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Cross-Isobath Freshwater Exchange Within the Labrador Sea

Clark Pennelly[1], Xianmin Hu[1,2], Paul G. Myers[1]

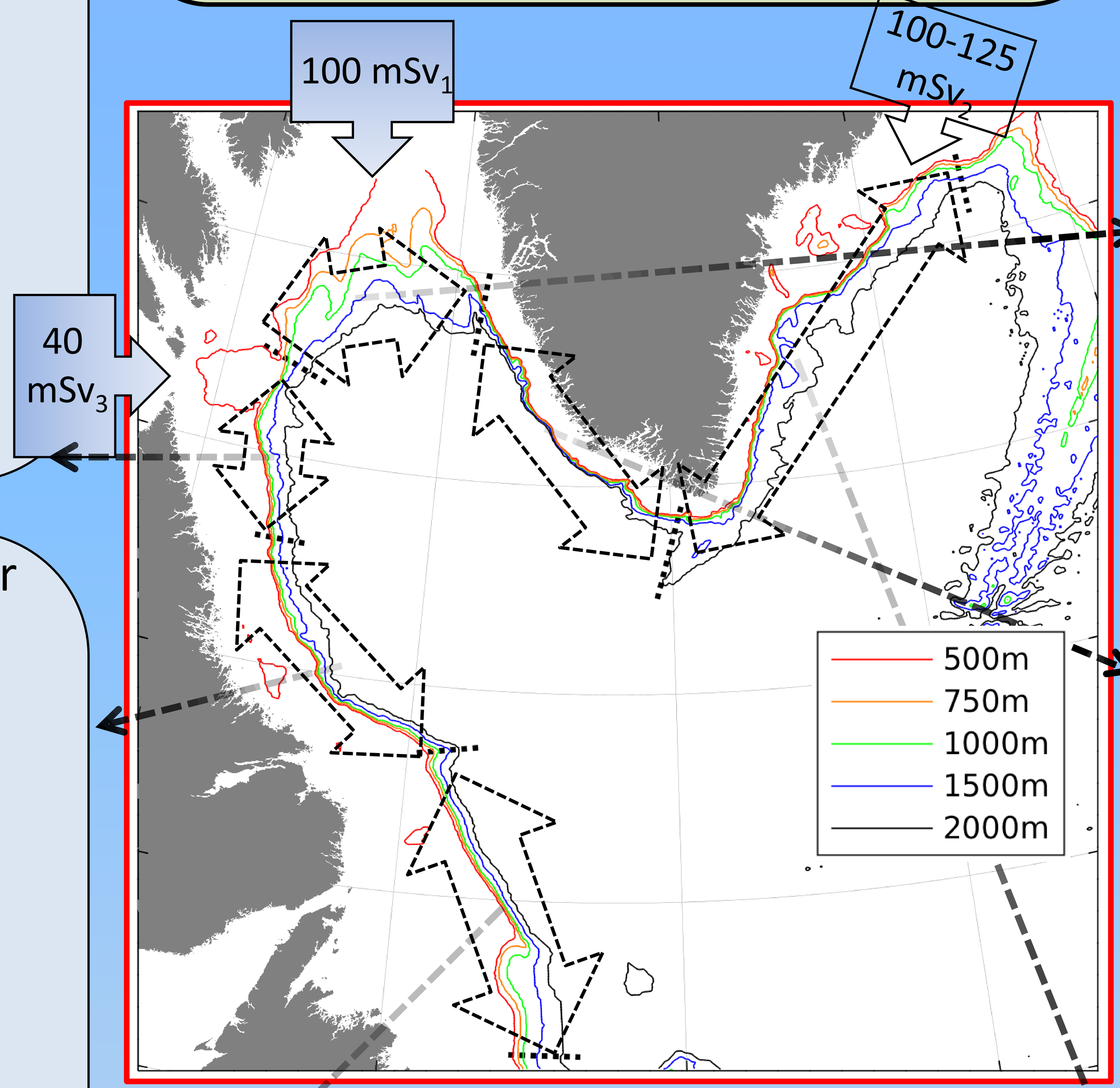
[1]Department of Earth and Atmospheric Sciences, University of Alberta, Canada

