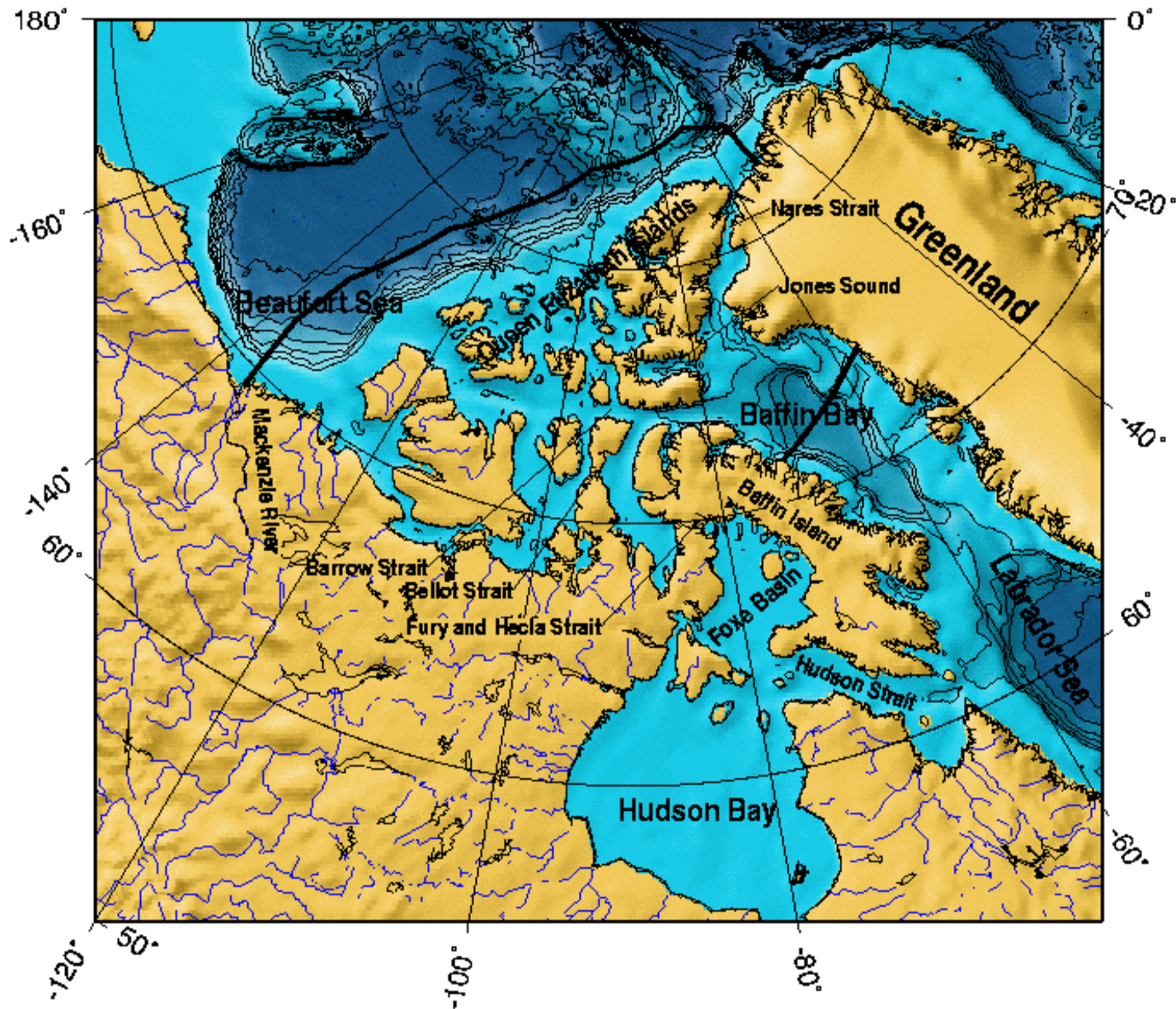


Ocean Modelling of the Canadian Arctic Archipelago

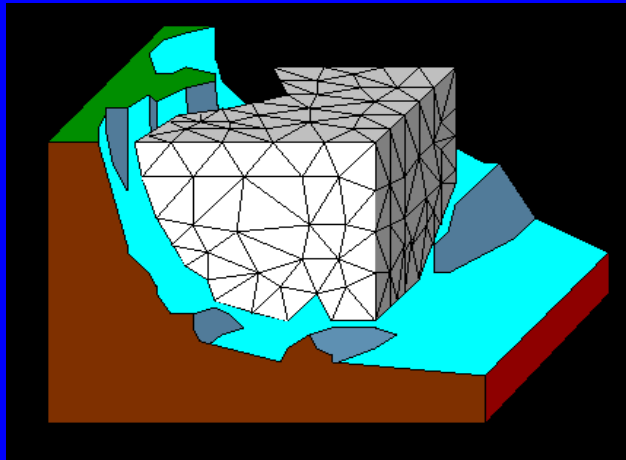
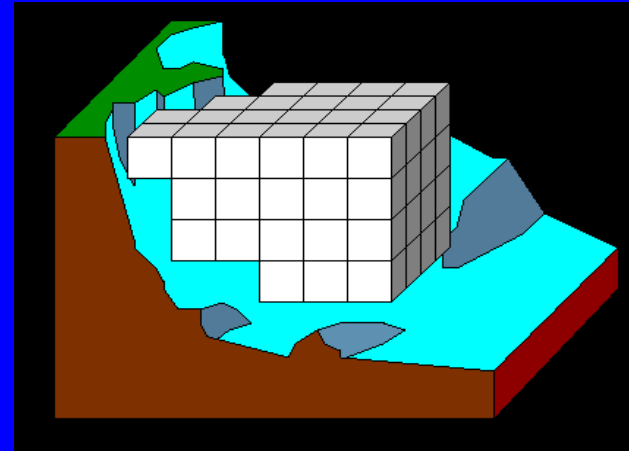
Frédéric Dupont, Louis Fortier
Québec-Océan, Laval University

Dave Greenberg, Simon Prinsenber
Bedford Institute of Oceanography

The Canadian Arctic Archipelago

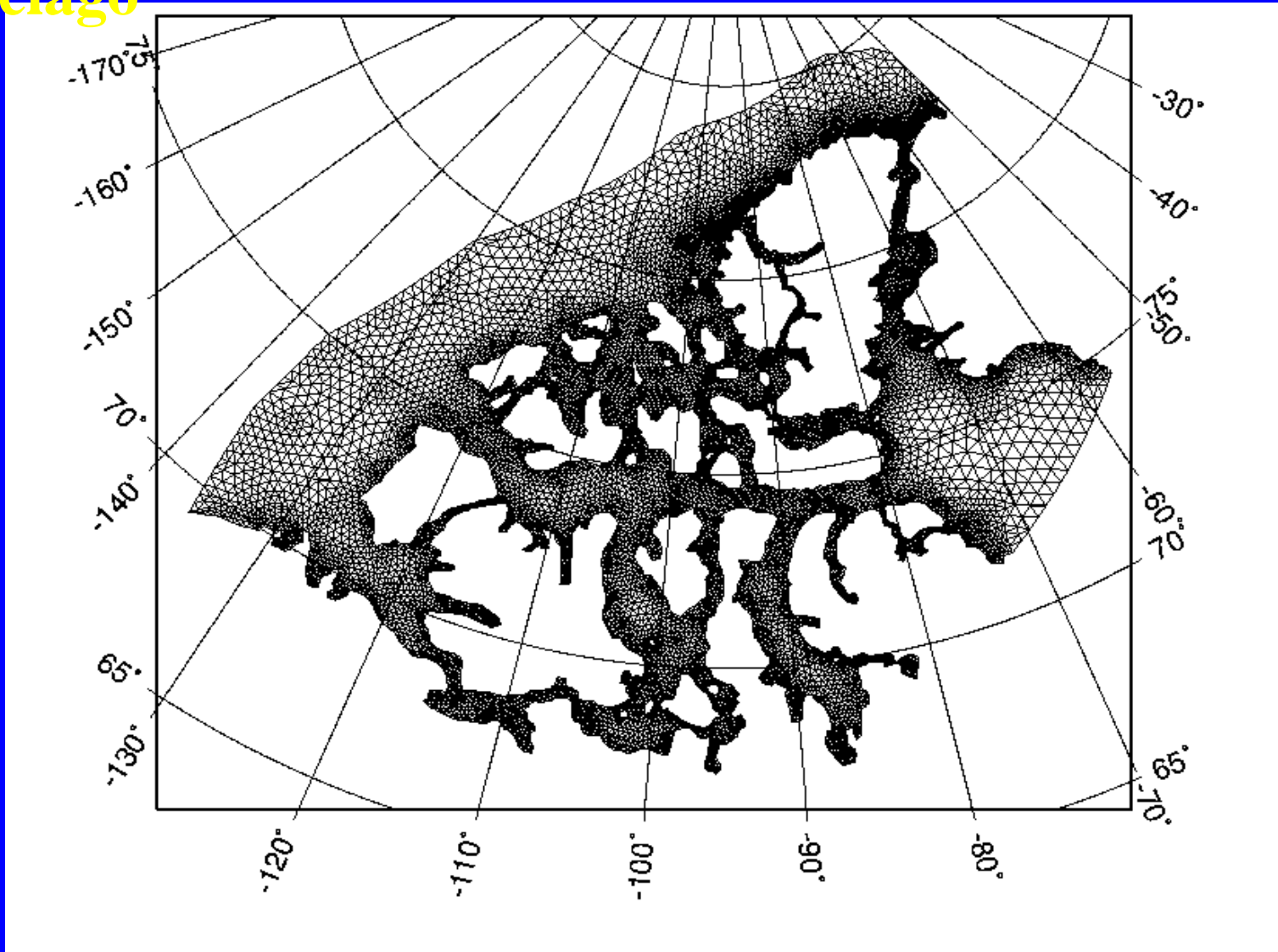


- In FD methods, the ocean is discretized into small cubes that cause a crude representation of the complex geometries.



- This motivates the use of alternative modelling techniques that discretize more accurately the irregular geometries such as FE/FV and SE methods.

Example of unstructured mesh: the Canadian Arctic Archipelago



Goals:

- Effect of tidal mixing on the mean circulation
- Sensitivity of the mean circulation to the closing of the passages
- Flow seasonality
- Biology

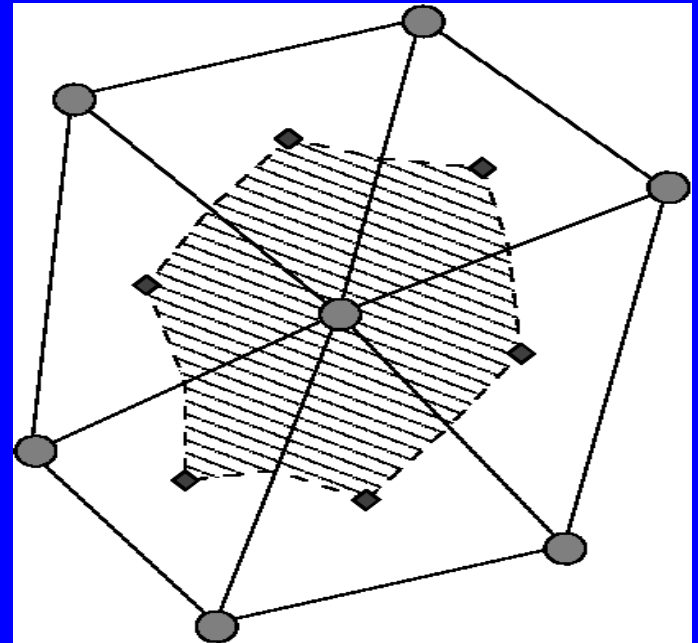
The model:

FVCOM (Chen et al., 2003)

