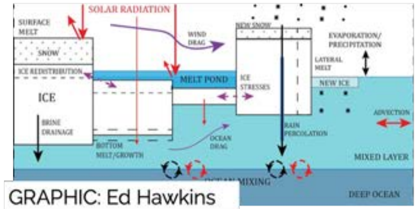
Machine learning is a useful tool to predict and understand sea-ice motion.

Lauren Hoffman[1], Matthew Mazloff[1], Sarah Gille[1], Donata Giglio[2], Cecilia Bitz[3], Patrick Heimbach[4]
[1] Scripps Institution of Oceanography, [2] University of Colorado Boulder, [3] University of Washington, [4] University of Texas at Austin

Predictability

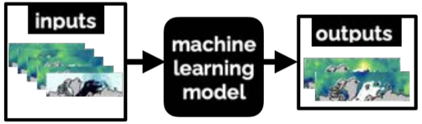
Machine learning models can be used to predict sea-ice dynamics and are more computationally efficient than traditional physics-based models.

Physics-based Models

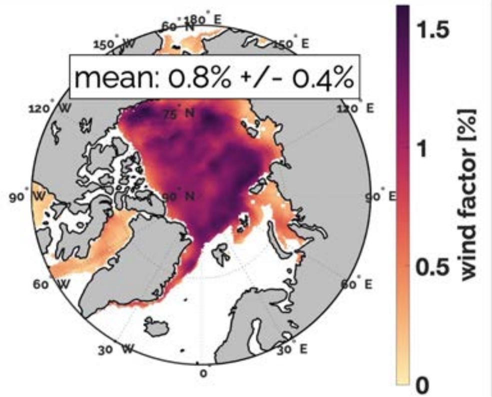


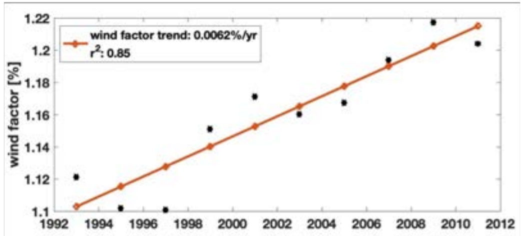
GRAPHIC: Ed Hawkins

Machine Learning Models



Understanding sea-ice motion





As the ice melts it is becoming more responsive to wind forcing.

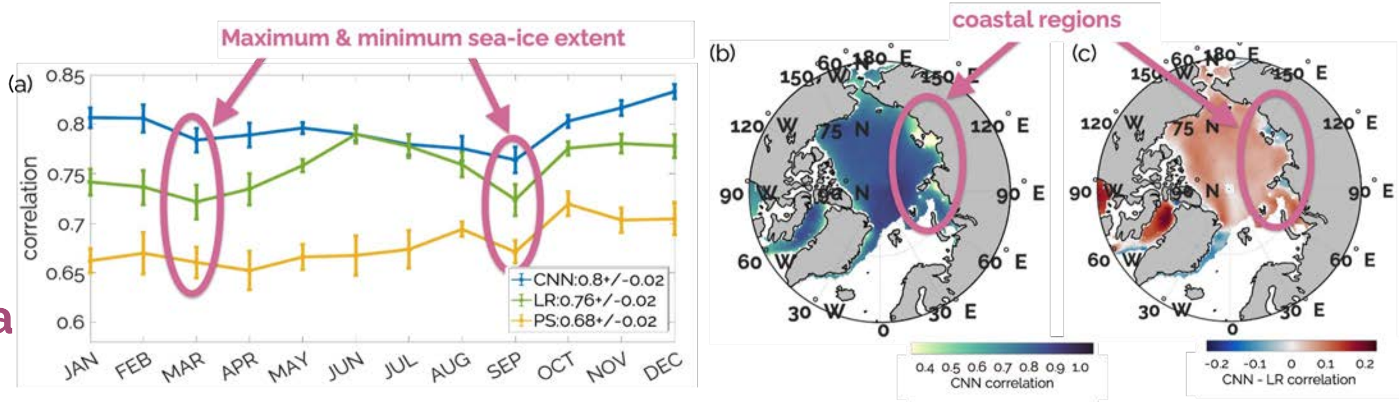
wind factor: ratio of sea-ice speed to wind speed

The **wind factor is increasing!**

lahoffma@eng.ucsd.edu

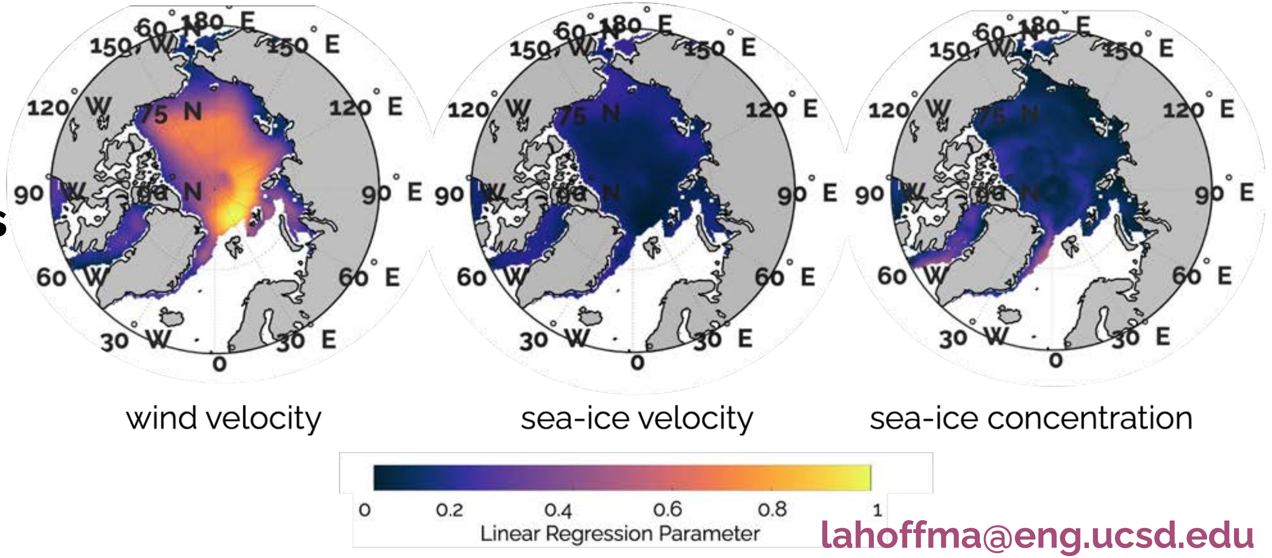
Predictability

Machine learning models can make skillful predictions of sea-ice motion, with a few caveats.



