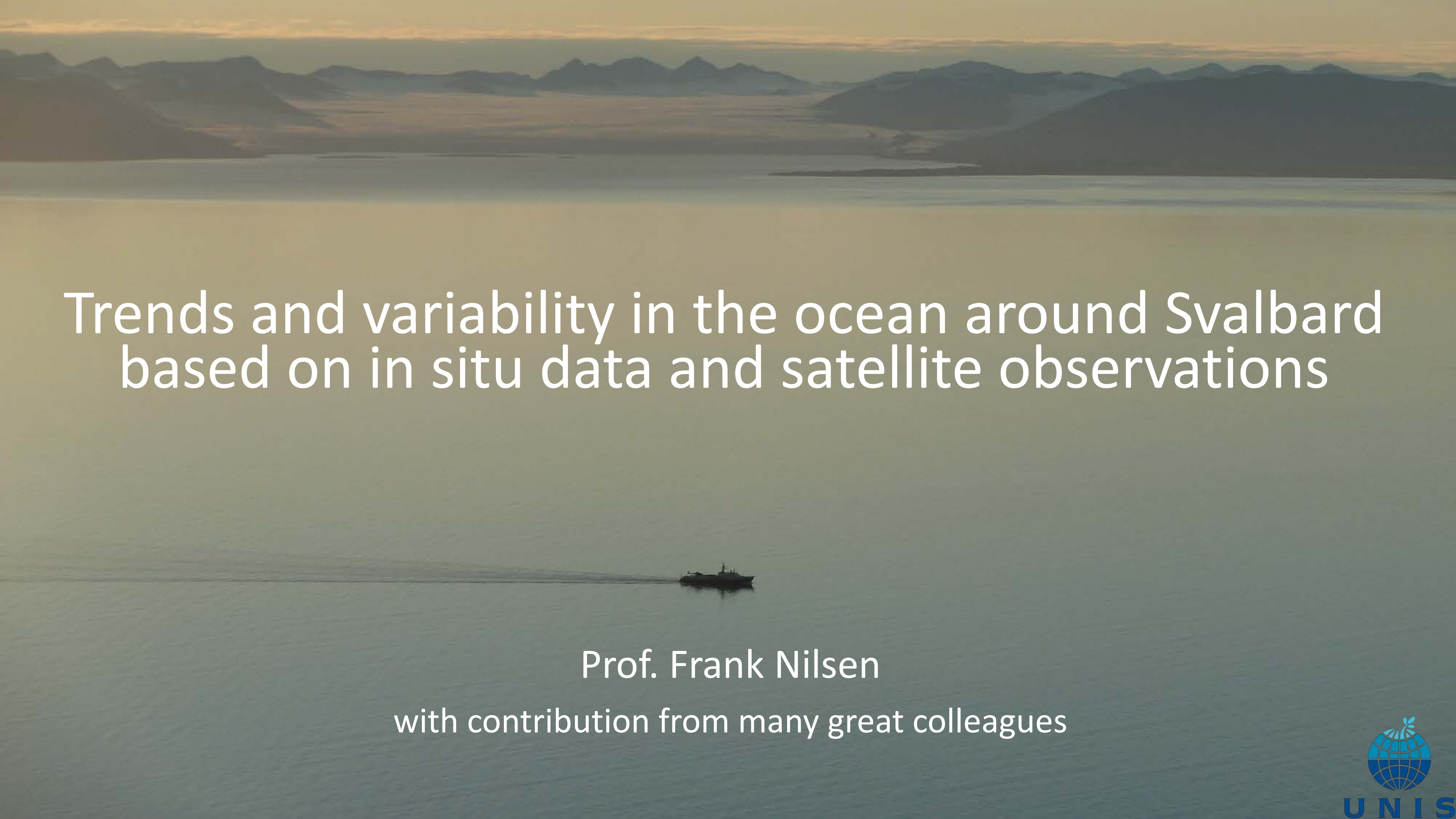


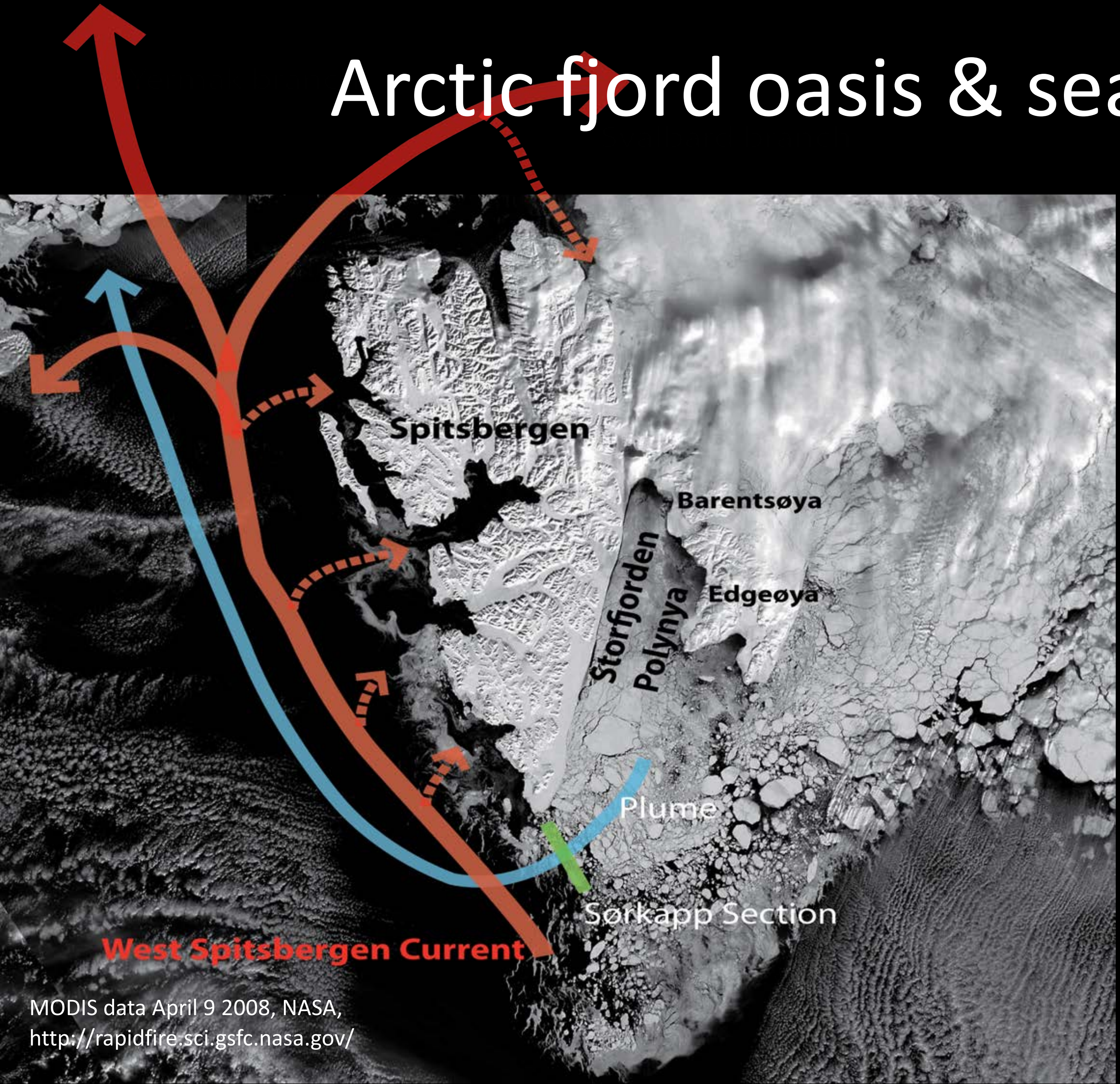
Trends and variability in the ocean around Svalbard based on in situ data and satellite observations

Prof. Frank Nilsen

with contribution from many great colleagues

UNIS

Arctic fjord oasis & sea ice factories



MODIS data April 9 2008, NASA, http://rapidfire.sci.gsfc.nasa.gov/

The field work laboratory for the Air-Cryosphere-Sea Interaction (ACSI) Group

Nilsen et al. (2016), J. Phys. Oceanography

Muckenhuber et al., (2016), The Cryosphere

UNIS

Progress in Oceanography 187 (2020) 102394

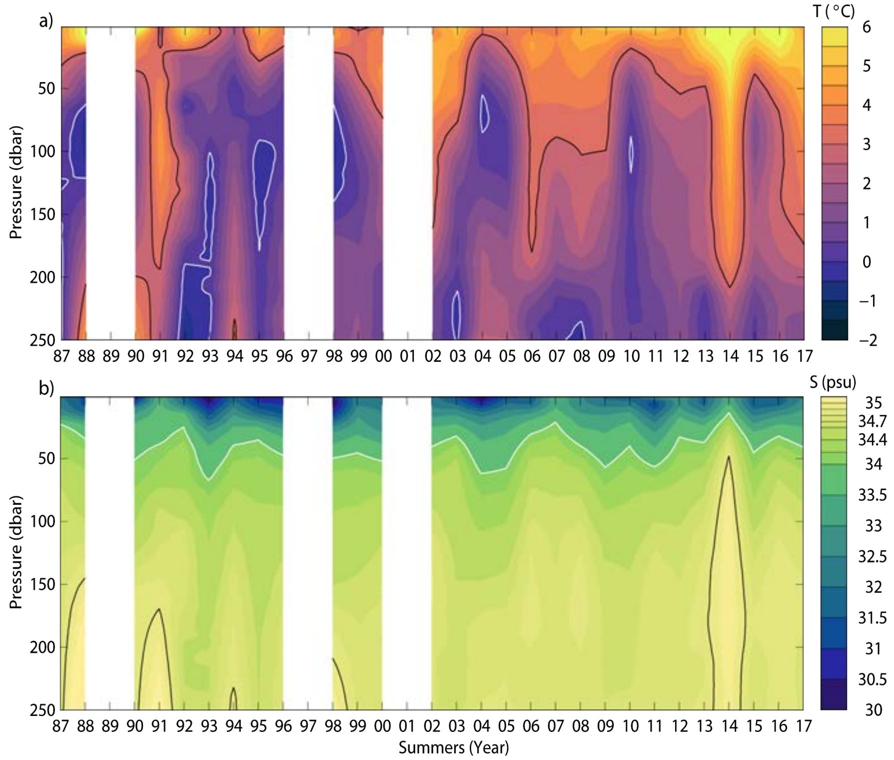
Contents lists available at ScienceDirect

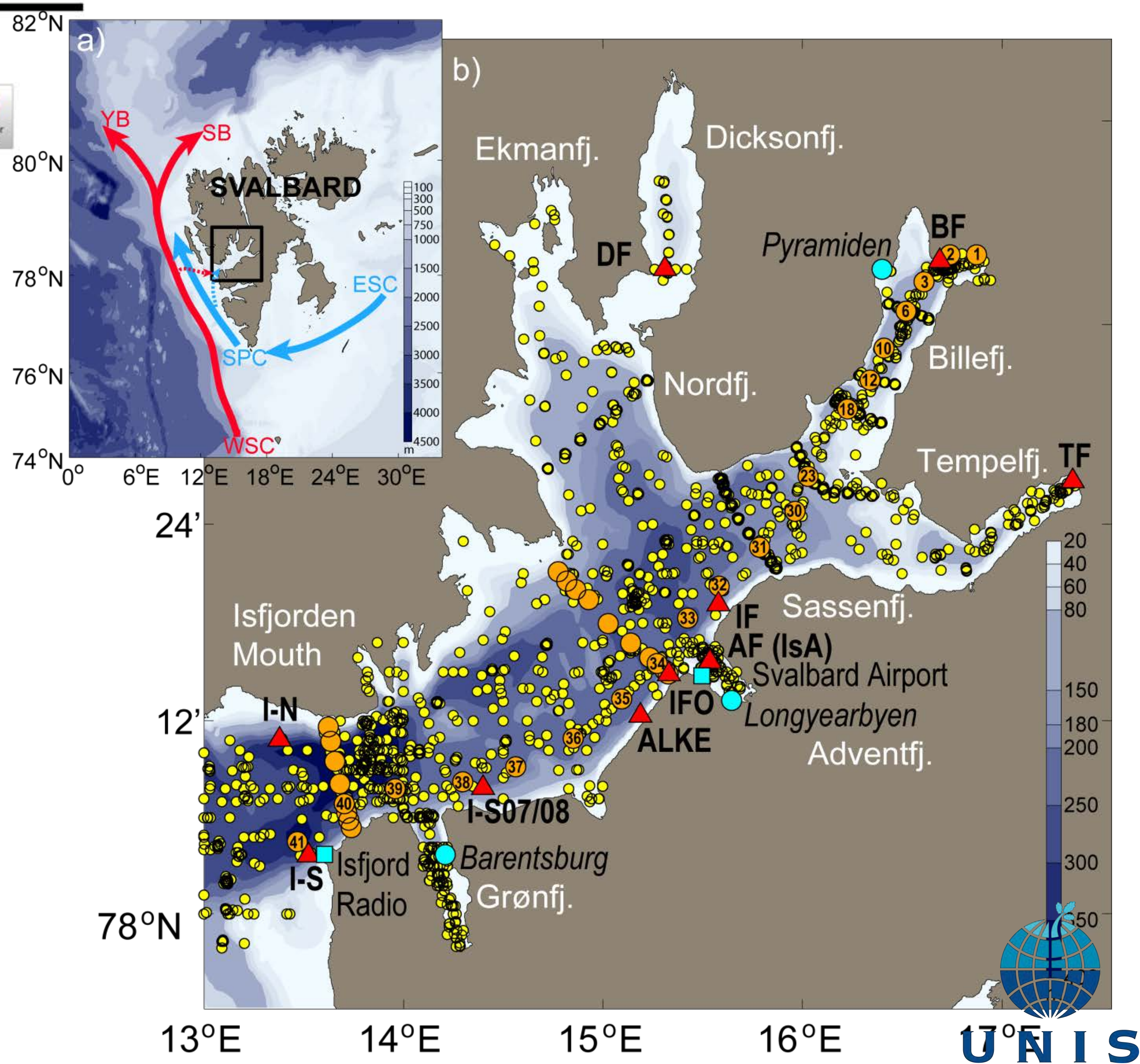
Progress in Oceanography

journal homepage: www.elsevier.com/locate/pocean

Variability and decadal trends in the Isfjorden (Svalbard) ocean climate and circulation – An indicator for climate change in the European Arctic

R. Skogseth[a,*], L.L.A. Olivier[a,b], F. Nilsen[a,c], E. Falck[a,c], N. Fraser[d], V. Tverberg[f], A.B. Ledang[g], A. Vader[a], M.O. Jonassen[a,c], J. Søreide[a], F. Cottier[d,e], J. Berge[a,e], B.V. Ivanov[h,i], S. Falk-Petersen[j,e]





Publication of trend analysis on the ocean climate in Isfjorden ->

An inter-departmental collaboration gathering and using all available oceanographic data collected

1) by UNIS collegues and students
2) in collaboration with partner institutions
3) from public marine databases

Publication of oceanographic data sets from Isfjorden!

