AN UPDATED NORDIC SEAS OVERVIEW –
WITH SOME NEW OBSERVATIONS ON TRANSPORTS

1) **Continued Warming**
2) **Continued «high» Variable flow**
3) **Poleward Sea Ice Edge & Cooling Migration**

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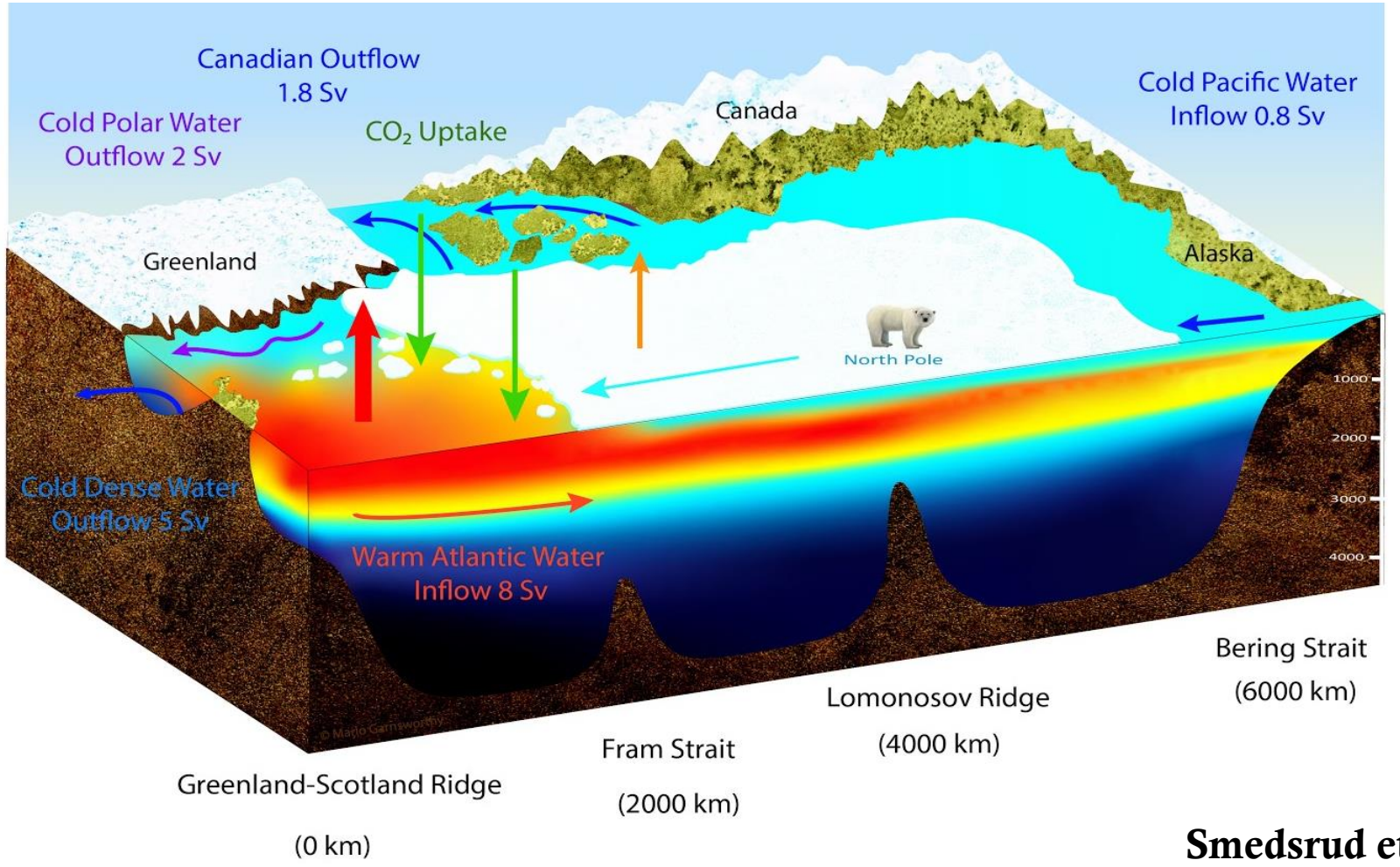
Reviews of Geophysics https://doi.org/10.1029/2020RG000725

Atlantic Water is the key heat source for the Arctic Ocean *[Nansen, 1902]*

"Nordic Seas Heat Loss, Atlantic Inflow, and Arctic Sea Ice Cover Over the Last Century"



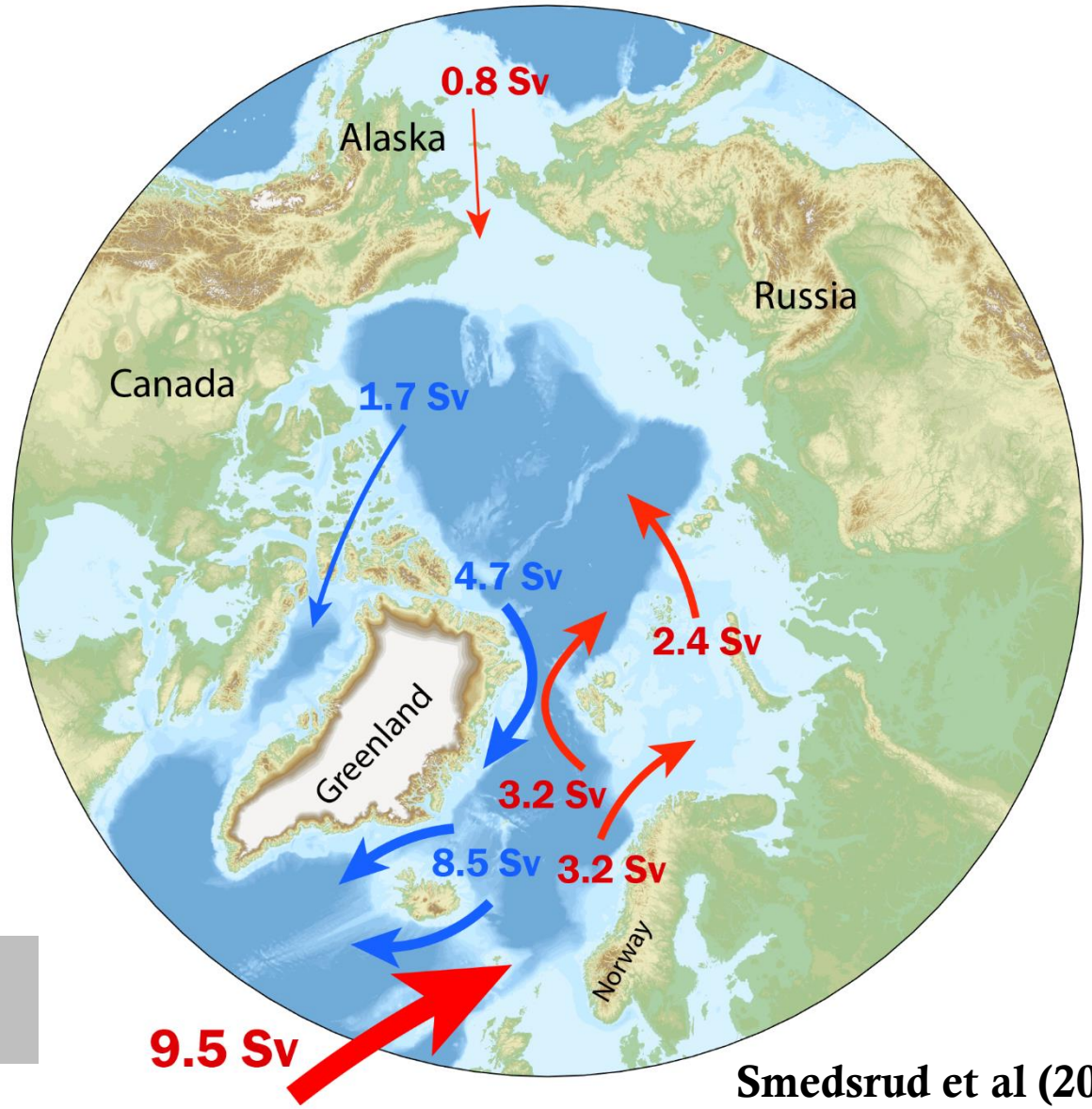
Smedsrud et al (2022)

ARCTIC OCEAN VOLUME BUDGET MEAN 1900-2000

GSR Inflow + 9.5 Sv
Bering Strait + 0.8 Sv

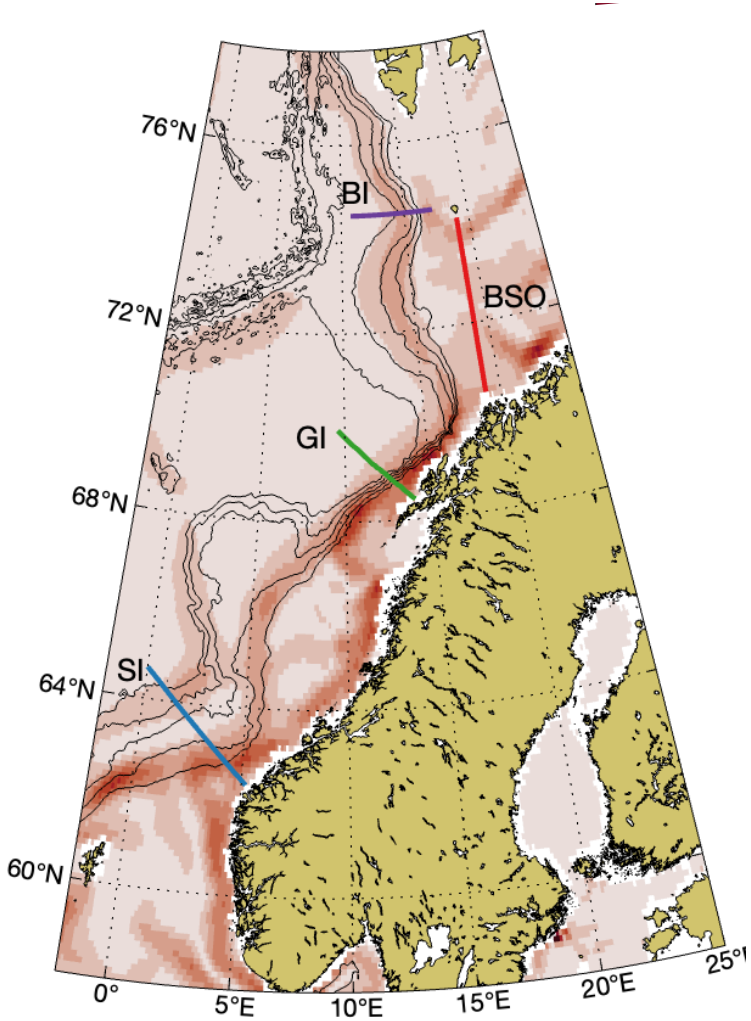
Archipelago – 1.7 Sv
GSR Outflow – 8.5 Sv

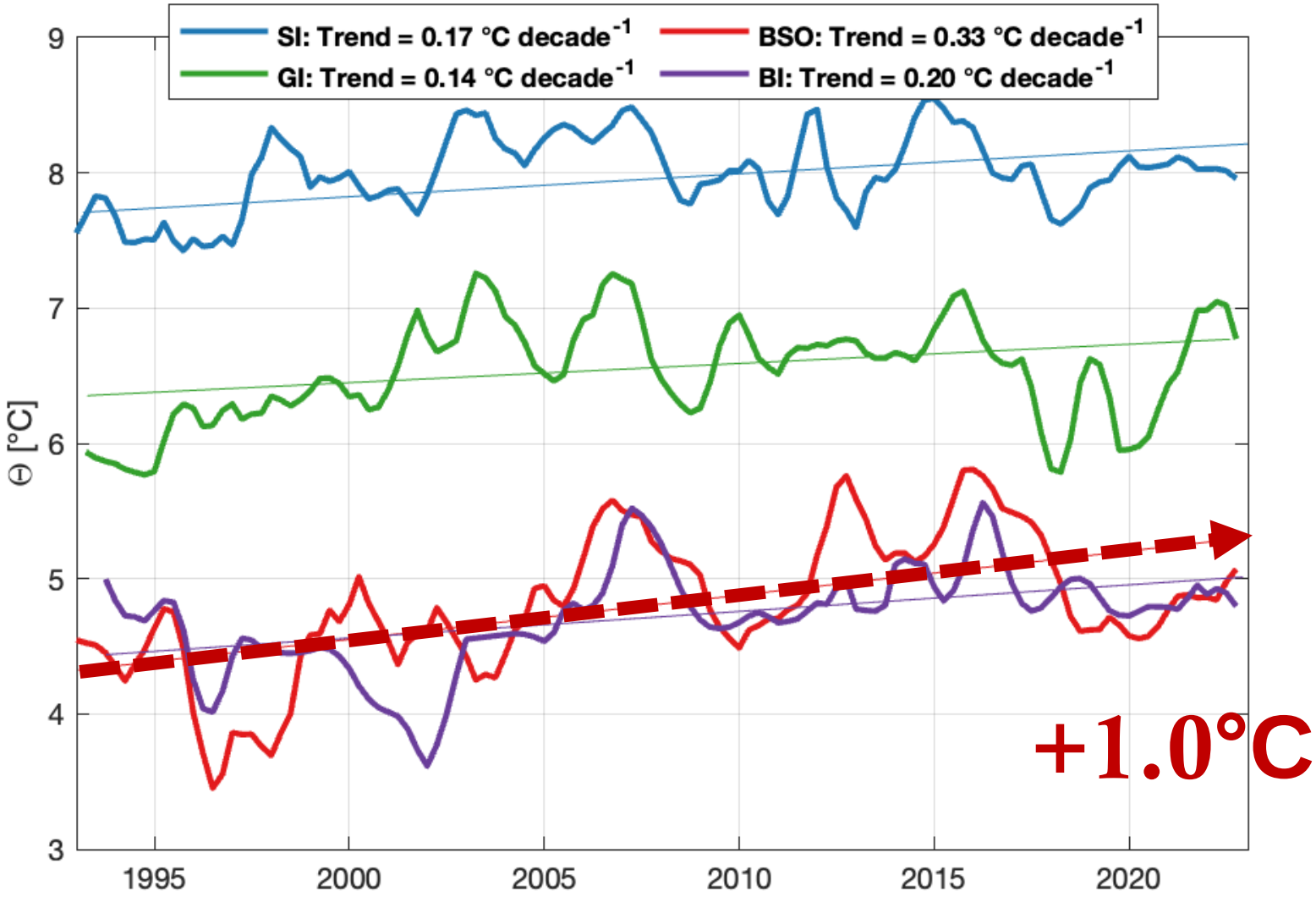
This implies **+1 Sv MORE in inflow** than **outflow** across the Greenland Scotlan Ridge (GSR)



