values of the end members (see Stedmon and Markager 2003).

This sentence was rewritten as following:

“The value of S varies with the source, aromatic content, and molecular weight of the CDOM (Blough and Del Vecchio, 2002; Helms et al., 2008; Granskog et al., 2012). In near-shore regions, which are under the influence of terrestrial sources with high concentrations of CDOM, S values increase due to the conservative mixing of terrestrial CDOM (high a_{λ} , low S) with oceanic CDOM (low a_{λ} , high S) (Stedmon and Markager, 2003).” (Lines 151-155).

Line 169. Include reference for relationship between S and aromatic content/molecular weight

Done. (Line 152)

Line 172. Several of these references did not even measure or report the spectral slope at 275-295.

This section was rewritten as following:

“Following recommendations by Helms et al. (2008) a wavelength interval of 275-295 nm was chosen for detailed spectral analysis because it demonstrates the biggest variability of optical parameters when mixing waters with contrasting optical characteristics.” (Lines 156-159).

Line 182. First sentence is repetition.

This sentence was rewritten (Lines 276-277).

Line 190. What do you mean by spectral dependency of S₂₇₅₋₂₉₅? The spectral range should be constant.

This sentence was rewritten as following:

“CDOM absorption spectra for September 2004 surface waters at two stations (stations 118 and 97) located in contrasting shelf zones (Fig. 1) are shown at Figure 5. Spectrum for station 60 located in the East Siberian Sea (in a moderate zone of mixing river and ocean waters) is also presented. CDOM absorption spectra measured for different waters have substantially different levels of absorption.” (Lines 278-281).

Line 193-209. Why not expand the comparison of slope values and ratios with data available from other Siberian rivers Eg. In Walker et al 2013 doi: 10.1002/2013JG002320 (they have seasonal data to compare to). Stedmon et al 2011; Mann et al 2014 & 16. And Gon9alves-Araujo et al 2015 10.3389/fmars.2015.00108

We compared our data with data available from other Siberian rivers in Sections 4.2 and 4.3 of the revised ms.

Line 201-214. Is this analysis/interpretation only based on the 2004 data. Why not expand to include all data and compare where you see the qualitative change with where there also is a large drop in CDOM? Is it at the same region the drop in SUVA occurs across all years or is it more salinity that is driving the drop seen in the figure?

Yes, this analysis/interpretation is only based on the 2004 data. We expanded this to 2005, and 2011 (no spectral data are available for 2008) with a special emphasizes at the areas with large drop in CDOM (a_{350}) (Figures 6 and 7 in the revised ms).

*As can be seen from this new Figure 6, SUVA ($C_{Ar} = 6.52 * \text{SUVA} + 3.63$) is correlated with salinity. SUVA and CDOM (a_{350}) are also closely related. Then we can say that the distribution of CDOM (a_{350}), Sr and SUVA values is driven by increased salinity across all years. Furthermore, the position of the region of large change of CDOM and other parameters demonstrated inter-annual dynamics.*

Figure 9a and b. It would be more robust to derive the relationship for the 2004 data and test in on the data from other years. I wonder if you carried out the regression analysis between DOC and salinity if you get the same predictive power. The data here look to be very conservative. Mixing is dominating.

Yes, mixing is dominating. Following this reviewer's comment, we combined the data for 2004 and 2008 (Figure 9 in the revised ms).

As seen in Fig. 9, the CDOM-DOC predictive power is high and can likely be used in other studies ($r = 0.99$ for 2004 and 2008). Unfortunately, the relationship between DOC and salinity is not so strong, because of melt water that lowers this correlation. For example, in 2004 the pair salinity-DOC demonstrates high negative correlation ($- 0.91$) in the ESS nearshore zone, while this correlation drops down to $- 0.77$ in 2008.

Dissolved organic matter and its optical characteristics in the Laptev and East Siberian seas: Spatial distribution and inter-annual variability (2003-2011)

Svetlana P. Pugach^{1,2}, Irina I. Pipko^{1,2}, Natalia E. Shakhova^{2,3}, Evgeny A. Shirshin⁴, Irina V. Perminova⁵, Örjan Gustafsson^{6,7}, Valery G. Bondur⁸, Alexey S. Ruban⁸, Igor P. Semiletov^{1,2,3}

¹V.I. Il'ichev Pacific Oceanological Institute, Russian Academy of Sciences, Vladivostok, 690041, Russia

²National Research Tomsk Polytechnic University, Tomsk, 634050, Russia

³International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, AK 99775, USA

⁴Department of Physics, Lomonosov Moscow State University, Moscow, 119991, Russia

⁵Department of Chemistry, Lomonosov Moscow State University, Moscow, 119991, Russia

⁶Department of Environmental Science and Analytical Chemistry, Stockholm University, Stockholm, 10691, Sweden

⁷Bolin Centre for Climate Research, Stockholm University, Stockholm, 10691, Sweden

⁸Aerocosmos Research Institute of Airspace Monitoring, Moscow, 105064, Russia

Correspondence to Svetlana P. Pugach (pugach@poi.dvo.ru)

Abstract. The East Siberian Arctic Shelf (ESAS) is the broadest and shallowest continental shelf in the World Ocean. It is characterized by both the highest rate of coastal erosion in the world and a large riverine input of terrigenous dissolved organic matter (DOM). DOM plays a significant role in marine aquatic ecosystems. The chromophoric fraction of DOM (CDOM) directly affects the quantity and spectral quality of available light, thereby impacting both primary production and ultraviolet (UV) exposure in aquatic ecosystems.

A multi-year study of CDOM absorption, fluorescence, and spectral characteristics was carried out over the vast ESAS in the summer-fall season. The paper describes observations accomplished at 286 stations and 1766 in situ high-resolution optical measurements distributed along the nearshore zone. Spatial and inter-annual CDOM dynamics over the ESAS were investigated, and driving factors were identified. It was shown that the atmospheric circulation regime is the dominant factor controlling CDOM distribution on the ESAS.

This paper explores the possibility of using CDOM and its spectral parameters to identify the different biogeochemical regimes in the surveyed area. The analysis of CDOM spectral characteristics showed that the major part of the Laptev and East Siberian seas shelf is influenced by terrigenous DOM carried in riverine discharge. Western and eastern provinces of the ESAS, with distinctly different DOM optical properties were also identified; a transition between the two provinces at around 165-170° E, consistent also with hydrological and hydrochemical data.

In the western ESAS, a region of substantial river impact, the content of aromatic carbon within DOM remains almost constant. In the eastern ESAS, a gradual decrease in aromaticity percentage was observed indicating contribution of Pacific-origin waters, where allochthonous DOM with predominantly aliphatic character and much smaller absorption capacity predominates. In addition, we found a stable tendency towards reduced concentrations of CDOM and dissolved lignin, and increase of spectral slope and slope ratio values eastward from the Lena River delta; the Lena is the main supplier of DOM to the Eastern Arctic shelf.

The strong positive correlation ($r = 0.97$) between dissolved organic carbon (DOC) and CDOM values in the surface shelf waters influenced by terrigenous discharge indicates that it is feasible to estimate DOC content from CDOM fluorescence assessed in situ using a WETStar fluorometer. This approach is reliable over the salinity range of 3 to 24.5. The fact that there is little difference between predicted and observed parameters indicates that the approach is justified. The direct estimation of DOM optical characteristics in the surface ESAS waters provided by this multi-year study will also be useful for validating and calibrating remote sensing data.

Определение стиля: Основной шрифт абзаца

Удалено: DOM

Отформатировано: По ширине

Отформатировано: не все прописные

Отформатировано: Высота: 29,7 см

Отформатировано: Цвет шрифта: Авто

Удалено: volume of

Удалено: colored (

Удалено:)

Удалено: DOM optical parameters

Удалено: the

Удалено: of the DOM chromophoric fraction were

Удалено: in

Удалено: seasons

Удалено: characteristics of CDOM were applied

Удалено: provinces

Удалено: ¶

Удалено: Sea

Удалено: (making up the ESAS)

Удалено: with high aromaticity, stemming from

Удалено: The atmospheric circulation regime is the dominant factor controlling CDOM spatial distribution on the ESAS. A western

Удалено: an

Удалено: regime

Удалено: ESAS, separated around 165-170° E, were identified

Удалено: Strong

Удалено: concentrations

Удалено: feasibility of estimating

Удалено: the

Отформатировано: Шрифт: не курсив

Удалено: of DOM

Удалено: validation

Удалено: calibration of

1 Introduction

Current climate change is particularly evident and amplified in the high latitudes of the Northern Hemisphere. The system change is characterized by an increase in the average annual temperature and atmospheric circulation intensity, a reduction in sea ice coverage and thickness, and accelerated degradation of permafrost, as well as an increase in coastal and bottom erosion and river flows (IPCC, 2013). Unlike other oceans, the Arctic Ocean is completely surrounded by permafrost. The Arctic region contains an abundance of organic carbon (OC) buried inland and within the sedimentary basin of the Arctic Ocean, which might become a part of the current marine biogeochemical cycle due to thawing of on-land and sub-sea permafrost, increased coastal and bottom erosion, accelerated river discharge, and soil-based carbon losses (Günther et al., 2013; Shakhova et al., 2009, 2017; Semiletov, 1999; Vonk and Gustafsson, 2013; Vonk et al., 2012, 2014). The recent studies accomplished within the framework of the International Siberian Shelf Study project (Semiletov and Gustafsson, 2009; Semiletov et al., 2011; Tesi et al., 2014; Bröder et al., 2016; Charkin et al., 2011) demonstrate that coastal erosion is the main source of particulate OC (POC) to the East Siberian Arctic Shelf (ESAS), the broadest and shallowest shelf in the World Ocean. Oxidation of POC exported from thawing coastal (and bottom) permafrost, and freshening due to growing Siberian river runoff from extensive permafrost-underlain watersheds, play a major role in the severe ESAS acidification that has been reported (Semiletov et al., 2016). At the same time, river discharge to shelf waters supplies terrestrial carbon in the form of dissolved OC (DOC) and waters enriched by carbon dioxide (CO₂) (Alling et al., 2010; Amon et al., 2012; Anderson et al., 2009, 2011; Semiletov et al., 2011, 2012; Pipko et al., 2010).

