Sources of the Arctic Atlantic Water Biases in CESM2

Who M. Kim

** NSF National Center for Atmospheric Research*

Gokhan Danabasoglu*, Young-Oh Kwon (WHOI), Steve Yeager*

Claude Frankignoul (LOCEAN/IPSL), Dylan Oldenburg*

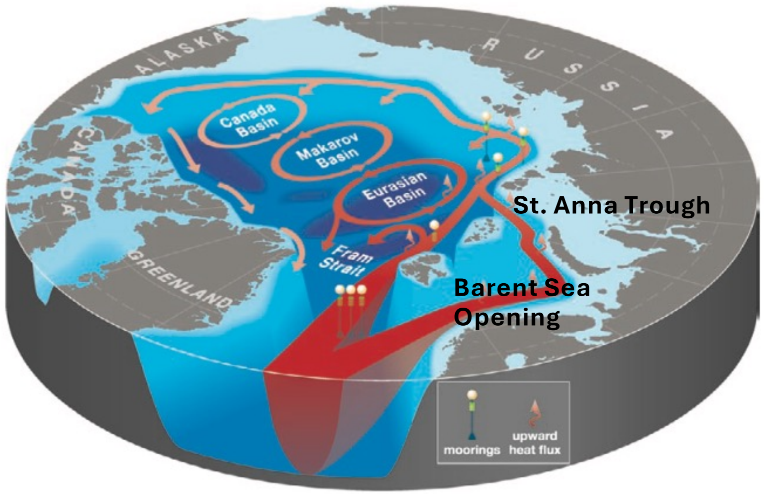
2nd CAMAS Workshop

April 16, 2025

NCAR

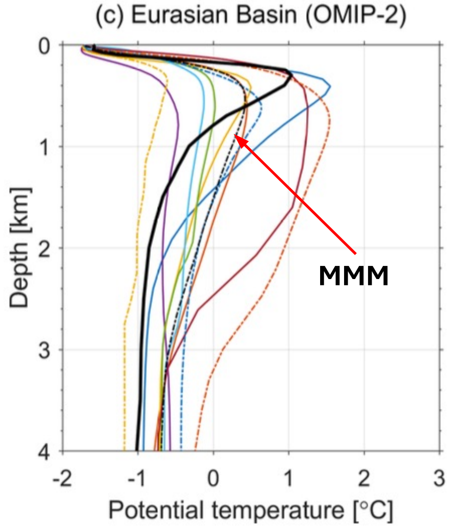
This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

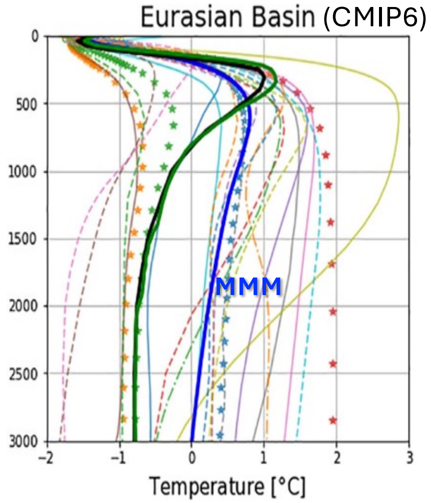
Arctic Atlantic Water (AW) and Its Biases



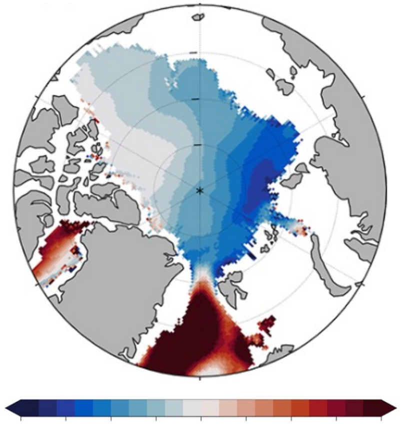
Polyakov et al. (2011)

Simulated AW layer: too thick and too deep





Khosravi et al. (2022)

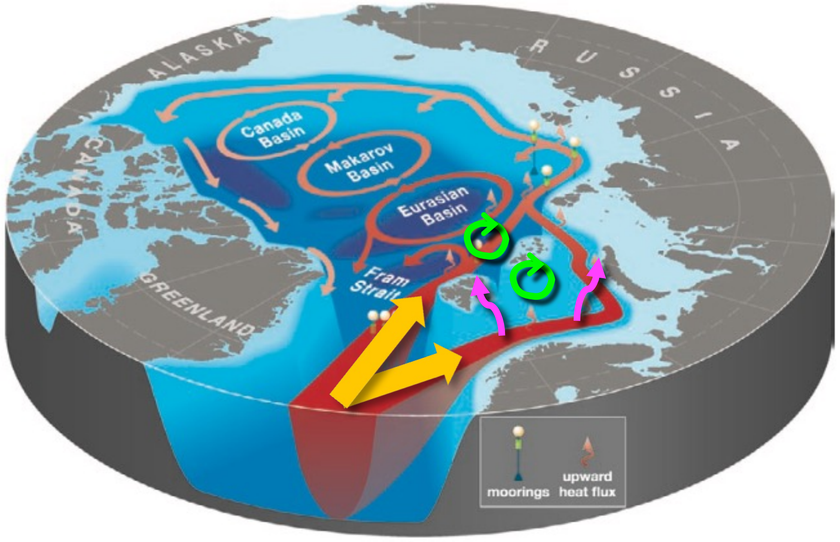


Shu et al. (2023)

