Climatology of the Arctic Ocean based on NEMO results

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Outline

- Motivation
- Model description
- Basic results of 10-y's standard run (global and Arctic)
- Scientific interest
  - Pacific inflow's effect on sea ice distribution and upper layer ocean
  - How to get a reasonable middle layer water from Atlantic with a coarse resolution model?

Motivation

- Realistic modelling Arctic conditions (climatology and variability) and its influences on global ocean climate
- Understanding the Pacific inflow and Atlantic inflow's influences on Arctic Ocean

Model Description

- A coupled ice-ocean model under the NEMO framework
  - the Ocean model: OPA (Madec, et al., 1998) ;
  - The ice model: LIM2 (Fichefet and Morales, 1997;Christian and Gurvan)
- Initial field:
  - January climatology of temperature and salinity based on **PHC3.0**
  - Sea ice thickness: 3m in northern hemisphere; 1m in southern hemisphere
- Surface forcing:
  - OMIP daily climatology (from1957 -2002 ERA-40) of wind stress, air temperature, cloud cover, relative humidity, precipitation, wind speed;
  - SSS restored
- Boundary forcing
  - Arctic model takes boundary forcing from global model

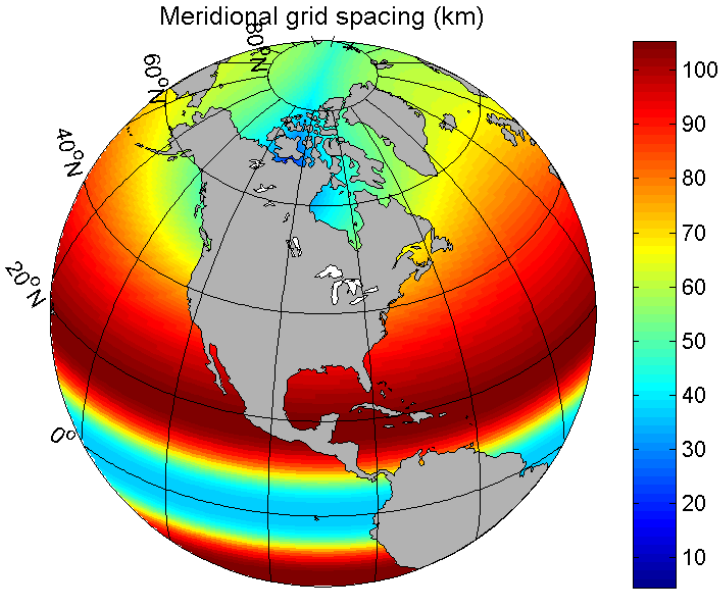
Model's Grid

- Tri-polar grids
- The horizontal resolution: 1 degrees Mercator mesh with finest resolution in CAA is 25km
- The vertical resolution is 46 levels (interval: 6-250m)
- The time step is 1800s.

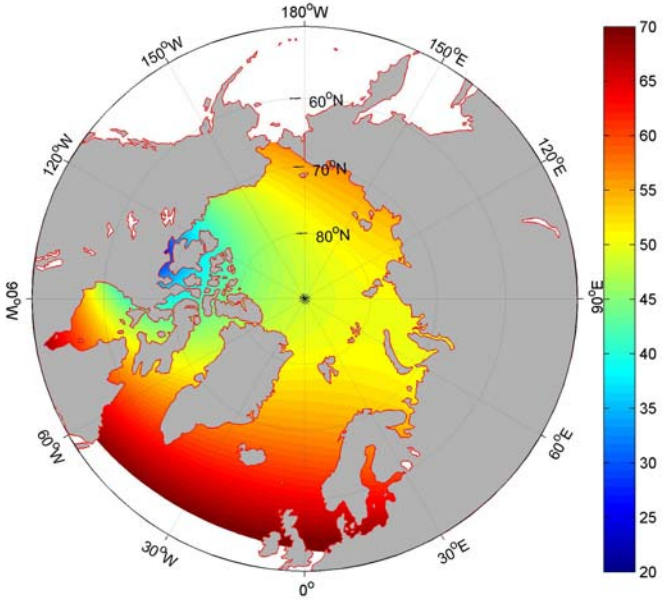
➢Standard run include both global and arctic domain

➢Model is integrated for 10 years

ORCA1 glob grids



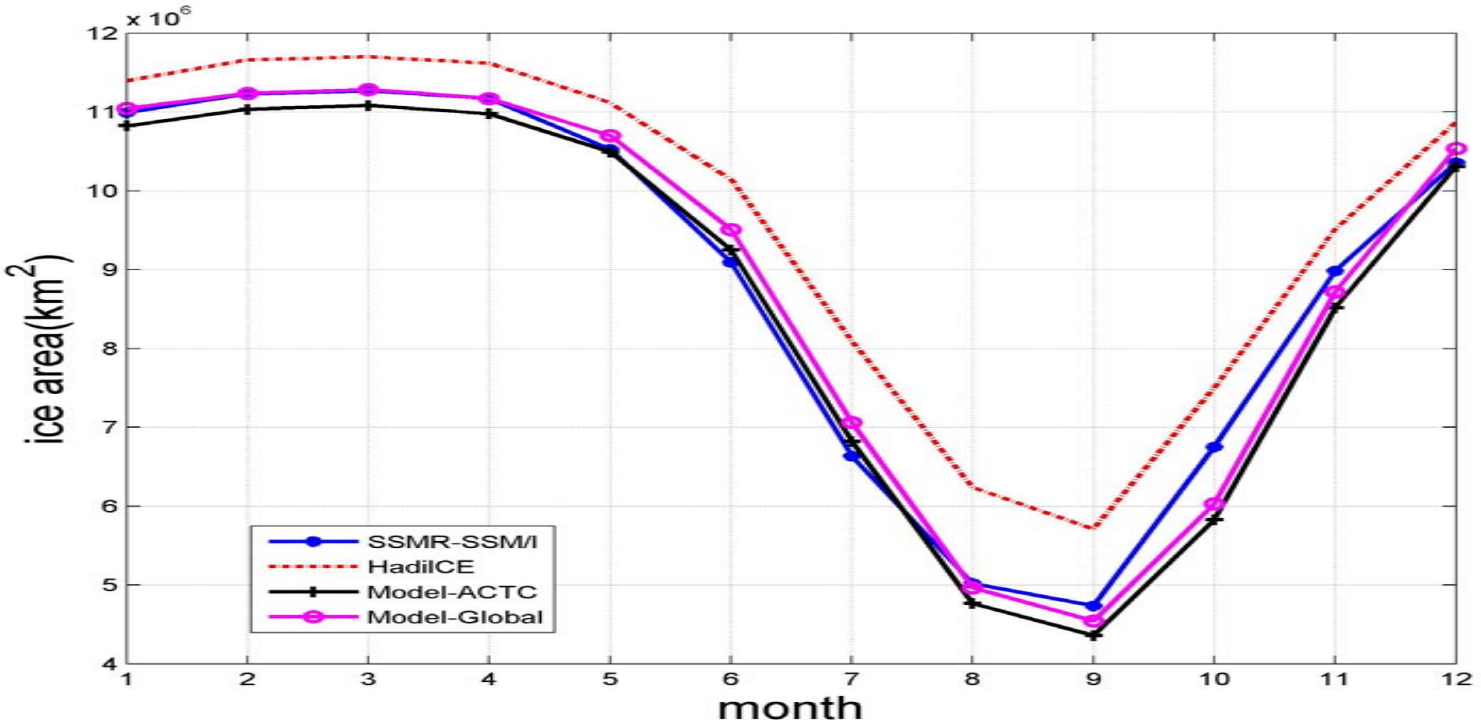
ORCA1 actc grids



Basic results of 10-y's global and Arctic standard run

- Ice area
- Ice concentration
- Ice motion
- Ocean current (upper 100m and 450m)
- Sea temperature field (10m and 450m)
- Vertical temperature profile