1) UNIS Hydrographic Database (Skogseth et al., 2020).
2) Several data sets with yearlong time series from moorings (Skogseth and Ellingsen, 2019).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Variability and decadal trends in the Isfjorden (Svalbard) ocean climate and circulation – An indicator for climate change in the European Arctic

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[a] The University Centre in Svalbard, Postboks 156, 9171 Longyearbyen, Norway
[b] Geosciences Department, Ecole Normale Supérieure, PSL Res. Univ., Paris, France
[c] University of Bergen, Geophysical Institute, Postboks 7803, 5020 Bergen, Norway
[d] Scottish Association for Marine Science, Scottish Marine Institute, Oban, Argyll PA37 1QA, Scotland, United Kingdom
[e] Department of Arctic and Marine Biology, University of Tromsø - The Arctic University of Norway, 9037 Tromsø, Norway
[f] Nord University, Faculty of Biosciences and Aquaculture, Bodø, Norway
[g] Norwegian Institute for Water Research, Gaustadalléen 21, NO-0349 Oslo, Norway
[h] Arctic and Antarctic Research Institute, Atmosphere-Sea Ice-Ocean Interaction Department, Saint-Petersburg, Russian Federation
[i] Saint-Petersburg State University, Oceanography Department, Saint-Petersburg, Russian Federation
[j] Akvaplan-niva AS, The Fram Centre, Hjalmar Johansens Gate 14, 9007 Tromsø, Norway

ARTICLE INFO

Keywords:
Oceanography
TSD distribution, water masses and circulation
Ocean circulation and currents
Nearshore dynamics
Tides, surges and sea level
Atlantic Water intrusion
Arctic Ocean, Svalbard, West Spitsbergen Shelf, Isfjorden

ABSTRACT

Isfjorden, a broad Arctic fjord in western Spitsbergen, has shown significant changes in hydrography and inflow of Atlantic Water (AW) the last decades that only recently have been observed in the Arctic Ocean north of Svalbard. Variability and trends in this fjord's climate and circulation are therefore analysed from observational and reanalysis data during 1987 to 2017. Isfjorden experienced a shift in summer ocean structure in 2006, from AW generally in the bottom layer to AW (with increasing thickness) higher up in the water column. This shift, and a concomitant shift to less fast ice in Isfjorden are linked to positive trends in the mean sea surface temperature (SST) and volume weighted mean temperature (VT) in winter (SST_W/VT_W: 0.7 ± 0.1/0.9 ± 0.3 °C 10 yr^{-1}) and summer (SST_S/VT_S: 0.7 ± 0.1/0.6 ± 0.1 °C 10 yr^{-1}). Hence, the local mean air temperature shows similar trends in winter (1.9 ± 0.4 °C 10 yr^{-1}) and summer (0.7 ± 0.1 °C 10 yr^{-1}). Positive trends in volume weighted mean salinity in winter (0.21 ± 0.06 10 yr^{-1}) and summer (0.07 ± 0.05 10 yr^{-1}) suggest increased AW advection as a main reason for Isfjorden's climate change. Local mean air temperature correlates significantly with sea ice cover, SST, and VT, revealing the fjord's impact on the local terrestrial climate.

In line with the shift in summer ocean structure, Isfjorden has changed from an Arctic type fjord dominated by Winter Deep and Winter Intermediate thermal and haline convection, to a fjord dominated by deep thermal convection of Atlantic type water (Winter Open). AW indexes for the mouth and Isfjorden proper show that AW influence has been common in winter over the last decade. Alternating occurrence of Arctic and Atlantic type water at the mouth mirrors the geostrophic control imposed by the Spitsbergen Polar Current (carrying Arctic Water) relative to the strength of the Spitsbergen Trough Current (carrying AW). During high AW impact events, Atlantic type water propagates into the fjord according to the cyclonic circulation along isobaths corresponding to the winter convection. Tides play a minor role in the variance in the currents, but are important in the side fjords where exchange with the warmer Isfjorden proper occurs in winter. This study demonstrates that Isfjorden and its ocean climate can be used as an indicator for climate change in the Arctic Ocean. The used methods may constitute a set of helpful tools for future studies also outside the Svalbard Archipelago.

Abbreviations: AW, Atlantic Water; ArW, Arctic Water; CTD, Conductivity, temperature and depth; DAC, Depth-averaged current; DFI, Days of fast ice; ESC, East Spitsbergen Current; IW, Intermediate Water; LW, Local Water; SPC, Spitsbergen Polar Current; SST, Sea surface temperature; STC, Spitsbergen Trough Current; SW, Surface Water; TAW, Transformed Atlantic Water; UNIS HD, UNIS hydrographic database; VM-ADCP, Vessel-mounted acoustic Doppler current profiler; VT, Volume weighted mean temperature; VS, Volume weighted mean salinity; WCW, Winter-Cooled Water; WSC, West Spitsbergen Current; WSS, West Spitsbergen Shelf

* Corresponding author at: The University Centre in Svalbard, P.O. Box 156, 9171 Longyearbyen, Norway.
E-mail address: Ragnheid.Skogseth@unis.no (R. Skogseth).

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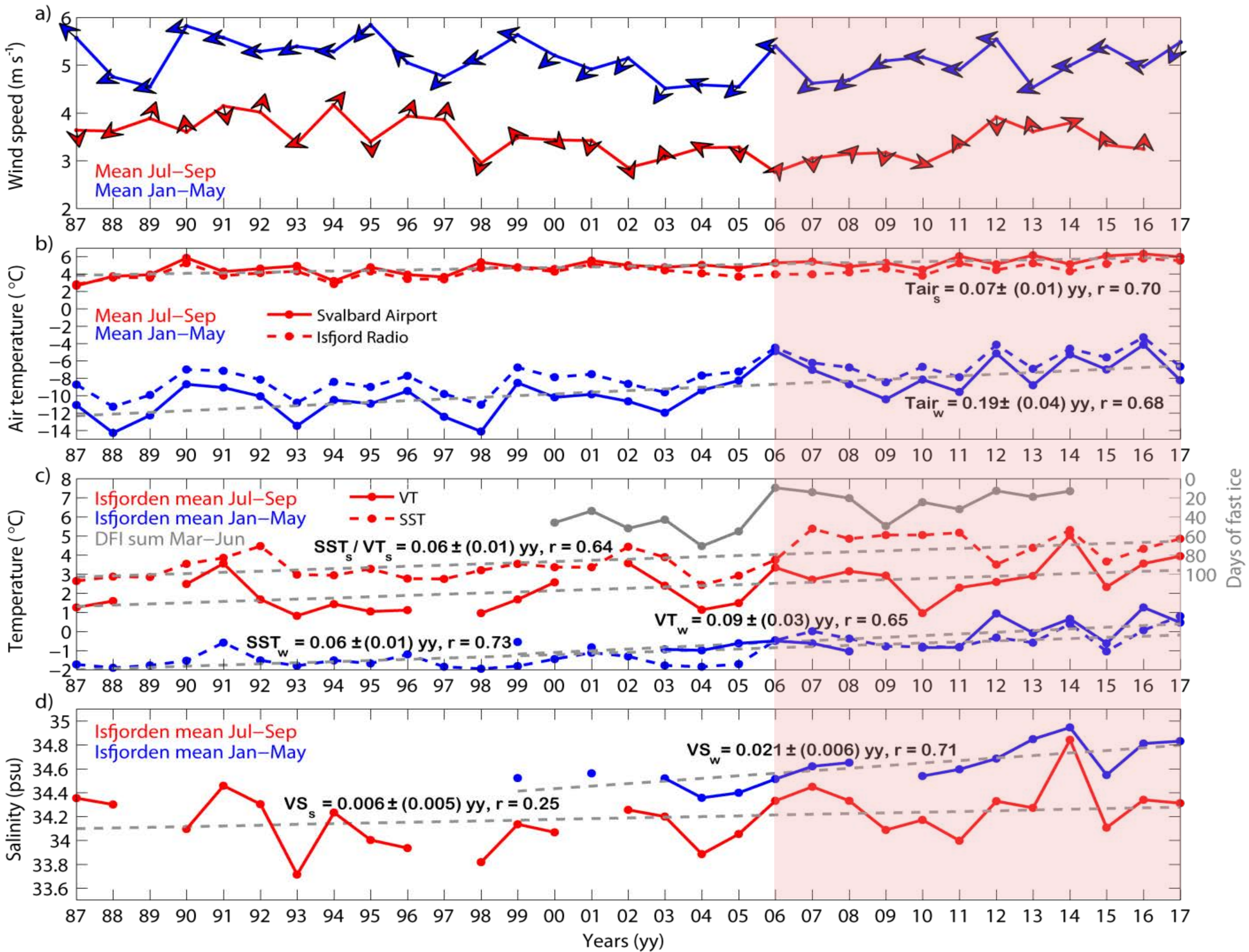
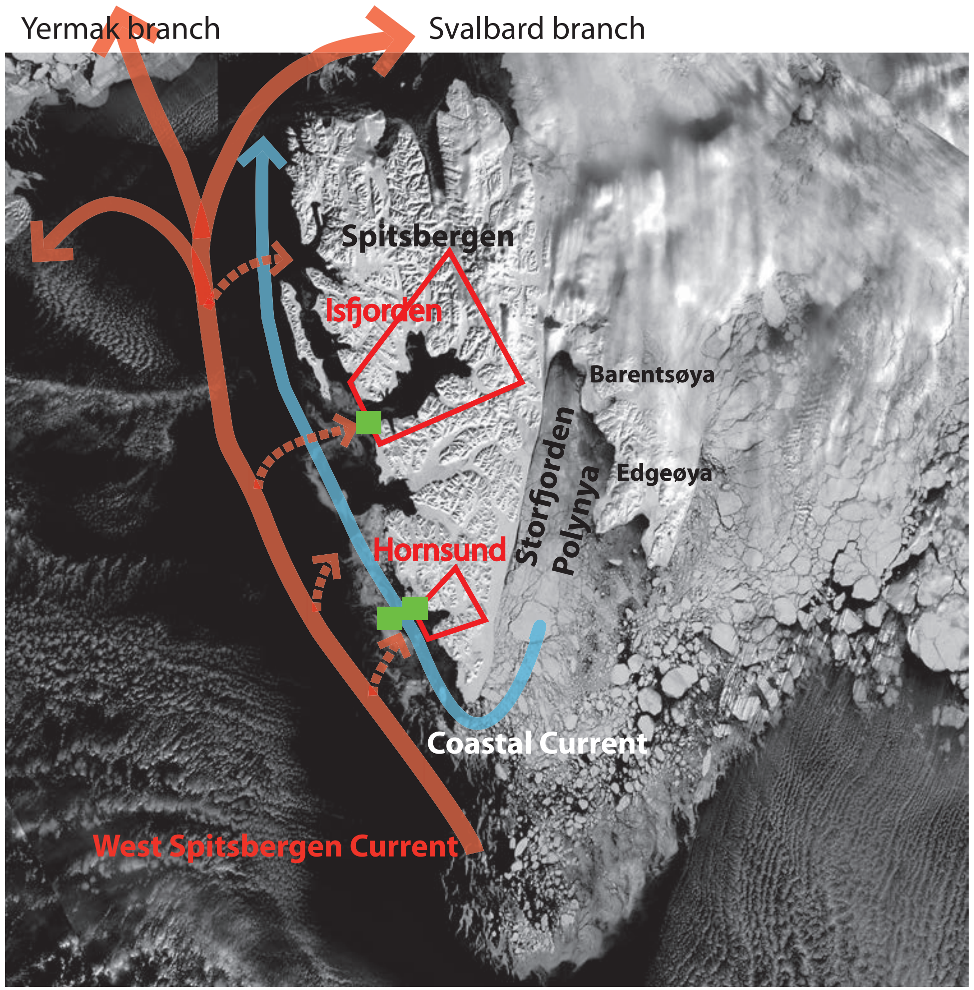
Received 4 April 2019; Received in revised form 9 January 2020; Accepted 17 June 2020
Available online 03 July 2020

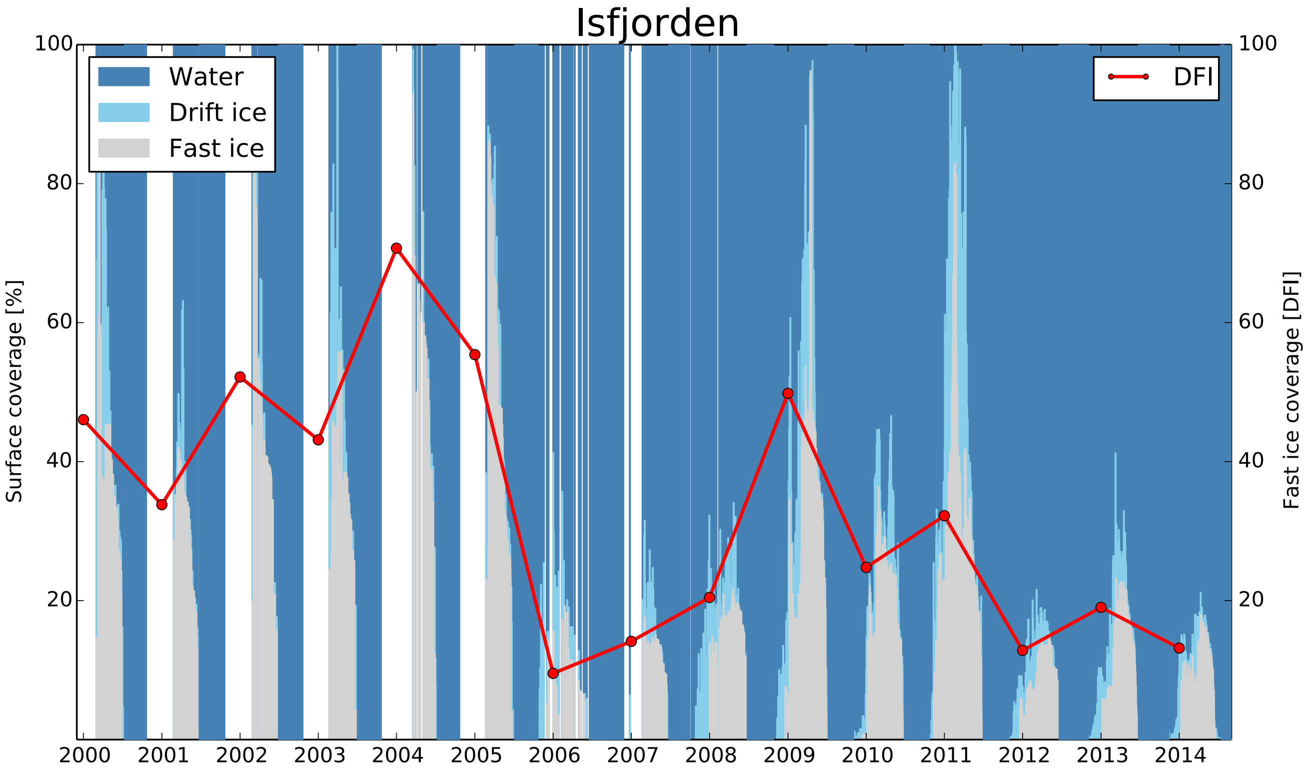
Connectivity to local atmospheric forcing and sea ice cover



Skogseth et al. (2020)

Increased intrusion of warm Atlantic Water





Muckenhuber et al. (2016)

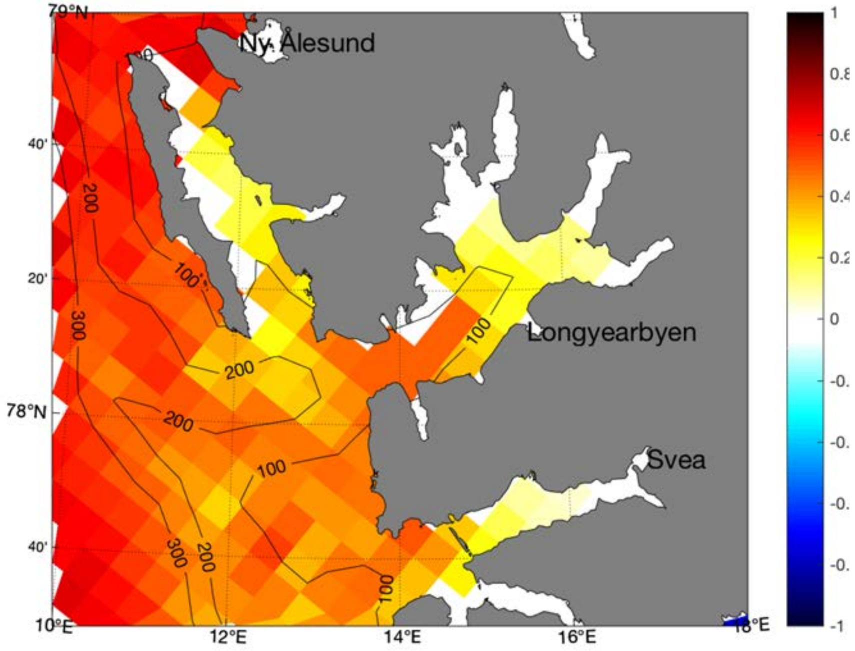
Hanssen-Bauer et al. (2019): Climate in Svalbard 2100 – a knowledge base for climate adaptation.

