Freshwater variability and transport in the East Greenland Current

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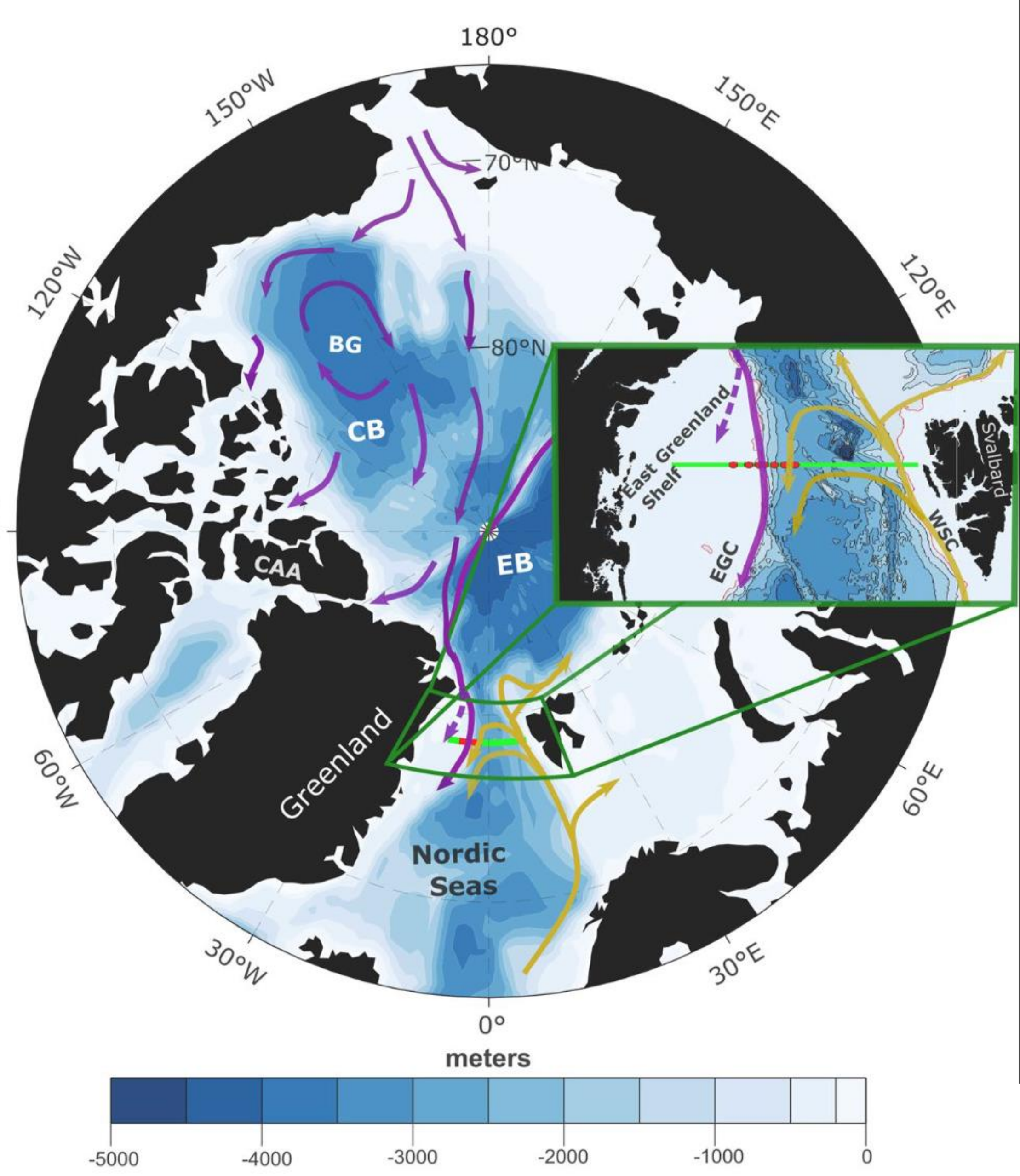
ABSTRACT

The East Greenland Current (EGC) transports fresh and cold Polar Water (PW) southwards from the central Arctic Ocean. Observations of strength and properties of the EGC have been monitored through moored instruments in Fram Strait since 1997. Freshwater transport since 2015 has decreased, with an exception for 2017. The general decrease is caused by a velocity reduction of the EGC and PW. Results points to an "Atlantification" of the western Fram Strait section. Mechanisms controlling the export of freshwater from the EGC, both in liquid and solid forms are explored using an idealized numerical model and scaling theory. Climate models predict an increase of offshore winds and decrease in Arctic export of sea-ice for the coming future. This leads to a decrease in offshore sea-ice transport. Uncertainties occur for onshore freshwater transport, as it may both increase or decrease depending on the changing effects of Ekman transport and offshore eddy fluxes.