Annually, the Arctic rivers transport 25-36 Tg of DOC to the Arctic Ocean, which is ~10 % of the global riverine DOC discharge (Raymond et al., 2007). Siberian rivers are high in DOC, with a mean concentration of more than 500 μM (Gordeev et al., 1996; McClelland et al., 2012; Amon et al., 2012). These concentrations are an order of magnitude higher than in the inflowing Atlantic (60 μM) and Pacific (70 μM) waters, but the volume flux of the two oceans is about 60 times larger than that of continental runoff (Anderson and Amon, 2015). Furthermore, Arctic and subarctic regions contain approximately 50 % of the global terrestrial OC in their frozen soils (Hugelius et al., 2011). Warming and intensification of the hydrologic cycle is leading to an increased rate of water and dissolved organic matter (DOM) discharge from the Siberian rivers (Savelieva et al., 2000; Semiletov et al., 2000; Stein and Macdonald, 2004).

The absorbance and fluorescence properties of the chromophoric fraction of DOM (CDOM) are “optical markers”, comparable to traditional biomarkers used in geochemistry (e.g., lignin) (Stedmon and Nelson, 2015). According to Coble (2007), up to 70 % of DOM in shelf waters is represented by CDOM, which is critical in a number of biochemical and photochemical processes and which defines the optical properties of natural waters, thus affecting the depth of the photic layer (Granskog et al., 2007; Hill, 2008). Quantitative descriptions of the dynamics and variability of CDOM optical properties are often required, particularly in coastal waters, in order to accurately predict light penetration and primary production (Matsuoka et al., 2007). It should be noted that reliable estimation of coastal water optical characteristics is crucial for validating and calibrating remote sensing data processing results (Vantrepotte et al., 2012). High CDOM values are typical for the eastern Laptev Sea; in the western East Siberian Sea they result from large discharge of the Lena River which is characterized by high CDOM concentrations (Semiletov et al., 2013; Pugach and Pipko, 2013). Most likely, the color that indicates the presence of CDOM in this water, when seen from space, is due to the presence of chlorophyll (Heim et al., 2014). This may explain the recently proposed increase in the net primary production rates reported for these ESAS areas based on satellite data interpretation (Arrigo and van Dijken, 2011).

Empirical relationships between the optical properties of DOM and DOC have already been the subject of investigation in the Arctic Ocean (Stedmon et al., 2011; Guéguen et al., 2005, 2007; Fichot and Benner, 2011; Gonçalves-Araujo et al.,

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- Удалено: The present study synthesizes recent observations on the remote ESAS with the focus on exploring the extent and dynamics of riverine DOC, using colored or chromophoric DOM (CDOM) as a proxy. In recent years an interest in CDOM and its characterization has increased substantially due to: 1) rapid development of satellite monitoring methods elaborated to study various processes in seas and oceans, including the coastal water areas (Coble, 2007; Bondur et al., 2006; Vantrepotte et al., 2012)
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2015; Kaiser et al., 2017). The present study synthesizes the authors' multi-year observations on the remote ESAS with the focus on exploring the extent and dynamics of riverine DOC, using CDOM as a proxy.

This paper aims (1) to study the spatial and inter-annual dynamics of DOM optical characteristics in shelf waters of the Eastern Arctic seas on the basis of multi-year summertime (August–September) expedition data (2003, 2004, 2005, 2008, 2011); (2) to examine the relationship between CDOM fluorescence and DOC in order to validate a useful method for accurately predicting DOC concentration from CDOM properties in the ESAS; and (3) to demonstrate the feasibility, using DOM optical characteristics, of determining the terrigenous DOM distribution and identifying different biogeochemical provinces in the shelf water.

2 Study area

This study is focused on the Laptev and East Siberian seas, where the influence of river discharge and the biogeochemical signal of permafrost degradation are the most prominent (Alling et al., 2010; Nicolsky and Shakhova, 2010; Sánchez-García et al., 2011; Shakhova et al., 2015, 2017; Vonk et al., 2012). The shelf area of these seas covers 40% of the Arctic shelf and 20% of the entire Arctic Ocean area (Stein and Macdonald, 2004). Annually, 767 km³ of fresh water flows into the Laptev Sea with discharges of the Lena, Khatanga, Anabar, Olenek, and Yana rivers; this amounts to over 30 % of the total river discharge into all Arctic seas in Russia. The Lena River, which is the largest river in the ESAS region, accounts for more than 70 % of the total discharge to the Laptev Sea (Semiletov et al., 2000; Cooper et al., 2008). Over 85 % of its discharge flows into the sea through channels of the eastern Lena delta. Therefore, the hydrological and biogeochemical regime of the Laptev Sea, and its southeast part in particular, is mainly controlled by discharge fluctuations of the Lena River (Pipko et al., 2010; Semiletov et al., 2011, 2012; Bröder et al., 2016). Moreover, it has been found that in the past the Lena River played a dominant role in sediment discharge, flushing out soil OM from its vast watershed (Tesi et al., 2016); a significant fraction of “fresh” terrestrial OM contributes to the DOM pool (Vonk et al., 2013; Karlsson et al., 2016).

The East Siberian Sea is one of the least-studied seas; this lack of attention is mainly attributed to severe ice-bound conditions. The Kolyma and Indigirka are the main rivers for which the East Siberian Sea serves as a receiving basin; however, their total average annual discharge does not exceed 180 km³. According to Nikiforov and Shpaikher (1980) a major part of the Lena River fresh water plume usually transits the East Siberian Sea eastward within the coastal zone. Depending on hydrometeorological conditions, this plume reaches 165° E (typical under anticyclonic circulation conditions), and as far as Long Strait at 180° E (typical under cyclonic circulation conditions) (Semiletov et al., 2005).

3 Materials and methods

3.1 Field work

This paper presents data from research expeditions conducted during the summer-fall seasons of 2003 and 2004 (HV Ivan Kireev), 2005 (MV Auga), 2008 (HV Yakob Smirnitsky), and 2011 (RV Academician M.A. Lavrentyev) on ice-free regions of the Laptev and East Siberian seas (Fig. 1).

The study was carried out using a hydrological conductivity-temperature-depth (CTD) SBE 19plus SEACAT Profiler probe (www.seabird.com) with CDOM sensor (WETStar DOM Fluorometer, www.wetlabs.com). This enabled in situ synchronous high-precision measurements of vertical temperature distribution, conductivity, and CDOM.

In 2003, 2004, 2005, and 2011 the measurements were carried out at 286 oceanological stations and in 2008 along the ship's track using a seawater intake (SWI) system. Water was pumped from 4 m depth at 30 L min⁻¹ through stainless steel and silicon tubes into an on-deck 300 L barrel, and then through a distribution network, from which samples were collected.

Temperature, salinity/conductivity, and CDOM in the surface water were measured continuously using sensors installed on

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the CTD Seabird 19+ deployed in the barrel; measurements were averaged every 10 min. Table 1 shows detailed information on cruises, including dates, number of stations, and parameters measured.

3.2 Methods for determining dissolved organic carbon

In 2004, DOC concentration was measured in an International Arctic Research Center laboratory at the University of Alaska (Fairbanks, Alaska, USA), in 2008 on board the RV *Yakov Smirnitsky*. All samples were analyzed using the Shimadzu TOC-V_{CPH} system (Alling et al., 2010). The 1-3 L seawater samples were vacuum-filtered onboard with 25 mm diameter pre-combusted borosilicate glass fiber filters (Whatman GF/F, nominally 0.7 μm cut-off), within an all-glass filtration system. The samples were stored in 60 mL Nalgene high-density polyethylene bottles. DOC was analyzed via high-temperature catalytic oxidation. Inorganic carbon was removed by acidifying the samples to pH 2 with 2 M HCl and sparging for 8 min prior to analysis. All procedures for calibration and data analysis followed Sharp et al. (1995). Certified Reference Materials (CRMs, from the University of Miami) of low carbon content (1-2 μM C) and deep-sea reference water (41-44 μM C) were run prior to each analysis batch (Alling et al., 2010).

3.3 Absorbance and fluorescence analysis

Absorbance of CDOM was measured using a UNICO 2804 spectrophotometer with a 1 cm quartz cuvette over the spectral range from 200 to 600 nm at 1 nm intervals. Milli-Q (Millipore) water was used as the reference for all samples. Water samples underwent filtration through acid-washed Whatman glass fiber filters (GF/F, nominal pore size 0.7 μm). The absorption coefficient (a_{λ} , m⁻¹) was calculated as follows:

$$a_{\lambda} = 2.303A_{\lambda}/L, \quad (1)$$

where A_{λ} is optical density at wavelength λ , and L is the cell pathlength in meters.

The absorption coefficients at 350 nm (a_{350}) were chosen to quantify the concentrations of CDOM because of their correlations to DOC, and to permit comparison with other results (Spencer et al., 2009; Stedmon et al., 2011; Walker et al., 2013; Gonçalves-Araujo et al., 2015; Mann et al., 2016).

The dependence of a_{λ} on λ is described using Equation (2):

$$a_{\lambda} = a_{\lambda_0} \exp \{-S(\lambda - \lambda_0)\}, \quad (2)$$

where a_{λ_0} is the absorption coefficient at reference wavelength λ_0 , and S is a spectral slope defining the spectral dependence of the absorption coefficient resulting from CDOM presence (Blough and Del Vecchio, 2002).

