Development and Evaluation of a High-Resolution Pan-Arctic Ocean-Sea Ice Coupled Model Using MOM6: Insights from Zstar and Hybrid Coordinate System

Mehmet ILICAK

Ocean Model Working Group Meeting 2025, Boulder, NCAR

101081568

Motivation

Outline

- Motivation
- Model setup
- Results
- Conclusion

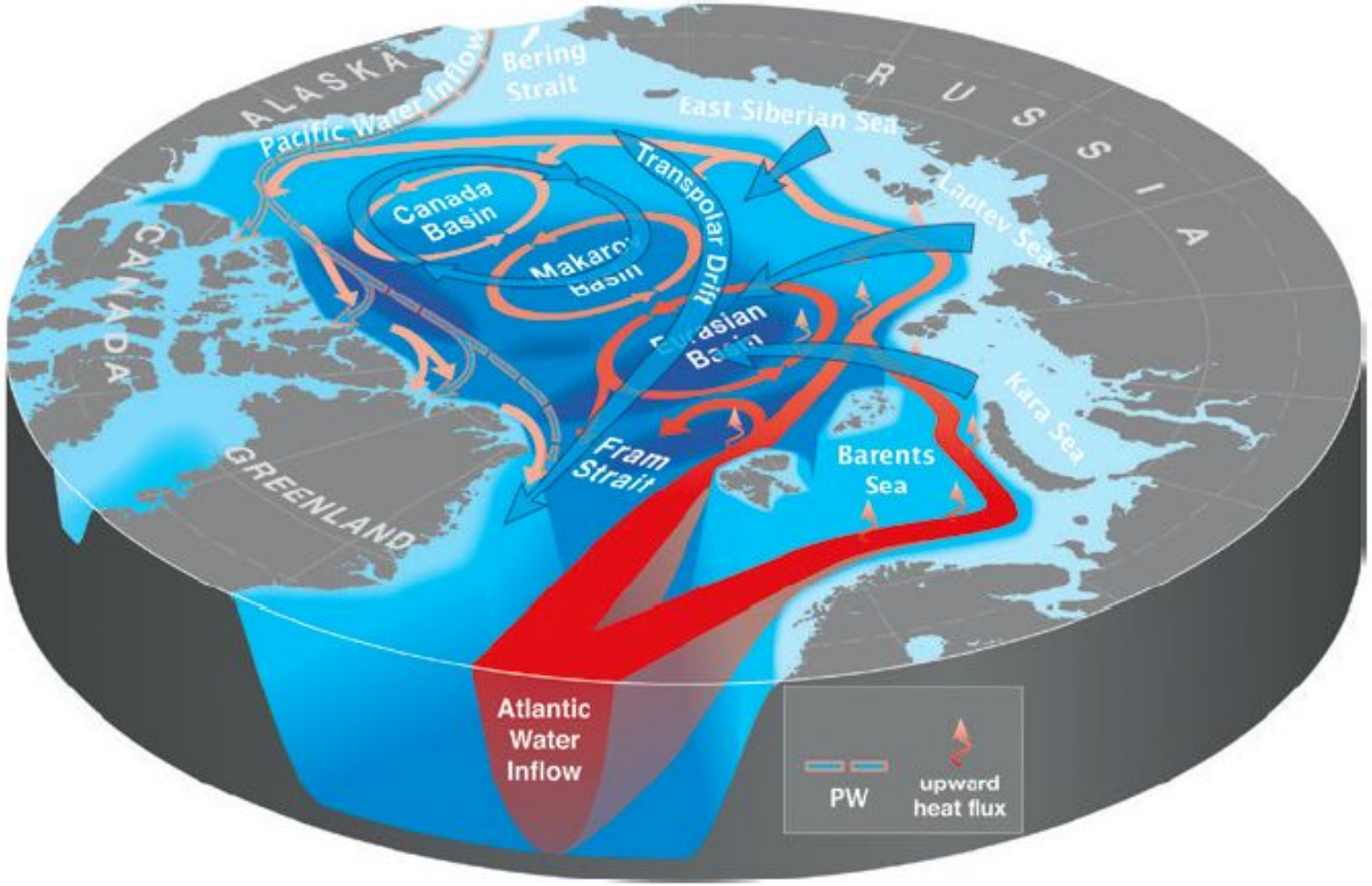
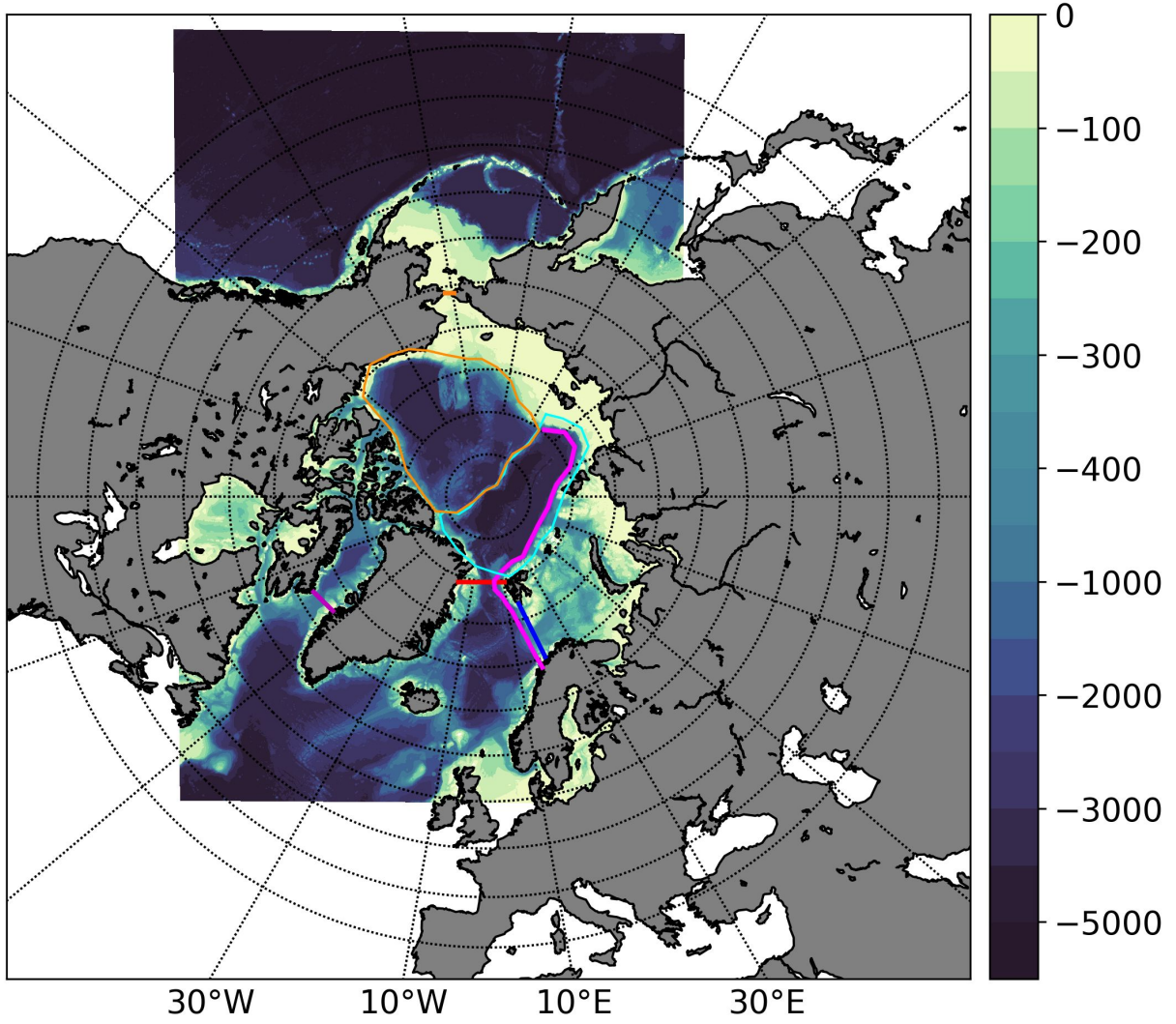


FIG. 3. Circulation of the surface water (blue), intermediate Pacific Water (pink/blue), and Atlantic Water (red) of the Arctic Ocean.

Carmack et al. 2015

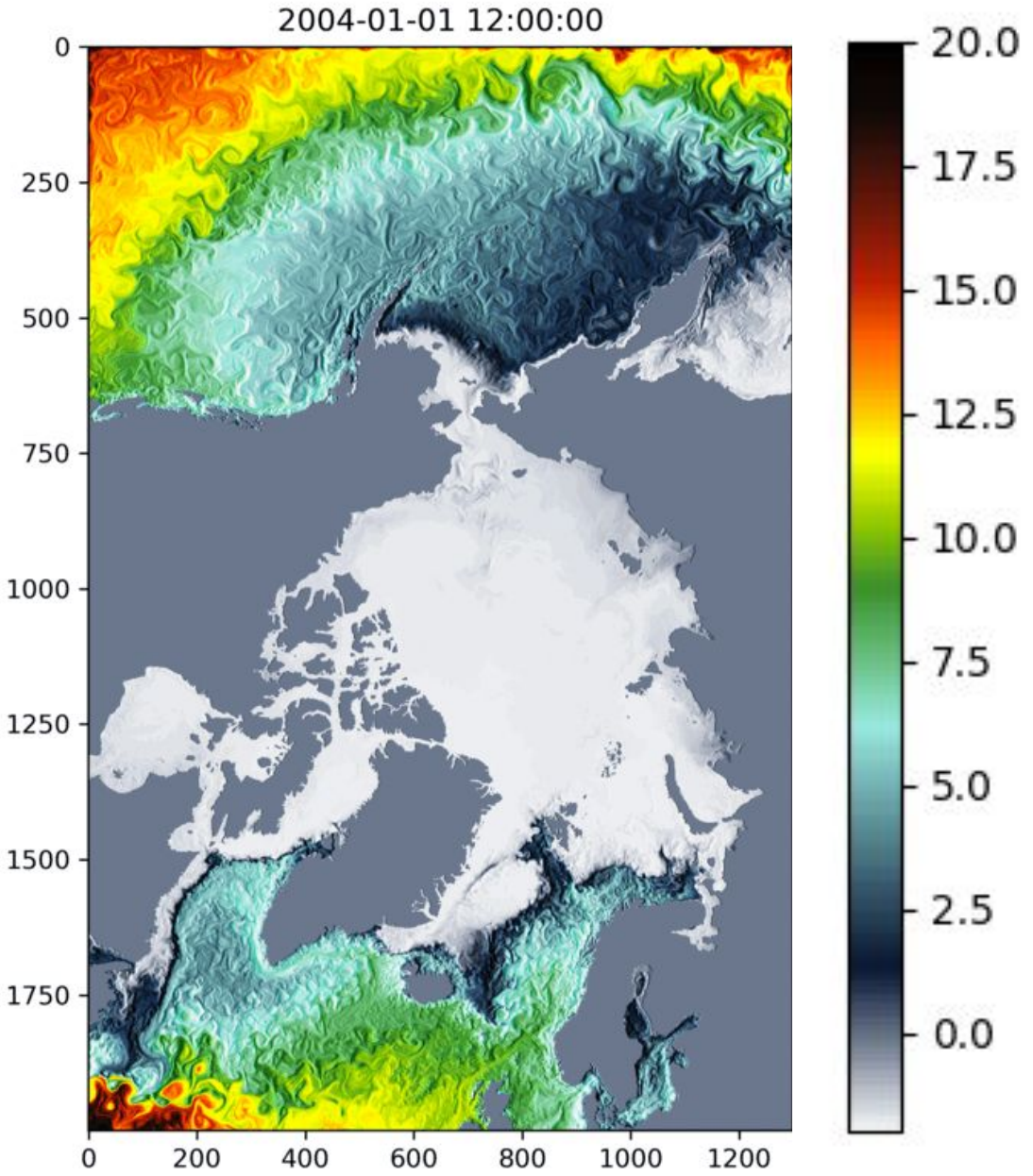
Model setup

- A regional Pan-Arctic MOM6 model.
- 4-5 km horizontal resolution
- 75 vertical levels, **zstar, hybrid**
- ERA5 hourly atmospheric forcing.
- GLORYS ocean reanalysis lateral open boundary conditions.
- GLOFAS daily river forcing.
- 1996-2017 simulation length.



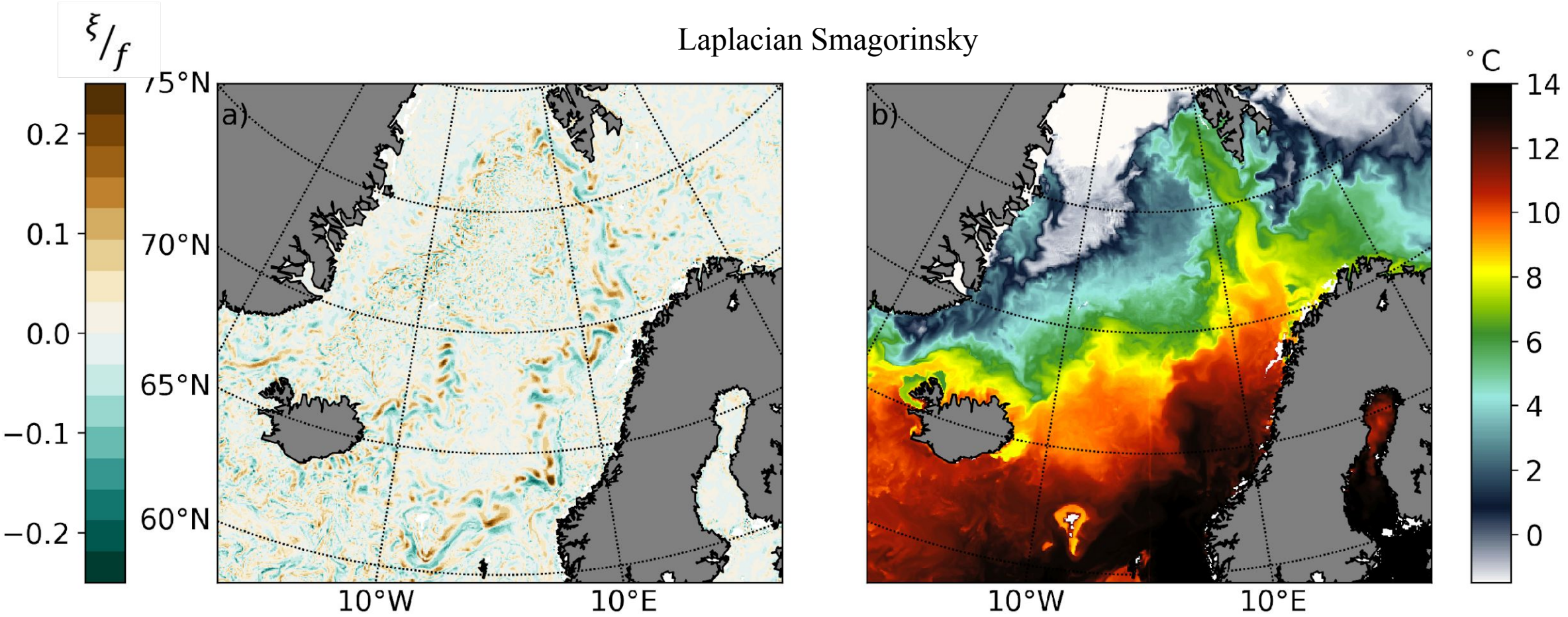
Model setup

- GM and thickness diffusion is off.
- Initial conditions are from GLORYS reanalyses. No SSS relaxation.
- Flather, radiation boundary conditions.
- Tested both Laplacian and Biharmonic Smagorinsky with coeff. of 2 and 0.06, respectively.
- EPBL vertical mixing scheme (Kd_bck=1e-5).
- Climatological chl based SW scheme.



