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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.

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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 issues that made me tick the "major" box here. My "major" science concern is the contribution from sea-ice melt. I think you

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need to do a somewhat better job at addressing this possible contribution. It is difficult, but it can potentially explain much of the freshwater available. If delta-18 O samples were available, one could differ between these two 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?

Answer:

Thank you very much for your recommendations! We discuss the delta-O18point below. We reorganised the paper and moved a part of the “Results” section to the “Data” section, as it was suggested by the reviewer 2. We also added some information and citations to the Introduction part, and tried to separate the Discussion from the Conclusion, to bring forward the main message of the paper (yes, in our opinion, the river waters were driven northwards by the winds). The CTD cast at the most northern point of 126°E section was done at the beginning of September, so we suggest that the wind conditions in August resulted in this arrival of river water to the north of the Laptev Sea).

I also have a general suggestion: Provide the spatial mean vertical profile down to 100 m 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.

Answer:

Below, we provide the two requestions profiles (temperature and salinity; the shaded area represents the median +/- STD values). As you can see, the “mean stratification” is not really representative for the Laptev and East-Siberian Seas, because the physical characteristics of the upper-layer water masses vary a lot at the end of the summer season. Additionally, we did a lot of measurements in very shallow areas where the depths were between 30 and 50 m, so the calculated mean (or median) vertical profile is a composite of "shallow" and "deep" vertical profiles. Finally, we have only 45 measurements at 2 m depth, and most of the vertical profiles (141) start at 5 m depth (Fig.2). The vertical profiles from th point-measurements (CTD stations) are very useful, but cannot be used to discuss the temporal changes from these CTD profiles, as stations were not repeated. We presented the spatial and temporal changes using satellite (surface) data, as they had better coverage, both in time and space Nevertheless, we added these figures to the manuscript along with a figure with our calculations of MLD for each profile (Fig.1), please, see an answer to the RC2 and the revised manuscript for further details.

The full caption of Figure 1: (Left column)Vertical profiles of conservative temperature (a) and 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 (see details in the text). Colored profiles show the cases when the MLD is deeper than 7 m and gray profiles indicate when the MLD is shallower than 7 m. (Right column) : Vertical profiles of median conservative temperature (a) and practical salinity (b) with their STD (calculated for 146 CTD stations in both shallow and deep areas).

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 abstract. Is this all wind-driven?

Answer:

We suggest thatat this mainly is wind-driven. The abstract was corrected to: "... The surface gradients and mixing of river and sea water in the ice free and ice covered areas were described with a special attention to the marginal ice zone. The Ekman transport was calculated to better understand the pathway of surface water displacement. We suggest that the fresh water was pushed northward, close to the MIZ and under the sea ice, which was confirmed by the oxygen isotope analysis. T-S diagrams using surface satellite estimates were used to investigate the transformation of the surface water masses at synoptic scales and reveal the presence of river waters on the shelf of the East-Siberian Sea."

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

Answer: Corrected

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

Answer: Corrected to "SST DMI and SSS SMOS"

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???

Answer: Yes, corrected to "the number of measurements is low due to the presence of the coast and islands even without the sea ice".

Page 10 and other places. Is it ok to use PSS as salinity unit? Should it not be absolute salinity, or unit less?

Answer: Corrected to unitless for salinity, as all reviewers advised

Figure 5: Please provide the section in a map.

Answer: Added the maps to the figures 5 and 7 with section positions

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 should be in the method section.

Answer: Corrected

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. . ..)

Answer: Corrected, thank you for your suggestion!

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?

Answer: " By September 13, the SST and SSS variability slows down." We can hypothesize that the vertical mixing, a weaker river discharge (Fig. 3), and a continuously decreasing radiative income (Fig. 4) impact the variability of surface water characteristics. The second yearly maximum of river discharge occurs at 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 several cyclones at the beginning of September, there is no additional important source of heat and fresh water that would maintain the variability of water masses. Over all, in September, the water mass CS (ex 6) progressively occupy the ice-free surface of the Laptev sea instead of other ("transformed") water masses observed there in August. The ice formation starts at the end of September but is achieved only by November, so it seems that freezing will begin only after the heat accumulated during the summer season is released to the atmosphere and the water temperature at the surface drops to the freezing point (Fig.5).

The full caption for Fig. 5: "Ice chart for the Arctic Ocean for September 3 - September 11, 2018. Colors indicate total sea ice concentration according to the analysis done at AARI (Sept 11), Canadian Ice Service (Sept 3), National Slow and Ice Data Center (Sept 6). Colored lines show the occurrence of sea ice edge for September 11-15 over the period 1979-2012 with SSMR-SSM/I-SSMIS data (NASATEAM algorithm). From http://wdc.aari.ru/datasets/d0042/2018/aari_20180903-20180911.pdf"

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.

