Physical shelf processes operating in the NOCL Arctic Ocean model

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1.MOTIVATION:

- Shelf sea processes have a strong impact on the formation and propagation of water masses in the Arctic Ocean.
- Dense water overflows forming on the Russian shelf can modify the Atlantic waters. Tidal currents significantly affect the vertical mixing on the shelves, production of sea ice, and hence the salinity field.
- Recent numerical results of an Arctic model with 1/12° resolutions (NOCS , UK) demonstrated that modelled ecosystem is strongly dependent on the resolved physical processes and their representation in ocean hydrodynamic models.
- Existing model are not capable of resolving both shelf processes and deep dynamics in the Arctic Ocean.

OBJECTIVE: to develop a high resolution Arctic Ocean model that captures the shelf water formation processes.

3.CHOICE OF VERTICAL COORDINATES

- Z-coordinates: poorly reproduce dense water cascade and bottom boundary layers.
- σ– coordinates : can induce spurious currents even with ideal pressure gradient algorithm

Problem 1: *What is the estimate of spurious errors generated by sigma-coordinates in upper layer?*

Initially horizontally- homogeneous 3 layer stratification

Upper layer: 200m / σ_ρ= 26.72, - linear stratification

"Atlantic" layer 200m-1000m / σ_ρ= 27.97,

Deep layer from 1000m / σ_ρ=28.08

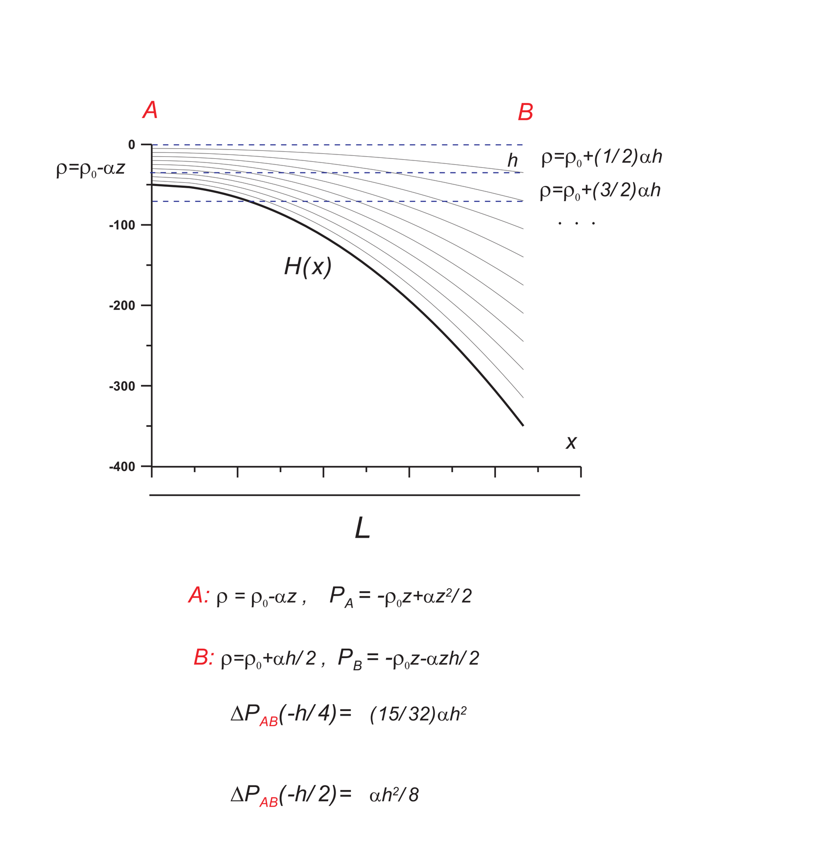

Figure 2. Illustration of mechanism of inducing the spurious pressure gradients from initially horizontally homogeneous density field in s-coordinates domain.

