Some lessons from the AOMIP coordinated spin-up

and new INM RAS model results for the 1948-2002 hindcast

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Questions:

- **Atlantic Water transport towards the Central Arctic**

Mechanisms maintaining AW transport along continental shelf;

Two branches of the AW pathways and their relative role in the large-scale variability;

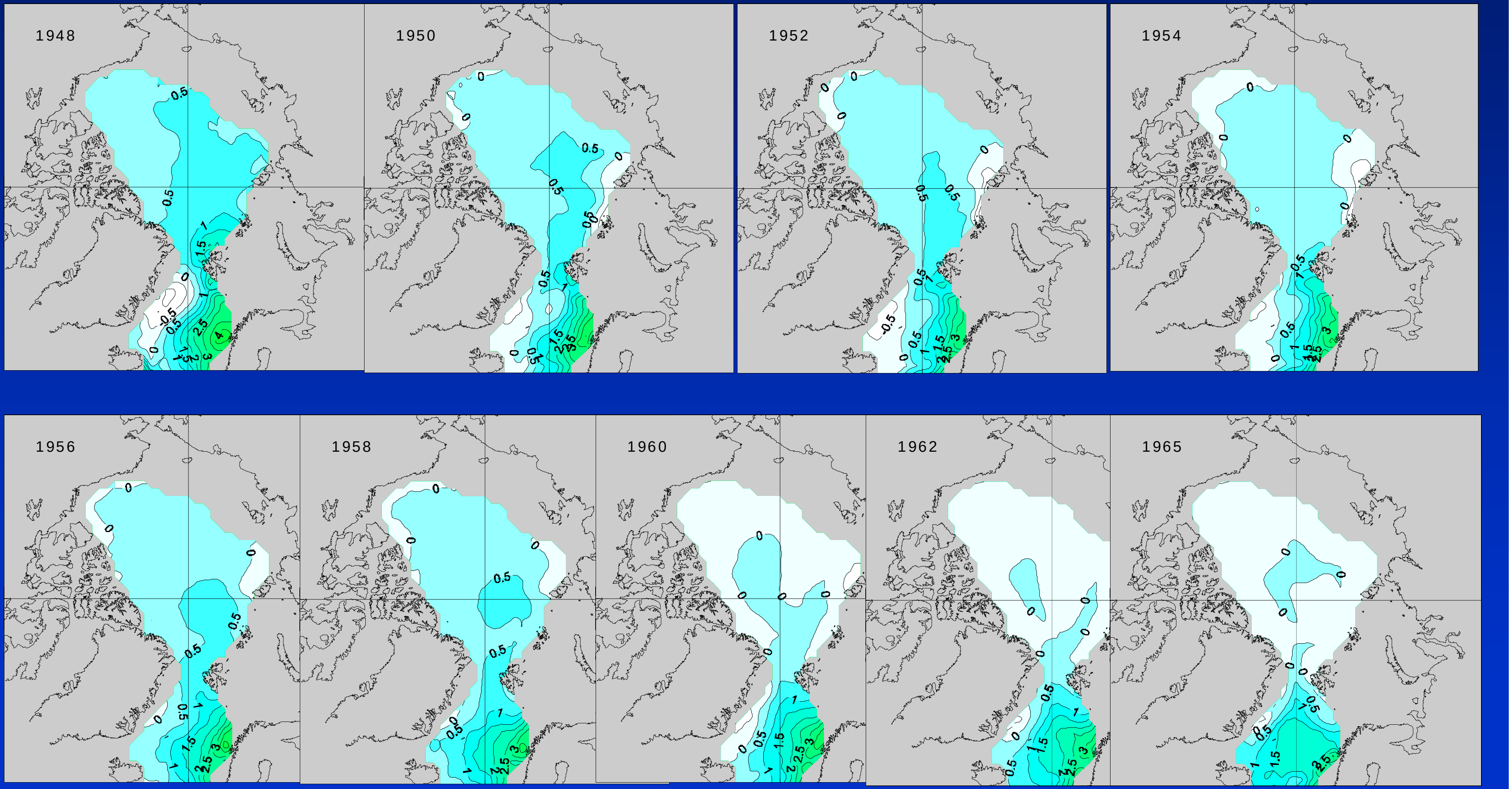
Model improvements to simulate observed AW transport and some a priori requirements formulation.

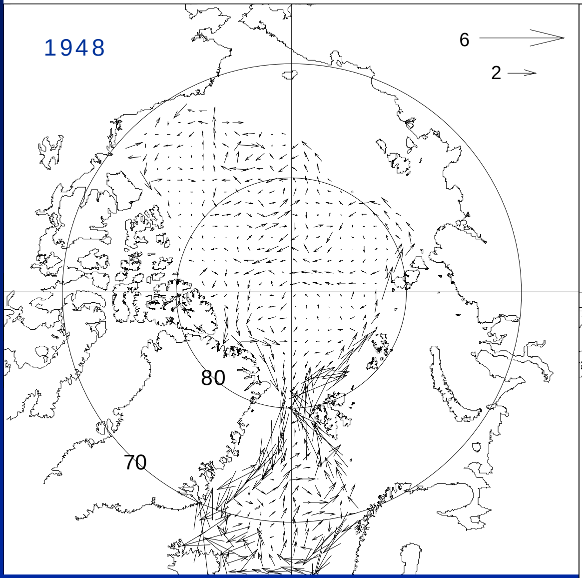
- **Freshwater and salt content balance and mechanisms of their temporal variability**

Beaufort Gyre freshwater content – physical mechanisms ruling the phenomenon;

Freshwater and salt content balances in the coupled sea ice – ocean general circulation model – (possible?) model reformulation