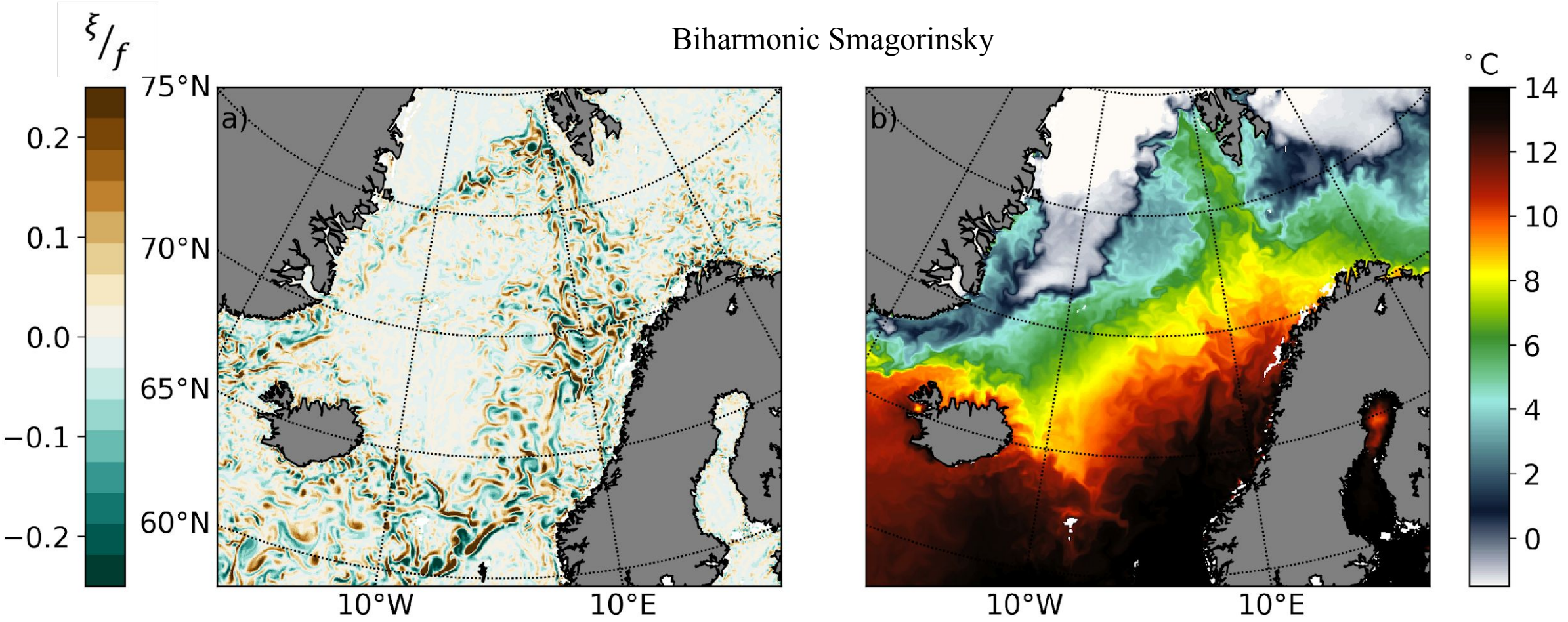
Daily snapshot of vorticity and SST

Laplacian Smagorinsky



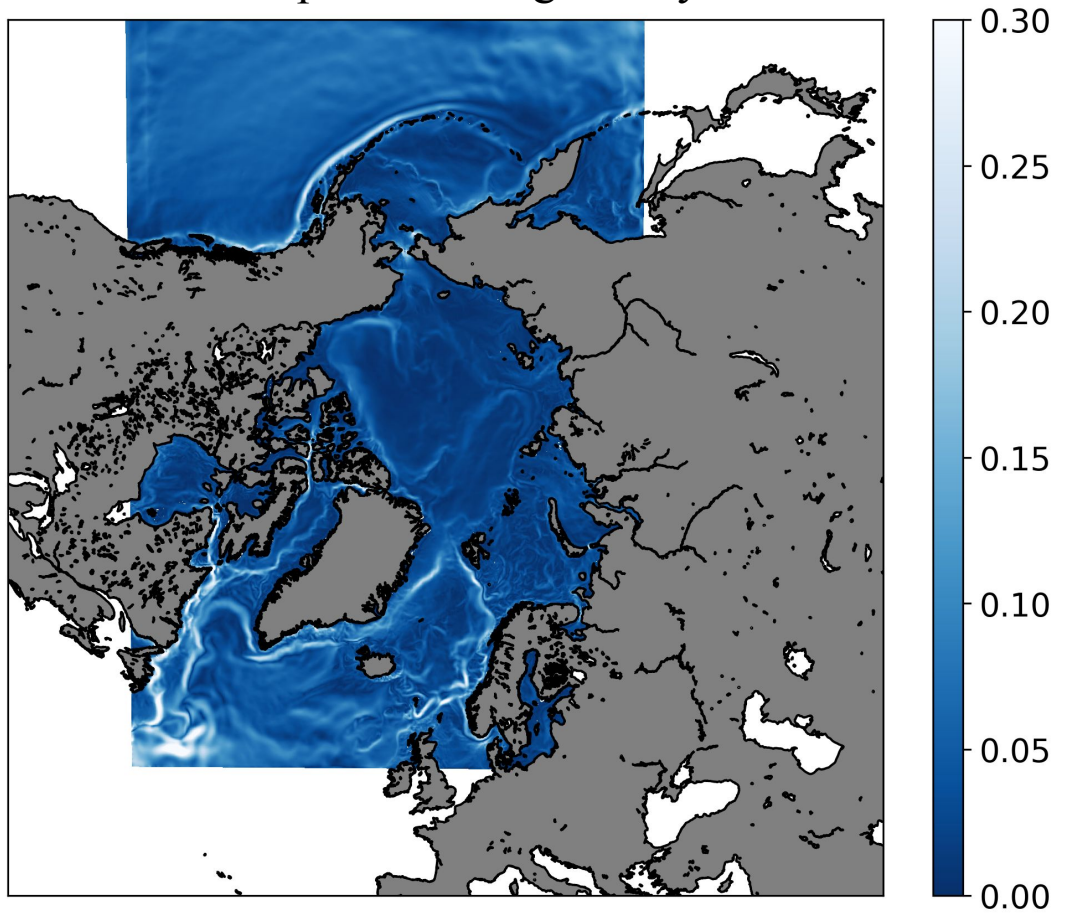
Daily snapshot of vorticity and SST

Biharmonic Smagorinsky

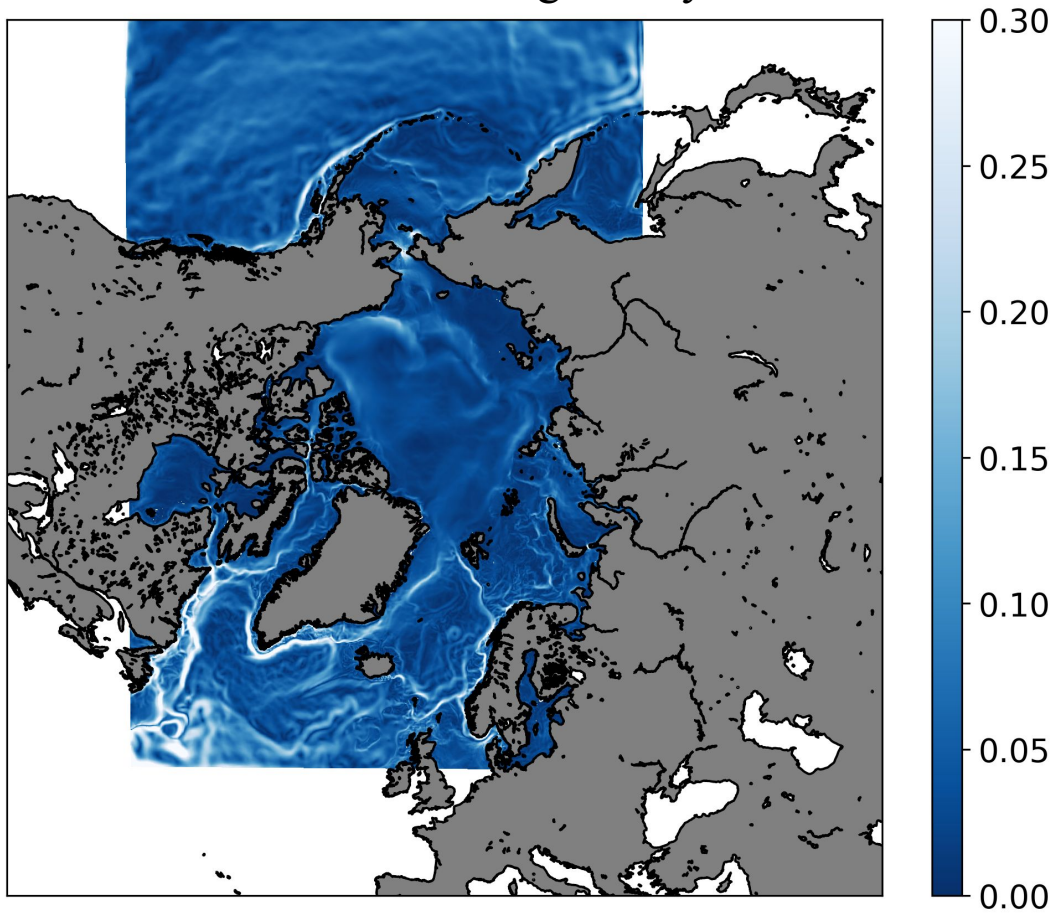


Mean circulation and transports

Laplacian Smagorinsky



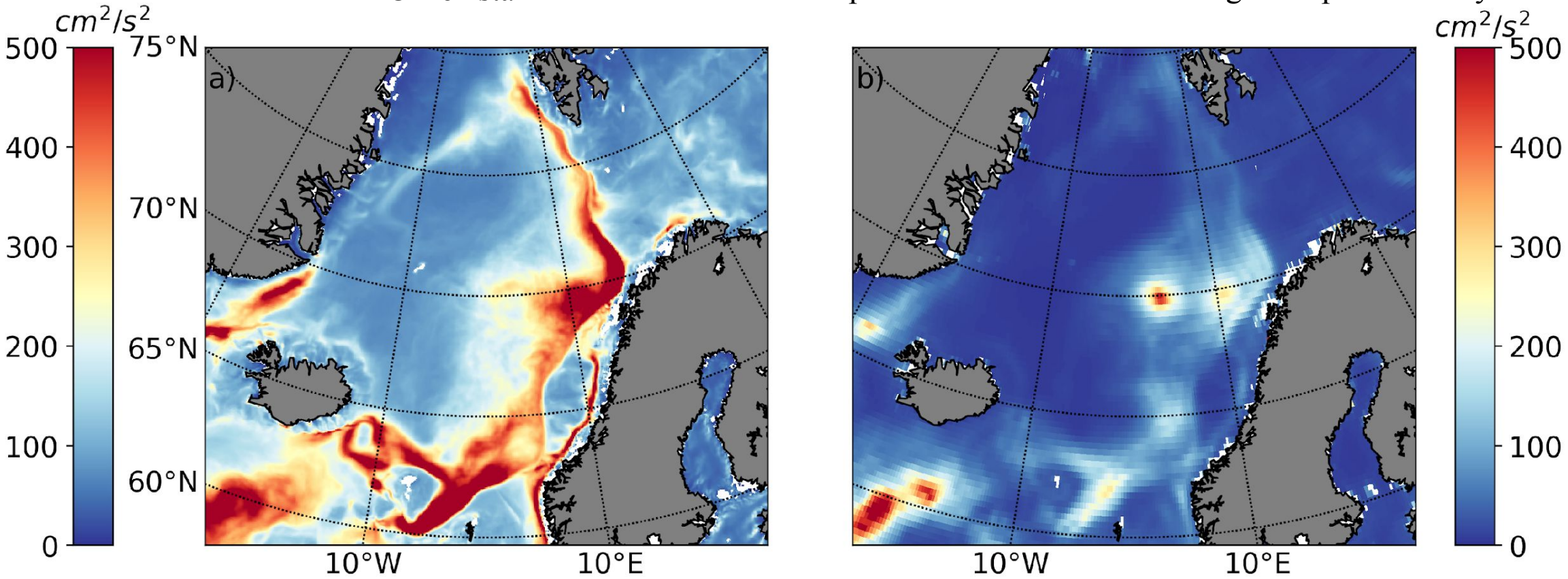
