Arctic Science Summit Week 2022
INTAROS Open Webinar, 28 March 2022

Integrating Arctic Observing Systems

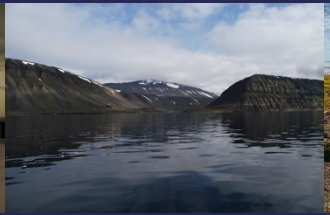
INTAROS

Observing the Arctic Ocean north of Svalbard










Agnieszka Beszczynska-Möller[1)], Marie-Noelle Houssais[2)], Christophe Herbaut[2)], Truls Johannessen[3)], Ian Allan[4)], Andrew King[4)], Andreas Rogge[5)], Hanne Sagen[6)]

[1)]IOPAN, [2)]CNRS-LOCEAN, [3)]UiB-GFI, [4)]NIVA, [5)]AWI, [6)]NERSC

INTAROS WP3 Enhancement of *in situ* observations in the Arctic

To develop an efficient integrated Arctic Observation System by extending, improving and unifying existing and evolving systems in the different regions of the Arctic

INTAROS reference sites and distributed observatories:

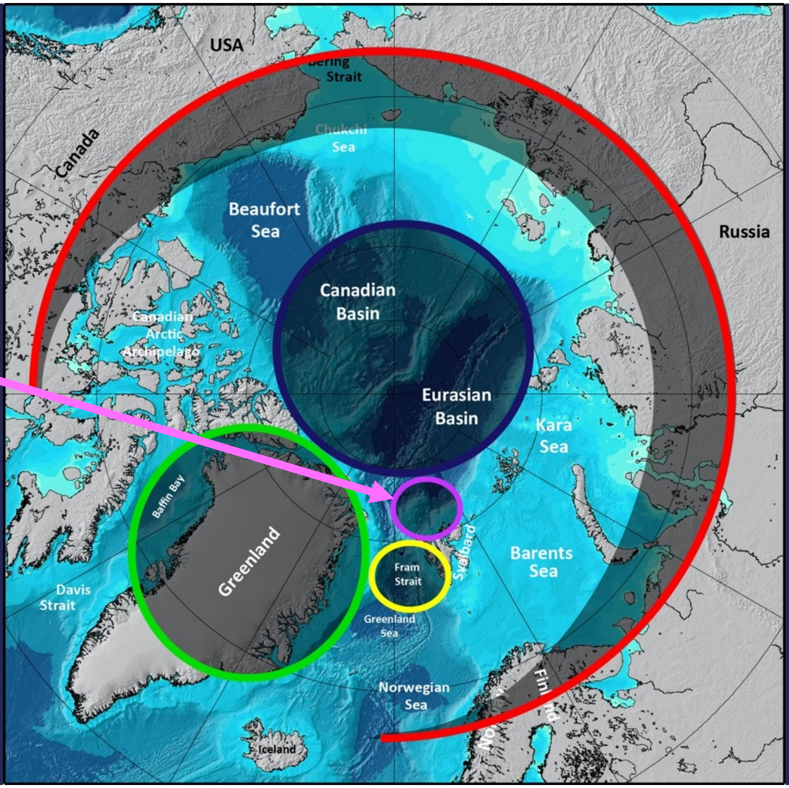
Coastal Greenland and Baffin Bay

North of Svalbard towards the deep Nansen Basin

Fram Strait and Kongsfjorden

Central Arctic distributed systems for ocean and sea ice

Pan-Arctic region distributed systems for atmosphere and land



WP3 objectives:

- make best use of existing reference sites and distributed observatories providing data for Arctic climate and ecosystems but missing multidisciplinary dimension or technical advancement
- extend temporal and geographic coverage of available infrastructures and add key geophysical and biogeochemical variables through implementing novel technologies integrated with standard observations

GEUS
ILMATIETEEN LAITOS METEOROLOGISKA INSTITUTET FINNISH METEOROLOGICAL INSTITUTE
AARHUS UNIVERSITY
POLITÉCNICA
AWI
PAN
LOCEAN
NERSC
NIVA Norwegian Institute for Water Research
UNIS
INSTITUTE OF MARINE RESEARCH
cnrs
UNIVERSITAS BERGENSIS
LOV
The University Of Sheffield.
TAKUVIK
iuem
UNIVERSITY OF EXETER
GFZ Helmholtz Centre Potsdam
Max Planck Institut for Biogeochemistry
Stockholm University

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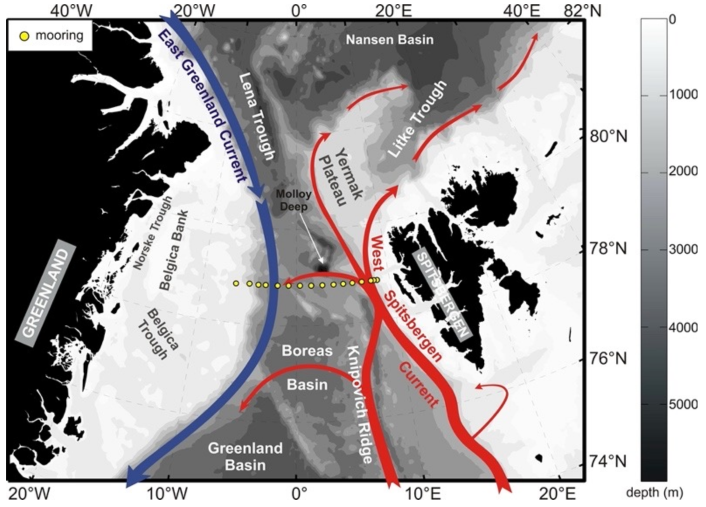
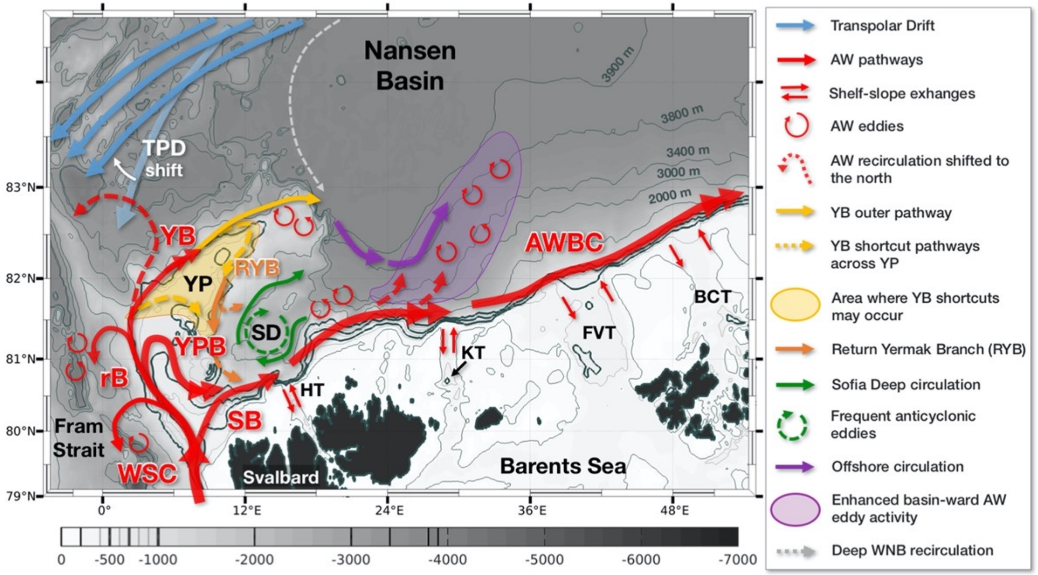
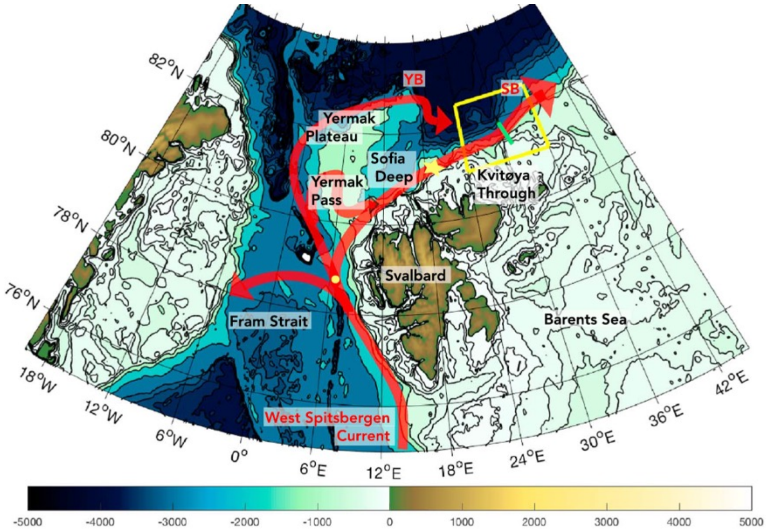
Pathways of Atlantic water west and north of Svalbard (Beszczynska-Möller et al., JMS, 2012)



Schematic circulation and water pathways north of Svalbard in the 2011–2020 period from the Mercator Ocean Operational System PSY4 (Athanase et al., JGR, 2021)



Pathways of Atlantic water north of Svalbard (Perez-Hernandez et al., JGR, 2019)



During Atlantic water flow north of Svalbard:

- ➥ the upper part of the AW transformed into a less saline surface layer by melting sea ice and mixing with fresher Arctic water
- ➥ AW preserves its warm core, losing less heat to the atmosphere but AW flow is complex and modified by lateral exchanges
- ➥ in the recent decade, occasionally ice-free conditions even in winter, positive subsurface ocean temperatures, highly variable MLD, and ocean-to-atmosphere heat fluxes => deeper convection cooling and freshening AW => "marginal convection zone" (Athanase et al., 2020)

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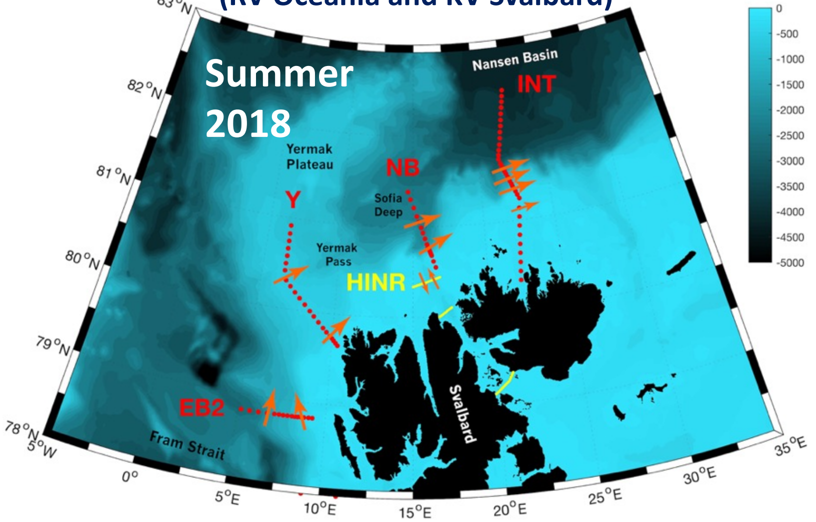
Temperature and salinity sections across the AW inflow west and north of Svalbard measured in summer 2018 (RV Oceania and KV Svalbard)



