IMPACT OF MESOSCALE EDDY PARAMETRIZATION ON ARCTIC ATLANTIC WATER CIRCULATION IN THE EDDY-PERMITTING GREY ZONE

Per Pemberton

per.pemberton@smhi.se

Swedish Meteorological and Hydrological Institute

Arctic Atlantic Water, boundary currents and eddies

The topographically steered boundary current is the main **contributor of northward heat transport** to the central Arctic Ocean.

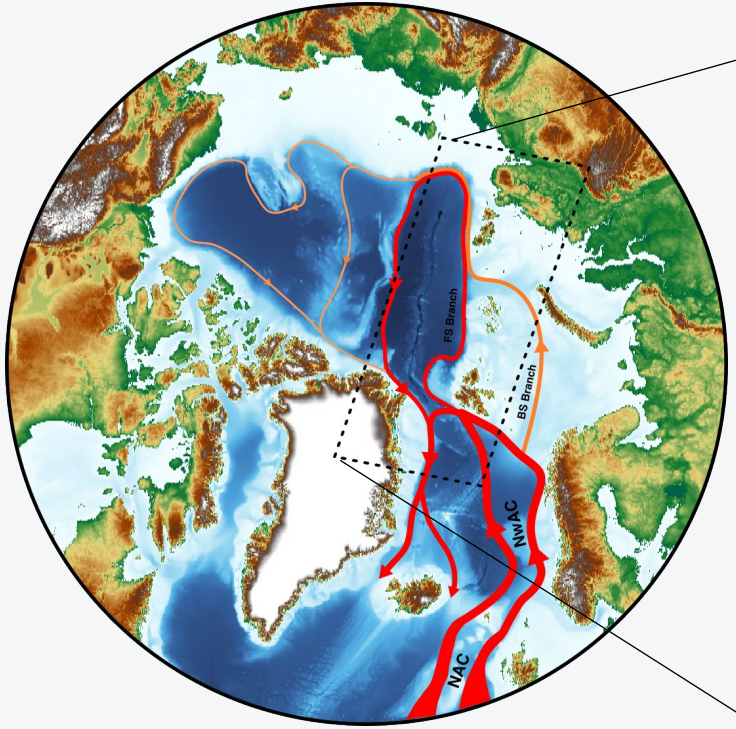
High res. models show lots of mesoscale **eddy activity and interaction with boundary current**.

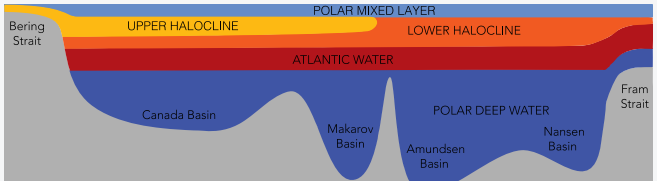
Coarse res. **CMIP6-type** climate models have a **poor representation** of the Arctic Ocean water masses (e.g. Heuzé et al, 2023).

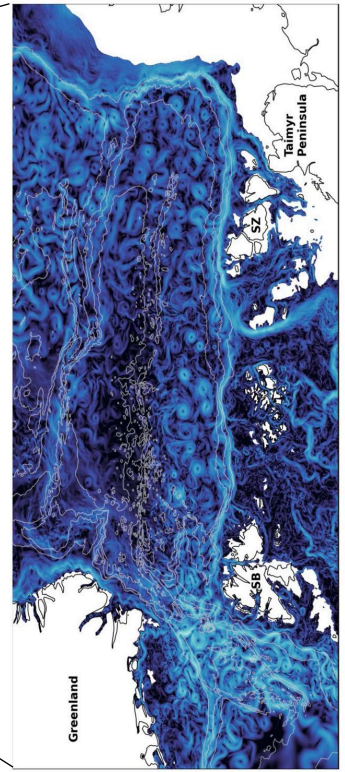
When resolution increases ocean models go from non-eddying to eddy-permitting and **enter a grey zone whether GM scheme** should be used or not.

GM scheme can **impact the flow and eddy generation negatively** when some part of eddy spectra is resolved (e.g. Hallberg, 2013).

