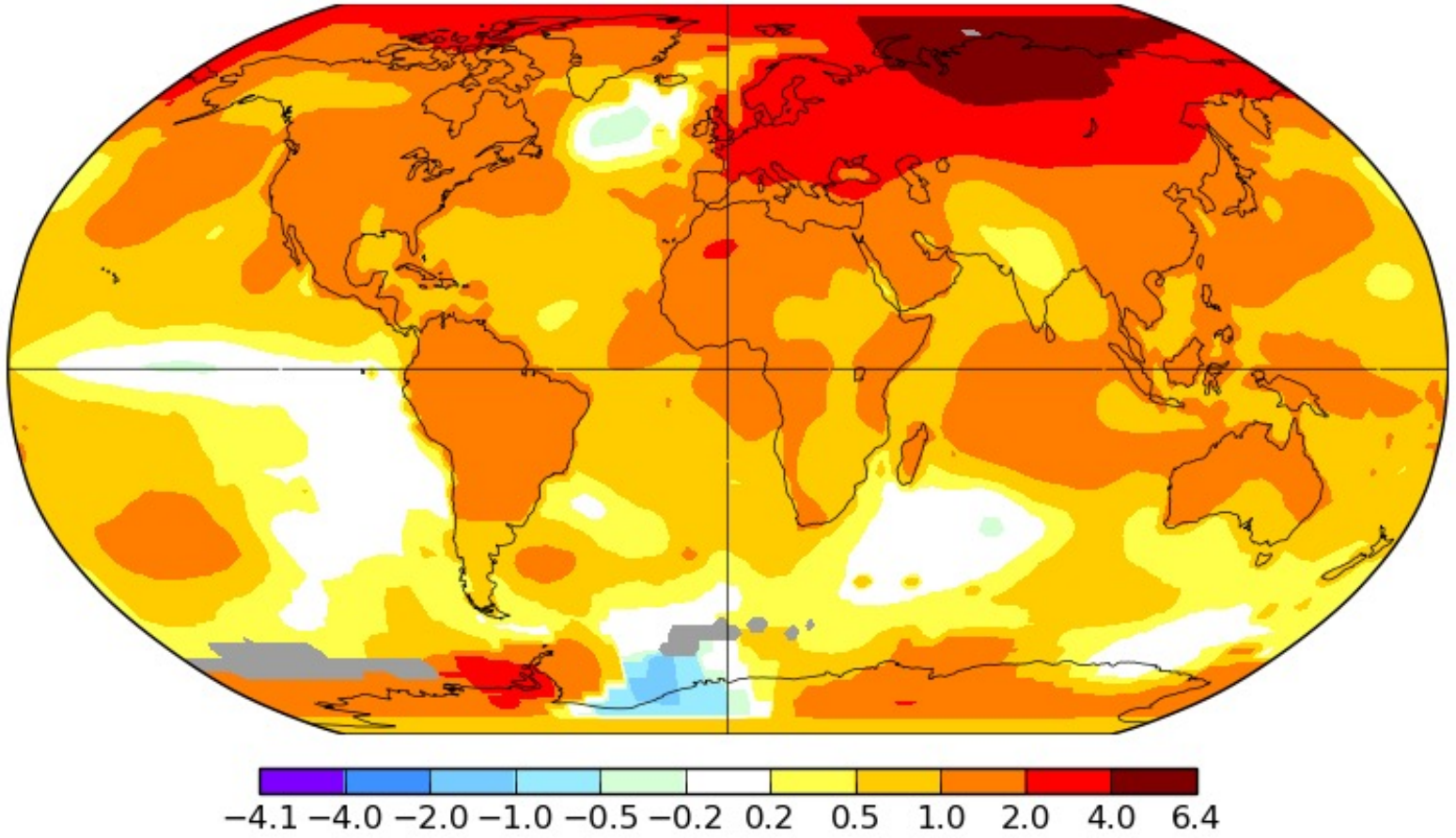
M. Nicolaus
and the MOSAiC team

MOSAiC
The greatest Arctic expedition of our time


Photo: M. Nicolaus

The Arctic: Epicenter of global warming

Source: data.giss.nasa.gov/gistemp/maps/



Observed temperature change in 2020 [°C]
(compared to 1951-1980)

Surface air temperature in the Arctic

… has increased by more than double the global average over the last two decades

… has exceeded 2 °C already now

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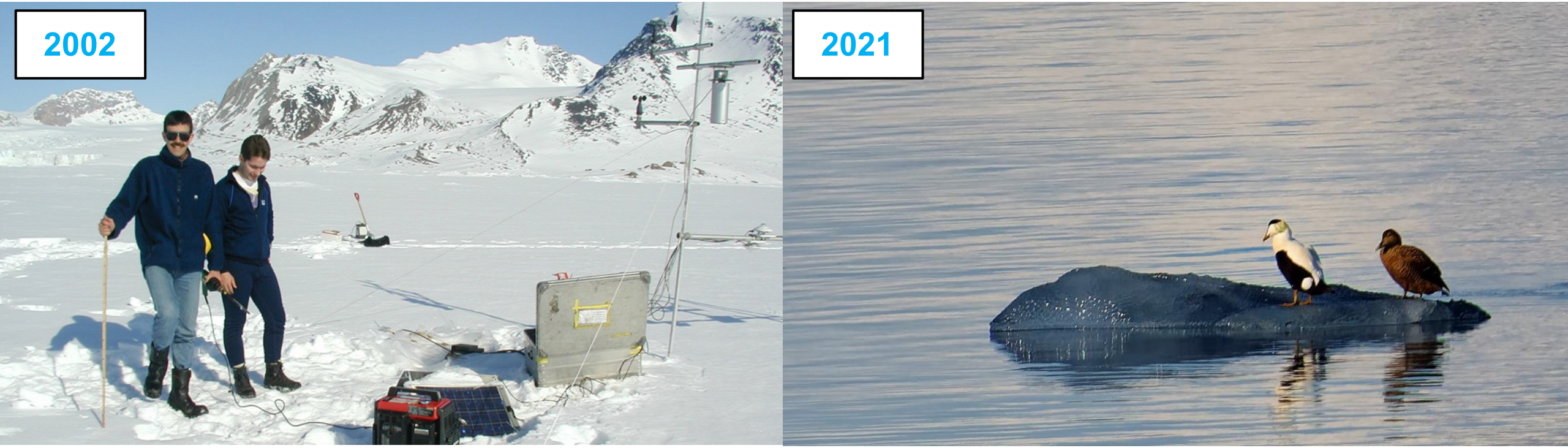
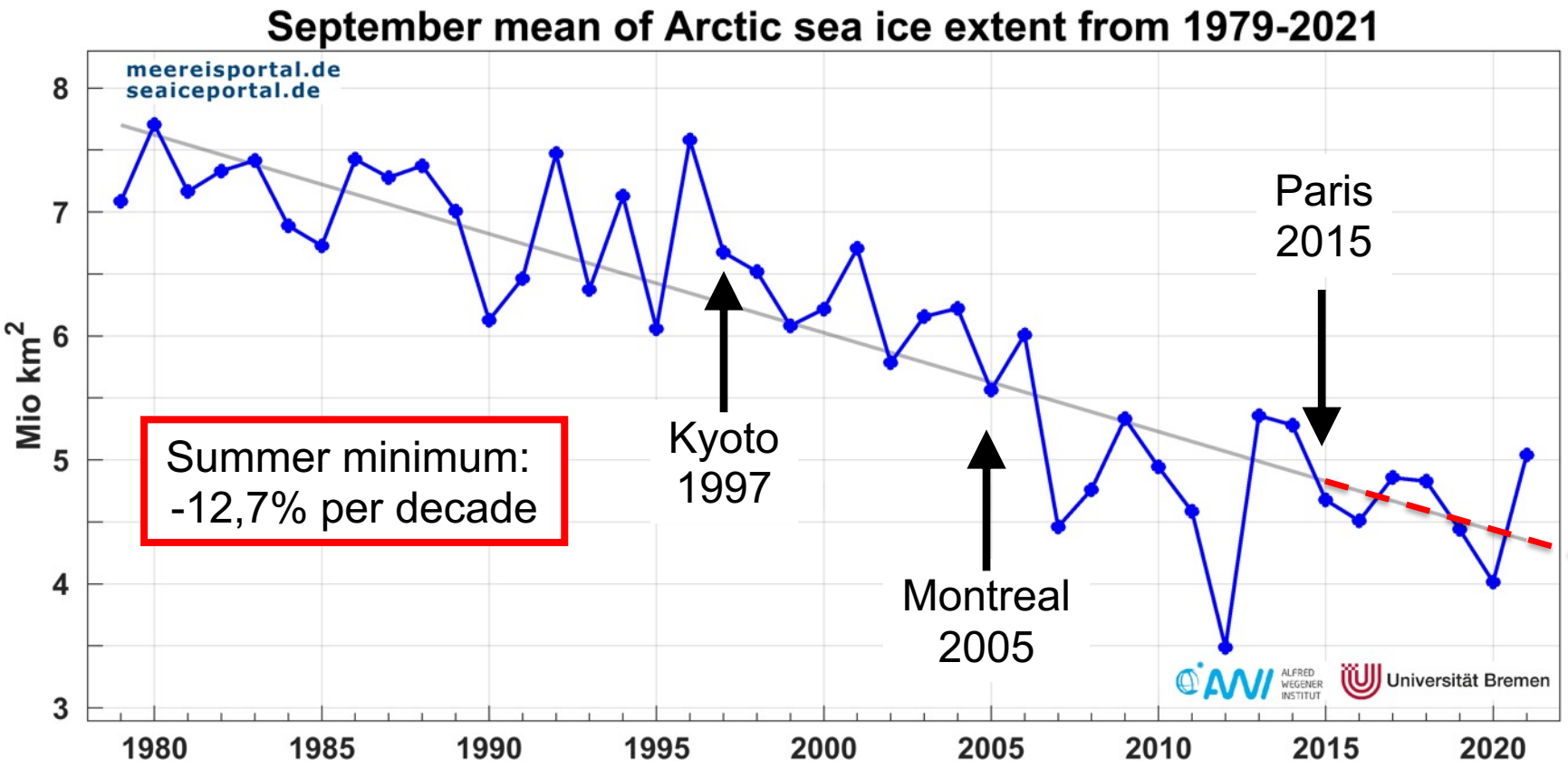
Arctic change is dramatic

"What used to be skidoo or skiing trips are boat trips now"



Spring in Kongsfjorden, Svalbard

The future of Arctic sea ice



IPCC 2021:
The Arctic is likely to be practically sea ice free in September at least once before 2050 under all scenarios

