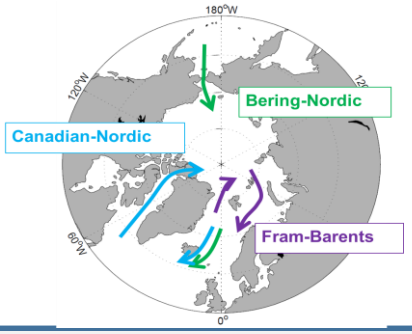
On the inter-connectivity of volume transports through Arctic Straits

By Agatha de Boer, Estanislao Gavilan Pascual-Ahuir, David Stevens, Leon Chafik, David Hutchinson, Qiong Zhang, Louise Sime, Andrew Willmott.

Motivation: Given that the Arctic Ocean is a closed basin with volume roughly conserved on annual timescales, the strait flows cannot behave independently. But how are they inter-dependent?

Result 1: In both global coupled climate models, HiGEM1.1 and HadGEM3, **strong correlations were found between the annual volume transports through:**

1) Bering Strait and Nordic Seas, **HiGEM, r = -0.8; HadGEM, r = -0.6**
2) Bering Strait and Canadian Arctic Arcipelago (CAA), **HiGEM, r = -0.7; HadGEM, r = -0.9**
3) Fram Strait and Barents Sea, **HiGEM, r = -0.9; HadGEM, r = -0.5**



Result 2: The Bering-Nordic and Canadian-Nordic correlations can be partially explained as a simultaneous response to external forcing such as the Arctic Oscillation (AO). However, the AO explains less than half the variance in these strait transports. **Thus external non-causal reasons behind the correlations exist, but their role is limited.**

Result 3: A preliminary process study in a high resolution barotropic ocean model (NEMO), with idealized Arctic Basin, suggest that **Bering strait transport variability is flushed out in the Nordic Seas because of the wide Eastern Arctic shelf and deep Fram Strait channel** - otherwise it would have been adjusted in the CAA.

Conclusion: Arctic strait volume transports depend not only on local forcing, but also on how other strait flows are forced and vary. In order to predict future Arctic strait transport variability, we need better understanding of how and on which timescale the straits adapt to anomolous transport in other straits, and what is the role of stratification, winds, and bathymetry on this.

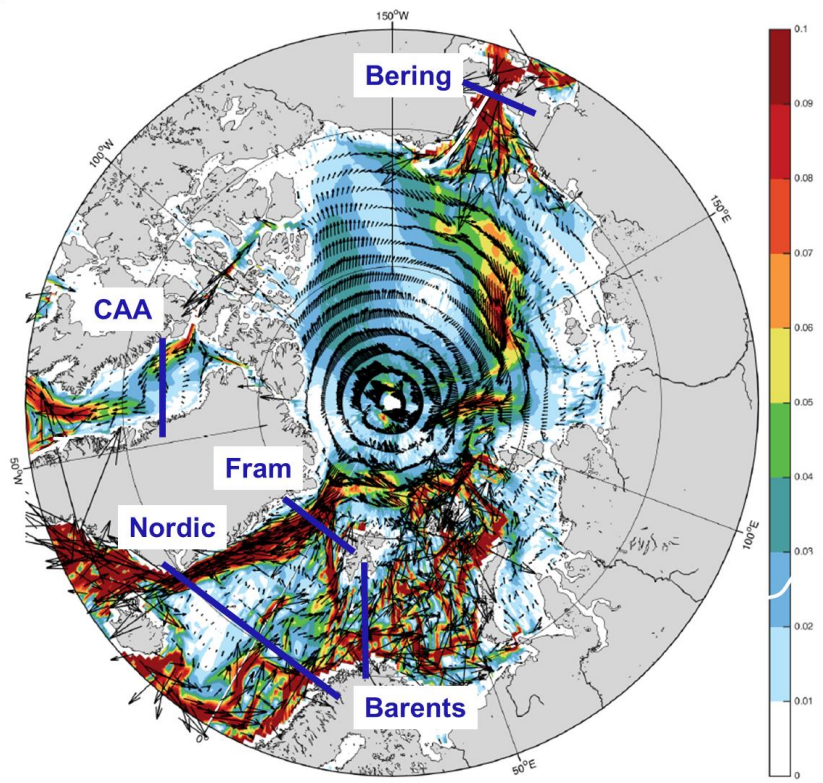
Abstract ID: 2704
EGU2020 OS1.11: Changes in the Arctic Ocean, sea ice and subarctic seas systems: Observations, Models and Perspectives