Understanding sea-ice motion

Machine learning methods confirm historical results that wind velocity has the largest relevance in determining sea-ice velocity.



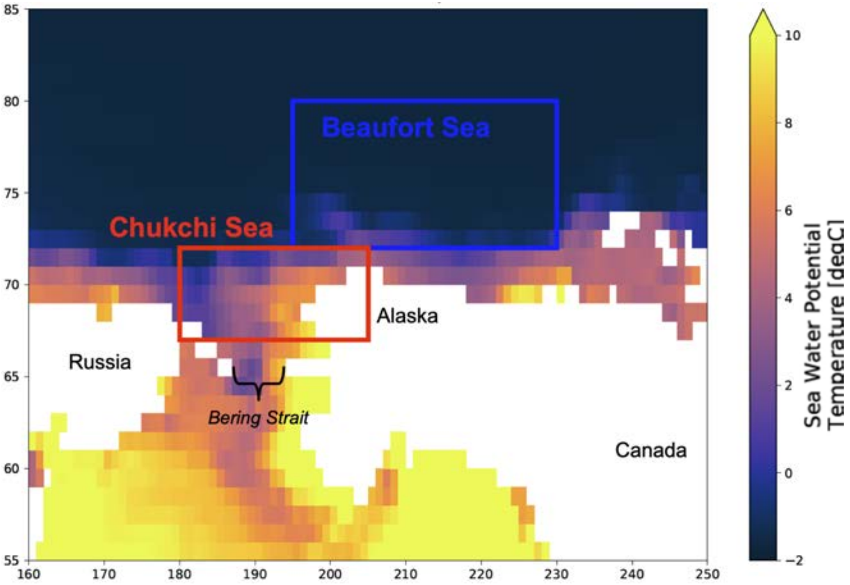
lahoffma@eng.ucsd.edu

Evaluation of GFDL coupled climate models for western Arctic seasonal heat budgets

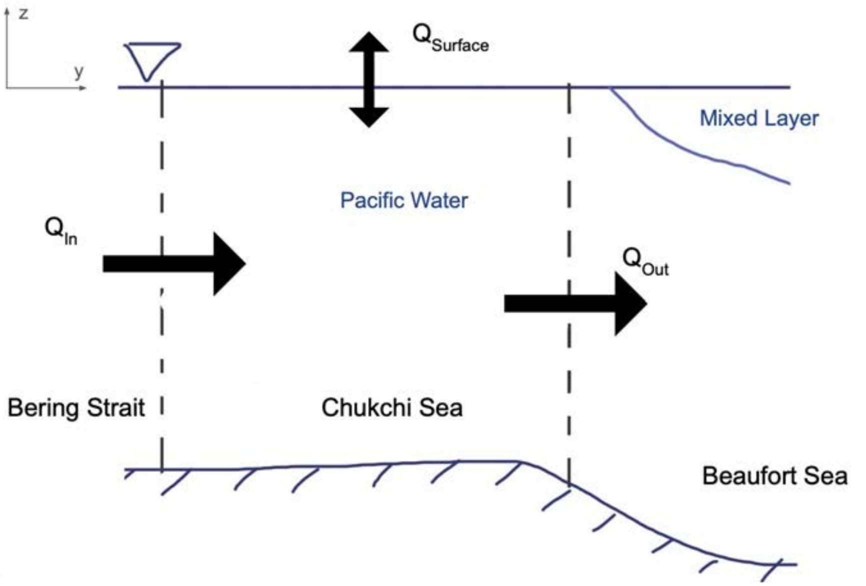
Marion Alberty*[1], Mary-Louise Timmermans[2], Sonya Legg[1], Robert Hallberg[3]

[1]Princeton University, [2]Yale University, [3]NOAA Geophysical Fluid Dynamics Laboratory

Region of Interest



Chukchi Sea Heat Budget



While the Chukchi Sea plays a critical role in modulating the heat content of Pacific Water subducted into the Beaufort Gyre halocline on seasonal timescales, inconclusive observational evidence leaves the Chukchi Sea's role in this heat transport unclear.

malberty@princeton.edu

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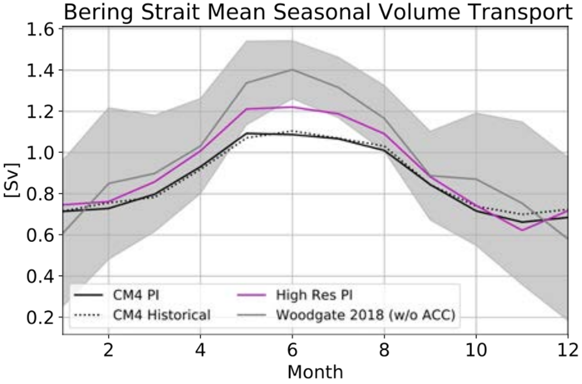
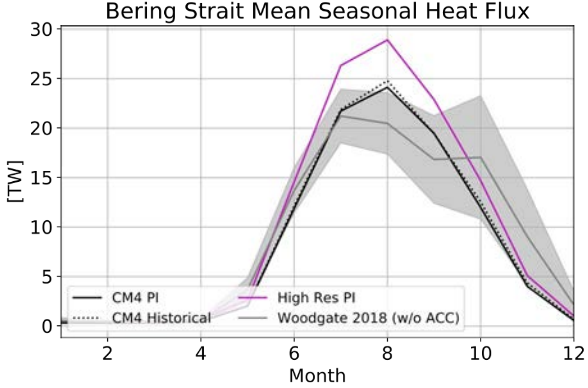
Q_{in}: Bering Strait Inflow

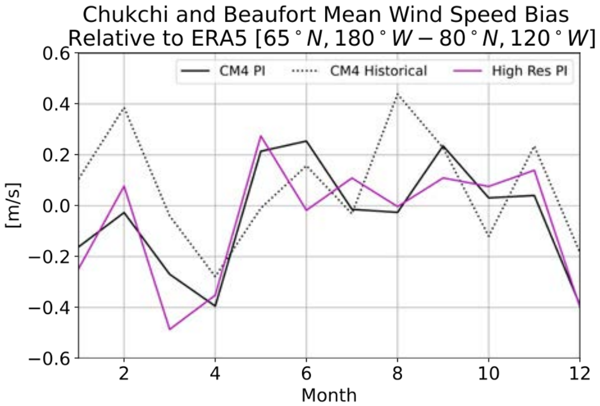
	Woodgate 2018	CMIP6 CM4 PI	CMIP6 CM4 Hist	High Res PI
$\overline{T_{vol}}$ [Sv]	1.07 ± 0.12	0.86 ± 0.06	0.87 ± 0.07	0.92 ± 0.08
$\sum T_{heat}$ [10^{20} J]	4.38 ± 1.20	2.57 ± 0.40	2.63 ± 0.45	3.13 ± 0.48



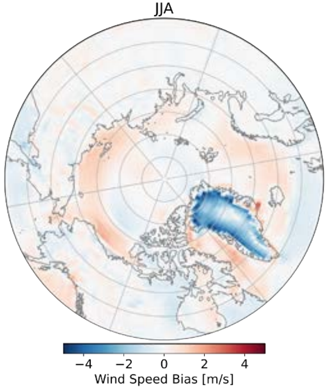


Simulated transports and fluxes are low relative to the observational estimate, however there is improved agreement between the observational estimates and the High Resolution simulation.

