Supporting Information for "Observed changes in Arctic Freshwater Outflow in the Fram Strait"

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Introduction The first part of the supporting information (S1) describes the data-gap filling process that has been followed in case of few, damaged, or lost instruments of the mooring array. The data-gap filling is applied at different interpolant points of the cross-section and S1 provides information on the method followed to define the uncertainty at those points. The second part (S2) contains information on the process that have been followed to correct earlier estimates of freshwater transport, when the coverage of the mooring array was lower.

S1. Data-gap filling & Uncertainty of interpolants

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Before gridding, the salinity and velocity data-gaps (few, damaged, or lost instruments) at essential positions in the section are filled with regression or with the long term mean. At those interpolant points, velocity is linearly regressed from nearby instruments, with coefficients from other years' deployments, while salinity is linearly regressed with coefficients from the CTD climatology. More specifically, when an entire mooring is missing, velocity is regressed from instruments in nearby moorings or filed with the long term mean. When only some instruments of a mooring are missing, velocity is regressed from the above/below instruments. Then, in the absence of IceCATs, salinity at 5 m and 25 m is regressed from observations at 55 m, while for the cases with IceCATs deployed at 25 m, salinity at 5 m is regressed from 25 m. Similarly, in the absence of instrumentation at $\sim$ 155 m, salinity is regressed from the closest instrument in the vertical.

According to the above, the interpolants are divided in to three categories. The instrument positions, the gaps filed with the long term mean value, or with regression from an other mooring, and the gaps filed with regression from an other instrument of the same mooring. To include the uncertainty at the interpolants, while accounting for the random occurrence of the errors, we allow the subsampled (from the baseline dataset) velocity/salinity to randomly vary around the baseline value (see Section 2.4 main text). For that we assume:

$$S_\alpha = S_b \pm \delta S, \qquad V_\alpha = V_b \pm \delta V,$$

where S and V are the salinity and velocity, the subscripts α and b stand for the approximated and baseline (observed) values, and δS and δV are the respective errors. The values of δS and δV are randomly selected from a normal distribution centered around zero, with a standard deviation representative of the interpolant category and the position in the section. Example given, instruments have lower uncertainty than data gaps, while filling gaps with the long term mean near the bottom has lower uncertainty than filling gaps near the surface where the water properties vary more in time. Following that, at the instrument positions we consider the standard deviation to be equal to the uncertainty of the instrument, while at the gaps we use the long term (2003-2019) standard-deviation from the mooring dataset, and to allow for seasonal variations we calculate the standard deviation for each month. More specifically, for the gaps filed with the long term mean, or with regression from an other mooring, we use the value of one standard deviation of the velocity/salinity at the interpolant point, and for the gaps filed with vertical regression we use one standard deviation of the variable's vertical change between five consecutive grid cells. As the standard deviation of the velocity/salinity varies spatially, Figure S1 shows the normal distributions with the maximum (blue) and minimum (red) standard deviation for each interpolant type.

Time series correction

In the period after Sept. 2013, new instruments providing three new datasets have been added on the moorings in the Fram Strait (iceCAT sensors at 25 m, SBE sensors at $\sim$ 155 m, and a new mooring at $5.5^o W$). To calculate the offset of freshwater transport (FWT) in earlier years, when those datasets were not in place, we excluded the respective instruments, and at their positions, salinity and/or velocity are recalculated with interpolation ($5.5^o W$) or regression (25 m, 155 m). The seasonally averaged monthly-mean offsets (observed minus estimated) of the salinity/velocity and the respective FWT are presented in Figure S2. Although the single point FWT offset at 155 m and the mean FWT offset at $5.5^o W$ are one order of magnitude smaller than the offset at 25 m, this is not reflective of their effect on the integrated FWT, as the radius of influence of the first two through interpolation is much larger (see section 3.1 of main text).

The offsets of Figure S2 are used as corrections for salinity and/or velocity, that in the absence of novel data, are calculated with the seasonally biased CTD climatology, or with interpolation. We apply the seasonal correction, in the absence of novel data, for the whole period between 2003-2019. At 155 m, we correct the salinity at the moorings F14, F13 and F12 for the offsets in panels a, c and e, respectively. At 5.5^oW, we correct the velocity profiles for the offset in panel f, before vertical averaging. At 25 m of moorings F17 and F13b we correct the salinity for the offsets in panels b and d, and for the in-between mooring F14 we use the mean of the two. For the moorings east of F13b we correct up to F12 (4^oW) with the offset of F13b, and we don't correct further east as there, the stratification appears to change significantly with longitude (Figure S3).