Total ice area of Arctic



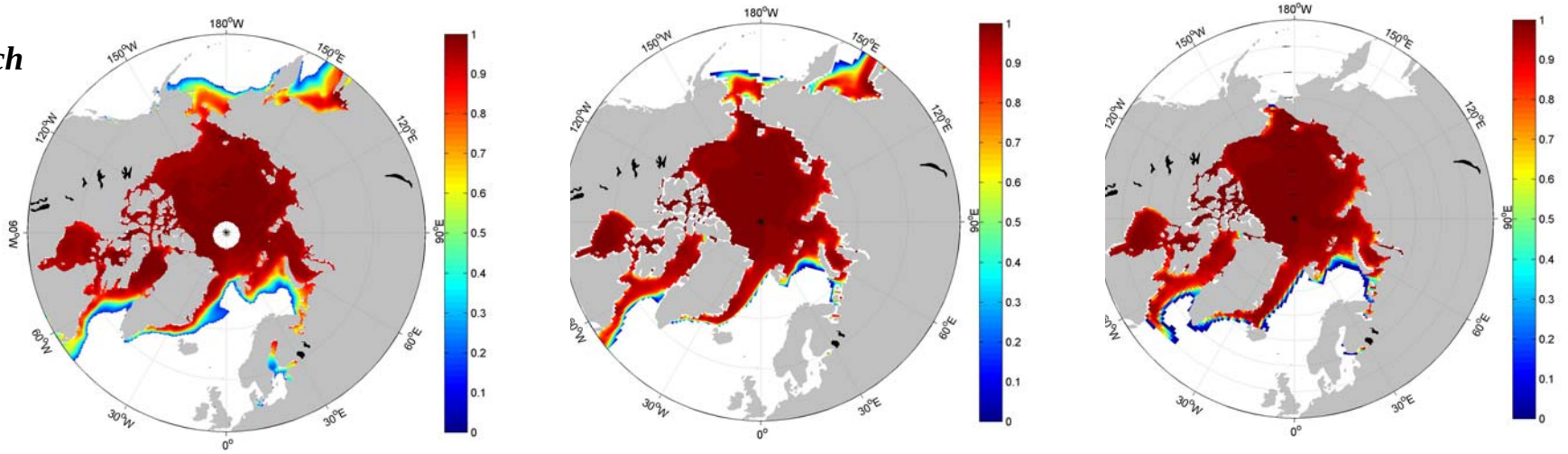
Sea ice concentration

SSM/I 1979-2002

Modeled-glob

Modeled-actc

March



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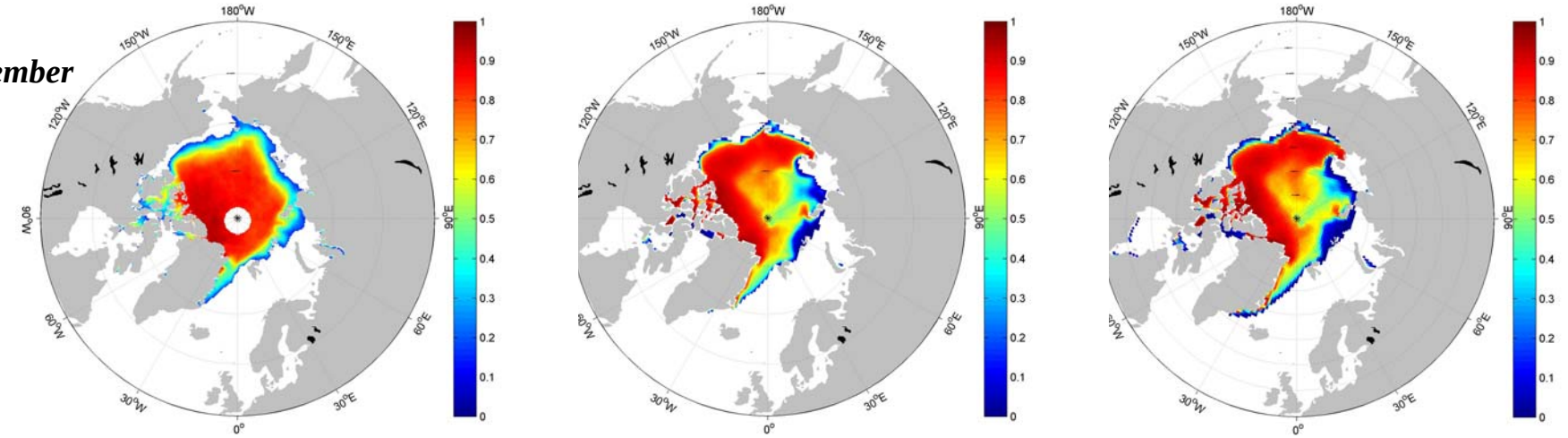


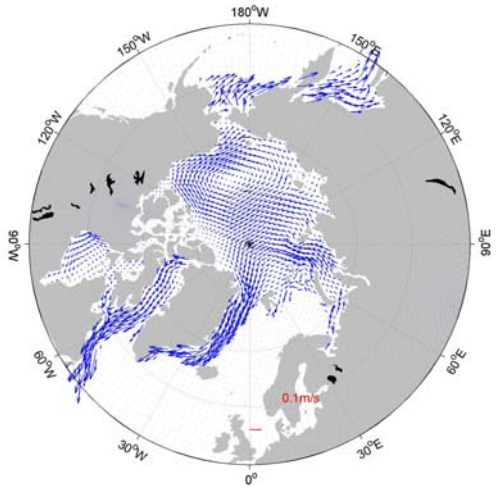
Sea ice motion

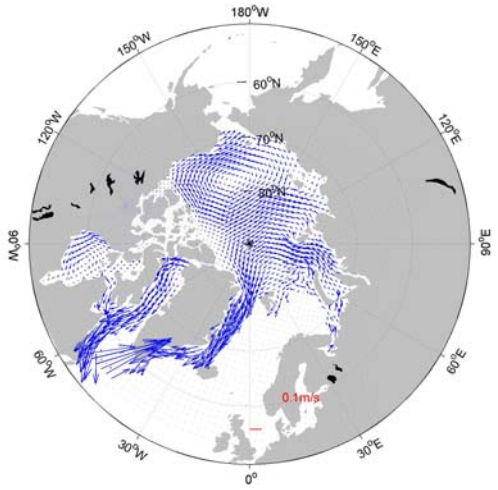
NSIDC 1979-2002

Modeled-glob

Modeled-actc

March





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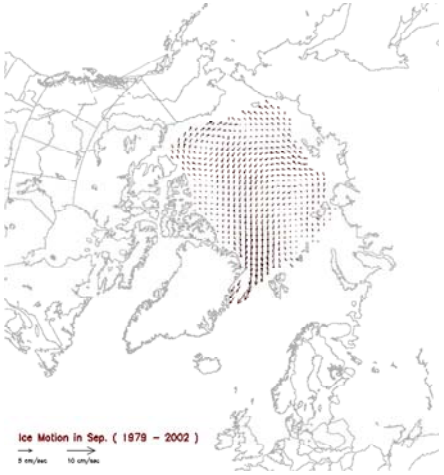
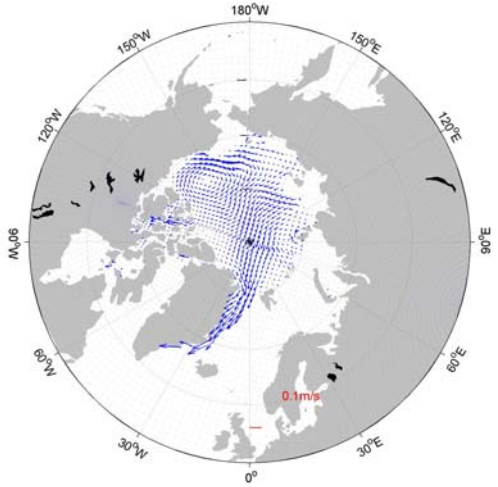
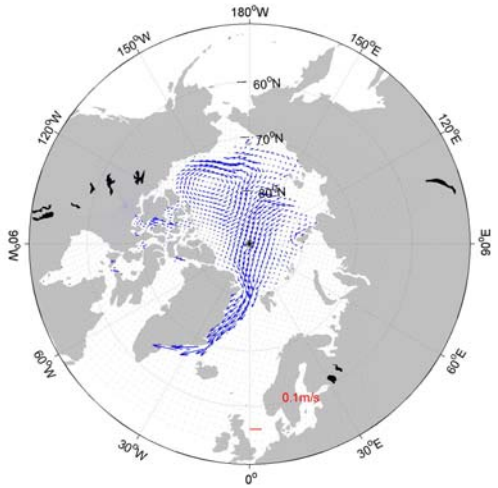


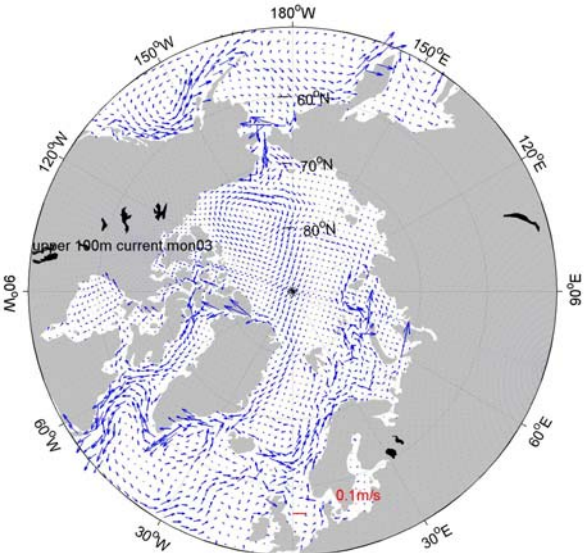




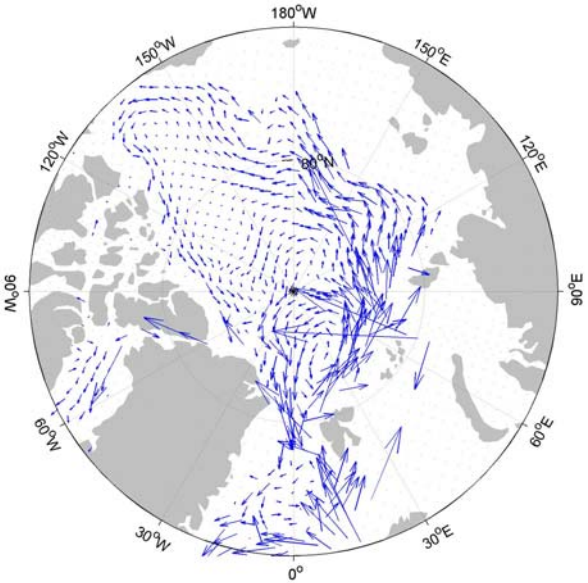
Ocean current

upper 100m ***450m***

March



lm03data15



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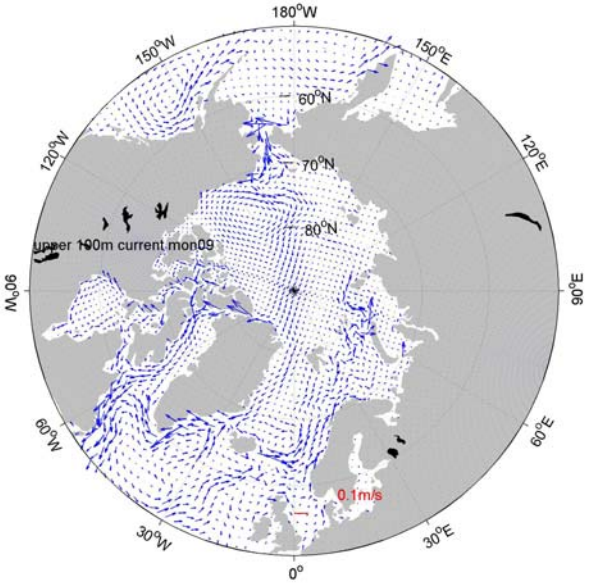