$Q_{Surface}$: Surface Winds



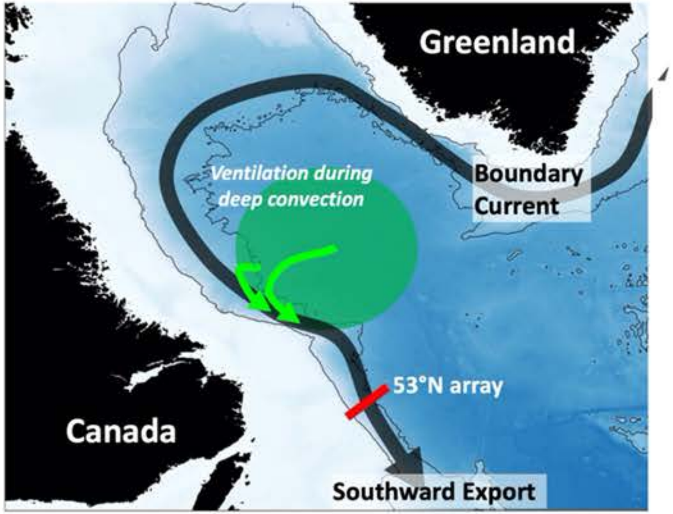
For all three simulations, surface wind speed biases are weaker in summer when air-sea heat fluxes are strongest.



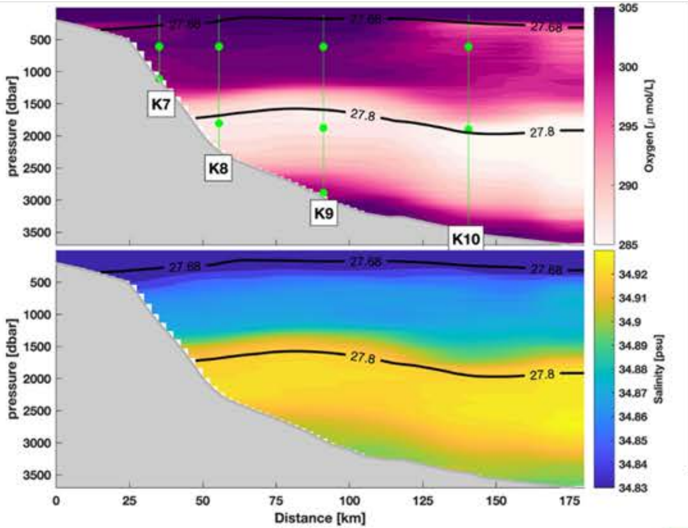
malberty@princeton.edu

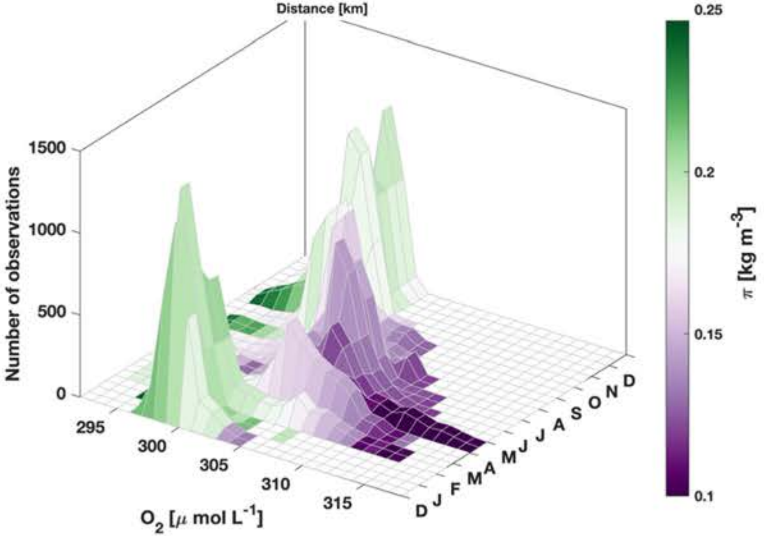
Gateway to the gateway to the Arctic: Oxygen export from the Labrador Sea

Jannes Koelling (j.koelling@dal.ca)



- Oxygen measurements at 53N
- Increased oxygen levels due to direct export of recently convected Labrador Sea Water
- 1.6 Tmol/year of southward oxygen export from newly ventilated LSW (50% of interior uptake)