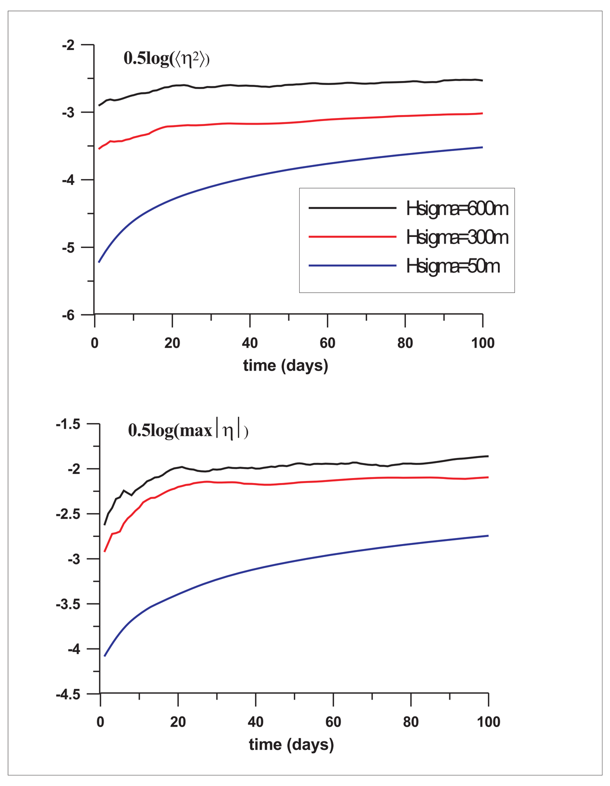

Figure 3. Sea surface heights η induced by errors in pressure gradients associated with sigma coordinates in upper layer .
Initial conditions - horizontally homogeneous stratification. basin mean standard deviation from.

Problem 2: *What is an optimum depth of sigma layer, that allows to resolve cascading?*

Dense water anomalies are placed on the bottom of the shelf (see Figure 1).

Height of anomalies: 100m,

Radius of anomalies: 40km or 80km , density is / σ_ρ= 28.10

Passive tracer concentration: C=1 at the dense water anomalies.

