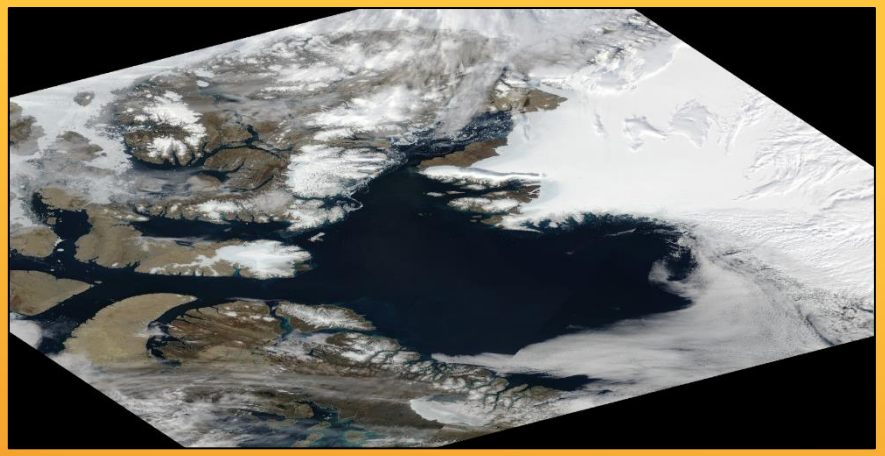
Reversal of Baffin Bay Transport Through Davis and Nares Strait Towards the Arctic Ocean



Paul G. Myers, Laura Castro de la Guardia, Chuanshuai Fu, Laura C. Gillard, Nathan Grivault, Xianmin Hu, Craig M. Lee[2], G.W.K. Moore[3], Clark Pennelly, Mads H. Ribergaard[4], Joy Romanski[5]

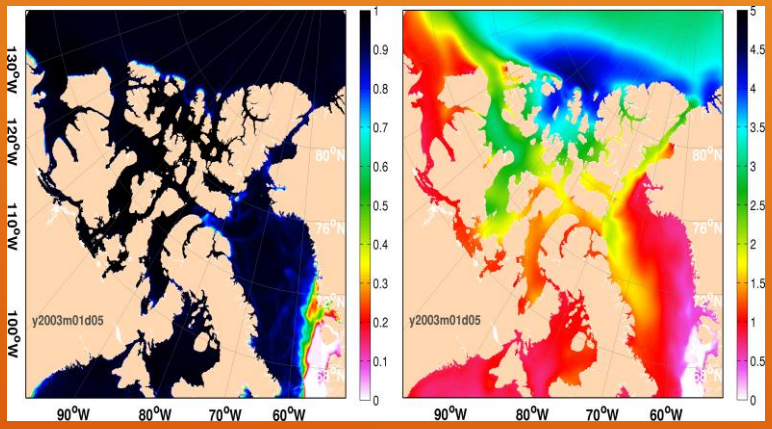
1 - Department of Earth and Atmospheric Sciences, University of Alberta

2 – Applied Physics Laboratory, University of Washington

3 - Department of Physics, University of Toronto

4 - Centre for Ocean and Ice, Danish Meteorological Institute

5 - NASA GISS, Columbia University Center for Climate Systems Research



ArcticNet

compute canada | calcul canada

MEOPAR

NSERC CRSNG

People. Discovery. Innovation.

UNIVERSITY OF ALBERTA

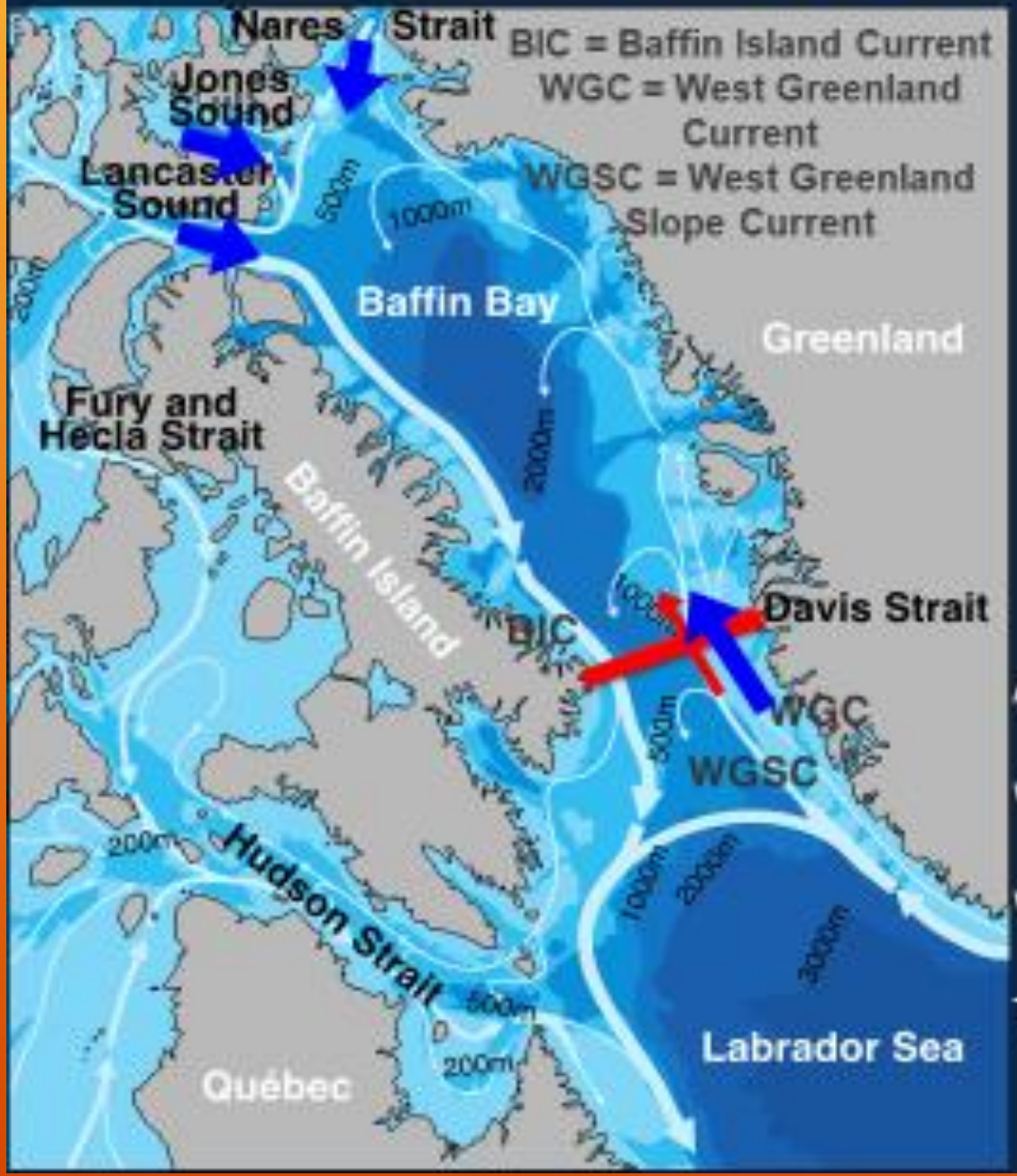
QUAECUMQUE VERA

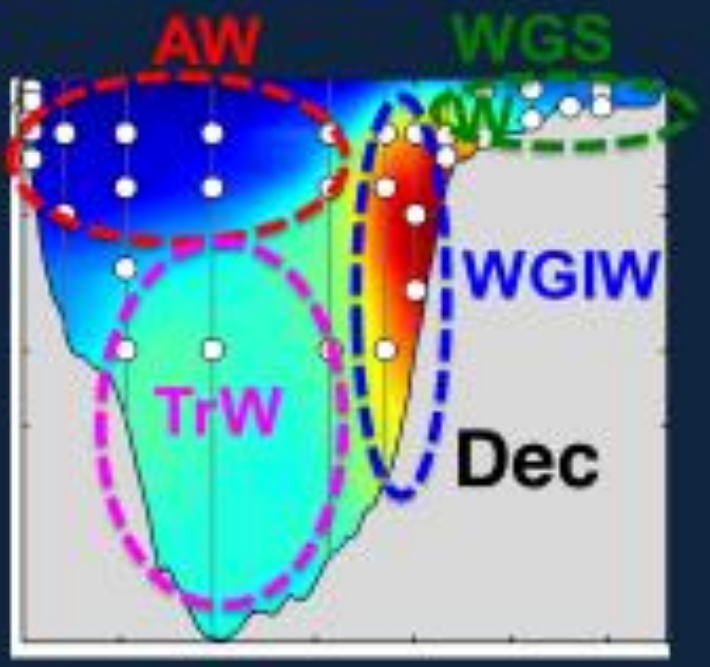
eas Earth & Atmospheric Sciences

OUTLINE

- Baffin Bay
- ANHA NEMO Configuration
- The Signal at Davis Strait, December 2010
- Upstream Changes in the Labrador Sea
- Baffin Bay Impacts
- Discussion
- Summary

Circulation and Water Masses





Water Masses

Arctic Water (AW)
- ≤ 2 °C S < 33.7

West Greenland Irminger Water (WGIW)
- > 2°C S > 34.1

West Greenland Shelf Water (WGSW)
- < 7°C S < 34.1

Transitional Water (TrW)
- < 2°C S > 33.7

ANHA: Arctic and Northern Hemisphere Atlantic

ANHA12 & ANHA4

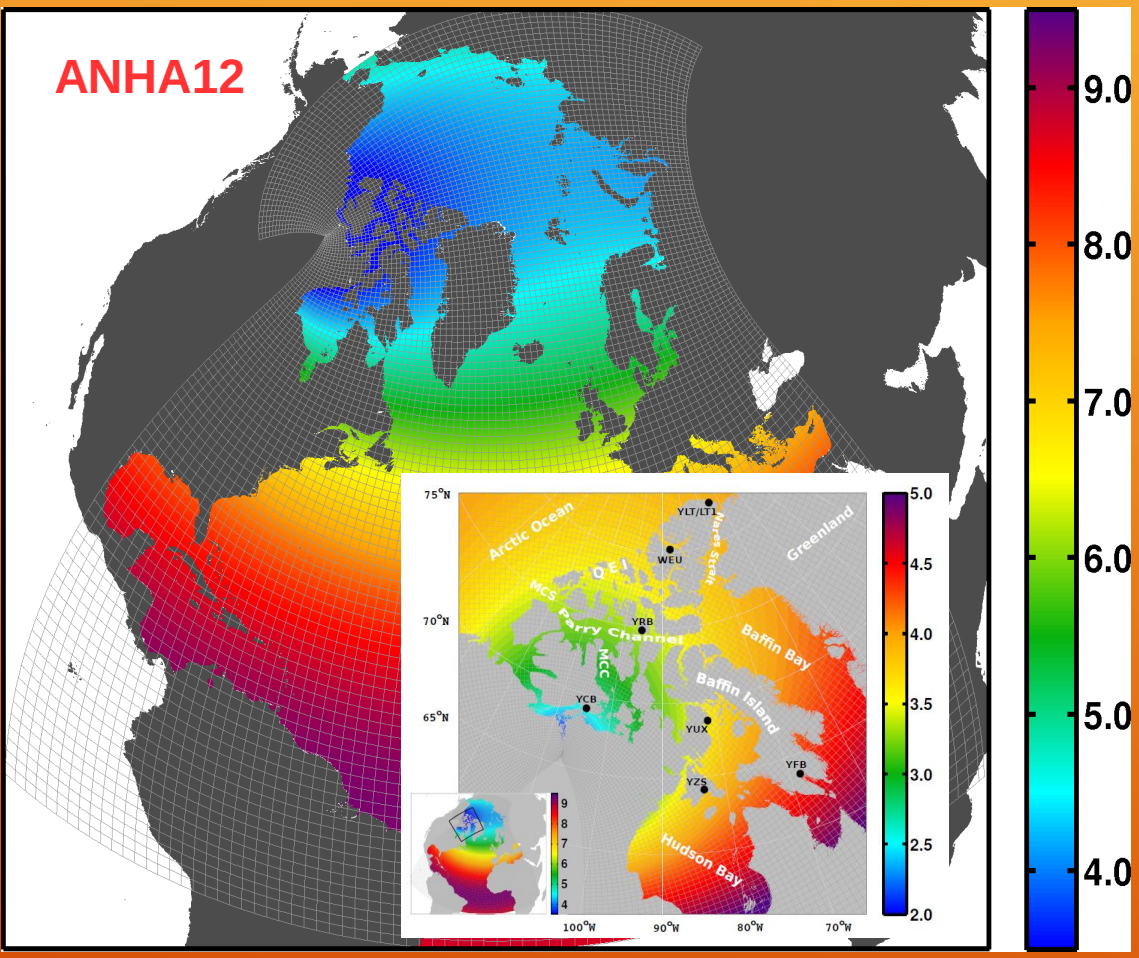
Model : NEMO 3.4
LIM2 + EVP

Resolution : 1/12 degree
¼ degree

Mesh : 1632 x 2400
544 x 800
50 levels

LS : ~ 5 km
~ 15 km

CAA : ~ 4 km
~10 km



Initialization:

3D T, S, U and V (GLORYS2v3, Jan02)
Sea Ice

Atmospheric forcing:

T2, Q2, U10, V10
Precipitation
Radiation (SW & LW)

CGRF hourly 33km

Snow: Calculated from precipitation

Runoff: Dai and Trenberth inter-annual
Greenland Mass Loss (Bamber)
+ Iceberg Module

OBC: U, V, T and S (GLORYS2v3)

NO temperature & salinity restoring

Jan 2002 – Dec 2019

CGRF: CMC GDPS reforecasts
GDPS: Global Deterministic Prediction System

CMC: Canadian Meteorological Centre
GLORYS: GLobal Ocean ReanalYses and Simulations

ANHA4 | ANHA12

Volume Flux (Sv)

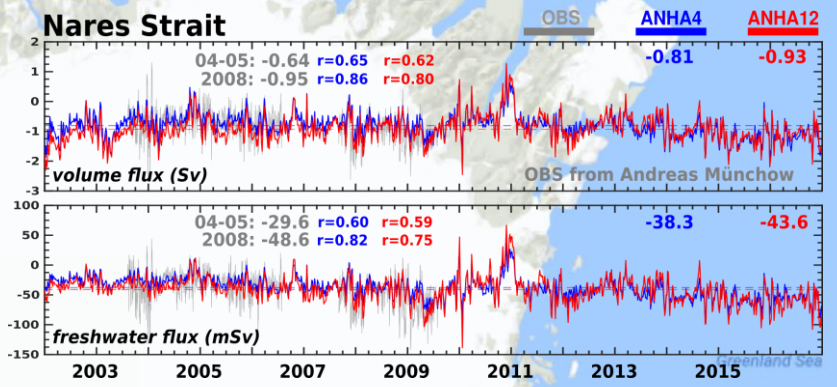
FW Flux (mSv)

0.81 | 0.93

37.4 | 41.5

0.64~0.95

29.6~48.6



0.12 | 0.01

5.7 | -0.2

0.66 | 0.71

0.47

33.1

50.1 | 52.7

Model vs Observations Transport Evaluation

top-600m

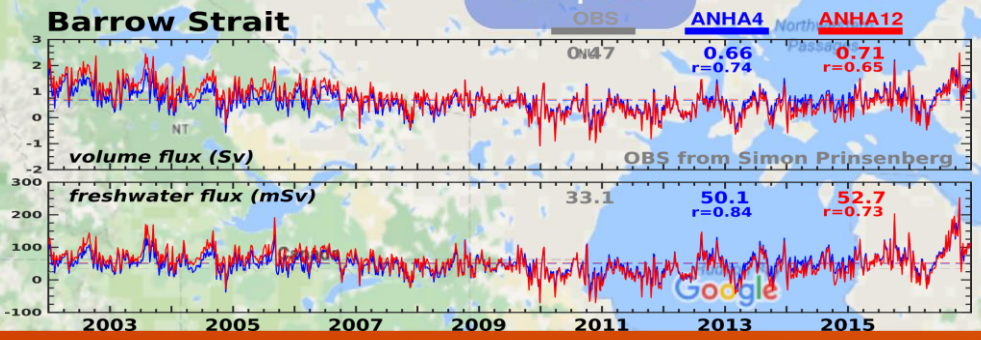
1.50 | 1.48

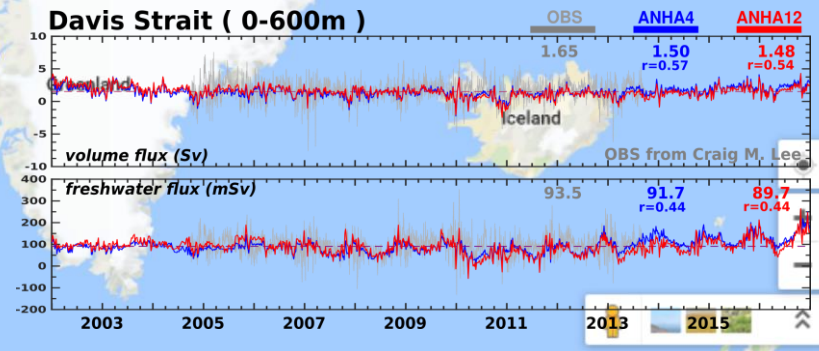
91.7 | 89.7

1.65 | 93.5

0.04 | 0.04

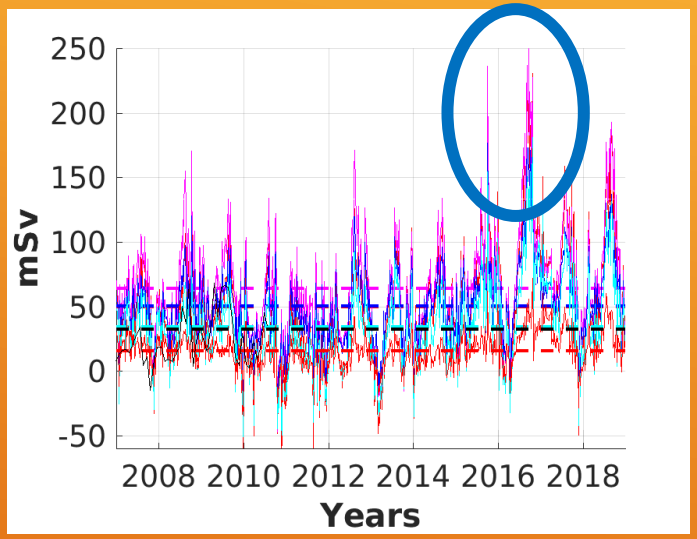
6.4 | 5.7



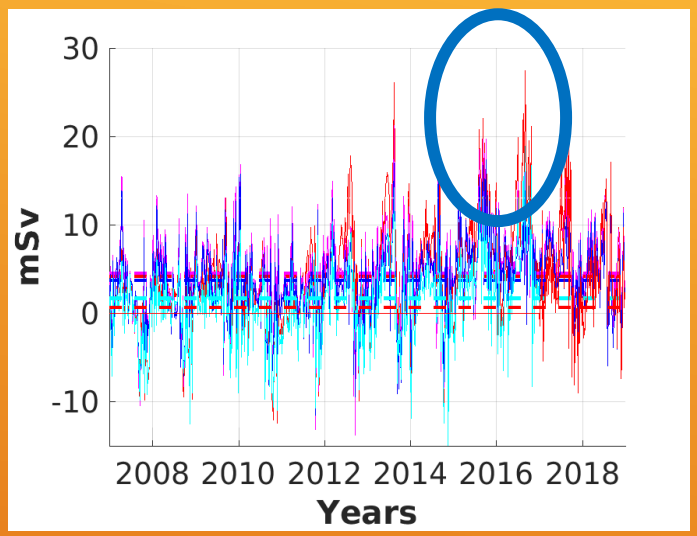


MODEL ARCTIC GATEWAY STRAIT FRESHWATER TRANSPORT (REL. TO 34.8)