Increased ocean temperature and reduced sea ice cover

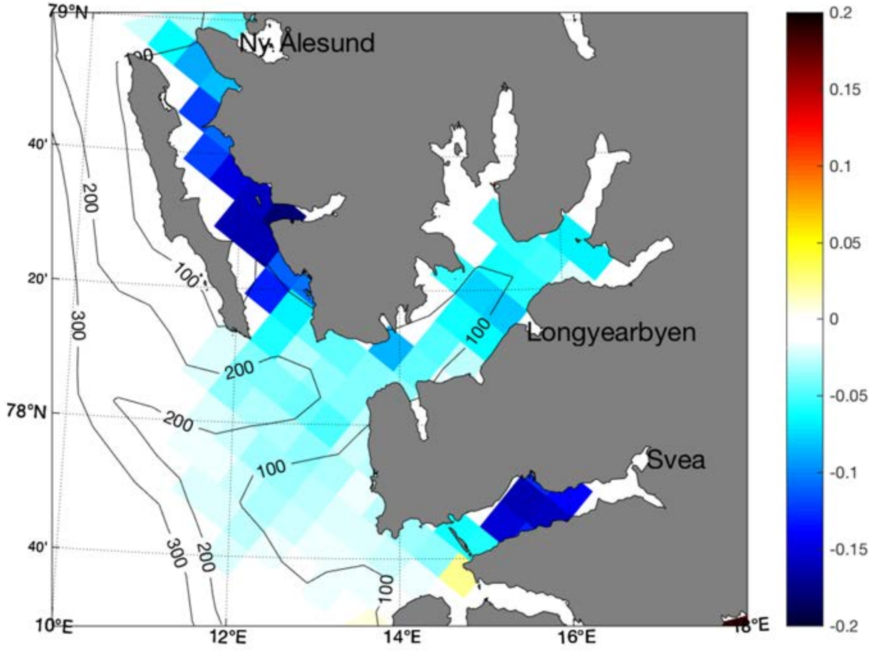
Hanssen-Bauer et al. (2019): Climate in Svalbard 2100 – a knowledge base for climate adaptation.

UNIS

The future ocean climate: (2060-2069) – (2010-2019) March



Endring i havtemperatur (°C)



Endring i sjøisdekket (brøkdel)

Hanssen-Bauer et al. (2019): Climate in Svalbard 2100 – a knowledge base for climate adaptation.

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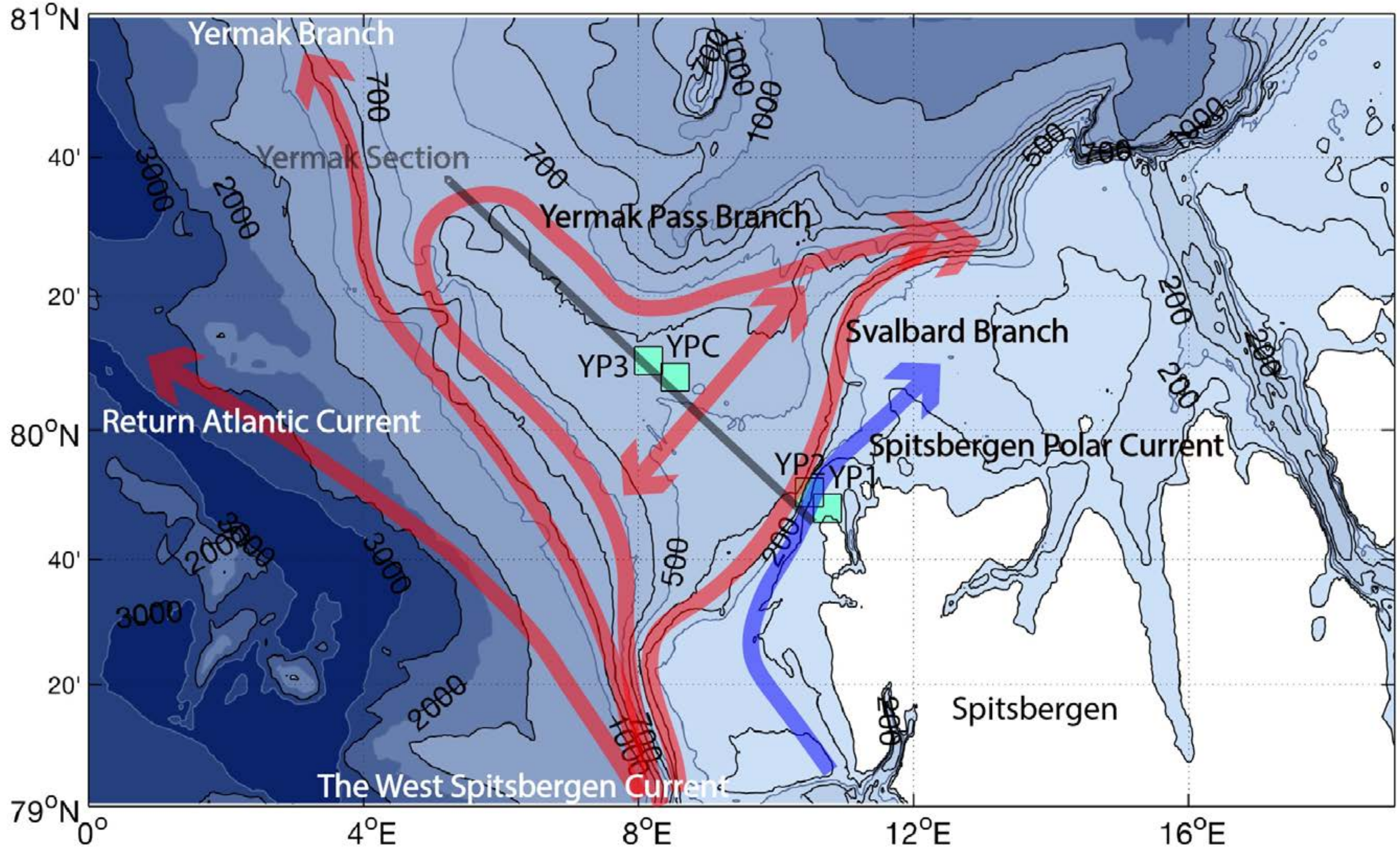
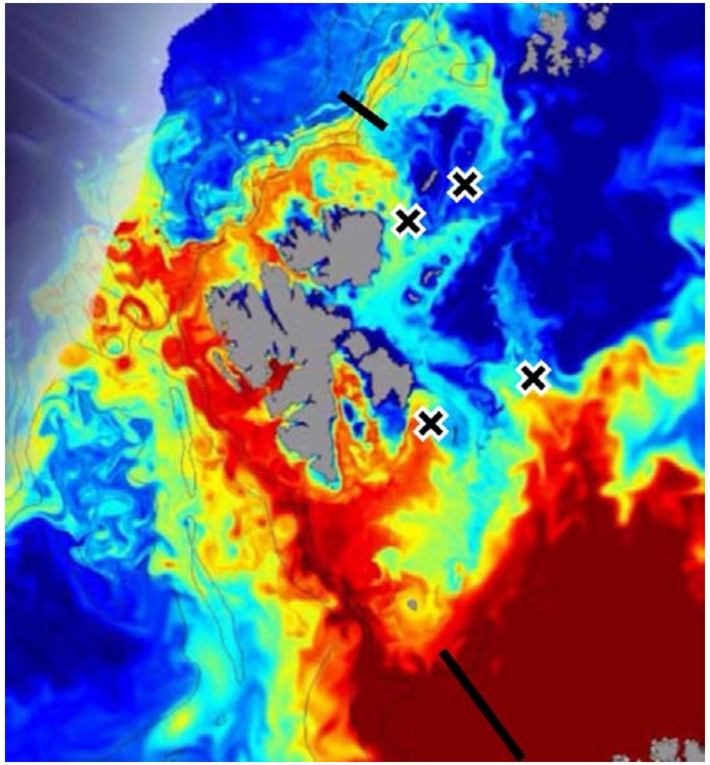
NORCE

Wind-Driven Variability in the Spitsbergen Polar Current and the Svalbard Branch Across the Yermak Plateau



Nilsen et al. (2021)

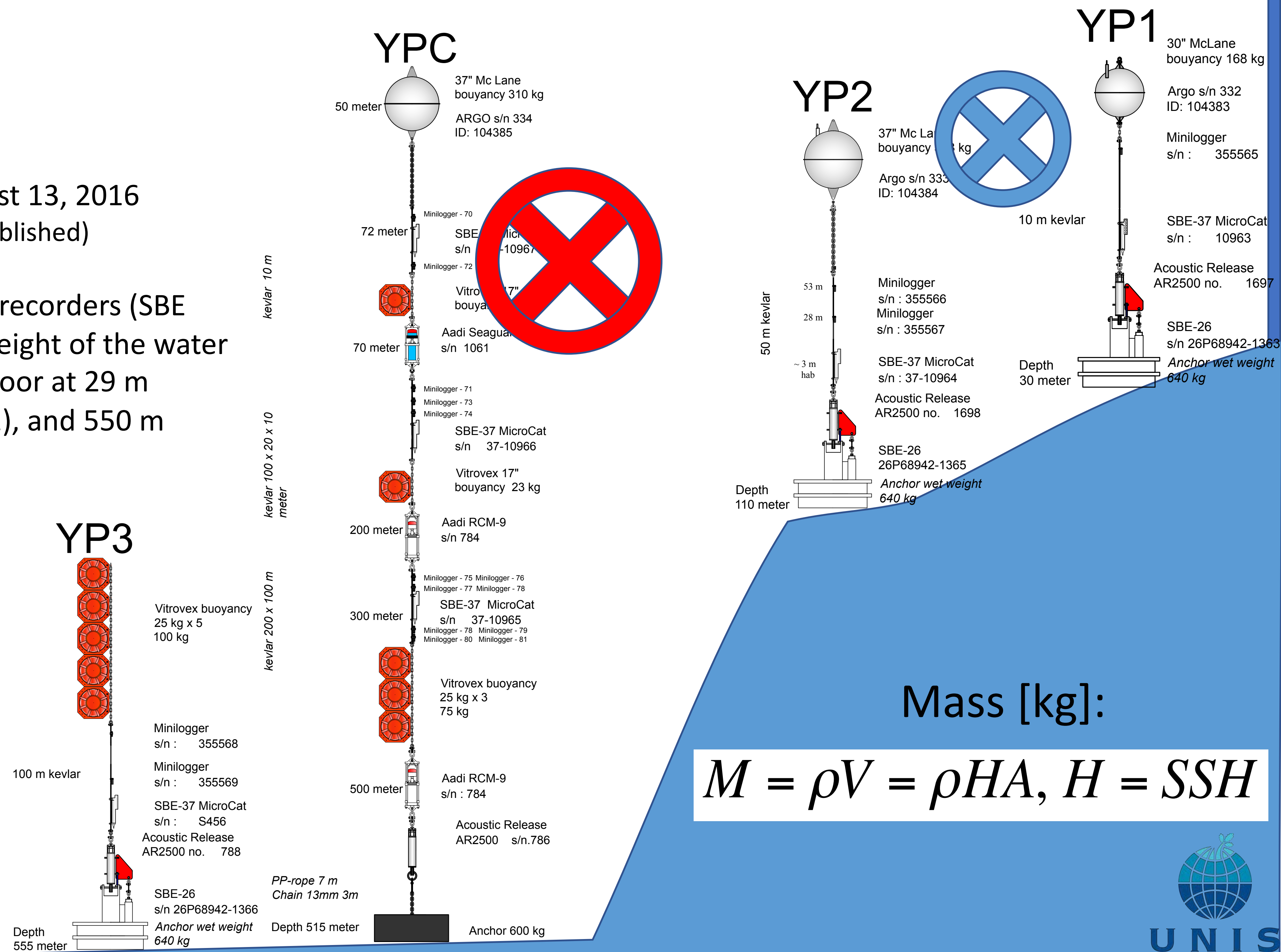


Hattermann et al. (2016)

From August 28, 2014 to August 13, 2016
(but also data from 2017-18, unpublished)

Ocean Bottom Pressure (OBP) recorders (SBE 26plus) were measuring the weight of the water column above the ocean sea floor at 29 m depth (YP1), 110 m depth (YP2), and 550 m depth (YP3).

In addition, a current meter mooring (YPC) was deployed 8.8 km southeast of YP3 at 515 m depth.