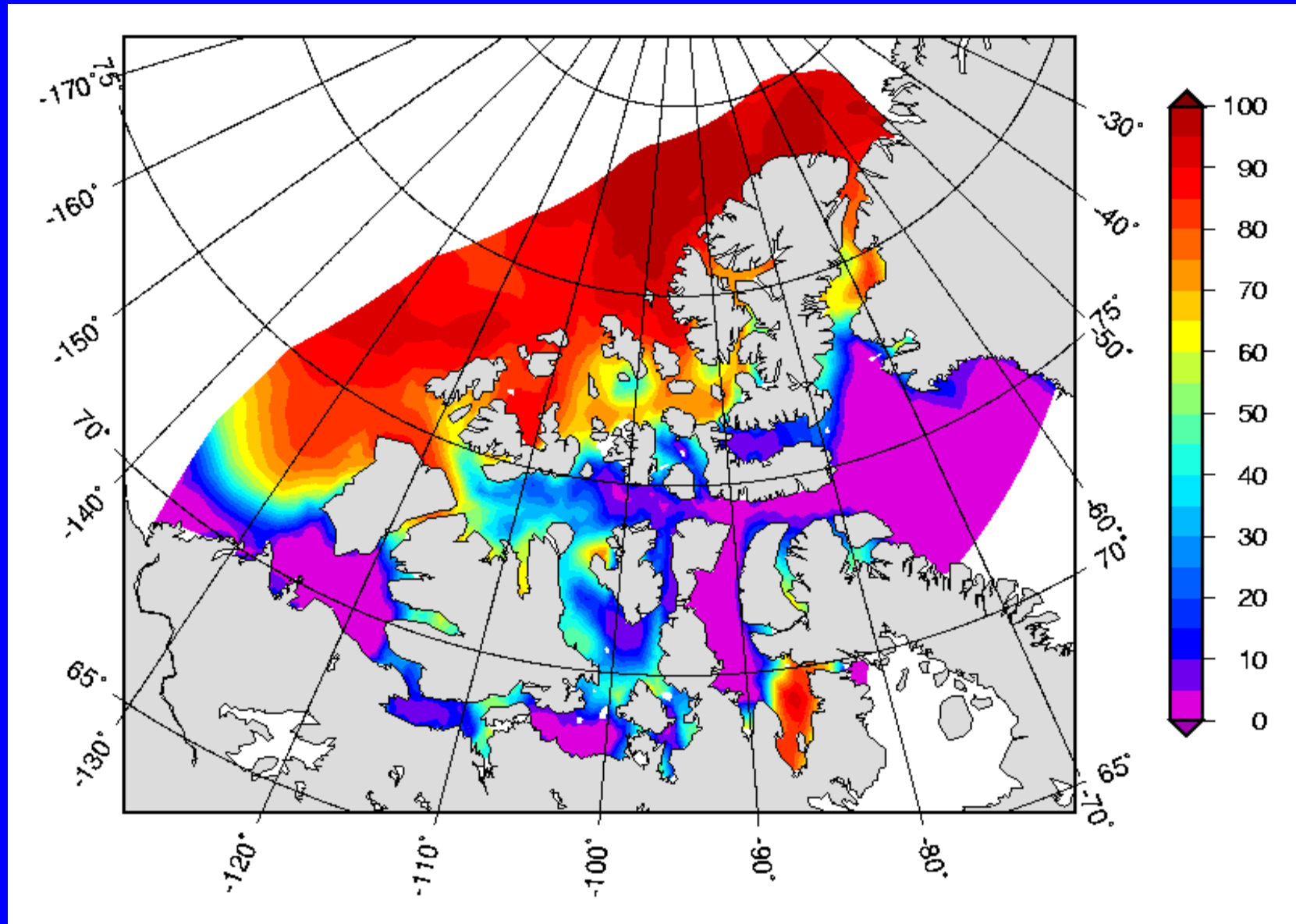
3D Finite volume unstructured ocean model with a vertical Sigma coordinate
Baroclinic PG computed at fixed z-levels

Modifications:

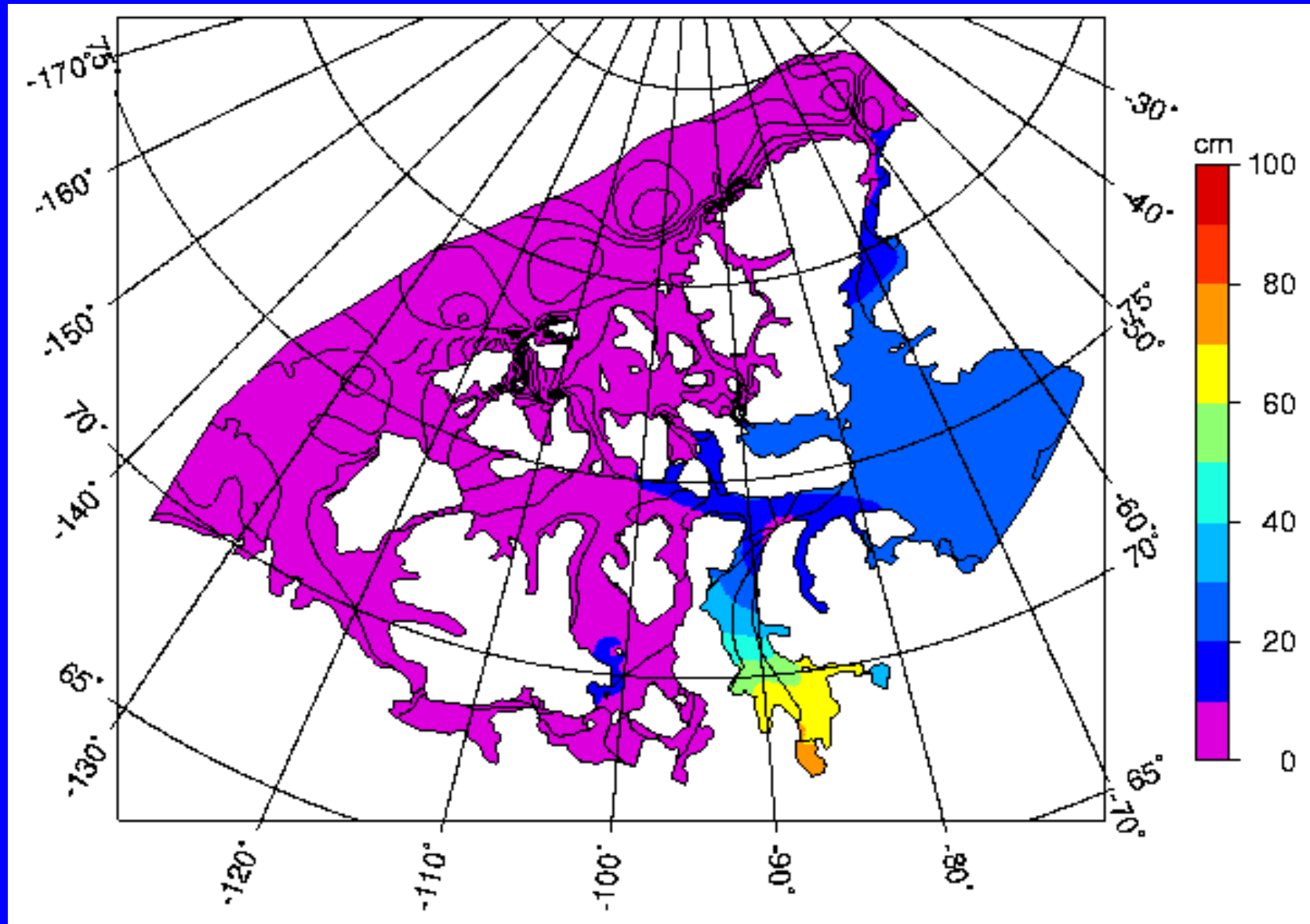
- Generalized vertical Sigma coordinate with z-levels
- semi-implicit time integration for the external mode
- no horizontal diffusion in the tracer equation
- Thermodynamic/dynamic ice
- Atmospheric forcing



