# The Arctic Ocean volume and heat transports in 2004-2010

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## 1. Introduction

Entire Arctic boundary through Bering, Davis, Fram Straits and Barents Sea Opening (BSO) has been monitored since 2004 (fig. 1). Gathering of all the data together allows for a comprehensive estimate of oceanic transports across the Arctic gateways.

**In this study, we focus on Oct. 2004 - May. 2010 and aim to**

- quantify volume & heat transport variabilities both on seasonal & inter-annual time scale.
- discuss reference values to calculate heat transports.

## 2. Data

- ~ 1,000 moored instruments in Davis, Fram, Bering Straits and BSO.
- 37 repeat CTD sections in BSO during Aug. 2004 - Jun. 2010.
- PIOMAS sea ice thickness & velocity output data.

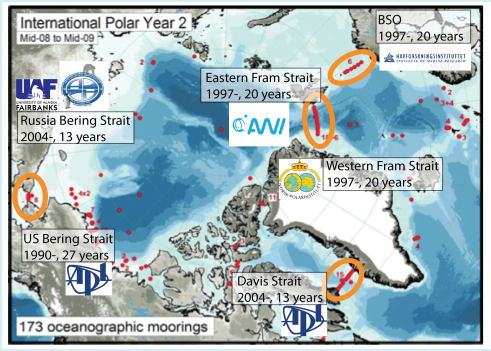



Fig. 1. Mooring array maintained during 2008-09. Modified from Dickson et al. [2009]

## 3. Method

### 3.1. Monthly TSV fields

- Hourly data are lowpass filtered with a 27 days cutoff Butteworth filter.
- Data gaps are filled by its mean annual cycle.
- Linear interpolation is applied for vertically and horizontally (fig. 2).

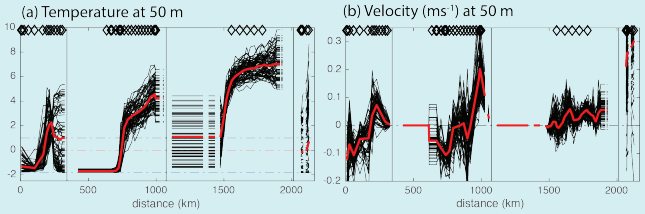



Fig. 2. Temperature and velocity at 50m. Monthly values in black, mean value in red.

### 3.2. Box inverse model

- Obtain volume conserved velocity fields for 68 consecutive months.

1. Provide first guesses for each parameter.
   - Ocean circulation , Sea ice (PIOMAS) , surface FW input (set 180 mSv).
2. 1,283 unknowns are derived from 12 constraints.
   - Mass & salt constrains for 5 defined layers & whole layer.
   - Unknowns: Bottom vel., Sea ice vel.,Diapyncal vel., Surface FW input.

## 4. Results

### 4.1. Volume conserved velocity field

- Initial monthly imbalances are -3.0±2.2 Sv.
- Most of the adjustment happens in the Fram Strait and BSO (fig. 3).
- The velocity field captures major currents across the gateways (fig. 3).

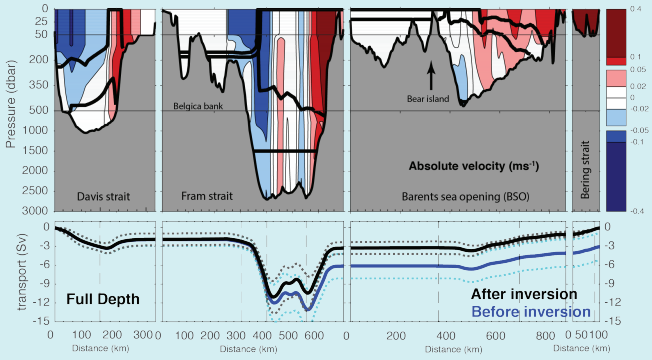



Fig. 3. Inverted velocity section averaged over the 68 months and associated cumulative full depth volume transport (Sv). Dashed lines show the standard deviation.

### 4.2. Volume transport variabilities

- Net transports is almost zero in each month (fig. 4).
- Seasonality (fig. 4, table 1).

  e.g. strong BSO inflow in winter, strong Bering Strait inflow in summer.