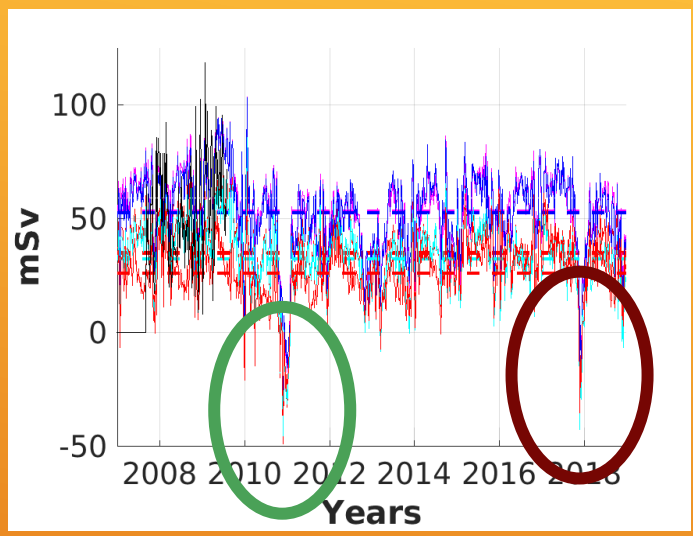
Barrow



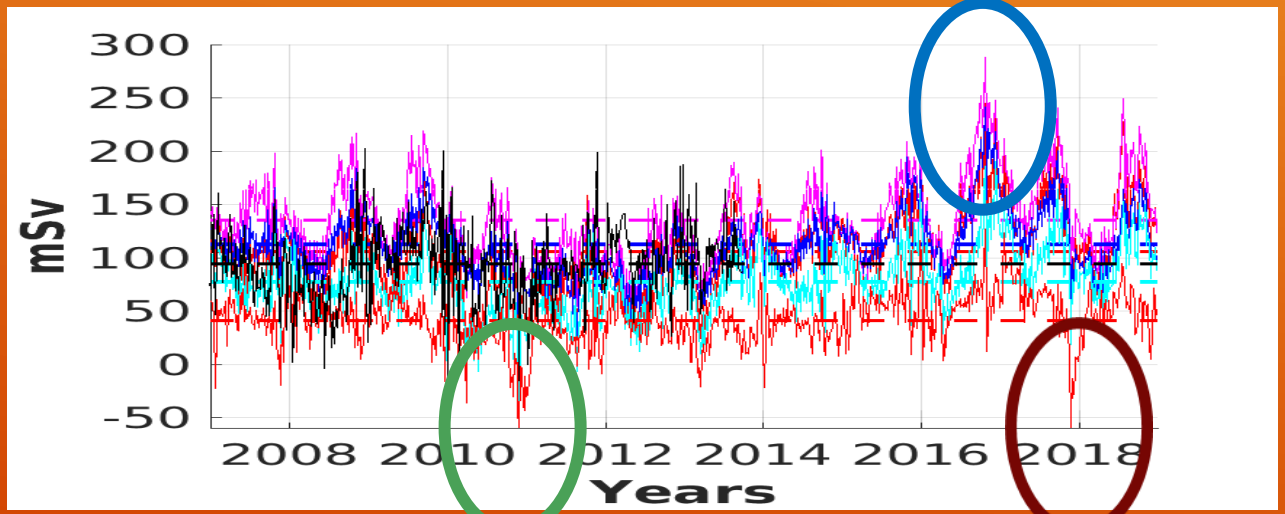
Jones Sound



Nares Strait



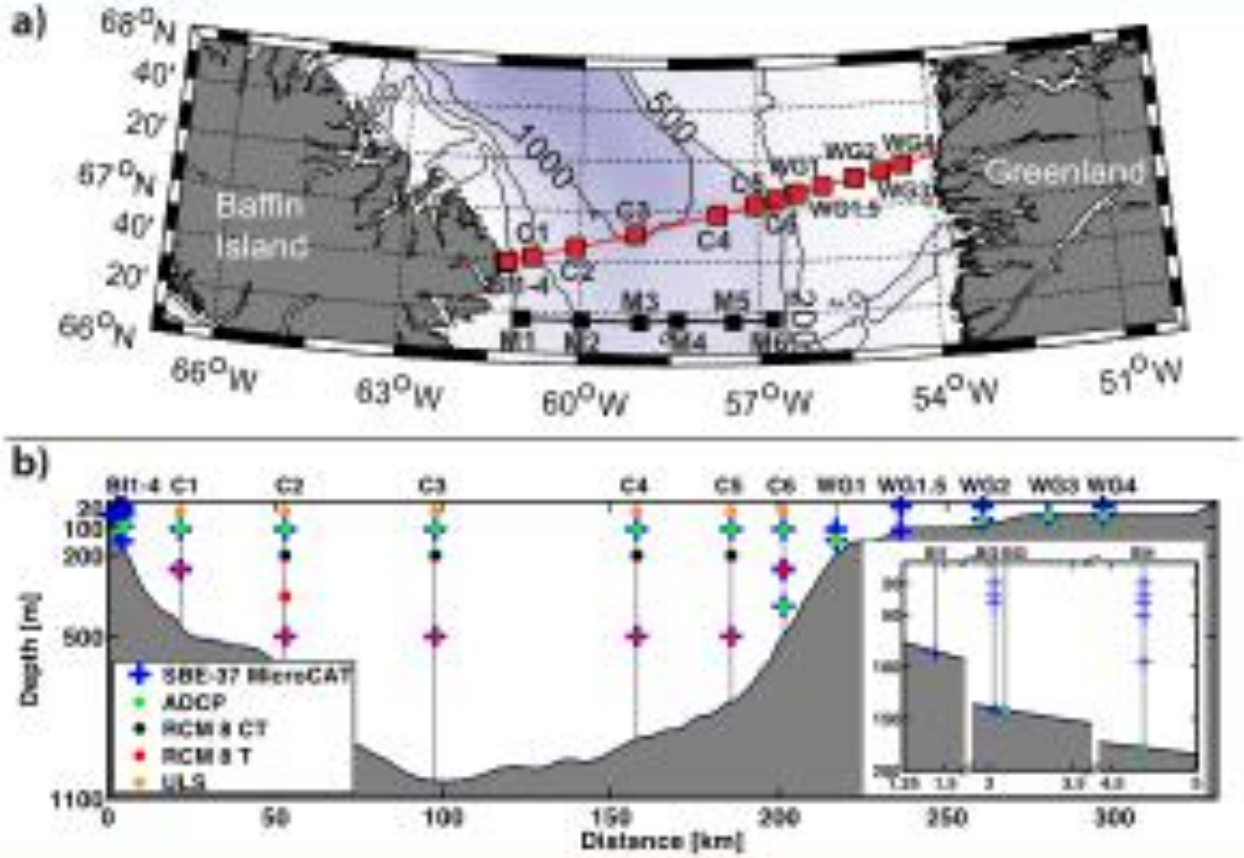
Davis Strait

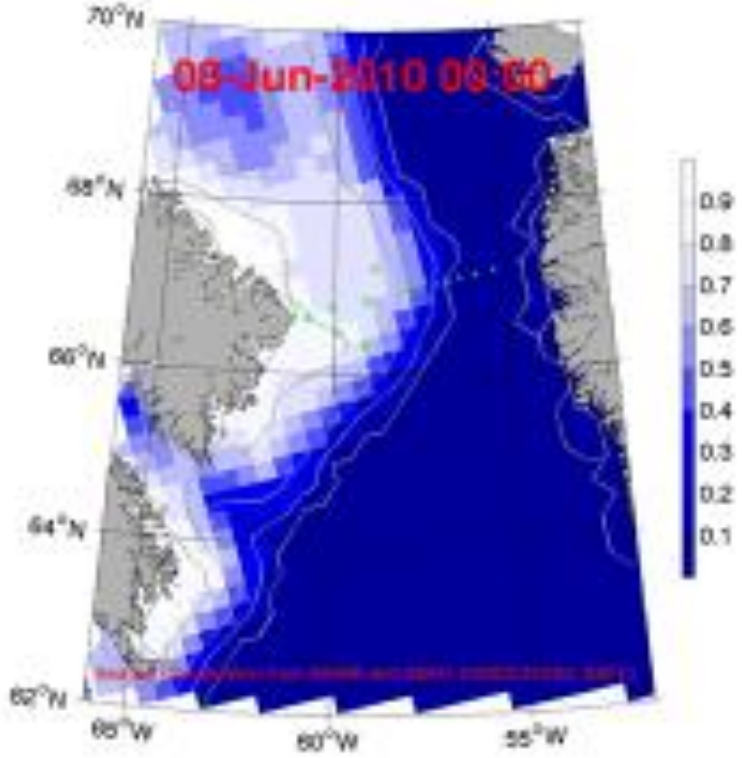


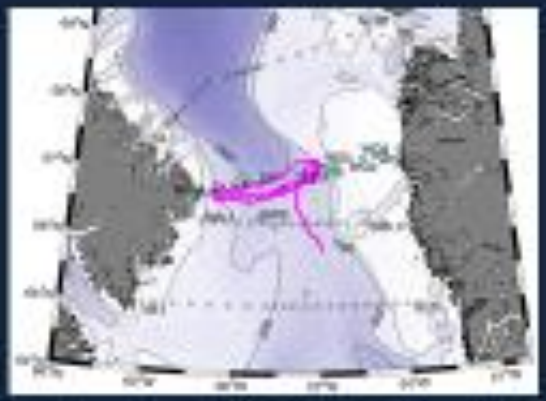
LEGEND

- Maroon – ERA5/HYPE/BT18
- Blue – ERA5/DT/BT12
- Cyan – GDPS/DT/BT12
  - All above with tides
- Red – ANHA12/DT/BT12
- Black - Obs

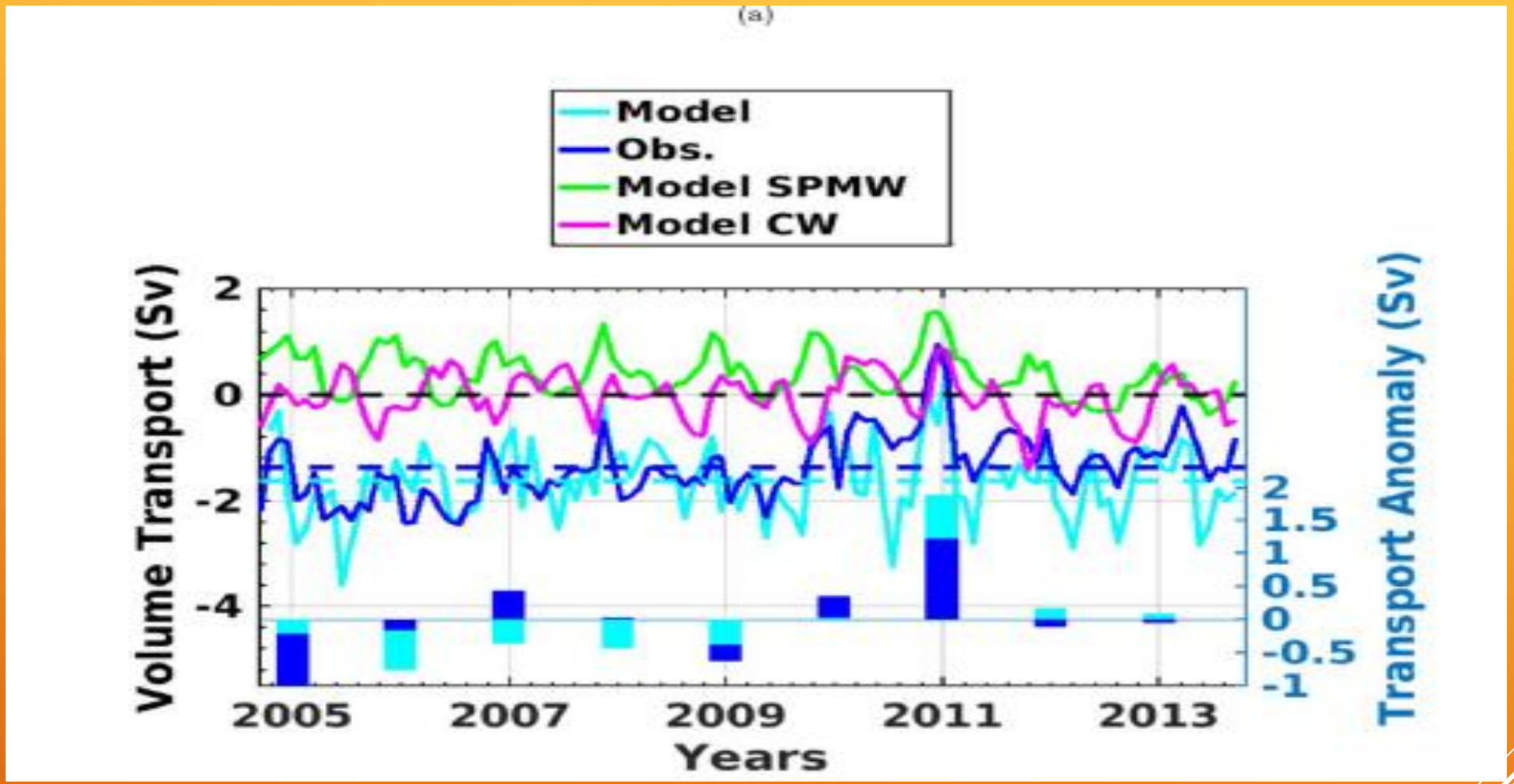
The Davis Strait Observational Program



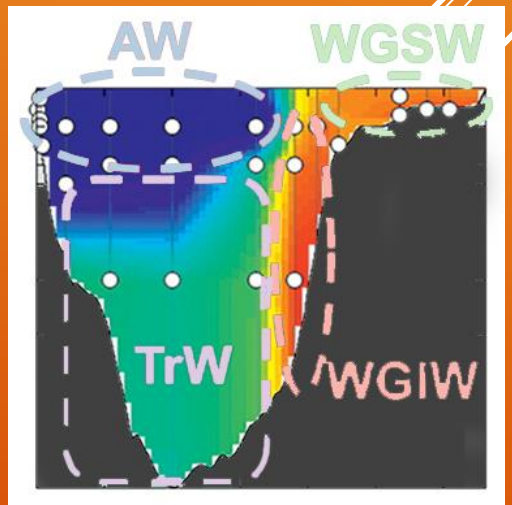




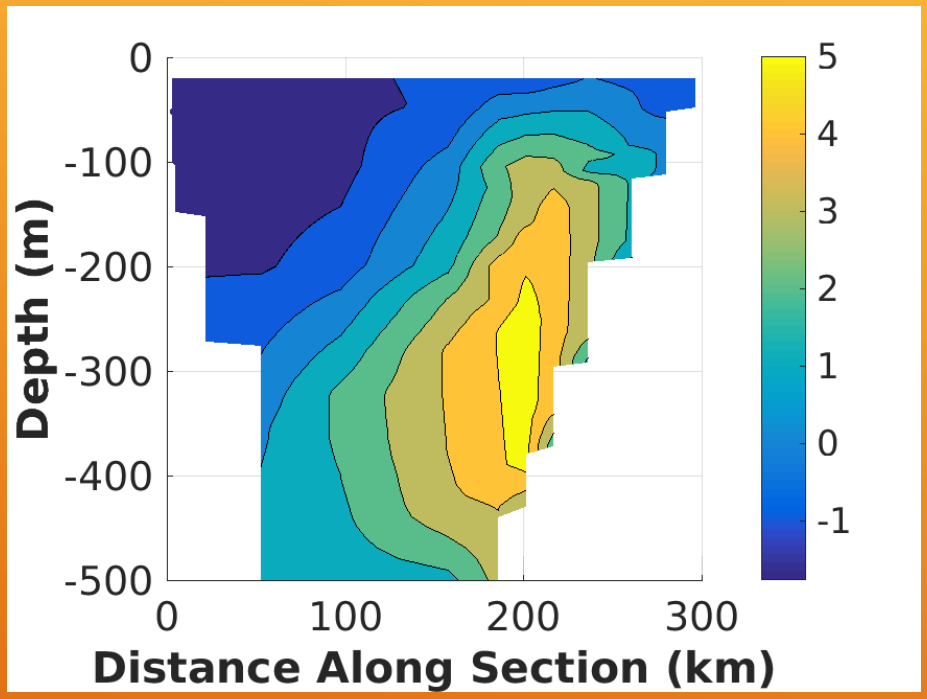
- Moorings (u, T, S, ice thickness, marine mammal acoustics), including ice-ocean interface and shelves.
- Glider-based sections. Year-round.
- Annual (biennial) hydrography with extensive chemistry.