AW inflow to the Arctic Ocean

- Fram Strait branch (~2 Sv): relatively warmer and saltier
- **Barents Sea branch (~2 Sv)**: relatively colder and fresher due to heat loss and mixing, entering the Arctic Ocean mainly through the St. Anna Trough (SAT)
- Flows cyclonically along the continental slope
- AW in the interior Arctic Ocean: $\theta > 0$°C
  - Roughly 700 m thick with the core around 250 m

Potential Sources of the Biases



Polyakov et al. (2011)

- Biased AW inflow from the GIN Seas
- Incorrect water mass transformation related to surface fluxes and/or mixing over the shelf and/or within the troughs and channels
- Inaccurate or misrepresented horizontal and vertical mixing processes along the slope and in the interior
  - **No study systematically examining the bias sources using a single model**

Model and Experiments

Forced ocean–sea-ice simulations

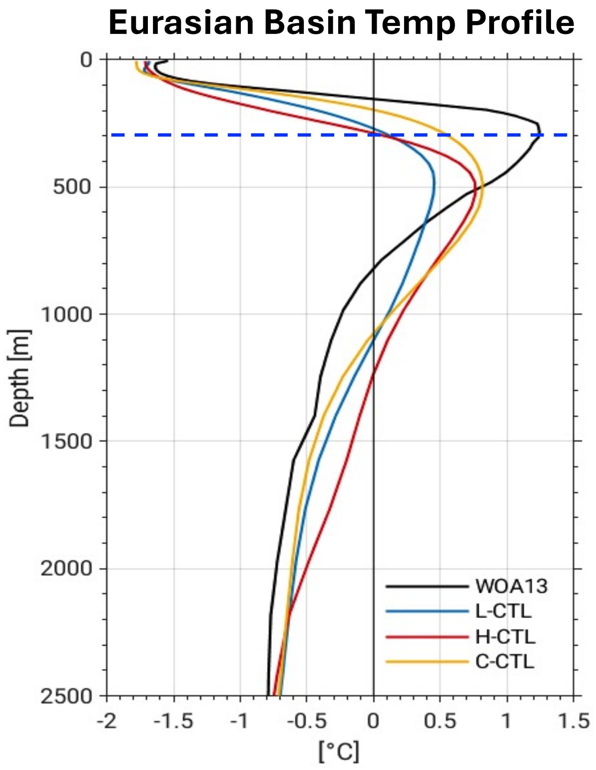
- Both low- (LR) and high-resolution (HR) configurations of CESM2
- **Sensitivity experiments (L-*Exp_Name*)**
    1) Interior T&S restoring experiments
    2) Mixing parameter experiments
    3) Combinations of (1) and (2)
- Selected experiments repeated using HR (H-*Exp_Name*)
- 2003-2004 Repeat Year Forcing (RYF), starting from WOA13 ICs
    - *Similar biases appear whether IAF or different RYFs are used*

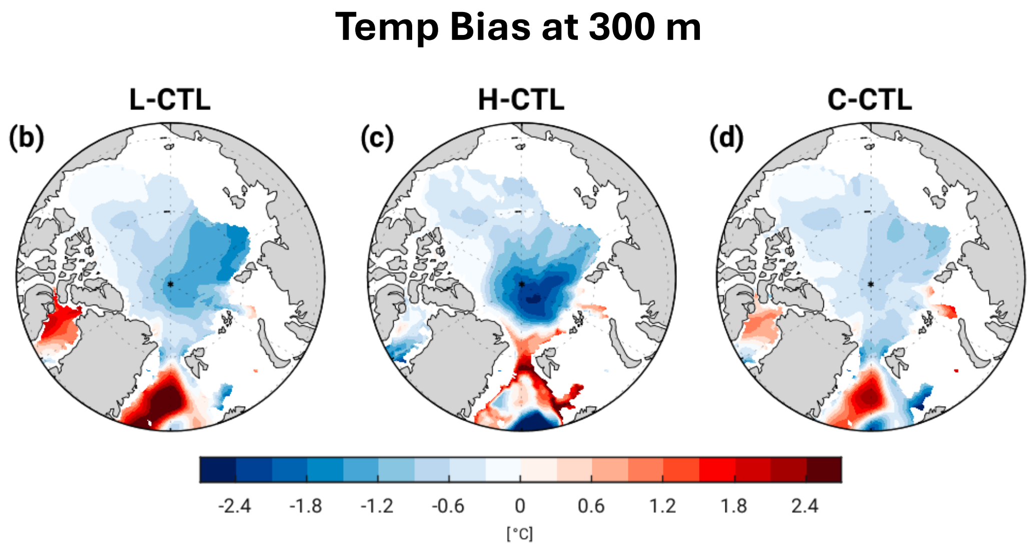
Fully Coupled simulations

- Standard, LR configuration of CESM2
- New pi-control, starting from WOA13 ICs
- Selected experiments repeated (C-*Exp_Name*)

- All simulations run for 30 years
- Last 5-year averages used to examine biases, focusing on the temperature and circulation in the Eurasian Basin (EB)