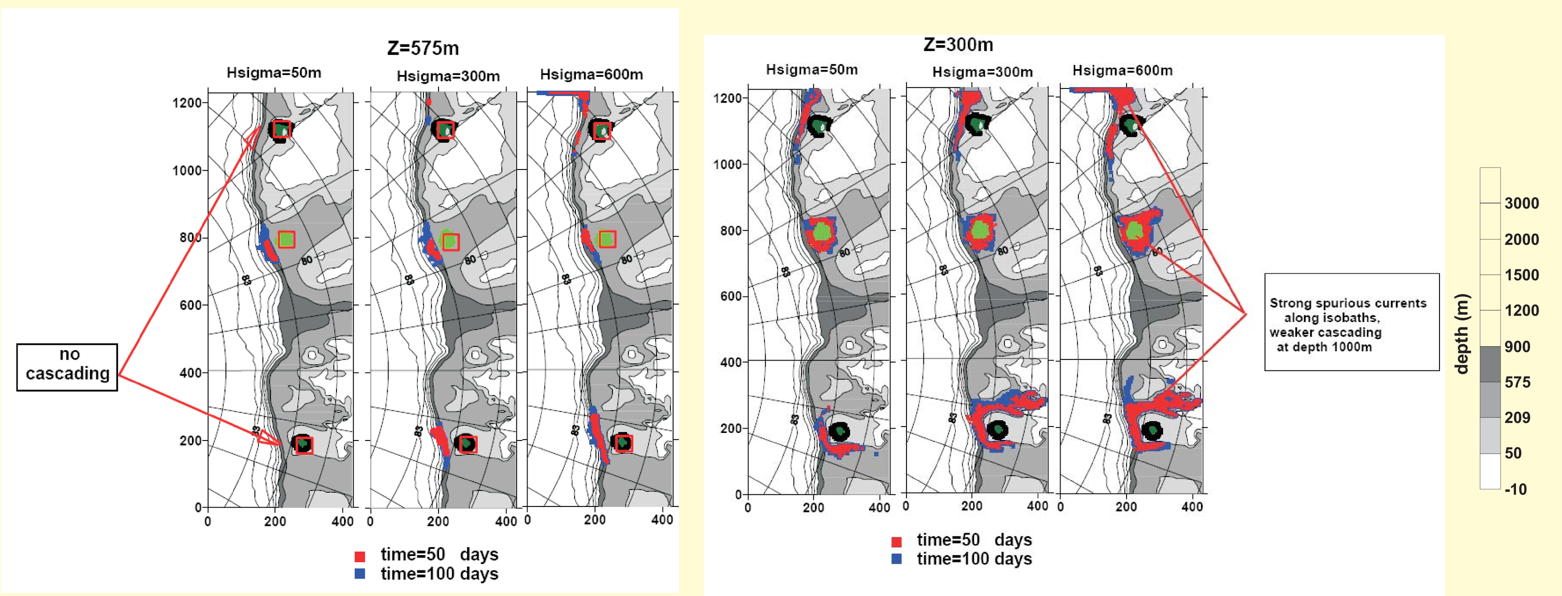

Figure 4: Evolution with time and depth of concentration (C > 0.005) associated with dense water in dependence of σ-layer depth.

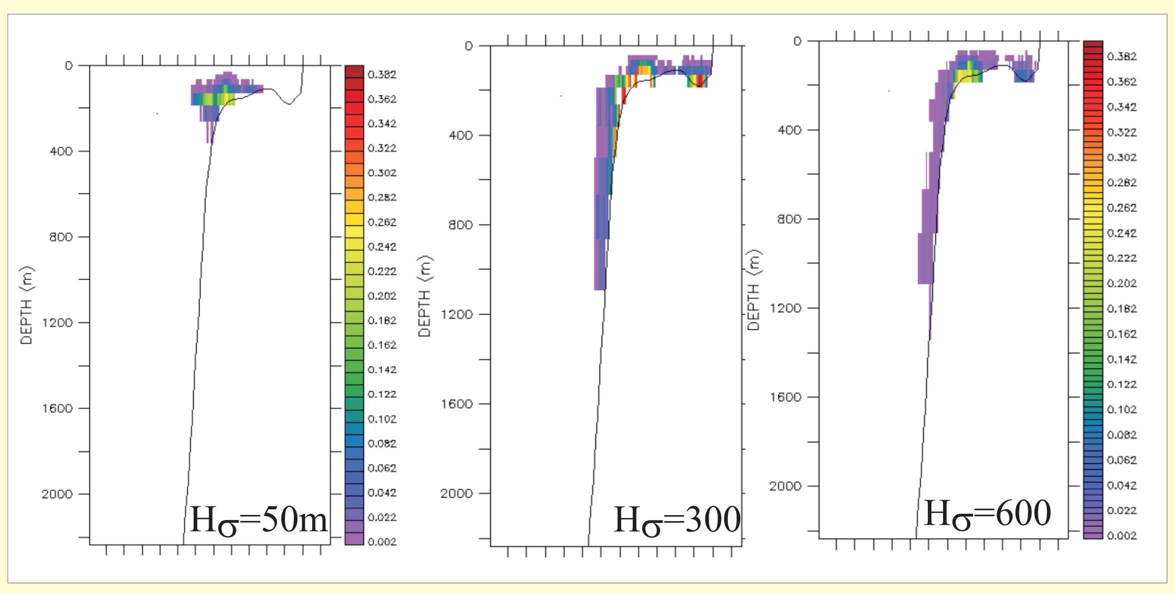

Figure 5. The concentration of passive tracer indicating the presence of cascading water at time t=100 days for different depth of σ-layer.

2. MODEL under development:

NEMO with for shelf seas = NEMO-SHELF Developed in MYOCEANS project by: Met. Office, MERCATOR, L'OCEAN and NOCL

- Horizontal resolution is 1/36°
- new generalised terrain following coordinates- s-coordinates= (σ-z with partial step)
- New high precision Horizontal Pressure Gradient algorithm (the Pressure Jacobian Method)
- New algorithm for vertical advection (Piecewise Parabolic Method)
- Nonlinear free surface with variable volume throughout depth.
- Explicitly resolved tides.
- Vertical mixing formulated using a Level 2.5 turbulence closure model.

