Bridging the gap: gathering observational data for model evaluation and improvement

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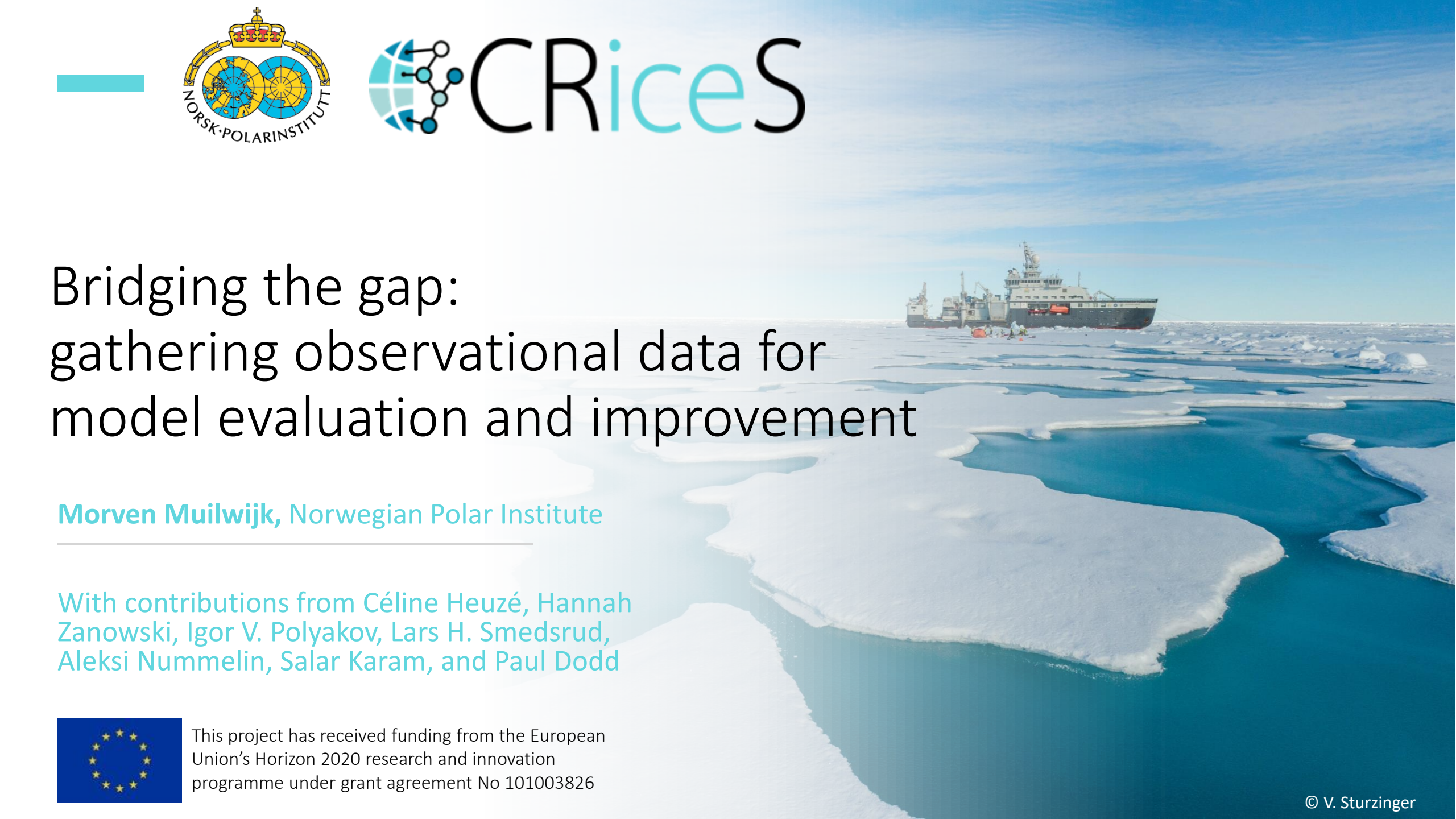