What is the effect of using GM scheme on the Arctic Atlantic Water in the eddy-permitting grey zone? Does it degrade the tracer and flow fields?







(Müller et al, 2024)

Mesoscale eddy parametrization in ocean models

Mesoscale eddies stir the mean flow, downward cascade leads to small scale mixing.

Parametrized with a combination of isopycnal **diffusion** (Redi) and **eddy induced advection** (Gent-McWilliams) tracer fluxes.

Isopycnal diffusion reduce tracer variance along isopycnals surface.

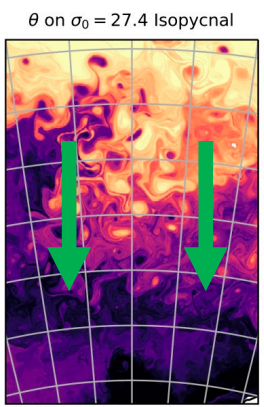
Eddy induced advection (GM scheme) of tracers extract available potential energy to kinetic energy and **flattens the isopycnals**.

$$\frac{\partial T}{\partial t} = -\nabla \cdot (T\,U) + D^T + F^T$$

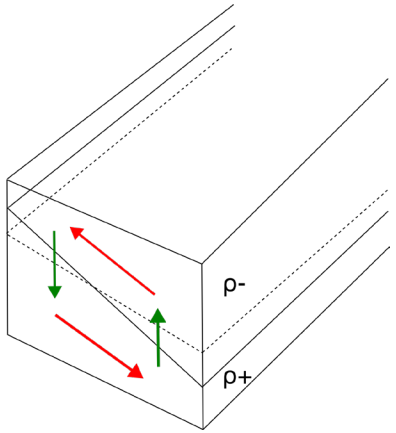
$$D^{lT} = \nabla \cdot \left(A^{lT}\ \Re\ \nabla T\right) + \nabla \cdot (U^*\,T)$$

Isopycnal diffusion (Redi scheme)

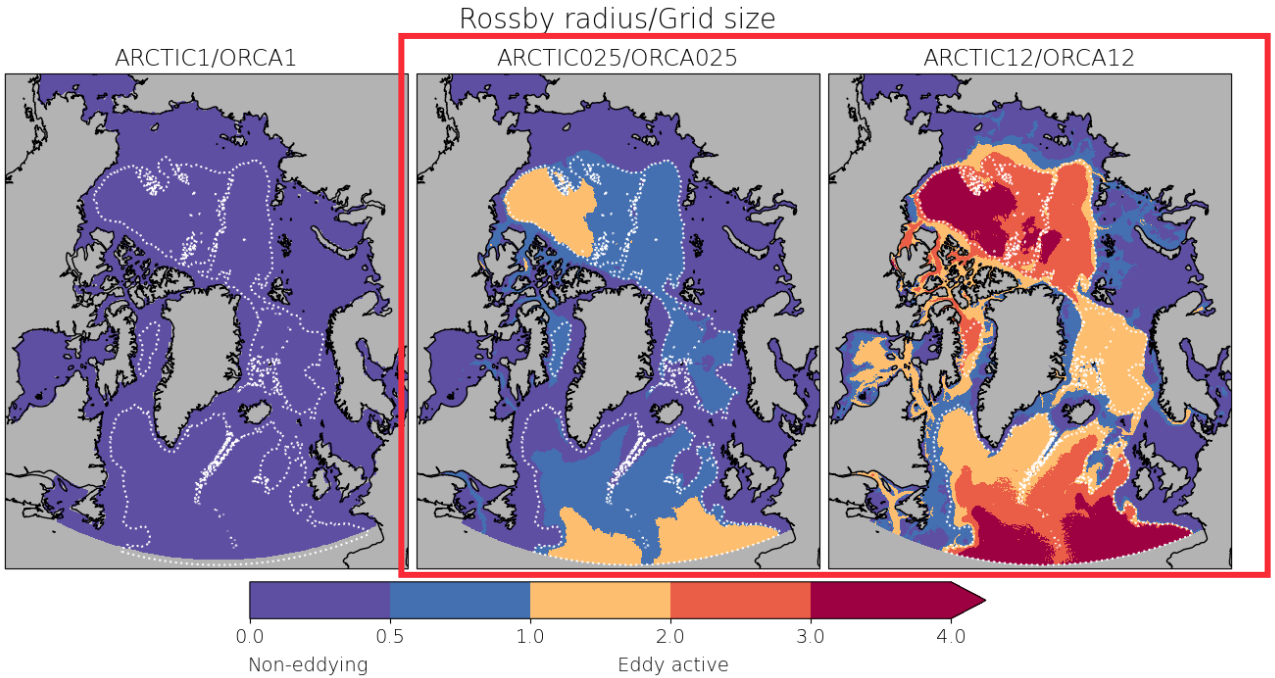
Eddy induced adv. (GM scheme)