Freshwater cycle

In the Arctic Ocean, freshwater originates from runoff, inflow from the Pacific Ocean through the Bering Strait, precipitation, and the seasonal cycle of sea-ice freezing and melting (Spall et al., 2024). The pathways of freshwater transport (Figure 1) indicate an outflow through the Canadian Arctic Archipelago (CAA) or Fram Strait via the East Greenland Current (EGC). The inflow of Atlantic Water (AW) from the Norwegian Atlantic Current (NwAC) enters both the Barents Sea and the West Spitsbergen Current (WSC), bringing warm AW to the central Arctic Ocean.

Figure 1. Map of the central Arctic Ocean and Nordic Seas, focusing on Fram Strait. Red dots mark the mooring array, and the green line shows the annual CTD section. Yellow arrows indicate Atlantic Water pathways, and purple arrows show suggested freshwater pathways. The dashed purple arrow over the Greenland shelf indicates Polar Water transport not captured by the mooring array. EB, CB, BG, and CAA stand for the Eurasian Basin, Canadian Basin, Beaufort Gyre, and Canadian Arctic Archipelago, respectively. From Karpouzoglou et al. (2022).

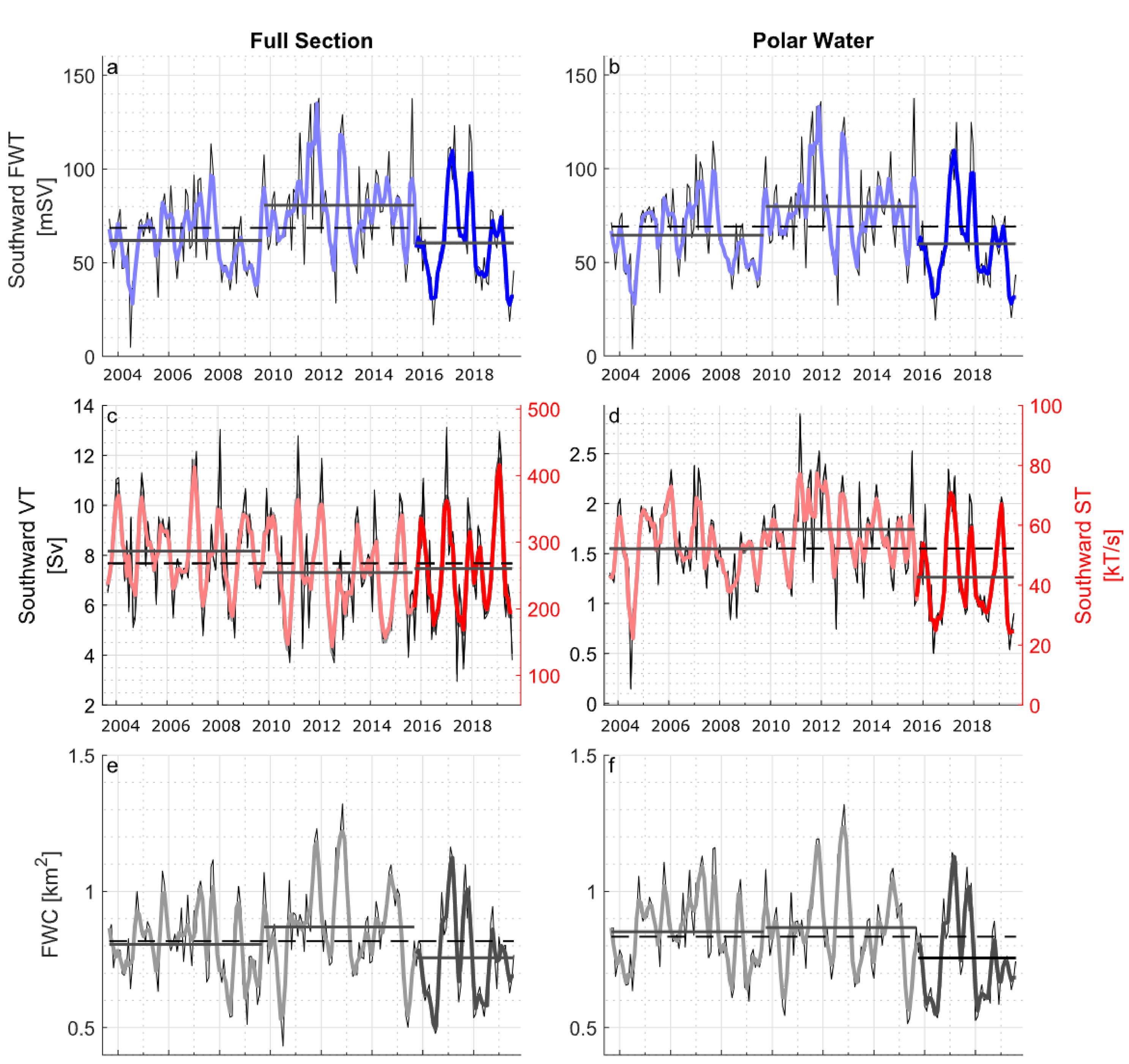


Figure 2. Time series of southward freshwater (a, b), salt and volume transport (c, d), and freshwater content (e, f) integrated for the full section (left) and Polar Water ($\sigma < 27.7 \frac{kg}{m^3}, T < 0°C$) (right) ($S_{ref} = 34.9$). Monthly values are shown with a thin black line, and a 3-month running mean with a thick colored line. Horizontal lines indicate long-term means, with solid lines divided into three periods and dashed lines representing the total mean. From Karpouzoglou et al. (2022).

Freshwater transport (FWT)

- FWT has reduced after 2015