Smedsrud et al (2022)

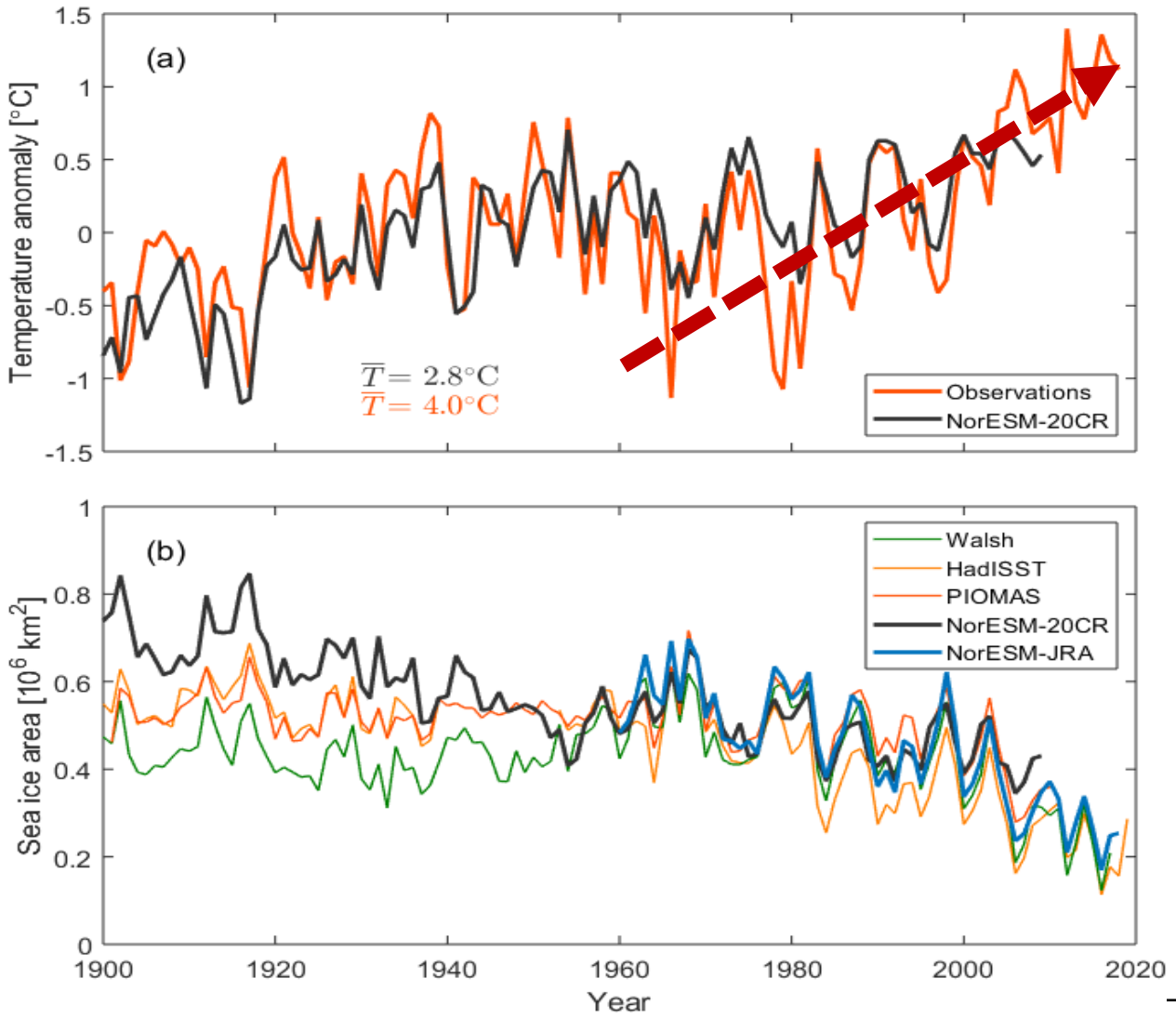
CONTINUED WARMING ALONG THE NORWEGIAN COAST





Baumann & Skagseth (IMR) (In Progress)

WARMING: BARENTS SEA



+2°C

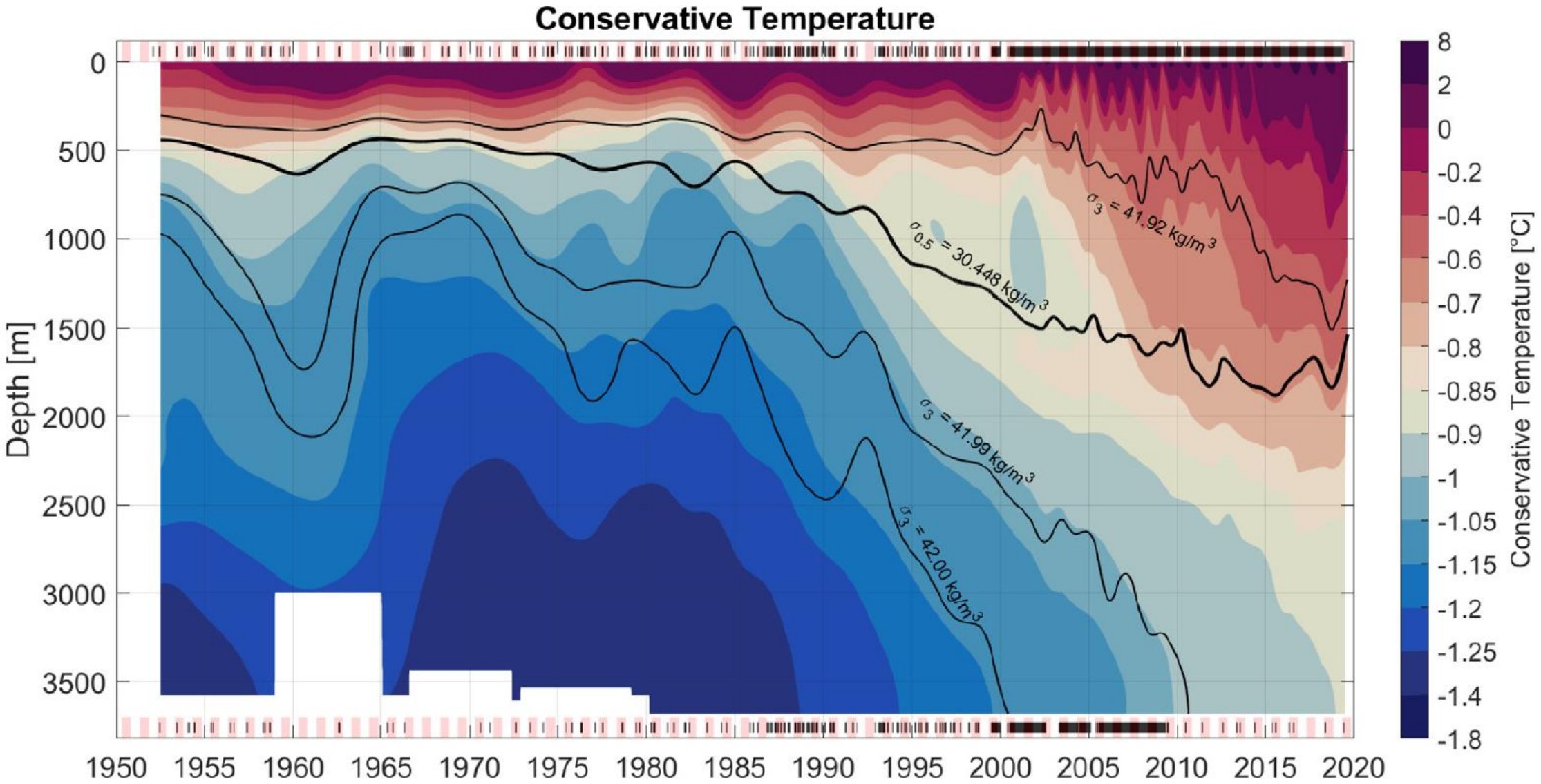
SIMULATED NORESM TEMPERATURE IN THE BARENTS SEA OPENING (BLACK LINE) AND CORRESPONDING KOLA SECTION OBSERVATIONS (RED LINE, PINRO).

THERE IS A COLD BIAS IN THE SIMULATIONS OF ABOUT 1.2°C.

Sea Ice Area (SIA) variability after 1950 is well constrained, but we trust the simulations as much as we do the early «observations»

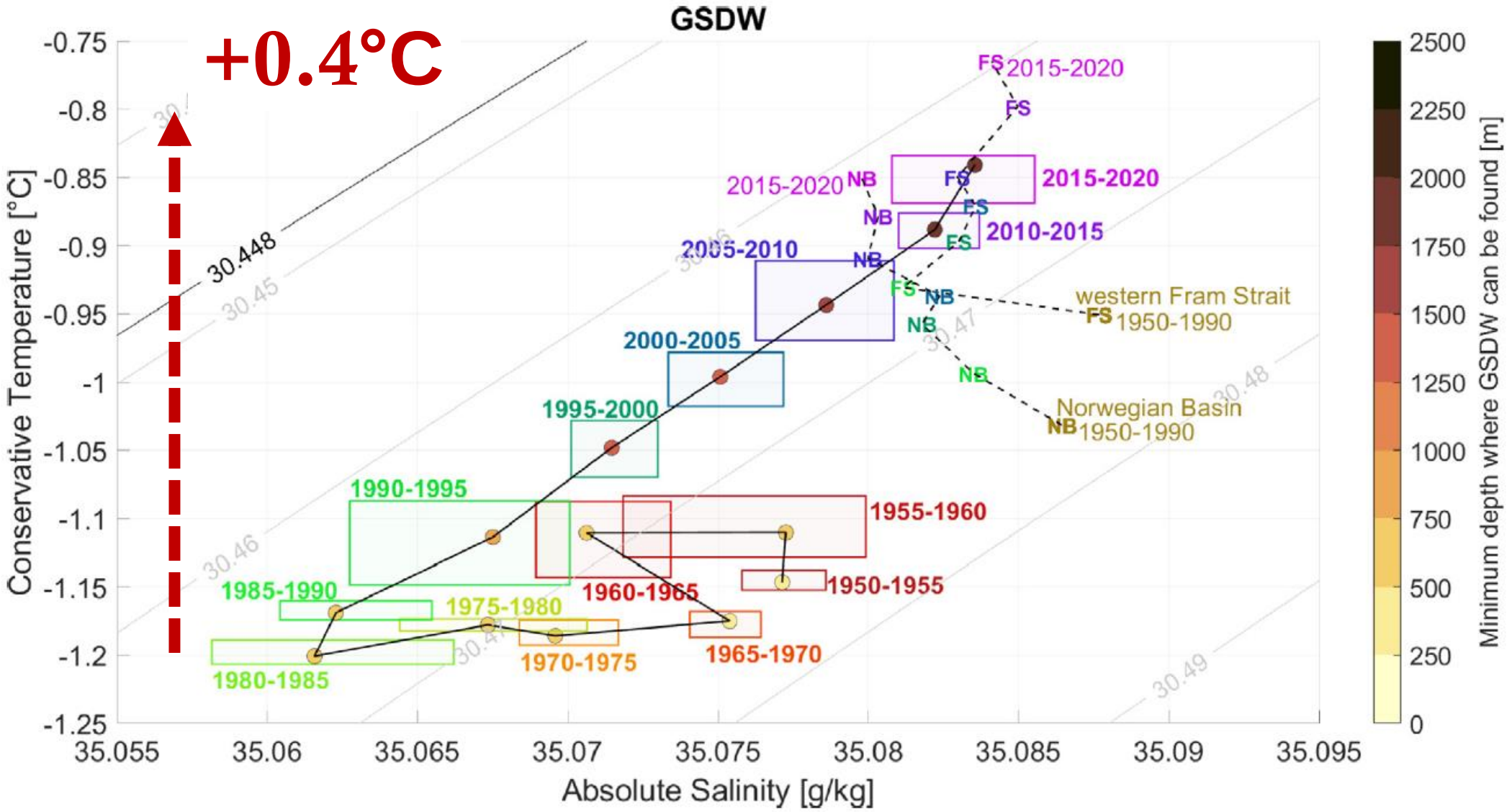
Smedsrud et al (2022)