Bolin Centre for Climate Research | Stockholm University

Details of straits

Five straits were considered in this study:

- Bering strait,
- Canadian Arctic Archipelago (CAA),
- Nordic Seas throughflow,
- Fram Strait
- Barents Sea Opening.



(colors and arrows are strength and direction of surface currents in HiGEM - not of importance at this point)

Details of models

Two climate models were used to calculate correlations between the annual variability in the volume transport through the five straits**:**

HiGEM1.1

- Ocean resolution 1/3° in both directions
- 40 depth levels
- 130 year control run
- 1985 forcing

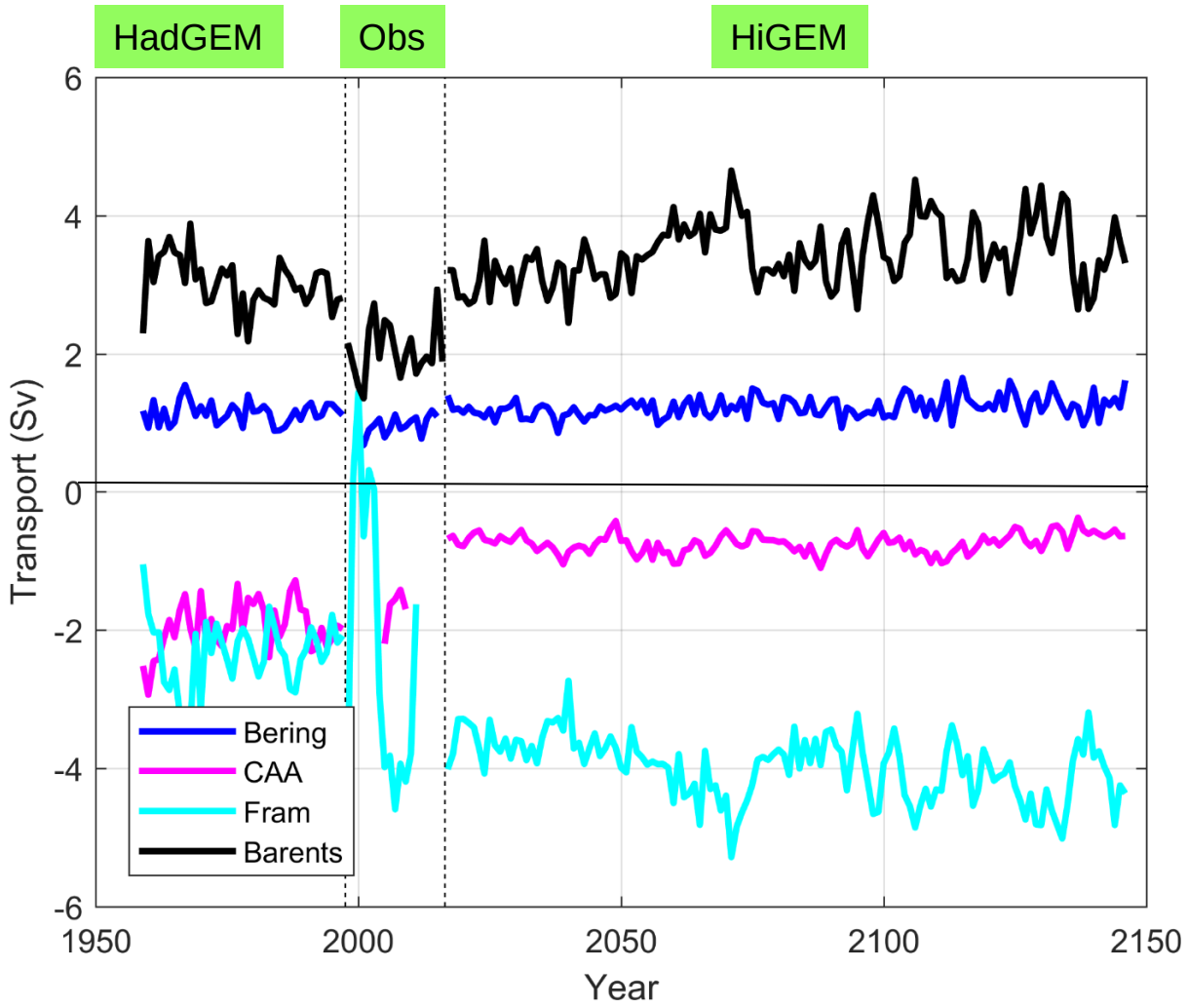
HadGEM3

- Ocean resolution 1/10° in both directions
- 75 depth levels
- 39 year control run
- 1950's forcing

Abstract ID: 2704
EGU2020 OS1.11: Changes in the Arctic Ocean, sea ice and subarctic seas systems: Observations, Models and Perspectives

Bolin Centre for Climate Research
Stockholm University

Volume transports in observations and the models



(only observations correspond to actual years)

Sources of observations:
Bering Strait (online, ref: Woodgate 2018), Fram Strait (from von Appen, ref: Beszczynska-Möller et al. 2015), Davis Strait (from Curry, ref: Curry et al., 2013), and Barents Sea (from Ingvaldsen, ref: Ingvaldsen et al., 2004)

=> Observations are not yet adequate for studying the correlations between interannual variability in Arctic Straits volume transports

(De Boer et al., 2018: https://doi.org/10.1029/2018JC014320)

Abstract ID: 2704
EGU2020 OS1.11: Changes in the Arctic Ocean, sea ice and subarctic seas systems: Observations, Models and Perspectives