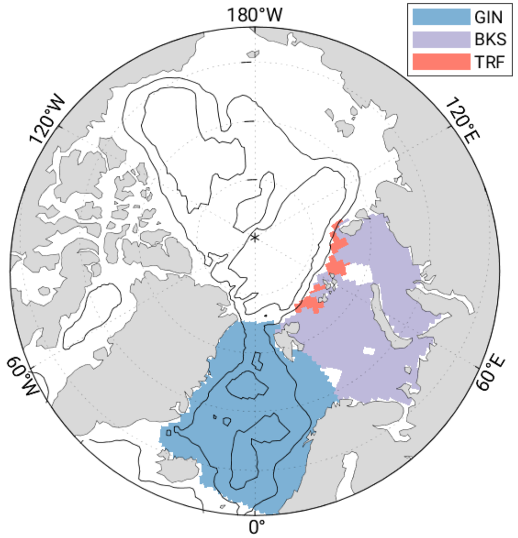
AW Biases in the Control Simulations



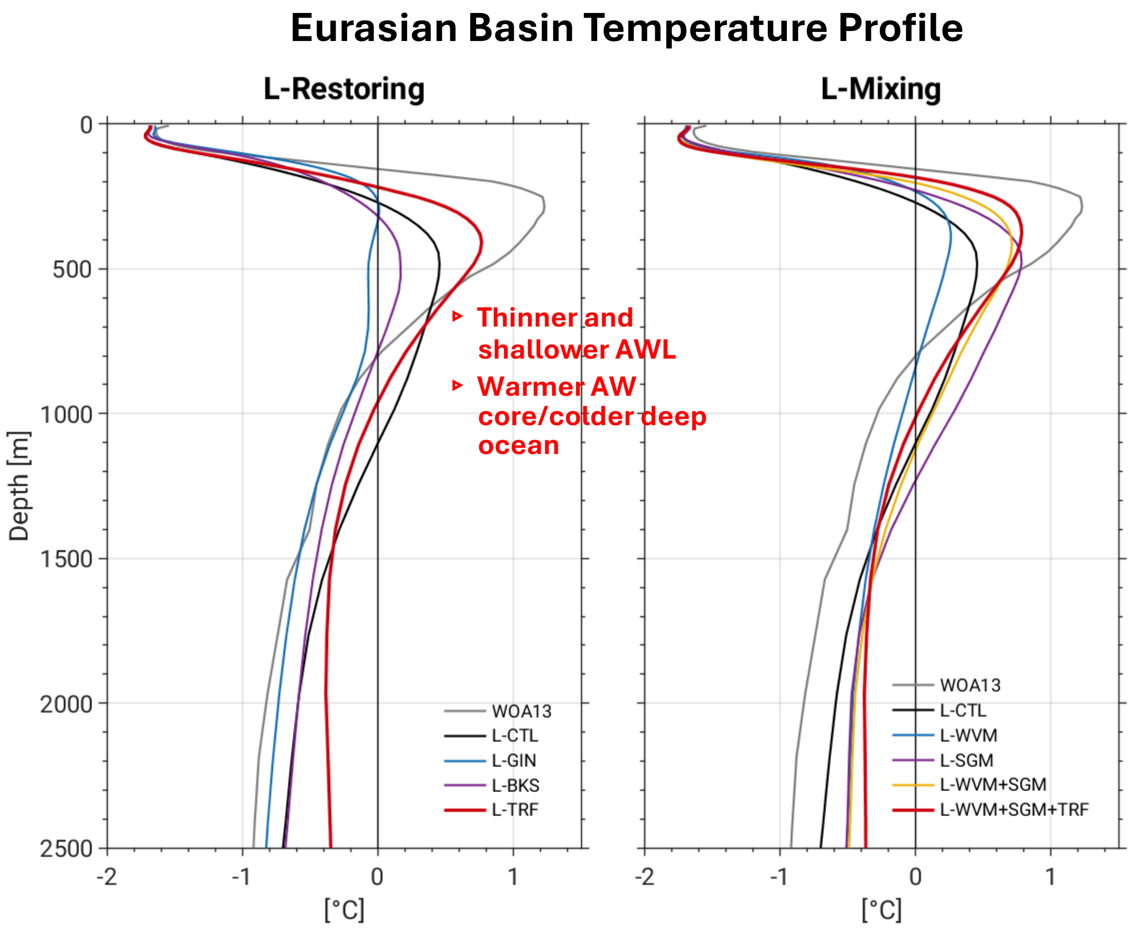


- AW core found at deeper depths
  - ~450-500 m vs. 250 m in WOA13
- Thicker AW layer
  - ~800-900 m vs. 700 m in WOA13
- Colder at the observed core depth and warmer below