WARMING: GREENLAND SEA



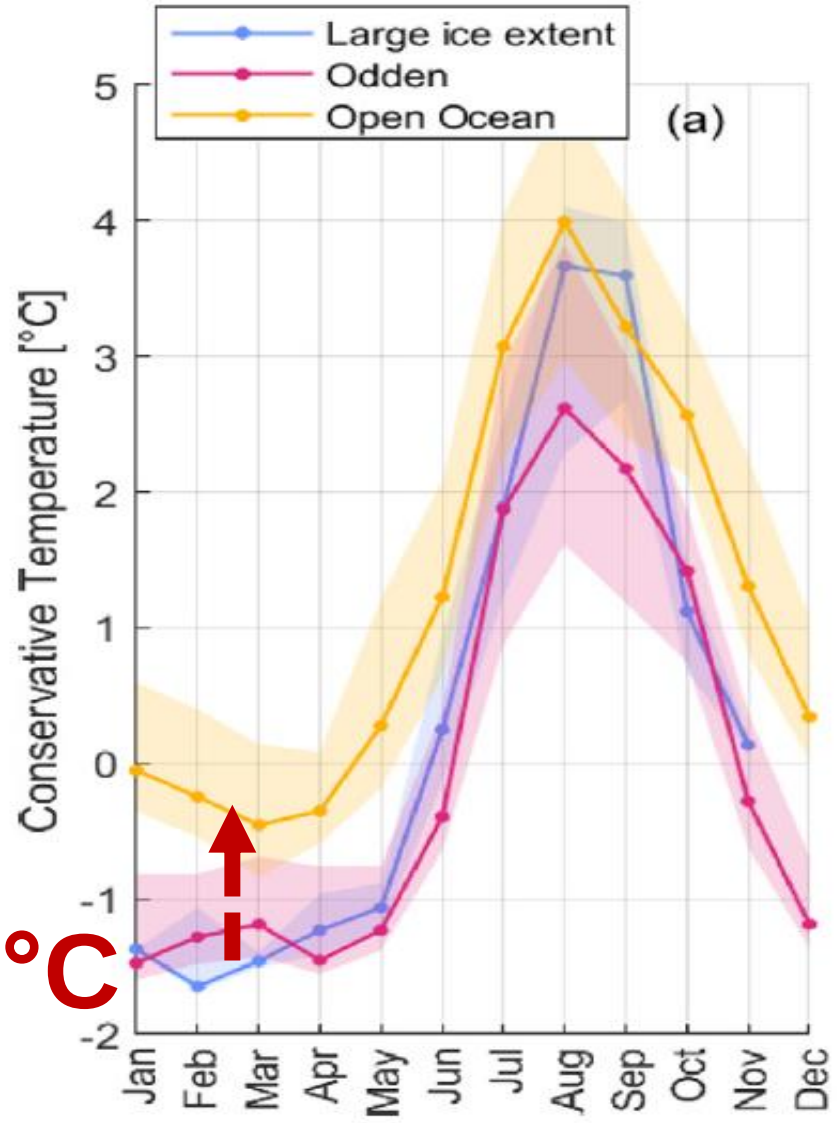
Strehl et al (2024)

WARMING: GREENLAND SEA DEEP WATER

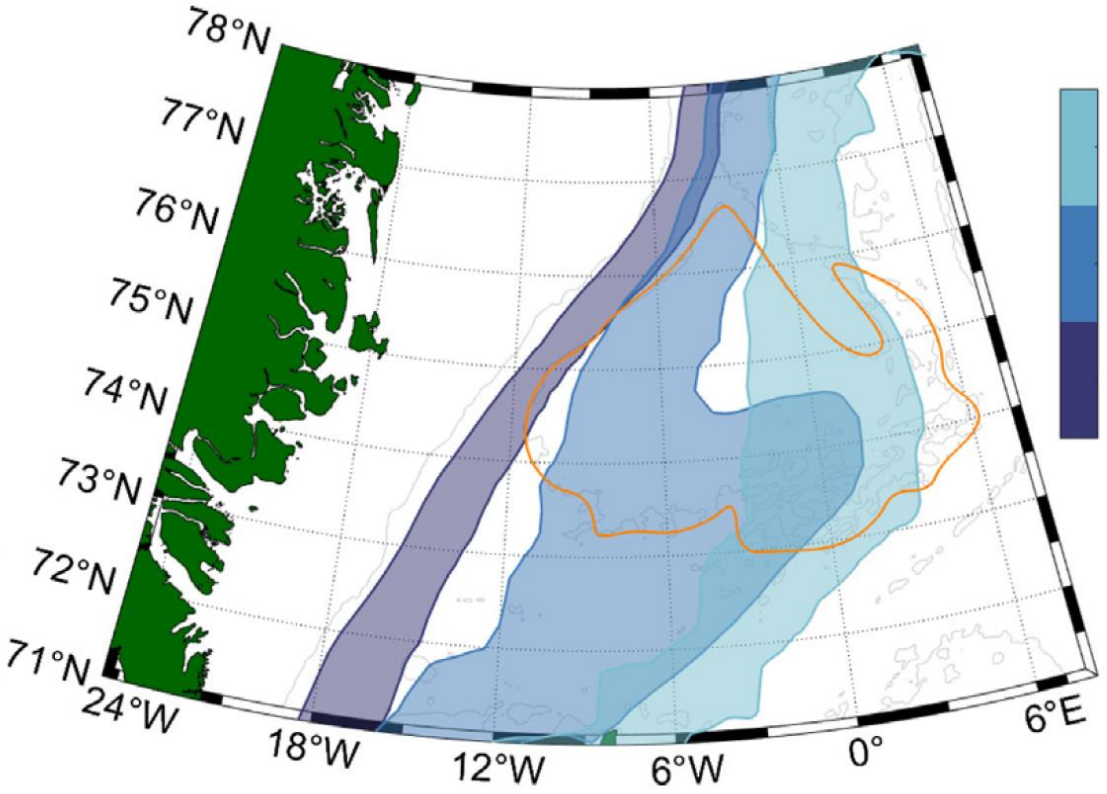


Strehl et al (2024)

WARMING: GREENLAND SEA SURFACE



+1.0°C

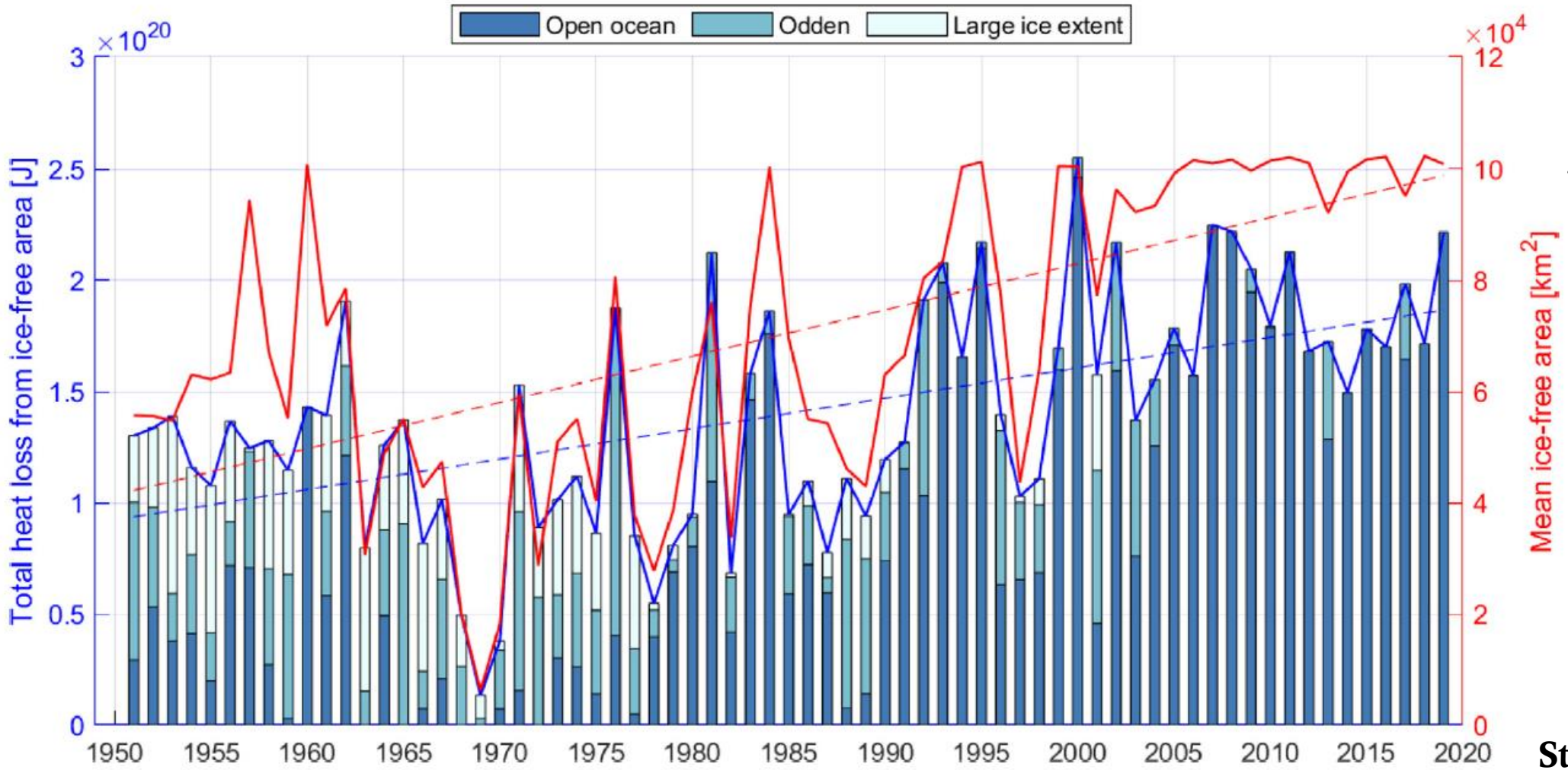


Large Ice
< 1980
Odden
80's + 90's
Open Ocean
> 2000

February Sea Ice Concentration (SIC) - self-organizing maps
Colored patches show Marginal Ice Zone (15–50 % SIC).
Central Greenland Sea in orange (>3000m)

Strehl et al (2024)