Bolin Centre for Climate Research
Stockholm University

Inter-strait annual volume transport correlations

Shown are correlations significant at 95% confidence level, and |r|> 0.3

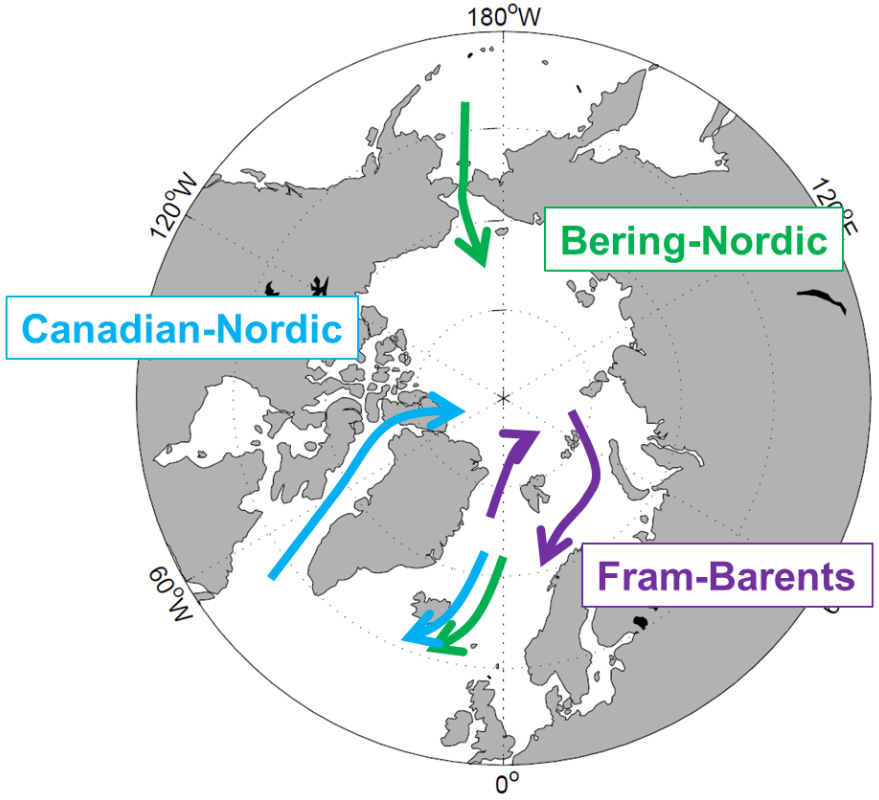
r < -0.5

r > 0.5

HiGEM1.1	Bering	Nordic	CAA	Fram	Barents
Bering	1	---	---	---	---
Nordic	-0.8	1	---	---	---
CAA		-0.7	1	---	---
Fram				1	---
Barents	-0.3	0.4	-0.4	-0.9	1

HadGEM3	Bering	Nordic	CAA	Fram	Barents
Bering	1	---	---	---	---
Nordic	-0.6	1	---	---	---
CAA		-0.9	1	---	---
Fram	-0.3	0.7	-0.7	1	---
Barents				-0.5	1

Three circled pairs: correlations where |r|>0.5 in both models and |r|>0.7 on average in the models

