Ocean Data Dojo Workshop I
Bergen, Grand Hotel Terminus, 1 November 2022

IOPAN oceanographic measurements from vessels and moorings in the Svalbard region

Long-term Arctic monitoring program AREX and A-TWAIN/INTAROS moorings

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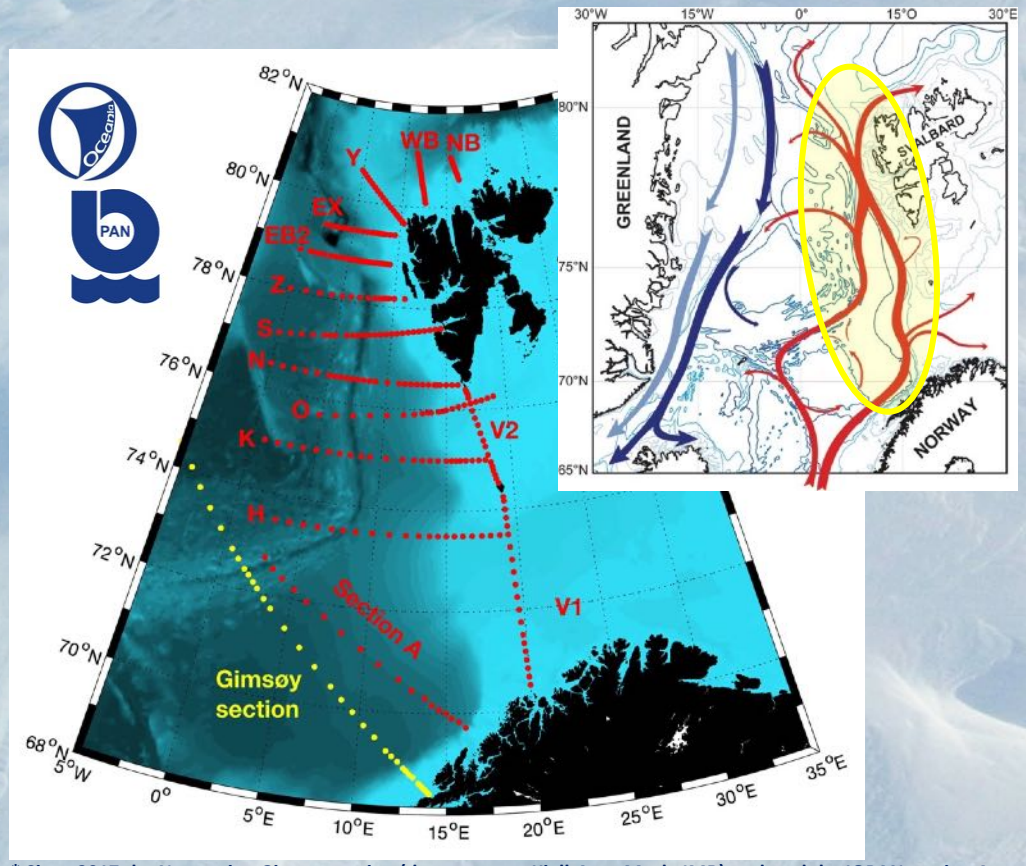
IOPAN strategic research themes in the European Arctic:

- Role of the ocean in climate system and consequences of climate change in the European seas
- Contemporary changes of ecosystems in the shelf seas

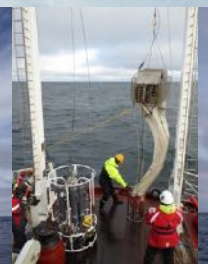
- **Long-term changes of properties and circulation of Atlantic water and its inflow to the Arctic Ocean – causes, mechanisms, and climatic consequences, ocean-atmosphere-sea ice interactions.**
- **Interactions and feedbacks between ocean, atmosphere, tidal glaciers, and sea ice in the Svalbard fjords and fjord-shelf exchanges of water masses and biological matter.**
- **Changes in the Arctic marine ecosystem resulting from environmental changes, in particular warming of ocean and atmosphere and Atlantification processes.**
- **Biogeochemical characteristics of the European Arctic Seas – carbon cycling, biogeochemistry of natural and artificial isotopes and trace metals, transport of microplastic.**

Long-term large scale Arctic monitoring program
AREX 1987-2022 (ongoing)



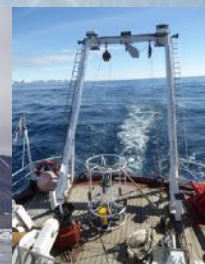
* Since 2017 the Norwegian Gimsøy section (data courtesy Kjell-Arne Mørk, IMR) replaced the IOPAN section A

- Annually repeated summer campaigns (June-September) AREX Arctic Experiments of the IOPAN research vessel RV Oceania (shiptime about 90 days)
- 36 AREX expeditions in 1987-2022, covering the main regions of the Atlantic inflow to the Arctic Ocean (eastern Norwegian and Greenland seas, Barents Sea Opening, Fram Strait, SW Nansen Basin, west Spitsbergen fjords (Hornsund, Kongsfjorden, Isfjorden, less regularly other fjords)
- Oceanographic measurements repeated on the regular station grid covering 10-15 repeated sections (since 2000), some sections since 1996 (CTD, VM-ADCP, LADCP)
- Optical, chemical, and biological measuremets and water sampling on selected stations, continuous underway chemical and atmospheric measurements
- Complementary high resolution CTD sections with towed scanning CTD proble (scanfish) in the upper layer of ~ 300 m
- Extensive long-term measurement and sampling program in Svalbard fjords (Hornsund and Kongsfiord), mainly physical and biological observations, recently also more biogeochemical measurements
- 2-3 profiling Argo floats deployed each year since 2009 oraz occasionally glider deployments for collaborating partners

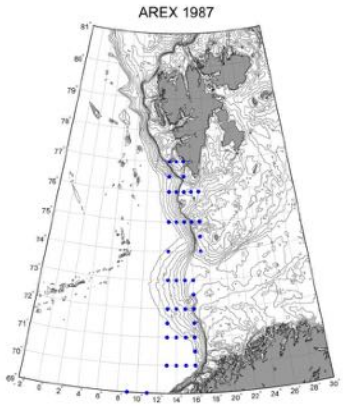





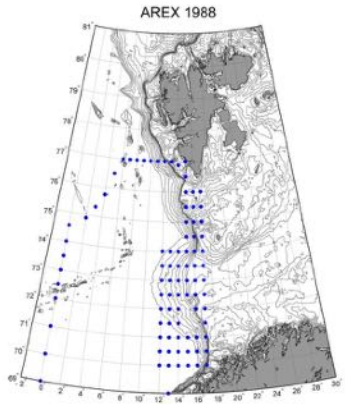


Early AREX measurements in 1987-1999



1987



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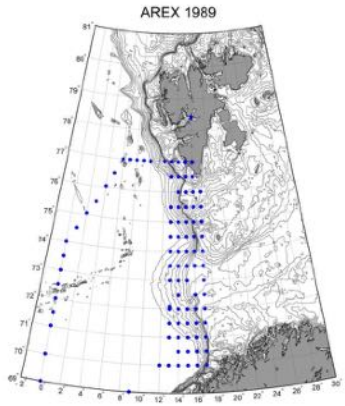
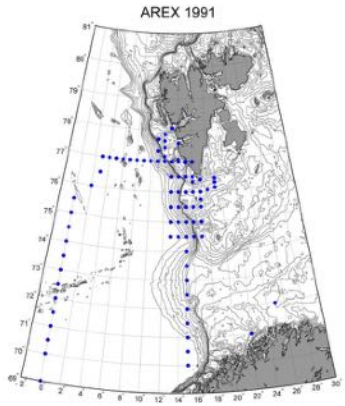


1989



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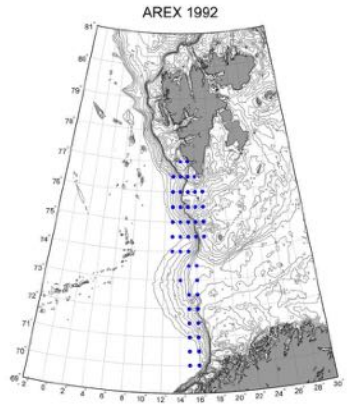

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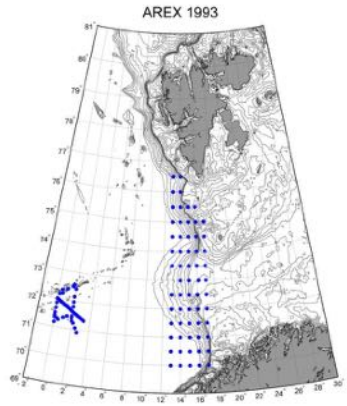
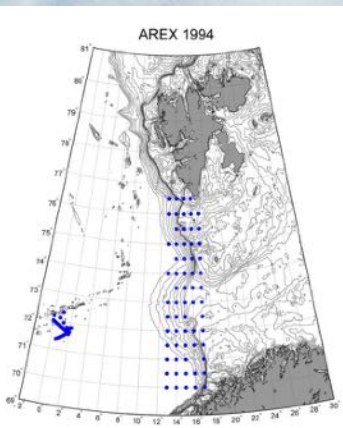
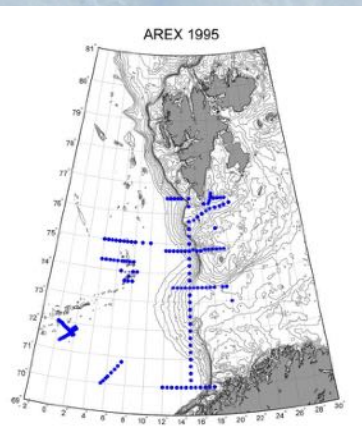


1993



1994



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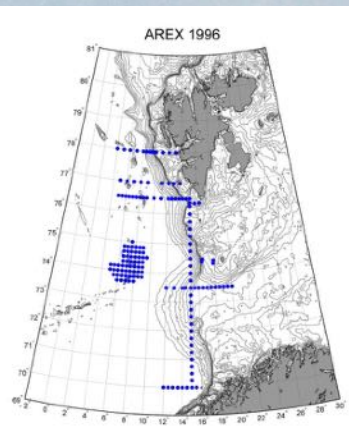
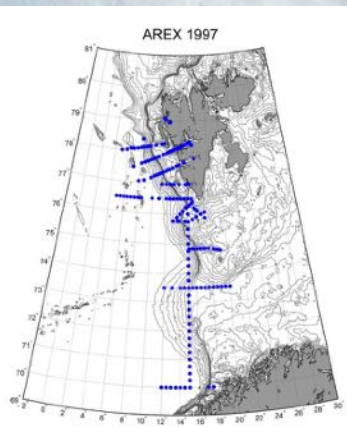
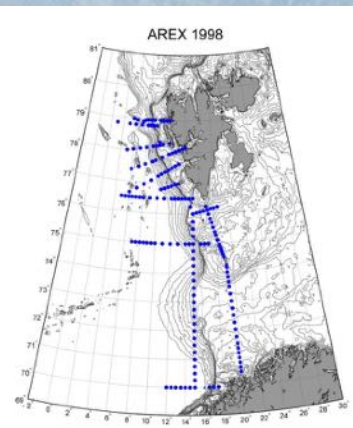


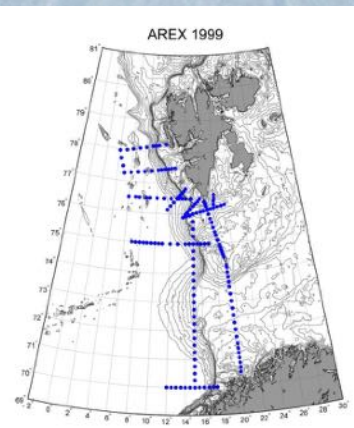
1996



1997



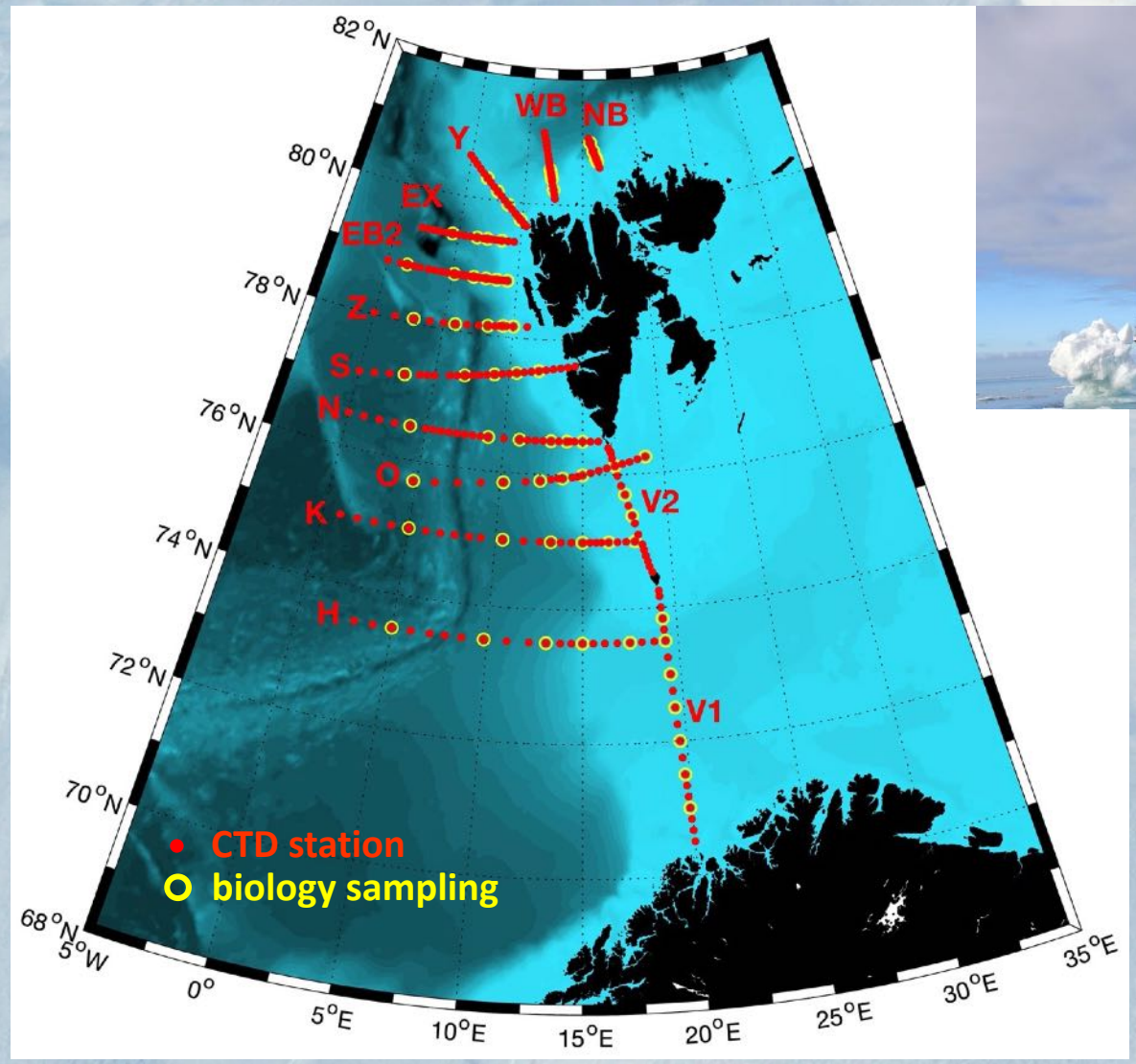
1998

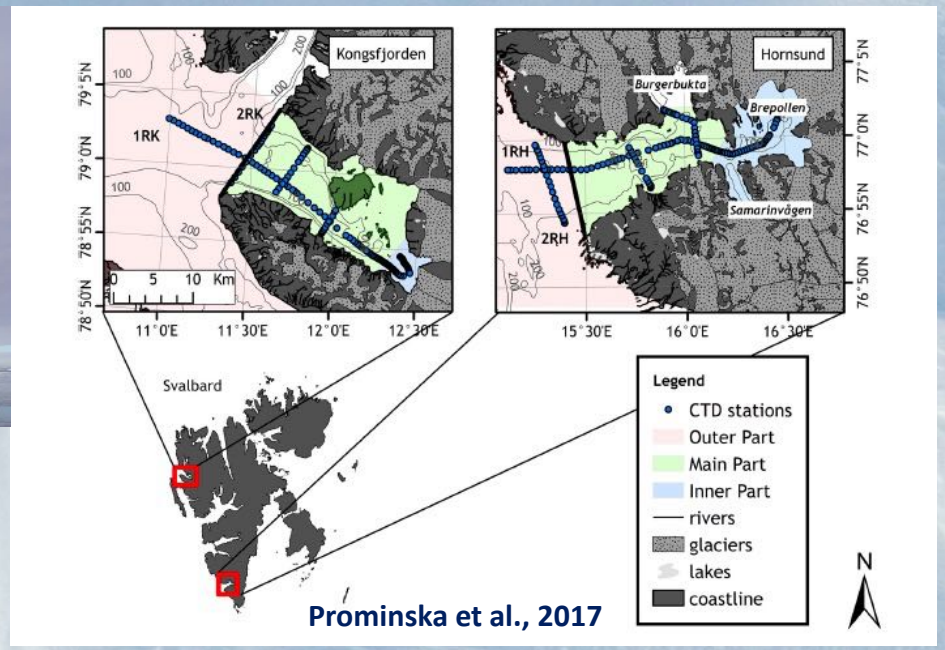


1999

Establishing regular station grid (standard AREX sections) in 2000-2022:

