Ocean Sci. Discuss.,
https://doi.org/10.5194/os-2019-60-RC1, 2019

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Interactive comment on "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" *by* Anastasiia Tarasenko et al.

Anonymous Referee #1

Received and published: 26 November 2019

Overview.

This manuscript uses a variety of resources, including in situ measurements, satellite measurements and reanalysis products, to describe the evolution of the Laptev and East Siberian Seas in late summer of 2018. The manuscript begins with a correct statement: that the region of interest is understudied. I think that the manuscript should be publishable, but only after significant attention has been directed (1) at the introduction (for context) and conclusions (for the meaning of the results in context), and (2) at Ekman fluxes and Ekman pumping. For the Ekman point, I believe the calculations to be invalid in shallow and coastal waters; see specific point 10 below. More on point (1)

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follows, because at present, I think that the manuscript reads more like a report than a paper.

The manuscript introduction has some weaknesses. It tells the reader some of what happens in the region, but it does not really say why the region is important, why it matters. If I were making a case as to why a reader should care about the region, I would be looking at freshwater fluxes, specifically the role of the Siberian shelves in modulating the inflow to the Arctic Ocean of the great Siberian rivers, either those that discharge directly into the Laptev and East Siberian Seas, or those west of Severnaya Zemlya, some of whose freshwater runoff enters the region through the Vilkitskiy Strait. The most recent (and very good) review of such issues is the Eddy Carmack paper (JGR 2016).

Also, if the region is understudied (and I agree that it is) then the introduction needs to describe whatever of importance has been published on the region. Item 4 below gives three references led by Tom Armitage. They are pan-Arctic remote sensing papers that have quite a bit to say about the Siberian Shelves, and they are not mentioned. Plus I could add Johnson & Polyakov (GRL 2001), Semiletov et al. (GRL 2005), Lenn et al. (GRL 2009 and JPO 2011), and the Lenn papers remind me that the manuscript talks about currents but does not mention tides, which are important in the shelf seas. There may be more papers, these are just a few that come to mind. I am not confident that the authors have thoroughly reviewed the literature.

Then concerning the final section called Discussion and conclusions; this section is really not much more than a brief restatement of the work reported in the preceding sections. If the introduction does not tell the reader why the region is important, then the conclusions cannot then tell the reader why the new results matter.

Specific comments are in order of occurrence.

1. The first paragraph on pp 1-2 describes the region. Reference should be added to the map of Figure 1; all locations in the text should be labelled, so please add text

"Severnaya Zemlya" to the map. Later you refer to Arkticheskiy Cape, add this as well.

2. In the same first paragraph, it is correctly stated that the region is little-studied, but I think there should be a sentence stating why the authors think the region is important. At the end of para. 1 on the top of p 2, add a sentence "The region is important because ...".

3. When talking about salinity, it is not appropriate to use "PSS". If using the new Absolute Salinity, then you can say parts per thousand, ppt, or use the "per mille" symbol. If not, then just "salinity of nn.n" or "nn.n in salinity" is correct.

4. Recent papers led by Armitage using Envisat, Cryosat and GRACE between 2003-2014 seem not to have been looked at: JGR 2016 is about sea surface height variability, with discussion of Siberian shelf seas; Cryosphere 2017 is about surface geostrophic circulation; GRL 2018 is about sea level & surface circulation response to the Arctic Oscillation. Some the material in these papers is directly relevant, and this omission should be corrected.

5. All figures with multiple panels, please label them a, b, c, etc. and refer to the panels as such in the manuscript text. All captions must state all plotted quantities and their units.

6. Section 3.1.2 on salinity, and cf SMOS text in 2.2.2. I doubt that the spatial resolution is as high as it appears in Figure 3. I understood SMOS to resolve at about 100 km, in 2.2.2 the authors mention sampling at 15 km resolution, but adjacent points are surely not independent. How does this affect their statistics?

7. Section 4 first & second lines, your temperature accuracy cannot be 1 m°C, so why are you quoting temperature values to three decimal places?

8. Figures 5 and 7, Hovmoller plots: you are inconsistent. Figure 5, longitude (x-axis), days (y-axis); figure 7, vice-versa. Pick one orientation and stick to it.

9. Figure 8, temperature sections. Improve your presentation, please. Viewing the

PDF, about half of the figure is just black and any temperature structure is obscured. The simplest solution would be to plot contours in white – not black!

10. Section 4.1.2. Please improve your terminology. "Transport" is typically a volume transport, units mˆ3/s. In your eq. 1, stress (N/m2) divided by [density (kg/m3) * Coriolis (sˆ-1)] has units m2/s. These units appear in tiny (almost unreadable) notation in figure 9. This is neither a velocity nor a transport. Importantly, though: are your Ekman calculations valid in shallow water? Ekman's assumptions included (1) no boundaries (remote from coasts), and (2) deep water (typically >200 m). What is the Ekman layer depth? Is it not more likely that upwelling / downwelling are dominated by sea surface height changes in shallow water? For instance, a wind from the west will cause surface water movement to the right (the south) in the northern hemisphere. Water "piles up" against the coast, and that induces downwelling (at the coast): see papers by Steven Lentz, for example. Is this in accord with your calculated vertical velocities in figure 9? I would say not.

Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2019-60, 2019.

Ocean Sci. Discuss.,
https://doi.org/10.5194/os-2019-60-AC2, 2020

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Interactive comment on "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" *by* Anastasiia Tarasenko et al.

Anastasiia Tarasenko et al.

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Received and published: 15 May 2020

General comments: "The manuscript introduction <...> does not really say why the region is important, why it matters <. . .>: freshwater fluxes, specifically the role of the Siberian shelves in modulating the inflow to the Arctic Ocean of the great Siberian rivers, either those that discharge directly into the Laptev and East Siberian Seas, or those west of Severnaya Zemlya, some of whose freshwater runoff enters the region through the Vilkitskiy Strait. The most recent (and very good) review of such issues is the Eddy Carmack paper (JGR 2016). Item 4 below gives three references led by Tom Armitage. They are pan-Arctic remote sensing papers that have quite a bit to say

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about the Siberian Shelves, and they are not mentioned. Plus I could add Johnson & Polyakov (GRL 2001), Semiletov et al. (GRL 2005), Lenn et al. (GRL 2009 and JPO 2011), and the Lenn papers remind me that the manuscript talks about currents but does not mention tides, which are important in the shelf seas." (+ commentary 2) "In the same first paragraph, it is correctly stated that the region is little-studied, but I think there should be a sentence stating why the authors think the region is important. At the end of para. 1 on the top of p 2, add a sentence "The region is important because ...". " (+commentary 4) " Recent papers led by Armitage using Envisat, Cryosat and GRACE between 2003- 2014 seem not to have been looked at: JGR 2016 is about sea surface height variability, with discussion of Siberian shelf seas; Cryosphere 2017 is about surface geostrophic circulation; GRL 2018 is about sea level & surface circulation response to the Arctic Oscillation. Some the material in these papers is directly relevant, and this omission should be corrected.

Answer: Thank-you, we have rewritten introduction, conclusion and annex A to take into account these general and specific comments, and correct these omissions.

Specific comments: 1. The first paragraph on pp 1-2 describes the region. Reference should be added to the map of Figure 1; all locations in the text should be labelled, so please add text "Severnaya Zemlya" to the map. Later you refer to Arkticheskiy Cape, add this as well.

Answer: Corrected, please see a new version of Fig.1

The full version of caption of Fig.1: Legs and stations of the ARKTIKA-2018 expedition overlayed on the bathymetry from ETOPO1 "1 Arc-Minute Global Relief Model" " (Amante and Eakins (2009)). CTD stations are shown with white dots. The color indicates the number of days since August 1, 2018. The sea ice edge position is indicated with a red dashed line for the beginning (August 21) and with the purple dashed line for the end of the expedition (September 21). The ice edge is based on the sea ice mask provided in the SST DMI product. Numbers indicate positions of 10 oceanographic

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transects discussed below. The black triangle in the north of the Komsomolets Island shows the Arkticheskiy Cape. The Severnaya Zemlya Archipelago consists mainly of the Komsomolets, the October Revolution, and the Bolshevik Islands (with smaller islands not shown here). The black box indicates the Shokalskiy Strait between the October Revolution and the Bolshevik Islands. The Yana River estuary is situated southward the Yanskiy Bay (out of the map).

2. In the same first paragraph, it is correctly stated that the region is little-studied, but I think there should be a sentence stating why the authors think the region is important. At the end of para. 1 on the top of p 2, add a sentence "The region is important because ...".

Answer:

Please, see a new version of the introduction.

3. When talking about salinity, it is not appropriate to use "PSS". If using the new Absolute Salinity, then you can say parts per thousand, ppt, or use the "per mille" symbol. If not, then just "salinity of nn.n" or "nn.n in salinity" is correct.

Answer:

Agree that the use of PSS is not appropriate. Nevertheless, the community of satellite-derived salinity widely uses the psu, practical salinity unit, to quantitatively describe the salinity; “in situ” practical salinity is computed from CTD measurements of conductivity, and also uses the “psu” scale. For the validation of SSS we use practical salinity. Absolute salinity was used only to calculate water density. We would prefer to change the units from pss to psu, but agree to make it unitless.

4. Recent papers led by Armitage using Envisat, Cryosat and GRACE between 2003-2014 seem not to have been looked at: JGR 2016 is about sea surface height variability, with discussion of Siberian shelf seas; Cryosphere 2017 is about surface geostrophic circulation; GRL 2018 is about sea level & surface circulation response to the Arctic

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Oscillation. Some of the material in these papers is directly relevant, and this omission should be corrected.

Answer:

Corrected, please, see a new version of Appendix A.

5. All figures with multiple panels, please label them a, b, c, etc. and refer to the panels as such in the manuscript text. All captions must state all plotted quantities and their units.

Answer:

Corrected.

6. Section 3.1.2 on salinity, and cf SMOS text in 2.2.2. I doubt that the spatial resolution is as high as it appears in Figure 3. I understood SMOS to resolve at about 100 km, in 2.2.2 the authors mention sampling at 15 km resolution, but adjacent points are surely not independent. How does this affect their statistics?

Answer:

The "initial" SMOS instrument (radiometric) resolution is 50 km (which we meant to explain in 2.2.2, line 17-18), but the SMOS SSS product distributed by ESA is already sampled in the ISEA grid with a resolution of 15 km. In other words, the spatial resolution of SMOS SSS Level 2 v662 product is 15 km, we just resampled all satellite products at the same grid for convenience. This "oversampling" of SMOS SSS at 15 km is practical for two reasons. First, to retain the real salinity gradients observed with in situ measurements and not to smooth them to 50 km when comparing with SMOS SSS. The spatial resolution of ship measurements depends on the ship speed (8 knots $\sim$ 3 m/s), pumping speed (16 l/s) and the CTD measurement frequency (24 Hz), and is of order (o) 1 m. After processing the raw data, its resolution is (o)250 m. A 7.5-km in situ measurement average corresponds to 30 minutes of TSG measurements, as line 6, p.3.1.1 (and a 15-km pixel represents one hour of measurements). Second, this retains SSS on the same grid as the rather high resolution SST for further calculations, e.g., density.

7. Section 4 first & second lines, your temperature accuracy cannot be 1 degree C, so why are you quoting temperature values to three decimal places?

Answer:

Corrected, and temperature reported to 2 decimals

8. Figures 5 and 7, Hovmoller plots: you are inconsistent. Figure 5, longitude (x-axis), days (y-axis); figure 7, vice-versa. Pick one orientation and stick to it.

Answer:

The orientation of the Hovmoller plots was chosen to have a better geographical representation: meridional section has longitude in y-axis, and thus, days in x-axis, and zonal section have latitude in x-axis, and days in y-axis. We added the maps with the positions of these virtual sections to illustrate it (Fig.2, 3).

The full caption to figures 2-3 are the following: Fig. 2. "Hovmoller diagram of DMI SST (a), SMOS SSS "A" (b), ASCAT wind speed (c) and ERA5 SLP (d) for the virtual meridional transect at 126 degree E. Sea ice concentration (AMSR2) is indicated with a blue color, see Fig. [SSS validation] for the color scale. The bathymetry along the transect (e) is extracted from "1 Arc-Minute Global Relief Model" " (Amante and Eakins (2009)). The position of a virtual transect is shown on SST SMI and SMOS SSS "A" maps for August 26, 2018 (f, g)."

Fig. 3 "Hovmöller diagram of DMI SST (a), SMOS SSS "A" (b), ASCAT wind speed (c), and ERA5 sea level pressure (d) for the zonaltransect at 78 degree N. Small circles at SST and SSS diagrams show in situ measurements of temperature and salinity (first CTD or TSG at 6.5m). Sea ice concentration (AMSR2) is indicated with a blue color, see Fig.5 for the color scale. The bathymetry along the virtual transect (e)is extracted from "1 Arc-Minute Global Relief Model" (Amante and Eakins (2009)). The position of

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a virtual transect is shown at SST SMIand SMOS SSS "A" maps for August 26, 2018 (f, g)"

Figure 8, temperature sections. Improve your presentation, please. Viewing the PDF, about half of the figure is just black and any temperature structure is obscured. The simplest solution would be to plot contours in white – not black!

Answer:

Corrected, please see Fig. 4 here. The full title of this figure is: "Temperature, degree C, (a, e, i, first column), salinity, (b, f, j, second column), water density, kg/m3 (c, g, k, third column) and buoyancy frequency, 1/s, (d, h, l, fourth column) obtained from CTD measurements in the upper 50 m for section 1 northward of Arkticheskiy Cape (upper row), section 10 across the Shokalskiy Strait (second row), and section 4 across the Vilkitskiy Strait (lower row). See Fig.1 for the section's positions. The zero km is always placed at the southern point of each section "

10. Section 4.1.2. Please improve your terminology. "Transport" is typically a volume transport, units mËĘ3/s. In your eq. 1, stress (N/m2) divided by [density (kg/m3) * Coriolis (sËĘ-1)] has units m2/s. These units appear in tiny (almost unreadable) notation in figure 9. This is neither a velocity nor a transport. Importantly, though: are your Ekman calculations valid in shallow water? Ekman's assumptions included (1) no boundaries (remote from coasts), and (2) deep water (typically >200 m). What is the Ekman layer depth? Is it not more likely that upwelling / downwelling are dominated by sea surface height changes in shallow water? For instance, a wind from the west will cause surface water movement to the right (the south) in the northern hemisphere. Water "piles up" against the coast, and that induces downwelling (at the coast): see papers by Steven Lentz, for example. Is this in accord with your calculated vertical velocities in figure 9? I would say not.

Answer:

The assumption with Ekman transport is exploited as the region of study has a very strong vertical stratification during the survey, which isolates the surface Ekman layer from the bottom. It was used as an illustration of possible mixing mechanisms, although we agree that over the most shallow areas this concept is not realistic. Please, see a new version of calculated horizontal Ekman transport et pumping (Fig. 5, 6)

The conclusions cannot then tell the reader why the new results matter.

Answer:

For the first time, we followed how the river water input was distributed and where it was stored in the Laptev and the East-Siberian Sea at synoptic scale. It became possible, first of all, due to a new satellite-derived salinity field in this region, a vast range of in situ measurements and also results of geochemical analysis. The shelf area of the Laptev and the East-Siberian Seas was described as a substantial region of sea ice production for the central Arctic by, e.g. Ricker et al., 2016, so the fresh water pathways in the Arctic should be understood better. The transformation of fresh river water input occurs and diminish very quickly during the Arctic summer, on the order of 1-2 weeks. Part of the fresh water was clearly mixed over the shelf of the Laptev Sea by wind-driven mixing, but a very important part was transported northward and to the East-Siberian Sea, under the ice. This result is different from a concept that fresh river water propagates mainly eastward, following the coastline under the Coriolis force. It is also different from the suggestion of Morisson et al.2012, where the displacement from the Eastern shelf Seas is northward (to the Central Arctic) with a low Arctic Oscillation Index (AO) and eastward with a high AO. In 2018 the mean AO index was high , but we showed that an important part of the river water was transported to the central basin. To better evaluate the freshwater budget, we suggest that future models assimilate the estimates of river discharge, a new satellite-derived sea surface salinity, and winds.

Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2019-60, 2019.

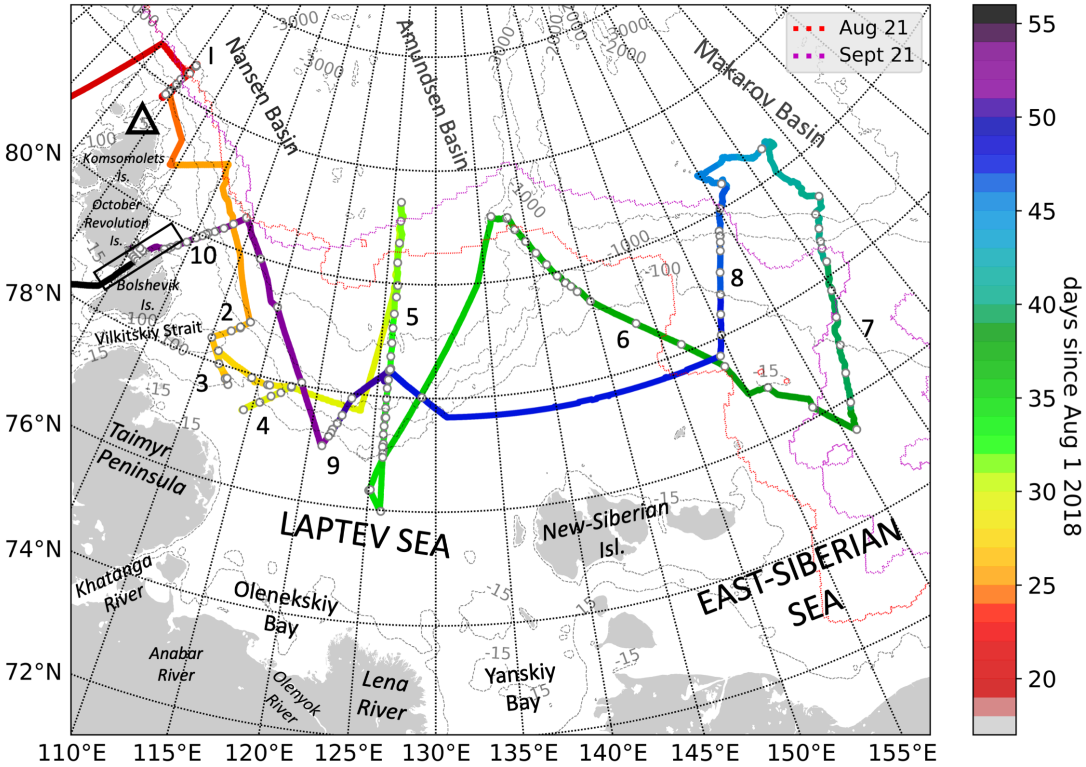

Fig. 1. Legs and stations of the ARKTIKA-2018 expedition overlayed on the bathymetry

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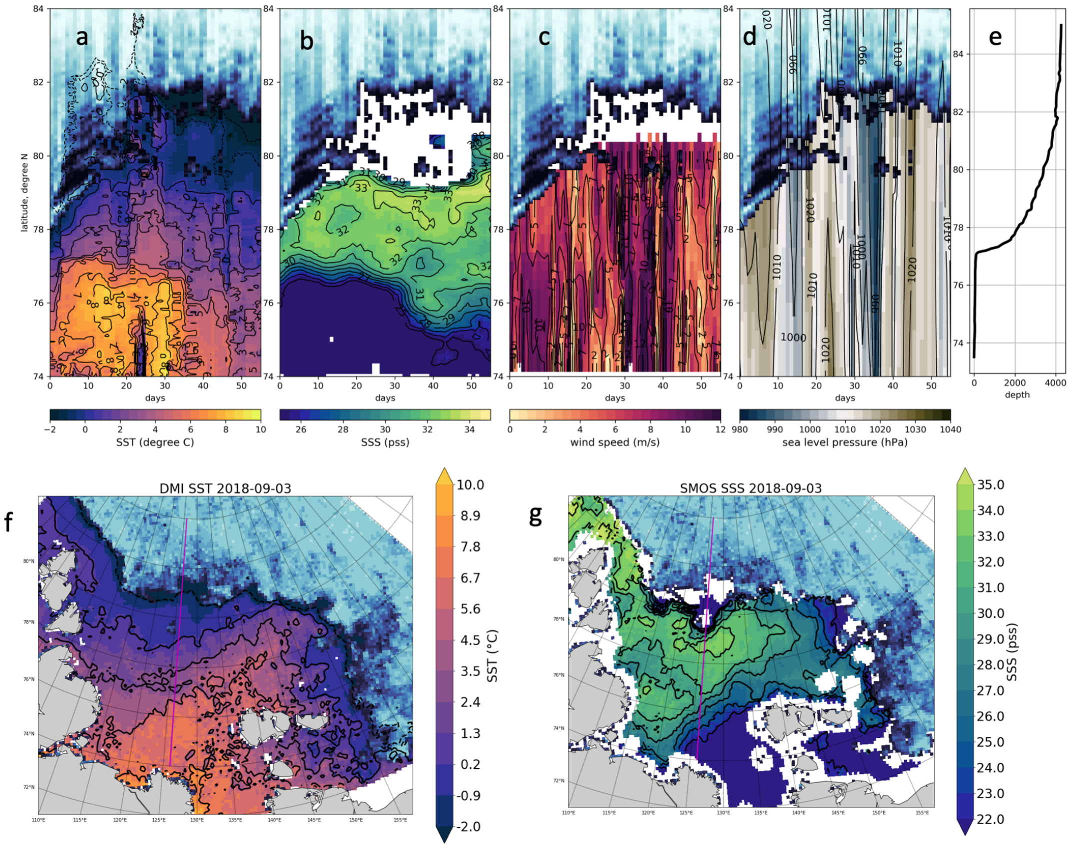

Fig. 2. Hovmoller diagram of DMI SST (a), SMOS SSS "A" (b), ASCAT wind speed (c), and ERA5 sea level pressure (d) for the meridional transect at 126 E

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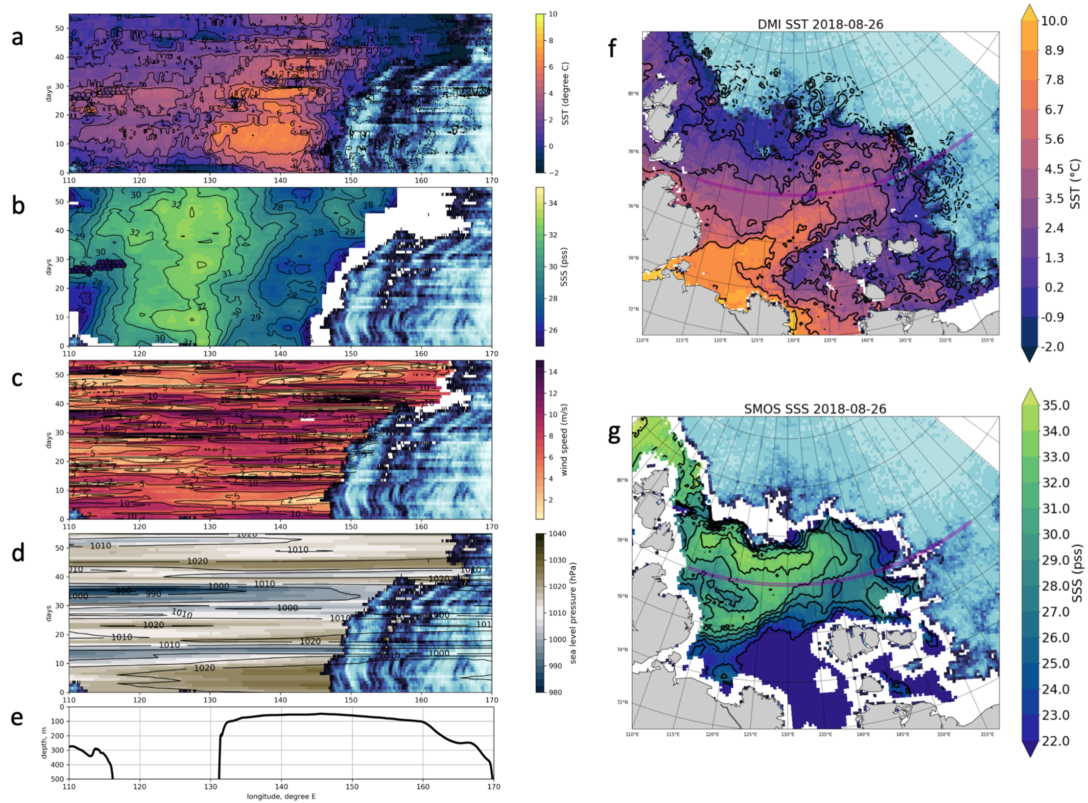

Fig. 3. Hovmoller diagram of DMI SST (a), SMOS SSS "A" (b), ASCAT wind speed (c), and ERA5 sea level pressure (d) for the zonaltransect at 78 N. Small circles at SST and SSS diagrams show in situ measurements

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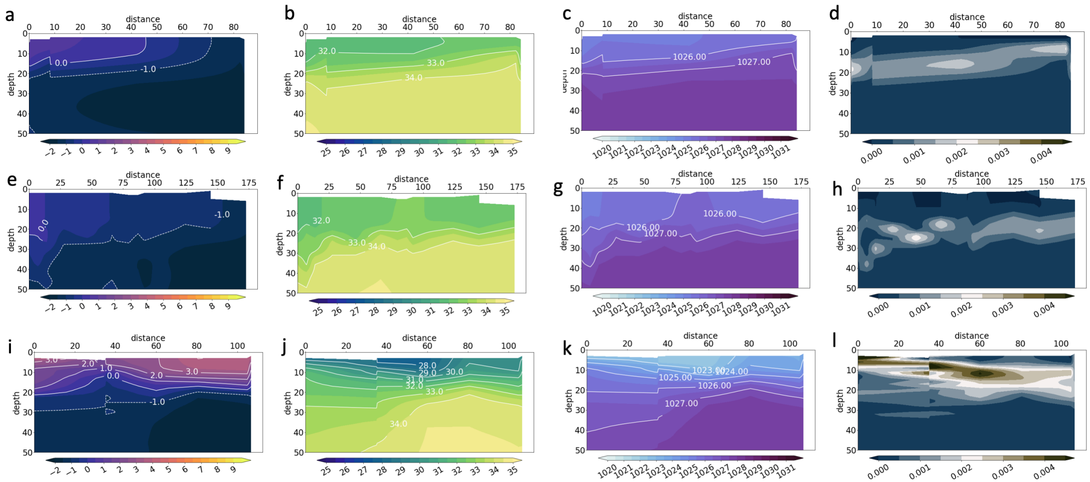

Fig. 4. Temperature, salinity, density obtained from CTD measurements in the upper 50 m for sections 1, 10, and 4

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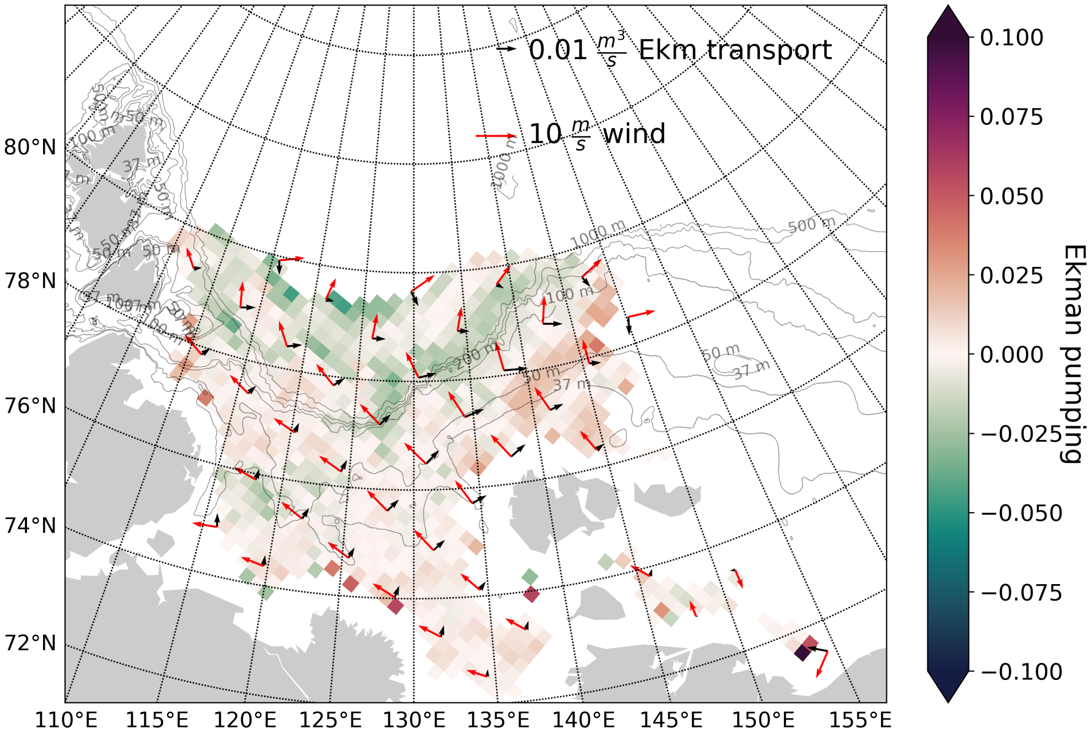

Fig. 5. Mean monthly Ekman transport and pumping together with wind speed in August 2018

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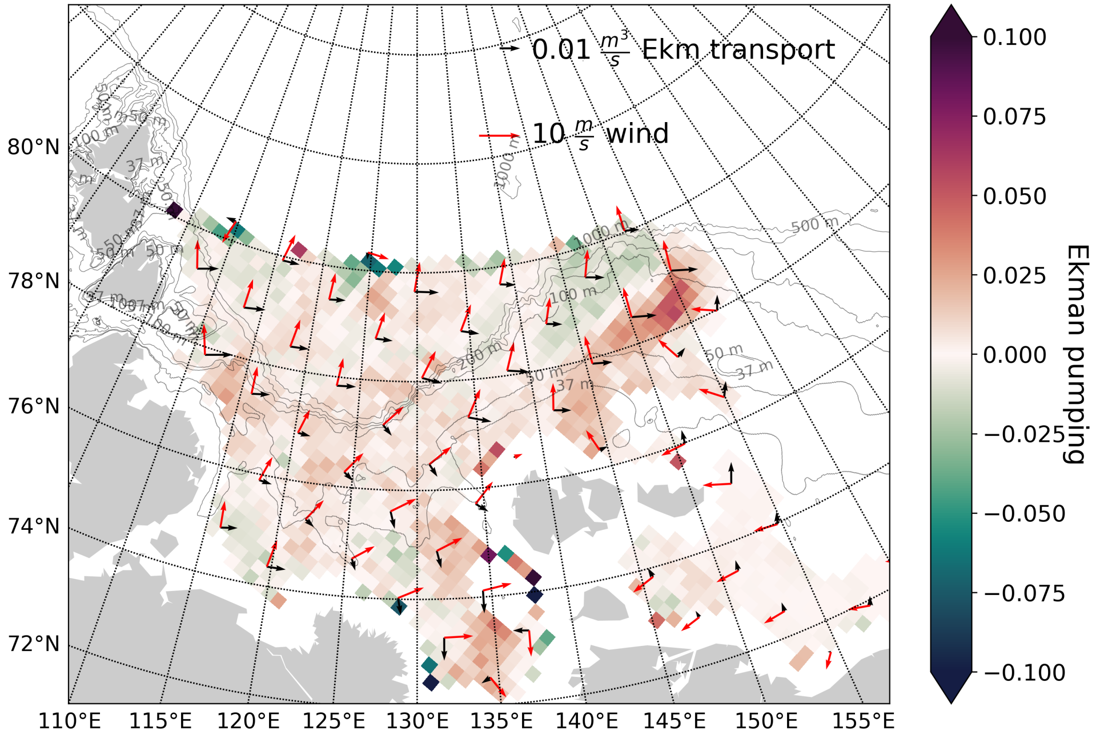

Fig. 6. Mean monthly Ekman transport and pumping together with wind speed in September 2018

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Ocean Sci. Discuss.,
https://doi.org/10.5194/os-2019-60-RC2, 2020

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Interactive comment on "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" *by* Anastasiia Tarasenko et al.