Biharmonic Smagorinsky



EKE in the Nordic Seas

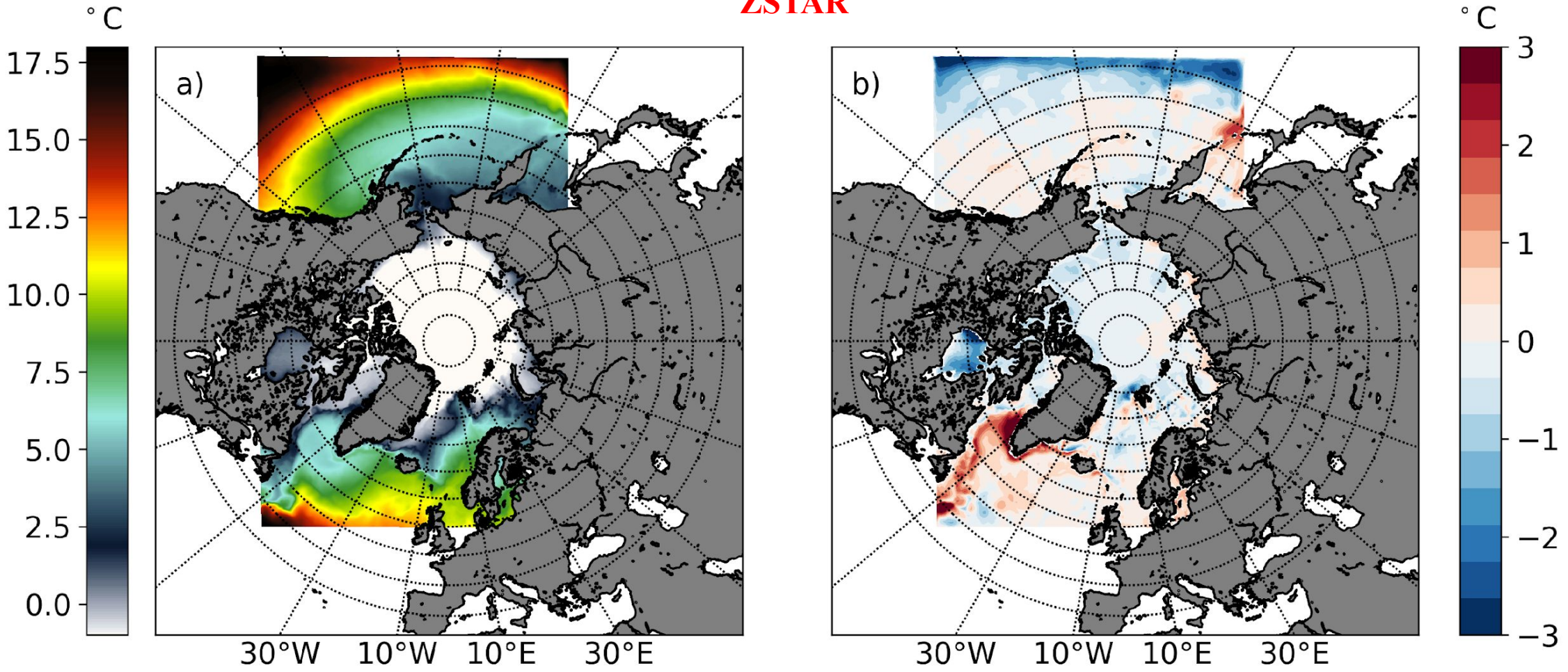
MOM6 zstar

Copernicus L4 Sattelite dataset geostrophic velocity



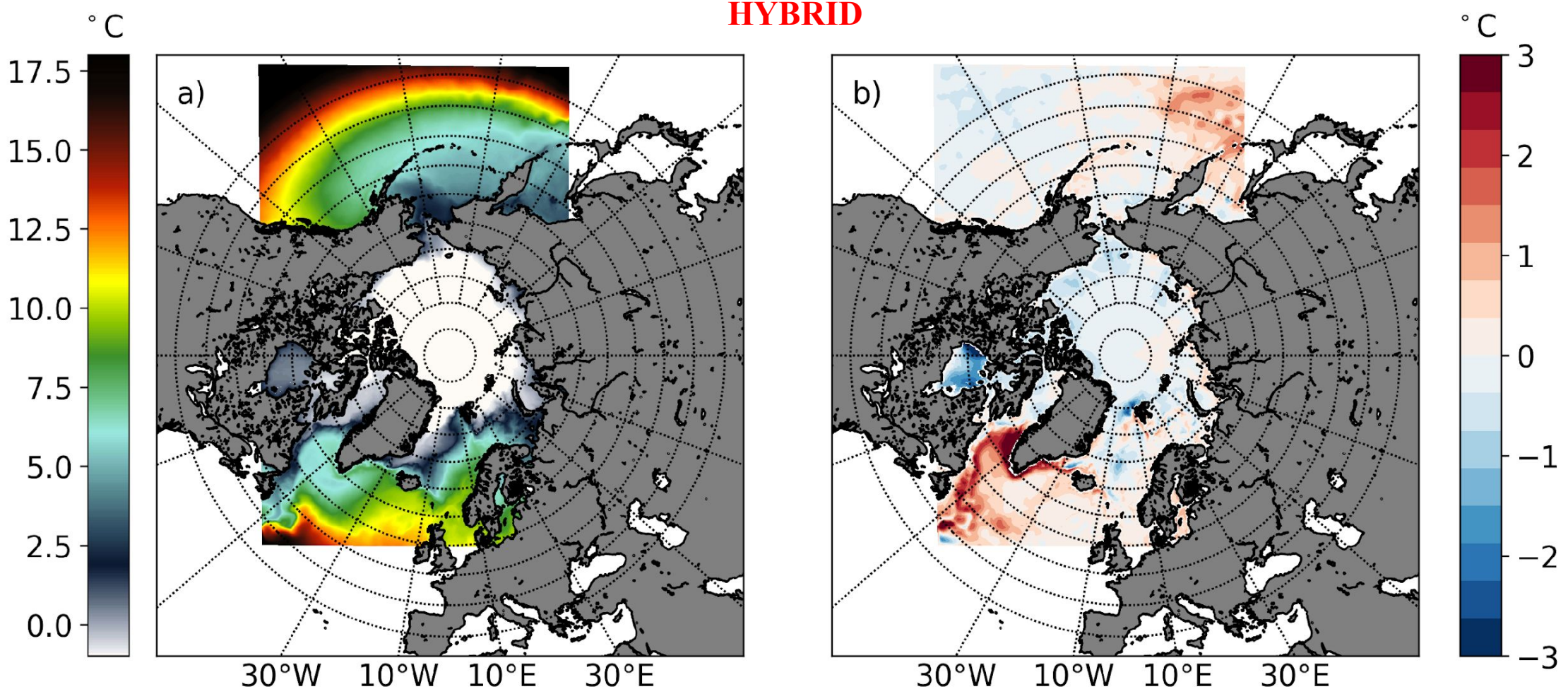
Mean SST and bias from WOA18

ZSTAR

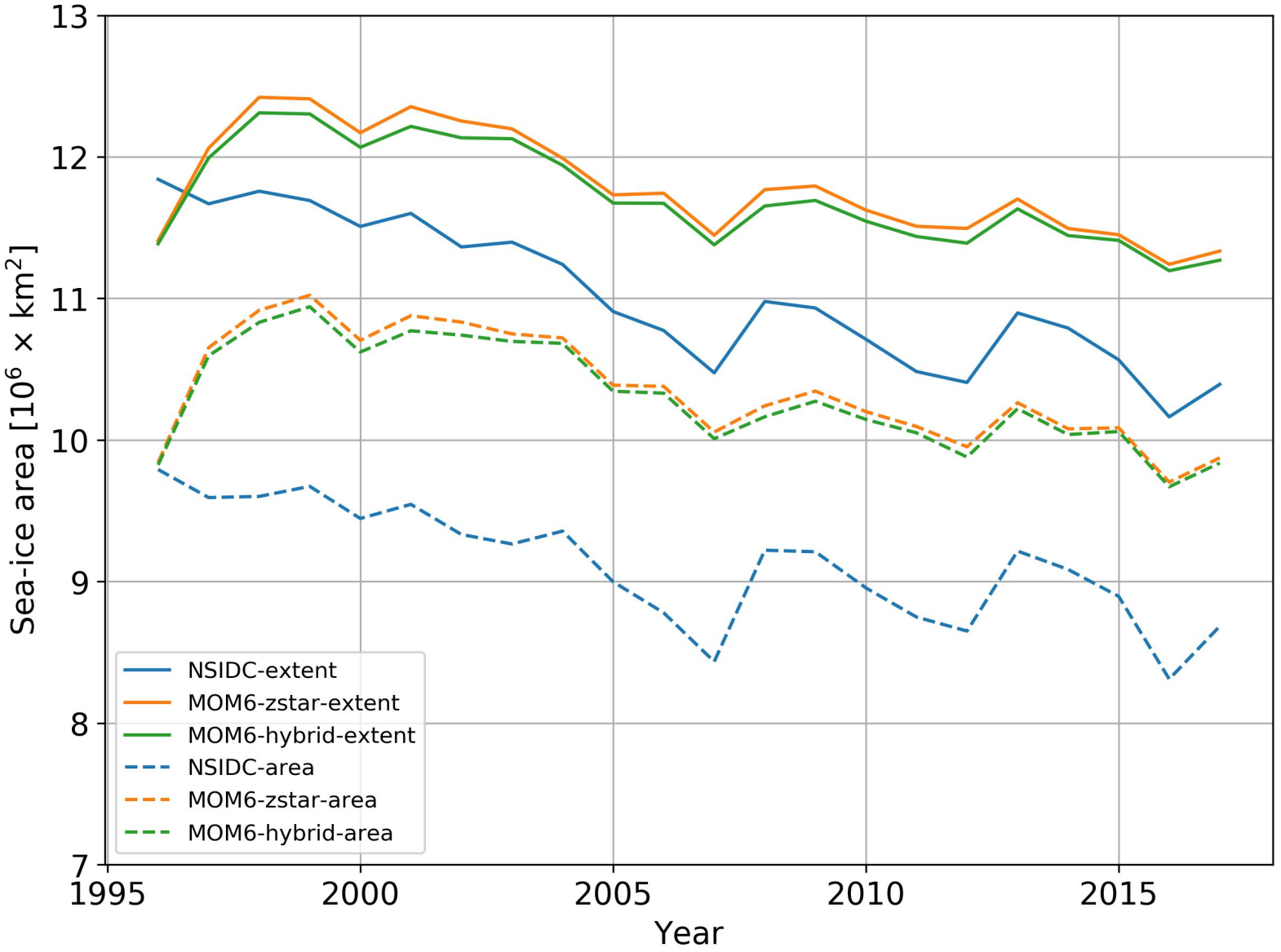


Mean SST and bias from WOA18

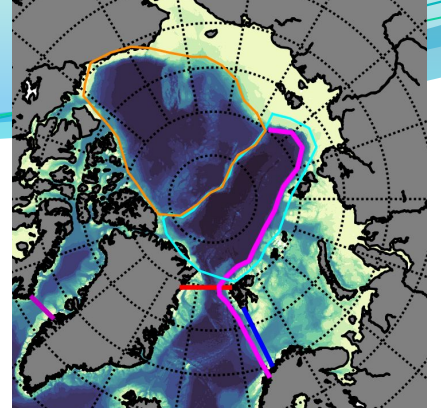