The spectral slope, S , indicates the rate at which the CDOM absorption coefficient decreases with wavelength increase (Carder et al., 1989). The value of S varies with the source, aromatic content, and molecular weight of the CDOM (Blough and Del Vecchio, 2002; Helms et al., 2008; Granskog et al., 2012). In near-shore regions, which are under the influence of terrestrial sources with high concentrations of CDOM, S values increase due to the conservative mixing of terrestrial CDOM (high a_{λ} , low S) with oceanic CDOM (low a_{λ} , high S) (Stedmon and Markager, 2003). Therefore, it is also widely accepted that the spectral slope S can be used as a proxy for CDOM composition. However, its usefulness is limited by the fact that S depends on the wavelength interval over which it is calculated (Carder et al., 1989; Stedmon et al., 2000). Following recommendations by Helms et al. (2008) a wavelength interval of 275-295 nm was chosen for detailed spectral analysis because it demonstrates the biggest variability of optical parameters when mixing waters with contrasting optical characteristics. The ratio of S values from the shorter (275-295 nm) and the longer wavelength region (350-400 nm), termed the slope ratio, S_R , was calculated as described by Helms et al. (2008). S_R values for terrestrial CDOM typically are <1 whereas oceanic CDOM and extensively photodegraded terrestrial CDOM are typically >1.5 (Stedmon and Nelson, 2015). Specific UV absorbance (SUVA), defined as the UV absorbance of a water sample at 254 nm normalized for DOC concentration, is used to estimate the degree of aromaticity in bulk CDOM (Weishaar et al., 2003):

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$$C_{Ar} = 6.52 \cdot SUVA_A + 3.63, \quad (3)$$

where C_{Ar} is the percentage of total carbon existing as aromatic carbon.

480 This equation is applicable for a wide range of aquatic environments (seas, bogs, lakes) since the authors used humic substances that have different chemical characteristics and demonstrated a strong correlation ($r = 0.98$) between the specific UV absorbance and aromatic carbon content (Weishaar et al., 2003).

Dissolved lignin is a well-established biomarker of terrigenous DOM in the ocean and has been successfully applied as a tracer of riverine inputs in the Arctic Ocean (Fichot et al., 2016). To assess its content in coastal waters two empirical models for the retrieval of the sum of nine lignin phenols (TDLP₉, nmol L⁻¹) from a_i were applied (Fichot et al., 2016). For $a_{250} < 4$ m⁻¹, a “low-CDOM” sub-model based on a simple linear regression was used,

$$\ln(TDLP_9) = 0.7672 \cdot a_{263} - 0.3987 \quad (4)$$

For $a_{250} \geq 4$ m⁻¹, a “high-CDOM” sub-model based on a multiple linear regression was used,

$$\ln(TDLP_9) = -2.282 \cdot \ln(a_{350} - 8.209 \cdot \ln(a_{275}) + 11.365 \cdot \ln(a_{295}) + 2.909 \quad (5)$$

490 CDOM fluorescence was measured with a WETStar DOM fluorometer, which is suitable for in situ measurements without prior filtration of water (Belzile et al., 2006). The raw voltage from the fluorometer was converted to quinine sulfate units (QSU) (Belzile et al., 2006).

3.4 Statistical treatment and graphical representation of the data

495 Data were tested statistically using an empirical distribution function test in the Statistics 7.0 software package. Descriptive statistics were calculated for the 95 % confidence interval of the mean ($P = 0.95$, $\alpha = 0.05$). Most of the plots and maps in this study were created with the Ocean Data View software (Schlitzer, 2011).

4 Results and Discussion

4.1 Hydrometeorological situation and CDOM spatial variability

500 The spatial distribution of sea-surface salinity obtained in September 2003, 2004, 2005, 2008, and 2011 is shown in Fig. 2a. During summertime, the coastal currents transport a large part of the Lena River water eastward into the East Siberian Sea. The overall hydrological conditions in the near shore zone were mainly determined by the interaction of river and marine water (Fig. 2a). The sea surface salinity showed a general eastward increasing trend. The salinity values varied between 3.1 (2004) and 32.34 (2011), with the lowest values associated with fresh water input from the Lena River and the higher values attributed to the presence of Pacific water. The maximum eastward spreading of river water was detected in September 2004 when the freshwater signal was found in the vicinity of Long Strait.

505 Comparative analysis of 2003, 2004, 2005, 2008, and 2011 data showed that, in general, CDOM concentration in ESAS surface waters varies depending upon distance from the river water source: the maximum CDOM was recorded near river mouths, and the minimum in regions remote from direct river discharge. However, the spatial distribution of waters with high CDOM values on the ESAS differed significantly in different years (Fig. 2b). The CDOM isoline equal to 15 QSU in Figure 2b can be used to compare the distribution of river water in different years. Location of this CDOM isoline correlates spatially with isohaline 24.5 which has been suggested as a marker for the boundary of surface shelf waters diluted by riverine runoff in the Siberian seas (Nikiforov and Shpaikher, 1980; Semiletov et al., 2000, 2005).

510 Comparison of the discharge of the main rivers flowing into the Laptev and East Siberian seas (the Lena and Kolyma rivers), which was based on Tiksi Hydromet data and the <http://rims.unh.edu> website, demonstrated that the maximum total discharge of the Lena and Kolyma rivers during the study period was recorded in 2008 (829 km³) and the minimum in 2003 (543 km³). However, the maximum distribution of ESAS waters with high CDOM concentrations was observed in 2004 and

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Удалено: of CDOM spectral characteristics (a , S , S_R and a_i) in shelf waters of the Eastern Arctic seas was conducted on the basis of data obtained during summer-fall season (August-September) of 2004, 2005, and 2011 in the East Siberian and eastern Laptev seas (Fig. 1). The 2004 survey was chosen for detailed analysis of specific UV absorbance spatial variability along a wavelength of 254 nm (a_{254}) in the surface water of the ESAS.

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660 the minimum was observed in 2011 (Fig. 2b). This indicates a complex and multifactorial correlation between river discharge and distribution of CDOM-enriched waters on the ESAS.

Following Proshutinsky et al. (2015), dominant atmospheric processes and differences in ice-coverage area mainly determine surface hydrology in the wind-driven ESAS. Therefore, we assume that inter-annual variability of the sea surface CDOM distribution on the ESAS is also determined by atmospheric processes.

665 National Centers for Environmental Prediction (NCEP) sea level pressure (SLP) data were employed to describe the atmospheric circulation over the Arctic Ocean (www.esrl.noaa.gov). The SLP fields, averaged over the summer season (July – September) for each year, are shown in Figure 2c.

During the 2003 summer season cyclonic atmospheric circulation dominated over the central Arctic Ocean. SLP as low as 1005 mbar extended over the Laptev and the East Siberian seas (Fig. 2c). The development of a deep atmospheric depression caused onshore winds on the western periphery of the cyclone and transferred freshened shelf waters to the east (Pipko et al., 2008; Savel'eva et al., 2008). Waters with high CDOM concentrations spread to 165° E although river discharge was at a minimum in 2003 (Fig. 2b). The September 2003 sea-ice extent was at a maximum from 2003 to 2011 in the Arctic Ocean ($6.1 \cdot 10^6 \text{ km}^2$, http://nsidc.org/data/seaice_index/), but Dmitry Laptev Strait was clear of ice in early August; thus, intensive water exchange occurred between the Laptev and East Siberian seas under a prevailing west wind.

670 In 2004 the summer low pressure north of the East Siberian Sea was weaker while an anticyclone formed above the Canadian Arctic Archipelago (Fig. 2c). High river discharge, ice conditions, and offshore winds determined the maximum distribution of river waters in the ice-free East Siberian Sea (Fig. 2b).

Predominance of cyclonic atmospheric circulation over the western Laptev Sea and anticyclonic circulation over the Beaufort Sea created significant SLP gradients and, thus, strong winds in 2005 (average wind speed of up to $\sim 11.2 \text{ m sec}^{-1}$, Fig. 2c). Strong southeastern winds prior to the expedition hampered the spread of river waters north and east of the river delta (Fig. 2b), intensified the processes of thermoabrasion (Günther et al., 2013), and facilitated the release of eroded carbon into the water. The volume of river discharge was the second largest in the period of research. This is the year when the maximum absolute CDOM value (over 100 QSU, compared to an average of 25 QSU during the study period) was recorded in Buor-Khaya Bay surface water.

685 In 2008, the summer atmospheric pressure field was conditioned by the dominant anticyclone over the Beaufort Sea and a weak cyclone over Siberia, which caused southeastern winds over the ESAS (Fig. 2c). Thus, although the river discharge was great (the Lena River maximum discharge occurred during the investigated period), freshened waters were located in the southeastern Laptev Sea and the western East Siberian Sea and did not penetrate into the eastern part of the sea. It should be noted that the ice extent was less in September 2008 compared with the previous study periods. The whole shelf was ice-free that year and the ice boundary moved north of 80° N in some areas (<http://www.aari.nw.ru/>).

690 An area of high SLP over the Arctic Basin and low SLP above the continent occurred in the summer season (July–August) of 2011 (Fig. 2c). The averaged meridian wind speed was 1.5 m s^{-1} and the averaged area wind speed was 3.5 m s^{-1} (<http://www.cdc.noaa.gov>), which determined weak offshore east and southeast winds of 4 m s^{-1} . September sea-ice extent in the Arctic Ocean was smaller in 2011 than in 2008 (4.6 and $4.7 \cdot 10^6 \text{ km}^2$, respectively), but the ESAS ice edge was markedly closer to the median extent for 1981-2010 in 2011 (http://nsidc.org/data/seaice_index/). During the summer season, the East Siberian Sea ice edge did not reach 73° N and meltwater was transported from the East Siberian Sea to the Laptev Sea under the influence of east and southeast winds. The fraction of meltwater depleted of CDOM reached 20 % (Anderson and Amon, 2015) in the surface waters of the Laptev Sea shelf in September 2011 (Pipko et al., 2015). The situation radically changed in September, when low SLP dominated over the Arctic Basin. The wind changed towards the north and northwest and became stronger. Low river discharge, weak winds in preceding summer months, and strong onshore winds during the study period provided for a weak spreading of river water and intensive mixing of seawater. High meltwater content and a deeper mixed layer relative to September 2005 and 2008 (Pipko et al., 2016) also contributed to a

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decrease of CDOM concentration. Eventually, the lowest absolute CDOM values and the minimum distribution area for CDOM-enriched waters were recorded in September 2011 (Fig. 2b).