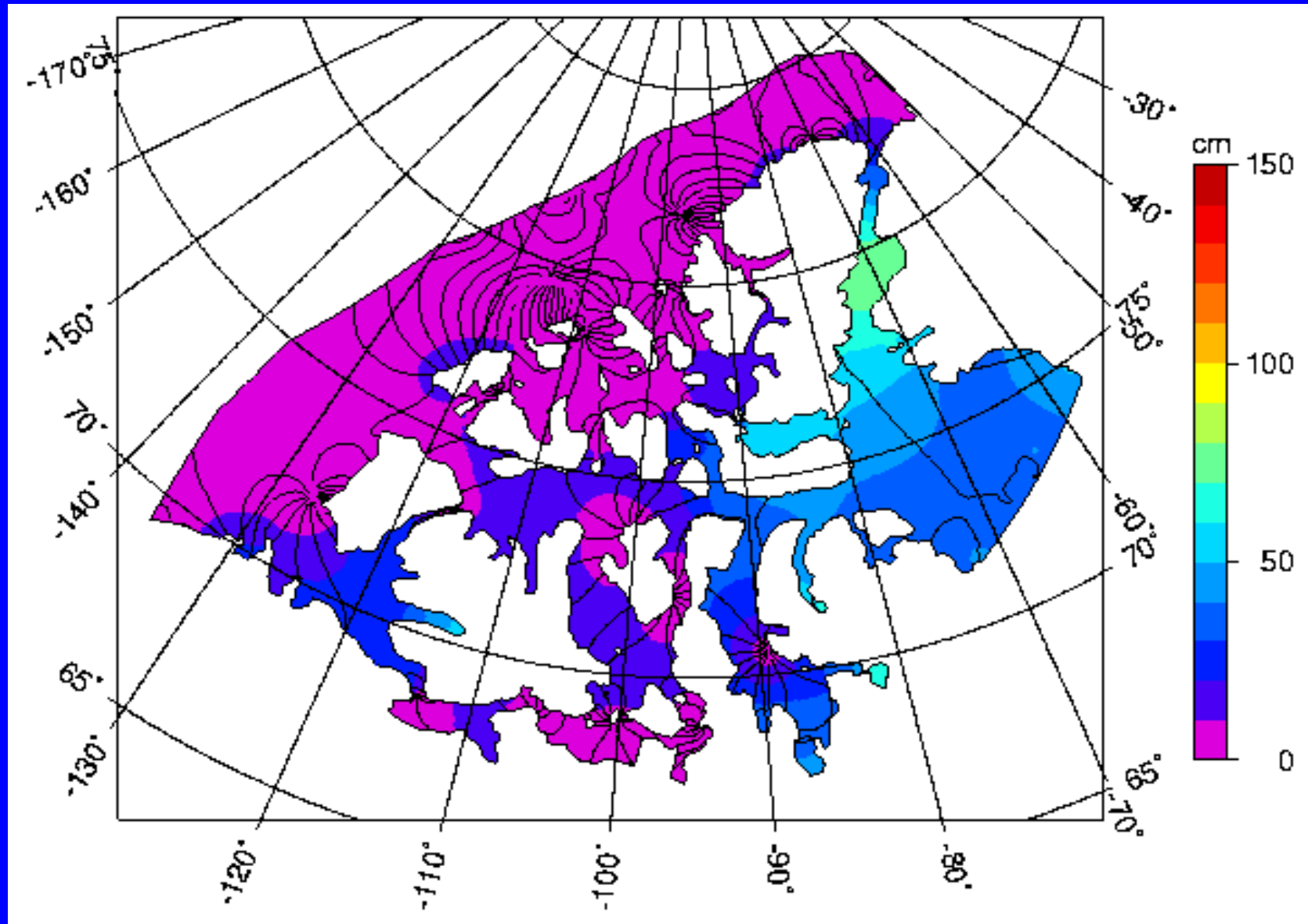
Ice cover for the summer case: partial



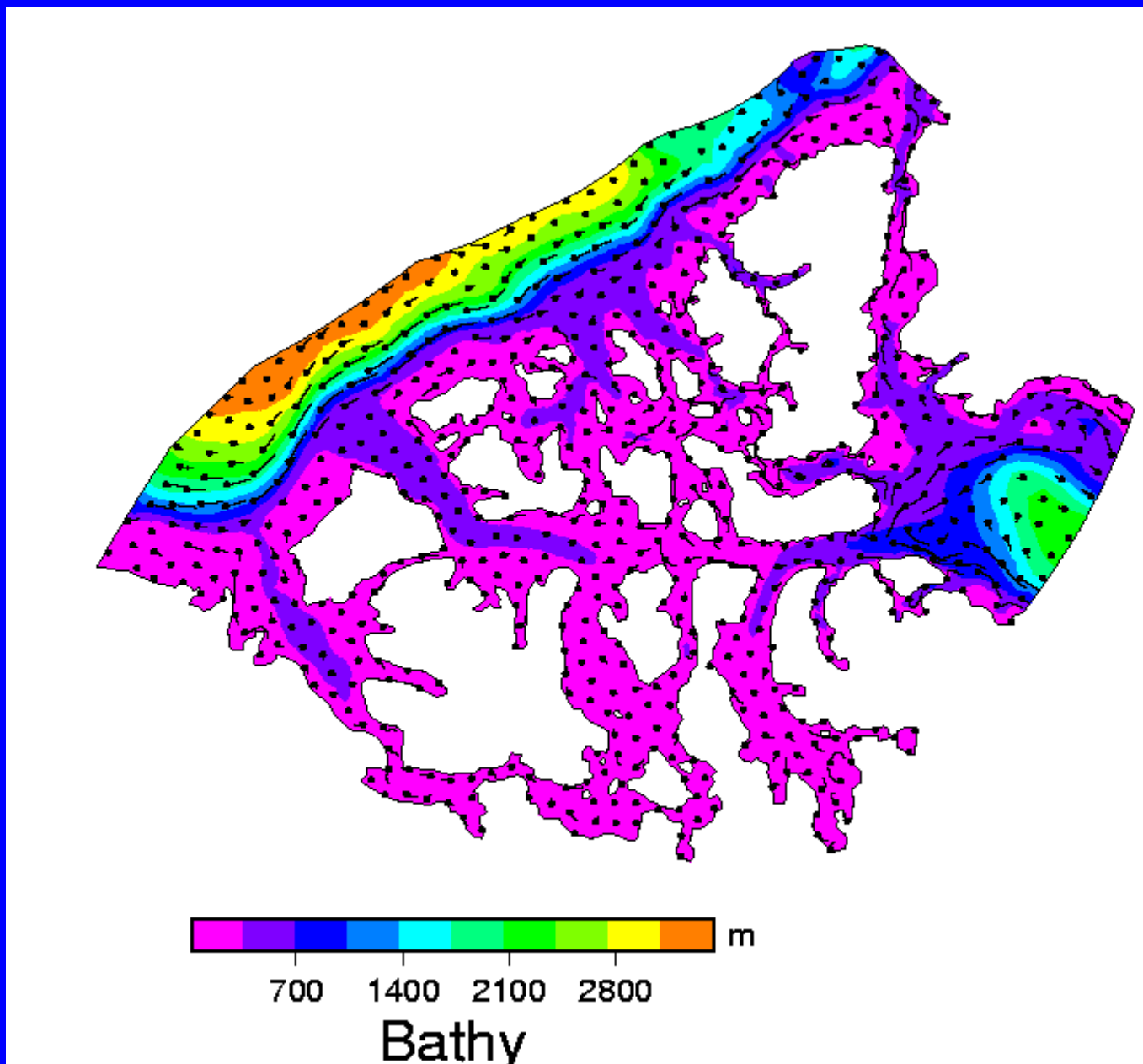
Tides: K1



Tides: M2



Winter case: prognostic circulation with tides

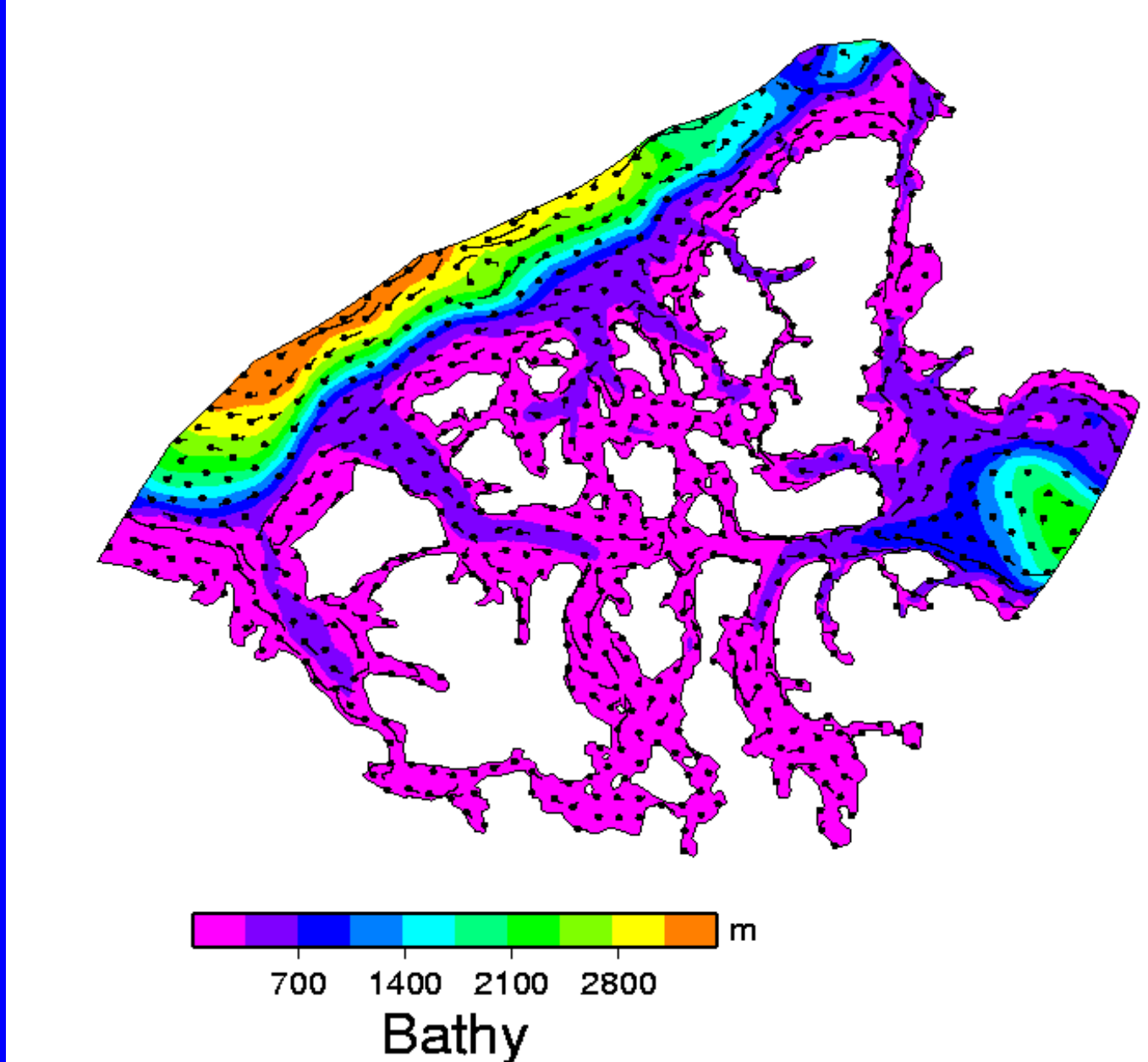


Convention:

Depth averaged currents
circle: start of path
length of line: 12 days

(10 days run+10
days of
diagnostic
spinup)

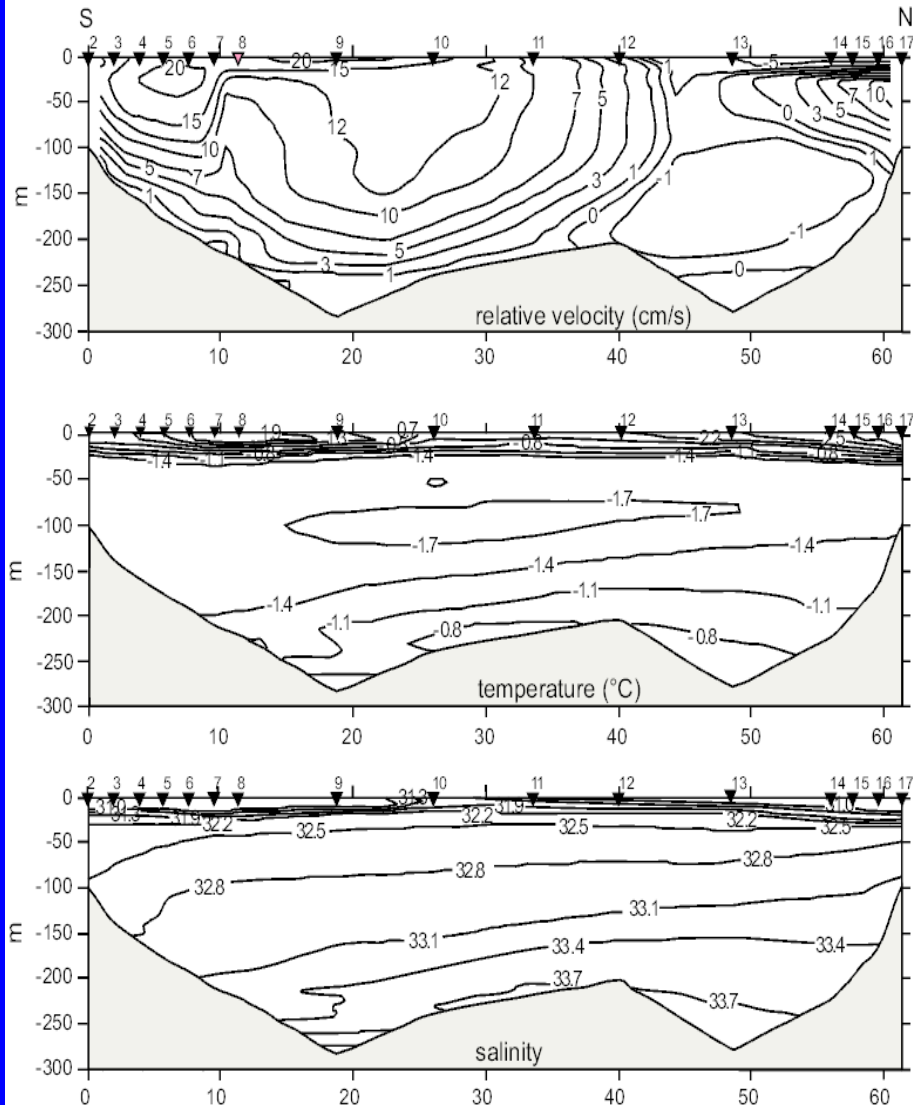
Summer case: prognostic circulation with tides



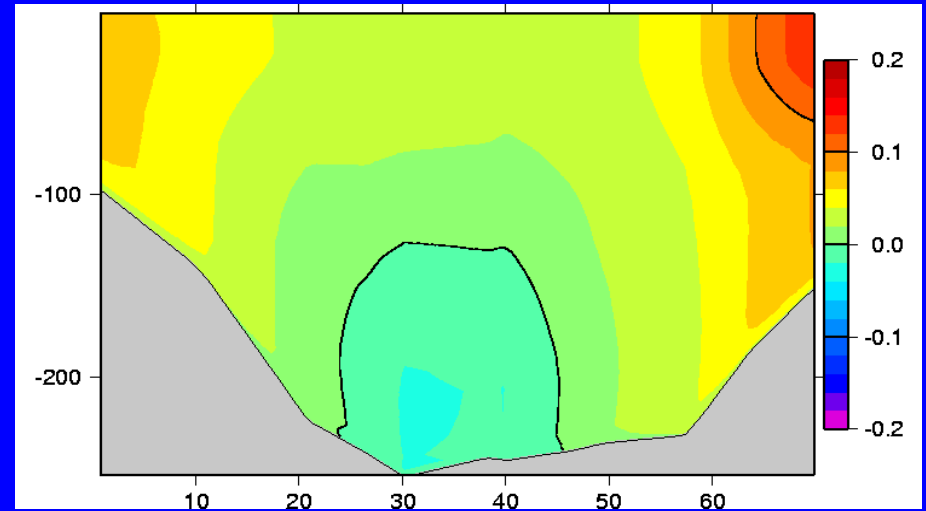
(10 days run+10
days of
diagnostic
spinup)

