Attività di ricerca in Oceano Artico: spedizione MOSAiC

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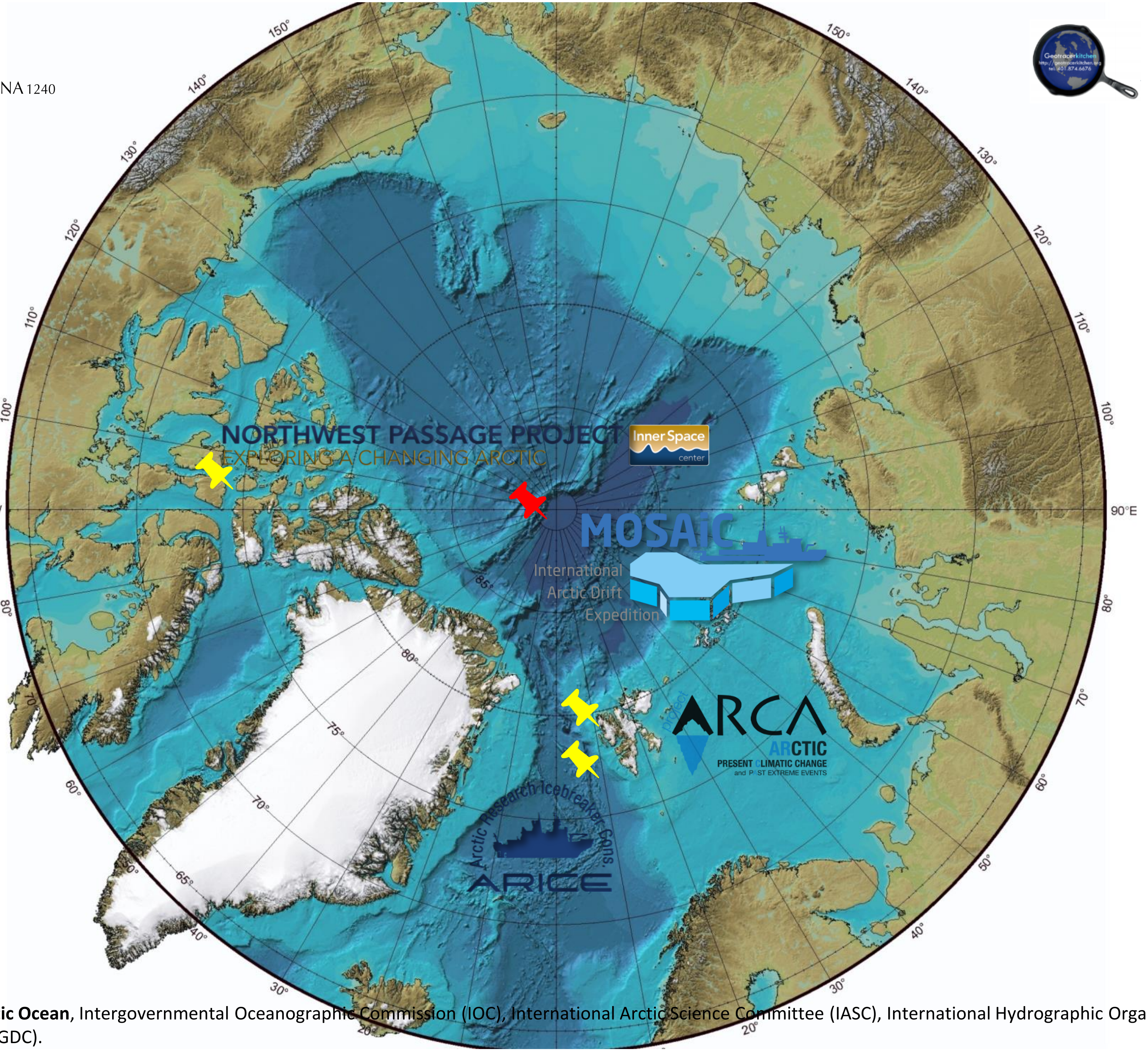


The International Bathymetric Chart of the **Arctic Ocean**, Intergovernmental Oceanographic Commission (IOC), International Arctic Science Committee (IASC), International Hydrographic Organization (IHO), US Office of Naval Research (ONR), US National Geophysical Data Center (NGDC).

Circolazione in Oceano Artico

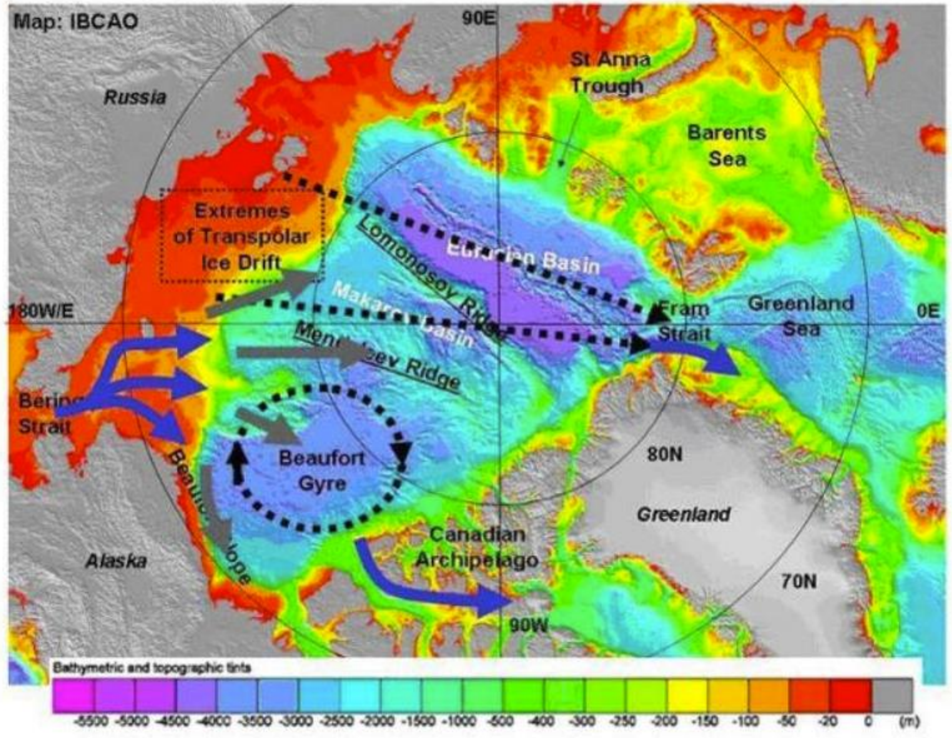


Figure 3: Schematic of Pacific Water Circulation.
Dashed straight black arrows from Russia to Fram Strait indicate extremes of the Transpolar Drift of sea-ice under different Arctic Oscillation conditions (see e.g., Rigor *et al*. 2002). Dashed circle with arrows indicates anticyclonic circulation of sea-ice (and presumably Pacific Waters) in the Beaufort Gyre. Blue arrows entering through the Bering Strait (left) indicate the branches of Pacific Waters crossing the Chukchi Sea (Woodgate *et al*. 2005b). Dark grey arrows indicate possible pathways of Pacific Waters into the Arctic and along the Beaufort Slope. Blue arrows in the Fram Strait and the Canadian Archipelago indicate exit paths of Pacific Waters from the Arctic into the Atlantic. Note arrows are schematic only.

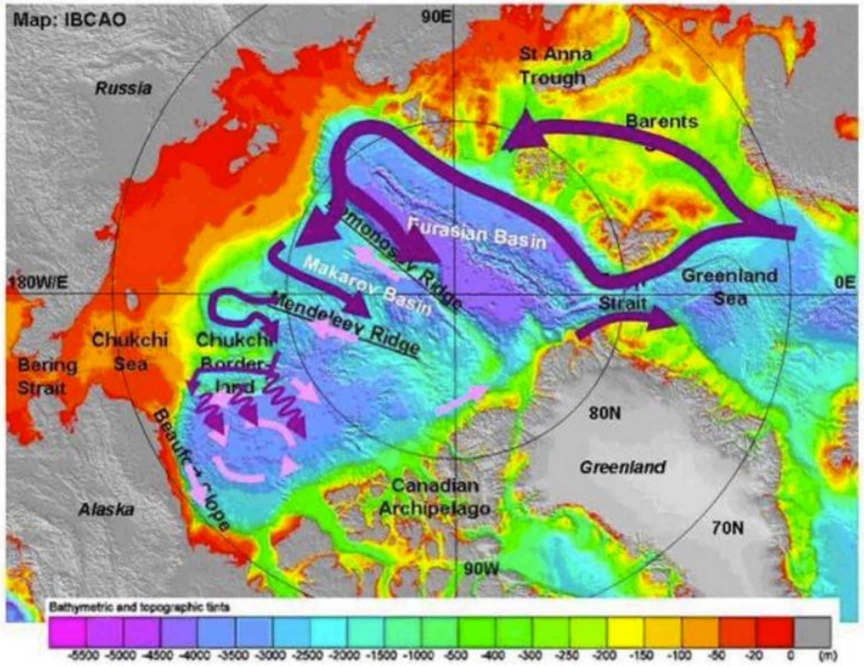
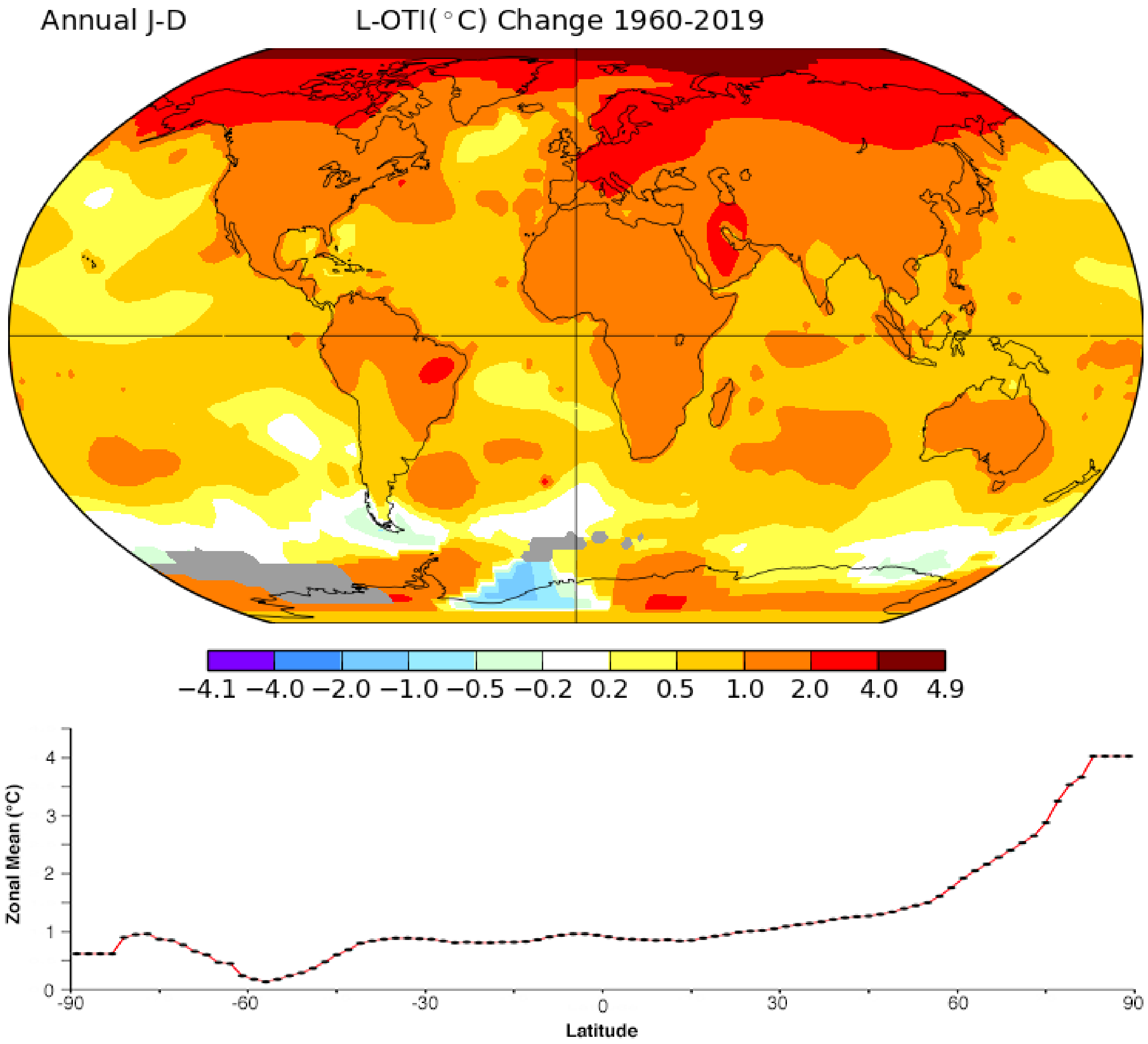