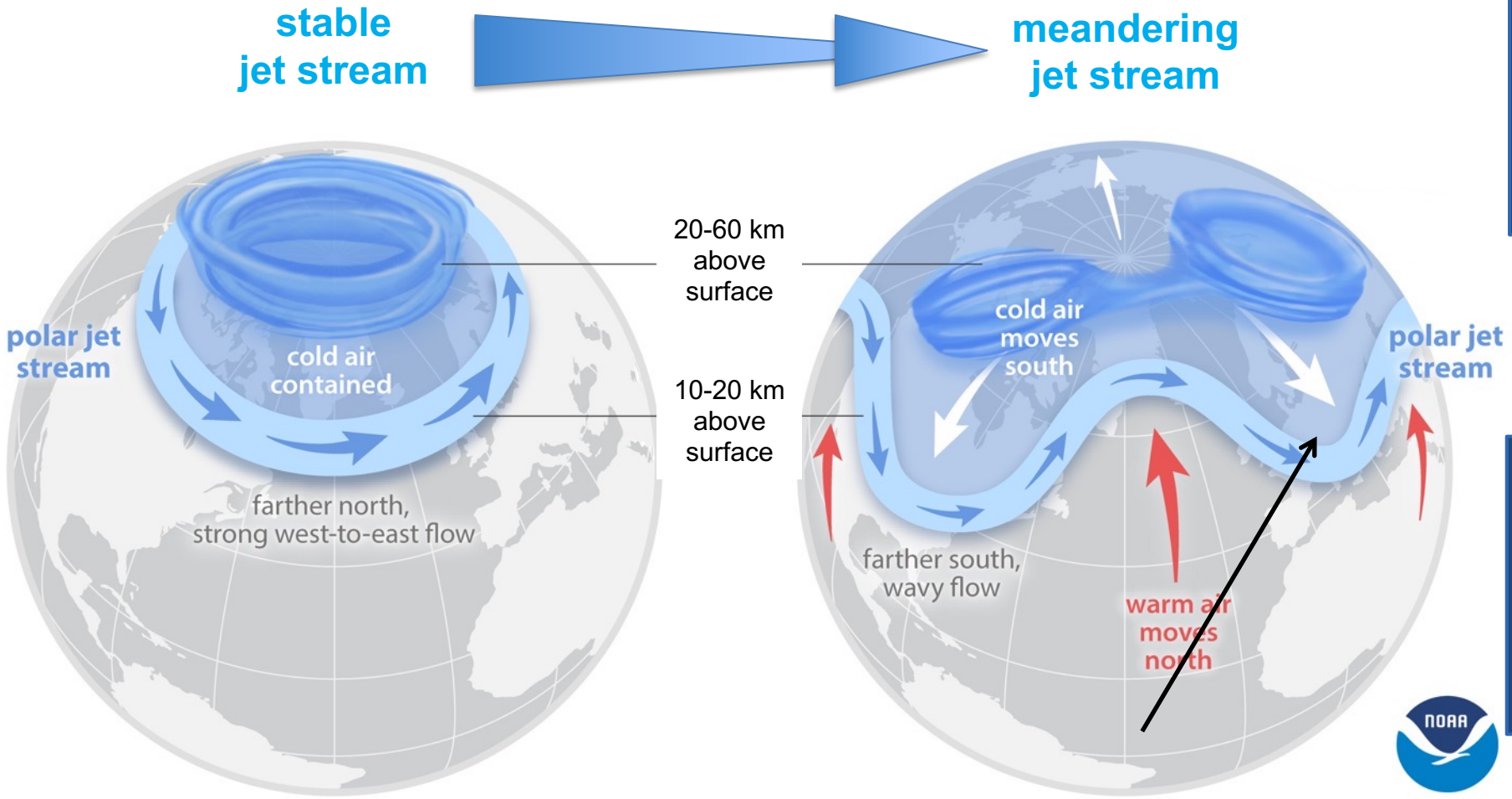
Changes also in sea ice volume, timing and properties

2050? 2070?

Source: www.meereisportal.de

Consequences for lower latitudes

More extremes

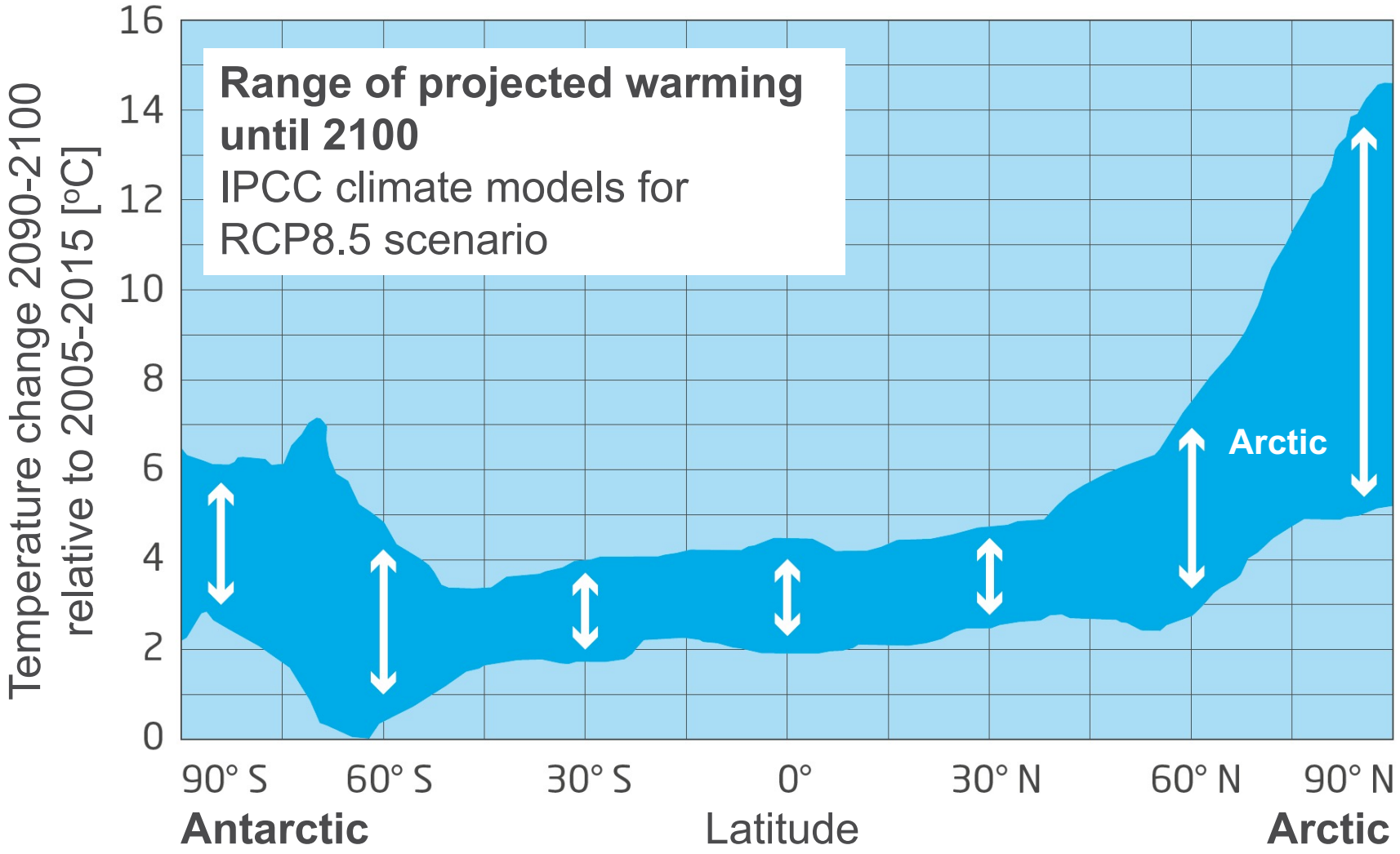


Potential for cold air outbreaks => Cold spells in Europe and US

Warm and humid air advection into the Arctic

Source: www.climate.gov/media/11999

Largest uncertainties of climate projections

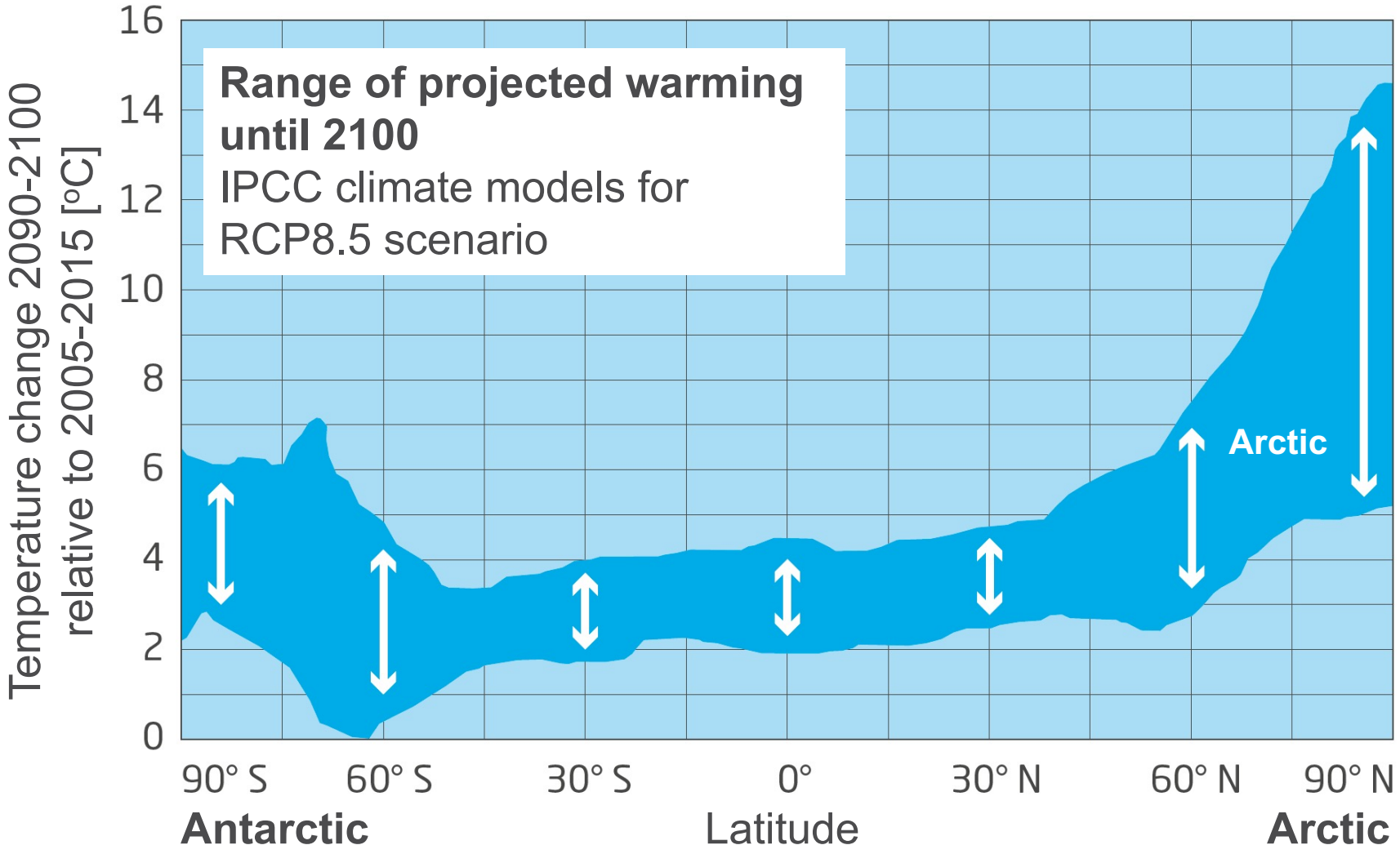


Warming of more than 2 °C in most regions

Arctic warming: 5 to 15 °C

Huge uncertainty in the Arctic

Largest uncertainties of climate projections



Many processes in the Arctic climate system only roughly represented in Climate Models

Understanding of key climate processes in the Arctic is limited by lack of observations!