LR FOSI Experiments

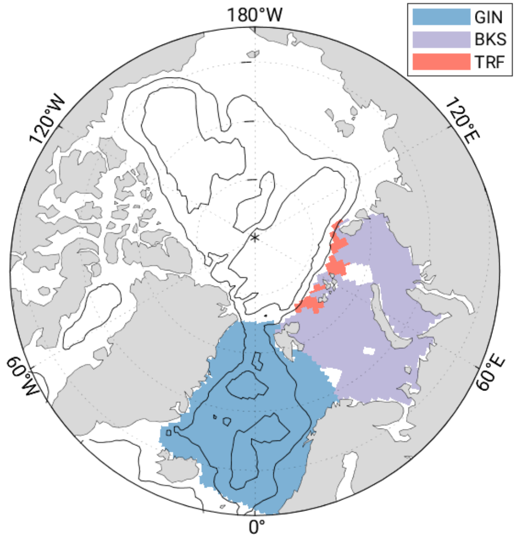


GIN & BKS: 10 m < z < bttm
TRF: 250 m < z < bttm



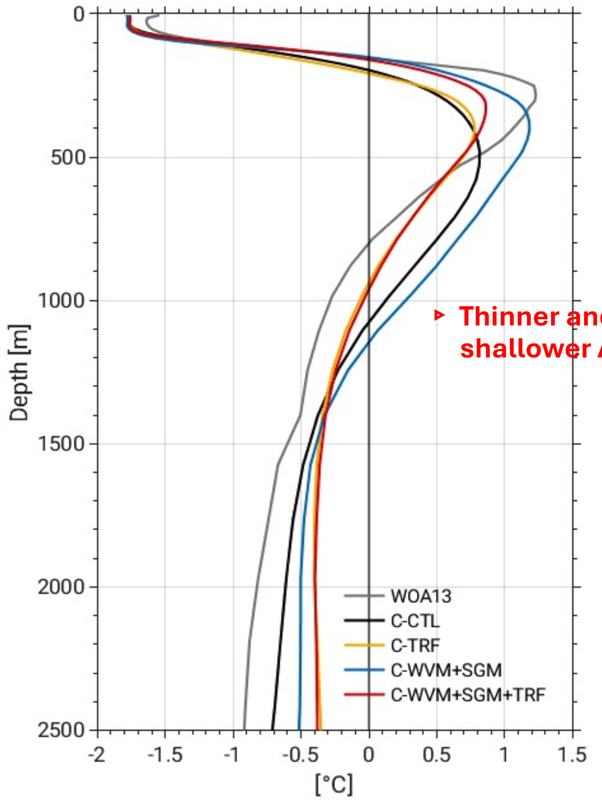
- L-GIN, L-BKS, L-WVM: too weak signature of AWL
- L-WVM: shallower core
- L-SGM: Too warm deep ocean – stronger circulation brings warm-biased water from the Nordic Seas
- TRF substantially improves the AW properties