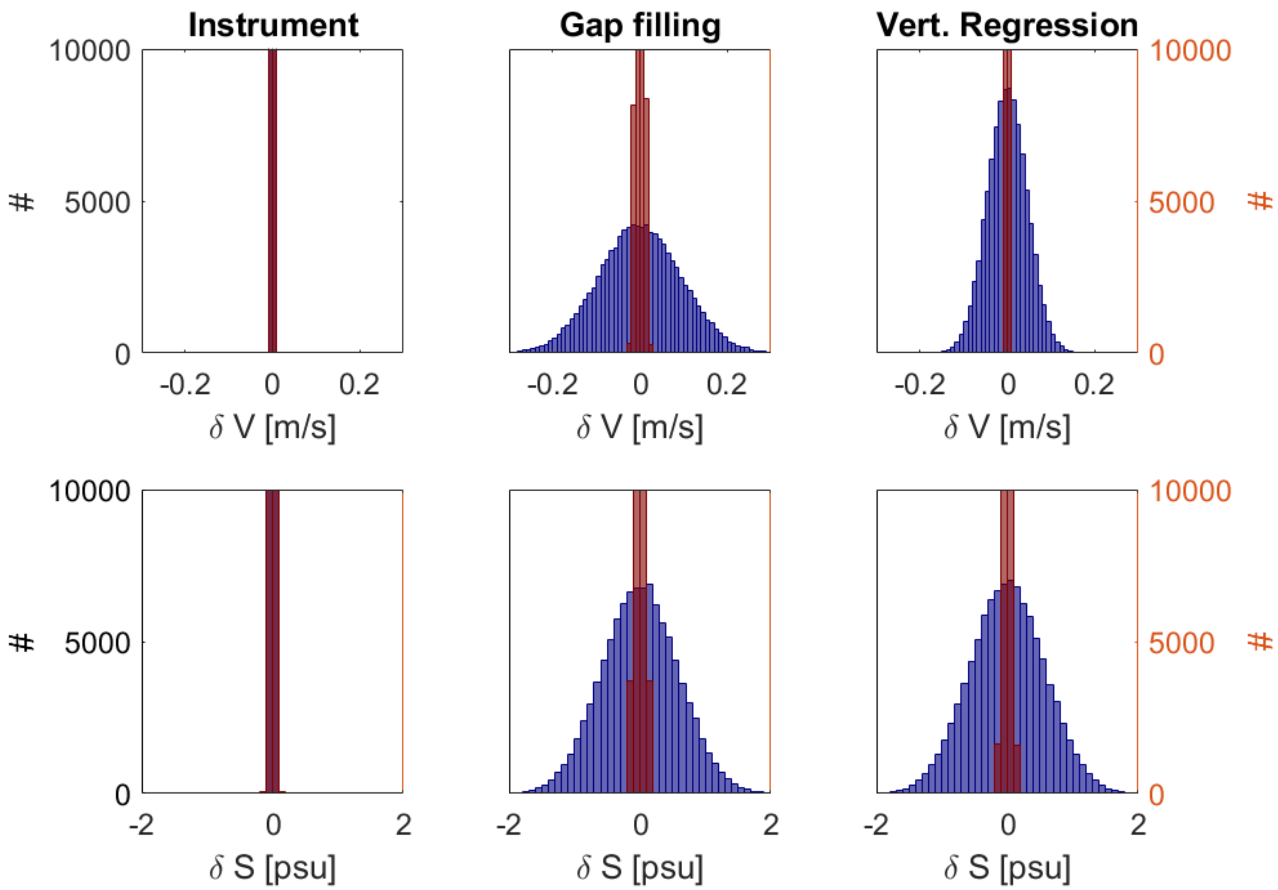

Figure S1. Normal distributions defining the value domain of δS and δV, for salinity and velocity at the three different interpolant categories. The blue distribution corresponds to the maximum standard deviation observed in a section while the red distribution corresponds to the minimum standard deviation.