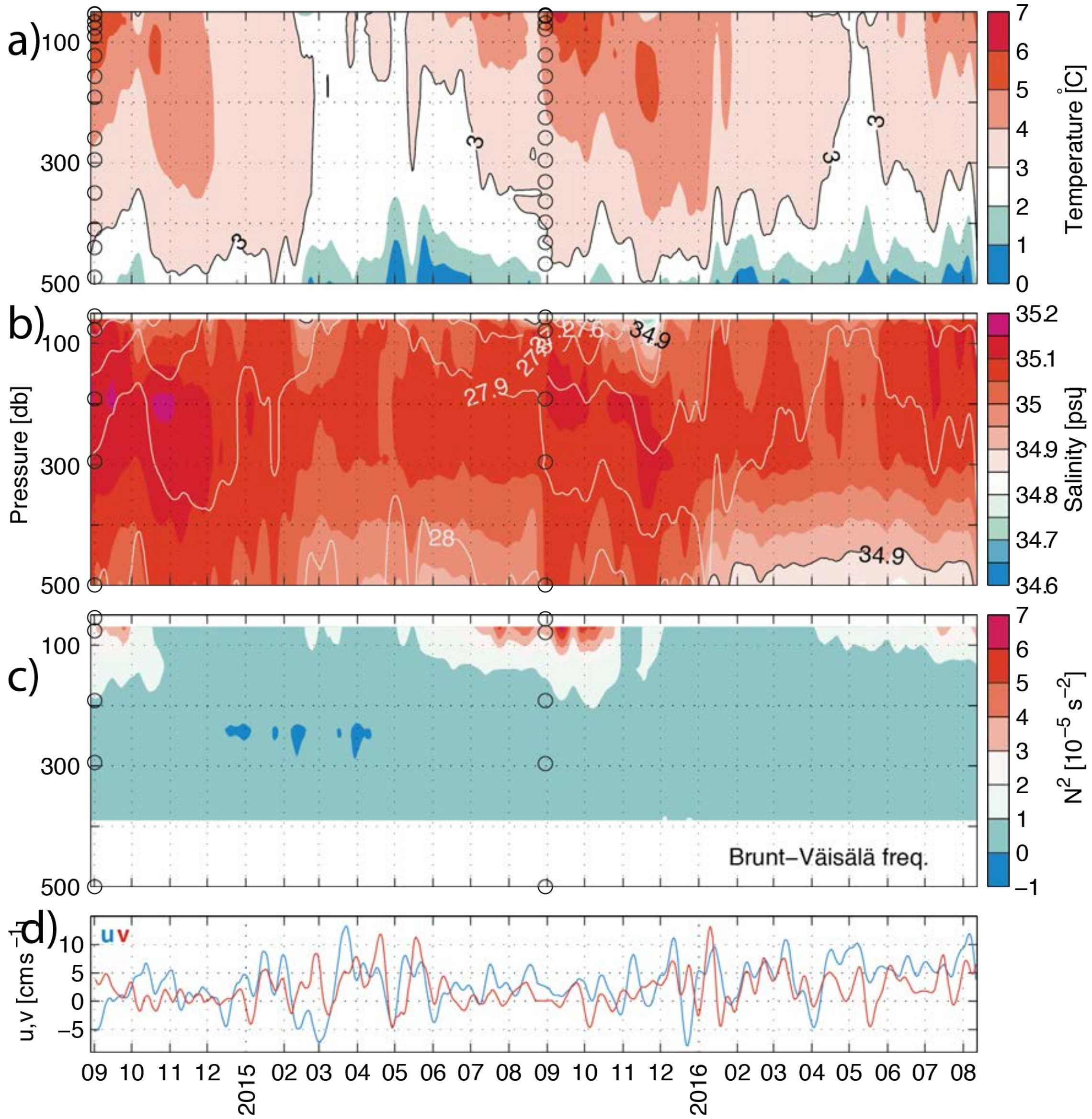


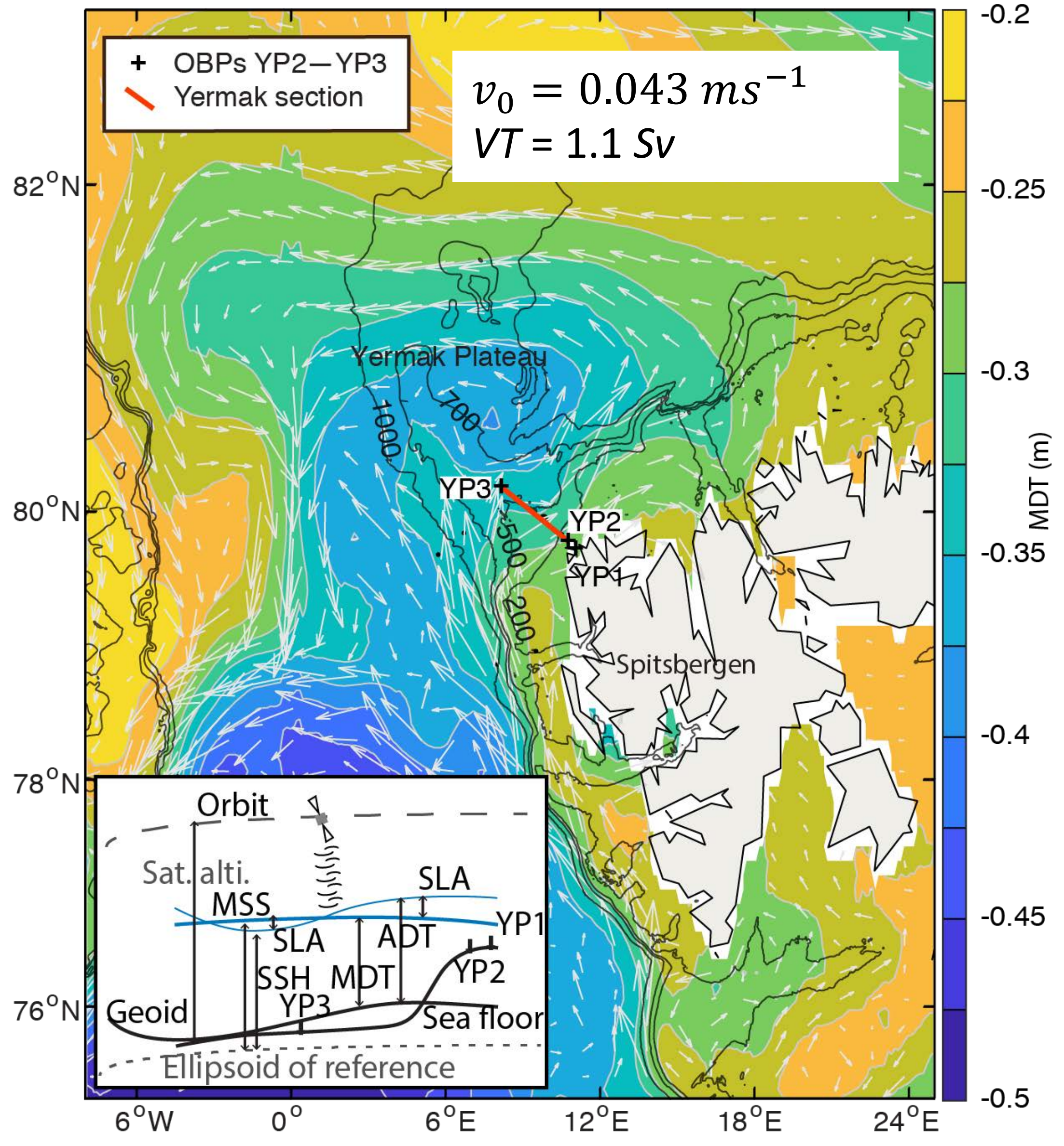
Mass [kg]:

$$M = \rho V = \rho H A,\ H = SSH$$

Nilsen et al. (2021)

YPC





CNES-CLS18 1/8° MDT by Ssalto/Duacs, downloaded from CMEMS; http://www.marine.copernicus.eu

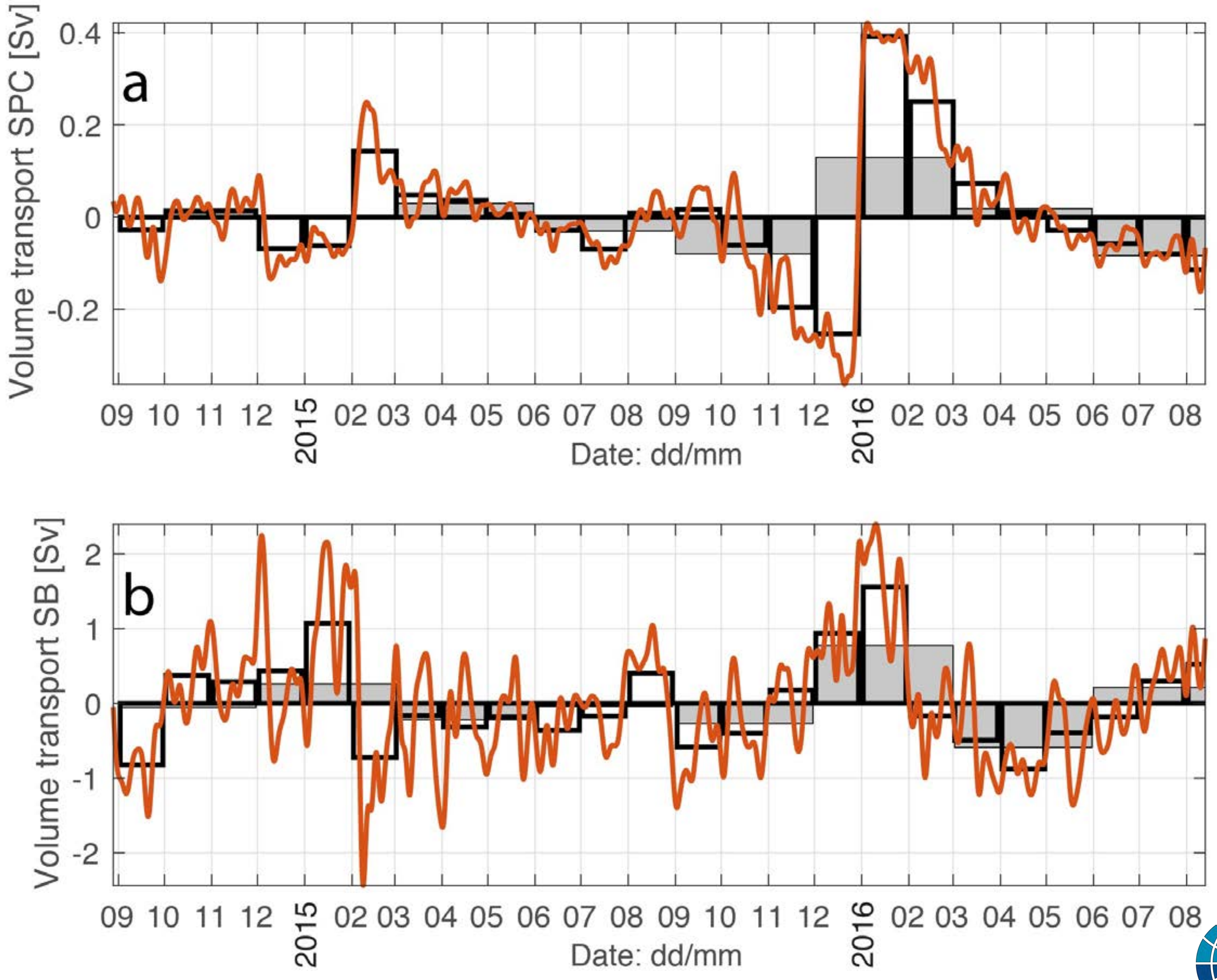
Volume transport anomaly (barotropic)

1 Sv = 10^6 m^3s^{-1}

The transport across the YP can increase by up to 0.4 Sv in the SPC and 2 Sv in the SB in the winter period when the average temperature in the northward-flowing AW is close to the highest temperature in this region.

Time series show a distinct seasonal variability with the highest transport in the DJF months, and an interannual variability between the 2 years.

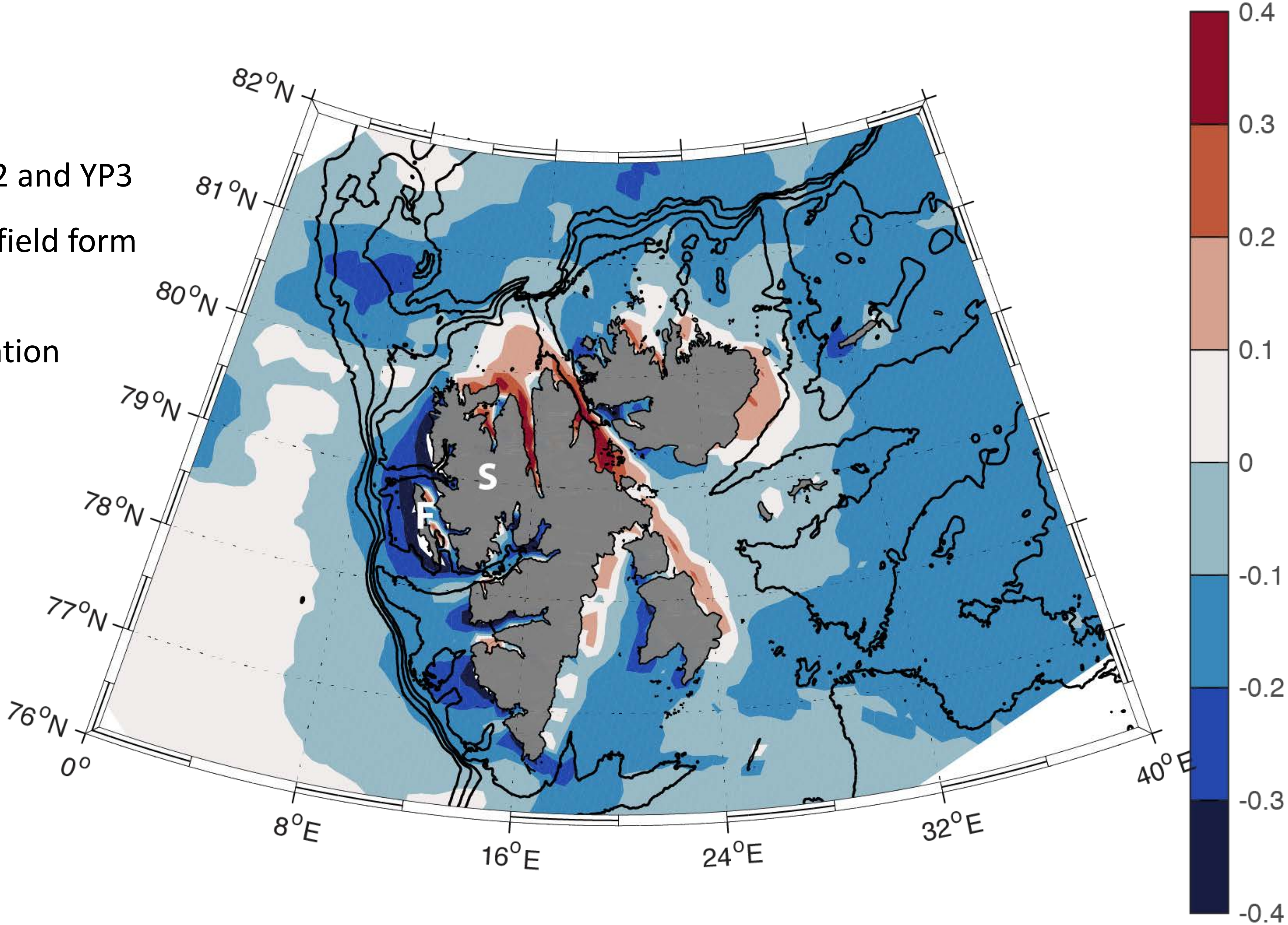
Flow variability in both the SPC and the SB is controlled by the sea surface pressure gradient, driven by strong windstorms.



Nilsen et al. (2021)

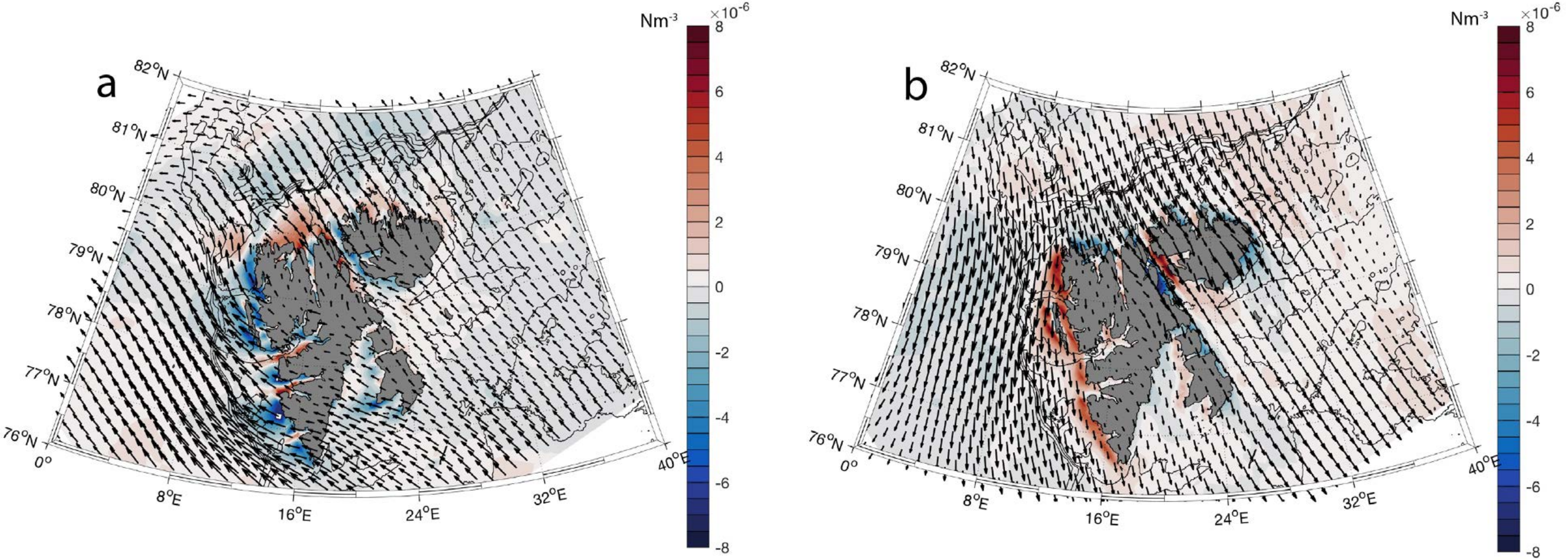
Wind stress curl field correlated with the Svalbard Branch

- $\overline{v_{dP}}$ between YP2 and YP3
- Wind stress curl field form NORA10 data
- Pearson's correlation coefficient



Nilsen et al. (2021)

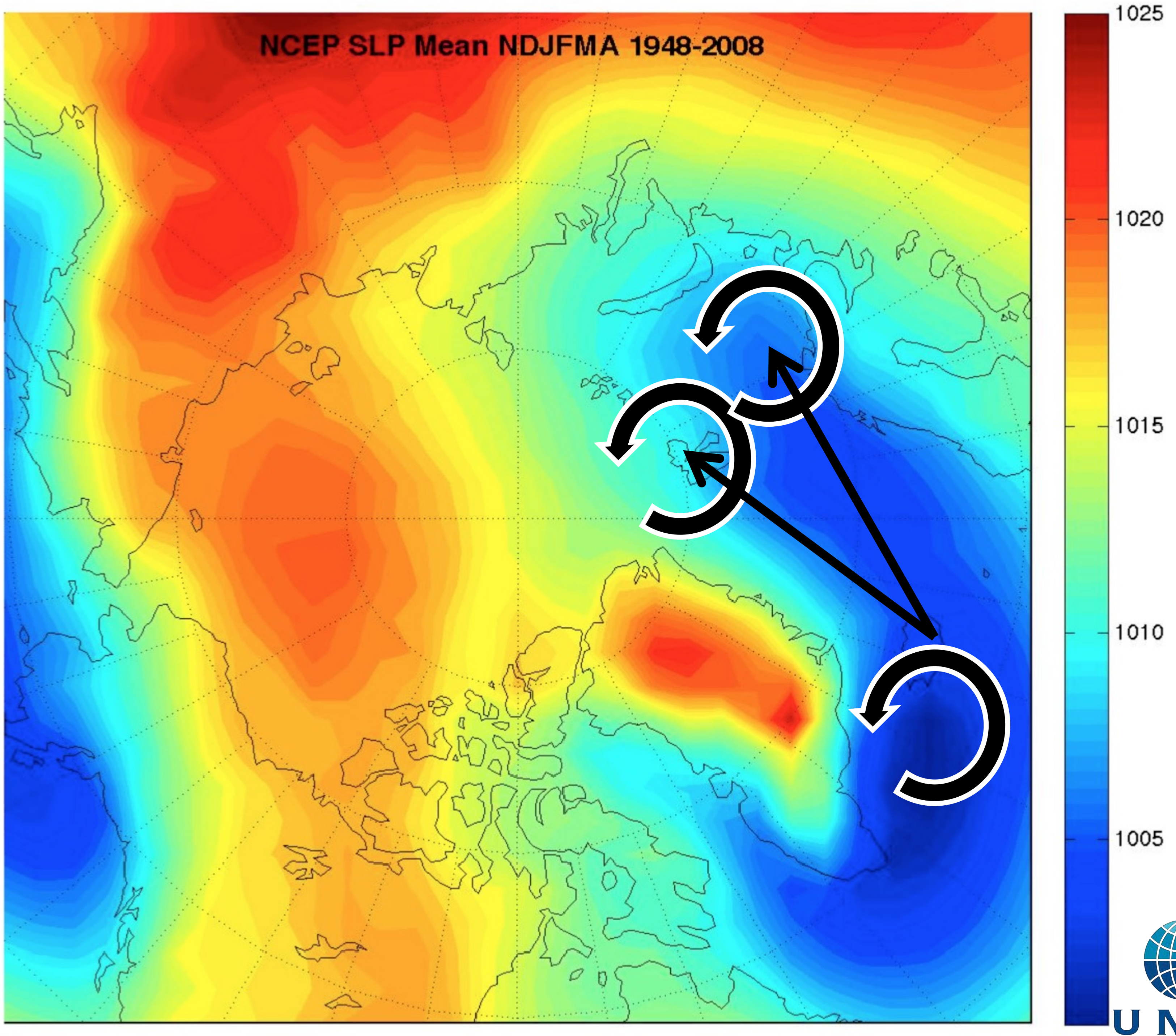
Compositing all wind stress curl field for cases when the Svalbard Branch is (a) >2STD($\overline{v_{dP}}$) and (b) <-2STD($\overline{v_{dP}}$)