Anonymous Referee #2

Received and published: 4 February 2020

The submitted manuscript "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" by Tarasenko et al., presents and validates DMI SST L4 and SMOS SSS products (including errors) in a novel way against in situ temperature and salinity data (CTD profiles from the upper 6.5 m and TSG data at 6.5 m depth) obtained during the ARKTIKA-2018 expedition in the Laptev Sea and the East–Siberian Sea in August and September 2018. Since this region is highly under sampled, this study is of high relevance for the scientific community focusing on air-ice-ocean interaction processes in the Arctic Ocean. In the study, they follow the north-eastward spreading of warm and fresh river water from the Lena River Delta towards the central Laptev Sea and further towards and under the sea ice

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in the East-Siberian Sea. Also, river water inflow from the Kara Sea to the Laptev Sea is followed. By combining SST and SSS data products with satellite-derived products of sea ice concentration, wind speed (and direction), and ERA5 reanalysis fields of sea level pressure, they investigate wind-induced horizontal displacements of the river water plume due to Ekman transport and change in the strength of the stratification across different shelf-slope transects due to Ekman pumping (downwelling/upwelling). Based on the satellite-derived SST and SSS data, they also suggest different types of surface water masses for the area, and further present their distribution and presence during the studied period.

Even though this study is of high relevance, the submitted manuscript needs a major revision before suited for publication in Ocean Science. First of all, the English language needs to be improved and corrected. There are simply too many grammatical and syntax mistakes and typos for me to point out, so I will only mention some of the most general mistakes below. Secondly, I spent too many hours reading the manuscript due to an unfinished appearance with in some places lack of background information or a logical flow. Hence, I found it a bit hard to get the main objectives, the main results, and the main conclusions from the study. More specific comments follow below.

General on language:

Use definite (the) or indefinite (a/an) articles where suitable.

Remember to use capitol letter S in named seas: Laptev Sea, Kara Sea, East-Siberian Sea etc. This is not used consistently in the text. Same with named rivers, use capitol letter R (Lena River etc.) Same with named archipelagos, use capitol letter A (Severnaya Zemlya Archipelago etc.) Write the Arctic Ocean with capitol letter O. Use capitol letter W in named water masses: Atlantic Water, Arctic Water, etc.

Be consistent with use of present (is) or past (was). Use past and not present when referring to others work.

Avoid plural in surface water, river water, etc. if you don't have several named surface or river waters.

"Ice free areas" instead of "free of ice areas"?

In the north/south/east/west, not on the north/south/east/west.

Practical salinity scale (PSS) or practical salinity unit (PSU) is termed salinity with no unit, while absolute salinity is termed absolute salinity with unit g/kg.

Title

Perhaps change the title to "Properties of surface water masses . . ." To use surface water in plural seems a bit strange to me. You are suggesting six different water masses in the surface, not several surface waters, or?

Introduction

Generally, the introduction lacks objectives and proper background information of the study area. What is known in this region already, what studies have been done in this under-sampled area of the Arctic Ocean, what about river discharges into the study area (the river water plume is the main research focus of the study), and why is this area important?

Page 1, Line 19: "In the Arctic region, a strong seasonal warming and cooling with sea ice melting and freezing modify . . ."

Page 2, Line 5: ". . . the upper ocean water displacement . . ." Not plural.

Page 2, Line 9: " via the energy vertical distribution . . ." What energy?

Page 2, Lines 14-19: Rewrite this paragraph and improve language, for instance:

Line 14: Rewrite to i.e. ". . . proposes to use the term "surface layer" instead of "mixed layer" for the Arctic Ocean, because the water . . ."

Line 15: What is meant with "the water horizon lying between the sea surface and the

Arctic main halocline"? Use another word than horizon?

Line 17: "m depth in the Eastern Arctic Ocean (Dmitrenko et al., 2012) and at 100-200 m depth in the Western Arctic Ocean . . ."

Page 2, Line 23: Rewrite to i.e. ". . . the saline waters, which was considered the mean Arctic Ocean salinity at that time."

Page 2, Line 25: Reorder sentence to "Cherniavskaia et al. (2018) reported an overall salinity in the upper 5-50 m layer to lie within the range from 30.8 to 33 based on in situ data in the Laptev Sea during 1950-1993 and 2007-2012.

Page 2, Line 31: Remember unit on density (kg m-3)

Page 3, Line 8: Define L-band satellites.

Data and Methods

All information regarding the data and methods (presentation of the in situ hydrographic sections, processing and analysis methods) that are described and included in the results section should be moved to the data and method section. More details are given later. It would also be useful to include a link or doi to the downloaded data products (DMI SST L4, SMOS SSS L2 (you are making weekly averages of these, are you using any other SSS products?), AMSR2 SIC (and specify all SIC products used), ASCAT C-2015 L3 for wind speed and direction, ERA5 reanalysis for SLP and air temperature). Several data products are mentioned and utilised in this study, and to better clarify which ones that are actually used, it would be good to start the description of the used data products, why these ones are chosen, and what has been done with the data products in this study (post-processing). Then, other alternative products used in other studies can be mentioned afterwards for comparison? This goes especially for Section 2.2.2, which now appears a bit messy with a lot of mixed information about others products and work and the products used in this study.

Page 3, Lines 19-21: Put all place names on the map in Figure 1.

Page 3, Line 27: Did you find a typical error estimate from the comparison with CTD measurements?

Page 4, Line 2: What interpolation methods were used?

Page 4, Line 6: Define AVHRR, MODIS and VIIRS

Page 4, Line 8: Define AMSR2

Page 4, Line 11: Your write "(hereafter referred to as "SST DMI")", then make sure you do. Several names are used on this product later in the manuscript (DMI SST L4, the SST field from DMI L4 product, blended DMI product?, temperature estimates provided by DMI, and others).

Page 4, Line 11: Define Level 4.

Page 5, Line 7: You write "100-km averaged ship SSS . . ." Is this TSG?

Page 5, Lines 12-13: Define SMAP CAP/JLP and SMOS BEC L3, REMSS

Page 5, Line 16: Define ESA.

Page 5, Line 17: Be consistent with naming of products. Here you use L2 SSS and not SMOS SSS L2.

Page 5, Line 18: What do you mean with individual SMOS SSS? Explain how the SMOS SSS are sampled over an Icosahedral Snyder Equal Area grid at 15 km resolution. Is this the interpolation?

Page 5, Line 23: Define ECMWF.

Page 5, Lines 26-29: Specify the correction with numbers. Also, give the criterion on the ACARD parameter. And what are the typical errors in the weekly SMOS SSS and the individual SMOS SSS?

Page 5, Lines 32-34: Where is the river plume? Define and introduce it. How does this affect the weekly SSS error?

Page 6, Line 4: Define all the ice masks provided.

Page 6, Line 10: Define ASCAT.

Results

Move all method and technical descriptions to Data and Methods. Only results should be presented here. The results section should have more focus on the SST and SSS distribution, the hydrographic sections, and highlight results to be discussed, not so much on technical details, error analysis and discussion, which I recommend you to move to the data and method section. In general when presenting and discussing the results, please be consistent and distinguishing between the parameters SST/SSS and in situ temperature/salinity. Don't use temperature or salinity on both.

Page 6, Line 22: Please define the river waters. Use plural form if there are several types of river water, it not, use singular form (river water).

Page 6, Lines 24-25: Move to Data and Method.

Page 7, Lines 1-7: This paragraph belongs in data and methods.

Page 7, Line 2: What are "basic statistics"?

Page 7, Lines 4-5 & 8-9: How much does the temperature and salinity change in the upper meters? Perhaps show a mean +/- std profile of the upper 10 meters?

Page 7, Lines 10-11: And how is it in ice free conditions?

Page 7, Line 15: In-situ surface layer temperature is then the upper 6.5 m (but not including the uppermost 2? meters typically)?

Page 7, Lines 17-19: This is a complicated sentence, so please rewrite. Can this be shown?

Page 7, Line 21: What grid? Please describe in data and method, and refer to it.

Page 7, Lines 28-29: I guess the 15 km SMOS resolution is the interpolated resolution?

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Please be more precise when naming the different SMOS SSS products, which should all be clearly defined and stated in the data and method section.

Page 7, Line 31: Use either ARKTIKA-2018 expedition or Akademik Tryoshnikov measurements. Be consistent with the naming of data both in the text and in the figures.

Page 7, Line 33: Again, be consistent with naming of data products, I guess the vessel SSS is the CTD and TSG data from the upper 6.5 m from the ARKTIKA-2018 expedition?

Page 7, Lines 33-34: This belongs in the method description.

Page 8, Line 1: "SMOS post-processed SSS", what is this product compared to the other named products?

Page 9, Lines 2-3: Is the precision so high that you can use three decimals in SST?

Page 9, Lines 2-4: Put place names on the map in Figure 1.

Page 9, Lines 9-10: Please define river water somewhere (in data and method?). What is the definition of the river water plume?

Page 9, Line 10: Standard deviation of what?

Page 10, Line 1: What about the Katanga River Estuary?

Page 10, Line 2: Define the thermal fronts.

Page 10, Line 15: "at 125 E, . . ." what latitude?

Page 10, Line 20: Distribution of freshwater input, is that water with S = 0? Please define the characteristics of this freshwater.

Page 10, Line 21: Please refer to Figure 1. What Section number or longitude/latitude limits?

Page 10, Line 21: Temporal evolution of what? Introduce Figure 6 before Figure 7.

Page 10, Line 25: “shelf break” instead of “edge of the shelf”?

Page 10, Line 29: What was the wind direction during these series of cyclone passages?

Page 10, Line 30: Change to “. . . salinity increased by 1 . . .”

Page 10, Line 34: Change to “. . . mixing event induced by the wind.”

Page 10, Lines 30-34: How does this relate to any river discharge data from the same period? Are there any model data to compare with?

Section 4.1.1

Change to something like “Water from the Kara Sea”. You have not defined Kara Sea waters anywhere in the text.

Page 11, Lines 6-7: The temperature is decreasing?

Page 11, Line 7: Where and when has the exchange with the atmosphere taken place? Is the atmosphere colder here than in the central Laptev Sea?

Page 13, Line 1: You write “. . . significantly greater than . . .” How can you see relative amount of freshwater from one snap-shot and with different timing on each section occupation?

Page 13, Lines 2-5: Show place names on map in Figure 1. Also, define the hydrographic sections in data and methods with time, wind condition, and air temperature during their occupations. Then stick to the named Sections (Section numbers) later in the text.

Page 13, Line 7: 1024-1027 kg m-3?

Page 13, Line 14: What happens during cyclone passages? Clouds? Have you discussed this effect in Data and Methods? If yes, refer to it.

Page 13, Line 15: Can you provide any T and S limits?

Page 13, Line 17: By depression passage you mean low-pressure or cyclone passage?

Page 13, Lines 18-19 & Page 14 Lines 1-4: What about wind direction? Wind speed alone will not give the complete forcing pattern. Perhaps make some cross-correlation maps between wind speed/direction and SLP with SST and SSS? SLP and wind direction should be highly correlated.

Page 14, Lines 5-7: This belongs in Data and Methods.

Page 14, Line 9: Absolute salinity and conservative temperature are shown in Figure 8. Either change the text to absolute salinity and unit g/kg or change to practical salinity in figure.

Page 14, Line 11: You refer to different observations at specific latitudes in the figure, but the figure is presented with distance in km, so please refer to km as well. This applies for the other sections as well.

Page 14, Lines 12-16: What about melting under the sea ice due to the presence of warmer (above freezing point temperature) river water? This will cool the river water and still keep the water under the ice relatively fresh. Are there any δ180 data (or other tracers) to be able to identify the source of this water?

Page 14, Line 15: You write: "The heat exchange with the sea ice might be more effective than with the atmosphere, . . ." Why?

Page 14, Line 19: "Below the pycnoclines, . . ." to what depth?

Page 15, Line 1: The 34.5 isohaline is not shown in the figure.

Page 15, Lines 2-3: What are the T and S characteristics of AW is this region? I don't agree that AW is seen at 100-120 m depth in Figure 8? Why is it instability in the AW layer?

Page 15, Line 5: Define all hydrographic sections in Data and Method (see earlier comment on this).

Page 15: Please remember to refer to figures.

Page 15, Line 11: You write: "… which is clearly seen in temperature signal that is negative even close to the surface." Is the temperature still above the freezing point, i.e. any melting under the ice?

Page 15, Lines 13-14: What kind of mixing?

Page 15, Line 19: How can you see an efficient mixing from these data?

Page 15, Line 20: Are the temperatures still above freezing?

Page 15, Lines 25-26: The river discharge information should be introduced in the introduction.

Page 15, Lines 27-28: Was the atmosphere colder or warmer than the river water or the mixed upper layer water? What about melting of sea ice from below? Is the river water warmer than the freezing point temperature?

Section 4.1.2

Some more background information is needed in the beginning of this section. It is also an analysis method and should be moved to the data and method section. The surface fronts in question should be defined. To get the Ekman transport, you need to integrate over the Ekman depth, what is the Ekman depth in this region? Assumptions made by Ekman were no boundaries, infinitely deep water, and no geostrophic flow. How are these assumptions met in this region? What happens when you have boundaries (coastlines)?

Page 16, Line 8: Give the reference to TEOS-2010 and show the formula for the drag coefficient CD.

Page 16, Line 10: Use Ekman pumping instead of vertical Ekman speed?

Page 17, Line 12: You write "… mixing of different water masses, …" What are these

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water masses? You should introduce the water masses in the region in the introduction section.

Section 5

Perhaps start the results with this section?

Page 17, Line 17: And below 200 m?

Page 17, Line 23: Specify which of the Arctic Ocean waters that quickly change.

Page 17 Line 24: Add "…, and the synoptic satellite data provide …"

Page 17, Line 32: The "classical" water masses, do they have a name?

Page 18: Refer to figures.

Page 18, Line 1: Add "… larger range than the near-surface (upper 6.5 m) in situ measurements …"

Page 18, Line 7: A recognisable river front or a river plume front? Define.

Page 18; Line 8: 145 E? How do you define the sea edge? Is it a specific sea ice concentration limit?

Page 18, Line 11: You write "… captured under the ice and exposed back." How or when? What about melting sea ice from below?

Page 18, Lines 21-22: Show place names on map in Figure 1.

Page 18, Lines 24-25: There is also a high density within the range 22.5-30 and 3-4 °C.

Discussion and conclusion

This section provides little discussion or conclusions, mostly summary. There is more discussion in between the presentation of the results in the Results section.

Page 19, Lines 11-12: You write “The fresh waters displacement was associated with the Ekman transport.” How? This is not well presented or described in the results.

Page 19, Lines 15-16: You write “. . . and there is no evidence that the sea ice melting itself can create such a considerable layer of freshwater.” How or where have you presented this lack of evidence?

Page 19, Lines 18-20: What about river water melting sea ice from below? Are there any δ18O data (or other tracers) to evaluate this?

Page 19, Line 24: Add “Calculated monthly Ekman pumping indicates the area of most intense mixing processes induced by wind.”?

Page 19, Lines 25-26: Why is this included? This is not used in the discussion. Are there any conclusions from this?

Appendix

Page 20, Lines 7-10: What about Ekman transport to the south in September piling up water on the shelf and toward the coast in the south? This might induce downwelling (see Figure 9).

Figures

Figures with more than one panel should be labelled with a), b), c) etc. and then properly referred to in the figure captions and the text when the figures are described. Also use same font size in the figures with several panels. Remove titles on figures and add this text in the figure caption instead.

Figure 1: What is the definition of the sea ice edges? Add all place names mentioned in the text on the map.

Figure 2 and 3: Last sentences in the figure captions: this information should be provided in the data and method section.

Figure 4: Missing numbers on y-axis in lower left panel. Use white isolines below 0 degree Celsius/28 PSS? It is hard to see black lines on dark background. This is also the case for Figures 6 and 8.

Figures 5 and 7: Where is the data from? What bathymetry data is used?

Figure 8: Why do you show conservative temperature and absolute salinity in this figure and not in

Figure 6? At least use proper units when referring to Figure 8 in the text.

Figure 9: Increase the fonts. The two upper rows are not described in the text. What are the arrows in the lowest row, and why is the resolution higher than in the row above? Write units in the figure caption. Where is the data from?

Figure 10: Add the freezing point temperature line. Remove the figure title.

Figure 11: What are the boxes? Are the lines the freezing point temperature line?

Figure 12: Put the dates inside the plots instead.

Figure A1: Remove the titles from the figures. Write units in the figure caption. Increase the fonts.

Tables

Table 1: Add more information to the table caption.

Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2019-60, 2019.

Ocean Sci. Discuss.,
https://doi.org/10.5194/os-2019-60-AC3, 2020

Interactive comment on "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" *by* Anastasiia Tarasenko et al.

Anastasiia Tarasenko et al.

tad.ocean@gmail.com

Received and published: 15 May 2020

General comments on language:

Use definite (the) or indefinite (a/an) articles where suitable. Remember to use capital letter S in named seas: Laptev Sea, Kara Sea, East-Siberian Sea etc. This is not used consistently in the text. Same with named rivers, use capital letter R (Lena River etc.) Same with named archipelagos, use capital letter A (Severnaya Zemlya Archipelago etc.) Write the Arctic Ocean with capital letter O. Use capital letter W in named water masses: Atlantic Water, Arctic Water, etc. Be consistent with use of present (is) or past (was). Use the past and not present when referring to others' work. Avoid plural in surface water, river water, etc. if you don't have several named surface or river waters. "Ice free areas" instead of "free of ice areas"? In the north/south/east/west, not on the north/south/east/west. Practical salinity scale (PSS) or practical salinity unit (PSU) is termed salinity with no unit, while absolute salinity is termed absolute salinity with unit g/kg.

Answer:

Thank you very much. We have thoroughly edited the paper to follow your recommendations.

Title. Perhaps change the title to "Properties of surface water masses ..." To use surface water in plural seems a bit strange to me. You are suggesting six different water masses in the surface, not several surface waters, or?

Answer:

We will follow this recommendation and change the title of the paper.

Introduction. Generally, the introduction lacks objectives and proper background information of the study area. What is known in this region already, what studies have been done in this under-sampled area of the Arctic Ocean, what about river discharges into the study area (the river water plume is the main research focus of the study), and why is this area important?

Answer:

We have rewritten the introduction with more focus of the undersampling of this region and on the most important river discharges in this area. We have also added the following figure for the Lena river discharge in the Data and Methods section (Fig. 1).

Page 1, Line 19: "In the Arctic region, a strong seasonal warming and cooling with sea ice melting and freezing modify . . ." Answer: Corrected

Page 2, Line 5: ". . . the upper ocean water displacement . . ." Not plural. Answer:

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Corrected

Page 2, Line 9: " via the energy vertical distribution . . ." What energy? Answer: We meant the thermal energy

Page 2, Lines 14-19: Rewrite this paragraph and improve language, for instance: Line 14: Rewrite to i.e. ". . . proposes to use the term "surface layer" instead of "mixed layer" for the Arctic Ocean, because the water . . ." Answer: Corrected

Line 15: What is meant with "the water horizon lying between the sea surface and the Arctic main halocline"? Use another word than horizon? Answer: Corrected for "layer"

Line 17: "m depth in the Eastern Arctic Ocean (Dmitrenko et al., 2012) and at 100-200 m depth in the Western Arctic Ocean . . ." Answer: Corrected

Page 2, Line 23: Rewrite to i.e. ". . . the saline waters, which was considered the mean Arctic Ocean salinity at that time." Answer: Corrected

Page 2, Line 25: Reorder sentence to "Cherniavskaia et al. (2018) reported an overall salinity in the upper 5-50 m layer to lie within the range from 30.8 to 33 based on in situ data in the Laptev Sea during 1950-1993 and 2007-2012. Answer: Corrected

Page 2, Line 31: Remember unit on density (kg m-3) Answer: Corrected

Page 3, Line 8: Define L-band satellites. Answer: Corrected, 1.43 GHz

Data and Methods. All information regarding the data and methods (presentation of the in situ hydrographic sections, processing and analysis methods) that are described and included in the results section should be moved to the data and method section. More details are given later. Answer: Thank you for your recommendation. We reorganized some sections and added information and one figure on CTD and in situ measurements on Page 3, Line 27 (see below).

It would also be useful to include a link or doi to the downloaded data products (DMI SST L4, SMOS SSS L2 (you are making weekly averages of these, are you using any other SSS products?), AMSR2 SIC (and specify all SIC products used), ASCAT C-2015 L3 for wind speed and direction, ERA5 reanalysis for SLP and air temperature). Several data products are mentioned and utilised in this study, and to better clarify which ones that are actually used, it would be good to start the description of the used data products, why these ones are chosen, and what has been done with the data products in this study (post-processing). Then, other alternative products used in other studies can be mentioned afterwards for comparison? This goes especially for Section 2.2.2, which now appears a bit messy with a lot of mixed information about others products and work and the products used in this study.

Answer:

Corrected where possible. We tried to unify the products names used in the paper and clarified the representation and processing.

Page 3, Lines 19-21: Put all place names on the map in Figure 1.

Answer:

Corrected, please see a new version of the figure (Fig. 2 here). The full version of caption of Fig.1: Legs and stations of the ARKTIKA-2018 expedi- tion overlayed on the bathymetry from ETOPO1 "1 Arc-Minute Global Relief Model" " (Amante and Eakins (2009)). CTD stations are shown with white dots. The color indi- cates the number of days since August 1, 2018. The sea ice edge position is indicated with a red dashed line for the beginning (August 21) and with the purple dashed line for the end of the expedition (September 21). The ice edge is based on the sea ice mask provided in the SST DMI product. Numbers indicate positions of 10 oceanographic transects discussed below. The black triangle in the north of the Komsomolets Island shows the Arkticheskiy Cape. The Severnaya Zemlya Archipelago consists mainly of the Komsomolets, the October Revolution, and the Bolshevik Islands (with smaller islands not shown here). The black box indicates the Shokalskiy Strait between the October Revolution and the Bolshevik Islands. The Yana River estuary is situated southward the Yanskiy Bay (out of the map).

Page 3, Line 27: Did you find a typical error estimate from the comparison with CTD measurements? Answer: Yes, we did it. We added it as well as further information on the vertical profiles in this section to clarify the applicability of the CTD data for satellite validation studies : When calculating a linear regression between the CTD measurements at 6.5 meters depth and the TSG measurements, we obtained a good correlation for both temperature and salinity (correlation coefficients equal to 0.9789 and 0.9656, respectively). The standard error was 0.0231 for temperature and 0.0251 for salinity, and the standard deviation for the difference of measurements (CTD-TSG) was STD_temp = 0.4134, and STD_sal = 0.4296. We applied the obtained linear regression equation to TSG data to obtain adjusted temperature and salinity data.

Finally, to investigate if the TSG measurements can be used to study the surface layer in a highly stratified Laptev sea, we estimlated a summer mixed layer depth following de Boyer Montégut et al. (2004) method based on density and temperature gradient thresholds (Fig.2). The MLD base is found at a depth of the first maximum temperature gradient exceeding (or equal to) a defined (by a threshold) gradient (see de Boyer Montégut et al. (2004)). Using a similar approach, we also computed MLD independently with density, temperature and salinity vertical profiles. The thresholds chosen for the gradients were the following: 0.3 kg/m3 per 1 m for density, 0.2 degrees per 1 m for conservative temperature and 0.2 psu per 1 m for practical salinity gradient. For the MLD calculated from salinity (MLDsal), most (75.17%) vertical profiles had a MLDsal larger than 7 m , with a median value of MLDsal of 11.99 m. As for the temperature-based MLD (MLDtemp), 81.37% of profiles had the MLD larger than 7 m, with a median value of MLDtemp = 13.50 m. Thus, we conclude that in most cases the upper 12 m of the surface layer was homogeneous, and our CTD and TSG measurements can be used for the validation of satellite data.

The full caption for Figure 3: Vertical profiles of conservative temperature (a, b) and practical salinity (c, d) from CTD measurements in the upper ocean layer. Figures (a) and (c) show all vertical profiles in the upper 50 m, where red stars indicate the mixed layer depth, calculated using de Boyer Montégut et al. (2004) method (see details in the text), colored profiles show the cases, when the MLD is below 7 m depth and gray profiles indicate when the MLD is above 7 m depth. Figures (b) and (c) show the median vertical profiles of temperature and salinity in the5-100 m layer, respectively, where the shaded area shows the associated STD.

Page 4, Line 2: What interpolation methods were used? Answer: Linear interpolation, added to the text.

Page 4, Line 6: Define AVHRR, MODIS and VIIRS Answer: Corrected

Page 4, Line 8: Define AMSR2 Answer: Corrected

Page 4, Line 11: Your write "(hereafter referred to as "SST DMI")", then make sure you do. Several names are used on this product later in the manuscript (DMI SST L4, the SST field from DMI L4 product, blended DMI product?, temperature estimates provided by DMI, and others). Answer: Corrected

Page 4, Line 11: Define Level 4. Answer: "Level 4 product" means that several swath measurements were interpolated to achieve a regular resolution in time and space

Page 5, Line 7: You write "100-km averaged ship SSS . . ." Is this TSG? Answer: Yes, corrected to clarify to "100-km averaged TSG surface salinity measurements"

Page 5, Lines 12-13: Define SMAP CAP/JLP and SMOS BEC L3, REMSS Answer: Corrected. "However, existing L3 ("Level 3" means a product resampled at a uniform time-spatial grid, different from swath) SSS products: SMAP CAP/JPL (Soil Moisture Active Passive satellite, a product created using the Combined Active Passive algorithm by Jet Propulsion Laboratory) or SMOS BEC (Barcelona Expert Center), are spatially averaged from 60 km to more than 100 km." REMSS (Remote Sensing Systems)

Page 5, Line 16: Define ESA. Answer: ESA (European Space Agency)

Page 5, Line 17: Be consistent with naming of products. Here you use L2 SSS and not SMOS SSS L2. Answer: Corrected. The paragraph describing postprocessing of SMOS SSS L2 data from ESA to the used SMOS SSS L3 product was re-written to clarify the naming (see a new part 2.2.2)

Page 5, Line 18: What do you mean with individual SMOS SSS? Explain how the SMOS SSS are sampled over an Icosahedral Snyder Equal Area grid at 15 km resolution. Is this the interpolation?

Individual SMOS SSS" was mentioned to refer to the radiometric resolution of L1 (Level-1 product, thus brightness temperatures at swath grid) and is an initial resolution for all L2 products, Your text hereindependent from their producer. The SMOS SSS L2 product mentioned in the text is interpolated at ISEA grid by ESA and distributed on this grid. We changed the text as following: "The mean spatial (radiometric) resolution of SMOS product is close to 50 km, but SSS SMOS ESA L2 products are distributed resampled over an Icosahedral Snyder Equal Area (ISEA) grid at 15 km resolution."

Page 5, Line 23: Define ECMWF. Answer: (European Centre for Medium-Range Weather Forecasts)

Page 5, Lines 26-29: Specify the correction with numbers. Also, give the criterion on the ACARD parameter. And what are the typical errors in the weekly SMOS SSS and the individual SMOS SSS? Answer: We add the formula of the correction in the paper. The criterion on the ACARD parameter is : we consider only SSS measurements with an ACARD value over 45. Typically, theoretical error of weekly SSS measurements may reach values under 0.5 pss in the center of the Laptev Sea and reach values higher than 2 pss close from sea ice and in coastal areas. For the individual SMOS SSS the theoretical error is very variable and may reach value higher than 10 pss.

Page 5, Lines 32-34: Where is the river plume? Define and introduce it. How does this affect the weekly SSS error? Answer: The definition of river plume will be introduced later. We changed the sentence to: Concerning the way on how a river plume may influence the SMOS SSS “A” error : here, a river plume is associated with an increase of SST that induces a theoretical decrease of SMOS SSS “A” error. Nevertheless, river plumes are closer to the coast and SST (used as prior during SMOS SSS retrieval) has a higher error in these areas : these will increase the SMOS SSS “A” error.

Page 6, Line 4: Define all the ice masks provided. Answer: The AMSR2 ice masks were used in addition to the masks provided with every satellite product discussed (SST DMI, SMOS SSS "A", ASCAT (Advanced SCATterometer) winds L3).

Page 6, Line 10: Define ASCAT. Answer: ASCAT (Advanced SCATterometer)

Results. Move all method and technical descriptions to Data and Methods. Only results should be presented here. The results section should have more focus on the SST and SSS distribution, the hydrographic sections, and highlight results to be discussed, not so much on technical details, error analysis and discussion, which I recommend you to move to the data and method section. In general when presenting and discussing the results, please be consistent and distinguishing between the parameters SST/SSS and in situ temperature/salinity. Don’t use temperature or salinity on both. Page 6, Lines 24-25: Move to Data and Method. Page 7, Lines 1-7: This paragraph belongs in data and methods. Page 7, Lines 33-34: This belongs in the method description. Answer: Thank-you very much. We have taken these recommendations into account. The whole part 3.1 was moved to section 2: the validation of SST and SSS satellite productsis now presented after the description of the product.

Page 6, Line 22: Please define the river waters. Use plural form if there are several types of river water, if not, use singular form (river water). Answer: Corrected for the singular form. The definition of river water cannot be givenat this point, as we are only later defining the water masses.

Page 7, Line 2: What are “basic statistics”? Answer: Linear regression equation, correlation coefficients, STD. . . Excluded this part from the text as unnecessary.

Page 7, Lines 4-5 & 8-9: How much does the temperature and salinity change in the upper meters? Perhaps show a mean +/- std profile of the upper 10 meters? Answer: The vertical profiles of in situ temperature and salinity were added in the "data" section (new Figure 2). A "mean" vertical profile of temperature or salinity is not representative for the areas where surface temperature varies from +6 to -1.8°C and salinity, from 24 to 34.5.

Page 7, Line 15: In-situ surface layer temperature is then the upper 6.5 m (but not including the uppermost 2? meters typically)? Answer: In-situ surface layer temperatureincludes all measurements from 0 to 6.5 m depth, thus "upper 6.5 m layer". Indeed, the "uppermost 2 meters" are typically not measured, due to how a CTD cast is done and data processing. The postprocessing of the CTD data usually eliminates the top 1-3 meters, because the Rosette with CTD is by itself 1.5 m tall itself and also because surface waves and the close-by ship hull affect the near-top ends of the profiles.

Page 7, Lines 17-19: This is a complicated sentence, so please rewrite. Can this be shown? Answer: Please, see the Figure 3, where the surface CTD measurements are shown. "This value seems to be realistic, and the in situ data justifies it. According to CTD measurements, in average, the 0-3 m water layer is 0.3 degree warmer than the 3-6.5 m layer..."

Page 7, Line 21: What grid? Please describe in data and method, and refer to it. Answer: All products were interpolated on a regular polar stereographic grid (15 km)

Page 7, Lines 28-29: I guess the 15 km SMOS resolution is the interpolated resolution? Please be more precise when naming the different SMOS SSS products, which should all be clearly defined and stated in the data and method section. Answer: Yes, we meant the spatial resolution of interpolated at 15 km ISEA grid, SMOS SSS "A" product. Corrected.

Page 7, Line 31: Use either ARKTIKA-2018 expedition or Akademik Tryoshnikov measurements. Be consistent with the naming of data both in the text and in the figures.

Answer: Corrected to “in situ measurements” here, using ARKTIKA-2018 expedition further

Page 7, Line 33: Again, be consistent with naming of data products, I guess the vessel SSS is the CTD and TSG data from the upper 6.5 m from the ARKTIKA-2018 expedition? Answer: Yes, corrected to “in situ measurements”

Page 7, Lines 33-34: This belongs in the method description. Answer: Corrected

Page 8, Line 1: “SMOS post-processed SSS”, what is this product compared to the other named products? Answer: In the revised draft we write (and weearlier meant it) about SMOS SSS “A” - it is always the same product.

Page 9, Lines 2-3: Is the precision so high that you can use three decimals in SST? Answer: The indicated accuracy is arbitrary. It can be reduced to two decimals as in typical SST-validation reports, e.g. http://www.osi-saf.org/sites/default/files/dynamic/page_with_files/file/validation_report_sentinel3_slstr_sst_calval_v1p0.pdf

Page 9, Lines 2-4: Put place names on the map in Figure 1. Answer: Added

Page 9, Lines 9-10: Please define river water somewhere (in data and method?). What is the definition of the river water plume? Answer: We implicitly did it in section 5 and Table 1 when discussing the surface water masses in the Laptev Sea. There was no particular definition of the river plume in this study, as collected in situ data was not covering the freshest waters sufficiently close to river discharge deltas. In general, we meant the furthest (from river deltas) salinity gradient position as a front of “river plume” . It roughly corresponds to the 29 isohaline position (Fig.4). We added the definition of “river plume” in the last paragraph of the Introduction section.

Page 9, Line 10: Standard deviation of what? Answer: “Standard deviation of SST”, corrected

Page 10, Line 1: What about the Katanga River Estuary? Answer: Indeed, changed to: “Standard deviation of SST in Fig.\ref{fig: sst-sss-mean-and-std} is the largest in the

Olenekskiy Bay (over 2.5°C), along the coastline close to the Khatanga estuary (2.5-3°C), the Lena River delta (about 4°C) and in marginal ice zone (mostly over 1.5°C)."