[2]Department of Fisheries and Oceans, Bedford Institute of Oceanography, Canada

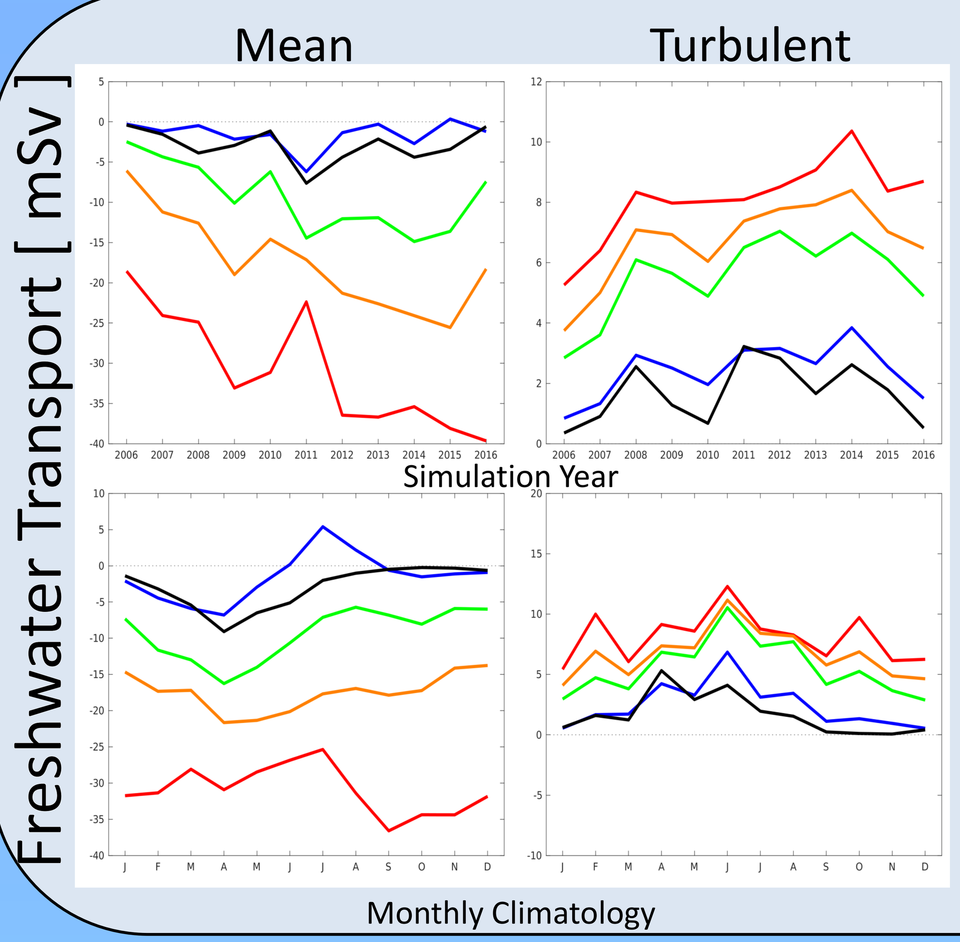
pennelly@ualberta.ca

Motivation

- The Labrador Sea contains an important region of deep convection
- An input of freshwater increases stratification within the Labrador Sea, reducing convection strength
- Convection in this region produces Labrador Sea Water
- Labrador Sea Water is part of the Atlantic Meridional Overturning Circulation (AMOC)
- Reduced Labrador Sea Water causes a reduction in AMOC
- Changes in AMOC strength have climate implications
- Freshwater currents along the east coast of Greenland, in Davis Strait, and Hudson Strait
- Set out to study and quantify where freshwater exchange occurs