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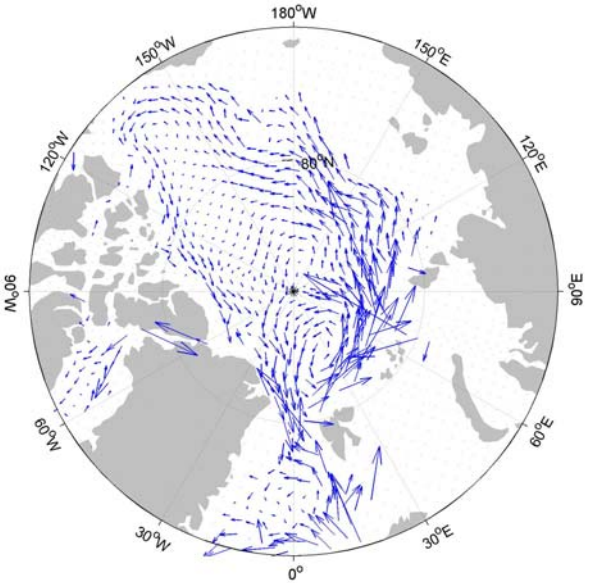
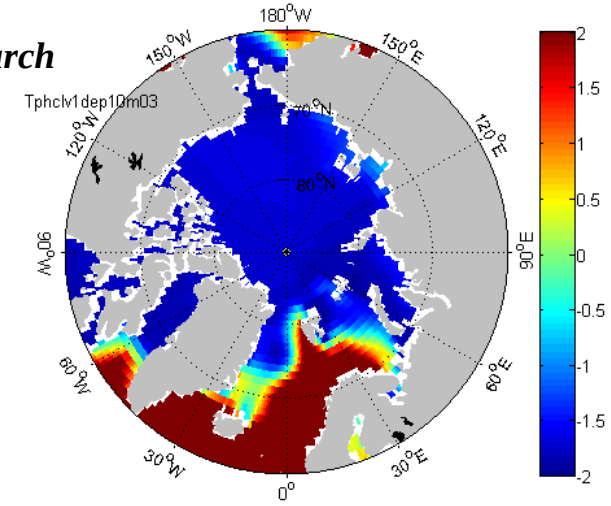
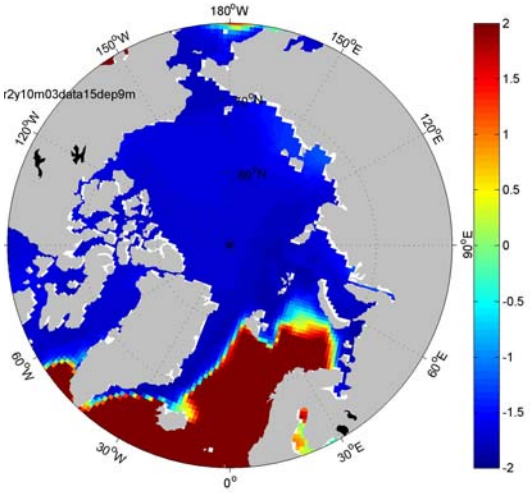


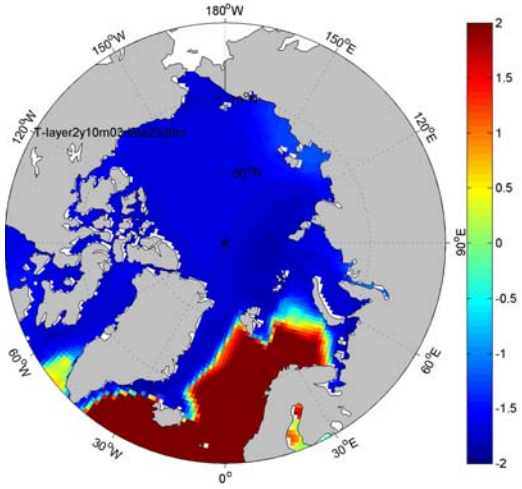
10m sea temperature

PHC3.0 ***Modeled-glob*** ***Modeled-actc***

March







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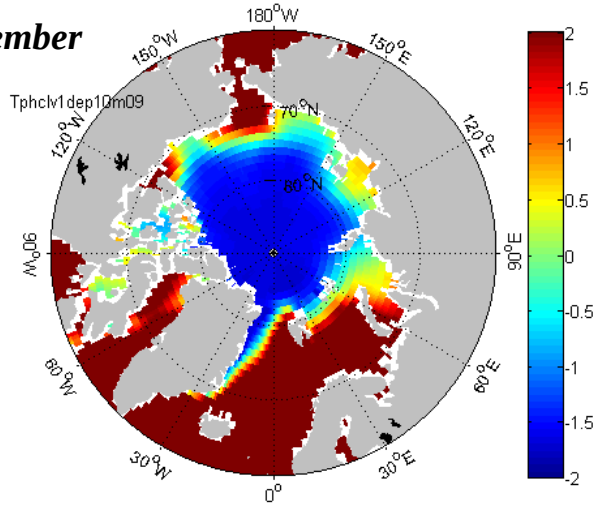
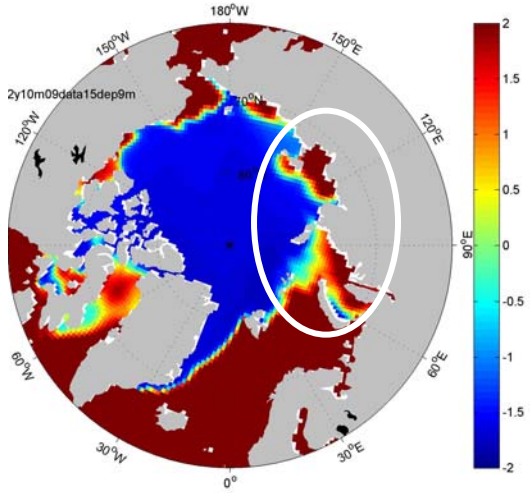
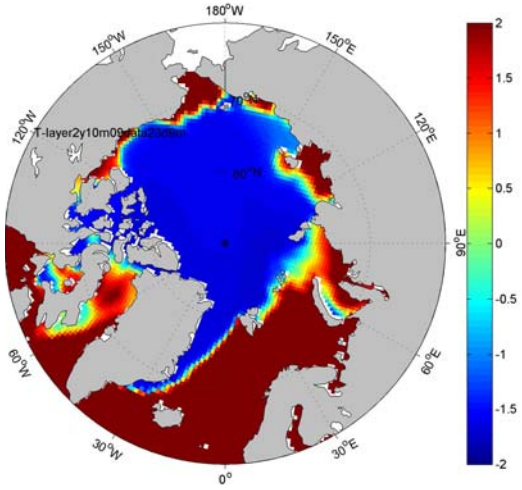