4.SPECIFICS OF SHELF PROCESSES IN THE ARCTIC OCEAN

The Arctic basin has steep slopes and ridges.

Compromise solution is hybrid s-z coordinates where the depth of upper σ– coordinates are small enough to avoid the strong spurious currents in very deep water and large enough to resolve a dense water cascading.

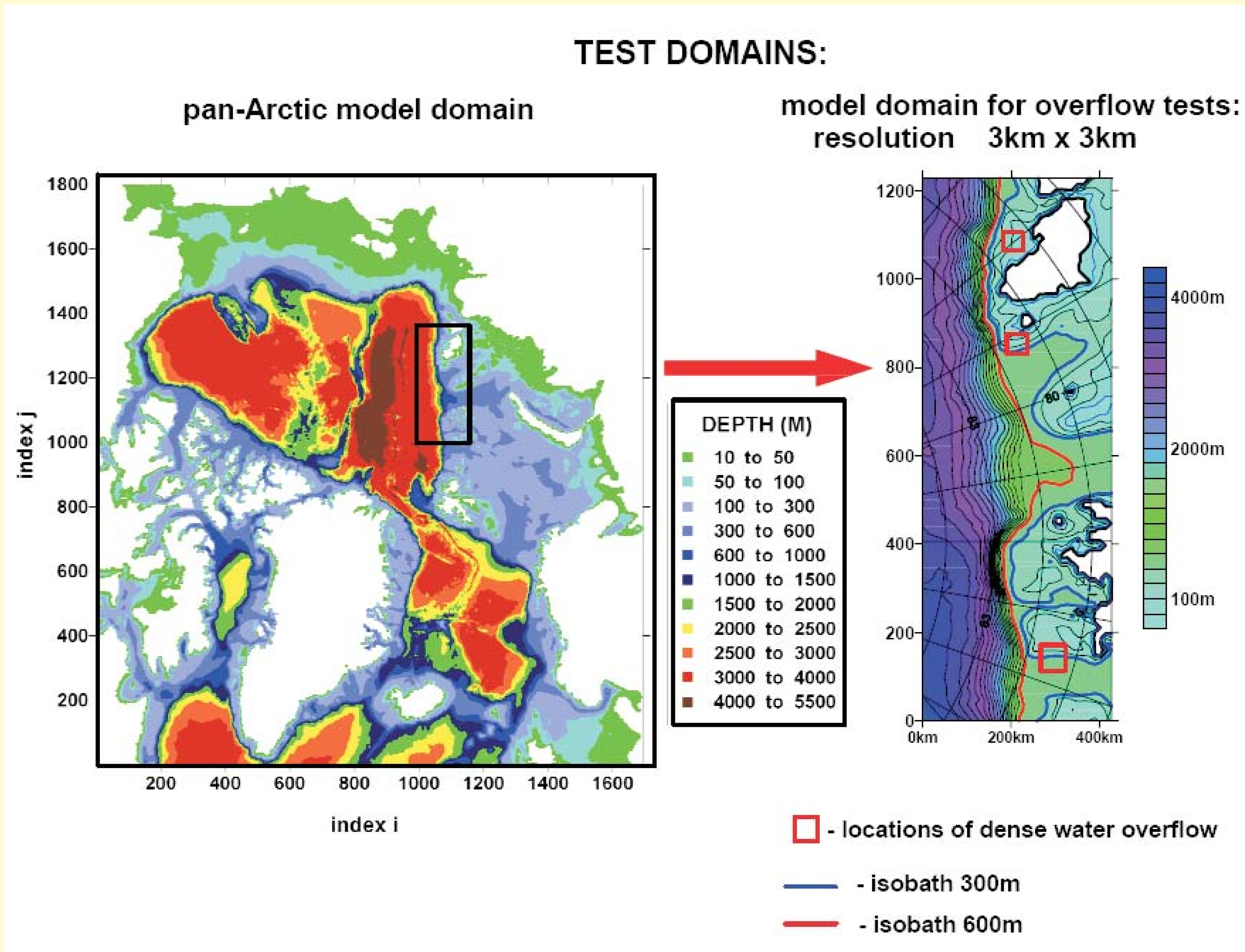

Figure 1: Pan-Arctic model domain and Local domain on the Russian shelf (450kmX1200km), 3km resolution . Vertical coordinates: s-z: variable depth of s-layer. Initial locations of dense water corresponds to observed.