Taken together, field data analysis showed that the prevailing type of atmospheric circulation and the position of action centers relative to each other were the dominant factors controlling the ESAS surface CDOM spatial distribution, while inter-annual variabilities of river discharge and ice extent were also significant. The greatest offshore propagation of waters with high CDOM content was recorded in 2004 when a cyclone was located above the central region of the Arctic Ocean basin and a high atmospheric pressure field formed over the Beaufort Sea. In September 2004 the East Siberian Sea surface salinity from Kolyma Bay (near 160°E) to Long Strait (roughly near 178°E) varied from 20 to 24, much lower than in other years (Semiletov et al., 2005), which is reflected in high CDOM values. Note that the prevailing type of atmospheric circulation and the position of atmospheric action centers are also dominant factors controlling variability in Siberian river discharge (Semiletov et al., 2000; Savelieva et al., 2000). Thus, this interplay between atmospheric forcing factors, riverine discharge, and redistribution of fresh water traced by CDOM values across the arctic seas should be studied further to achieve a better understanding of Arctic system complexity.

A significant negative correlation between CDOM and salinity in surface ESAS water ($r = -0.88$, Fig. 3) in the salinity range from 3 to 24.5 indicates a terrigenous source for CDOM, and somewhat conservative mixing of CDOM between fresh water and seawater. Deviations of CDOM values from the trend line are determined by the presence of both meltwater depleted in CDOM (Anderson and Amon, 2015) and multiple riverine sources with varying DOM properties. At higher salinities (> 24.5) correlation in the surface layer between these parameters is practically absent (Fig. 3), and the distribution of CDOM throughout the water column is completely different in different ESAS areas (Fig. 4).

Figure 4 additionally illustrates two examples of representative salinity and CDOM profiles measured on the ESAS in September 2004 at station No.118 located near the Lena River mouth and at station No. 97 located in Long Strait, farther away from direct riverine influence (Fig. 5). Note that a significant negative correlation between CDOM fluorescence and salinity was found for the whole water column data in the 2004 survey ($r = -0.84$, $N = 8920$), indicating a predominantly riverine origin of CDOM. Inspection of these individual profiles shows a more complex situation (Fig. 4c). Each of the two profiles collected in the relatively shallow shelf water of the Laptev and East Siberian seas showed a significant correlation between CDOM and salinity, but these correlations had opposite signs. At the western station No.118 CDOM values decreased with higher salinity ($r = -0.99$), while at the eastern station No.97 CDOM values were positively correlated with the salinity ($r = 0.84$). Thus, at higher salinity on the eastern ESAS, the presence of water masses with distinctive optical properties was responsible for the different behavior of CDOM.

4.2 Spatial variability of CDOM spectral characteristics

Spectral characteristics (a_{350} , $S_{275-295}$, S_R) that provided both quantitative and qualitative information about CDOM, were determined during field work in 2004, 2005, and 2011.

CDOM absorption spectra for September 2004 surface waters at two stations (stations 118 and 97) located in contrasting shelf zones (Fig. 1) are shown at Figure 5. Spectrum for station 60 located in the East Siberian Sea (in a moderate zone of mixing river and ocean waters) is also presented. CDOM absorption spectra measured for different waters have substantially different levels of absorption. Despite that CDOM dominates the absorption spectra in the blue and UV wavebands, the absorption coefficient a_{350} for these stations demonstrated considerable spatial variability, from 0.7 m^{-1} (station 97) to 11.1 m^{-1} (station 118). Values obtained in the area of maximal Lena River influence coincided well with data given in Walker et al. (2013) for a mid-flow regime of the Lena River (about 13.1 m^{-1}). It was shown that during all flow regimes a_{350} was highest in the Lena River relative to other large Arctic rivers (Walker et al., 2013).

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The relationship between river water a_{350} values and river discharge volume (Walker et al., 2013) also could be traced in the ESAS surface waters. According to our data, the a_{350} values also increased in the shelf waters with an increase in riverine runoff (Figs. 2b, 6).

790 The multi-year surface water a_{350} distribution showed the same feature for each year: the highest a_{350} values were observed in the Laptev Sea waters under direct Lena River influence, with a decrease in a_{350} toward the saltier waters of the Chukchi Sea (Fig. 6).

The $S_{275-295}$ values and spectral slope ratio S_R correlated well with both DOM molecular weight and source (Helms et al., 2008). The lowest $S_{275-295} = 14.7 \mu\text{m}^{-1}$ in September 2004 was found near the river delta in the Laptev Sea (Fig. 5). This value is in the same range as previously reported values characterizing the surface waters of the eastern Arctic seas, which are dominated by allochthonous DOM during the late summer season (Stedmon et al., 2011; Walker et al., 2013; Gonçalves-Araujo et al., 2015). This value is also comparable to values found in other rivers studied in the Pacific sector of the Arctic. For example, $S_{275-295}$ reaches $12 \mu\text{m}^{-1}$ in the Yukon River during the peak flood periods when the concentrations of DOM and its colored fraction are the greatest (Spencer et al., 2009). $S_{275-295}$ increases to $18.9 \mu\text{m}^{-1}$ in the western East Siberian Sea where river influence decreases. $S_{275-295}$ further increases to $21 \mu\text{m}^{-1}$ (Fig. 5) in Long Strait where primary production is high (Walsh et al., 1989) and the main portion of DOM is produced in situ. Overall, this value was significantly lower than values observed for open ocean waters, which are typically $25-30 \mu\text{m}^{-1}$ (Blough and Del Vecchio, 2002). The values characteristic for open seawater ($28-29 \mu\text{m}^{-1}$) were found in the east of the ESS in September 2011, when a weak spreading of the riverine waters was detected.

805 S_R was calculated for the shallow ESAS characterized by different intensities of terrigenous influence. The lowest values were obtained in the southeastern Laptev Sea (0.78) and the maximum S_R (4.0) was found in the area influenced by the highly productive Pacific-origin waters in Long Strait where the optical properties are determined by phytoplankton-derived autochthonous CDOM with low molecular weight and lower amounts of aromatic functional groups (Fig. 6). High values of S_R in the surface waters of the eastern East Siberian Sea confirm conclusions about weak spreading of riverine waters on the ESAS in 2011 and point to effective transport of Pacific-origin water on the ESAS under the anticyclonic type of atmospheric circulation (Fig. 2).

815 Figure 6a demonstrates the spatial distribution of aromatic carbon (C_{Ar}) in ESAS surface water in September 2004. The corresponding calculations show that the content of aromatic carbon within DOM remains almost constant in the region of substantial river impact to $\sim 165^\circ \text{E}$ (Fig. 6a). In the eastern part, a gradual decrease in aromaticity percentage was observed indicating the contribution of Pacific-origin waters, where allochthonous DOM with predominantly aliphatic character and much lesser absorption capabilities predominates.

4.3 Optical characteristics of the ESAS biogeochemical provinces

820 As was shown in previous studies, the concentrations of CDOM vary significantly within the ESAS (Belzile et al., 2006; Gonçalves-Araujo et al., 2015; Stedmon et al., 2011; Walker et al., 2013), mainly because of variations in the sources of DOM. The current multi-year investigations of the ESAS extend previous studies showing not only the inhomogeneity of spatial DOM variability, but also temporal DOM variability and its spectral characteristics distribution in the shallow shelf waters.

825 We found a stable tendency to a reduction in the concentrations of CDOM and aromaticity, and an increase of S_R and $S_{275-295}$ values in the eastern (and northern) direction from the delta of the Lena River, which is the main supplier of dissolved OM to the eastern Arctic shelf. Our comprehensive data set made it possible to distinguish two ESAS provinces with contrasting biogeochemical regimes based on their spectral characteristics (Table 2). We used an approach described by Semiletov et al. (2005) and Pipko et al. (2005), which shows that, based on the hydrological and hydrochemical data distribution, two biogeochemical provinces (areas) could be identified in the shallow ESAS; a western area (heterotrophic biogeochemical

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830 province) that is influenced strongly by freshwater flux and transport of coastally-eroded particulate material enriched by
OC, and an eastern area (autotrophic biogeochemical province) which is under the influence of highly productive Pacific-
derived waters. A salinity of 24.5 was the conventional boundary of the western area. The spectral characteristics of CDOM
were significantly correlated with salinity in this part of the ESAS; correlation coefficient between a_{350} and salinity for three
years combined was -0.81. The relationship indicates that the conservative mixing of riverine and ocean waters plays a
dominant role in regulating the variability of their values in this area. A similar pattern was established for the distribution of
835 CDOM fluorescence values (Fig. 3). There was no relationship between optical parameters and salinity for the eastern part of
the ESAS (Fig. 3); correlation between spectral indices and salinity was also absent in the eastern part with correlation
coefficient between a_{350} and salinity at -0.16 and between S_R and salinity at 0.02. From year to year, depending on the
dominant wind regime, the longitudinal boundary between western and eastern areas may shift by 10 degrees longitude and
more.