ATLANTIC WATER

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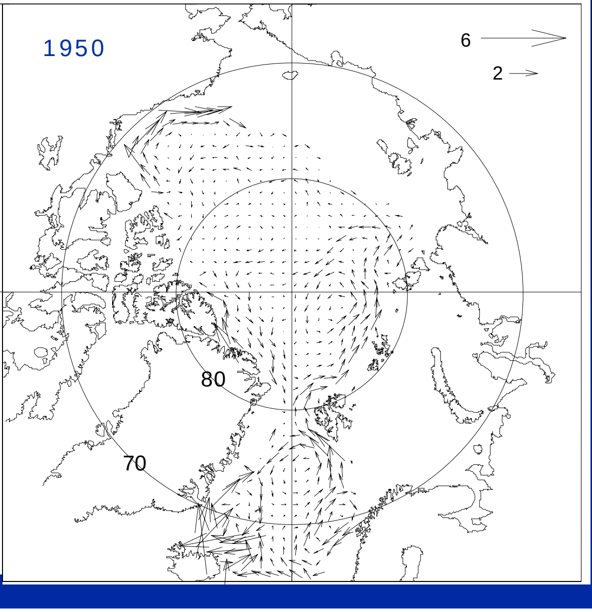
70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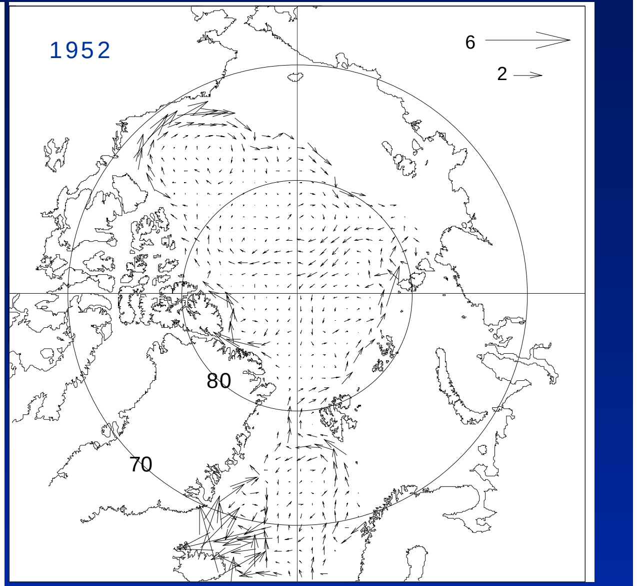
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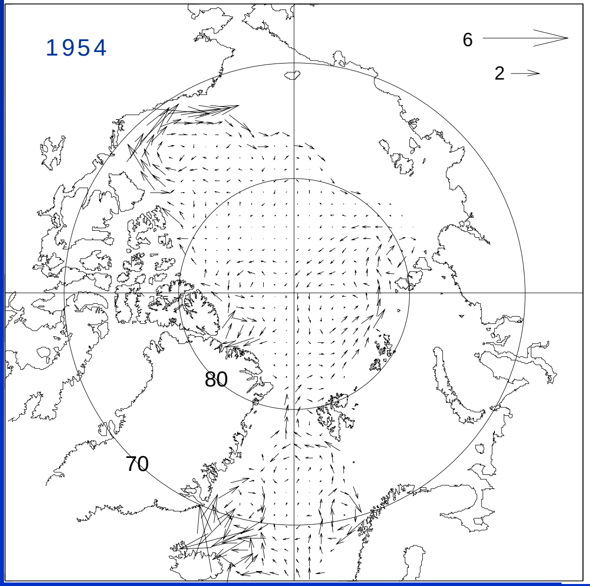
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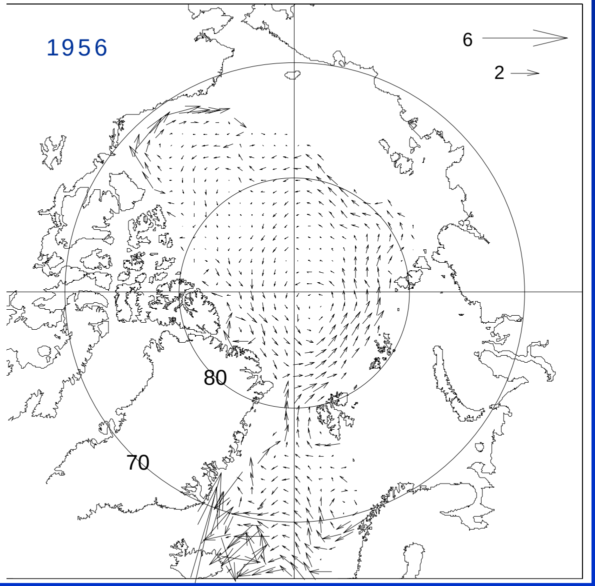
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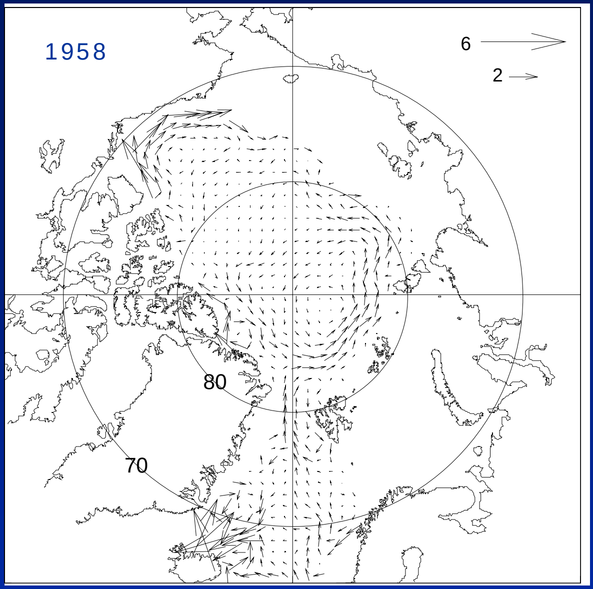
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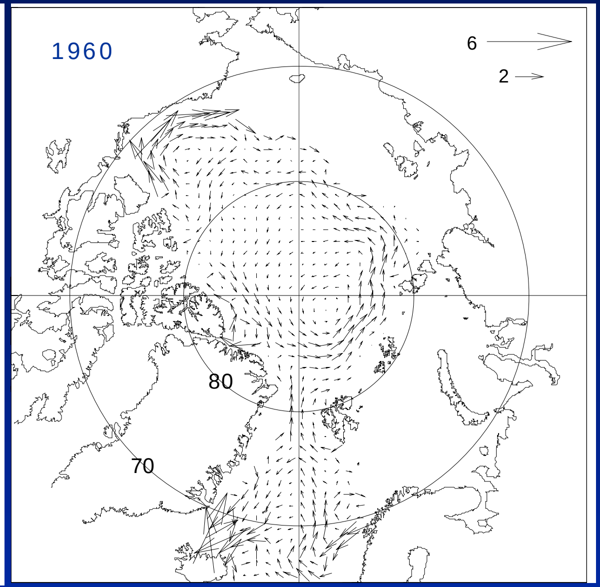