(Abernathey et al, 2022)



Experiments and eddying regime in the pan-Arctic region

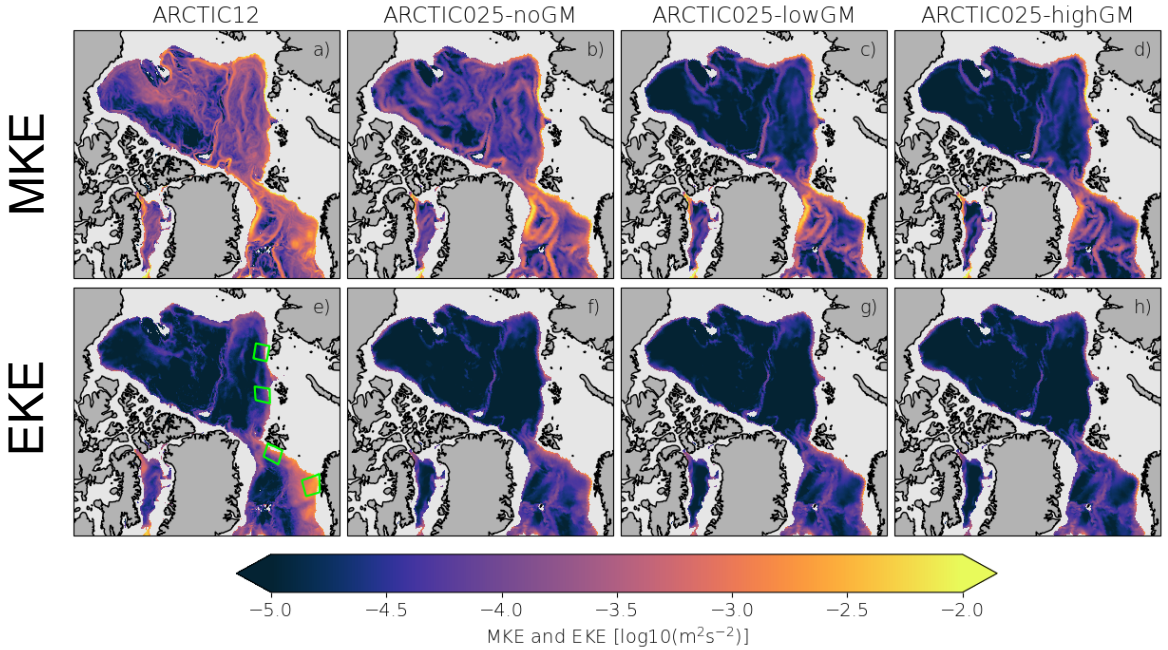


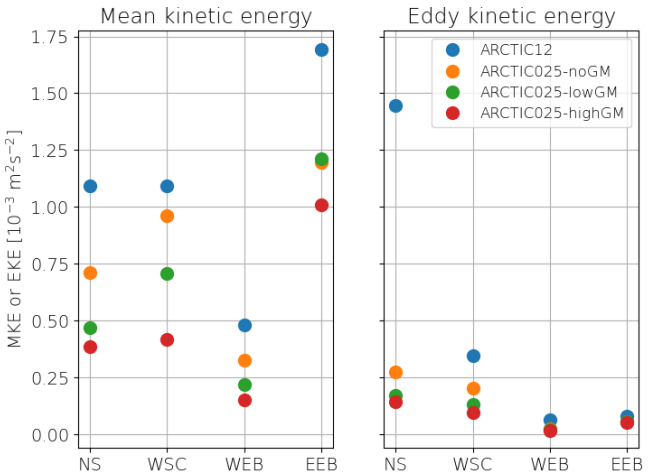
NEMO4.0.4 ORCA-based configurations

Tracer	FCT 4/4 advection, isoneutral laplacian diffusivity and GM (Treguier et al, 1997)
Momentum	VEC advection, EEN scheme, horizontal bilaplacian diffusivity
Vertical phys.	TKE with background viscosity/diffusivity reduced
Forcing	JRA55-do, Trenberth-Dai and ORAS4 (1979–2017)

Experiment	Horizontal resolution [m]	κ_{Redi} [$m^2 s^{-1}$]	κ_{GM} [$m^2 s^{-1}$]