840 Obtained data allowed us to calculate the lignin content in surface waters of the inner and middle ESAS based on CDOM
spectral characteristics (Fig. 7) and to estimate the average values in each of the provinces. The most significant difference in
the average values which characterize the western and eastern shelf regimes were found for the dissolved lignin
concentration (Table 2). Lignin is a well-established biomarker of terrigenous OM in the ocean (Hedges et al., 1997; Fichot
and Benner, 2014; Fichot et al., 2016). It is exclusively produced on land by vascular plants. As a result, lignin extracted
845 from seawater and marine sediments has long been used to derive qualitative and quantitative information about the origins,
transformations, and fates of terrigenous OM in the ocean (Amon et al., 2012; Fichot and Benner, 2014; Tesi et al., 2014;
Fichot et al., 2016). The three large Siberian rivers, Lena, Yenisei, and Ob, which also have the highest proportion of forests
within their watersheds among the six largest Arctic rivers, contribute about 90% of the total lignin discharge to the Arctic
Ocean; the Lena River alone contributes about 48 % of the total annual lignin discharge into the Arctic Ocean (Amon et al.,
850 2012). The calculated dissolved lignin concentration on the west ESAS in the late summer – fall season ranged from 11.9 –
263.2 nmol L⁻¹ with a mean of 89.5 nmol L⁻¹, indicating a strong influence of continental runoff on the shelf waters. The
obtained values were much higher than lignin concentrations in the surface waters of the outer shelf and the continental slope
of the Laptev and East Siberian seas (Fichot et al., 2016; Kaiser et al., 2017), where the influence of river flow is much
weaker. The maximum concentrations of dissolved lignin were found in the shelf waters near the mouth of the Lena,
855 Indigirka, and Kolyma rivers (263, 101, and 96 nmol L⁻¹, respectively) (Fig. 7); the observed values were significantly lower
than the concentrations measured in the main streams of these rivers in the late summer-fall season (Mann et al., 2016).
According to the obtained data, the concentrations of dissolved lignin decreased from the mouth of the Lena River to the
mouths of the Indigirka and Kolyma rivers; thus, we can trace the signature of each river on the shelf from the measured
spectral characteristics, as well as from the parameters calculated on the basis of those characteristics. Thus, at salinities
860 equal to ~ 10, in the shelf waters near the river deltas, concentrations of dissolved lignin decrease in the eastern direction,
from 180 nmol L⁻¹ near the Lena Delta to 101 and 85 nmol L⁻¹ near the mouths of the Indigirka and Kolyma, respectively.
This tendency agrees well with the distribution of lignin phenol concentrations in Siberian river waters (Mann et al., 2016).
In eastern ESAS surface waters (Pacific-influenced province) the average dissolved lignin concentration decreased by more
than an order of magnitude compared to the western part (from 89.5 to 5.1 nmol L⁻¹, Table 2). This indicates a minor effect
865 of the terrigenous OM source on the biogeochemical regime of eastern ESAS waters. Together with the distribution of other
optical parameters, the dynamics of lignin content indicate the "marine" DOM origin in the eastern ESAS and a transition
from a heterotrophic to an autotrophic water regime over this part of the shelf. Note that the obtained values were slightly
lower than the concentrations of dissolved lignin calculated for the surface water of the deep parts of the Laptev and East
Siberian seas, where river water penetration is only possible under certain atmospheric circulation conditions (Bauch et al.,
870 2011; Pipko et al., 2015, 2017; Kaiser et al., 2017).

The presented values of CDOM spectral parameters are comparable to findings from other studies previously conducted in this region (Stedmon et al., 2011; Walker et al., 2013; Gonçalves-Araujo et al., 2015; Mann et al., 2012, 2016). However, our data allow us to trace the dynamics of CDOM spectral characteristics in a highly dynamic shallow region of the Arctic shelf, between heterotrophic riverine waters (Stedmon et al., 2011; Walker et al., 2013; Gonçalves-Araujo et al., 2015; Mann et al., 2012, 2016) and autochthonous seawater (Fichot et al., 2016; Kaiser et al., 2017).

4.4 Rapid assessment of dissolved organic carbon based on optical characteristics of dissolved organic matter

Conventional methods for the analysis of DOC are restricted to measurements of discrete samples and are limited to providing synoptic coverage on relatively small spatial scales. Estimating DOC concentrations via measuring optical DOM properties (absorption and fluorescence) therefore represents a compelling alternative (Fichot and Benner, 2011).

880 Methods to predict DOC concentrations from absorbance characteristics have been attempted since the early 1970s (Banoub, 1973; Lewis and Tyburczy, 1974). However, a prerequisite for successfully predicting DOC concentration is that the non-absorbing DOC is at a constant or low level (Ferrari and Dowell, 1998). The processes responsible for DOC and CDOM distribution in the open ocean are typically independent, and the two pools usually demonstrate a negative rather than a positive correlation (Coble, 2007). The situation is different in shelf areas where terrestrial discharge is strong, and distribution of river water and seawater controls the distribution of both DOC and CDOM. A novel method to accurately retrieve DOC concentrations from CDOM absorption coefficients for the salinity range of 0-37, typically encountered in river-dominated ocean margins, was successfully developed by Fichot and Benner (2011).

Here we present a method to estimate DOC concentration from in situ CDOM fluorescence using data collected in September 2004 and 2008 in surface waters of the shallow ESAS, where the Lena River is the main riverine source.

890 DOC and CDOM concentrations were measured simultaneously in the surface shelf waters of the Laptev and East Siberian seas during the 2004 and 2008 surveys to determine relationships between the two parameters.

In 2004, along with the study of filtered seawater sample absorption coefficients, CDOM was measured in situ using a WETStar fluorometer. Strong positive correlation ($r = 0.98$) was observed between a_{350} measured in the filtered samples and CDOM of the unfiltered samples measured simultaneously in the ESAS surface water at 46 stations (Fig. 8).

895 This confirms previous results based on data obtained exclusively in the East Siberian Sea (Belzile et al., 2006) showing that the presence of suspended matter in water samples has little impact on CDOM values, even in regions of intensive terrigenous discharge. We have now compared the relationship between CDOM and a_{370} , which quantifies CDOM, using the East Siberian Sea data reported by Belzile et al. (2006) and our data obtained in the Laptev and East Siberian seas. A good agreement was found between Belzile's and our data (Fig. 8b). The correlation coefficient between CDOM and a_{370} have been found to be the same in the ESAS ($r = 0.97$, $N = 92$) and in the Belzile et al. samples from Boothbay Harbor, West Harbor Pond, the Beaufort Sea, and the East Siberian Sea ($r = 0.98$, $N = 74$).

The relationship between DOC and CDOM showed a strong positive correlation for the 2004 and 2008 cruises ($r = 0.99$ for each survey, Fig. 9). We combined the two data sets to obtain a general equation connecting these parameters and to explore our capability to predict DOC concentration from the linear relationship between DOC and CDOM in the studied season.

905 An important implication of the obtained total relationship between DOC and CDOM (Fig. 9d) is the capability to constrain the DOC concentration for the ESAS surface waters in the late summer season using information about in situ CDOM fluorescence. It allows DOC values to be calculated with a high spatial resolution based on direct fluorescence measurements, avoiding various artifacts induced by filtering and storing samples and, thus, adding to the limited available data on DOC distribution over the ESAS.

910 Overall, this simple empirical model provides a practical means to derive reasonably accurate estimates of DOC concentrations from CDOM in coastal waters of the Siberian Arctic shelf (Fig. 9, 10). The model adequately reproduces the most important features of the measured DOC distribution in the shelf waters. A comparison of the measured and calculated

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Удалено: Figure 8 demonstrates the linear dependence of DOC/DOM-FL for 2004 and 2008, which is characterized by a high correlation ($R^2 = 0.99$ and 0.98 , respectively) that makes it possible to calculate DOC concentrations from DOM-FL using the equations given in Figure 8. This high linear correlation was used to calculate DOC values

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Удалено: measured in the laboratory for isolated points of the ESS surface layer in September 2004 (Fig 9a) and DOC distribution calculated from DOM-FL (Fig. 9b). It can be seen that the measured DOC vs calculated CDOM/DOC values demonstrate similar distribution patterns.

DOC indicates that the model restored DOC values within $\pm 10\%$ of the measured values (Fig. 9). The % error was significantly higher than 10% only for two points in Long Strait, where influence of the Pacific-origin water was significant (Fig. 9d). The model might also slightly overestimate some low DOC concentrations found in water with increased salinity (in the vicinity of Long Strait).

Therefore, this rapid assessment of DOC concentrations on the ESAS using a WETStar fluorometer is an effective tool for obtaining information on DOC distribution in summer seasons. This approach is reliable over the salinity range of 3 to 24.5; the lower limit is defined as the lowest conventional salinity level at which all the major marginal filters have already been passed (Lisitsyn, 1994) and the upper limit is a border of riverine water distribution (Nikiforov and Shpaikher, 1980).

5 Conclusions

A multi-year study of DOM optical parameters and the spectral characteristics of the DOM chromophoric fraction was carried out repeatedly probing the summer-fall season on the broadest and shallowest shelf in the World Ocean, the vast ESAS, from the Lena River delta in the Laptev Sea to Long Strait in the East Siberian Sea. For the first time, CDOM/DOC interannual variability in connection with atmospheric pressure fields and wind-driven water circulation was considered. The atmospheric circulation regime is the dominant factor controlling hydrography and spatial expansion of the area of freshwater influence which determines CDOM/DOM spatial distribution on the ESAS.

The dynamics of DOM optical properties provided a new insight into biogeochemical processes in the ESAS. The spectral characteristics of CDOM were applied to identify two clearly distinct biogeochemical provinces in the surveyed area. The analysis of CDOM spectral characteristics has clearly shown that the major part of the Laptev and East Siberian Sea shelf is influenced by terrigenous DOM with high aromaticity and high lignin content, transported by riverine discharge.

The content of aromatic carbon within DOC remains almost constant in the western ESAS, which is the region of substantial river impact, while in the eastern ESAS, a gradual decrease in aromaticity percentage was observed indicating an increasing contribution of Pacific-origin waters, where allochthonous DOM with predominantly aliphatic character and much lesser absorption capabilities prevails.

We found a stable tendency of CDOM and dissolved lignin concentrations to be reduced and S_R and $S_{275-295}$ values to increase in the eastern direction from the delta of the Lena River, which is the main supplier of dissolved OM to the Eastern Arctic shelf.

The strong correlation between DOC and CDOM concentrations in surface shelf waters that are influenced by terrigenous discharge makes it possible to calculate DOC content from CDOM values assessed in situ using the WETStar fluorometer. Moreover, the reliable estimation of optical characteristics of coastal waters is crucial for validating and calibrating remote sensing data processing results. Employing optical techniques can increase the temporal and spatial coverage of DOM measurements across the ESAS and help to more accurately estimate the amount of terrigenous DOM; this estimation is necessary for understanding how carbon budgets and fluxes will be altered under future climate change scenarios.

Data availability. DOM and all data will be made publicly available at the open-access Stockholm University Bolin Centre Database (<http://bolin.su.se/data/>), once the manuscript is published.