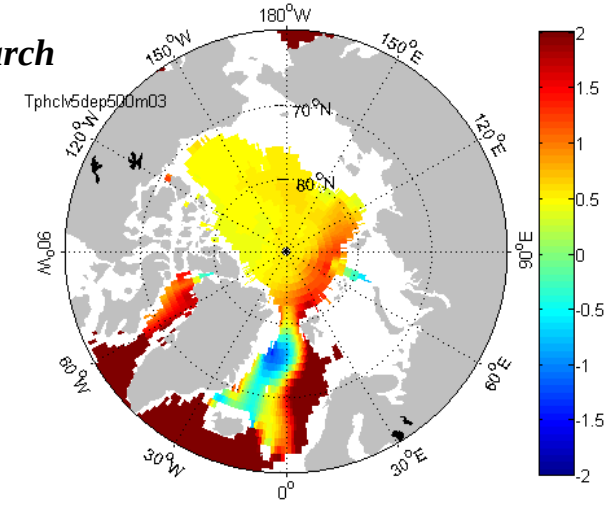


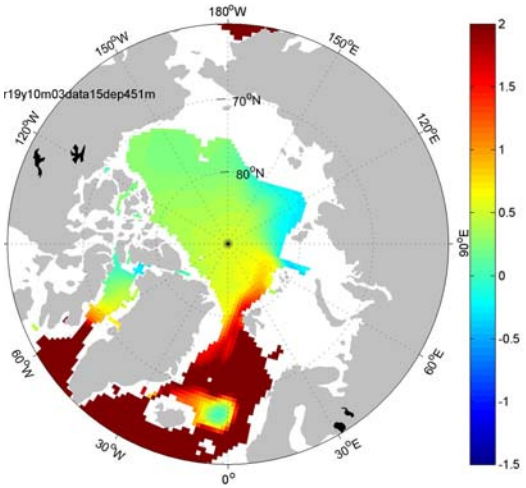


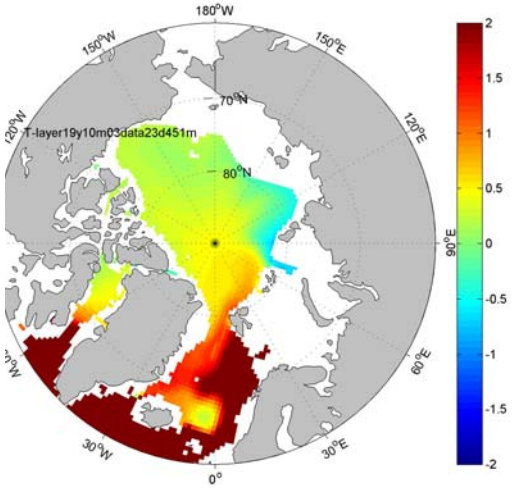
450m sea temperature

PHC3.0 ***Modeled-glob*** ***Modeled-actc***

March







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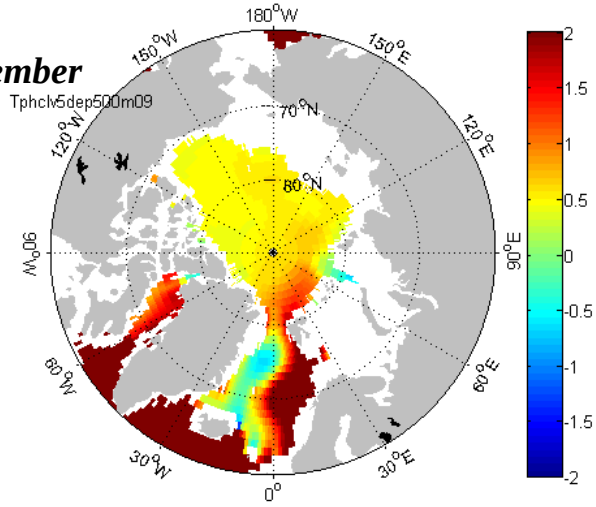
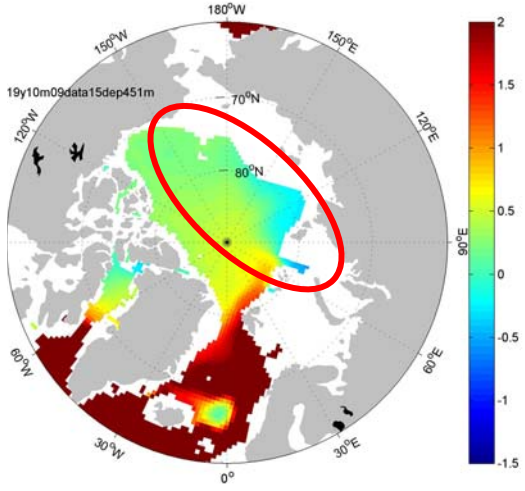
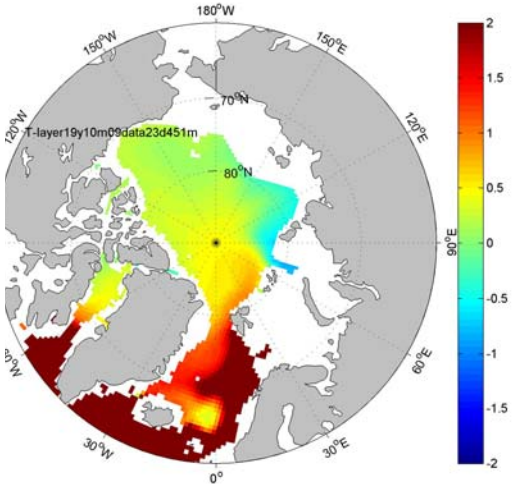
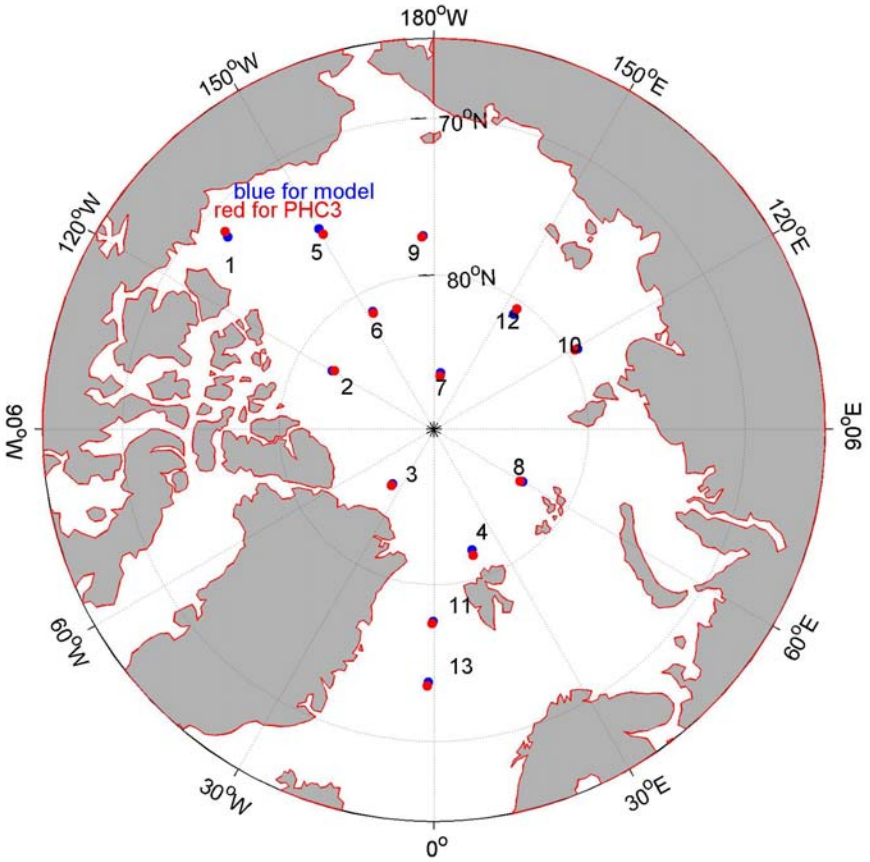