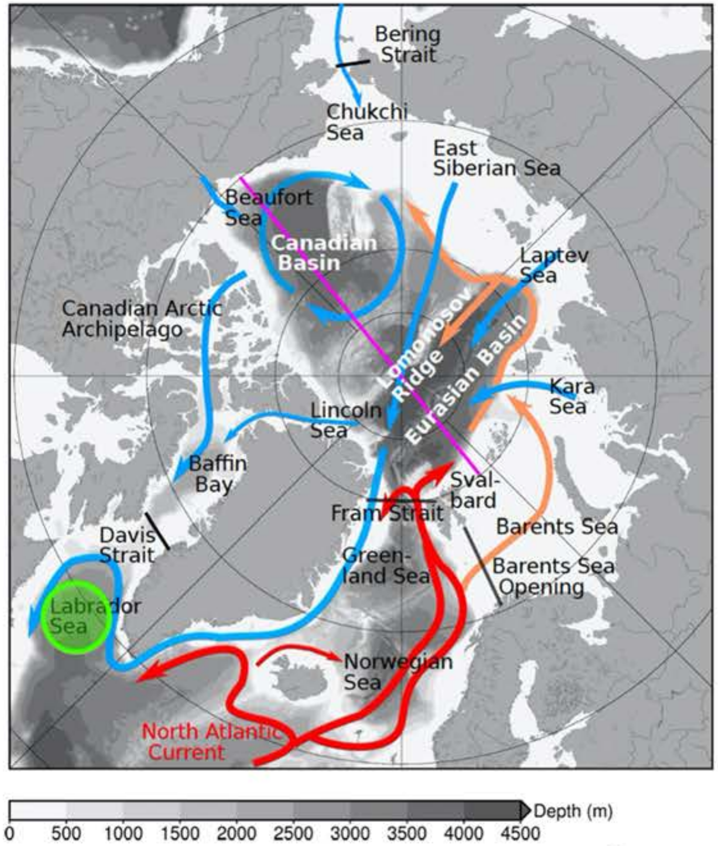
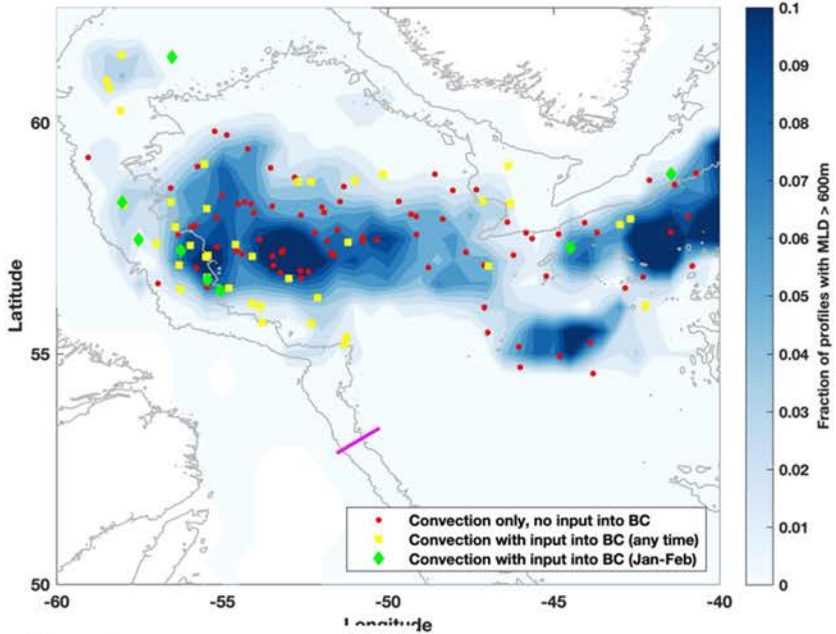


Figure from Wang et al. (2018)

- Convection in boundary current as well as interior
- Impacted by input of cold, fresh, high-oxygen water from the Arctic near the surface



Oxygen export to the deep ocean following Labrador Sea Water formation

Jannes Koelling[1], Dariia Atamanchuk[1], Johannes Karstensen[2], Patricia Handmann[2], and Douglas W. R. Wallace[1]

[1]Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada

[2]GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

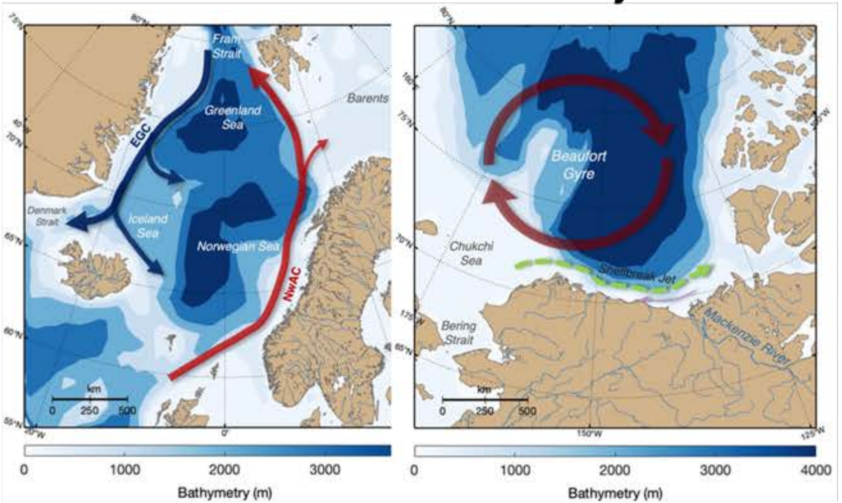
Contact: j.koelling@dal.ca

3D reconstruction of upper ocean dynamics in the Nordic and Beaufort Seas. Assessment of the Surface Quasi-Geostrophic Approach

Marta Umbert [1], Jordi Isern-Fontanet [1], Marina Gutierrez [1], Carolina Gabarró [1] , Laurent Bertino [2], Roshin Raj [2]
(1) Institue of Marine Sicences (CSIC) and Barcelona Expert Center (BEC), Barcelona
(2) Nansen Envirnomental and Remote Sening Center (NERSC) Bergen, Norway

- OBJECTIVE → See if surface information may be used to reconstruct 3D ocean dynamics in two key areas of the Arctic Ocean

Beaufort Sea



- METHOD → **Surface Quasi-Geostrophy (eSQG)**
  - **Reconstruction from SSH :**

Stream function

$$\hat{\psi}_\eta(\vec{k},z) = \exp(n_0 k z)\hat{\psi}_s(\vec{k})$$

SSH

$$\psi_s(\vec{x}) = \frac{g}{f_0}\eta(\vec{x})$$

  - **Reconstruction from SSB:**

$$\hat{\psi}_b(\vec{k},z) = \frac{1}{n_0 f_0 k}\exp(n_0 k z)\hat{b}_s(\vec{k})$$

Surface Density (SSS & SST)

$$b_s(\vec{x}) = -g\frac{\rho'(\vec{x})}{\rho_0}$$

  - **Reconstruction from SSV:**

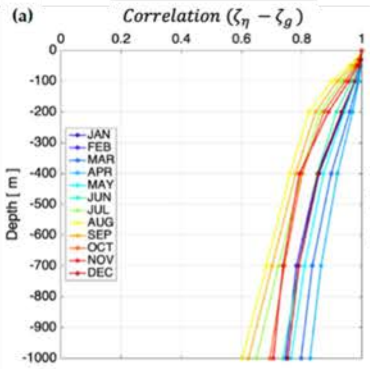
Prandtl ratio

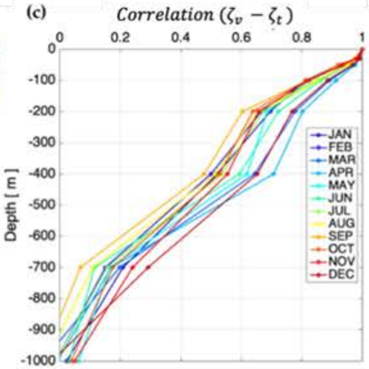
$$\hat{v}_{vel}(\vec{k},z) = \exp(n_0 k z)\hat{v}_s(\vec{k})$$