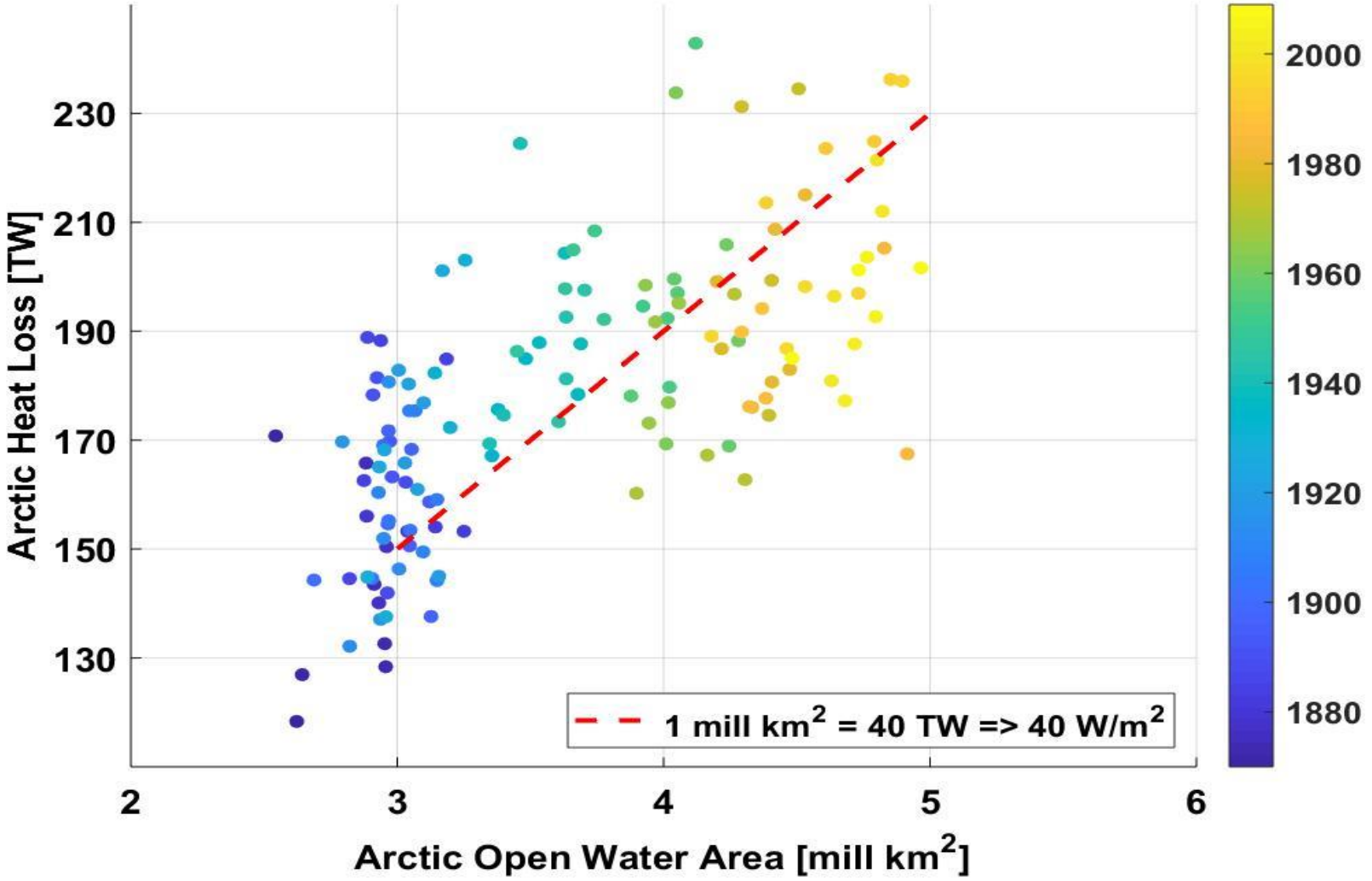
GREENLAND SEA ICE LOSS ➡ STRONGER COOLING



ERA 5
heat-fluxes +
Sea Ice
Daily Means
from hourly data

Strehl et al (2024)

ARCTIC SEA ICE LOSS ⇒ STRONGER COOLING



the "Ice loss Number" ?

1 m² ice-loss =>
40 W/m² larger heat flux

NorESM simulations from: Smedsrud et al (2022)

Nordic Seas Centennial Mean Heat Fluxes

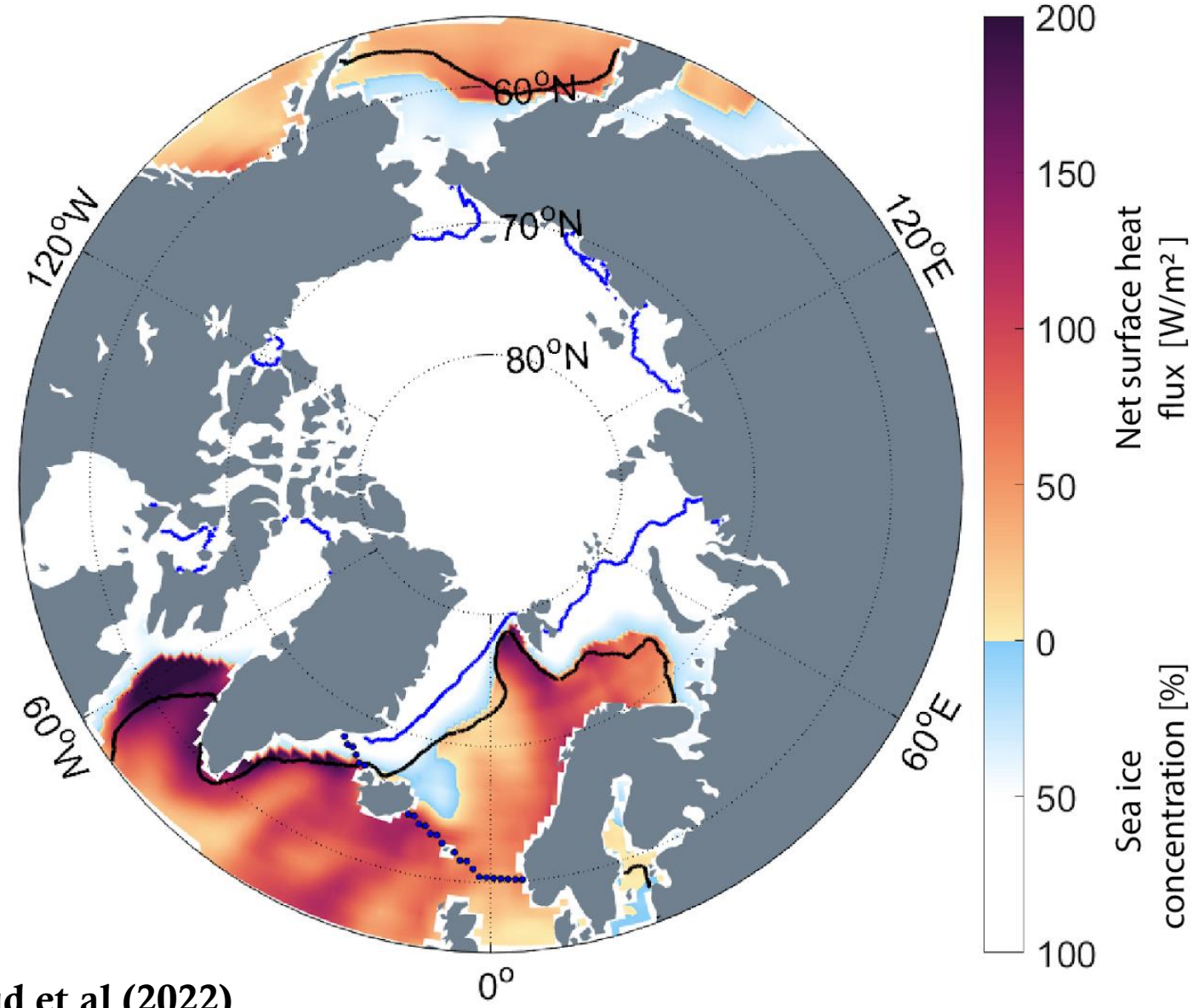
Nordic Seas: 45 W/m²
Barents Sea: 57 W/m²
Polar Sea: 2 W/m²

Arctic Ocean Mean: 15 W/m²

Note: southern extent of Arctic Ocean along the GSR (Dotted line)

Norwegian Earth System Model (NorESM)

- Forced with 20th century reanalysis 1871-2009
- 1° resolution, tripolar grid → 40km in the Arctic
- 51 ispoycnal layers
- Decent sea ice cover



Smedsrud et al (2022)

So – The Northern Oceans are Warming..

The Arctic Sea Ice is decreasing

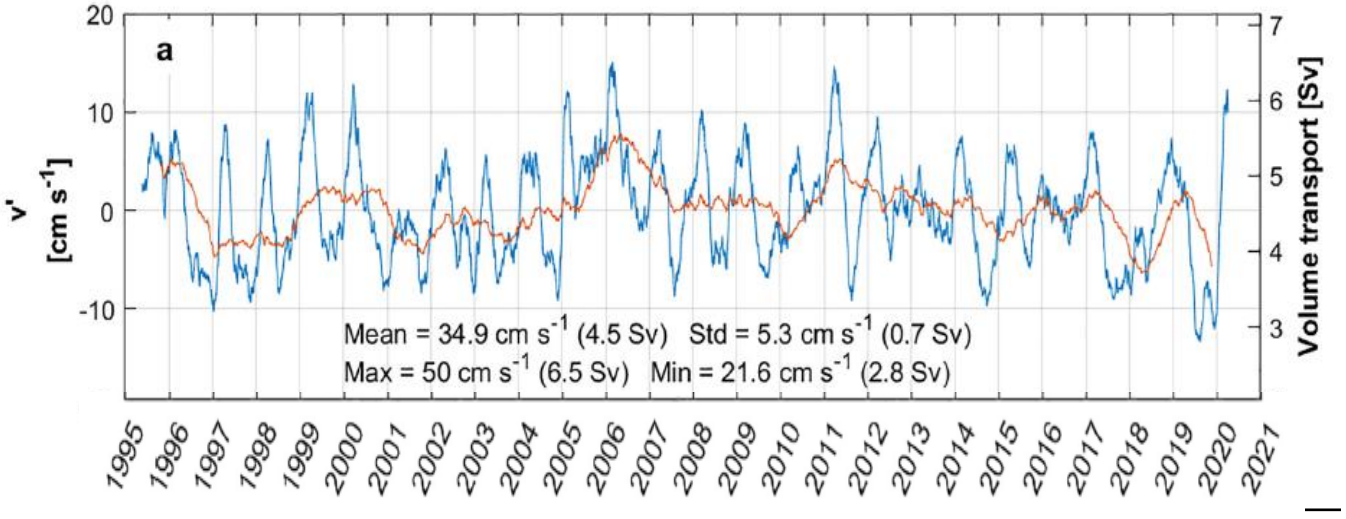
There is a LARGER heat loss .....

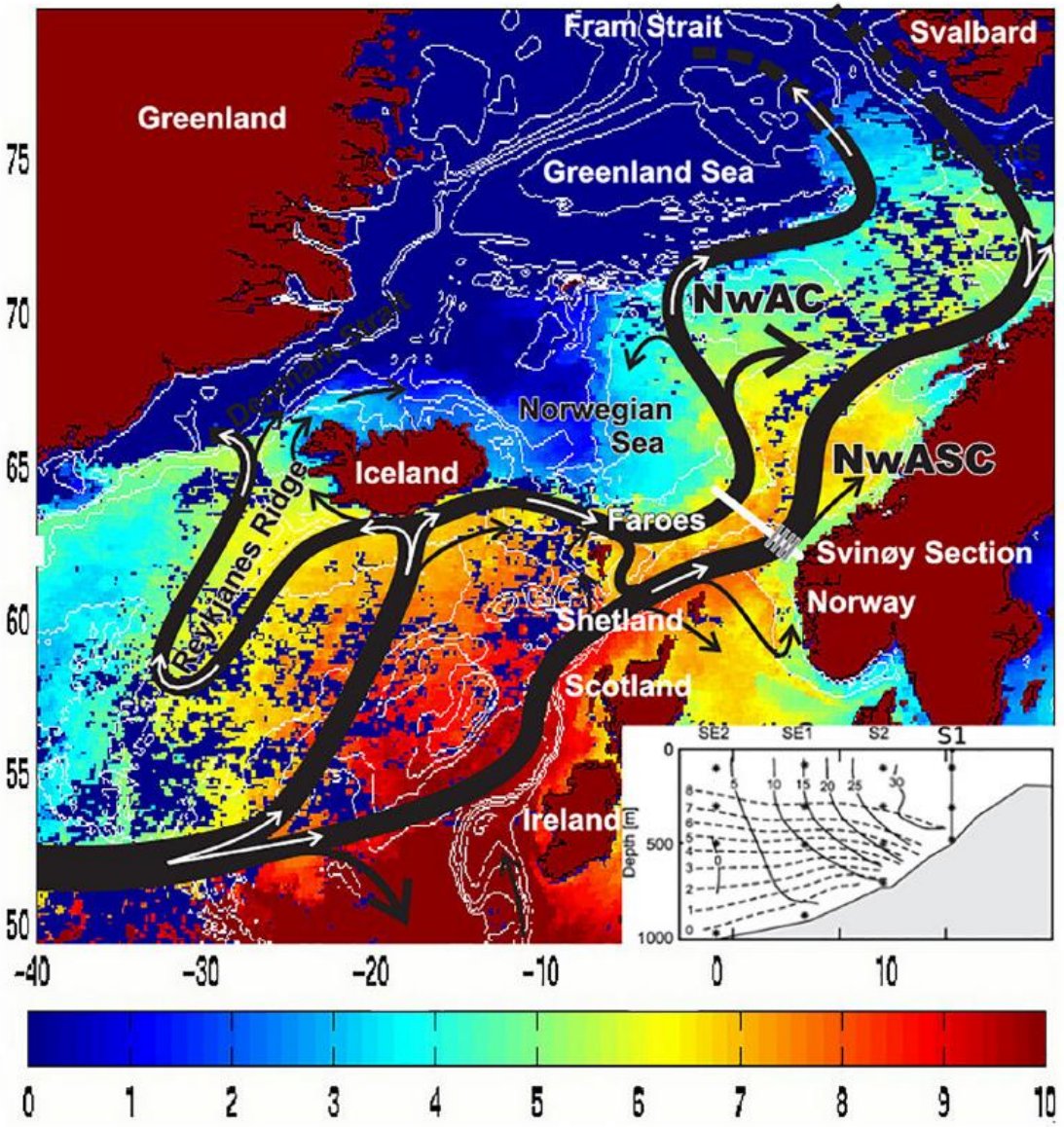
Where is the heat coming from ??