HYBRID

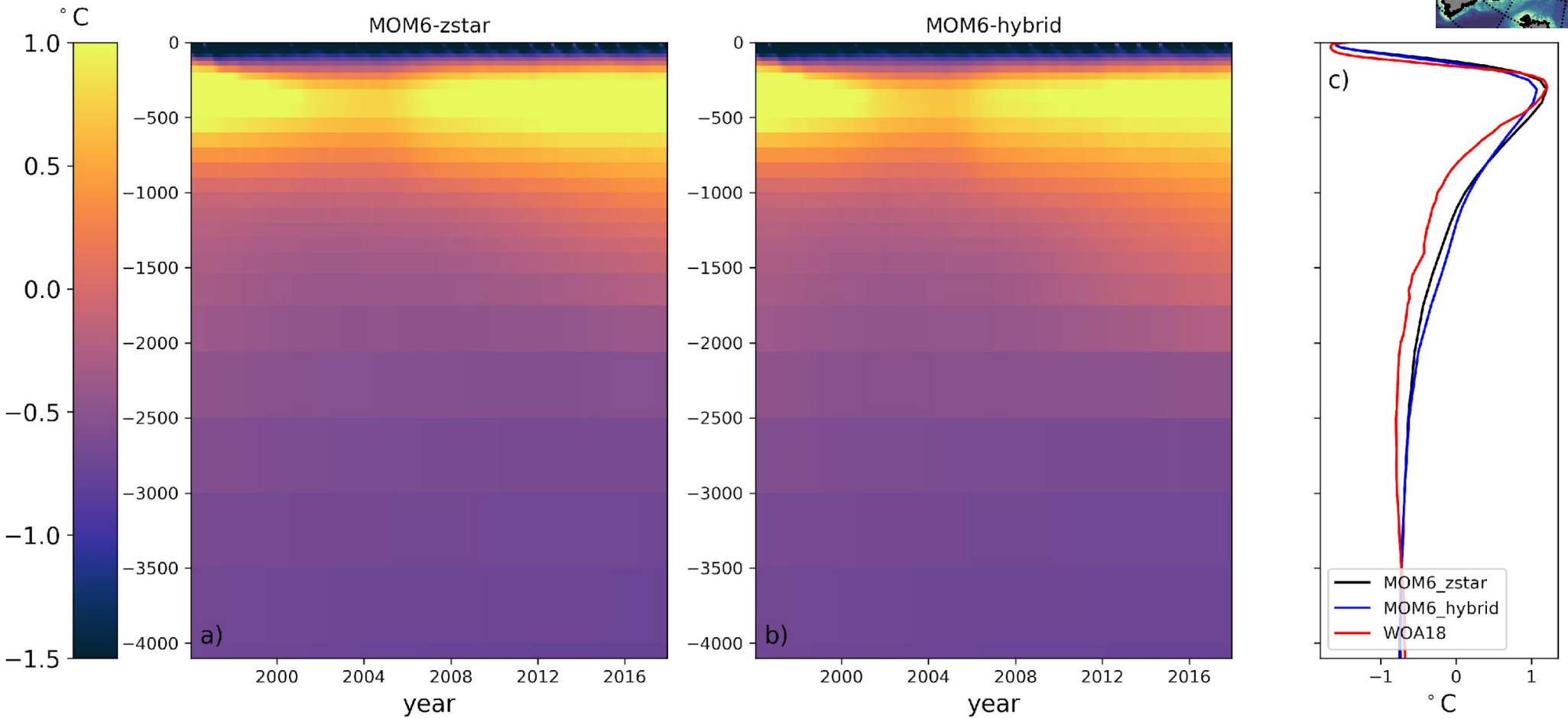


Sea ice extent and area



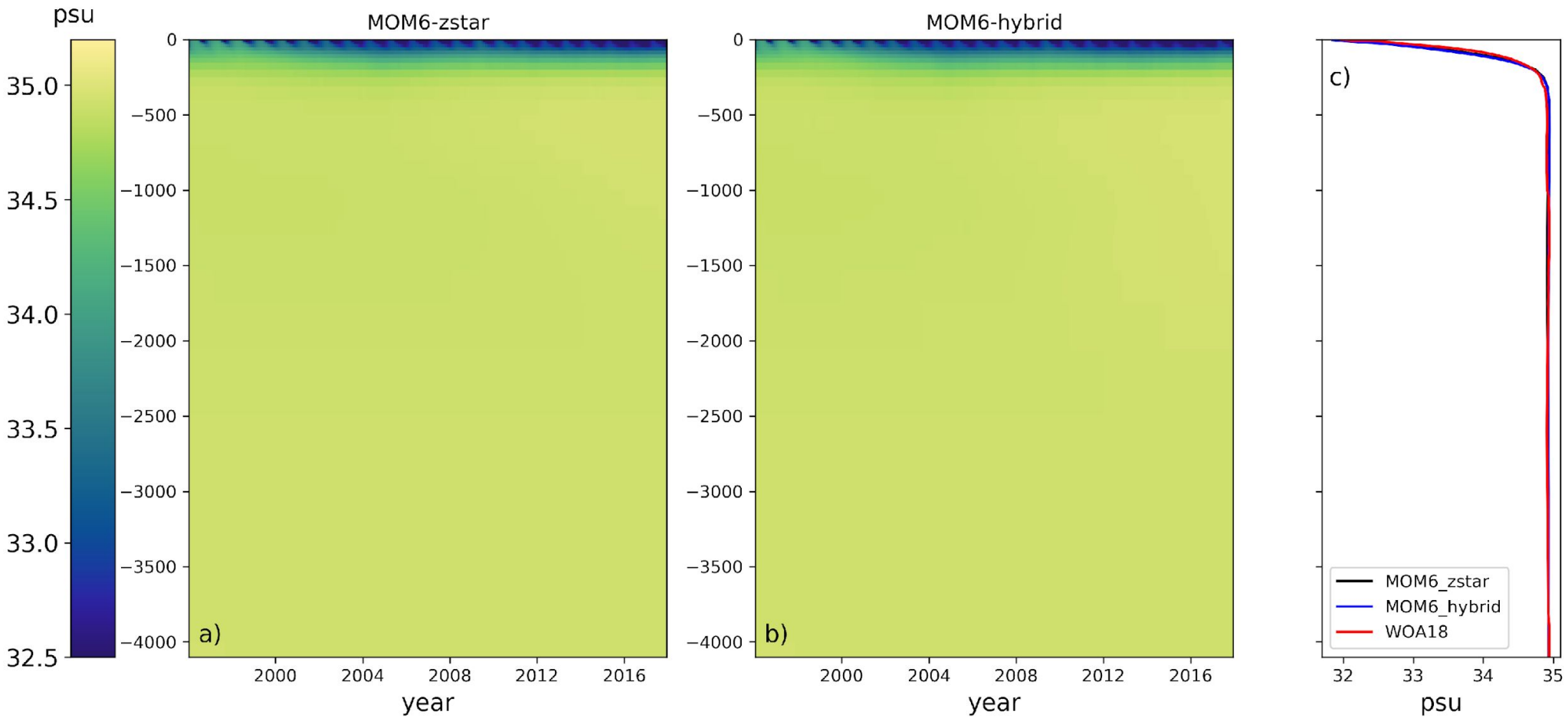
Eurasia Basin temperature



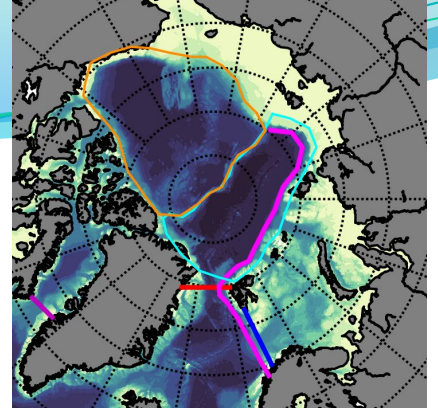


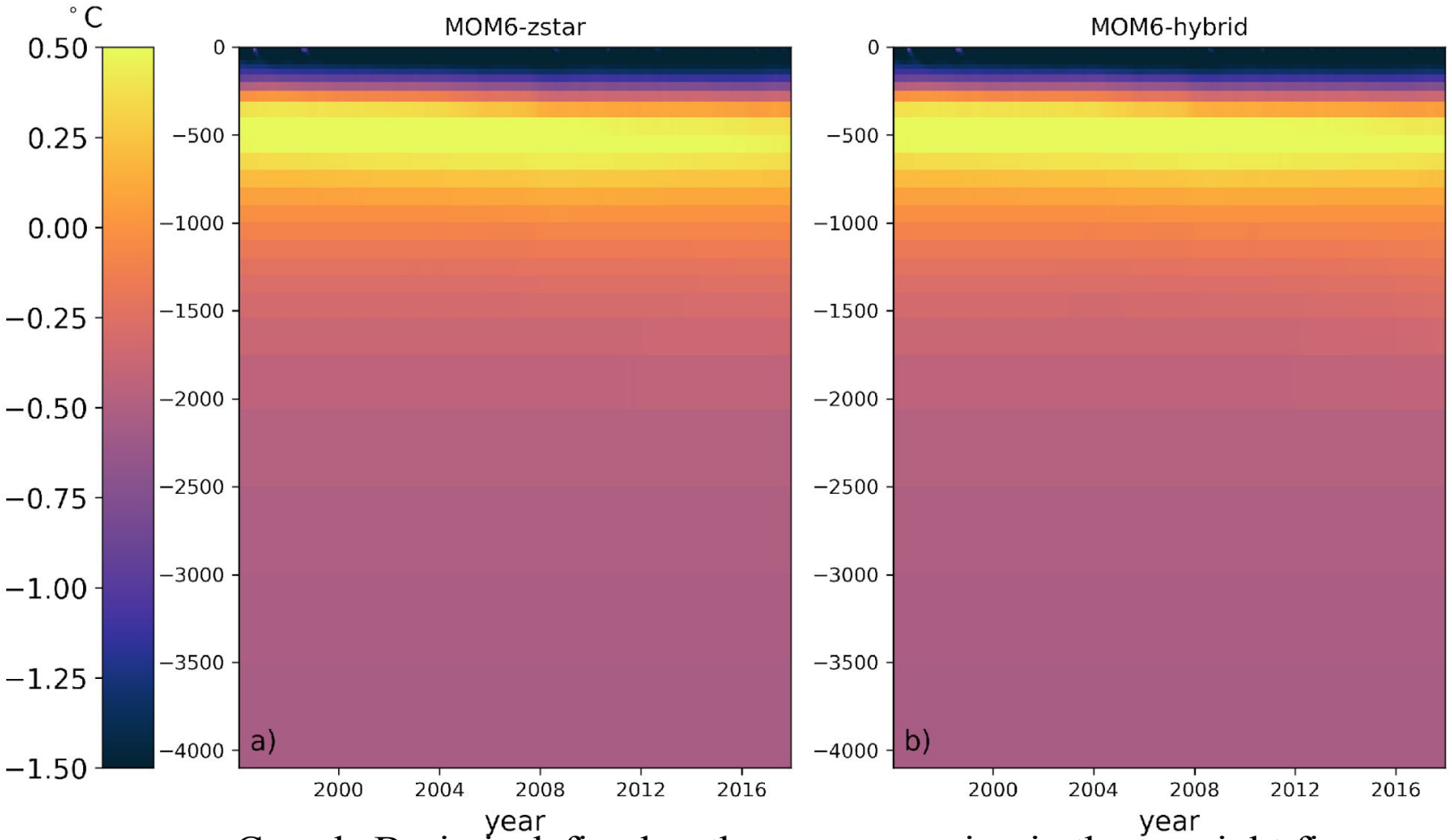
Eurasia Basin is defined as the **cyan** region in the top right figure where the bathymetry is deeper than 500 meter