- Increased salinity in the halocline linked to "Atlantification"
- EGC's current velocity
- Beaufort Gyre (BG) storage of freshwater

The EGC transports about half of the Arctic Ocean's liquid freshwater and nearly 90% of its sea ice (Haine et al., 2015; Karpouzoglou et al., 2022). Freshwater Transport (FWT) increased initially, followed by a rise in Volume Transport (VT) and Fresh Water Content (FWC) in the PW (Figure 2). From period 2 to period 3, FWT decreased due to lower VT and FWC in the PW, caused by a reduced southward velocity of the EGC and halocline salinification (Karpouzoglou et al., 2022). FWT and FWC in the western Fram Strait are primarily influenced by processes within the PW, accounting for 95% of the FWT and FWC above the isohaline ($S = S_{ref} = 34.9$) which is linked to atmospheric interactions in the BG (Karpouzoglou et al., 2022). Currently, the FWT on the Greenland shelf west of the mooring array is unknown and remains the largest uncertainty, with unclear contributions from EGC variability or changing freshwater pathways (Karpouzoglou et al., 2022).

Mechanisms of liquid freshwater transport

- Offshore eddy transport during summer
- Onshore Ice-ocean stress during winter

Offshore liquid FWT (Figure 3b) occurs when and where eddies are strong (Figure 3c), typically in late summer and fall when the density gradient is pronounced and the ice is sparse enough to be advected by ocean currents (Spall et al., 2024). Onshore liquid FWT occurs when eddies are weak and the winds are strong. This is driven by the Ekman layer, which advects freshwater back onto the shelf (Spall et al., 2024).

The detailed dynamics and significance of FWT through eddies in the EGC have not been quantified (Spall et al., 2024) and will be a focus of further investigation.