Nilsen et al. (2021)

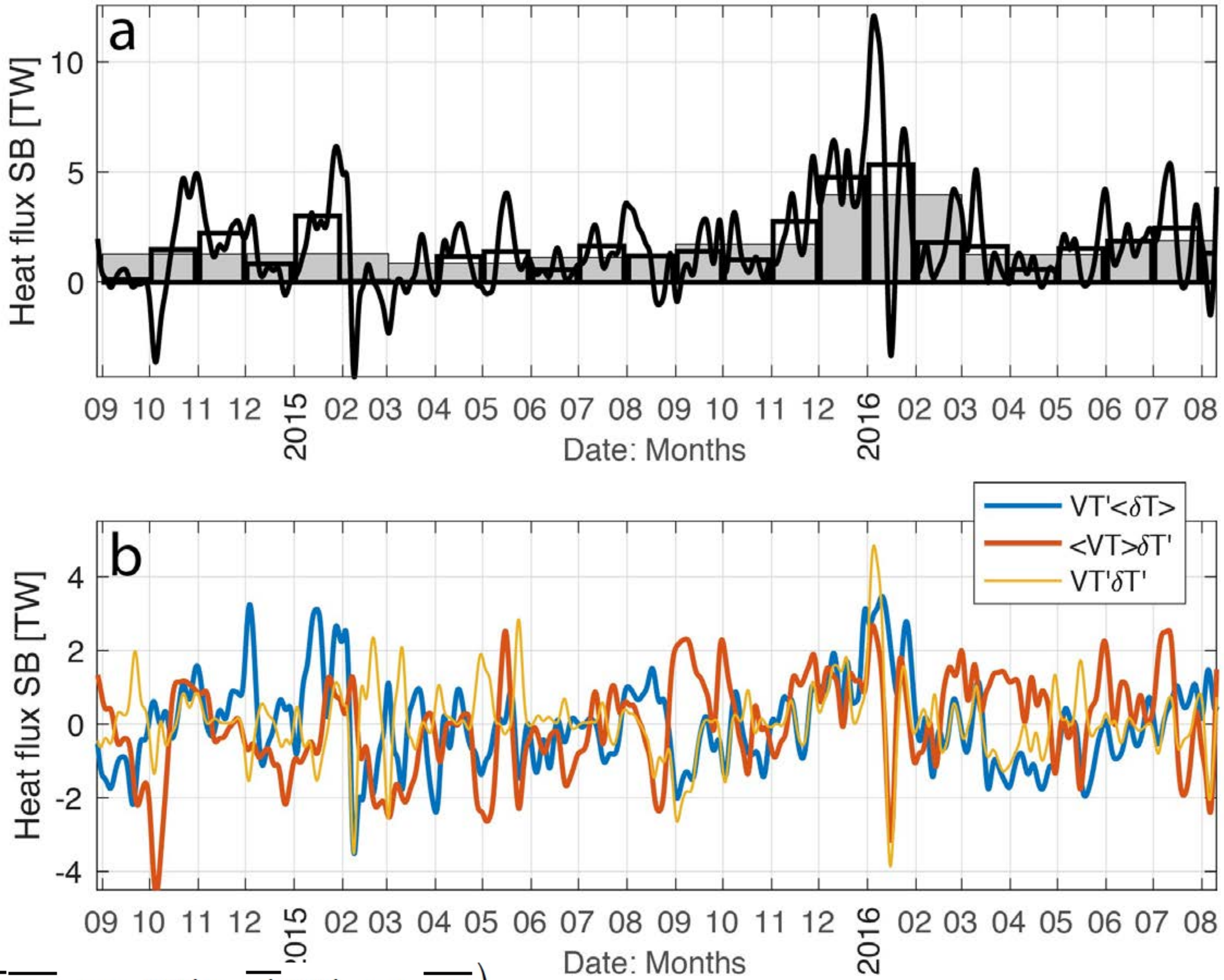
Mean sea level pressure

Low-pressure systems approaching Svalbard and the Barents Sea from the south show an increased impact on the wind patterns during autumn and winter (Wickström et al., 2020)



Background figure from Morison et al. (2012)

The total heat flux in the Svalbard Branch that alters the heat content north of Svalbard



Nilsen et al. (2021)

$$\rho c_p A v_b (T - T_m) = \rho c_p A\left(\overline{v_b'}\,\overline{\delta T} + v_0 \delta T' + \overline{v_b'}\,\delta T' + v_0 \overline{\delta T}\right)$$

- More frequent winter-cyclones will increase the volume transport variability and pulses of warm water to the shelf areas north of Svalbard
- Term (a) tends to be large for strong windstorm events in winter and give a short-period "weather" response, while term (b) is more linked to interannual variations and long-time changes in water mass temperature on the YP with a "climatic" effect on the heat transport.
- However, with a shift in the atmospheric circulation pattern toward an increasing number of cyclones influencing Svalbard during winter, the heat transport term (a) controlled by the volume flux variation will amplify the warming trend during years with anomalous atmospheric circulation patterns.

Nilsen et al. (2021)

JGR Oceans

RESEARCH ARTICLE
10.1029/2020JC016734

Key Points:
- Bottom geostrophic velocity anomaly in the Spitsbergen Polar Current and the Svalbard Branch is calculated from ocean bottom pressure and CTD measurements
- Significant correlation is found between the wind stress curl over the northeastern Fram Strait and the volume transport anomaly across the Yermak Plateau
- More frequent winter-cyclones will increase the volume transport variability and pulses of warm water to the shelf areas north of Svalbard

Correspondence to:
F. Nilsen,
frank.nilsen@unis.no

Citation:
Nilsen, F., Ersdal, E. A., & Skogseth, R. (2021). Wind-driven variability in the Spitsbergen Polar Current and the Svalbard Branch across the Yermak Plateau. *Journal of Geophysical Research: Oceans, 126*, e2020JC016734. https://doi.org/10.1029/2020JC016734

Received 20 AUG 2020
Accepted 24 AUG 2021

Wind-Driven Variability in the Spitsbergen Polar Current and the Svalbard Branch Across the Yermak Plateau

Frank Nilsen[1,2], Eli Anne Ersdal[1], and Ragnheid Skogseth[1]

[1]The University Centre in Svalbard, Longyearbyen, Norway, [2]University of Bergen, Geophysical Institute, Bergen, Norway

Abstract The Yermak Plateau (YP) acts as a guidance or barrier for the West Spitsbergen Current (WSC), which either crosses the plateau or flows around it to enter the Arctic Ocean. Closer to the West Spitsbergen coast, the Spitsbergen Polar Current (SPC) also flows over the YP in a narrow passage between the Svalbard Branch (SB) and the coast. A 2-year ocean observing program combined with altimetry and re-analysis wind data has given new knowledge on the variability and dynamics of the SPC and SB. The variability in the SPC and SB is controlled by the sea surface pressure gradient driven by the wind stress along the West Spitsbergen coast and locally on the YP. A peak-to-peak volume transport variability of 0.8 Sv and a positive heat transport anomaly of 3 TW were found in the SPC. The variability in the SB is mainly controlled by the upstream wind stress curl field along the West Spitsbergen Shelf where the negative wind stress curl field force the barotropic WSC branch directly into the SB. The peak-to-peak variability in the SB can exceed 4 Sv and in January 2016, an episodic heat flux was estimated to be 10 TW. Hence, an increasing number of winter cyclones affecting Svalbard will increase the volume transport variability and pulses of warm water to the shelf areas north of Svalbard.

Plain Language Summary This study shows how the variability in the wind pattern over the western and northwestern part of the Spitsbergen continental shelf controls the variability of the West Spitsbergen Current (WSC) branches flowing over the Yermak Plateau (YP). The WSC can bifurcate into the Svalbard Branch (SB) as a direct route across the YP or continue to flow along the YP, depending on the wind forcing in the area. The Spitsbergen Polar Current (SPC), bringing cold Arctic Water north of Svalbard, also flows over the YP, but closer to the Svalbard coast. The flow variability in both the SPC and the SB is controlled by the sea surface pressure gradient, and by measuring the pressure changes at the sea floor along the YP, the corresponding changes in the currents could be detected. Episodes of large heat flux toward the Arctic Ocean, capable of melting a 1-m sea ice thickness over a large area in only matter of days, were calculated in connection to a strong windstorm in January 2016. This demonstrates that the heat flux controlled by the volume transport variation can significantly amplify the warming trend during years with anomalous atmospheric circulation patterns showing more frequent cyclones influencing Svalbard during winter.

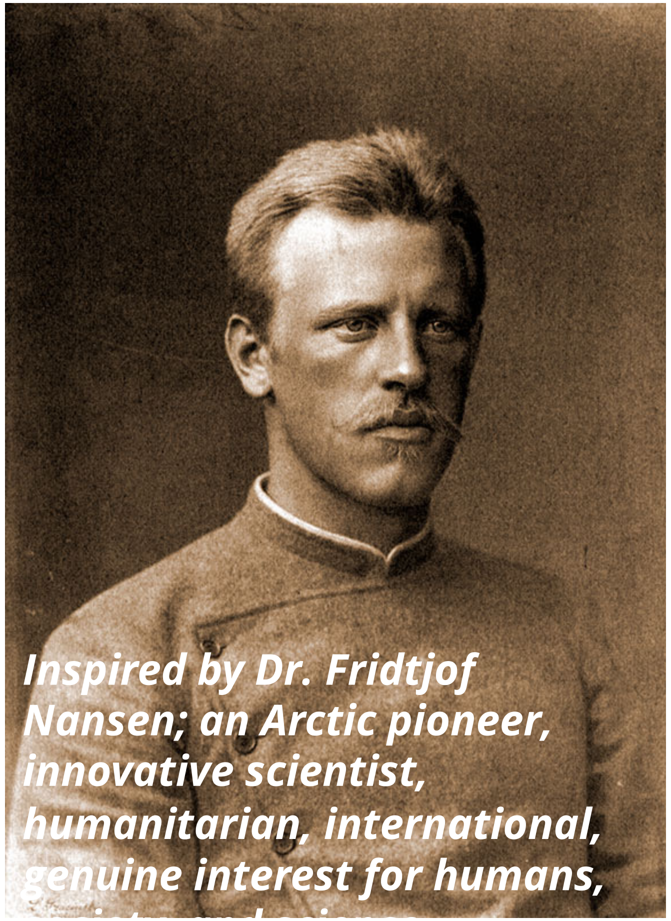
1. Introduction

During the past four decades, the Arctic has warmed approximately two times as rapidly as the entire Northern Hemisphere (Francis & Vavrus, 2012; Serreze & Barry, 2011; Stroeve et al., 2012). In Svalbard, the warming during winter has been particularly strong over recent decades with 5–6 C increase in winter temperatures (Hanssen-Bauer et al., 2019). Recent changes in large-scale atmospheric circulation patterns have brought warm Atlantic Water (AW) from the West Spitsbergen Current (WSC) onto the West Spitsbergen Shelf (WSS) and further into the fjords even during winter (Cottier et al., 2007; F. Nilsen et al., 2008, 2016; Pavlov et al., 2013; Skogseth et al., 2020; Tverberg et al., 2019). This has halted sea ice from forming (Muckenhuber et al., 2016) and opened up large areas of ice-free waters west and north of Svalbard (Cottier et al., 2007; Onarheim et al., 2014; Tverberg et al., 2014) with a potential impact on the Arctic ecosystem (Berge et al., 2005; Hegseth & Tverberg, 2013). Reduction and thinning of sea ice north and east of Svalbard in recent years are consistent with global warming and have likely led to more wind-generated upward mixing of warm and saline AW from about 200 m depth, preventing the formation of sea ice (Iv... et al., 2016).

Norwegian Ministry of Education and Research

The Research Council of Norway

the Nansen LEGACY

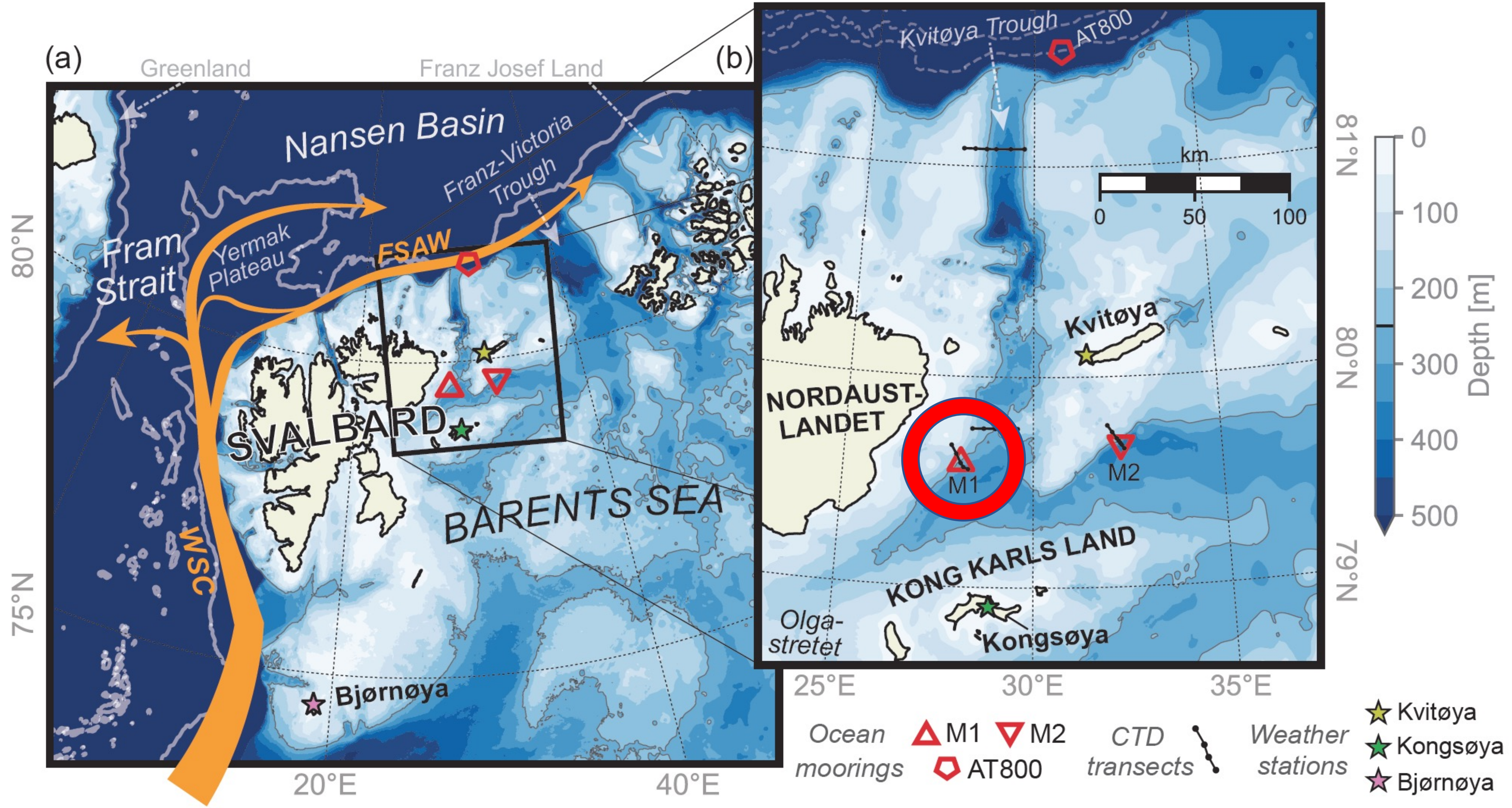


An interdisciplinary research project on the ecosystem of the Barents Sea – a gateway to a changing Arctic