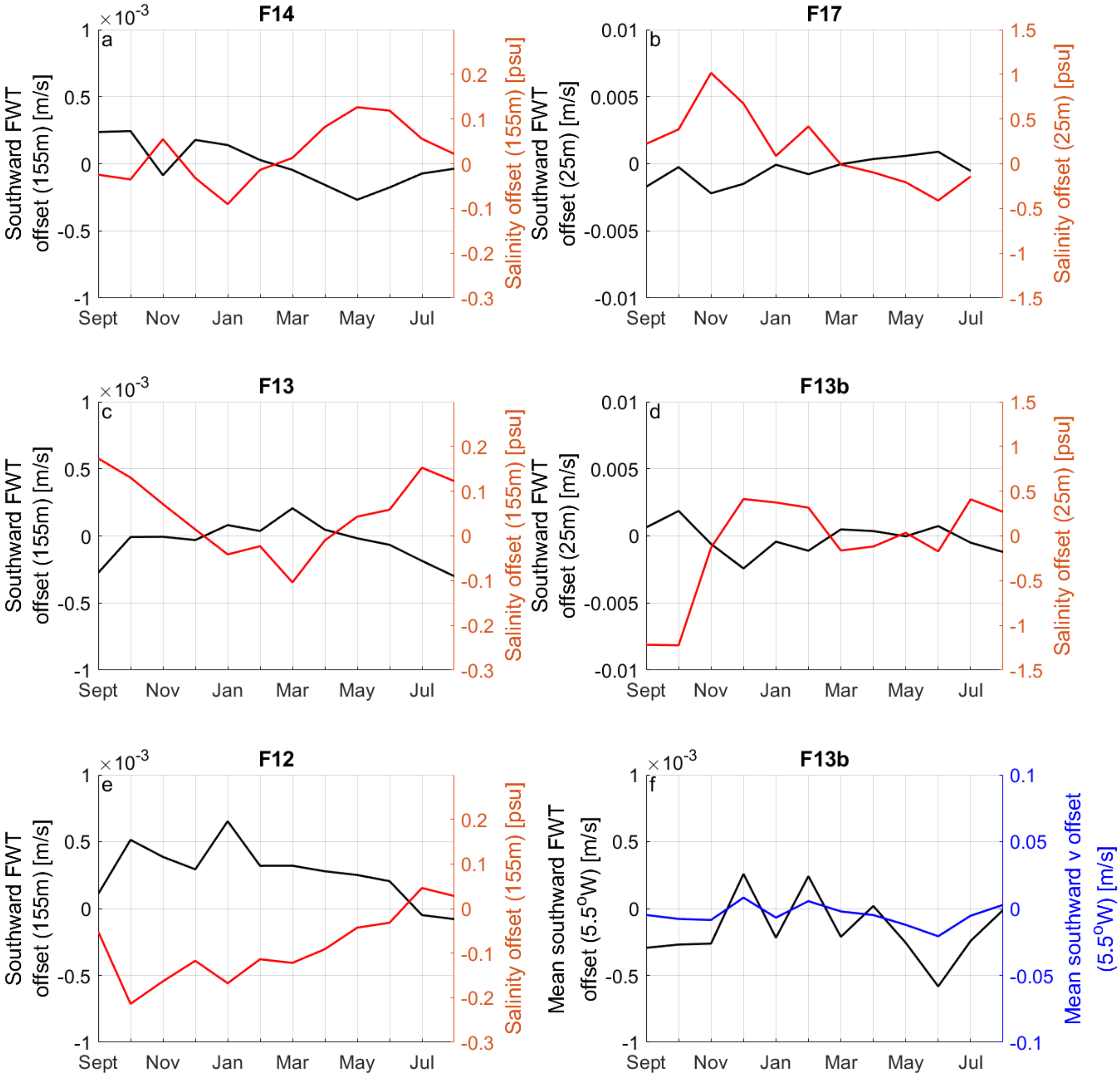

Figure S2. Seasonally averaged offsets between the novel data of salinity/velocity at the different moorings, and the estimated values considered in their absence. The equivalent offset for the southward freshwater transport (FWT) are presented as well.