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Удалено: The analysis of CDOM spectral characteristics has proved that the major part of the Laptev and ESS shelf is influenced by terrigenous DOM with high aromaticity, transported by riverine discharge. It has also been shown that the type of atmospheric circulation is the dominant factor controlling CDOM spatial distribution on the ESAS.¶ Strong

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Отформатировано: Поз.табуляции: 5 см, по левому краю

Отформатировано: Поз.табуляции: 5 см, по левому краю

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Удалено: 2016a

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Отформатировано: Цвет шрифта: Черный

Отформатировано: Цвет шрифта: Авто

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Отформатировано: Шрифт: 12 пт, Цвет шрифта: Черный

Отформатировано: Шрифт: 12 пт

Удалено: Ferrari, G., Dowell, M. D., Grossi, S., Targa, C.: Relationship between optical properties of chromophoric dissolved organic matter and total concentration of dissolved organic carbon in southern Baltic Sea region, *Mar. Chem.*, 55 (3–4), 299–316, 1996.¶

Отформатировано: Шрифт: 12 пт

Отформатировано: Шрифт: 10 пт

Отформатировано: Шрифт: 10 пт

Отформатировано: Поз.табуляции: 5 см, по левому краю

Удалено: Gramberg, I. S., Kulakov, Yu. N., Pogrebitsky, Yu. E., and Sorokov, D. S.: Arctic oil and gas super basin, pp. 93–99. London, UK: X World Petroleum Congress. 1983.¶

Отформатировано: Цвет шрифта: Авто

Отформатировано: Поз.табуляции: 5 см, по левому краю

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Удалено: carbon export, *Global Biogeochem. Cy.*,

Отформатировано: Цвет шрифта: Черный

Удалено: 18, GB1036

Удалено: 1029/2003GB002087, 2004

Удалено: [

Удалено: D.

Удалено: G.-K.

Удалено: M.

Удалено: S.K.

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- Удалено: A.
- Удалено: Y.
- Удалено: V.
- Удалено: P.M.
- Удалено: (eds.).
- Удалено: . S.,
- Отформатировано: Цвет шрифта: Черный
- Отформатировано: Цвет шрифта: Черный
- Удалено: Semiletov I., Vonk, J. E., Sánchez-García, L., Andersson, A.,
- Отформатировано: Цвет шрифта: Черный
- Отформатировано: Цвет шрифта: Черный
- Отформатировано: Цвет шрифта: Черный
- Удалено: Carbon isotopes and lipid biomarker investigation of
- Удалено: , transport
- Отформатировано: Цвет шрифта: Черный
- Отформатировано: Цвет шрифта: Черный
- Удалено: terrestrial
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- Отформатировано: Цвет шрифта: Черный
- Отформатировано: Поз.табуляции: 5 см, по левому краю
- Отформатировано: Поз.табуляции: 5 см, по левому краю
- Удалено: .
- Удалено: Matsuoka, A., Bricaud, A., ...
- Удалено: Pavlov, A. K., Granskog, M ...
- Отформатировано ...
- Отформатировано ...

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Удалено: Savel'eva

Отформатировано: Цвет шрифта: Авто

Удалено: Aspects

Отформатировано: Цвет шрифта: Черный

Отформатировано: Поз.табуляции: 5 см, по левому краю

Отформатировано: Цвет шрифта: Другой цвет (RGB(35;31;32))

Отформатировано: Цвет шрифта: Черный

Отформатировано: Цвет шрифта: Черный

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Отформатировано: Поз.табуляции: 5 см, по левому краю

Удалено: Shiklomanov, A. I., Yakovleva, T. I., Lammers, R. B., Karasev, I. Ph., Vörösmarty, C. J., and Linder, E.: Cold region river discharge uncertainty - estimates from large Russian rivers, *J. Hydrol.*, 326, 231–256, 2006.¶

Отформатировано: Цвет шрифта: Черный

Отформатировано: Цвет шрифта: Черный

Отформатировано: Поз.табуляции: 5 см, по левому краю

Удалено: Tarnocai, C., Canadell, J.G., Schuur, E.A.G., Kuhry, P., Mazhitova, G., and Zimov, S.: Soil organic carbon pools in the northern circumpolar permafrost region, *Global Biogeochem. Cy.*, 23, GB2023, doi:10.1029/2008GB003327, 2009.¶

Удалено: Semiletov, I., Dudarev, O., Andersson, A., and Gustafsson, Ö.: Matrix association effects on hydrodynamic sorting and degradation of terrestrial organic matter during cross-shelf transport in the Laptev and East Siberian shelf seas, *J. Geophys. Res.*

Отформатировано: Цвет шрифта: Авто

Удалено: - - Biogeosci., 121, doi:10.1002/2015JG003067,

Отформатировано: Цвет шрифта: Авто

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Отформатировано: Поз.табуляции: 5 см, по левому краю

Table 2. DOM optical characteristics, dissolved lignin, and salinity in two biogeochemical provinces of the inner and middle ESAS surface water (obtained during the 2004, 2005, and 2011 surveys).

Parameter Region	Absorption coefficient (a_{350}), m^{-1}					$S_{275-295}$, μm^{-1}					S_R					CDOM, QSU					Dissolved lignin (TDLP ₉), $nmol L^{-1}$					Salinity						
	AV G	Md	STD	Min	Max	AV G	Md	STD	Min	Max	AV G	Md	STD	Min	Max	AV G	Md	STD	Min	Max	AV G	Md	STD	Min	Max	AV G	Md	STD	Min	Max		
Western province	5.2	4.2	2.5	3.0	5.5	17.3	17.6	17.5	1.7	10.4	21.1	1.1	1.1	1.0	0.2	0.8	1.8	43.4	37.4	28.5	3.4	135.9	89.5	73.4	53.0	11.9	263.2	14.4	15.7	5.3	0.1	24.4
Eastern province N = 9	0.6	0.6	0.4	0.1	1.4	22.6	23.3	4.7	13.1	29.0	2.9	3.2	1.5	0.8	4.8	1.6	1.1	1.4	0.4	5.1	5.1	4.6	3.0	1.6	10.8	28.0	28.1	2.7	24.7	32.1		

AVG – average value, Md – median value, STD – standard deviation, N – number of measurements.

Удалено: Разрыв страницы

Отформатировано

Отформатированная таблица

Удалено: a_{254}

Отформатировано

Отформатировано

Удалено: Specific UV absorbance,

Отформатировано

Удалено: N

Удалено: N

Удалено: N

Отформатировано

Отформатировано

Удалено: 22.4

Удалено: 19.7

Удалено: 11.9

Удалено: 74

Удалено: 2.2

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Отформатировано

Удалено: 9

Отформатировано

Удалено: 65.

Удалено: 75

Удалено: 1

Удалено: 23.3

Удалено: 20

Удалено: 3

Отформатировано

Удалено: 2

Удалено: 30.3

Удалено: 75

Отформатировано

Отформатировано

Удалено: 3.9

Отформатировано

Удалено: 3

Отформатировано

Отформатировано

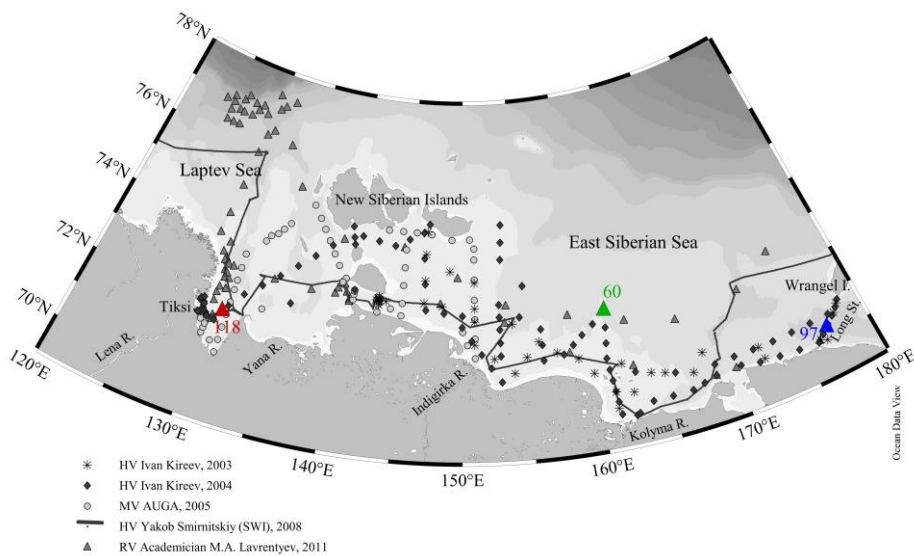
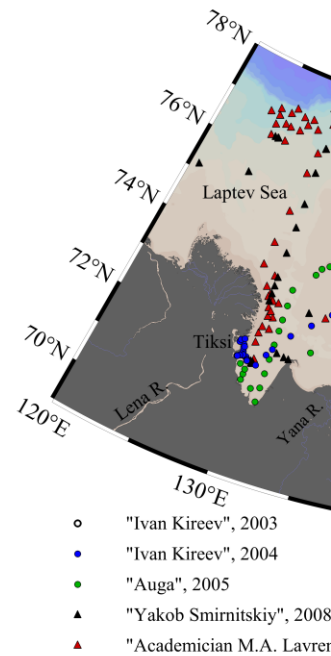


Figure 1. Study area: Location of oceanographic stations accomplished in August-October 2003, 2004, 2005, 2008, and 2011. Location of selected stations on the ESAS in September 2004 is shown in color.

Отформатировано: Нумерация: начинать на каждой странице

Удалено: — Разрыв страницы —



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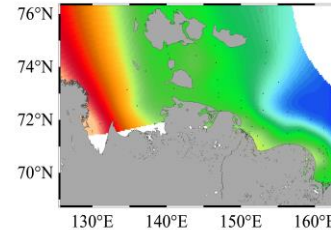


Figure 2. Spatial distribution of (a) DOM absorption coefficient at the 254 nm wavelength (a_{254} , m^{-1}) and (b) of salinity (S) in the ESAS surface waters, September 2004.

¶ Разрыв страницы

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Удалено: East Siberian Shelf (a), and surface CDOM absorption coefficient spectra a_{254} (b) for station (St.) 25, 60, and 97, September 2004.