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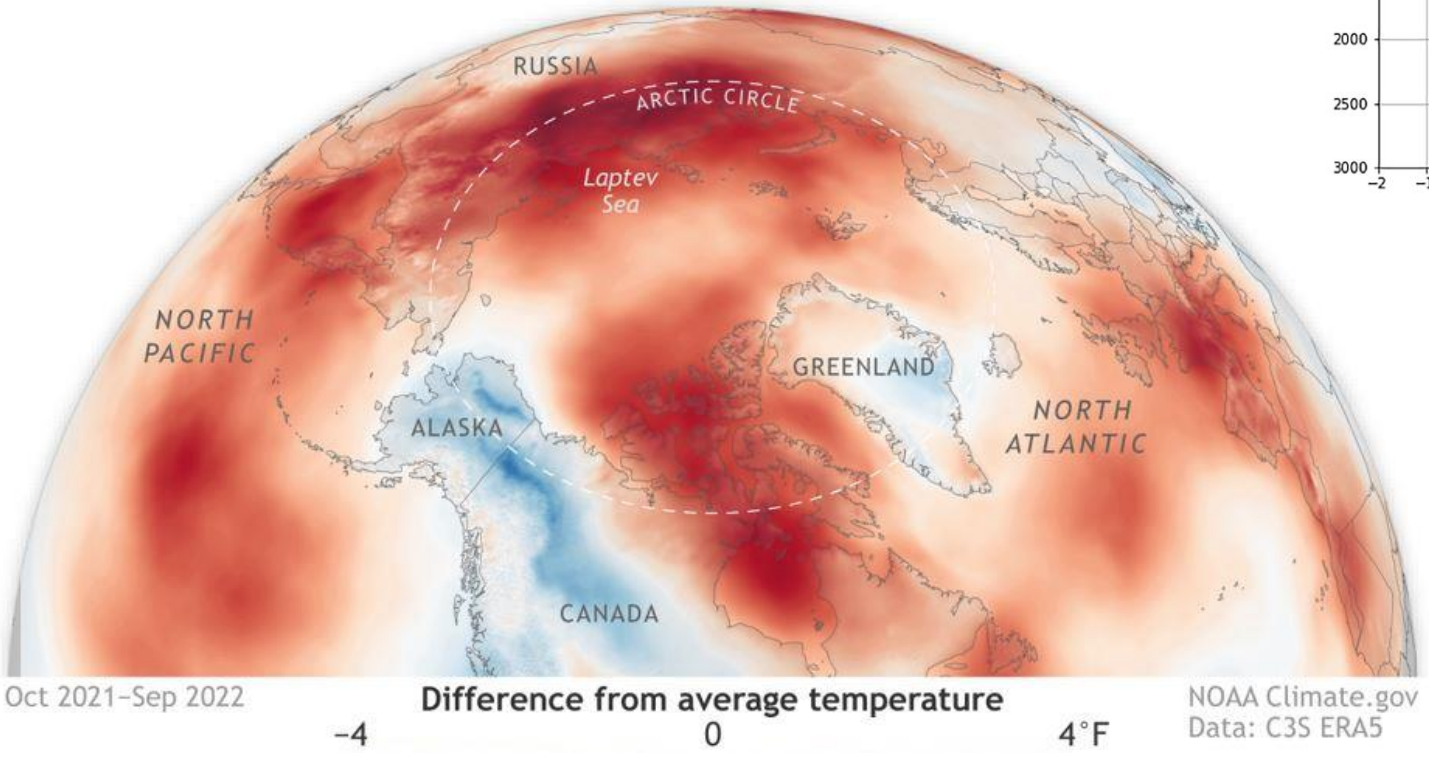
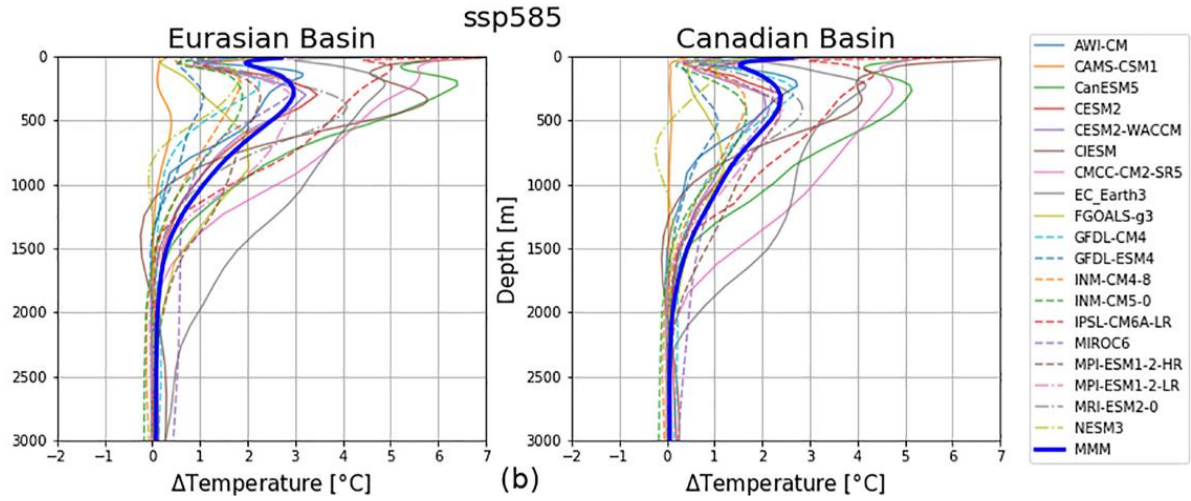
The Arctic is changing fast – and expected to continue to change

Coupled climate models are the key tools for predicting future change and understanding atmosphere-ice-ocean interactions

HOWEVER.. there is considerable uncertainty and inter-model differences, especially on feedback mechanism and teleconnections





Khosravi et al., 2022

Mainly related to mean state representation and the ability of climate models to accurately simulate key polar processes