Barrow Strait

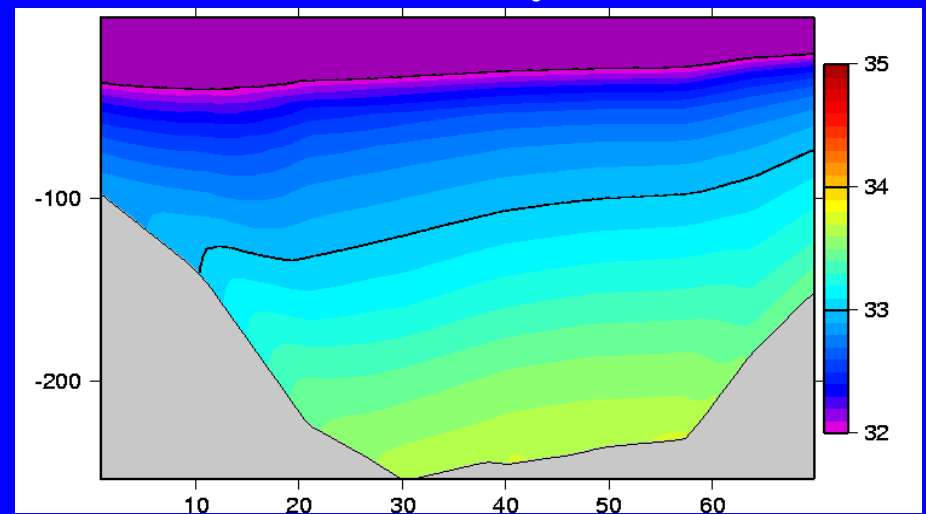
1998 SUMMER East Barrow Strait



Zonal velocity



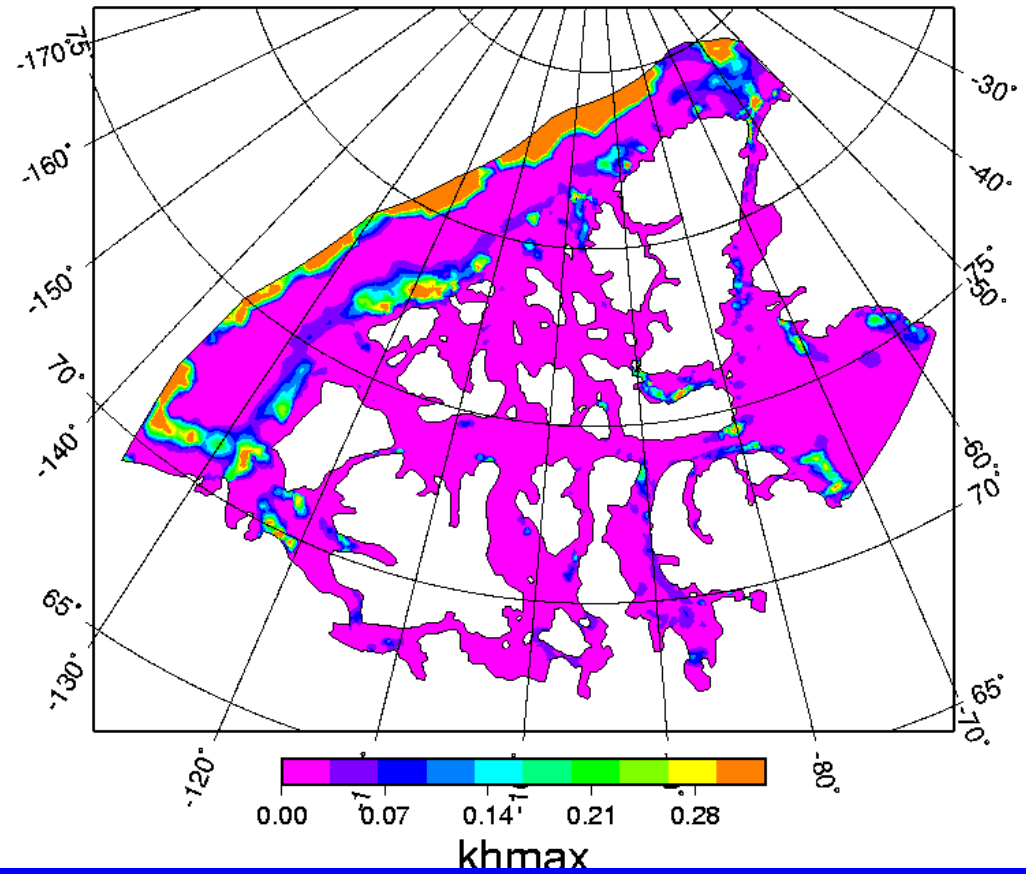
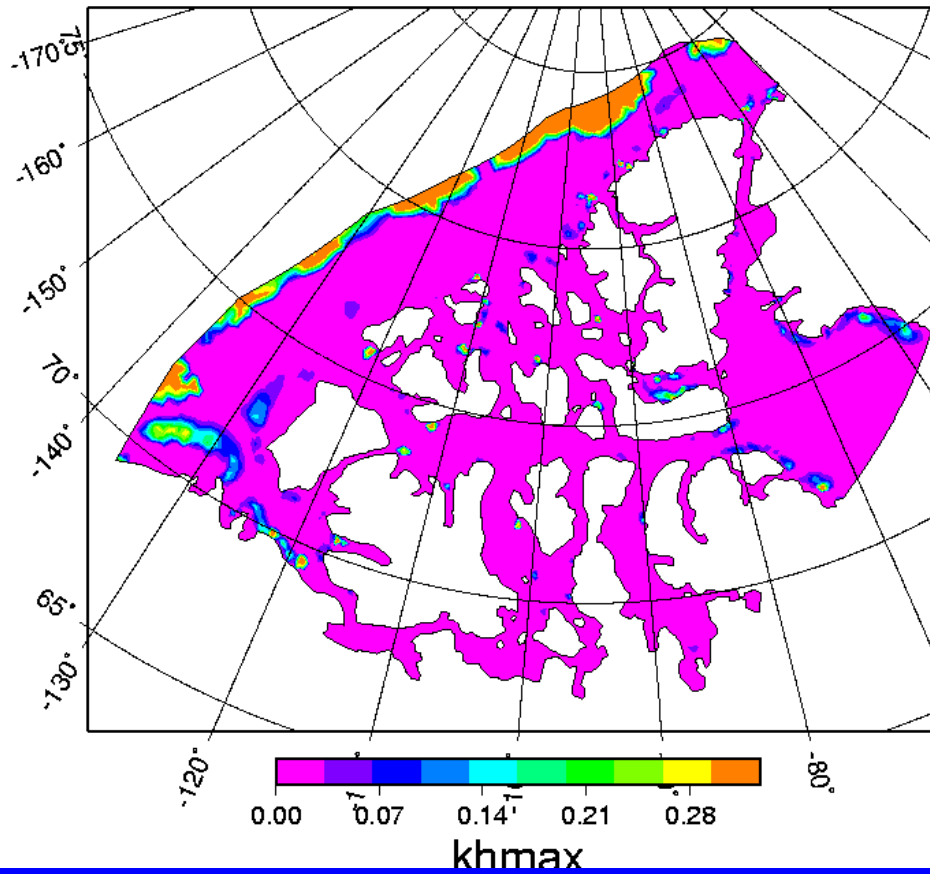
salinity



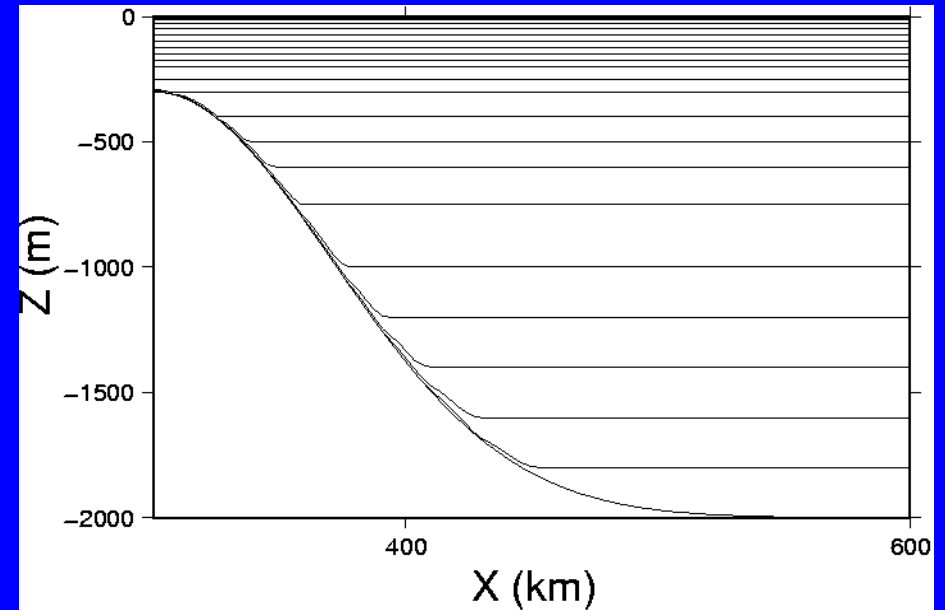
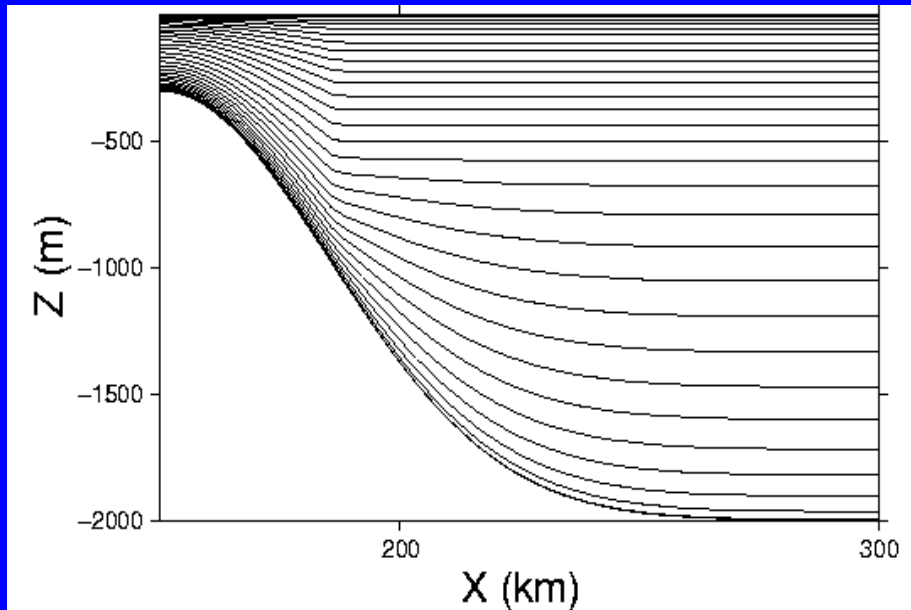
Max vertical heat diffusivity

No tide

With tides

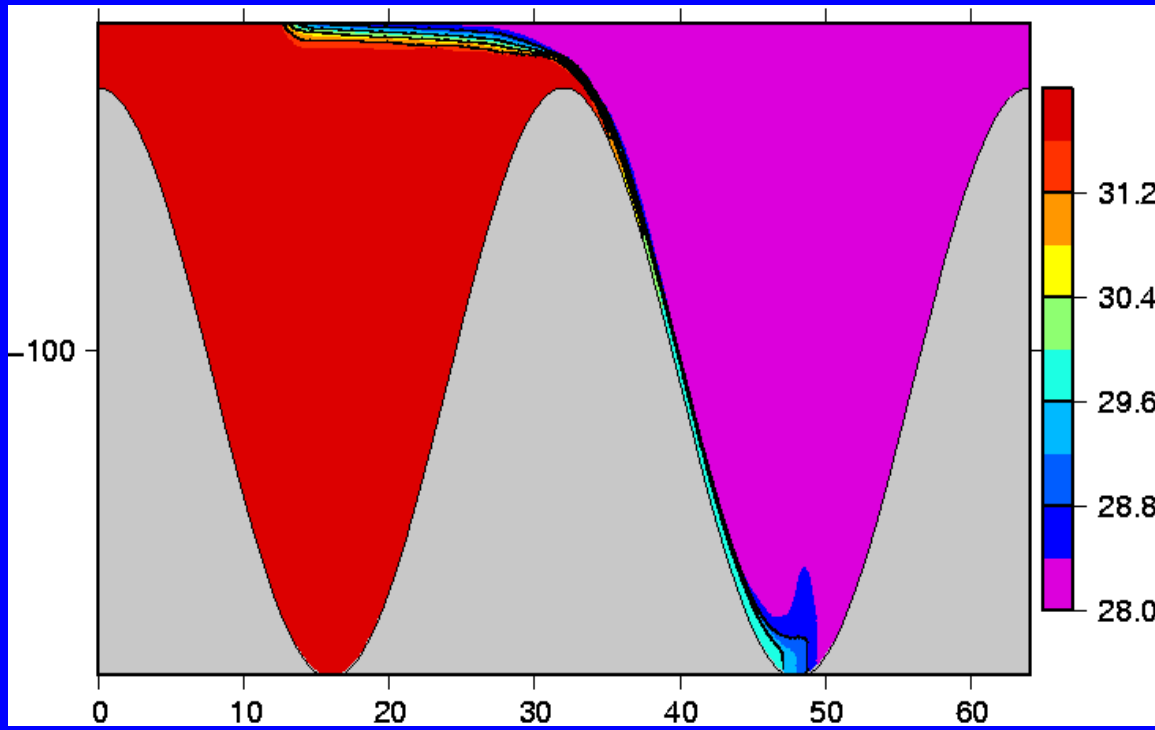


Sigma versus Z-levels coordinates



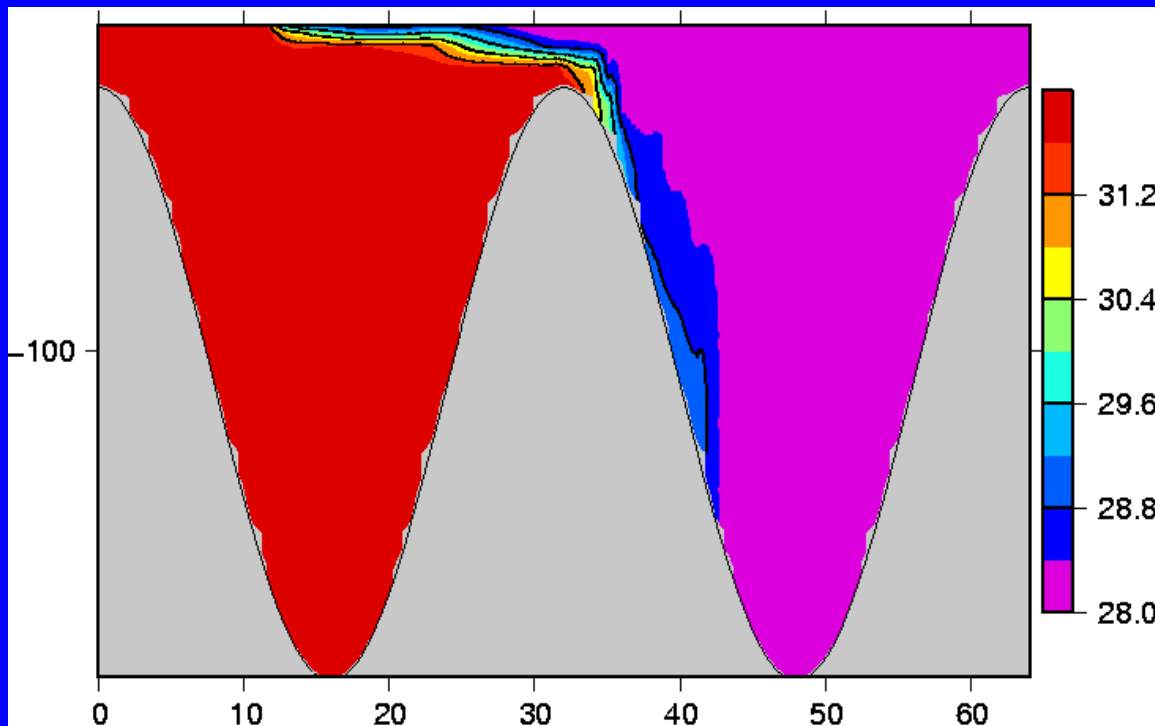
In generalized sigma, the top 500 m are set to be horizontal for depth greater than 1000 m

In Z-levels, a constrain is added for the representation of the bottom boundary layer with 2-3 points