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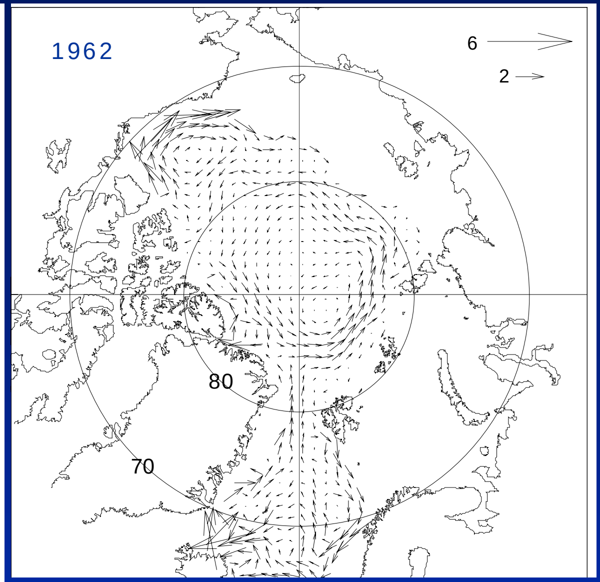
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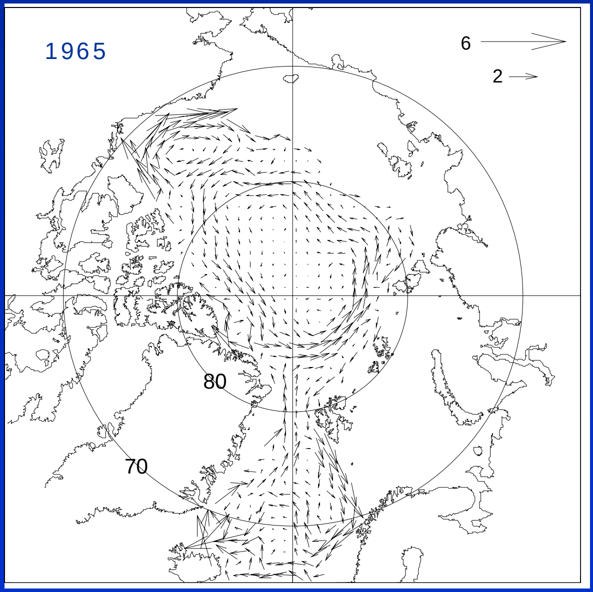
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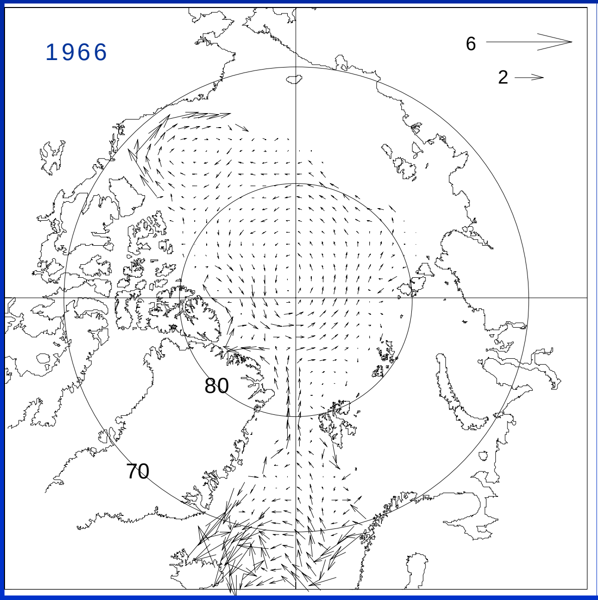
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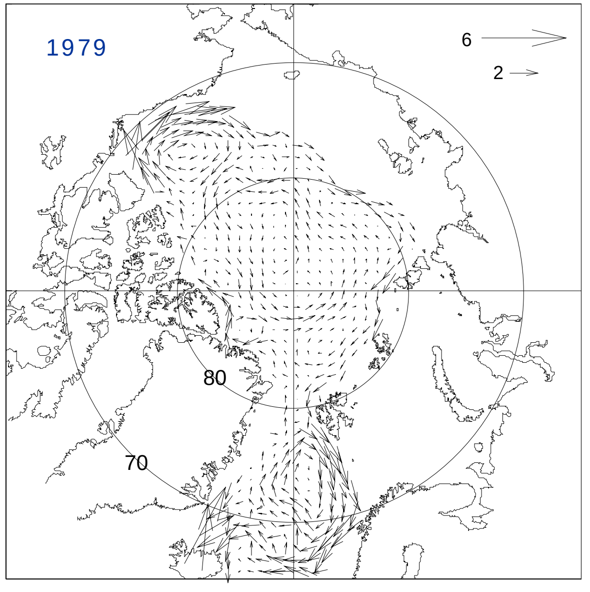
1979
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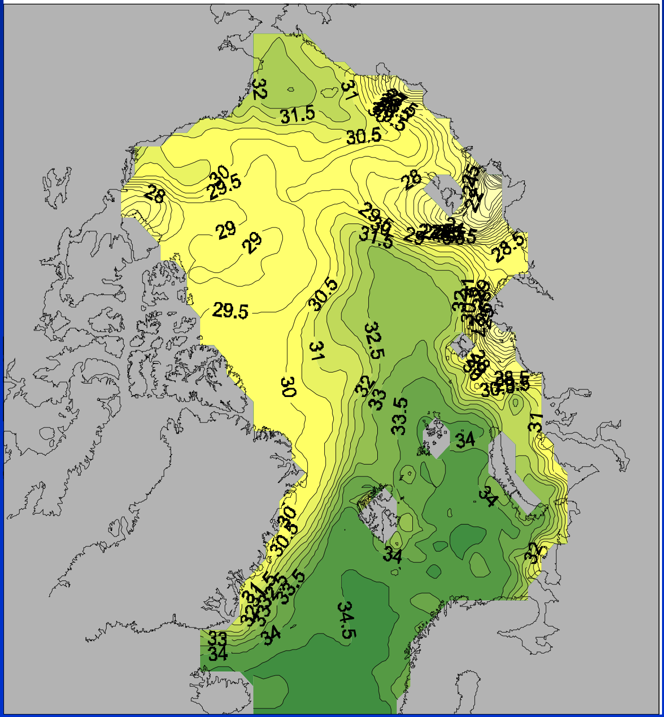
ATLANTIC WATER: WHAT TO DO?