LR Coupled Experiments



GIN & BKS: 10 m < z < bttm
TRF: 250 m < z < bttm

Eurasian Basin Temperature Profile

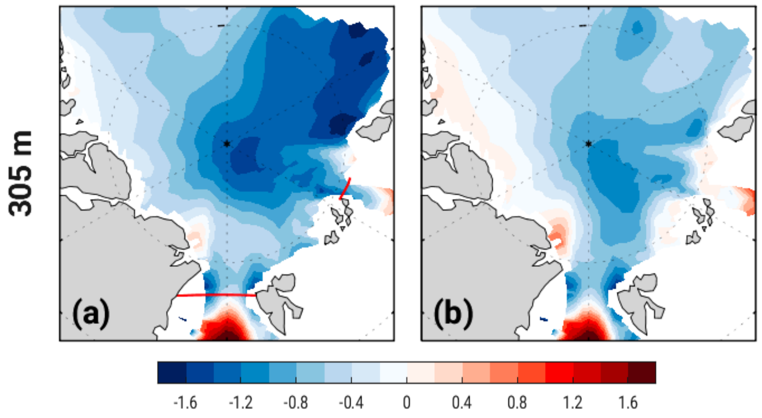


- Thinner and shallower AWL

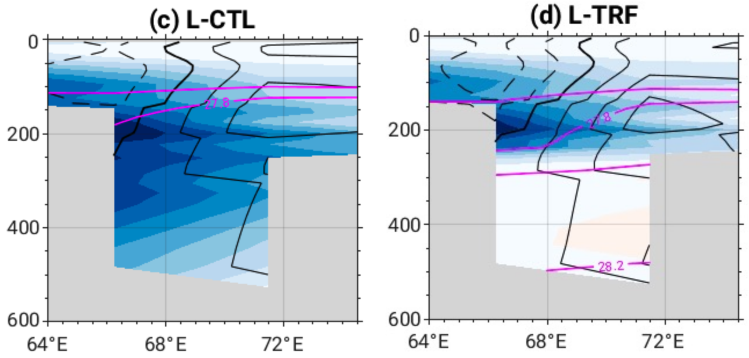
Impact of the TRF restoring

Temp Bias at 300 m

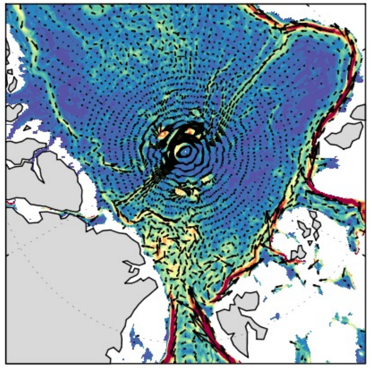
L-CTL L-TRF



SAT Temp Bias

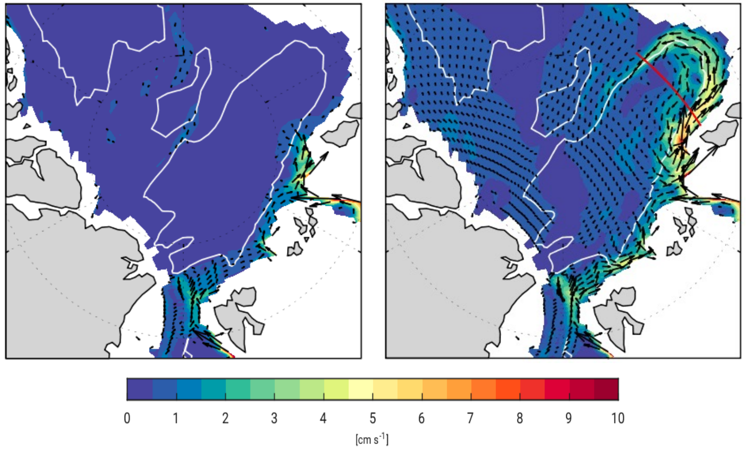


(a) RARE



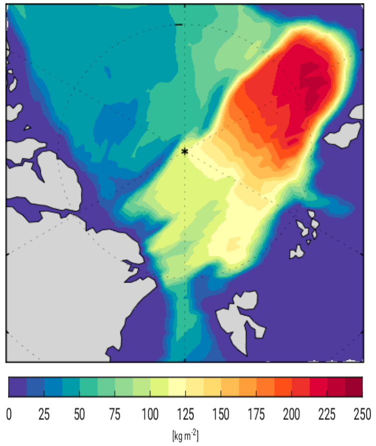
Regional Arctic Reanalysis
(Carton & Chepurin 2023)

Uo at 300 m



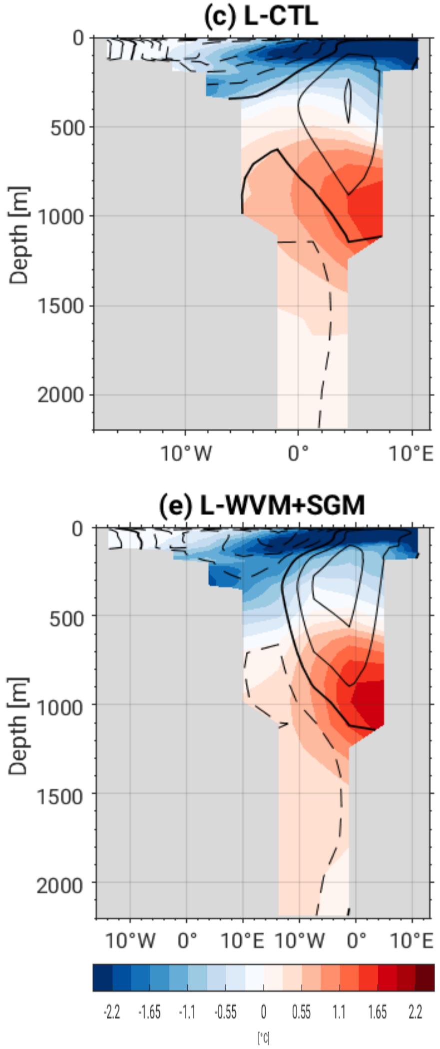
Integrated Density (>300m)