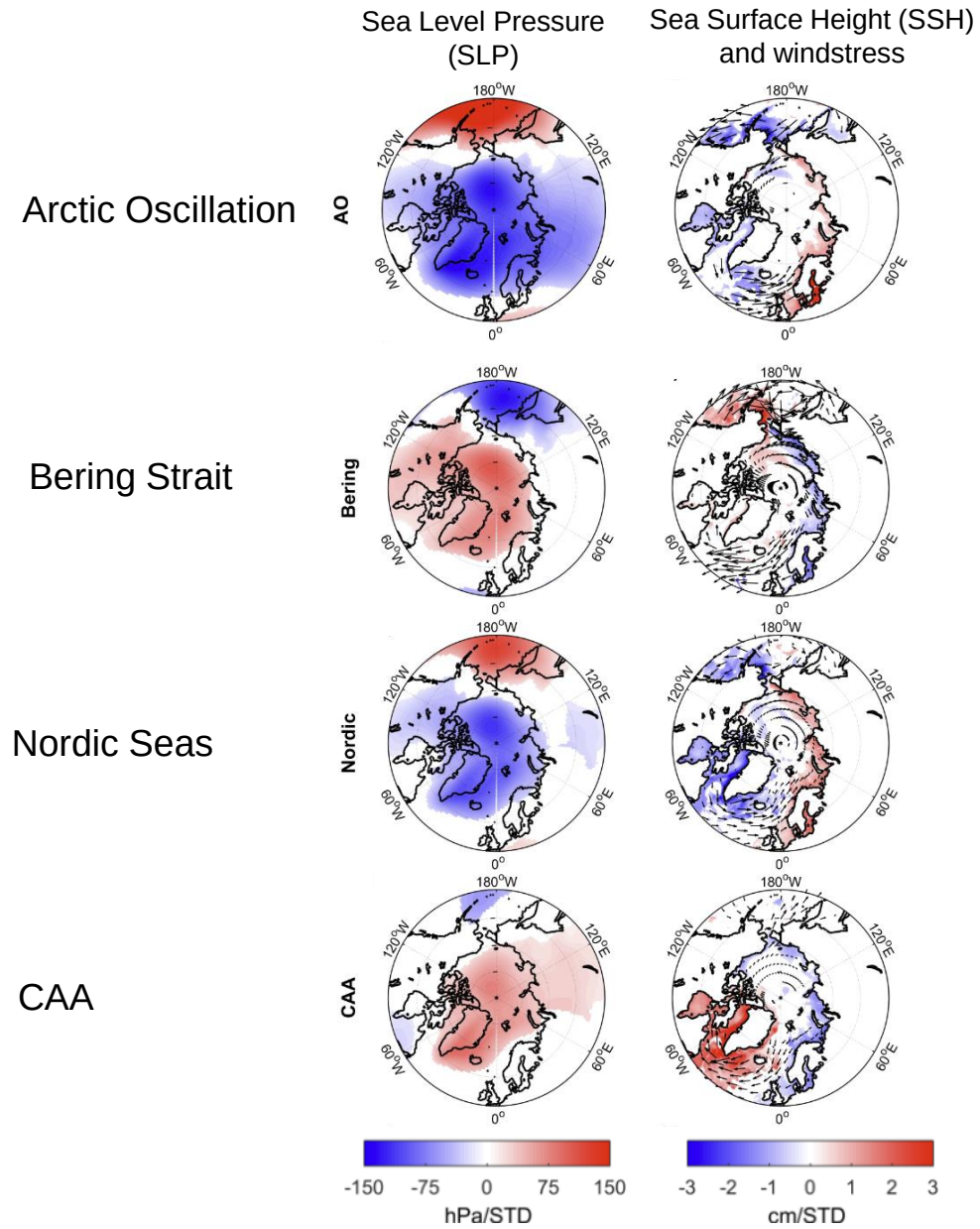


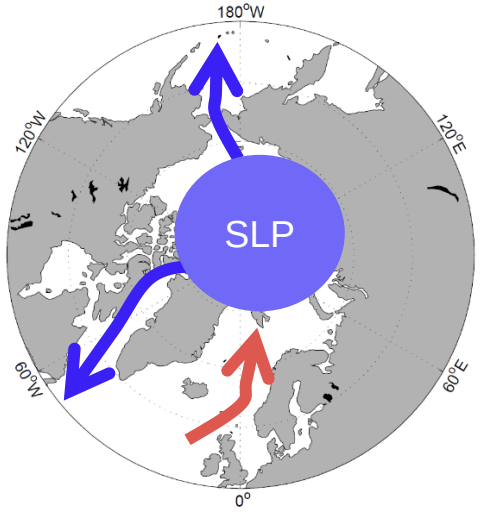
(De Boer et al., 2018: https://doi.org/10.1029/2018JC014320)

Abstract ID: 2704
EGU2020 OS1.11: Changes in the Arctic Ocean, sea ice and subarctic seas systems: Observations, Models and Perspectives

Bolin Centre for Climate Research
Stockholm University

Regression of AO and strait transports on SLP, SSH and windstress





Low Sea Level Pressure in central Arctic is associated with:

+ Arctic Oscillation

- Bering flow anomaly

- CAA flow anomaly