σ -level

**Example: The
dense overflow
problem over
variable
bathymetry**

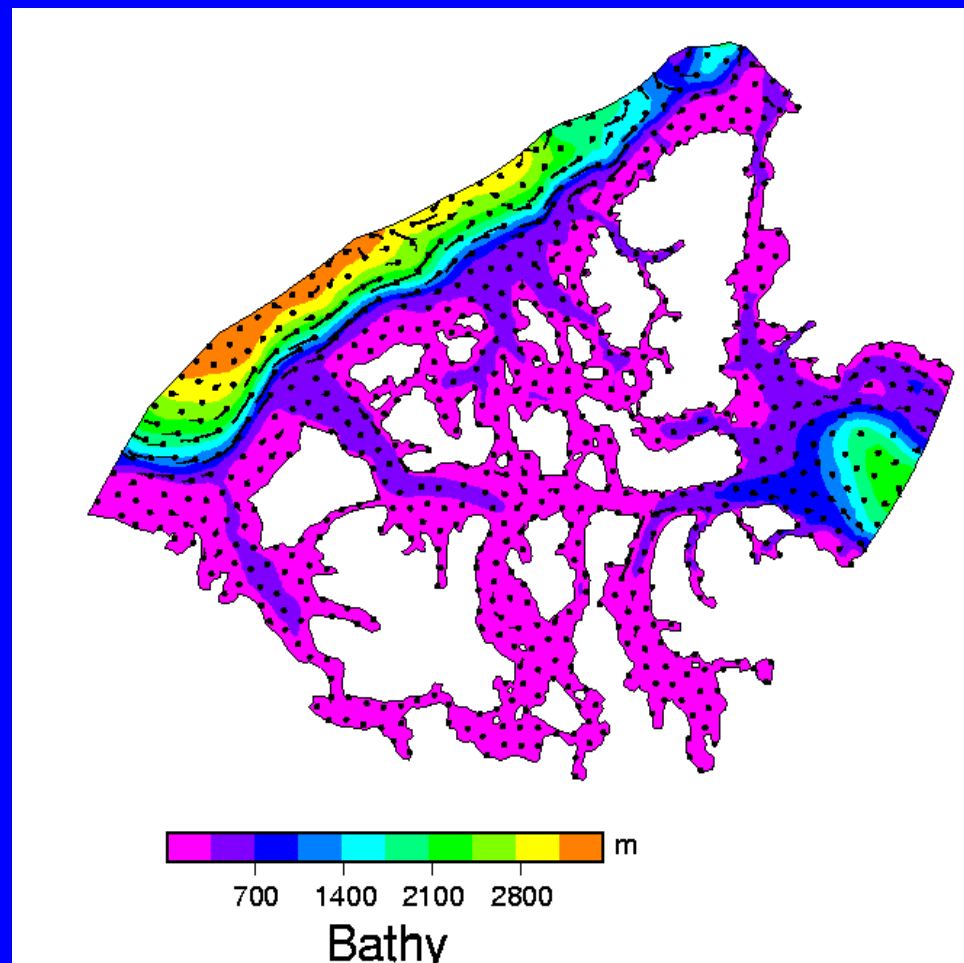
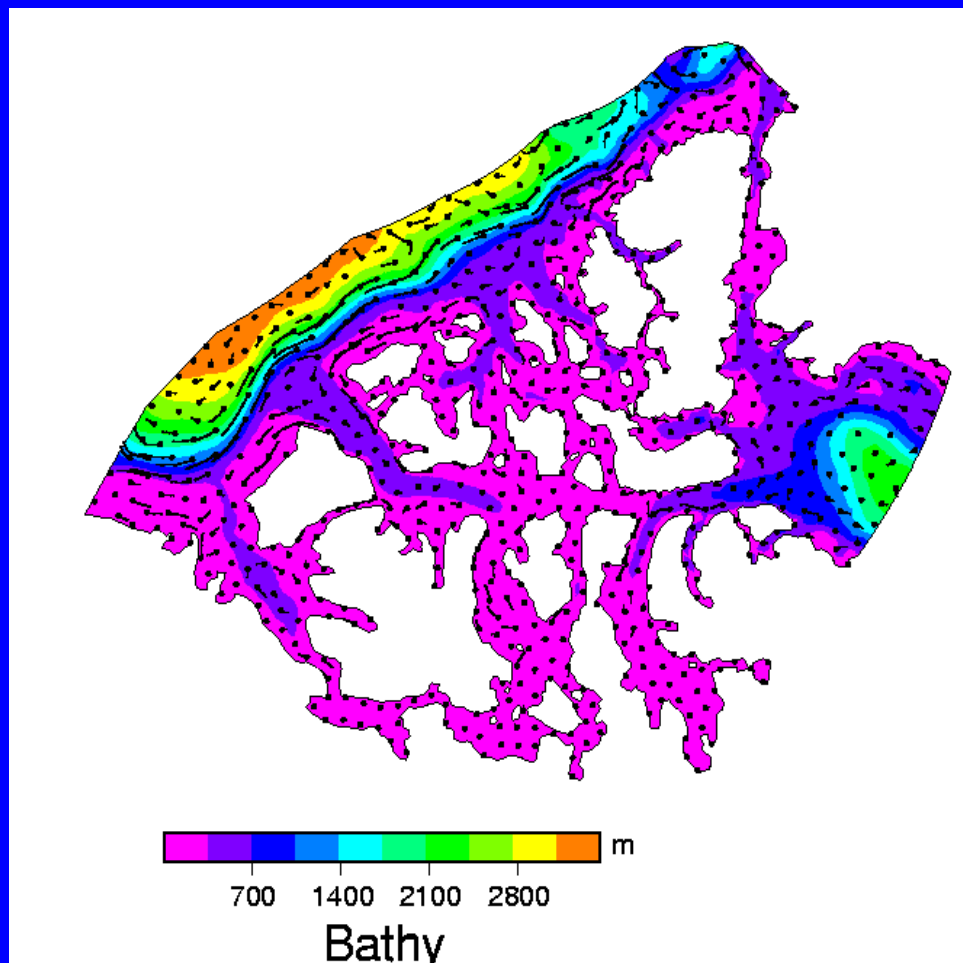


z-level

Particle tracking using the mean depth-averaged fields of the last 10 days of a 60 run with full ice and atmospheric forcing (ECMWF) with summer condition and steric height B.C. on elevation

Sigma

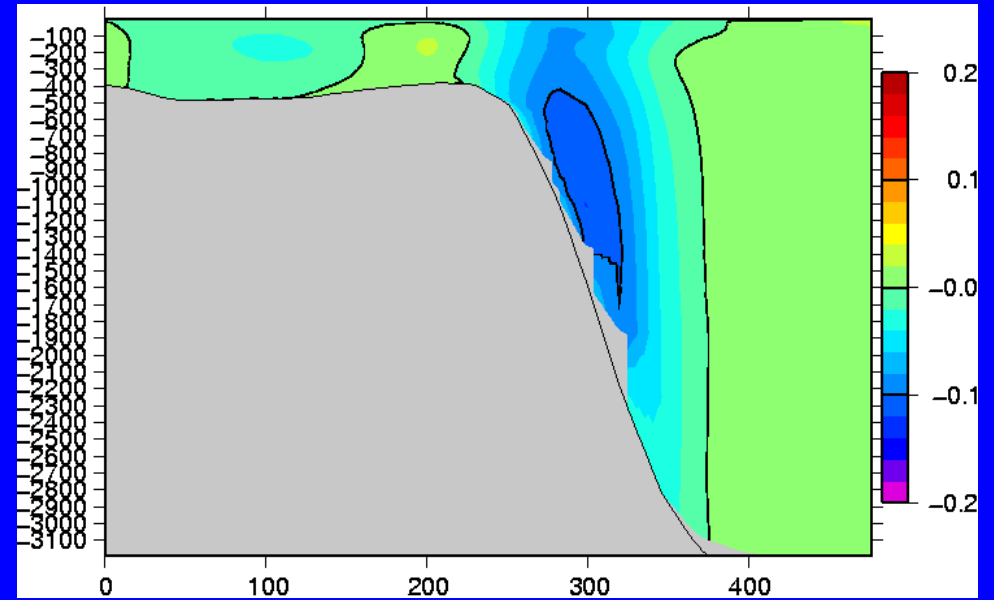
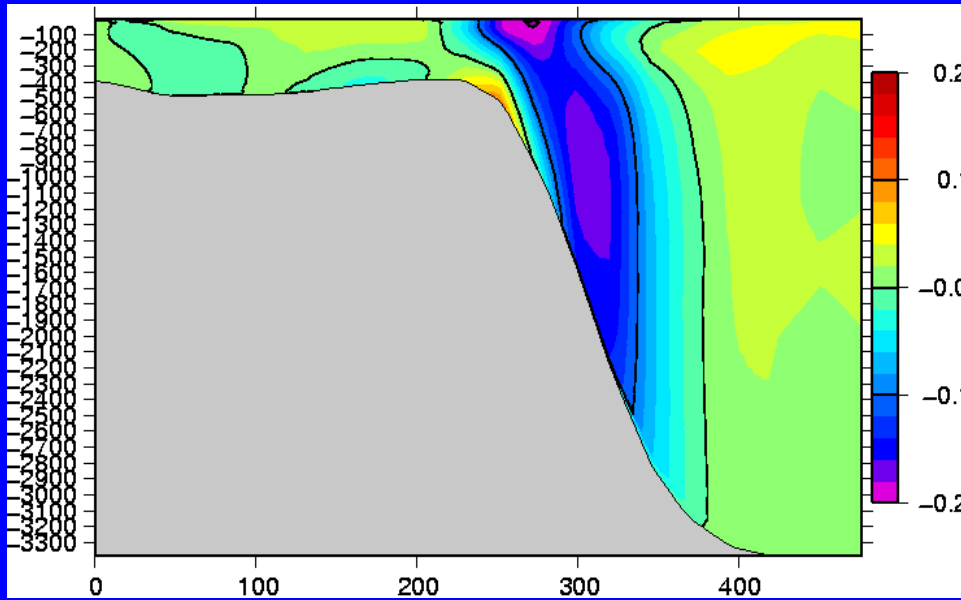
Z-levels



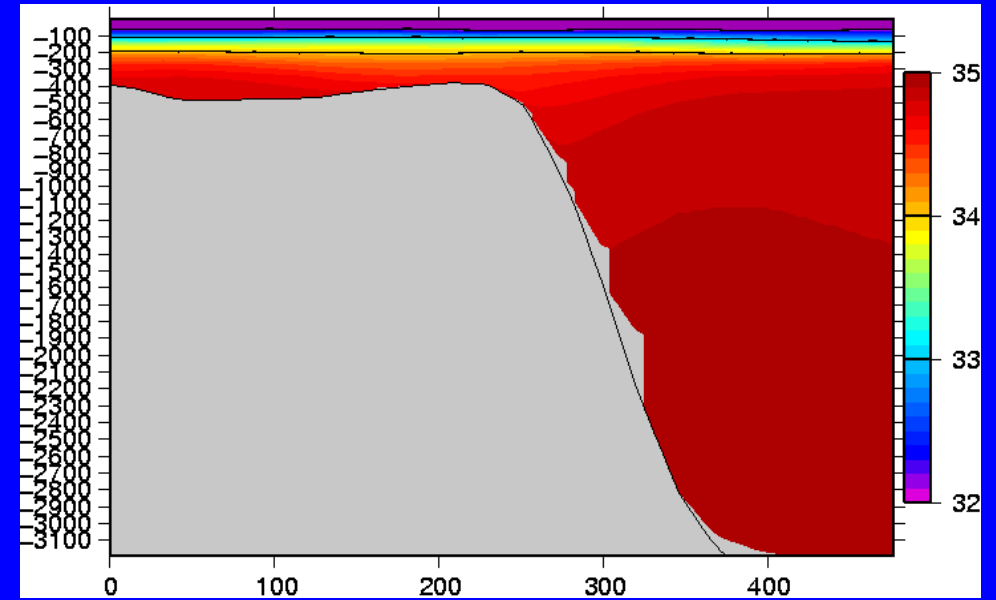
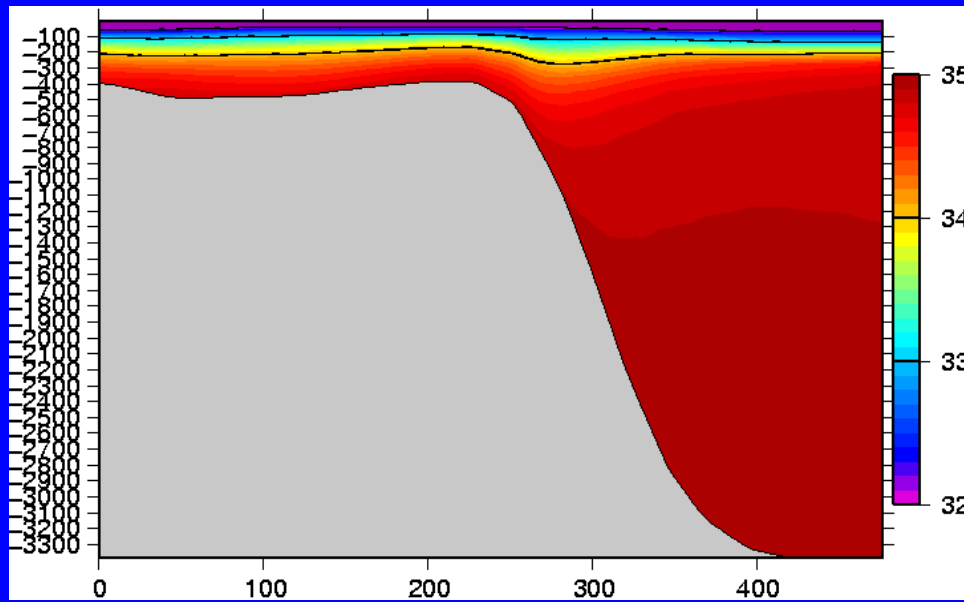
Sigma