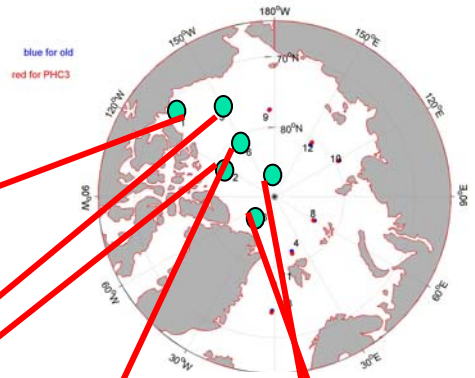


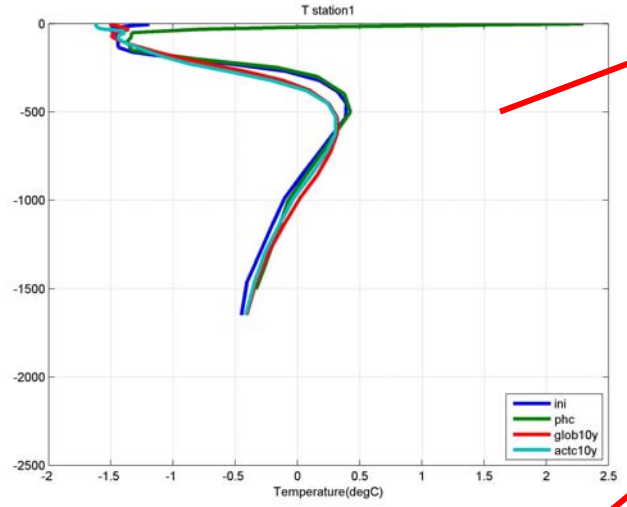


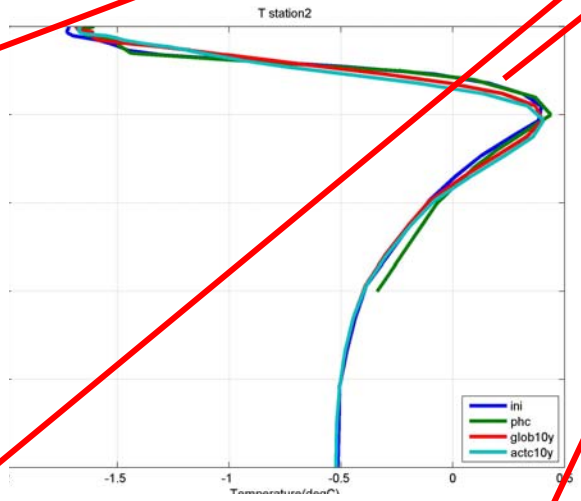
Vertical temperature profile

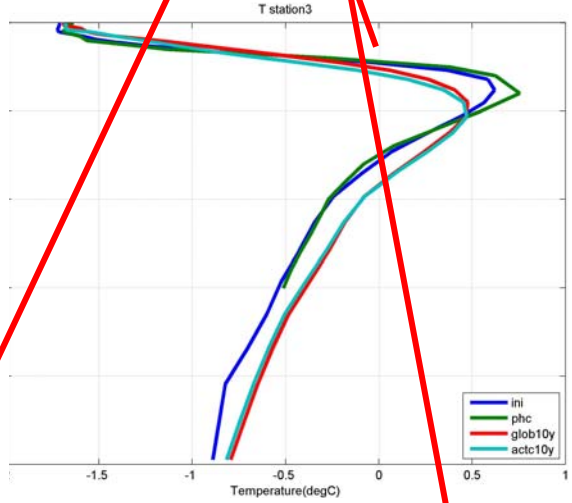


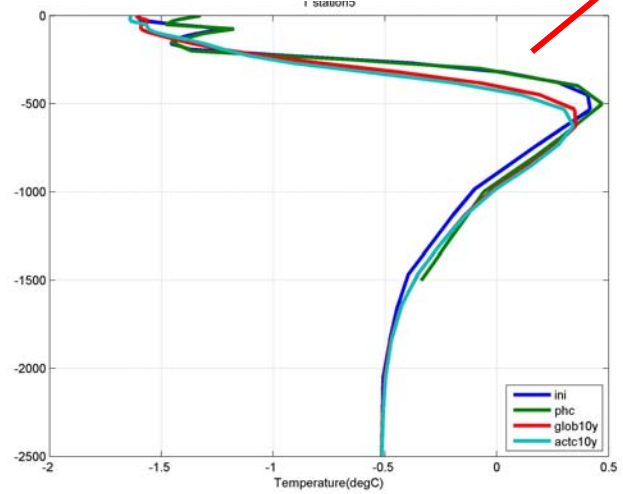
Station 1,2,3,5,6,7

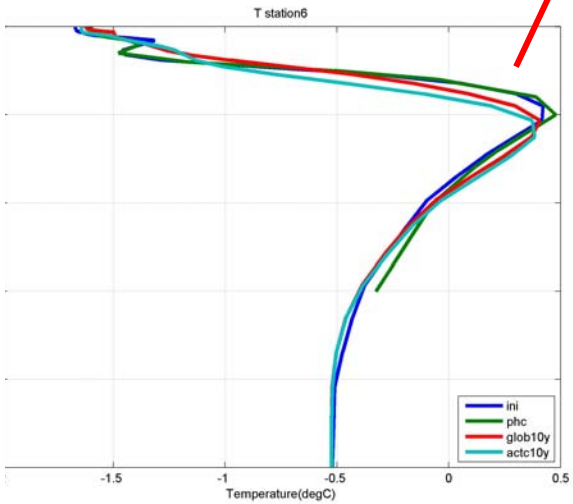


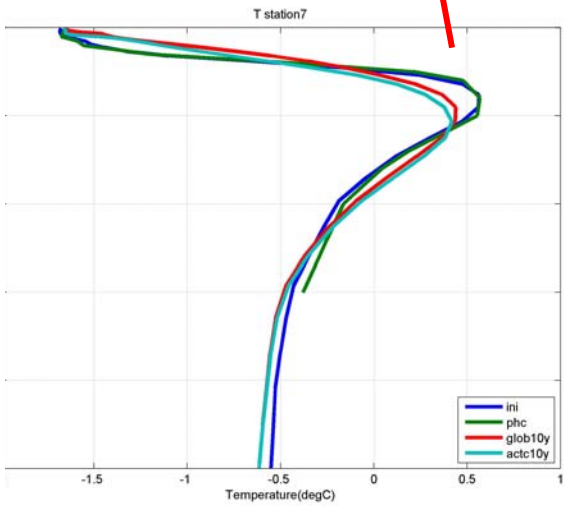












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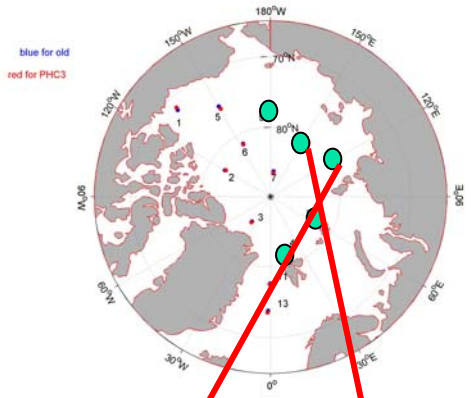
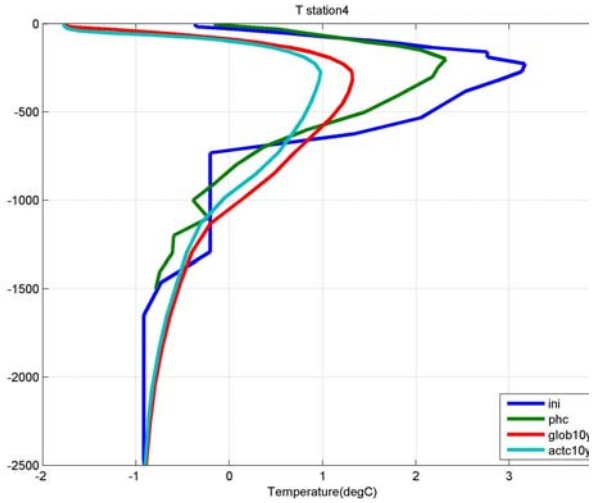
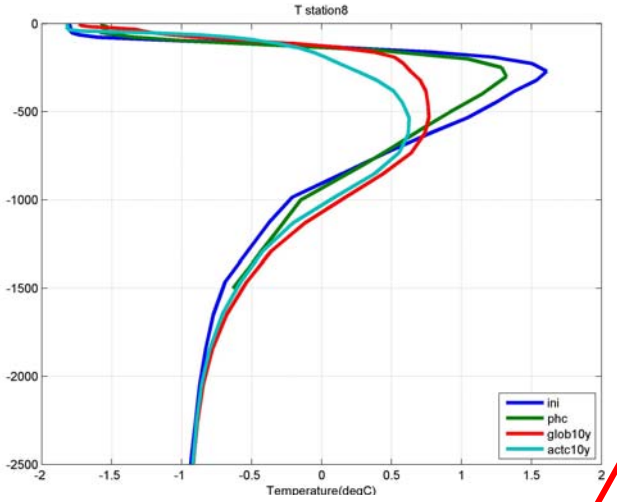
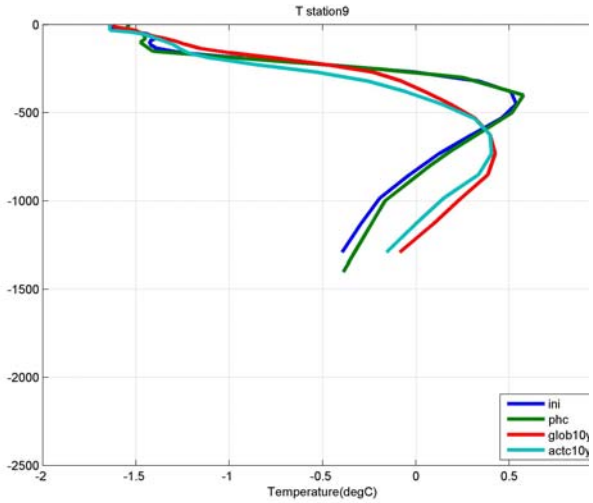
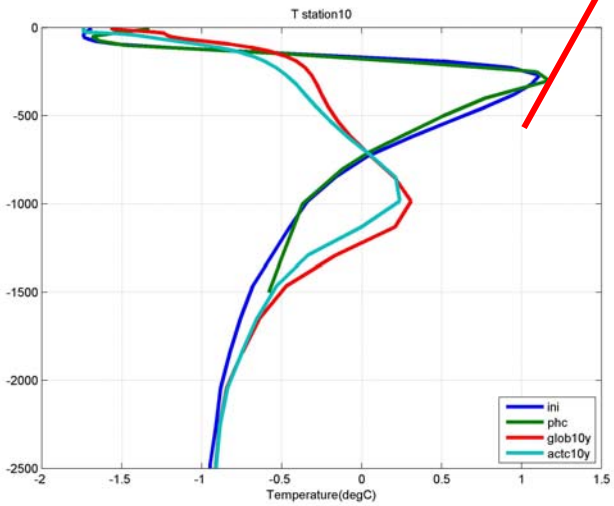
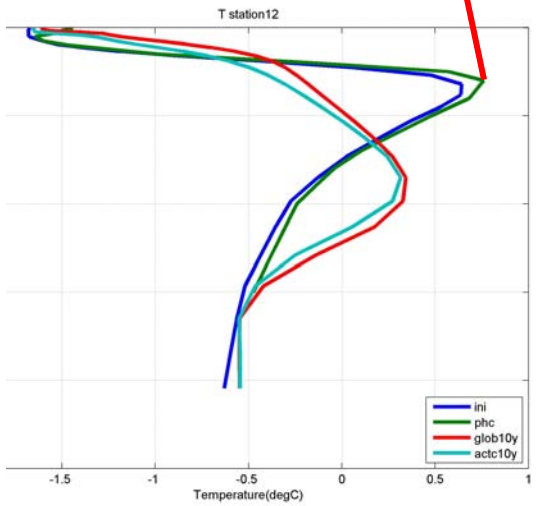