Отформатировано: Шрифт: 10 пт

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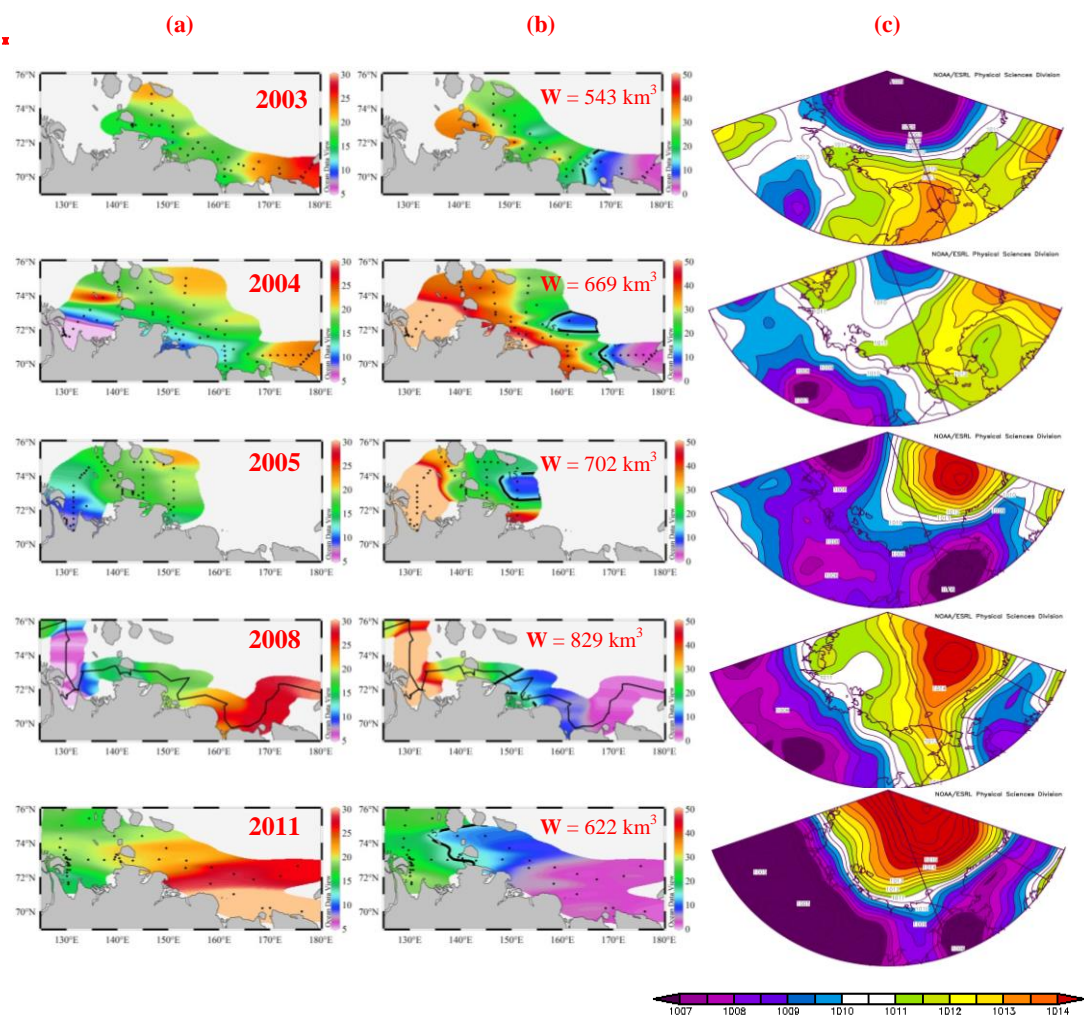
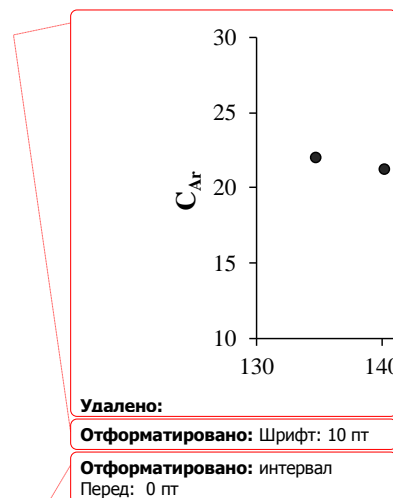
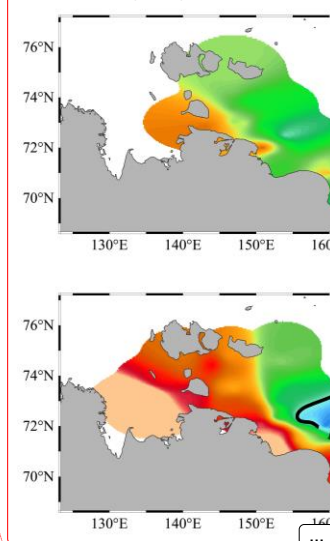


Figure 2. Distributions of surface salinity (a) and CDOM (b) in September 2003, 2004, 2005, 2008, and 2011, and (c) sea level pressure fields (mbar), averaged over the summer season (July–September) from NCEP data. **W** - total annual river discharge.



Удалено: Figure 4. Distribution of aromatic carbon (C_{Ar} , %) in the ESAS surface waters, September 2004.



Удалено: CDOM (left)

Удалено: Salinity (right)

Удалено: ; W - annual total river discharge.

Удалено: in 2003 (a), 2004 (b), 2005 (c), 2008 (d), 2011 (e), and September 2011 (f),

Отформатировано: Шрифт: 11 пт
Отформатировано: Шрифт: 10 пт
Отформатировано: По ширине

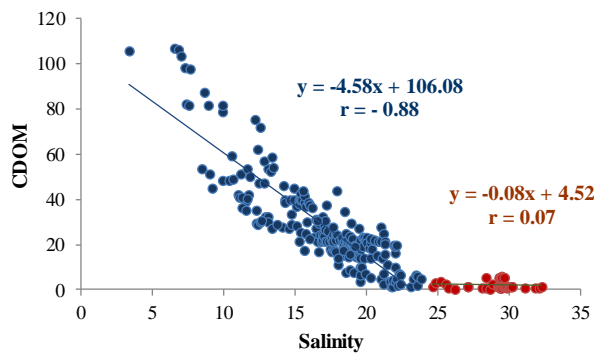
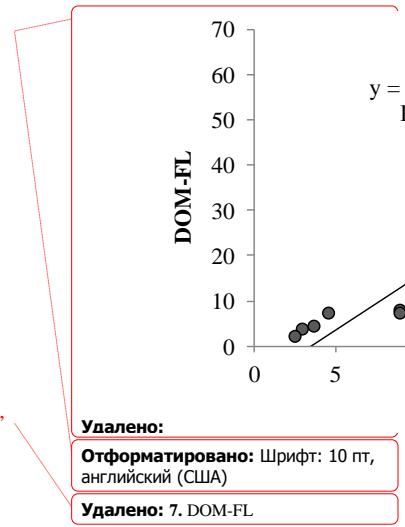


Figure 3. The relationship between the salinity and CDOM₄ (QSU) in the ESAS surface water in August-September 2003, 2004, 2005, 2008, and 2011 (blue circles – salinity < 24.5, red - > 24.5).



Удалено:

Отформатировано: Шрифт: 10 пт, английский (США)

Удалено: 7. DOM-FL

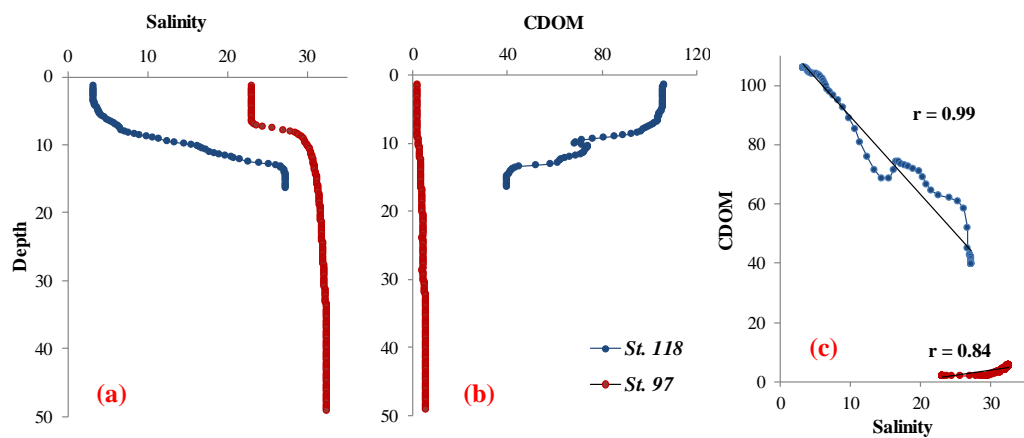


Figure 4. Depth profiles of salinity (a) and CDOM (b) measured at two stations on the ESAS, and (c) relationship between CDOM and salinity.