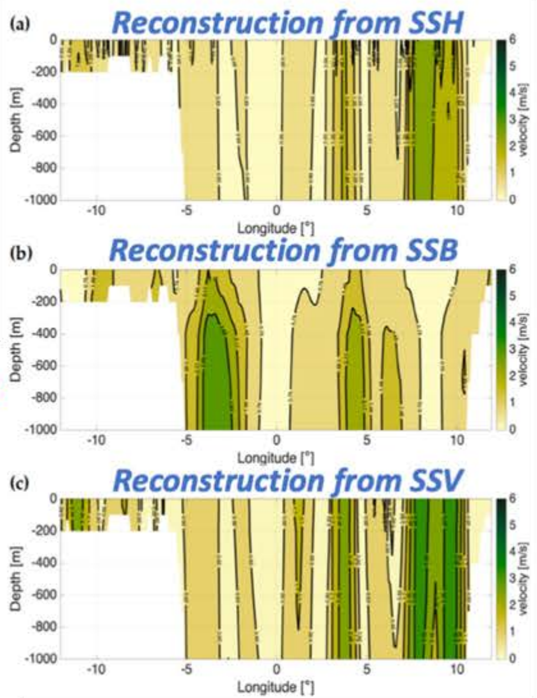
Contact Marta Umbert at → mumbert@icm.csic.es

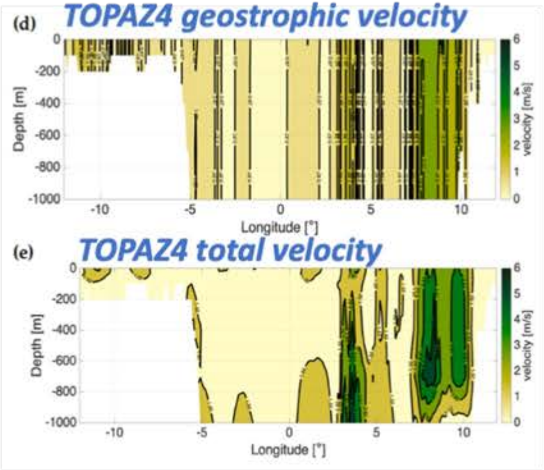
3D reconstruction of upper ocean dynamics in the Nordic and Beaufort Seas. Assessment of the Surface Quasi-Geostrophic Approach

- **Reconstruction form SSH** and model geostrophic current, **show good agreement (corr.>0.8) up to 400 meters.**
- **Reconstruction from SSV** and model total currents, **exhibit fairly good agreement (corr.>0.6) up to 200 meters.**
- **Reconstructions are better in the winter and spring when the water column is less stratified**









MARIE CURIE ACTIONS

BEC Barcelona Expert Center IEEC

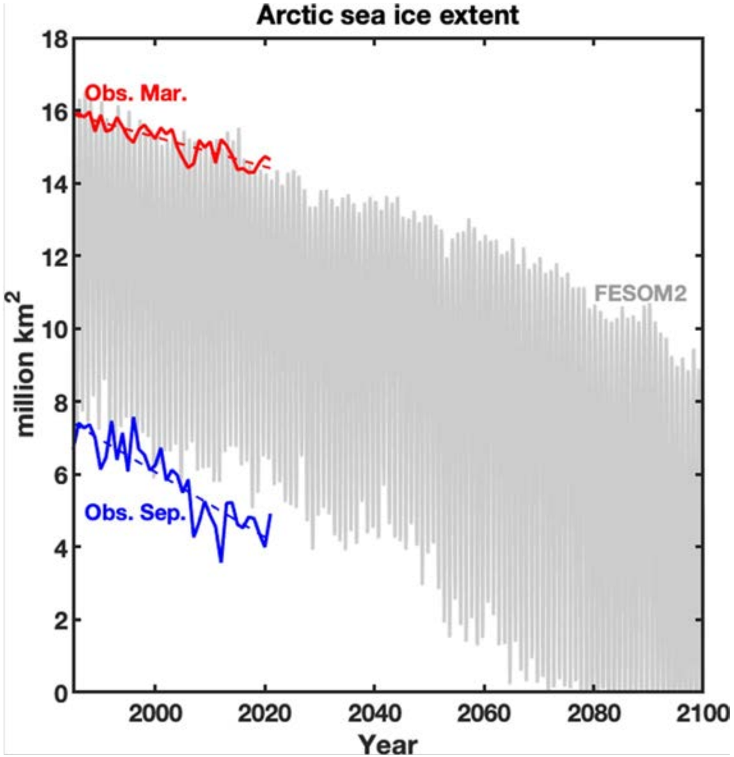
NERSC

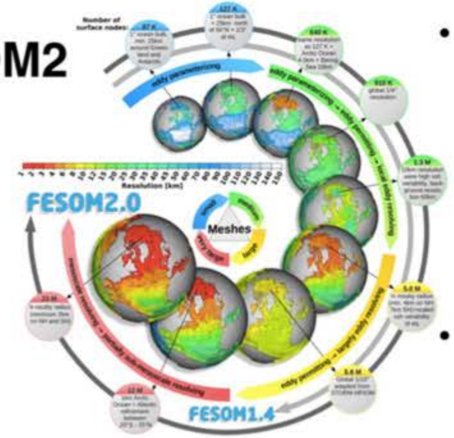
Contact Marta Umbert at → mumbert@icm.csic.es

Toward understanding future development of Arctic using FESOM2

Xinyue Li*, *Qiang Wang, Nikolay Koldunov, Dmitry Sidorenko, Thomas Jung, Sergey Danilov, Vasco Müller*

**Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research*

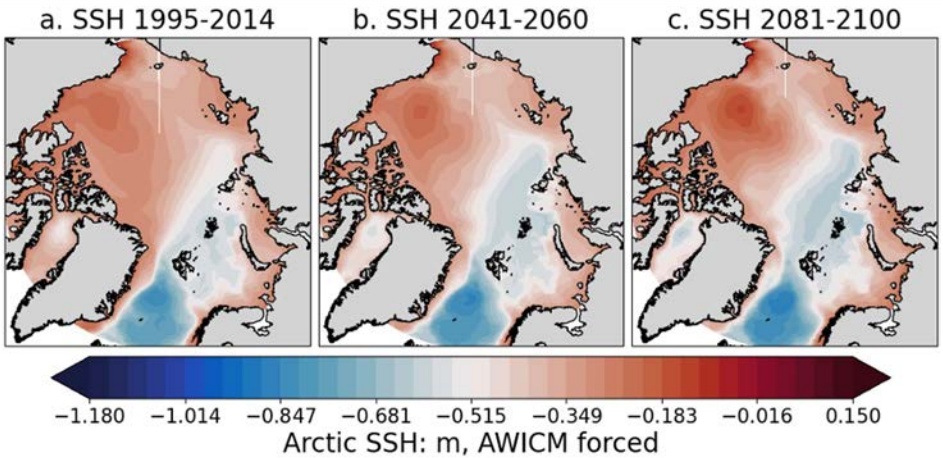




- Existing CMIP models tend to underestimate the strength of mesoscale eddies.