Page 10, Line 2: Define the thermal fronts. Answer: Thermal fronts are the areas with largest gradients of temperature.

Page 10, Line 15: "at 125 E, . . ." what latitude? Answer: "At 78-80° N 125°E, free-floating patches of broken ice detached from compact sea ice edge were observed during several weeks in August-September 2018"

Page 10, Line 20: Distribution of freshwater input, is that water with S = 0? Please define the characteristics of this freshwater. Answer: Freshwater is defined in comparison to the "marine water", eg. less than 34.92 as in the studies of (Bauch and Chernyavskaya, 2018) or 34.80, as defined by Aagard et al., 1989. As the 0-salinity river water quickly mixes with saltier marine water, in reality the "freshwater" we consider is more "brackish" than "fresh". Nevertheless, for the simplicity assuming a river plume front at 29 isohaline, the "freshwater" corresponds to all water masses with a salinity lower than 29.

Page 10, Line 21: Please refer to Figure 1. What Section number or longitude/latitude limits? Answer: Virtual meridional section corresponds to section 5, and the virtual zonal section does not correspond to any real oceanographic sections. The maps of the virtual sections positions were added to both Hovmöller diagrams.

Page 10, Line 21: Temporal evolution of what? Introduce Figure 6 before Figure 7. Answer: Corrected to : "To evaluate the distribution of freshwater input in the Laptev Sea in August-September 2018, we considered virtual zonal and meridional transects along 78° N and 126° E, respectively, and plotted the temporal evolution of SST DMI, SSS SMOS "A", wind speed and SLP in Hovmöller diagrams"

Page 10, Line 25: "shelf break" instead of "edge of the shelf"? Answer: Corrected

Page 10, Line 29: What was the wind direction during these series of cyclone pas-

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sages? Answer: Below, there is an initial version of Fig. 5 with the wind speed and wind directions instead of SLP. We found it too complex to present in paper, so have chosen the pressure for clarity. The wind directions had 0-90° azimuth (north-east in "oceanographic convention").

Page 10, Line 30: Change to ". . . salinity increased by 1 . . ." Answer: Corrected

Page 10, Line 34: Change to ". . . mixing event induced by the wind." Answer: Corrected

Page 10, Lines 30-34: How does this relate to any river discharge data from the same period? Are there any model data to compare with? Answer: It is possible that a small peak observed in the Lena River discharge in the very beginning of September (Fig. 1) contributed to an additional portion of fresh water that arrived at 78 N latitude in several weeks.

Section 4.1.1 Change to something like "Water from the Kara Sea". You have not defined Kara Sea waters anywhere in the text. Answer: Corrected the title. The Kara Sea receives the two other large Siberian Rivers, the Ob' and the Yenisey, and thus presents a low salinity compared to the central Arctic Basin. In the absence of significant river sources on the Severnaya Zemlya Archipelago, we considered that the freshwater input close to the Vilkitskiy and the Shokalskiy Straits, arrives from the Kara Sea.

Page 11, Lines 6-7: The temperature is decreasing? Answer: We suppose so, but the SST of the Kara Sea should be additionally studied.

Page 11, Line 7: Where and when has the exchange with the atmosphere taken place? Is the atmosphere colder here than in the central Laptev Sea? Answer: The comparison of the Kara and the Laptev seas summer conditions should be additionally studied and can become a subject of another paper. Nevertheless, we can suppose that a passage through the Vilkitskiy Strait diminish the temperature of arriving waters. The

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Severnaya Zemlya Archipelago is known for its icebergs (thus, the Kara Water heat might be lost in their vicinity). There is also a system of countercurrents in the Vilkitskiy Stait. Together with tidal currents and steep topography it creates turbulent instability, and a loss of energy.

Page 13, Line 1: You write ". . . significantly greater than . . ." How can you see the relative amount of freshwater from one snapshot and with different timing on each section occupation? Answer: There is no other possibility to have simultaneous measurements of freshwater amount than moorings or a dedicated campaign with several ships. The only mooring installed in the studies in this section area, is situated northward of the Bolshevik Island. Another solution is numerical modeling, but it is out of scope of this study, and in any case, without good initial and boundary conditions (meaning good measurements of all river discharges, estimated of glaciers melts, etc), the model will have some difficulties to reproduce the freshwater budget very accurately. Indeed, in this paragraph we compare the quantities measured in situ with a time difference of 4 weeks between section 1 (northward of the Arkticheskiy Cape) and section 10 in the Shokalskiy Strait. Nevertheless, the satellite images as the only source of continuous information on the surface layer, do not show any significant inflow of freshwater northward of the Severnaya Zemlya Archipelago.

Page 13, Lines 2-5: Show place names on map in Figure 1. Also, define the hydrographic sections in data and methods with time, wind condition, and air temperature during their occupations. Then stick to the named Sections (Section numbers) later in the text. Answer: The names of hydrographic sections were indicated both in Fig.1 and Fig.6 of the previous version of the manuscript. In the paragraph that you mention, we mention their geographical distribution. As for the conditions during every section, it can be found in the cruise report on the NABOS web-site https://uaf-iarc.org/wp-content/uploads/2019/09/NABOS-2018_report.pdf The wind speed and the air temperature during the cruise are shown in Fig. 6.

Page 13, Line 7: 1024-1027 kg m-3? Answer: Yes, corrected

Page 13, Line 14: What happens during cyclone passages? Clouds? Have you discussed this effect in Data and Methods? If yes, refer to it. Answer: Yes, as it was mentioned in the DMI SST-product description, clouds are opaque for the IR measurements, and the DMI SST dataset is blended from the IR measurements.

Page 13, Line 15: Can you provide any T and S limits? Answer: Yes, corrected Page 13, Line 17: By depression passage you mean low-pressure or cyclone passage? Answer: We call a low-pressure system a cyclone, and a high-pressure system an anticyclone

Page 14, Lines 5-7: This belongs in Data and Methods. Answer: "Oceanographic sections are used to estimate a thickness of the freshwater layer and how far the river water propagates under the ice. Section 5 provides complementary information to the meridional Hovmöller diagram (Fig.8, upper row) as it was done along the same 126E parallel from 76 to 81.4 N on September 1-4 2018." We do not provide the figures for all 10 oceanographic sections but do it to illustrate some particular processes or phenomena, so we introduce the largest meridional section in the discussion of meridional Hovmöller section.

Page 14, Line 9: Absolute salinity and conservative temperature are shown in Figure 8. Either change the text to absolute salinity and unit g/kg or change to practical salinity in figure. Answer: Corrected to practical salinity

Page 14, Line 11: You refer to different observations at specific latitudes in the figure, but the figure is presented with distance in km, so please refer to km as well. This applies for the other sections as well. Answer: Corrected the figure: added the latitude axis.

Page 14, Lines 12-16: What about melting under the sea ice due to the presence of warmer (above freezing point temperature) river water? This will cool the river water and still keep the water under the ice relatively fresh. Are there any $\delta 180$ data (or other tracers) to be able to identify the source of this water? Answer: Yes, there is. We added a section on the isotopes of the oxygen 18 to the Discussion part. The salinity/delta-18O scatter plot for the surface water samples is presented in Fig. 7. Using a three-component model (marine water / river water (meteoric water) / sea ice melt water) described in Bauch and Chernyavskaya, 2018 and the results of isotopes analysis from surface water samples, we calculated the fractions of each water. The isotopes analysis revealed that the most important fraction of river waters was transported to the shelf and continental edge of the East-Siberian Sea. At the same time, the water samples at the northern part of the 126°E section consist of 10-15 % of river water and only 0-5% by the sea ice melt. (Fig.7)

The full caption of Fig.7: Fractions of river water (a), sea ice melt water (b) and marine water (c), calculated using d-O18 measurements and Bauch andCherniavskaia (2018) 3-components model of freshwater balance. A thin black line shows the position of sea ice edge on August 31, 2018,when the northern stations of the meridional (5) section along 126E were done in the MIZ, and the blue line shows the sea ice edge onSeptember 16, 2020, when the ARKTIKA-2018 expedition was working in the MIZ of the East-Siberian Sea. Please, note that the colorbar scale is different for each water fraction

Page 14, Line 15: You write: "The heat exchange with the sea ice might be more effective than with the atmosphere, . . ." Why? Answer: "The heat exchange with the sea ice might be more effective than with the atmosphere," because it is a transfer of energy from a liquid to a solid body, which is more effective than to the gas. At the same time, it depends on thermal conductivity in the ice, and its initial temperature profile, so this question needs a special attention.

Page 14, Line 19: "Below the pycnoclines, . . ." to what depth? Answer: To the depth of 25 meters, which comes from p.14, lines 18-19

Page 15, Line 1: The 34.5 isohaline is not shown in the figure. Answer: Corrected

Page 15, Lines 2-3: What are the T and S characteristics of AW in this region? I don't agree that AW is seen at 100-120 m depth in Figure 8? Why is there instability in the AW layer? Answer: AW's main characteristics in this region is its positive temperature (Pnyushkov et al.2018, Section 2.1). In oceanographic section 5, the 0°C isotherm is situated at the depth 100-150 m, so we conclude that AW is situated below. An apparent weak "instability" is due to the colored representation.

Page 15, Line 5: Define all hydrographic sections in Data and Method (see earlier comment on this). Answer: The names of the different hydrographic sections were indicated in Fig.1 of the previous version of the manuscript.

Page 15, Line 11: You write: ". . . which is clearly seen in temperature signal that is negative even close to the surface." Is the temperature still above the freezing point, i.e. any melting under the ice? The temperature is above the freezing point in most of cases. To obtain a more detailed information on the sea ice formation/melting during the ARKTIKA-2018 expedition, please see the Fig. 7.

Page 15, Lines 25-26: The river discharge information should be introduced in the introduction. Answer: Corrected

Section 4.1.2 Some more background information is needed in the beginning of this section. It is also an analysis method and should be moved to the data and method section. The surface fronts in question should be defined. To get the Ekman transport, you need to integrate over the Ekman depth, what is the Ekman depth in this region? Assumptions made by Ekman were no boundaries, infinitely deep water, and no geostrophic flow. How are these assumptions met in this region? What happens when you have boundaries (coastlines)?

For the Ekman transport we assume that there is a layer with no vertical momentum flux, and that it is not the sea bottom (no friction at the ocean floor). Of course, coastlines are discontinuities, where the approach will not work, and close to them (and in the very shallow areas), the assumption of no bottom friction does not hold either.

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Page 16, Line 8: Give the reference to TEOS-2010 and show the formula for the drag coefficient CD. For the wind speed below 10 m/s : u* = 0.051*Uw - 0.14 for stronger winds, u* = 0.051*(Uw-8) + 0.27, where Uw is a wind speed (from FOREMAN AND EMEIS, 2014 http://www.atmo.arizona.edu/students/courselinks/fall10/atmo551a/DragCoef_2010jpo4420%252E1.pdf)

Page 16, Line 10: Use Ekman pumping instead of vertical Ekman speed? Answer: Corrected

Page 17, Line 12: You write ". . . mixing of different water masses, . . ." What are these water masses? You should introduce the water masses in the region in the introduction section. The common names of the surface water masses do not exist, as there was no previous study at this temporal scale to define them. The most well-known water masses are defined in the new version of the Introduction.

Section 5 Perhaps start the results with this section? Answer: We aggree, so this section was moved to the beginning of Results part

Page 17, Line 17: And below 200 m? Answer: We discuss only the upper 200 m in this Figure.

Page 17, Line 23: Specify which of the Arctic Ocean waters that quickly change. Answer: Corrected to "surface water"

Page 17 Line 24: Add ". . ., and the synoptic satellite data provide . . ." Answer: Corrected

Page 17, Line 32: The "classical" water masses, do they have a name? Answer: Corrected to the "main surface water masses"

Page 18, Line 1: Add "... larger range than the near-surface (upper 6.5 m) in situ measurements . . ." Answer: Corrected

Page 18, Line 7: A recognisable river front or a river plume front? Define. Answer:

Corrected to “river plume front”

Page 18; Line 8: 145 E? How do you define the sea edge? Is it a specific sea ice concentration limit? Answer: It is a typo. Corrected to “sea ice edge”, which is defined with 1% sea ice concentration from AMRS2 SIC product.

Page 18, Line 11: You write “. . . captured under the ice and exposed back.” How or when? What about melting sea ice from below? Answer: We added a section on oxygen isotopes that clarifies this point.

Page 18, Lines 21-22: Show place names on map in Figure 1. Answer: Corrected

Page 18, Lines 24-25: There is also a high density within the range 22.5-30 and 3-4 Answer: Corrected

Discussion and conclusion. This section provides little discussion or conclusions, mostly summary. There is more discussion in between the presentation of the results in the Results section. Answer: Corrected, please see an improved version of this section.

Page 19, Lines 11-12: You write “The fresh waters displacement was associated with the Ekman transport.” How? This is not well presented or described in the results. Answer: Corrected. Please see a new paragraph on "wind forcing".

Page 19, Lines 15-16: You write “. . . and there is no evidence that the sea ice melting itself can create such a considerable layer of freshwater.” How or where have you presented this lack of evidence? Answer: We added a section on oxygen isotopes that clarifies this point.

Page 19, Lines 18-20: What about river water melting sea ice from below? Are there any δ18O data (or other tracers) to evaluate this? Answer: Please, see a new section on oxygen isotopes that clarifies this point.

Page 19, Line 24: Add “Calculated monthly Ekman pumping indicates the area of most

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intense mixing processes induced by wind."? Answer: Corrected

Figures with more than one panel should be labelled with a), b), c) etc. and then properly referred to in the figure captions and the text when the figures are described. Also use the same font size in the figures with several panels. Remove titles on figures and add this text in the figure caption instead.

Figure 1: What is the definition of the sea ice edges? Add all place names mentioned in the text on the map. Answer: Corrected. Here the ice edge is based on the sea ice mask provided in the SST DMI product

Figure 2 and 3: Last sentences in the figure captions: this information should be provided in the data and method section. Answer: Corrected.

Figure 4: Missing numbers on y-axis in lower left panel. Use white isolines below 0 degree Celsius/28 PSS? It is hard to see black lines in the dark background. This is also the case for Figures 6 and 8.

Figures 5 and 7: Where is the data from? What bathymetry data is used? Answer: Corrected to "Hovmöller diagram of SST (a), SSS (b), wind speed (c), and sea level pressure (d) for the zonal transect at 78N. Small circles at SST and SSS diagrams show in situ measurements of temperature and salinity (first CTD of TSG at 6.5 m). Sea ice concentration (AMSR2) is indicated with a blue color, see Fig.5 for the color scale. The depth profile along the transect (e) is extracted from "1 Arc-Minute Global Relief Model" (Amante and Eakins (2009). The position of a virtual transect is shown at SST SMI and SSS SMOS "A" maps for August 26, 2018 (f, g)."

Figure 8: Why do you show conservative temperature and absolute salinity in this figure and not in Figure 6? At least use proper units when referring to Figure 8 in the text. Answer: Corrected to practical salinity. These two figures explain transformation of different water masses. Fig.6 illustrated the processes of Kara and Laptev waters mixing in the western part of the Laptev Sea, and Fig. 8 shows the propagation of river

waters above the shelf and the shelf break.

Figure 9: Increase the fonts. The two upper rows are not described in the text. What are the arrows in the lowest row, and why is the resolution higher than in the row above? Write units in the figure caption. Where is the data from?

Figure 10: Add the freezing point temperature line. Remove the figure title.

Figure 11: What are the boxes? Are the lines the freezing point temperature line? Answer: The boxes show the cores of 6 water masses described in text. Red line show the freezing point.

Figure 12: Put the dates inside the plots instead.

Figure A1: Remove the titles from the figures. Write units in the figure caption. Increase the fonts.

Answer: Corrected in most of cases.

Tables. Table 1: Add more information to the table caption. Answer: Corrected

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Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2019-60, 2019.

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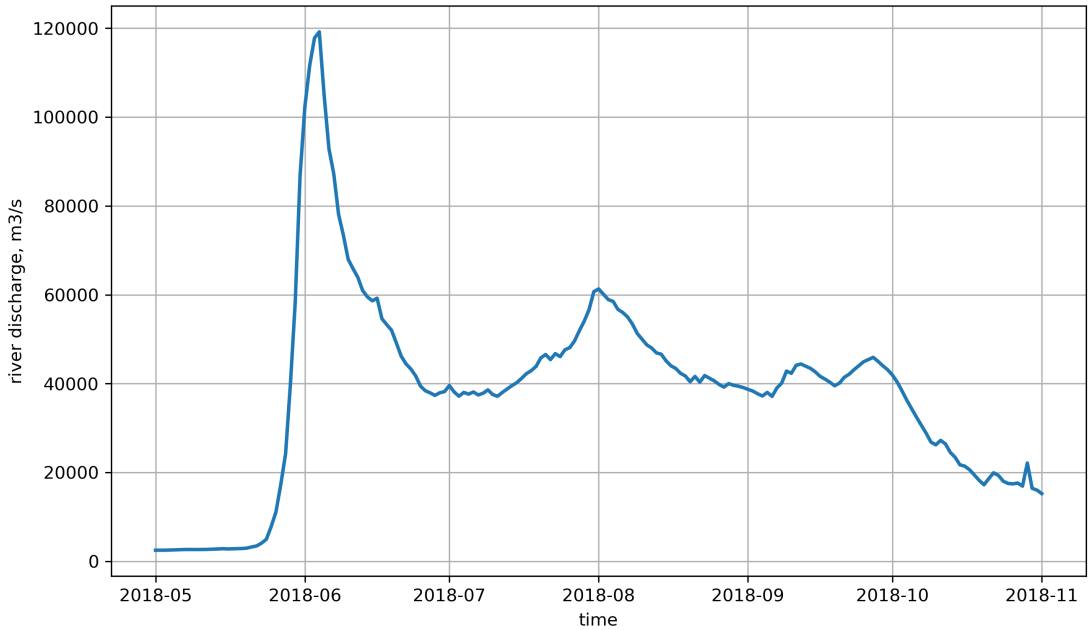

Fig. 1. The Lena River discharge in 2018, data from Arctic GRO dataset (https://www.arcticrivers.org/data)

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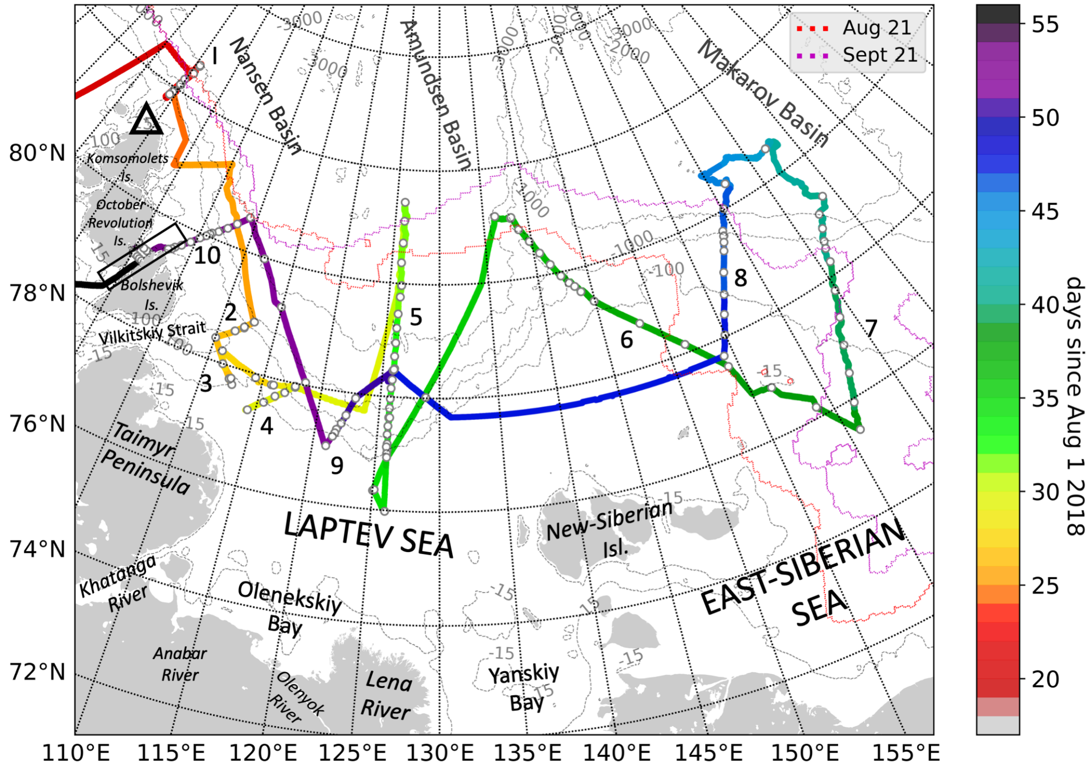

Fig. 2. Legs and stations of the ARKTIKA-2018 expedition overlayed on the bathymetry

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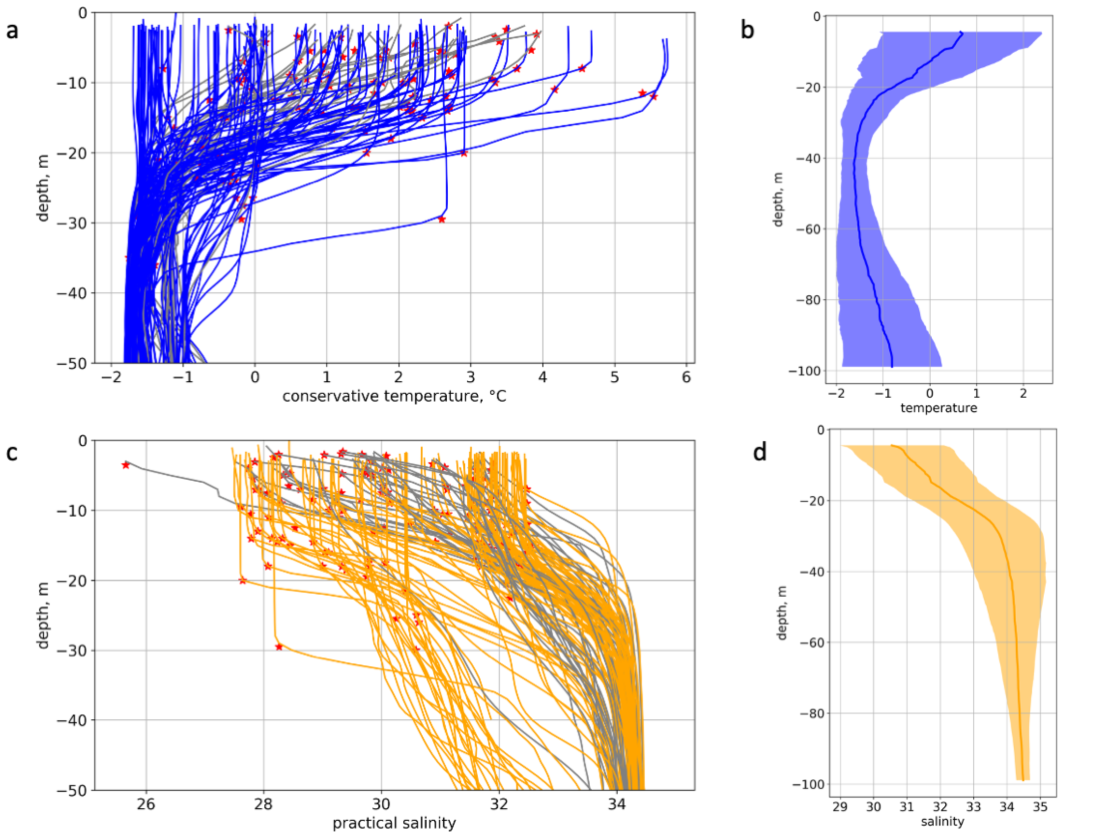

Fig. 3. Vertical profiles of temperature (a) and salinity (b) from CTD measurements in the upper 50 meters. The red stars indicate MLD, colored profiles have MLD larger than 7 m, gray - smaller than 7 m.

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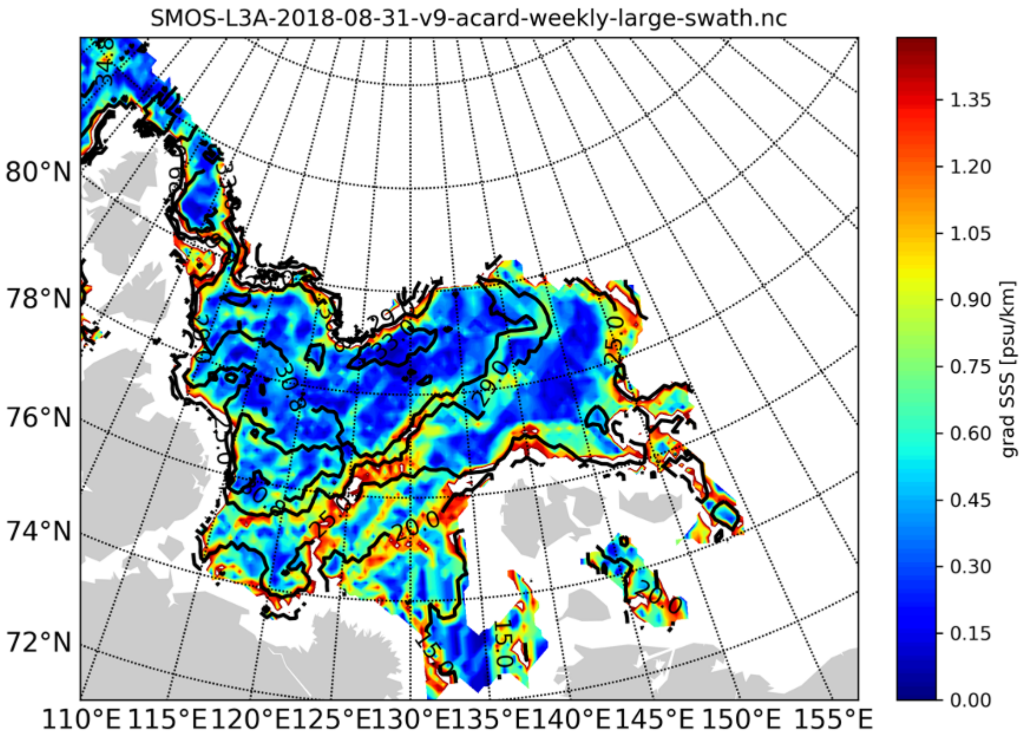

Fig. 4. Gradient of salinity for August 31, 2018 calculated from SSS SMOS "A" (see the description of product in a new version of manuscript), [psu/km]

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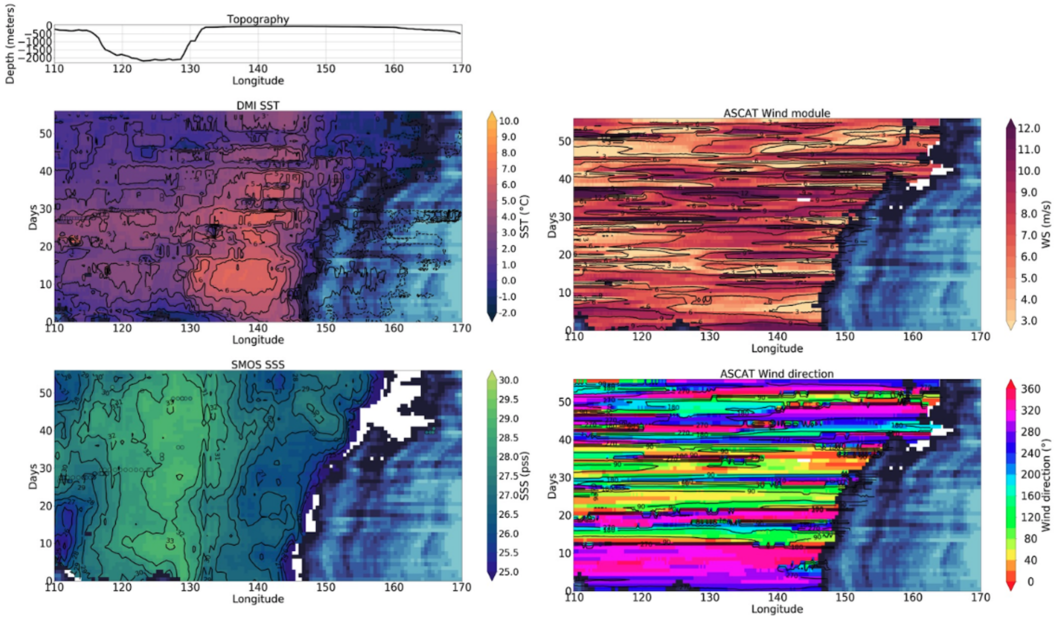

Fig. 5. Hovmoller diagram for zonal virtual section along 78 N: SST DMI (upper left), SSS SMOS “A” (lower left), ASCAT wind speed (upper right) and direction (lower right).

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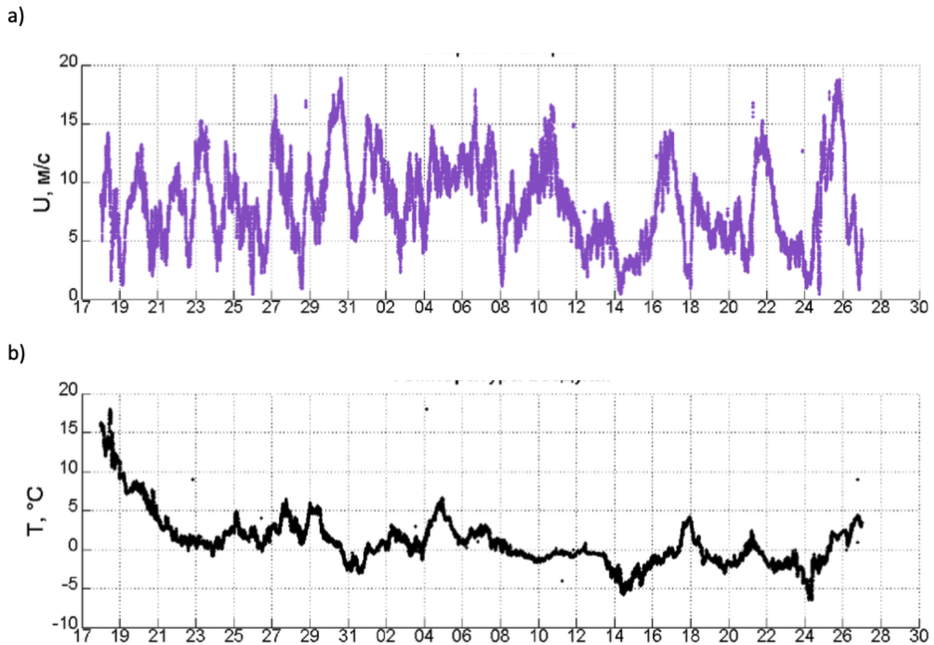

Fig. 6. Wind speed and air temperature measured in the ARKTIKA-2018 expedition (from August 17 to 26 of September).

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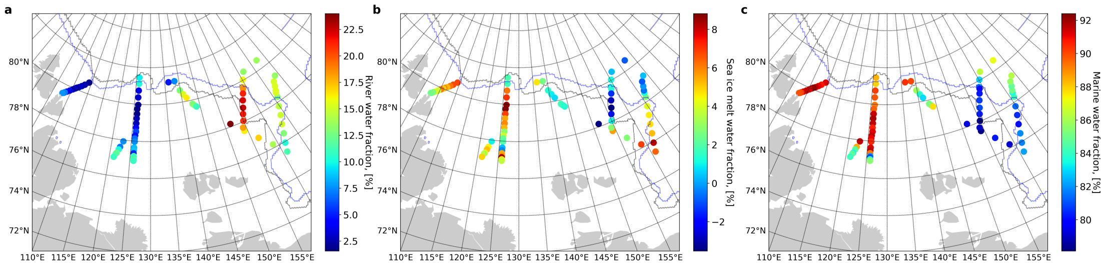

Fig. 7. Fractions of river water (a), sea ice melt water (b) and marine water (c), calculated using d-O18 measurements and Bauch andCherniavskaia (2018) 3-components model of freshwater balance

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Ocean Sci. Discuss.,
https://doi.org/10.5194/os-2019-60-RC3, 2020

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Interactive comment on "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" *by* Anastasiia Tarasenko et al.

Anonymous Referee #3

Received and published: 10 February 2020

The presented observations of surface freshwater distribution is from an interesting area of the Arctic Ocean. The observations are presented in a nice manner. And there is plenty of figures, with many detailed results. This is all fine.

There is not much available knowledge on how the river-water spreads north along the shallow Siberian shelves, so this paper is potentially a significant contribution in that regard. Beside some issues already noted by the other reviewers, like language, I have two larger issue that made me tick the "major" box here.