Sections covering the Atlantic inflow and repeated lines in fjords



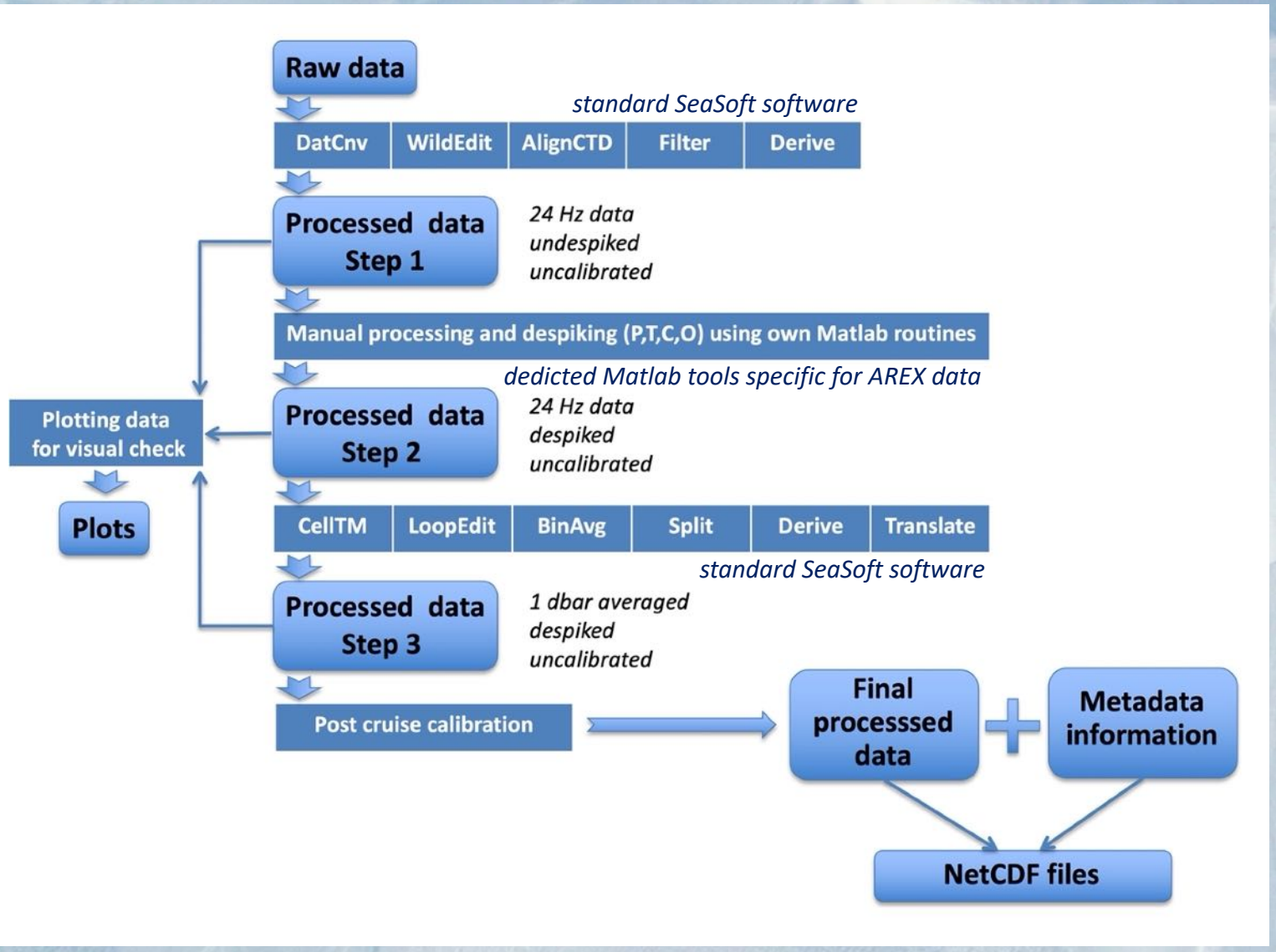


Prominska et al., 2017

- Since 2000 standard station grid includes 10-15 sections (over 200 stations), some since 1996 (CTD, continuous underway VM-ADCP recording and in the last decade LADCP measurements on stations)
- CTD measurements in the West Spitsbergen fjords. Ollected both with standard CTD system and with the towed scanfish CTD (high resolution sections)

Physical measurements with SeaBird CTD 9/11+ system with LADCP

Standard processing of CTD measurements collected from RV Oceania



- A mixture of standard SeaBird processing software (SeaSoft) and own processing tools used
- Due to strong pitching and rolling of Oceania under rough weather conditions, additional steps required to remove loops due to up and down movements of CTD
- Additional despiking and removing wrong CT data done on salinity and then CT reprocessed and salinity calculated again
- Potential density calculated, density inversions removed and corrected TS recalculated
- Finally corrected raw (24 Hz) data averaged in 1 dbar bins
- Sensors calibrated shortly before the summer cruise, re-checked against post-cruise calibrations

NetCDF format (old) of AREX CTD data

Global Attributes:

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topiccategory = 'oceans'
keywords = 'Oceanography Pressure Temperature Conductivity Salinity Oxygen Fluorescence Potential Temperature Potential Density'
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conventions = 'CF-1.0'
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history = '24-Mar-2022 creation'
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northernmost_latitude = '81.4'
westernmost_longitude = '5.0'
easternmost_longitude = '20.0'
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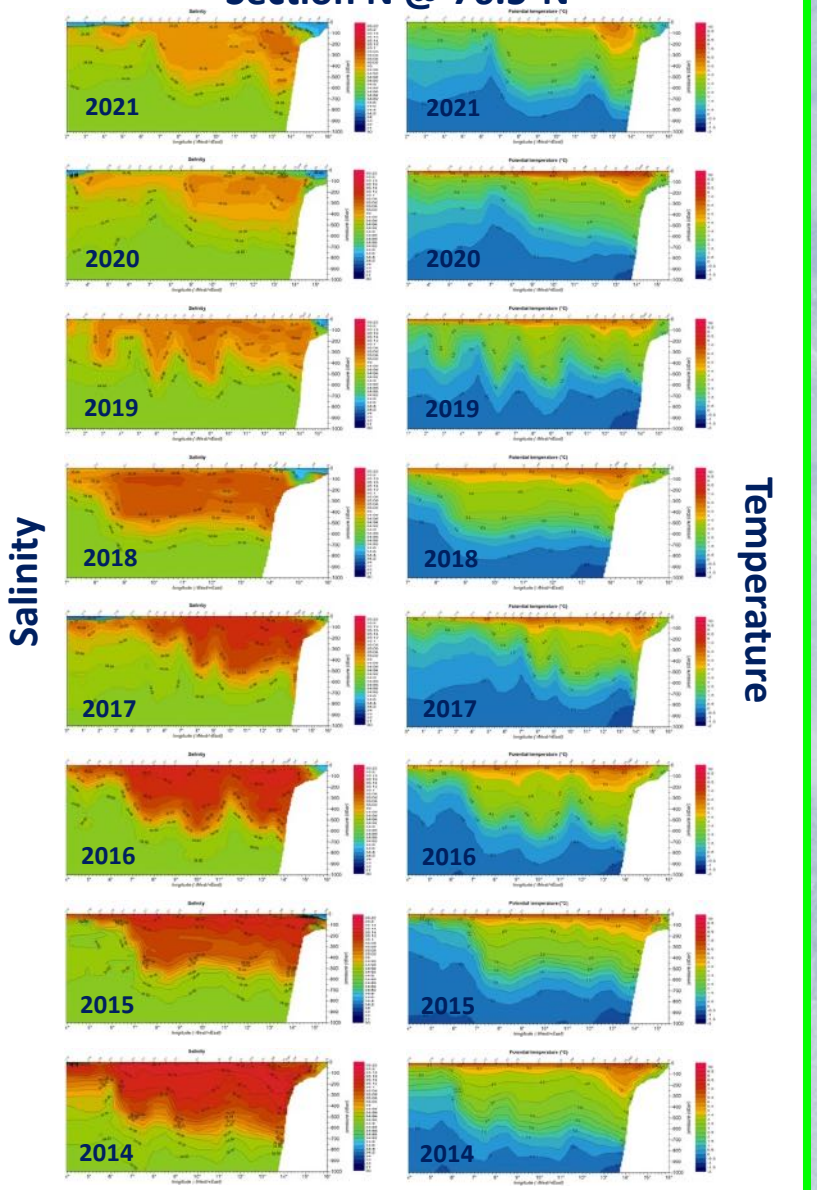
stop_date = '2021-07-21 17:02:00 UTC'
institution = 'Institute of Oceanology Polish Academy of Sciences'
PI_name = 'Agnieszka Beszczynska-Möller'
PI_email = 'abesz@iopan.pl'
Author_name = 'Agnieszka Beszczynska-Möller'
Author_email = 'abesz@iopan.pl'
distribution_statement = 'These data are public and free of charge. User must display citation in any publication or product using data. User must contact PI prior to any commercial use of data.'
citation = 'These data were collected and made freely available by the IOPAN long-term program AREX as a contribution to the statutory research areas (Task I.4). '
project_name = 'AREX2021'
station_name = 'Z13'

Currently working on the updated netCDF format with more extensive metadata set (including DOI) and compliant with standards

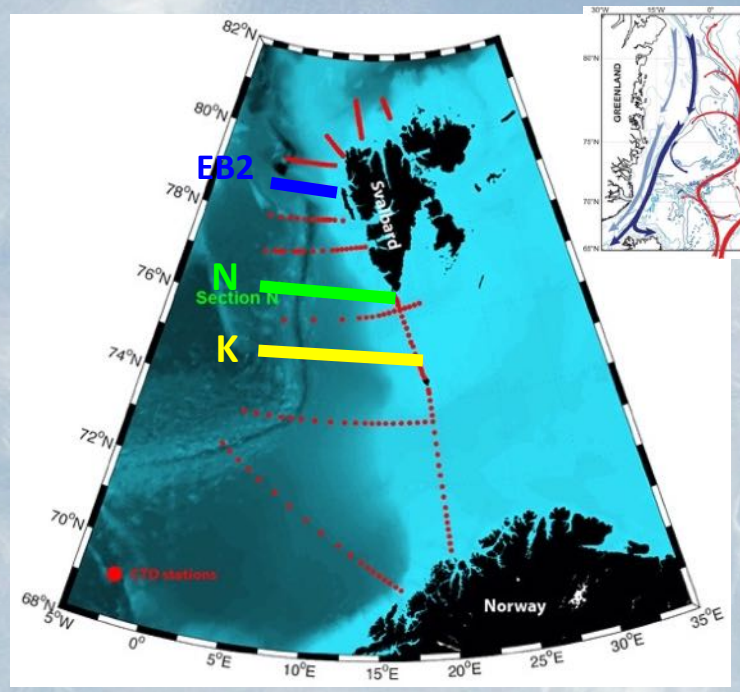
Long time series of physical variables for ocean climate changes

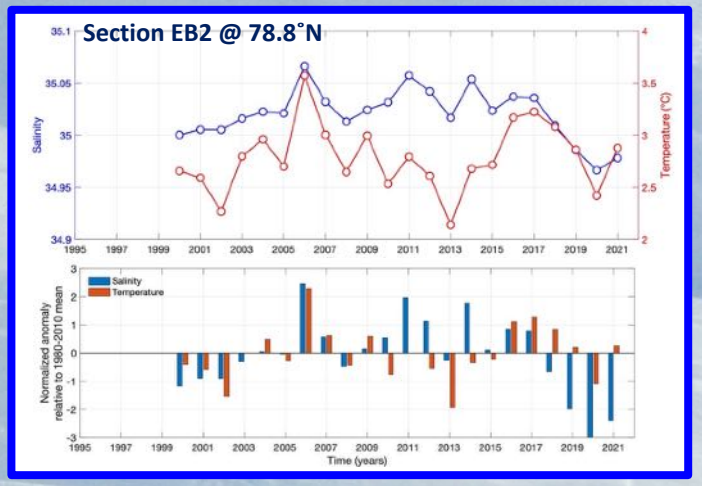
Section N @ 76.5˚N

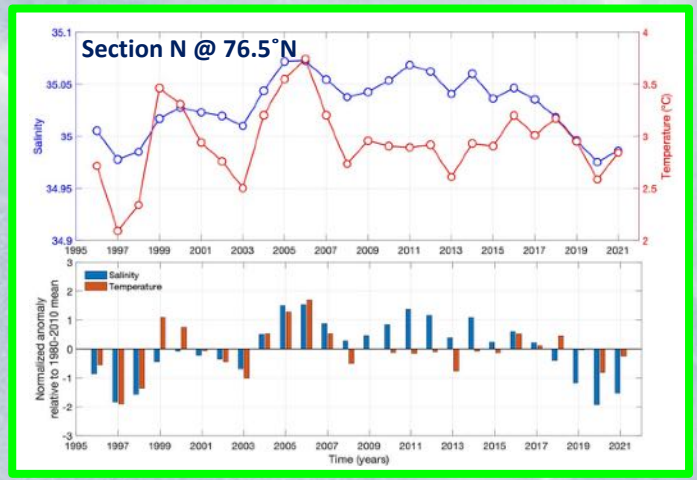


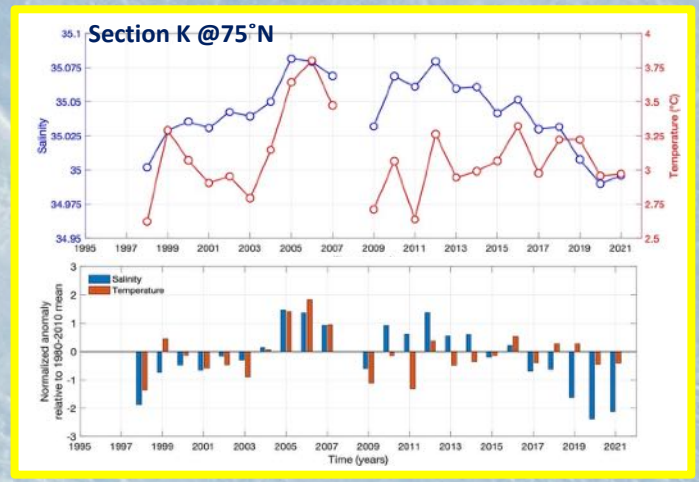
…2013, 2012, 2011… …1996

Time series of temperature and salinity of Atlentic water on the main sections in the West Spitsbergen Current (WSC)



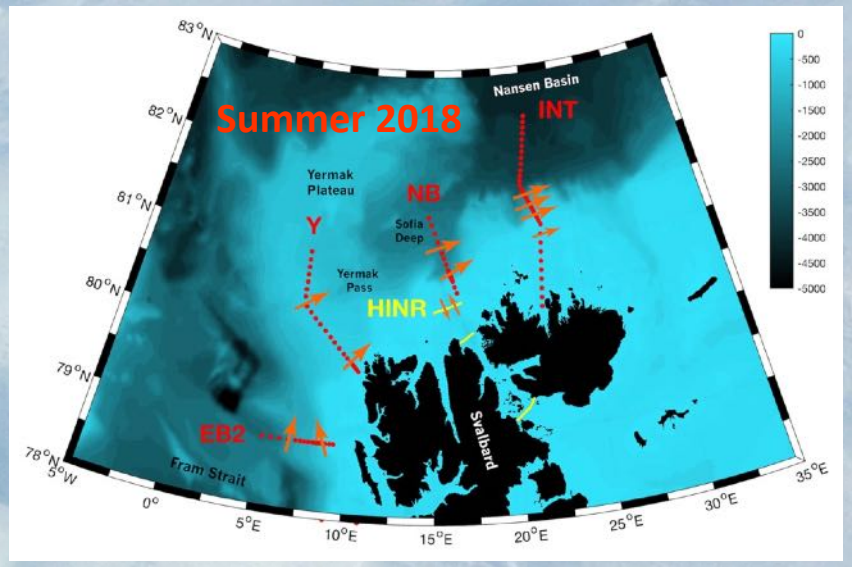




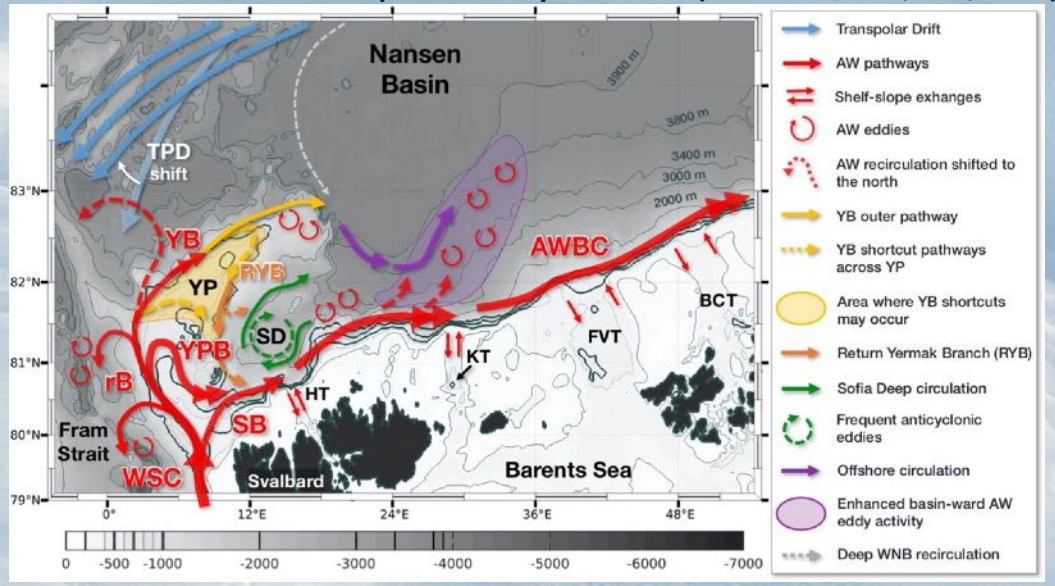


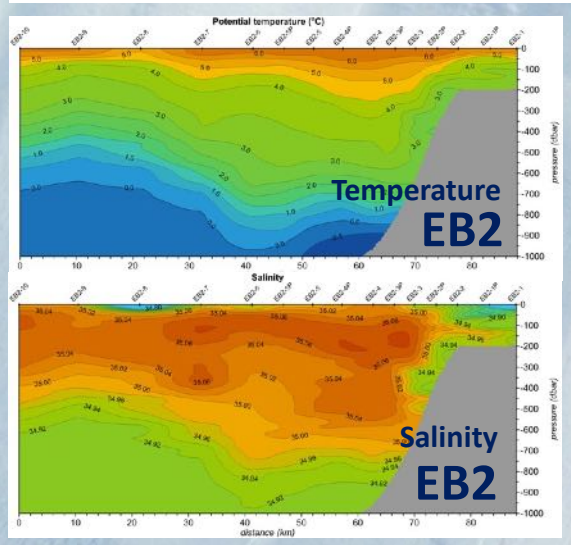
Extention of AREX measurements north of Svalbard (dependent on ice)

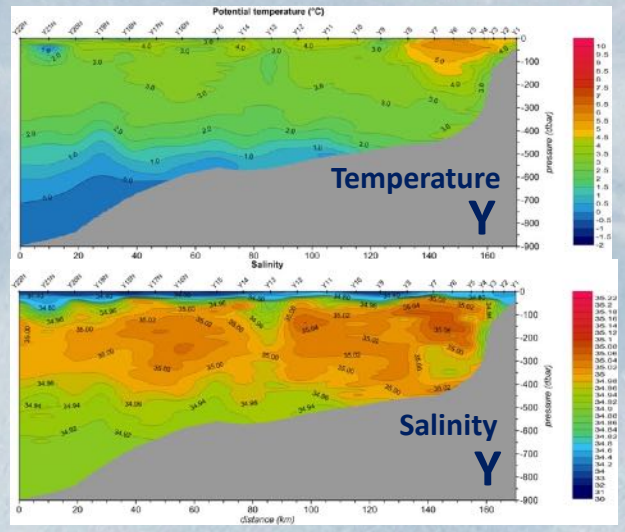
Temperature and salinity at the sections along the AW inflow NW and N of Svalbard in summer 2018 (RV Oceania and KV Svalbard)