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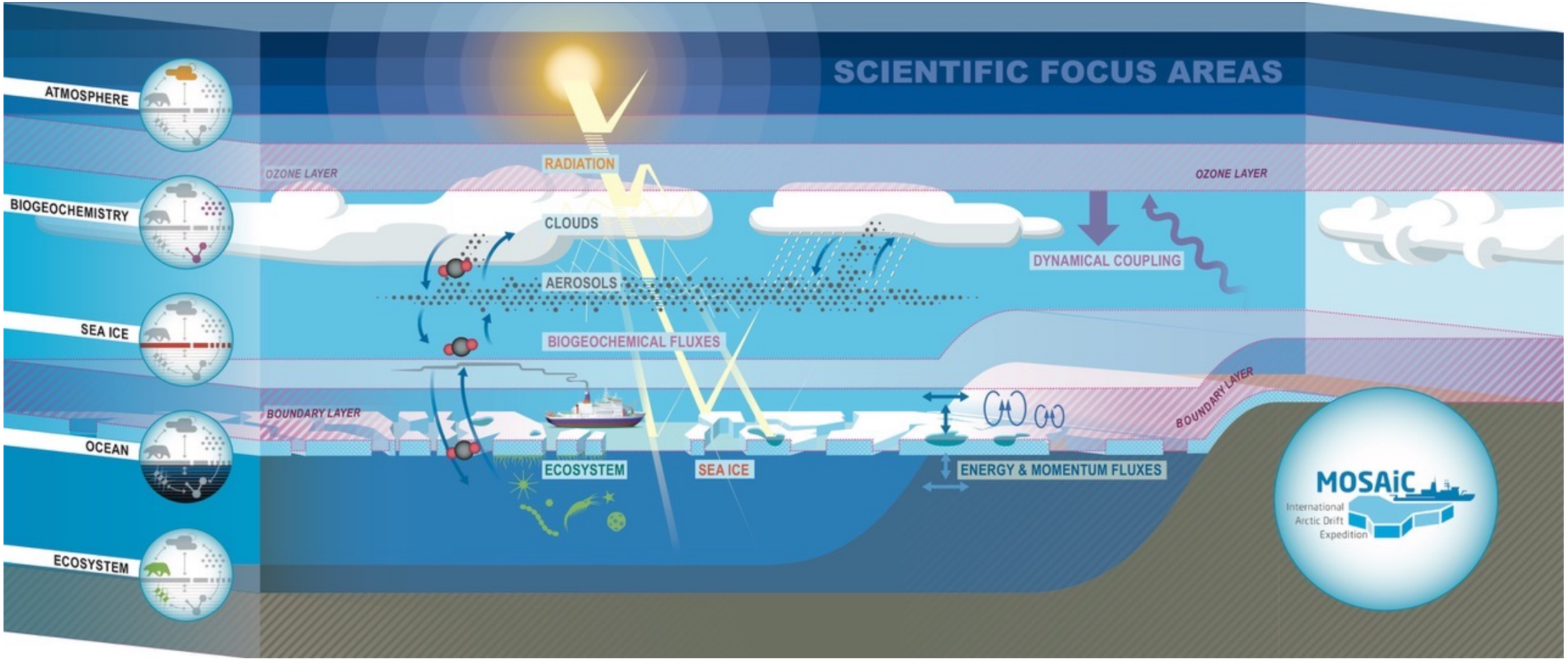
The challenge: Our future



- Better understand the coupled system
- Improved forecasts with reduced uncertainties

Graphic: M. Künsting (AWI)

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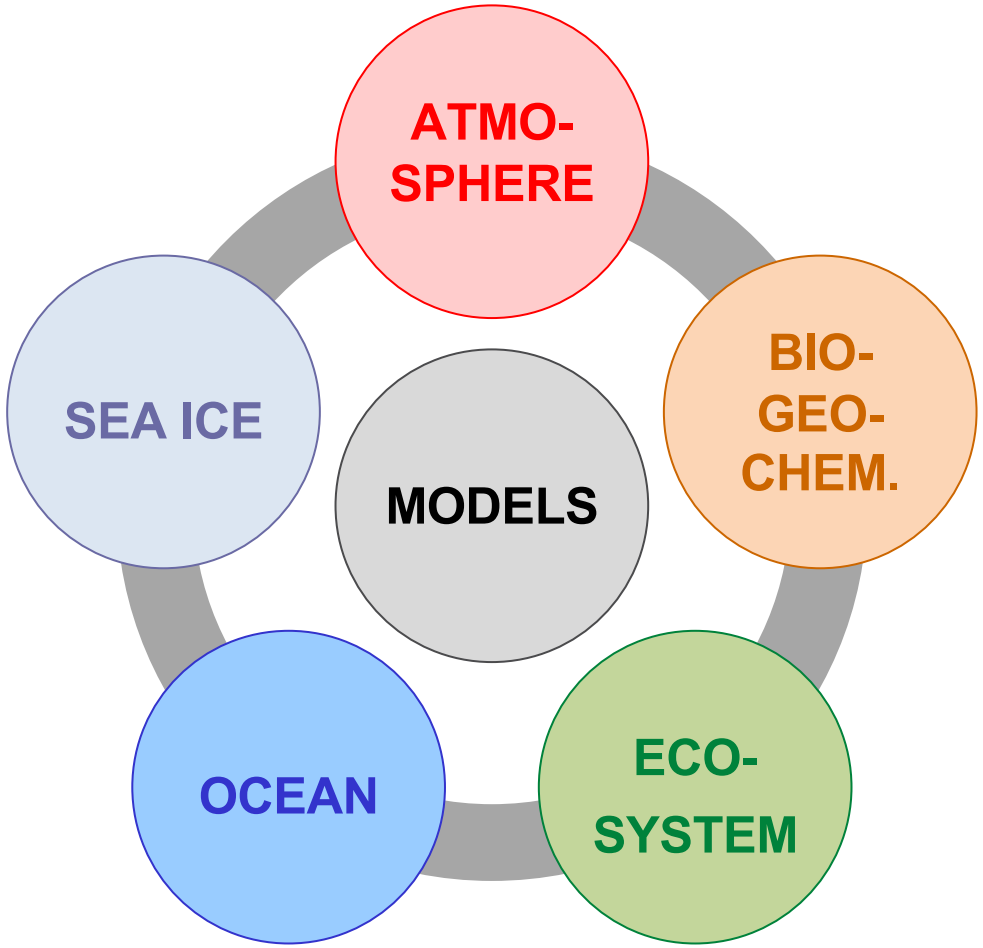
What are the causes and consequences of the Arctic sea ice retreat?

Five teams --- One mission



Specific challenges

- Energy exchange between atmosphere, sea ice and ocean ?
- Formation, properties and life cycle of clouds and aerosols ?
- Exchange rates of (climate) gases ?
- Reaction of the eco-system to environmental changes ?
- Global consequences of Arctic change ?

Understanding the mechanics of the Arctic climate system

Illustration: Lianna Nixon

Need of field observations
- All seasons
- All disciplines => linkages
- All scales

Need of models
- Describe processes
- Couple the components
- Enable reliable predictions