Answer:

Yes, there is. We added a section on the use of the delta18 oxygen isotopic data to the Results and Discussion. Using a three-component simple model (marine water / river water (meteoric water) / sea ice melt water) described in Bauch and Chernyavskaya, 2018 and the isotopic analysis from surface water samples, we calculated the fractions of each source (Fig. 6). The isotopic analysis revealed that the most important fraction of river waters was brought 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.

The full caption for the Figure 6: 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 126 E 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

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.

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. This 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 very quickly during the Arctic summer and disappears as well on the order of 1-2 weeks. Some part of the fresh water was clearly mixed over the shelf of the Laptev Sea under the wind-driven mixing, but a very important part was brought 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 Morison 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.

Please, see a new version of Discussion and conclusions.

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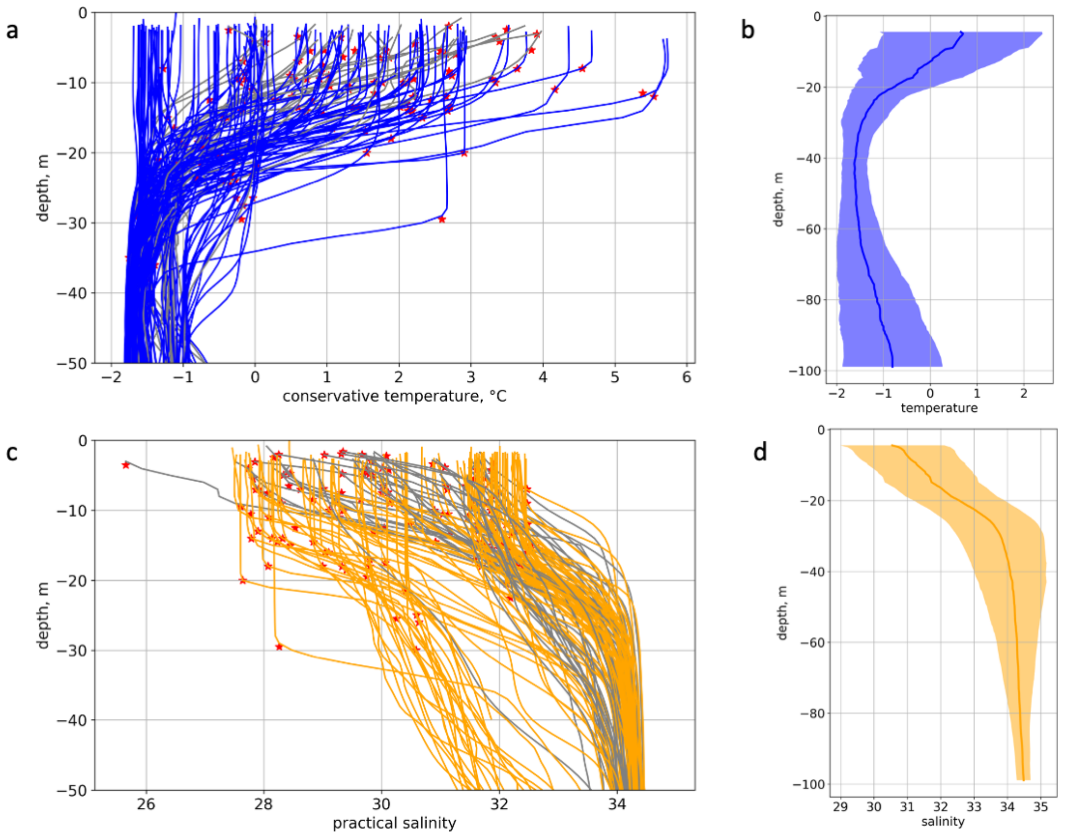

Fig. 1. Vertical profiles of median conservative temperature (a) and practical salinity (b) with their STD (calculated for 146 CTD stations in both shallow and deep areas), and T and S with calculated MLD