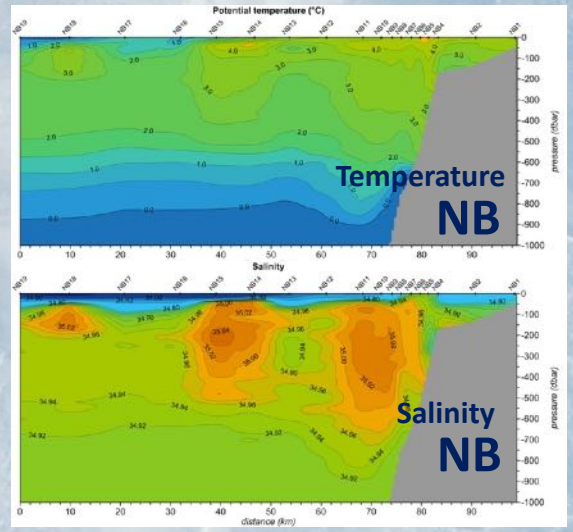


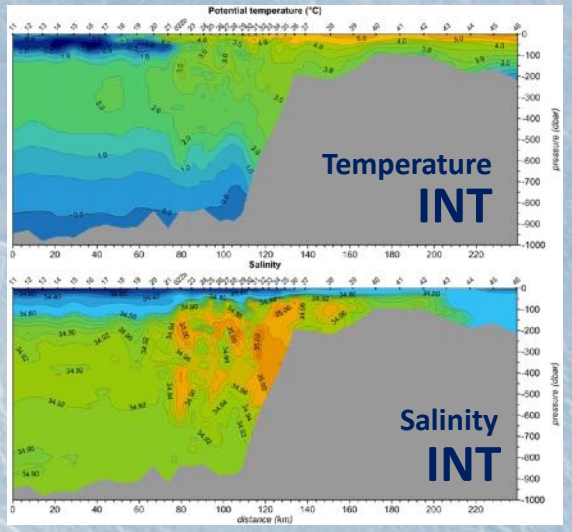
Ocean circulation and main currents north of Svalbard in 2011–2020 based on Mercator Ocean Operational System PSY4 (Athanase et al., JGR, 2021)





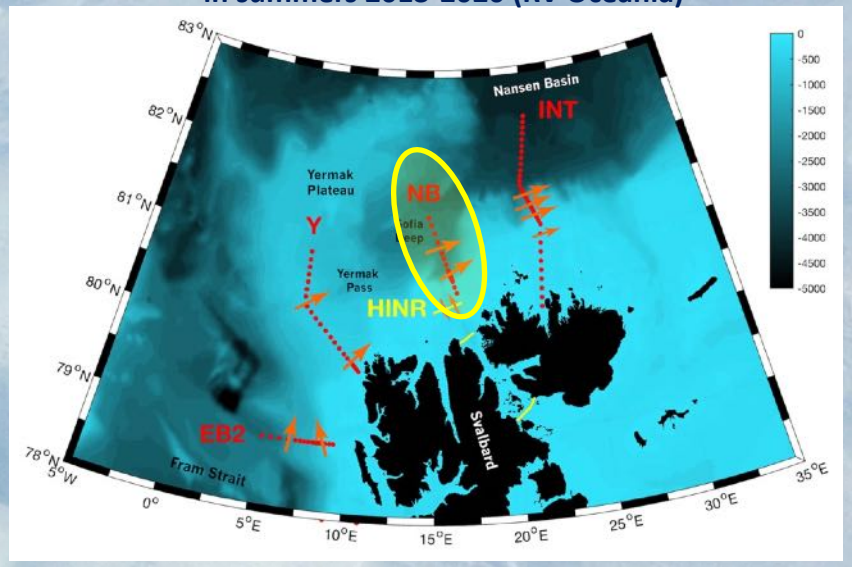




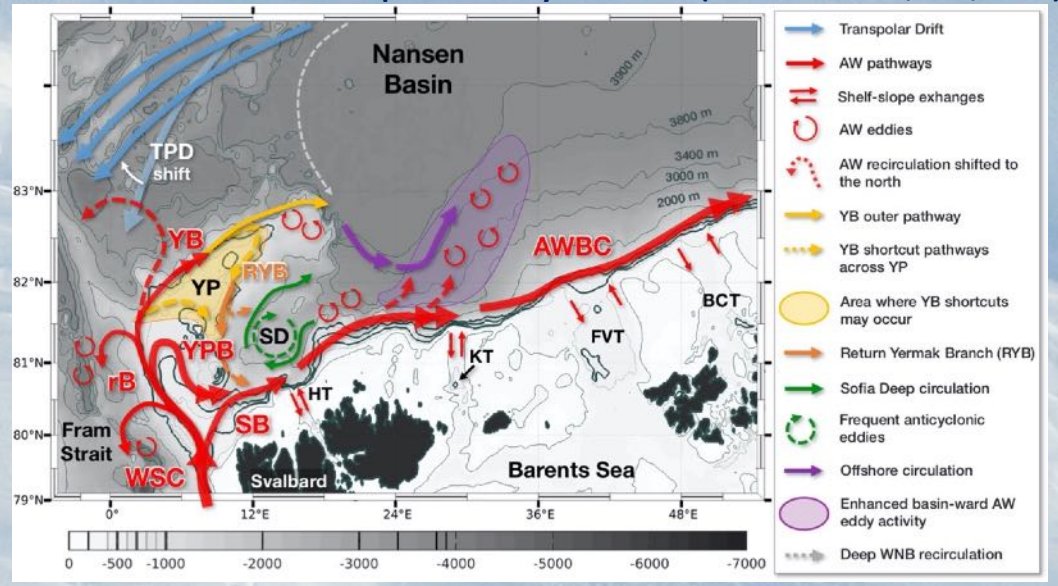


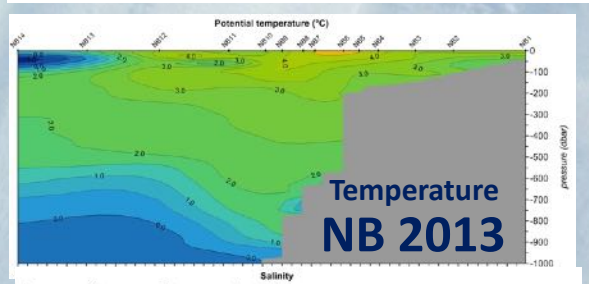
Extention of AREX measurements north of Svalbard (dependent on ice)

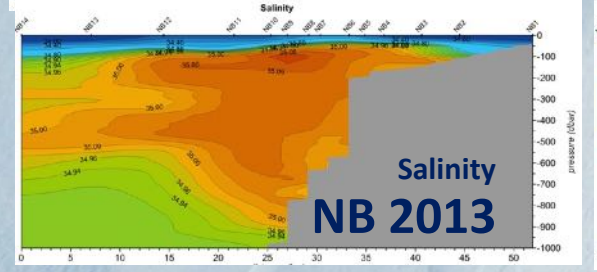
Temperature and salinity at the section NB north of Svalbard in summers 2013-2020 (RV Oceania)

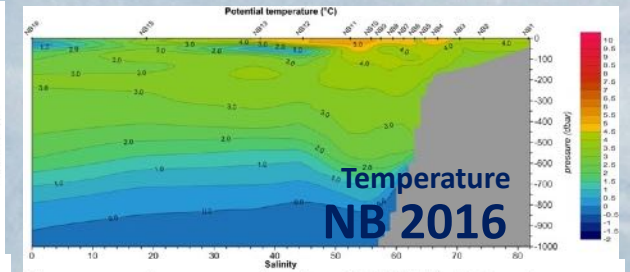


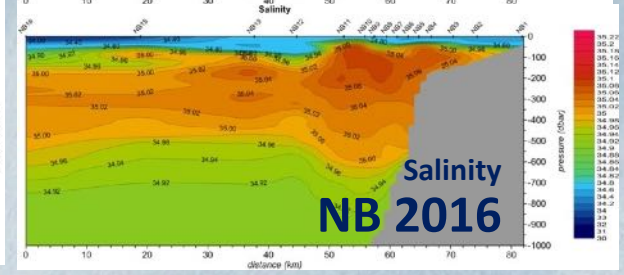
Ocean circulation and main currents north of Svalbard in 2011–2020 based on Mercator Ocean Operational System PSY4 (Athanase et al., JGR, 2021)

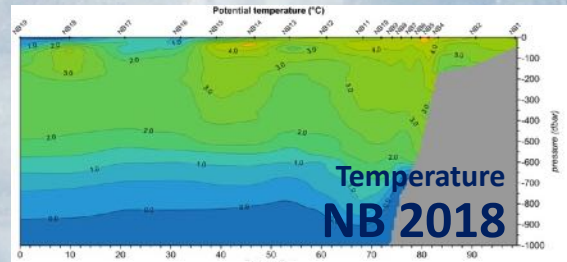


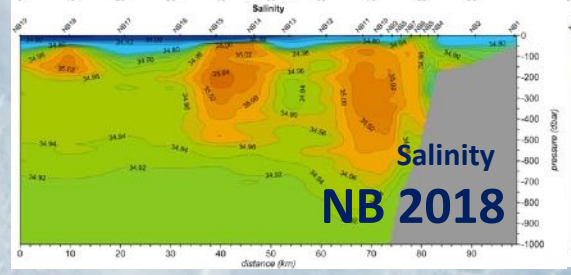


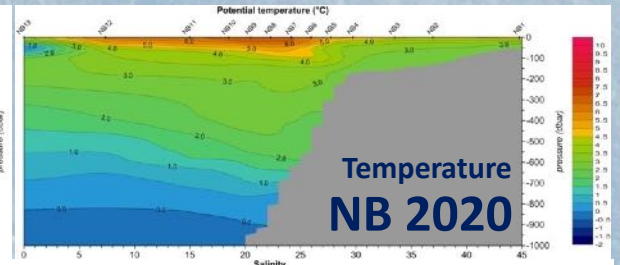


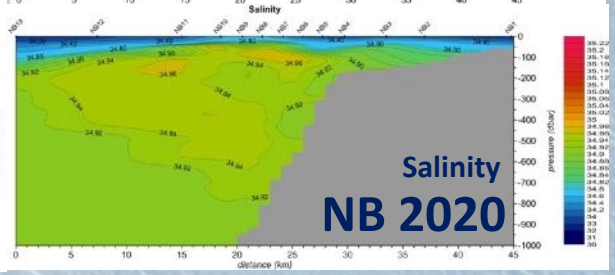






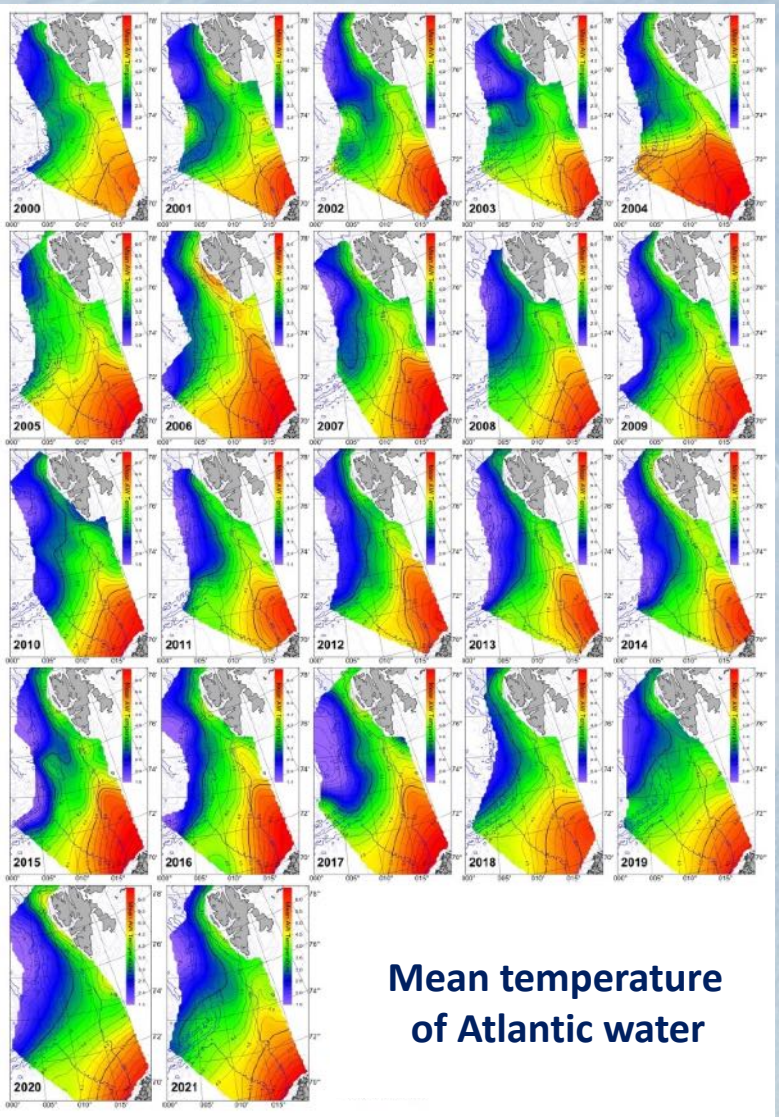




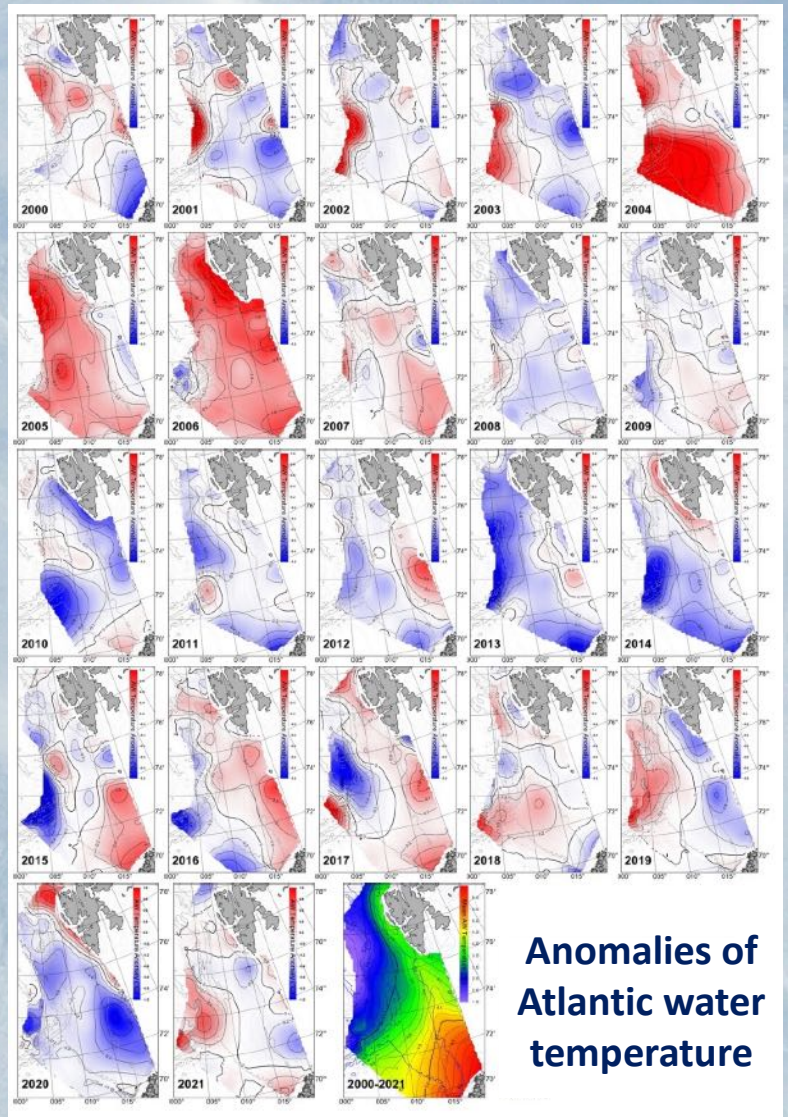


Long time series of physical variables for ocean climate change

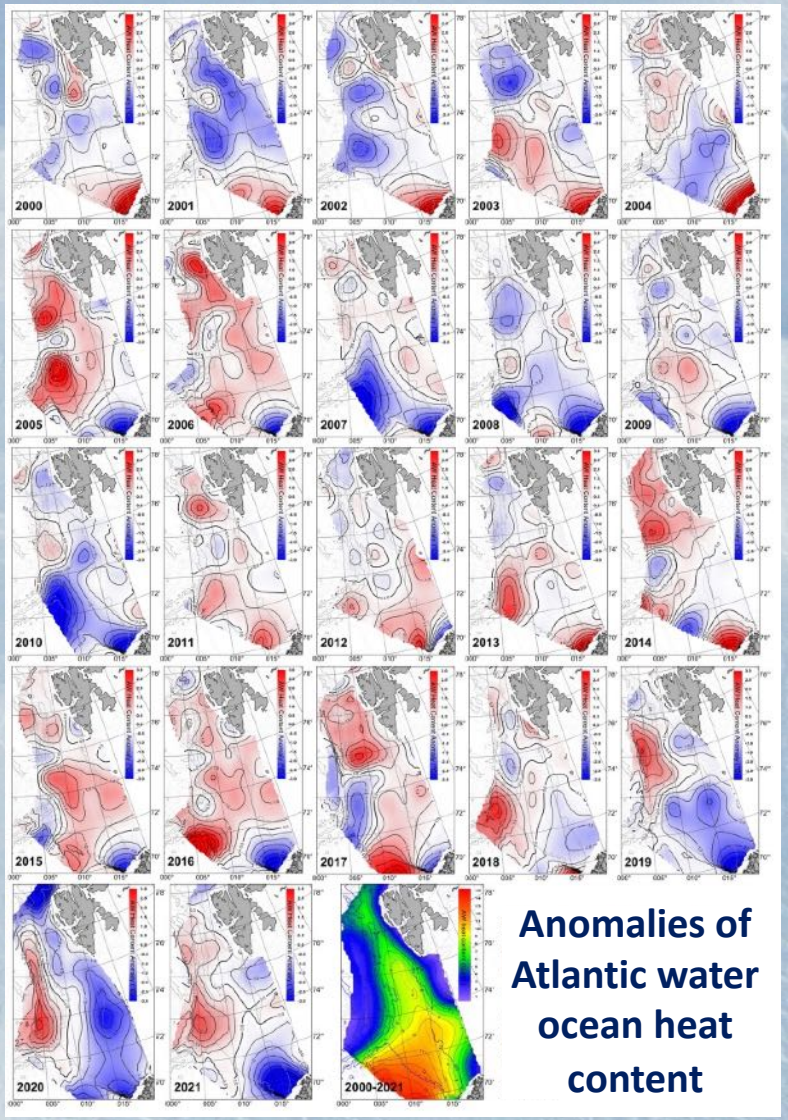
Derived data products: spatial or 3D fields, vertical or spatial averages, anomalies, derived quantities