PI Marit Reigstad (UiT), Co-PIs Tor Eldevik (UiB) & Sebastian Gerland (NPI)
A national team of >130 scientists from 10 institutes/ universities
>50 recruitment positions

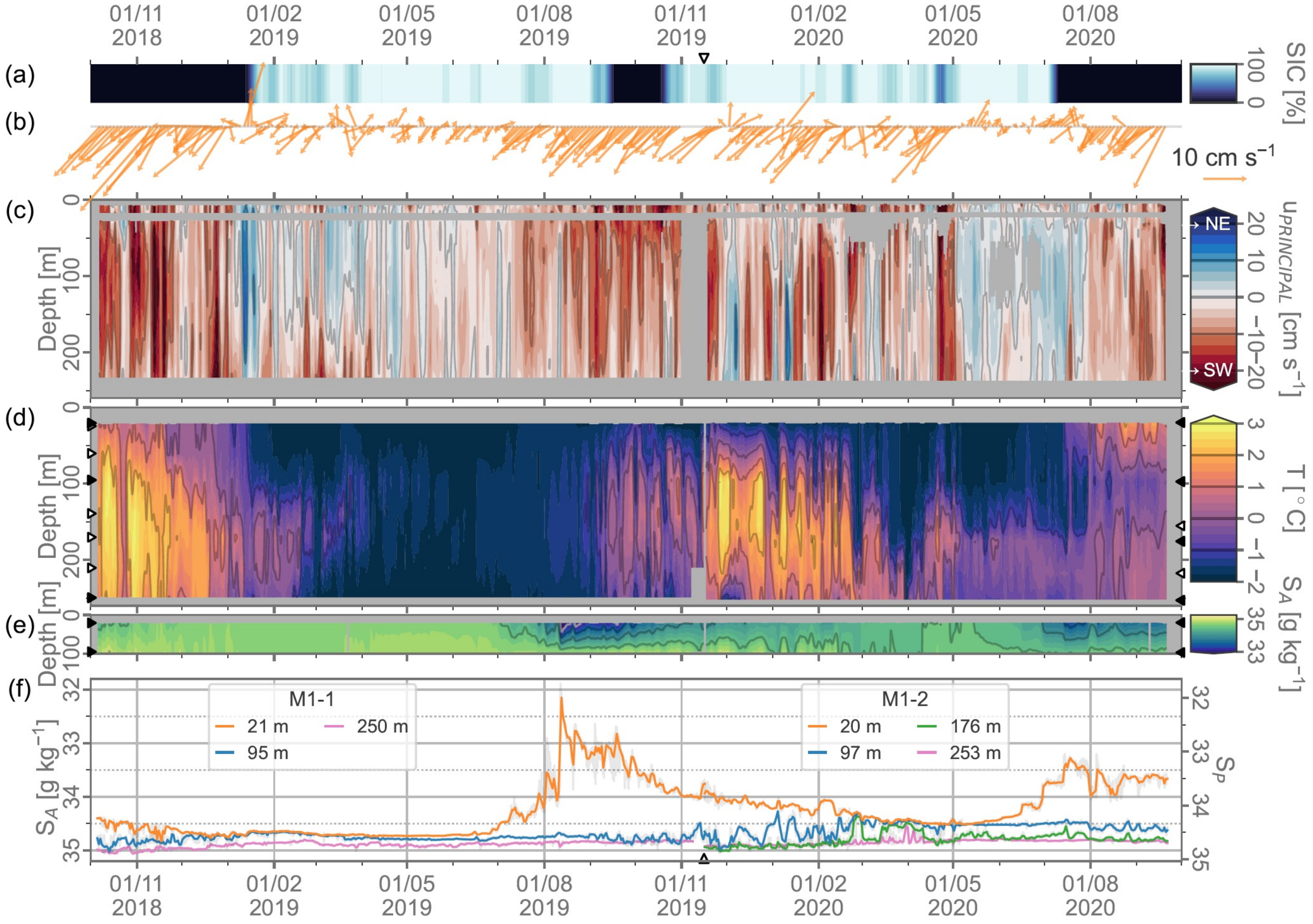
UNIS The University Centre in Svalbard · Norwegian Meteorological Institute · Havforskningsinstituttet · Norwegian Polar Institute · NTNU · NERSC · Akvaplan niva

Import of Atlantic Water and sea ice control the ocean environment in the northern Barents Sea



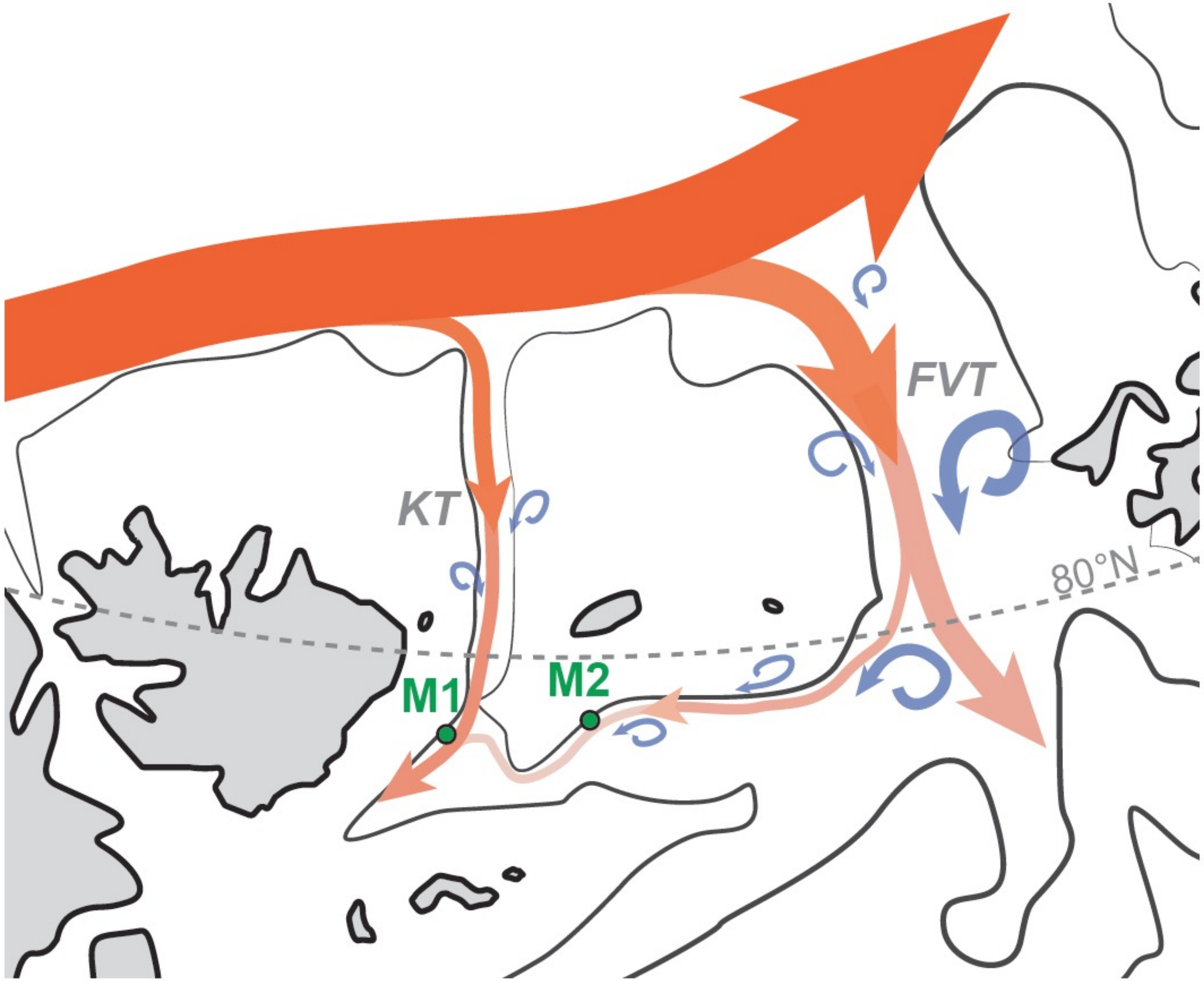
Lundersgaard et al. (2022) in Ocean Science Discussions

M1



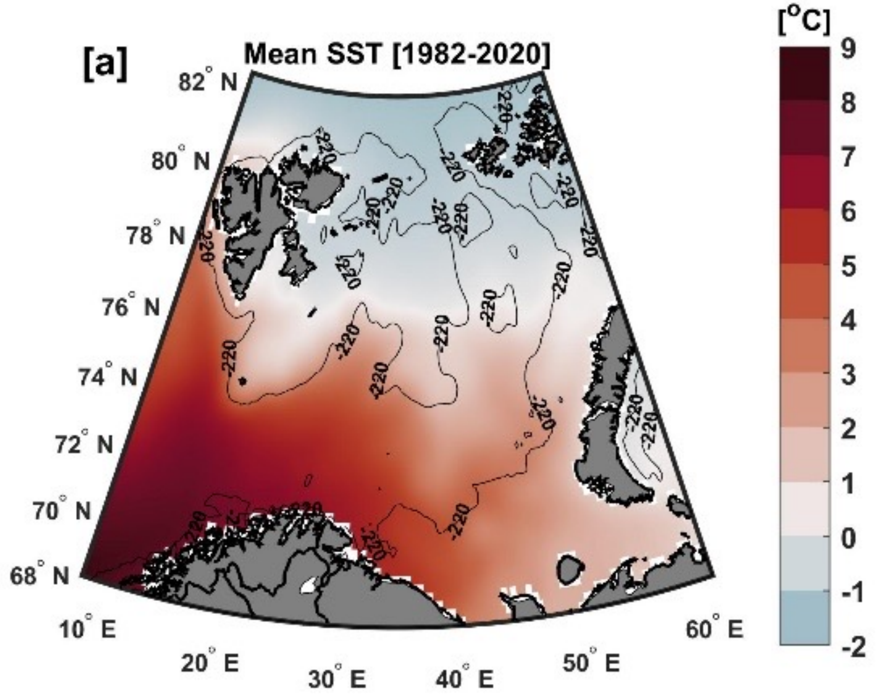
Lundersgaard et al. (2022) in Ocean Science Discussions

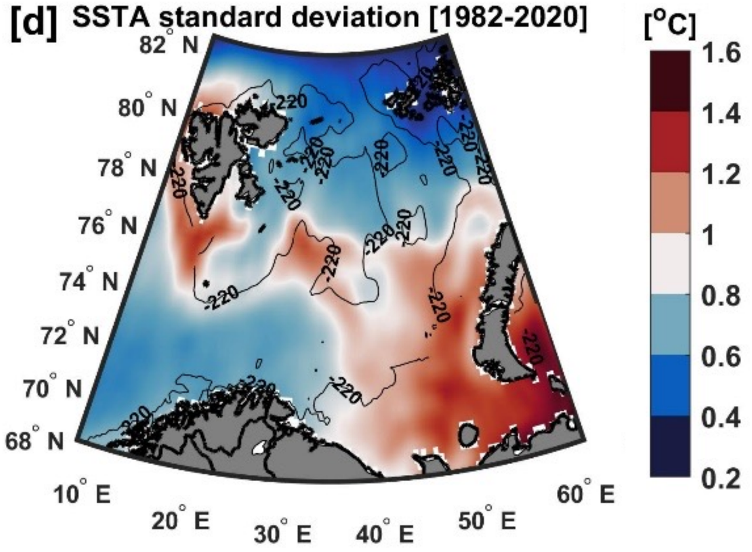
Conceptual interpretation of the advection of Atlantic Water