My "major" science concern is the contribution from sea-ice melt. I think you need to do a somewhat better job at addressing this possible contribution. It is difficult, but it

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can potentially explain much of the freshwater available. If delta-18 O samples where available, one could differ between these to sources perhaps, although I think much of the river-water from previous summers probably freeze-up, and some of the newly melted sea ice could thus just be old river water.

I also find that you mix Results and Discussion in the 3. Results section. This may be OK, but then you need to call this 3. Results and Discussion. And then the sections 4.X are somewhat also Results and discussion. And then you cannot have "Discussion and Conclusion" in section 6. See? A re-struction is needed. There is also no general conclusion drawn on what actually spreads the freshwater to the north. Is this wind driven mostly? Or not?

I also have a general suggestions: Provide the spatial mean vertical profile down to 100m for T and S, and use that to describe the mean stratification. THEN – AFTERWARDS, you can present, the spatial and temporal changes from this mean profile.

Minor issues:

Abstract: Your main explanation for how the river water is transported out from the river mouth area should be lifted up into the abstrat. Is this all wind-driven?

We use the term "ice-free" not "free of ice" in general.

Page 3, Line 7: Add what products is "validated".

Page 5. Last line. "Ice sheet" is used for the large inland thick glaciated areas in Antarctica and Greenland. You probably mean "sea-ice" here??? Page 10 and other places. Is it ok to use PSS as salinity unit? Should it not be absolute salinity, or unit less?

Figure 5: Please provide the section in a map.

Page 16: 4.1.2. This section is really about “Wind Forcing” and nothing else. So it should have this name, and not “Mean Monthly Observations”. The Ekman equations

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should be in the method section.

Table 1: Use other "names" than 1-6. Cold and Warm, Fresh, Salty and Medium Salinity? SO 1=WF, 2=WMS, for example... (Numbers are more difficult to remember than names. . ..)

Page 18. Line 20: Why? Mixing with saltier water below? Or sea ice formation. When is the first onset of freezing? And what is the "normal/mean" for this freeze-up?

Page 19. Line 15-16. While there is "no evidence that "sea-ice melting can create such a layer of freshwater" – is there evidence that it can not? This is my major point #1.

Conclusion: The evaluation is OK, and described nicely. But what is the main message? What is learned of the river water flow? This still needs to be described. Main point#2.

Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2019-60, 2019.

Ocean Sci. Discuss.,
https://doi.org/10.5194/os-2019-60-SC1, 2019

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Interactive comment on "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" *by* Anastasiia Tarasenko et al.

Alexander Osadchiev

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Received and published: 23 October 2019

Review of "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" by Anastasiia Tarasenko et al. Submitted to: Ocean Science Manuscript number: 2019-60

Summary: In this paper the authors focus on distribution of surface water masses based on satellite salinity and temperature and in situ measurements at the shelf of the Laptev and East-Siberian seas. They report several features registered by satellite and in situ data in the surface layer, namely, variability of surface salinity and temperature in August-September 2018, inflow of freshwater from the Kara Sea to the Laptev Sea,

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seasonal cooling of surface water in autumn. The paper is interesting insofar as the authors focus on the Arctic seas which hydrological structure and dynamics remain largely unstudied. Thus, the topic addressed in this manuscript is of great scientific and practical interest. Despite my enthusiasm for the topic, I don't think this article is ready to be published in Ocean Science due to several drawbacks of this work. Generally, this article seems like a cruise report, it describes structure of SSS and SST in the Kara Sea to the Laptev Sea, but lacks scientific novelty and new insights into processes in the study area. I recommend the authors to improve their study by providing more thorough analysis of in situ data including vertical profiles and to focus on certain processes that occur at the shelf of the Laptev and East-Siberian seas, rather that providing brief description of multiple processes.

General comments: 1. The authors define the plume as water mass with salinity less than 30 (e.g., page 10, line 28). However, the majority of works that deal with river plumes in different World coastal areas define river plumes as relatively shallow surface-advected water masses bounded with large salinity gradient at their border with ambient sea. Existence of this salinity gradient determines significantly different dynamics of river plumes (governed by buoyancy force), as compared to ambient sea, which is the main reason to distinguish river plumes as individual water masses. River plumes formed at the shelf of the Laptev and East-Siberian seas generally have sharp salinity gradient at isohalines of 15-25, while water masses with greater salinity are regarded as ambient shelf water. Thus, I recommend the authors to determine salinity border of the Lena plume based on maximal salinity gradient and to distinguish wind-driven dynamics and variability of river plumes and more "typical ocean dynamics" of shelf water mass. 2. In this study you use SSS data from SMOS satellite which spatial resolution is 50 km (page 5, line 18). However, you deal with salinity maps with 15 km spatial resolution (page 5, line 18). Did you reduce spatial resolution only by reprojection? 3. In this study you deal with in situ thermohaline data obtained from the depth of 6.5 m (page 7, line 3). However, salinity at this depth can be significantly different from surface salinity (even more than several units) especially within the river plumes. Thus, your usage of this data to compare and validate satellite data require additional proof, e.g., based on vertical thermohaline measurements. 4. The results of validation of satellite SSS and in situ salinity obtained from the depth of 6.5 m does not seem convincing, especially at the areas influenced by freshwater discharge (Section 3.1.2 and Figure 3). We see underestimation of salinity by several units for almost all measurements. I recommend authors to deal with salinity gradients rather than absolute salinity values, e.g., to show that satellite SSS data reproduces well shows relative salinity differences if it really does. 5. Ranges of temperature and salinity values used to determine different water masses at the study area are heuristic and are not based on any precise idea (Section 5 and Table 1). What is the reason to select T = 3 °C and S = 25 and 29 as borders between water masses? Why you determine 6 water masses? Why not to determine 5 or 7? 6. Reconstructed circulation in the Laptev and East-Siberian sea based on Ekman theory does not seem convincing, especially the presented patchy distribution of upwelling and downwelling areas (Section 4.1.2 and Figure 9e). These results have to be supported by in situ measurements and/or numerical modelling. 7. Propagation of freshened water from the Kara Sea and its presumed missing with Lena plume in the Olenekskiy bay requires additional proof by in situ measurements and/or numerical modelling (page 19, lines 6-9). The role of the Khatanga plume in this process (as well as the plume of the Olenyok River surprisingly not mentioned here) also should be supported by additional data.

Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2019-60, 2019.

Ocean Sci. Discuss.,
https://doi.org/10.5194/os-2019-60-AC1, 2020

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Interactive comment on "Surface waters properties in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data" *by* Anastasiia Tarasenko et al.

Anastasiia Tarasenko et al.

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Received and published: 15 May 2020

General comments:

1. The authors define the plume as water mass with salinity less than 30 (e.g., page 10, line 28). However, the majority of works that deal with river plumes in different World coastal areas define river plumes as relatively shallow surface-advected water masses bounded with large salinity gradient at their border with ambient sea. Existence of this salinity gradient determines significantly different dynamics of river plumes (governed by buoyancy force), as compared to ambient sea, which is the main reason to distinguish river plumes as individual water masses. River plumes formed at the shelf of the

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Laptev and East-Siberian seas generally have sharp salinity gradients at isohalines of 15-25, while water masses with greater salinity are regarded as ambient shelf water. Thus, I recommend the authors to determine salinity border of the Lena plume based on maximal salinity gradient and to distinguish wind- driven dynamics and variability of river plumes and more "typical ocean dynamics" of shelf water mass.

Answer:

When we discuss the river waters (and the "river plume"), we mean some water mass with a river-origin, already transformed to some mix of river and sea waters (not taking into account precipitation and brine from sea ice formation and melting now, as their substantially smaller contribution cannot be estimated with current satellite data). As in other studies that mean that the definition of "river plume" or "river water" becomes arbitrary, depending on the authors of study and the region of interest. Before writing this paper, we regarded the gradients of salinity as well, and found that the highest values of salinity gradients roughly correspond to the position of 29 isohaline. In Fig. 1, there are high gradients of salinity at 15, 20, 25, and 29 isohalines. Knowing that the freshwater input in this area comes mainly from the rivers, as we demonstrate it later with the oxygen isotope analysis (please, see a new version of manuscript), we have just chosen the furthest position of "river water presence" as a virtual "river plume".

2. In this study you use SSS data from SMOS satellite which spatial resolution is 50 km (page 5, line 18). However, you deal with salinity maps with 15 km spatial resolution (page 5, line 18). Did you reduce spatial resolution only by reprojection?

Answer:

The "initial" SMOS instrument resolution is 50 km (which we meant to explain in 2.2.2, line 17-18), but the SMOS SSS product distributed by ESA is already oversampled in the ISEA grid with a resolution of 15 km. In other words, the spatial resolution of SMOS SSS Level 2 v662 product is 15 km, we just resampled all satellite products at the same grid for convenience. This "oversampling" of SMOS SSS at 15 km is practical

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for two reasons. First, to conserve the real salinity gradients observed with in situ measurements and not smooth them to 50 km for the further comparison with SMOS SSS. The spatial resolution of ship measurements depends on the ship speed (8 knots $\sim$ 3 m/s), pumping speed (16 l/s) and the CTD measurement frequency (24 Hz), and is of order O(1) m. After processing the raw data, its resolution is O(250) m. A 7.5-km in situ measurement average corresponds to 30 minutes of TSG measurement, as we mention at line 6, p.3.1.1 (and 15-km pixel represents one hour of measurements). Second, to put SSS on the same grid as rather high-resolution SST for the further calculations, e.g., density.

3. In this study you deal with in situ thermohaline data obtained from the depth of 6.5 m (page 7, line 3). However, salinity at this depth can be significantly different from surface salinity (even more than several units) especially within the river plumes. Thus, your usage of this data to compare and validate satellite data requires additional proof, e.g., based on vertical thermohaline measurements.

Answer: To investigate if the TSG measurements can be used to study the surface layer in a highly stratified Laptev sea, we calculated a summer mixed layer depth following de Boyer Montégut et al. (2004) method based on density and temperature gradient thresholds (Fig.2, 3: Colored profiles show the cases when the MLD is below 7 m depth and gray profiles indicate when the MLD is above 7 m depth). The MLD is found at a depth of the first maximum temperature gradient below a depth of defined (by given threshold) density gradient (see de Boyer Montégut et al. (2004) for details). Using the same logic, we computed MLD also with density and salinity vertical profiles. The threshold chosen for practical density gradient was 0.3, and 0.2 units for conservative temperature and practical salinity gradients. Regarding the MLD calculated from salinity (MLDsal), most of the measured vertical profiles had the MLDsal below 7 m depth 75.17%. The median value of MLDsal was 11.99 m. As for the temperature (MLDtemp), 81.37% of profiles had the MLD below 7 m depth, with a median value of MLDtemp = 13.50 m. Thus, we conclude that in most of the cases the upper 12 m of the surface layer was homogeneous, and our CTD and TSG measurements can be used for the validation of satellite data.

4. The results of validation of satellite SSS and in situ salinity obtained from the depth of 6.5 m does not seem convincing, especially at the areas influenced by freshwater discharge (Section 3.1.2 and Figure 3). We see underestimation of salinity by several units for almost all measurements. I recommend authors to deal with salinity gradients rather than absolute salinity values, e.g., to show that satellite SSS data reproduces well and shows relative salinity differences if it really does.

Answer: Indeed, both SST and SSS compared to in situ measurements have some biases. Nevertheless, we consider that the bias (or "mean of difference" between SSS and in situ data) is close to be linear, so we extract it from the initial dataset. This study was a case study for a particular period of time and a particular region, and one of the important milestones of this work was a prototype of the "Arctic SSS" product created for it. The quality of this SSS product was the best for the Arctic at the moment of writing the manuscript (we compared it with others, such as other SMOS or SMAP SSS, but didn't present). Later on, we created a first version of SMOS SSS for the whole Arctic (Supply Alexandre, Boutin Jacqueline, Vergely Jean-Luc, Kolodziejczyk Nicolas, Reverdin Gilles, Reul Nicolas, Tarasenko Anastasiia (2020). SMOS ARCTIC SSS L3 V1.0 maps produced by CATDS CEC LOCEAN. SEANOE. https://doi.org/10.17882/71909. It can be check it here: https://www.seanoe.org/data/00607/71909/). To convince that the resulting SSS (before additional filtering of MIZ areas) resembles the measurements of TSG, we propose another graphical form of comparison: the timeseries of SSS and TSG-measured salinity in Fig. 4. The largest difference between SSS and in situ salinity is observed when the ship was working in MIZ areas (beginning of September and September 13-17). These "ice" pixels were filtered afterwards.

As for the high error at 74°N 136°E, we suppose, it is the effect of the Stolbovoy Island present there. In the section with SSS description we mention that the closeness to the coastline deteriorates the quality of SSS estimates. To avoid the “coastline” contamination we applied a 25-km mask around all islands and coasts.

5. Ranges of temperature and salinity values used to determine different water masses at the study area are heuristic and are not based on any precise idea (Section 5 and Table 1). What is the reason to select T = 3°C and S = 25 and 29 as borders between water masses? Why you determine 6 water masses? Why not to determine 5 or 7?

Answer: This section is based on the same principles as a classic T-S analysis, with the main difference that the amount of available points when use SST-SSS diagram is several orders higher than from classical CTD measurements. Identifying the core of each water mass stays heuristic in both cases. A chosen number of water masses corresponds to the number of “water mass cores”, defined by the density of points on the SST-SSS diagram.

6. Reconstructed circulation in the Laptev and East-Siberian sea based on Ekman theory does not seem convincing, especially the presented patchy distribution of upwelling and downwelling areas (Section 4.1.2 and Figure 9e). These results have to be supported by in situ measurements and/or numerical modelling. Answer: The Ekman transport was recalculated for the updated version of manuscript using the recommendations of all reviews (Fig. 5, 6). Numerical modeling is out of scope of this study.

7. Propagation of freshened water from the Kara Sea and its presumed missing with Lena plume in the Olenekskiy bay requires additional proof by in situ measurements and/or numerical modelling (page 19, lines 6-9). The role of the Khatanga plume in this process (as well as the plume of the Olenyok River surprisingly not mentioned here) also should be supported by additional data. Answer: Unfortunately, no in situ measurements were carried out in the coastal area during the period of our study neither by the expedition Arktika-2018, nor by any other expedition to the best of our knowledge. The results of numerical modeling should be validated separately, so we consider satellite data the only available source of information. The Kara-origin of the

freshwater appearing in the Vilkitskiy Strait and northward is well-seen on the time series of SSS fields. A special role of the Khatanga, the Anabar, the Olenyok, and the Yana Rivers should be studied additionally. It was not discussed in this paper, because we had neither the appropriate information on their discharge, nor in situ/satellite measurements in the close vicinity of their estuaries/deltas.

Interactive comment on Ocean Sci. Discuss., https://doi.org/10.5194/os-2019-60, 2019.

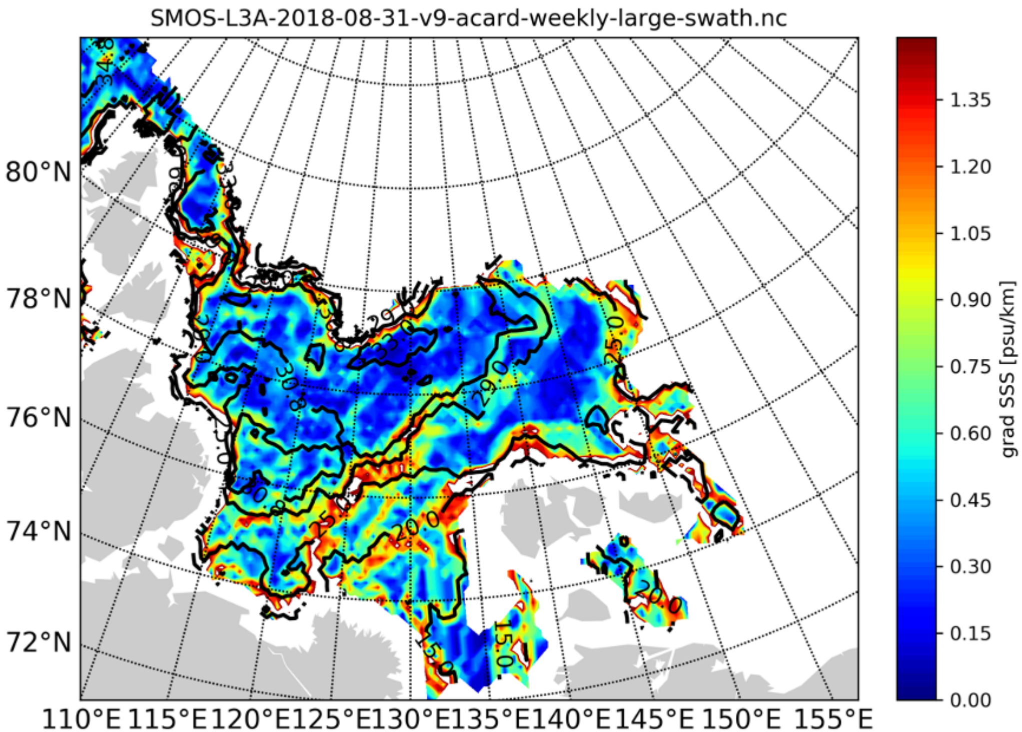

Fig. 1. Gradient of salinity for August 31, 2018 calculated from SSS SMOS "A" (see the description of product in a new version of manuscript), [psu/km]

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Discussion paper

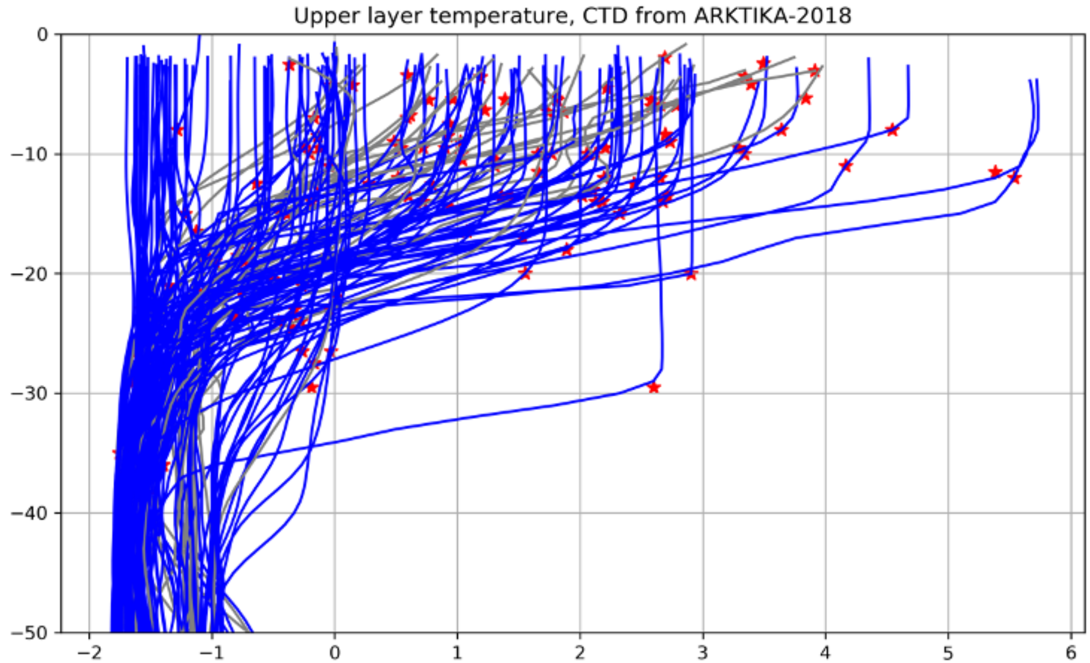

Fig. 2. Vertical profiles of conservative temperature from CTD measurements in the upper 50 meters. Red stars indicate the mixed layer depth, calculated using de Boyer Montégut et al. (2004) method

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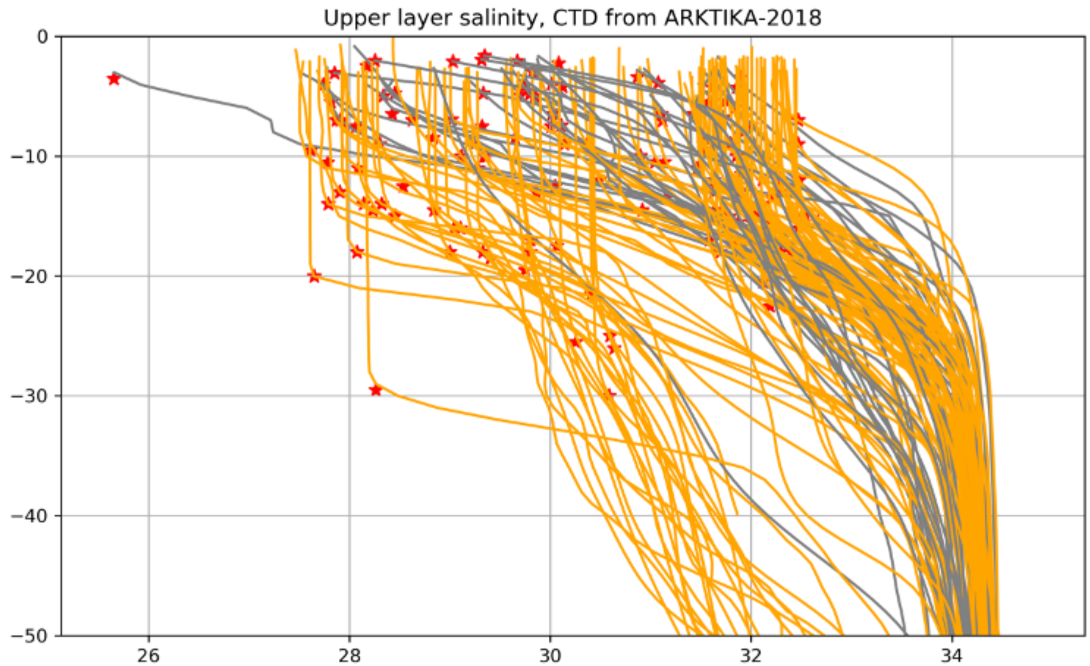

Fig. 3. Vertical profiles of practical salinity (b) from CTD measurements in the upper 50 meters. Red stars indicate the mixed layer depth, calculated using de Boyer Montégut et al. (2004) method

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Fig. 4. The time series of TSG-measured salinity (black line) and collocated SMOS SSS measurements.

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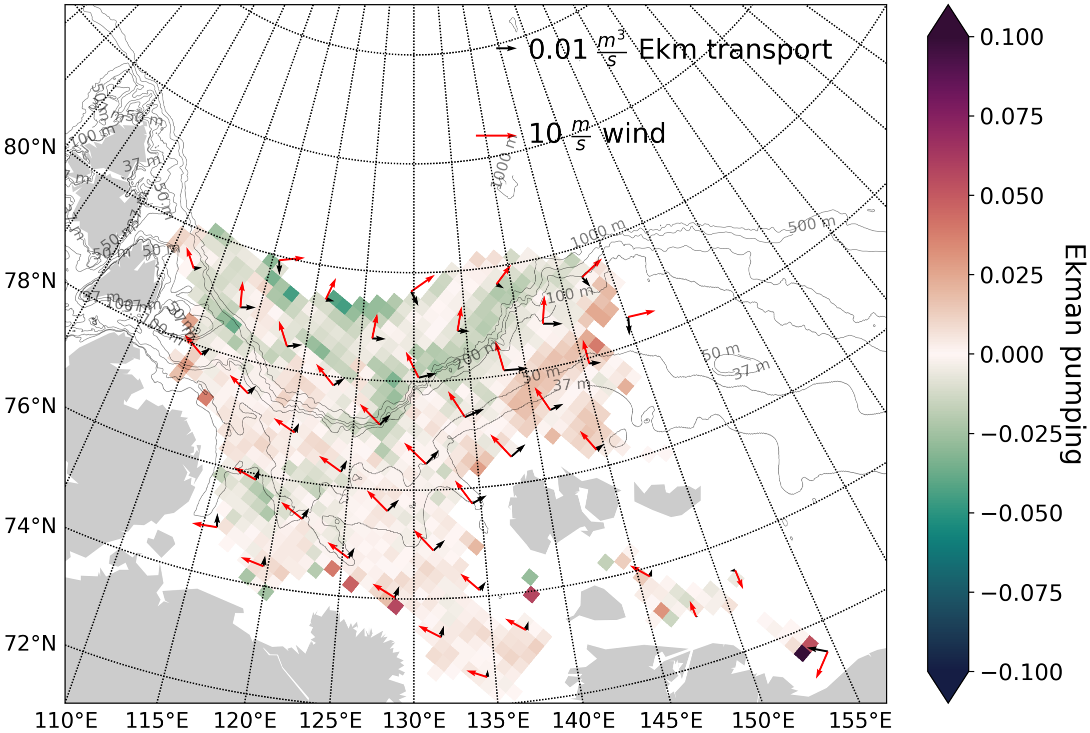

Fig. 5. Ekman pumping (in color) and horizontal transport for August 2018 calculated from satellite data

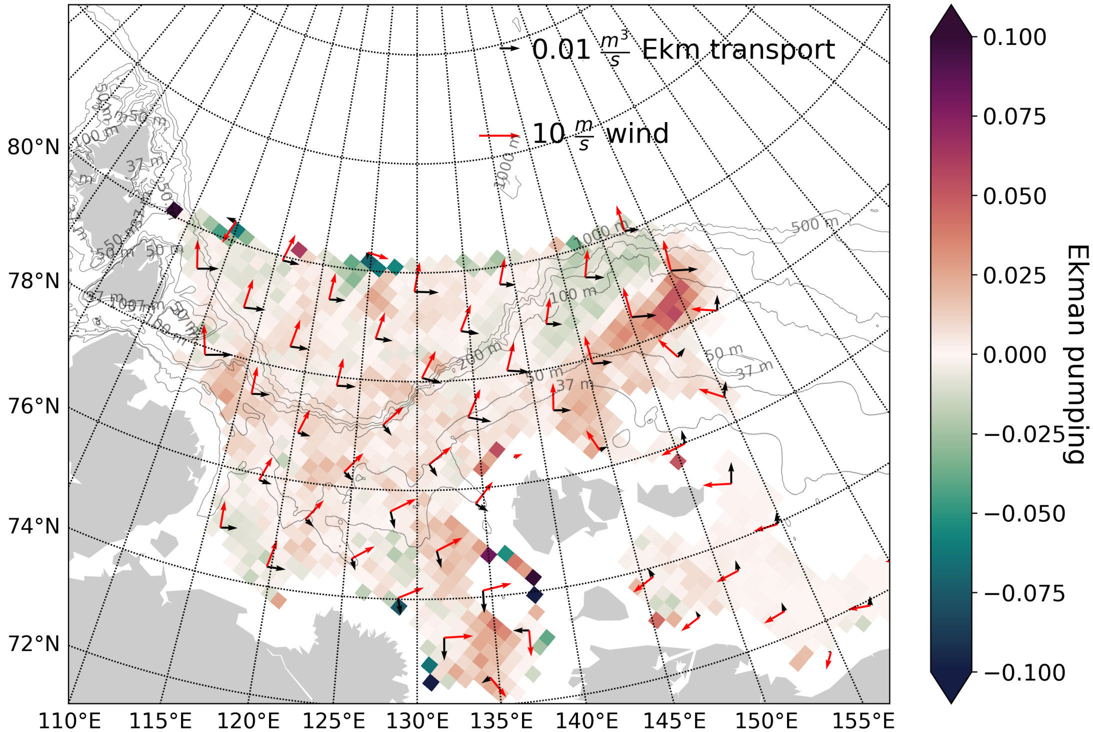

Fig. 6. Ekman pumping (in color) and horizontal transport for September 2018 calculated from satellite data

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Discussion paper

~~Surface waters properties~~ Properties of surface water masses in the Laptev and the East-Siberian Seas in summer 2018 from in situ and satellite data

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Abstract. Variability of surface water masses of the Laptev and the East-Siberian ~~seas~~ Seas in August-September 2018 is studied using in situ and satellite data. In situ data ~~was~~ were collected during ARKTIKA-2018 expedition and then completed with ~~satellite estimates of~~ satellite-derived sea surface temperature (SST) and salinity (SSS), sea surface height, ~~satellite-derived~~ wind speeds and sea ice concentrations. ~~Derivation of SSS is still~~ The estimation of SSS fields is challenging in high latitude regions, and the ~~quality~~ precision of Soil Moisture and Ocean Salinity (SMOS) SSS retrieval ~~was~~ is improved by applying a threshold on SSS weekly error. The validity of ~~SST and~~ DMI (Danish Meteorological Institute) SST and SMOS SSS products is ~~demonstrated~~ thoroughly studied using ARKTIKA-2018 expedition continuous thermosalinograph measurements and CTD casts. The surface gradients and mixing of river and sea ~~waters in the free of ice~~ water in the ice-free and ice covered areas ~~is~~ are described with a special attention to the marginal ice zone at a synoptic scale. The Ekman transport ~~was~~ is calculated to better understand the pathway of surface water displacement. ~~T-S~~ We suggest that the freshwater is pushed northward, close to MIZ and under the sea ice, which is confirmed by the oxygen isotopes analysis. The SST-SSS diagram using surface satellite estimates ~~shows a~~ showed that it offers the possibility to investigate the surface water masses transformation ~~in detail~~at synoptic scales and reveal the presence of river water on the shelf of the East-Siberian Sea.

1 Introduction

The eastern part of the Eurasian Arctic remains one of the ~~understudied~~ less studied areas of the Arctic Ocean. ~~The recent ARKTIKA-2018 expedition combined with novel satellite sea surface salinity and other parameters provide an unprecedented documentation of the temporal evolution of the surface water properties in the~~ **?** described this region as an "interior shelf" (Kara, Laptev, East-Siberian, together with Beaufort Seas), where 80% of the Arctic basin river discharge is released. The Arctic Ocean stores 11% of global river discharge, so its role in the planetary water budget should be considered with attention. Surface stratification and freshwater content are regarded as key parameters that have to be followed to better understand the changing state of a "New Arctic" climate (**?**). Overall, a freshening of the Arctic Ocean in 2000-2010 was reported in the

American basin (?), and at the same time, a decrease in freshwater content of about 180km^3 was calculated from altimetry measurements by ?. ? discussed the salinification of the Laptev sea since 1989 up to 1997, explaining it by the eastward freshwater displacement and an excessive brine release in the sea ice leads. The importance of shelf seas for the freshwater content distribution was outlined in several recent studies (?, ?, ?), and its exchange with the deep basins is apparent (500 km^3 for the Laptev and East-Siberian Seas~~in summer 2018. The Laptev sea~~ , ?).

The processes occurring at the Eastern Eurasian Arctic shelf are important, as the redistribution of this freshwater income in this region and its further path is still unclear and its amount is supposed to increase (?). Complex topography, several sources of fresh and saline water masses, unstable atmospheric conditions and other parameters, like mesoscale activity and tidal currents, can alter the direction of this freshwater distribution. Close to the coast the riverine water from several sources is considered to propagate eastward as a "narrow (1-20 km) and shallow (10-20 m) feature" (?), but its transformation and mixing with saline sea water and sea ice melting and freezing is less studied. The shelf area of the Laptev and the East-Siberian was described as a substantial region of sea ice production for the central Arctic (?), and to better understand the impact of the freshwater income on the sea ice formation, the freshwater pathways in the Arctic should be understood better. Despite several studies on the freshwater in the Eastern Arctic (e.g., ?, ?, ?, ?), to the best of our knowledge, no study has shown yet the evolution of the water masses on a synoptic scale in the Laptev Sea.

The Laptev Sea is shallow in its southern and central ~~part (50-100~~ parts (less than 100 m) with a very deep opening ~~on~~ in the north (3000 m) ~~.~~ (Fig. 1). Several water masses are ~~mixing there~~mixed in the Laptev Sea. The Lena~~and the Khatangarivers~~ , the Khatanga, the Anabar, the Olenyok, and the Yana Rivers discharge fresh water in the shallowest part of the Laptev ~~sea on the south, the Kara sea~~ Sea in the south. The Kara Sea water enters via the Vilkitskiy and Shokalskiy straits, the Atlantic ~~water~~ Water (AW) ~~arrives~~ propagates along the continental slope to the north of the Severnaya Zemlya ~~archipelago~~ Archipelago and further eastward, the Arctic ~~water~~ Water exists in the northern part (?, ?, ?). The direction of surface freshwater circulation is supposed to correspond to the general displacement of the intermediate Atlantic Water (?). This eastward transport brings the water masses of the Laptev Sea over the shelf of the East-Siberian Sea where it falls under an additional impact of Pacific-derived waters (?, ?).