Mean temperature of Atlantic water



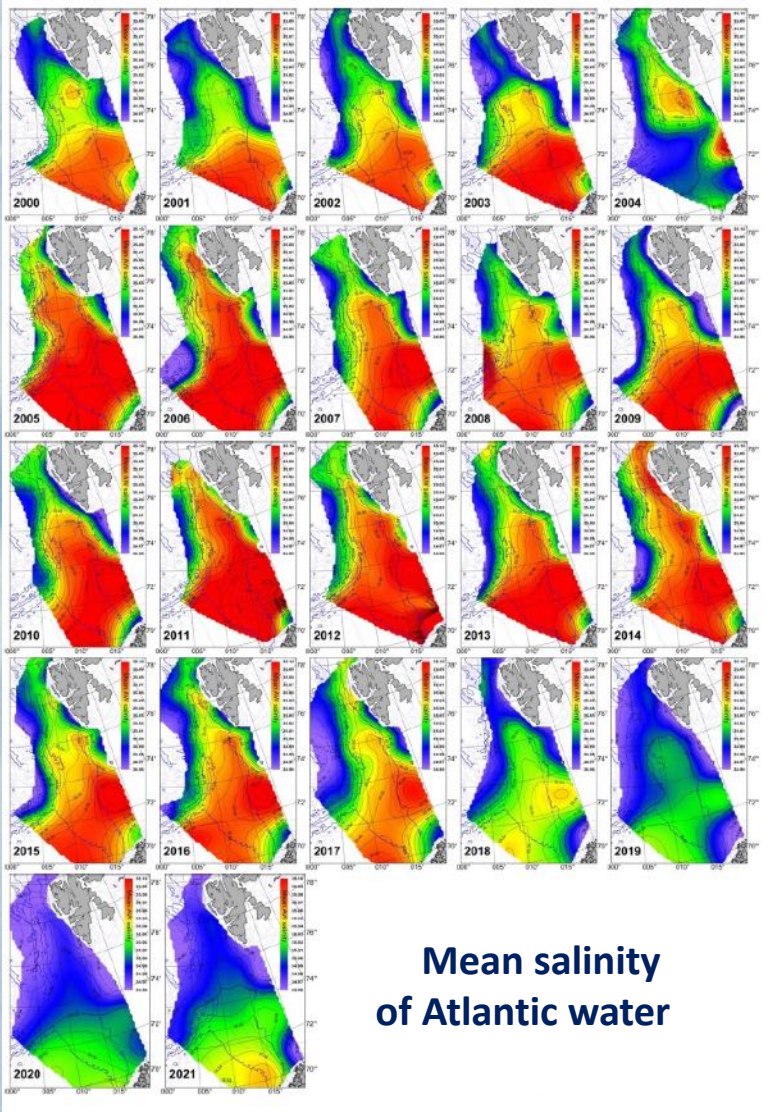
Anomalies of Atlantic water temperature



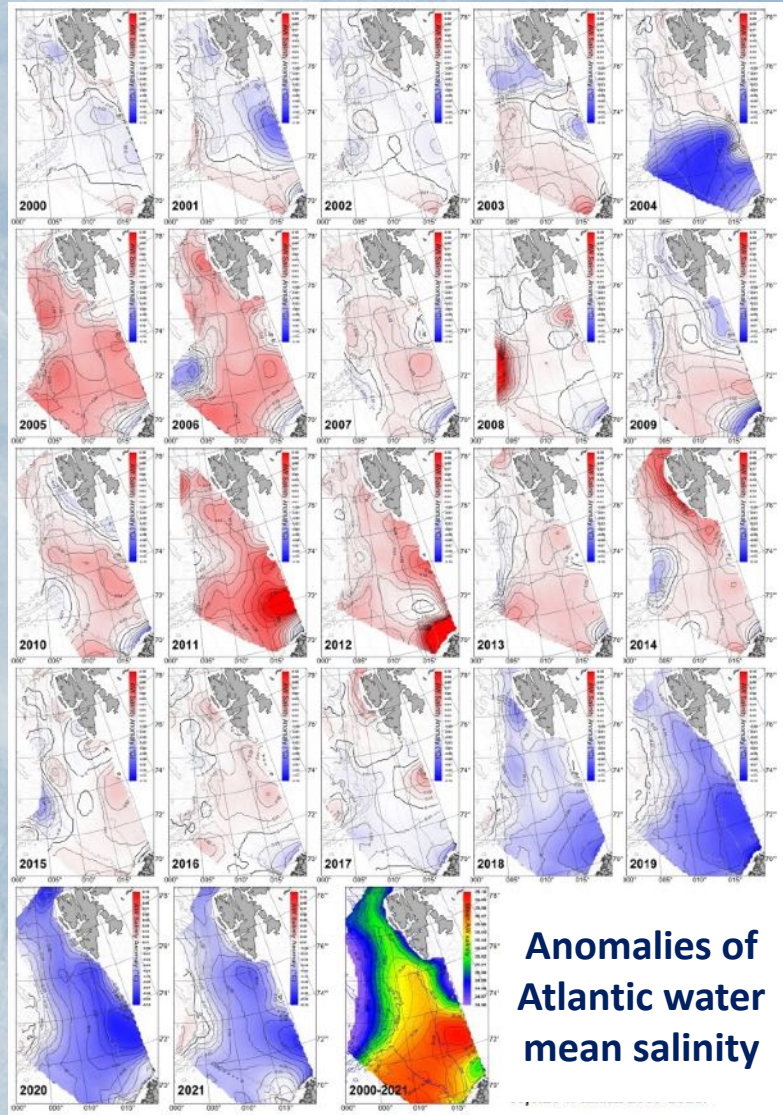
Anomalies of Atlantic water ocean heat content

Long time series of physical variables for ocean climate change

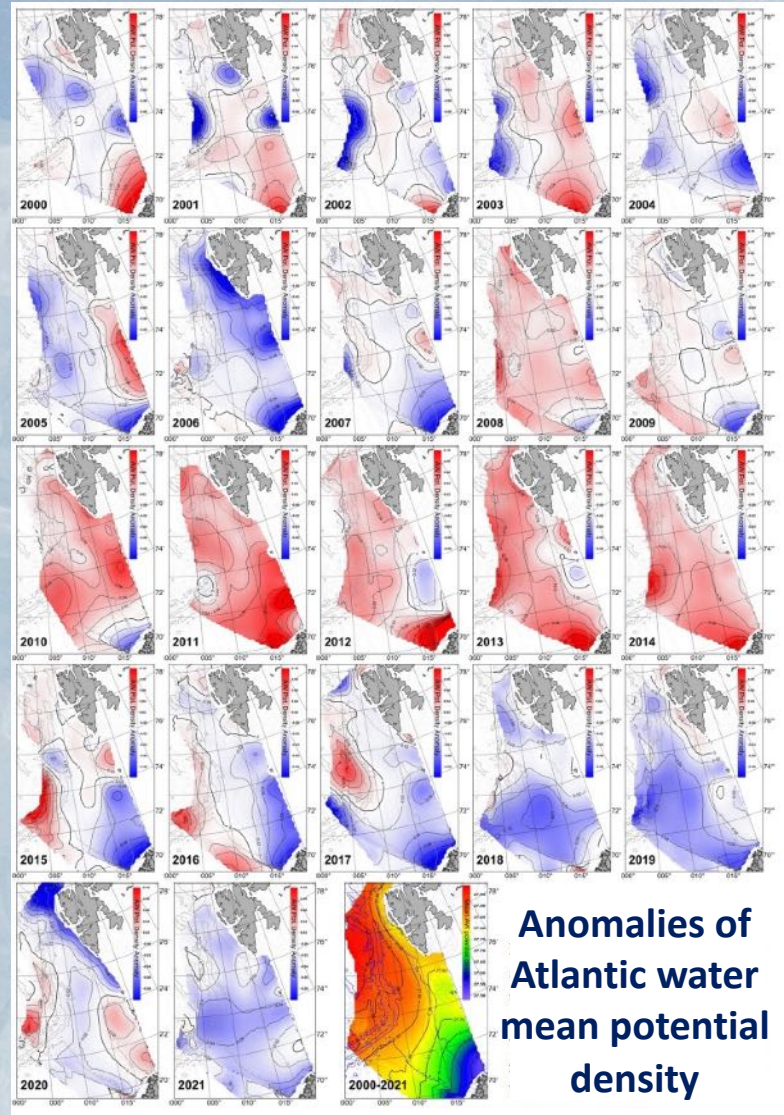
Derived data products: spatial or 3D fields, vertical or spatial averages, anomalies, derived quantities



Mean salinity of Atlantic water



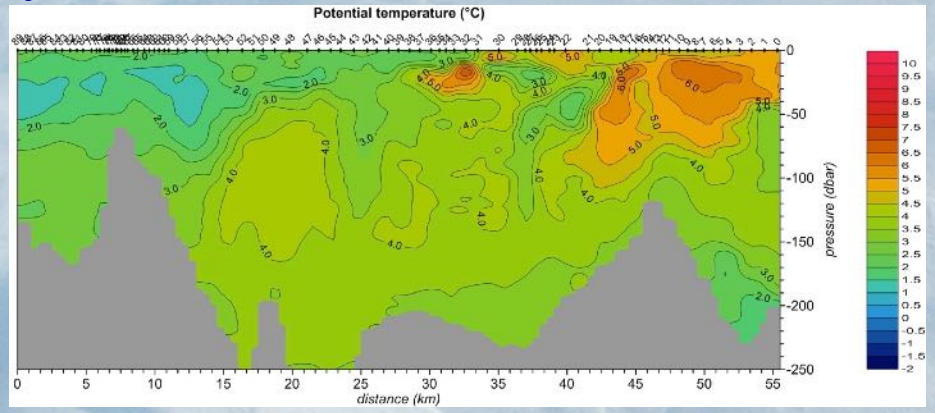
Anomalies of Atlantic water mean salinity

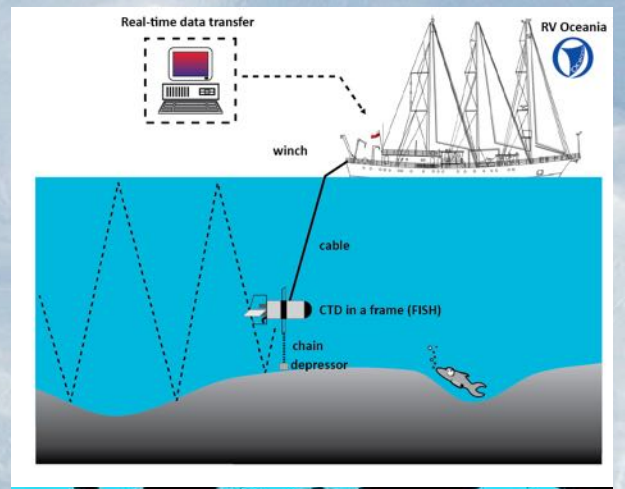


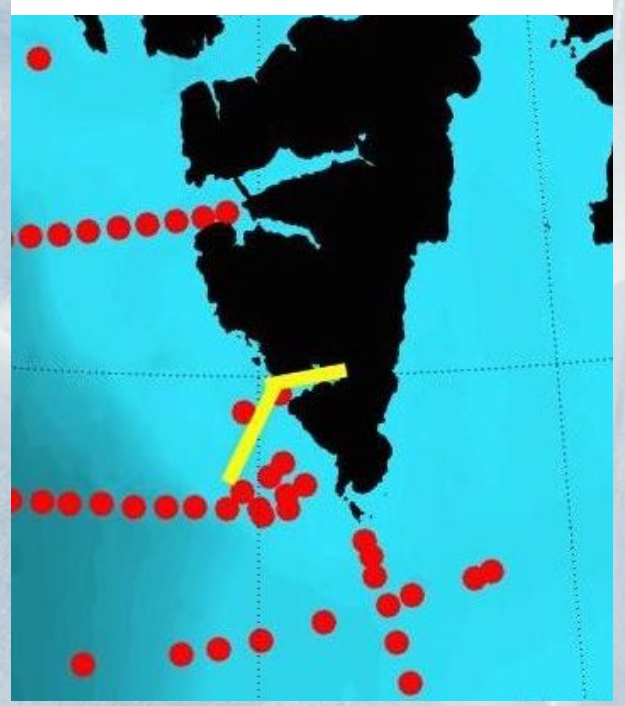
Anomalies of Atlantic water mean potential density

High resolution measurements with towed scanfish CTD on the shelf and in the fjord (Hornsund)

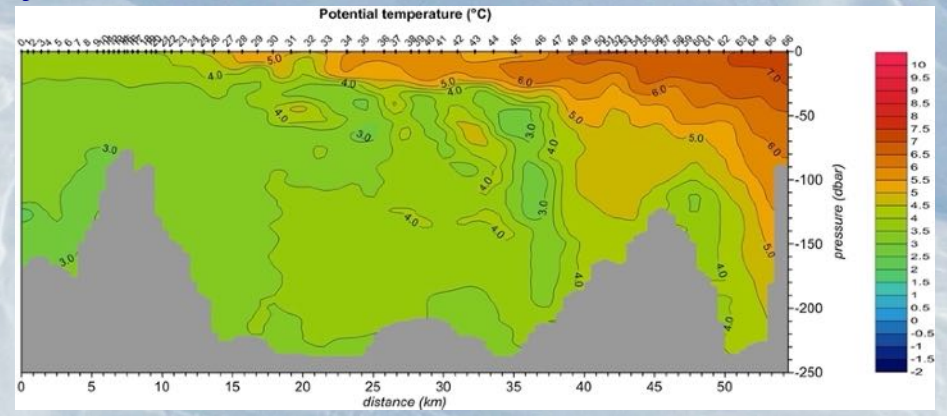
fjord **Temperature 2015** shelf



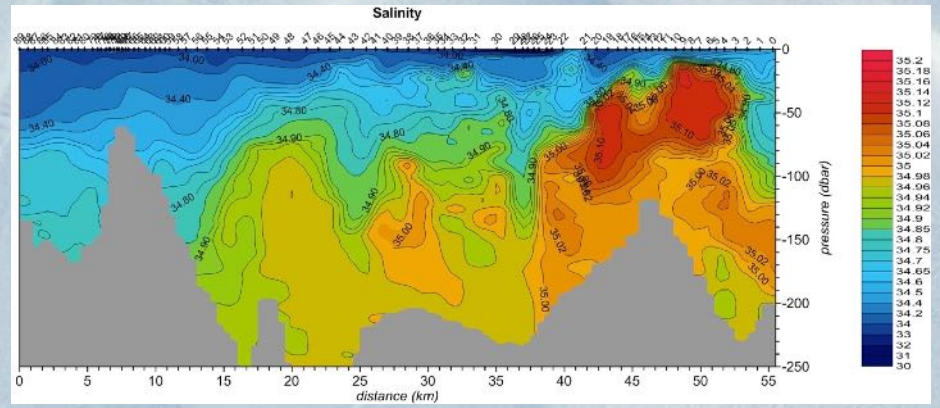




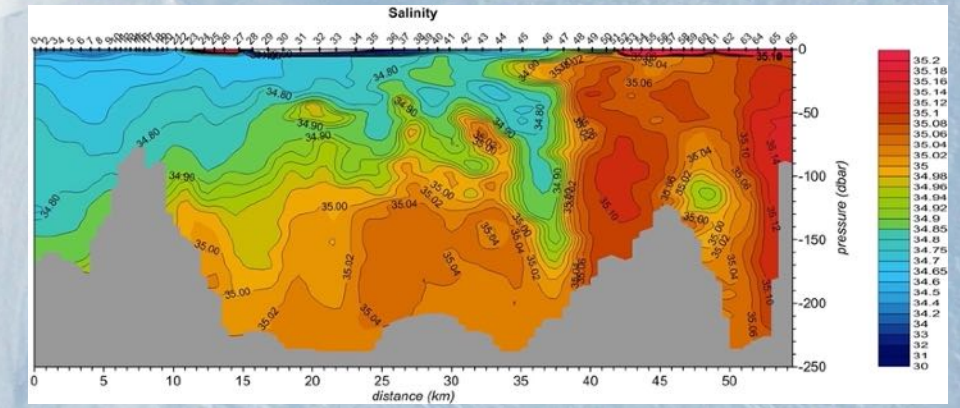
fjord **Temperature 2016** shelf



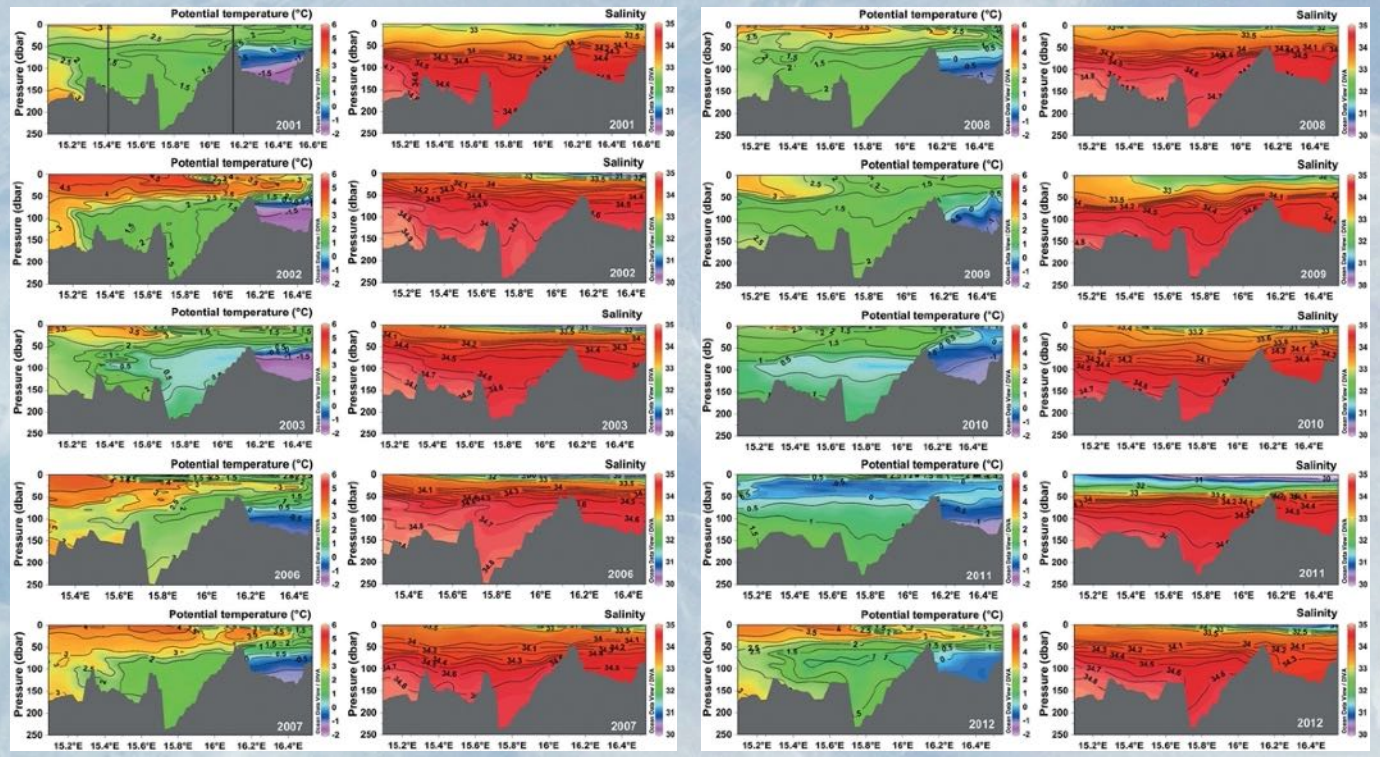
fjord **Salinity 2015** shelf



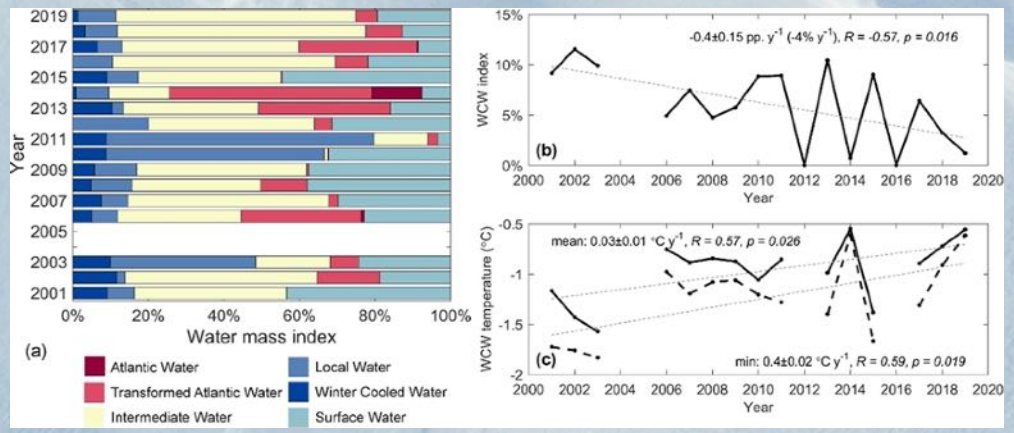
fjord **Salinity 2016** shelf



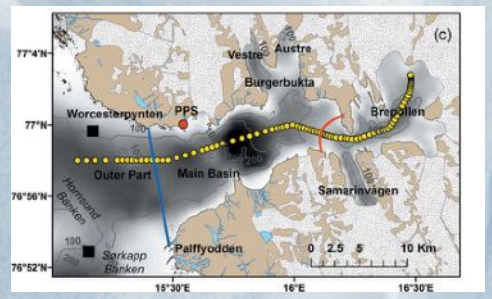
High resolution measurements with towed scanfish CTD in Hornsund in 2001-2019