Orvik (2022)

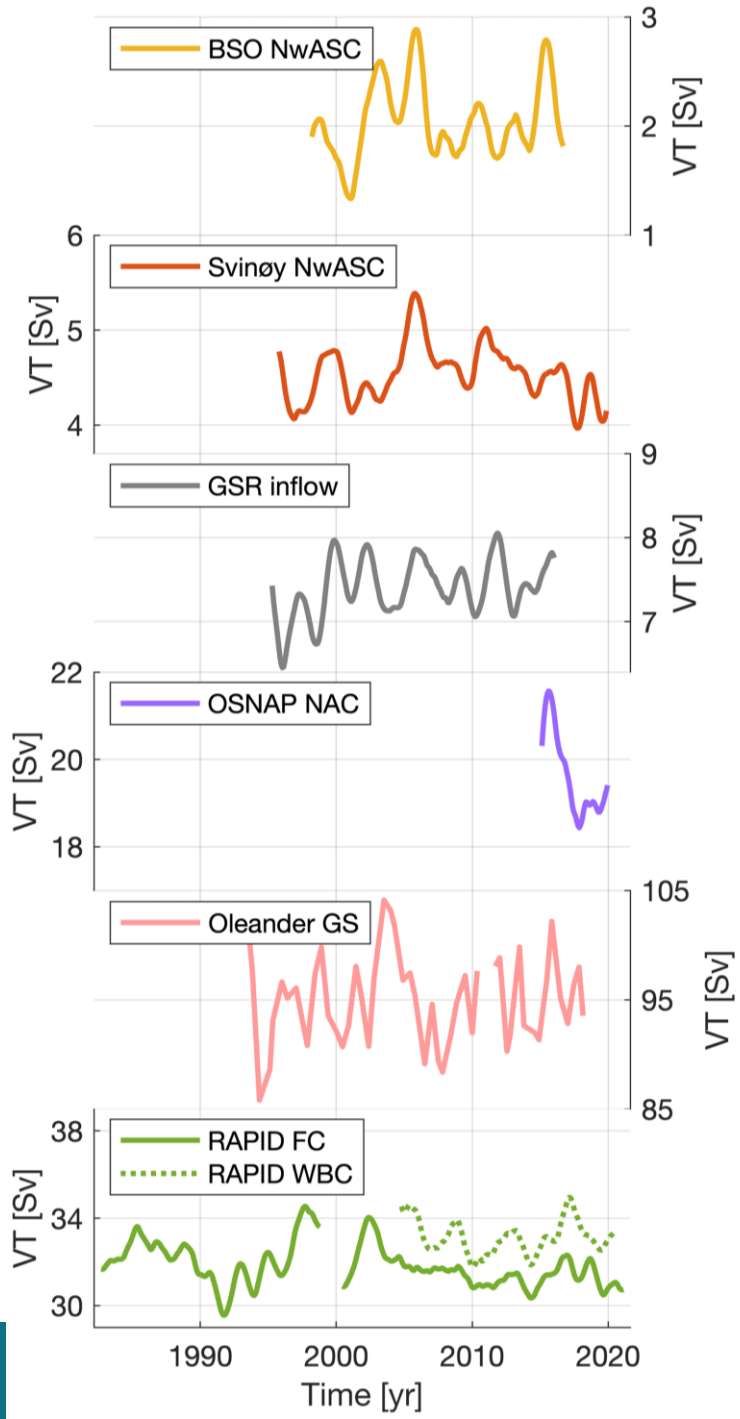
A STRONGER ATLANTIC INFLOW ??

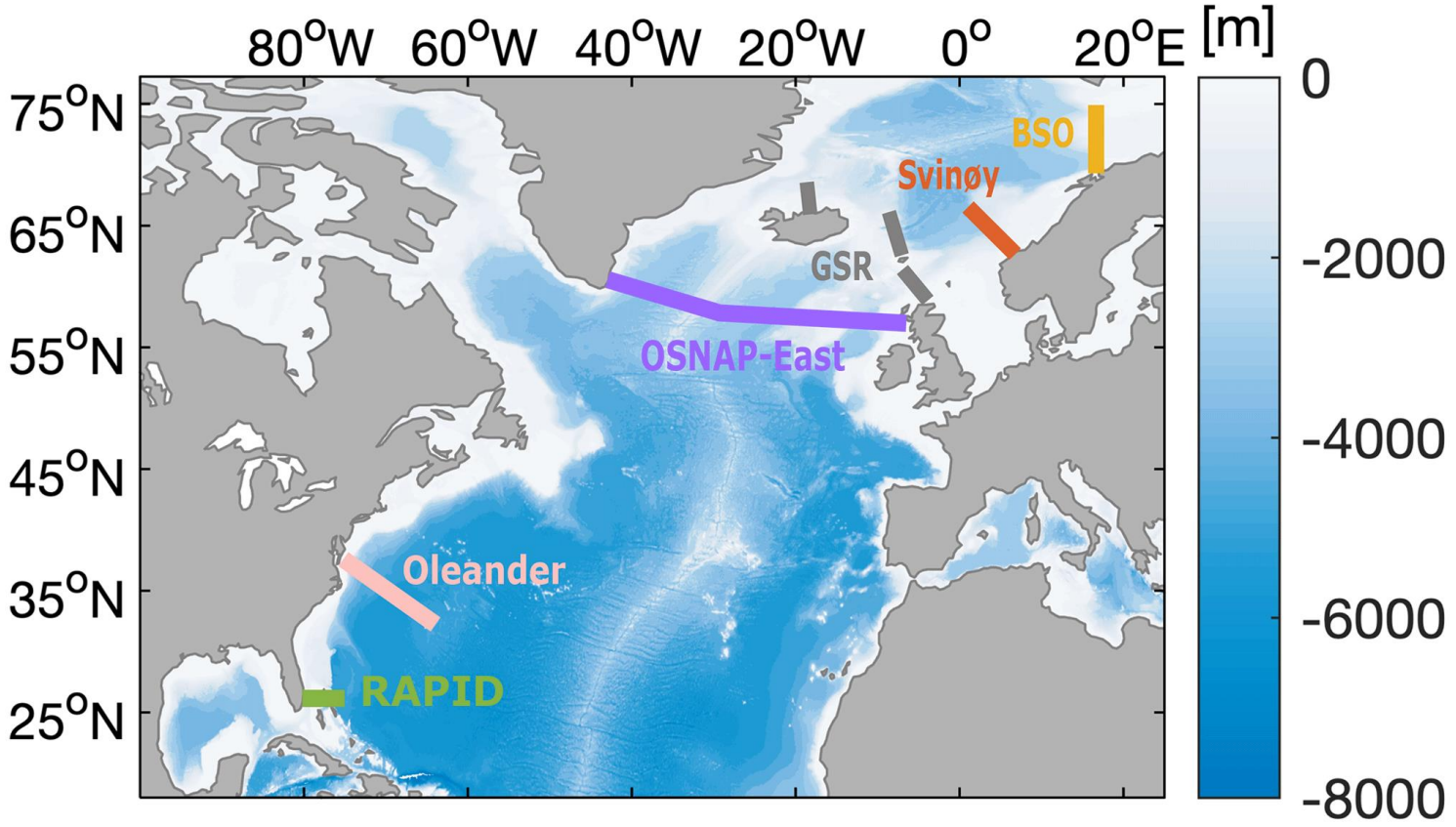
Long-Term Moored Current and Temperature Measurements of the Atlantic Inflow Into the Nordic Seas in the Norwegian Atlantic Current; 1995–2020





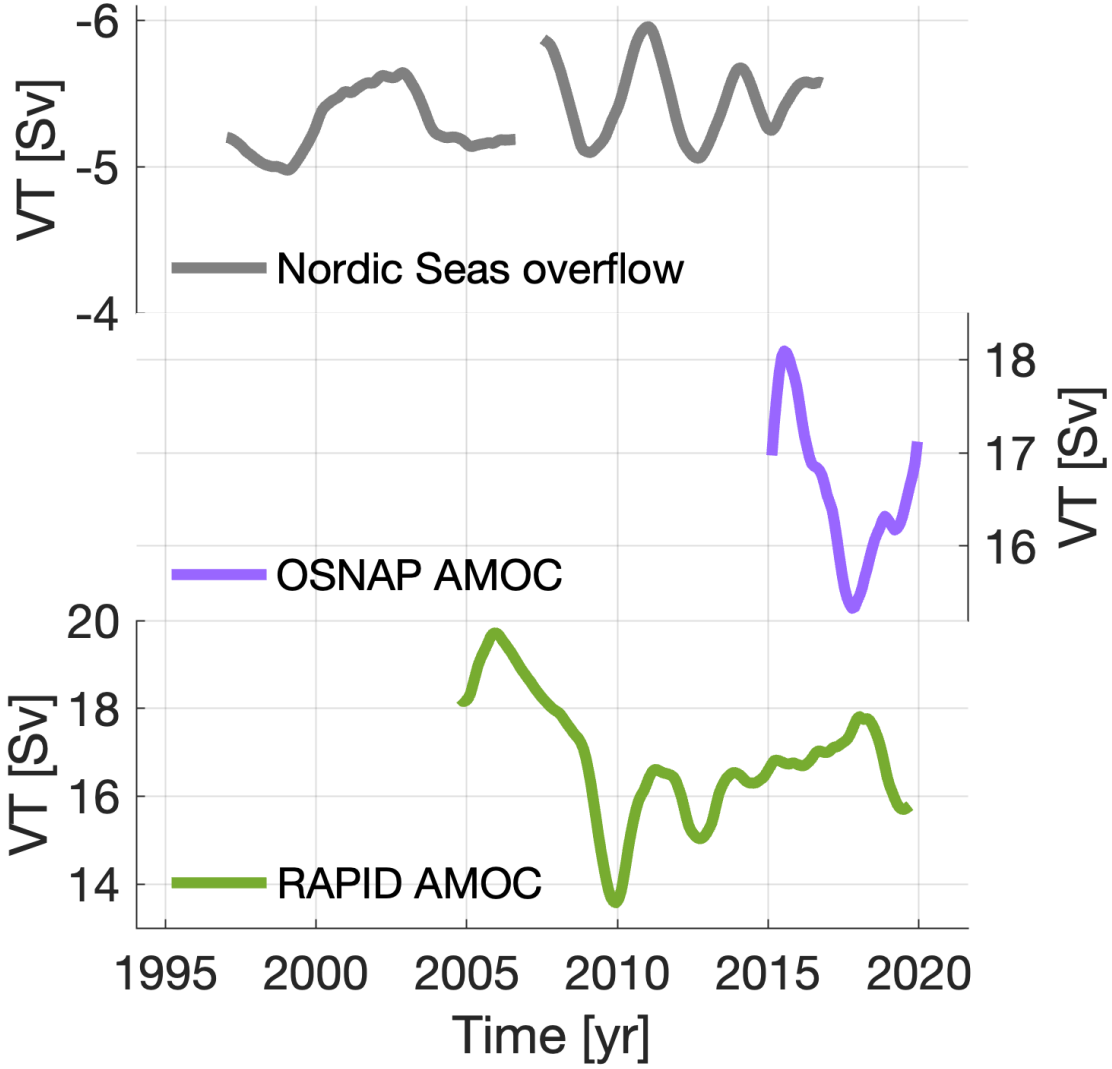
MEASUREMENTS OF UPPER-OCEAN BRANCHES EXTENDED GULF STREAM SYSTEM

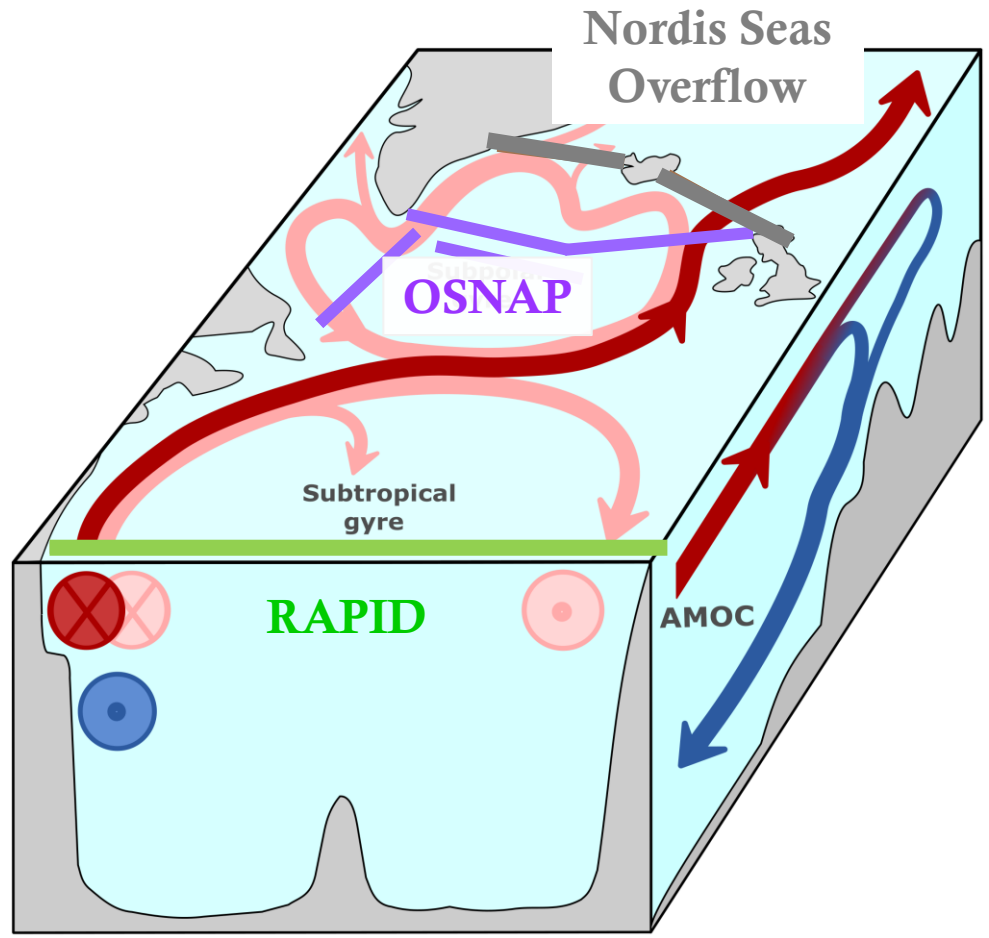




Asbjørnsen et al. (2024)