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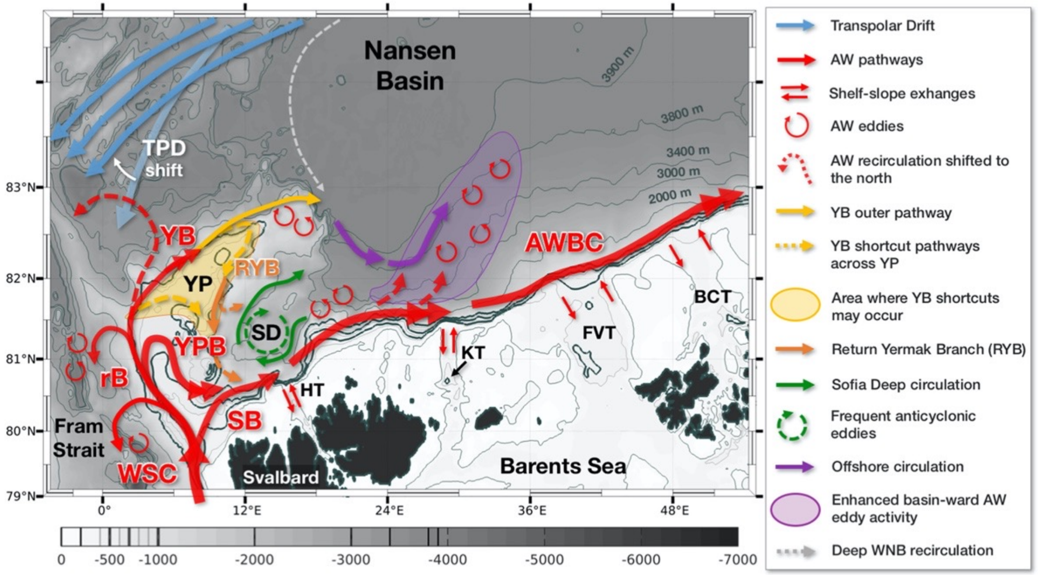

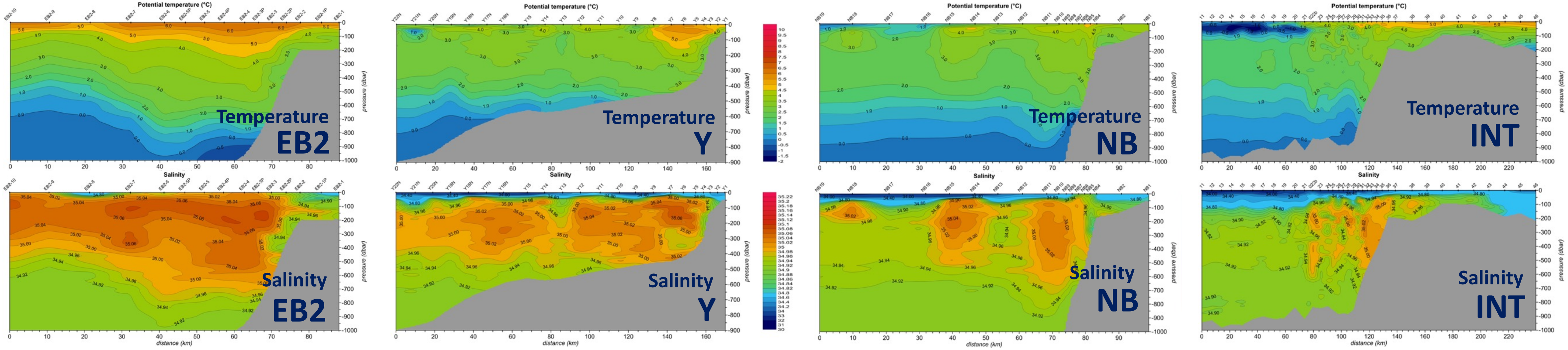

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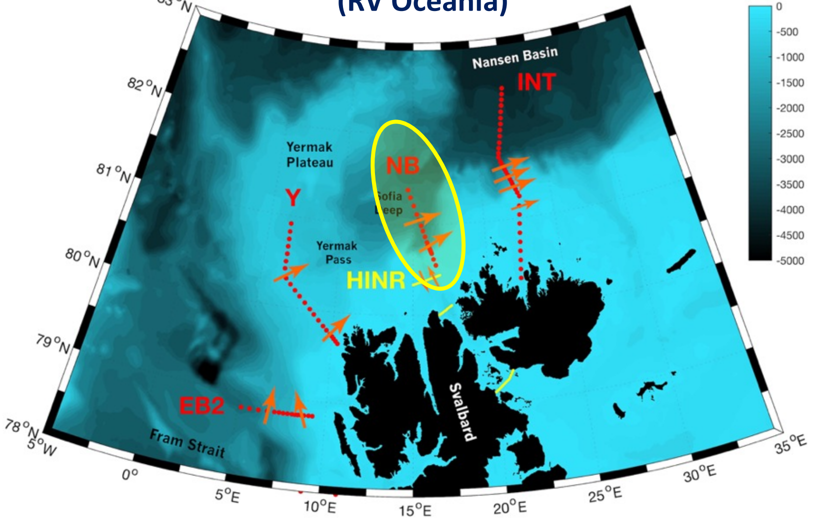
Observing the Arctic Ocean north of Svalbard

Temperature and salinity at the NB section across the AW inflow west and north of Svalbard measured in summers 2013-2020 (RV Oceania)



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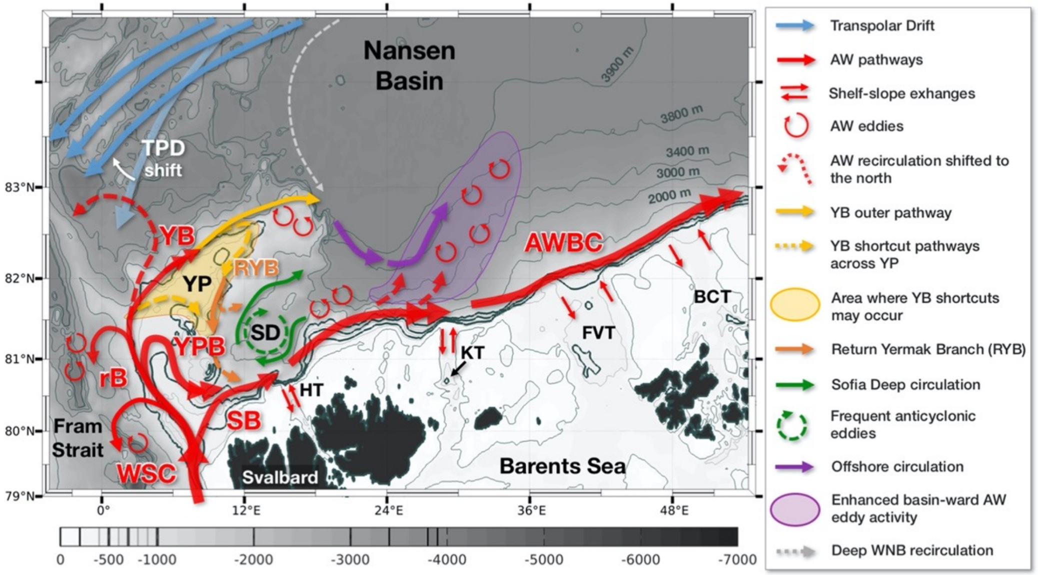
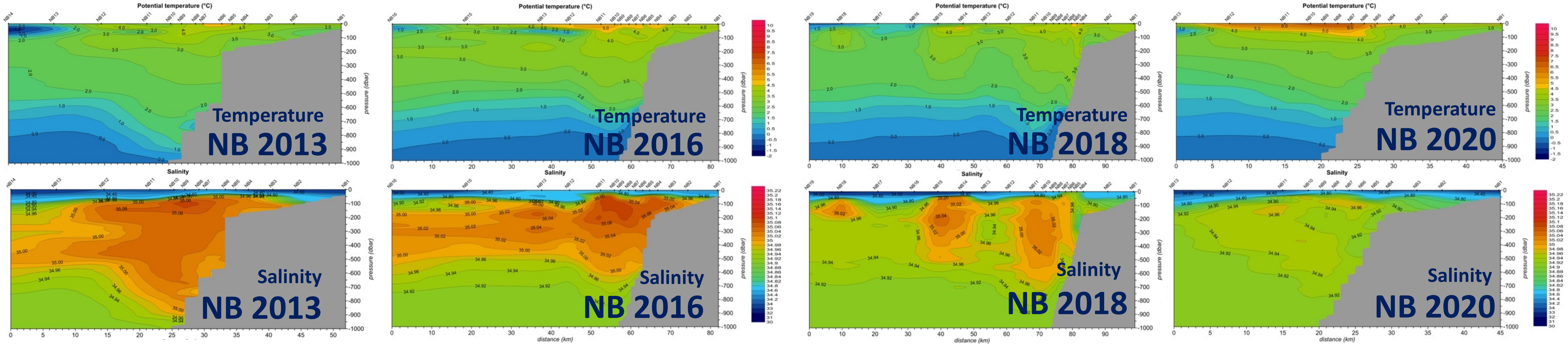
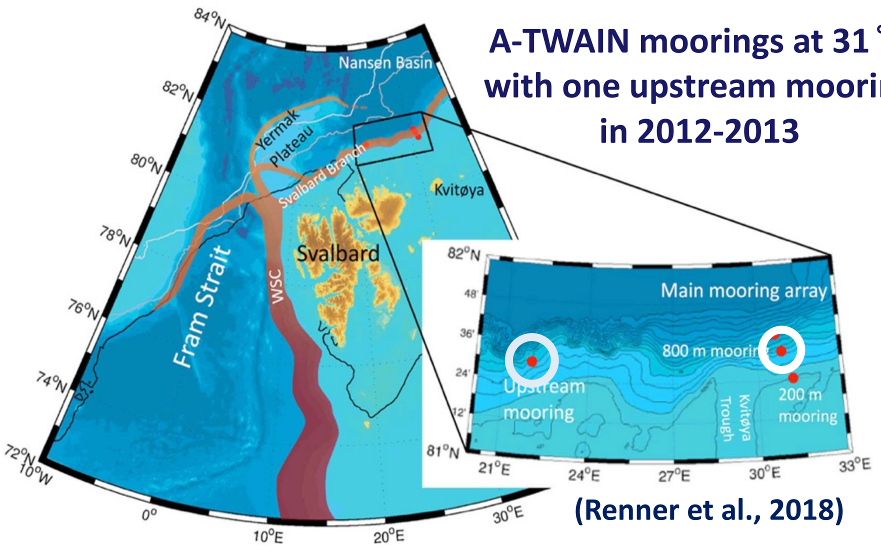