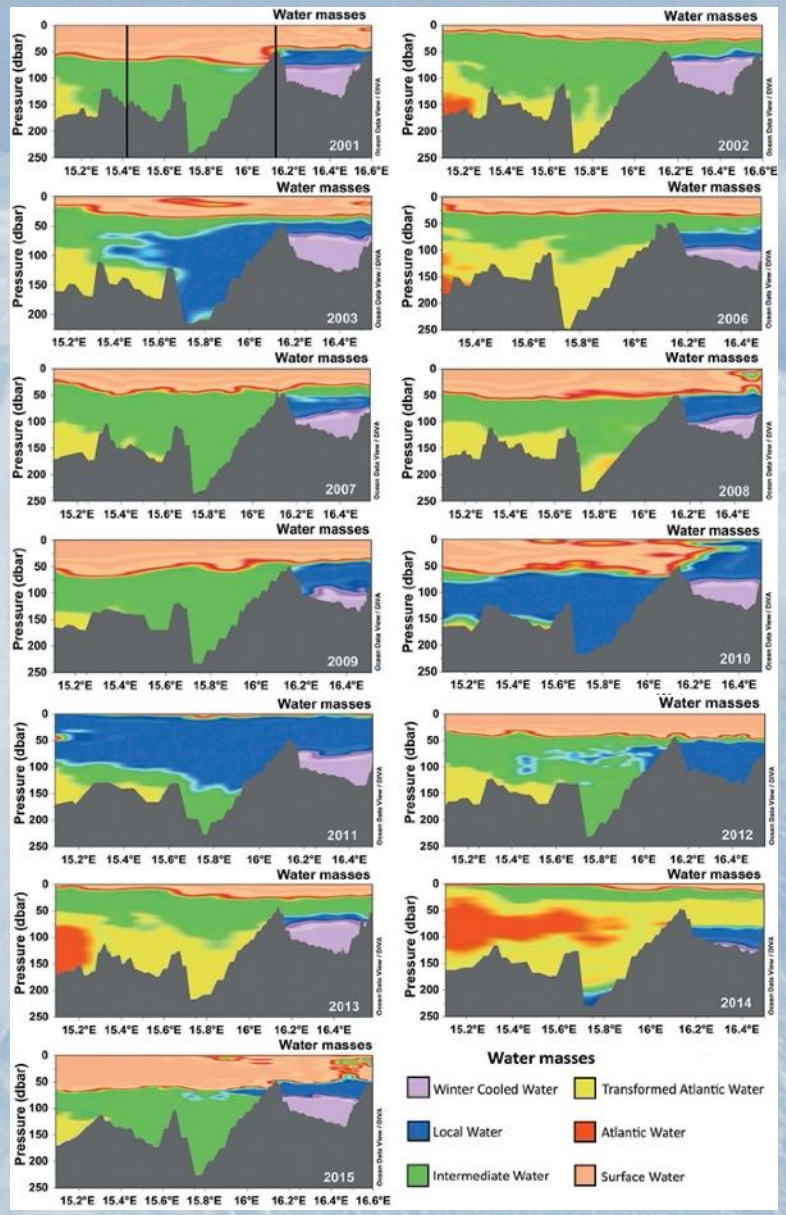


Promińska at al, 2018



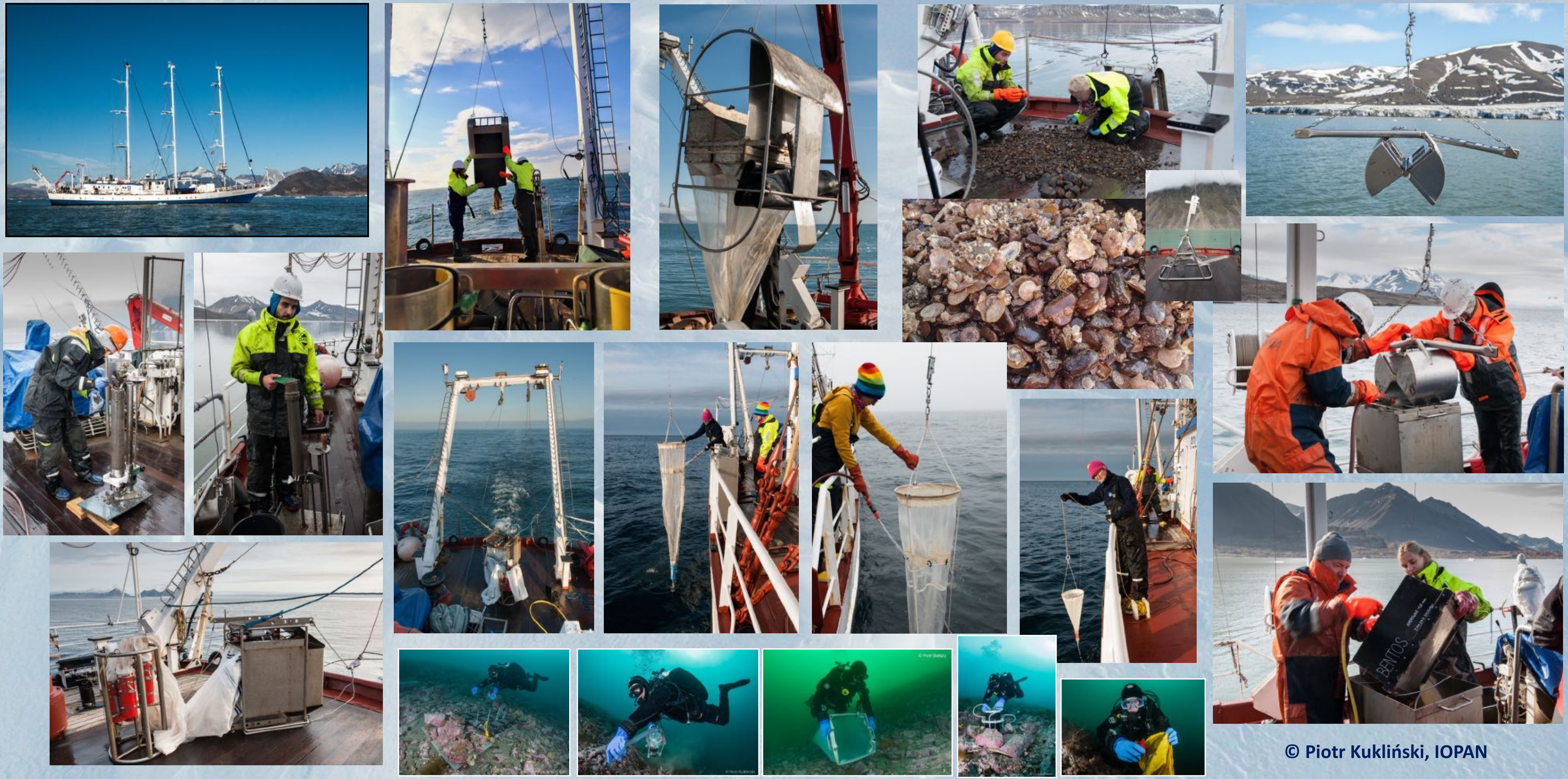
Promińska i in, 2022





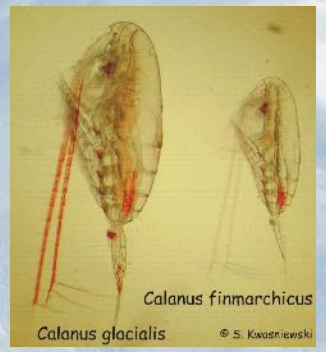
Promińska at al, 2018

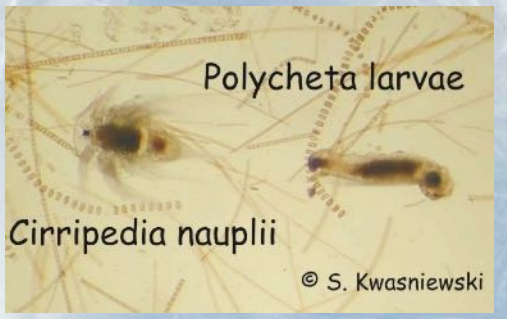
Collection of biological samples at the selected open ocean AREX stations and in the West Spitsbergen fjords



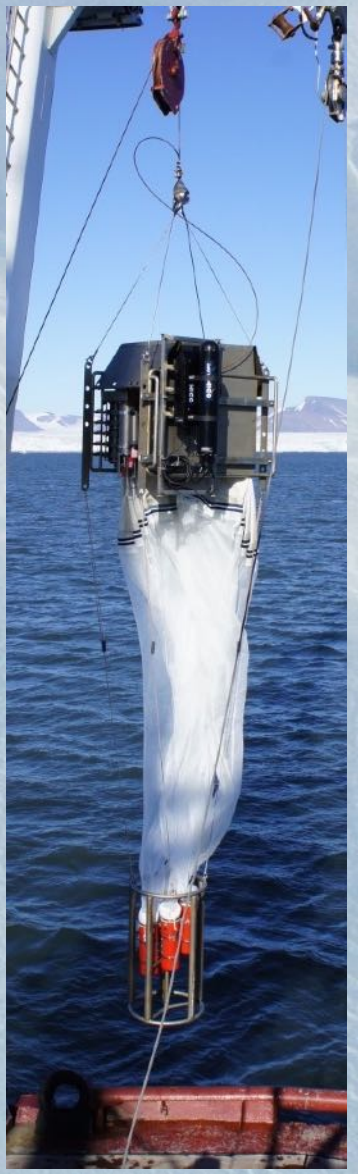
Collection of biological samples at the selected long-term open ocean AREX stations and in the West Spitsbergen fjords

Plankton net WP2





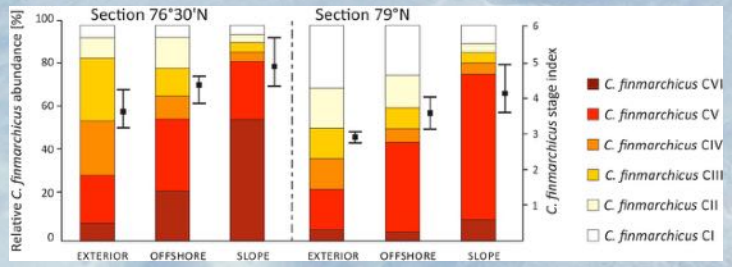
Examples of zooplankton samples

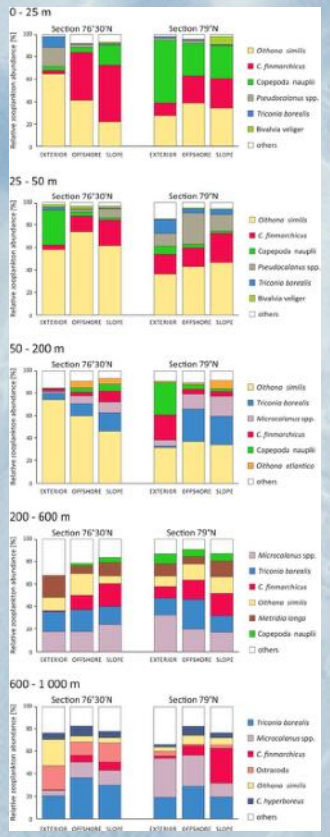


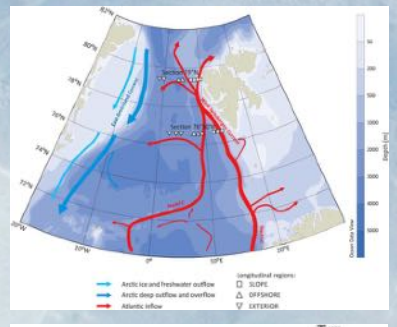
Multinet

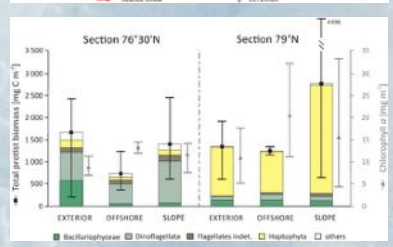
Examples of zooplankton studies based on the long-term open ocean AREX stations and in the West Spitsbergen fjords

Structure and diversity of zooplankton along the vertical and spatial environmental gradients

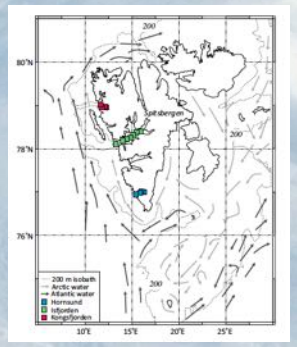








Głuchowska i in., PONE, 2017



Zooplankton structure and abudance in the Svalbard fjords at the Arctic-Atlantic water boundary

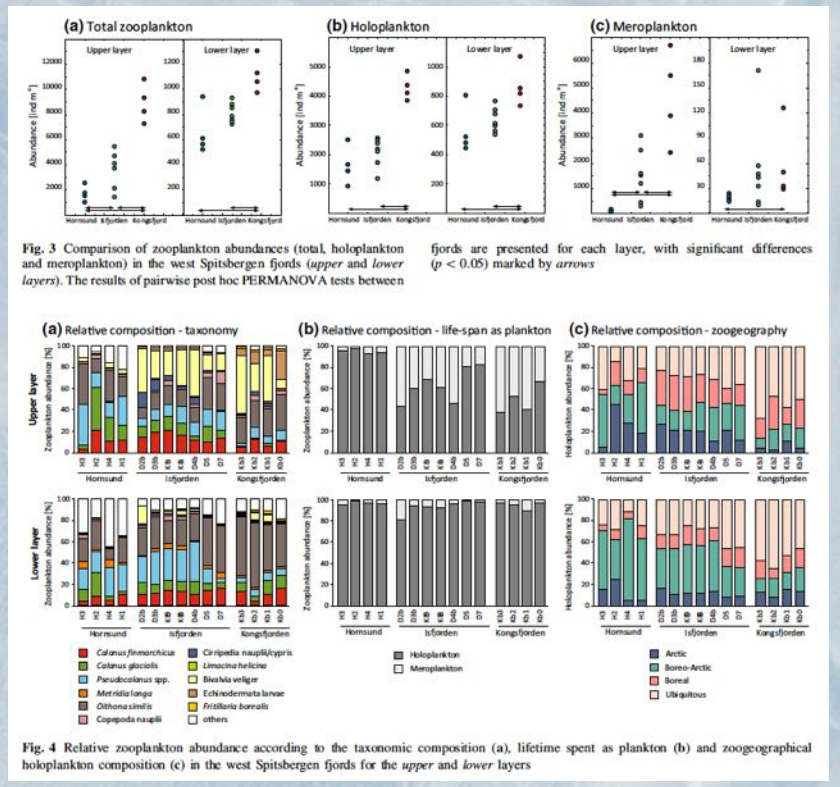
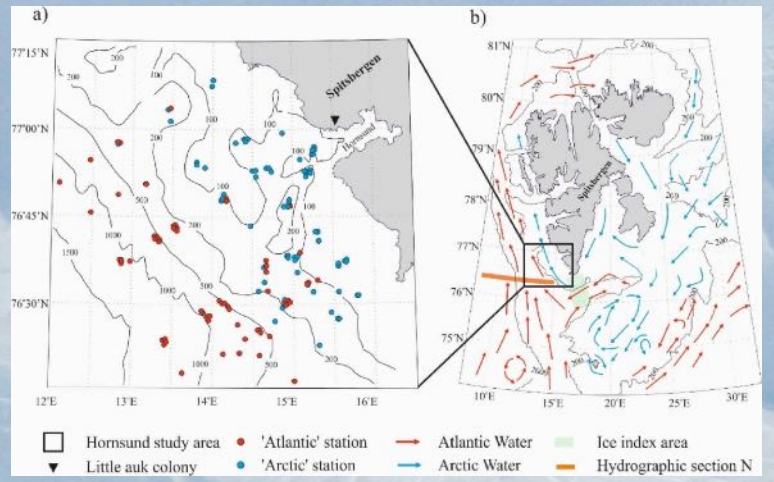


Fig. 3 Comparison of zooplankton abundances (total, holoplankton and meroplankton) in the west Spitsbergen fjords (*upper* and *lower layers*). The results of pairwise post hoc PERMANOVA tests between fjords are presented for each layer, with significant differences ($p < 0.05$) marked by *arrows*

Fig. 4 Relative zooplankton abundance according to the taxonomic composition (a), lifetime spent as plankton (b) and zoogeographical holoplankton composition (c) in the west Spitsbergen fjords for the *upper* and *lower* layers

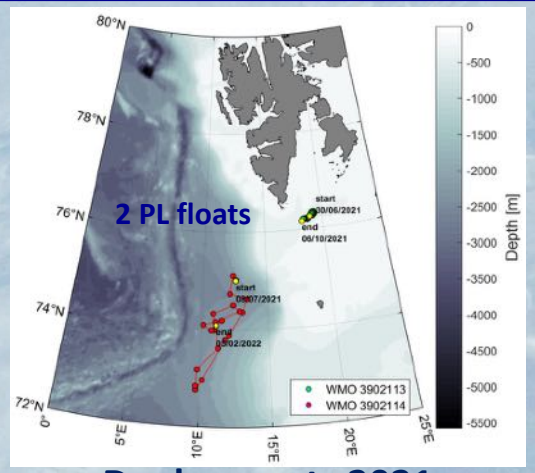
Głuchowska i in., PolarBiol, 2016



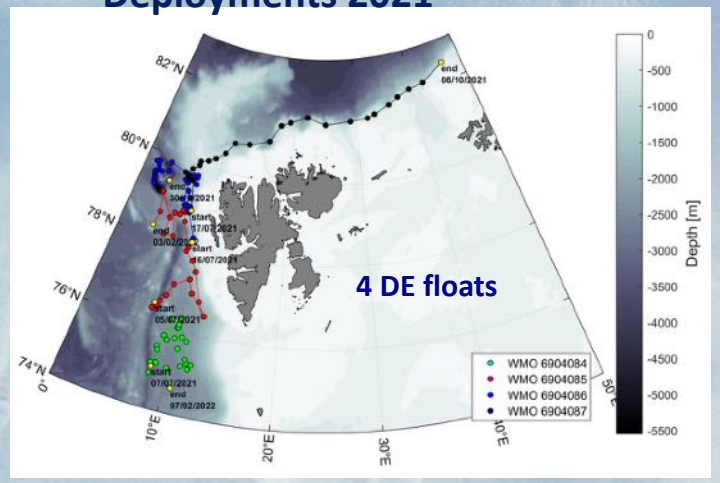
Long-term variability of zooplankton on the Svalbard shelf in relation to oceanographic changes and its consequences for the diet of carnivorous birds