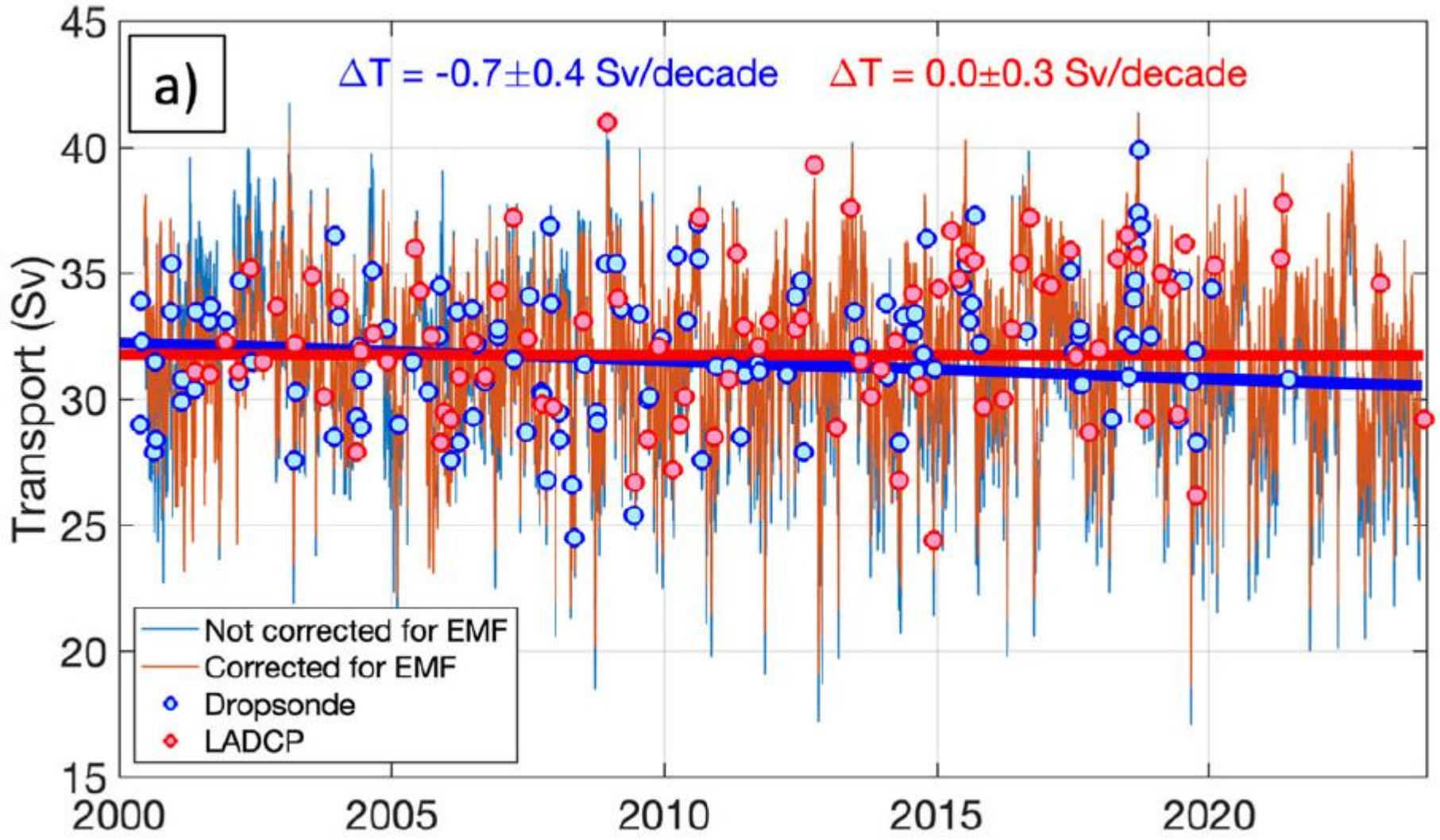
OVERTURNING – NO SIGNS OF 'COLLAPSE'





Asbjørnsen et al. (2024)

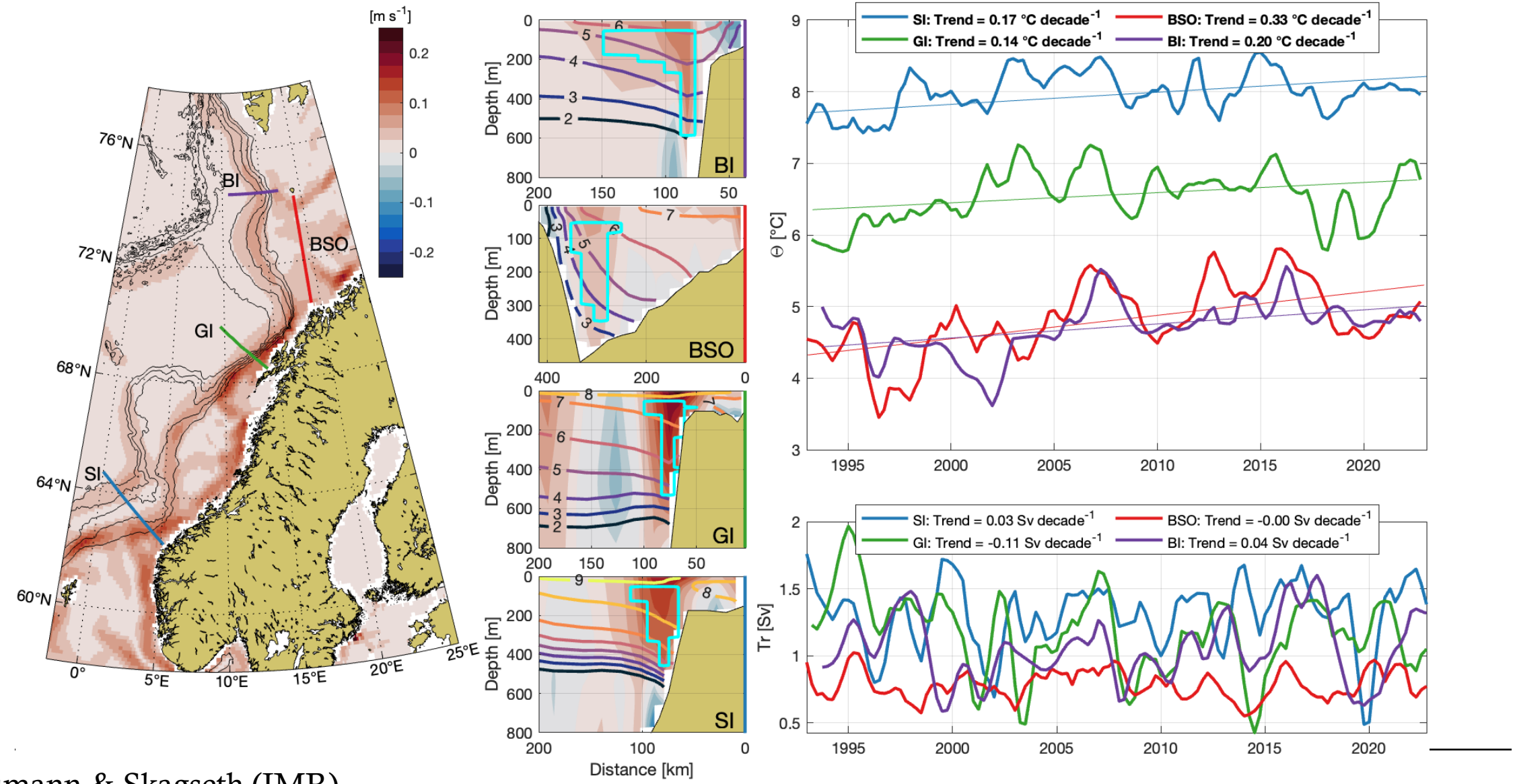
THE FLORIDA CURRENT HAS REMAINED REMARKABLY STABLE



Volkov et al. (2024)

Florida Current (FC) transports corrected for change in the Earth's Magnetic Field (EMF)

A WARMING INFLOW ALONG THE NORWEGIAN COAST

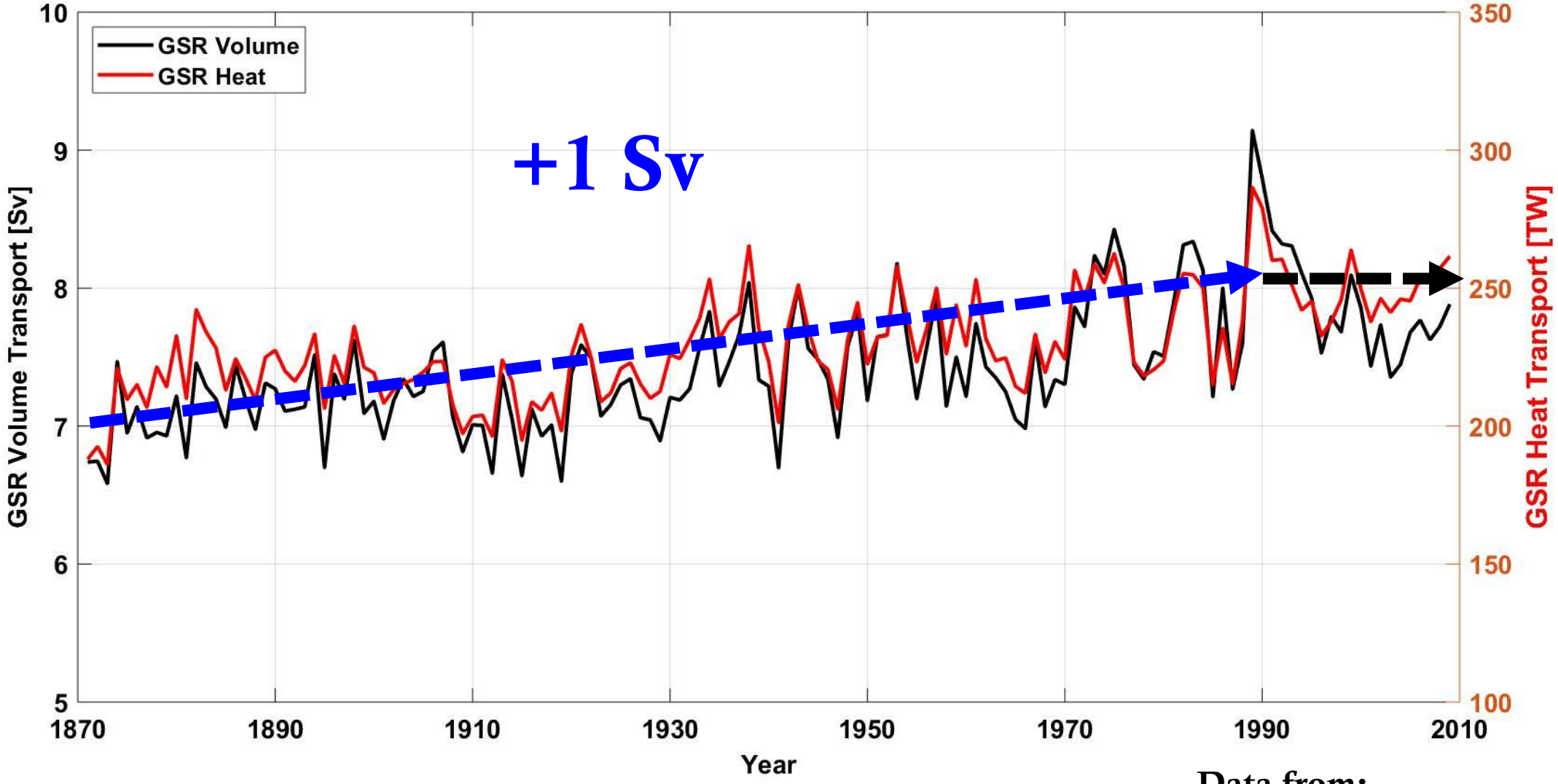


Baumann & Skagseth (IMR)
(In Progress)