  We planned to apply the ***4.5-1km*** *grid of FESOM2.*

- Arctic sea ice is expected to decline in the future, somehow affecting strength of future Beaufort flows.



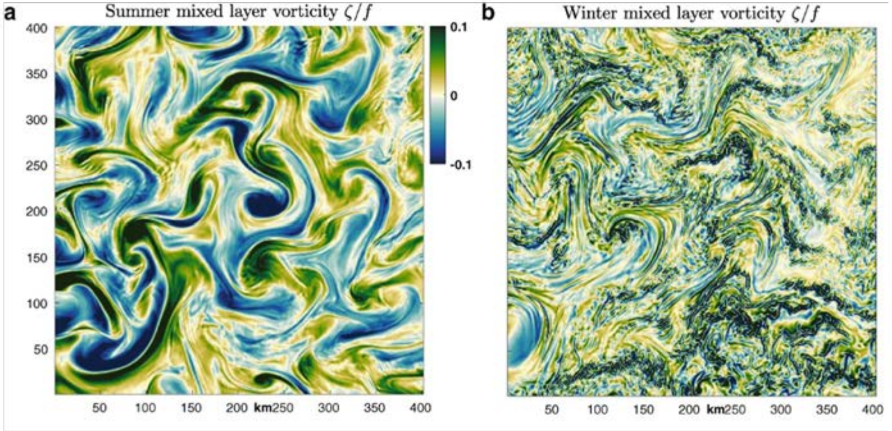
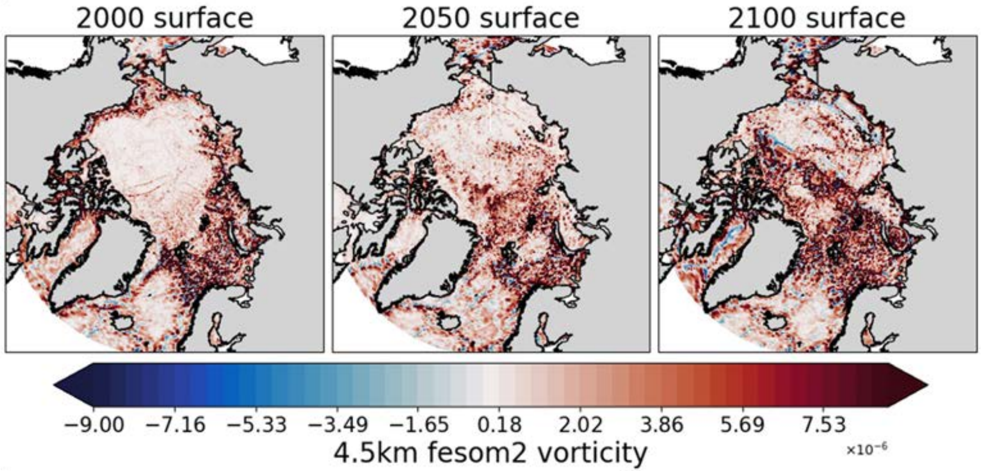


Figure from (Manucharyan and Thompson, 2022)

- In this recent study, high resolution model (1km) clearly captures more eddy activities than low resolution model.
- Stronger eddy activity in summer compared to winter reflects role of Arctic sea ice change.

- Using 4.5km resolution model, changes of Arctic eddy activities can still be observed.
- In 2100, sea ice may be largely receding, Arctic eddy activities would be greatly enhanced. These results contribute to simulations applying future 1km grids.



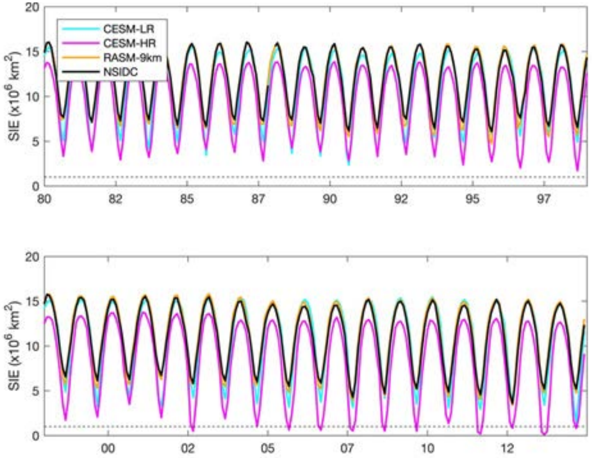
Contact: xinyue.li@awi.de

Oceanic Fluxes Across Arctic Gateways in the Regional Arctic System Model (RASM)

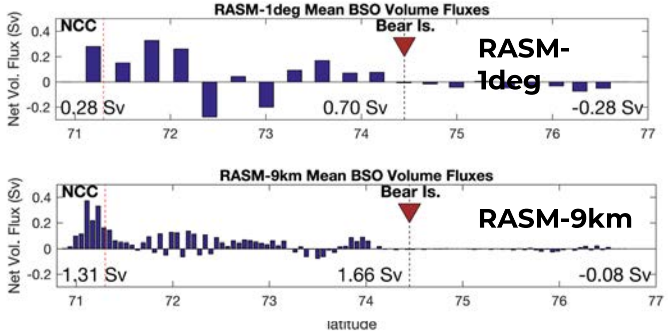
Younjoo J. Lee[1](ylee1@nps.edu), Wieslaw Maslowski[1], Robert Osinski[2], and Jaclyn Clement Kinney[1]
[1]Naval Postgraduate School, Monterey, CA, USA; [2]Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

Case		CESM-LR	CESM-HR	RASM-1deg	RASM-9km	RASM-2km
Name (Experiment)		CESM1-CAM5-SE-LR (hist-1950)	CESM1-CAM5-SE-HR (hist-1950)	R2200tGcdaa01f (hindcast)	R2200rGcsph02f (hindcast)	R2300uGcspn01f (hindcast)
Arctic Ocean (>65 N) Horizontal Resolution Range: Min.-Max. (Mean)		7.8 ~ 72 km (45 km)	2.7~7.0 km (5.0 km)	7.8 ~ 72 km (45 km)	8.5 ~ 9.3 km (9.2 km)	2.1 ~ 2.3 km (2.3 km)
Vertical # of Ocean		60	62	60	45	45
Atm.-Ocean-Ice-Land Models (forcing)		CAM5.2-POP2-CICE4-CLM4		POP2-CICE6 (JRA55-do)		
Net Volume Flux ($Sv=10^6\ m^3/s$)	**BS**	0.77	1.41	0.65	0.70	0.65
	BSO	1.91	4.04	0.70	2.89	2.59
	DS	-1.49	-2.79	-1.21	-1.72	-2.34
	FS	-1.18	-2.61	-0.14	-1.86	-0.86
Arctic Ocean Heat Convergence (TW)		64	196	54	116	104