Observing the Arctic Ocean north of Svalbard

INTAROS mooring line at 22°E extended the existing A-TWAIN moored observatory with upstream measurements



A-TWAIN moorings at 31˚E with one upstream mooring in 2012-2013

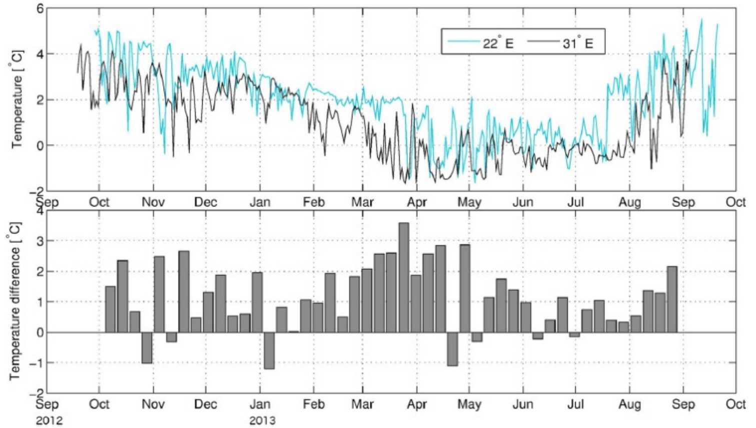
(Renner et al., 2018)

Vaage et al. (2016) – from CTD in 2012:
AW transport 1.6 ± 0.3 Sv (AW def after Rudels)

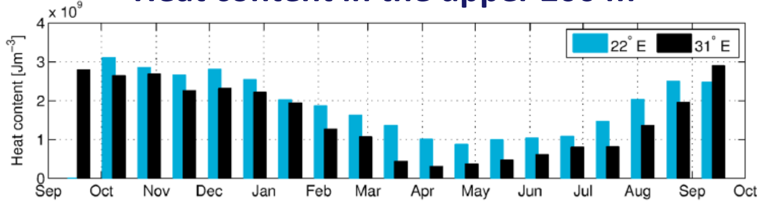
Perez-Hernandez et al. (2017) – from CTD in 2013:
AW transport 2.31 ± 0.29 Sv
(AW def SigTh>27.6, S>34.9, ϴ>1°C)

Perez-Hernandez et al. (2019) – from WHOI/NPI/IMR moorings in 2012-2013: AW transport 2.08 Sv

Temperature at 50 m and its difference between moorings at 22 and 31˚E in 2012-2013



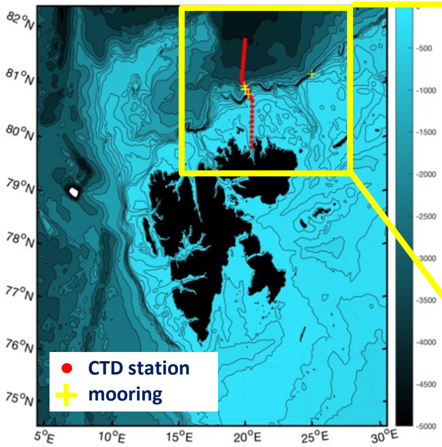
Heat content in the upper 200 m

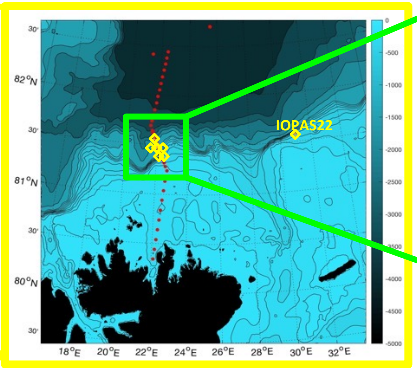


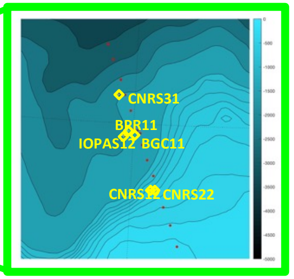
Mean heat loss of 16.7 W/m² between 22 and 31°E with max > 100 W/m² in autumn and early winter (Renner et al., 2018)

Observing the Arctic Ocean north of Svalbard

Moorings with profiling and point measurements of physical and sea ice variables (IOPAN, LOCEAN, UiB-GFI, NERSC)







INTAROS mooring cluster

Pilot experiment in 2017-2018: 2 moorings for physical variables

First deployment 2018-2019: 7 multidisciplinary moorings

Second deployment 2019-2020: 4 moorings

Third deployment: 2021-2023: 4 moorings

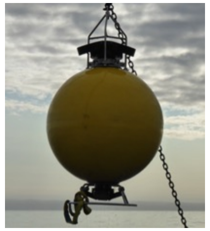
- Mooring operations in collaboration with CAATEX and the Norwegian Coast Guard (using the icebreaker KV Svalbard) and A-TWAIN/Nansen Legacy using RV Kronprins Haakon
- Ship-borne CTD measurements during mooring cruises

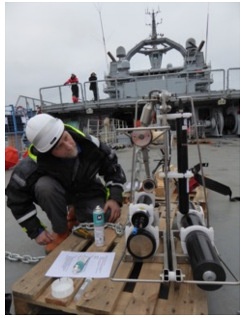
INTAROS mooring line at 22°E extended the existing A-TWAIN moored observatory with upstream measurements

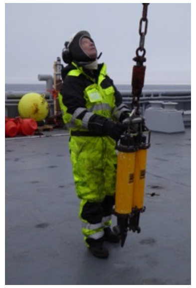
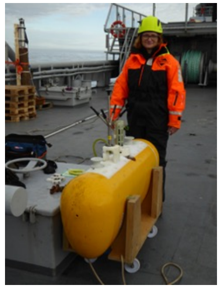
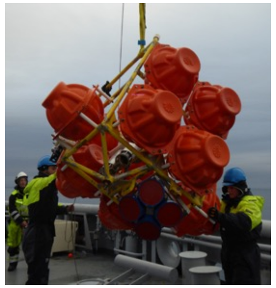
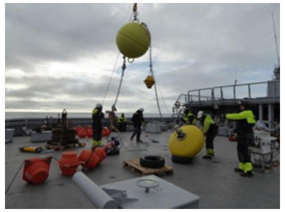
INTAROS moorings 2017-2021 instrumented with:

- Moored McLane Profilers (temperature, salinity, currents)
- TRDI QM and LR ADCPs (ocean currents)
- Signature 55 Dual Freq Nortek ADCPs (ocean currents, dual res./range)
- Nortek Signature 250 ADCPs (ocean currents, sea ice drift and draft)
- Microcats SBE37 CTD(O) sensors
- RBR and SBE56 temperature and pressure recorders







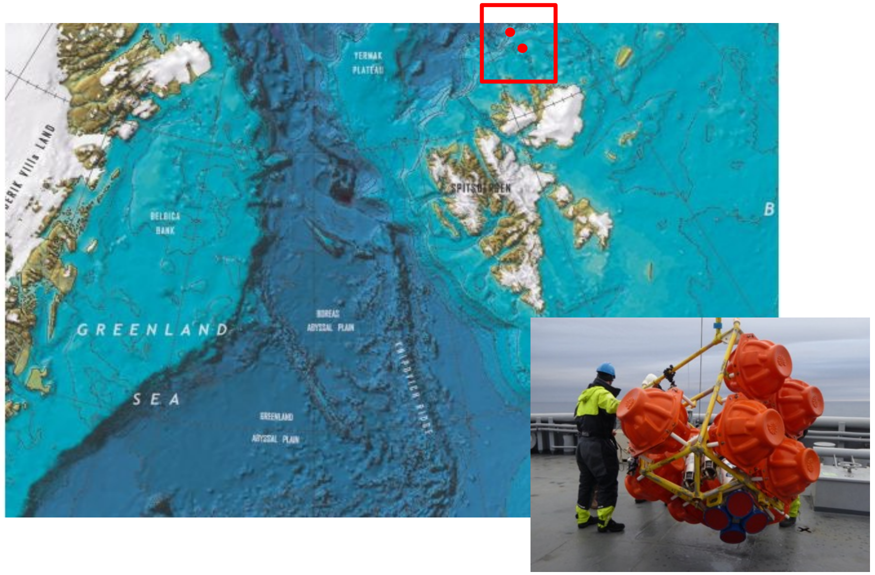
Observing the Arctic Ocean north of Svalbard

Marie-Noelle Houssais, Christophe Herbaut, Matthieu Labaste, Herve Le Goff, Julie Carles (CNRS-LOCEAN)

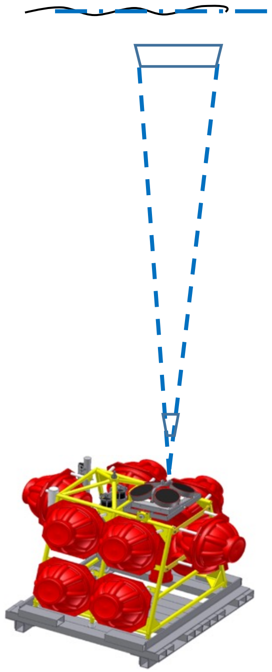
INTAROS CNRS moorings at 500m (the upper slope) and 1500 m (the lower slope)

Two mooring sites: bottom depth 500 m (CNRS1/CNRS2) and 1500 m (CNRS3)

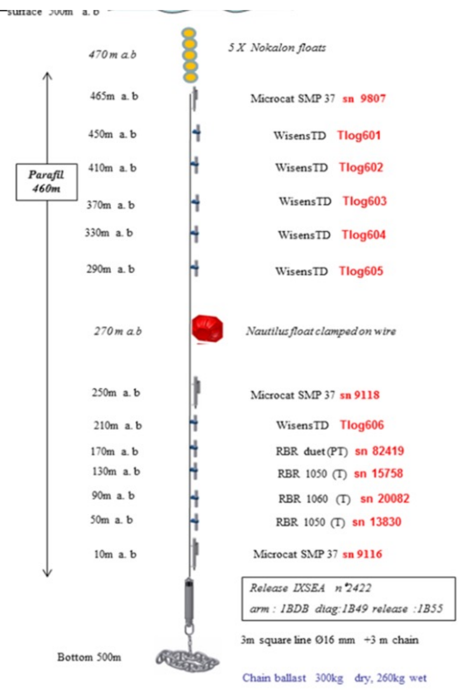
- CNRS1 / CNRS2 (bottom depth 500 m)
  - PTC sensors (Sept. 2017-June 2021)
  - ADCP (Sept. 2017 - Aug. 2019)
- CNRS3 (bottom depth 1500 m)
  - PTC sensors (Aug. 2018 – Oct. 2019 / Jul. 2020)
  - ADCP (Aug. 2018 – Jul. 2019)