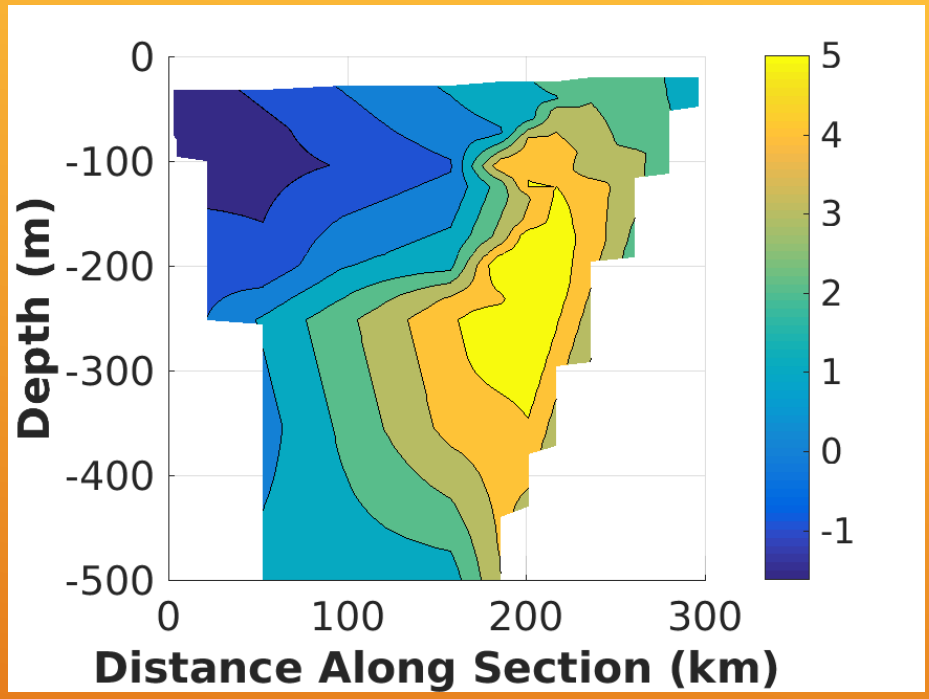
DAVIS STRAIT TRANSPORTS



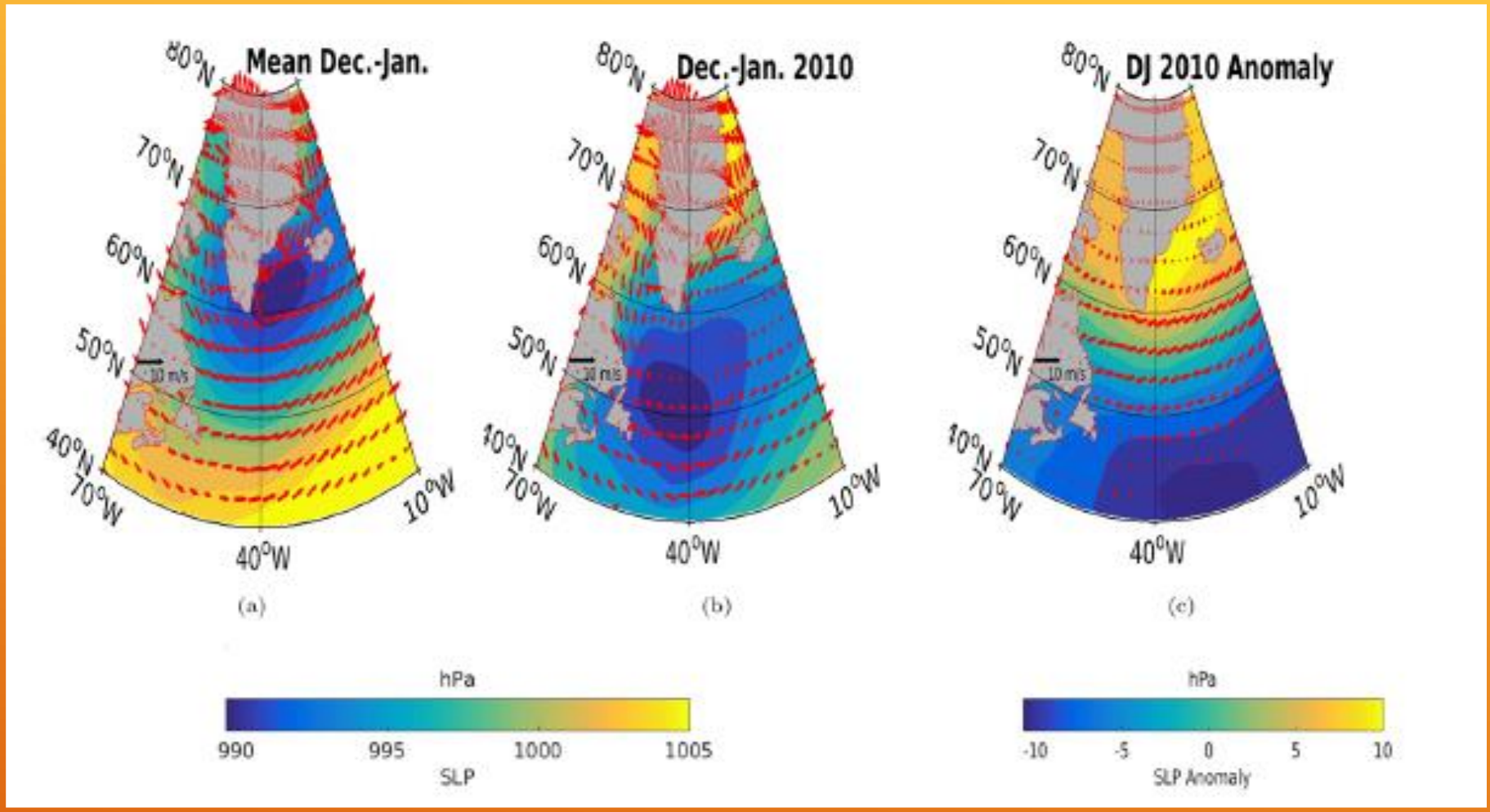
MEAN DEC-JAN TEMP.



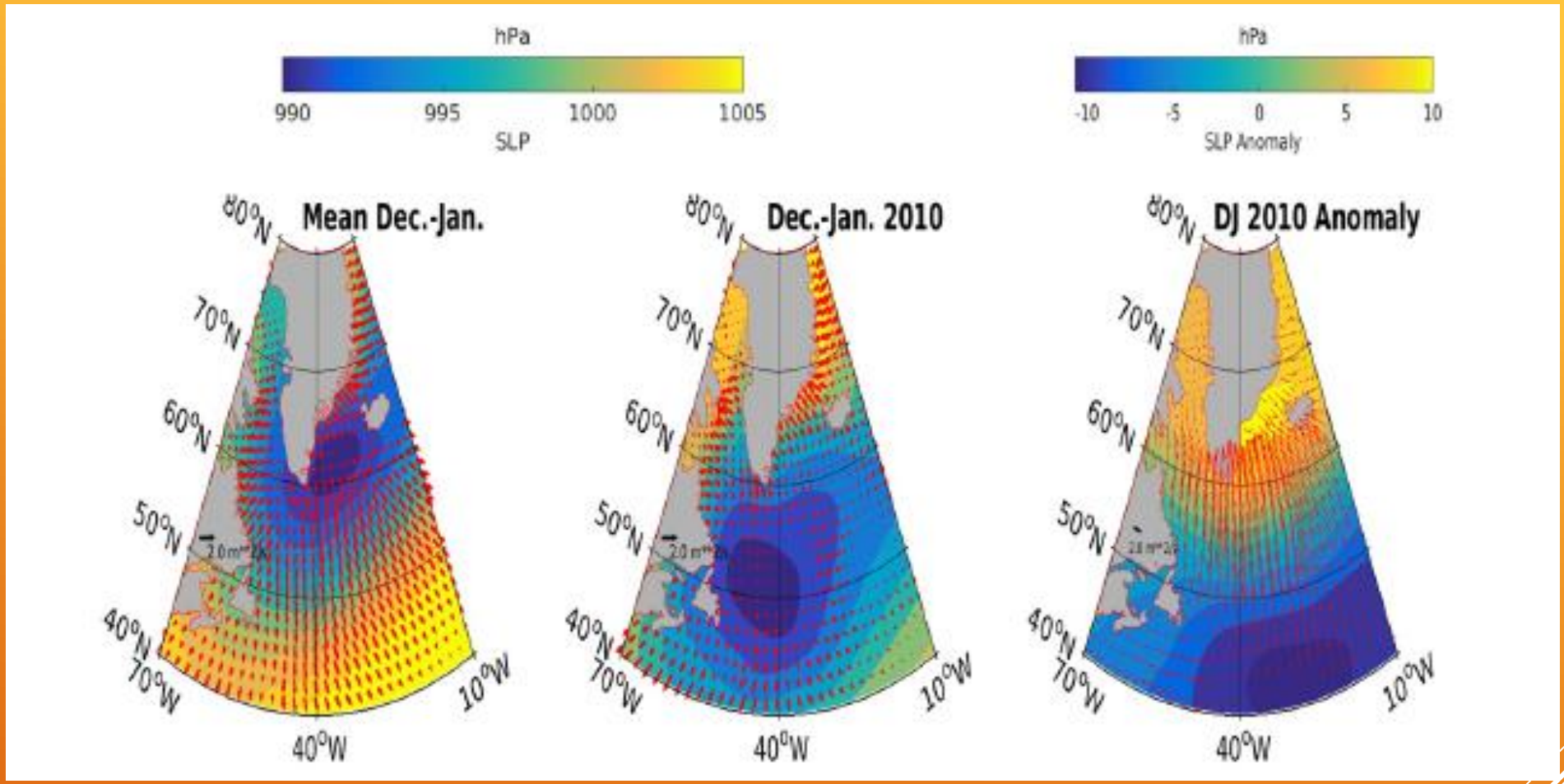
DEC 2010 – JAN 2011 TEMP.