Hudson Strait

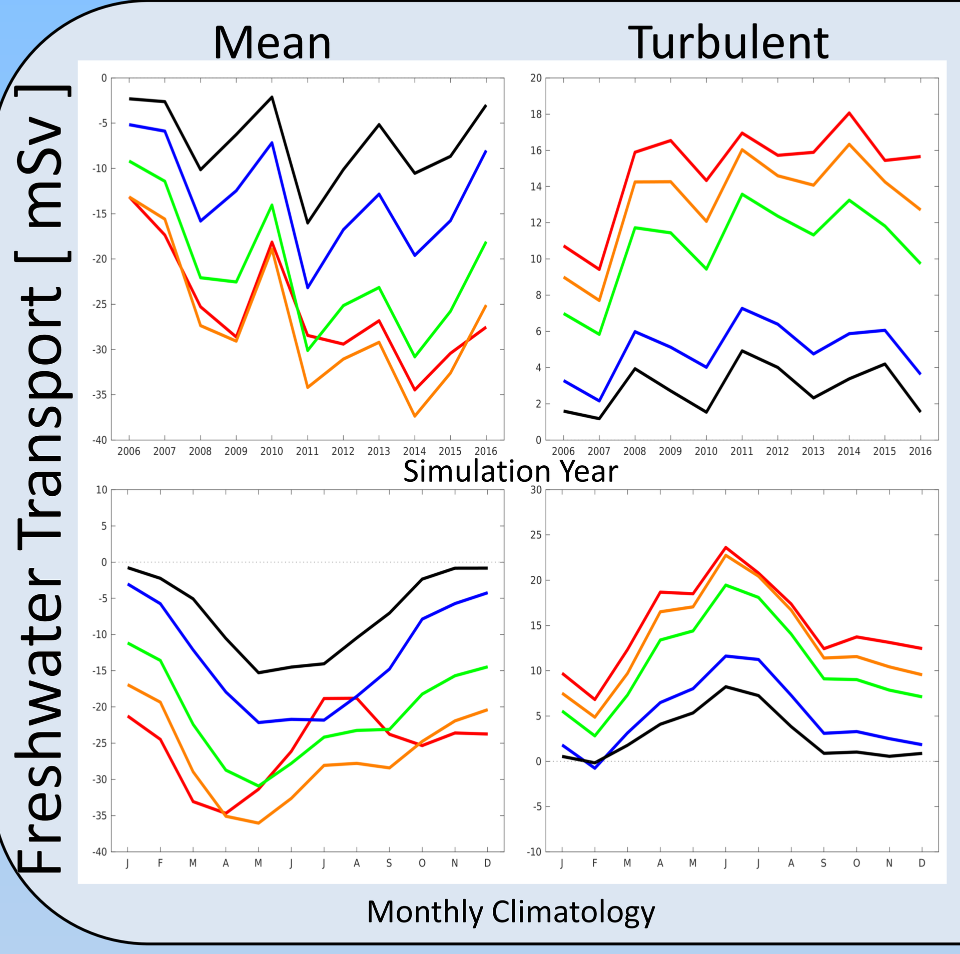


Mean freshwater transport:
- Shallow isobaths: large onshore transport
- Stronger transport in later years
- Minimal seasonal cycle

Turbulent freshwater transport:
- Some offshore transport
- Little seasonal cycle