L-TRF – L-CTL

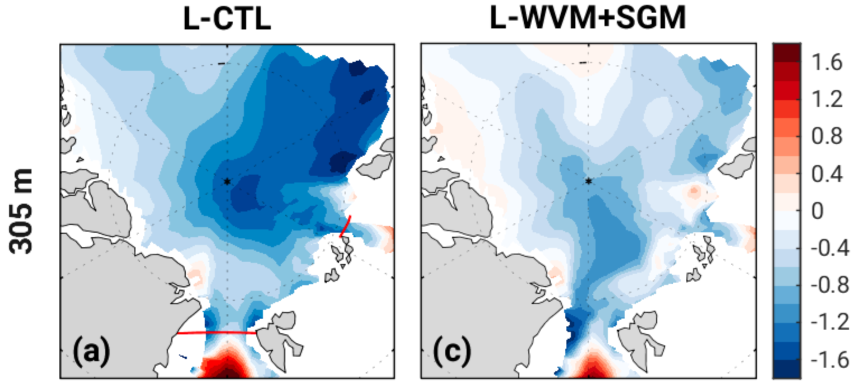


Impact of the Scaled GM diffusivity

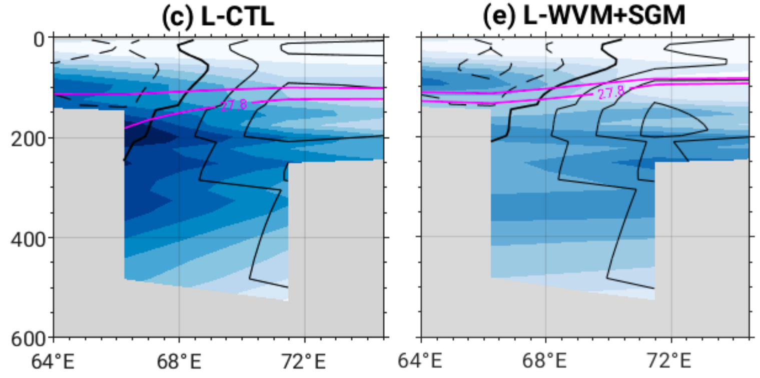
Fram Strait Temp Bias



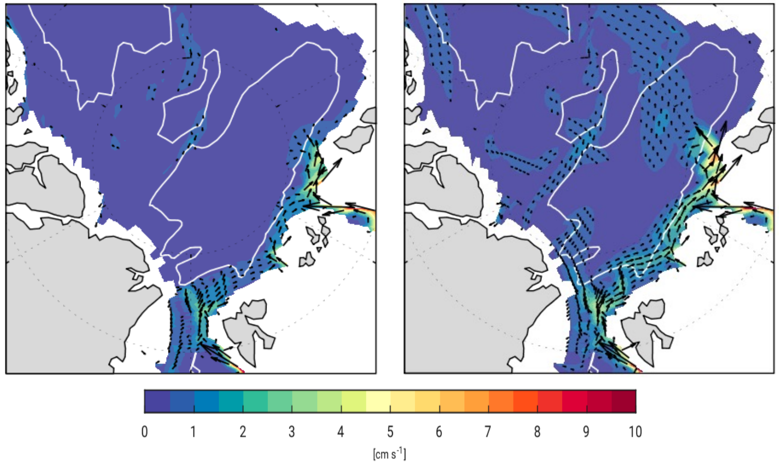
Temp Bias at 300 m



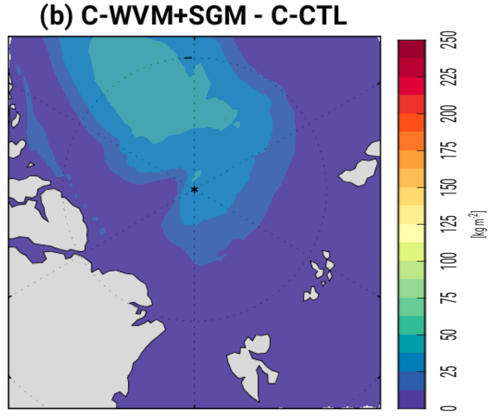
SAT Temp Bias



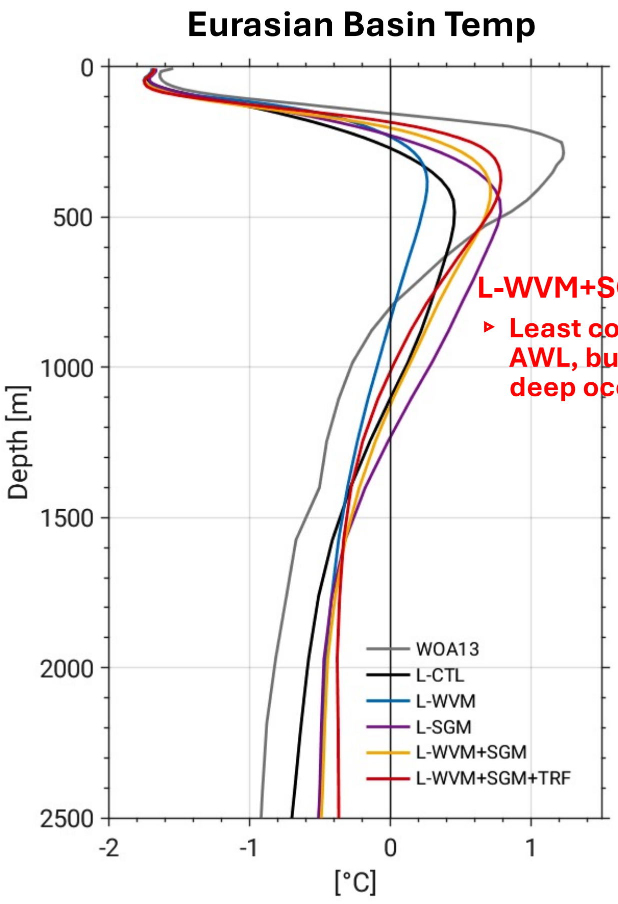
Uo at 300 m



Integrated Density (>300m)