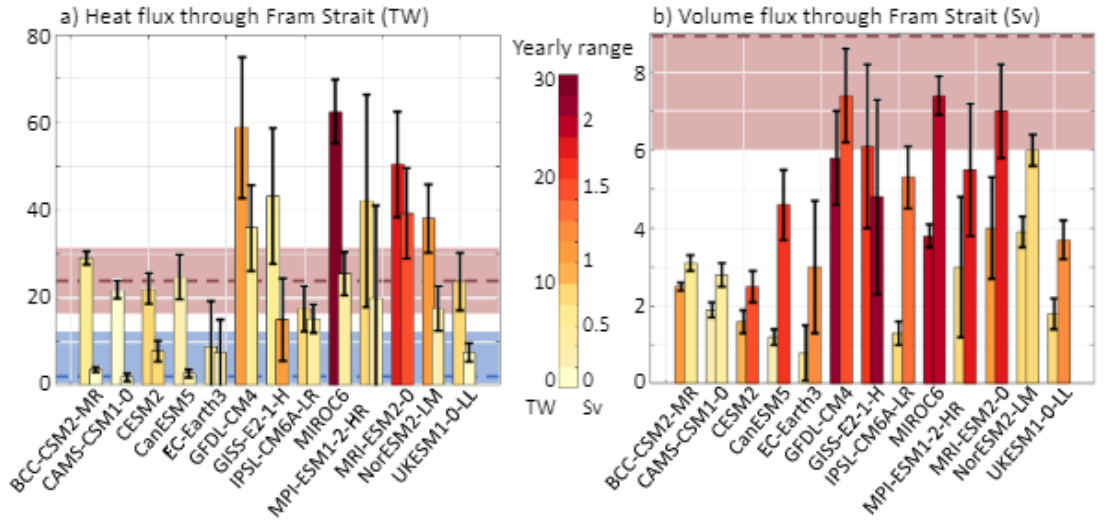
Challenges persist in accurately capturing the Arctic Ocean's mean state

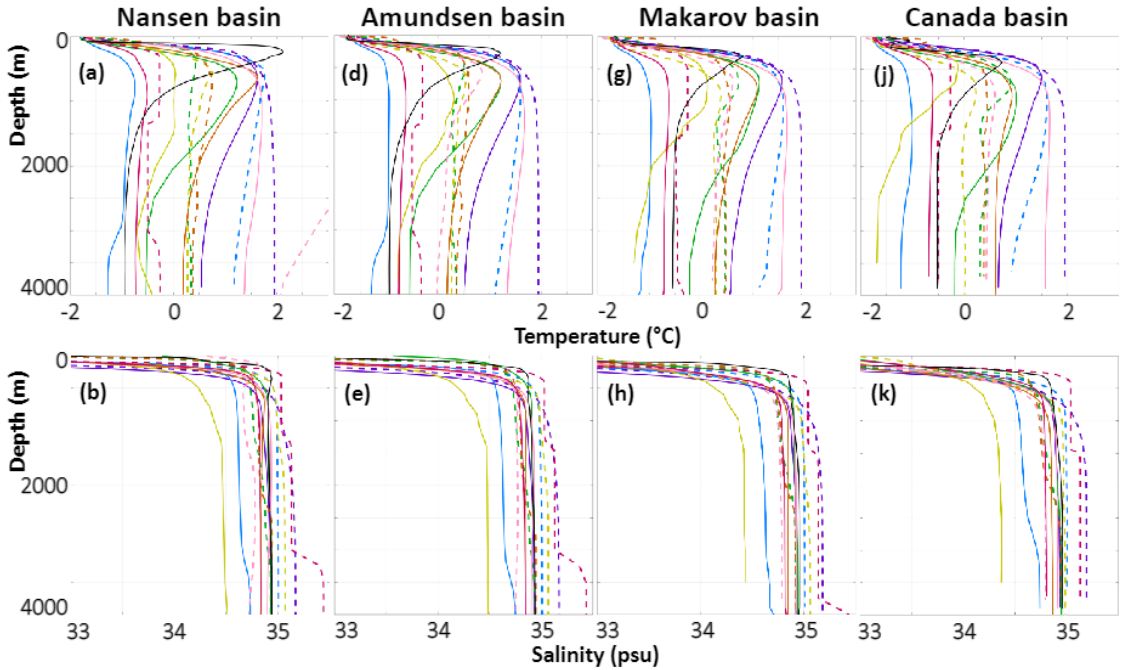
- In a recent study, we evaluated the performance of state-of-the-art (CMIP6) models in simulating Arctic Ocean hydrography and circulation

"The deep Arctic and Fram Strait in CMIP6 models " Heuzé et al. 2023

The analysis unveiled:

- Large T/S biases
- Atlantic Water too and deep too cold
- Inaccurate volume transport through gateways
- Large bias in flow speed and poor coherency of flow
- + +





Biases contribute to uncertainty and divergence in future Arctic Ocean projections

- We investigated future change in stratification and the opposing effects of freshening (Pacification) and Atlantification (warming + shoaling of AW)
- CMIP6 models agree on a future change in the Amerasian sector of the Arctic but diverge in the Eurasian sector