Need of an expert consortium

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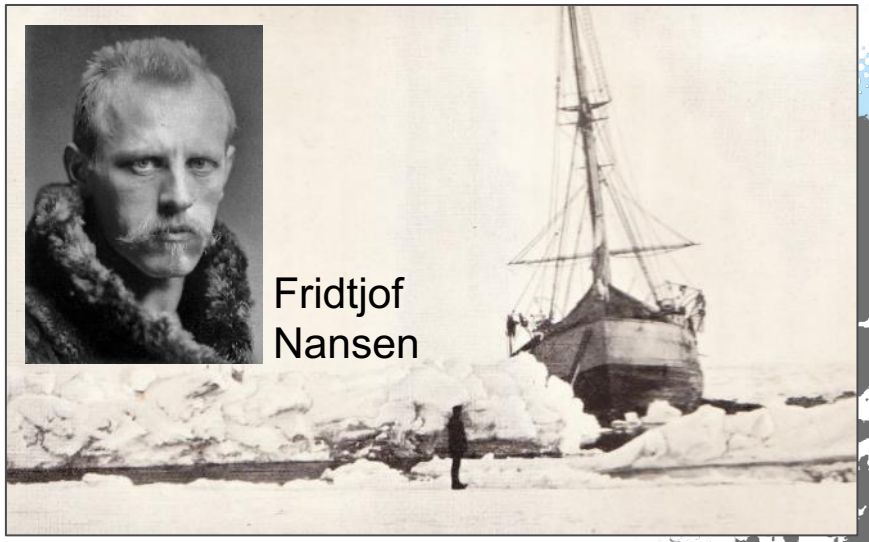
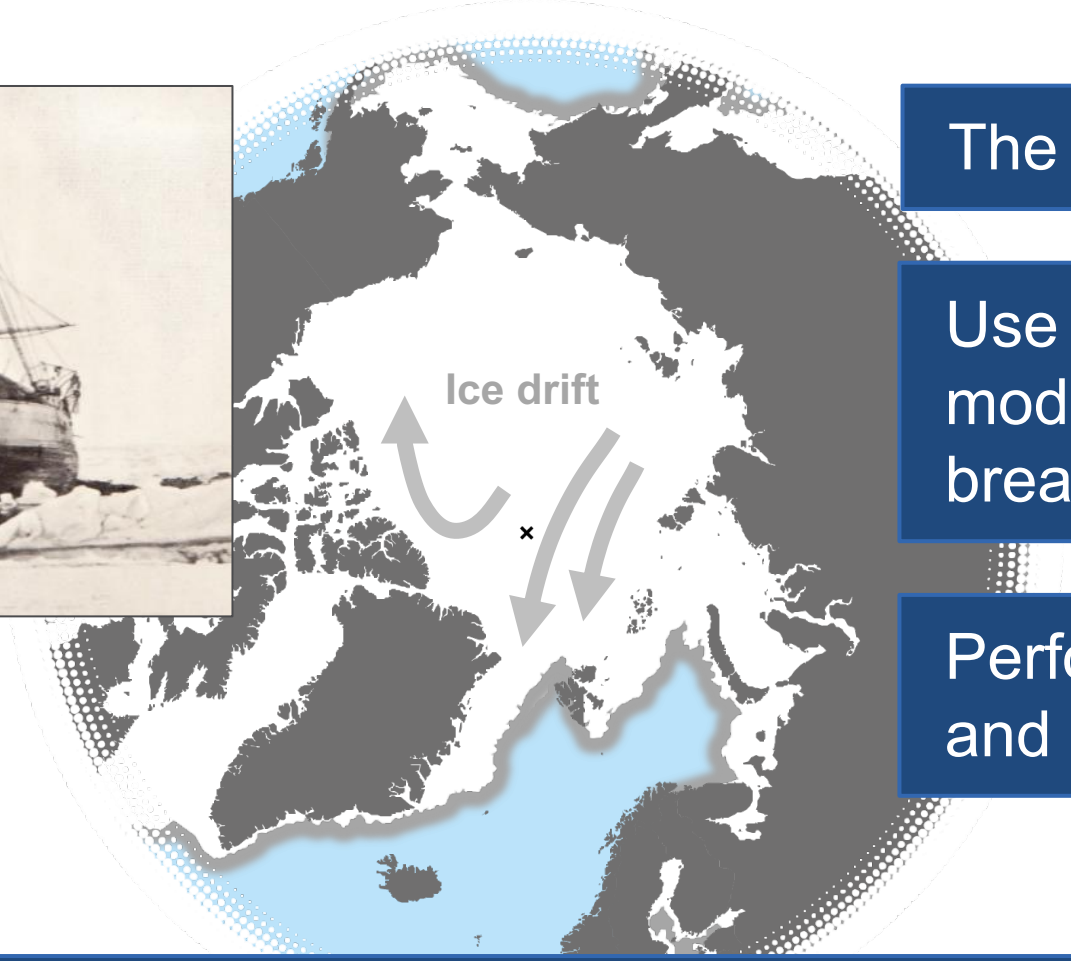
The MOSAiC-Expedition

How can we observe and reach the central Arctic in winter?



1893-1896: Fram-Expedition



- The legacy of F. Nansen
- Use a fully equipped modern research ice breaker
- Perform a well coordinated and consistent program

MOSAiC: Multidisciplinary drifting Observatory for the Study of the Arctic Climate

The largest Arctic expedition ever

- 7 icebreakers & research vessels
- 90 institutions
- 20 nations, 37 on board
- 450 people

One mission:
Explore the climate processes of the central Arctic year round

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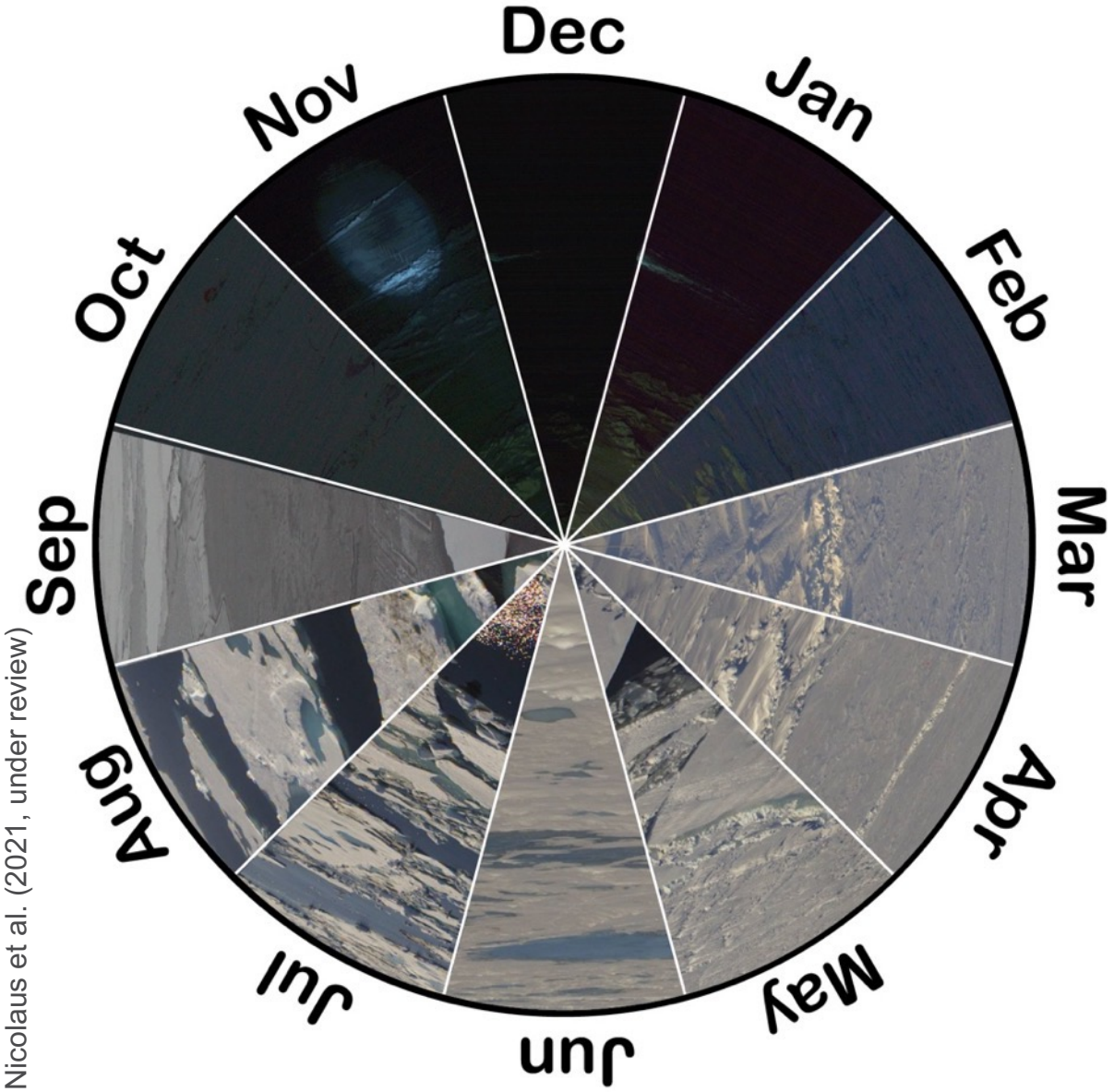
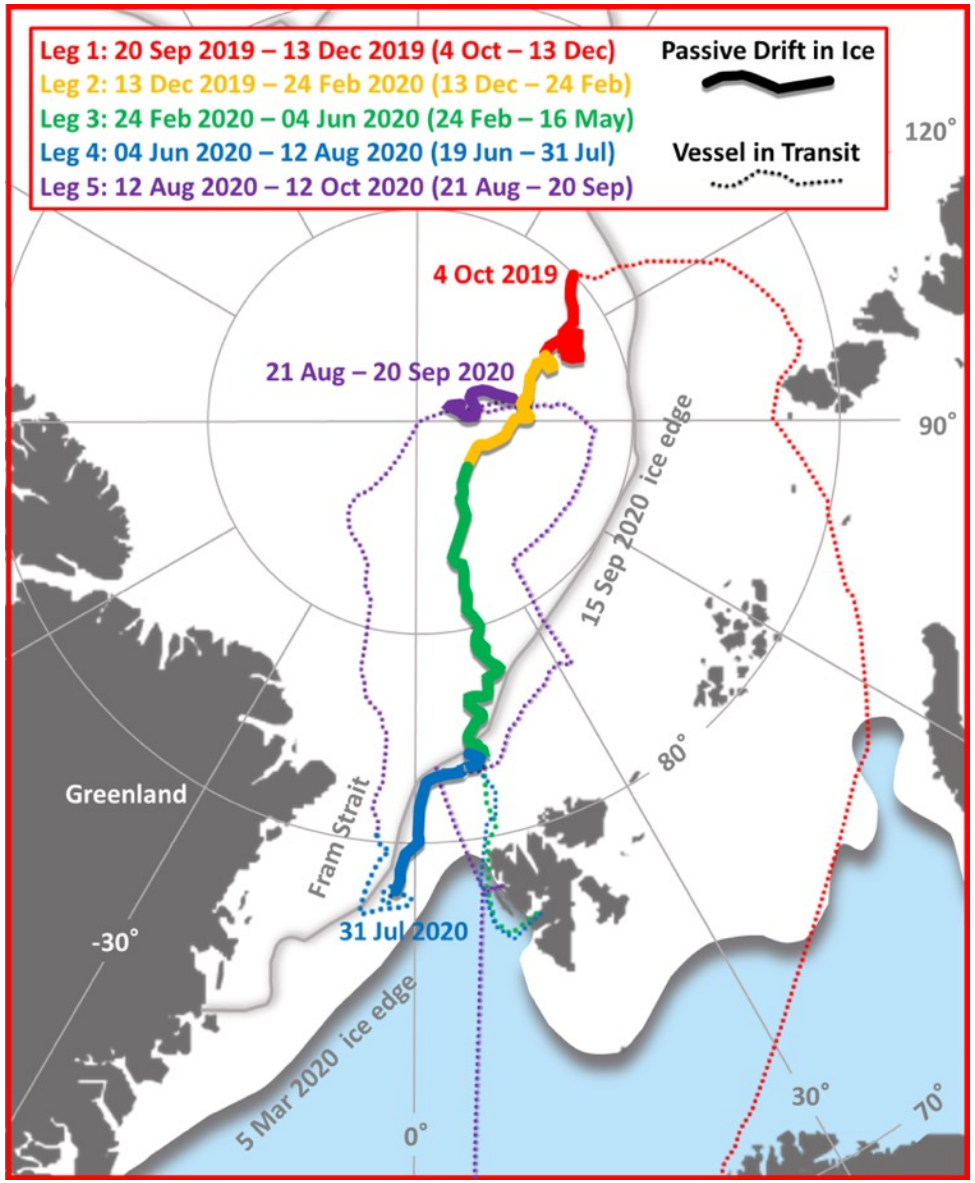
One year in the Arctic Ocean