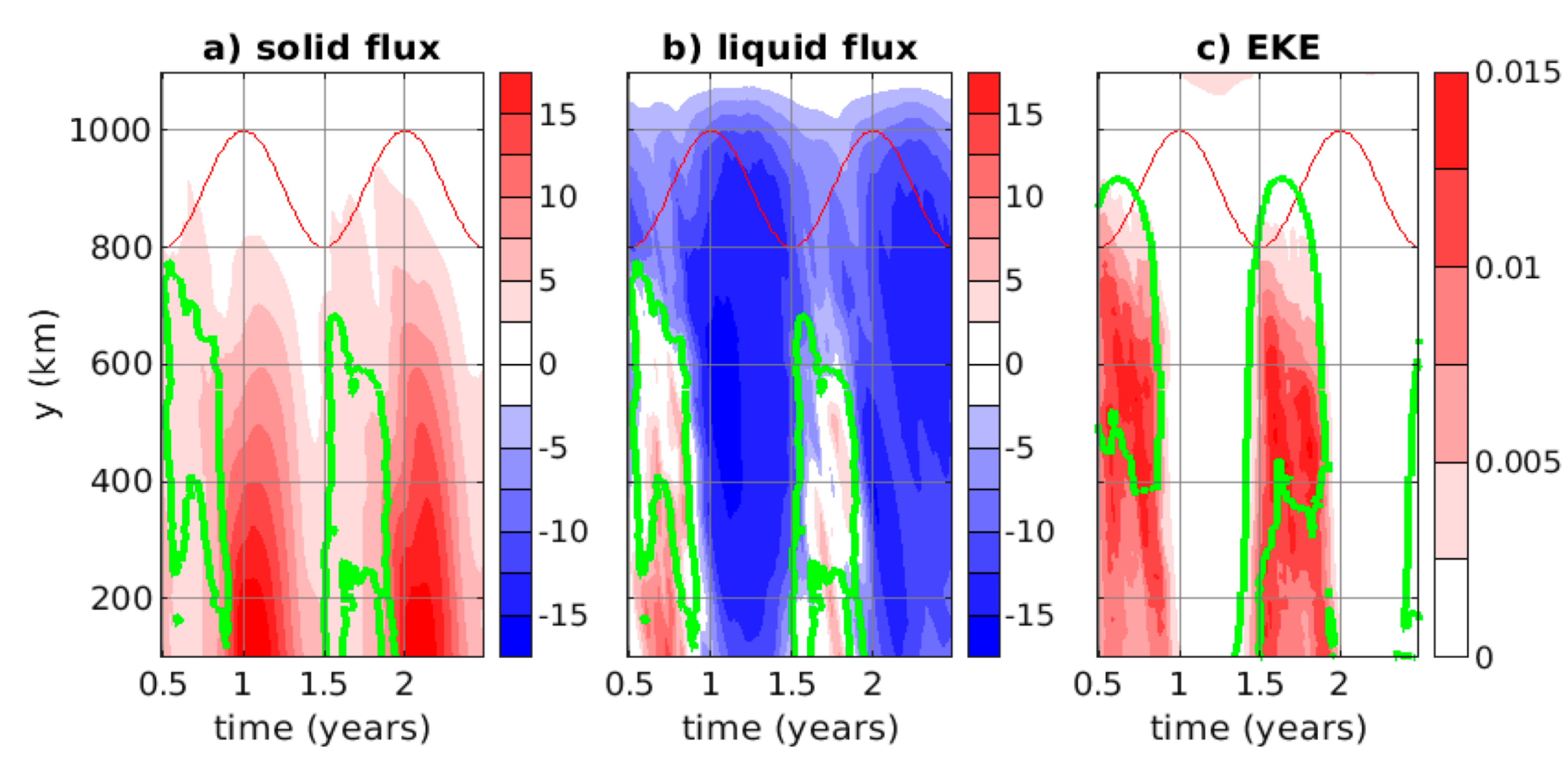


Figure 3. Freshwater flux at the model shelf break by latitude and time: (a) solid freshwater flux (mSv), (b) liquid freshwater flux (mSv), and (c) Eddy Kinetic Energy (EKE) ($m^2 s^{-2}$) at 25-m depth averaged over the shelf region. The solid red line indicates model seasonality, with peaks in winter and troughs in summer. Green contours in (a) and (b) show the 0.01 $m^2 s^{-2}$ EKE, while in (c) they indicate regions with less than 80% ice cover and Richardson number below 75 occurs. From Spall et al. (2024).

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