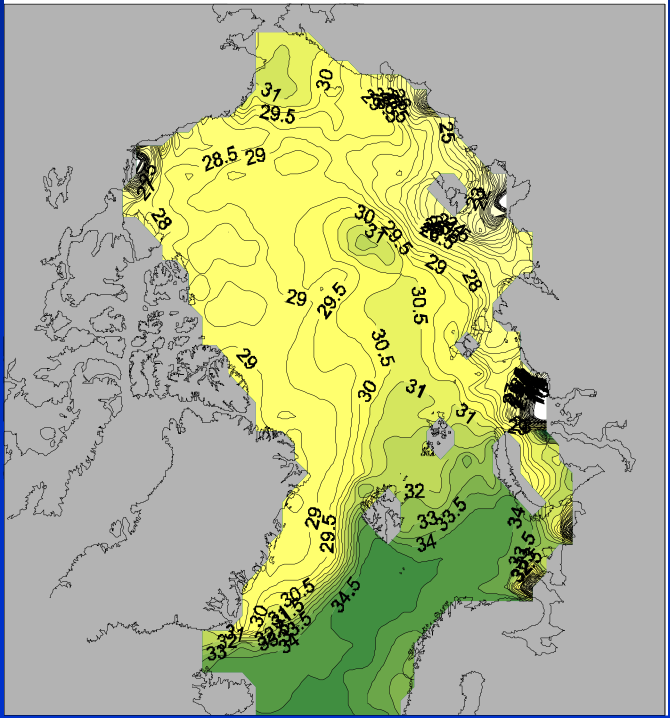
1. To improve resolution.
2. To use the PV-balanced schemes.
3. To use (quasi)monotone schemes for temperature and salinity. Momentum transport schemes?
4. To understand the nature of coastal jets and along-coast transport in baroclinic ocean: mechanisms and parameterizations (Neptune, etc.). Residual tidal currents?

1. Very noisy salinity field even with comparatively high diffusion;
2. Salinity restoring;
3. “Virtual” salinity fluxes at river estuaries and upper surface;
4. Different treatment of rivers and passages;
5. No freshwater balance.

Salinity 0m. February 1978.



Salinity 0m. August 1978.



TEMPERATURE AND SALINITY ADVECTION

Galerkin approximations with Streamline Upwinding (SU). Here coefficient of the diffusion k assumed to be tensor of the form

$$k_{i,j} = C u_i u_j, \quad C = \frac{\delta h}{2|\vec{u}|}, \quad \delta h \text{ - size of a triangle}$$

WOCE\TOGA drifting bouys: $k_{\parallel} \approx 10^7\, cm^2 s^{-1}, \quad k_{\perp} \approx 0.5 k_{\parallel}$

Crosswind diffusion: General idea – proportional to streamline diffusion.

1. Induced by horizontal flows

$$k_{11} = C u_1^2 + C_1 C u_2^2,$$
$$k_{12} = C(1 - C_1) u_1 u_2,$$
$$k_{22} = C u_2^2 + C C_1 u_1^2, \quad \mathrm{C}_1 \approx 0.1 \div 0.5$$

2. Induced by vertical flows

$$k_{ii} = k_{ii} + C_2 \cdot k_{33}, \quad i = 1,2,$$
$$C_2 = L / H,$$

L – Horizontal length scale,

H – Vertical length scale.

Total numerical diffusion $k_{i,j} \to 0, \quad \delta h \to 0$.

THE TRANSPORT SCHEME FOR SEA ICE/SNOW ADVECTION

Monotone scheme for ice and snow transport is a key feature of the ice model. 3 types of schemes were used:

1. Ordinary Galerkin approximation with high artificial diffusivity to suppress numerical oscillations

$$\int \tilde{m}(\partial_t m + \nabla(\vec{u}m))d\Omega + \int div(k\nabla m)\tilde{m}d\Omega = F$$

or, after integration by parts and assuming no diffusive fluxes at boundary Γ

$$\int(\tilde{m}\partial_t m - \vec{\nabla}\tilde{m}\cdot\vec{u}m)d\Omega - \int k\vec{\nabla}m\vec{\nabla}\tilde{m}d\Omega = -\int_{\Gamma}\tilde{m}m(\vec{u}\cdot\vec{n})d\Gamma + F$$

2. Galerkin approximations with Streamline Upwinding (SU). Here coefficient of the diffusion k assumed to be tensor of the form