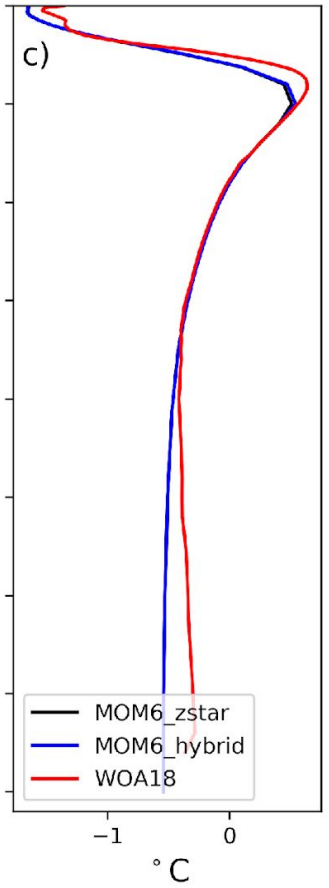
Eurasia Basin salinity



Canada Basin temperature



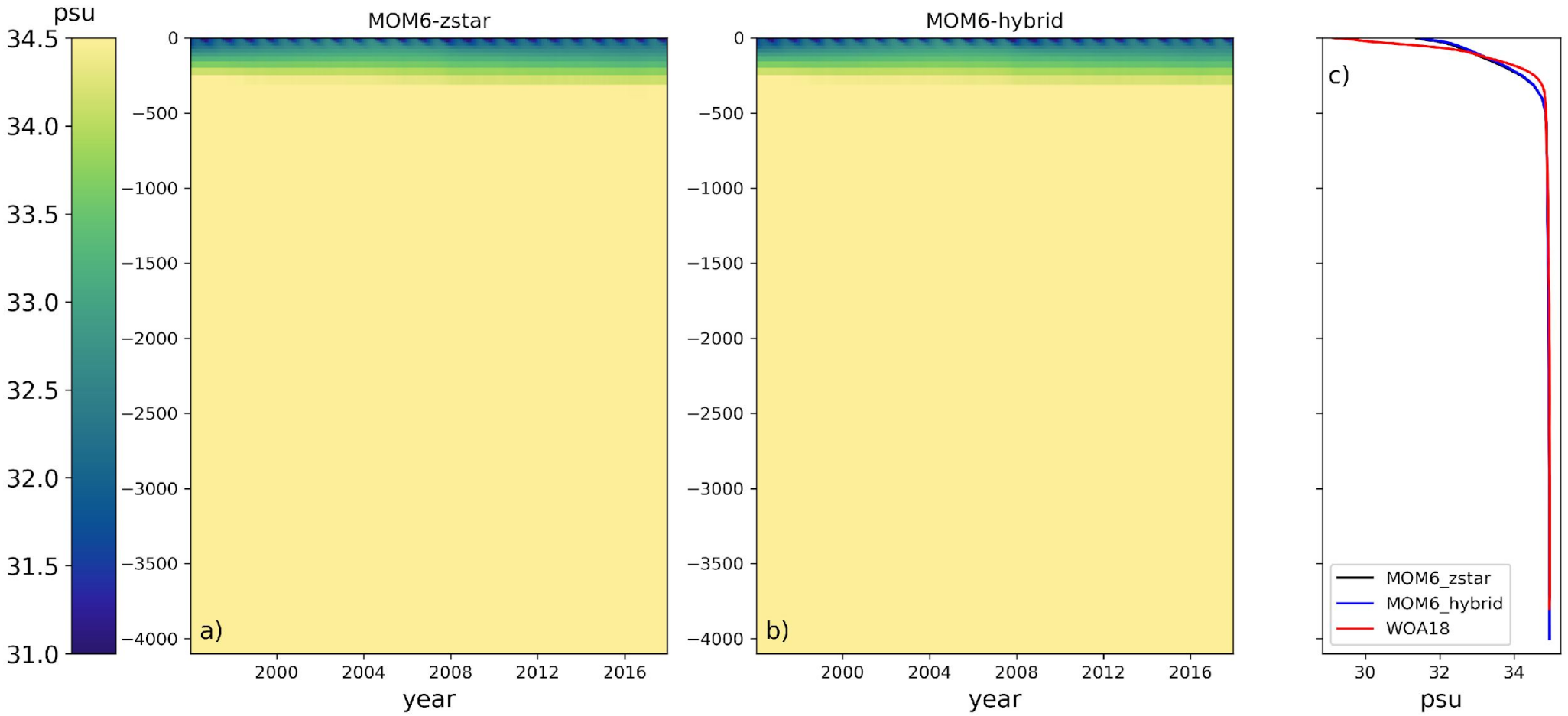




Mean of last 10 years

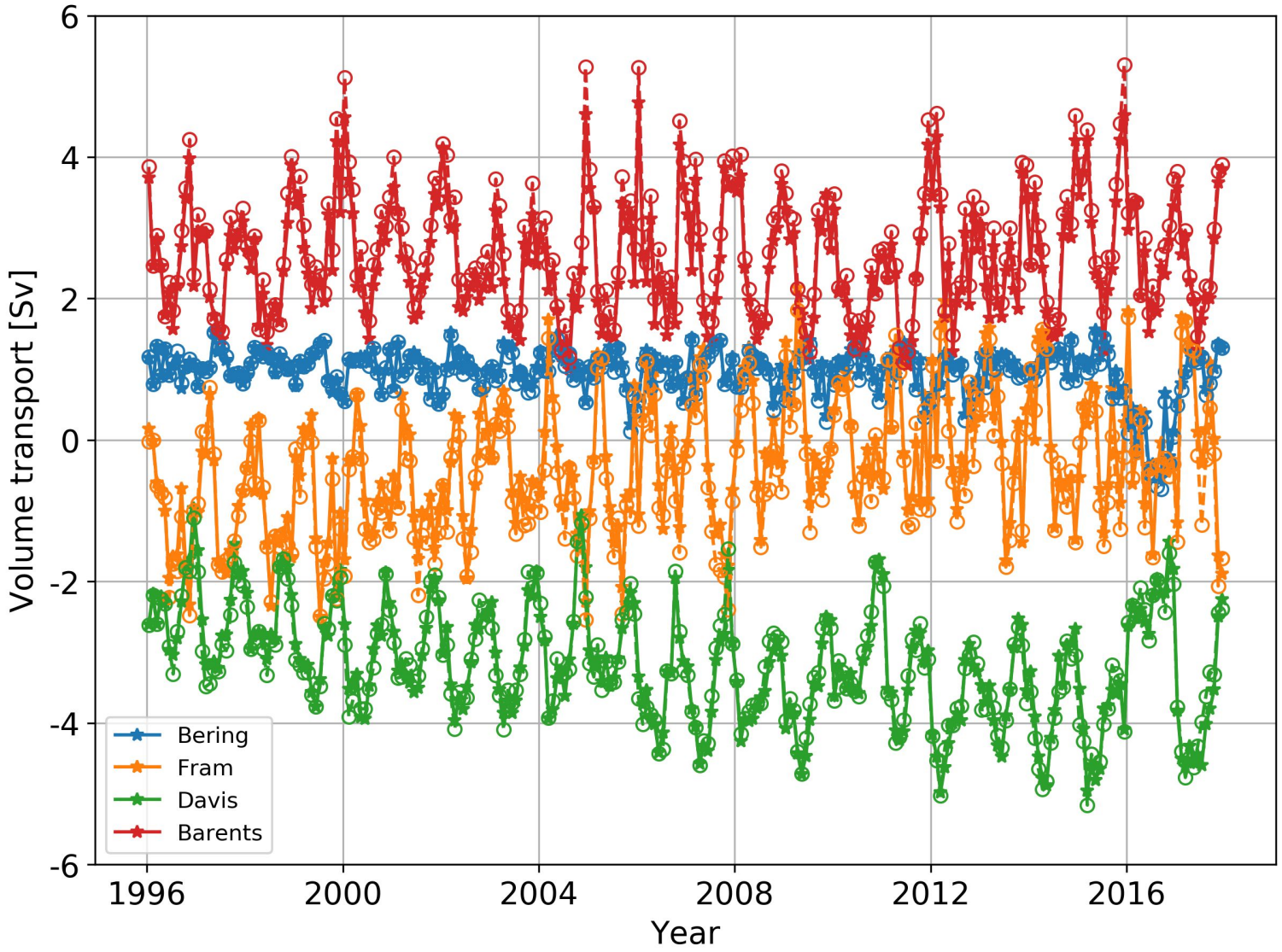
Canada Basin is defined as the **orange** region in the top right figure where the bathymetry is deeper than 500 meter

Canada Basin salinity



Net Volume Transports

* zstar coordinate
o Hybrid coordinate

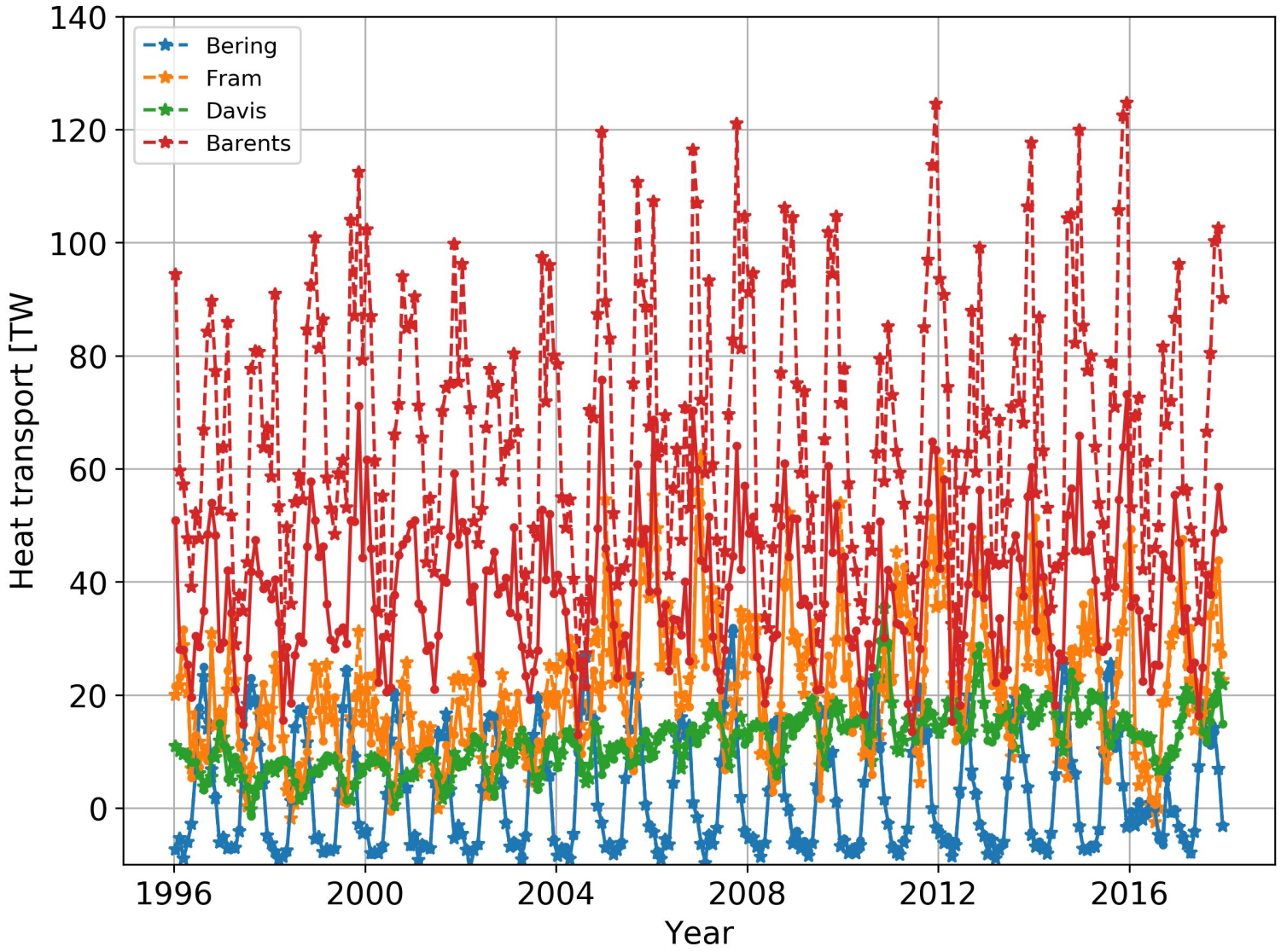


Net Volume Transports

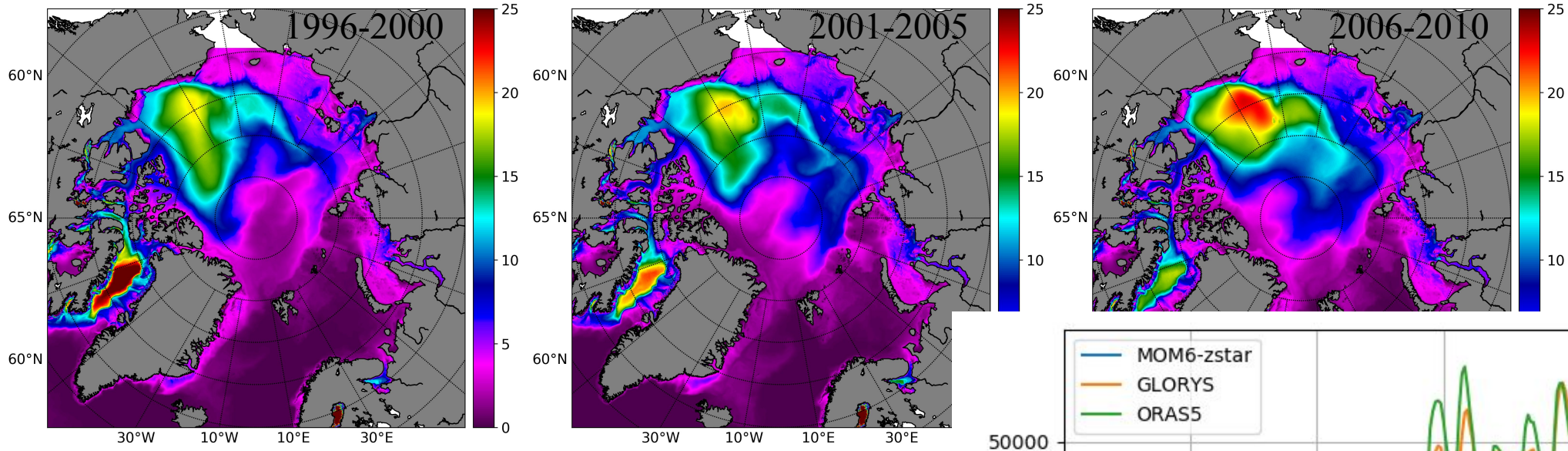
[Sv]	Observations (Smedsrud et al. 2013)	MOM6 zstar
Bering	0.8 ± 0.2	0.98
Barents	2-2.3	2.5
Fram	−2.0 ± 2.7	−0.3
Davis	−2.6 ± 1.0 to−1.6 ± 0.2	−3.1

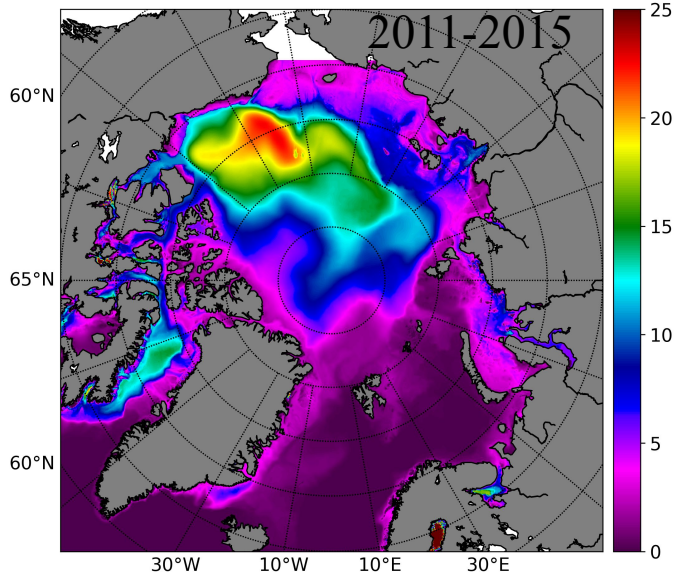
Net Heat Transports

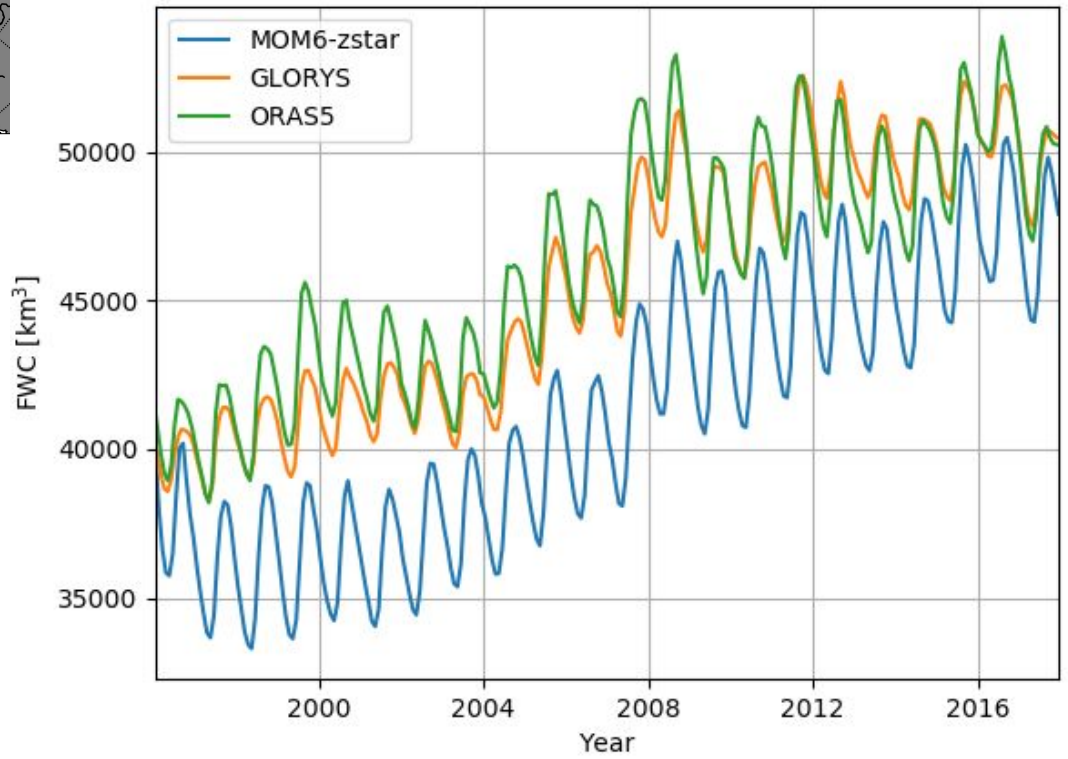
* zstar coordinate
o Hybrid coordinate



Fresh Water Content (FWC)