Results of Problem 2:

- High depth of s-layer: strong spurious the along-slope currents and lateral mixing (Figure 3,4).
- Too shallow an s-layer: no cascading.
- The depth and width of downwelled water depends on the shape of local bathymetry(Figure 4,5).
- Very deep s- layer: spurious currents move water along slope and stop cascading
- For typical values of densities of the Arctic Ocean waters Hσ=300m is optimal depth:
  - -enough to resolve dense water overflow
  - -errors induced in σ-layer are reasonably low.

6.TEST : CHOICE OF HORIZONTAL FRICTION:

Tracer equations (ecosystem, passive concentration) are very sensitive to lack of positiveness.
We examined the lateral diffusion schemes :

1. Smagorinsky / constant diffusivity
2. Laplacian/ bi-laplasian operators.

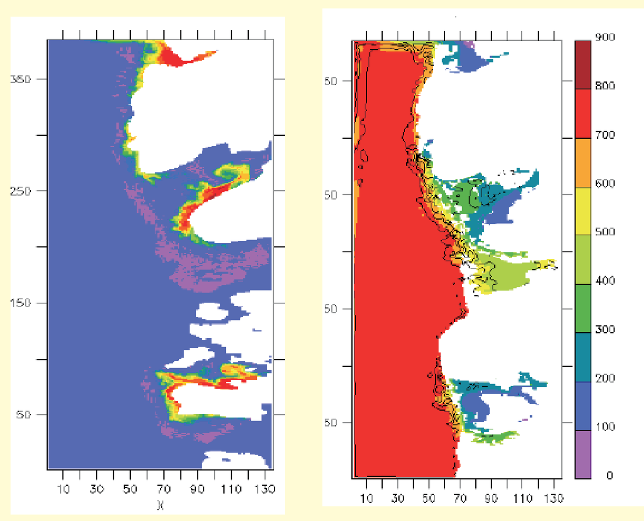

Figure 6: LEFT Passive concentration (negative values are purple) and RIGHT: depth of isotherm 0C.

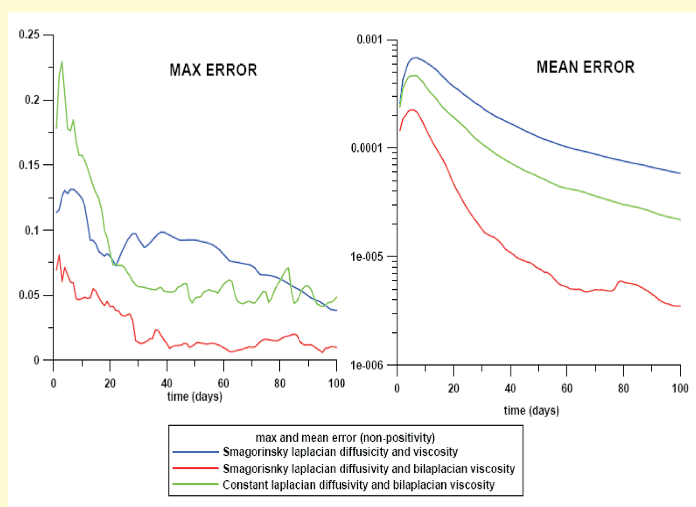

Figure 7: Basin maximum and mean errors (non-positivity) with time for different choice of lateral diffusion.

The best option is Smagorinsky laplacian operator for tracer and bilaplacian for momentum.
- reduces the errors by 3 order.
- no errors associated with vertical advection in cascading process
- can not remove alle errors associated with small-scale internal waves