Dear Reviewer,

Thank you for your comments, you addressed some important points. You can find our reply enclosed.
We really appreciate your time and insight in reviewing our manuscript!

Kind regards,

Susanna (on behalf of all co-authors)

General comments

There is often a comma missing when the sentence starts with “However”, “Hence”, “Further”, “Furthermore” etc. (see e.g., L36, 75, 149, 161, 163, 180, 200, 239, 251, 259, 309 etc., and other places in the text) Please check this throughout the manuscript.

Thanks, we revised the whole text and added commas where necessary.

Please make it clear in the figure captions what period the time series are referring to, especially in those cases where graphs show different time series, e.g., Figure 6.

We adapted the figure captions accordingly and changed the labeling of the graphs to make them clearer.

If you by fluxes refer to freshwater fluxes, please indicate this in the text.

We specified whether the mentioned fluxes are freshwater of volume fluxes.

Specific comments

L21: Consider revising to “However, on a seasonal scale budget residuals….”

L24: Change “that” to “which” or remove the comma.

L40: Revise to Rivers’

L41: remove “also”, e.g. “Further, climatological conditions pose a hindrance….”

L88: Add comma “In contrast, discharge…”

L91: Add comma “For the Pan-Arctic approach, river discharge…”

L136: Add comma “In addition, volumetric fluxes…”

L137: Revise to “observation-based estimates”

L161: Move e.g., to the beginning (e.g., Serreze et al….)

L165: Add comma after “budgets”

L205: Is “Hence” needed here?

L228: Consider removing “in order” at the beginning of the sentence and start with “To” – and – do you mean “we follow methods by Mayer…”

L267: Change heading to “4 Results and Discussion”

L275: Add comma before “as well as”

L276: Add comma before “and weak runoff…”

L301: Revise to “but is mostly caused due…”

L302-303: Consider revising: “For example, at the upper part of the Ob river, ice breaks up around April to May, while the lower part breaks up between May and June (Yang et al., 2004b).”

L310: Add comma “In autumn and winter, land water…”

L545: Add comma after summer “In late summer, river discharge…”

L596: suggest to revise “too low” to “underestimated” – and revise “errors” to “discrepancies”

L608: Suggest to remove “(see next bullet point)”

L629: Suggest to revise to “In summary, …”

L636, 647, 654: Consider revising “quite”

L838: Muntjewerf et al. 2020 should come after Muñoz Sabater et al. 2019

We revised, corrected, or rephrased all the points above.

L96-98: This sentence is not clear to me. By “separately” – do you mean the monthly time step or for each river? With “certain timestamp” – are you referring to the 1979-1999 period?

By separately we meant the monthly time step and with “at this certain timestamp” we referred to each of those time steps. We reformulated the sentence to the following:

We calculated an observation-based Pan-Arctic river discharge for the whole period of 1979 to 2019, by calculating discharge separately for every time step (= every month), using all river discharge measurements available at those time steps.

Figure 1: Is it possible to also include the additional 20 river basins, or are they too small to display on the map?

Yes, we included the additional basins.

Figure 3: The graph appears to be cut-off at the bottom. Please make it clear in the figure or caption what the x-axis (80-20) represents (e.g., 1979-2019).

We added the time period in the caption and also adapted the x-axis to full years (1980 etc.).

Table 4-5: Why is there a difference in time period compared to Figure3 (1979-2019)?

That’s because ERA5-Land data are not available before 1981, hence all trends are calculated over the coinciding period 1981-2019 (we mention this in line 260 of the manuscript). Figure 3 shows the fully available timeseries of all datasets and hence most of the lines go back to 1979.

L378: Could maps be shown in appendix?

Yes, we added maps for GRACE land and ocean water storage changes to the appendix.

We further found some strong land to ocean leakages in the GRACE data that we used, and therefore we exchanged the GRACE data using spherical harmonics solutions to the GRACE Mascon solutions, where the leakage effect is considerably reduced. This led to changes in some figures, tables, the variational optimization, and the corresponding text passages. However, we note that the main results did not change considerably, and the outcome of our study was not affected. The biggest difference was a change of the sign of the oceanic water storage, as we now get an increase in water

mass stored in the Arctic Ocean. We therefore adapted the discussion of those results to the following (Line 552 in the revised manuscript):

The reported increase in oceanic storage is driven by mass increases over the western Arctic Ocean and the coastal areas of Eurasia and North America (see Fig. A1 in the appendix). For the western Arctic Ocean various studies (e.g., Proshutinsky et al., 2019) indicate an accumulation of freshwater in the Beaufort Gyre, due to a combination of favourable wind forcing, redirection of Mackenzie River discharge, inflow of low salinity waters through Bering Strait and sea ice melt. Mass increases along the coastal areas are the result of runoff increases. Mass decreases in Barents and Kara Sea , as well as in Baffin Bay (Fig. A1 in the appendix) counteract those increases, resulting in the reported minor trends for the whole Arctic Ocean. Mass decreases to the west of Greenland are mainly caused due to lowering of the geoid associated with nearby ice mass losses, however Jeon et al. (2021) also found residual land-leakage effects that were not removed in the GRACE Mascons. Furthermore, oceanic storage is strongly affected by decadal wind variations (Volkov and Landerer, 2013; Fukumori et al., 2015) and circulation patterns and exhibits strong nonseasonal fluctuations, further aggravating the detection of real oceanic mass trends. Volkov and Landerer (2013) found that an intensification of the westerly winds over the North Atlantic and over the Russian Arctic continental shelf lead to a decrease of ocean mass in the central Arctic. Further, they found positive correlation between Arctic Ocean mass fluctuations and northward wind anomalies over the Bering Seas and the northeastern North Atlantic. They also revealed that cyclonic/anticyclonic anomalies of the large-scale ocean circulation lead to negative/positive Arctic ocean mass anomalies.

Figure 6: Make it clear in the figure caption what time period right graphs are referring to.

We added the time periods in the caption.

Figure 12: Is this figure representing the fluxes of the hydrological cycle? If so, consider revising to – 1993-2018 adjusted long term means of freshwater fluxes in the Arctic hydrological cycle. Units are km3 per year; arrows are scaled by the magnitude of the freshwater flux.

Yes, however the oceanic fluxes represent volume instead of freshwater fluxes. We changed the caption to the following:

1993-2018 adjusted long term means of atmospheric and terrestrial freshwater fluxes and storage terms in the Arctic hydrological cycle, as well as oceanic volume transport and storage change. Units are km3 per year; arrow areas are scaled by the magnitude of the represented terms.

Figure 13: Caption – by cycle – do you mean freshwater fluxes? (see comment on Figure 12), e.g., "1993-2018 adjusted mean annual freshwater fluxes of the Arctic Ocean's hydrological cycle. Shading represents the uncertainties of the a priori estimates." Consider to update the text in related sections accordingly.

We changed the caption to the following:

1993-2018 adjusted mean annual cycles of atmospheric and terrestrial freshwater fluxes in the Arctic hydrological cycle as well as oceanic volume transports and storage changes before (left) and after (right) the optimization. Shading represents the uncertainties of the a priori estimates.

We also adapted the figure to include the seasonal cycles before and after the optimization and added lines showing the seasonal residual, this did not change any results and just made the figure easier to understand for the reader.