ARCTIC12	2–7	22–56	-
ARCTIC025-noGM	3–20	54–167	-
ARCTIC025-lowGM	3–20	54–167	< 75
ARCTIC025-highGM	3–20	54–167	unbounded

Partitioning mean and eddy kinetic energy



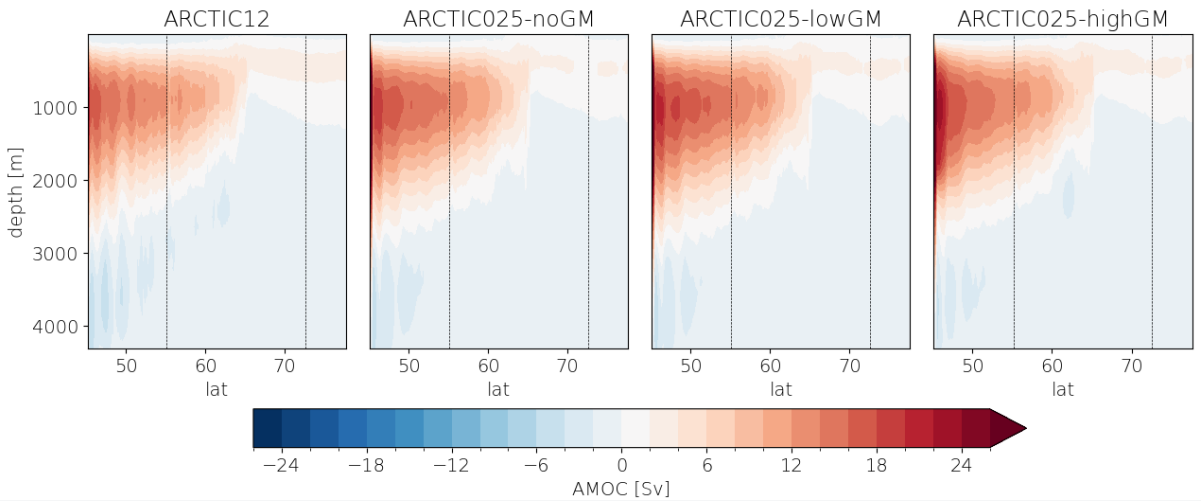


The **mean kinetic energy** in the central Arctic Ocean and Nordic Seas is **much higher without GM scheme**.

On the Norwegian Sea slope **eddy kinetic energy** is much **higher ARCTIC12** (~60% of TKE).

Stronger GM parametrization leads to **lower mean and eddy kinetic energy** in boundary current regions.