Net freshwater transport:
- 500m: onshore 23 mSv
- 2000m: onshore 1.3 mSv

Northern Labrador

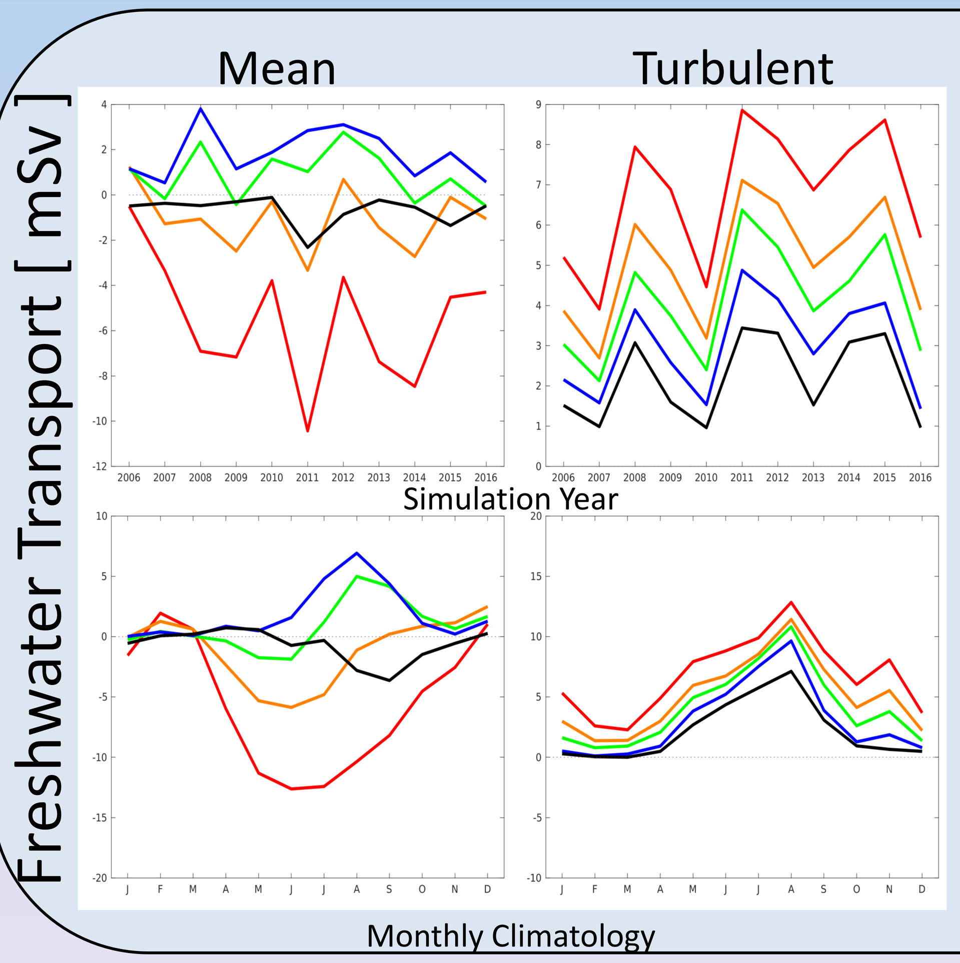


Mean transport:
- Strong onshore transport
- High inter-annual variability
- Seasonal cycle

Turbulent transport:
- Strong offshore transport
- Strong seasonal cycle

Net transport:
- 500m: onshore 10 mSv
- 2000m: onshore 4 mSv
- Seasonal cycles out of phase

Southern Labrador



Mean transport:
- Primarily onshore
- Low amounts of transport
- Seasonal cycle depends on isobath

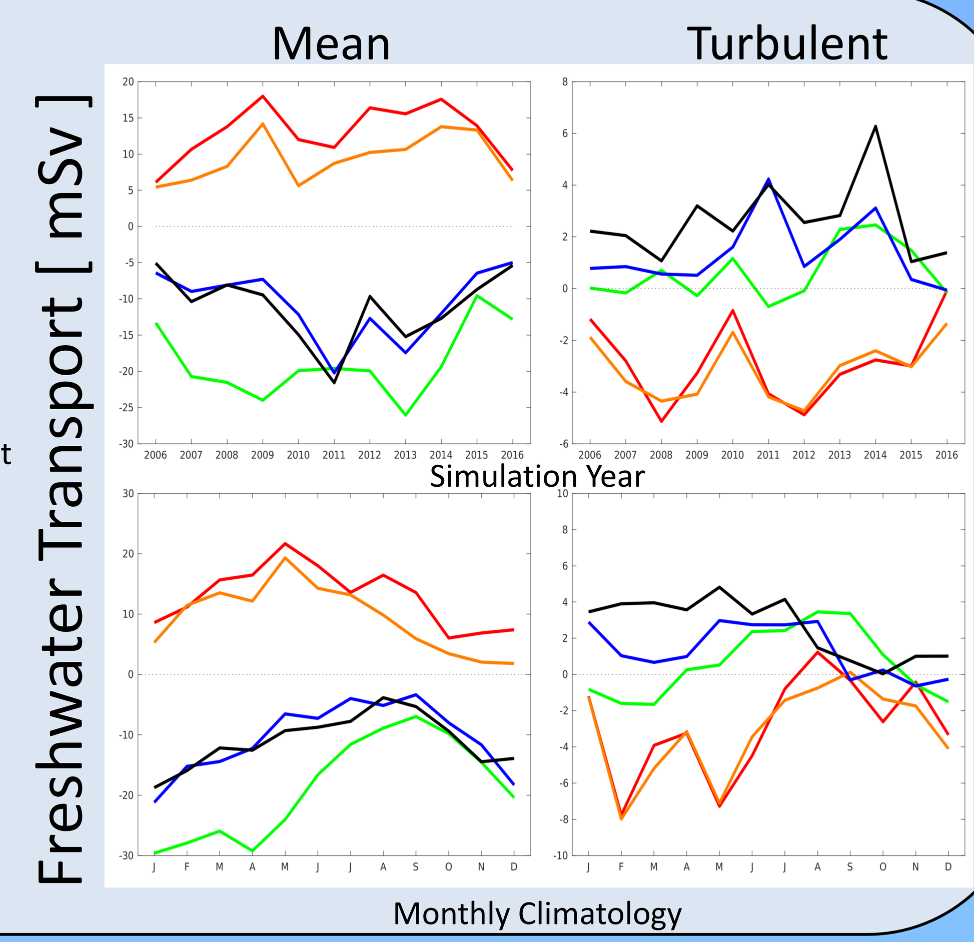
Turbulent transport:
- Stronger than mean transport
- Offshore
- Seasonal cycle: Max in summer