Nicolaus et al. (2021, under review)



Shupe et al. (2020)

3 October 2019: Last exchange with Ak. Fedorov

Photo: M. Rex

4 October 2019: First day on floe and last ray from sun

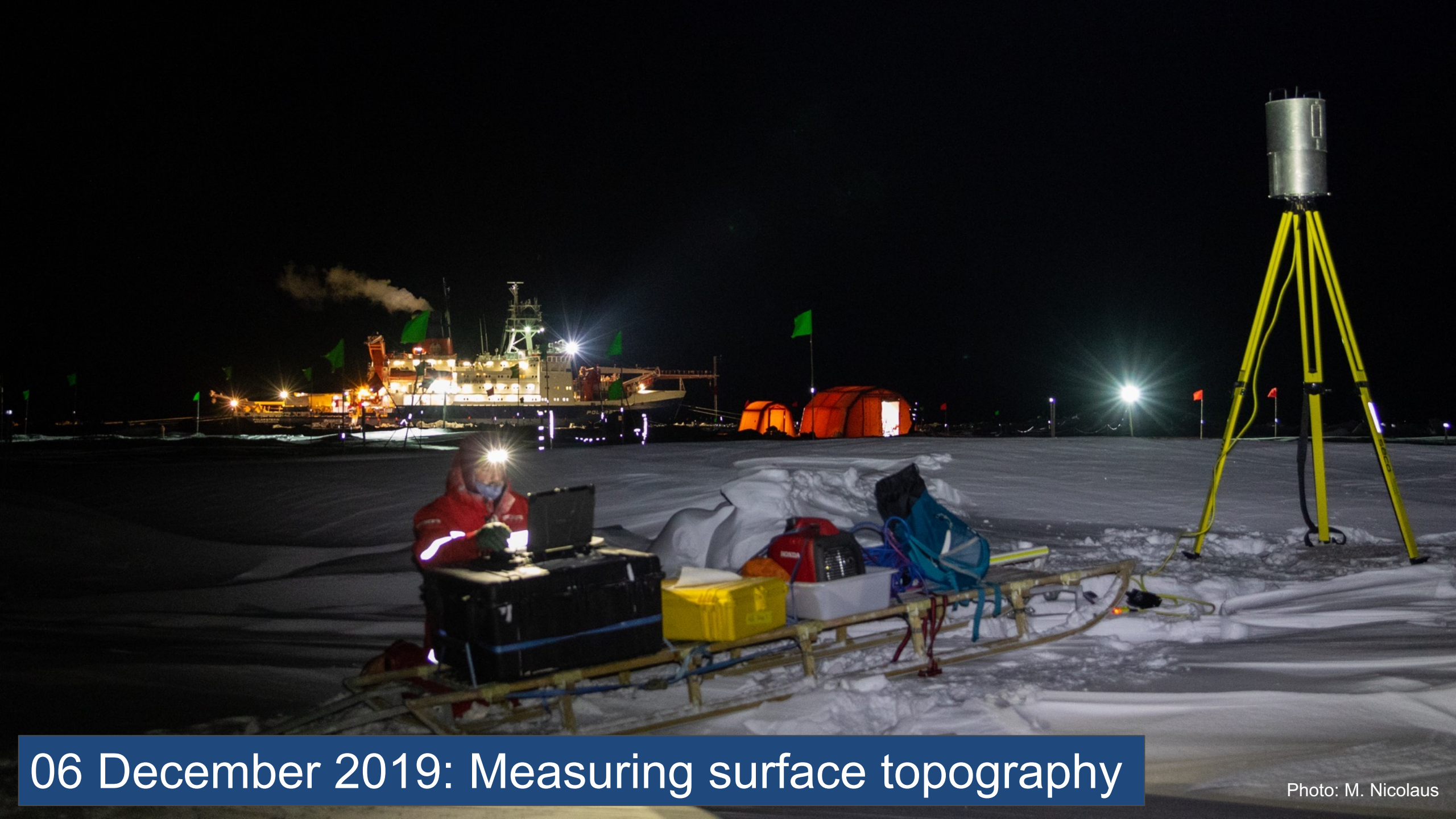
Photo: M. Rex

16 October 2019: Securing equipment from ridges

Photo: S. Hendricks

28 October 2019: Ice coring at the “dark site”

Photo: J. Creamean



06 December 2019: Measuring surface topography

Photo: M. Nicolaus

28 February 2020: Exchange in winter at 88.5°N

Photo: UFA Show Facutal

5 March 202: Balloon town at twilight

Photo: M. Gutsche

10 March 2020: Ice Camp after sun rise

Photo: M. Ernst

16 April 2020: Snow sampling and measurements

Photo: S. Fons

1 May 2020: Sea ice thickness survey

Photo: C. Rohleder

4 June 2020: Rotation in Svalbard

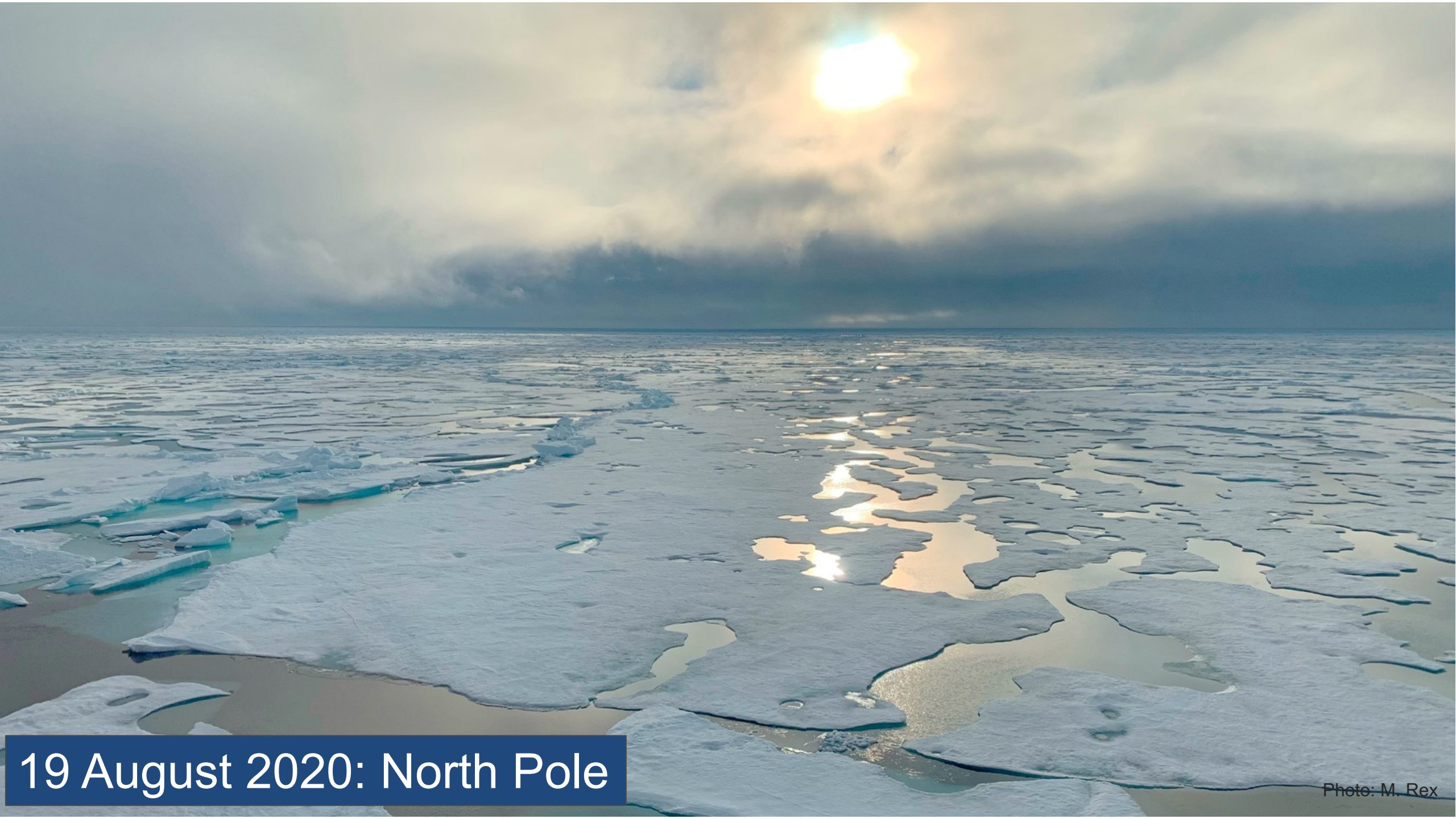
Photo: M. Ernst

30 June 2020: Summer melt

Photo: M. Rex

31 July 2020: Decay of the MOSAiC floe

Photo: M. Rex


19 August 2020: North Pole
Photo: M. Rex

21 August 2020: Drift with the new floe

Photo: M. Nicolaus

10 September 2020: Freezeup

Photo: S. Graupner