Figure 4: Schematic of Atlantic Water Circulation.
Solid mauve lines (right) indicate Atlantic Waters entering through the Fram Strait and the Barents Sea, and the Arctic Ocean Boundary Current (AOBC) flowing cyclonically along the slope of the Eurasian Basin. The AOBC is split by the Lomonosov Ridge, with roughly half moving north along the ridge and half entering the Makarov Basin (Woodgate *et al*. 2001). Beyond this, thinner, lighter arrows indicate more uncertainty about the flow. Atlantic Waters flow around the Chukchi Borderland and are believed to continue cyclonically along the Beaufort slope, although observations are sparse (pink arrows) (Aagaard 1984). Within the Beaufort Gyre, an anticyclonic flow may exist in the same sense as the sea-ice gyre above, opposing the AOBC flowing cyclonically along the slope (Newton and Coachman 1974). Squiggly lines extending from the Chukchi Borderland into the basin indicate transfer of waters from the AOBC to the interior by double diffusive processes (McLaughlin *et al*. 2009). The AOBC is believed to continue cyclonically along the Canadian Archipelago (Newton and Sotirin 1997) and exit the Arctic primarily through the Fram Strait. Note arrows are schematic only.

Arctic amplification

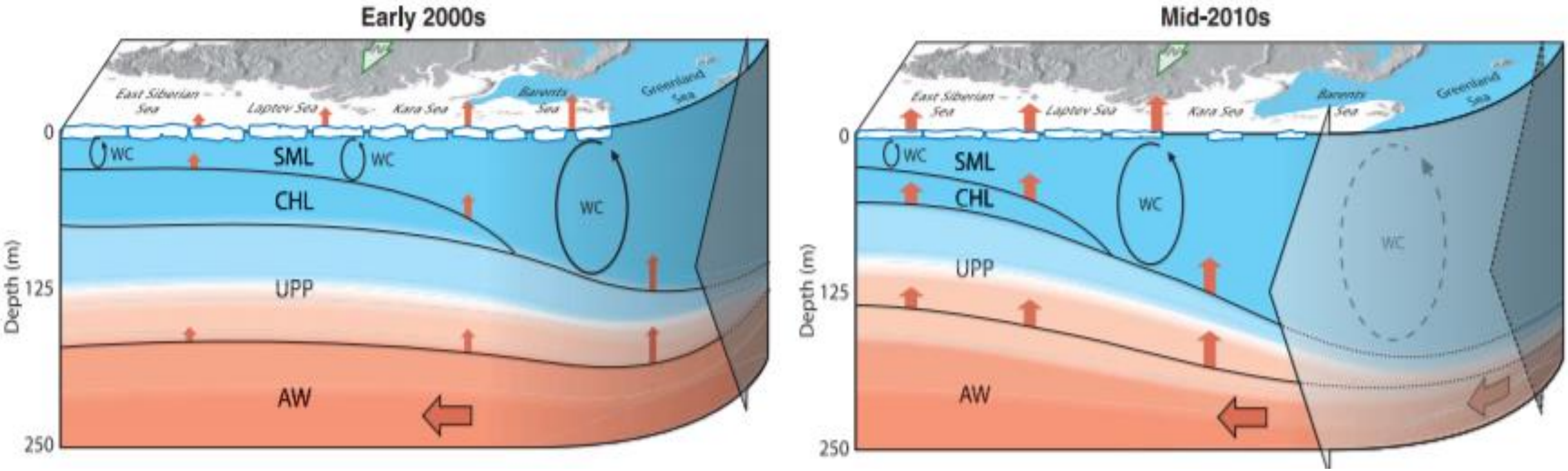
Changes in the Arctic much faster than the rest of the world in both observations and model simulations (Dai et al., 2019).



Trends in mean surface air temperature over the period 1960 to 2019. The graph shows linear trends over the period by latitude. —*Credit:* [NASA GISS]

Arctic amplification

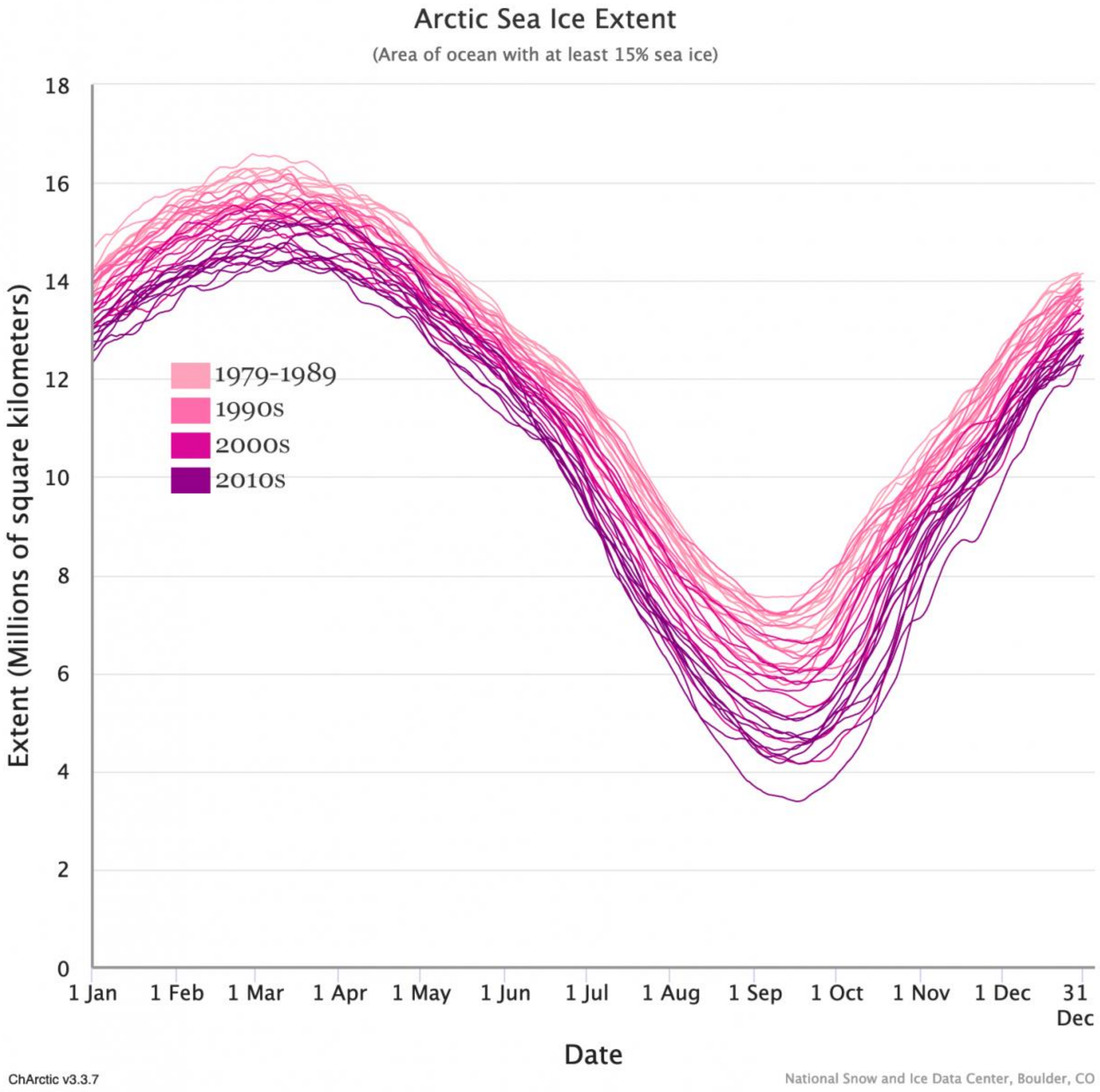
Atlantification of Eurasian Arctic Basin, warm water from the Atlantic due to effective insulation of the overlying cold halocline layer that separates the cold and fresh surface mixed layer and pack ice from heat carried by the warm and saline Atlantic Water (Polyakov et al., 2017)



Transformation of the permanent cold halocline layer (CHL) to a seasonal halocline. SML and UPP indicate the surface mixed layer and upper permanent pycnocline. WC shows winter convection; red arrows indicate upward heat fluxes. Horizontal red arrows show inflows (Polyakov et al., 2017).