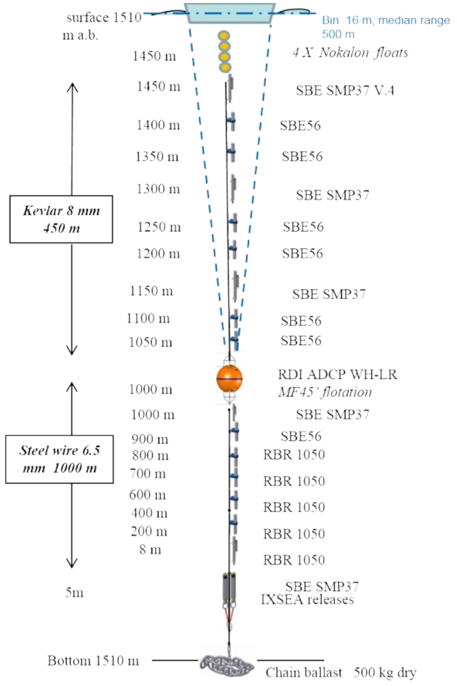
CNRS1



CNRS2



CNRS3



Funding provided through H2020 INTAROS project and French Polar Institute INTAROS-Svalbard project

Observing the Arctic Ocean north of Svalbard

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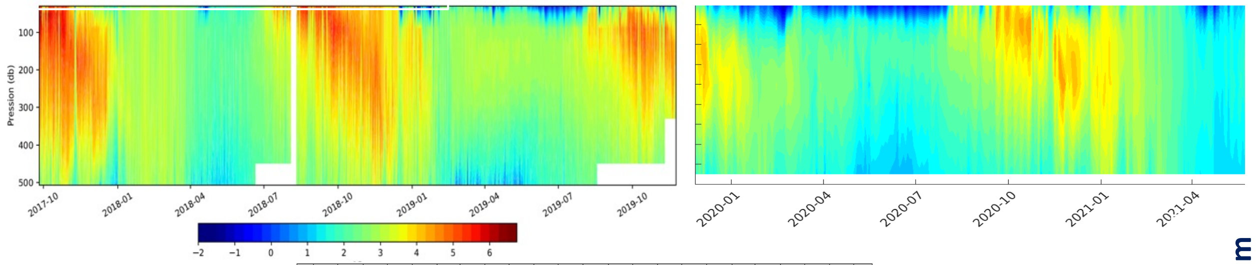
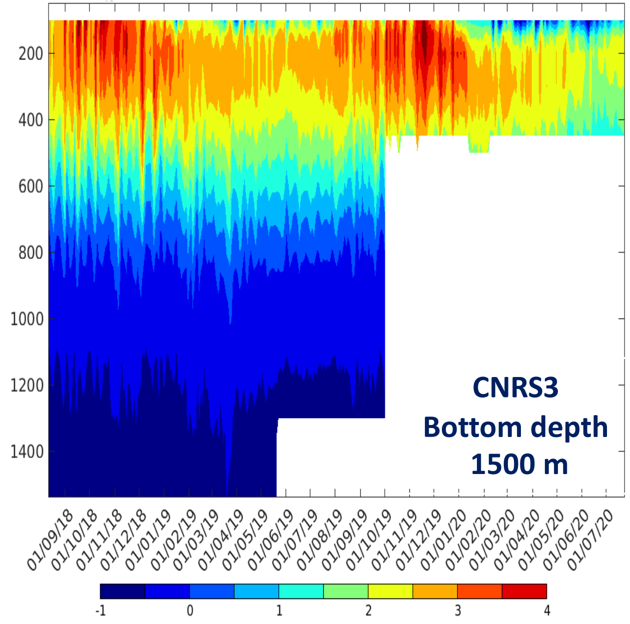
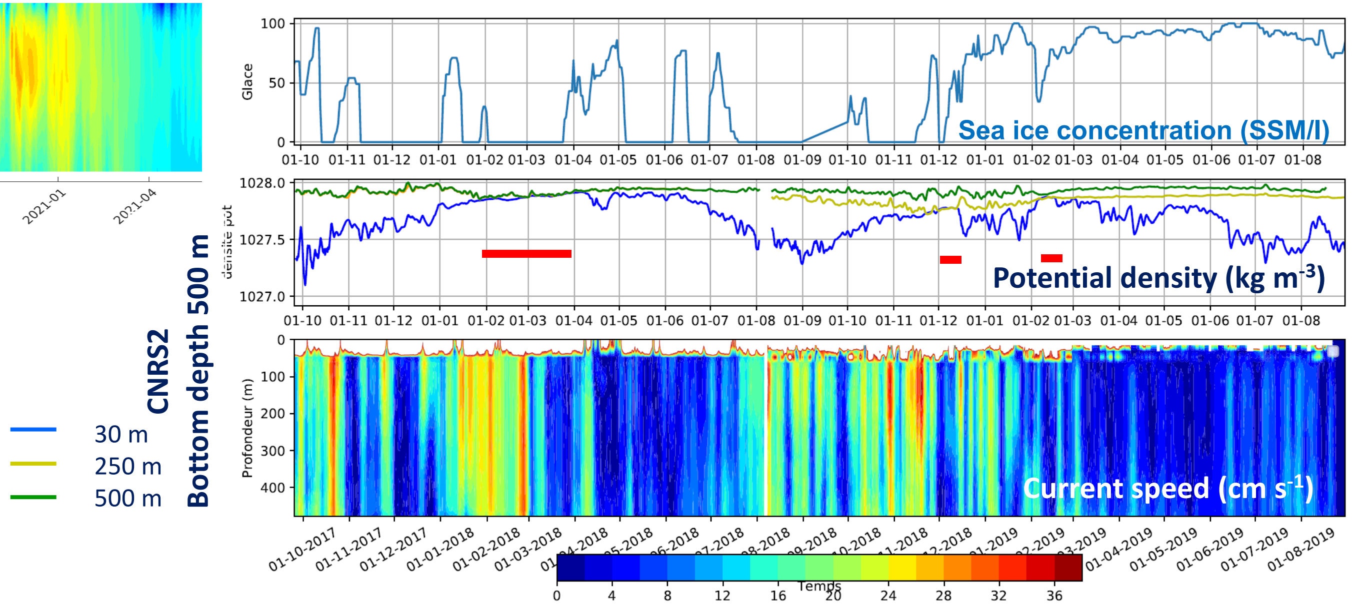
Temperature 2017-2021

CNRS2 Bottom depth 500 m

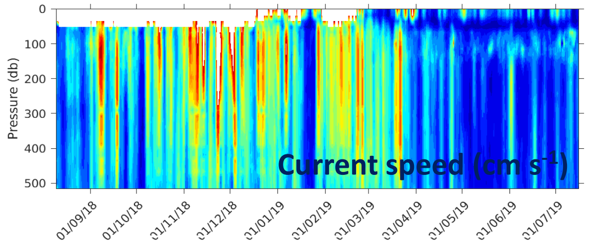




CNRS1 / CNRS2 current speed (September 2017 – August 2019)



- Strong contrast in sea ice and water column stratification between winter 2017-18 and 2018-19
- Red bars indicate weak stratification at CNRS2
- Period of high velocities over Feb-March 2019 at CNRS3 while velocities have already started to decrease at CNRS1: lateral displacement of the current core?



CNRS3 Bottom depth 1500 m

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INTAROS CNRS moorings at 500m (the upper slope) and 1500 m (the lower slope)

February-March 2018 : 2 months of open water conditions
Frequent episodes of very weak winter stratification

Sea ice

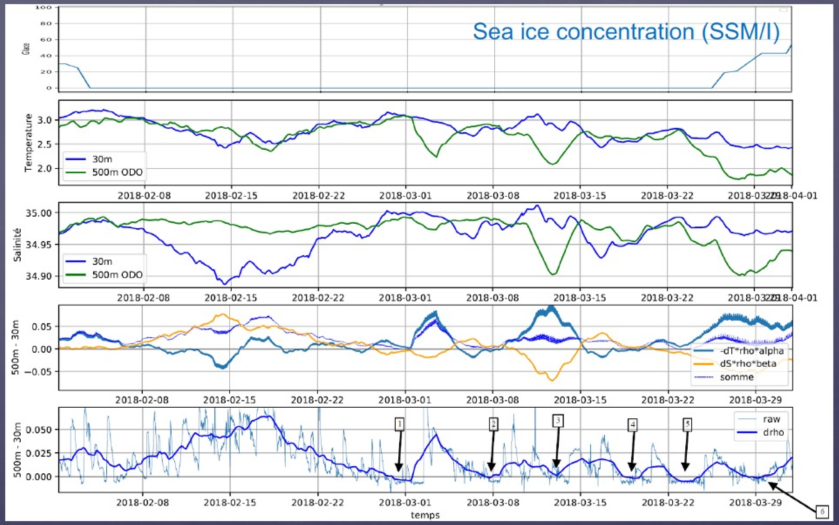
T

S

30 m
500 m

$-\alpha\,\rho_0 (T_{500} - T_{30})$
$\beta\,\rho_0 (S_{500} - S_{30})$

$\sigma_{500} - \sigma_{30}$



Two types of episodes
- Fresher, colder bottom layer
- Saltier, warmer upper layer

Winter 2018:
No ice. Warm upper layer throughout the winter
Episodes of freshening and cooling of the bottom water (e.g. 3) may correspond to downslope intrusion of shelf water. Episodes of warming and salinity increase of the top layer (eg. 1, 4, 5) may indicate AW entrainment

Winter 2019:
More ice, upper layer at freezing point,
More stratified water as compared with previous year.
But correlated episodes of concomitant increase of T and S and weakening of the 30-250 m layer stratification

Winter 2019 : persistent ice cover
A few episodes of destratification down to 250 m depth, coinciding with lighter ice conditions