In the Arctic region, a strong ~~seasonal warming and cooling,~~ seasonality of air-sea heat fluxes with sea ice melting and freezing modify temperature and salinity in the upper layer, and therefore, ~~complexify the~~ result in a complicated vertical structure of water column ~~creating fronts at sea~~ with fronts at the surface and "modified layers" in the interior (?, ?, ?). ~~? and ? have shown that interannual changes of river discharge and wind patterns define the position of the oceanographic fronts in the central part of the Laptev Sea. To the best of our knowledge, no study has shown yet the evolution of the water masses on a synoptic scale in this region. In this study, we propose to follow the upper ocean waters displacement and its causes on a daily basis.~~

The most common concept of the upper ocean layer is a "mixed layer~~depth~~" ~~(MLD)~~ concept: between the ocean surface being in contact with the atmosphere and a certain depth, temperature and salinity are homogeneous. It ~~is defined via a certain~~ extends until a specified vertical gradient in density and/or temperature (?, ?), the maximum of Brunt-Väisälä frequency (?), or via the energy vertical distribution (?). ~~For~~ In the Arctic, the reported mixed layer depth ~~varies~~ (MLD) vary between 5-7 m and 30-50 m depending on ~~a~~ region: open water or under the ice, the Barents Sea, the East-Siberian Sea or the central Arctic (**?**, **?**, **?**, **?**).

At the same time, ~~the study of **?** proposes to use for the Arctic ocean a~~ **?** proposed to use the term "surface layer" instead of ~~the~~ "mixed layer" for the Arctic Ocean, because the water ~~horizon laying~~ layer lying between the sea surface and the Arctic main halocline can be weakly stratified even though the halocline hampers an active exchange of matter and energy. The main halocline is situated at 50-100 m depth in the Eastern Arctic ~~, **?**,~~ (**?**), and at 100-200 m depth in the Western Arctic ~~ocean~~ Ocean (**?**). Using the concept of "surface layer" with some assumptions, the processes ~~above the mentioned depths~~ in that layer can be discussed separately from the ~~interior.~~ ones in the deeper layer. The freshwater is supposed to be delivered to the central (European) Arctic from the Siberian shelf, roughly along the Lomonosov Ridge and to the western Arctic, partly along the continental slope.

The position of the pycnocline in the Arctic is mostly defined by the salinity. One of the first studies of **?** devoted to the freshwater content was using 34.80 ~~PSS~~ as a reference salinity value separating the "fresh" and the "saline" ~~waters, as at that moment it was a mean Arctic salinity~~water, which was considered the mean Arctic Ocean salinity at that time. This value is used as well in more recent overviews (~~**?**). In the study of **?**~~ e.g. **?**, **?**), and helps to define the "Atlantic Water" as saltier than this value. **?** used a depth of 34 ~~PSS isohaline was used~~ isohaline to estimate the liquid freshwater content in the Arctic ~~ocean. **?** based on in situ data in the Laptev sea for 1950-1993 and 2007-2012 periods reported~~ Ocean. **?** considered the depth of "near-freezing freshwater mixed layer" in the Eurasian Arctic Ocean being 5-10 m. **?** reported an overall salinity in the ~~surface~~ upper 5-50 m layer ~~to lay within a~~ within the range from 30.8 to 33 ~~PSS~~based on in situ data in the Laptev Sea during 1950-1993 and 2007-2012. Between the very surface layer and the Atlantic ~~waters, **?** finds out a modified~~ Water, **?** found a Modified "~~lower halocline~~Lower Halocline" ~~waters~~ Water with typical characteristics of salinity (between 33 and 34.2~~PSS~~) and negative ~~temperatures~~ temperature (below -1.5°C); in 2002-2009 this layer was situated at 50-110 m ~~depths. A general~~ depth. The study of **?** on the Arctic ~~ocean freshening defines~~ Ocean freshening defined the upper ocean layer between 0 m and a depth of a density layer $\sigma_\theta = 27.35$ $kg \cdot m^{-3}$. This isopycnal is often located at 140–150 m depth, "slightly above the Atlantic ~~water~~ Water upper boundary defined by the 0°C isotherm".

~~To analyse the upper-ocean processes, we will focus on the very surface with satellite data and on the upper 250 m layer with the CTD casts, showing the isohaline and isopycnal positions. Such approach to the~~

The mixing can be induced by winds generating surface-intensified Ekman currents, mesoscale dynamics (eddies), shear in tidal and other currents (**?**, **?**, **?**). The tidal currents and internal waves amplified over the shelf edge are associated with the mixing in the interior of the water column, below or in the main Arctic pycnocline (**?**, **?**, **?**). **?** and **?** showed that interannual changes of river discharge and wind patterns define the position of the oceanographic fronts in the central part of the Laptev Sea. Based on the model results, **?** showed that in 1989-1997 the freshwater was driven eastward under the influence of winds associated with a "~~upper layer~~strong cyclonic vorticity over the Arctic"~~is necessary to know the upper limit of the Atlantic waters, though not being the subject of this study, but essential for the water mass transformation~~. The same study demonstrated that the associated salinification of the central Arctic Ocean weakens the vertical stratification of the water column. **?** discuss the importance of sea ice, as it creates a surface drag and establish the Ekman transport of the freshwater in the surface layer, which, in turn, impacts the dynamical ocean topography and geostrophic currents in the Arctic Ocean. **?** further mentioned that the alongshore winds correlated with AO (Arctic Oscillation) index create the onshore Ekman transport, changing the water properties over the shelf.

Concerning the seasonal dynamics, the summertime is of a particular interest for all Arctic studies. The sea ice melting usually starts in June and ends in August-September, while the sea ice formation can start already in September and by November the Laptev Sea is covered completely. The East-Siberian Sea is covered by sea ice most of the year, and is exposed to the air-sea interaction for a shorter period of time (in August-September) and smaller ice-free surface than the Laptev Sea. August and September are two summer months that are very important for the heat exchange between the open ocean and atmosphere over the Laptev seaSea. In a recent study, **?** reported that during this time period when the sea ice is melting and the ocean is opening, a radiative balance the net radiative balance at the sea surface changes from 100 W/m^2 to negative zero values, following the seasonal cycle of shortwave radiation. The sea level anomalies over the Eastern Arctic shallow seas are positive and largest in summer (up to 10 cm at 75°N, down to 3 cm at 80°N, as it was reported by **?**). The Laptev sea considered in this article

The Laptev Sea is not at all sampled by Argo products, so the recent ARKTIKA-2018 measurements offer a good opportunity to validate SST and SSS. Accurate measurements of surface salinity can enrich our understanding of freshwater content in the Arctic (**?**) and SSS estimates from L-band satellites can bring a valuable input.

In this paper, expedition measurements combined with novel satellite sea surface salinity and other satellite-derived parameters provide an unprecedented documentation of the temporal evolution of the surface water evolution of properties in the Laptev and the East-Siberian seas will be described and analysed considering wind speed and direction during the period of the ARKTIKA-2018 expedition. Firstly, data and methods used for the following study will be presented. Then, we compare SST and SSS satellite estimates with in situ measurements. The influence of the wind speed on Laptev sea is discussed considering Ekman transport and pumping. Finally, Seas during the summer 2018. In this study, we propose to follow the upper ocean water displacement and discuss what causes it on a daily basis. To analyse the upper-ocean processes, we will focus on the very surface with satellite data and on the upper 250 m layer with the CTD (conductivity, temperature, depth) casts, showing the isohaline and isopycnal positions. Such an approach to the upper layer is required to estimate the upper of limit of the Atlantic Water, which is one of the key contributors to the better understanding allows to describe the water masses water mass transformation. The surface water evolution of the Laptev sea and their transformation during August-September 2018. and the East-Siberian Seas is described and analysed considering wind speed and direction during the ARKTIKA-2018 expedition.

2 Data and Methods

2.1 In situ measurements during the ARKTIKA-2018 expedition

Oceanographic measurements during the ARKTIKA-2018 cruise expedition on board RV Akademik Tryoshnikov started on August 21, 2018 and ended on September 24, 2018 (Fig.1). Standard oceanographic stations (145 in total) were conducted with Sea-Bird SBE 911plus CTD instrument. Oceanographic sections were organized in the way to best represent the processes

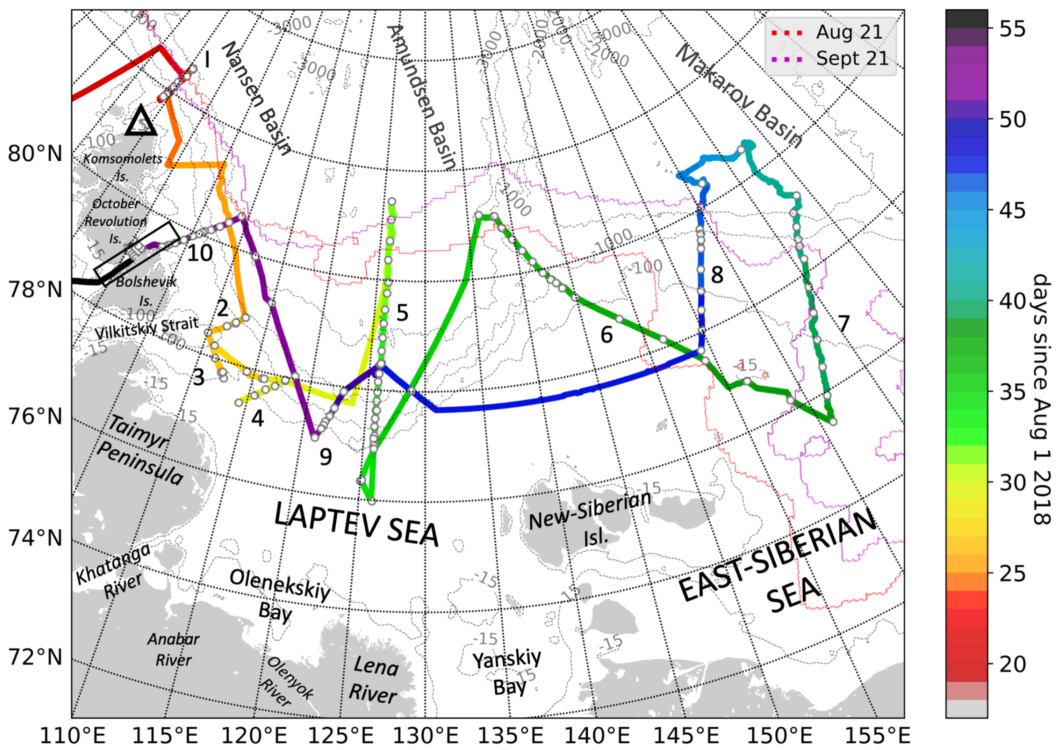


Figure 1. Legs and stations of the ARKTIKA-2018 expedition overlayed on the bathymetry from ETOPO1 "1 Arc-Minute Global Relief Model" (?). CTD stations are shown with white dots. The color indicates the number of days since August 1, 2018. The sea ice edge position is indicated with a red dashed line for the beginning (August 21) and with the purple dashed line for the end of the expedition (September 21). The ice edge is based on the sea ice mask provided in the SST DMI product. Numbers indicate positions of 10 oceanographic transects discussed below. The black triangle in the north of the Komsomolets Island shows the Arkticheskiy Cape. The Severnaya Zemlya Archipelago consists mainly of the Komsomolets, the October Revolution, and the Bolshevik Islands (with smaller islands not shown here). The black box indicates the Shokalskiy Strait between the October Revolution and the Bolshevik Islands. The Yana river estuary is situated southward the Yanskiy Bay (out of the map).

~~between the~~ to take into account the interests of different scientific expeditions on board, NABOS (Nansen and Amundsen Basin Observational System) and CATS (Changing Arctic Transpolar System) to observe both, shallow and continental slope ~~areas, but also~~ processes. NABOS sections were mostly cross-shelf (1, 5, 6-8, 10), and CATS sections were shallower (2-4, 9). Section 3 and 10 were made in the straits between the Kara and the Laptev ~~sea:~~ Sea: the section 3 in the Vilkitskiy Strait southward to the Bolshevik Island, with depths from 70 to ~~1500 and the~~ 200 m opening into the deep central part of the Laptev Sea (more than 1000 m) and the section 10 in the narrow and rather shallow (250 m) Shokalskiy Strait between the Bolshevik and the October Revolution Islands. ~~Part of the~~ Some measurements were carried out in marginal ice zone (MIZ) and ice-covered area ~~.~~ (see the sea ice edge positions at the beginning and the end of the cruise in Fig.1). In this study we define MIZ as an area with 0-30% sea ice concentration close to the ice edge. Standard oceanographic stations (145 in total) were conducted with SeaBird SBE911plus CTD instrument equipped with additional sensors. For this study, we use mainly the CTD measurements of potential temperature and practical salinity, but also the results of oxygen isotope analysis from the first (surface) bottle samples (**?**). All CTD data were processed and quality checked. The cruise data can be found at https://arcticdata.io/catalog/data (**?**) and **?**.

The ship was equipped with an underway measurement system Aqualine Ferrybox, widely known as a thermosalinograph, TSG. The instrument had a temperature and a conductivity (MiniPack CTG, CTD-F) sensors and a CTG UniLux fluorometer installed; thus, continuous temperature, salinity and chlorophyll-a estimations were obtained along the ship's trajectory. The inflow is situated at 6.5 m below the surface (the inflow hole is on the ship's hull). All data were processed and filtered for random noise and bad quality datameasurements, and then compared and calibrated with CTD measurements. Standard ongoing meteorological measurements of wind speed and direction make it possible to partly assess the impact of real atmospheric forcing. When calculating a linear regression between CTD measurements at 6.5 meters depth and TSG measurements, we obtain a good correlation for both temperature and salinity (correlation coefficient equal to 0.979 and 0.966, respectively, not shown). The standard error is 0.023 for temperature and 0.025 for salinity, and the standard deviation for the difference of measurements (CTD minus TSG) was $STD_{temp} = 0.413$, and $STD_{sal} = 0.423$. To adjust the continuous TSG measurements to the more precise CTD measurements, we applied the obtained linear regression equation to TSG data. We only use these adjusted temperature and salinity data further on.

The vertical profiles of the conservative temperature and practical salinity in the upper layer are presented in Fig.2. To investigate if the TSG measurements can be used to study the surface layer in a highly stratified Laptev sea, we calculated a summer mixed layer depth following **?** method based on density and temperature gradient thresholds (Fig.2, a, c). The MLD is found at a depth of the first maximum temperature gradient below a depth of defined (by given threshold) density gradient (see **?** for details). Using the same approach, we computed MLD with density and salinity vertical profiles. The threshold chosen for practical density gradient was 0.3 degree per 1 Arc-Minute Global Relief Model" (**?**). CTD stations are shown with white squares. Color bar indicates the number of days since August m, and 0.2 salinity units per 1 , meter for conservative temperature and practical salinity gradients. Regarding the MLD calculated from salinity (MLD_{sal}), most of the measured vertical profiles (75.17%) had the MLD_{sal} below 7 m depth with the median of MLD_{sal} 11.99 m. As for the temperature (MLD_{temp}), 81.37% of the measured profiles had the MLD below 7 m depth with a median of $MLD_{temp} = 13.50m$. Thus, in most cases the upper 12 m of the surface layer was homogeneous, and our CTD and TSG measurements can be used for the validation of satellite data. The median vertical profiles of temperature and salinity in the upper 5-100 m are presented as well as the associated STD in Fig.2, b, d). We observe rather cold (0.5°C) and fresh (30.5) water at 5 m, followed by a smooth thermo- and halocline down to 30 m depth. Below the temperature is slightly rising to -1 °C, and salinity stays close to 34.5. The STD of conservative temperature is the largest at the surface (1.55°C) and smallest at 40 m depth (0.27°C). The STD of salinity is also the largest at the surface, 1.50, but is diminishing with depth up to 0.20 at 100 m. Nevertheless, it is clear that at the end of a summer season in the region with very different water origins, these median profiles are not representative for all water masses. Additionally, we did an important number of CTD casts in very shallow areas with depths between 30 and 50 m,

~~Time of the ARKTIKA-2018 expedition works and bathymetry from ETOPO1~~

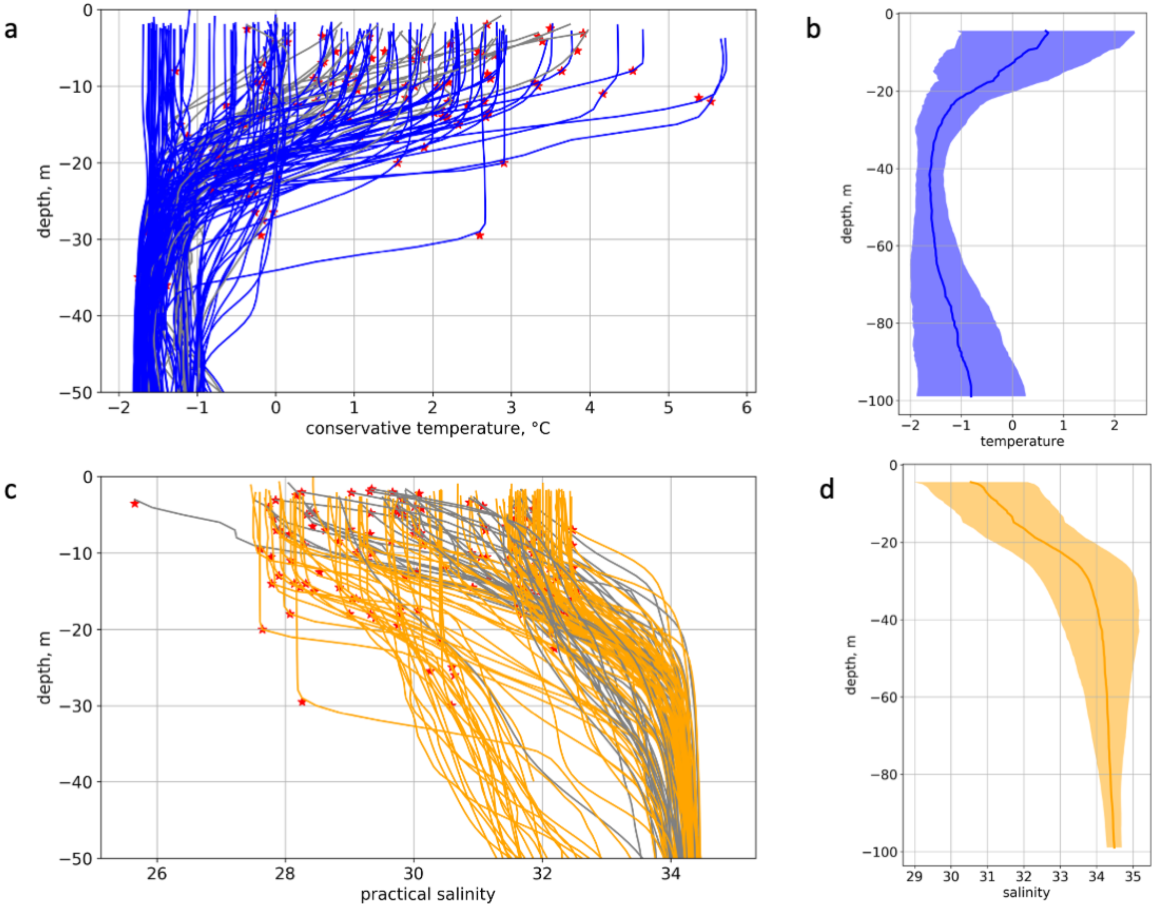


Figure 2. Vertical profiles of conservative temperature (a, b) and practical salinity (c, d) from CTD measurements in the upper ocean layer. Figures (a) and (c) show all vertical profiles in the upper 50 m, where red stars indicate the mixed layer depth, calculated using **?** method (see details in the text), colored profiles show the cases, when the MLD is below 7 m depth and gray profiles indicate when the MLD is above 7 m depth. Figures (b) and (c) show the median vertical profiles of temperature and salinity in the 5-100 m layer, respectively, where the shaded area shows the associated STD.

so the calculated averaged (median) vertical profile is a composite of "shallow" and "deep" vertical profiles. We do not include the very surface measurements above 5 m, because we had only 45 CTD measurements at 2 m depth among 146 possible, and taking them into account would bias the median profiles as well.

2.1.1 River discharge

To illustrate the amount and temporal variability of the river discharge in 2018, we used daily measurements of the Lena River discharge from the Arctic Great Rivers Observatory (GRO) dataset (https://www.arcticrivers.org/data)). In Fig.3 we present a

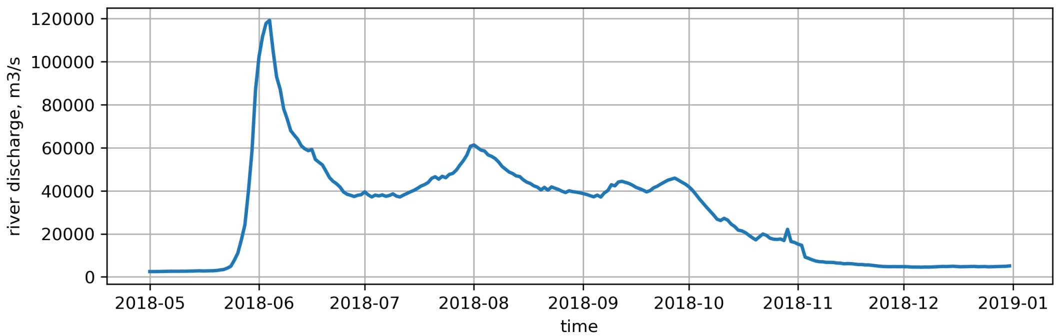


Figure 3. The sea ice edge positions are indicated with a dashed lines for the beginning (August 21) and the end of expedition (September 21). The numbers indicate 10 transects that will be studied later Lena River discharge in the paper.2018, data from Arctic GRO dataset (https://www.arcticrivers.org/data)

time series of the Lena River discharge from May to November 2018. The river stayed under the ice with a very small discharge up to the end of May. The main peak of the Lena River discharge occurred in the beginning of the Arctic summer in June and corresponds to the snow and ice melting over the river basin in Siberia. In two weeks, the discharge changed from 2 500 to 120 000 m^3/s. The second, smaller peak of the river discharge occurred in the beginning of August (60 000m^3/s), which might be associated with the summer precipitation. In August 2018 the river discharge was decreasing from 60 000 to 40 000 m^3/s, and in September it varied very little staying close to 40 000 m^3/s. A significant diminution of the river discharge started in the beginning of October and continued up to the beginning of November. Since the beginning of November the river discharge was very weak and close to its minimum values (4500 m^3/s).

The described seasonal dynamics is typical for the Lena River and consistent with existing results, e.g. demonstrated in **?**. It can be complemented by the results of **?** study of the Siberian great rivers using satellite data. **?** showed that the maximum of precipitation over the basins of the Lena, the Ob' and the Yenisey Rivers occurs in July, and the mean monthly air temperature is maximum at this moment.

2.2 Satellite data

Satellite data provide an instant information about surface distribution of geophysical characteristics over the whole study area and together with their temporal evolution.

All listed below products were are considered from August 1, 2018 to September 25, 2018 (the last day of ARKTIKA-2018 expedition). If not indicated additionally, for consistency all products were For consistency, when not specifically indicated all products are linearly interpolated on a regular grid within the bounding box 74-85N 90-170E, with 0.01 degree step in latitude, and 0.05 degree in longitude. The spatial resolution of selected grid roughly corresponds to 1 kmon the studied latitudes.

2.2.1 ~~Sea surface temperature~~

2.2.2 Sea surface temperature

The SST-retrieving instruments with the highest resolution, such as AVHRR ~~, MODIS and VIIRS~~ (Advanced Very High Resolution Radiometer), MODIS (Moderate Resolution Imaging Spectroradiometer) and VIIRS (Visible Infrared Imaging Radiometer Suite) work in Near Infrared (NIR) and Infrared (IR) bands and ~~depend strongly~~ strongly depend on atmospheric conditions (provide measurements for clear sky). For lower resolution microwave instruments, such as AMSR2 (Advanced Microwave Scanning Radiometer 2), the clouds are ~~not opaque, but SST retrieval~~ transparent, but the SST retrievals may still be hampered by high wind speed and precipitation events. As satellite measurements in IR and NIR ranges are sparse because of the frequent cloudiness over the Arctic ~~ocean, a use of a blended productcan be favorable~~Ocean, we uses a blended product. In this paper we use the Danish Meteorological Institute Arctic Sea and Ice Surface Temperature product (hereafter referred as "SST DMI"). SST DMI is a Level 4 daily product provided by the Copernicus Marine service ("Level 4 product" means that several swath measurements were interpolated to achieve a regular resolution in time and space). Daily surface temperatures over the sea and ice are ~~calculated~~ derived on a 5 km spatial grid from several instruments: AVHRR~~and~~ , VIIRS for SST and AMSR2 for sea ice concentration, using optimal interpolation (**?**).

Besides the full coverage over the studied area, the advantage of the blended SST DMI product is that it takes into account the ice temperature, so the marginal ice zone (MIZ) is better represented and not masked out. The total number of SST measurements ingested over the studied area from August 1 to September 25, 2018 varies from 1000 to 2500 measurements per pixel.

2.2.3 Validation of SST DMI

The first step of the SST DMI validation was its value-by-value comparison with a collocated in situ dataset (nearest neighbour SST DMI pixel). For this analysis, we collocated SST DMI with the in situ potential temperature measurements in the upper 6.5 m layer: all available CTD measurements averaged every half a metre above 6.5 m depth and all TSG measurements at 6.5 m depth averaged every 30 minutes. The median depth of the collocated CTD measurements is 5.25 m. As for the TSG, the ship was moving with a median speed of 8 knots during the cruise, so an average of 30-minutes TSG measurements is an average over approximately 7.5 km. Thus, 30-minutes TSG average is comparable with one SST DMI pixel (10 km). There were 1707 collocated points in the analysis.

Although, in fact, satellite SST estimates may differ from the in situ temperature measurements in the upper 6.5 m, we expect some overall consistency between the datasets. Studies carried out by **?** devoted to the validation of MODIS SST in the MIZ, and by **?**, which described in situ measurements in the iced-covered area, reported that the first 7-10 m layer below the surface was mostly homogeneous. As it is shown in Fig.2, most of our measurements (more than 75%) were homogeneous in the upper 12 m (and were done in the ice-free areas). Nevertheless, a diurnal warming and a local vertical mixing can affect the vertical temperature distribution in the very surface layer. The SST diurnal amplitude can reach more than 3 K in the Arctic Ocean (**?**), but local diurnal variations of temperature are supposed to be filtered out in the SST DMI product, as it only uses

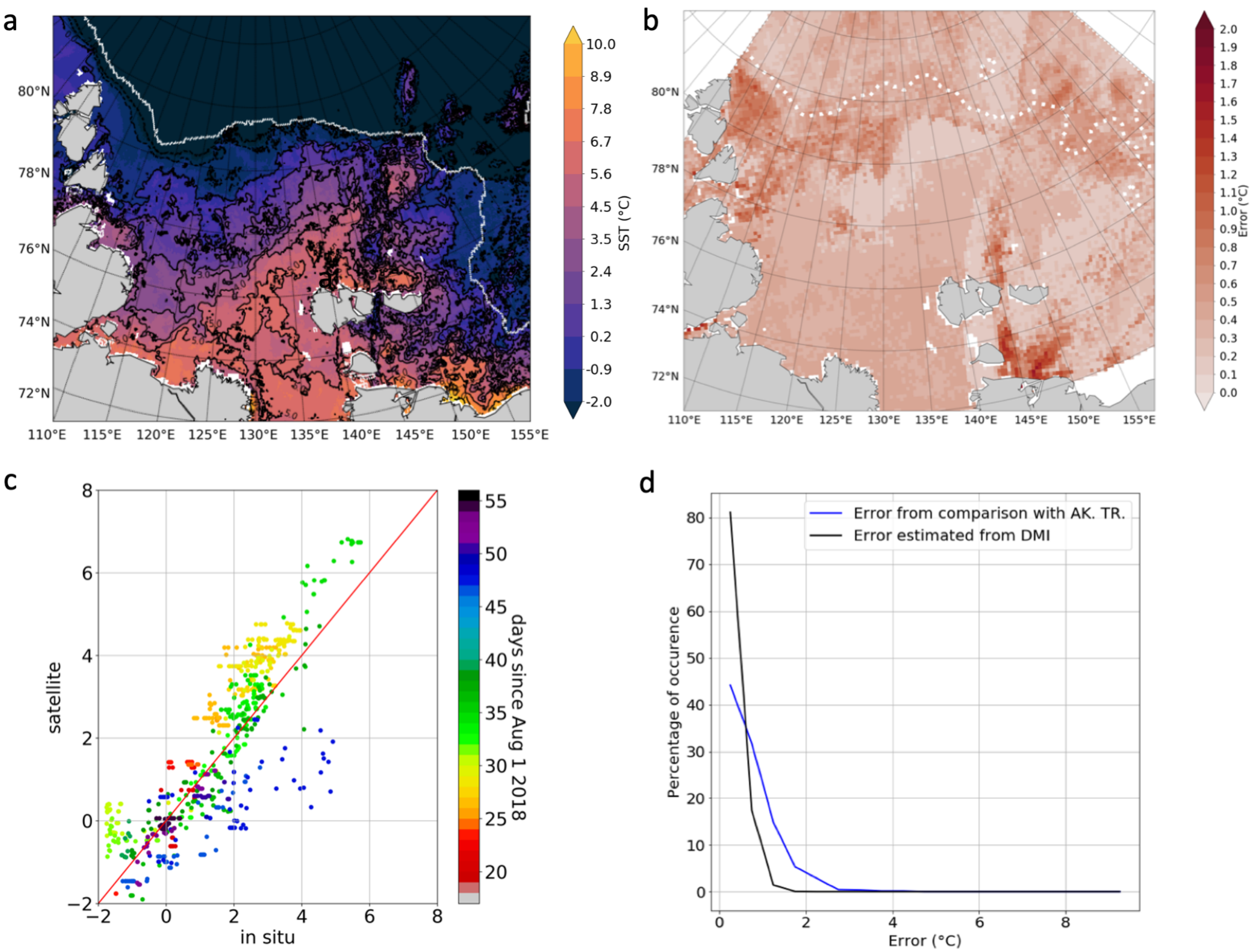


Figure 4. Sea surface temperature validation: example of SST DMI L4 image for September 13 (a) with the error estimates (b); comparison of collocated SST and in situ data (CTD and TSG) in the upper 6.5 m (c) and distribution of error provided by DMI and absolute difference derived from comparison with in situ data (d).

observations between 21:00 and 7:00 local time (**?**). Diurnal SST variation might be present in real in situ measurements in case of strong diurnal warming events, but no particular observations allowing to investigate this question were done during the cruise.

To illustrate the consistency of SST and in situ temperature datasets, September 13, 2018 was considered as it was one of the rare days in summer 2018, when the central part of the Laptev Sea was cloud-free, which is especially important for SST DMI.

The SST DMI product for September 13, presented in Fig. 4 (a) shows a rather complex pattern with a pronounced gradient associated with warm river water in the central part of the Laptev Sea. The error in SST estimates provided by DMI, is shown in Fig.4 (b, d). The percentage of occurrence is computed in temperatures classes with a size of 0.5 degrees that starts at 0 degrees (Fig.4, d). The highest potential error (up to 2.5°C), was observed over some open sea areas (due to potential cloudiness), but was mostly associated with the sea ice due to its heterogeneity (Fig.4 (b)). Over most of the southern and the central part of the ice-free Laptev and the East-Siberian Seas, the error is below 0.5°C and over the eastern part, it is below 1°C.

Comparison of the SST DMI and in situ surface-layer temperature (Fig. 4, c) shows a very good agreement almost independent on area and time during the ARKTIKA-2018 expedition. The correlation coefficient is 0.89, and the RMS is 0.77°C. The difference between mean in situ and mean SST DMI data is -0.19°C, where the SST DMI is higher than the in situ temperature. This value seems to be realistic, as the CTD data justifies it. According to CTD measurements, the 0-3 m water layer is on average 0.3°C warmer than the 3-6.5 m layer (not shown). The largest deviations are observed when the expedition is working in the MIZ or more compact sea ice, so they might be associated with either imperfect sea ice flagging of some stages of sea ice in the SST DMI product or a noise introduced after re-interpolation of data on a regular grid. This noise together with the different sampling of in situ potential temperature measurements and SST DMI product lead to a standard deviation of the difference between in situ and SST DMI larger than the error provided in the SST DMI product (Fig. 4, lower right). Overall, SST DMI agrees well with in situ data, so we use this product for the following analysis of SST time-series.