Net transport:
- 500m : offshore 1.5 mSv
- 2000m: onshore 1.5 mSv

Key Points

1. Large amounts of freshwater released from West Greenland Current
2. Other regions provide a saline water flux to the Labrador Sea
3. Many regions have a clear seasonal cycle of freshwater exchange
4. Large fluxes across shallow isobaths, often far less at depth
5. Across all regions, Polar Water transfers ~9 mSv across the 2000m isobath
6. Mean transport generally stronger than turbulent transport
7. Turbulent and mean transport often act in opposite directions

Davis Strait

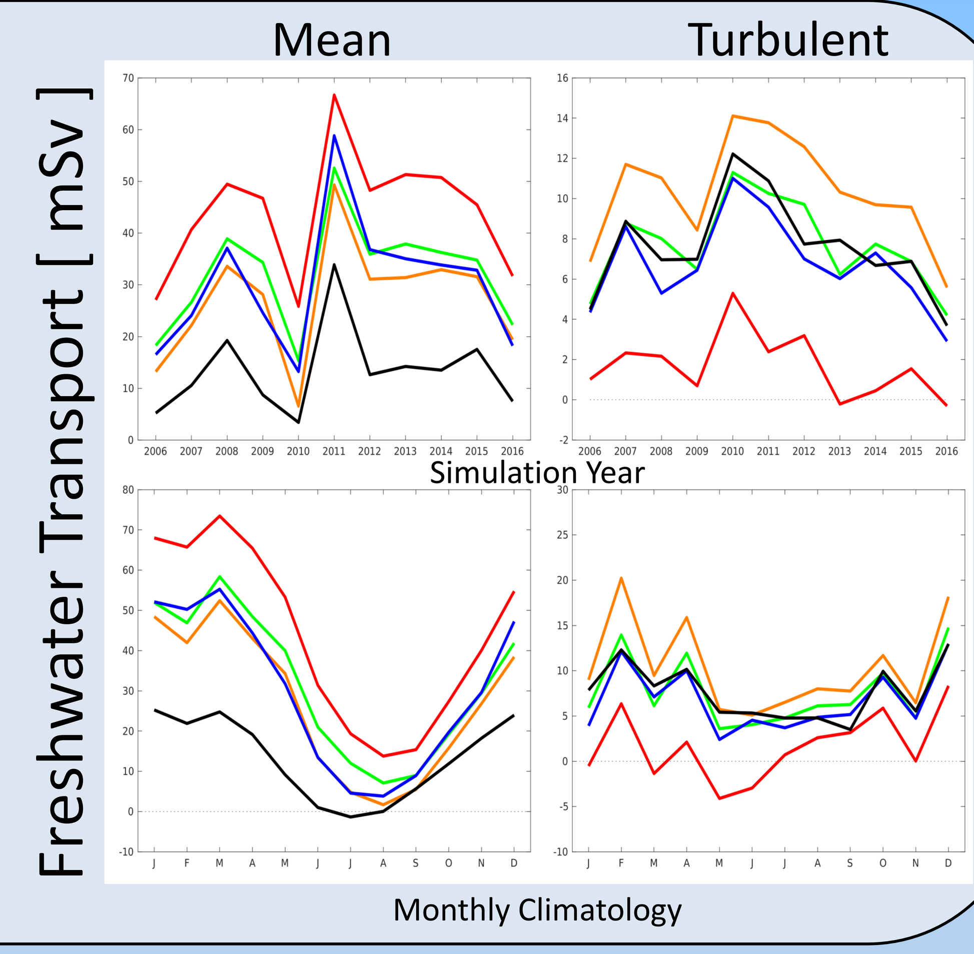


Mean freshwater transport:
- Offshore at shallow isobaths
- Onshore across deeper isobaths
- Clear season signals

Turbulent freshwater transport:
- Opposite direction as mean transport
- Low transport
- Some seasonal signal

Net freshwater transport:
- 500m: offshore 10 mSv
- 2000m: onshore 7.5 mSv

West Greenland

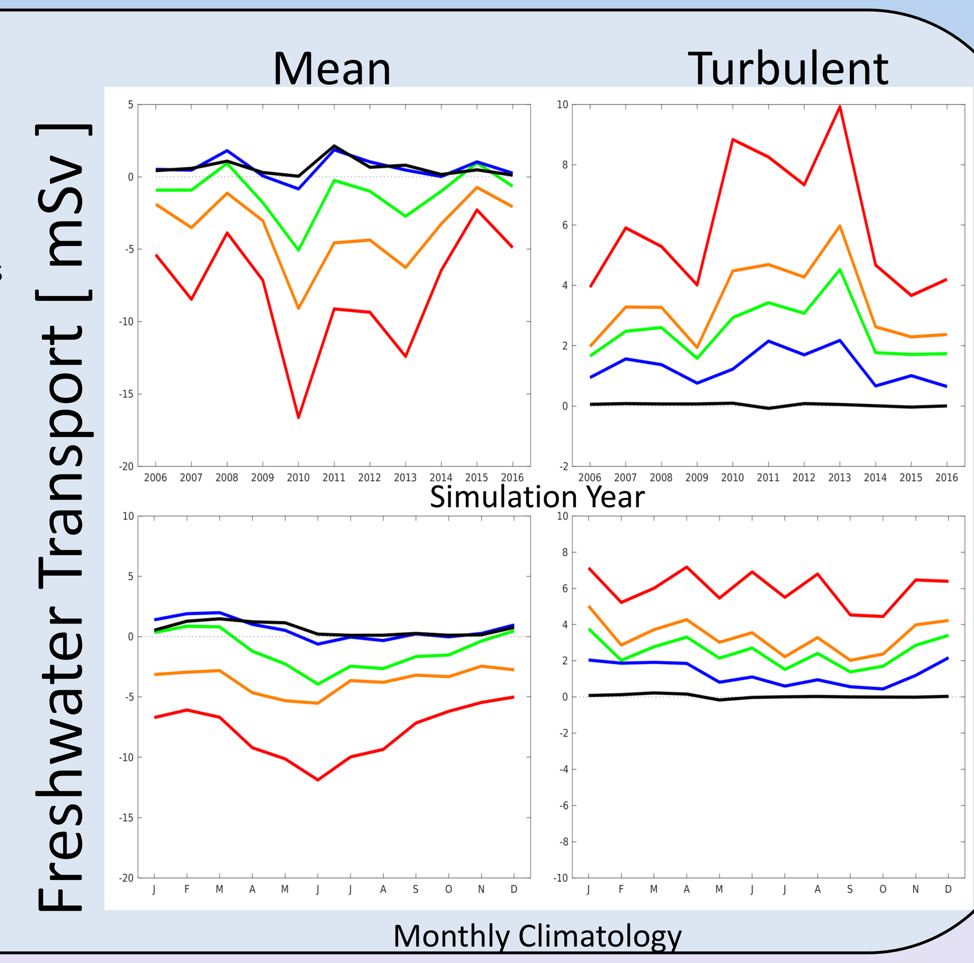


Mean transport:
- Offshore transport of freshwater
- Very strong
- Large inter-annual variability
- Clear and strong seasonality