Meridional velocity

Z-levels



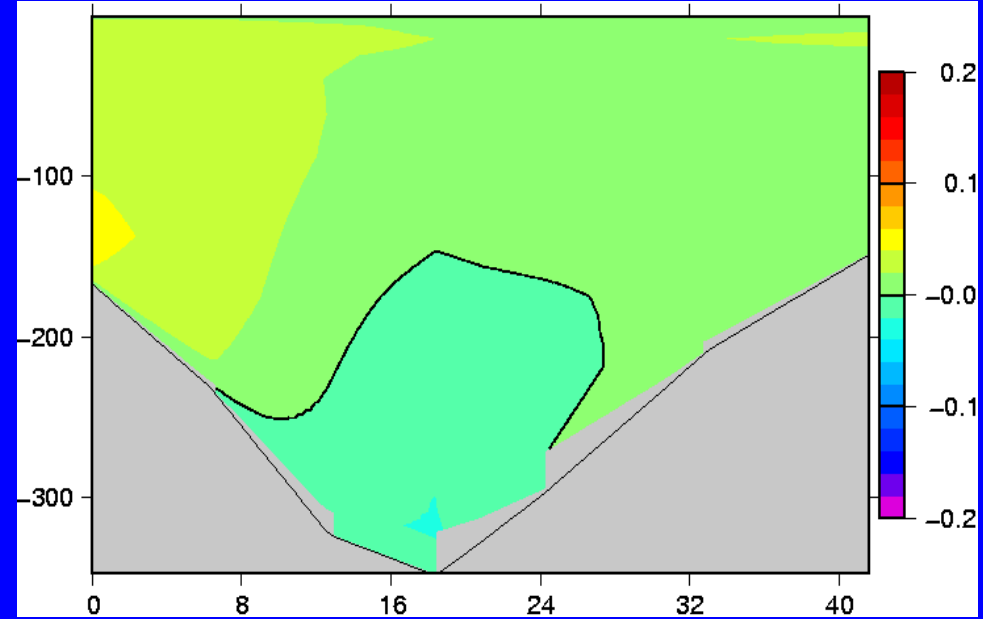
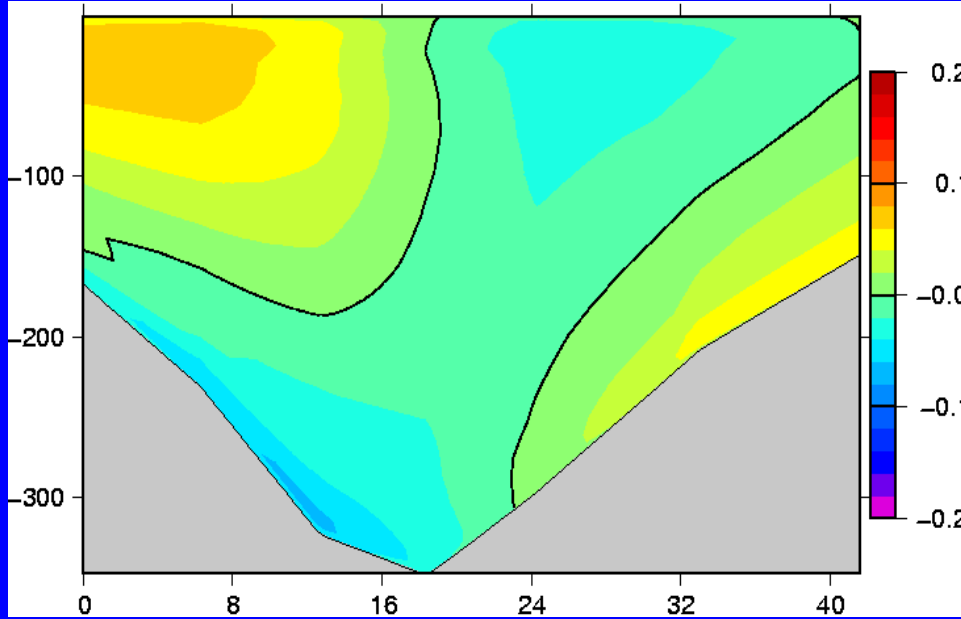
Salinity across the arctic shelf



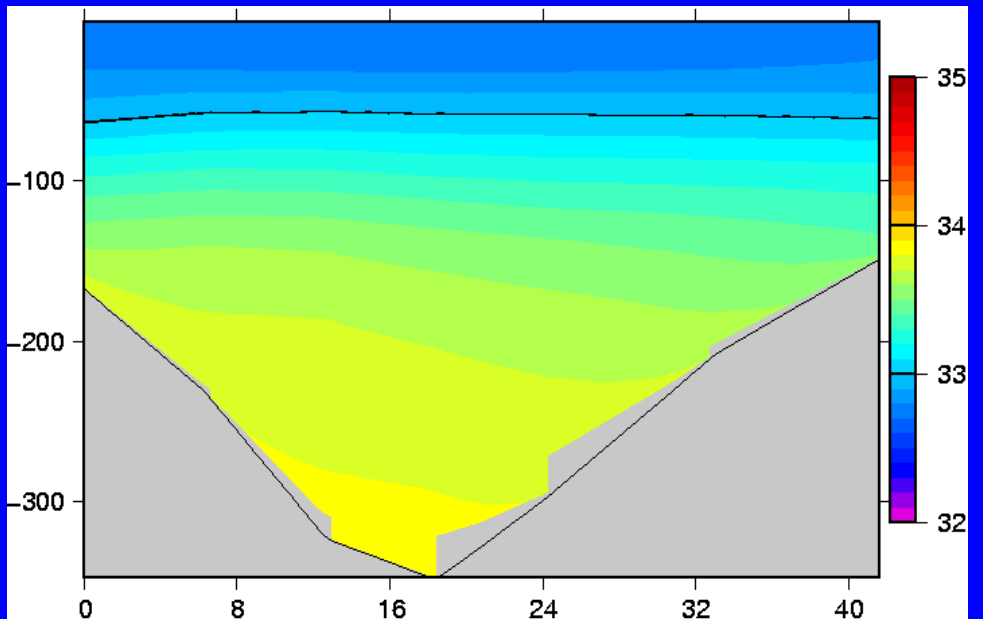
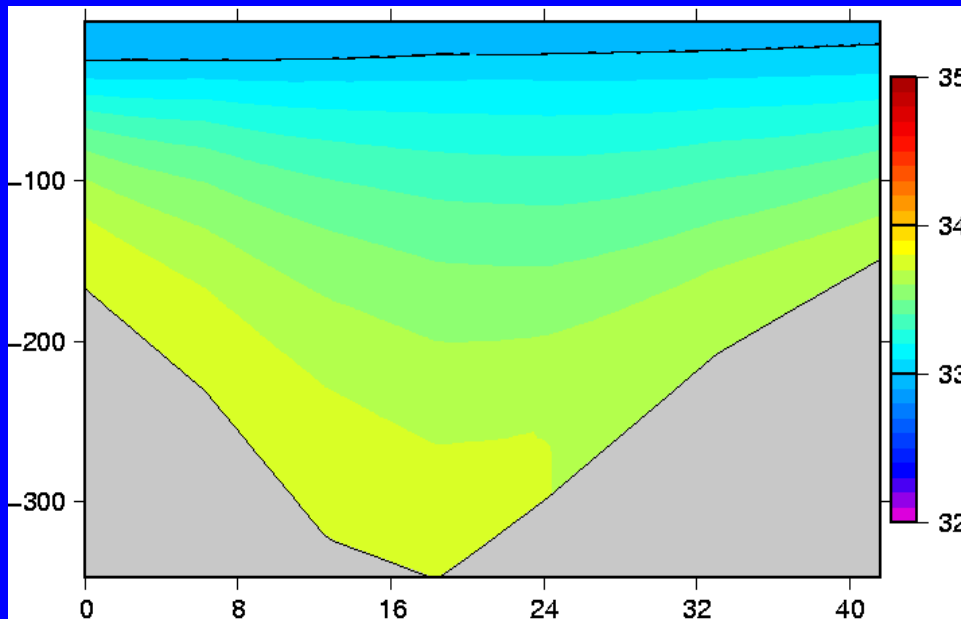
Sigma

Meridional velocity

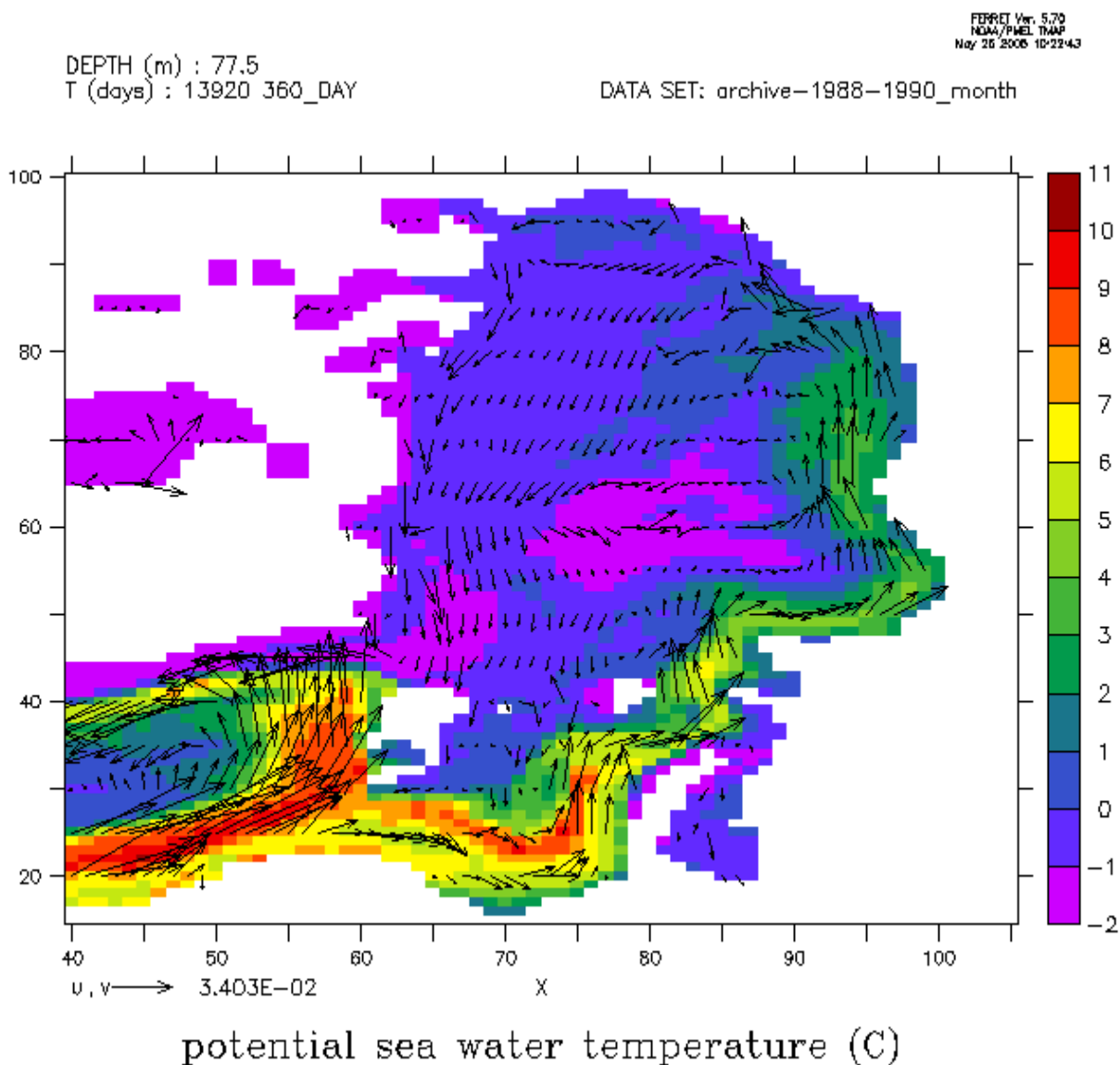
Z-levels



Salinity across Nares strait



Pan-Arctic modelling using AIM (Holloway)

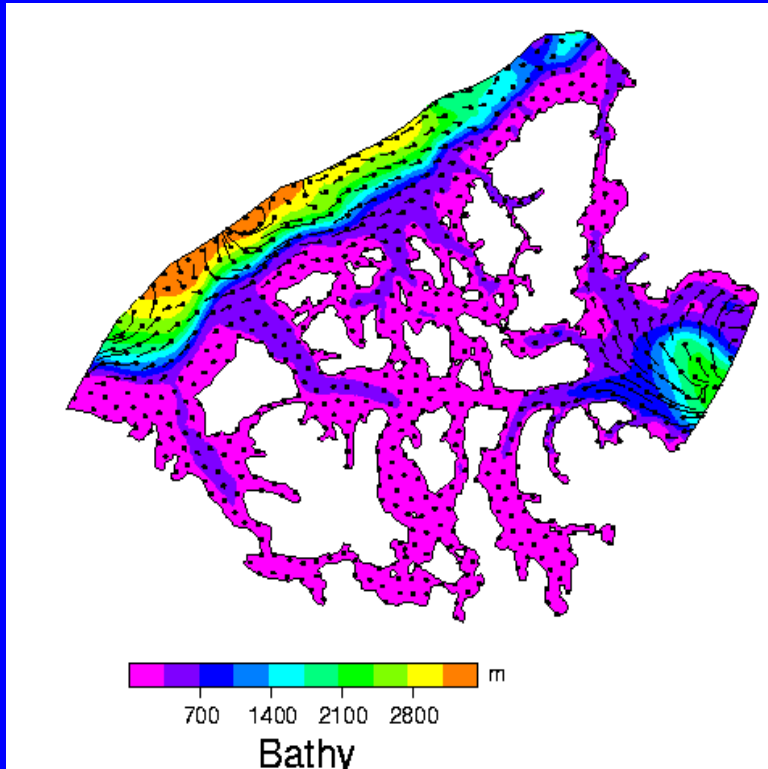


Ocean component:
MOM
Ice dyn: Hibler type (79)
Ice thermo: Parkinson
and Washington (79)

Forcing: 50 years of air
wind, pressure,
temperaure (NCEP)
Climatology:
precipitation, humidity,
runoff and OBCs.