OTHER CHANGES AT THE DAVIS STRAIT ARRAY DEC 2010

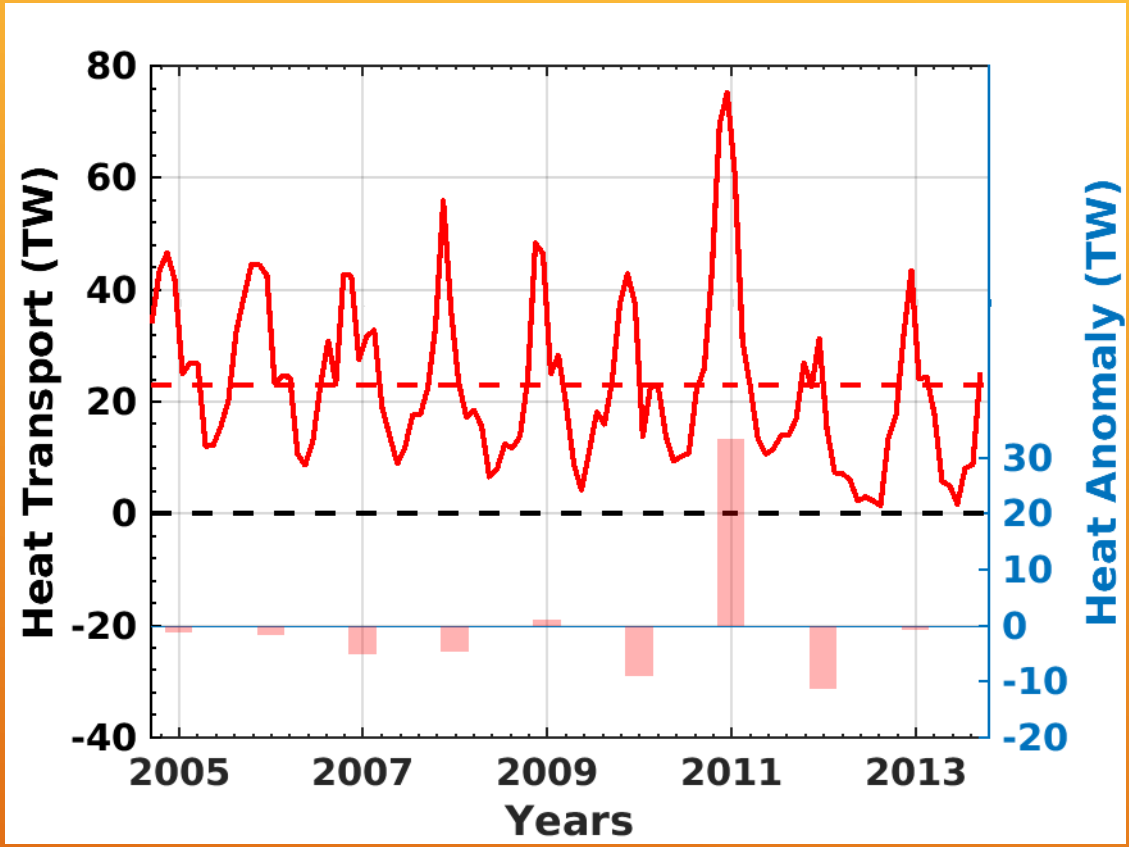


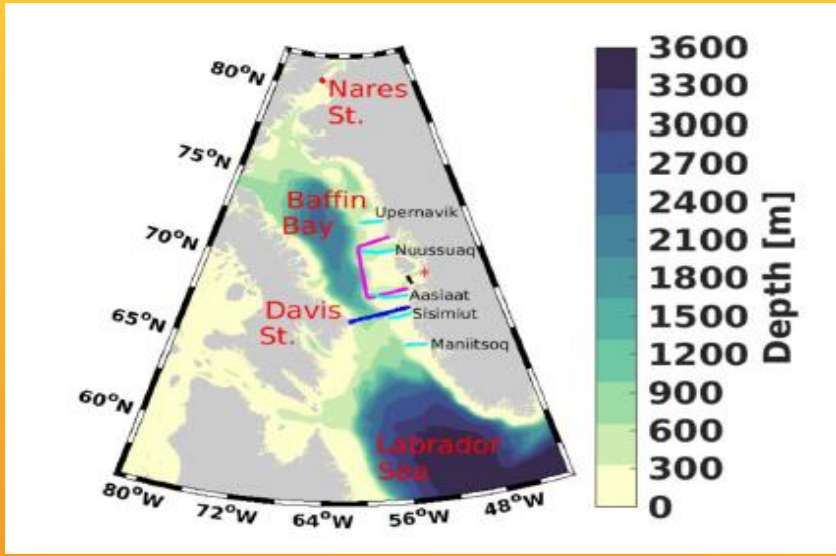
LABRADOR SEA WINTER WINDS

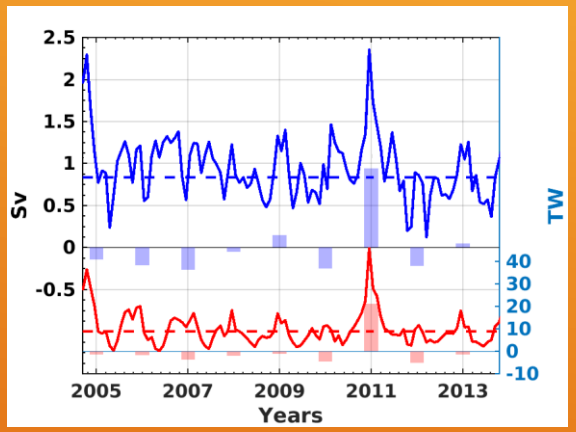


LABRADOR SEA EKMAN TRANSPORTS

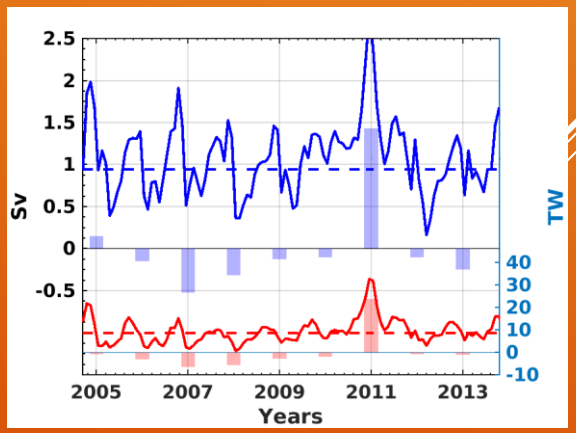
DAVIS STRAIT MODEL HEAT TRANSPORT





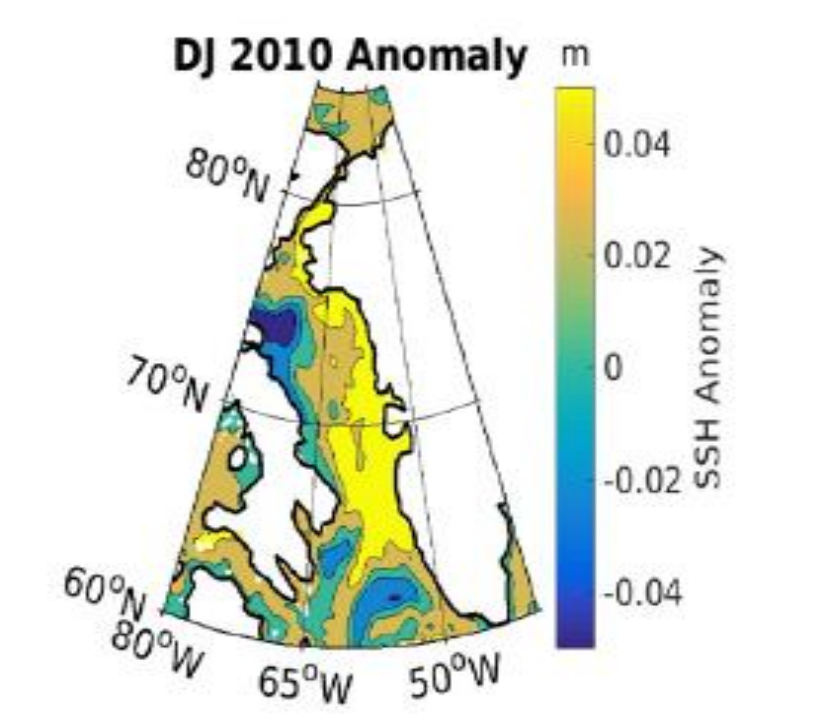


Aasiaat

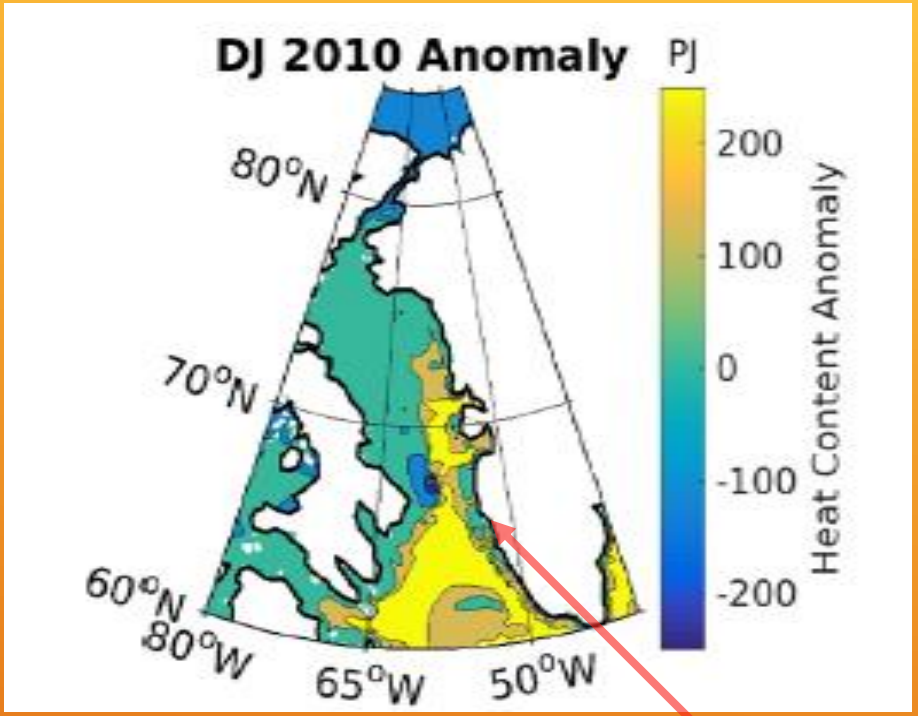


Nuussuaq

SSH ANOMALY

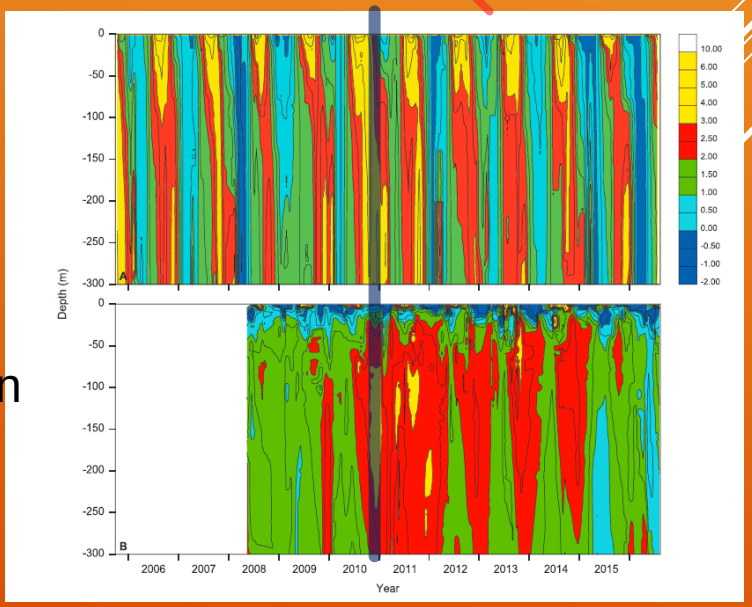


TOP 500 M HEAT CONTENT ANOMALY

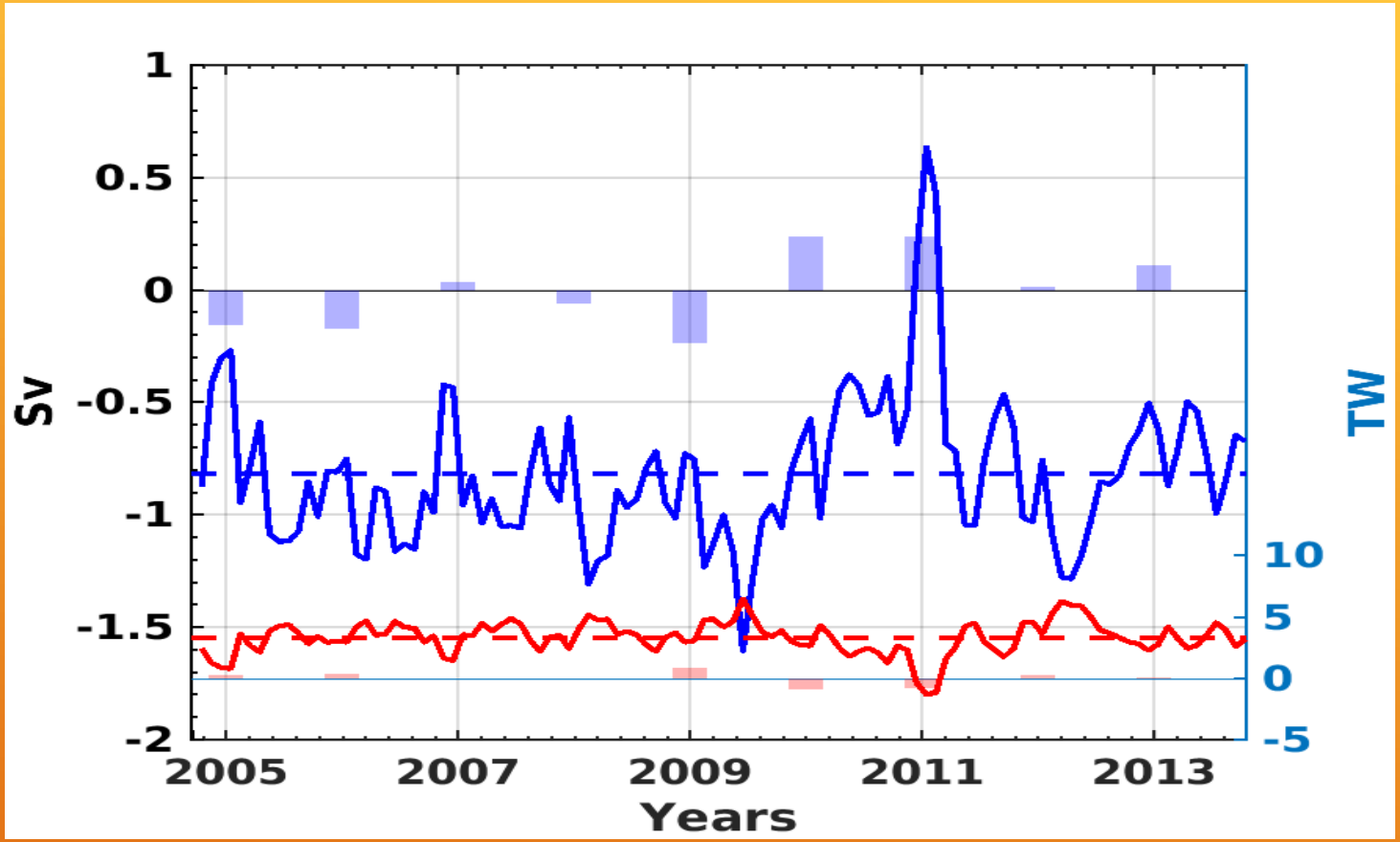


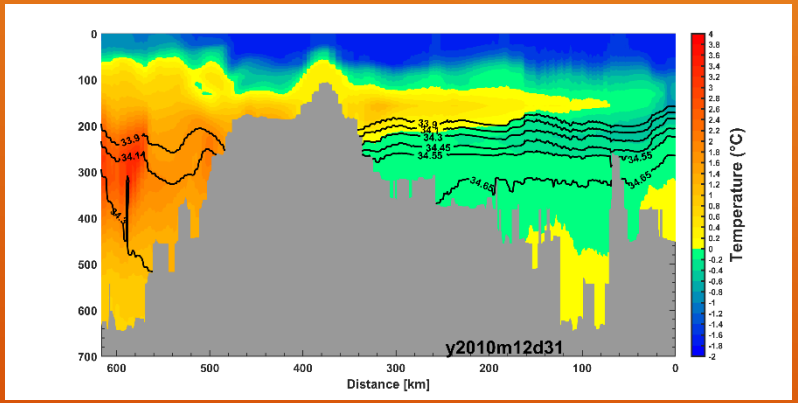
BAFFIN BAY SSH AND HEAT CONTENT DEC 2010 – JAN 2011

Mortensen et al., 2018, JGR – observational temp. – Nuuk, outer station (top), inner station (bottom)