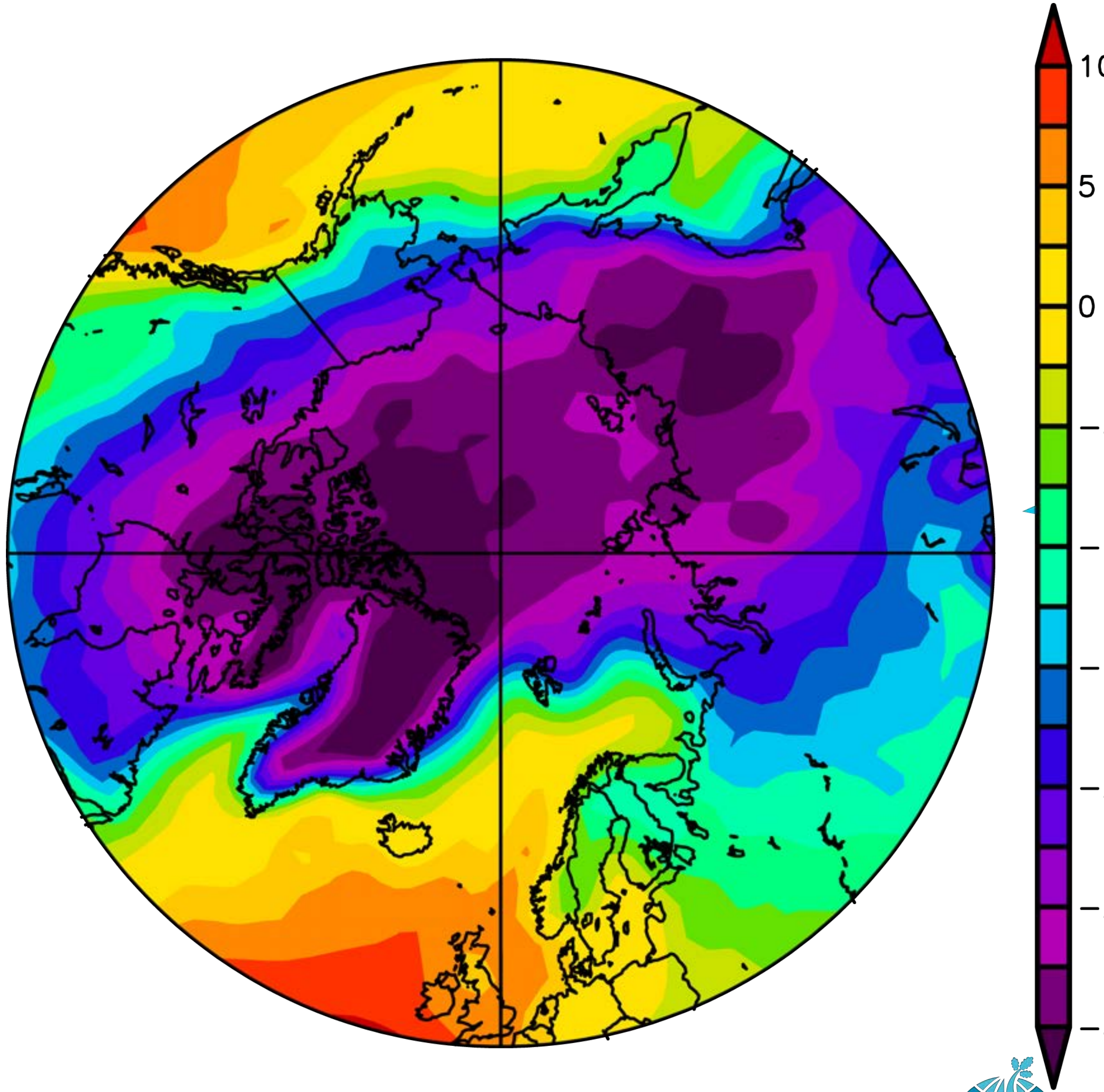


Lundersgaard et al. (2022) in Ocean Science Discussions

Surface temperature Dec.-Feb. 1980-2010





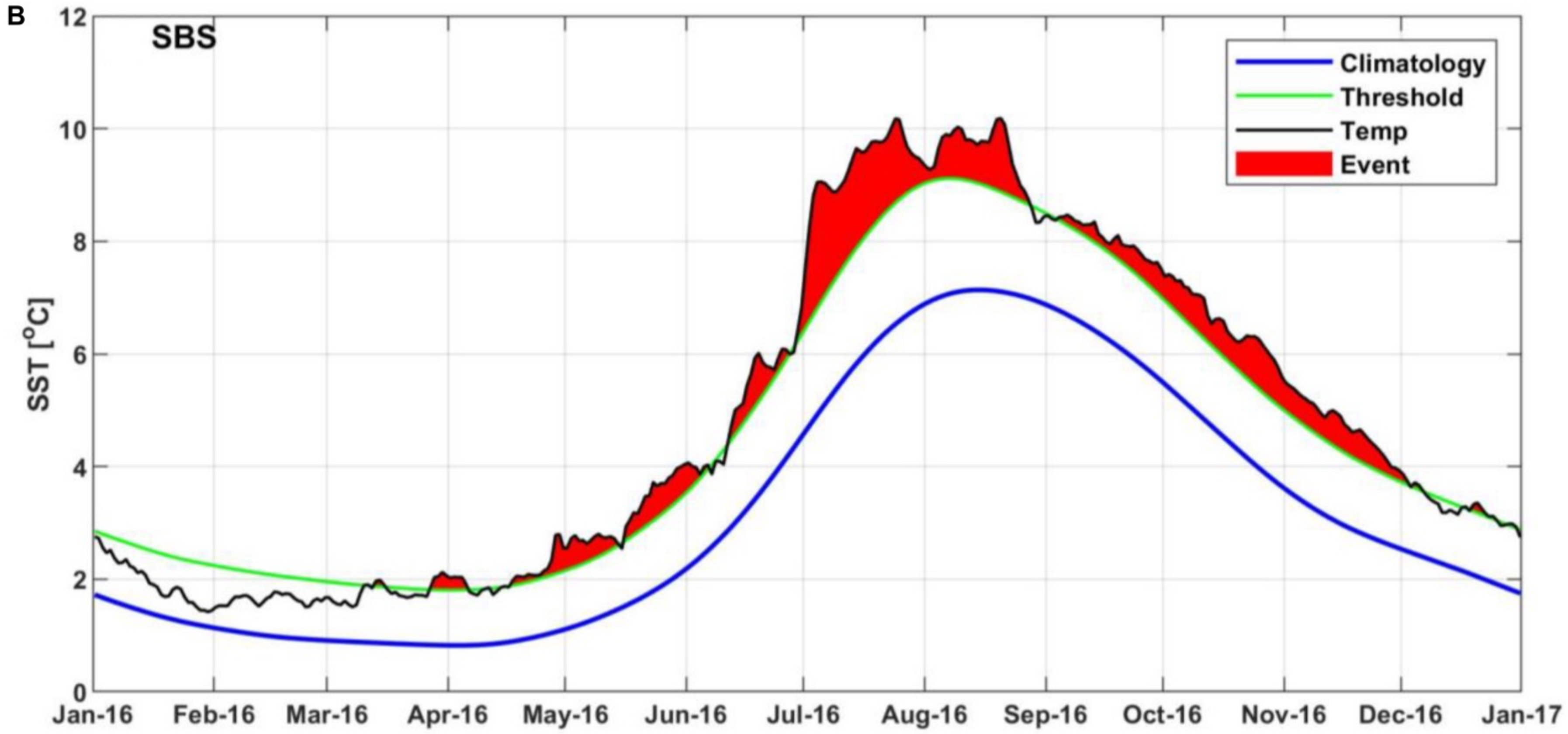


Mohamed et al. (2022)

Marine Heatwaves in the Barents Sea

Bayoumy Mohamed, Frank Nilsen, and Ragnheid Skogseth

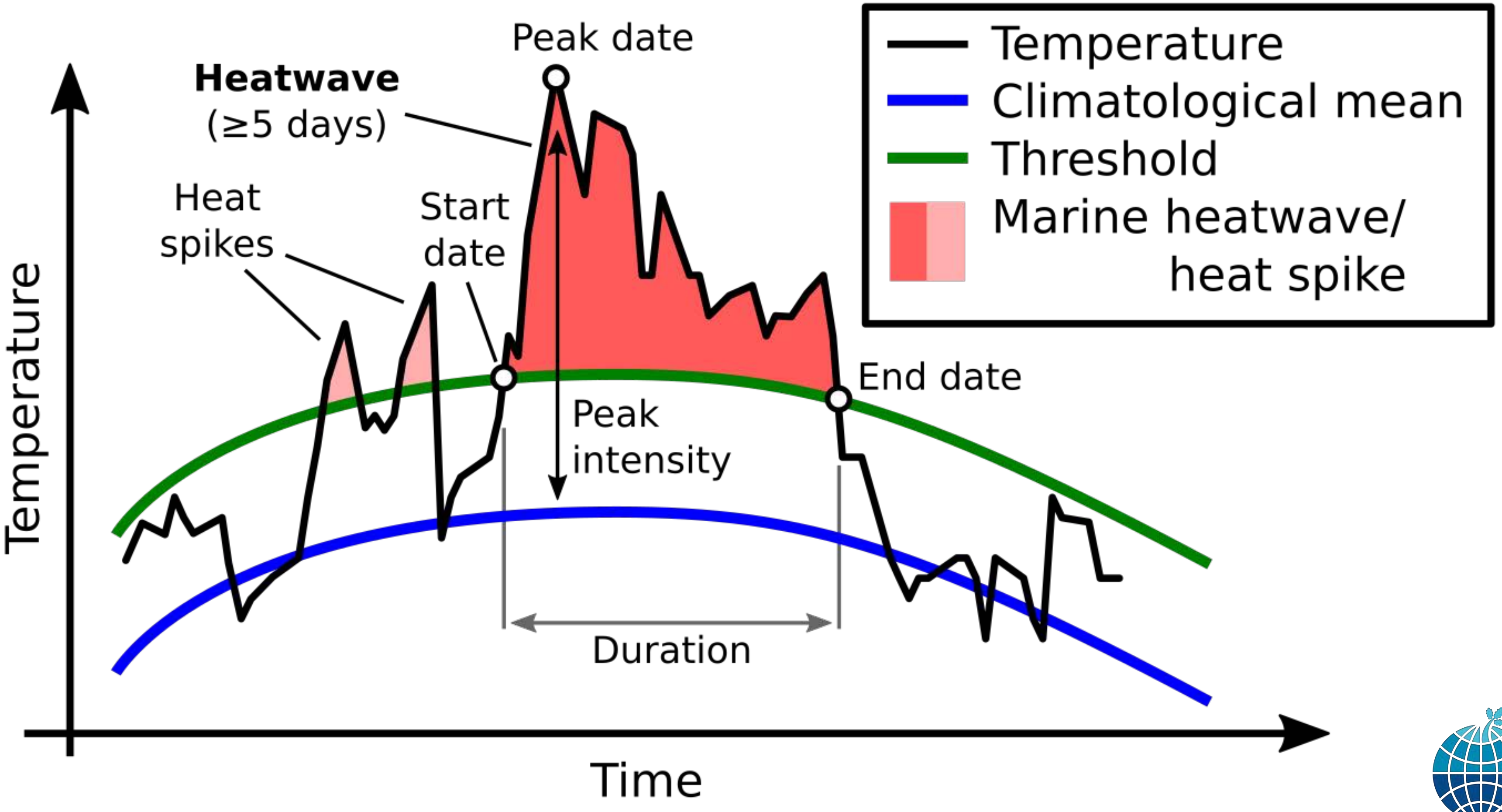
MHWs have become one of the major concerns and a hot topic in climate change research in recent decades (Marx et al., 2021), due to their destructive impact on marine biodiversity, ecosystems, and fisheries (Mills et al., 2013).



Mohamed et al. (2022)

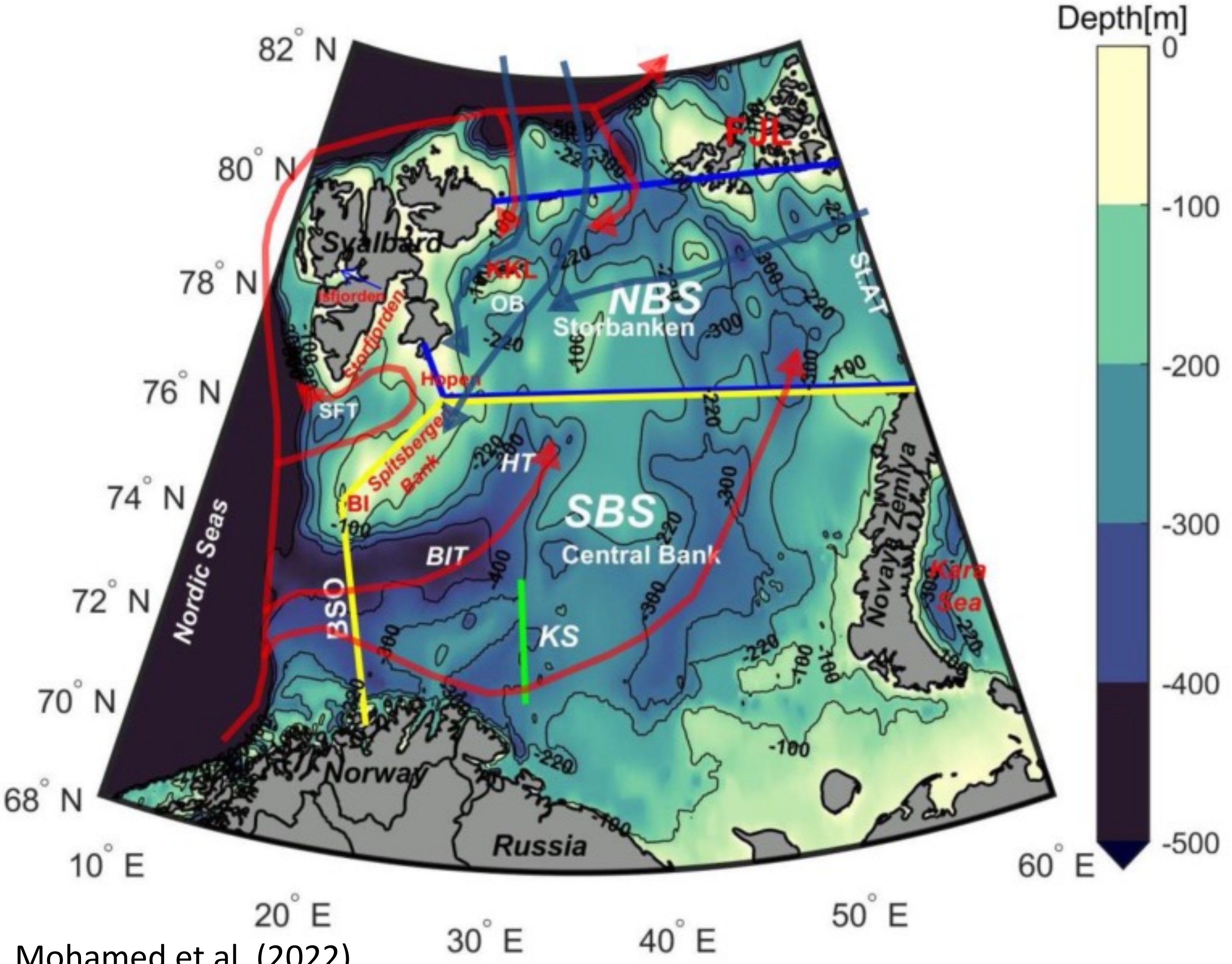
Marine Heatwaves in the Barents Sea

MHW is an abnormally warm water event that lasts at least 5 days with SST above the seasonally-varying threshold (usually the 90th percentile) for that time of year (Hobday et al., 2016)



Source: http://www.marineheatwaves.org/all-about-mhws.html

STUDY AREA AND DATASET

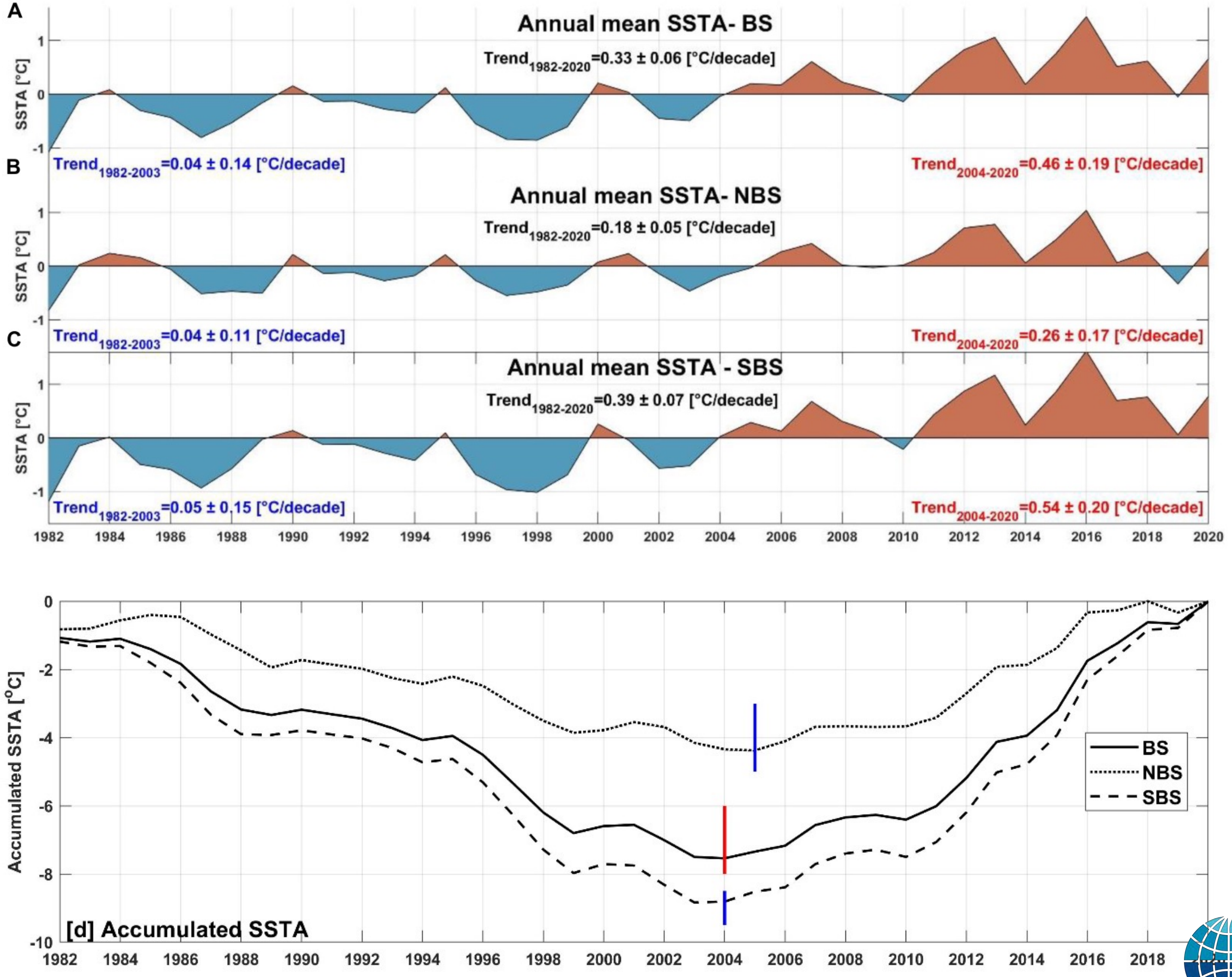


Mohamed et al. (2022)

- Daily Optimum Interpolation Sea Surface Temperature V2.1 (OISST V2.1) and sea ice concentration (1982-2020) from NOAA.
- Hourly atmospheric variables from ECMWF (ERA5 data) during the same period 1982-2020:
  - Surface Air Temperature (SAT),
  - Wind Speed Components (u10 and v10),
  - and Mean Sea Level Pressure (MSLP)
- Finally, the normalized time series of climate indices from NOAA
  - North Atlantic Oscillation (NAO)
  - East Atlantic Pattern (EAP)

Warming Shift In The Barents Sea 1982-2020

For the post-2004 period (2004-2020), warming trends were amplified, with a spatially averaged trend of 0.25 ± 0.18 °C/ decade and 0.58 ± 0.21 °C/ decade for NBS and SBS, respectively.