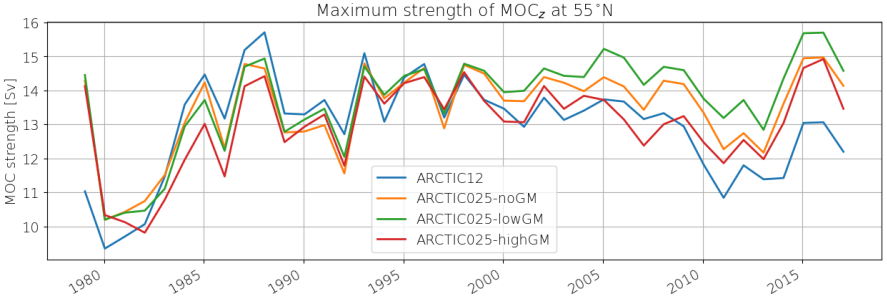
Impact on meridional overturning circulation

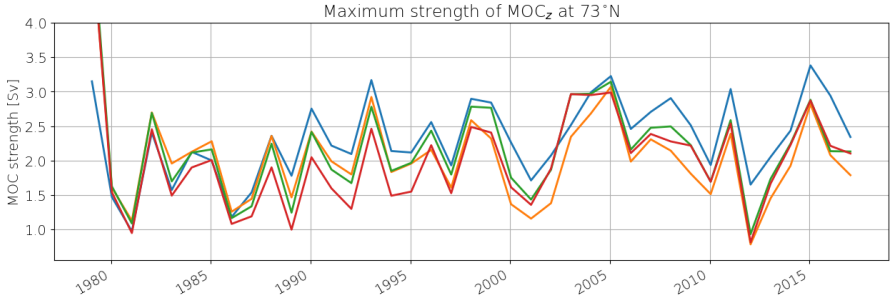


In the northern North Atlantic high res. (ARCTIC12) has **weaker** overturning at 55°N (~1-3 Sv)

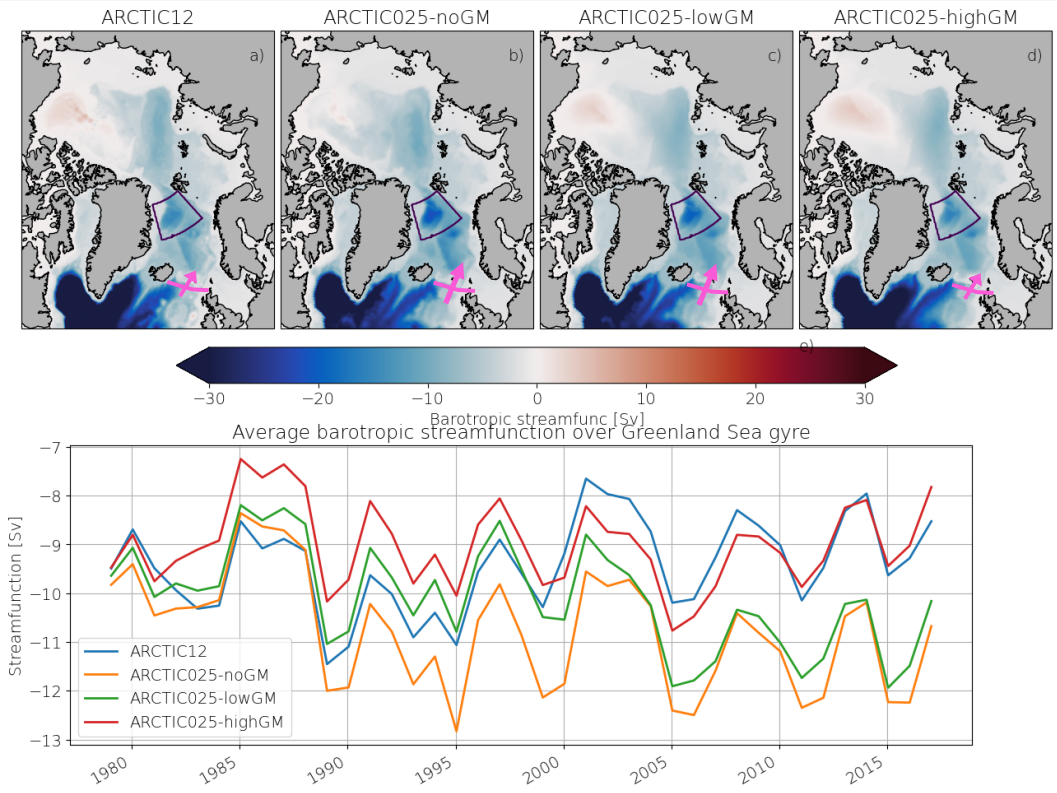
In the Nordic Seas at 73°N high res. (ARCTIC12) overturning is **stronger**.