Sea ice

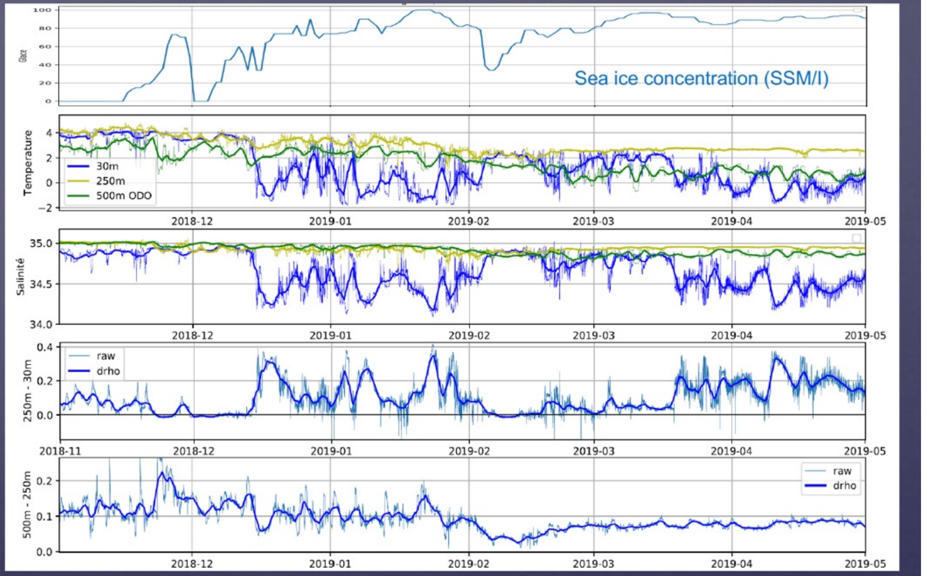
T

S

30 m
250 m
500 m

$\sigma_{250} - \sigma_{30}$

$\sigma_{500} - \sigma_{250}$



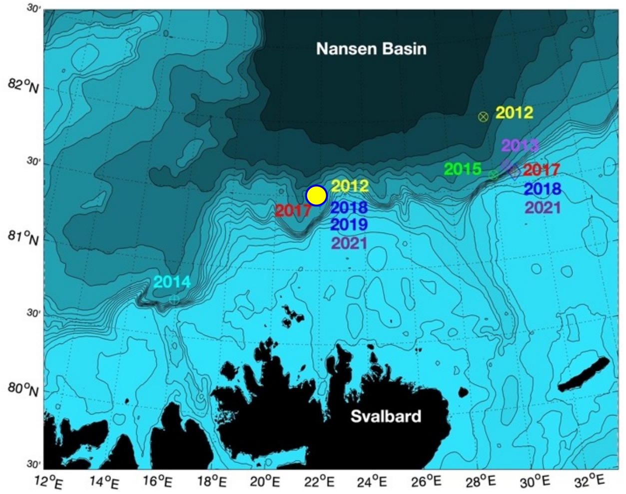
LOCEAN

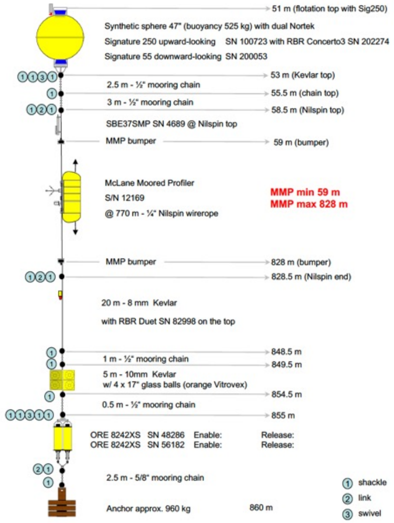
cnrs

Observing the Arctic Ocean north of Svalbard

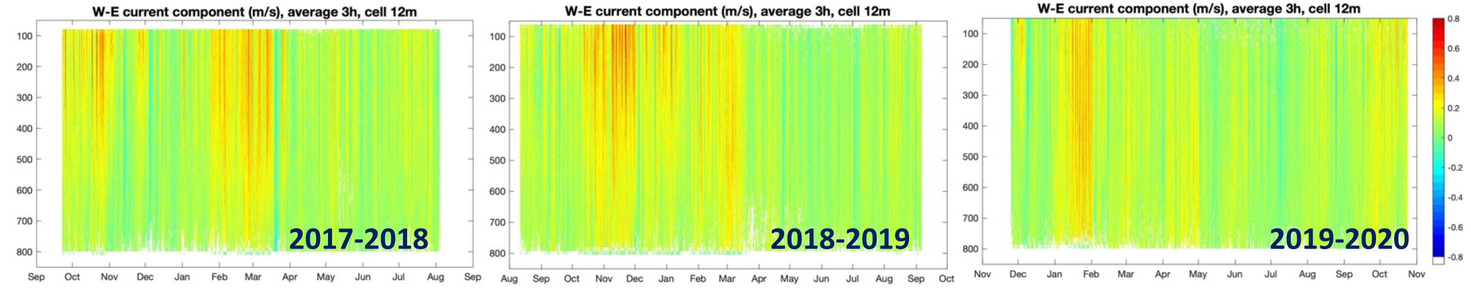
Agnieszka Beszczynska-Möller, Waldemar Walczowski, Piotr Wieczorek (IOPAN)

IOPAN INTAROS mooring at 22°E at 850m (the middle slope)

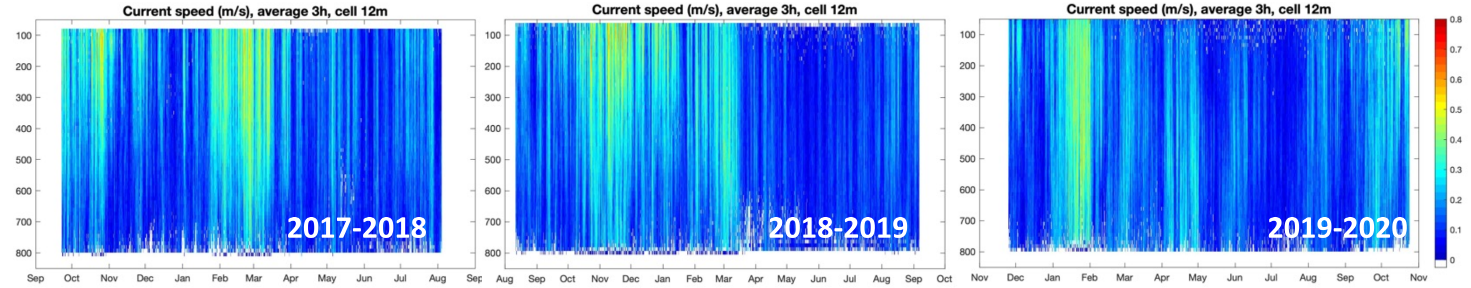




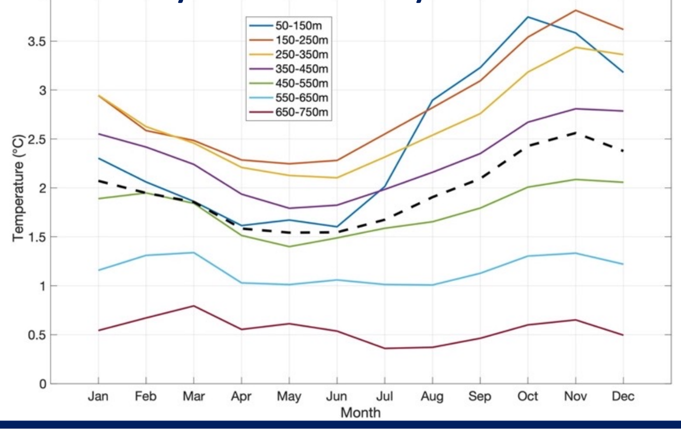
Zonal (W-E) current velocity variability at 22°E at 850m in 2017-2020



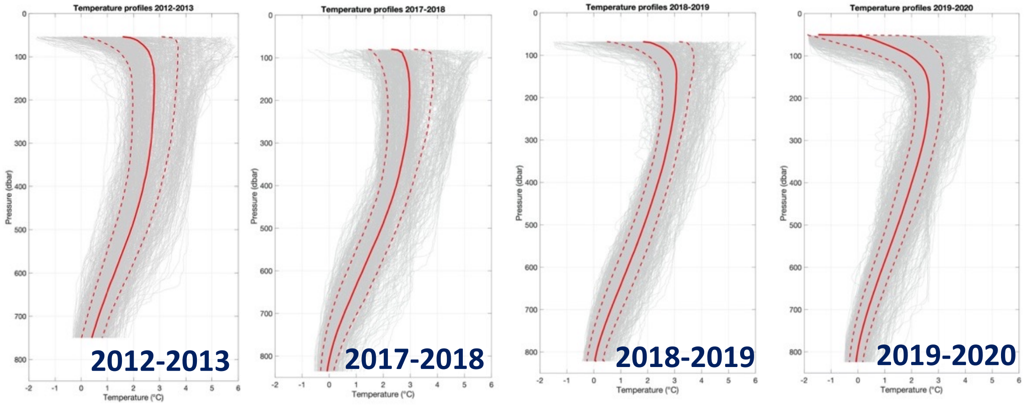
Current speed variability at 22°E at 850m in 2017-2020



Annual cycle in different layers at 22°E



Annually averaged temperature profiles at 22°E at 850m

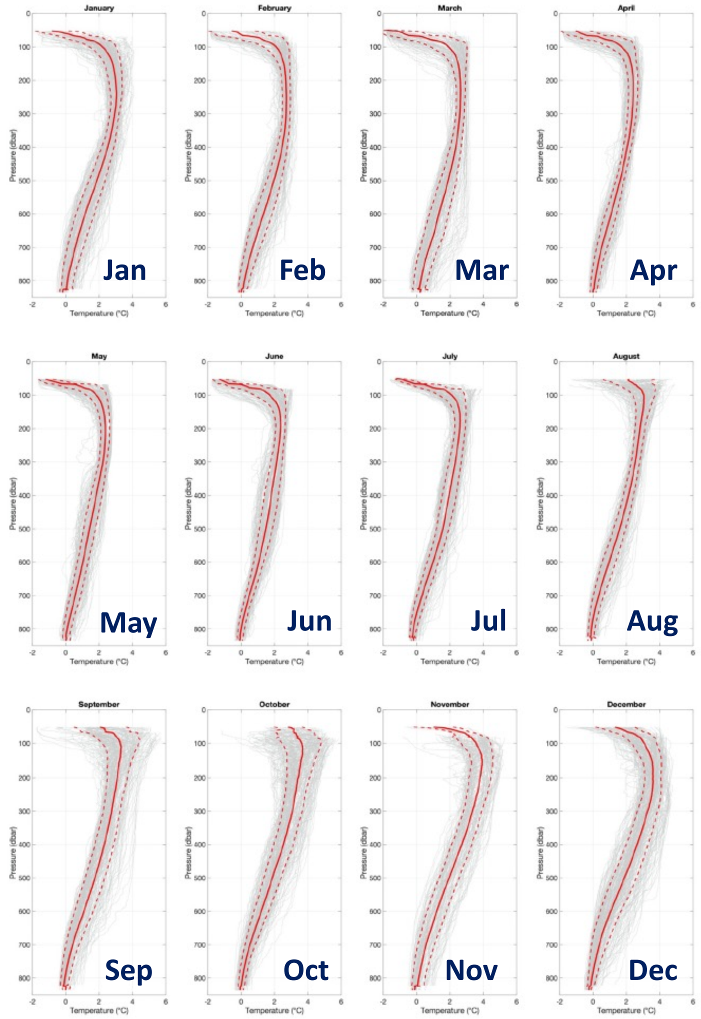


Observing the Arctic Ocean north of Svalbard

Agnieszka Beszczynska-Möller, Waldemar Walczowski, Piotr Wieczorek (IOPAN)