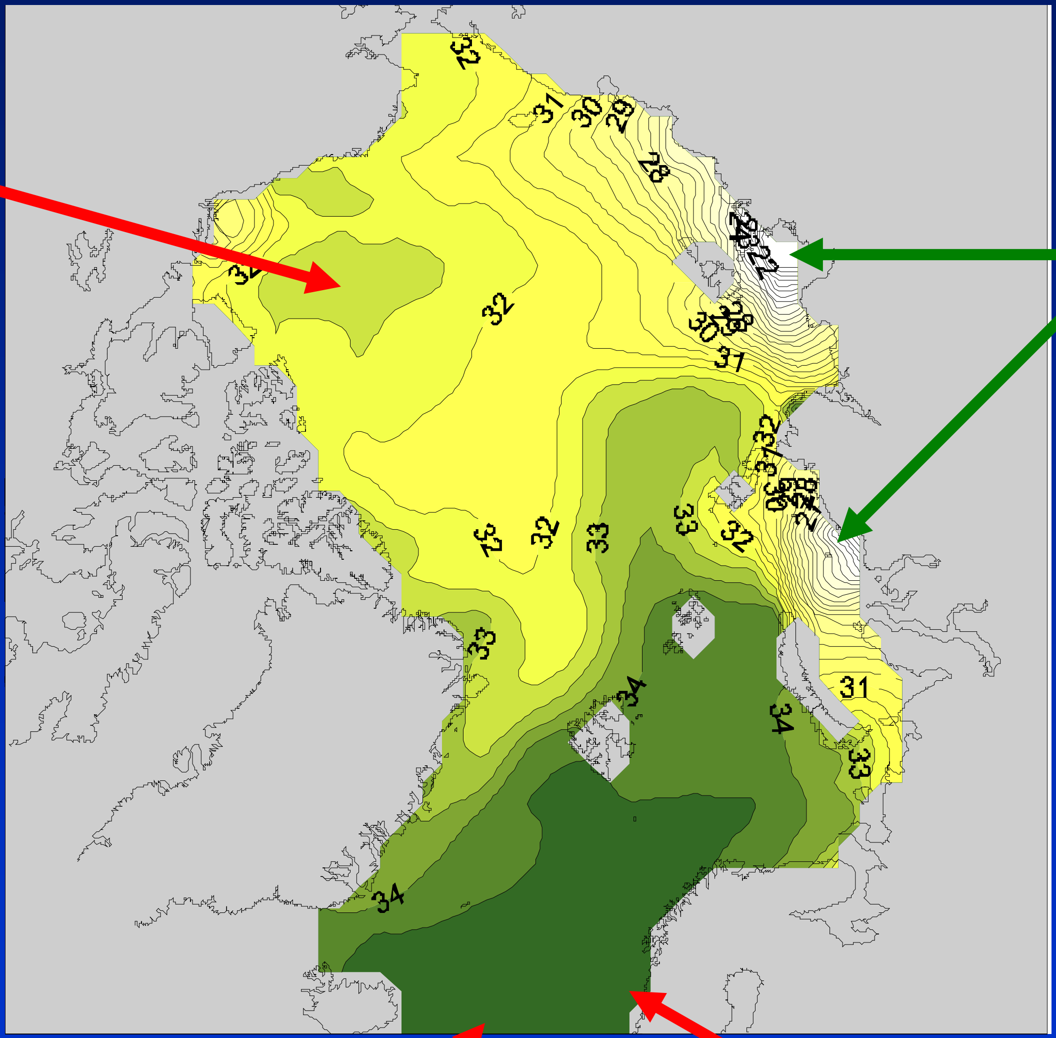
$$k_{i,j} = C\frac{u_i u_j}{|\vec{u}|}, \quad C = \frac{\delta h}{2|\vec{u}|}, \ \delta h \text{ - size of a triangle}$$

3. Galerkin approximations with SU plus "shock capturing"

$$k_{i,j} = C_1\frac{u_i u_j}{|\vec{u}|} + C_2\frac{a_i a_j}{|\vec{u}|}, \quad \text{where} \quad \vec{a} = \frac{(\vec{u}\cdot\vec{\nabla}m)}{|\vec{\nabla}m|^2}\vec{\nabla}m.$$

This scheme proved to produce the most realistic results. It was assumed that $C_1 = C_2 = \frac{\delta h}{4|\vec{u}|}$. Some background diffusivity is necessary to suppress oscillations due to non-slip boundary conditions for drift velocities.

A typical winter surface salinity



Maximum salinity in the Beaufort Sea

Intense salinity fronts, regular solution even for large time steps

No saline water

No freshwater

New boundary conditions for salinity:

At ALL BOUNDARIES salinity flux

$$Q_s = u_n S$$

accompanied with the linearized kinematic condition

$$w = -\frac{\partial \zeta}{\partial t}, \; z = 0.$$

Then if one has volume transport balance

$$\int_\sigma u_n d\sigma = 0$$

there is no control on salt content, for

$$\int_\sigma S u_n d\sigma \neq 0,$$

and

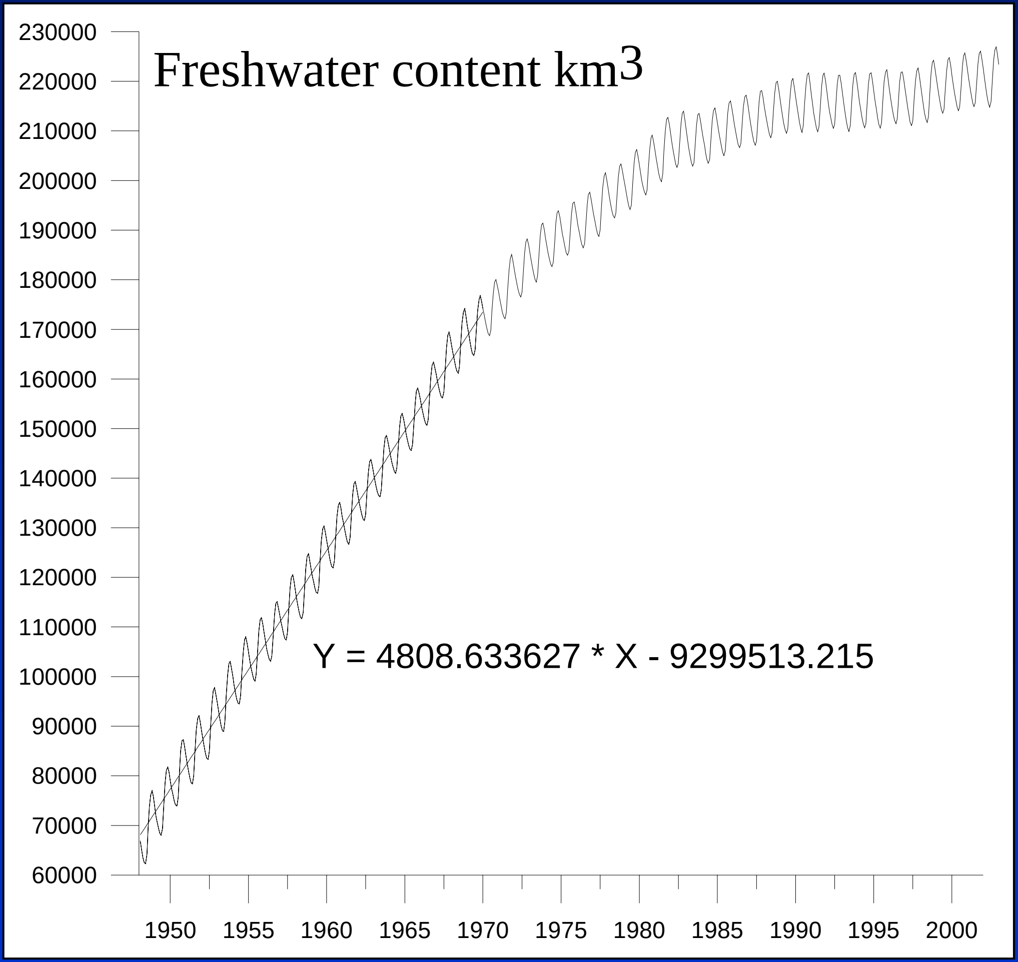
$$\frac{\partial}{\partial t} \int_D S dD \neq 0.$$

Beron-Vera F.J., J. Ochoa and P. Ripa. A note on boundary conditions for salt and freshwater balances. Ocean Modelling, v. 1, 1999, P. 111-118

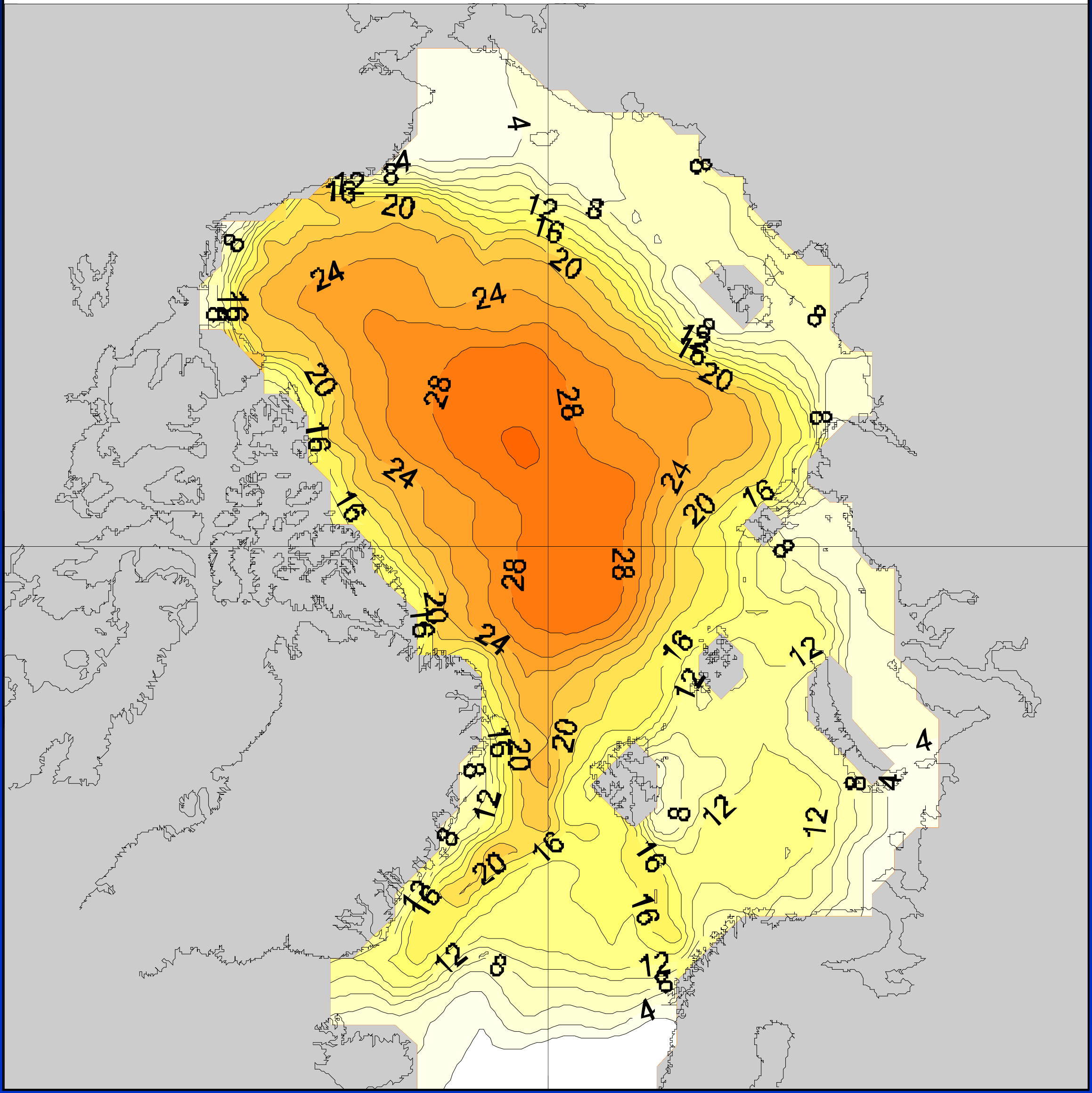
Only precipitation and evaporation. Resume: Model should be formulated with boundary conditions on moving boundary, linearized kinematic conditions are incorrect.