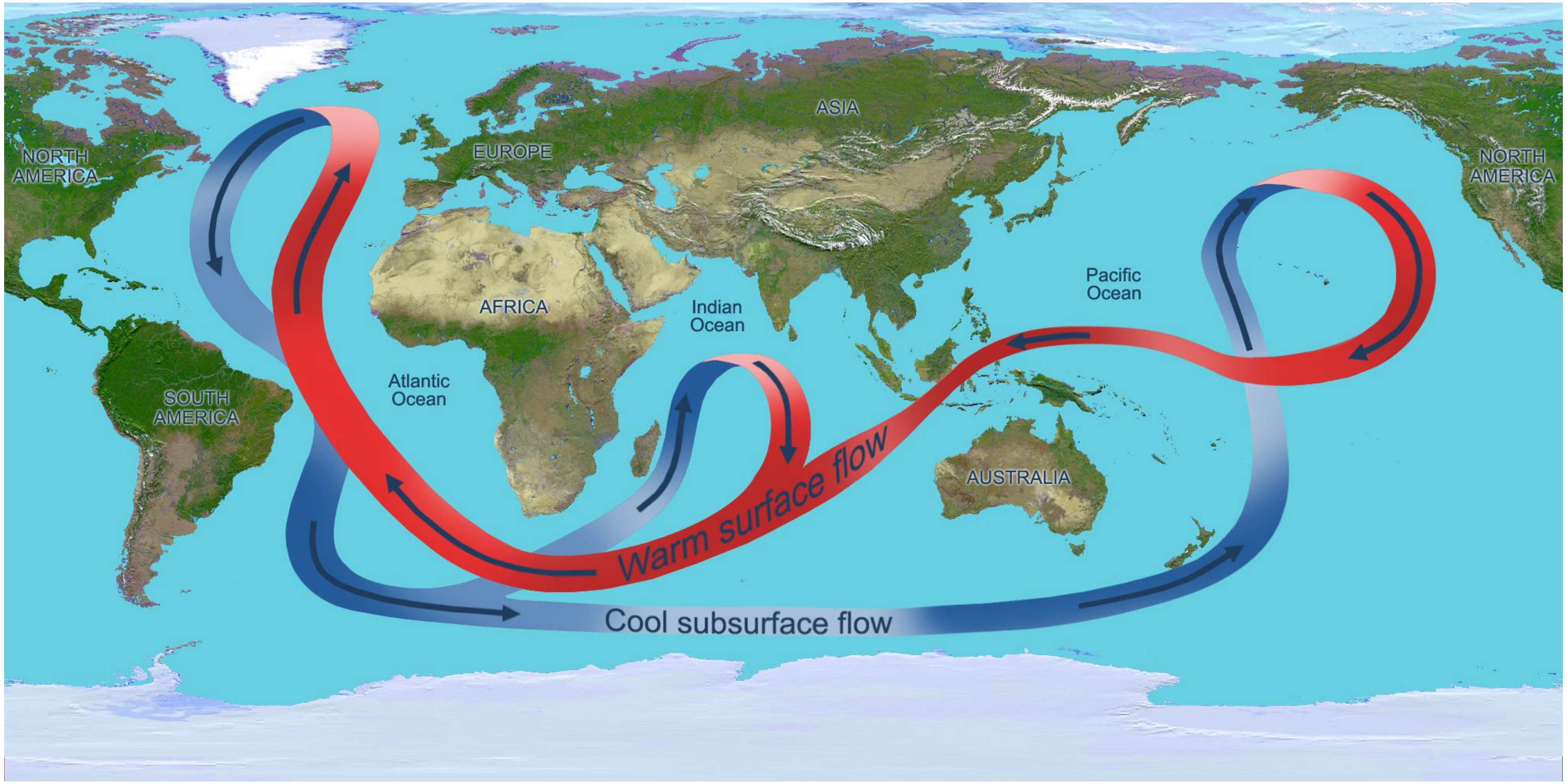
“Unknown consequences for the wider ecosystem”

Arctic amplification



Importanza delle Regioni Artiche

- Formazione di acque dense
- Input di acque di fusione glaciale e di ghiaccio marino



Sistema climatico globale

- Habitat di specie animali e vegetali marine e terrestri

photo: Lianna Nixon

© TOMER KETTER

- Casa di popoli indigeni

Come ottenere dati da regioni così estreme?

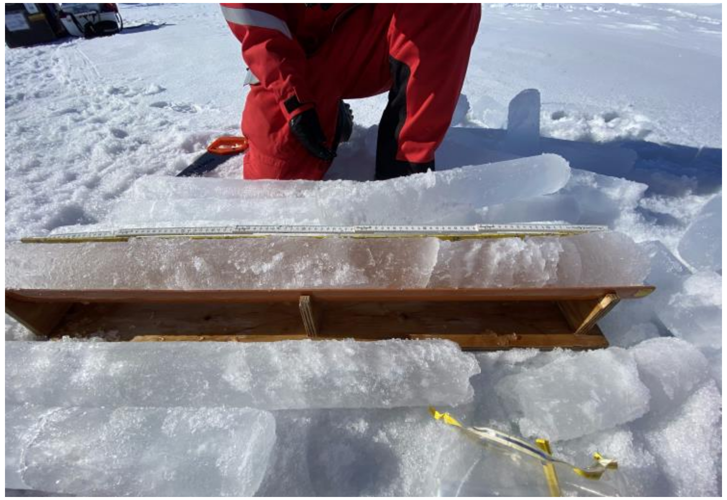
Campionamenti *in-situ*: campagne oceanografiche

Oden Icebreaker, Northwest Passage Project, Summer 2019. Ph: Dong Lai

Polarstern Icebreaker, MOSAiC expedition, 2019-2020.

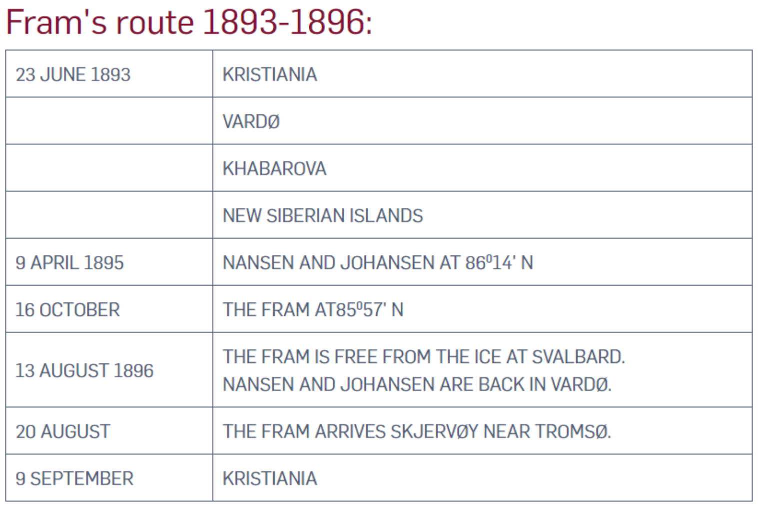
Attivita’ di campionamento

Photo: Jessie Gardner



Un po’ di storia

Fridtjof Nansen oversaw the scientific side and Otto Sverdrup captained the ship. Her subsequent drift across the Arctic Ocean confirmed Nansen´s theory to the hilt, locked in the ice, the Fram was carried for hundreds of miles between the North Pole and Franz Josef Land. Nor did they get as close to the Pole as Nansen had. When Nansen realized that the Fram would not get as close to the North Pole as he had expected, he and Hjalmar Johansen left the ship on March 14th, 1895 and set out with three dog-drawn sledges in a bold bid to make the Pole across the ice. But the pack ice was in constant motion and they were compelled to abandon the attempt on April 9th, by which time they had reached 86° 14’ N. They then set course for Franz Josef Land, where they built a crude hut in which they were forced to spend the winter. In Cape Flora on June, they met the British explorer F. G. Jackson, who took them back to Norway on board his ship the Windward. By August 13th, 1896 they were back in Vardø. The Fram finally emerged from the ice off the north coast of West Svalbard, the same day that Nansen arrived in Vardø.



Fram's route 1893-1896:

23 JUNE 1893	KRISTIANIA
	VARDØ
	KHABAROVA
	NEW SIBERIAN ISLANDS
9 APRIL 1895	NANSEN AND JOHANSEN AT 86°14' N
16 OCTOBER	THE FRAM AT85°57' N
13 AUGUST 1896	THE FRAM IS FREE FROM THE ICE AT SVALBARD. NANSEN AND JOHANSEN ARE BACK IN VARDØ.
20 AUGUST	THE FRAM ARRIVES SKJERVØY NEAR TROMSØ.
9 SEPTEMBER	KRISTIANIA

SHEBA

SURFACE HEAT BUDGET OF THE ARCTIC OCEAN (SHEBA)

1 SEPTEMBER 1997 - 1 SEPTEMBER 1998
LEAD SCIENTIST: RICHARD MORITZ
OBSERVATORY: NSA

CAMPAIGN LINKS

- SHEBA Website
- ARM News
- Media
- Images

The overarching purpose of the Surface Heat Budget of the Arctic Ocean (SHEBA) was to produce year-long retrievals of cloud properties, including crystal/droplet sizes, optical depths, water contents, and cloud boundaries through the depth of the troposphere. These results were intended to enhance the understanding of the thermodynamic coupling between the atmosphere and the ocean when covered with sea ice.

In 1997, SHEBA participants placed a Canadian icebreaker, DesGroseilliers, in the Arctic ice pack 570 kilometers northeast of Prudhoe Bay, Alaska. During its year-long deployment, the DesGroseilliers powered a comprehensive suite of atmospheric, ocean, and ice sensors that were operated on the ship and the surrounding ice floe. In addition, ARM deployed two dozen instruments, including a lidar and millimeter cloud radar, and gathered 10 sets of vertical profiles of clouds and aerosol properties data from over the SHEBA site.

The interdisciplinary effort between ARM and NOAA for SHEBA consisted of three phases. The first began in 1995 with the examination of existing Arctic data and models, the second involved the deployment and operation of instruments as part of SHEBA field effort, and the third ended in 2002 with in-depth analysis of processes and feedback mechanisms from data obtained during the SHEBA deployment. Both ARM and NOAA contributed equipment, data, and personnel to this NSF-funded multiseason field experiment, which helped develop detailed models of physical processes on a local and aggregate scale.