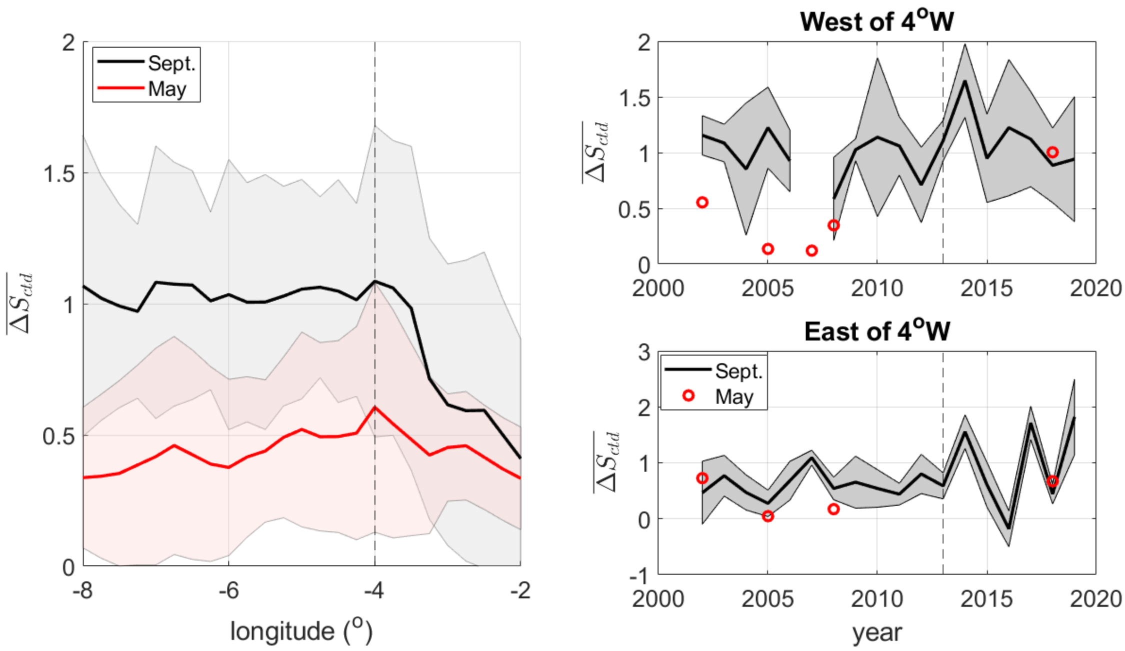

Figure S3. Salinity difference between 55 and 25 m from the available CTD observations (ΔS_{ctd}) against longitude (a), and against time (b), for months September and May. The solid lines (red dots) show the average ΔS_{ctd} (left panel: time average, right panels: longitudinal average) and the shaded areas show the value of one standard deviation from the mean.

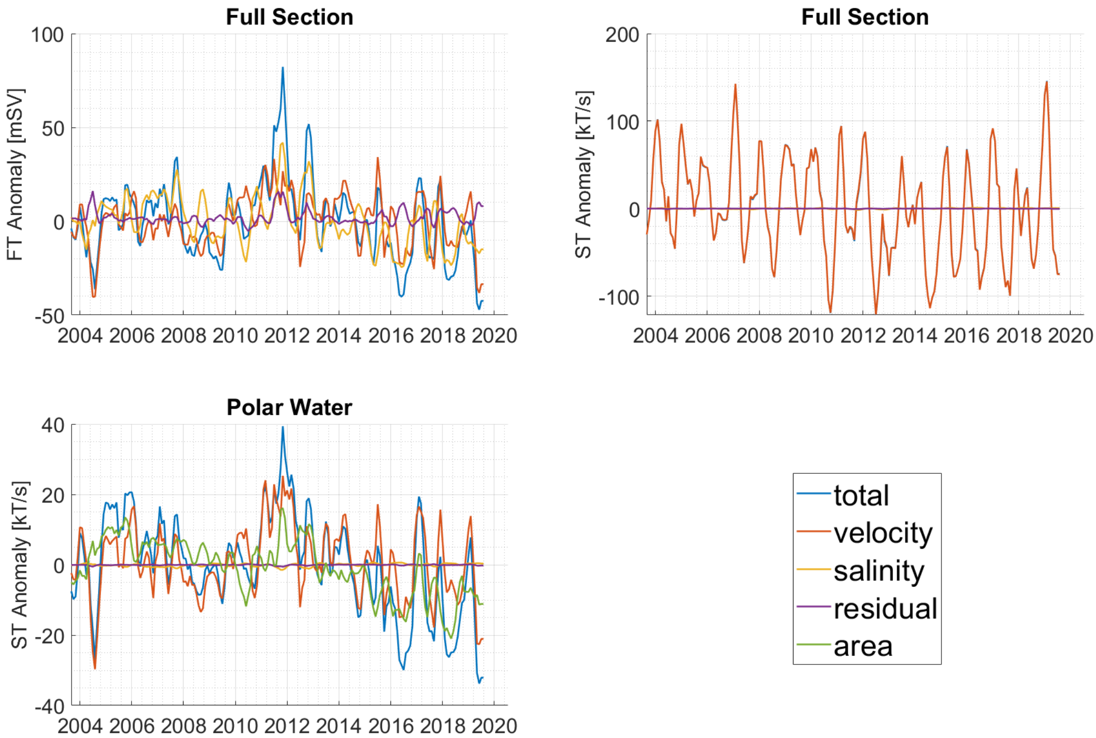

Figure S4. Freshwater (FWT) and Salt (ST) transport anomaly and the different anomaly terms, integrated in the full section and in the Polar Water.