1. Tides?
2. Sea ice?
3. New formulation with boundary conditions at moving upper boundary?

Freshwater balance



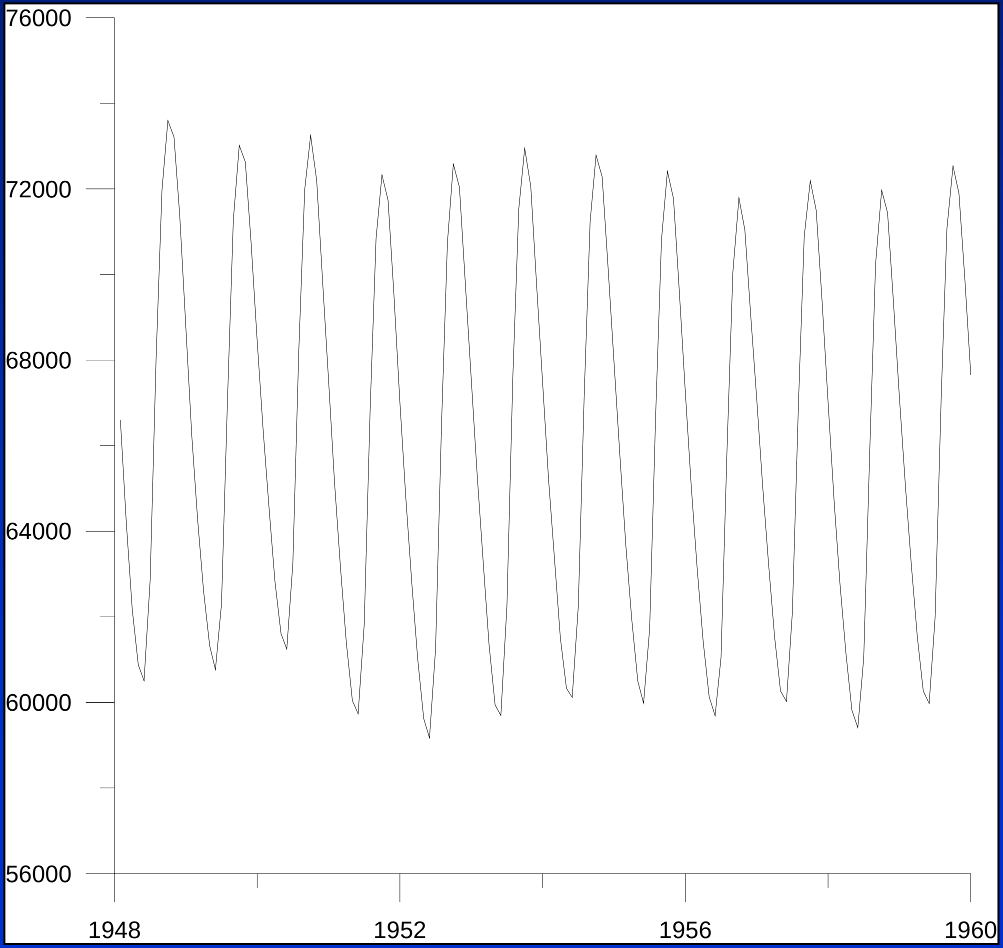
Freshwater Content



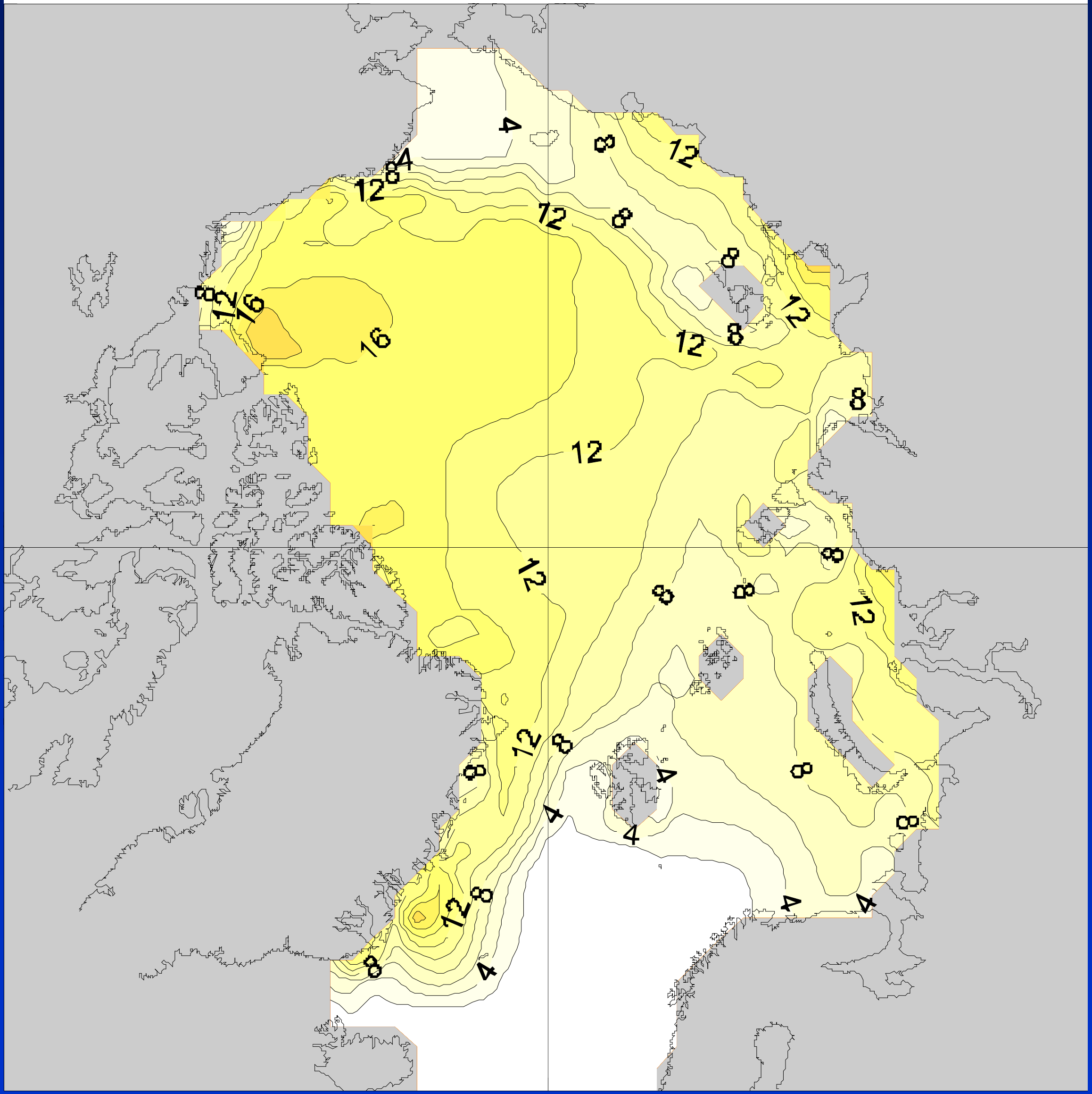
Problem of Freshwater content =
Problem of Atlantic Water inflow?