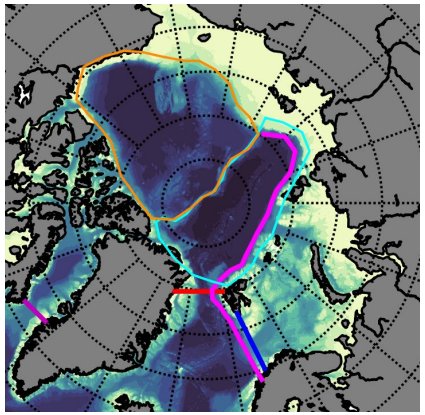


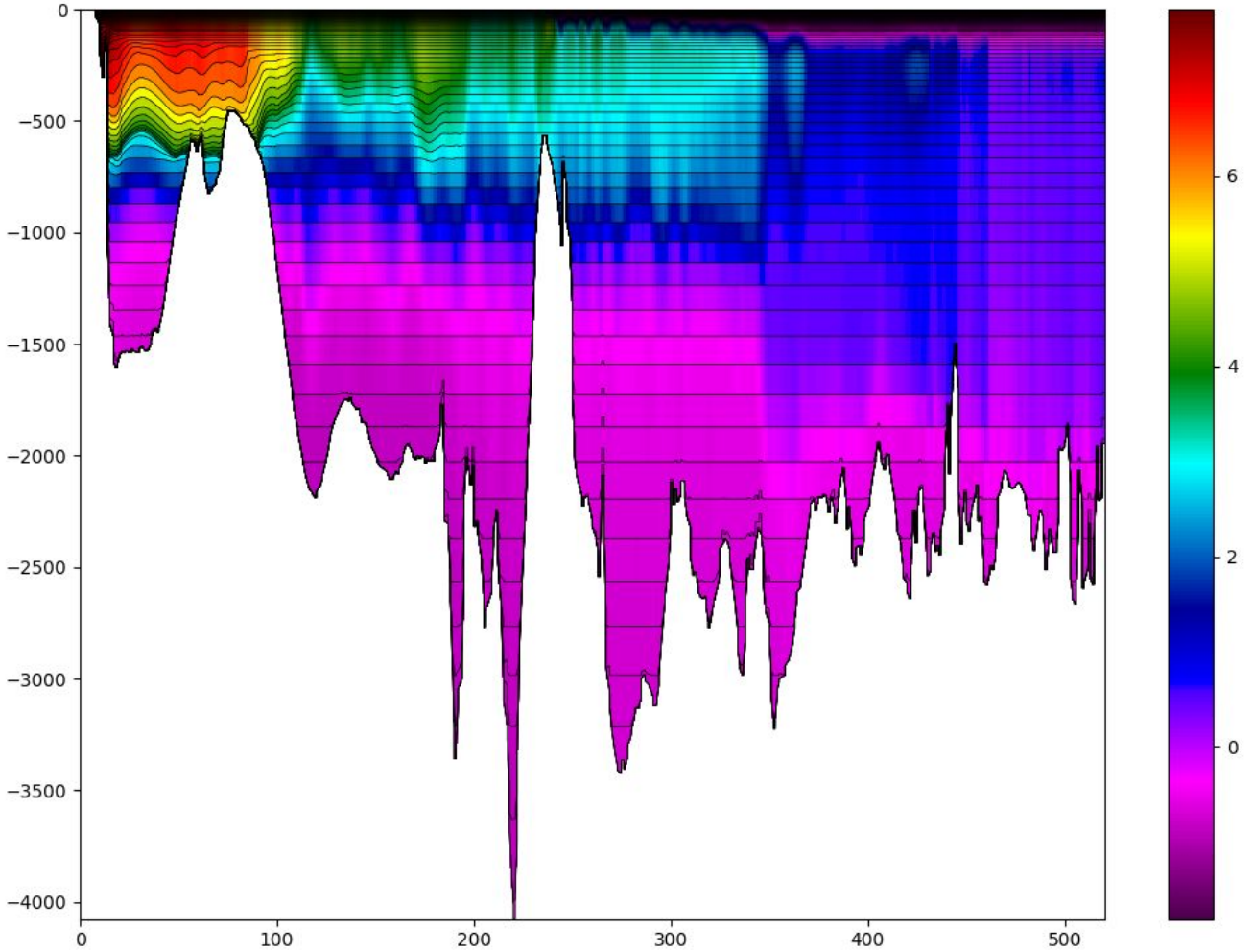




Hybrid coordinate at AW section

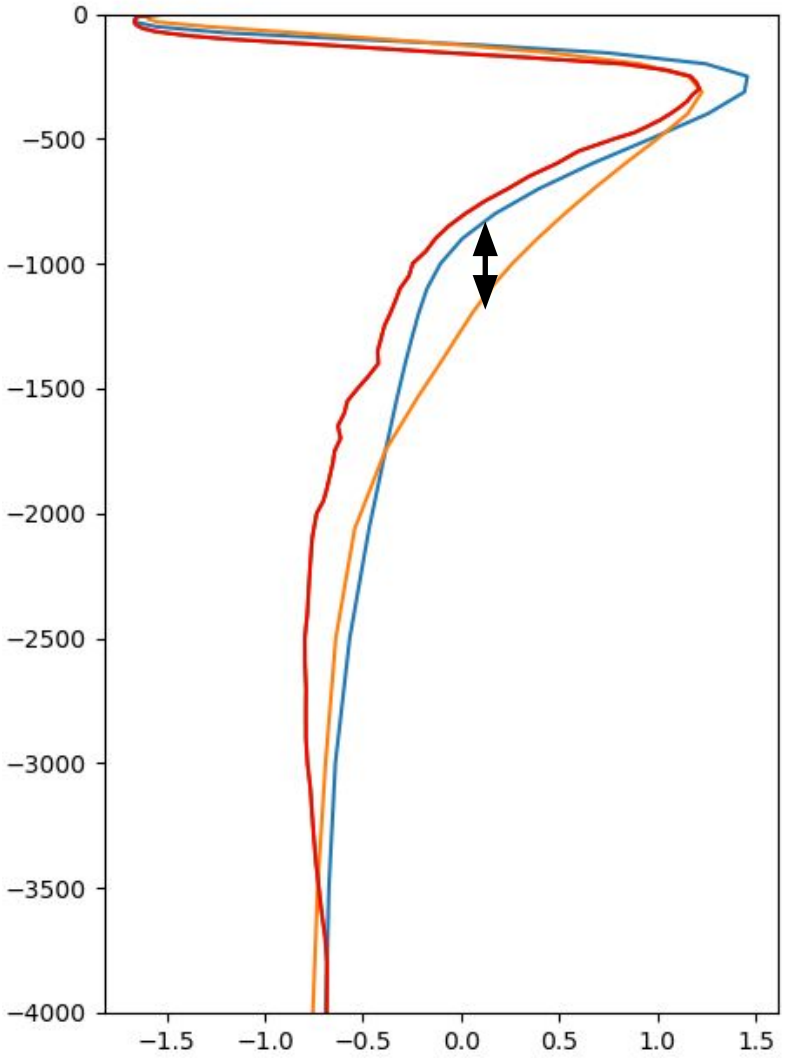
- The Atlantic Water (AW) temperature section (**purple** line in the bottom left figure) shows that hybrid coordinate turns to geopotential in the Arctic interior.





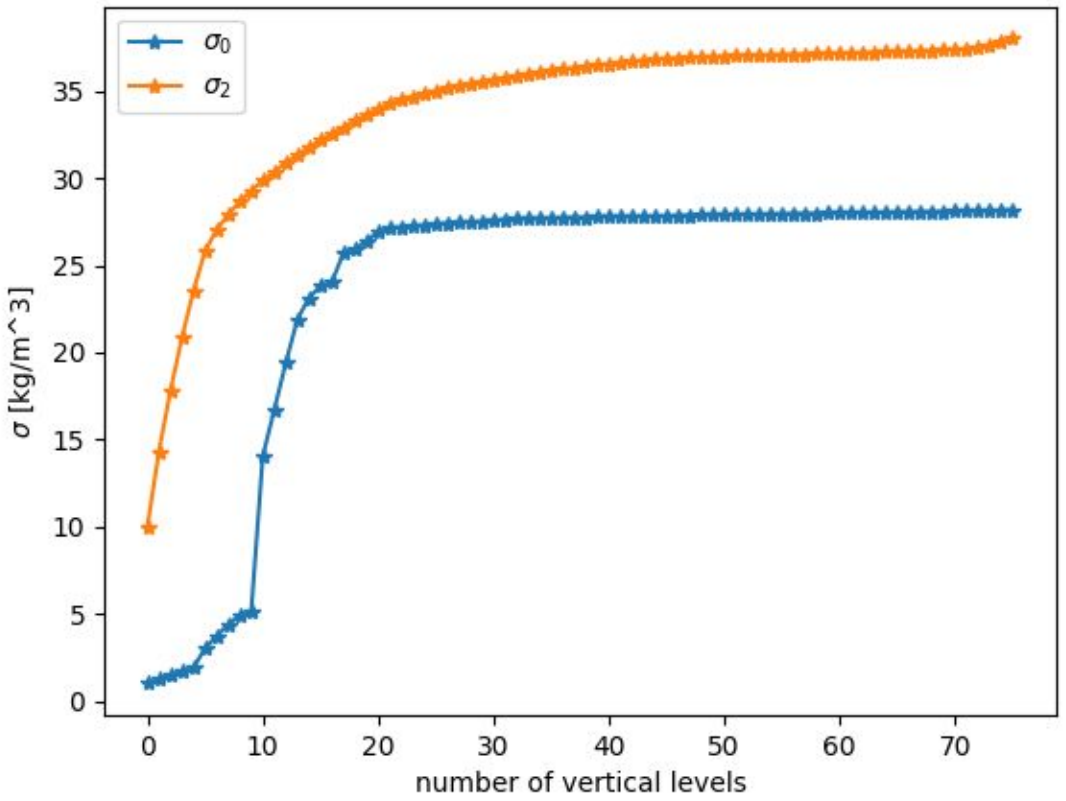
Eurasia Basin

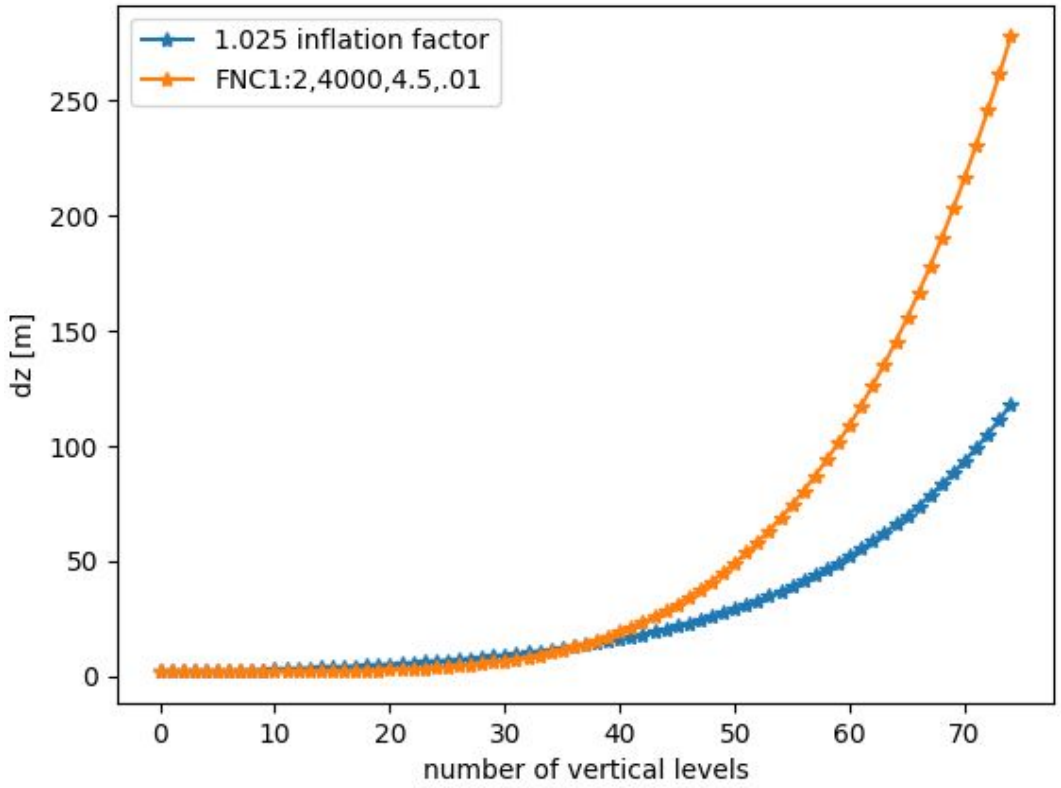
- **Red** is the WOA climatology.
- **Blue** line is the 1st year of the hybrid simulation.
- **Orange** line is the last year year of the hybrid simulation.



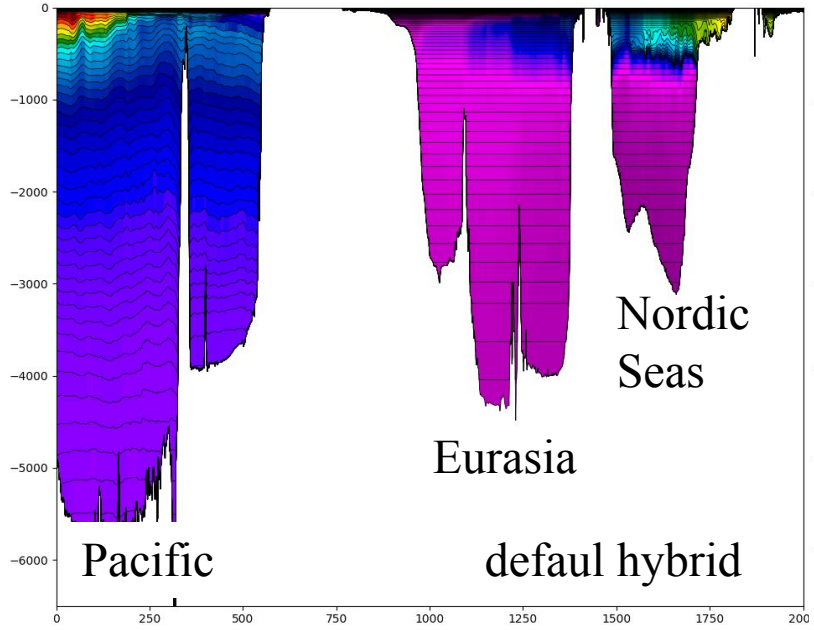
Testing different target densities/dz

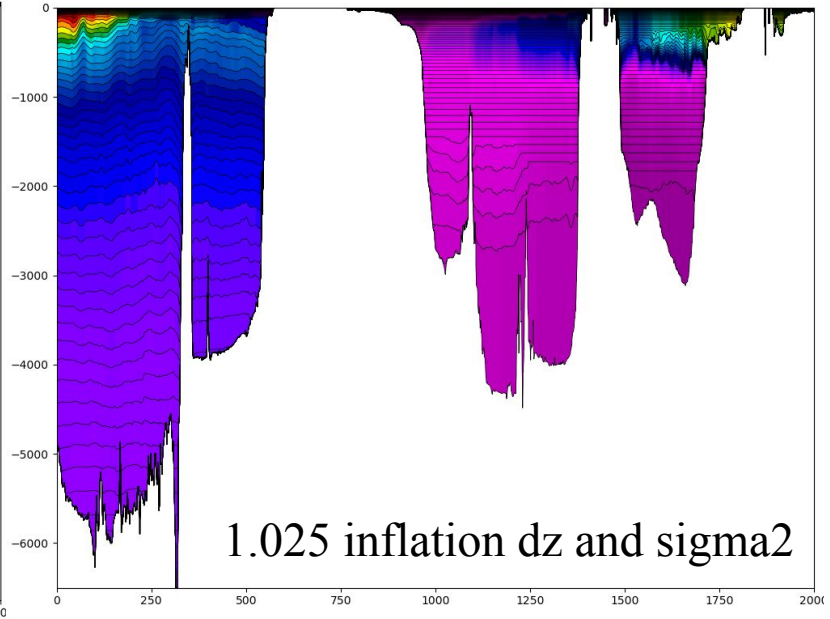
- I have tested 2 more cases;
  - 75 sigma0 layers with default dz (blue on the left panel, orange on the right panel)
  - 75 default sigma2 layers with 1.025 inflation factor dz (orange on the left panel and blue on the right panel).