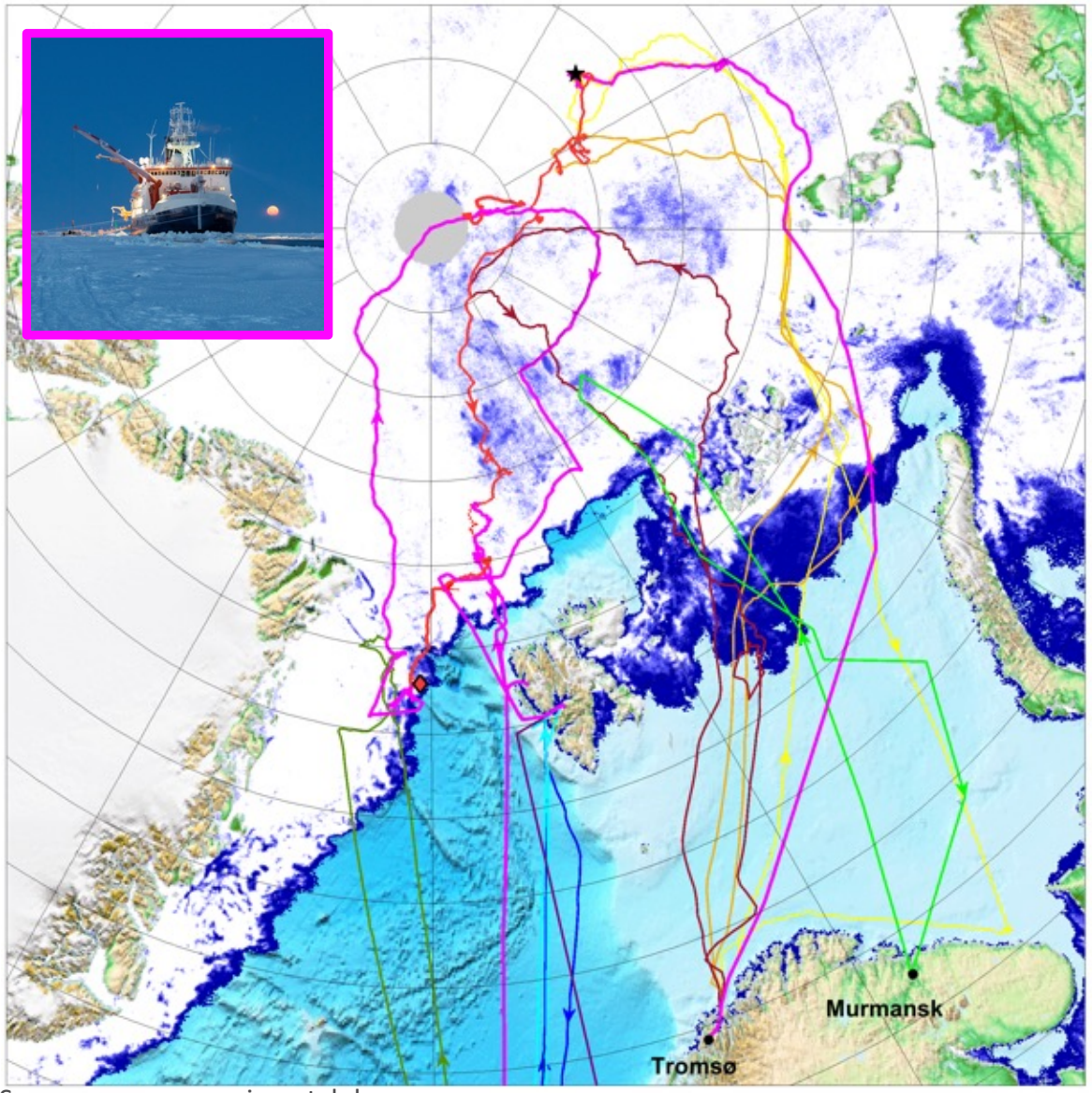
20 September 2020: Last day on the ice

Photo: M. Rex

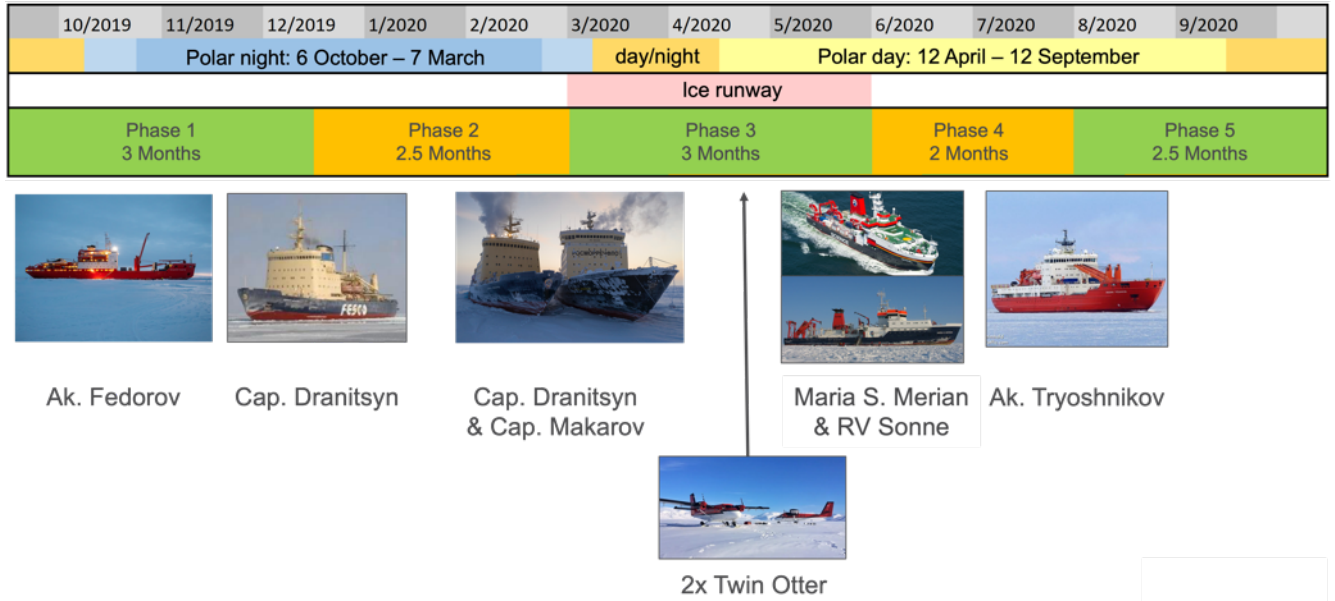
12 October 2020: Reception in Bremerhaven

Photo: M. Nicolaus

Logistics in the Arctic Ocean

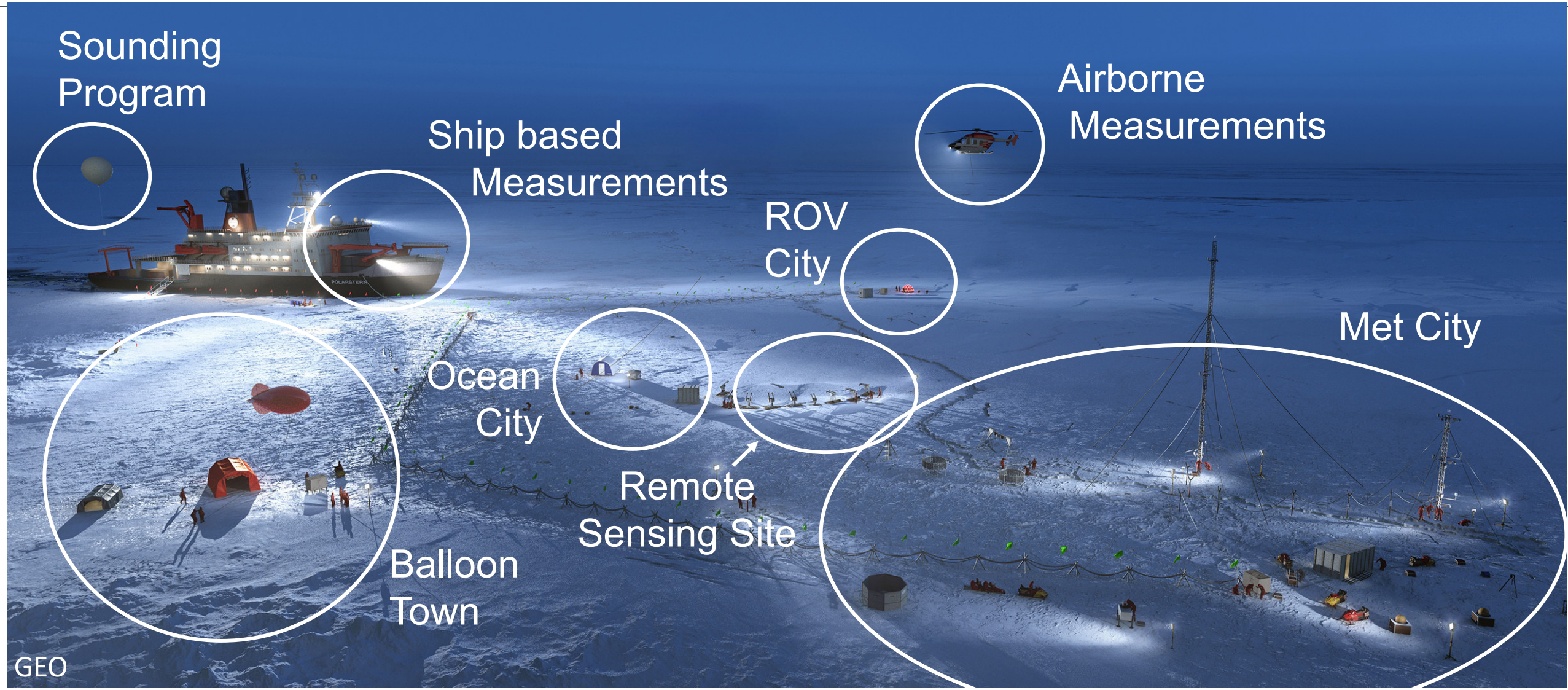


Source: www.meereisportal.de

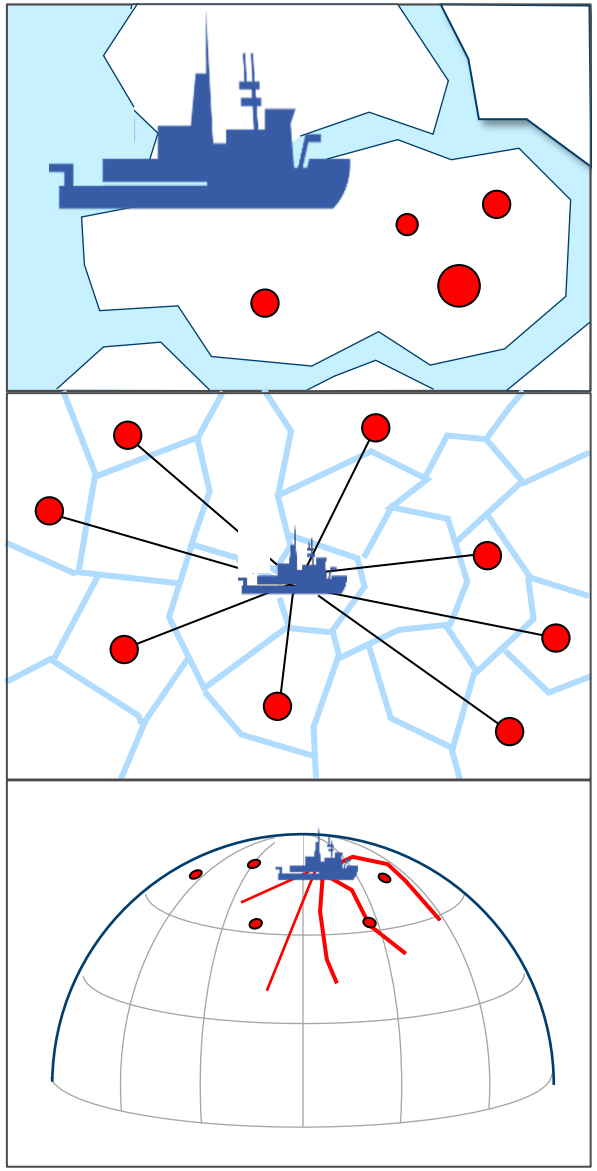


Unique logistical challenges
(… during the pandemic …)

Our city on the ice



Nested multiscale observations



Local: Central Observatory
- Ship based
- Central ice camp
- ➢ Process scale observations

< 5 km

Regional: Distributed Network
- Sea ice stations visited by helicopter
- Unmanned aircrafts
- Process & regional model
- ➢ Model grid cell

< 50 km

Arctic-wide linkages
- Measurements on supply vessels
- MOSAiC Aircraft campaign late summer 2020
- Arctic buoys, satellites
- ➢ Regional & global climate models

> 1000 km

Isolation

The expedition is in the hands of nature. The drift follows the natural movement of the ice, driven by winds and currents. It is completely isolated, with the next humans being 1000km away.