Transports from SSH (sattelite) + Geostrophy (sections ~ 3 months)

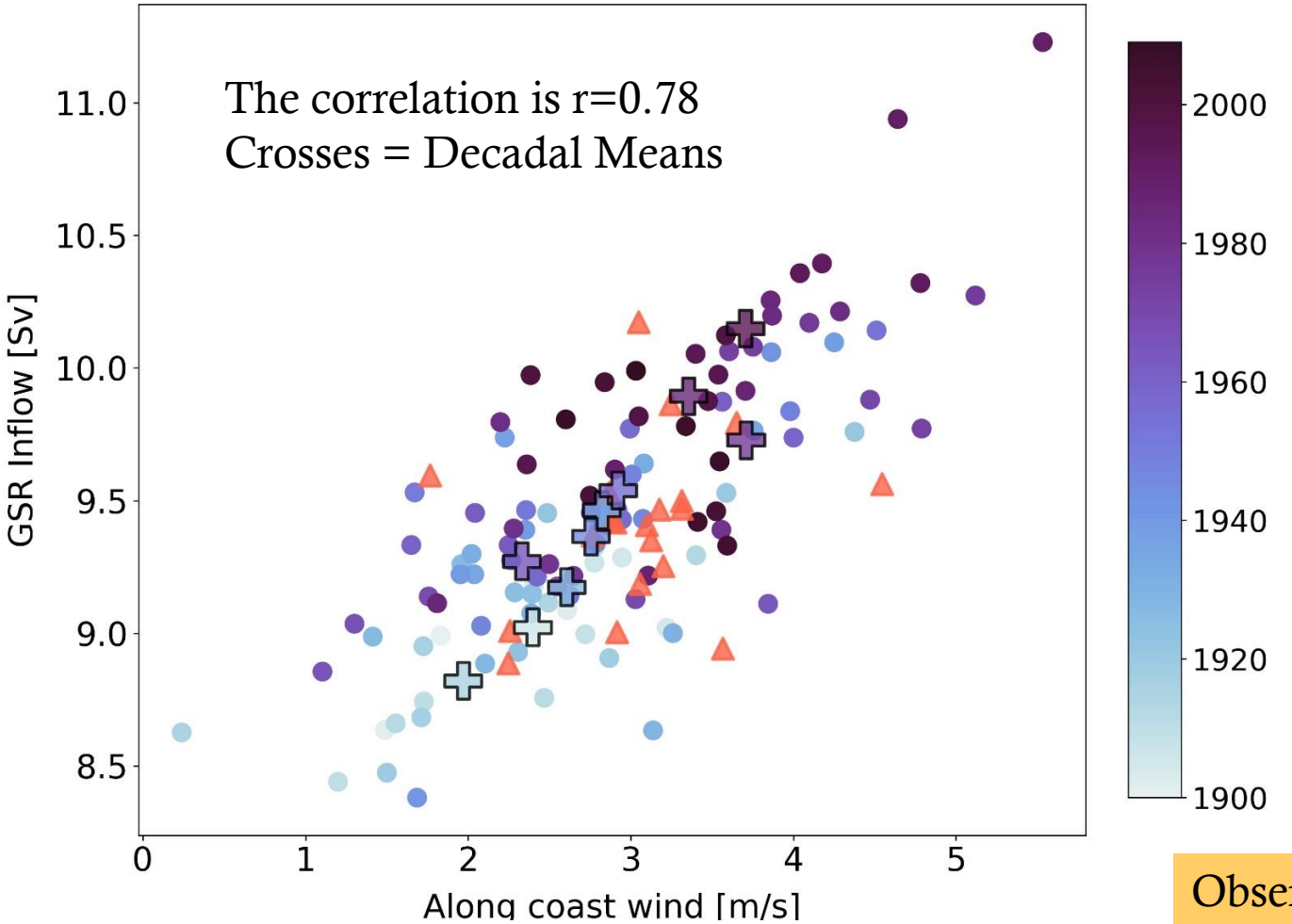
A stronger Atlantic Inflow ??

YES - but before 1990's…



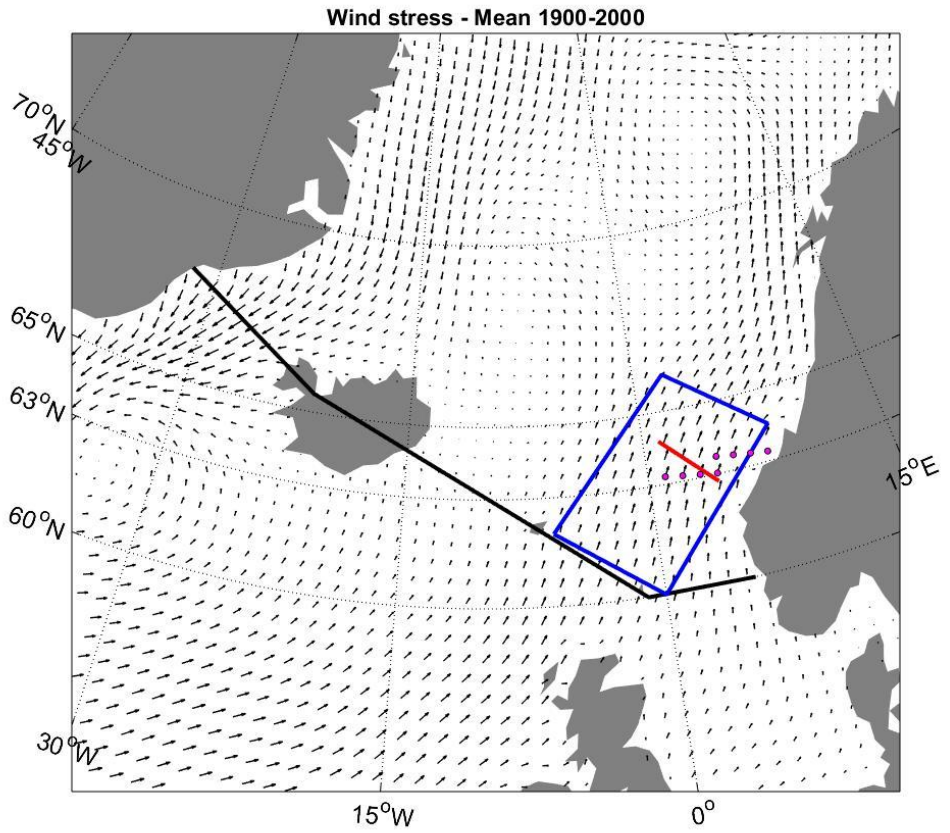
Data from:
Smedsrud et al (2022)

INCREASED INFLOW (< 1990'S) CAUSED BY WIND FORCING



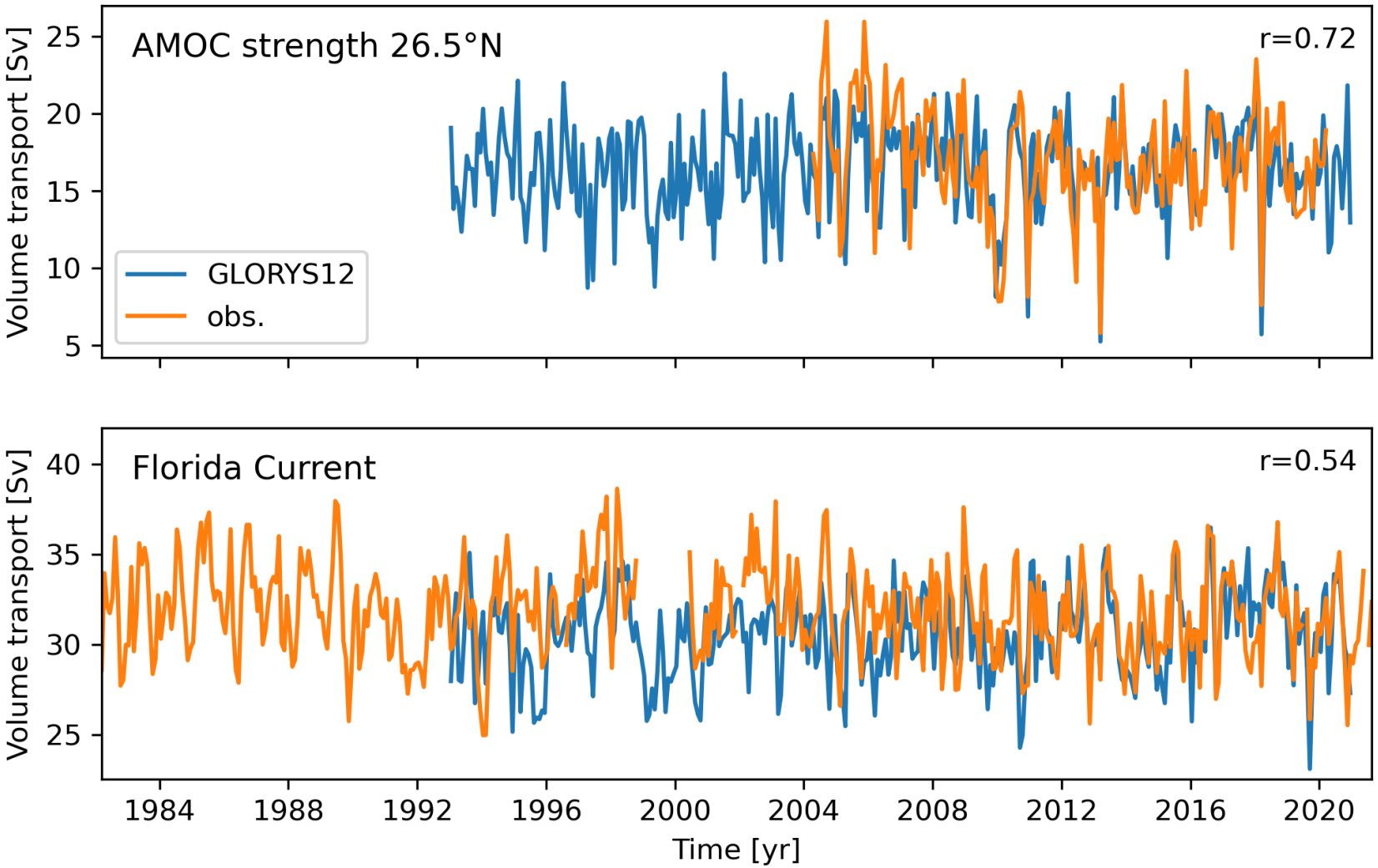
Colors show years

Smedsrud et al (2022)



Observations (1996-2016 – orange triangles):
Svinøy section volume anomalies + wind speed (Utsira)
Flow based on hydrography (Øystein Skagseth, IMR).

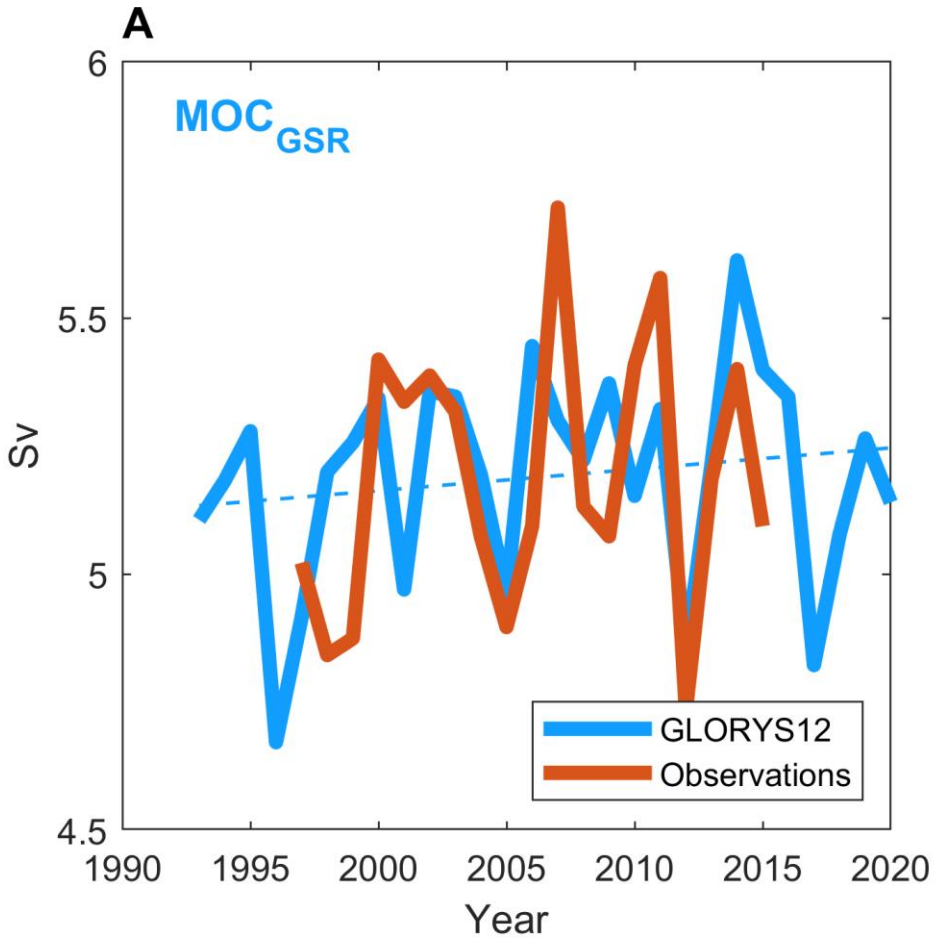
COMPARING OBSERVATIONS AND OCEAN RE-ANALYSIS