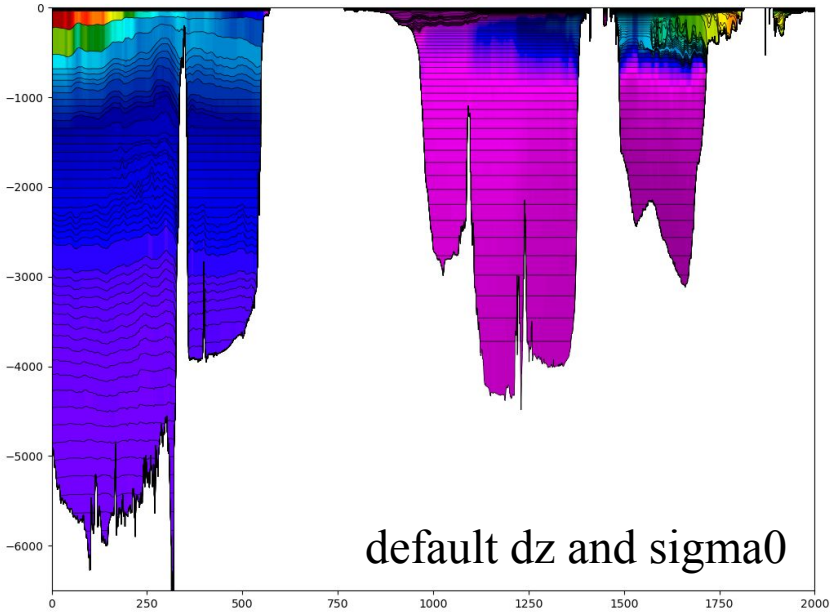


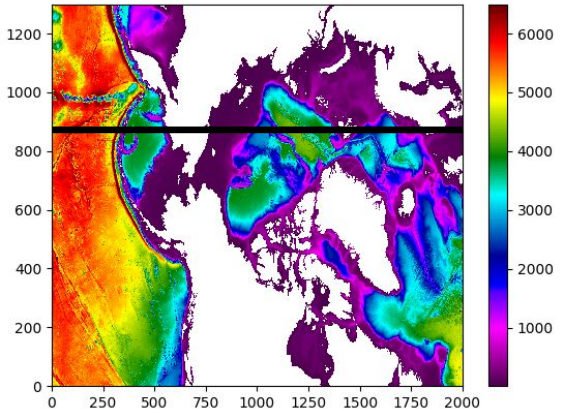


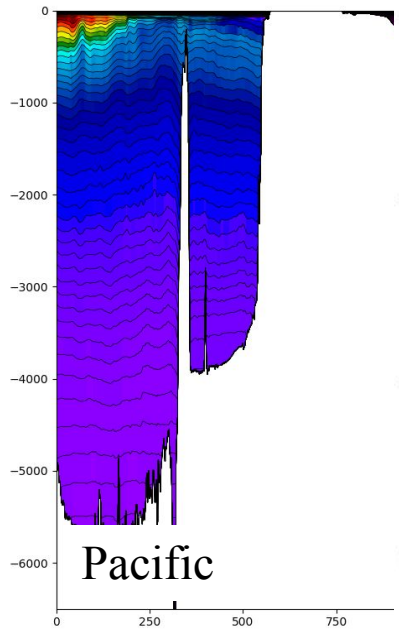
Different hybrid coordinate tests

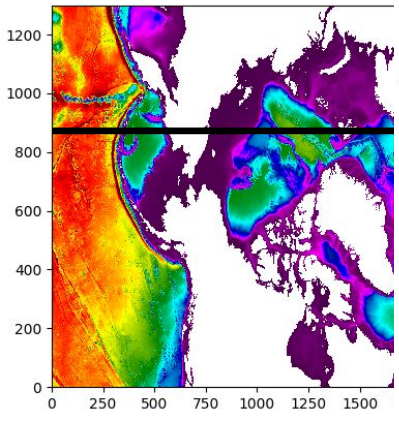


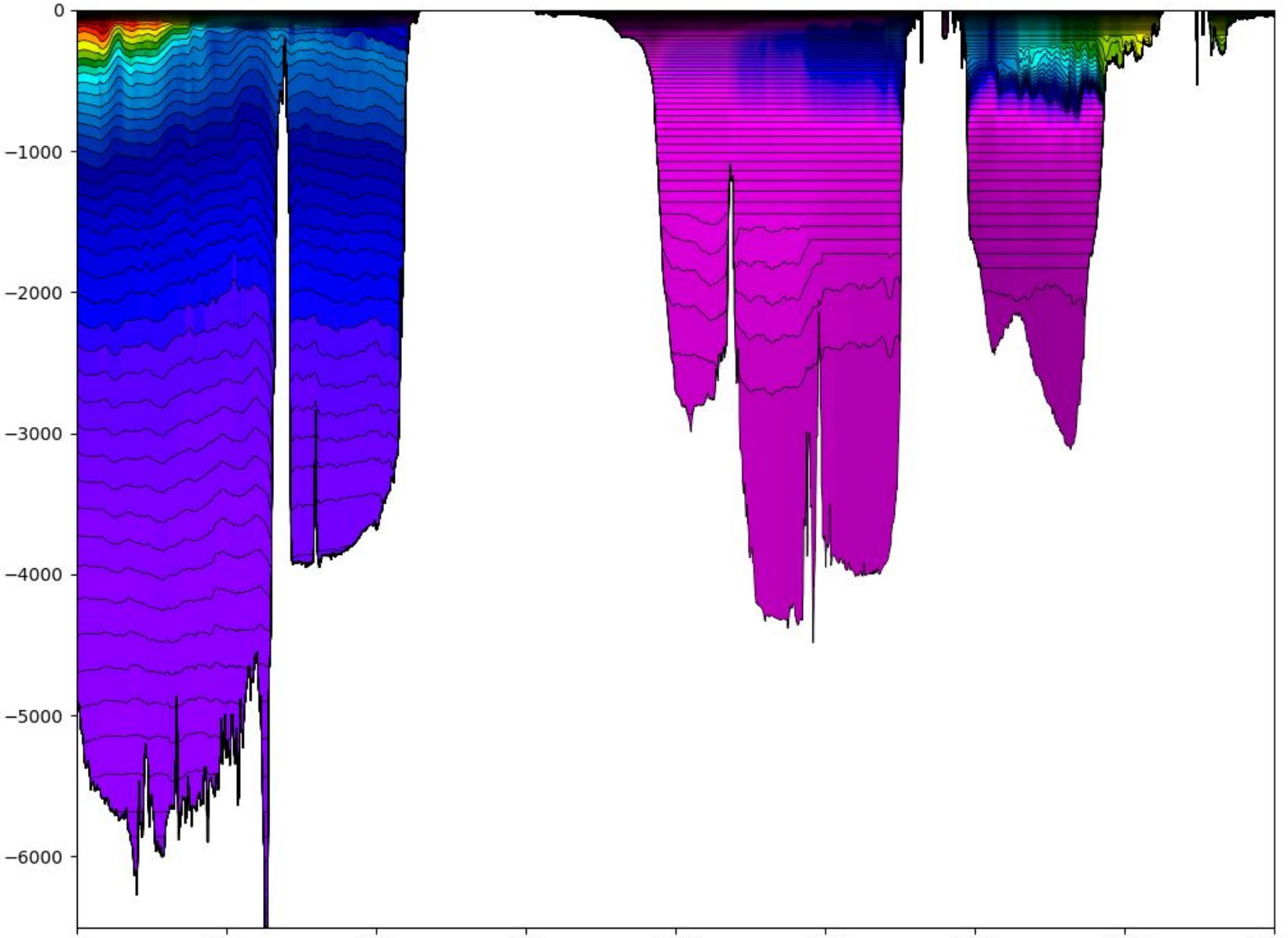


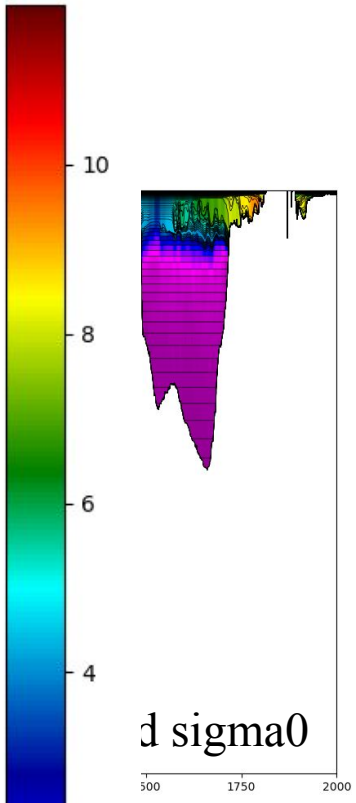




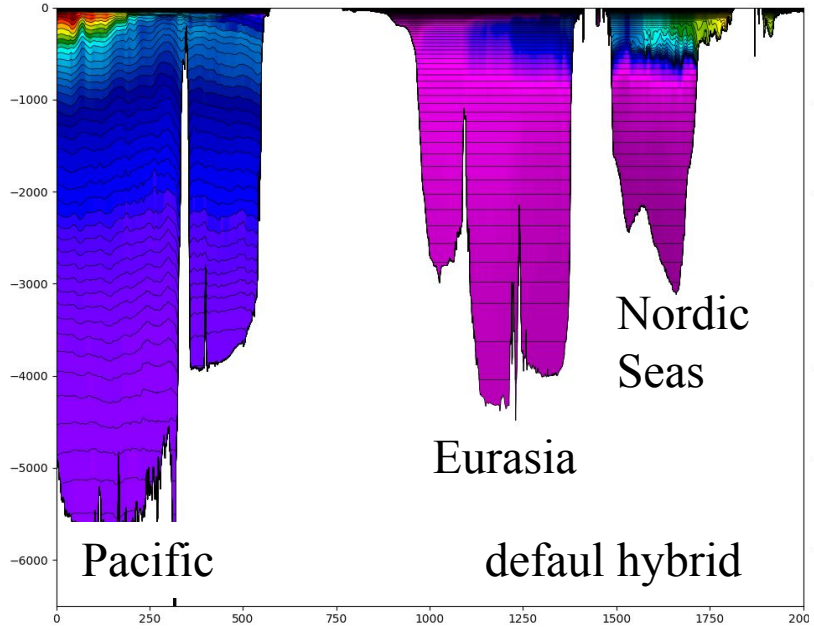

Pacific

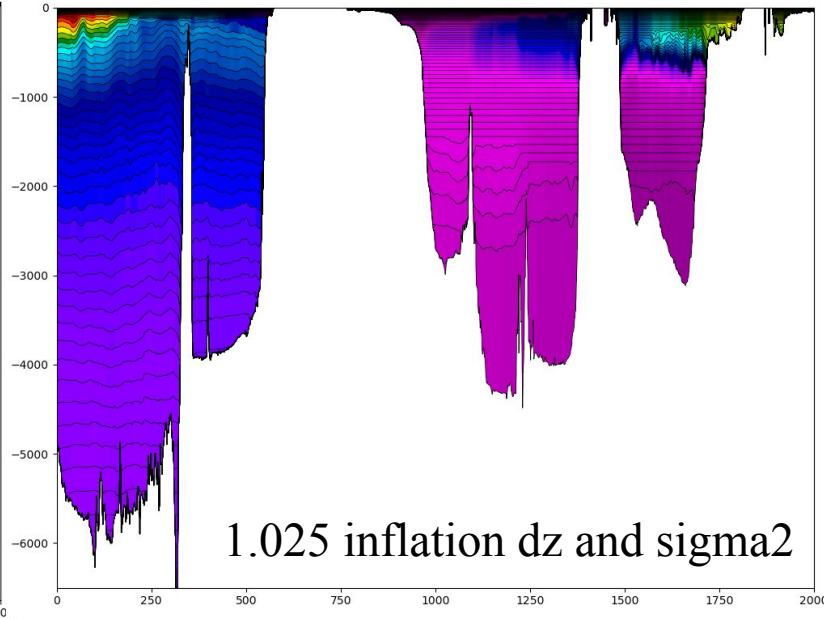


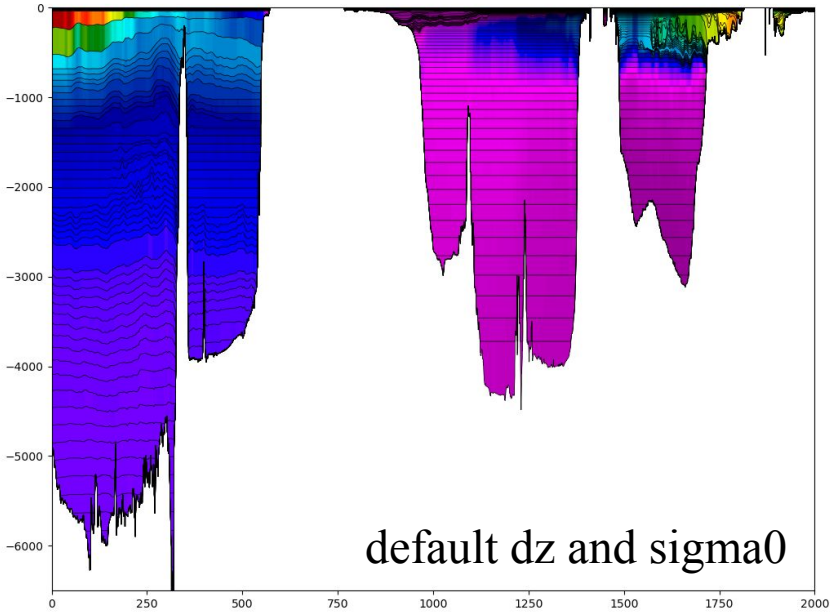


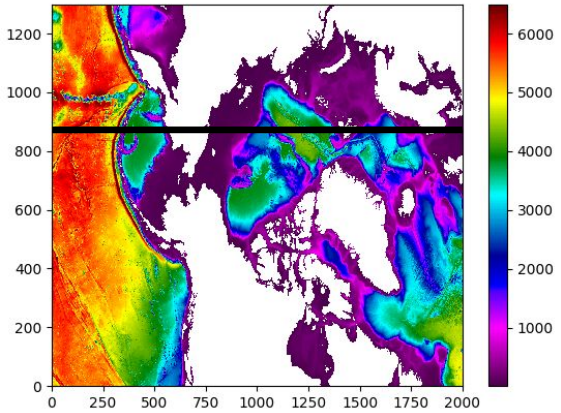

d sigma0

Different hybrid coordinate tests

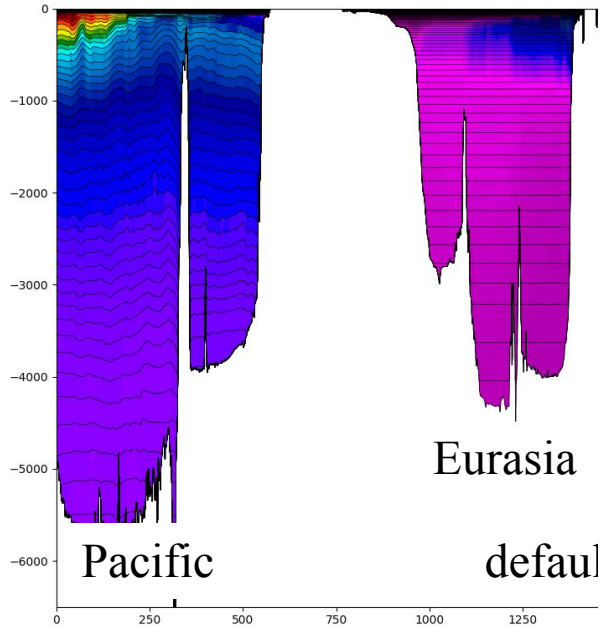


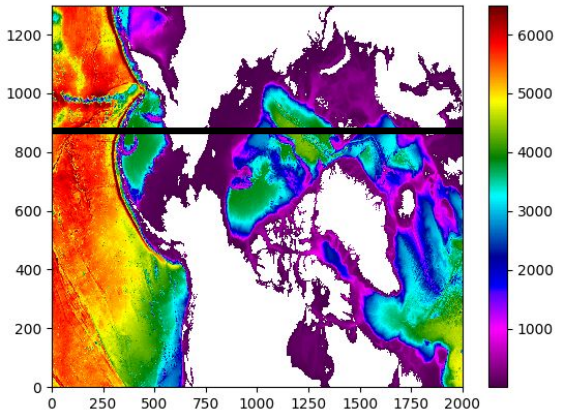