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Darkness

The polar night results in complete darkness between October and February. All work is carried out with the help of headlamps, creating small bubbles of light in the vast darkness.

Ice Camp

- 100t scientific equipment, 5km power lines, 70kW electrical power on ice.
- Continuous measurements of over 100 climate parameters to support modelling of dozens of climate processes.
- Dozens of first observations.

Cold

Temperatures of down to -40°C together with high wind speeds lead to wind chill temperatures below -55°C. Frostbites occur on unprotected skin within seconds.

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Storms

Fierce storms destroy infrastructure on the ice, power lines and scientific instruments. Snow drift massively affects visibility and make work on the ice extremely hard.

Pressure ridges

Pressure ridges form as the result of pressure in the ice within minutes. Some reach heights of a two story building. They bury power lines, tracks and instruments.

Cracks

Due to climate change the ice is thin and dynamic. New cracks form on a near daily basis. Sometimes parts of the ice floe move by several hundred meters relative to the ship or the main camp.

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Polar bears

The central Arctic is polar bear habitat. They are extremely curious and frequently explore the research camp. But they could attack humans. Permanent polar bear protection is essential.

Melt ponds

The summer sea ice surface is characterized by melt ponds. They form from melting snow and ice. They control most energy fluxes, create a fascinating landscape and make travelling across the ice most challenging.

Direct impressions from the Arctic

Illustration: Lianna Nixon

Winter:
Temperatures have been almost 10°C higher than during Fridtjof Nansen‘s expedition 130 years ago. The ice was only half as thick.

Summer:
We have seen the Arctic ice disappearing. If climate change continues like this, the Arctic will become ice free in summer in a few decades.

Understanding the mechanics of the Arctic climate system

Illustration: Lianna Nixon

Data set for generations
- 150 terabyte of scientific data
- 30,000 of samples from the atmosphere, snow, ice, ocean

will allow us to represent these processes much better in our climate models.

Already >30 (peer reviewed) scientific publications

High-impact news and media products

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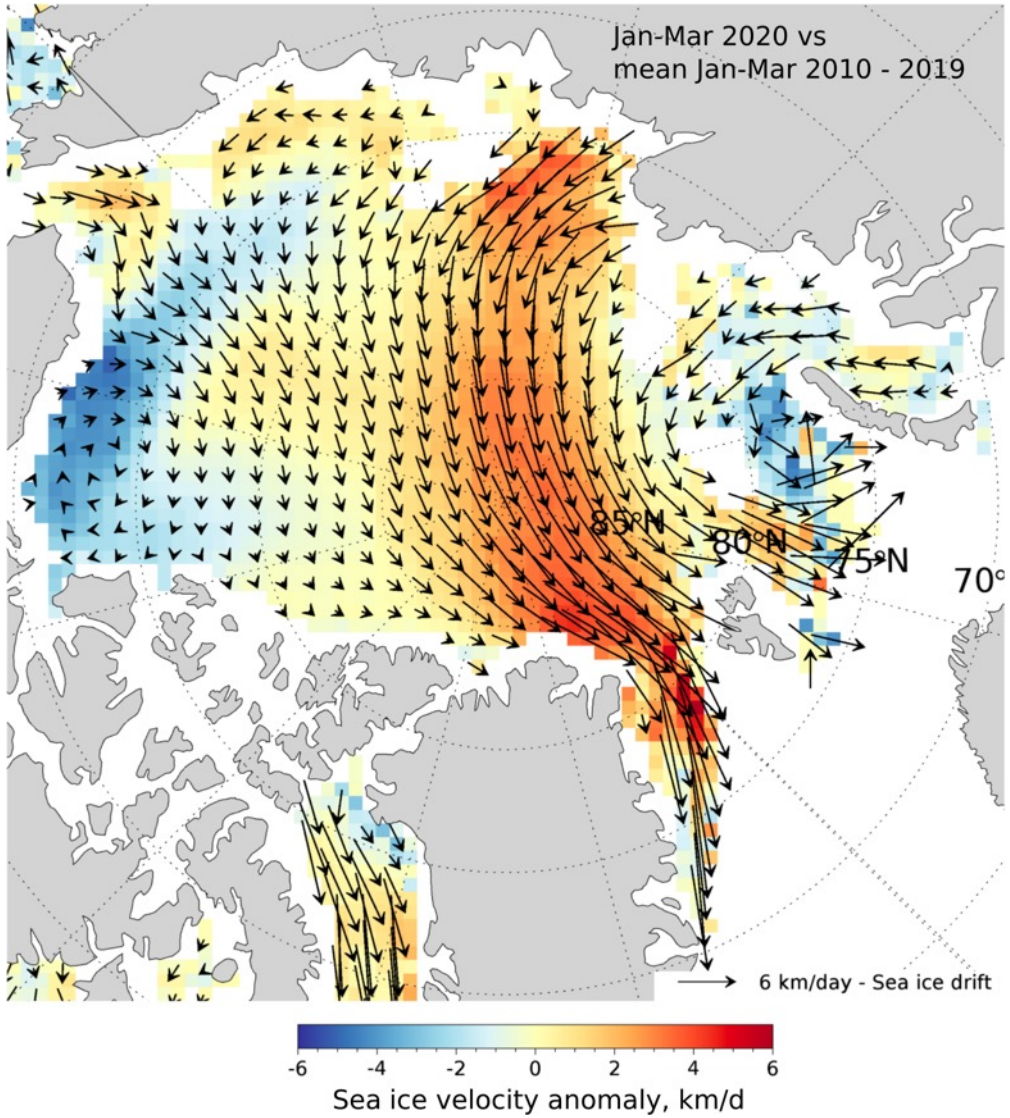
New scientific insights

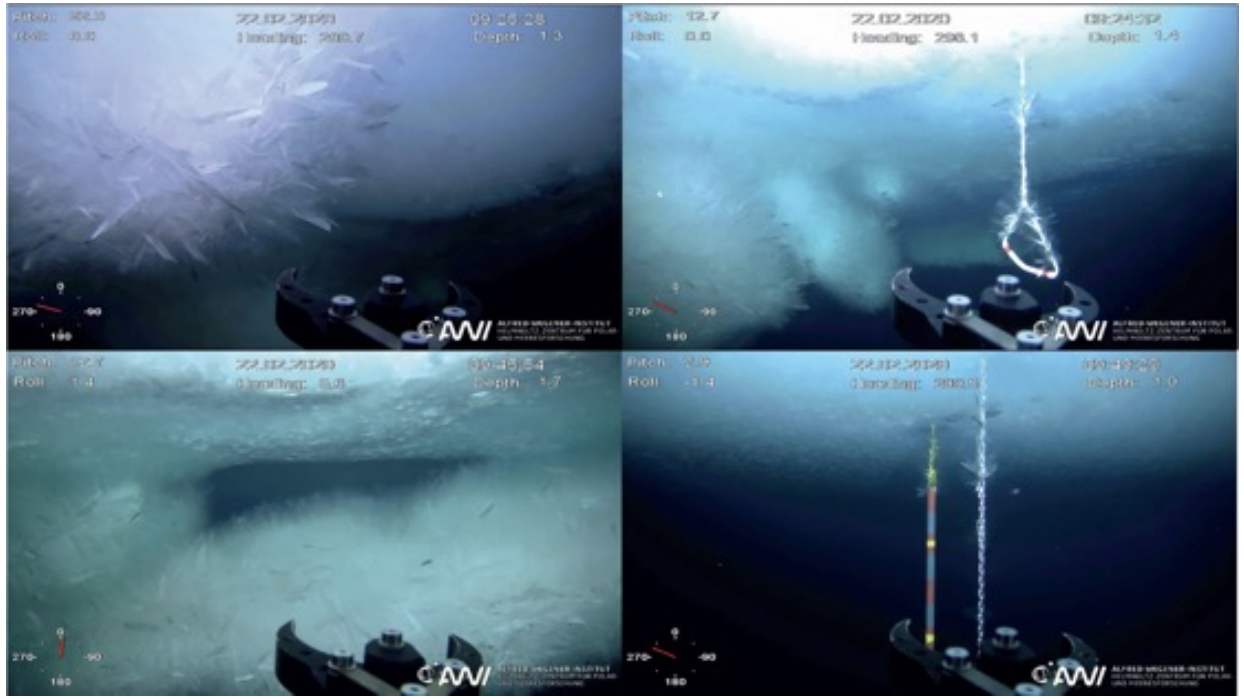
Krumpen et al. (2021)



Fast drift and high dynamics of sea ice

New scientific insights

Katlein et al. (2020)