Multidisciplinary drifting Observatory for the Study of Arctic Climate

MOSAiC

International
Arctic Drift
Expedition

https://mosaic-expedition.org/
https://www.youtube.com/watch?v=ptjvdyRKRE8

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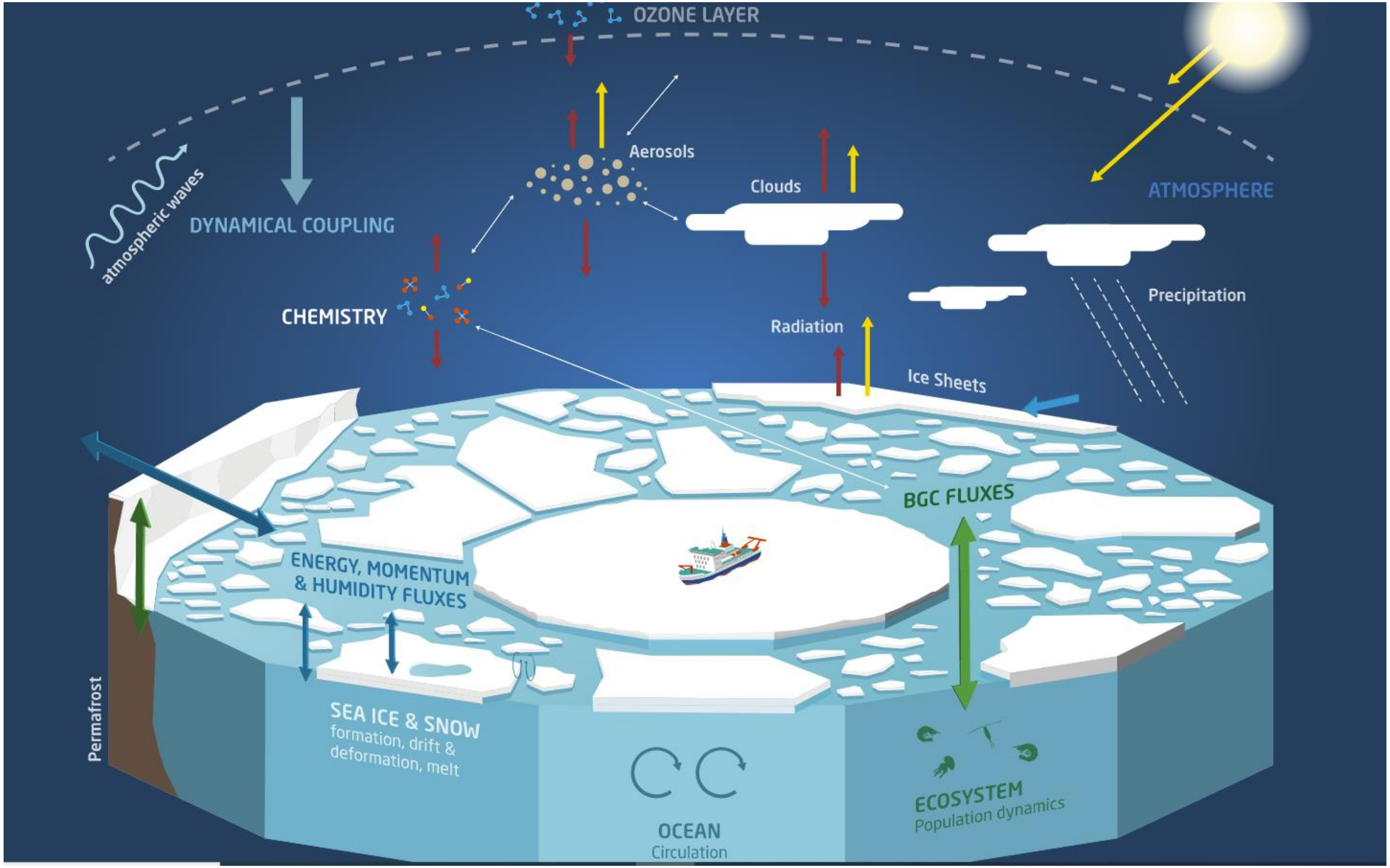
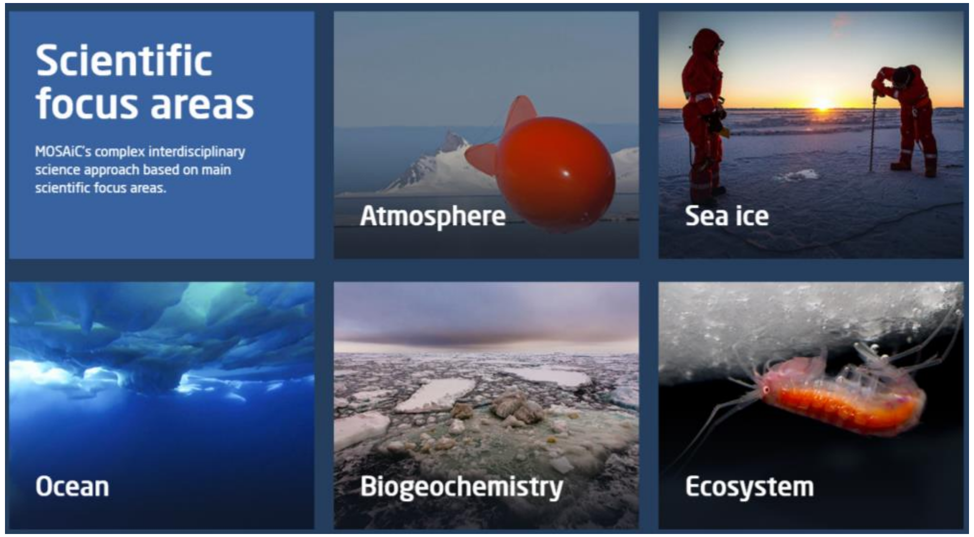
Science at 360° for 1 year long



MOSAiC
International
Arctic Drift
Expedition

- **MOSAiC** aims at a breakthrough in understanding the Arctic climate system and in its representation in global climate models. It will provide a more robust scientific basis for policy decisions on climate change mitigation and adaptation and for setting up a framework for managing Arctic development sustainably.

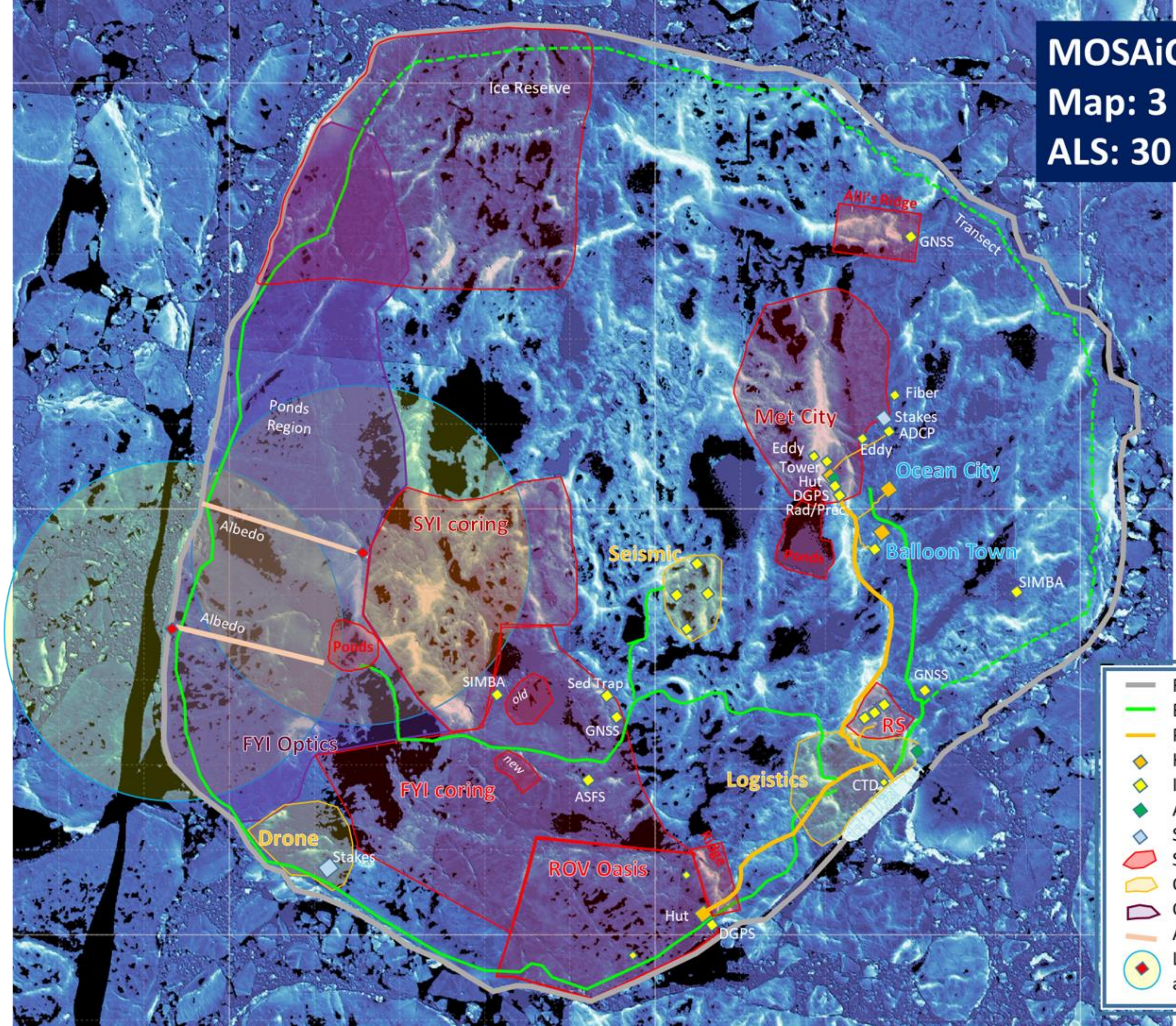


Scientific focus areas

MOSAiC's complex interdisciplinary science approach based on main scientific focus areas.

