Volume, Heat and Freshwater Transport in the Labrador Current off Nunatsiavut, Northern Labrador

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Research Questions

1. What are the relative magnitudes of geostrophic transport in the Labrador Current's inshore branch (ILC) and offshore branch (MLC)?
2. Are variations in heat and freshwater transport dominated by temperature and salinity, respectively, or by velocity?
3. Is the geostrophic transport coherent between different locations along and across the current?

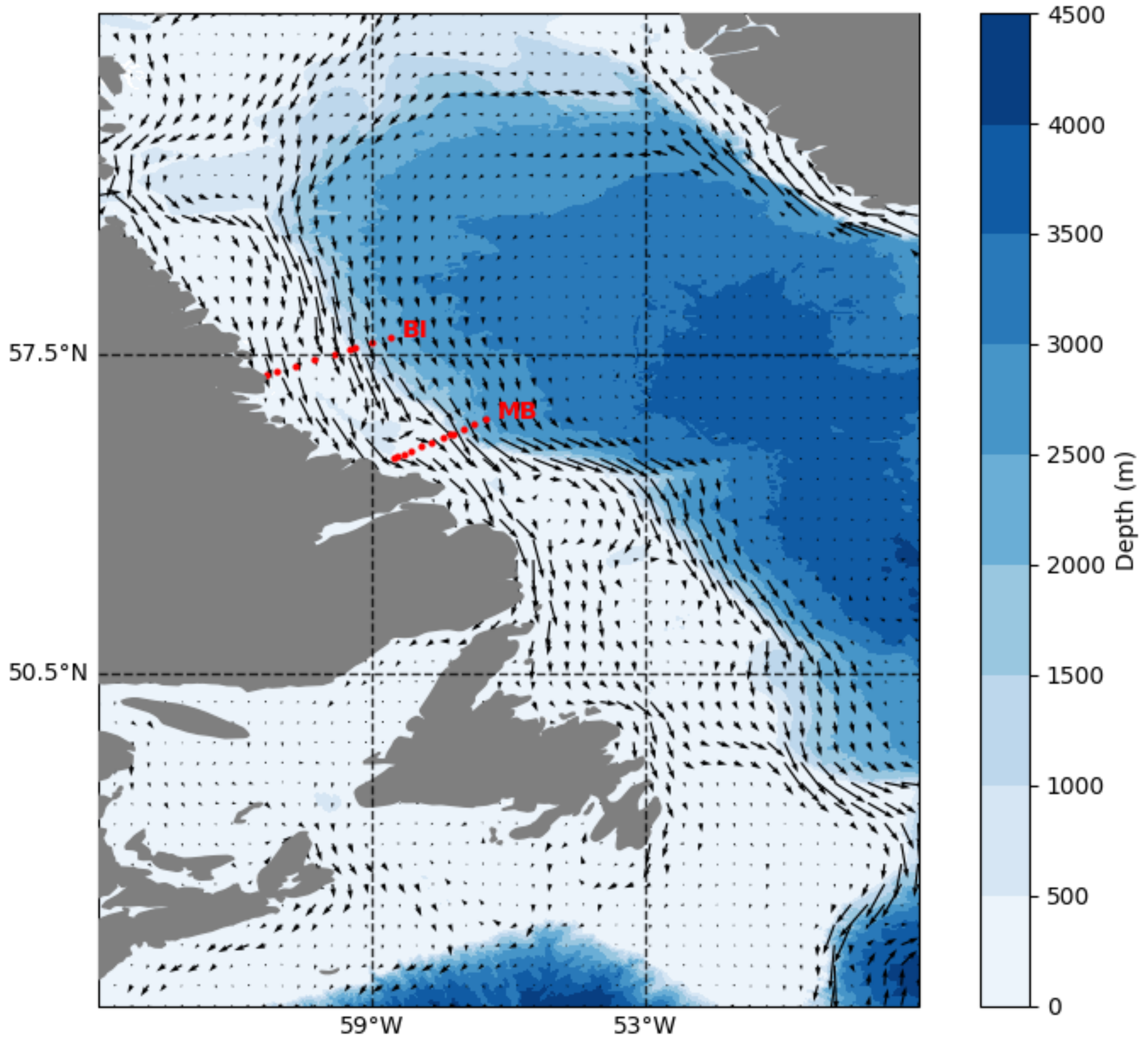

Figure 1. Map including mean surface ocean currents from GLORYS, and depth of the area of study. Atlantic Zone Monitoring Program (AZMP) lines are shown in red.