IOPAN INTAROS mooring at 22°E at 850m (the middle slope)

Monthly mean temperature profiles (2012-2020)



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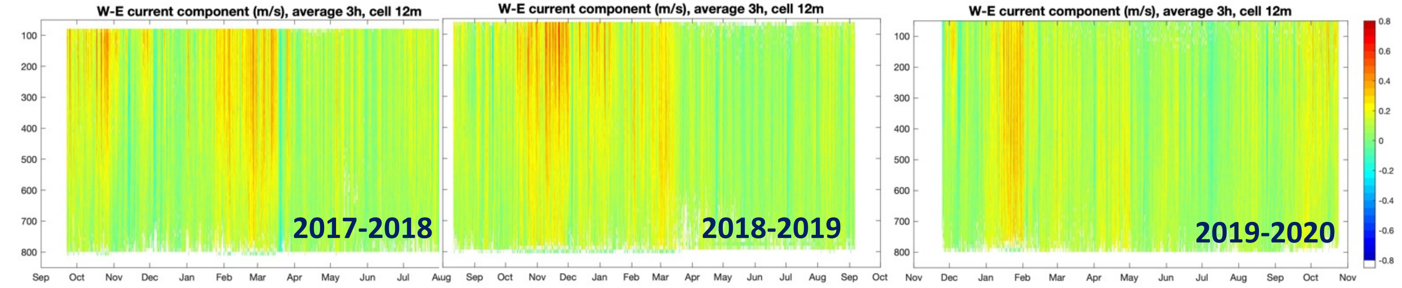
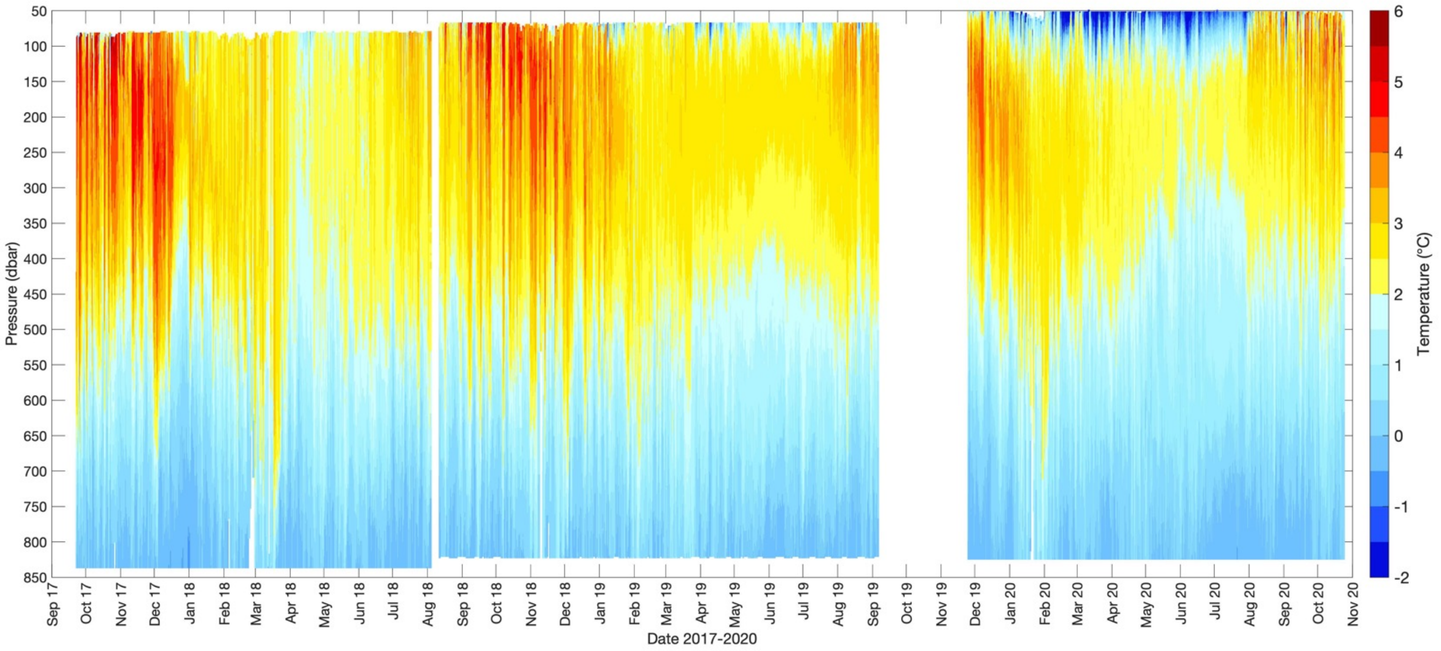


Temperature variability at 22°E at 850m in 2017-2020



Observing the Arctic Ocean north of Svalbard

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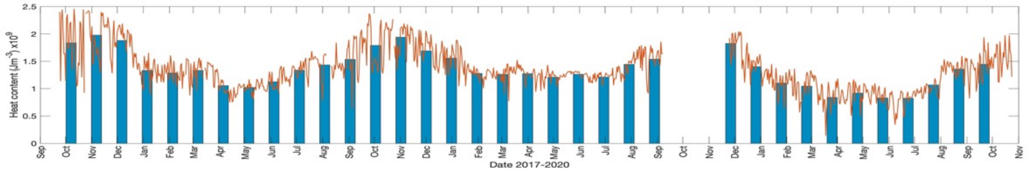
Agnieszka Beszczynska-Möller, Waldemar Walczowski, Piotr Wieczorek (IOPAN)

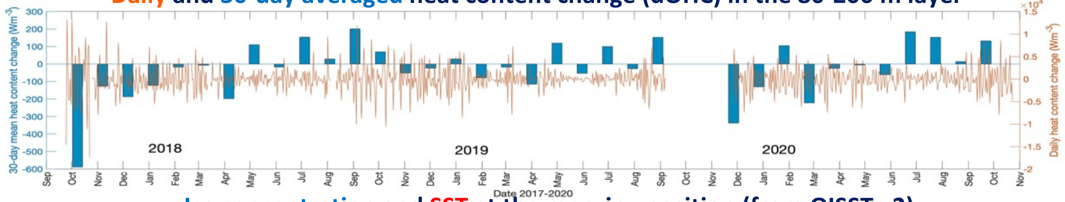
IOPAN INTAROS mooring at 850m (the middle slope) – comparison od 2012-2013 and 2017-2020

- **Strong seasonal variations with winter maxima**
- **Winter 18/19 outstanding with the thick and warm AW layer, maintained through following spring and summer**
- **Links between sea ice concentration changes and AW temperature and inflow not simple - other (atmospheric) mechanisms at play**
- **OHC changes in the upper layer of 200 m consistent with earlier estimates (2012-2013) but more variability in in 2017-2020**

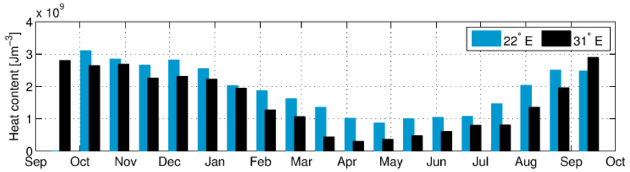
Ocean heat content (OHC) in the upper layer 80-200 m (daily values and 30-day means)



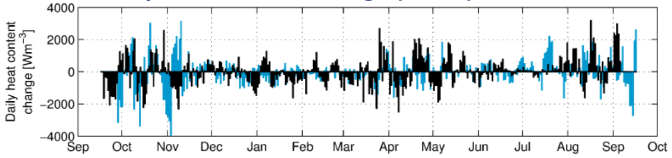
Daily and 30-day averaged heat content change (dOHC) in the 80-200 m layer



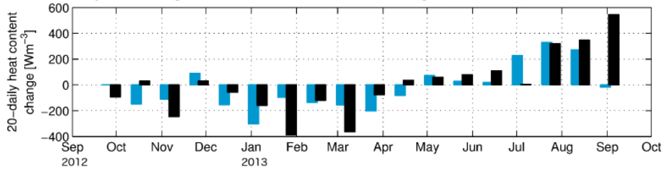
Ocean heat content (OHC) in the upper 200 m in 2012-2013



Daily heat content change (dOHC) in 2012-2013

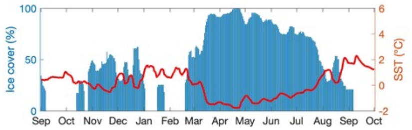


20-day averaged heat content change (dOHC) in 2012-2013

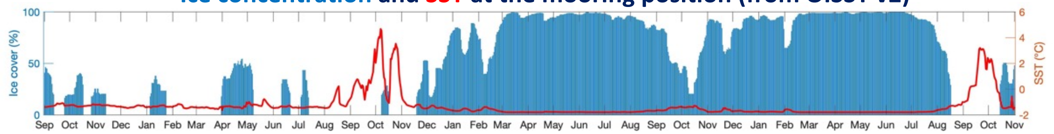


Renner et al., JGR, 2018

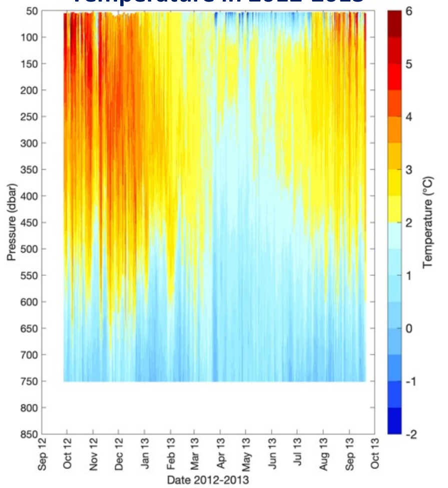
Ice concentration and SST



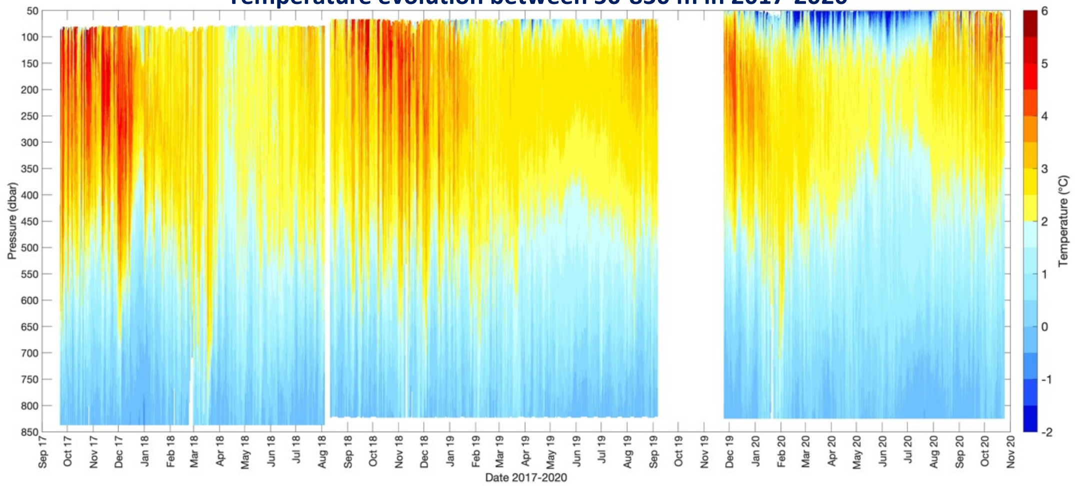
Ice concentration and SST at the mooring position (from OISST v2)