442 esperti
5 legs
3400 km drifted

MOSAiC Floe Map
Map: 3 July 2020
ALS: 30 June 2020

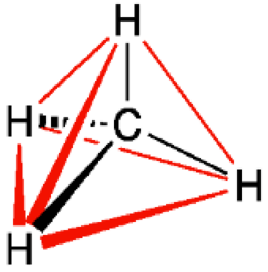


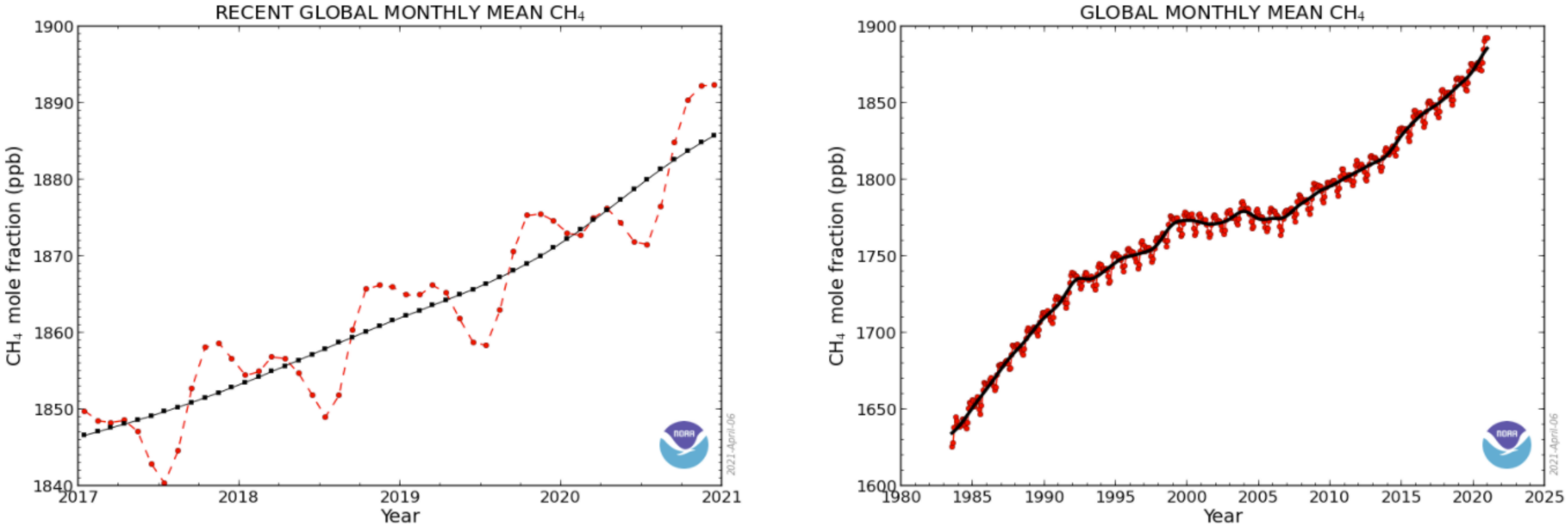
- Floe Boundary
- Established path
- Powerline
- Hut / Tent
- Installation
- AIS beacon
- Stake array
- Sample area (no go)
- Operational areas
- Optics domain (no go)
- Albedo line
- Laser surface scanner and danger area

Research questions:

- What’s the methane budget and which is the microbial oxidation rate potential in the Arctic Ocean?
- Which are the main communities triggering it?
- Where are the hotspots of methane microbial oxidation within the AO?

Methane, a climate-relevant gas



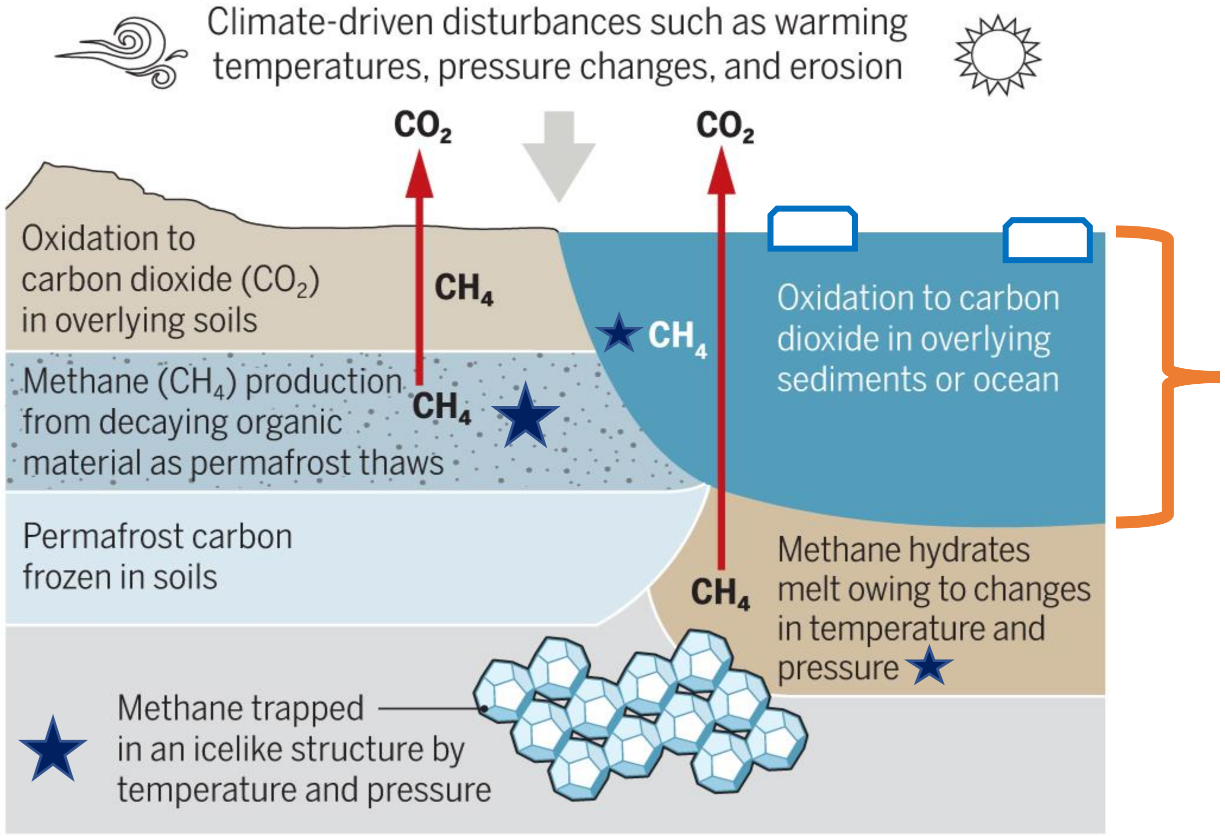

RECENT GLOBAL MONTHLY MEAN CH_4

GLOBAL MONTHLY MEAN CH_4

The graphs show globally-averaged, monthly mean atmospheric methane abundance determined from marine surface sites. The first graph shows monthly means for the last four years plus the current year, and the second graph shows the full NOAA time-series starting in 1983. Values for the last year are preliminary, pending recalibrations of standard gases and other quality control steps. https://esrl.noaa.gov/gmd/ccgg/about/global_means.html

Methane absorbs terrestrial radiation in the 4- to 100-nm region (infrared irradiation) more effectively than CO_2. Its equivalent warming potential is indeed **32 times** higher. The present-day concentration of CH_4 in the atmosphere is lower than that of CO_2, but its concentrations have **risen** dramatically since pre-industrial times (IPCC 2006). It contributes **16%** to the global greenhouse effect and has a lifetime of **~12 yr** in the atmosphere (IPCC 2014).

Some background
Methane cycle in the AO

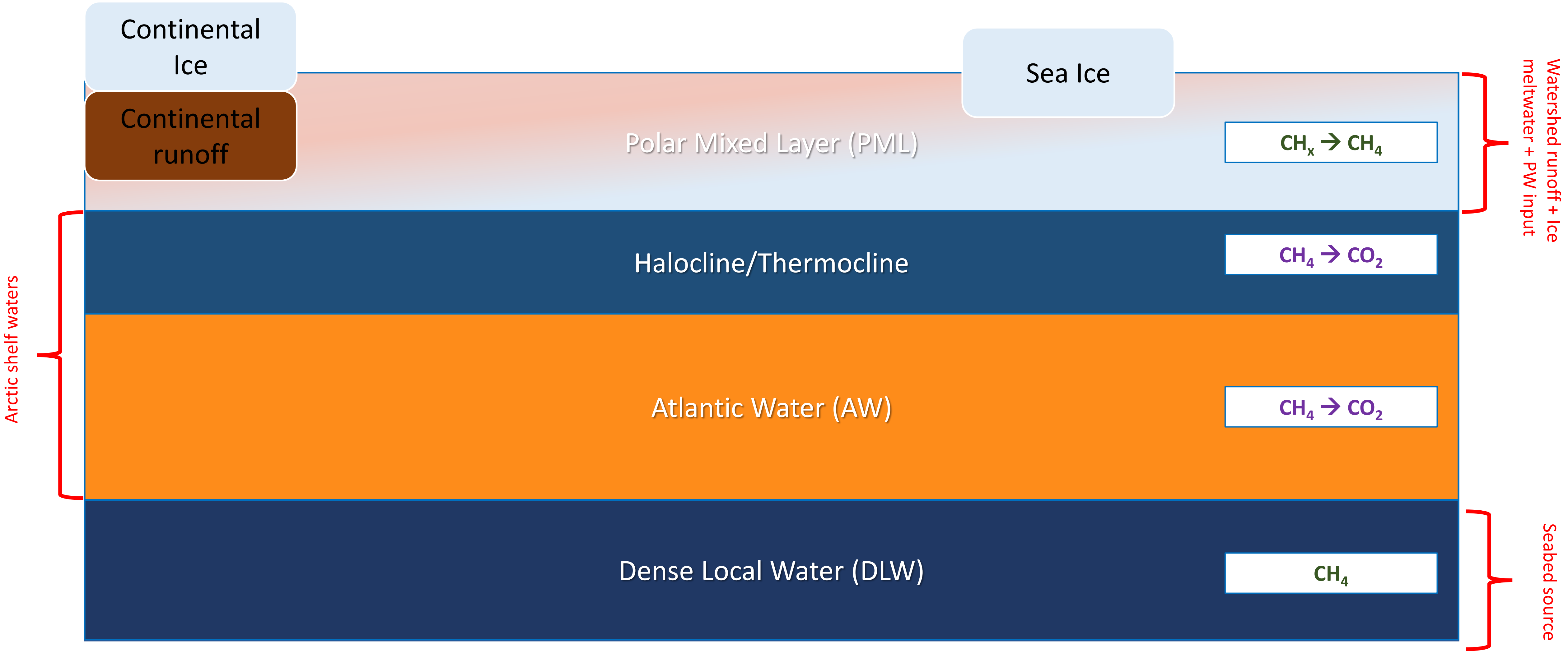


Old methane and modern climate change by JOSHUA F. DEAN, SCIENCE 21 FEB 2020: 846-848

★ The ocean continental shelves host the largest global reservoir of methane (CH_4). Most of the CH_4 dissolves in the water column, building up an aqueous CH_4 inventory.

↑ Once dissolved in ocean water, the CH_4 emitted can be aerobically oxidized and converted into either carbon dioxide (CO_2) or biomass.