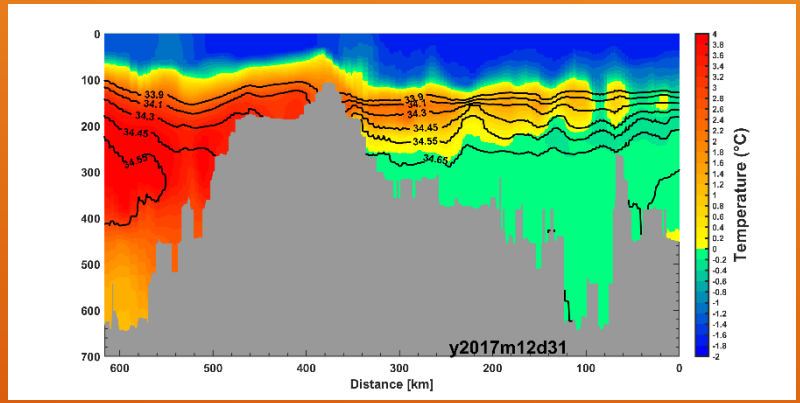
NARES STRAIT TRANSPORT





ANHA12 Output – Dec 31, 2010

- Right: Lincoln Sea
- South: Smith Sound

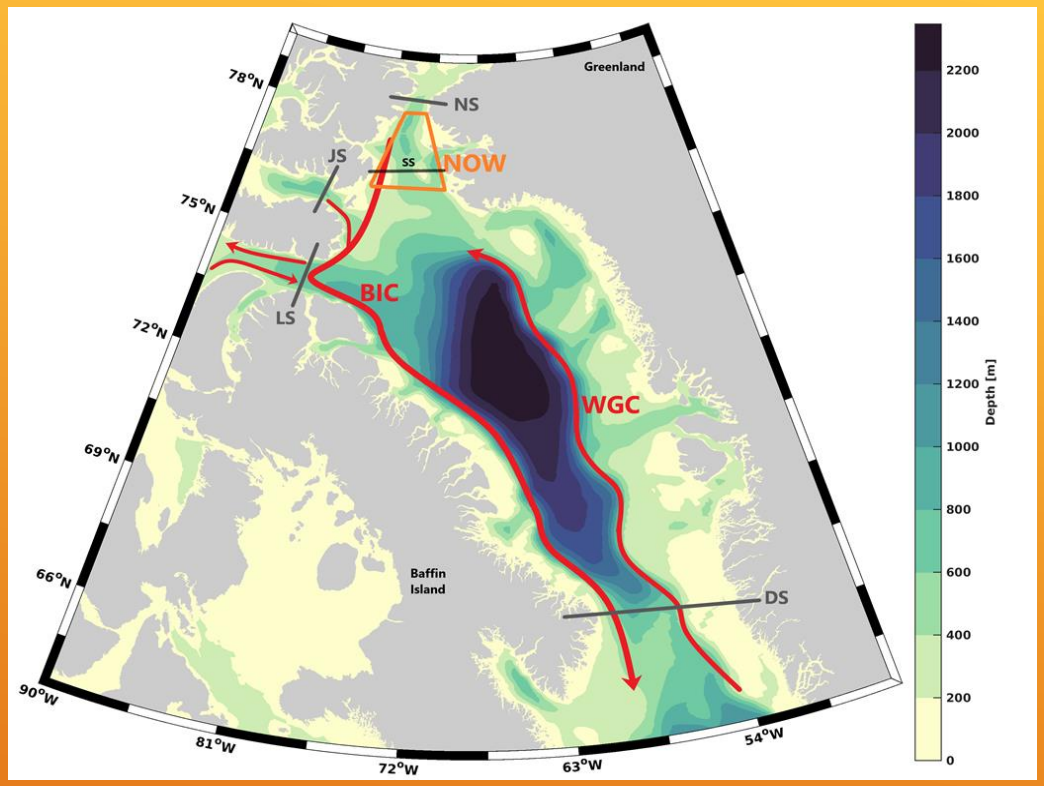


ANHA12 Output – Dec 31, 2017

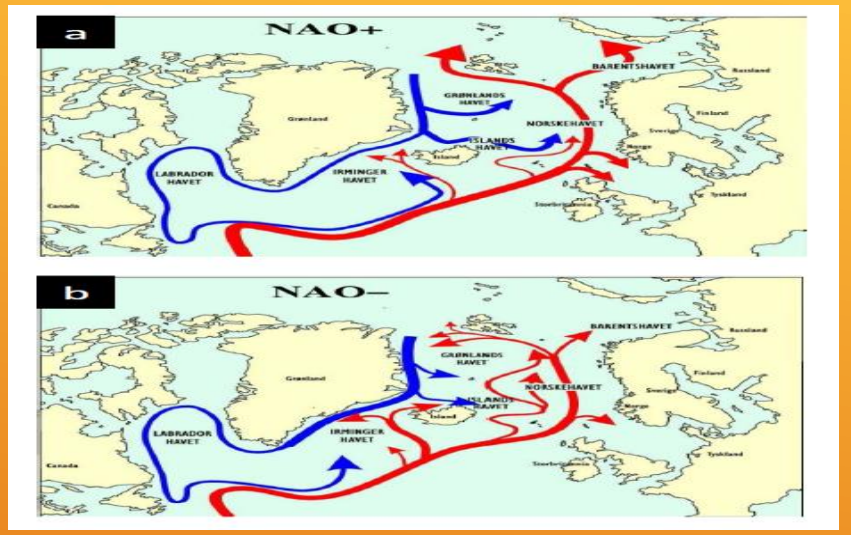
- Right: Lincoln Sea
- South: Smith Sound

Garcia-Quintana et al., 2021, in preparation

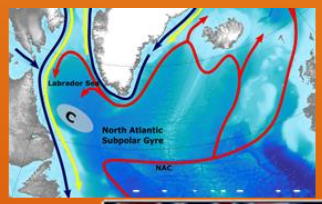
BAFFIN BAY CIRCULATION, WARM MODIFIED ATLANTIC WATER AND TIDEWATER GLACIAL IMPACT

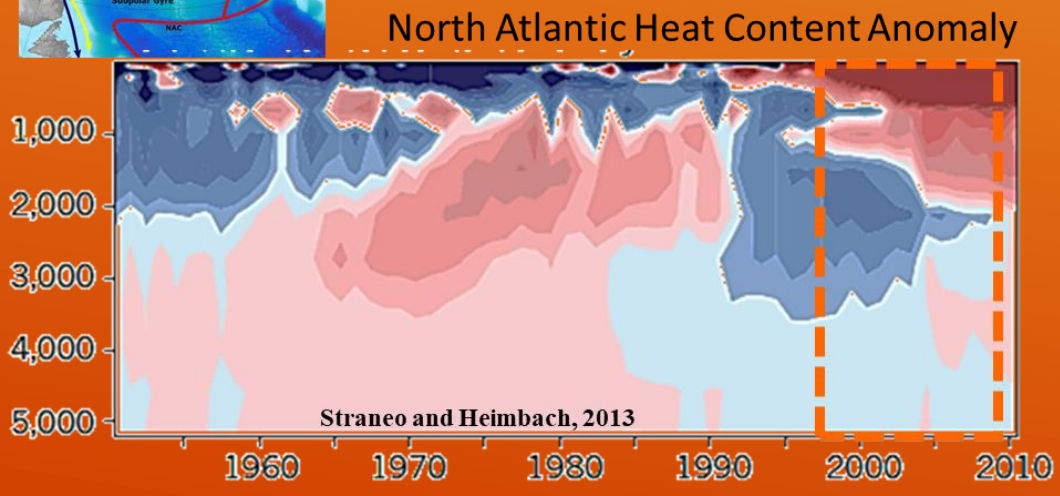


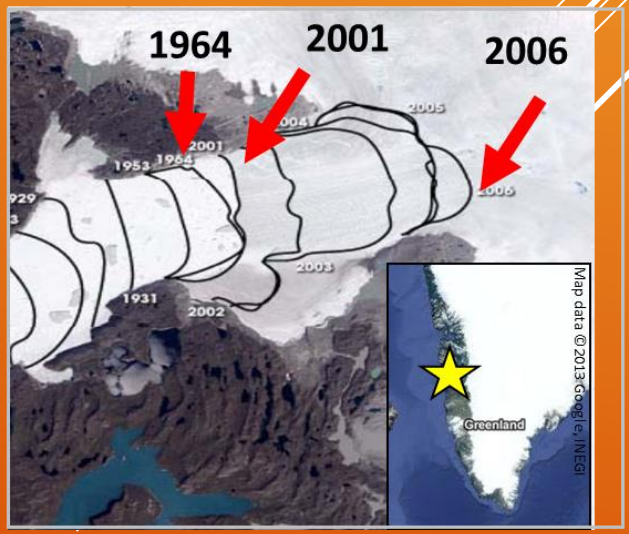
JS – Jones Sound, SS – Smith Sound, NS – Nares Strait, LS – Lancaster Sound,
DS – Davis Strait, BIC – Baffin Island Current, WGC – West Greenland Current