"Divergence in Future Arctic Atlantification" Muilwijk et al. 2023

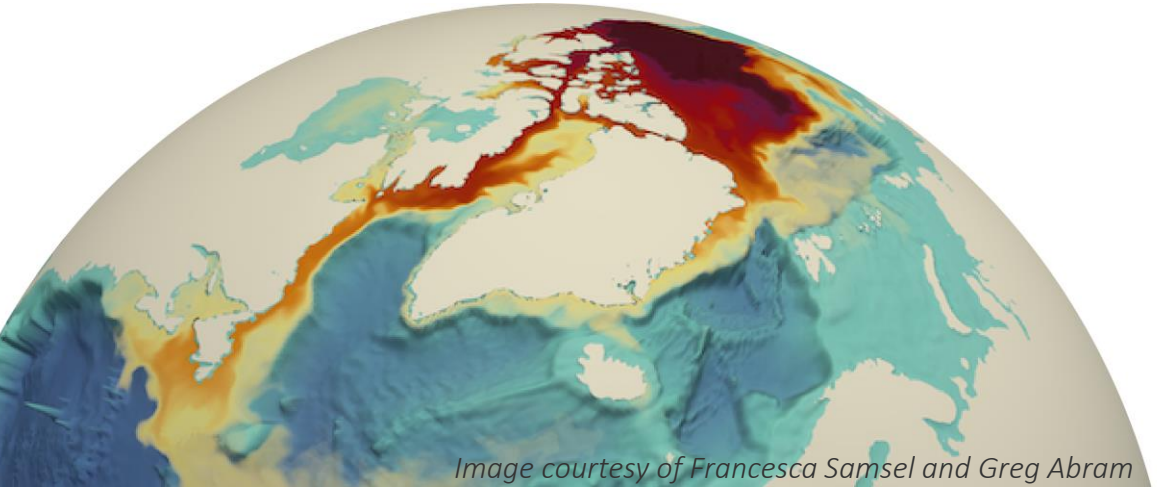
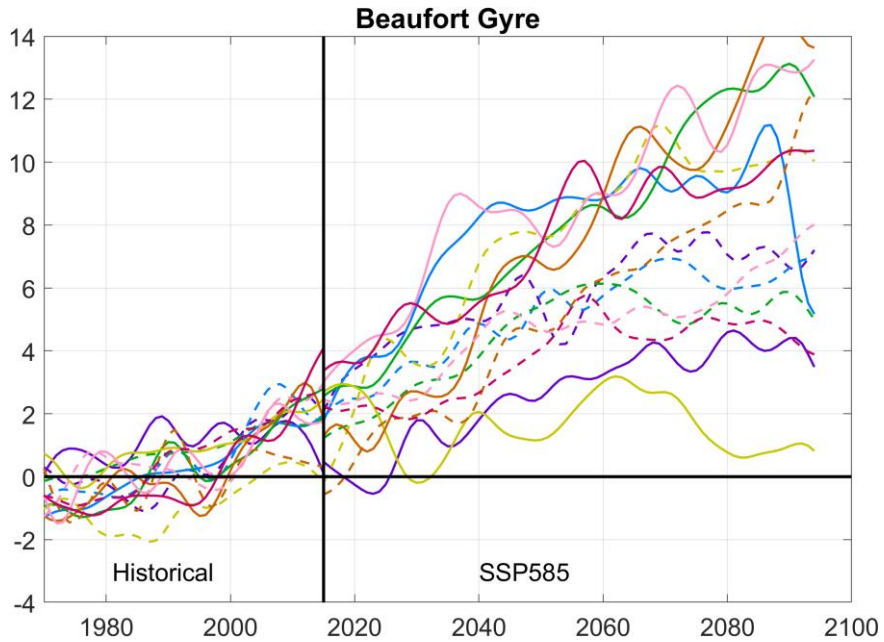
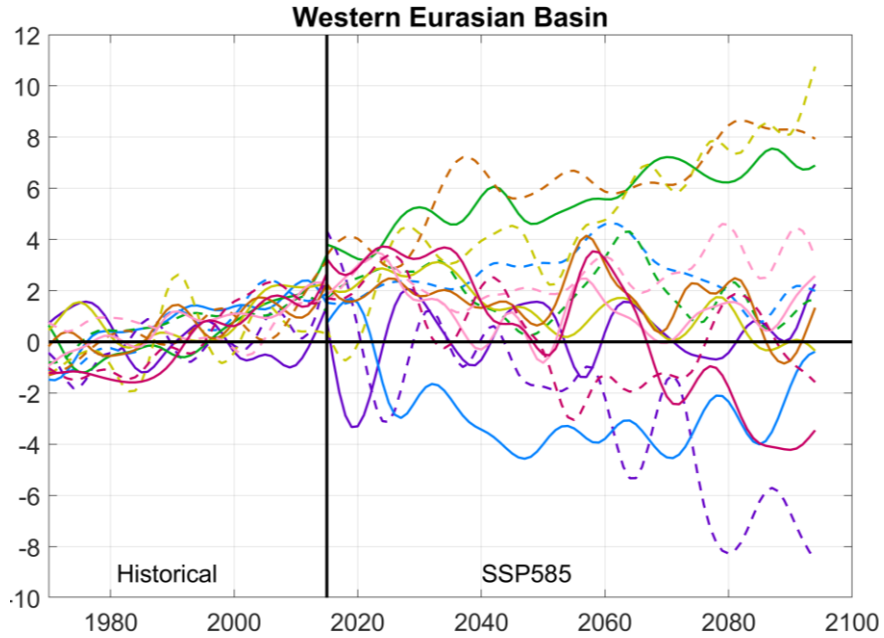