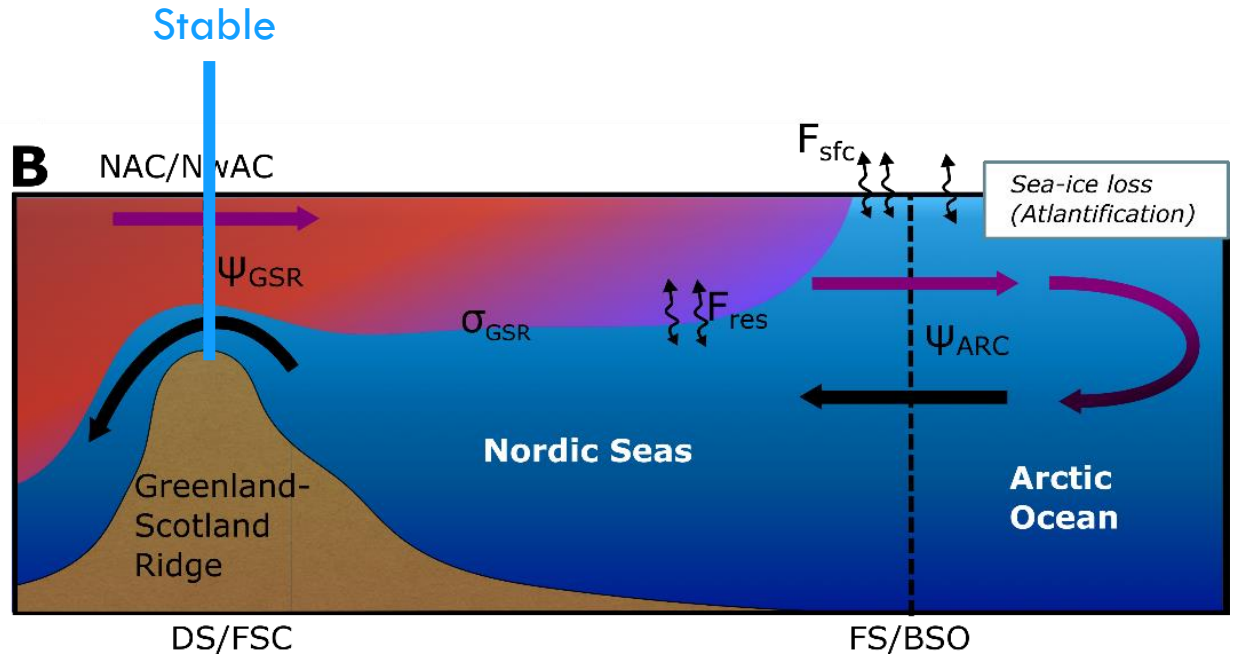


GLORYS12 reanalysis –
ERA-Interim surface forcing

Assimilates: SST, SIC,
SSH from satellite obs.
Temp & Salinity from EN4.
Uses a Kalman filter etc.

THE ARCTIC OVERTURNING IS STABLE

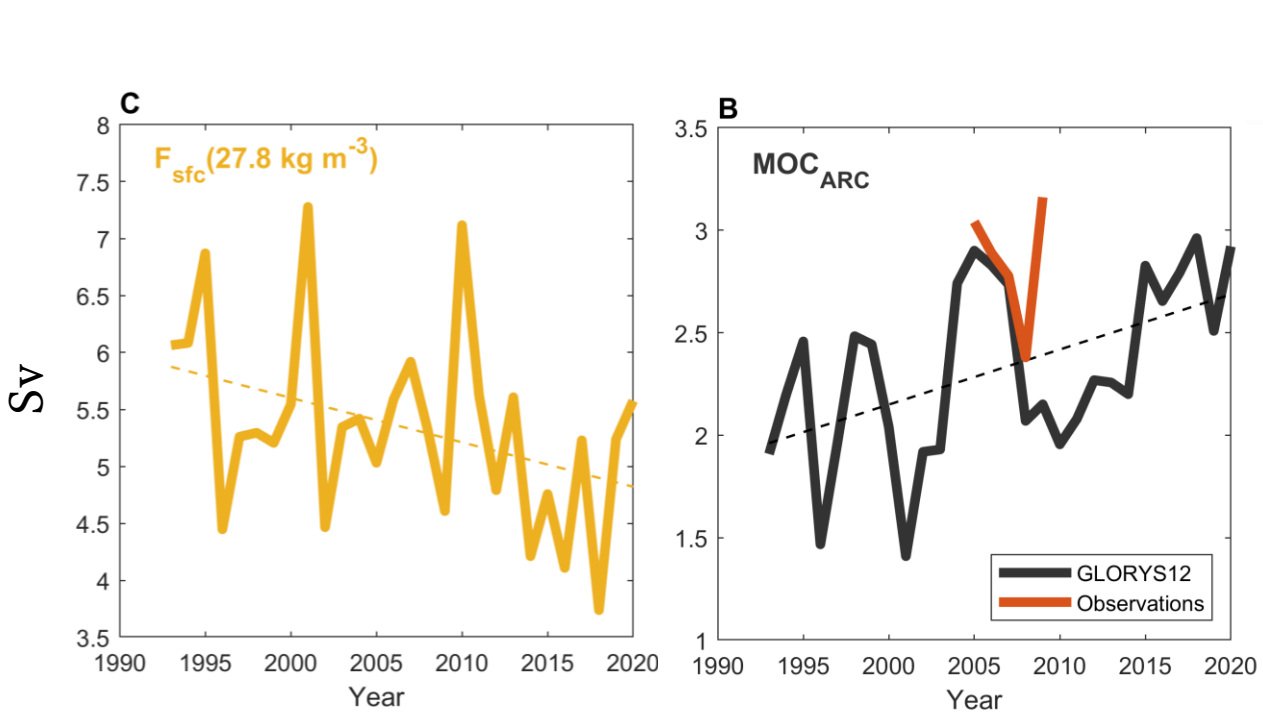


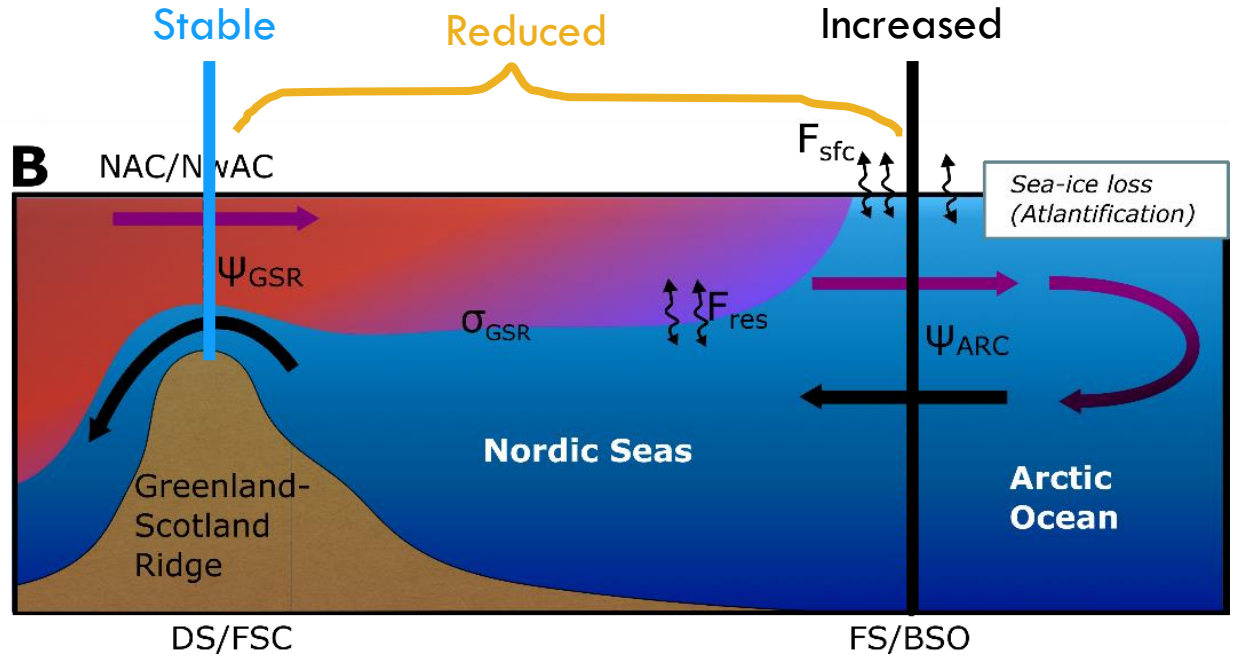


Årthun et al (Submitted - 2025)

THE ARCTIC OVERTURNING IS STABLE

Reduced dense-water transformation within the Nordic Seas is compensated by increased dense-water formation in the Arctic Ocean



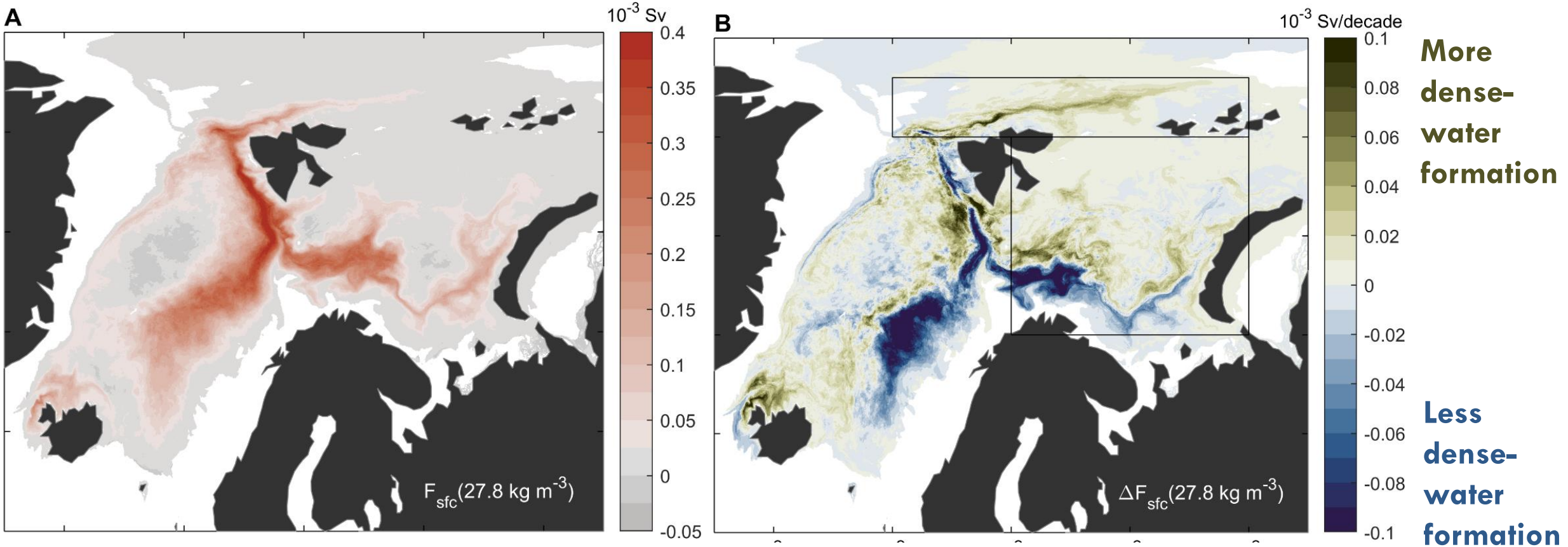


Årthun et al (Submitted - 2025)

WHY IS THE ARCTIC OVERTURNING STABLE?

Northward migration of ocean cooling…

Årthun et al (Submitted - 2025)



More dense-water formation

Less dense-water formation

Mean cooling/densification

Change in cooling/densification (1992 – 2020)

SUMMARY: +1 Sv +2°C

- Warming AW since 1970's: Max +2°C
- Increased AW inflow 1900 – 1990's: +1 Sv
  "Steady" inflow since 1990's
- Increased Ocean Heat Transport: + 50 TW
- Arctic Sea Ice Loss:
  - Barents & Greenland Sea
  - Causes larger heat loss
- Arctic Overturning is 'stable'
  - Larger heat loss further north
  - Warming and more buoyant water in Nordic Seas
  - Greenland Sea Deep Water is not produced – but intermediate water