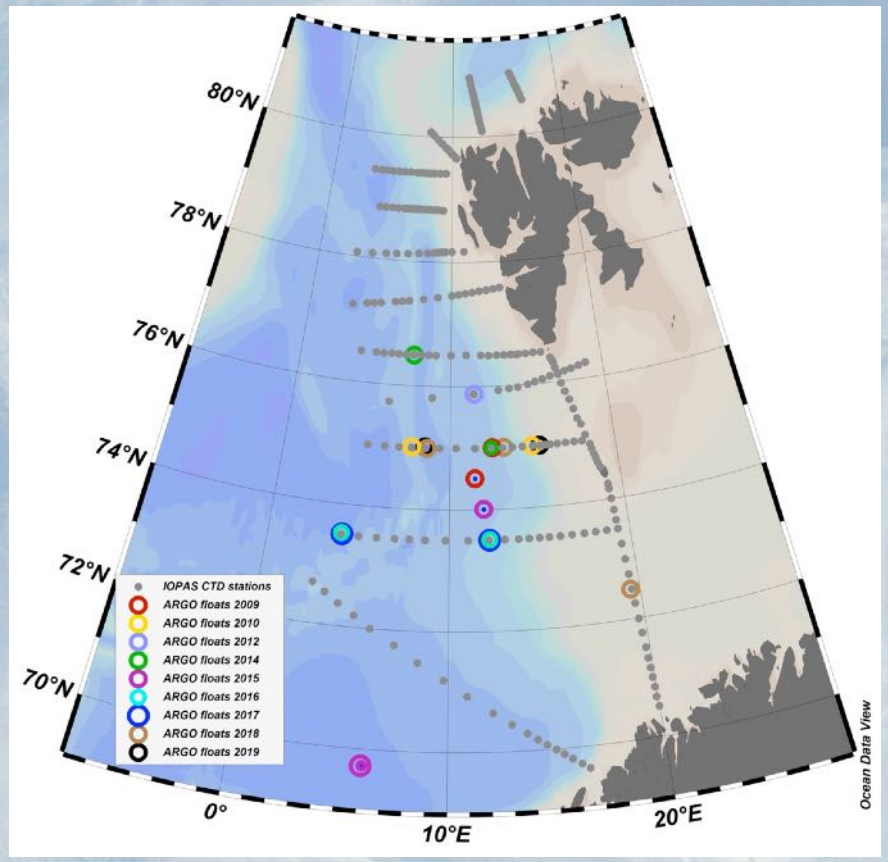
Kwasniewski i in., JMS, 2012

Argo floats deployments during AREX cruises since 2009



Deployments 2021





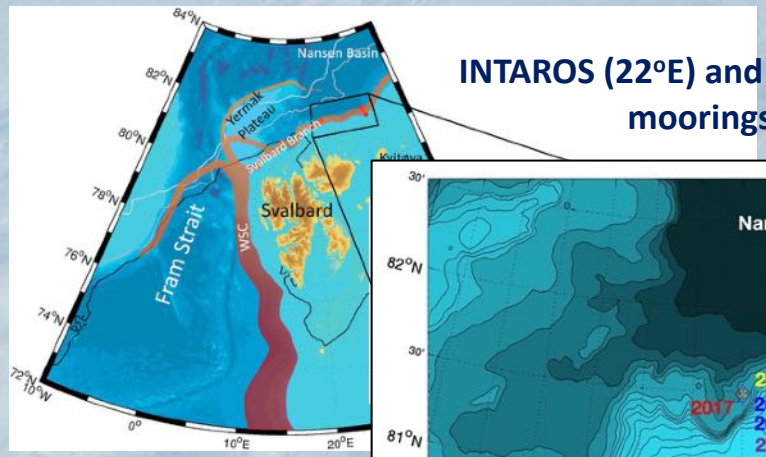
Deployments 2009-2019

7 floats

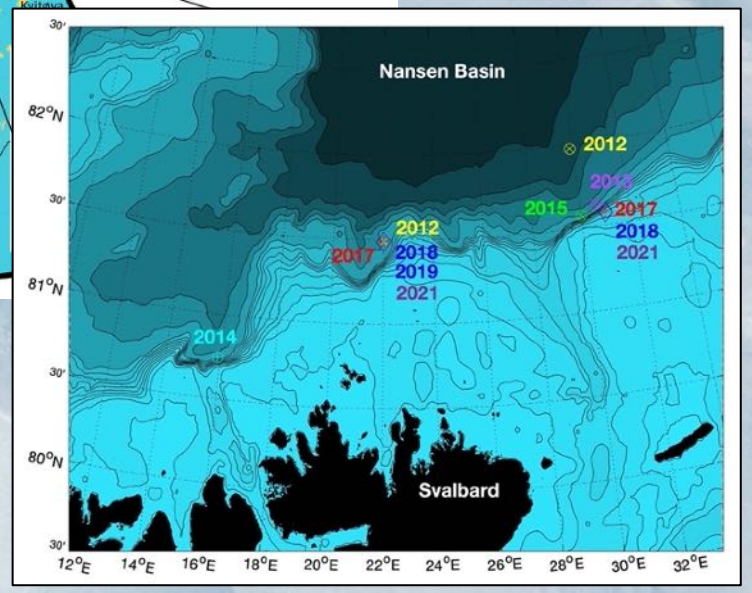
A	WMO	Float S/N PTT	Float	Last Tx	Last cycle	Battery	Launch date	Cruise	Last cycle Pmax (dbar)
	3901851	AI2600-16FR014 360310	ARVOR	05/02/2022 11:47:00	206	10.5	25/06/2016	AREX2016	2025.9
	3902102	AI2600-17EU026 596222	ARVOR	01/02/2022 08:46:20	132	9.5	30/06/2018	AREX2018	1065
	3902112	AI2600-19EU030 863058	ARVOR	27/01/2022 06:39:30	64	9.6	08/07/2020	AREX2020	2040
	3902114	AI2632-21EU010 055474	ARVOR	05/02/2022 04:09:30	22	9.7	07/07/2021	AREX2021	1972.4
	3901850	AI2600-16FR013 360010	ARVOR	04/02/2022 11:47:30	206	10.3	24/06/2016	AREX2016	1977.5
	3901911	AI2600-16FR074 360522	ARVOR	03/02/2022 17:55:20	241	9	27/06/2017	AREX2017	2024
	3902103	AI2600-17EU027 596261	ARVOR	24/01/2022 08:26:20	132	9.3	30/06/2018	AREX2018	2003

- 2-3 Argo floats deployed by IOPAN every year since 2009 in the Greenland and Norwegian seas during the AREX cruise
- Activities under EuroArgo with the ArgoPoland program – mostly national funding
- Data available in NRT via Coriolis (https://fleetmonitoring.euro-argo.eu/dashboard)

IOPAN moorings north of Svalbard in A-TWAIN (31°E) and INTAROS (22°E) arrays since 2012

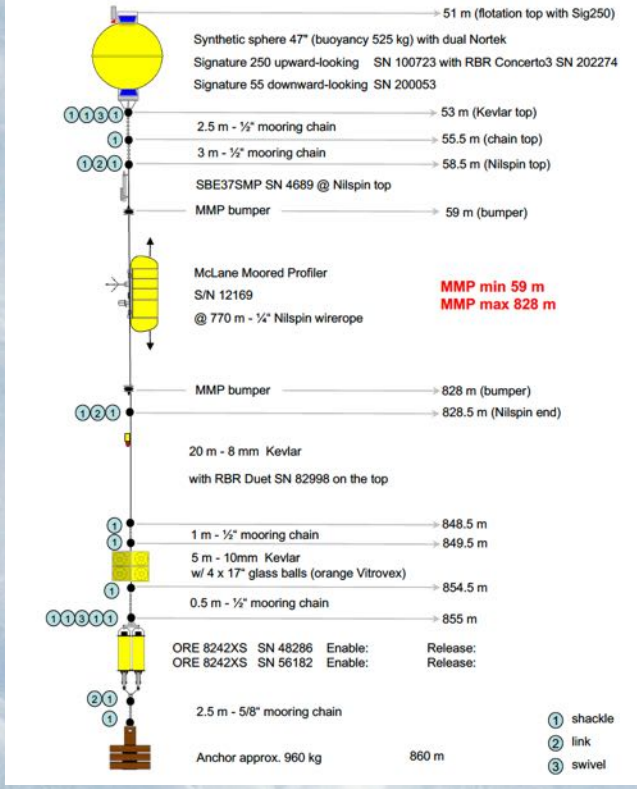


INTAROS (22°E) and A-TWAIN (31°E) moorings lines

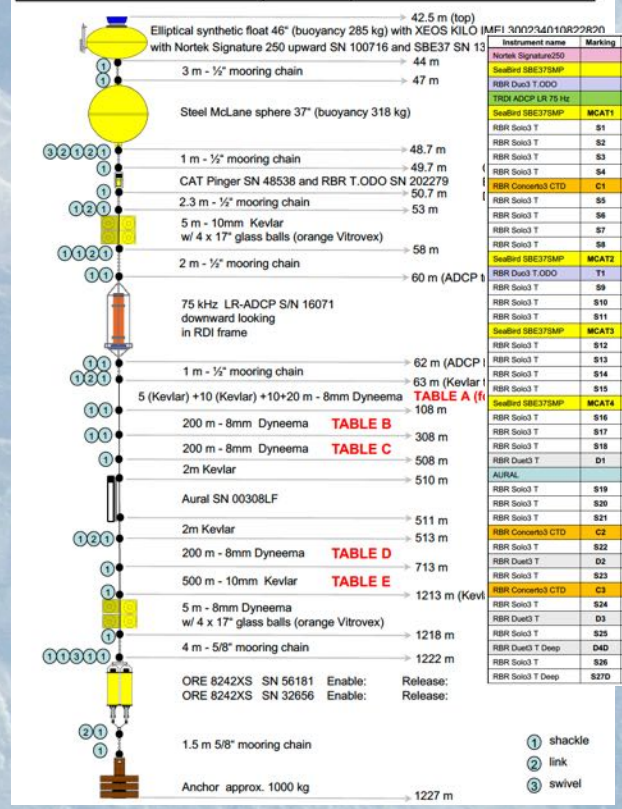


Two moorings deployed in November 2021 from KPH to be recovered/redeployed in 2023

Mooring ID	IOPAS14	Latitude	81° 29.148'N
Deployed	07.11.2021 21:02 UTC	Longitude	021° 56.616'E
Release method: lowered to bottom and released with release at about 50m working rope length		Water depth	860 m



Mooring ID	IOPAS23	Latitude	81° 34.545' N
Deployed	09.11.2021 01:30 UTC	Longitude	031° 00.000' E
Dropped with release hook with both spheres lowered to the surface (free fall about 40 m)		Water depth	1227 m



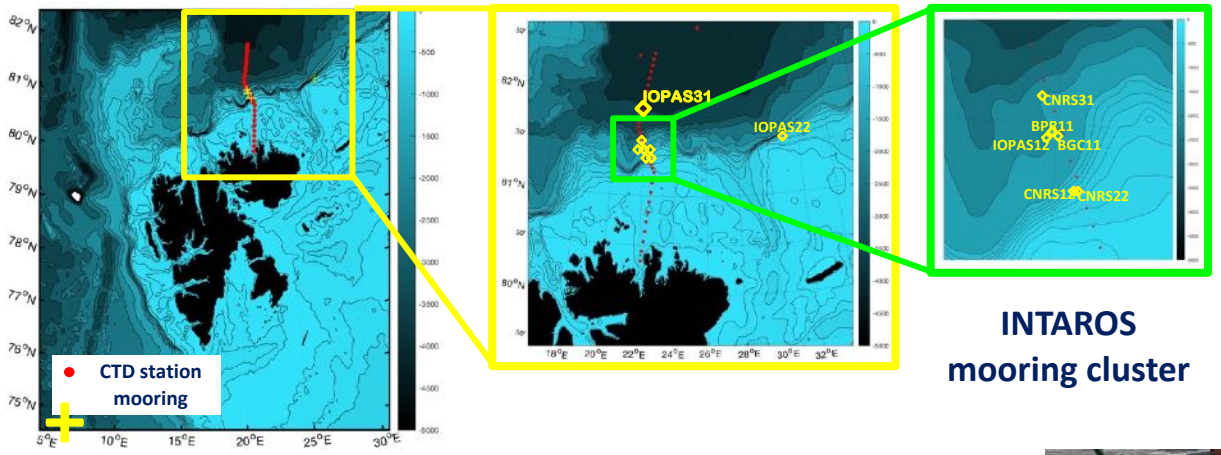
Instrument name	Marking	SN	Depth
Nortek Signature250		100716	47 m
SeaBird SBE37SMP		13042	47 m
RBR Duo3 T.ODO		202279	55 m
TRDI ADCP LR 75 Hz		16071	64 m
SeaBird SBE37SMP	MCAT1	11661	100 m
RBR Solo3 T	S1	201700	110 m
RBR Solo3 T	S2	201701	120 m
RBR Solo3 T	S3	201702	130 m
RBR Solo3 T	S4	201703	140 m
RBR Concerto3 CTD	C1	202275	150 m
RBR Solo3 T	S5	201704	160 m
RBR Solo3 T	S6	201705	170 m
RBR Solo3 T	S7	201706	180 m
RBR Solo3 T	S8	201707	190 m
SeaBird SBE37SMP	MCAT2	6762	200 m
RBR Duo3 T.ODO	T1	202280	220 m
RBR Solo3 T	S9	201708	240 m
RBR Solo3 T	S10	201709	260 m
RBR Solo3 T	S11	201710	280 m
SeaBird SBE37SMP	MCAT3	11662	300 m
RBR Solo3 T	S12	201711	320 m
RBR Solo3 T	S13	201712	340 m
RBR Solo3 T	S14	201713	360 m
RBR Solo3 T	S15	201714	380 m
SeaBird SBE37SMP	MCAT4	4543	400 m
RBR Solo3 T	S16	201715	425 m
RBR Solo3 T	S17	200843	450 m
RBR Solo3 T	S18	200844	475 m
RBR Duet3 T	D1	202268	500 m
AURAL		00308LF	516 m
RBR Solo3 T	S19	102883	525 m
RBR Solo3 T	S20	102884	550 m
RBR Solo3 T	S21	102885	575 m
RBR Concerto3 CTD	C2	202276	600 m
RBR Solo3 T	S22	102886	650 m
RBR Duet3 T	D2	202269	700 m
RBR Solo3 T	S23	102887	750 m
RBR Concerto3 CTD	C3	202277	800 m
RBR Solo3 T	S24	102888	850 m
RBR Duet3 T	D3	82997	900 m
RBR Solo3 T	S25	102889	950 m
RBR Duet3 T Deep	D4D	202272	1000 m
RBR Solo3 T	S26	102890	1100 m
RBR Solo3 T Deep	S27D	202267	1215m

- IOPAN mooring activities north of Svalbard started in 2012 as a part of the A-TWAIN project (with IOPAN internal funding), continued with one or two moorings until now under different projects (PAVE, INTAROS, …?)
- Nominal locations: one upstream mooring at 22°E, one downstream at 31°E but in early years location has been changing (particularly for downstream mooring)
- Moorings instrumented with Moored McLane Profilers (CTD, *currents*), TRDI QM and LR ADCPs (currents), Nortek Signature 55 ADCPs (dual res./range currents), Nortek Signature 250 ADCPs (currents, sea ice drift and draft), SeaBird SBE37 CTD, RBR CTD (Concerto3), TD (Duet3), T (Solo3), and TO (Duo3) sensors
- No deployment in 2020-2021 due to the lack of access to the mooring/ice capable vessel
- Two moorings deployed during the A-TWAIN cruise (led by NPI/IMR) in November 2021 for two-year period (recovery planned in 2023 with KPH or KVS or ???)

INTAROS moored array north of Svalbard along 22°E

Moored observatory north of Svalbard towards the deep Nansen Basin

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



INTAROS
mooring cluster

- Deployment 2017-2018: 2 moorings for physical obs
- Deployment 2018-2019: 7 moorings with multidiscipl. obs
- Deployment 2019-2020: 4 moorings (including deep mooring)
- Deployment 2021-2023: 3 moorings (2 LOCEAN and 1 IOPAN)

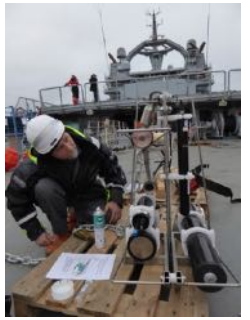
Mooring operations in collaboration with the Norwegian Coast Guard (from KV Svalbard) and with NPI and IMR under the A-TWAIN project (from Lance and RV Kronprins Haakon)

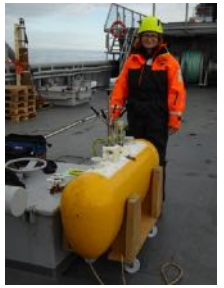
INTAROS moorings 2017-2021 instrumented with:

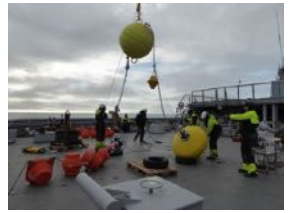
- Moored McLane Profilers (temperature, salinity, currents)
- TRDI QM and LR ADCPs (ocean currents)
- Signature 55 Dual Freq Nortek ADCPs
  (ocean currents, dual res./range)
- Nortek Signature 250 ADCPs
  (ocean currents, sea ice drift and draft)
- Microcats SBE37 CTD(O) sensors
- RBR and SBE56 temperature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