Image courtesy of Francesca Samsel and Greg Abram

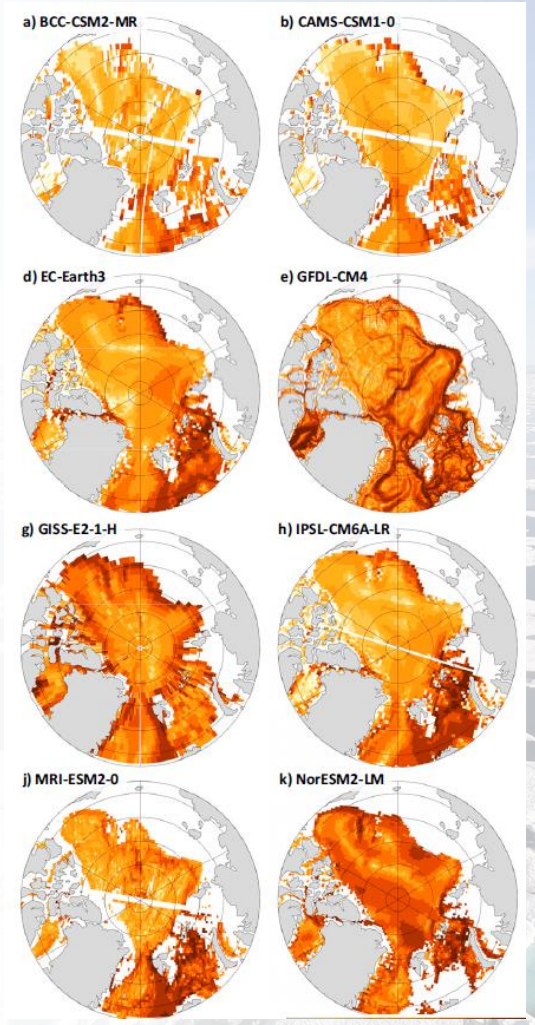




Change in future stratification from Muilwijk et al., 2023

Some (Arctic) challenges in CMIP6 models to be highlighted

- In some models Atlantic Water extends to the bottom, deep waters are not properly represented and do not change in time
- Strong decoupling between the upper layer and the rest of the deep Arctic
- Absence of ventilation: only three models appear to have dense water overflows
- Models are generally too diffuse (horizontally), and struggle to accurately represent vertical mixing
- Inaccurate fluxes through Fram Strait mainly related to upstream biases



Heuzé et al. 2023 & Muilwijk et al. 2023

What is the way forward for improving the representation of the Arctic Ocean in climate models?

Lots of smart people trying to answer this question….

Some is being worked on in the –EU projects CRiceS & PolarRES

CRiceS

PolarRES
Exploring future polar climates

- Higher horizontal resolution can mitigate some biases by resolving eddy activity and minimizing numerical mixing

- Obtaining additional observational data across multiple scales is imperative for purposes of evaluation, enhancing process understanding, and refining boundary conditions/initialization.

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The challenge: a substantial gap between modeling and observational communities

Lacks awareness of the modelers' needs or which parameters are inadequately constrained

Encounters difficulties due to scattered, overly detailed, and poorly accessible observational data.

Frequently resort to climatologies, which are based on older data and may not accurately represent current conditions.

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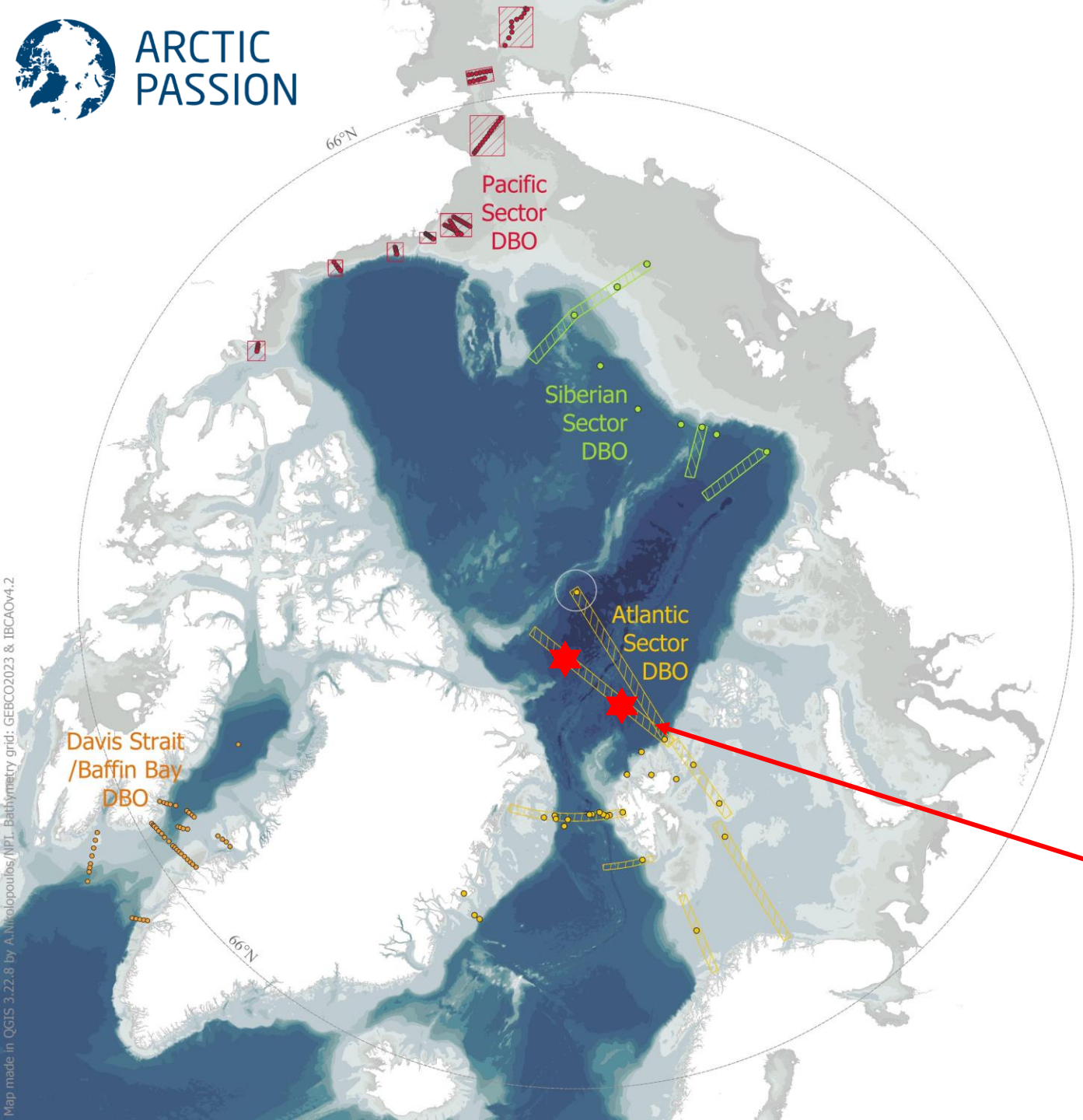
ARCTIC PASSION