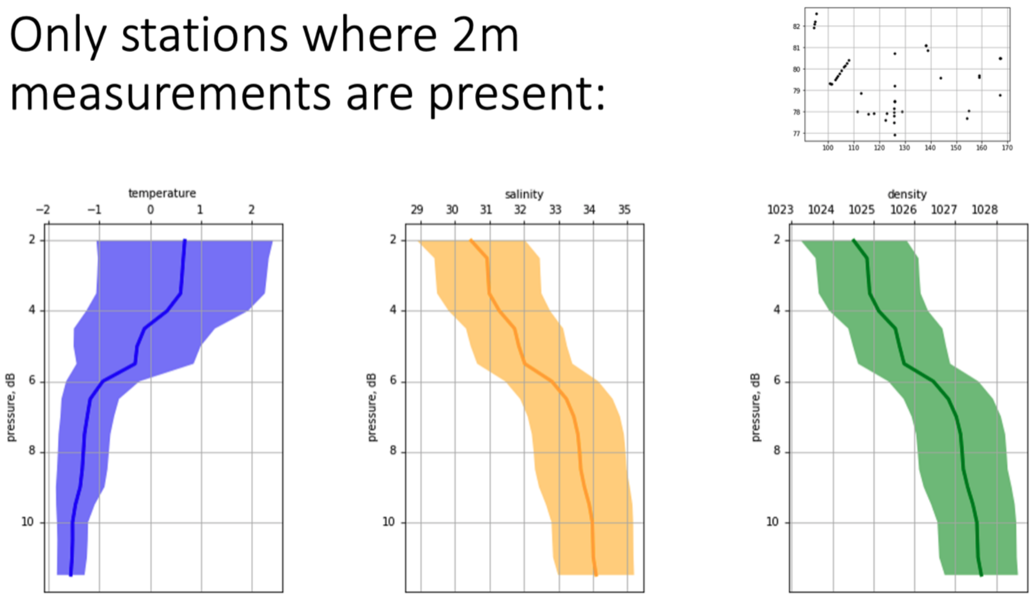

Fig. 2. The upper 10 meters of T, S, density from vertical CTD profiles

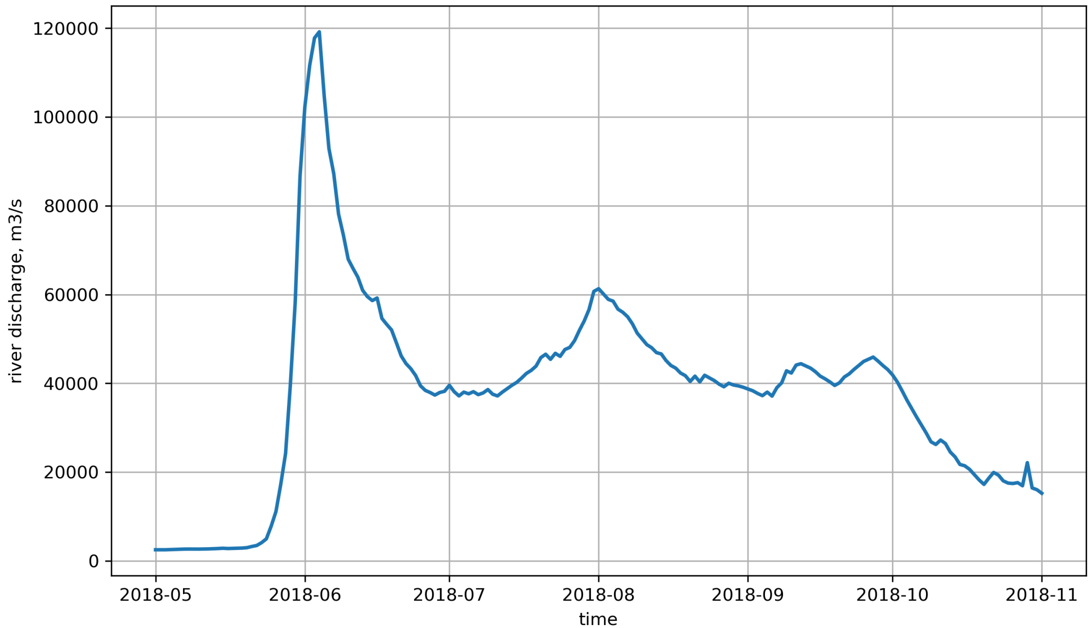

Fig. 3. The Lena River discharge in summer months 2018, data from Arctic GRO dataset, (https://www.arcticrivers.org/data)

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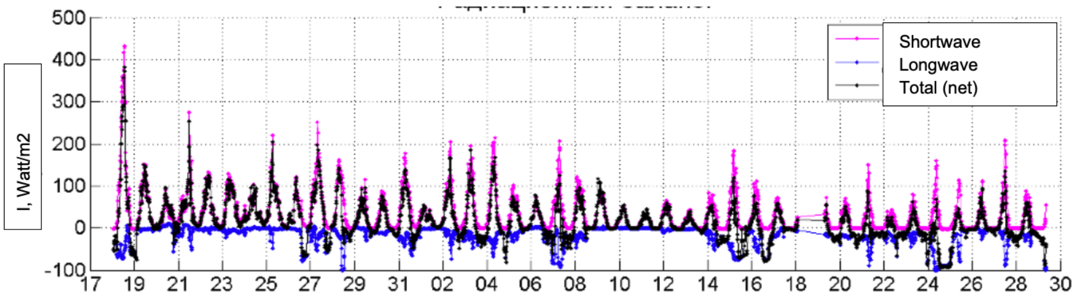