Experiment with neptune-type parameterization

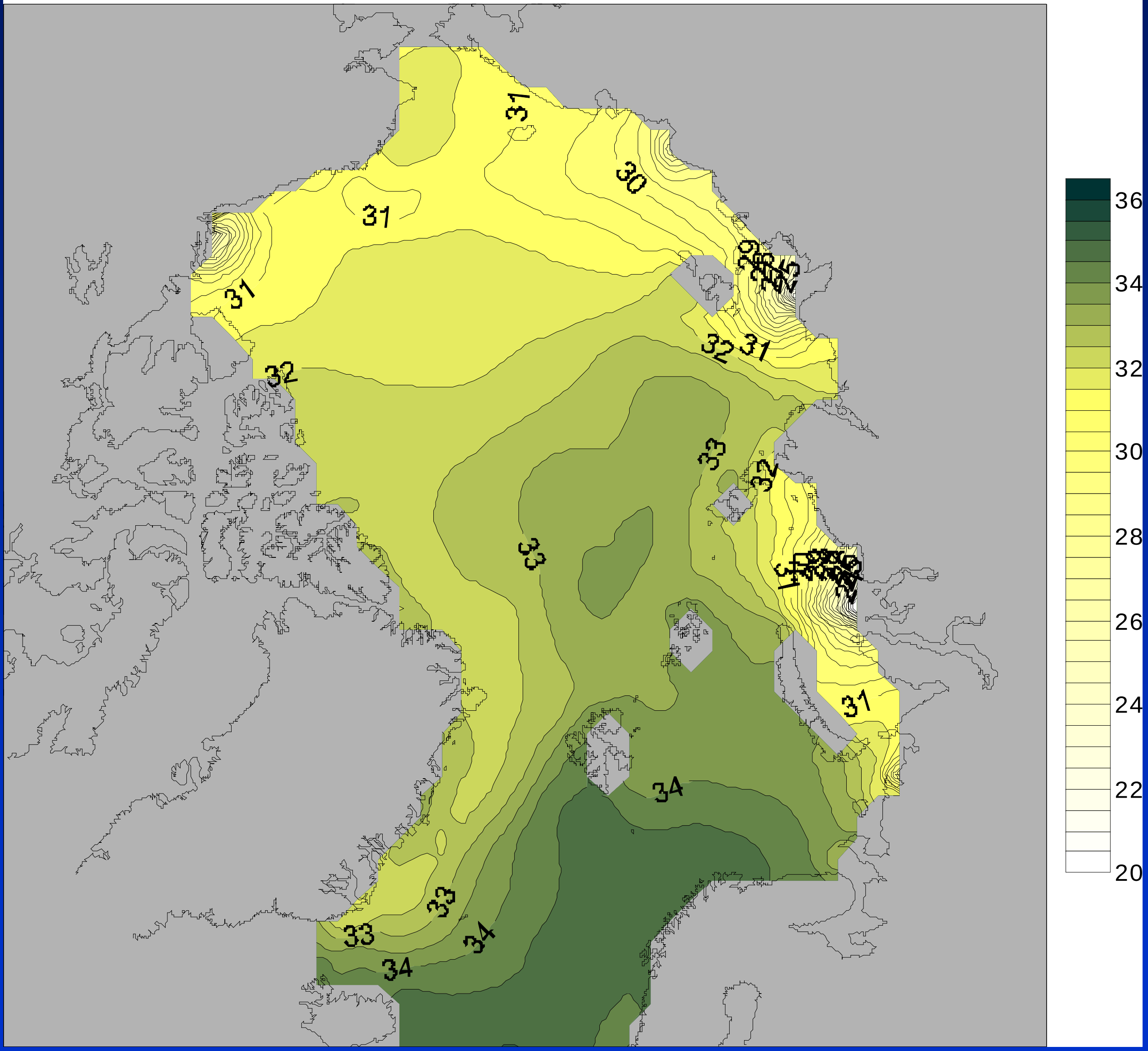
Freshwater volume km^3



Freshwater Content



Salinity 0m. September 1972.



BEAUFORT GYRE FRESHWATER POOL AND MECHANISMS OF ITS FORMATION

Proshutinsky, A.Y., R.H. Bourke and F. McLoughlin. The Role of the Beaufort Gyre in the Arctic climate variability: seasonal to decadal climate scales. Gephys. Res. Lett., 29(23), 2100, doi:1029/2002GL015847, 2002.

Transfer of the momentum from atmosphere to ocean:

- Ice thickness
- Air-ice and ice-ocean drag coefficients
- Parameters of ice rheology

Final Questions:

1. CAN WE FORMULATE
A PRIORI REQUIREMENTS FOR ARCTIC
OCEAN CLIMATE MODELS?

2. IS IT POSSIBLE TO USE REGIONAL
MODELS TO UNDERSTAND DECADAL
VARIABILITY OF THE ARCTIC OCEAN?