There is a need for long time series and winter data

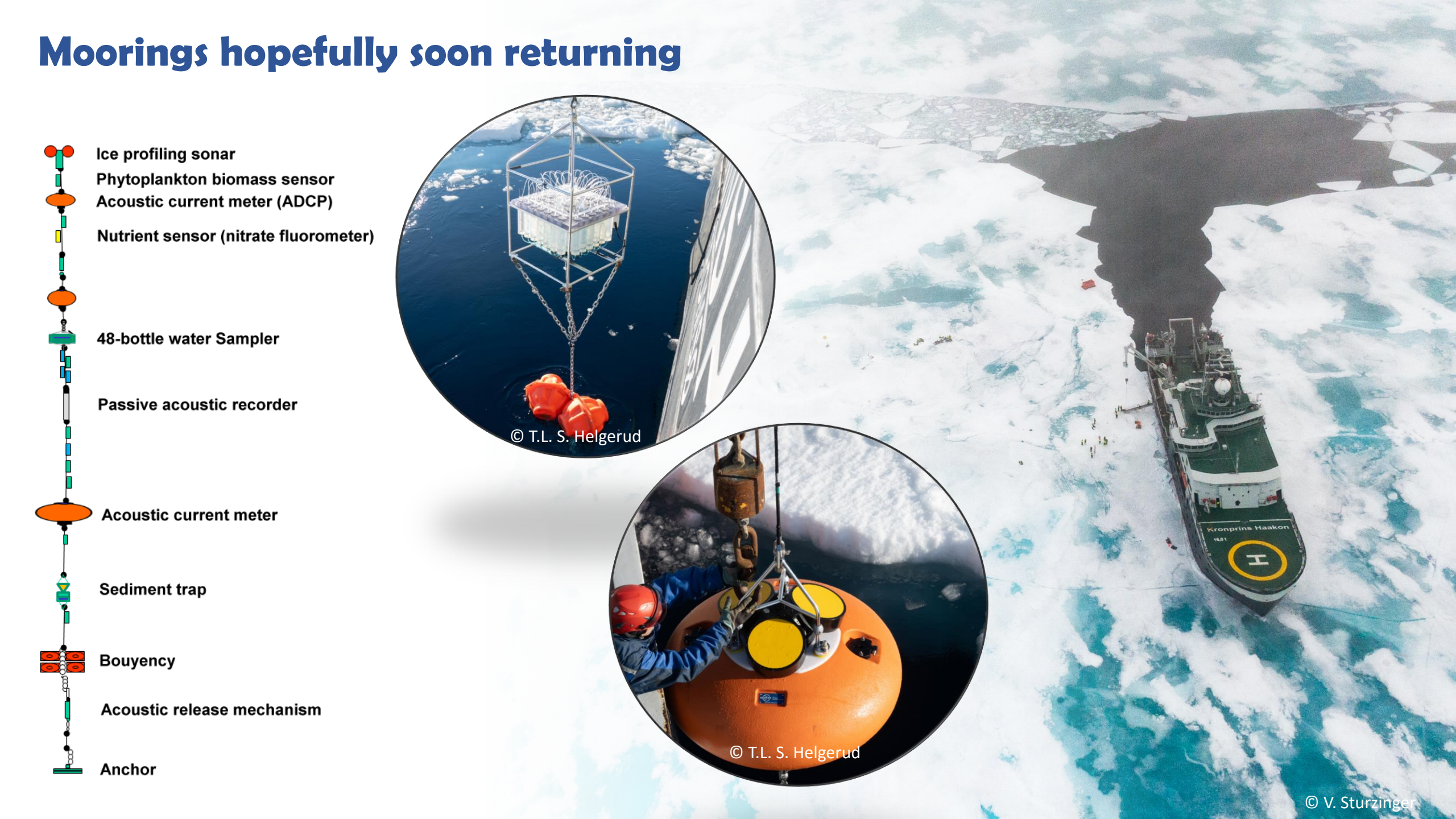
Many existing efforts: repeat sections and moorings

e.g., existing DBOs, NABOS, and efforts in the Beaufort Gyre, Canadian Arctic, +++

- Yet, limited moorings in the deep central Arctic
- Luckily: a growing focus on long-term measurements!