Temperature in 2012-2013



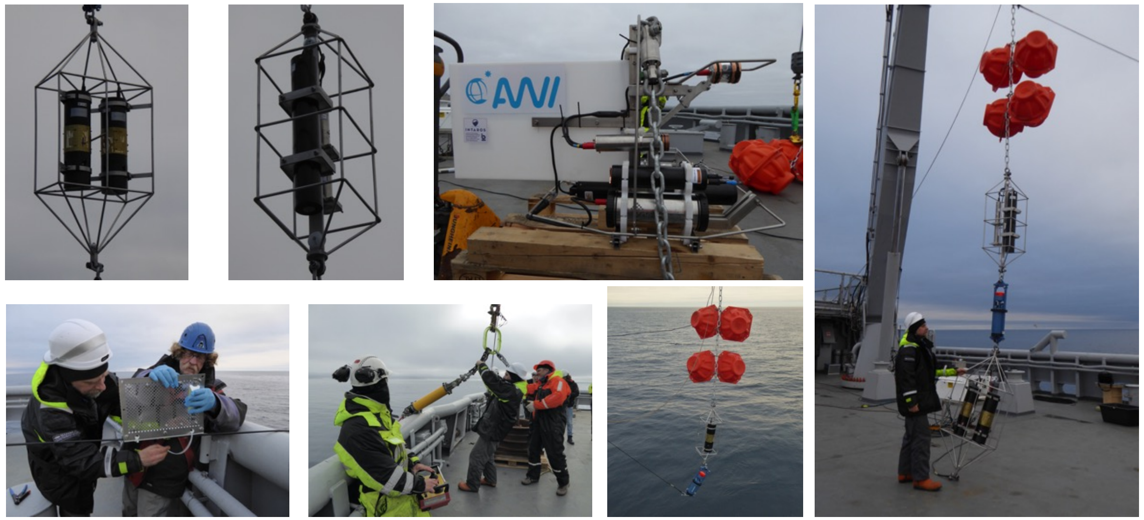
Temperature evolution between 50-830 m in 2017-2020



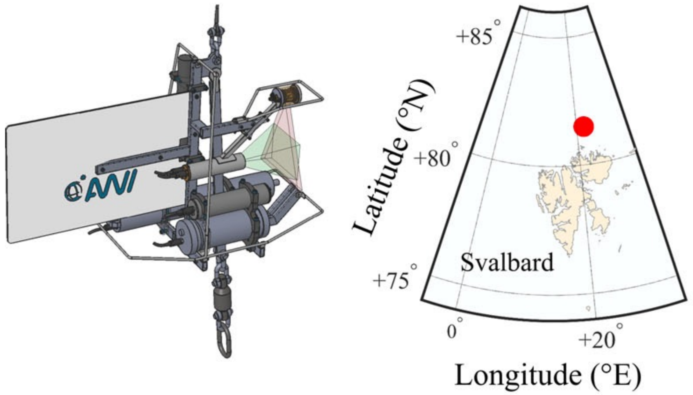
Observing the Arctic Ocean north of Svalbard

Multidisciplinary mooring for BGC and biological measurements (UiB-GFI, AWI, NIVA, IOPAN, NERSC)

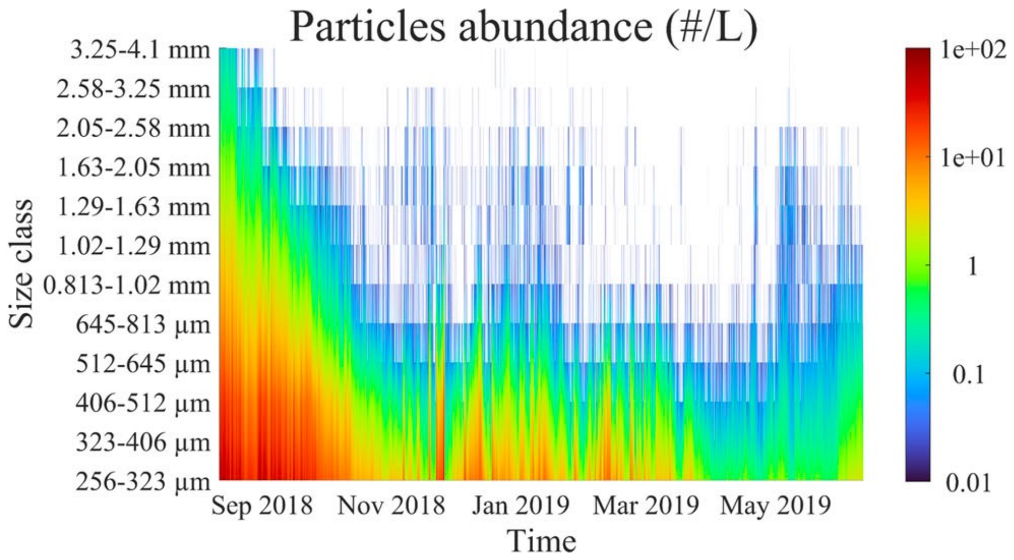
- A suite of instruments for carbon system, biological and physical parameters: pH, pCO2, nitrate, CTDO sensors, Octopus package (UVP particle camera, nitrate sensor and ECO Triplet-w for chl a and FDOM fluorescence and backscattering, passive contaminant samplers)
- Deployed for 2018-2019 in a cluster with the mooring at 850 m, measuring physical ocean and ice parameters



Andreas Rogge



Upper left: UVP6-LP mounted in its cage with other sensors.
Upper right: Map showing the location of the mooring north of Svalbard during the INTAROS experiment (81.4772 N, 21.8867 W).
Bottom: Abundance of particles in 11 selected size classes during the 10-month deployment of the UVP6.



Picheral et al., Limnology and Oceanography, 2021

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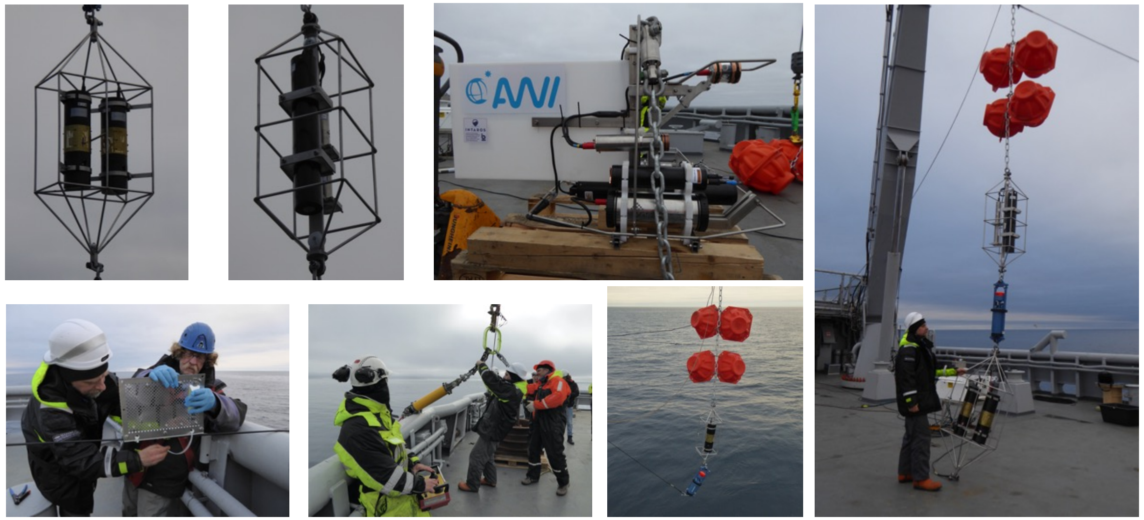
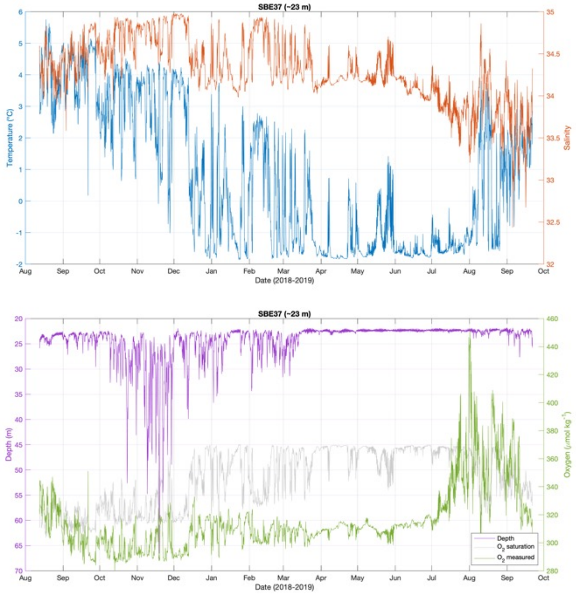
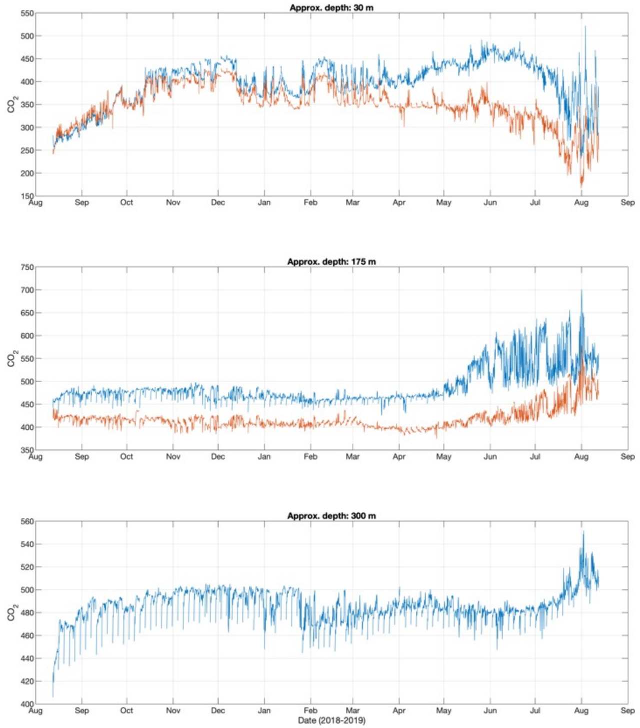