+ Nordic Seas flow anomaly

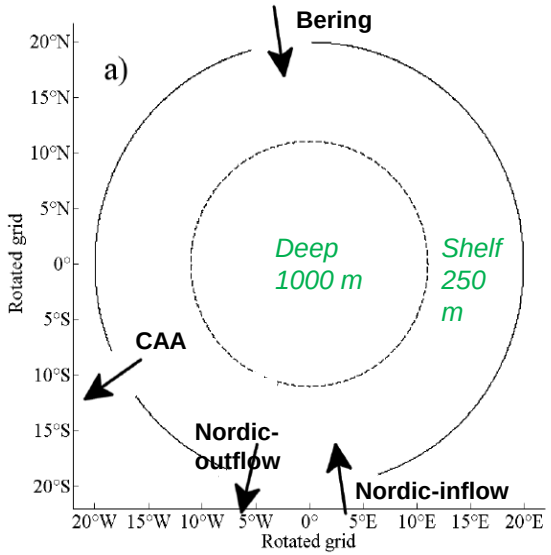
The AO could drive some correlations, but this is only half the story because:

1. The correlations between the AO and the straits transports are significant but relative weak (order 0.3-0.6).
2. The Bering and CAA transports are not significantly correlated. Thus, the Bering-Nordic and Canadian-Nordic transports must correlate at different frequencies.
3. It is not plausible that an independent external forcing would fortuitously create transport anomalies that perfectly compensate.