The impact of GM scheme is fairly small in Nordic Seas overturning.





Barotropic circulation and northward volume transport



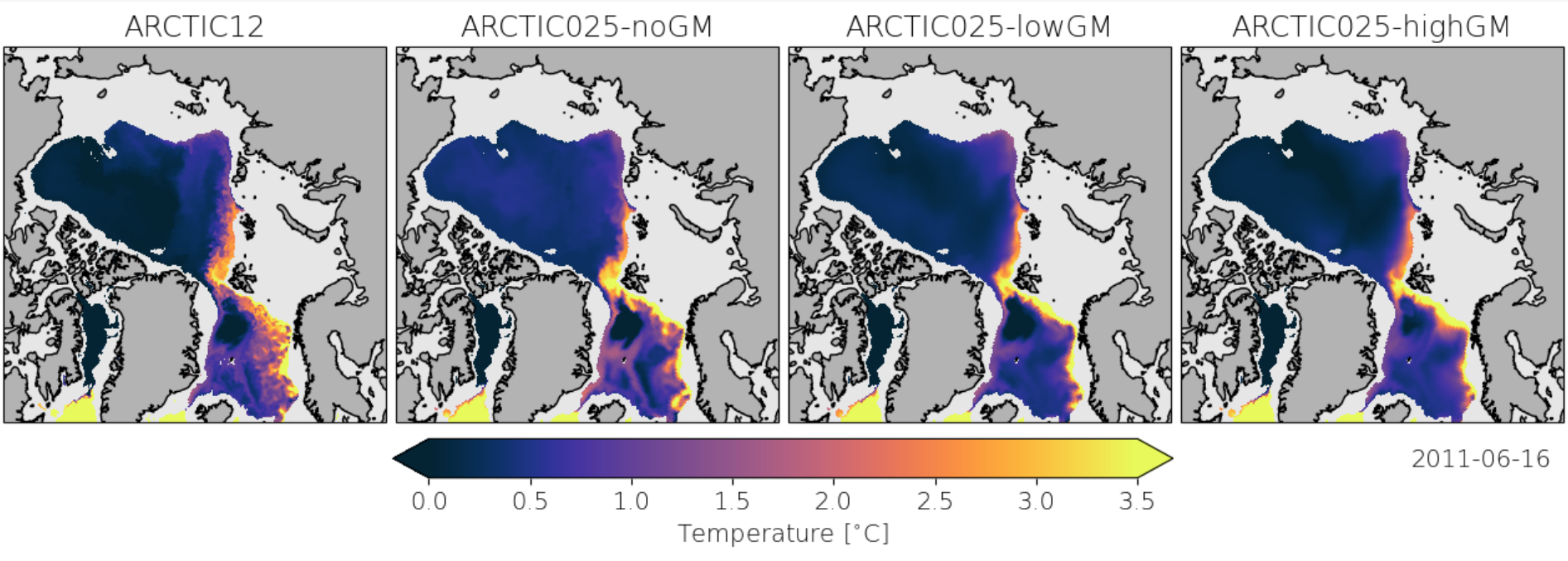
Without GM scheme much **stronger cyclonic Greenland Sea Gyre**, 2–4 Sv higher.

ARCTIC12/ARCTIC025-highGM are more in line with e.g. TOPAZ reanalysis (6-10 Sv) in the Greenland Sea Gyre.

Strong **GM scheme** gives a weaker northward volume transport across Greenland-Scotland Ridge and Fram Strait.

Atlantic Water Layer temperature

SMHI



GM scheme “kills” the resolved eddy heat fluxes from the boundary current to the basin interior.

Conclusions (so far)

SMHI

- Increased resolution (ARCTIC12) leads to a **warm and eddy-rich Arctic Atlantic Water layer** and improved representation of the circulation.
- The **GM parametrization** impact the strength of barotropic circulation, Greenland Sea Gyre, temperature variability, and northward volume/heat transport in intermediate resolution configuration (ARCTIC025*).