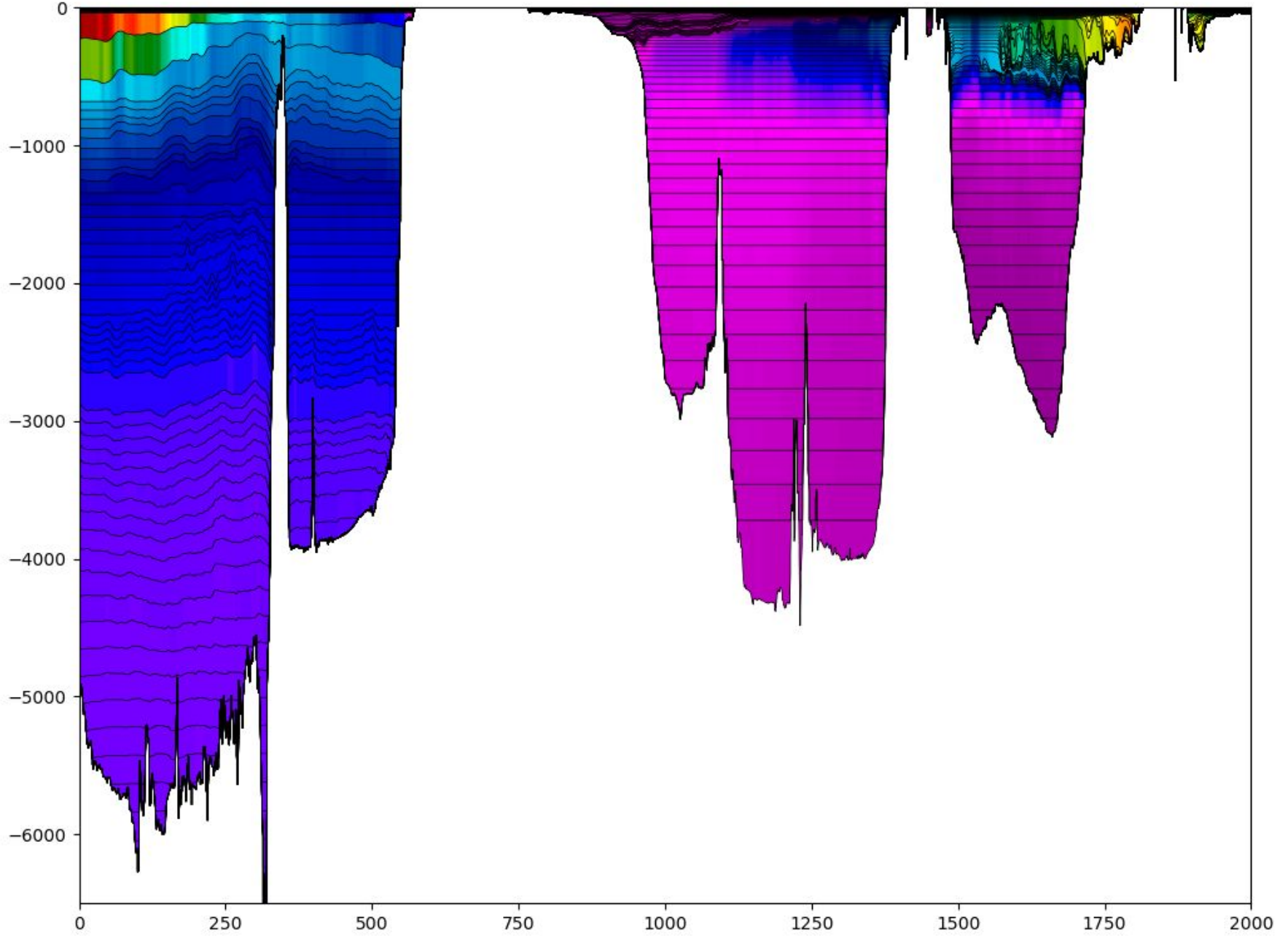




Diff



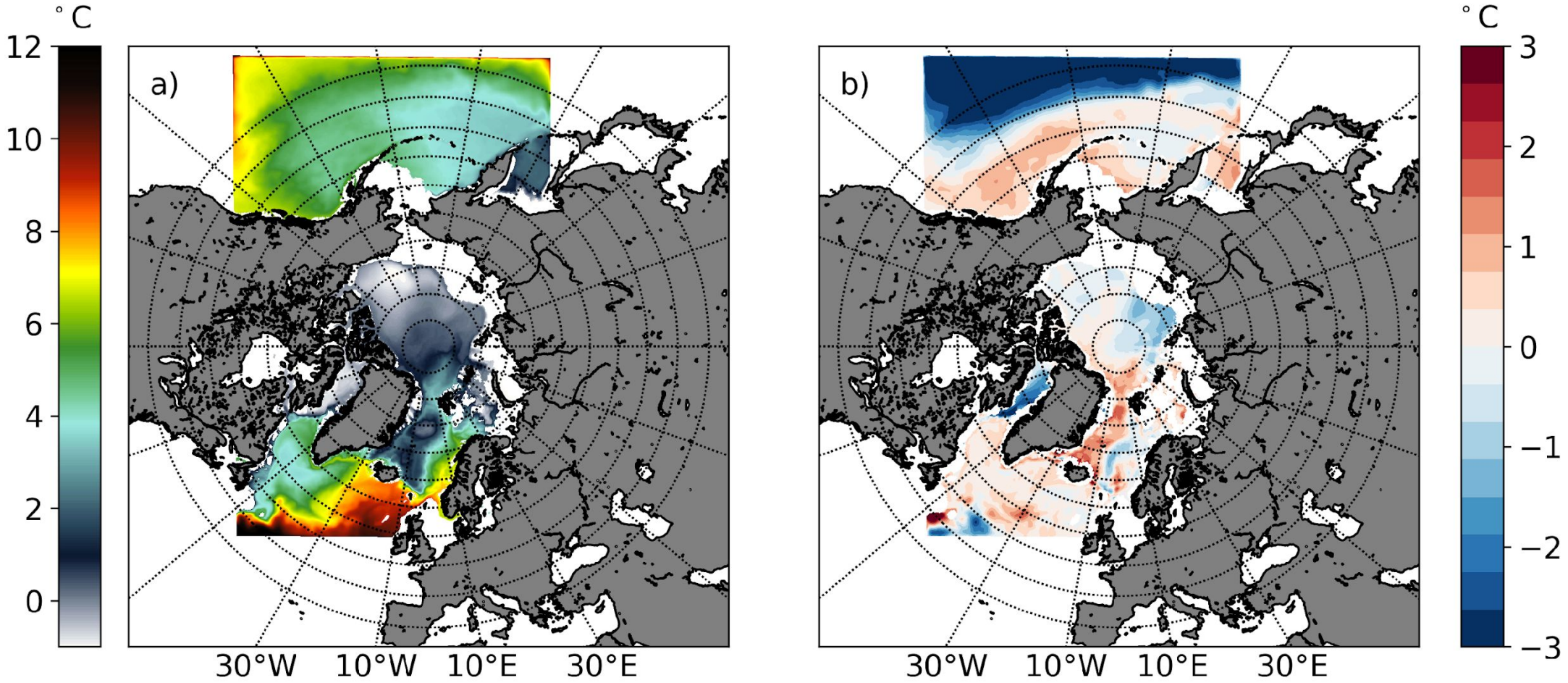




Conclusion

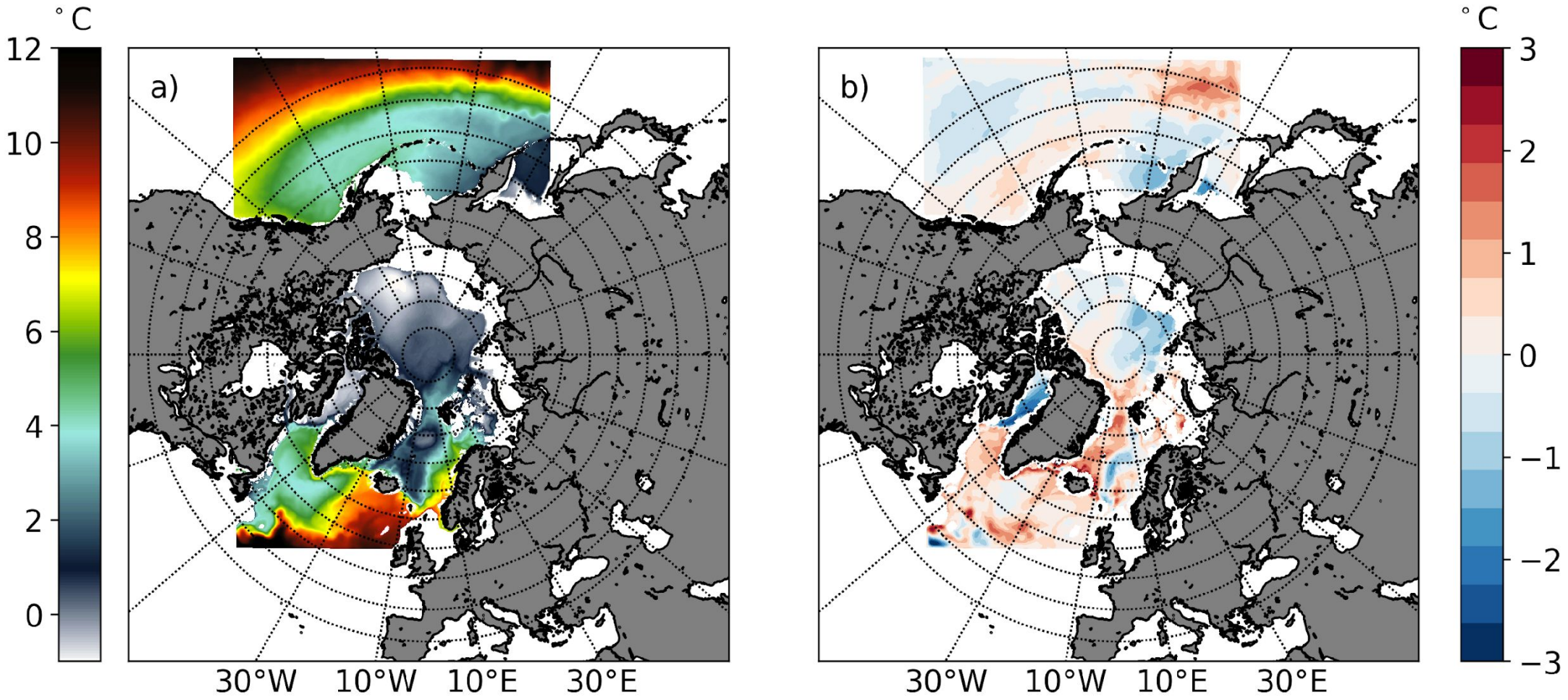
- A regional MOM6 PanArctic domain has been developed.
- Recent years, sea ice decline has been captured.
- Volume Transports at the Arctic gates are within observational estimates.
- Time evolutio of the fresh water content is similar to the reanalyis dataset.
- Different vertical coordinates have been tested to decrease heat uptake in the deep basin of the Arctic Ocean.

Mean temperature and bias at 250m



zstar

Mean temperature and bias at 250m



hybrid