Biogeochemical measurements on the INTAROS BGC mooring in 2018-2019

Truls Johannessen
Nicholas Roden



Temperature and salinity (top panel) and depth and oxygen concentration (bottom panel) measured on the BGC mooring in 2018-2019



pCO_2 data measured from the SAMI-CO_2 sensors from three different depths in 2018-2019. For redundancy, two sensors were used at each of the two shallowest depths

INTAROS

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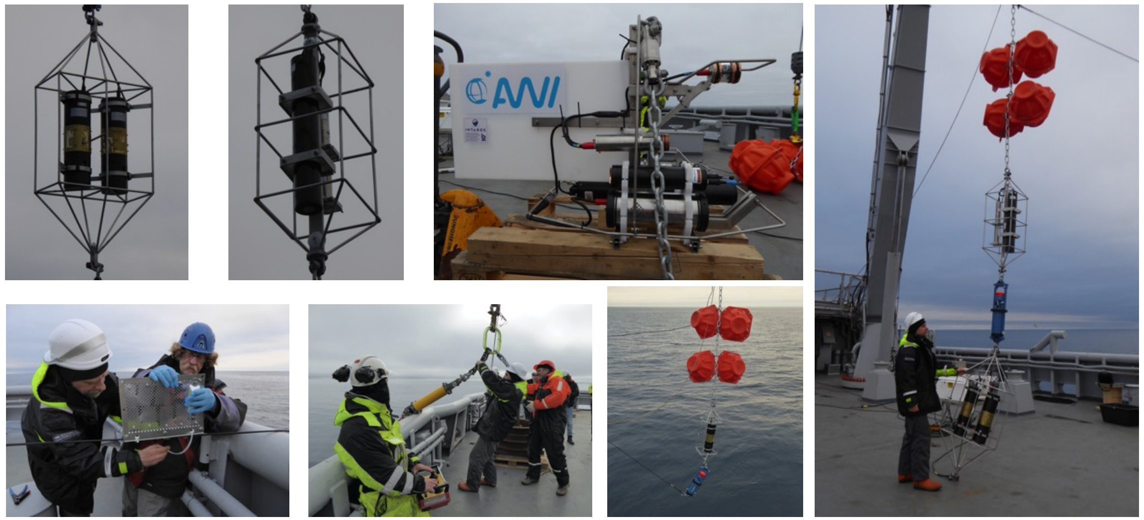
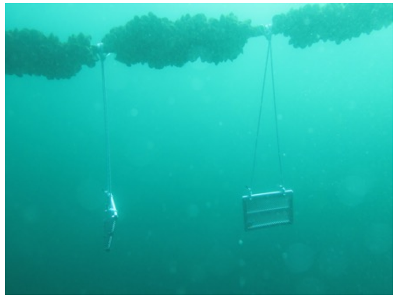
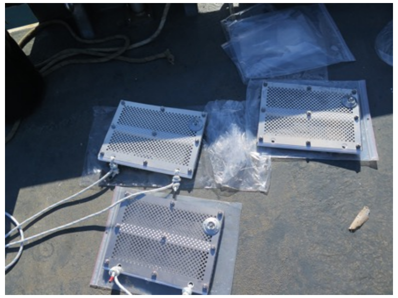


NIVA
Norwegian Institute for Water Research

Ian Allen
Andrew King
Luca Nizzeto
Alfhild Kringstad

Baseline contaminant levels in Arctic waters assessed with passive sampling on INTAROS moorings in 2018-2019





- The combination of deep moorings and passive sampler deployments enables us to determine baseline contaminant levels in Arctic water masses
- Silicone rubber (SR) with a high sorption capacity for hydrophobic organic contaminants
- SR sheets deployed in flat stainless steel caged for up to 2 years at 50, 700 and 1490 m deep
- Once retrieved, samplers are extracted and extracts were analysed for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and other organochlorinated compounds, and polybrominated diphenylether (PBDEs) flame retardants
- Performance reference compounds are used to estimate the rate of exchange of chemicals between water and the sampler
- Sampling rates of 4-8 L d^{-1} of water extracted by the sampler

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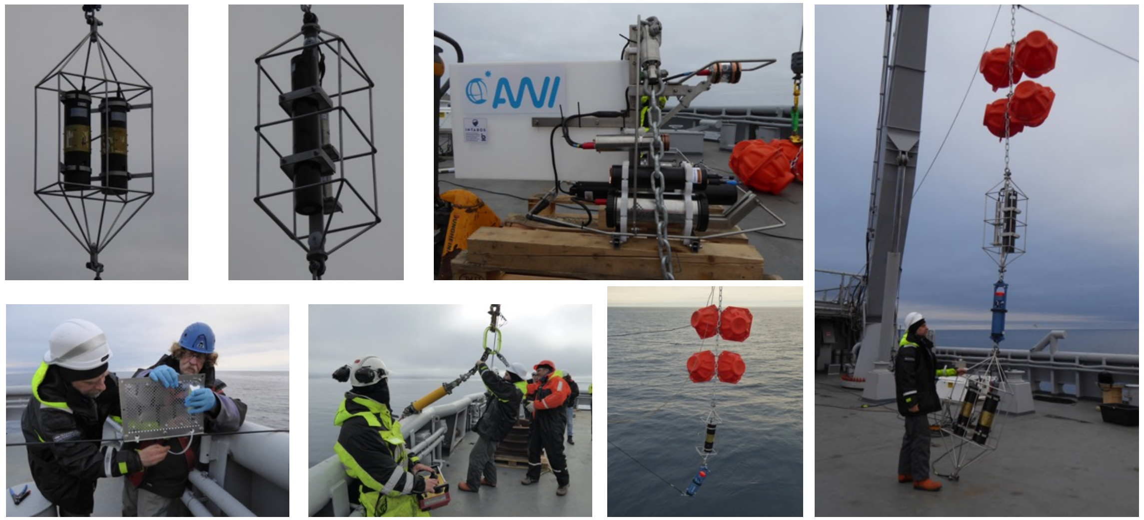


Baseline contaminant levels in Arctic waters

NIVA
Norwegian Institute for Water Research

Ian Allen
Andrew King
Luca Nizzeto
Alfhild Kringstad

- How can these numbers be used?
- Estimation of contaminant fluxes with water mass movements
- Contaminant mass balance/budget for the Arctic

- PAH concentrations in Arctic waters
- Lower than those found at Jan Mayen and Bear Island (2009) in the range of 0.6-0.95 ng L^{-1}
- Similar range to tha

	Freely dissolved concentration (ng L^{-1})			
Compound	CNRS22 50 m	CNRS 31 1490 m	CNRS31 50 m	CNRS31 700 m
Fluoranthene	0.091	0.13	0.21	0.14
Pyrene	<0.02	0.055	0.043	0.037
Benzo[a]pyrene	<0.003	<0.002	0.0038	<0.002

Baseline levels of persistent organic pollutants in Arctic waters

Hexachlorocyclohexane isomers (pesticide Lindane)

	Freely dissolved concentration (ng L^{-1})			
Compound	CNRS22 50 m	CNRS 31 1490 m	CNRS31 50 m	CNRS31 700 m
HCH-alpha	0.17	1.31	0.26	0.57
HCH-gamma (Lindane)	<0.4	0.97	0.17	0.34

Hexachlorobenzene 5-11 pg L^{-1}

Levels similar to measurements in the Irminger Sea (Booij et al., 2014) and to measurement by Lohmann et al (2009)

PCBs detected with limits of quantification in the femtogram per litre range

	Freely dissolved concentration (pg L^{-1})			
Compound	CNRS22 50 m	CNRS 31 1490 m	CNRS31 50 m	CNRS31 700 m
Hexachlorobenzene	5.5	8.4	8.9	11
p,p'-DDE	0.50	4.7	0.98	1.8
p,p'-DDT	0.16	5.3	0.62	3.1
PCB 52	0.43	3.0	0.58	2.4
PCB 153	0.064	0.80	0.16	0.61
PCB 180	<0.04	0.15	0.030	0.11

Observing the Arctic Ocean north of Svalbard - summary

Observations collected north of Svalbard:

- Processing nearly finalized, data are (or very soon will be) submitted to open repositories, BGC data need more time
- Analysis of individual data sets ongoing, integrative joint study (studies) still to come

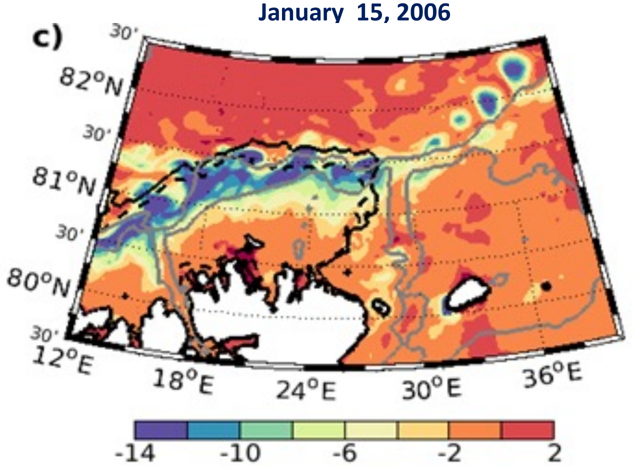
Observing system:

- Refined vertical resolution of observations in the 0-100 m layer: better understanding of vertical mixing efficiency, entrainment of Atlantic water, heat flux to the sea ice and atmosphere, variability of the surface layer properties
- Concomitant measurements of sea ice and ocean structure/properties for better understanding of ice-ocean interactions
- Coordination of upper slope monitoring with monitoring on the shelf and offshore, and upstream and downstream: 3D picture
- Monitoring of shelf-slope exchanges, including complementary information from BGC sensors
- Maintain long-term monitoring of the AW inflow

Planned joint scientific analysis of physical observations:

- Joint analysis of all mooring observations of ocean physics at 22°E
- Link to upstream and downstream observations (Fram Strait moored array, A-TWAIN moored array, perhaps NABOS in the EEB)
- Model-observations analysis: understanding of the dynamics of the boundary current and its interaction with the water column structure and sea ice, understanding of the long-term variability and mesoscale dynamics (slope-basin AW exchange)

Ocean simulation 2 km resolution
Sea ice growth rate (cm day^{-1})
January 15, 2006



Herbaut et al., under review

THANK YOU FOR ATTENTION

INTAROS

www.intaros.eu

Data collected during INTAROS field campaigns are registered in the INTAROS data catalogue: https://catalog-intaros.nersc.no and INTAROS observing systems in the ArcMap: https://arcmap.nersc.no