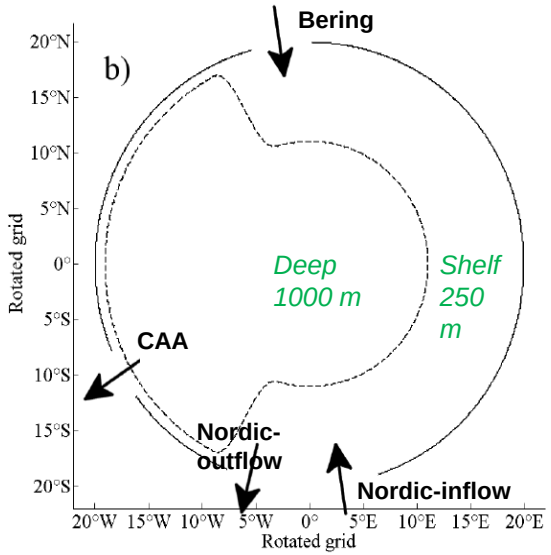
So what else determines the specific transport correlations in straits?

To investigate the role of bathymetry in strait connectivity, we determine the response of the CAA and Nordic Seas transports to a 0.8 Sv perturbation in the Bering Strait inflow, in three idealized bathymetric setups of NEMO.

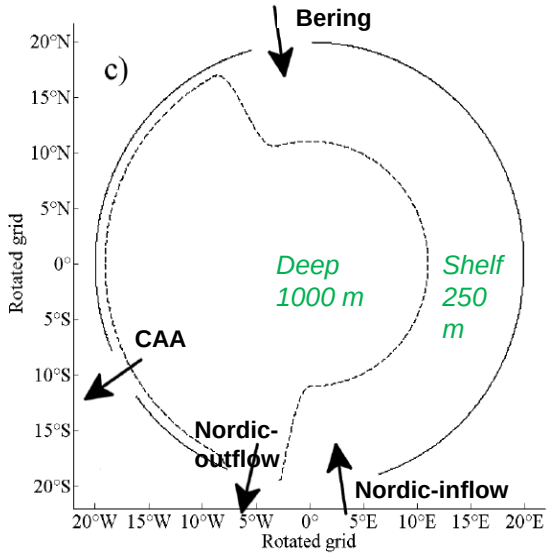
Uniform-width shelf



Irregular-width shelf



Irregular-width shelf, deep Nordic outflow



Model details: NEMO3.6 ocean model

- Barotropic, no wind forcing
- 1/10° × 1/10° horizontal resolution with 8 vertical levels
- Flather open boundary condition used
- Initial strait transports set to HiGEM transports in corresponding straits.

Abstract ID: 2704
EGU2020 OS1.11: Changes in the Arctic Ocean, sea ice and subarctic seas systems: Observations, Models and Perspectives