2.2.4 Sea surface salinity

Soil Moisture and Ocean Salinity (SMOS) ~~was~~ is the first satellite mission embarking an L-band (1.41 GHz) interferometric microwave radiometer, which measurements ~~make possible to derive~~ are used to retrieve the sea surface salinity (SSS). With recent processing, the standard deviation of the differences between 18-day SMOS SSS and 100-km averaged ~~ship SSS~~ TSG surface salinity measurements is 0.20 ~~PSS~~ in the open ocean between 45°N and 45°S (~~?~~?). However, the precision degrades in cold water as the sensitivity of L-band radiometer signal to SSS decreases when SST decreases, even though this effect on temporally averaged maps is partly compensated by the increased number of satellite measurements at high latitude. A possibility of using SSS estimates in cold regions derived from L-Band radiometry ~~was, however,~~ has been demonstrated recently by several working groups (**?**, **?**, **?**). However, existing L3 ("Level 3" means a product resampled at a uniform time-spatial grid, different from swath grid) SSS products: SMAP CAP/JPL (Soil Moisture Active Passive satellite, a product created using the Combined Active Passive algorithm by Jet Propulsion Laboratory) SSS or SMOS BEC ~~L3 products~~ (Barcelona Expert Center) SSS, are spatially averaged from 60 km to more than 100 km.

~~Soil Moisture Active and Passive (SMAP) L3 SSS~~ SMAP REMSS (Remote Sensing Systems) SSS L3 v3 ~~from REMSS provides a 40km resolution version~~provides a 40 km resolution version, but do not provide a sufficient coverage in the Laptev Sea. The methodology developed in this study ~~for retrieve SMOS weekly~~ to retrieve SMOS SSS aims at maintaining SMOS ~~SSS~~ original spatial resolution and at attempting to retrieve SSS as close as possible ~~from~~ to the ice edge.

~~Weekly SSS average~~ A new product, hereafter SMOS SSS "A" ("A" for the Arctic Ocean) L3, investigated in this study ~~are~~ was computed using SMOS ~~SSS~~ L2 ("Level 2" product means that a geophysical parameter, eg. SSS, was computed at the swath grid) SSS from the ESA (European Space Agency) last processing (v662, **?**). SMOS L2 SSS are available on the ESA SMOS Online Dissemination website. The mean spatial ~~resolution of individual SMOS SSS~~ (radiometric) resolution of SMOS product is close to 50 km~~. SMOS~~ , but SMOS ESA L2 SSS products are ~~sampled~~ oversampled over an Icosahedral Snyder Equal Area (ISEA) grid at 15 km resolution. ~~Seven days running means are computed each day in each pixel . SSS are temporally weighted using a Gaussian~~

SMOS "A" SSS was obtained as described below. Seven-day running means were computed for each day and each pixel of the ISEA grid, with a temporal Gaussian weighting function with a standard deviation of 3 days. The full width of SMOS ascending and descending orbits swaths ~~is~~ was considered in order to take advantage of better temporal and spatial sampling over the Arctic ~~ocean and~~ Ocean and to decrease the uncertainty with temporal averaging. In order to eliminate the SSS at very low and high wind speeds because of ~~their~~ its high uncertainties, SMOS ~~SSS are~~ ESA L2 SSS was considered only if the associated ECMWF ~~wind speeds are~~ (European Centre for Medium-Range Weather Forecasts) wind speed was between 3 and 12 m/s. ~~SSS measurements are~~ SMOS ESA L2 SSS measurements were also weighted by the estimated error of the SSS measurement (as in (**?**, equation A7). This error ~~is~~ was derived from the SSS theoretical error multiplied by the normalized χ^2 cost function. **?** ~~have shown that the Klein and Swift (**?**)~~ showed that the **?** dielectric constant model ~~is~~ was inaccurate at low SST. In order to mitigate this effect, a SST-dependent correction derived from the Fig. 16 of **?** (blue-circle line) ~~has been applied.~~ was applied: $SSS_{SMOS-"A"} = SSS_{SMOS-ESA-L2} - (-5 \cdot 10^{-4} \cdot SST^3_{ECMWF} + 0.02 \cdot SST^2_{ECMWF} - 0.23 \cdot SST_{ECMWF} + 0.69)$. Finally, a ~~criteria on~~ criterion on a SMOS-retrieved pseudo-dielectric constant (ACARD parameter) ~~is~~ was applied to discard SMOS measurements affected by sea ice (discarded when $ACARD < 45$). The error ~~on the weekly SSS mean is~~ of SMOS SSS "A" was derived from the propagation of the error on individual ~~SSS. It~~ SMOS ESA L2 SSS pixel during 7 days. The error increases strongly in the vicinity of sea ice. For this reason, in the following study, above 75°N, all pixels with ~~a~~ an SSS weekly error larger that 0.8 ~~PSS are~~ were not considered. South of 75°N, a higher threshold ~~is~~ was used (1.5~~PSS~~) allowing to maintain some measurements ~~close from the source of the river plume where the~~ closer to fresh river water from the Lena and the Khatanga Rivers near the coast. In this area, the χ^2 may increase due to the strong heterogeneity of SSS within SMOS multi-angular brightness temperatures footprints~~and where~~ , and the number of measurements is low due to the ~~combined~~ presence of the coast and islands ~~but without ice sheet.~~ even without sea ice. A theoretical error of SMOS SSS "A" field is below 0.5 in the center of the Laptev Sea and up to 2 and higher close to the coastline and MIZ.

2.2.5 Validation of SMOS "A" SSS

In this section, we compared the SMOS SSS "A" relative to in situ measurements. Figure 5 presents the SMOS SSS "A" on September 13, 2018, the same day as the DMI SST in Fig.4. We carried a collocation of SMOS SSS "A" and in situ measurements of salinity in the upper 6.5 m layer in a following manner: the averaging of the TSG salinity was done over one hour period (equal to $\sim$ 15 km distance, contrary to DMI SST validation) in order to be closer to SMOS SSS "A" spatial resolution. We used 985 collocated points.

Comparison between the in situ practical salinity and SMOS SSS "A" shows a very good agreement, not yet demonstrated before by any other salinity product in the Laptev Sea. The correlation coefficient is 0.86 with a RMS = 0.86. The mean

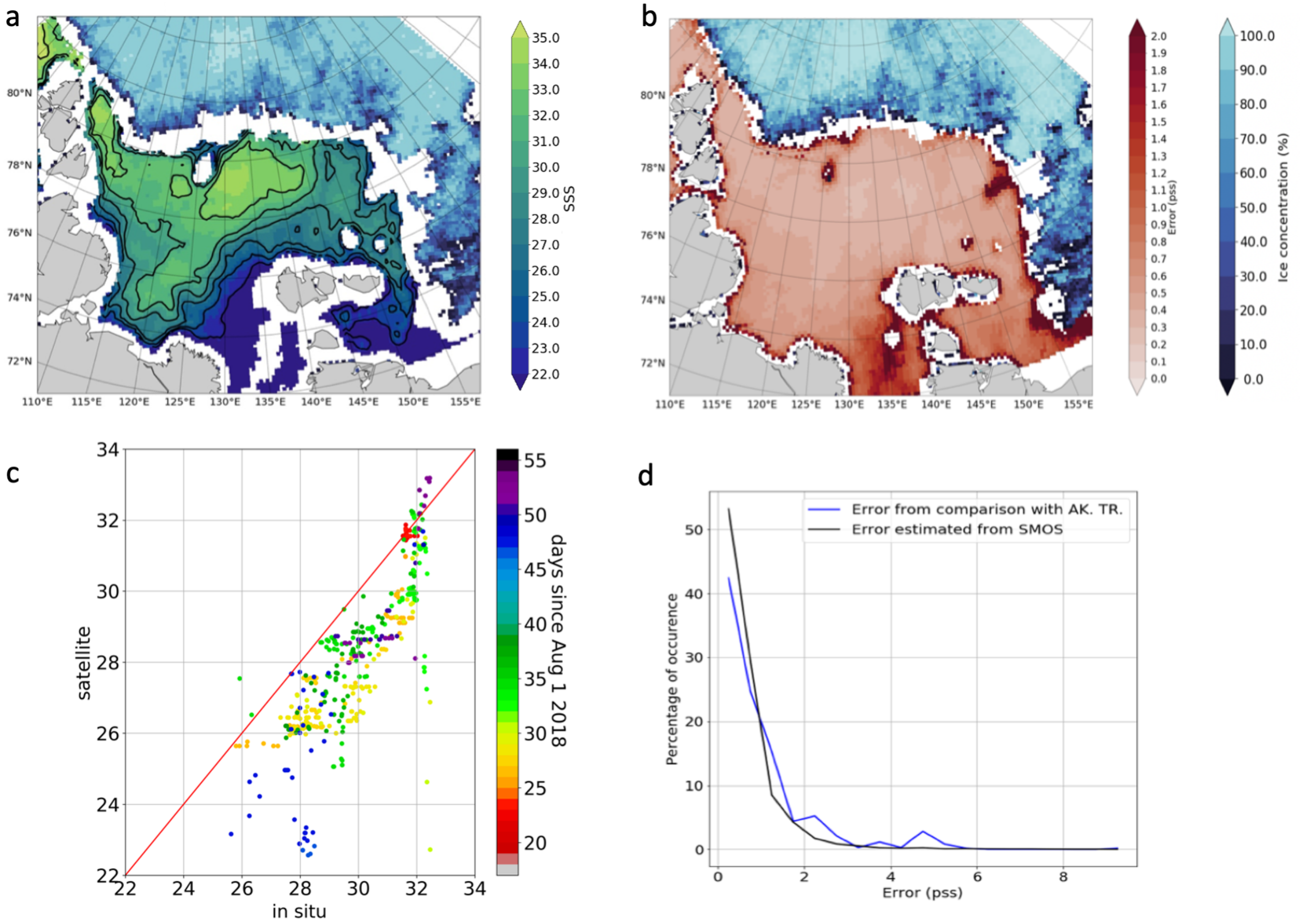


Figure 5. Sea surface salinity validation: example of SMOS SSS "A" for September 13, 2018 (a), computed error estimates for this day (b), comparison of collocated SSS and in situ data in the upper 6.5 m (c) and distribution of provided SMOS L2 error and measured absolute difference from comparison with in situ data (d). Sea ice concentration from AMSR2 is indicated with blue shading on the upper panels

difference is 2.06. In what follows, we subtract this mean difference from the entire SMOS SSS dataset. The standard deviation of SMOS SSS with respect to in situ SSS does not vary with the depth of the in situ salinity measurements above 6.5 m, either because in situ salinity was homogeneous vertically or because comparisons were too noisy to detect this small variations (not shown). Although SMOS SSS "A" shows a good agreement most of the time, some larger errors occur close to the ice margin or when pixels are contaminated by small ice pattern not detected by AMSR2 sea ice concentration algorithm (as at 80°N 125°E in Fig. 5, a).

Comparison between SMOS retrieved error and error based on comparison with in situ salinity measurements is presented in Fig. 5 (d). The percentage of occurrence is computed in salinity classes with a size of 0.5 that starts at 0. It shows a good agreement between the distribution of SMOS SSS "A" error estimated from retrieval process and the distribution of error obtained from comparison with in situ salinity measurements. This results allow us to use the SMOS SSS "A" error with a higher confidence in our further analysis. Using error filtering, the points too close to the ice edge were excluded.

2.2.6 Sea ice concentration and ice masks

Sea ice masks were obtained from AMSR2 sea ice concentrations products provided by the University of Bremen (**?**): they are weather-independent, thus, continuous for ~~all time~~ the whole period. The highest available spatial resolution is 3.125 km. The AMSR2 ice masks were used in addition to the masks provided with every satellite product discussed (DMI SST , SMOS SSS "A", ASCAT (Advanced SCATterometer) winds L3 (see its description below)). A continuous erroneous presence of ice along the Siberian coast was observed and had to be filtered: images in optical band and the ice charts from the Arctic and Antarctic Research Institute (AARI) were used as a reference. As ~~detailed in section 2.2.2, additional filterings were~~ it was detailed above, an additional filtering was applied to SMOS SSS ~~as~~ "A" as the L-Band measurements are sensitive to ice thicknesses less than 50 cm contrary to AMSR2 measurements.

The sea ice opening starts relatively late in the Laptev Sea: a coastal polynia appeared in the southern-central part of the Laptev Sea at the beginning of June in 2018 and by the beginning of August, the sea was ice-free only south to 79°N. The Laptev Sea was completely covered by the beginning of November in 2018. For this study, we define the sea ice edge with the position of 1% sea ice concentration and MIZ as 0-30%.

2.2.7 Wind speed

To investigate the ~~winds speed patterns, we used~~ wind speed pattern, we use ASCAT scatterometer daily C-2015 L3 data produced by Remote Sensing Systems. Data are available at www.remss.com. ~~"~~

2.3 Reanalysis data

Reanalysis data ~~were~~ are used to include some additional parameters not available from satellite and in situ data. Atmospheric forcing fields~~-~~: sea level pressure, SLP, and air temperature, ~~were~~ are obtained from the ERA5 reanalysis (**?**). The latest reanalysis of ERA5 ~~yet have~~ still has relatively crude spatial grid of 0.5°for the SLP and 0.25°for air temperature.

3 ~~Results~~

2.1 ~~Comparison of datasets~~Ekman transport

To ~~illustrate the consistency of the different satellite products, September 13~~investigate the role of the wind forcing, we compute mean monthly wind fields and the Ekman transport for August and September 2018. Horizontal transport is calculated as:

$$u_{Ekm} = \frac{\tau_v}{D_{Ekm} * \rho_w * f}$$
$$v_{Ekm} = -\frac{\tau_u}{D_{Ekm} * \rho_w * f} \quad (1)$$

where u_{ekm} and v_{ekm} are horizontal components of the Ekman transport, τ is a wind stress, calculated from ASCAT winds (u_{wind}, v_{wind}) using ERA5 air density ρ_{air}: $\tau_u = C_D * (u_{wind}) * u_{wind} * \rho_{air}$; ρ_w is a surface density, calculated from SST and SSS with TEOS-2010; C_D is surface drag coefficient calculated from wind speed according to **?**, $D_{Ekm} = 37m$ is the Ekman depth, according to **?** study in the same region), 2018 was considered as it is one of the rare days in summer 2018 when the central part of the Laptev sea was cloud-free, which is especially important for SST. f is the Coriolis parameter.

The Ekman pumping (upwelling and downwelling) was computed as:

$$w_{ekm} = \frac{1}{D_{Ekm} * \rho_w * f}\left(\frac{d\tau_v}{dx} - \frac{d\tau_u}{dy}\right) + \frac{\beta * \tau_u}{\rho_w * f^2} \quad (2)$$

where w_{ekm} is the vertical component of the Ekman transport and β is the y-derivative of the Coriolis parameter.

2.1.1 Temperature

The SST field from DMI L4 product for September 13, presented in Figure 4 shows a rather complex pattern with a pronounced gradient associated with river waters in the central part of the Laptev sea. Besides the full coverage over the studied area, the advantage of blended DMI product is that it takes into account ice temperatures, so the Marginal Ice Zone (MIZ) is better represented and not masked out. The total number of SST measurements ingested by SST DMI L4 over the studied area from August 1 to September 25, 2018 varies from 1000 to 2500 measurements per 1 pixel over the whole studied period. The error in temperature estimates provided by DMI, is shown on Fig.4. The highest potential error (up to 2.5°C), though observed over some open sea areas (due to potential cloudiness), is mostly associated with the sea ice due to its heterogeneity. Over most of the southern and the central part of the free-of-ice Laptev and the East-Siberian seas, the error is below 0.5°C and over the eastern part, it is below 1°C for selected day.

3 Results

The first step of satellite and in situ dataset evaluation was a value-by-value comparison of collocated dataset (nearest neighbor) and calculation of basic statistics. For this analysis, we collocated satellite-estimated temperature with the in situ measurements in the upper 6.5 m layer: CTD averaged every half a meter above 6.5 m depth and TSG at 6.5 m depth averaged every 30 minutes. The median depth of the collocated temperature measurements is 5.25 m due to the absence of CTD data in the very first meters. As the ship was moving with an average (median) speed of 8 knots, 30 minutes averaged TSG's temperature corresponds to the median of measured temperature over approximately 7.5 km, which is comparable with the spatial resolution of DMI SST L4 10 km. There were 1707 points in the analysis.

3.1 Overview of SST and SSS in the Laptev and East-Siberian Seas in August-September 2018

~~Though, in fact, satellite sea surface temperature estimates may differ from the measurements at 6.5 m, we expect some general consistence between the datasets. Studies carried out by ?, devoted to the validation of MODIS SST in the MIZ and that one by ? which describes in situ measurements in iced-covered area, report that the first 7-10 m layer below the surface is mostly homogeneous. Nevertheless, diurnal warming and local vertical mixing can affect the temperature distribution of in the very surface layer. Local diurnal variations of temperature are supposed to be filtered out in the blended DMI product, as it only uses observations between 21:00 and 7:00 local time (?), but can still be present in real in-situ measurements.~~

~~Comparison of the DMI SST and in situ surface-layer temperature (Fig. 4) shows a very good agreement almost independent on area and time during ARKTIKA-2018 expedition. The correlation coefficient is 0.89, and the RMS is 0.77C. The bias between mean in situ and mean DMI SST data is -0.19C, where the SST is higher than the in situ temperature. This value seems to be realistic, because according to CTD and TSG measurements, in average, the 0-3 m water layer is by 0.3 degree warmer than the 3-6.5 m layer. The largest deviations are observed when the expedition was working in the MIZ or compact sea ice, so they might be associated with either imperfect sea ice flagging of some stages of sea ice in the blended DMI "SST and sea ice temperature" product, or an introduced noise after re-interpolation of data on a regular grid. This noise together with the different sampling of SST by in situ and DMI L4 product lead to a standard deviation of the difference between in situ and DMI SST larger than the error provided in the DMI product (Fig. 4, lower right). Overall, DMI L4 blended SST agrees well with in situ data, so we use this product for the following analysis of SST time-series.~~

4 ~~Overview of SST and SSS in the Laptev and East-Siberian seas in summer 2018~~

The mean SST during the 2 summer months is ~~2.181~~2.18°C in the Laptev ~~sea (between Severnaya Zemlya archipelago and~~ Sea (between the Severnaya Zemlya Archipelago and the New Siberian Islands), and ~~1.126~~ 1.13 °C in the studied part of the East-Siberian ~~sea~~ Sea (Fig. 6). The highest temperatures (above 6°C, up to 9°C) were observed close to the Lena ~~river~~ River delta in the Yanskiy Bay and in the Olenekskiy Bay in front of the Khatanga ~~river~~River. A warm water pool associated with the river plume between 125°E and 135 °E progressively propagates northeast and warms up this part of the sea: 0°C isotherm at 140°E meridian is situated 100 km northward compared to its position at 120°E. The studied part of the East-Siberian ~~sea~~ Sea was not completely ~~free of ice~~ ice-free in August-September 2018. Negative temperatures are observed near the ice edge at a distance of 50-100 km almost everywhere, except for a small area at 80°N 160°E, where warm river water meets the sea ice and no open water with negative temperatures is seen. The strongest gradients are observed along the sea ice edge and the river ~~waters~~ water plume (up to 0.05° C/km, gradient). Standard deviation ~~on~~ of SST in Fig.6 ~~)~~ is the largest in the Olenekskiy Bay (over 2.5°C), along the coastline close to the ~~Lena river~~ Khatanga estuary (2.5-3°C), the Lena River delta (about 4°C) and in marginal ice zone (mostly over 1.5°C). The remarkable variation of ~~temperature~~ SST in the central part of the Laptev ~~sea~~ Sea should be associated with the thermal fronts (largest SST gradients) displacement.

The averaged SSS is 28.75 ~~PSS~~ in the Laptev ~~sea~~ Sea and 27.74 ~~PSS~~ in the studied part of the East-Siberian ~~sea~~ Sea (Fig. 6). The spatial distribution of mean salinity for ~~August September~~ August-September 2018 has several characteristic features.

The freshest ~~waters (~~water (salinity below 20~~PSS~~) are observed within the river plume northeast of the Lena ~~river~~ River delta and within the southern part of the East-Siberian ~~sea. Fresh waters~~ Sea. Freshwater with salinity below 28 ~~PSS~~ reach the sea ice edge ~~on the northeast of the Laptev sea~~in the northeast Laptev Sea. Additional freshwater from the Kara ~~sea~~ Sea enters via the Vilkitskiy and Shokalskiy straits in the west (salinity of 28-30~~PSS~~) and is also observed along the sea ice edge, so it could be associated with ice melting. The most saline ~~waters (~~water (salinity above 34~~PSS) are situated~~) is located in the central part of the Laptev ~~sea~~ Sea near 78-80°N 120-140°E, and in the northwest, along the Severnaya Zemlya Archipelago. As also observed in the SST, the SSS in the Olenekskiy Bay is highly variable, which can be explained by the variation of the freshwater discharge during the 2 months. Nevertheless, large SSS variability is also observed all along the sea ice edge: at 78-80°N in the north and northwest and at the boundary between the Laptev and East-Siberian ~~seas~~Seas. This large variability can be explained in two ways: physical (~~natural~~ haline fronts related to sea ice melting) and instrumental (remaining ice contaminated pixels, lower sensibility of L-band in cold ~~waters~~water). At 78-80°N 125°E, free-floating patches of broken ice detached from compact sea ice edge ~~were~~ are observed during several weeks in August-September 2018. Random pieces of broken ice are not always recognized by ice-mask filters, so can artificially increase the SSS variability. At the same time, this is the area where river ~~waters~~ water meet sea ice, which induces natural variability.

3.1 Observed surface water masses of the Laptev Sea and their transformation

To generalise our understanding of vertical structure of the studied area, we use the classical TS-analysis, first based on CTD measurements only. Fig. 7 shows the temperature-salinity distributions in the upper 200 m, where the color of marker indicates depth. The most prominent feature on the diagram is the transformed Atlantic Water mass with salinity close to 34.5-35, temperatures from -0.5 to 2.5 °C lying at a depth of 100-200 m. The water mass overlying the Atlantic Water (between 50 and 100 m depth) is the lower halocline water, described by **?** as having salinity in a range of salinity 33-34.5, and negative temperatures starting from the lowest values presented in Fig. 7, -1.7 to 2.5°C. The surface water observed in the upper 50 metres is in general the less saline (salinity below 34), but one can clearly observe two separate branches with negative and positive temperatures. It should be remembered that a T-S diagram based only on CTD measurements does not provide an instantaneous view on the ocean state, but is a collection of conditions encountered in different regions at different moments of time (from the end of August to the end of September 2018). During the summer months, the surface water of the Arctic Ocean quickly changes its characteristics, and the synoptic satellite data provide an additional information to the point-wise in situ measurements.

Using DMI SST and SMOS SSS weekly estimates, we plotted T-S diagrams similar to that on in Fig.7, but for several reference days: Aug 1, Aug 15, Aug 30, Sept 4, Sept 13, and Sept 30, 2018 (Fig.8). On the lower row, we present all in situ measurements in the upper 6.5 m and the differences between satellite-derived sea surface temperature and salinity of discussed days. It is observed that the DMI SST is rising only up to the end of August with the maximum temperatures from 8 to 11.5°C for some cases, and then decreases to 4.5°C by the end of September. The temperature is changing by 0.5 - 1°C per week (while increasing and decreasing).

Based on the Fig. 8 visual analysis, we propose to identify 6 surface water masses in the Laptev and East-Siberian Seas (Tab.1). The main surface water masses are warm and fresh (WF) river water and cold and saline (CS) open sea water. All other water masses show either different stages of transformation of these two water masses, or are advected from other regions. It should be noted that satellite-derived data have a larger range of temperature and salinity than near-surface (upper 6.5 m) in situ measurements, which makes this detailed classification possible. The locations of the different water masses for selected days are shown in Fig.9 together with the distribution of water masses in percentage (the whole studied area is 100%, and sea ice occupies some part of it).

On August 1, the sea ice still covers more than 80% of the studied area and extends on average to 78°N in the Laptev Sea, while the East-Siberian Sea is almost completely covered by ice. Warm and Fresh (WF) river water is well observable in the south between 74 and 76°N. It occupies almost the same amount of surface as the Cold and Saline sea Water (CS), the rest of the open area is occupied by a transformed river water (Warm and Medium Salinity, WMS, Cold and Medium Salinity, CMS), that already formed a recognisable river plume front: its signature is continuous from 115°E to 150°E up to the northern position of sea ice edge.

During the next two weeks the ice cover retreats, and a Cold and Fresh Water (CF) mass appears in the south-west East-Siberian Sea. The amount of this Water increased progressively in this area during the remaining period. We suggest that this water mass represents the river water trapped under the ice and then exposed back.

On the 15th of August, one can notice as well a water mass CMS appearing close to Vilkitskiy Strait. It is less pronounced by the end of August, but a thin stream of cooled and transformed river water from the Kara Sea descends along the Taimyr peninsula in September. The Lena River water mixing and cooling happens as well close to the sea ice edge in the north-east Kara Sea. All in all, the surface occupied by this water mass is steadily growing during the observed period, and is nearly 10% by the end of September. We suggest that water mass CMS is a transformed version of water mass CF.

The end of August is warmer as seen in Fig. 9 with the amount of saline water with temperatures above 3°C (water mass WS, Warm and Saline) occupying the central and the western part of the Laptev Sea (almost 10% of the studied area). This water mass is disappearing by the end of September with a decrease of temperature.

By September 13, the SST and SSS variability diminishes. The water mass CF in the north-east Laptev Sea consisting of cold fresh water becomes saltier (transforms into the water mass CMS). The freshwater cools south of the New Siberian island and by September 25 occupies all the ice-free area. The river plumes signature is shifted to the New Siberian island as well (Fig. 9). Cold and saline water dominates the surface of the Laptev Sea. Finally, by September 25, the T-S diagram shows that most of the points lay between 25 and 35 and -1°C and 4°C, with a main core within a salinity range 25-35 and temperature between -1 to 1°C, and the second one within the salinity range 22.5-30 and temperature of 3-4°C. The Laptev and the East-Siberian Seas start to refreeze, the most rapidly in the areas with cold and fresh river water.

3.2 Freshwater ~~plume extension~~variability in the Laptev Sea

To evaluate the distribution of freshwater input in the Laptev ~~sea during summer months, we considered~~ Sea in August-September 2018, we consider virtual zonal and meridional transects along 78°N and 126°E, respectively~~and plotted their temporal~~

Table 1. The temperature ans salinity of six defined surface water masses of the Laptev Sea using satellite data (see the text for the explication of water masses names)

Water mass	WF	WMS	CF	CMS	WS	CS
T	$\geq 3°C$	$\geq 3°C$	$\leq 3°C$	$\leq 3°C$	$\geq 3°C$	$\leq 3°C$
S	≤ 25	$25-29$	≤ 25	$25-29$	≥ 29	≥ 29

~~evolution on~~ , and plot the temporal evolution of DMI SST, SMOS SSS "A", wind speed and SLP in Hovmöller diagrams~~(Fig. 10, 12).~~ . The freshwater can be defined by comparison to the saline “marine water” (typically, 34.80 as in **?** or 34.92, as in **?**). As a 0-salinity river water quickly mixes with a saltier marine water, in reality the "freshwater" is more "brackish" than "fresh". Nevertheless, for simplicity assuming a river plume front at the 29 isohaline, the “freshwater” corresponds to all water masses with the salinity lower than 29, as we referred to it in a previous section.

3.2.1 Water from the Lena River plume

The zonal transect helps to investigate the mean stream position of the river plume away from the coast, in the central part of the Laptev ~~sea~~ Sea with more complex topography ~~.~~ (Fig. 10). This virtual section does not correspond to any real CTD-section, apart from some extracts of TGS profile following the ship’s route (see the position of virtual section on the SST and SSS maps in Fig.10, f-g). In the western part (up to 130 °E), the transect is located roughly above the continental slope and then over the shelf (Fig.~~12). It can be noticed that a displacement of river waters~~ 10, e). The river water displacement roughly follows that of sea ice edge ~~on~~ in the east and is bounded by the ~~edge of the shelf on~~ shelf break in the west. Overall, temperatures are higher in August than in September: a warm pool with SST over 6 °C is observed during the first 30 days at 78°N, 130-147 °E, with highest temperatures on August 26. These coordinates define the position of the river plume at 78°N latitude, as it can be clearly seen in the salinity values varying ~~from~~ in a range of 27-30 ~~PSS~~ there. Relatively strong daily winds (10-12 m/s) observed during the first 10 days of September ~~are~~ were associated with a ~~passage of~~ series of cyclones~~and strongly impact~~ , which strongly impacted the surface layer: the median temperature over the zonal transect ~~decreases~~ decreased from 3°C to almost 0°C, and salinity ~~changes by 1 PSS.~~ increased by 1. As the amount of incoming solar radiation diminishes in September, the maximum SST values ~~do not overpass~~ did not exceed 3°C anymore. Nevertheless, ~~in~~ at the end of September a new freshwater patch ~~is seen~~ was observed at 140°E (less ~~observed~~ visible in SST field) indicating that the ~~surface mixed layer~~ "upstream" surface mixed layer (in the southern part of the Laptev ~~sea) contains~~ Sea) contained a sufficient amount of freshwater to restore its previous state after a mixing event ~~.~~ induced by the wind. Another possible explanation is that a small peak observed in the Lena River discharge in the first days of September (Fig.3) helped to introduce an additional portion of freshwater that reached 78°N several weeks later.

3.2.2 Water from the Kara ~~sea waters~~Sea

~~Zonal~~

The zonal transect allows to see not only the Lena ~~river~~ River plume, but ~~to observe~~ as well the Kara water intrusions ~~on the West. Selected~~ in the west. The selected zonal transect at 78°N is partly ~~laying~~ lying above the Vilkitskiy Strait connecting the Kara and the Laptev ~~seas. In salinity fields of the zonal Hovmöller diagram, we~~ Seas. Being a reservoir for two other great Siberian Rivers, the Ob' and the Yenisei, the Kara Sea has a low salinity compared to the central Arctic Basin (**?**). In the absence of significant river sources on the Severnaya Zemlya Archipelago, we considered that the freshwater input close to the Vilkitskiy and the Shokalsky Straits, arrived from the Kara Sea.

We observe the freshwater arriving from the Kara ~~sea~~ Sea at 110-115°E with typical values of 25-28 ~~PSS~~ during the first 20 days of August and ~~in~~ at the end of September ~~. It is remarkable, that~~ (Fig.10, b). It is noteworthy that the SST fields do not indicate the presence of these intrusions ~~in such clearlyway. It might be possible, that fresh waters~~ so clearly. This suggests that fresh and warm water of the Ob' and Yenisei rivers arriving to the Laptev ~~sea~~ Sea have already lost a significant part of their heat content via exchange with the atmosphere, but ~~the fresh water layer wasn't~~ that the freshwater layer is not completely mixed with the surrounding sea environment. ~~The~~

In Fig. 11, the CTD data justify that the amount of ~~fresh water~~ freshwater arriving from the Kara ~~sea via Vilkitskiy strait is significantly higher than that one~~ Sea via Vilkitskiy Strait is significantly greater than freshwater arriving via the narrow and rather shallow (250 m) Shokalskiy Strait between the Bolshevik and the October Revolution Islands or ~~northward~~ north of the Severnaya Zemlya ~~archipelago~~ Archipelago at the traverse ~~of~~ near the Arkticheskiy Cape across the continental slope~~(Fig. ??).~~ . The temperature of the surface layer is increasing ~~from the North to the South from~~ between 0°C to 3.5°C from the North to the South. The salinity sections indicate the ~~freshwaters~~ freshwater with salinity above 29 ~~PSS~~ only in the Shokalskiy and the Vilkitskiy straits, which suggests ~~the very low~~ very little advection of the Kara-origin ~~fresh waters by~~ freshwater via the north. From the buoyancy cross-sections, one can find that the strongest stratification is at 5-20 m depth, which corresponds to the 1024-1025 kg/m^3 isopycnals position. This result argues against a definition of fresh-water content by the 1027.35 kg/m^3 isopycnal of **?**, as the surface salinity and temperature in the Siberian shelf seas are lower than in other regions. ~~The definition of fresh water content in the Arctic might be considered again.~~

3.2.3 Meridional transect

The meridional transect along 126°E (Fig. 12) partly corresponds to the standard oceanographic section 5 carried out during ARKTIKA-2018 expedition on September 1-4, 2018 (Fig.13). This transect helps to understand the northward propagation of the river plume and to evaluate the freshwater content using in situ data. The highest temperature observed at this longitude is 8°C in August (please note, that a small cold temperature intrusion on days 22-26 ~~most likely corresponds to the~~ probably corresponds to an error in DMI ~~L4~~ SST product due to a cyclone passage ~~, which is seen~~ and thus, strong winds, an assumption reinforced on when comparing DMI ~~to~~ SST to SST AMSR2 microwave data (not shown here)).