Methane distribution within the water column strongly depends on the water column structure



Continental Ice

Continental runoff

Sea Ice

Polar Mixed Layer (PML)

$CH_x \rightarrow CH_4$

Watershed runoff + Ice meltwater + PW input

Halocline/Thermocline

$CH_4 \rightarrow CO_2$

Atlantic Water (AW)

$CH_4 \rightarrow CO_2$

Arctic shelf waters

Dense Local Water (DLW)

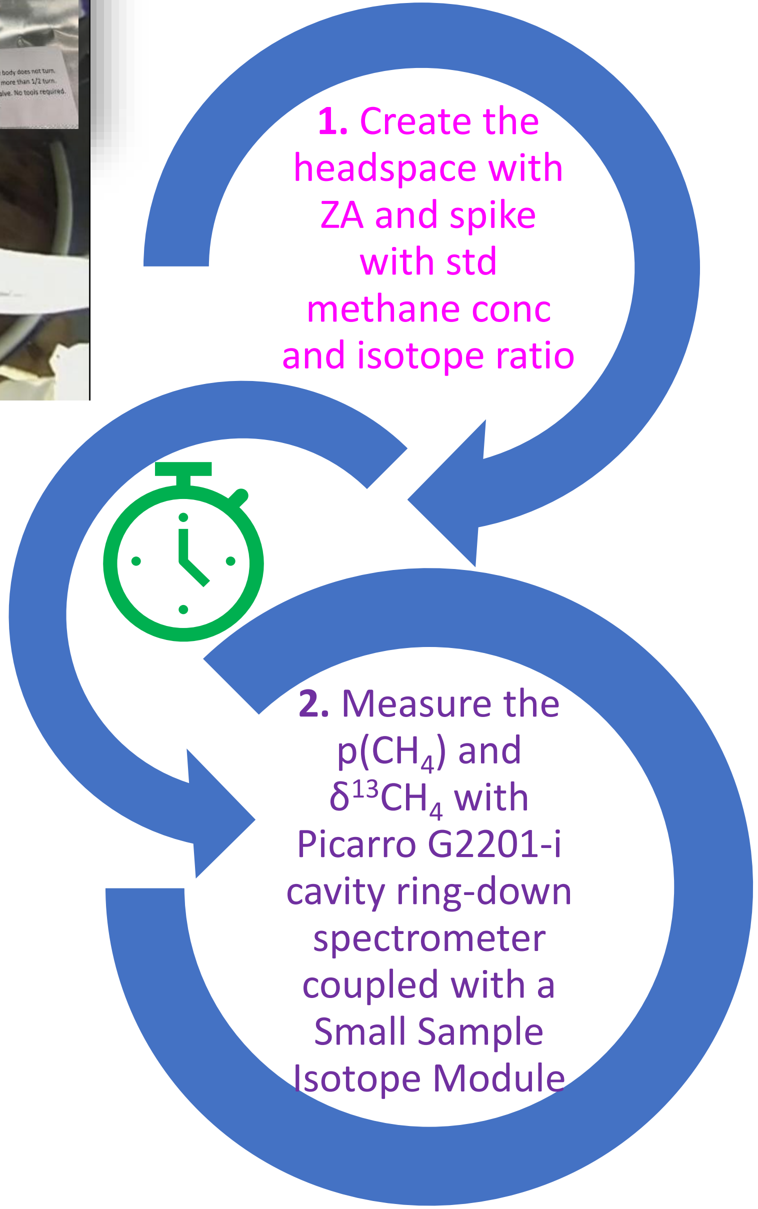
CH_4

Seabed source

Headspace method of gas tight foil bags

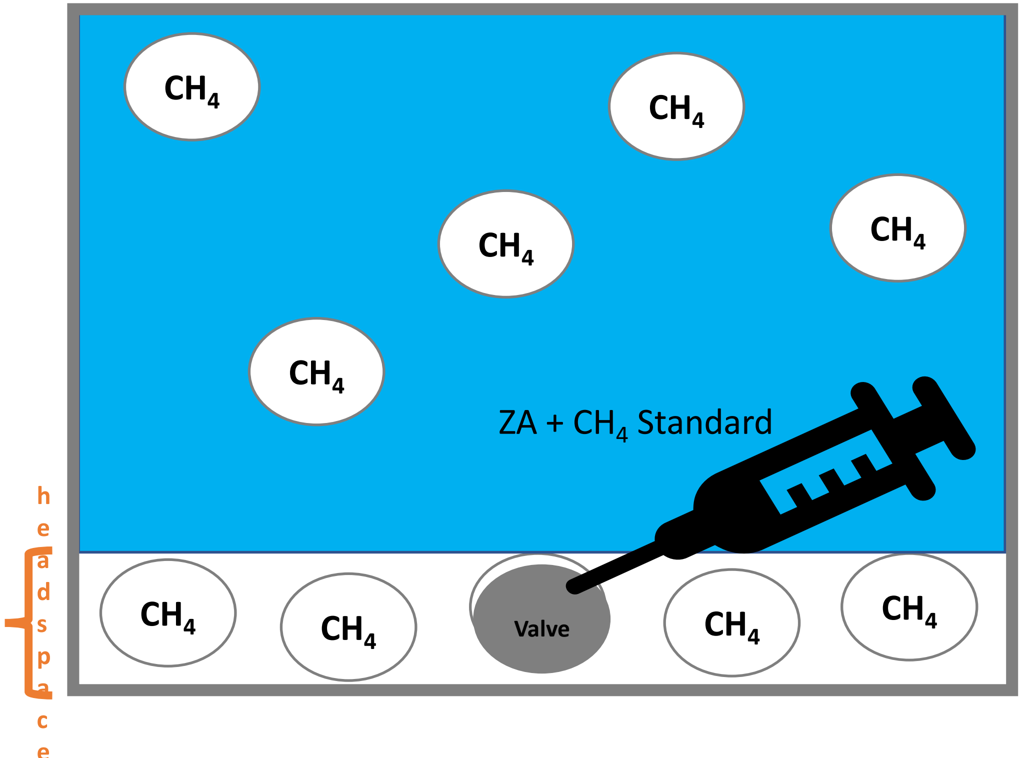
CAUTION

1) To open and close valve, turn cap only. Valve body does not turn.
2) To open valve, turn cap counterclockwise no more than 1/2 turn.
3) Overtightening cap with pliers will damage valve. No tools required.
4) Valve is supplied with cap in closed position.

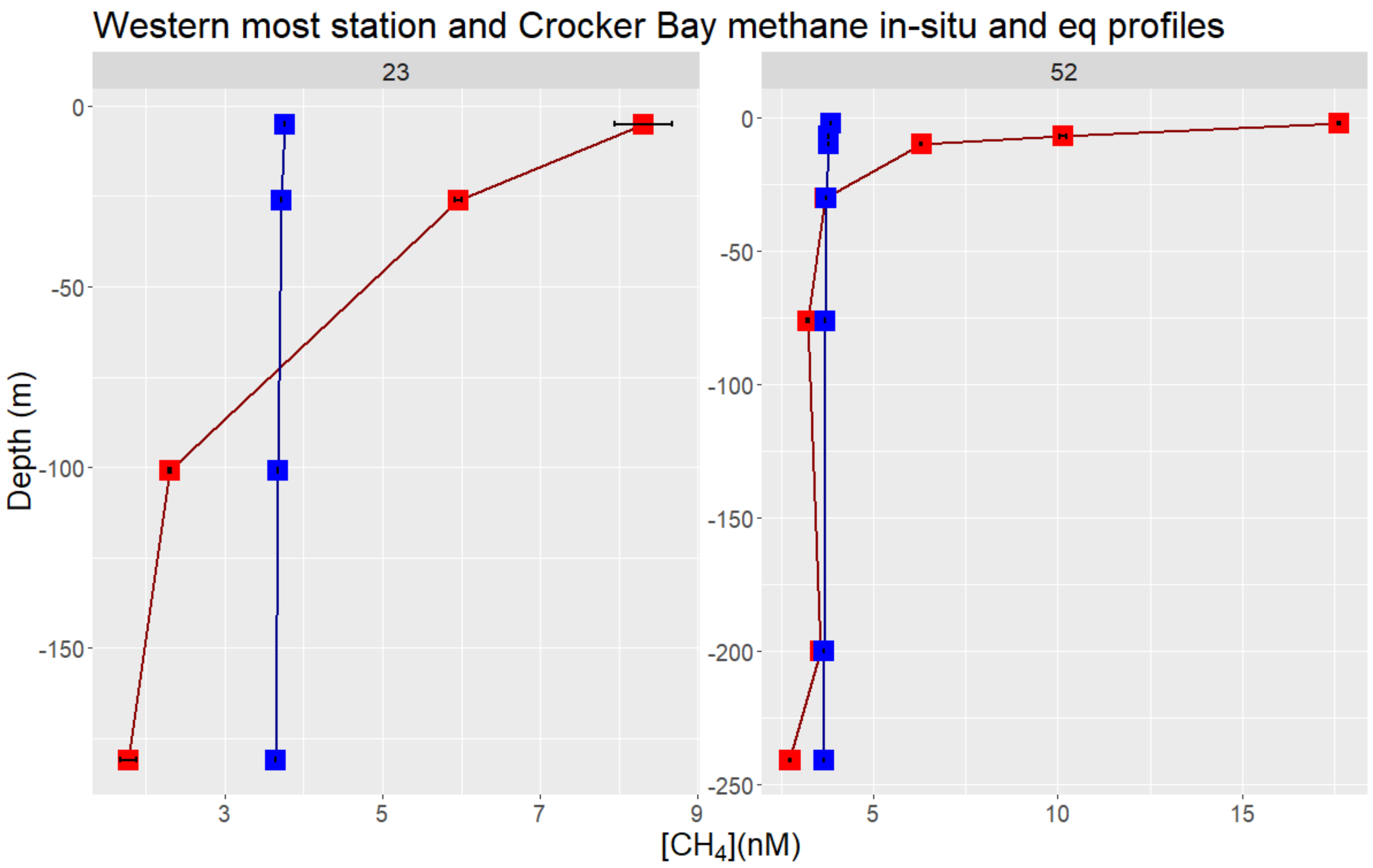


1. Create the headspace with ZA and spike with std methane conc and isotope ratio

2. Measure the p(CH_4) and $\delta^{13}CH_4$ with Picarro G2201-i cavity ring-down spectrometer coupled with a Small Sample Isotope Module