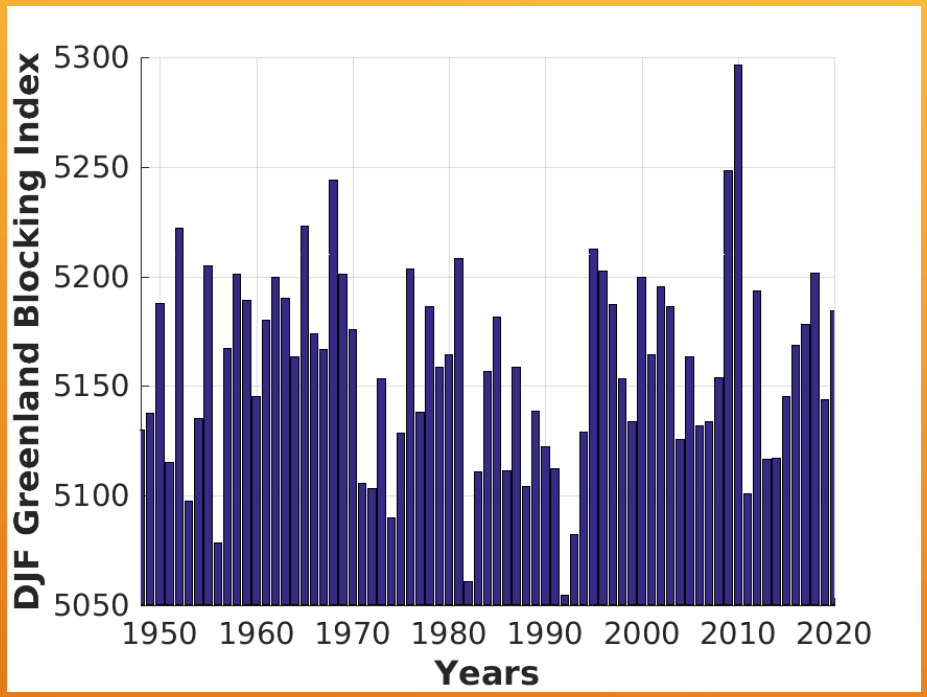
Holland et al., 2008, Nature Geoscience



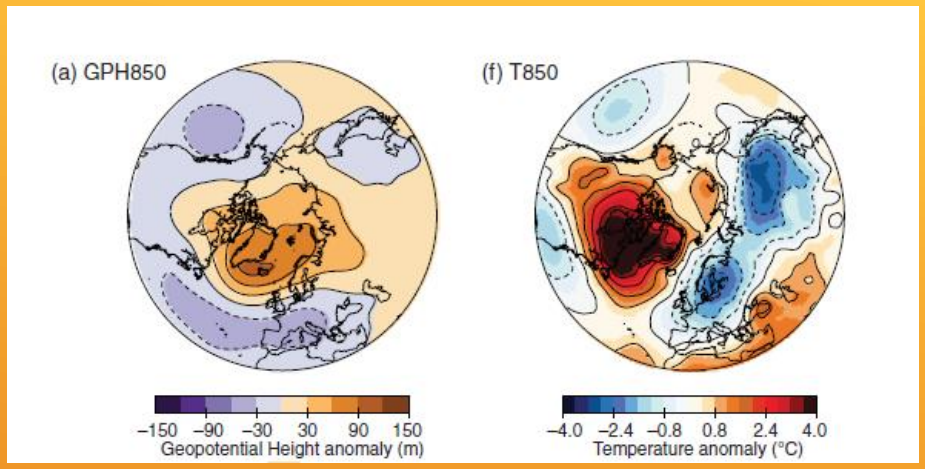


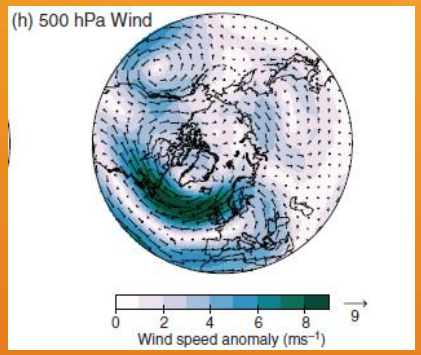


DJF BLOCKING INDEX (M)



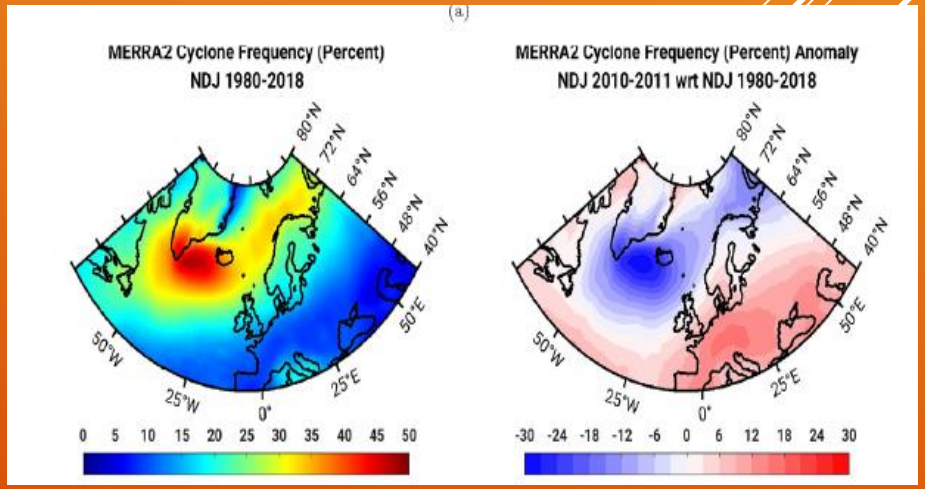
HIGH – LOW INDEX

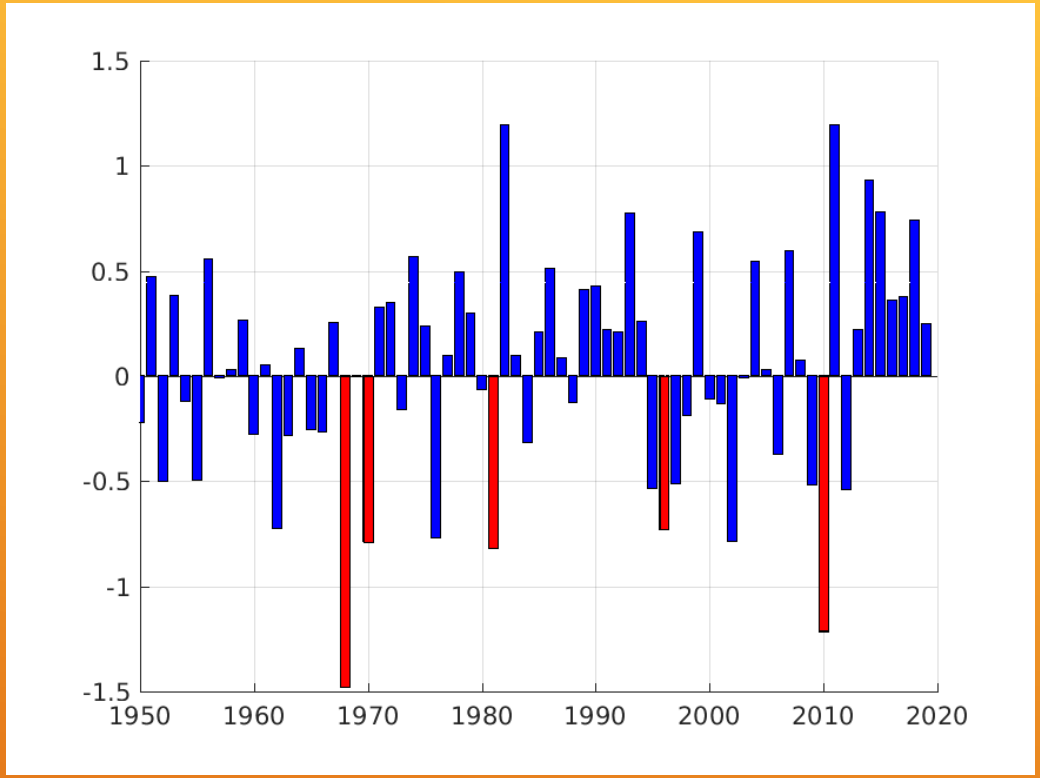




GREENLAND BLOCKING INDEX (500MB GEOPOTENTIAL HEIGHT AREA AVERAGED 60-80N, 280-340E FROM THE DAILY AVERAGED NCEP/NCAR REANALYSIS)

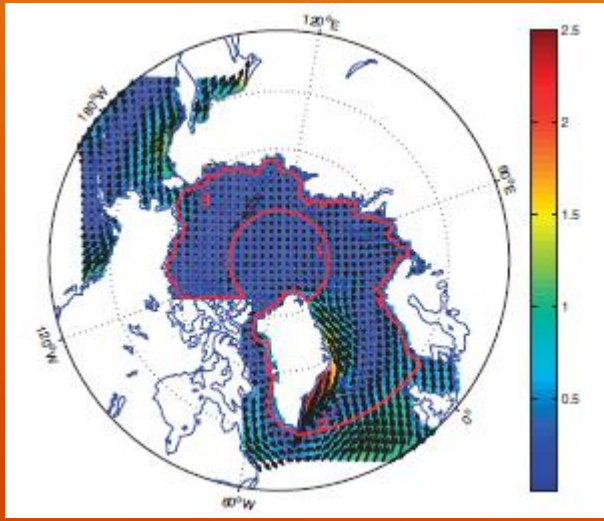
HANNA ET AL. 2016 INT. J. CLIM.





FALL-WINTER (SONDJ) NAO
RED – ALL 5 MONTHS NEGATIVE

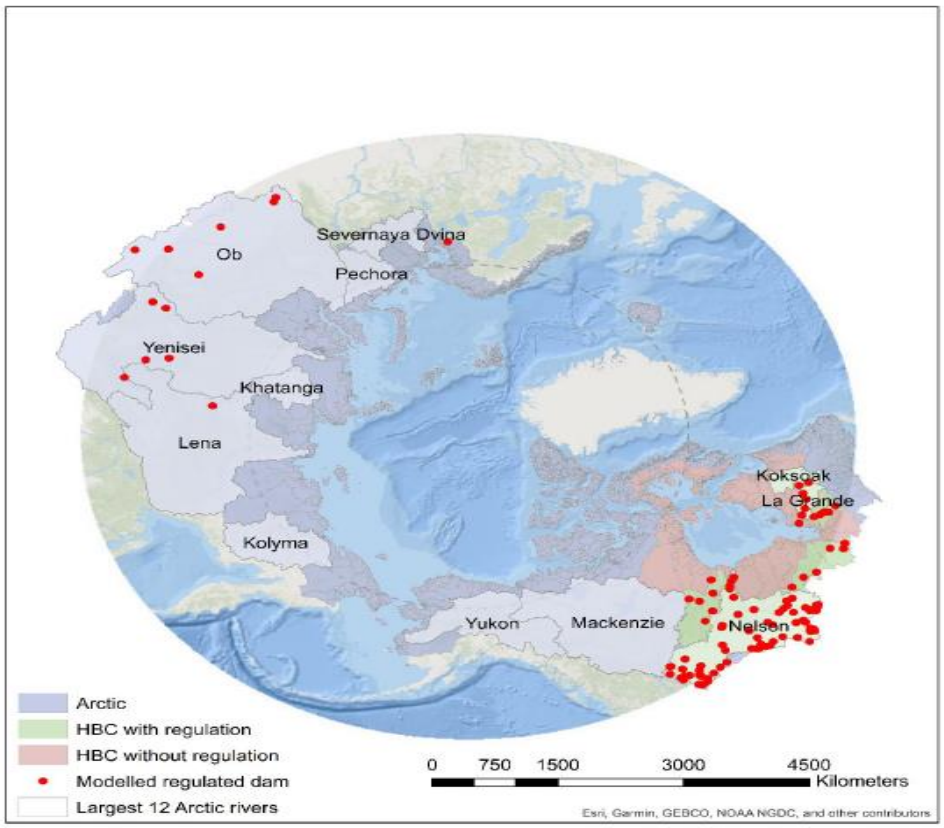
- Fits for 2010 event
- Fits for 1996 before JI retreat event first reported by Holland et al
- Does NOT fit for end of 2017…