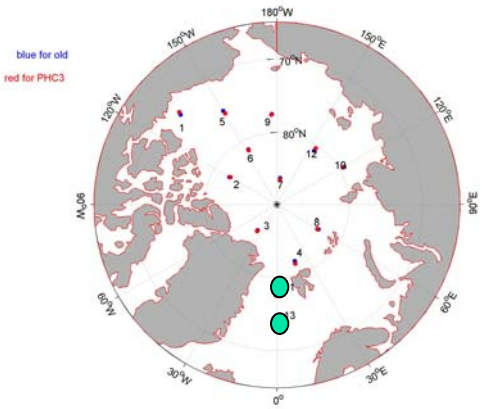


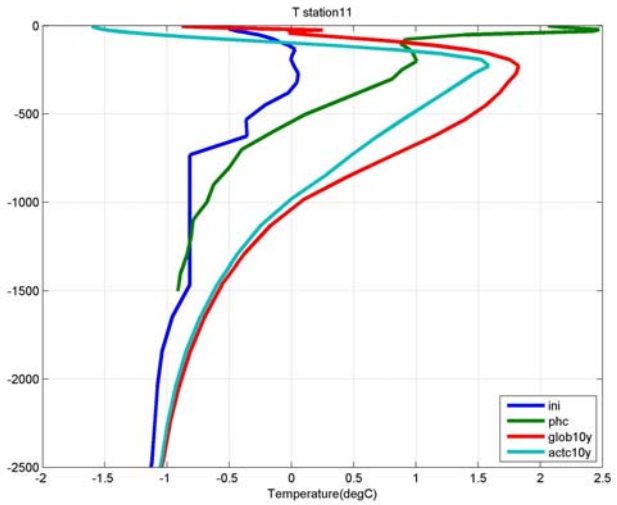


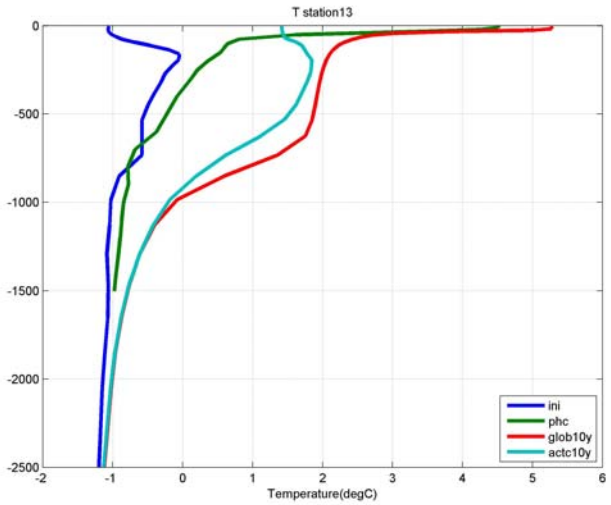




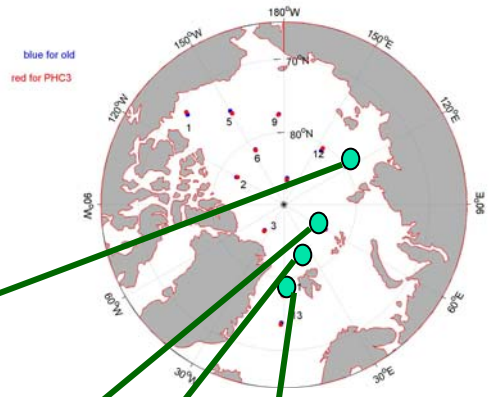
Station 11,13

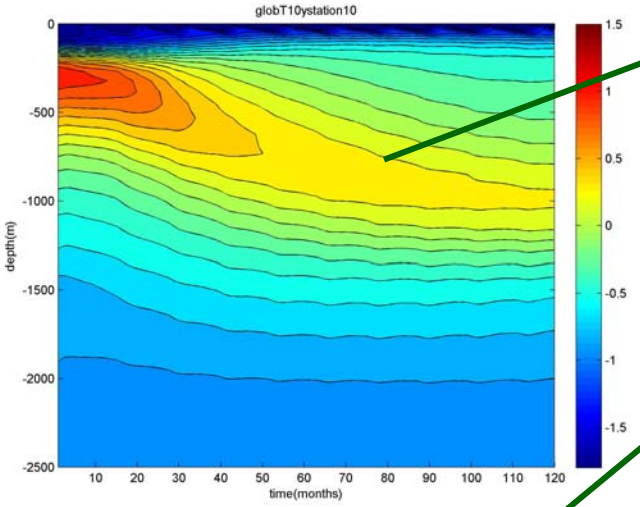


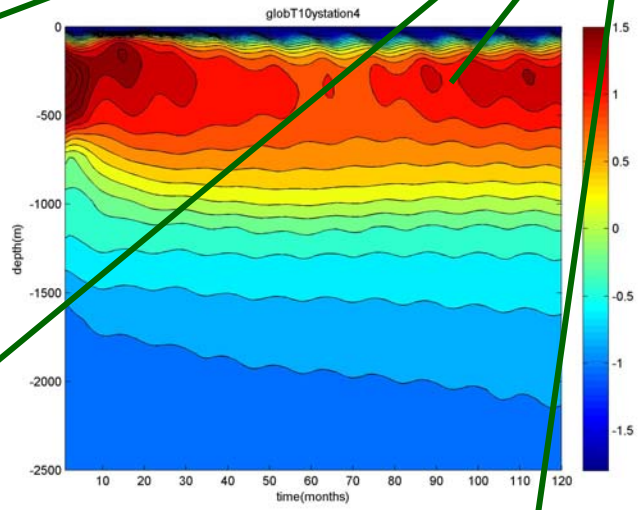


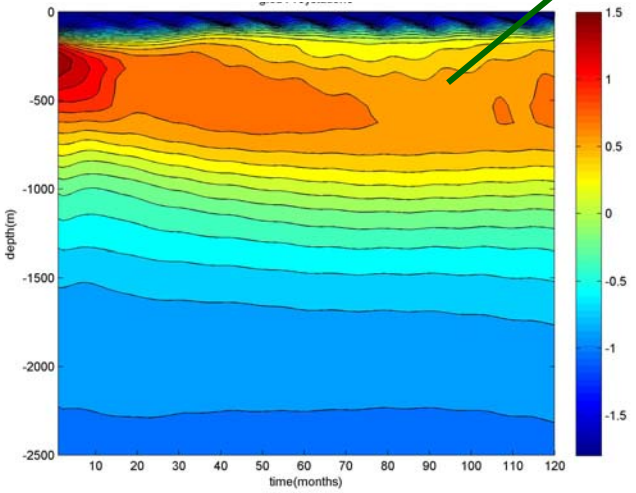


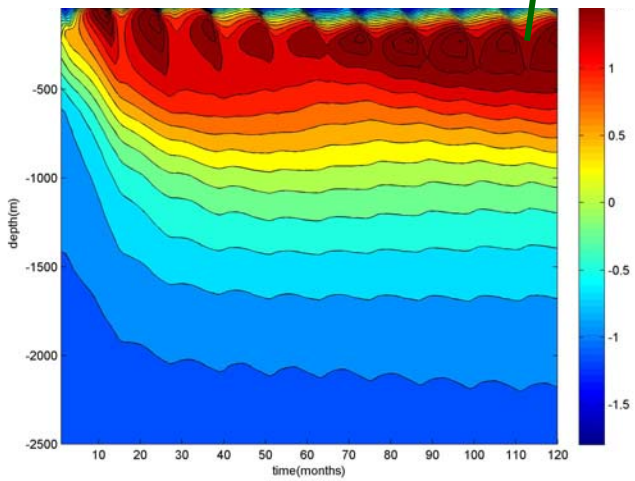
How to get a reasonable middle layer water from Atlantic in a coarse resolution model?