The warmest ~~and freshest waters of river plume occupy~~ (5-9°C) and freshest (salinity of 20-30) water of river plume occupies the area between 74-77°N in August and progressively ~~retreat~~ retreats in September: SST and SSS gradients become wider and less pronounced, temperature decreases to 3-4 degrees. High winds speed (10-12 m/s) associated with ~~a~~ an atmospheric depression passage during the first two weeks of September ~~are seen~~ is found both on the meridional and the zonal ~~Hövmoller~~

Hovmöller diagrams and might be related to this widening of the frontal area. Nevertheless, a point-wise cross-correlation between the time-series of wind speed and temperature or wind speed and salinity in a point with random coordinates does not give statistically significant results: both correlation coefficients are below 0.2 ~~with~~ at any time lag (0-10 days). Better correlation is observed with sea level pressure (up to 0.6 at some points), but over the 56 days of the studied period it is not statistically representative as only two passages of cyclone were observed. Higher values of cross-correlation coefficient are expected over the frontal zone, as this is ~~the~~ an area exposed to rapid changes.

~~Oceanographic~~ The oceanographic sections allow to estimate a thickness of the freshwater layer and how far the river water propagates under the ice. Section 5 provides a complementary information to the meridional Hovmöller diagram (Fig.13, upper row) as it was done along the same 126°E parallel from 76 to 81.4° N on September 1-4 2018. This ~~moment~~ date corresponds to the passage of several cyclones over the Laptev ~~sea~~Sea, which, in turn, displaced the river front to the south, unfortunately, almost ~~out of scope of~~ away from this oceanographic section. Nevertheless, at 76-78° N (first 200 km of the section), ~~the low salinity~~ low salinity between 29-33 ~~PSS~~ was still observed in the upper 25 meters. A thin upper layer with positive temperatures has the same thickness, but ~~vasts~~ extends further northward, up to 79° N. ~~On~~ In the north of the section, under the ice, the temperatures are below 0°C and salinity is rather low, below ~~32 PSS.~~ 32. The low salinity under the ice ~~can indicate~~ suggests that the residuals of the river ~~waters~~ water arrived in this area earlier. If the river ~~waters~~ water were propagating under the ice when the Laptev ~~sea~~ Sea was not yet completely open, ~~one~~ we should assume their further mixing with sea ~~waters~~ water when the sea started to open in its central part (mixed ~~waters~~ water with salinity between 30 and 32 ~~PSS~~ and still positive temperatures). The heat exchange with the sea ice might be more effective than with the atmosphere, so under the ice the temperatures are negative, and river water signal is not observed anymore, contrary to salinity. At the same time, it depends on thermal conductivity in the ice, and its initial temperature profile, so this question needs a special attention.

Overall, the first 150 km over the shelf, where the warmest and freshest ~~waters~~ water were observed, are characterized by the strongest stratification in the upper 25 m layer. This is the depth of a stable stratification for the whole section, though ~~less pronounced~~ stratification is less pronounced in the deeper part of the sea than over the shelf. Below the pycnocline, one can observe cold (with negative temperatures) and saline (salinity between 33 and 34.5~~PSS~~) water mass. The warm ~~and saline Atlantic water~~ (T above 0°C, following **?**) and saline (S above 34) Atlantic Water spreading along the continental shelf is best identified in temperature vertical profiles at 100-120 m depth, but is also detected by the instability signal (right column ~~on~~ in Fig. 13). The propagation of the Atlantic ~~waters in laying~~ Water is beyond the scope of this paper, and though Atlantic Water is observed in all ~~discussed~~ presented below oceanographic sections, it won't be ~~presented~~ discussed furthermore.

When considering other meridional sections (section 6, 8, and 7 according to their positions from the west to the east), one can follow the eastward propagation of the river ~~waters away from their origin, the Lena river~~ water away from the Lena River delta. Section 6 started on September 5 in the vicinity of the marginal ice zone ~~on~~ in the deep North-Eastern part of the Laptev ~~sea~~ Sea and ended in the ice-covered part of the East-Siberian ~~sea~~ Sea over the shelf on September 9. This section is not exactly perpendicular to the continental slope, so we can not estimate the width of the river ~~waters~~ water plume, but overall the thickness of the upper layer is similar to that ~~one~~ observed with section 5 in the deep part of the section (20-30 m). The ~~waters~~ water over the shallowest part (depth smaller than 60 m) were observed under the ice, which is clearly seen in temperature signal that is negative even close to the surface. At the same time, the main freshwater core with the highest temperature is observed above the shelf break. The second core is observed in the northern part of the section, with lower salinity than ~~on~~ in the north of section 5. The mixing over the shelf was effective enough to stretch the isopycnals ~~in the vertical up from the surfaceto the bottom~~between the bottom and the surface. Nevertheless, the depth of the maximum stratification is close to 20 ~~meters~~ metres as for the shallow part of the section 5. Over the edge of the continental slope, the maximum ~~value of~~ Brünt-Väisälä frequency ~~is deepen~~ deepens to 25 m, and over the deep-water part to 30 m depth.

Section 8 was started on September 15 in MIZ over the deep part of the East-Siberian ~~sea~~ Sea and finished by September 17 in the ~~free of ice~~ ice-free area over the shelf. The river signal is still very pronounced ~~in both temperature and~~ both in temperature and in salinity profiles, with an efficient mixing over the 60 m layer ~~at~~ on the shelf and more ~~condensed~~ concentrated isopycnals over the shelf edge. The most eastern section 7 was conducted under the ice. The temperatures are, thus, negative above the Atlantic ~~water~~Water, but salinity profile reveals the river water presence with the freshwater core having salinity below ~~29 PSS.~~ 29. The maximum value of Brünt-Väisälä frequency are ~~lower~~ less than for other sections and are observed at 20 m depth and at 55 m depth, following 1024 kg/m^3 and 1026.5 kg/m^3 isopycnals, accordingly.

To ~~resume, in~~ summarize, during the summer 2018, we observe a north-eastern displacement of the Lena ~~river waters~~ River water including in the MIZ and ice-covered area. We suggest that the active displacement started in the ice-covered conditions after the maximum of river discharge in ~~July~~ June-July (following the **?** study and the Lena River discharge measurements presented in Fig.3), then, with progressive opening, a part of the river ~~waters~~ water was mixed within the upper ~~layer of sea and exchanged the~~ sea layer and exchanged heat with the atmosphere. Regarding the ~~waters~~ water under the ice, the heat flux from the river water to the sea ice resulted in cooling of ~~the latter~~ these water to the ambient negative temperature, but, at the same time, the sea ice protected the freshwater layer from wind-induced mixing, so it conserved a pronounced ~~signal in salinity~~salinity signal.

3.2.4 Tracing surface water origin using oxygen isotopes (delta-O18)

The oxygen isotopes are considered as a "natural tracer of river runoff in the Arctic Ocean" (**?**) and are widely used to detect the origin of water masses (**?**, **?**, **?**). The most simple approach to detect a river water fraction in a water sample is to compute a ratio between the measured salinity and oxygen isotope 18 (delta-O18). As it was described in Data and Methods Section, we used only the first (surface) measurements in the upper 3 m layer.

Using a rather simple three-component model to distinguish the marine water, the river water (meteoric water), and the sea ice melt water described in **?**, we calculated the fractions of each water (Fig. 14). In the work of **?**, authors provide values of end-members of this model (typical salinity for each water mass and typical d-O18 concentrations), so after resolving a simple system of three linear equations using the values of the total (measured) salinity and the measured d-O18 concentration, we found a contribution of each fraction. As done in **?**, the role of precipitation is neglected in this model, as its amount is insignificant compared to the river water input. The sea ice melt fraction can be negative in case of sea ice formation.

3.2.5 Mean monthly observations.

This analysis indicates that the most important fraction of river water is brought over the shelf and the shelf edge of the East-Siberian Sea (Fig.14, a). At the same time, the water samples at the northern part of the 126°E section consist of 10-15 % of the river water and only of 0-5% of the sea ice melt fraction. Knowing that the main maximum of the river discharge occurs in June (Fig.3), this fact supports our hypothesis that a noticeable amount of river water was distributed under the ice far northward into the deep part of the Laptev Sea (north of 80.5°N), where it will enter the central Arctic Basin later. It is interesting that the areas with the highest sea ice melt fraction (Fig.14, c) (5-10%) follow the sea edge very slowly, so they were observed in the central and western part of the Laptev sea and in the MIZ area in the East-Siberian Sea. The sea ice formation (the negative values of sea ice melt fraction) is found in MIZ and its vicinity at 78-70°N - 150-150°E of the East-Siberian Sea. The presence of river waters may accelerate the sea ice formation if the air temperature favours it. The surface water samples of the western and central parts of the Laptev sea consist of large marine water fraction (90-95%). The lowest marine water fraction (75-80%) was found over a very shallow ice-free area between the New-Siberian islands and MIZ in the East-Siberian Sea, where both sea ice melt and river water fractions are relatively high (5-10% and 10-25% respectively). Actually, it is the area of the most intense surface mixing that was observed using in situ measurements during the ARKTIKA-2018 expedition.

3.3 Wind forcing.

In a previous study on this region (**?**) claimed that the surface fronts displacement is mainly governed by the wind and atmospheric pressure centers. To investigate it, we computed mean wind fields and the the role of the wind forcing at the synoptic scales, we compute mean monthly Ekman transport for August and September 2018 (Fig. 15). Horizontal transport was calculated for the first meter as: The calculation is described in the section 2.

$$u_{ekm} = \frac{\tau_v}{\rho_w * f}$$
$$v_{ekm} = -\frac{\tau_u}{\rho_w * f}$$

where u_{ekm} and v_{ekm} are horizontal components of the Ekman transport, τ is a wind stress, calculated from ASCAT winds (u_{wind}, v_{wind}) using ERA5 air density ρ_{air}: $\tau_u = C_D * (u_{wind}) * u_{wind} * \rho_{air}$; ρ_w is a surface density, calculated from The discussed displacement of the river plume extension in August and September are well seen in both SST and SSS with TEOS-2010; C_D is surface drag coefficient calculated from wind speed according to **?**, f is the Coriolis parameter.

Vertical Ekman speed (upwelling and downwelling)was computed as:

$$w_{ekm} = \frac{1}{\rho_w * f}\left(\frac{d\tau_v}{dx} - \frac{d\tau_u}{dy}\right) + \frac{\beta * \tau_u}{\rho_w * f^2}$$

where w_{ekm} is a vertical component of the Ekman transport and β is a beta-plane approximation of the Coriolis parameter.

The mean monthly fields (Fig.15 a, d and b, e, respectively). The most pronounced feature in the SST field is the drop of SST by 3°C in the central and southern part of the Laptev Sea. The salinification of the northern, central, and southwestern part is observed in August-September SSS fields. The average wind speeds ~~were~~ are low to moderate during ~~two discussed summer months~~August and September, 3-7 m/s ~~.~~ (Fig.15 c, f). The wind field in August ~~was~~ is more homogeneous and velocities are slightly higher with ~~general south-eastern~~ an overall south-easterly direction; the Ekman transport ~~pushed~~ pushes the river water out of the central part of the Laptev Sea favouring its propagation under the ice. A large area of convergence and downwelling is seen ~~eastward to~~ east of the Taimyr peninsula at 77°N 120°E. Almost the rest of the studied area is an upwelling zone, with large ~~values of~~ vertical velocity in the Vilkitskiy Strait and following the river front above the continental slope in the central part of the Laptev ~~sea~~Sea.

In September, the wind ~~changed~~ changes its main direction to ~~the south-western, which led to~~ south-westerly, which leads to a river water blocking in the Yanskiy bay, still favouring the freshwater flux propagation under the ice, but mostly into the southern part of the East-Siberian Sea. A large-scale divergence and upwelling ~~on the North-West of the Laptev sea~~ in the north-west Laptev Sea was observed as well. The Ekman vertical velocities in September ~~differed~~ differ from August. Several downwelling zones ~~were~~ are observed: in front of the Lena delta, close to MIZ ~~on the North-East~~in the north-east, and in the deep part of the central Laptev ~~sea~~Sea. The irregular pattern of the upwelling and downwelling facilitate the mixing of different water masses, which is more active, thus, in September.

4 ~~Observed water masses of the Laptev sea~~

~~To generalise our understanding of vertical structure of the studied area, we used the classical TS-analysis, first based on CTD measurements only. Fig. 7 shows the temperature-salinity distributions in the upper 200 m, where the color of marker indicates depth. The most prominent feature on the diagram is the transformed Atlantic water mass with salinity close to 34.5-35 PSS, temperatures from -0.5 to 2.5 °C laying at a depth of 100-200 m. The water mass overlaying the Atlantic water (between 50 and 100 m depth) is the lower halocline water, described by **?** as having salinity in a range 33-34.5 PSS, and negative temperatures starting from the lowest values presented on Fig. 7, -1.7 to 2.5°C. The surface water observed in the upper 50 meters is in general the less saline (below 34 PSS), but one can clearly observe two separate branches with negative and positive temperatures. It should be remembered that TS-diagram based only on CTD measurements does not provide an instantaneous view on the ocean state, but is a collection of sea states in different regions at different moments of time (from the end of August to the end of September 2018). During summer months, the Arctic ocean waters quickly change their characteristics, and satellite data provide additional information to the pointwise in situ measurements.~~

~~TS diagram based on the CTD data in the upper 200 m~~

~~Using~~

4 Discussion and conclusion

Based on in situ and satellite measurements, we document the evolution of the water masses during August and September in the Laptev and the East-Siberian Seas. The cross-validation of satellite DMI SST and SMOS SSS ~~weekly estimates , we plotted~~

T-S diagrams similar to that on on Fig.7, but for several reference days: Aug 1, Aug 15, Aug 30, Sept 4, Sept 13, and Sept 30, 2018 (Fig.8). On the lower row, we present all in situ measurements in the upper 6.5 m and the differences between satellite derived temperature and salinity of discussed days. It is clearly seen that the SST is growing only up to the end of August with the maximum temperatures from 8 to 11.5°C for some case, and then decreases to 4.5 °C by the end of September. The temperature is changing by 0.5 - 1 degree per week (while increasing and decreasing).

Based on the Fig. 8 visual analysis, we propose to identify 6 surface water masses "A" estimates is done with rare in this region continuous TSG measurements and CTD data. For the first time, we follow how the river water input is distributed and where it is stored in the Laptev and the East-Siberian seas (Tab. 1). The ”classical” water masses are warm and fresh river waters (“1”)and cold and saline open sea waters (“6”). All other water masses shows different stages of transformation of these two, either water masses advected from other regions. It should be noted that Sea at synoptic scale. It became possible thanks to new satellite-derived data have a larger range than surface salinity field (SMOS SSS "A"), a vast range of in situ measurements , which makes this detailed classification possible. Positions of defined water massesfor selected days are shown on Fig.9 together with the distribution of water masses in percentage (the whole studied area is 100% and sea ice occupies some part). and also results of geochemical analysis.

On August 1, the sea ice covers yet more than 80% of the studied area and extends in average to 78N in the Laptev sea, while the East-Siberian Sea is covered almost completely. Warm and To investigate local surface water masses, a variation of a classical TS analysis is studied using satellite measurements. It helped to define new surface water masses adapted for the Eastern Arctic Ocean with typically low salinity and discuss their transformation. As the validity of SMOS SSS was demonstrated successfully and SMOS measurements are accessible from 2010 to the present, this technique could be applied for the future studies of surface water transformation at different time scales.

The transformation of fresh river water ("1") is well observable on the South up between 74 and 76N. It occupies almost the same amount of surface as cold and saline sea water ("6"), the rest of the open area is a transformed river water (”2”, ”4”), that forms already a recognisable river front: its signature is continuous from 115E to 150E up to the northern position of sea edge. In two weeksthe ice cover retreats, and a fresh and cold water ("3") mass appear on the south-west of the East-Siberian sea. The amount of this waters will increase progressively in this area during the rest period. We suggest that this water mass represents the river waters captured under the ice and then exposed back.On the 15th of August, one can notice as well a water mass "4" appearing close to Vilkitskiy Strait. It is less pronounced in the end of August, but a thin stream of cooled and transformed river waters from the Kara sea descends along the Taimyr peninsula in input occurs and diminishes very quickly during the Arctic summer, of the order of 1-2 weeks. Our observations suggest that the vertical mixing, a weaker river discharge, and a continuously decreasing radiative income impact the variability of surface water characteristics, which is particularly seen in the beginning of September. The Lena river waters mixing and cooling happens as well close to the sea ice edge on the north-east of the Kara sea. All in all, the surface occupied by this water mass is steadily growing during the observed period, and is around 10% by the end of September. One can imagine that water mass "4" is a transformed version of water mass "3".

The end on Augustis the warmest, it is seen at Fig. 9 with the amount of saline waters with temperatures above 3°C (water mass "5") occupying the central and the western part of the Laptev sea (almost 10% of the studied area). This water mass is disappearing by the end of September with a decrease of temperature. By September13, the SST and SSS variability slow down. The water mass "3" on the north-east second yearly maximum of river discharge occurs in the beginning of August. The warm and fresh river water is redistributed and transformed in the surface layer of the Laptev Sea during the month of August, but after the passage of several cyclones in the beginning of September, there is no additional important source of heat and fresh water that would maintain the variability of water masses. Globally, in September, the water mass CS progressively occupies the ice-free surface of the Laptev sea consisting of cold fresh water becomes saltier (transforms into the water mass "4") . The fresh water cools on the south to the New Siberian island and by September 25 occupies all the area free of ice. The river plumes signature is shifted to instead of other (“transformed”) water masses observed there in August. The ice formation is to start in the end of September and will be finished by November, so it seems that freezing will begin only after the heat accumulated during the summer season is released to the New Siberian island as well (Fig. 9). Saline and cold water mainly dominates the surface of the Laptev Sea. Finally, by September 25, atmosphere and the T-S diagram shows that most of the points lay between 25 and 35 PSS and -1°C and 4°C, with a main core within a range 25-35 PSS and -1 - 1C. The Laptev and the East-Siberian seas start to refreeze, the most rapidly in the area with cold and fresh river waters. water temperature at the surface drops to the freezing point.

Surface water masses Water mass 1 2 3 4 5 6T $> 3C > 3C < 3C < 3C > 3C < 3C$S $< 25PSS$ $25 - 29PSS$ $< 25PSS$ $25 - 29PSS$ $> 29PSS$ $> 29PSS$

Temporal evolution of surface water masses in August-September 2018 for the following reference days (upper row): Aug 1, Aug 15, Aug 30, Sept 4, Sept 13, and Sept 30, 2018. Color represents the density of points (number of observations with this temperature and salinity). Lower row: T-S diagram based on CTD measurements in the upper 6.5 m only, and the differences (in density points) between the reference days.

Water masses spatial distribution in August-September 2018: upper row - Aug 1, Aug 15, Aug 30; lower row - Sept 4, Sept 13, Sept 30. Sea ice cover from AMSR2 is plotted as dashed area.

In this work, we discussed the water masses evolution in the summertime in the Laptev and the East-Siberian seas. The cross-validation of satellite-derived SST L4 distributed by DMI was done with continuous TSG measurements. For the first time the capacity of SMOS to follow a temporal evolution of the Lena river plume in the Laptev sea under influence of atmospheric forcing was demonstrated. A pathway of the low salinity Kara waters was water is observed during several days of the studied period. Kara waters propagated study. The Kara water propagates mostly through the Vilkitskiy Strait and partly through the Shokalskiy Strait, but no freshwater was is found northward of the Severnaya Zemlya Archipelago. Pursuing Propagating along the coastline, this low salinity water arrives into the low-salinity Kara water enters the Oleneksiy bay where it meets another freshwater flux from the Lena and Khatanga rivers.The Khatanga and the Lena rivers. The arrival of freshwater via the Vilkitsiy Strait was already studied using in situ data by **?**, **?**, this is the first time this event has been observed from satellite data which provide a unique regular monitoring. The freshwater input from the glaciers and icebergs of the Severnaya Zemlya Archipelago should probably also be taken into account, but this is out of scope of this study, and we assume this source of freshwater as negligible compared to the very fresh Kara Sea water.

The wind situation in August was favorable for the extreme propagation of river ~~waters into the central and the~~ water into the north-eastern part of the Laptev ~~sea~~ Sea with following penetration into the East-Siberian ~~sea~~ Sea in MIZ and under the sea ice. The ~~fresh waters displacement should be associated with the Ekman transport. We claim as well~~ propagation of river water under the sea ice is apparent in the western part of the East-Siberian Sea, where two branches with warm and fresh cores were observed with in situ data.

The Ekman transport illustrate a possible forcing for the freshwater displacement. As the theoretical Ekman depth is controlled only by the Coriolis parameter f, in the south of the Laptev and the East-Siberian Seas it exceeds the depth of some shallowest areas (see the position of 37-m isobath in Fig.15). Thus, the calculated Ekman transport should be regarded as a theoretical concept illustrating possible mechanisms of horizontal transport and vertical mixing in the central and northern areas. A new sea level dataset provided by DTU for the Arctic Ocean and calculated geostrophic currents, discussed in the Appendix, enriches the overview of the surface ocean dynamics during selected summer months.

On a larger scale, this situation can be also explained by a positive (in April-October 2018) Arctic Oscillation index favoring the eastward propagation of fresh water, as it was demonstrated in works of **?**, **?**, **?**. An important part of the northward propagation to the shelf edge is not explained by the positive AO. Based on the oxygen isotopes results, we claim that a similar propagation of river ~~waters far to the North~~ water far northward happened before the observed period (in June-July), when the Laptev ~~sea~~ Sea was still covered with ice and the Lena ~~river discharge was supposed to be the maximum (following the results of **?**). On~~ River discharge was the largest (Fig.3). In the north of the 126°E section, under the ice, the upper 25-m layer is ~~freshen to~~ fresher with a salinity below 33~~PSS~~, which supports this hypothesis~~; and there~~. There is no evidence that the sea ice melting itself can create such a considerable layer of freshwater. Our isotopes estimates could be refined using alkalinity to separate the meteoric water estimated with water isotopic analysis (river input from precipitation).

A study of **?** ~~defend the hypothesis of river waters, as~~ also supports the influence of river water, as a similar situation was observed in 2011. Unfortunately, the present spatial resolution of satellite-derived SSS and its uncertainty due to the ice proximity ~~make~~ makes it difficult to separate river water from the freshening associated with the sea ice melting~~from river waters. No direct measurements~~. No accurate satellite measurement of sea ice thickness ~~were carried out in this region at this moment of time neither~~in MIZ exists at present to the best of our knowledge, so it is complicated to evaluate the freshwater input due to the sea ice melting ~~only. The propagation of river waters under the sea ice is apparent in the western part of~~ on the scale of several months. Nevertheless, the ~~East-Siberian sea, where two brunches with warm and fresh cores were observed with in situ data. In September, we illustrated the processes of rapid autumn cooling of the surface waters in the Laptev sea associated with a series pf atmospheric depressions. Calculated monthly Ekman pumping indicates the area of most intense mixing processes. A new sea level dataset provided by DTU for the Arctic ocean and calculated geostrophic currents, discussed in the Appendix, enriches the overview of the surface ocean dynamics during selected summer months.To generalise the evolution of surface water masses, a variation of a classical TS analysis was proposed using satellite measurements. It helped to define new surface water masses adapted for the Arctic ocean with typically low salinity . As the validity of SMOS SSS was demonstrated successfully and SMOS measurements are accessible from 2010 to the present moment, this technique can be applied for further interannual analysis of surface water transformation~~existing satellite data already have a great potential for the Arctic studies of fresh water. To improve our evaluation of the freshwater budget in the Arctic Ocean, we suggest that appropriate numerical models assimilate the estimates of river discharge, new satellite-derived sea surface salinity and wind data.

Appendix A: Altimetry and geostrophic currents

Two monthly fields of absolute dynamic topography (ADT) and geostrophic currents were calculated from sea level anomalies (SLA) Arctic L4 product and mean dynamic topography (MDT) provided by Danish technological University (Fig. A1). Sea level anomalies are available as mean monthly values on ~~an~~ a grid adapted to polar regions ~~grid~~ with 0.25°step for latitudes, and 0.5°step for longitudes. Mean dynamic topography global one-minute model was used to compute ADT. The resulting monthly absolute dynamic topography ($ADT = MDT + SLA$) was calculated for selected summer months.

Overall, the ADT ~~follows remarkably~~ remarkably follows the ocean bottom topography with higher SLA over the shelf and lower SLA over the deep part of the studied area, which corresponds to the study of **?**. The only exception is negative SLA in the Olenekskiy bay in August 2018. We suggest that the general northward wind-induced displacement of the ~~waters~~ water over the very shallow southern part of the sea was compensated only by the river ~~waters~~ water inflow to the east of 122°E, close to the Lena ~~river~~ River delta. Positive SLA were more pronounced in September than in August, though in August the SST was higher over the southern and central part of the Laptev ~~sea~~Sea, and the salinity was lower in the Olenekskiy bay. The importance of sterical component in variation of the sea level in August-September is ~~, thus , doubtable,~~ thus doubtful, though several source of uncertainty can impact the quality of provided SLA data: uncertainty in tidal model, bathymetry precision, accuracy of the MDT over the shallow part of the Laptev ~~sea, etc~~Sea, etc, as **?** noticed in his work. It should be noted that SSH of the Laptev and the East-Siberian Seas presented in the work of **?**, had the lowest correlation with in situ gauge measurements in the Arctic Ocean, because of the "seasonal runoff".

The geostrophic currents were calculated following classical formula: $u_g = \frac{-g}{f}\frac{dh}{dy}$, $v_g = \frac{g}{f}\frac{dh}{dx}$, where h is ADT, x and y are the distance in ~~meters~~metres. Geostrophic currents presented ~~on~~ in Fig.A1 are very weak and demonstrate rather chaotic structures during selected months. Among the well-pronounced features, an outflow from the Laptev ~~sea~~ Sea in the Vilkitskiy ~~strait~~ Strait is noticeable. Above the continental slope edge, the principal direction of currents is ~~the eastern~~ westward with a maximum current speed of 0.5 m/s. ~~On~~ In the south, an outflow at 122 °E and 130°E ~~helps to bring the Lena waters~~ contributes to transport the Lena River Water into the central part of the Laptev ~~sea~~Sea. In the Yanskiy bay a vortex-like system exists in both ~~,~~ August and September 2018. Geostrophic currents in the East-Siberian ~~sea~~ Sea were calculated from the altimetric measurements in MIZ, so should be interpreted with care. ~~A~~ **?** precised that the SSH measurements there cannot reflect the mesoscale phenomena, because of the small Rossbi radius (of order 1 km) and the altimeter along-track resolution of 300 m. At the same time, at the shallowest areas the highest eddy kinetic energy was reported in the same study.
From our calculations, a cyclonic feature of 150 km in diameter is seen at 79°N, 157°E, and might be topographically induced, as well as a similar cyclonic feature at 78.5°N 135°E. An extended study should be carried out to validate the accuracy of altimetry-derived currents in this region with mooring or vessel mounted ADCP measurements.

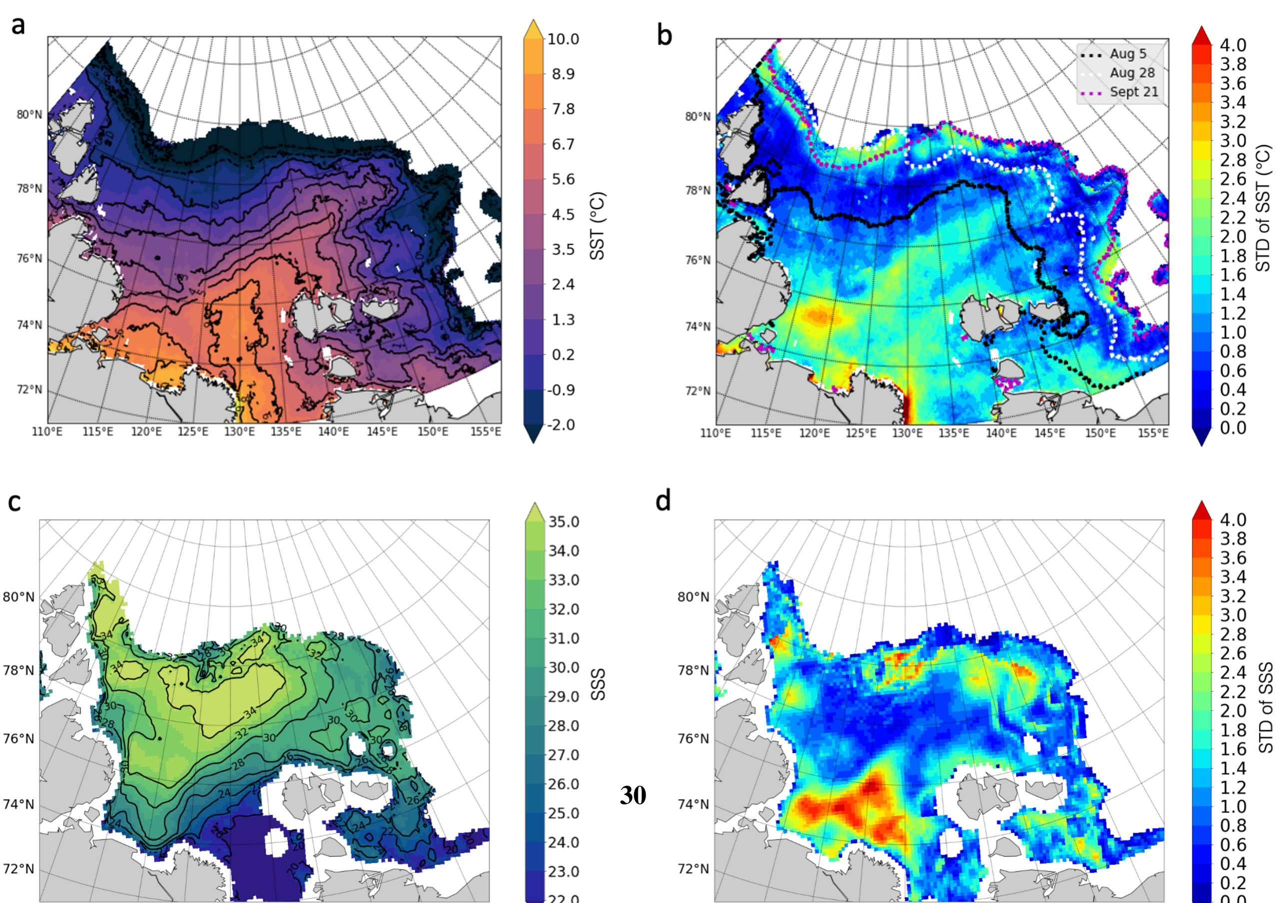
Competing interests. No competing interests are present

Acknowledgements. We thank Jean-Luc Vergely for fruitful discussions about SMOS SSS data filtering in the Arctic ocean. We thank for the discussion on the oxygen isotopes. We thank Mattew Alkire, Andrey Novikhin, Natalia Vyazigina, all hydrochemistry team of the ARKTIKA-2018 expedition and Ekaterina Chernyavskaya for the collection of water samples for the oxygen isotopes analysis, their analysis and further discussion. We thank all the scientific team of the ARKTIKA-2018 expedition and the crew of RV Akademic Tryoshnikov for their work. This study was supported by the French CNES-TOSCA SMOS-OCEAN project. Anastasiia Tarasenko, Vladimir Ivanov and Nikita Kusse-Tiuz ~~acknowledges~~ acknowledge financial support from the Ministry of Science and Higher Education of the Russian Federation, project RFMEFI61617X0076.

Sea surface temperature validation: example of DMI SST L4 image for September 13 (upper left) with the provided error estimates (upper right); comparison of collocated SST and in situ data in the upper 6.5 m (lower left) and distribution of error provided by DMI and absolute difference measured from comparison with in situ data (lower right)

3.1.1 Salinity

In this section, we compare SMOS SSS relative to in situ measurements. Figure 5 presents the SMOS SSS. We carry a collocation of SSS and in situ measurements of salinity in the upper 6.5 m layer, similar to that one for the temperature described above, except that the averaging of the TSG salinity was done over one hour period (equal to ~ 15 km distance) in order to be closer to SMOS resolution. Comparison between SMOS retrieved error and error based on comparison with cruise salinity measurements is presented on Fig. 5. It shows a good agreement between distribution of SMOS SSS weekly error estimated from retrieval process and distribution of error obtained from comparison with Akademik Tryoshnikov salinity measurements. This results allow us to use SMOS error with a higher confidence in our further analysis. Take into account the SMOS error makes possible to increase the quality of the comparison between the SMOS SSS and the vessel SSS. Using error filtering points too close to the ice edge are excluded. We used 985 collocated points. Comparison between the in situ salinity and SMOS post-processed SSS shows a very good agreement, not yet demonstrated before by any other salinity product in the Laptev sea. The correlation coefficient is 0.86 with a RMS = 0.86 PSS. The bias is 2.06 PSS. For the further analysis we subtracted this bias from the entire SMOS SSS dataset. Standard deviation of SMOS SSS with respect to in situ SSS do not depend on the depth of in situ salinity measurements above 6.5 m, either because in situ salinity is homogeneous vertically or because comparisons are too noisy to detect this small variations (not shown). Although SMOS shows a good agreement most of the time, some larger error can occur close to the ice margin or when pixels are contaminated by small ice pattern that are not detected by AMSR2 sea ice concentration (as observe at 125E and 80N on 5 top, left).