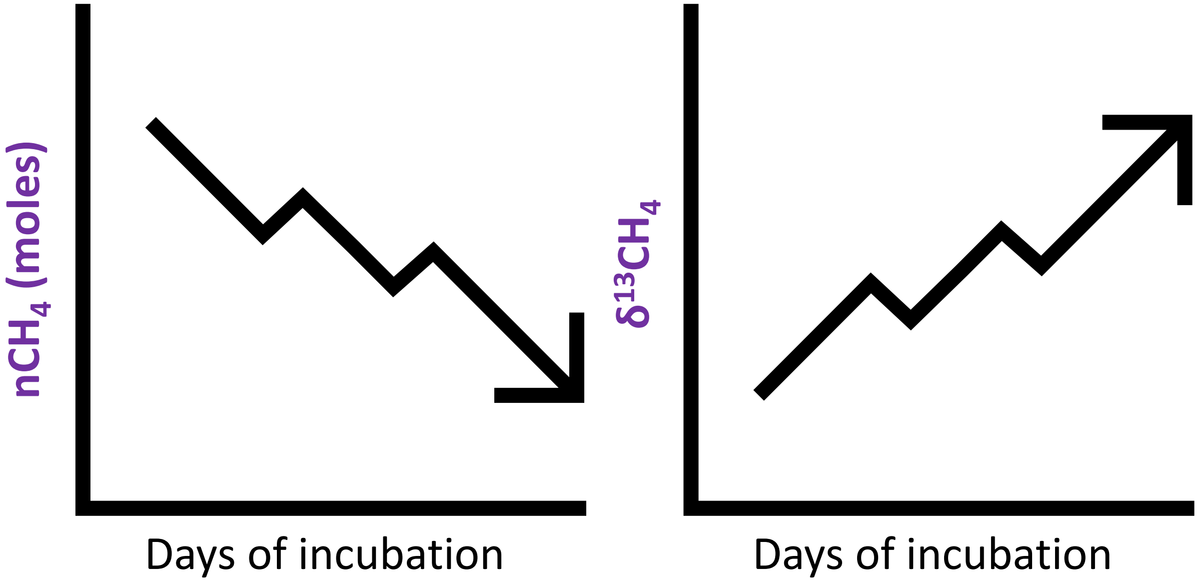
Results Northwest Passage Project:
In-situ seawater methane profiles



A

W

Measure the moles of methane and its isotopic ratio within a timeframe



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Microbial community structure through genetic analysis

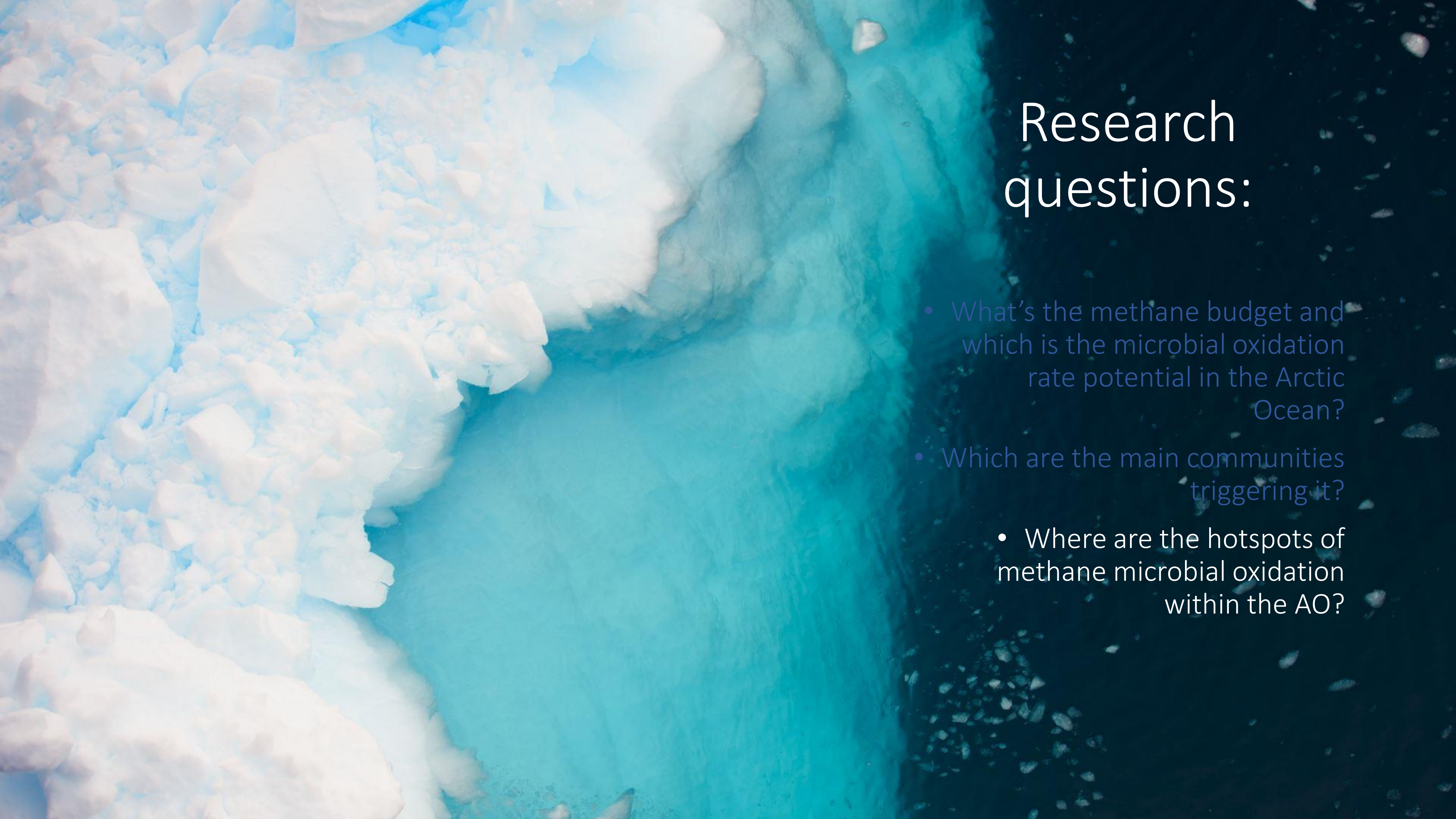
The first aerobic methanotrophs were discovered and isolated more than a century ago (Kaserer 1905; Sohngen 1906) all belonging to the **Alpha and Gammaproteobacteria** (Whittenbury, Phillips and Wilkinson 1970; Hanson and Hanson 1996).

At the beginning of the current century, a marine consortium of **methane-oxidizing archaea and sulfate-reducing bacteria** was discovered, mediating sulfate-dependent methane oxidation (Boetius et al. 2000).

Later, a consortium of **Methylomirabilis bacteria and Methanoperedens archaea**, capable of coupling anaerobic methane oxidation to denitrification of nitrite and nitrate, were isolated (Raghoebarsing et al. 2006).

Thermoacidophilic methanotrophs were isolated from hot and acidic volcanic ecosystems (Dunfield et al. 2007; Pol et al. 2007; Islam et al. 2008), belonging to the phylum **Verrucomicrobia**

Recently, the **Flavobacteria** were defined the secondary consumers of methane, oil, or cellular decay products (Redmond and Valentine, 2011).



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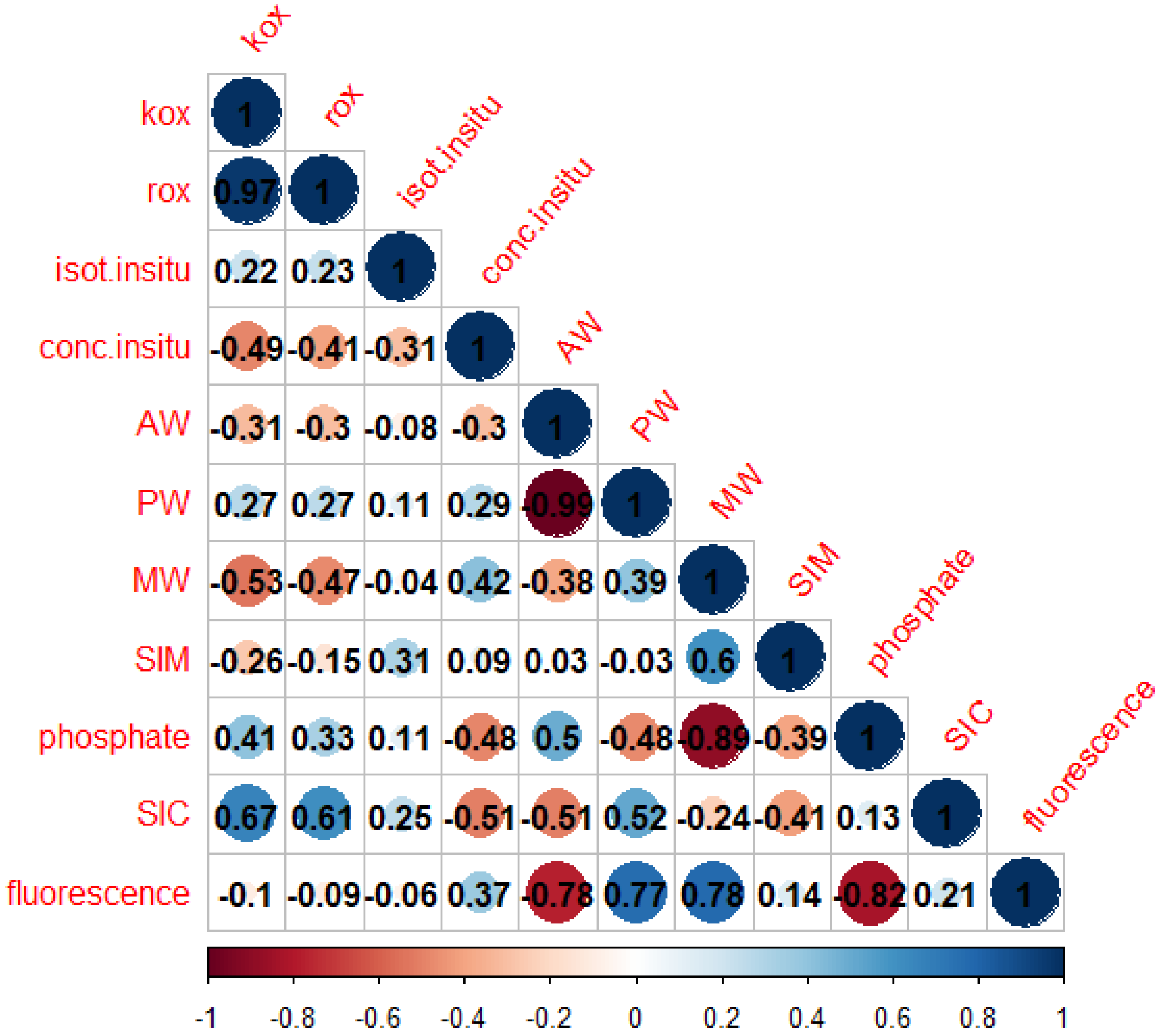
Results from the Northwest Passage Project water samples:

Analyze the methane data in the context of hydrographic features and taxonomical community structure



	kox	rox	isot.insitu	conc.insitu	AW	PW	MW	SIM	phosphate	SIC	fluorescence
kox	1										
rox	0.97	1									
isot.insitu	0.22	0.23	1								
conc.insitu	-0.49	-0.41	-0.31	1							
AW	-0.31	-0.3	-0.08	-0.3	1						
PW	0.27	0.27	0.11	0.29	-0.99	1					
MW	-0.53	-0.47	-0.04	0.42	-0.38	0.39	1				
SIM	-0.26	-0.15	0.31	0.09	0.03	-0.03	0.6	1			
phosphate	0.41	0.33	0.11	-0.48	0.5	-0.48	-0.89	-0.39	1		
SIC	0.67	0.61	0.25	-0.51	-0.51	0.52	-0.24	-0.41	0.13	1	
fluorescence	-0.1	-0.09	-0.06	0.37	-0.78	0.77	0.78	0.14	-0.82	0.21	1