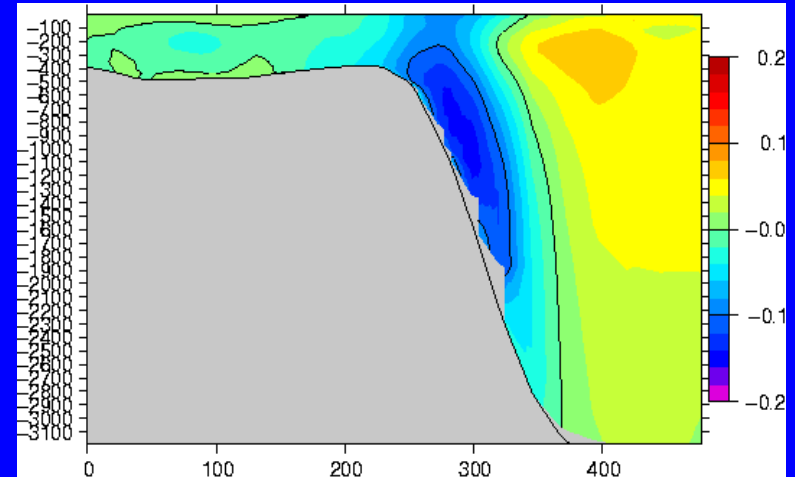
AIM provides boundary conditions to the regional model.

First results of coupling (one-way) between AIM and FVCOM after a 6 month run

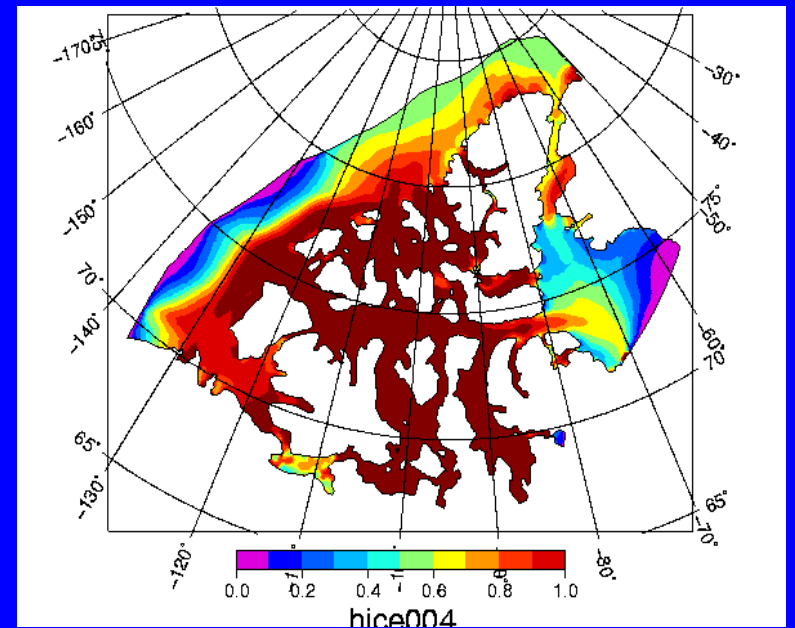


Mean ice velocity for February 1990

Meridional velocity across the arctic self



Mean ice thickness for February 1990

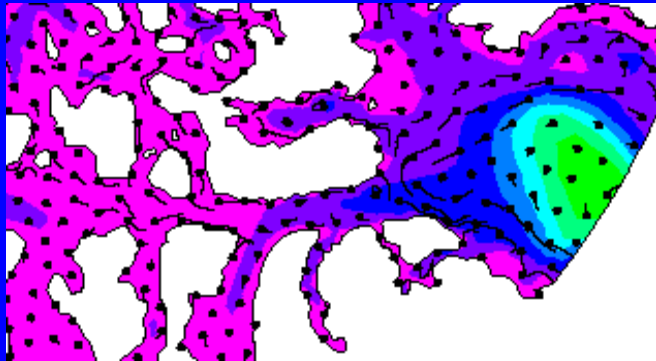


Conclusions

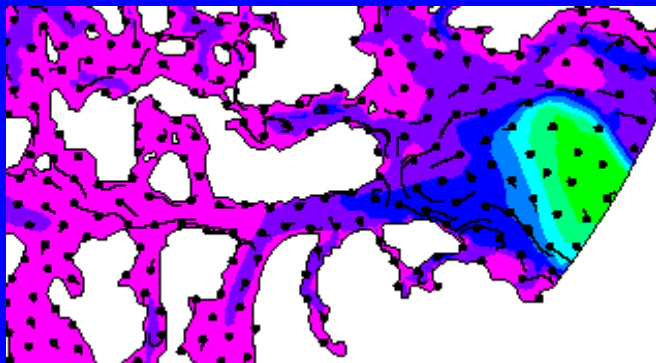
- We have demonstrated the operationability of the model with full ice and atmospheric forcing.
- The freshwater transport tends to be equally split between Nares Strait and Barrow Strait. The closing has little impact. The large scale still dominates. Barrow Strait seems more effective (Freshwater/volume)
- Z-coordinate yields a better representation than Sigma coordinate (too much advection/diffusion along the sigma layers in the latter case).
- Possibility to go to isopycnal representation but caution with bottom boundary!

Greg Holloway's Arctic Ocean model (AIM) will be used as a first step model for coupling with biology and in a second step for providing boundary conditions to a regional bio-physical model.

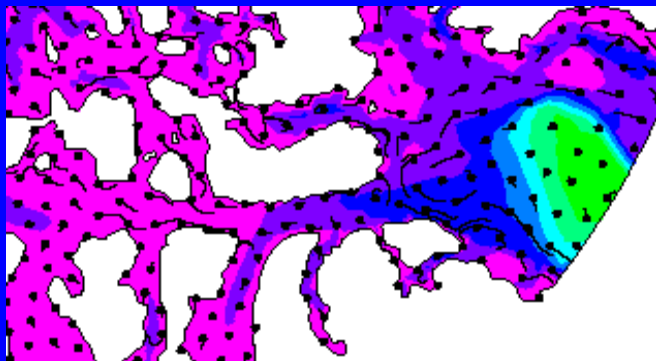
Sensibility to the closing of the passages for the winter case



Cardigan/
Hell Gates



Perry

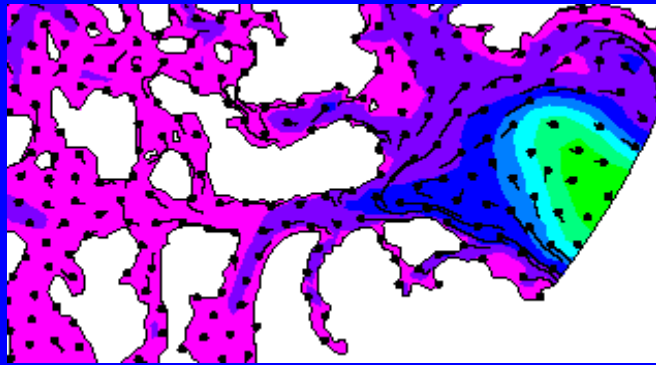


Byam M

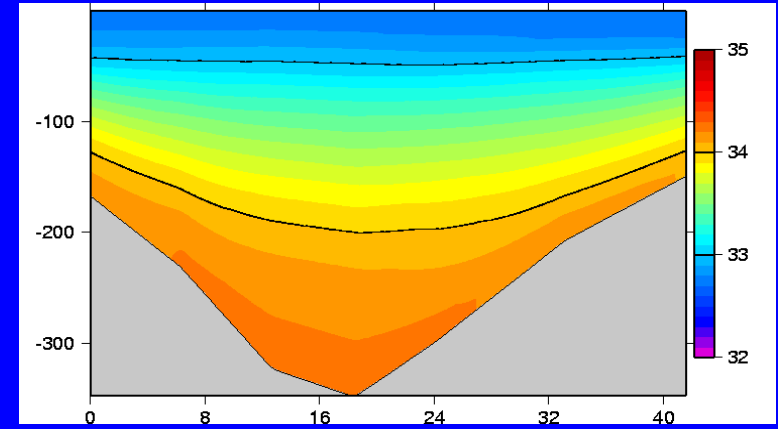
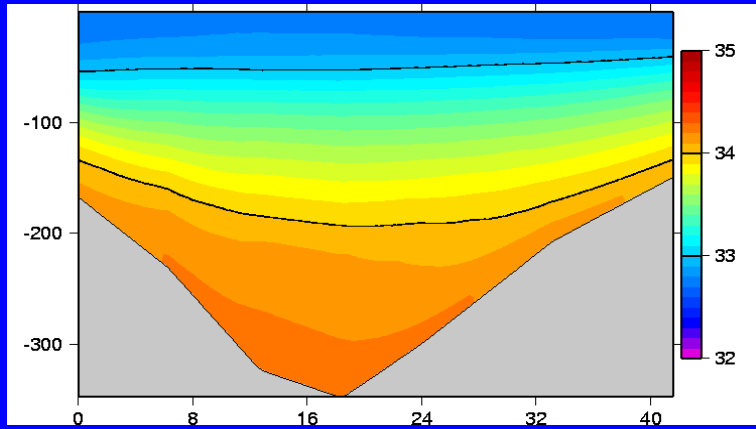
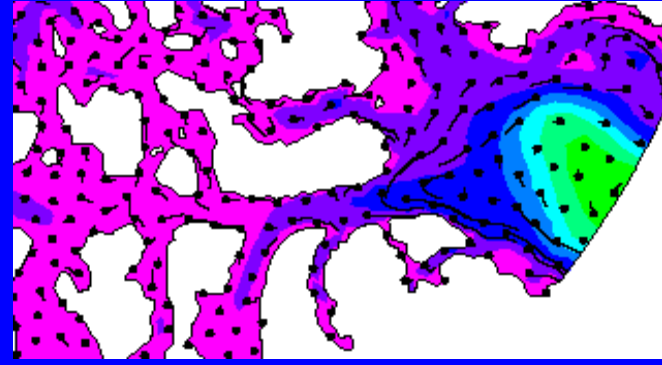
	Volume (10e6 m ³ /s)	Freshwater (10e6 m ³ /s)
Barrow	0.8-1.0	0.02-0.04
Nares	0.5-1.5	0.02-0.06
Cardigan	0.1-0.2	0.005-0.01
Closing of Perry		
Barrow	0.8	0.04
Nares	0.5-2.0	0.02-0.06
Closing of Byam		
Barrow	0.8-1.0	0.04-0.05
Nares	0.5-1.9	0.02-0.06

Effect of tide

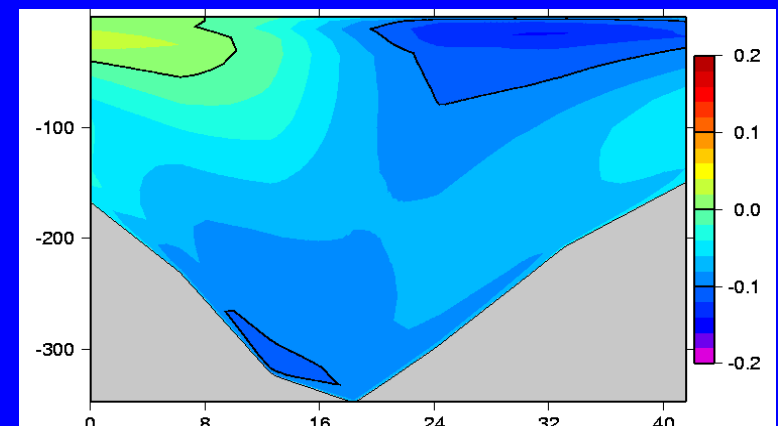
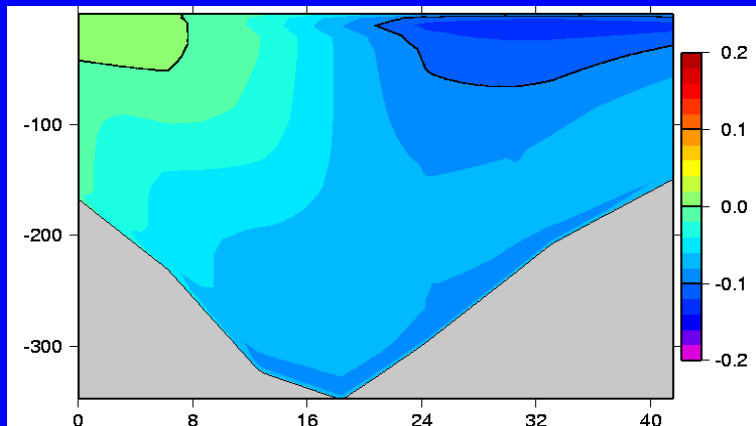
No tide