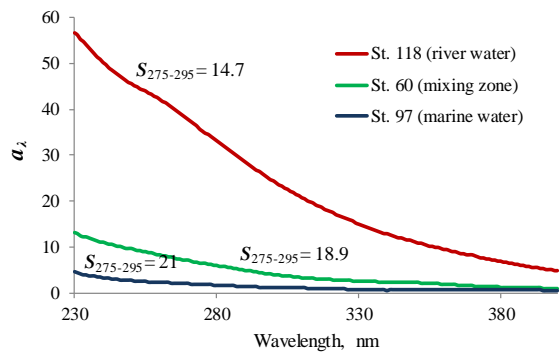
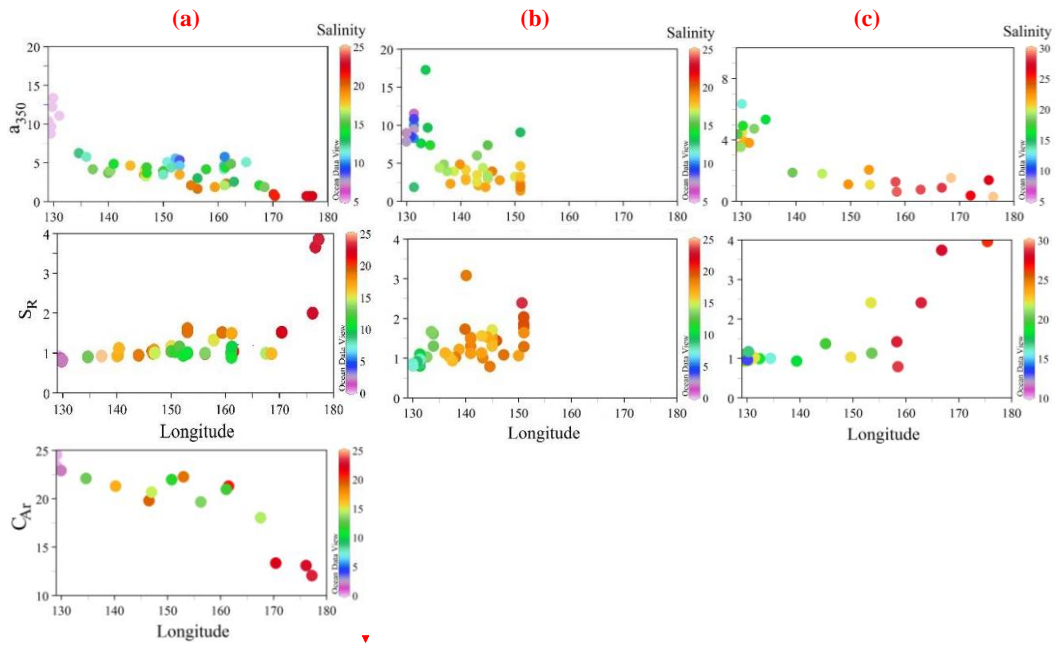


Figure 5. Surface CDOM absorption coefficient spectra a_λ for station (St.) 118, 60, and 97, September 2004.



Отформатировано: По левому краю, Отступ: Первая строка: 0,25 см

Удалено: using

Figure 6. The relationship between CDOM absorption coefficient at the 350 nm wavelength (a_{350} , m^{-1}), S_R and the aromatic carbon content (C_{Ar} , %) and salinity in the ESAS surface waters, September 2004 (a), 2005 (b), and 2011 (c).

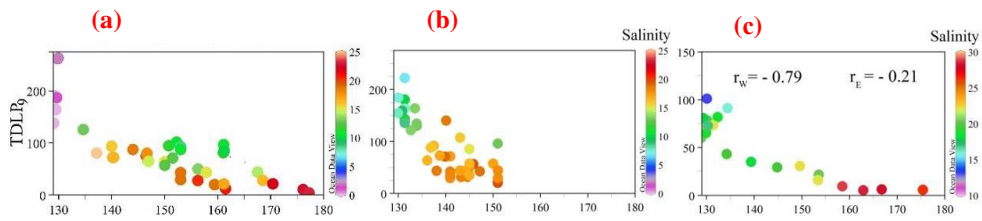


Figure 7. The relationship between the dissolved lignin concentrations (TDLP₉, nmol L⁻¹) and salinity in the ESAS surface waters, September 2004 (a), 2005 (b), and 2011 (c), where r_w , r_e represent correlation coefficients between TDLP₉ and salinity for western and eastern parts of the ESAS, respectively, for these three years combined.

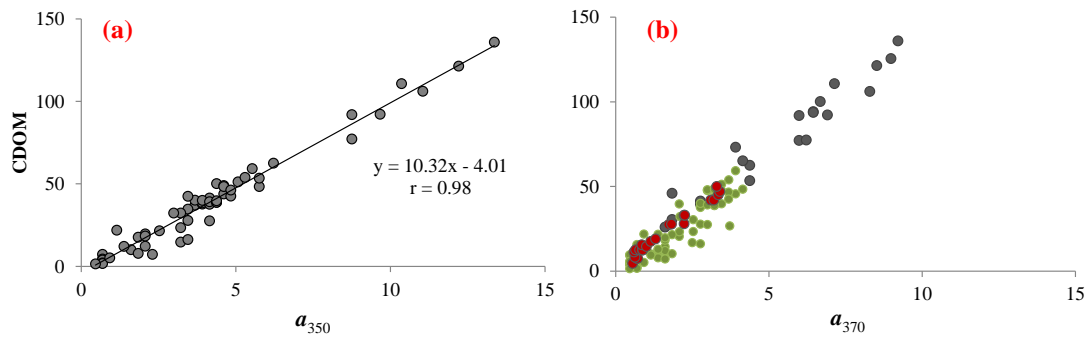


Figure 8. Correlation between CDOM (QSU) and absorption coefficient at 350 nm (a_{350} , m^{-1}) in ESAS surface water (a) and relationship between CDOM (QSU) and absorption coefficient at 370 nm (a_{370} , m^{-1}) in water column (b), September 2004. Grey – our data in the Laptev Sea (N = 23), green – our data in the East Siberian Sea (N = 69), and red – data from Belzile et al., 2006 (N = 23) ▾

Удалено: WETStar fluorometer versus DOM

Отформатировано: интервал
После: 0 пт, Автовыбор интервала между восточноазиатскими и латинскими буквами, Автовыбор интервала между восточноазиатскими буквами и цифрами

Удалено: (a_{254})

Отформатировано: Шрифт: не курсив

Удалено: , September 2004.

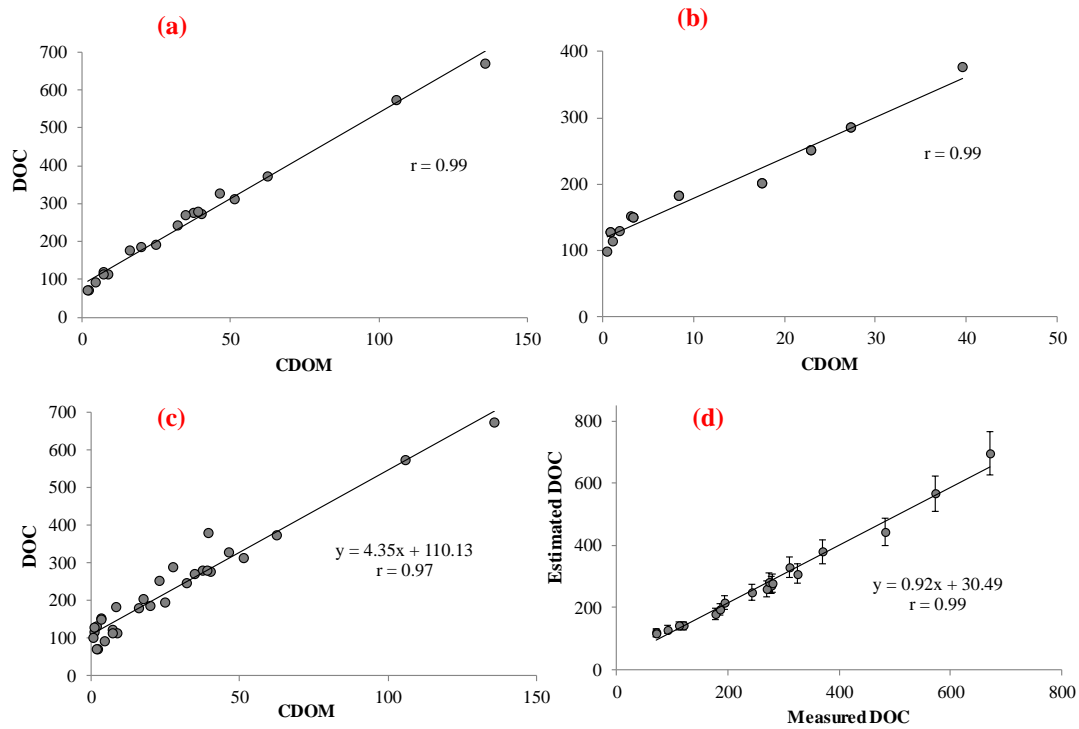
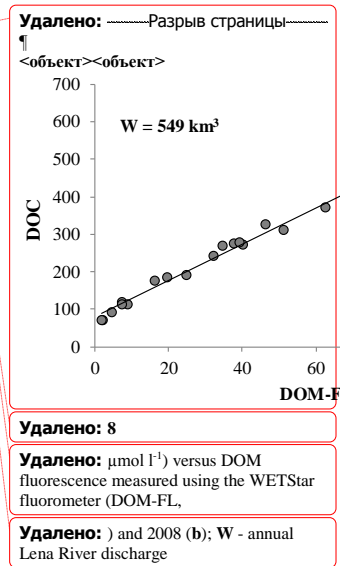


Figure 9. DOC concentration (μM) versus CDOM (QSU) in the ESAS surface water, September 2004 (a), 2008 (b), and combined for two years (c); (d) estimated DOC concentration against measured DOC concentration with 10% error bars.



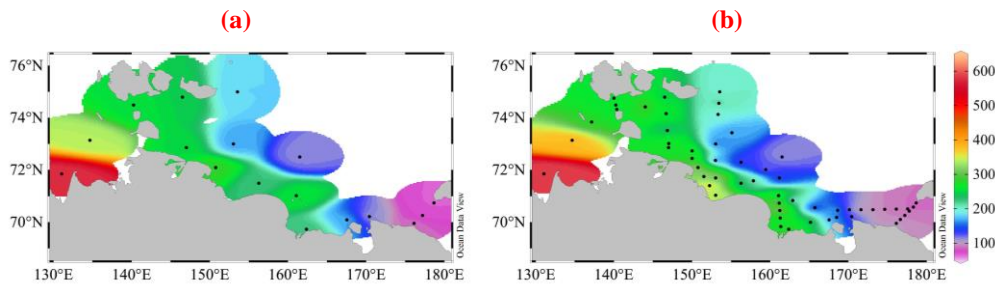


Figure 10. DOC distribution (μM) in the ESAS surface waters in September 2004: (a) measured DOC concentrations, (b) concentrations of DOC estimated from CDOM.

Удалено: —Разрыв страницы—

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Удалено: 9

Удалено: $\mu\text{mol l}^{-1}$

Отформатировано: Шрифт: не полужирный

Отформатировано: Шрифт: не полужирный

Удалено: laboratory measurements

Отформатировано: Шрифт: не полужирный

Отформатировано: Шрифт: не полужирный

Удалено: data

Удалено: DOM-FL.

Отформатировано: По левому краю, интервал После: 0 пт