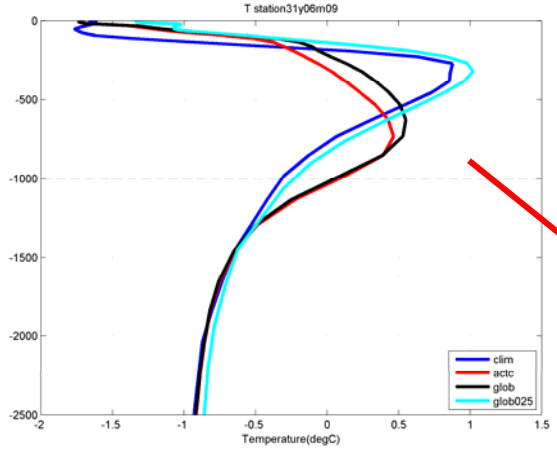


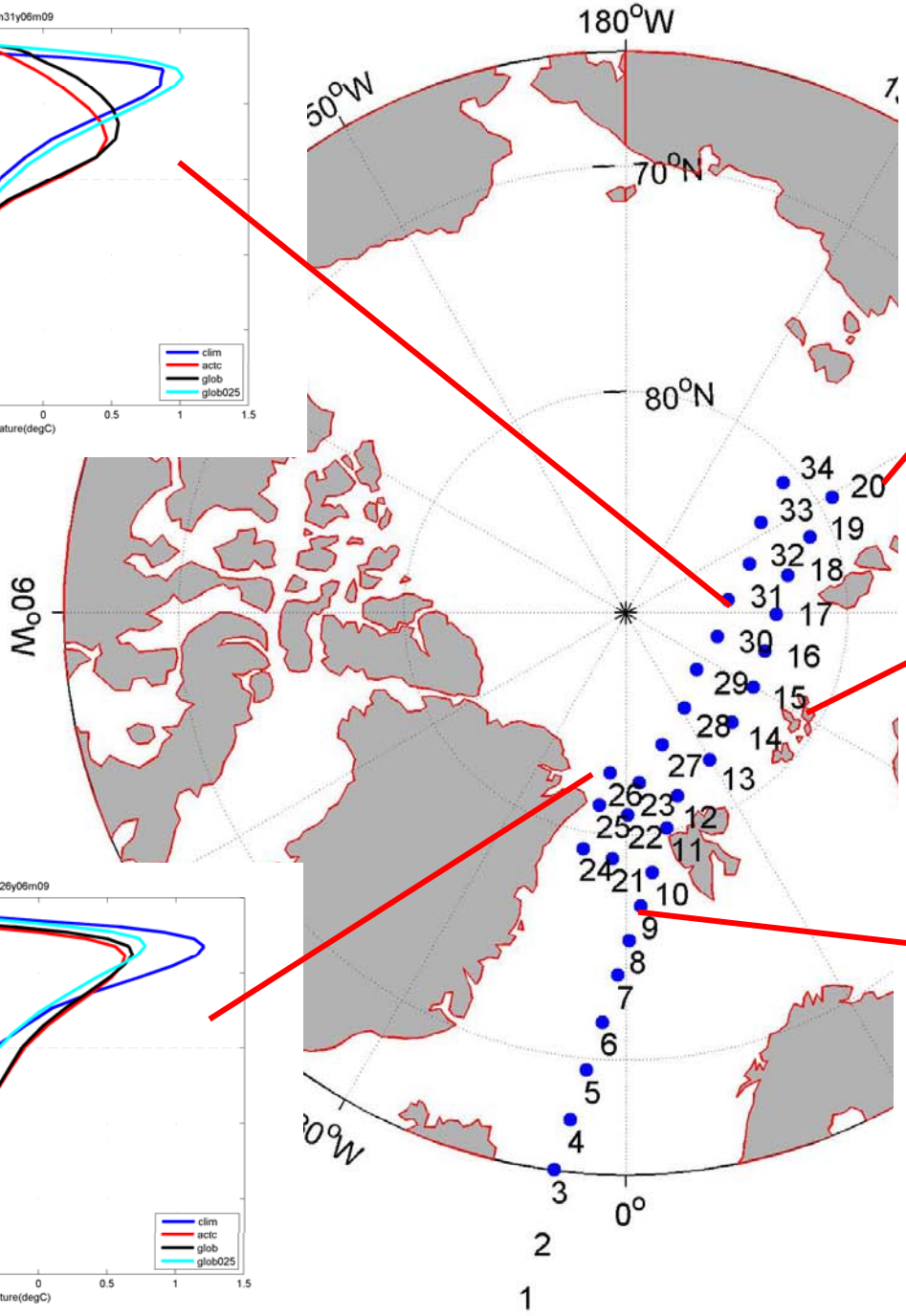


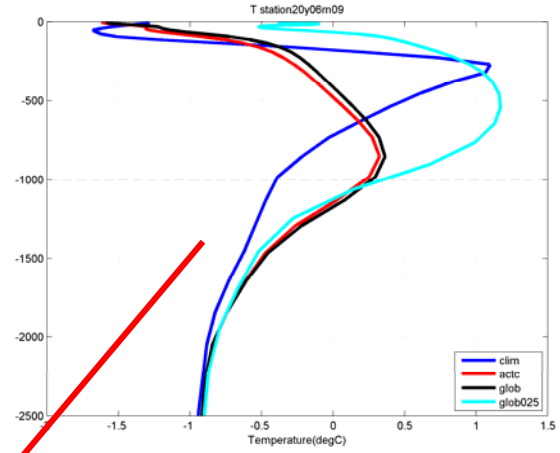


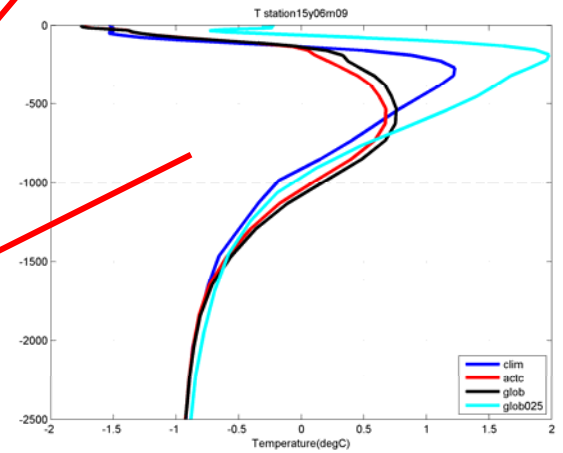


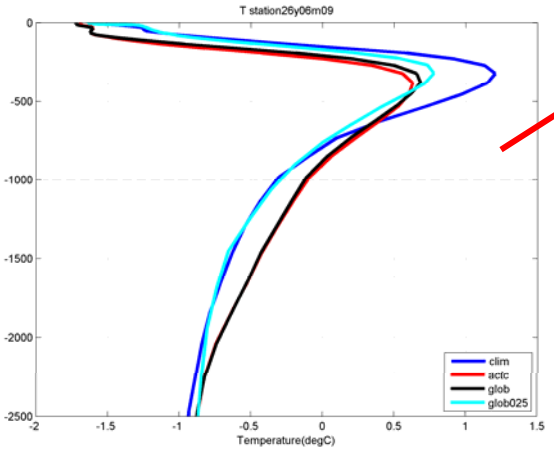
¼ degree resolution

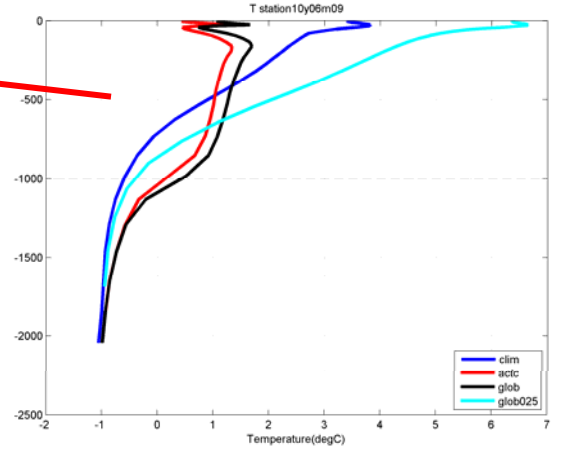




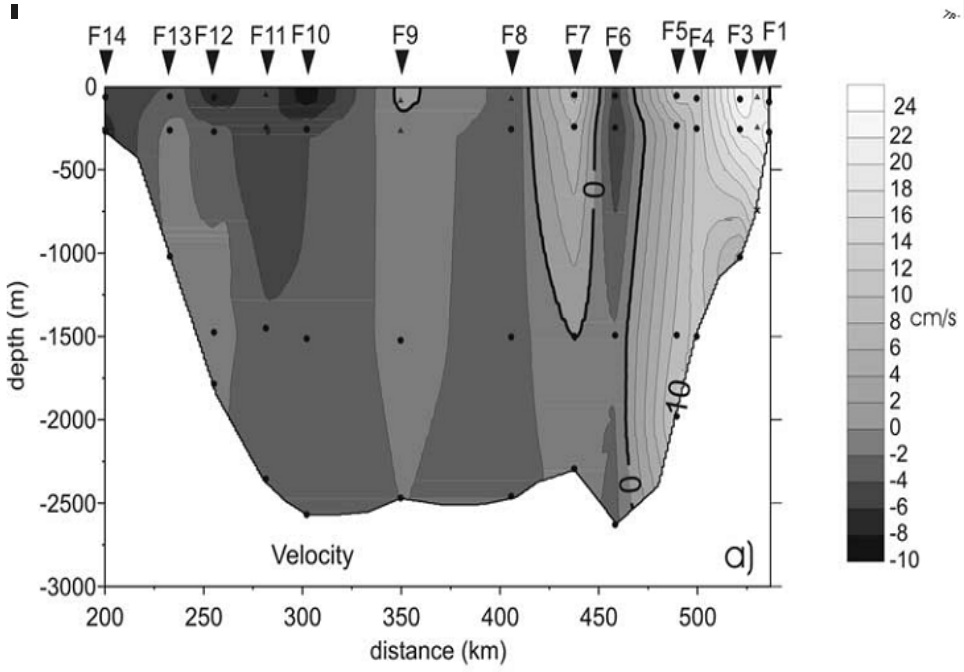


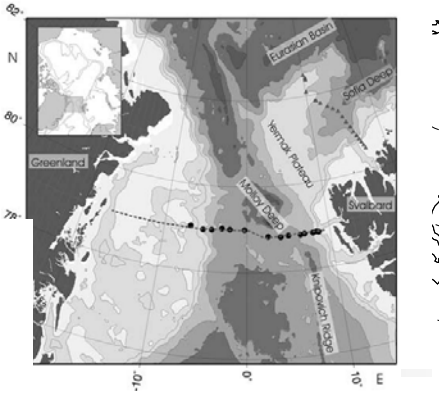


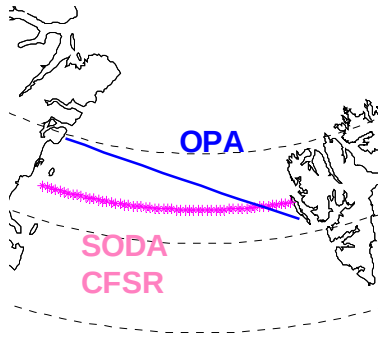




Velocity section of Fram Strait

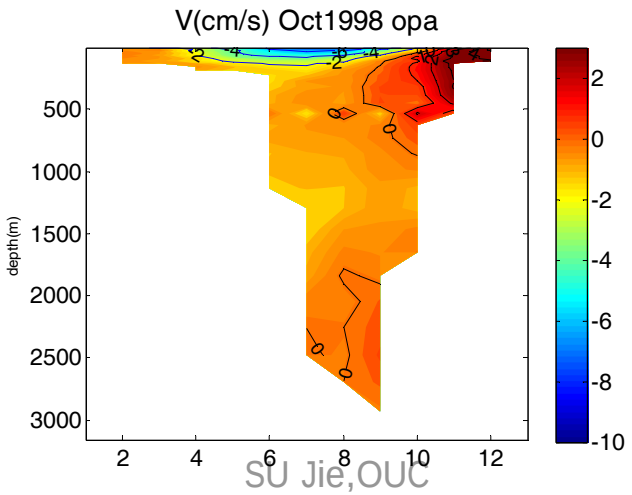


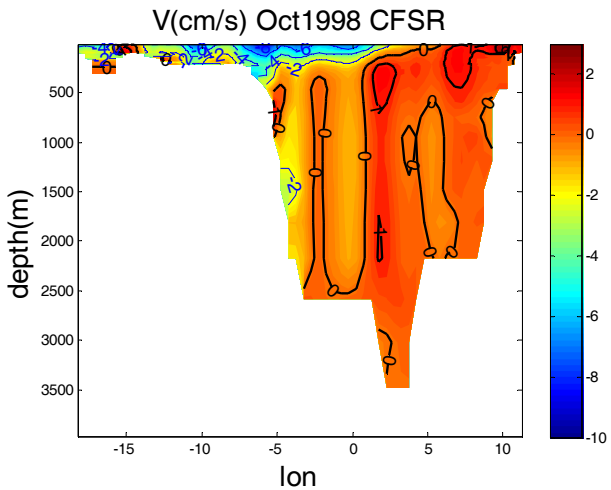


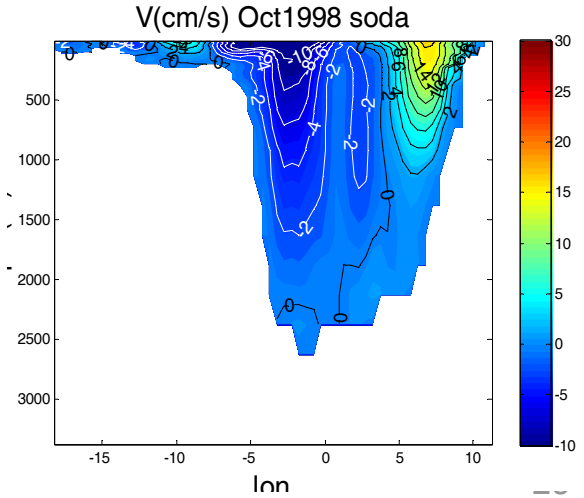


Schauer et al.(2004)
Oct. 1998 (Obs.)

Adding Neptune effect (Hollway,1992) did help to increase the current of Atlantic inflow, but still work not well for the vertical Temp. profile