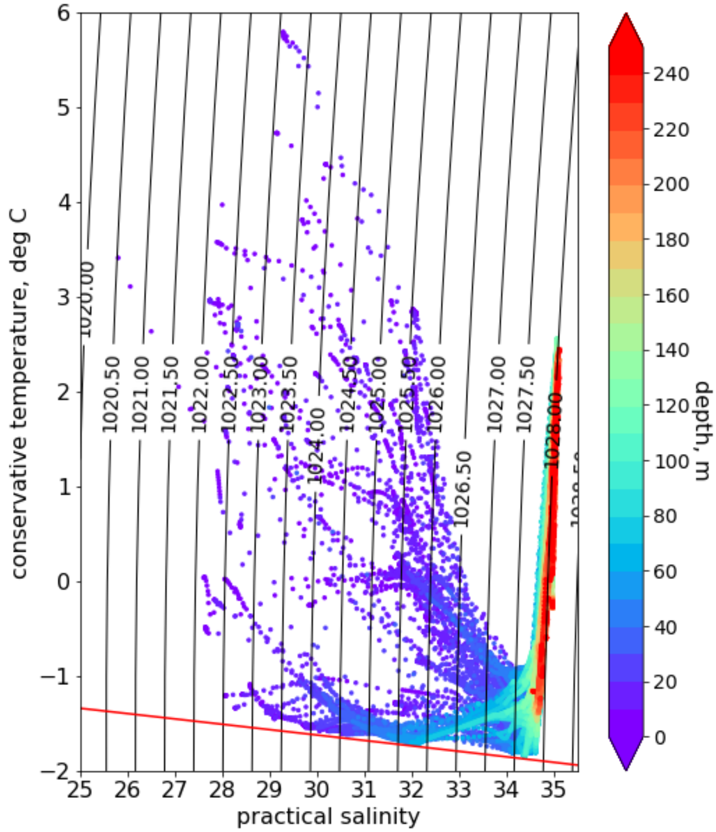


Figure 7. Mean DMI SST (T-S diagram based on the CTD data in the upper row) and SMOS SSS (lower row) 250 m. Depth of each measurement is shown with their standard deviation for August-September 2018color. Red line shows the freezing point.

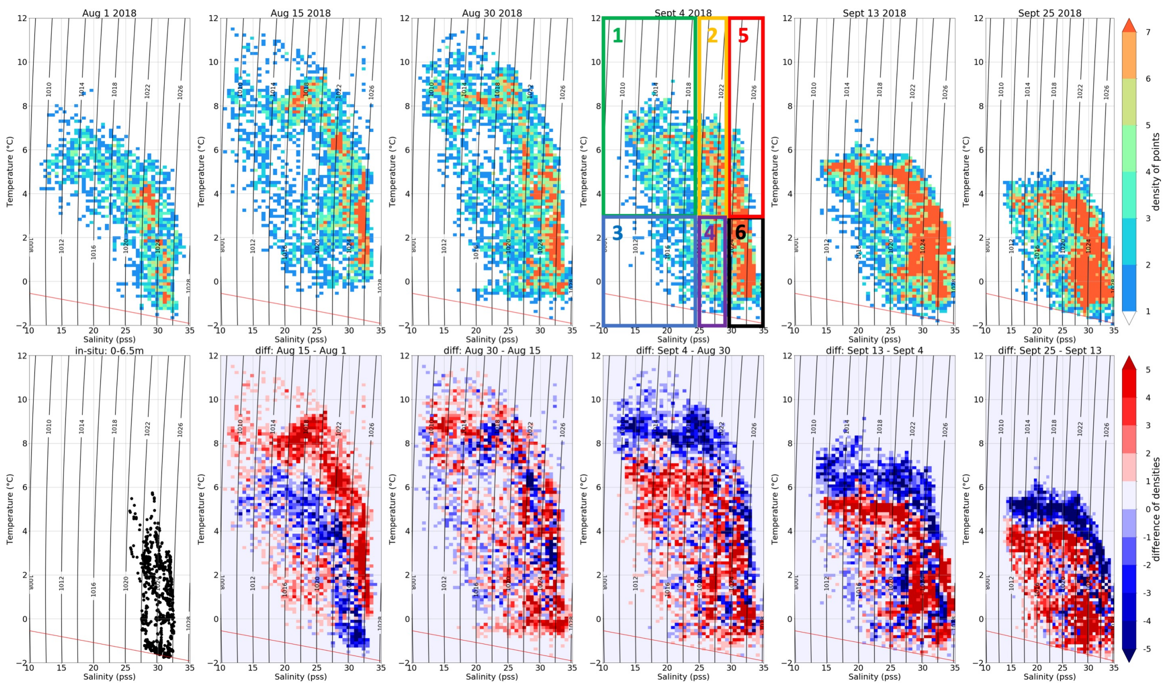


Figure 8. Temporal evolution of surface water masses in August-September 2018 for the following reference days (upper row): Aug 1, Aug 15, Aug 30, Sept 4, Sept 13, and Sept 30, 2018. Color represents the density of points (number of observations with this temperature and salinity). The boxes show the cores of 6 water masses described in text: 1 - WF, 2 - WMS, 3 - CF, 4 - CMS, 5 - WS, 6 - CS. Red line shows the freezing point. Lower row: T-S diagram based on CTD measurements in the upper 6.5 m only, and the differences (in density points) between the reference days.

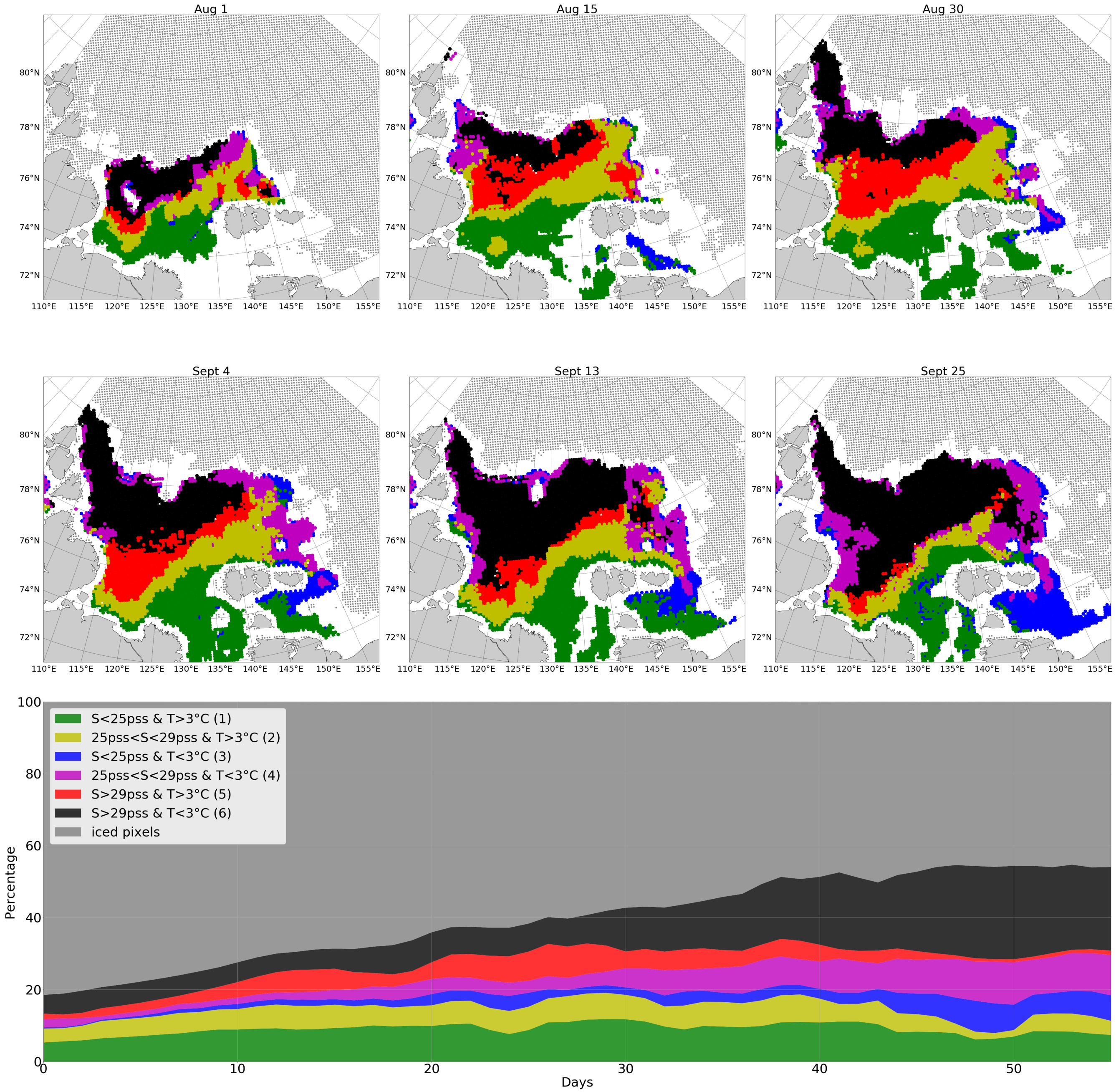


Figure 9. Spatial distribution of surface water masses in August-September 2018: upper row - Aug 1, Aug 15, Aug 30; lower row - Sept 4, Sept 13, Sept 30. Sea ice cover from AMSR2 is plotted as dashed area. The lowest panel show temporal evolution of surfaces occupied by each water mass or sea ice cover in the Laptev Sea (in % of the Laptev Sea surface).

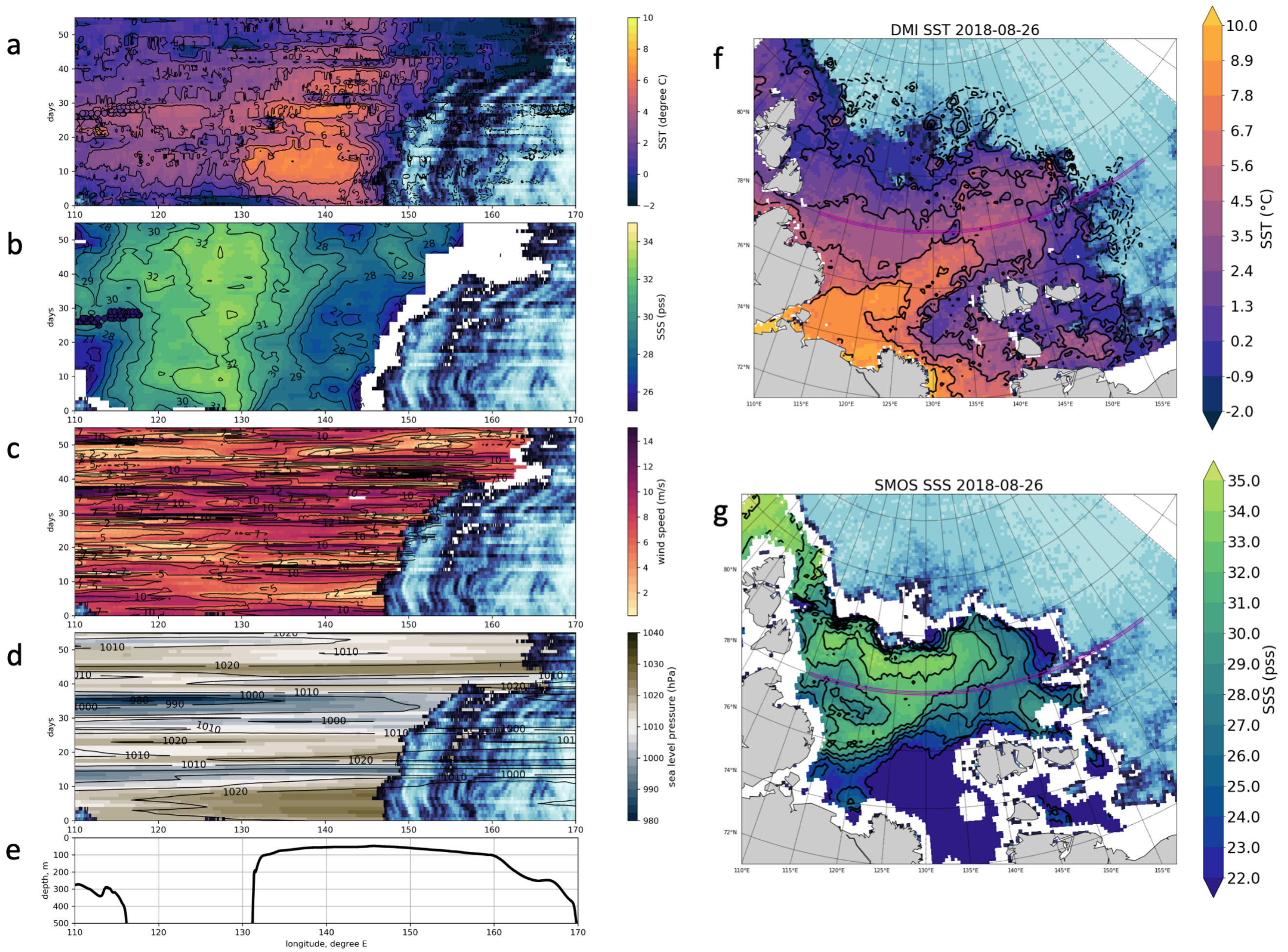


Figure 10. Hovmöller diagram of DMI SST (a), SMOS SSS "A" (b), ASCAT wind speed (c), and ERA5 sea level pressure (d) for the zonal transect at 78°N. Small circles at SST and SSS diagrams show in situ measurements of temperature and salinity (first CTD or TSG at 6.5 m). Sea ice concentration (AMSR2) is indicated with a blue color, see Fig.5 for the color scale. The bathymetry along the virtual transect (e) is extracted from "1 Arc-Minute Global Relief Model" (?). The position of a virtual transect is shown at SST SMI and SMOS SSS "A" maps for August 26, 2018 (f, g).

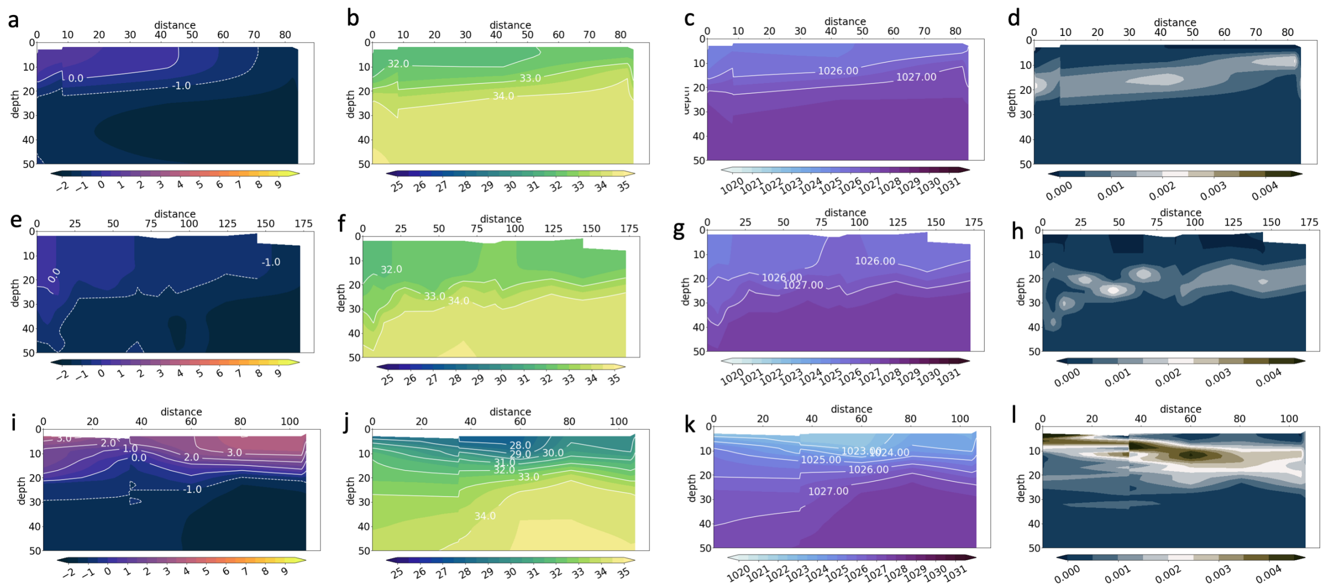


Figure 11. Temperature, °C, (left, first column), salinity, (second column), water density, kg/m^3 (third column) and buoyancy frequency, s^{-1}, (right, forth column) obtained from CTD measurements in the upper 50 m for section 1 northward of Arkticheskiy Cape (upper row), section 10 across the Shokalskiy Strait (second row), and section 4 across the Vilkitskiy Strait (lower row). See Fig.1 for the section's positions. The zero km is always placed at the southern point of each section

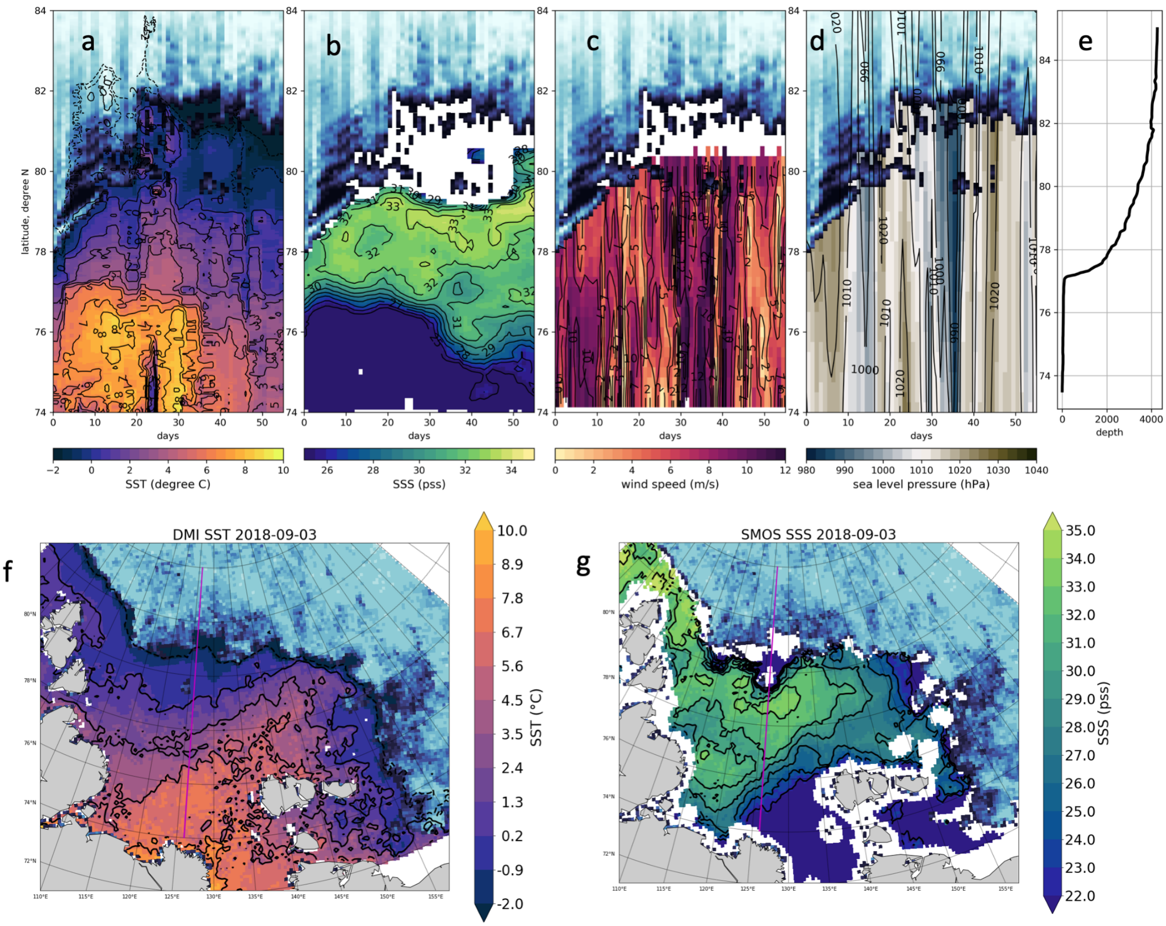


Figure 12. ~~Temperature, °C,~~ Hovmöller diagram of DMI SST (~~left, first column~~a), ~~salinity, PSS,~~ SMOS SSS "A" (~~second column~~b), ~~water density, kg/m^3~~ ASCAT wind speed (~~third column~~c) and ~~buoyancy frequency, $1/s$,~~ ERA5 SLP (~~right, forth column~~d) ~~obtained from CTD measurements in the upper 50 m~~ for ~~section 1 northward of Arkticheskiy Cape (upper row), section 10 across~~ the ~~Shokalskiy Strait~~ virtual meridional transect at 126°E. Sea ice concentration (~~second row~~AMSR2) is indicated with a blue color, ~~and section 4 across the Vilkitskiy Strait (lower row). See~~ see Fig.~~1~~ 5 for the ~~section's positions~~color scale. The ~~zero km is always placed at~~ bathymetry along the ~~southern point~~ transect (e) is extracted from "1 Arc-Minute Global Relief Model" (?. The position of ~~each section~~a virtual transect is shown on SST SMI and SMOS SSS "A" maps for August 26, 2018 (f, g).

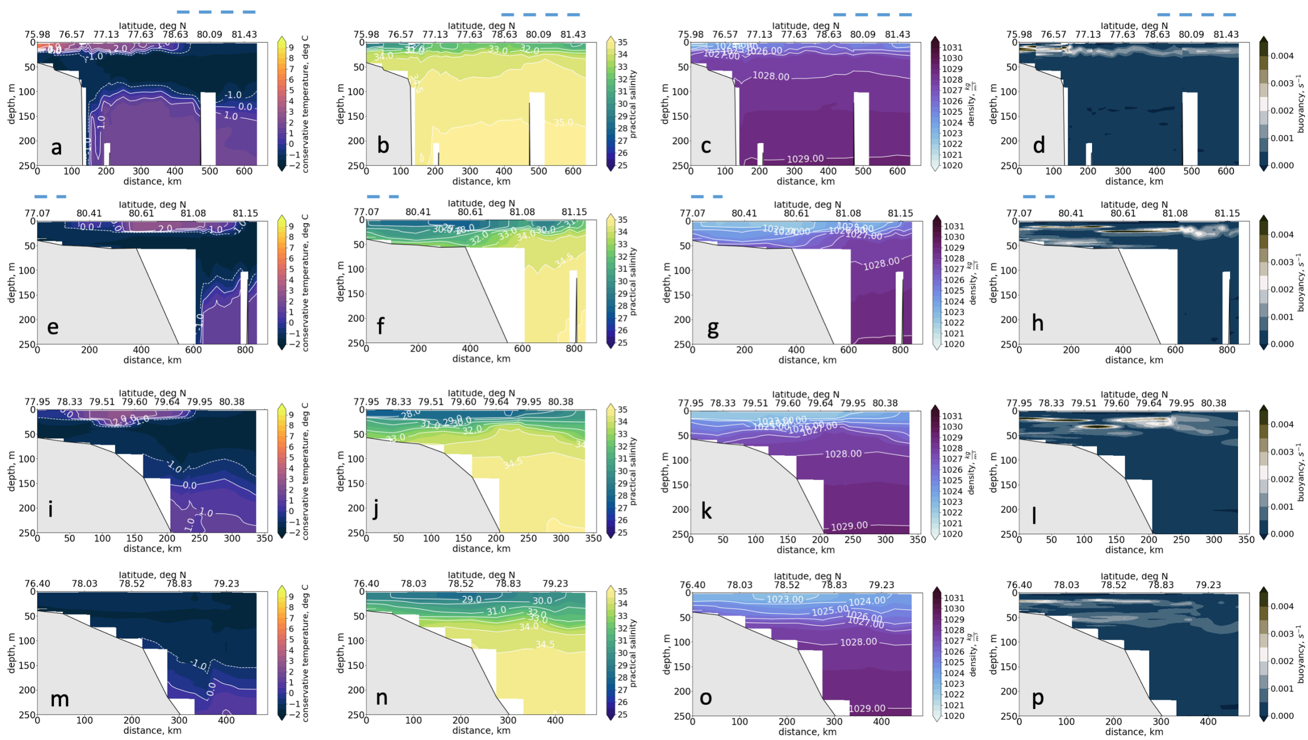


Figure 13. ~~Hovmöller diagram of SST~~Conservative temperature (left, ~~SSS~~first column), practical salinity (second column), density (third column) and ~~wind speed~~ Brünt-Vaisälä frequency (right, last column) in the upper 250 m along oceanographic section 5 (a-d); section 6 (e-h); section 8 (i-l); and section 7 (m-p). See Fig.1 for the ~~meridional transect at 126E~~section positions. ~~Sea ice concentration~~ The zero km is ~~indicated with~~ always placed at the southern point of each section. The dashed blue ~~color, see Fig~~line indicates the MIZ for sections 5 and 6 (the rest is ice-free area); the section 7 and 8 were done under the ice in MIZ.~~5~~

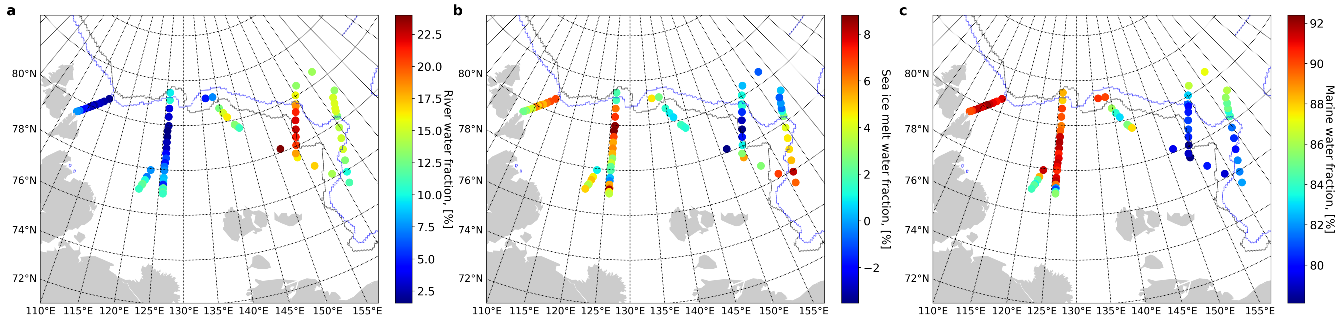


Figure 14. ~~Conservative temperature~~ Fractions of river water (~~left, first column~~a), ~~absolute salinity~~ sea ice melt water (~~second column~~b) ~~,~~ ~~density~~ and marine water (~~third column~~c), calculated using d-O18 measurements and ~~Brünt-Väisälä frequency (right~~? 3-components model of freshwater balance. A thin black line shows the position of sea ice edge on August 31, ~~last column) in~~ 2018, when the ~~upper 250 m along oceanographic section 5~~ northern stations of the meridional (~~upper row~~5) ~~;~~ section ~~6 (second row); section 8 (third row);~~ along 126°E were done in the MIZ, and ~~section 7 (lower row). See Fig.1 for~~ the ~~section positions (~~blue line shows the ~~zero km is always placed at~~ sea ice edge on September 16, 2020, when the ~~southern point~~ ARKTIKA-2018 expedition was working in the MIZ of the East-Siberian Sea. Please, note that the colorbar scale is different for each ~~section)~~water fraction.

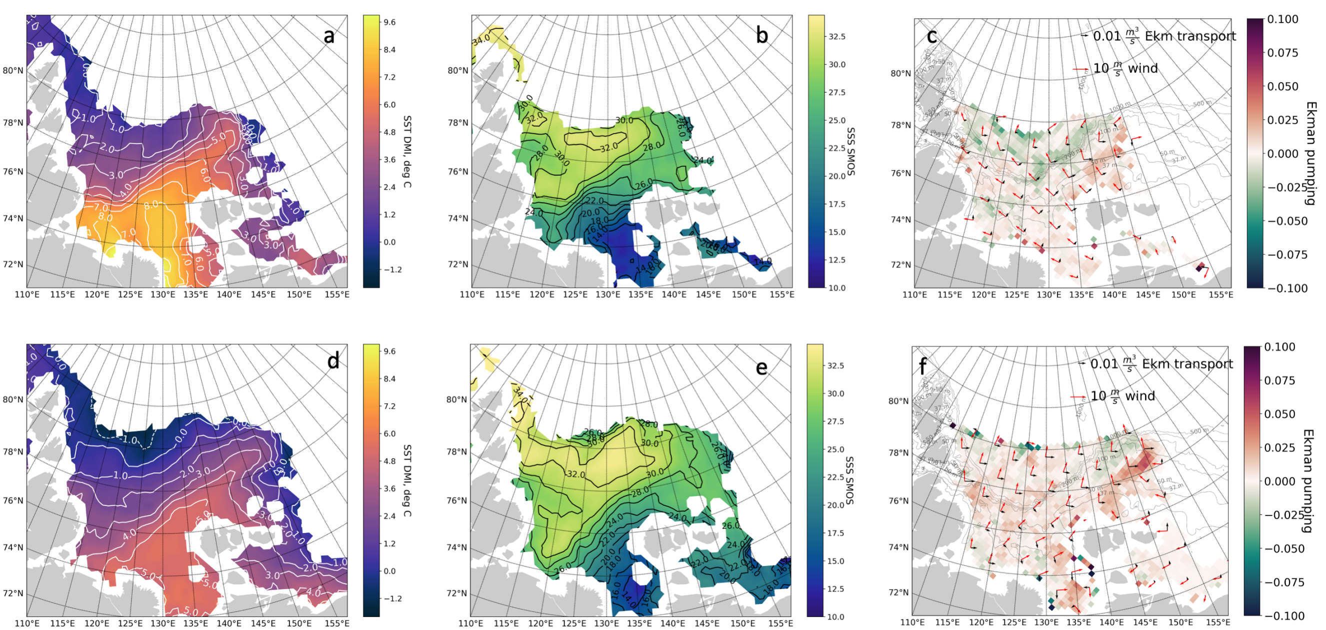


Figure 15. Mean monthly averages for August (upper row) and September (lower row): (a, d) SST, (b, e) SSS, (c, f) wind speed and direction~~;~~ ~~(d-e)~~ , horizontal and vertical Ekman transport

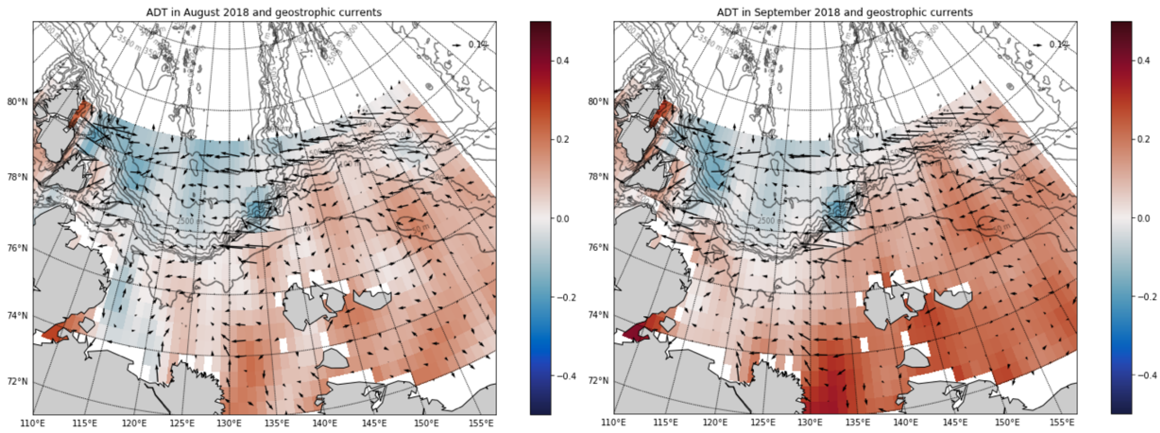


Figure A1. Absolute dynamic topography, cm and geostrophic currents, cm/s, in August and September 2018, calculated from DTU monthly Sea Level anomaly