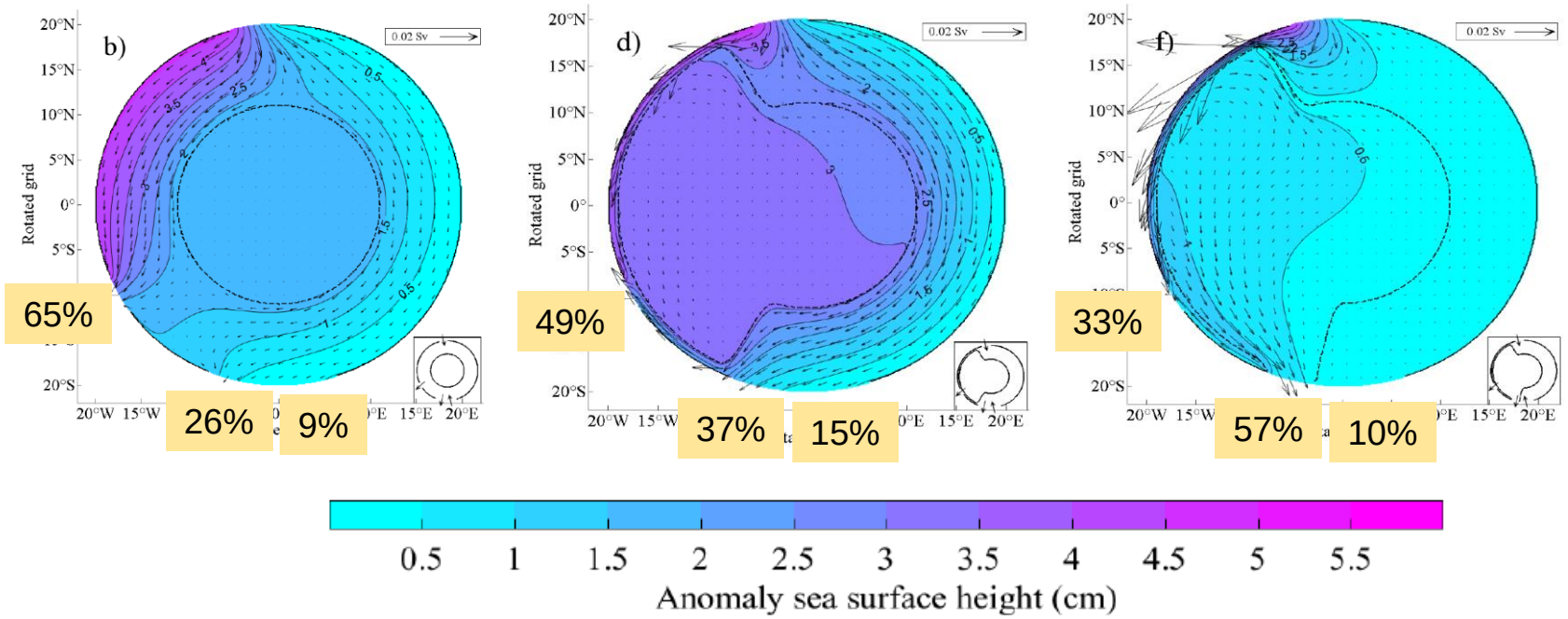
Bolin Centre for Climate Research
Stockholm University

Percentage response in other straits transports to a 0.8 Sv increased in Bering Strait transport

Uniform-width shelf

Irregular-width shelf

Irregular-width shelf, deep Nordic outflow



When including a more realistic shelf and a deep channel towards the Nordic seas, the adjustment of the Bering Strait anomaly is mostly in the Nordic Sea and in particular, the pseudo-Fram Strait.

(De Boer et al., 2018: https://doi.org/10.1029/2018JC014320)

Abstract ID: 2704
EGU2020 OS1.11: Changes in the Arctic Ocean, sea ice and subarctic seas systems: Observations, Models and Perspectives

Bolin Centre for Climate Research
Stockholm University

Conclusions and future perspective

Arctic strait transports are independently forced to some extent, but some variability must be the result of adaption to the transport anomalies in other straits.

In this study, we show that the volume transports through the Bering Strait and Canadian Archipelago are both correlated to the Nordic Seas transport but not to each other.

Correlations are partially explained by simultaneous response to, for example, the Arctic Oscillation.

An initial study suggest that Bering Strait transport anomalies are compensated in the Nordic Seas because of the depth in the Fram Strait and the Arctic shelf's form.

More details, such as role of the NAO and the AMOC and frequency analysis, can be found in De Boer et al., 2018 (doi.org/10.1029/2018JC014320).

In order to understand and predict future strait transports, many questions remain unanswered:

- For example, in which straits would an anomalous Nordic Seas transport (such as for instance forced by a shifted storm track) be compensated and why?
- What is the role of stratification, bathymetry, and winds in the adaption to a strait transport anomaly.
- What kind of wave response leads to the adaptions?