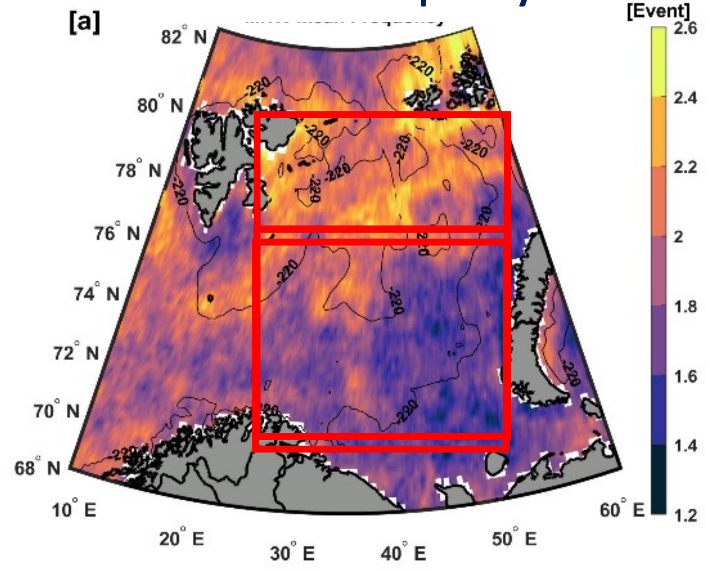


Mohamed et al. (2022)

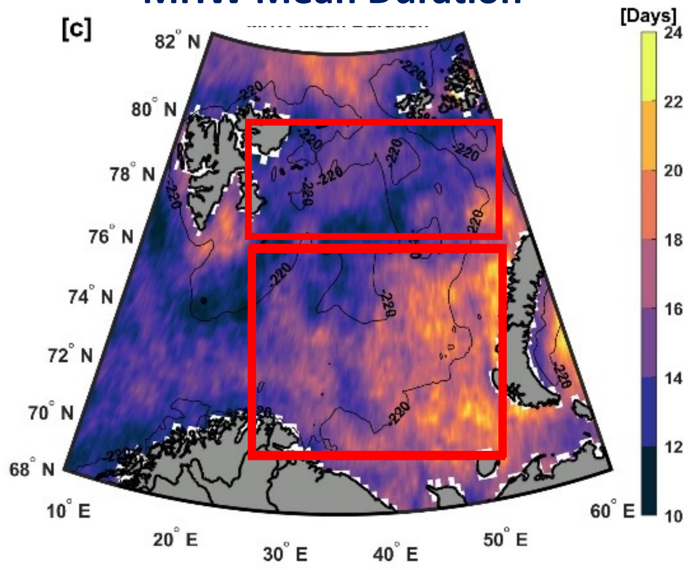
MHW Characteristics

In general, MHWs are characterized by high frequency, short duration, and low intensity in NBS, and low frequency, long duration, and high intensity in the SBS.

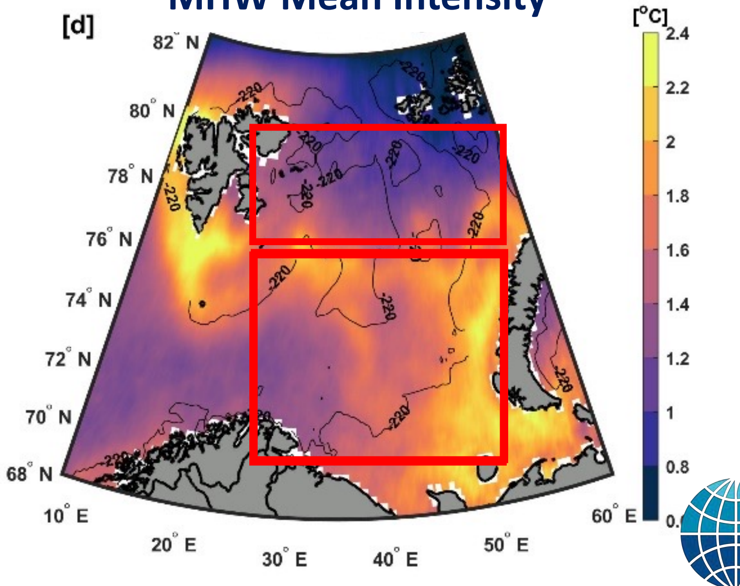
MHW Mean Frequency



MHW Mean Duration

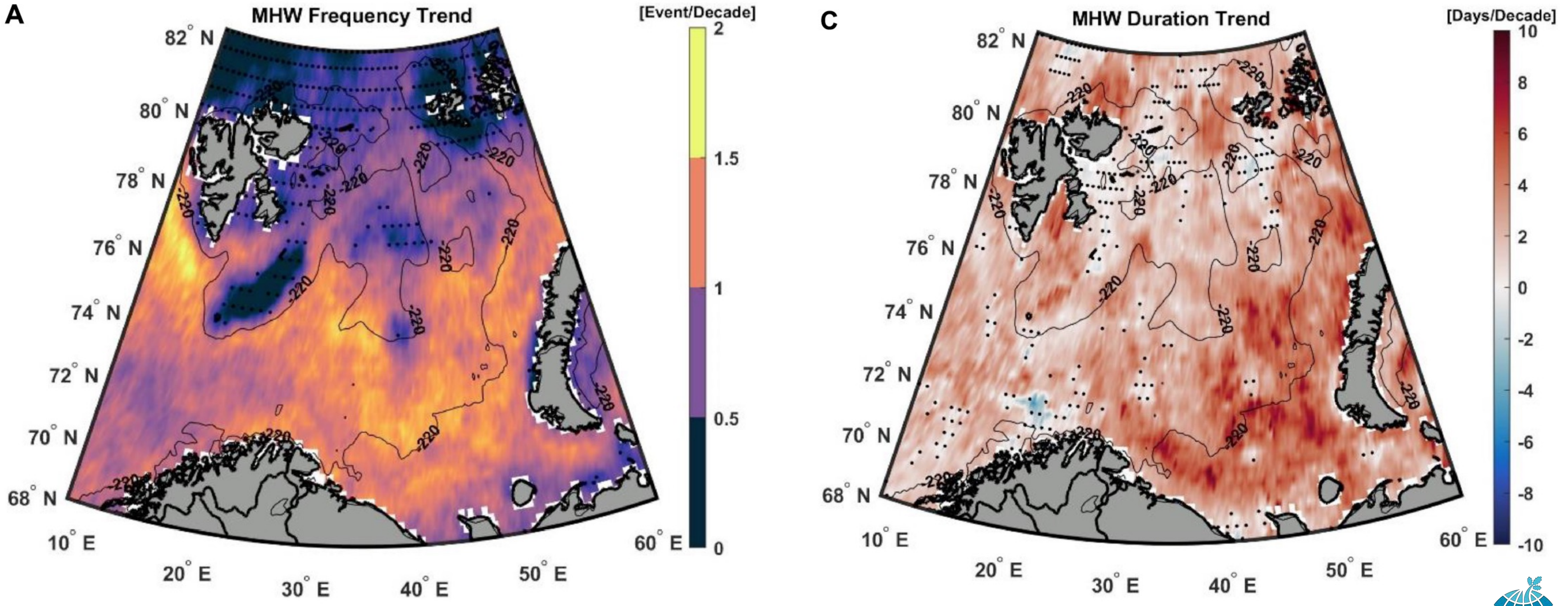


MHW Mean Intensity



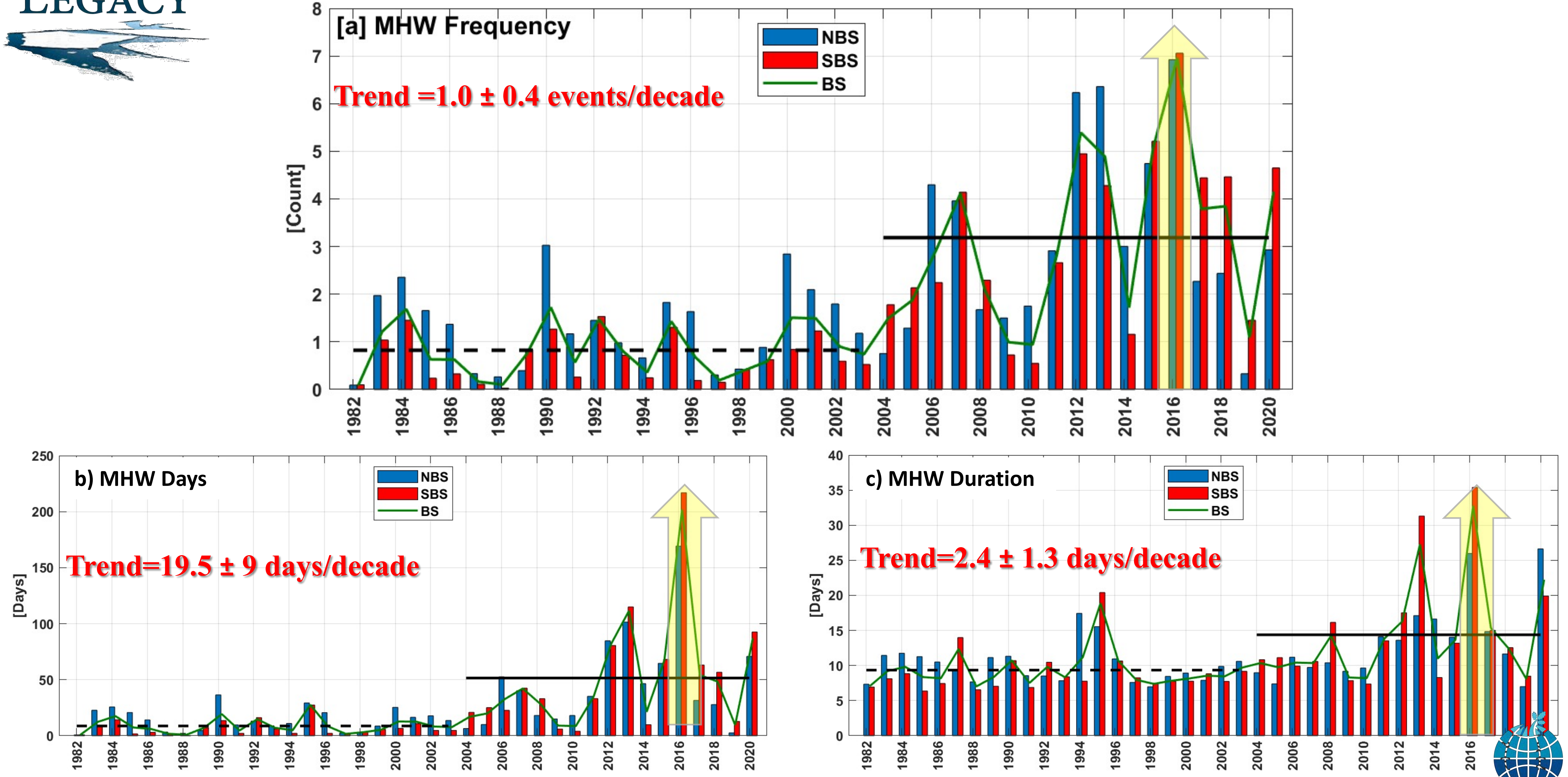
Mohamed et al. (2022)

MHW decadal trends (1892-2020)



Mohamed et al. (2022)

Temporal Variation of MHWs



Mohamed et al. (2022)

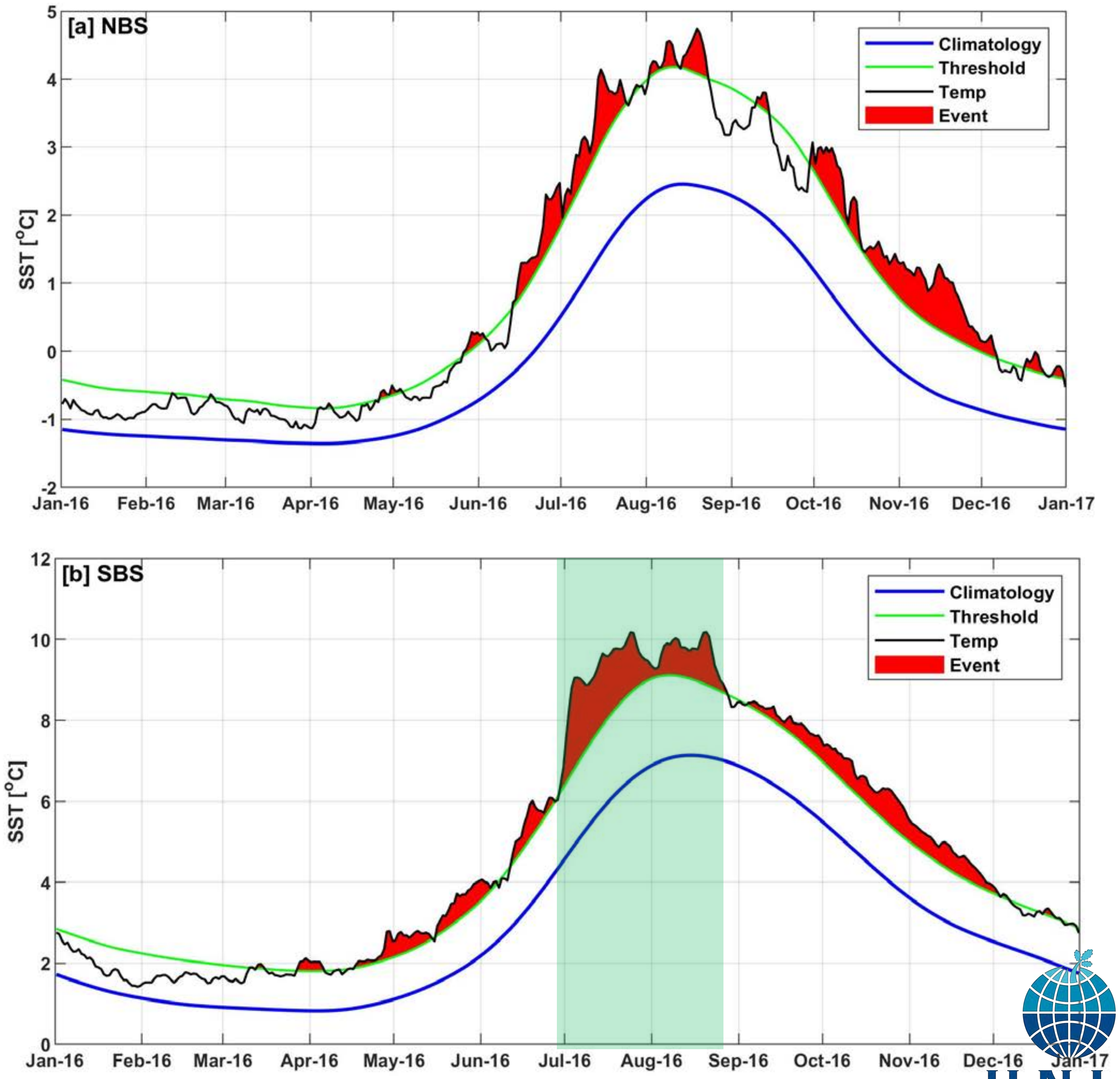
MHW 2016

Previous biological studies by Eriksen et al. (2020) have found that:

- **Some marine species reacted to the warm water condition during this strong MHW event by shifting their geographic distribution.**

- **Polar cod abundance was significantly lower and had nearly disappeared in the core area of the southeastern Barents Sea where the most intense MHWs are found.**

- **Species, such as capelin, haddock, herring, and long rough dab were more abundant than the long-term average.**



Mohamed et al. (2022)

Conclusions & Recommendations

The Barents Sea experienced a significant warming shift in 2004. The spatial average of the SST warming rate from 2004 to 2020 was about 0.25 ± 0.18 C/ decade and 0.58 ± 0.21 °C/ decade for the northern and southern Barents Sea, respectively.

The Barents Sea is most likely a high-risk region that has seen more frequent, longer lasting, and stronger MHWs in recent decades. The most intense MHW event was observed in 2016 and lasted for 63 days from 28 June to 29 August 2016, with mean and maximum intensities of 2.96 °C and 4.13 °C, respectively.

Recommendations: More research is needed to predict future MHWs in the Barents Sea using model experiments and to study their effects on marine life. To be able to implement appropriate early warning procedures related to thermal stress on various marine ecosystems. Particularly, the Barents Sea has diverse marine ecosystems and fishing grounds.

Mohamed et al. (2022)

the Nansen LEGACY

Thank you for your attention!

Barents Sea, Februar 2021

UNIS