- Recent establishment of the Atlantic-Arctic Distributed Biological Observatory will help
- In 2022 NPI deployed two deep moorings in the Amundsen and Nansen Basins

Moorings hopefully soon returning



Need for improved observational based process understanding and estimates for specific parameters

- Problem #1 If not resolved --> it has to be parameterized
  - Rooted in measurements from an earlier era characterized by thicker multiyear ice
- Problem #2 Polar-specific tuning is challenging
  - Global ocean models, where the Arctic Ocean is “small” but behaves very differently (e.g. β-ocean)
- Problem #3 Missing processes
  - Dense water formations, waves, tides, etc.
- Problem #4 Poorly constrained constants
  - Large regional/seasonal differences/variability but only one constant. E.g. drag coefficients

Process-focused studies are great and absolutely necessary. A good example is the MOSAiC.

But for observational data to be useful for modelers it needs to be accessible

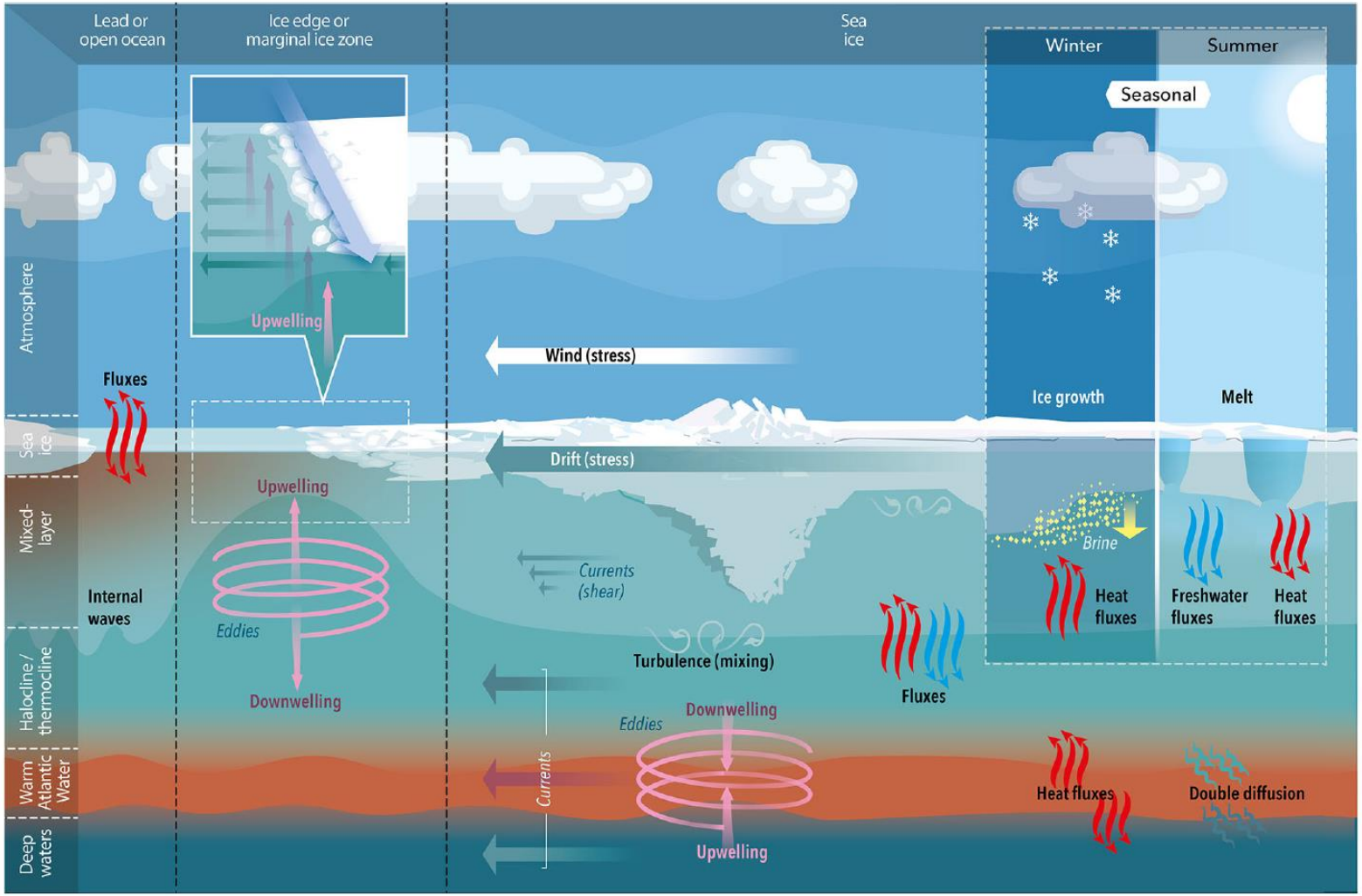


Figure from Rabe et al., (2022)