Fig. 4. Radiative balance components (Watt/m2) measured from RV Akademik Tryoshnikov during ARKTIKA-2018 expedition: magenta - shortwave radiation; blue, longwave radiation; black, total (done by A.Pashkov)

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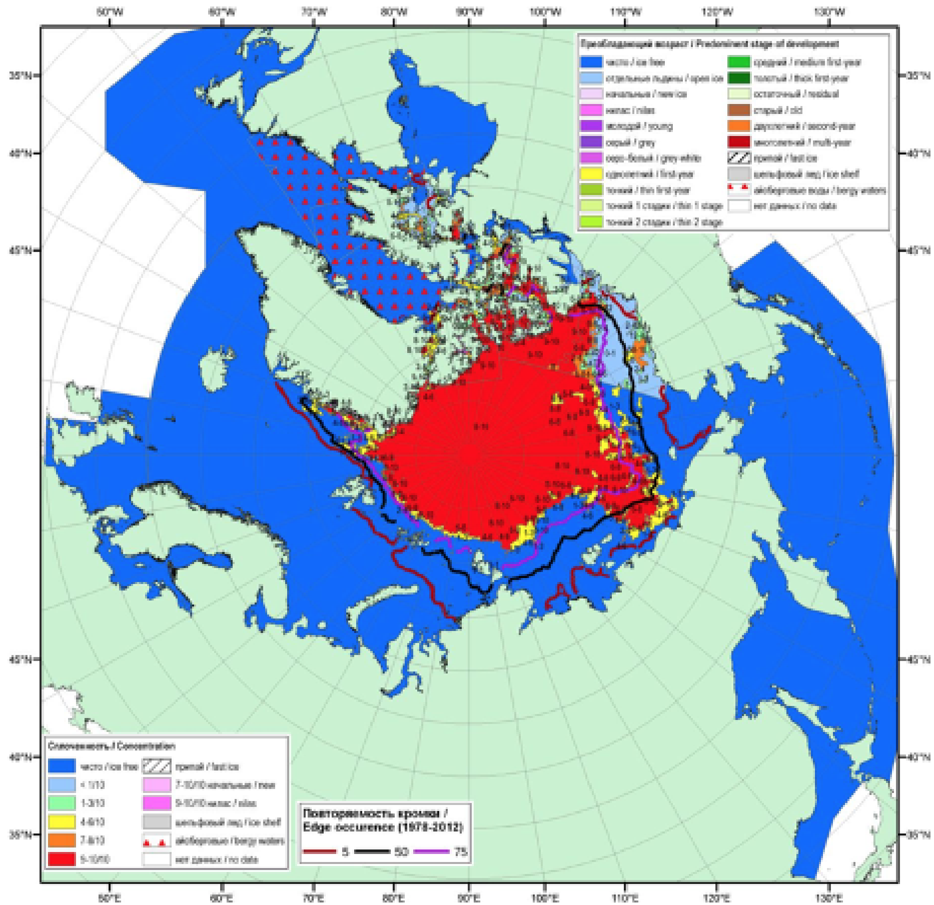

Fig. 5. Ice chart for the Arctic Ocean for September 3 - September 11, 2018. Colors indicate total sea ice concentration according to the analysis done at AARI (Sept 11), Canadian Ice Service (Sept 3),

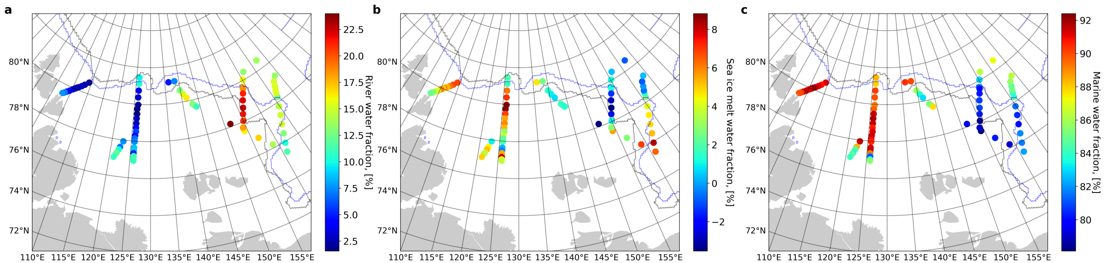

Fig. 6. Fractions of river water (a), sea ice melt water (b) and marine water (c), calculated using d-O18 measurements and Bauch andCherniavskaia (2018) 3-components model of freshwater balance.