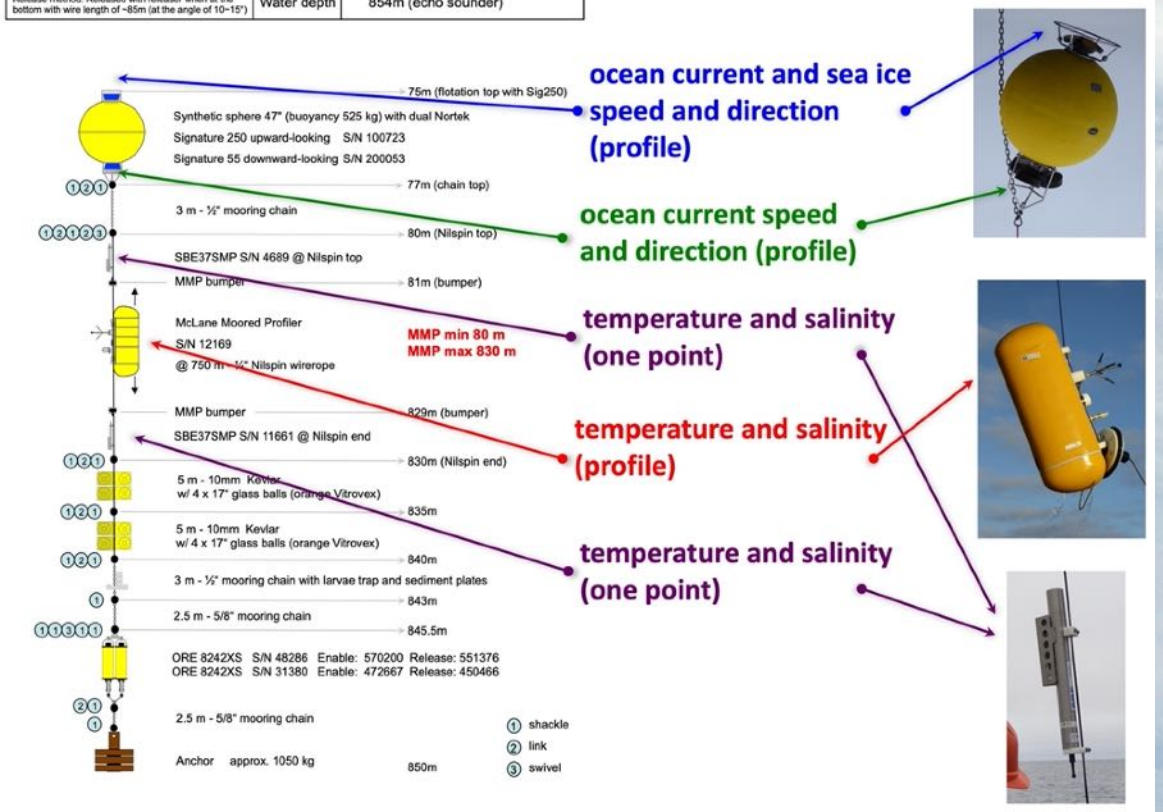


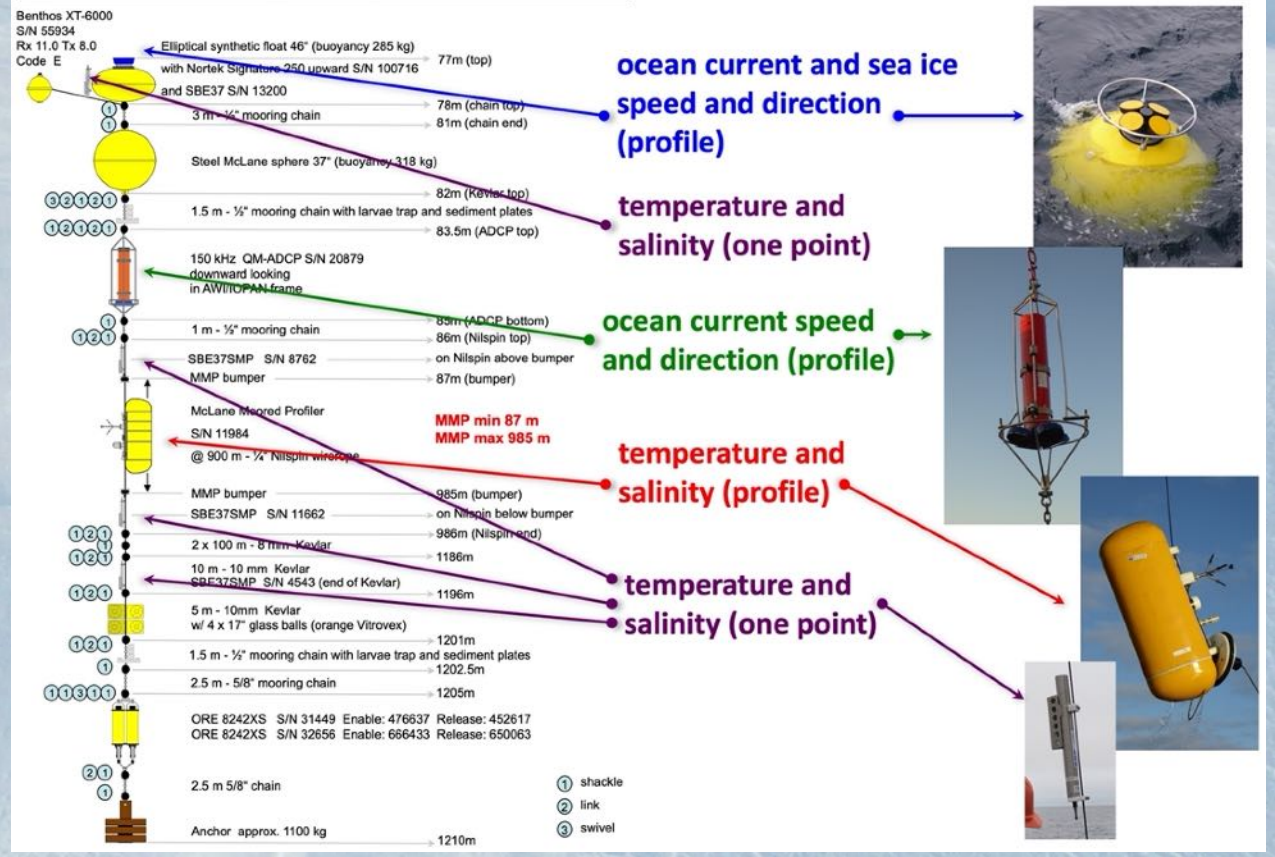


IOPAN moorings north of Svalbard in A-TWAIN (31°E) and INTAROS (22°E) arrays

Mooring ID	IOPAS9	Latitude	81° 29.3870'N
Deployed	22.09.2017 13:10 UTC	Longitude	022° 00.2295'E
Release method: Released with releaser when at the bottom with wire length of ~85m (at the angle of 10~15°)		Water depth	854m (echo sounder)



Mooring ID	IOPAS8	Latitude	81° 34.508' N
Deployed	20.09.2017 16:02 UTC	Longitude	031° 00.301' E
Release method: released with releaser after adjusting ship position to 2010m with ~80-90m release wire length		Water depth	1210 m (echo sounder)

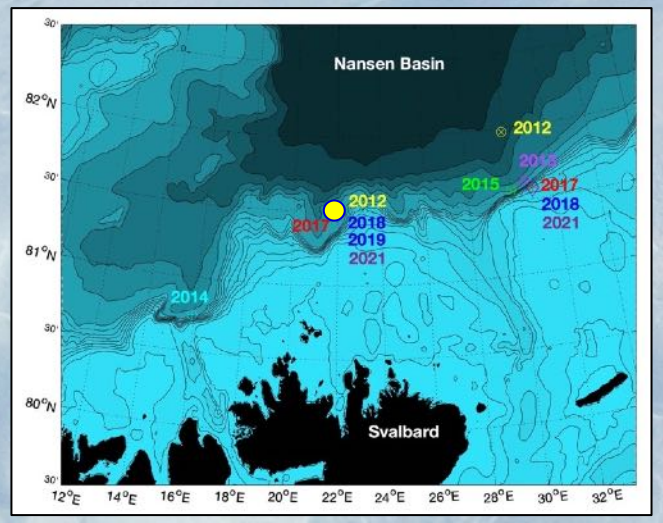


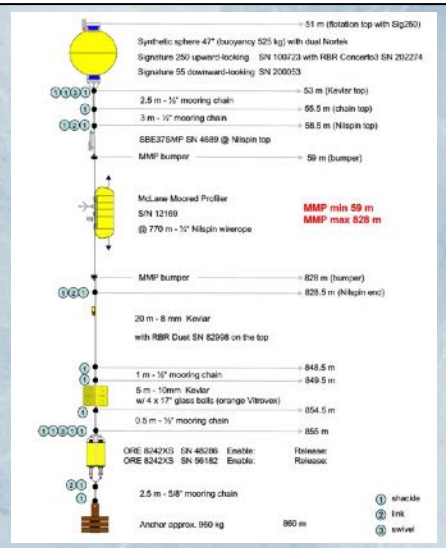
Summary of INTAROS data collected by IOPAN moorings north of Svalbard in 2017-2020

Instrument/location/ duration	Measurement type	Variables measured	Temporal resolution	Vertical resolution	Vertical range	Data processing
MMP times series (4 sets): IOPAS11@22°E 2017-2018 IOPAS21@31°E 2017-2018 IOPAS12@22°E 2018-2019 IOPAS13@22°E 2019-2020	Profiles	Temperature Salinity Currents	12 h	2 m bins	750 m @ 22°E 900 m @ 31°E	Not standard but some recommendations exist
QMADCP time series (2 sets): IOPAS21@31°E 2017-2018 IOPAS22@31°E 2018-2019	Profiles	Currents Temperature (point)	1 h	4 m bins	250-300 m	Standard General best practices exist for ADCPs
SBE37 time series (12 sets): IOPAS11@22°E 2017-2018 (2) IOPAS21@31°E 2017-2018 (4) IOPAS22@31°E 2018-2019 (4) IOPAS13@22°E 2019-2020 (2)	Point	Temperature Salinity	10 min	-	-	Standard Best practice exist
Signature 55 time series (3 sets): IOPAS11@22°E 2017-2018 IOPAS12@22°E 2018-2019 IOPAS13@22°E 2019-2020	Profiles	Currents Temperature (point)	1 h/6 h	6 m/12 m bins	400-500 m/ 800-900 m	Not standard but some existing best practices for ADCPs can be adopted
Signature 250 time series (5 sets): IOPAS11@22°E 2017-2018 IOPAS21@31°E 2017-2018 IOPAS12@22°E 2018-2019 IOPAS22@31°E 2018-2019 IOPAS13@22°E 2019-2020	Profiles	Currents Sea ice drift Sea ice draft Temperature (point)	1 h / 1 min	4 m bins	60-80 m/120m (ice)	Still experimental, very challenging
RBR Solo/Duet time series (12): IOPAS22@31°E 2018-2019 (11) BGC1@22°E 2018-2019	Point	Temperature	5 sec	-	-	Standard

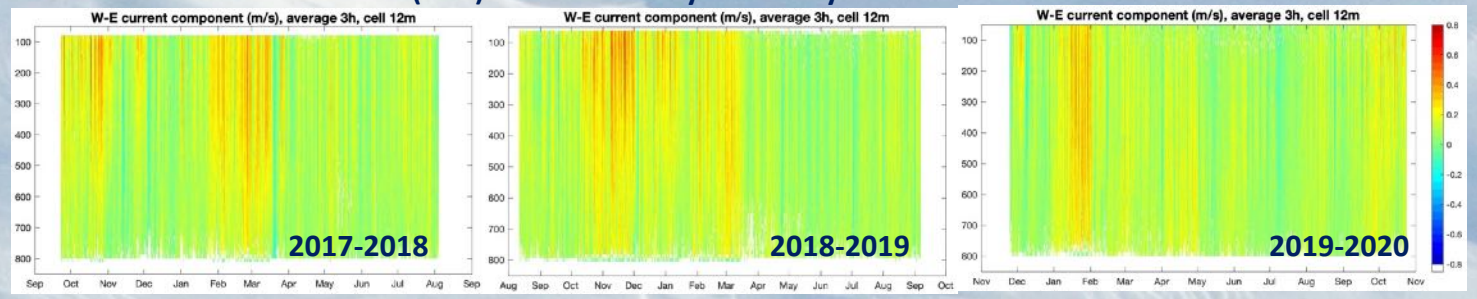
Observing the Arctic Ocean north of Svalbard

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

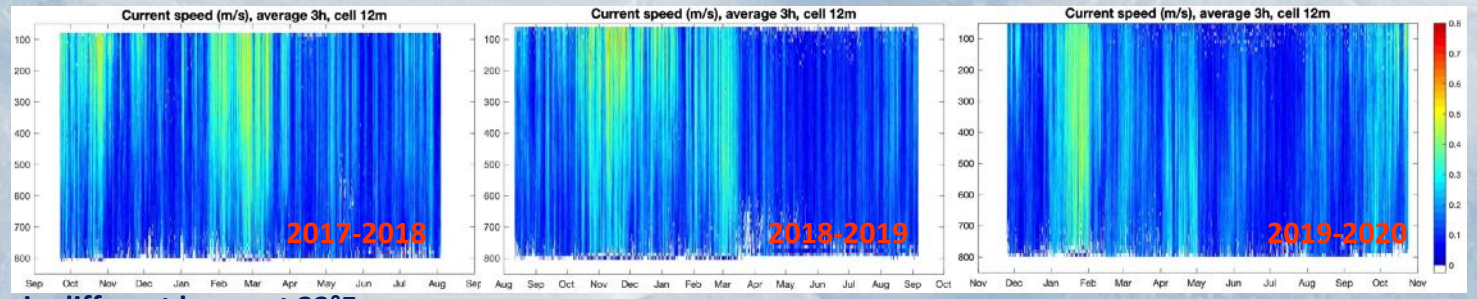




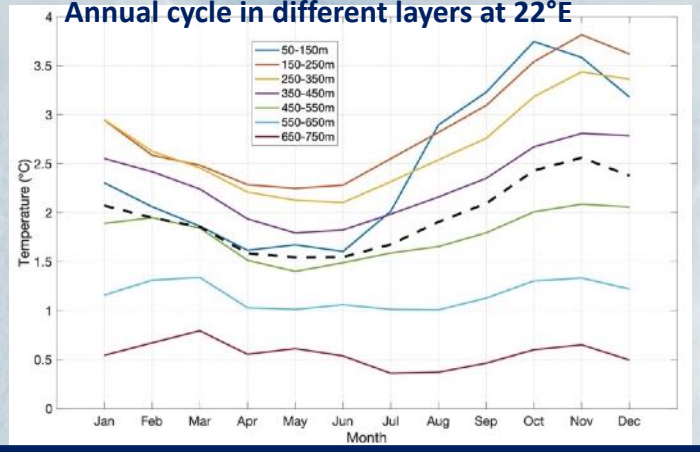
Zonal (W-E) current velocity variability at 22°E at 850m in 2017-2020



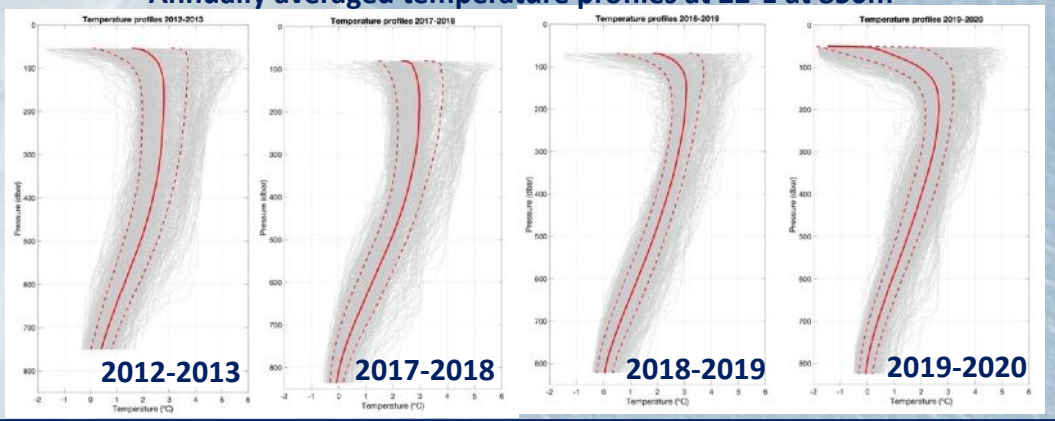
Current speed variability at 22°E at 850m in 2017-2020



Annual cycle in different layers at 22°E



Annually averaged temperature profiles at 22°E at 850m

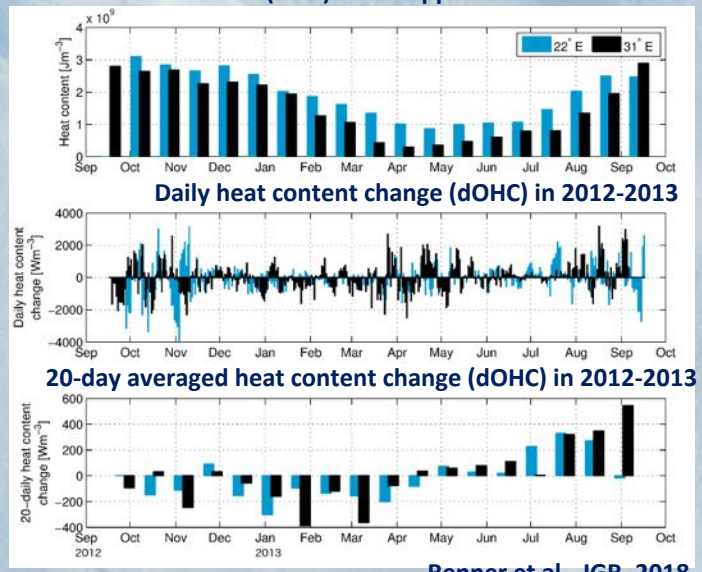


Observing the Arctic Ocean north of Svalbard

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

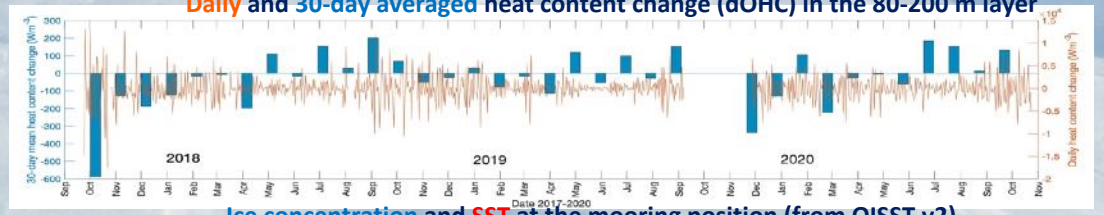
Ocean heat content (OHC) in the upper 200 m in 2012-2013



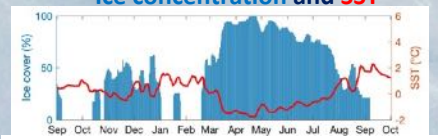
Renner et al., JGR, 2018

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

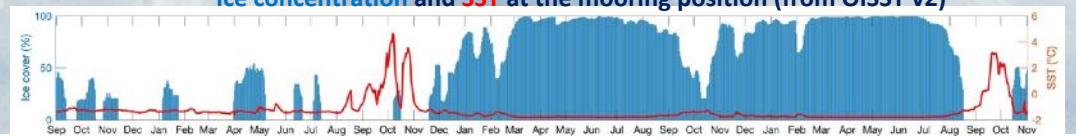
Daily and 30-day averaged heat content change (dOHC) in the 80-200 m layer



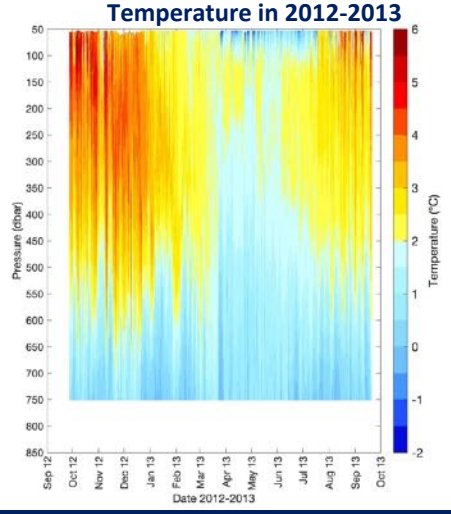
Ice concentration and SST



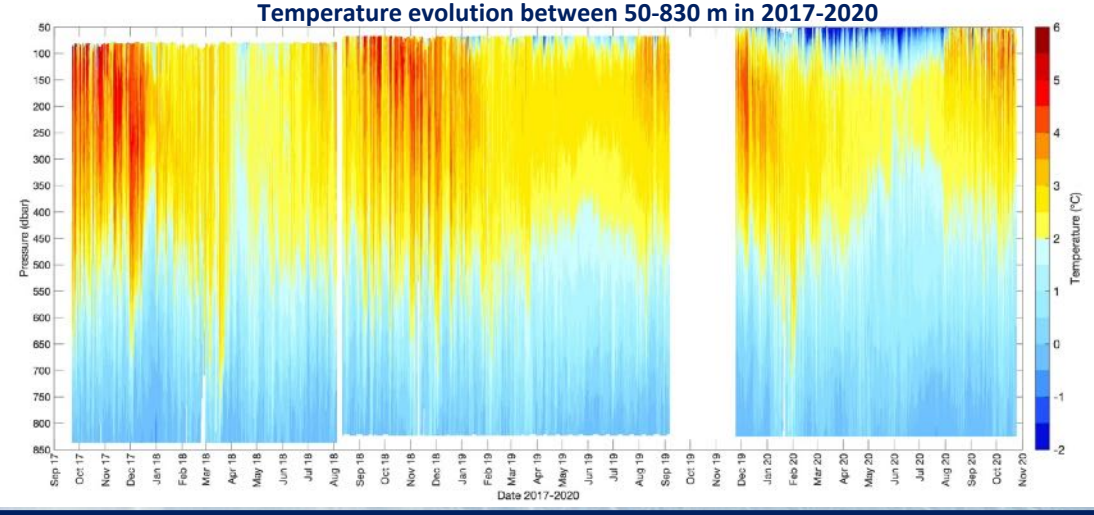
Ice concentration and SST at the mooring position (from OISST v2)