MOSAiC is a great example

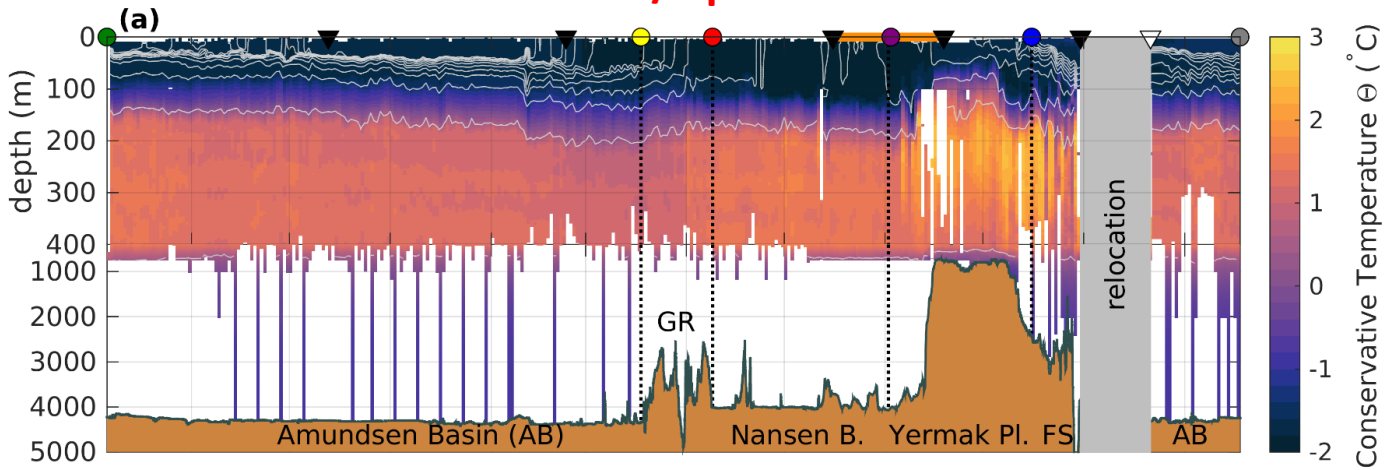
- Huge team effort that resulted in a large quantity of valuable ocean data
- Diverse oceanographic equipment used in MOSAiC
- Scattered datasets at different processing levels hinder access and utilization

→ Huge potential for interdisciplinary studies, but quickly overwhelming for non-experts

Advertisement for a new MOSAiC datasets beneficial for model development and evaluation

"The Eurasian Arctic Ocean along the MOSAiC drift"
Kirstin (Kiki) Schulz et al. (in review)

2434 T/S profiles!



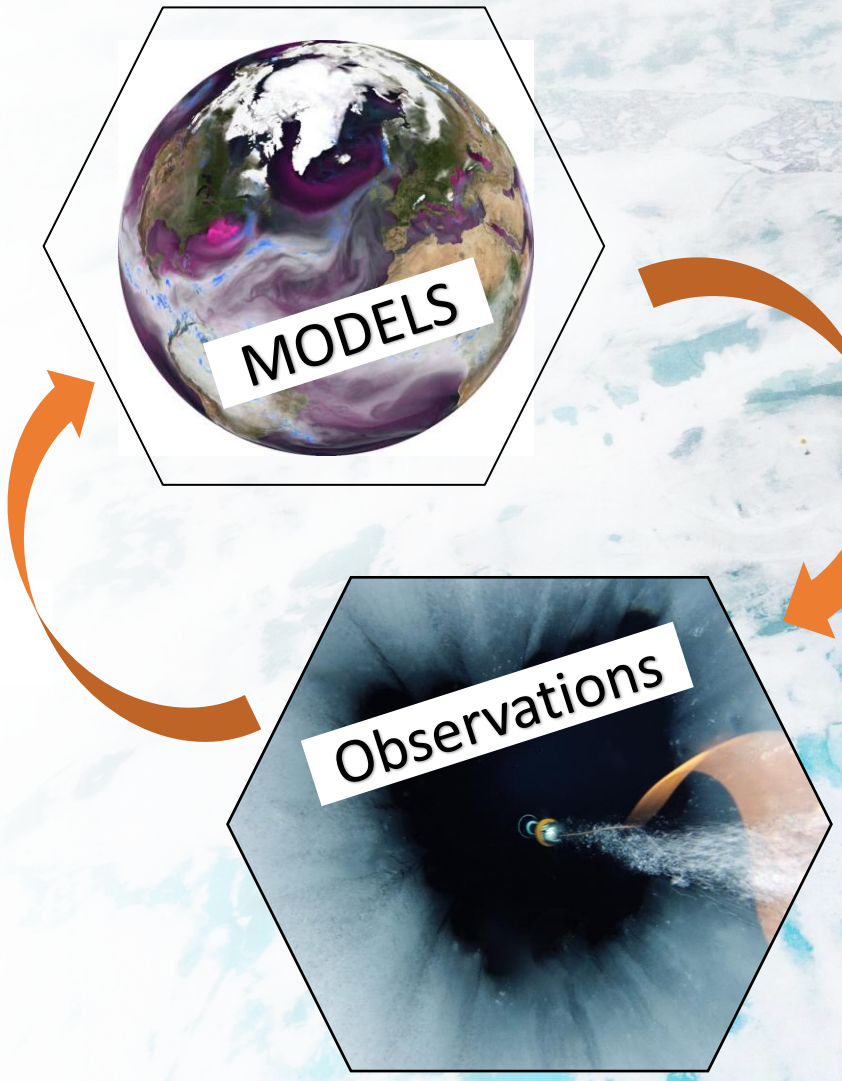
- a simple and comprehensive overview of the physical oceanography conditions during MOSAiC
- including an accessible, quality-controlled dataset, containing derived parameters for consistent use in interdisciplinary studies

Preprint available at EarthArXiv:
https://doi.org/10.31223/X5TT2W

Daily averaged parameters on Arctic Data Center:
https://doi.org/10.18739/A21J9790B

Some summarizing thoughts

- Significant effort is needed to improve the Arctic Ocean representation in CMIP6/CMIP7 models
- Be cautious! Good tools for some questions but poor for others
- Single model studies are perhaps not good enough, but be careful with multimodel-means!
- We need to talk together and perhaps design observational campaigns for the benefit of model improvement



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Thank you!

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