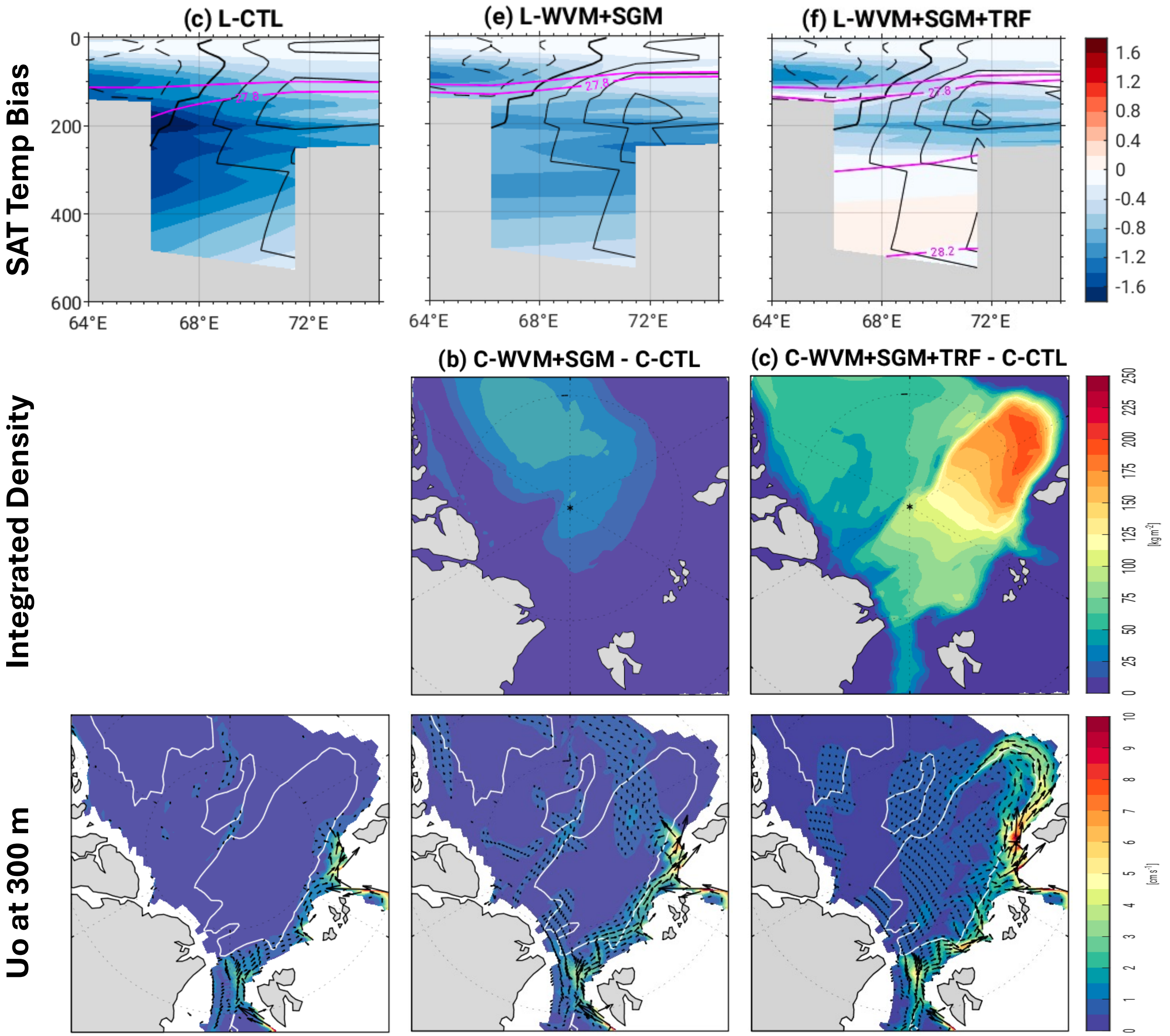


SGM+TRF



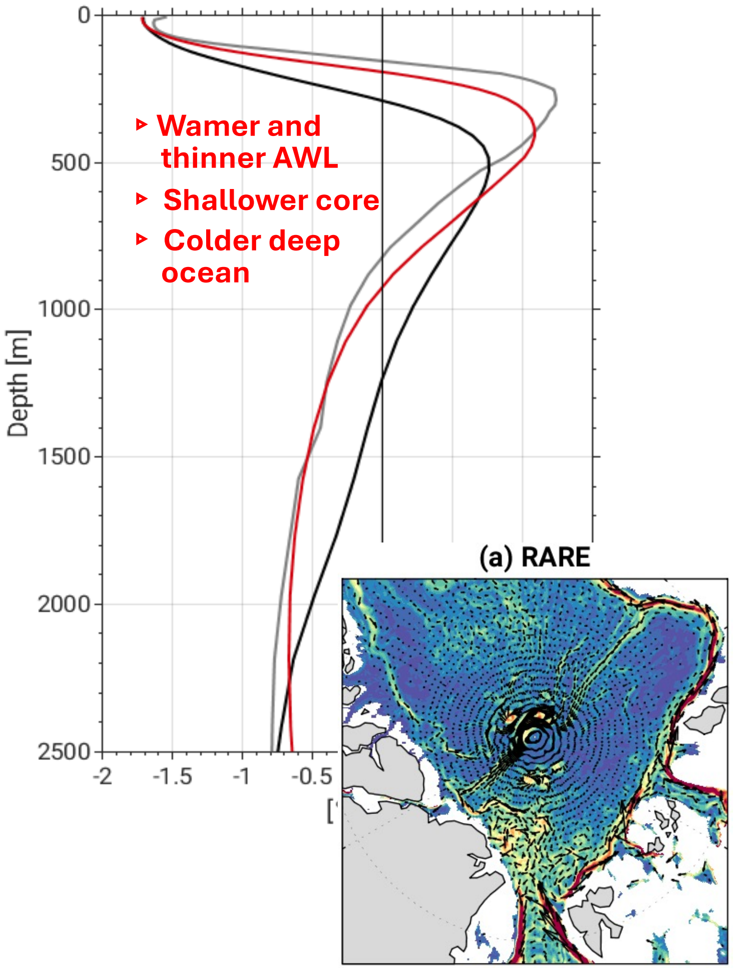
L-WVM+SGM+TRF:

- Least cold-biased in AWL, but warmer deep ocean

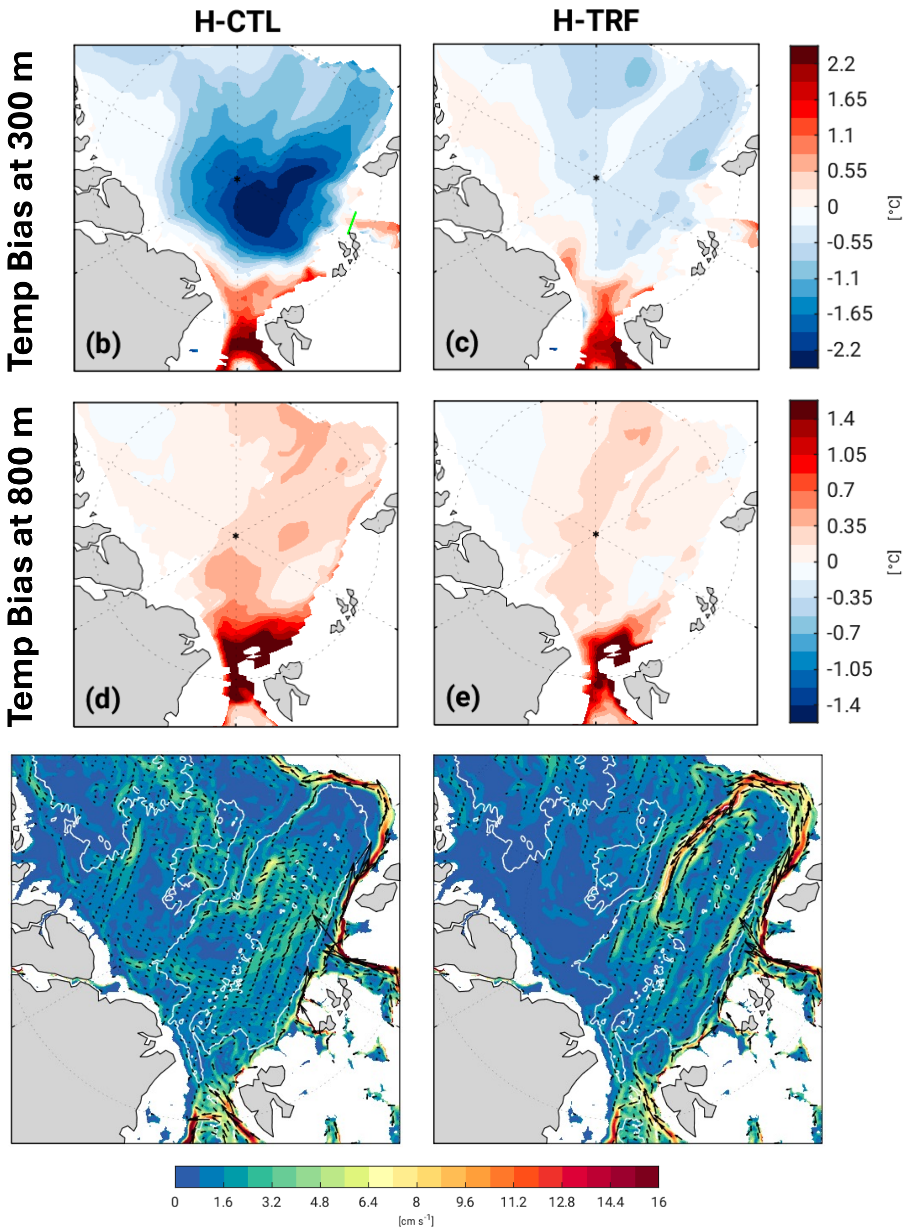


HR Experiments

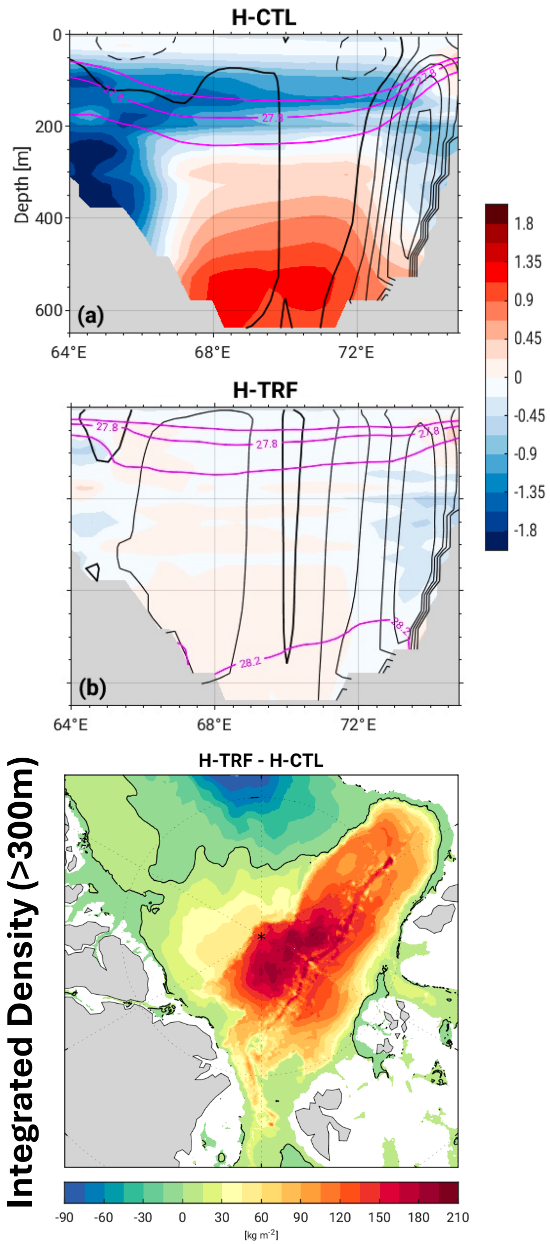
Eurasian Basin T Profile



- Wamer and thinner AWL
- Shallower core
- Colder deep ocean



SAT Temp Bias



Summary

1) **Important role of the inflows through the troughs and channels** in setting up the hydrographic properties and circulation of the AW
   - The AW biases are substantially reduced (warmer, shallower, and thinner)
   - The cyclonic circulation becomes substantially stronger in the eastern EB
   - Mixing within the trough and at the exit with the Fram Strait branch AW more matters than source waters over the shelf
   - **Calls for the development of a (overflow?) parametrization (even in HR)**

2) **Too weak Fram Strait branch**
   - The Fram Strait branch appears to be too weak even in HR
   - Scaling GM diffusivity coefficients to grid area (i.e., weaker mixing in the Arctic) strengthens the circulation in the western EB
   - **Tuning of mixing parameters** (viscosity and diffusivity for HR)
   - Stronger Fram Strait branch → Biases in the Nordic Seas (too warm in the deep ocean) become more matter