Data

- Temperature and salinity data from CTD profiles, Atlantic Zone Monitoring Program (2000-2019) [1]
- Surface current velocities are from drifters[2]
- 10m wind speeds are from the ERA5 reanalysis product[3]

[1]Data provided curtesy of Frederic Cyr, Fisheries and Oceans Canada

[2]Data provided curtesy of Eric Oliver, Dalhousie University, www.conoc.ca

[3] Hersbach, H., Bell, B., Berrisford, P., Biavati, G., Horányi, A., Muñoz Sabater, J., Nicolas, J., Peubey, C., Radu, R., Rozum, I., Schepers, D., Simmons, A., Soci, C., Dee, D., Thépaut, J-N. (2018): ERA5 hourly data on single levels from 1979 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). (Accessed on < 04-01-2021 >), 10.24381/cds.adbb2d47

Methods

- The thermal wind balance arises from assuming geostrophy and hydrostatic balance

$$\frac{\partial v}{\partial z} = -\frac{g}{\rho f}\frac{\partial \rho}{\partial x}$$

- We define the variables in the thermal wind equation above as follows;
  - g is gravitational acceleration in m/s^2
  - f is the Coriolis parameter
  - ρ is density in kg/m^3
  - v is velocity in m/s and is positive along the shelf to the NW
  - x is in m and is positive across the shelf to the NE
  - z is depth in m
- Thermal wind shears $\left(\frac{\partial v}{\partial z}\right)$ are calculated from the observed density gradients via the thermal wind equation
  - Density is calculated from temperature and salinity using the TEOS-10 using the "gsw" package in python
  - Density gradients are calculated using centered differencing
- Geostrophic velocities are then found using a constant of integration inferred from drifter-derived surface velocities corrected for wind-driven Ekman flow
- Transports are calculated according to the following equations where T_v is volume transport (Sv), T_h is heat transport (W), and T_{fw} is freshwater transport (Sv).

$$T_v = \int_{x_1}^{x_2}\int_{-H}^{0} v\,dz\,dx \qquad T_h = \int_{x_1}^{x_2}\int_{-H}^{0} \rho c_p \theta v\,dz\,dx \qquad T_{fw} = \int_{x_1}^{x_2}\int_{-H}^{0} \rho v\left(1-\frac{S}{S_0}\right)dz\,dx$$

  - H is the depth bound in m (we use H=250m)
  - x_1, x_2 is the cross shelf spatial bound of the current in m
  - c_p is isobaric heat capacity in J/(kg K)
  - θ is potential temperature in K
  - S is salinity in PSU
  - S_0 is a reference salinity in PSU
- We can decompose each time varying variable, T_ϕ, into the mean, and perturbations from the mean. Here we take T_ϕ to be the transport of an arbitrary variable, ϕ, and define the following variables as;
  - $\bar{v}$ the mean velocity
  - $\bar{\phi}$ the mean value of ϕ
  - v' the velocity perturbations
  - ϕ' the perturbations of ϕ

$$T_\phi = \int_A \phi v\,dA = \underbrace{\int \bar{\phi}\bar{v}\,dA}_{\text{Mean}} + \underbrace{\int \bar{\phi} v'\,dA}_{\text{Contributions of } v' \text{ to variations in } \phi \text{ transport}} + \underbrace{\int \phi'\bar{v}\,dA}_{\text{Contributions of } \phi' \text{ to variations in } \phi \text{ transport}} + \underbrace{\int \phi' v'\,dA}_{\text{Covariance term}}$$

Results

Table 1. Relative magnitudes of transports

AZMP Line	Branch of LC	Volume (Sv)	Heat (PW)	Freshwater (Sv)
Beachy Island	ILC	-1.80	-0.0511	0.110
Beachy Island	MLC	-2.42	-0.0708	-0.0915
Makkovik Bank	ILC	0.0378	0.00109	0.00152
Makkovik Bank	MLC	-0.356	-0.0100	-0.0265

Table 2. Pearson correlation coefficients for upstream/downstream transport

Branch of LC	Volume Transport	Heat Transport	Freshwater Transport
ILC	-0.52	-0.53	0.21
MLC	0.53	0.52	-0.17