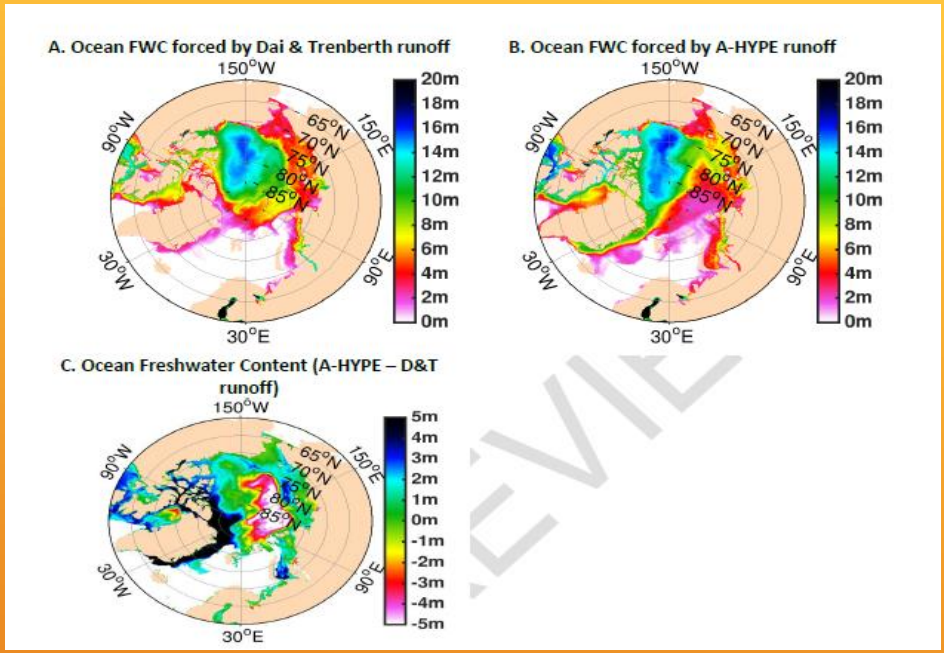


Greenland Island Rule – Joyce and Proshutinsky, 2007

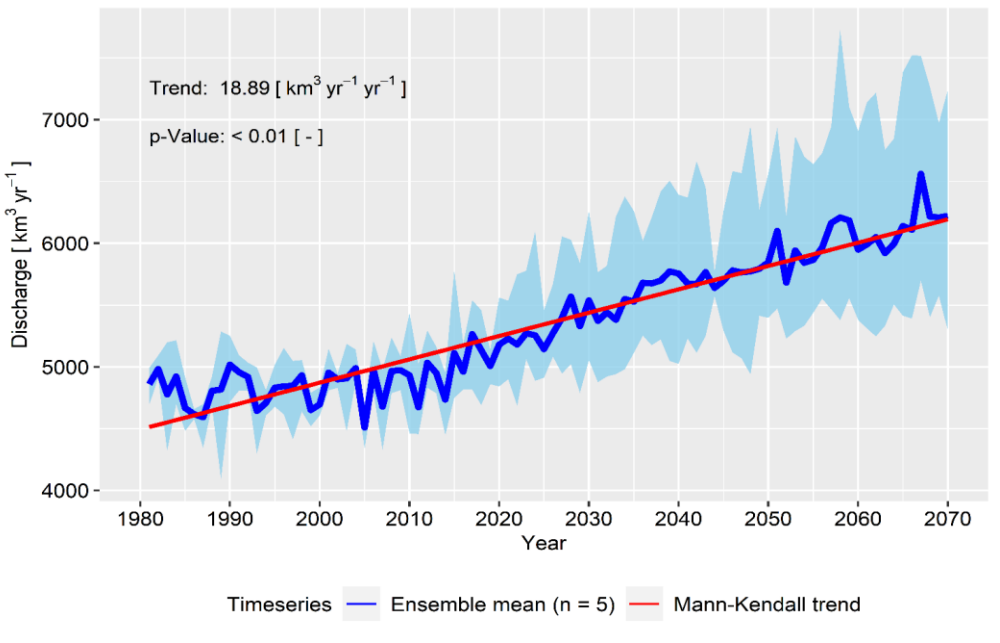
- Simple model to explain flow through Davis Strait
- Climatological Winds produce Cyclonic Flow around Greenland
    - Increases during positive AO/NAO Phase
    - But can decrease, or even reverse during a negative AO/NAO phase
- Suggest takes about 3 months to spin circulation up

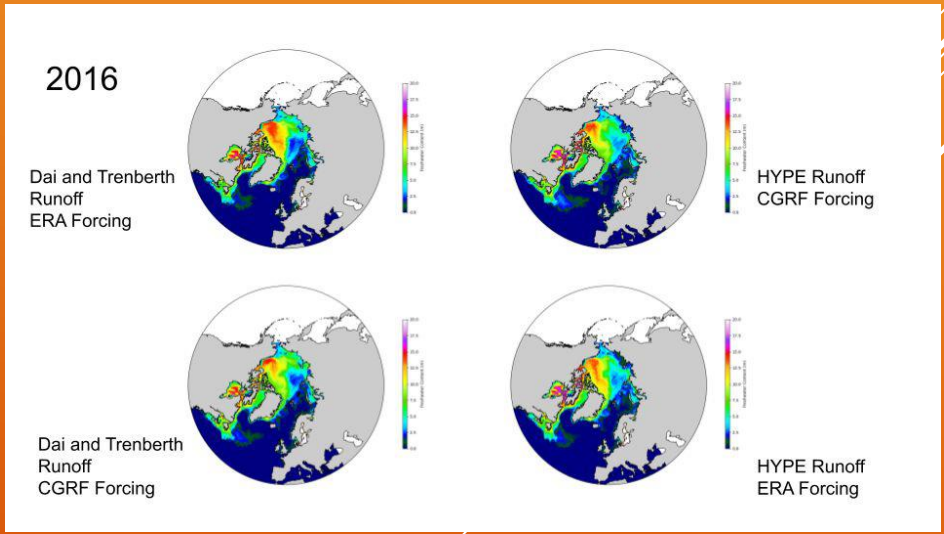
SENSITIVITY TO RIVER RUNOFF





Stadnyk et al., 2021, Elementa

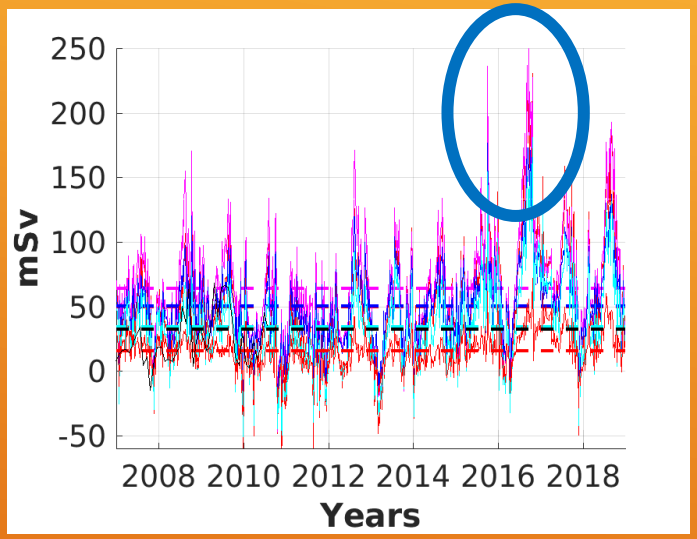




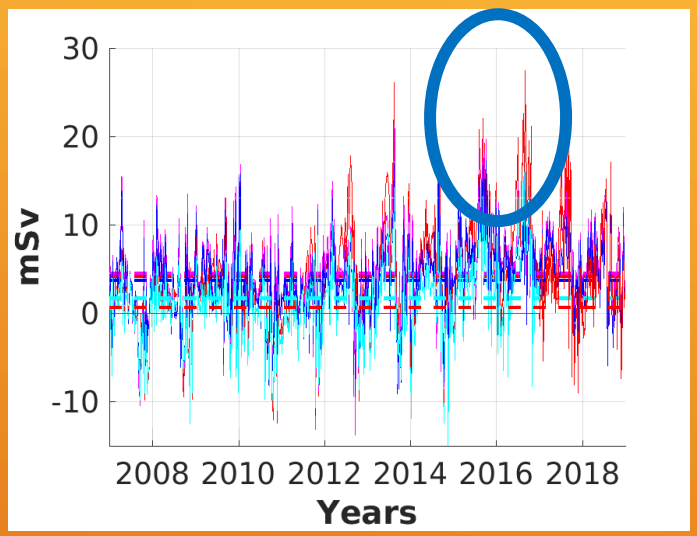
Tahya Weiss-Gibbons, ongoing MSc

MODEL ARCTIC GATEWAY STRAIT FRESHWATER TRANSPORT (REL. TO 34.8)

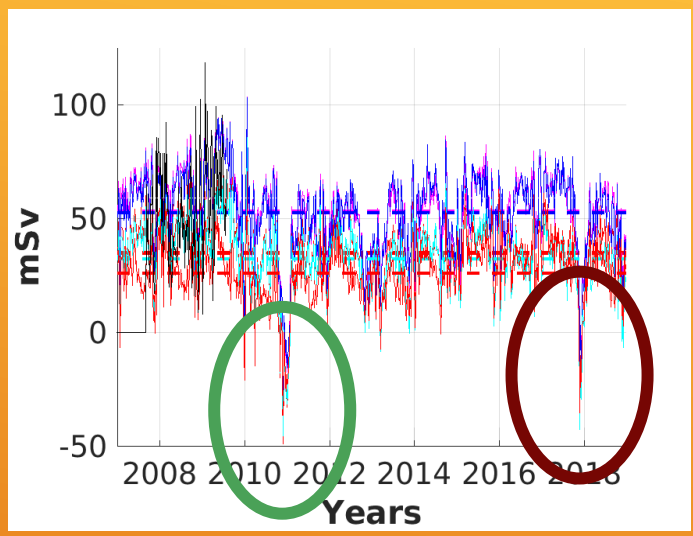
Barrow



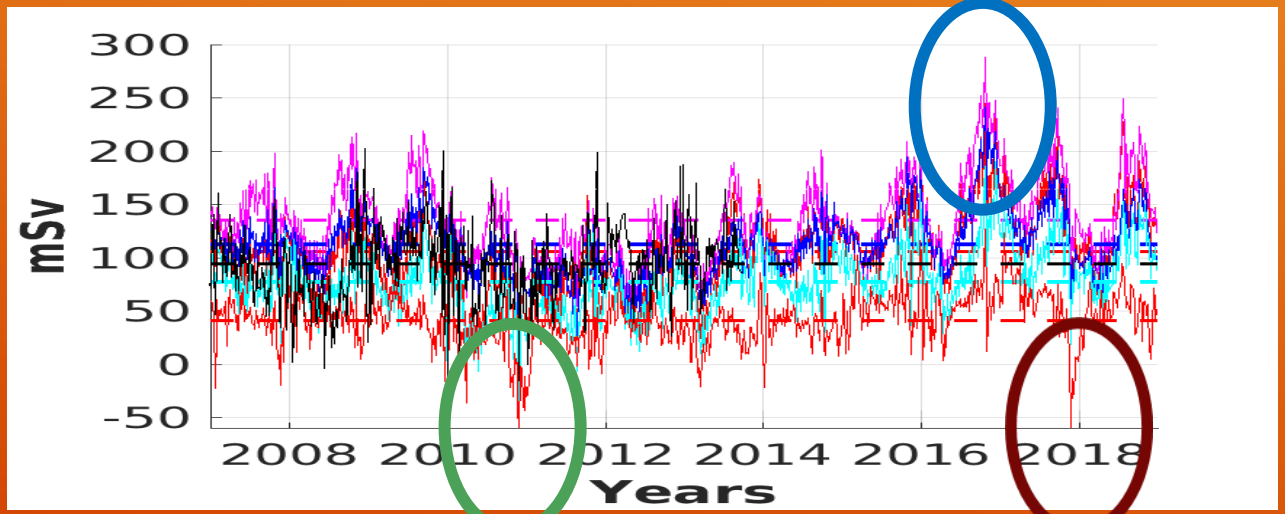
Jones Sound



Nares Strait



Davis Strait



LEGEND

- Maroon – ERA5/HYPE/BT18
- Blue – ERA5/DT/BT12
- Cyan – GDPS/DT/BT12
  - All above with tides
- Red – ANHA12/DT/BT12
- Black - Obs

SUMMARY

- Transport (volume, heat and freshwater) reverses at both Davis and Nares St, Dec 2010
  - Repeats in Dec 2017
- Seen in both observations and model
- The transport reversal was driven by anomalous winter winds, and associated Ekman transport. over the Labrador Sea
- Leads to enhanced transport of warm waters by the WGC
- Significant warm water enters Baffin Bay (and Lincoln Sea), impacting stratification and likely tidewater glaciers
- The anomalous winds were associated with a record high of the Greenland Blocking Index and a change in the storm track
- Good example of using models to identify processes to focus on in observational record