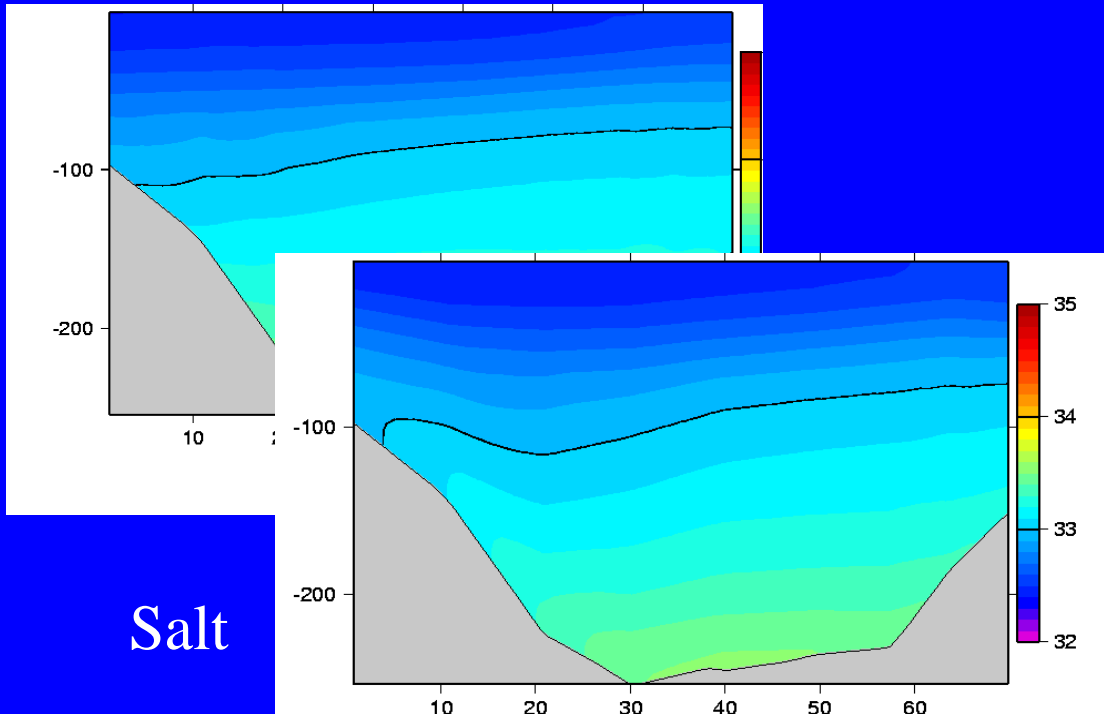
tide



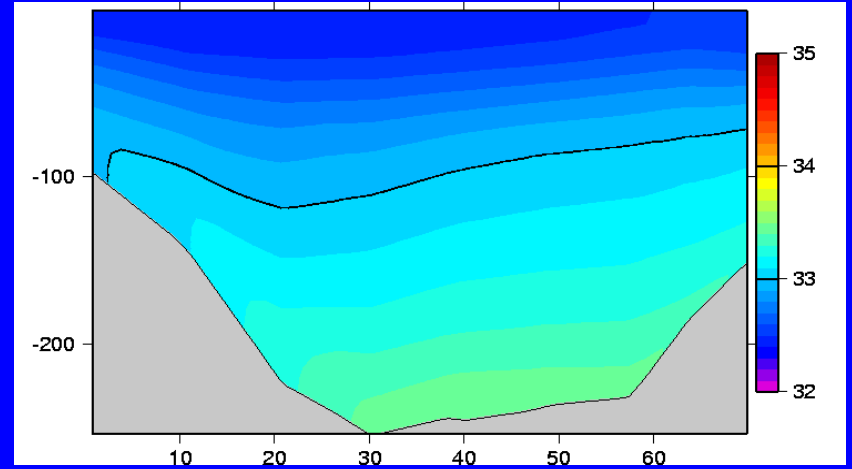
Nares Strait



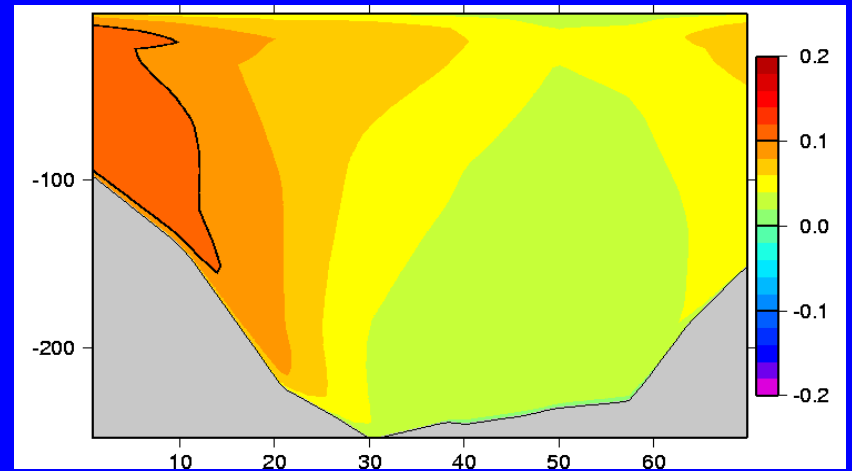
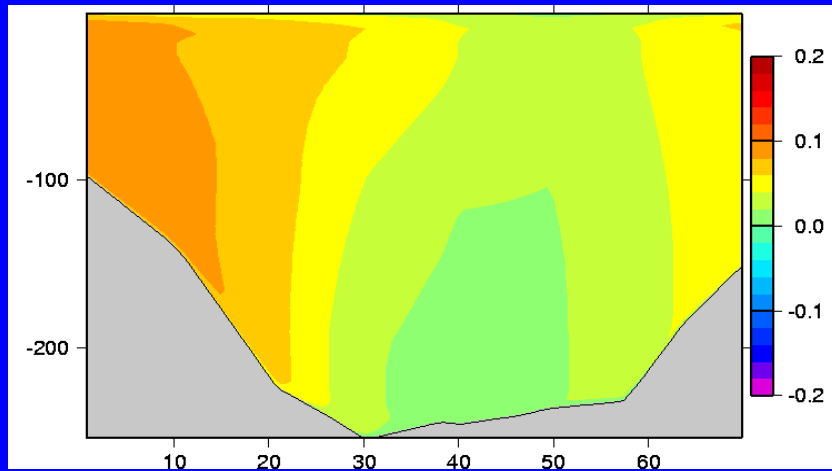
In Barrow Strait



Salt



Velocity



No tide - tide

In finite difference, the partial derivative are taken from a truncated Taylor development:

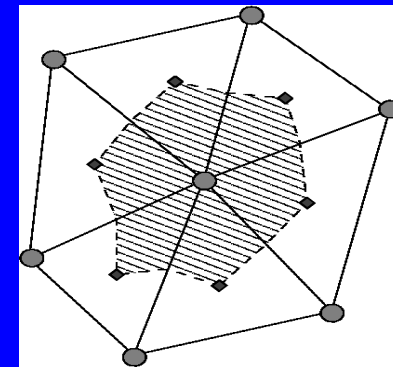
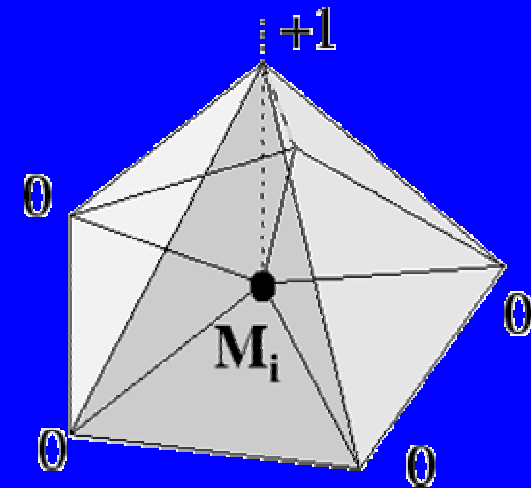
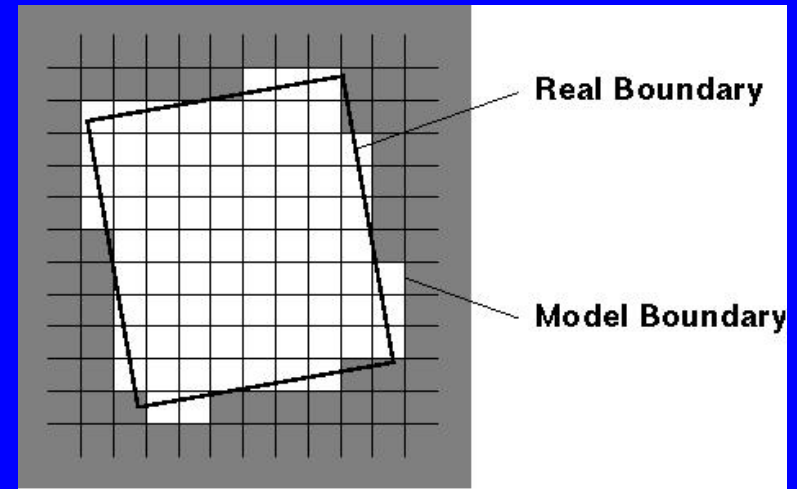
$$df/dx (x) = (f(x+\Delta x) - f(x-\Delta x)) / 2\Delta x + O(\Delta x^2)$$

In finite element, the residual for each equation is minimized through a weak Galerkin statement.

$$\text{Int} \{ g(x) [df/dt + df/dx] dx \} = 0$$

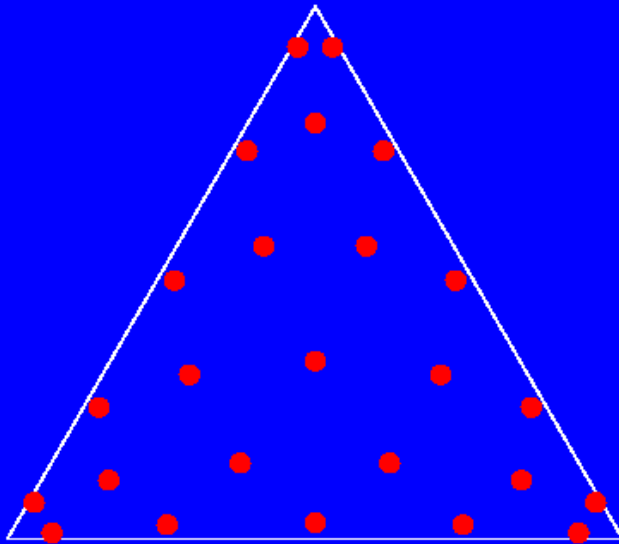
In finite volume, The equations are written in conservation form in order to take advantage of the Green (divergence) theorem:

$$\text{Int} \{ df/dt \} = -\text{Int} \{ df/dx \} = -\sum f \cdot n$$

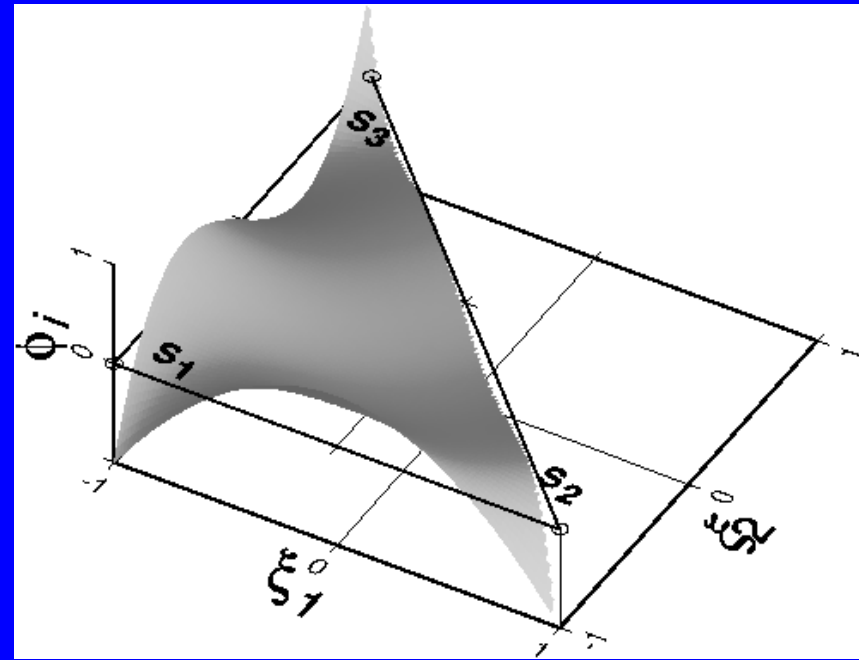


My interest:

- New numerical approach for ocean modelling with emphasis on unstructured approach.
- Development of 3d physical models of the ocean



Example for $n=10$
(basis of $n=5$)



Example with polynomial
 $\phi_i = L_2(\xi_1)L_3(\xi_2)$

Observations