Temperature in 2012-2013



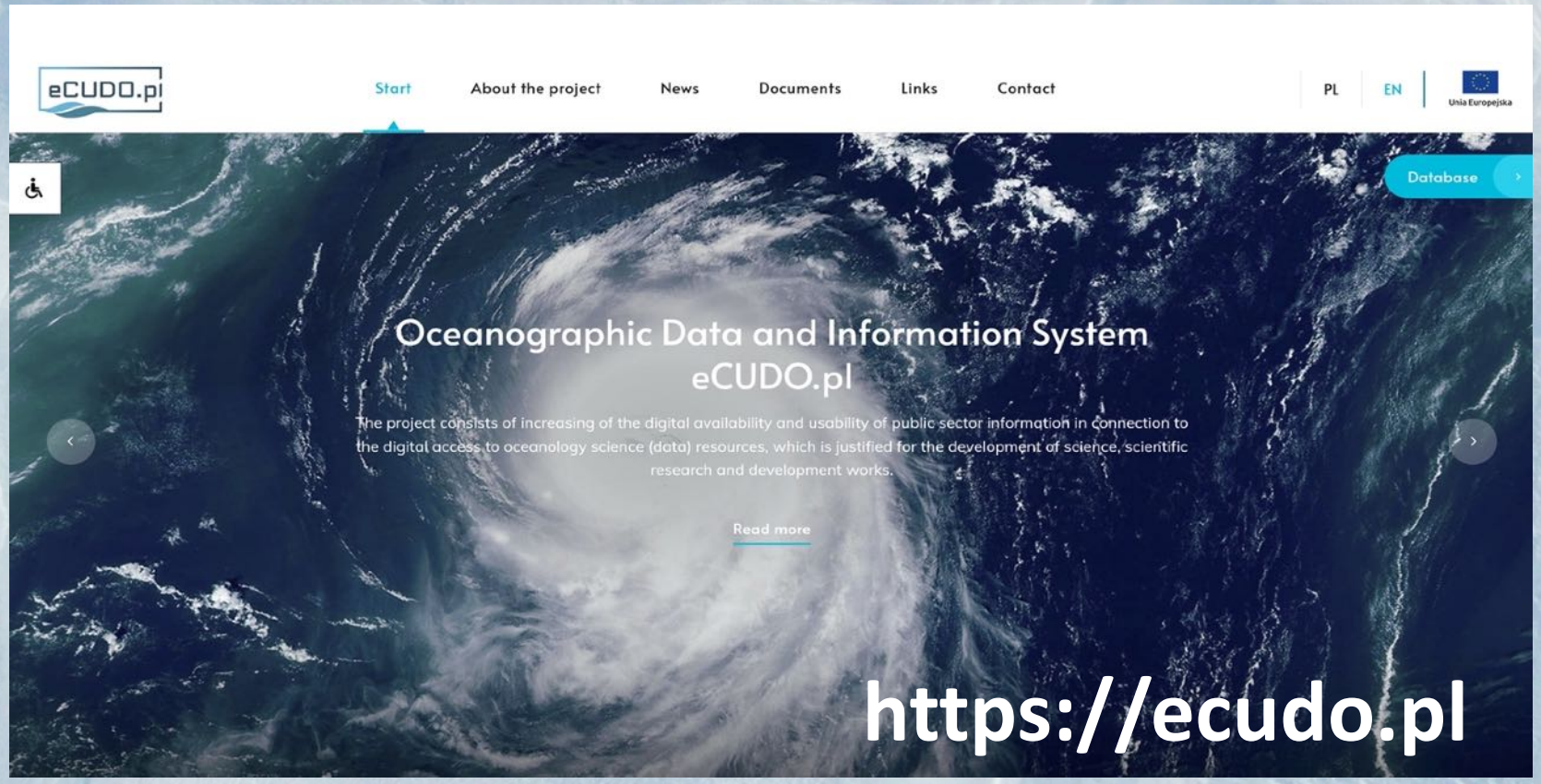
Temperature evolution between 50-830 m in 2017-2020



Oceanographic Data and Information System (ODIS) for Polish NODC

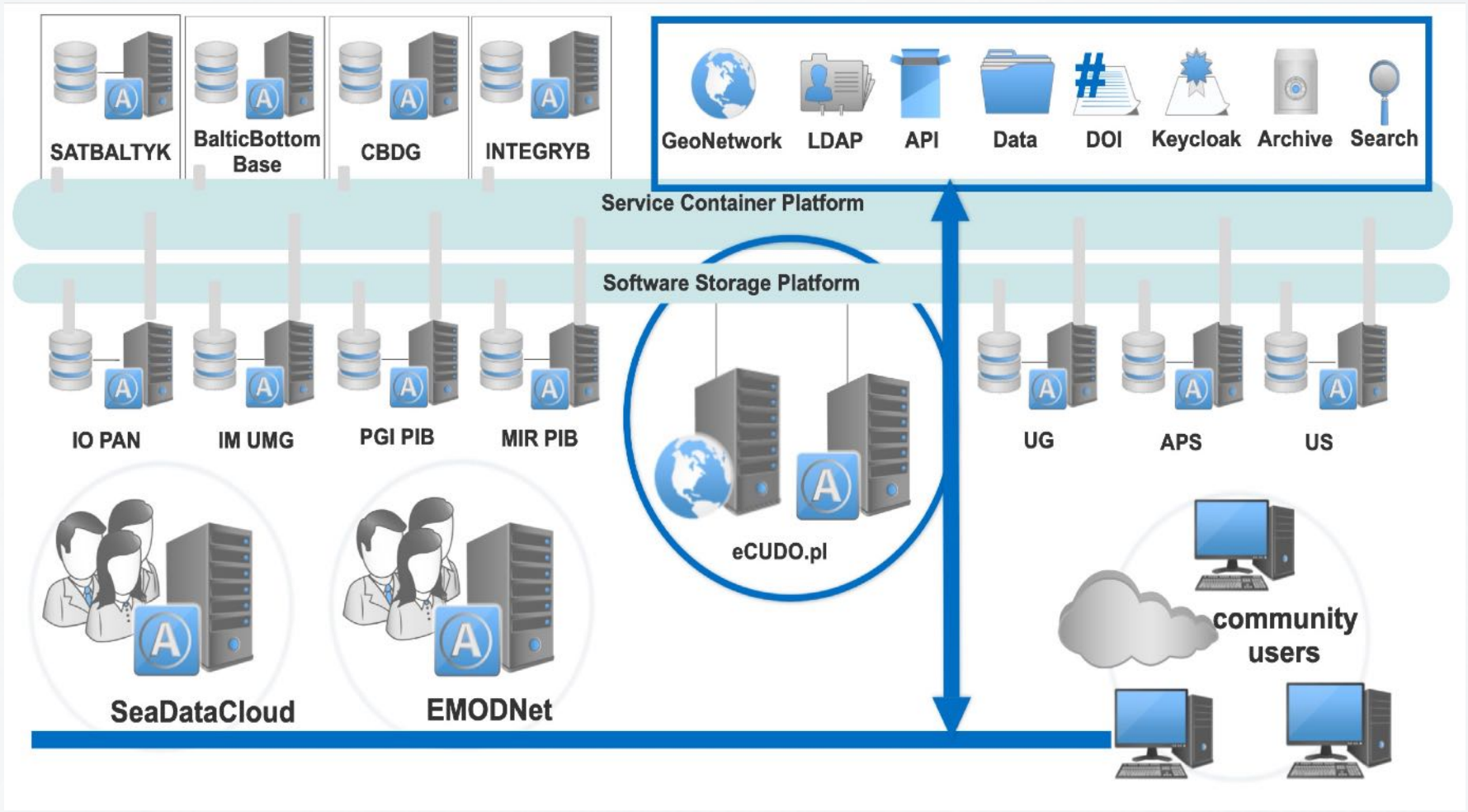
Elektroniczne Centrum Udostępniania Danych Oceanograficznych eCUDO.pl

is the project funded within the frame of Operational Programme Digital Poland for 2014-2020, managed by Digital Poland Project Centre (CPPC) with the goal to develop Oceanographic Data and Information System providing unified access to Polish oceanographic science data resources.



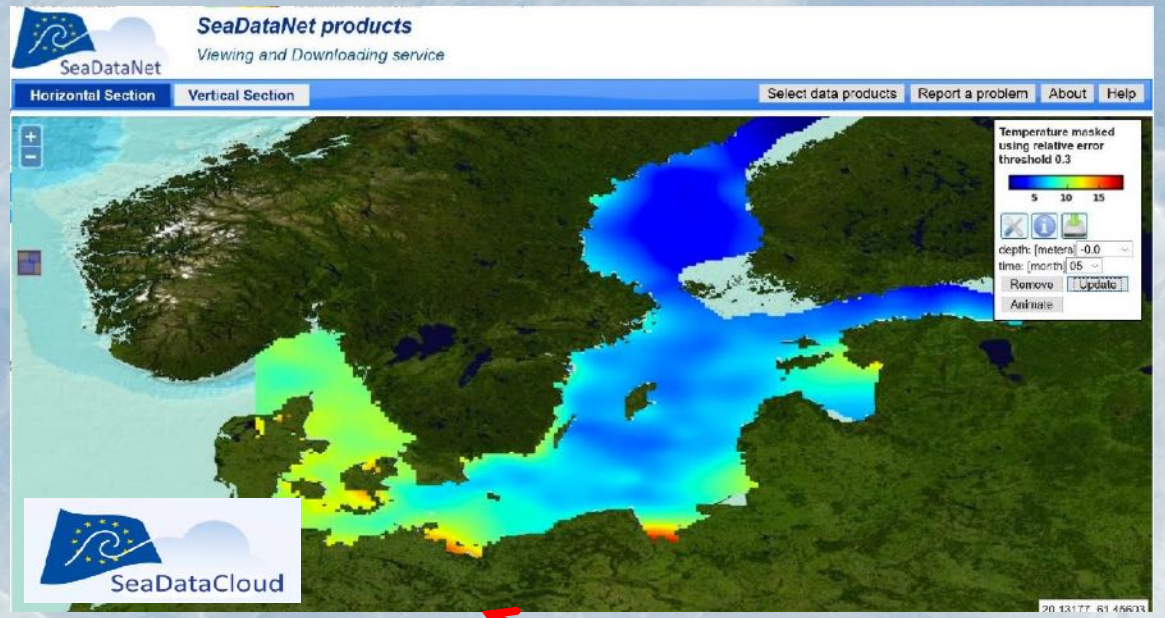
Oceanographic Data and Information System (ODIS) for Polish NODC

System structure



Oceanographic Data and Information System (ODIS) for Polish NODC

International cooperation



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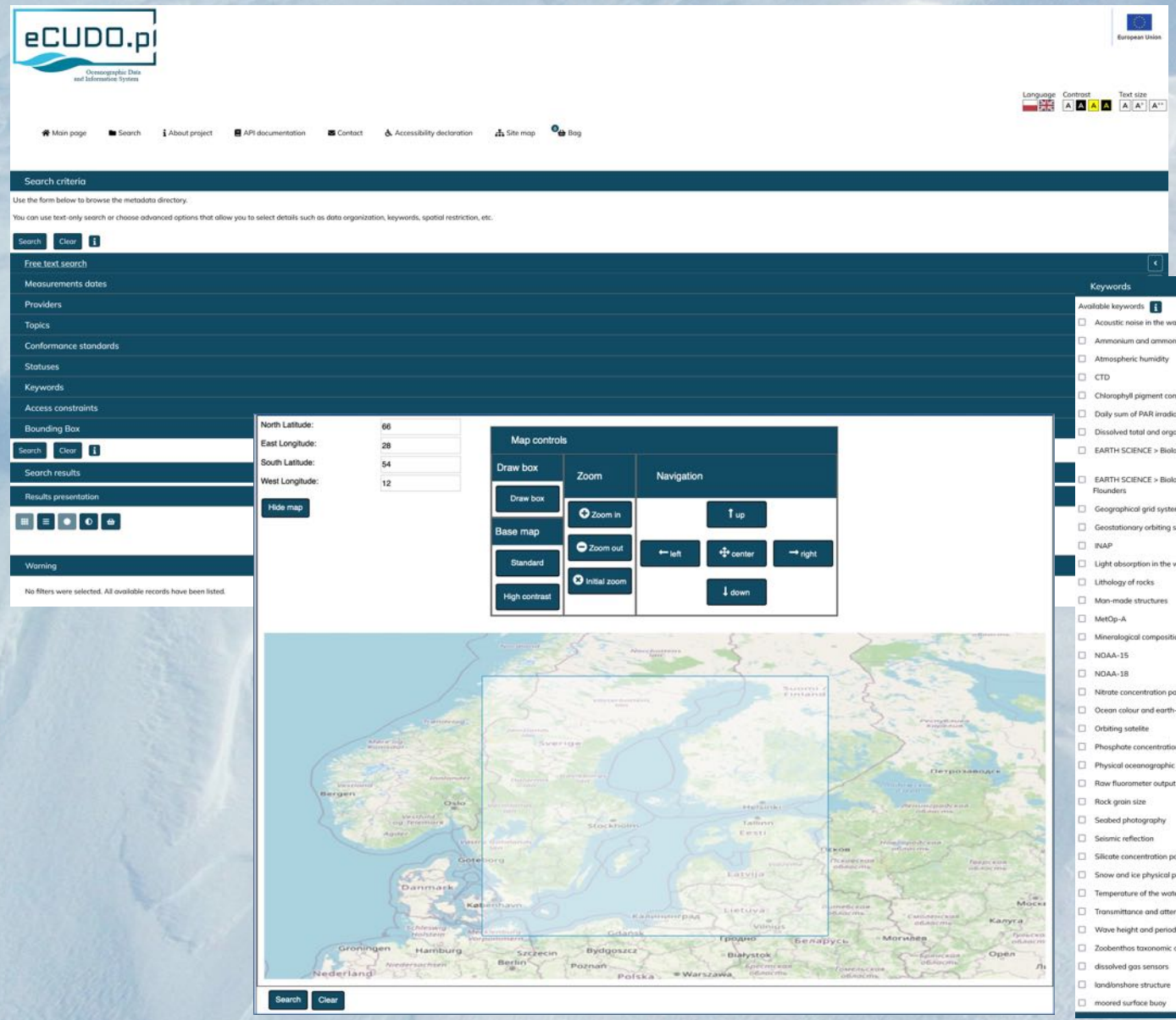
ICES CIEM

EMODnet
European Marine Observation and Data Network

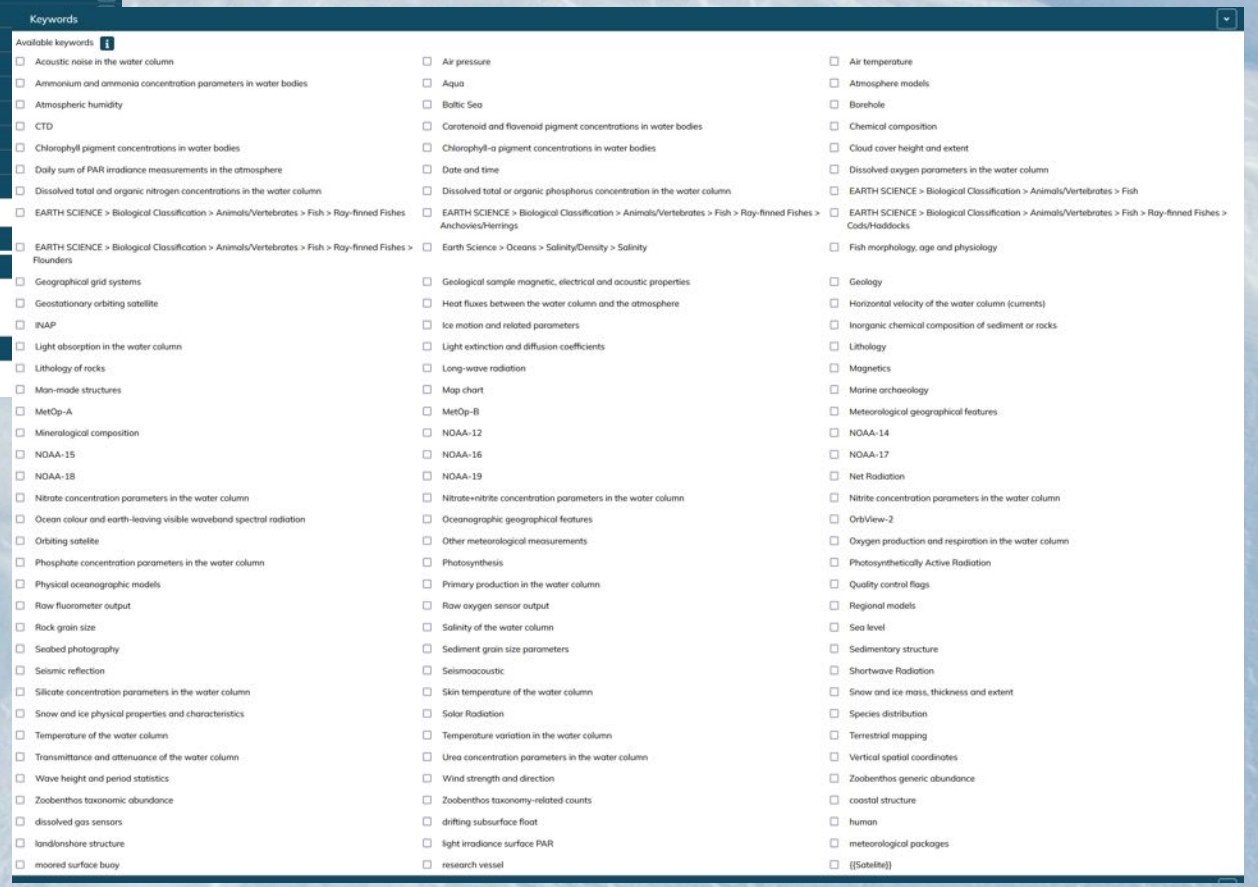
BOOS
Baltic Operational Oceanographic System

Oceanographic Data and Information System (ODIS) for Polish NODC



Data resources and access

https://odis.ecudo.pl



Thank you

for your attention