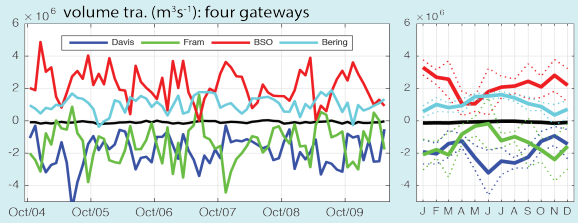



Table 1.Gateway volume transports statistics (Sv).

| (Sv) | long term | JFM | JAS |
|---|---|---|---|
| Davis | -1.9±1.0 | -1.8 | -2.4 |
| Fram | -1.4±1.2 | -2.0 | -1.2 |
| BSO | 2.2±1.0 | +2.9 | +2.2 |
| Bering | 1.0±0.5 | +0.8 | +1.4 |

Fig. 4. Monthly gateway volume transports ($m^3s^{-1}$) and its mean seasonal cycle.

### 4.3. Heat transport variabilities

- Oceanic plus sea ice heat transport is 180±57 TW (fig.5).
- Seasonality: ~250 TW in November, ~100 TW in May (fig.5).
- Inter-annual variability: 196±50 TW in 2004-05, 165±71 TW in 2007-08 (fig. 5).

*12 monthly ave & std from Oct. to following Sep.

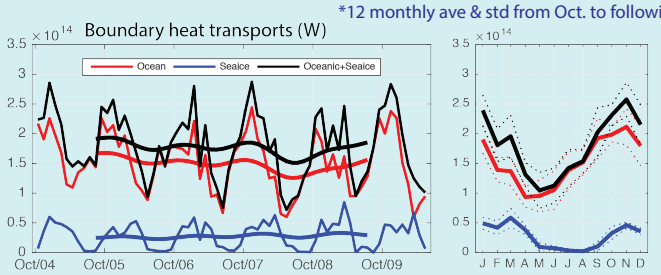
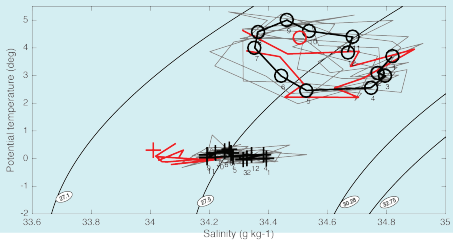



Fig. 5. Boundary heat transports (W) and its mean seasonal cycle. Bold line shows smooth time series using 21 point Hanning filter.

### 4.4. Inflow and outflow T&S

- Inflow T&S varies by 3.0˚C and 0.5 (g $kg^{-1}$; fig. 6).
- The Arctic cools and freshens the inflow of 10.3±1.6 Sv by 3.53±0.89˚C in temperature and 0.32±0.19 in salinity, respectively (fig. 6).

Fig. 6. Mean 12 month values of volume transport weighted potential temperature and salinity in inflow (circle) and outflow (crossed). Individual month estimates in grey, and estimates of Tsubouchi et al [2012 & in review] in red.




## 5. What changes by changing referece temperature?

- Total heat transport does not change (fig. 7).
- Partial temperature transport in the section does change (fig. 7).

  e.g. WSC: 33±14 TW-eq (1.01±0.18˚C), 113±34 TW-eq (-1.8˚C).

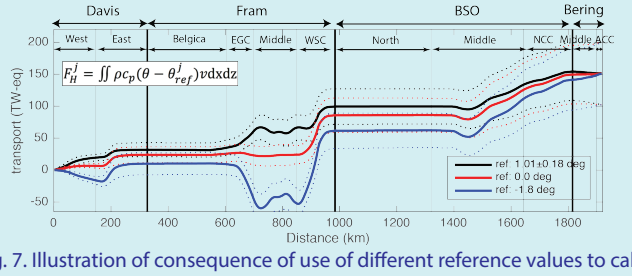



Fig. 7. Illustration of consequence of use of different reference values to calculate heat transports.

## 6. Summary

- Quantification of volume transport variabilities in the four Arctic gateways under mass and salt constraints using box inverse model.
- The oceanic plus sea ice heat transport is 180±57 TW.
- It's seasonal variability: ~250 TW in Nov., ~100 TW in May.
- It's inter-annual variability: 196±56 TW in 2004-05, 165±71 TW in 2007-08.

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