Turbulent transport:
- Offshore transport of freshwater
- Limited seasonality
- 500m has low transport, others are greater

Net transport:
- 500m:offshore 46 mSv
- 2000m: offshore 21 mSv
- Transport terms in same direction

East Greenland



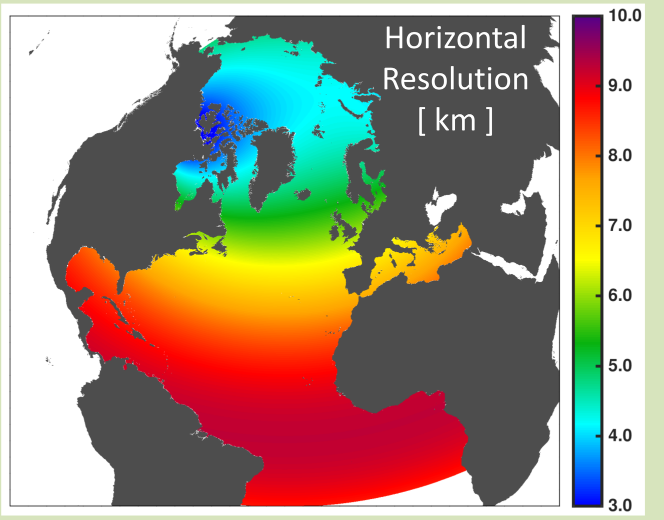
Mean transport:
- Offshore transport at shallow depths
- Onshore transport at deeper regions
- High variability at shallow depths
- Low seasonality

Turbulent transport:
- Offshore transport
- Little exchange across 2000m
- No seasonality

Net transport:
- 500m: onshore 1.8 mSv
- 2000m: offshore 0.6 mSv

Numerical Simulation

- Simulation performed using NEMO[4], an ocean model coupled with a sea-ice model
- Horizontal resolution was set to 1/12° with 50 vertical levels
- Simulations were forced by the high spatial and temporal resolution Canadian Meteorological Centre's Global Deterministic Prediction System[5]
- Initial conditions were taken from GLORYS 2v3: SSH, horizontal velocities, salinity, and temperature
- Boundary conditions were also taken from GLORYS 2v3
- The simulation was integrated from 2002 until the end of 2016. Output saved every 5 days
- First years used as a spin-up state; first year of analysis was 2006



Methods

- Freshwater was calculated based on a salinity reference of 34.8
- Freshwater transport was calculated for mean and turbulent transport
- Mean transport was taken over a 25 day moving mean.
- Turbulent transport was the deviation from the mean state
- Freshwater transport was integrated across 5 isobaths and 6 sections
- Freshwater was calculated for Polar Water: density < 27.68 kg/m^3, salinity < 34.8, any temperature

Freshwater Calculations

$$FW = \frac{Ref - Salinity}{Ref} : Ref = 34.8$$

$$Mean\ Velocity = \sqrt{U_{ave}^2 + V_{ave}^2}$$

$$Turbulent\ Velocity = \sqrt{(U_{ave} - U)^2 + (V_{ave} - V)^2}$$

$$Cross\ Isobath\ Freshwater\ Flux = \oint FW \times Velocity\, dA$$

Citations:

[1] Cuny et al., 2005: Davis Strait volume, freshwater, and heat fluxes. *Deep Sea Research Part 1: Oceanographic Research Papers.* 52.3, 519-542

[2] Dickson et al., 2007: Current estimates of freshwater flux through Arctic and subarctic seas, *Progress in Oceanography*, 73, 210-230

[3] Straneo and Saucier, 2008b: The Arctic-Subarctic Exchange Through Hudson Strait, *Arctic-Subarctic Ocean Fluxes*, Springer, Dordrecht, 249-261

[4] Madec and the NEMO team, 2008: NEMO ocean engine, Technical Note, Institut Pierre-Simon Laplace, France

[5] Smith et al., 2014: A new atmospheric dataset for forcing ice-ocean models: Evaluation of reforecasts using the Canadian global deterministic prediction system, *Quarterly Journal of the Royal Meteorological Society*, 140.680, 881-894