Spearman’s rank of the Northwest Passage Project dataset

- Methane data
  - Dissolved
  - Ex-situ

- Water masses
  - OMP analysis

- Nutrients’ data

- Sea Ice Concentration data

Attività trasversale durante MOSAiC

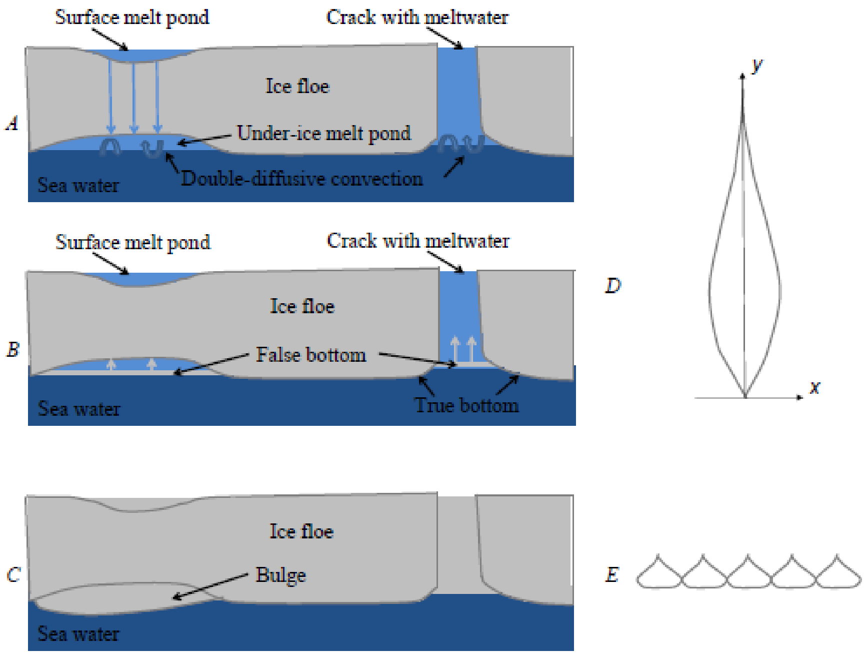


Fig. 2. A scheme of the false bottom formation drawn from Martin and Kauffman (1974) and Notz et al. (2003). **(A)** In the spring–summer time period, surface melt ponds, filled with low salinity meltwater, appear at the atmosphere–ice interface. This meltwater also collects in ice cracks above sea water level. Penetration of surface meltwater through the highly permeable ice matrix leads to the formation of under-ice melt ponds. Double-diffusive convection of heat and salt between this fresh (light) water and underlying salt (dense) water is responsible for the formation of false bottoms (panels **A** and **B**), **(B)** false bottoms grow upward sealing the under-ice pond from below, **(C)** the bottom and surface ponds as well as the water columns in cracks are completely frozen (winter). A slight bulge can be formed due to pressure build-up during the false bottom migration, **(D)** the crystal profile nucleated at the freshwater–seawater interface shown in accordance with the laboratory experiments and theoretical considerations presented by Martin and Kauffman (1974), **(E)** the ice sheet of growing crystals forming a false bottom (only schematic, not drawn to scale). A leveling mechanism of the under-ice topography is caused by the bottom ablation. Alexandrov et al., 2013

What's the methane budget

?

Attività extra-scientifiche…

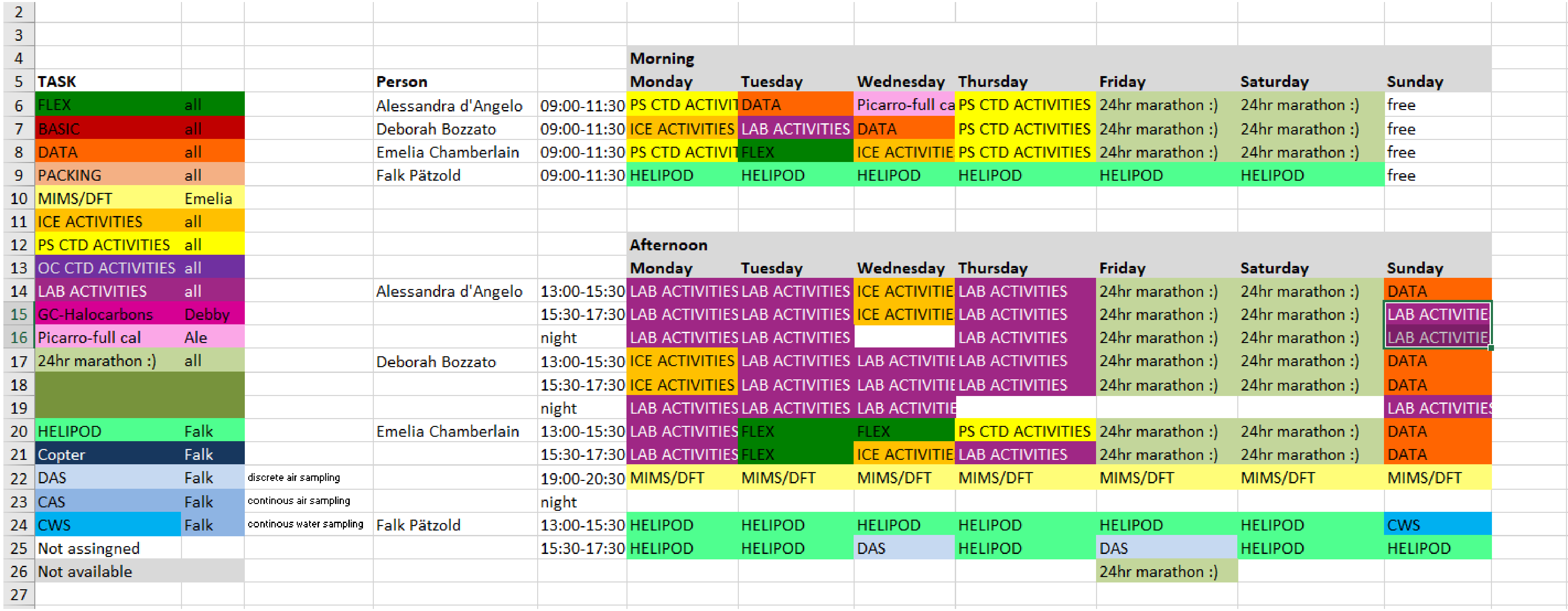
polar guard volunteering

leadership

data management

cargo

Settimana tipo a bordo della R/V Polarstern



2												
3												
4						**Morning**						
5	**TASK**			**Person**		**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
6	FLEX	all		Alessandra d'Angelo	09:00-11:30	PS CTD ACTIVIT	DATA	Picarro-full ca	PS CTD ACTIVITIES	24hr marathon :)	24hr marathon :)	free
7	BASIC	all		Deborah Bozzato	09:00-11:30	ICE ACTIVITIES	LAB ACTIVITIES	DATA	PS CTD ACTIVITIES	24hr marathon :)	24hr marathon :)	free
8	DATA	all		Emelia Chamberlain	09:00-11:30	PS CTD ACTIVIT	FLEX	ICE ACTIVITIE	PS CTD ACTIVITIES	24hr marathon :)	24hr marathon :)	free
9	PACKING	all		Falk Pätzold	09:00-11:30	HELIPOD	HELIPOD	HELIPOD	HELIPOD	HELIPOD	HELIPOD	free
10	MIMS/DFT	Emelia										
11	ICE ACTIVITIES	all										
12	PS CTD ACTIVITIES	all				**Afternoon**						
13	OC CTD ACTIVITIES	all				**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
14	LAB ACTIVITIES	all		Alessandra d'Angelo	13:00-15:30	LAB ACTIVITIES	LAB ACTIVITIES	ICE ACTIVITIE	LAB ACTIVITIES	24hr marathon :)	24hr marathon :)	DATA
15	GC-Halocarbons	Debby			15:30-17:30	LAB ACTIVITIES	LAB ACTIVITIES	ICE ACTIVITIE	LAB ACTIVITIES	24hr marathon :)	24hr marathon :)	LAB ACTIVITIE
16	Picarro-full cal	Ale			night	LAB ACTIVITIES	LAB ACTIVITIES		LAB ACTIVITIES	24hr marathon :)	24hr marathon :)	LAB ACTIVITIE
17	24hr marathon :)	all		Deborah Bozzato	13:00-15:30	ICE ACTIVITIES	LAB ACTIVITIES	LAB ACTIVITIE	LAB ACTIVITIES	24hr marathon :)	24hr marathon :)	DATA
18					15:30-17:30	ICE ACTIVITIES	LAB ACTIVITIES	LAB ACTIVITIE	LAB ACTIVITIES	24hr marathon :)	24hr marathon :)	DATA
19					night	LAB ACTIVITIES	LAB ACTIVITIES	LAB ACTIVITIE				LAB ACTIVITIES
20	HELIPOD	Falk		Emelia Chamberlain	13:00-15:30	LAB ACTIVITIES	FLEX	FLEX	PS CTD ACTIVITIES	24hr marathon :)	24hr marathon :)	DATA
21	Copter	Falk			15:30-17:30	LAB ACTIVITIES	FLEX	ICE ACTIVITIE	LAB ACTIVITIES	24hr marathon :)	24hr marathon :)	DATA
22	DAS	Falk	discrete air sampling		19:00-20:30	MIMS/DFT	MIMS/DFT	MIMS/DFT	MIMS/DFT	MIMS/DFT	MIMS/DFT	MIMS/DFT
23	CAS	Falk	continous air sampling		night							
24	CWS	Falk	continous water sampling	Falk Pätzold	13:00-15:30	HELIPOD	HELIPOD	HELIPOD	HELIPOD	HELIPOD	HELIPOD	CWS
25	Not assingned				15:30-17:30	HELIPOD	HELIPOD	DAS	HELIPOD	DAS	HELIPOD	HELIPOD
26	Not available									24hr marathon :)		
27												

End of the MOSAiC floe, 31 July 2020

Grazie per l’attenzione!

Acknowledgments:

- Prof. Brice Loose and MethOx project team
- National Science Foundation and Alfred Wegener Institute
- Leg 4 Cruise and Co-Cruise Leaders, Markus Rex and Mathew Shupe
- The Polarstern crew
- The Leg 4 colleagues
- The leg 4 polar bear guards
- BGC team members
- Voi, per avermi invitato ☺