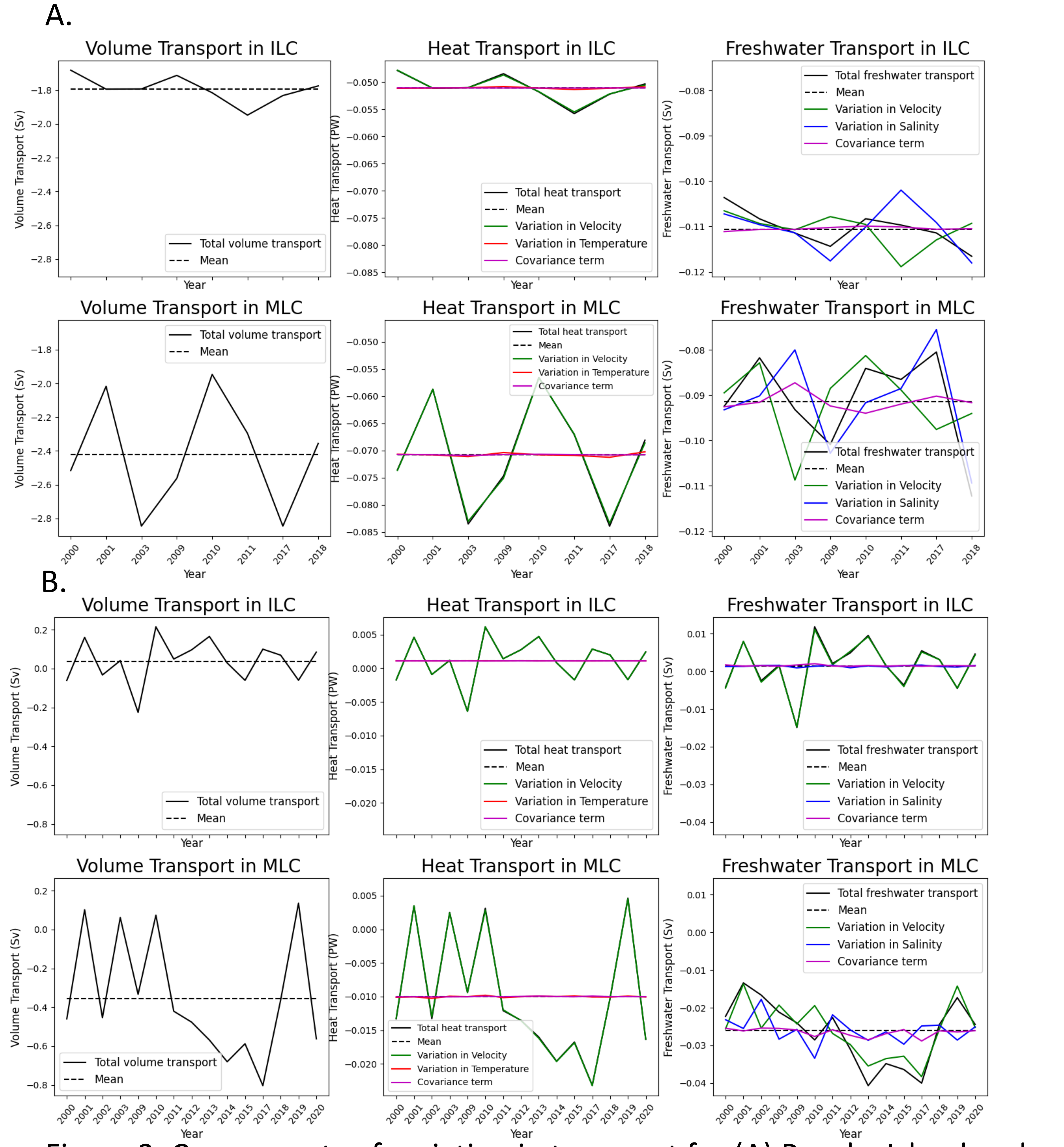

Figure 2. Components of variation in transport for (A) Beachy Island and (B) Makkovik Bank. Note that the time (x) axis as plotted is nonlinear.

Conclusions

- The results shown in figure 2 indicate that velocity perturbations dominate variations in heat transport in both branches of the current, and that salinity and velocity perturbations both play an important role on variations in freshwater transport
- Our results for transports in the Beachy Island line agree with the literature. In the Makkovik Bank line they do not.