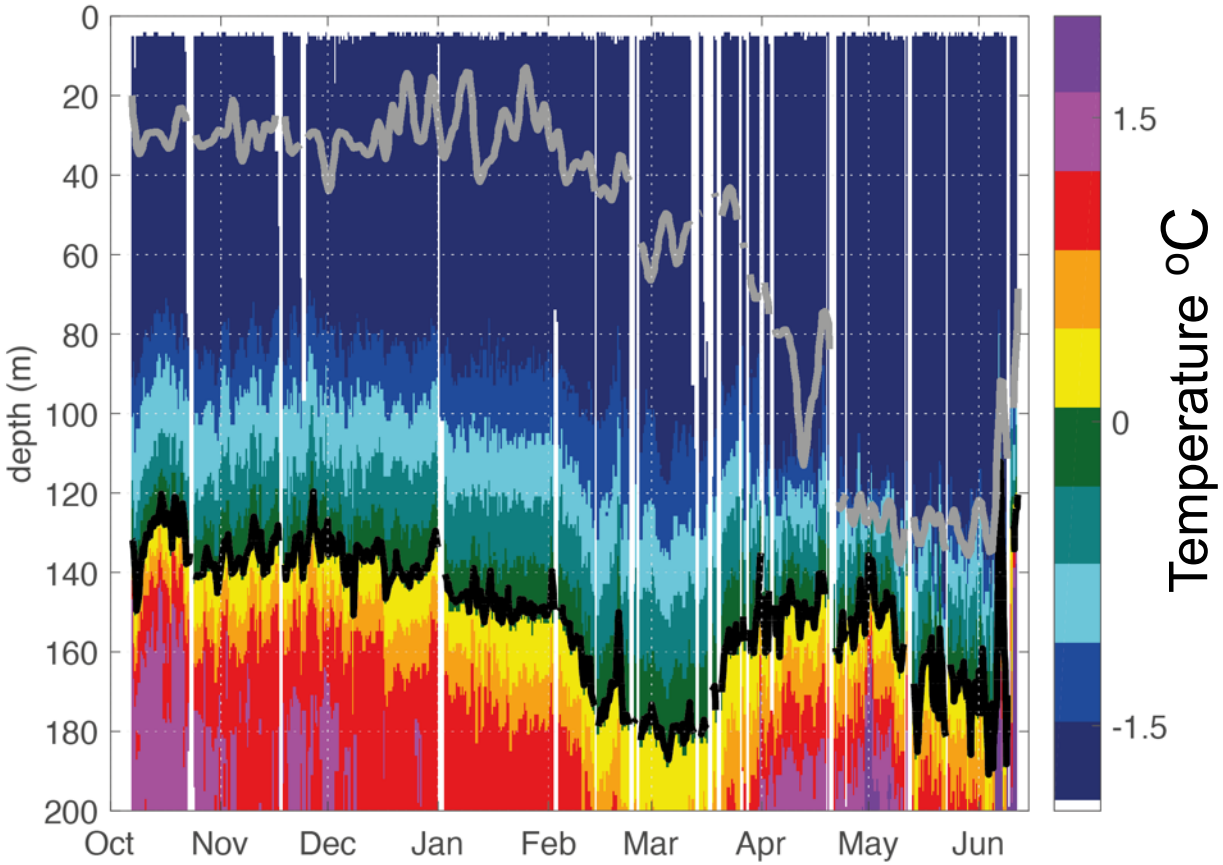
Fast drift and high dynamics of sea ice

Unknown and hidden winter processes and properties

New scientific insights

Rabe et al. (2021, under review)
Belter et al. (2021)

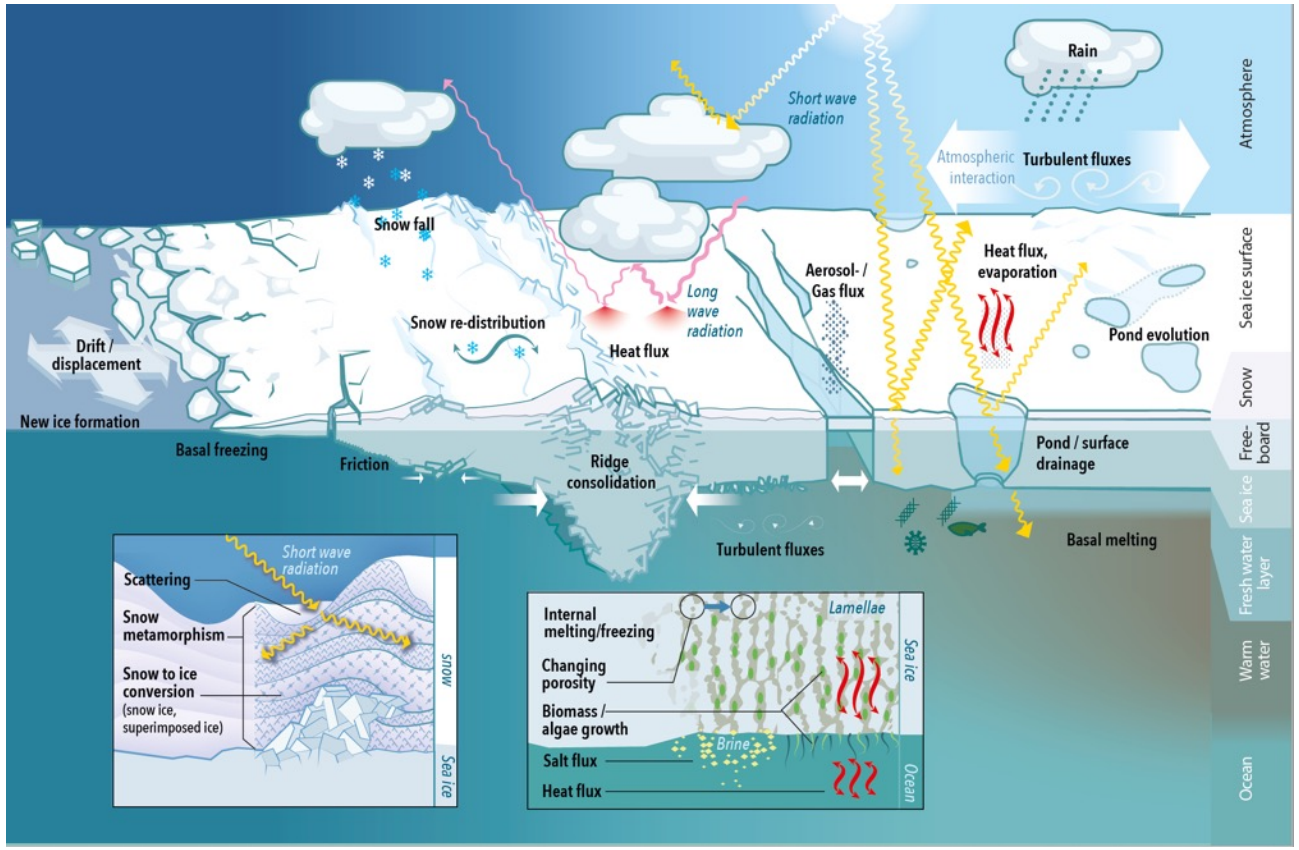
Ocean temperature during MOSAiC from autonomous measurements



- Fast drift and high dynamics of sea ice
- Unknown and hidden winter processes and properties
- Increased heat input from the ocean into the ice

New scientific insights

Nicolaus et al. (2021, under review)



- Fast drift and high dynamics of sea ice
- Unknown and hidden winter processes and properties
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New scientific insights

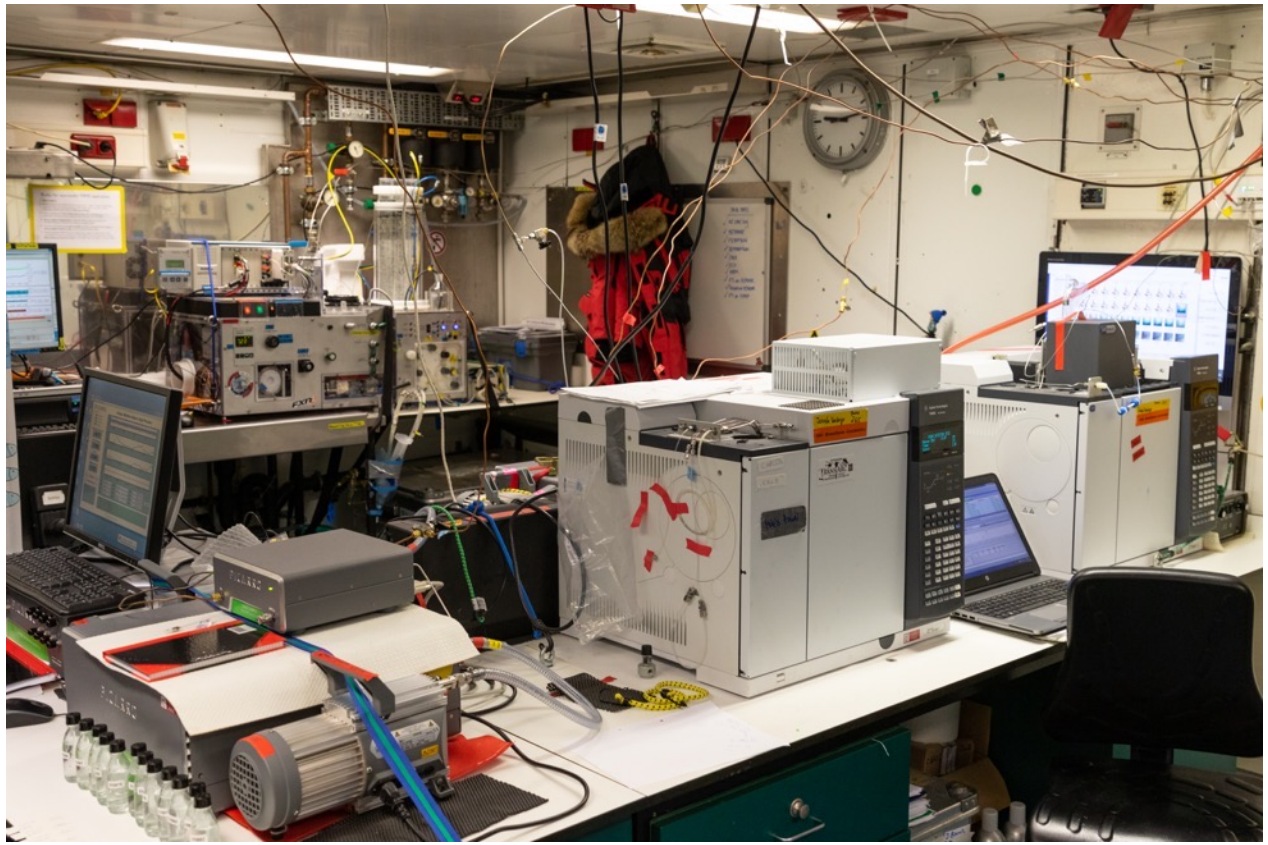

Photo: M. Nicolaus

- Fast drift and high dynamics of sea ice
- Unknown and hidden winter processes and properties
- Increased heat input from the ocean into the ice
- New description of snow accumulation on sea ice
- Pathways of trace gases (CO_2, methane) through the Arctic

What‘s next?

Involving indigenous communities

Courtesy: M. Karcher (AWI)

New EU-funded project, goal:

To achieve Arctic observations together with indigenous representatives to combine all forms of knowledge for environmental monitoring and finding solutions.

MOSAiC International Arctic Drift Expedition

AWI

Thanks to all MOSAiC participants & crew members, topic leads and teams on land

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