Arctic Sea Ice Extent



Barent Sea Opening Flux



Summary & Future Research

- ➔ Net volume fluxes across the Arctic main gateways varies between the simulations; the higher resolution, the larger fluxes across the gateways.
- ➔ CESM high resolution simulation may overestimate heat fluxes into the Arctic since sea ice almost disappears during summer of 2002.
- ➔ The low resolution models exhibit lack of skills representing coastal currents such as Norwegian Coastal Current, which is critical to understand the connection between the Arctic and the sub-Arctic regions.
- ➔ Hence, improved observational flux estimates are necessary to constrain ocean and other climate models.
- ➔ Also, Arctic-wide balanced volume exchanges are needed across the gateways.

Younjoo Lee (ylee1@nps.edu)

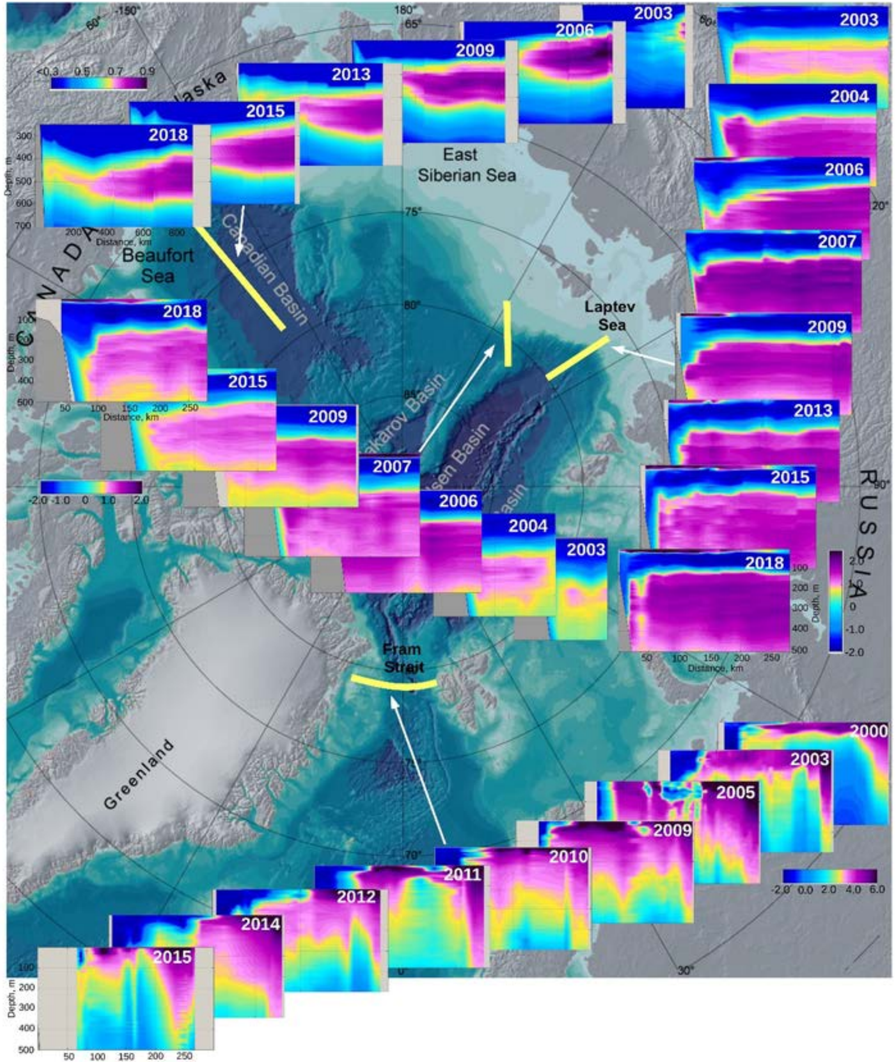
Understanding circulation in the eastern Arctic Ocean from NABOS observations

Igor Polyakov and NABOS team

June 24, 2022

Fairbanks, Alaska

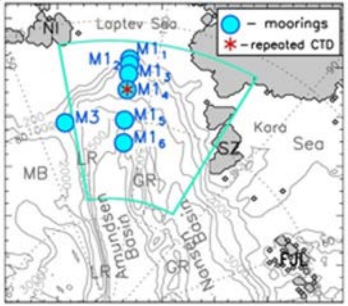
Atlantification: Atlantic water was ~1°C warmer in the 1990s compared with the 1970 and 0.24°C warmer in 2007 compared with the 1990s



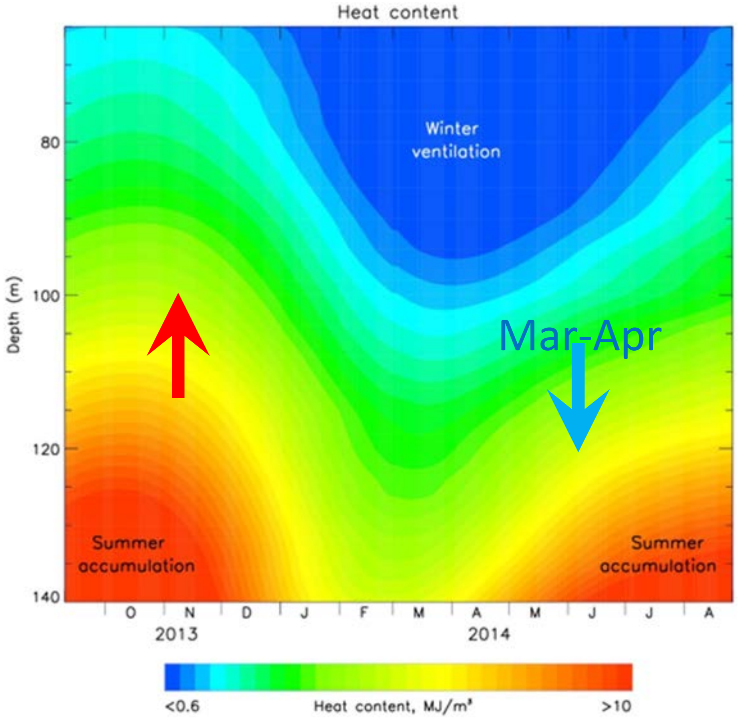
Pnyushkov and Polyakov 2022

New Arctic Ocean:

Sea ice loss due to stronger oceanic heat flux caused by weaker stratification and deep ocean winter ventilation



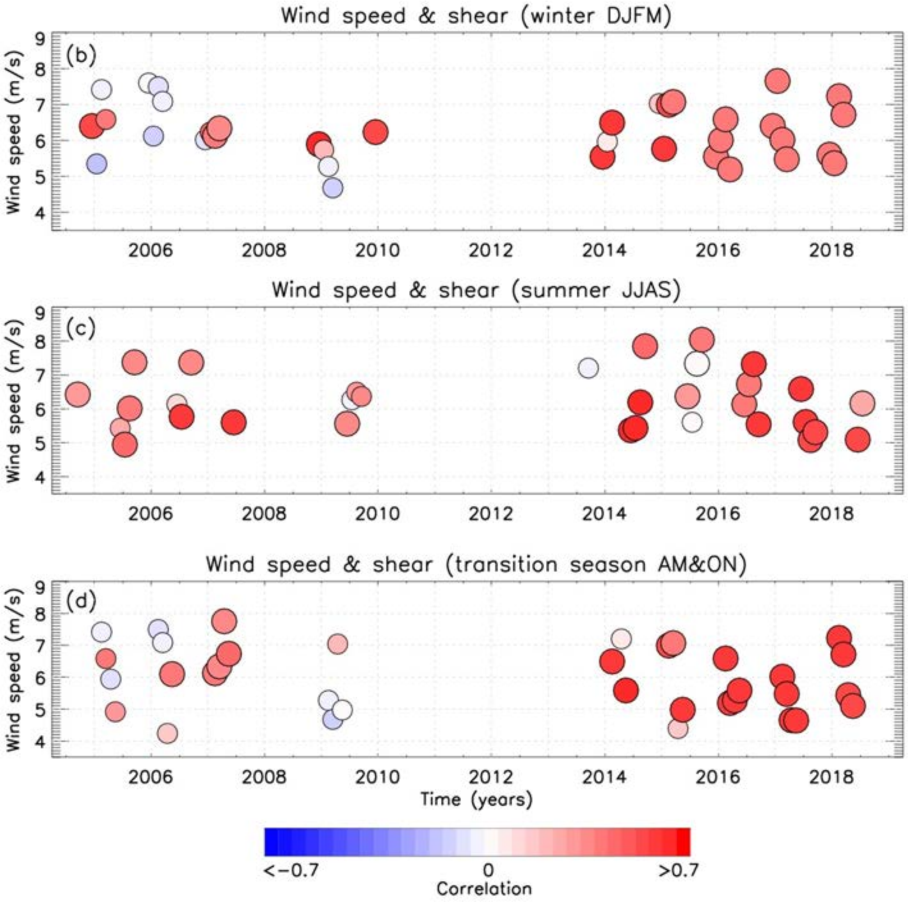
Blue arrow shows penetrative winter ventilation to the depths exceeding 140m. *Polyakov et al*. (2020).



2000s

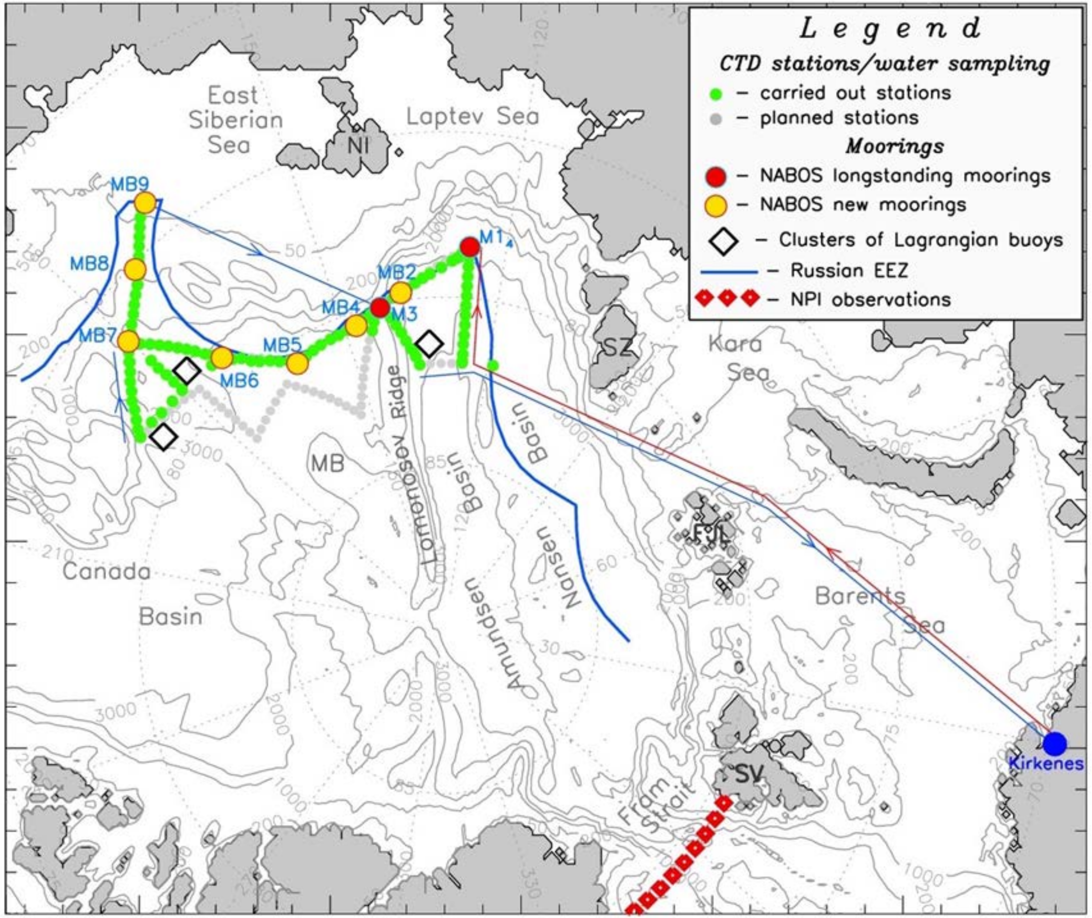
2010s

Increasing in time correlation between wind and upper ocean currents/shear suggests stronger air-ice-ocean coupling



Polyakov et al., 2020

2021 NABOS cruise



Conclusions

- Recent loss of cold halocline layer in the eastern Eurasian Basin makes this region similar to the western Eurasian Basin -> “atlantification” - a fundamental step toward a new Arctic climate state.
- Consequences include change of intensity of the upper ocean circulation and shear.
- The role of remote and local freshwater anomalies in establishing the observed changes in the eastern Arctic Ocean is not well constrained.