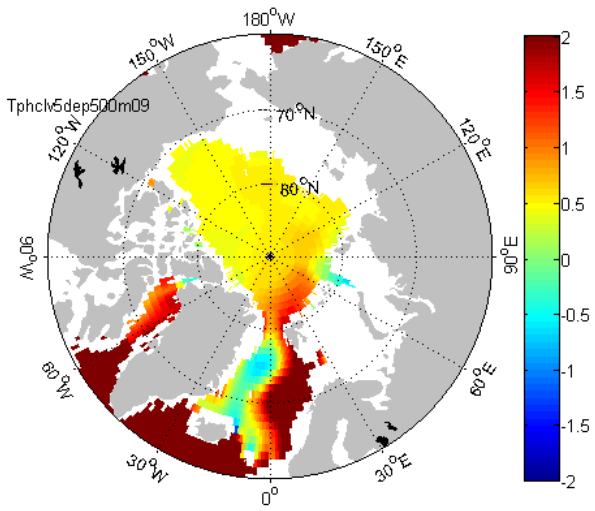




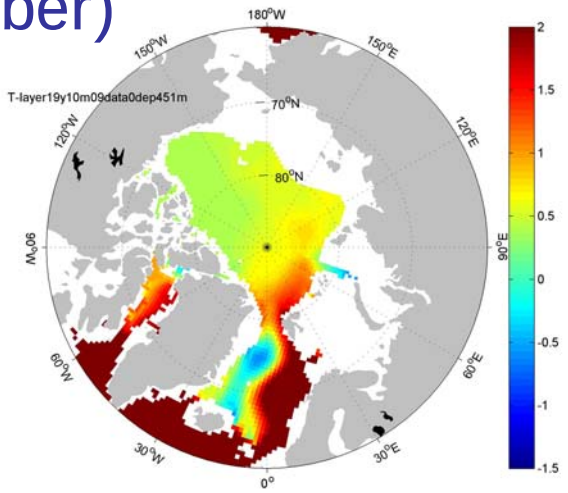


450m sea temperature

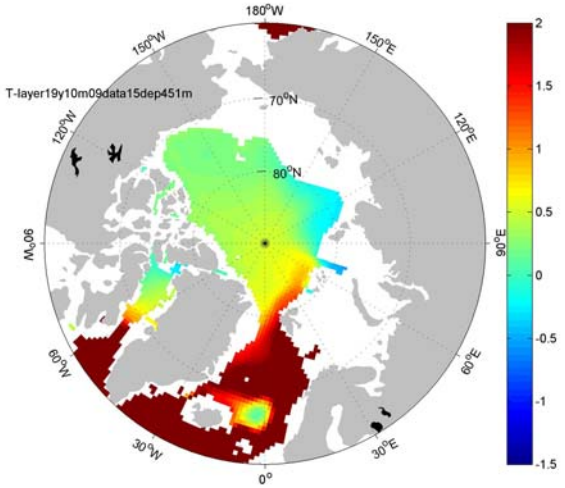
(September)



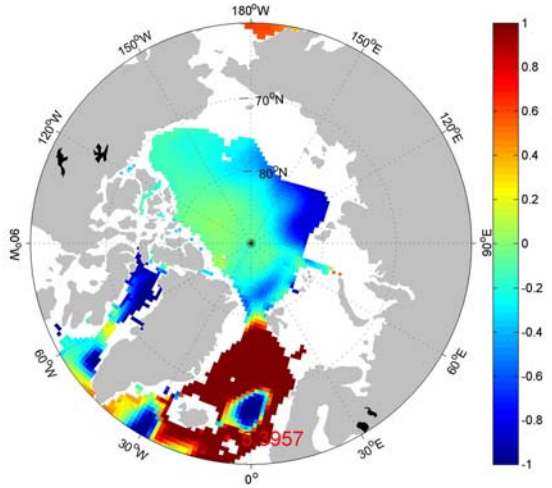
PHC3.0



initial



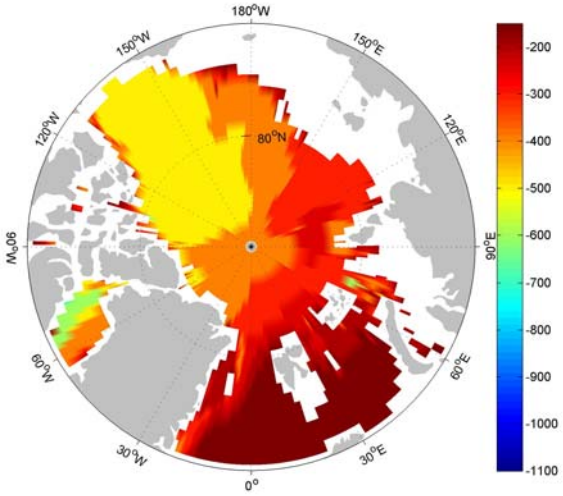
model result



model result - initial

Max Temp. depth of Middle layer water

(September)



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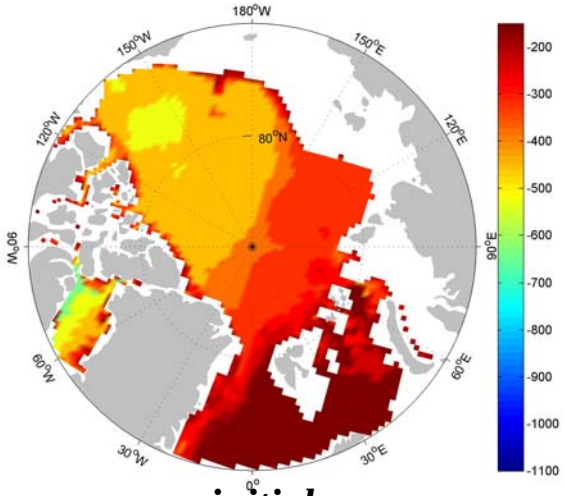
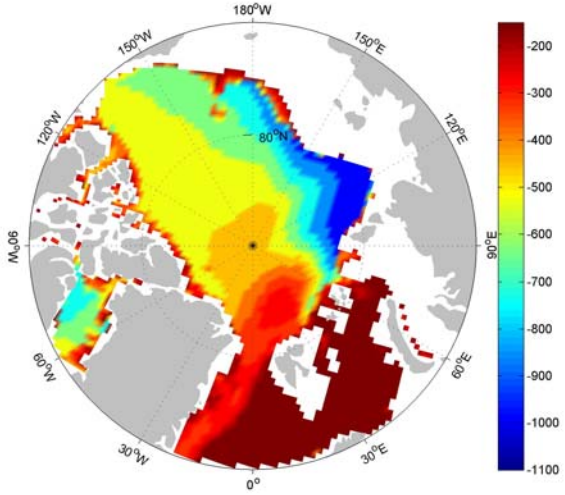
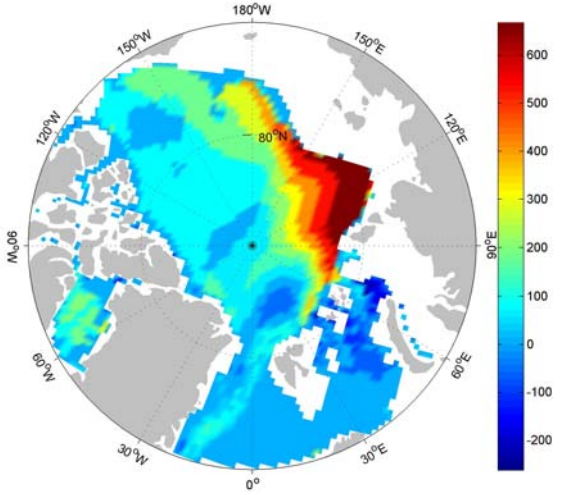


initial



model result



model result - initial

Experiments on vertical turbulence problem

- The vertical turbulent coefficient include three items:
  - TKE (turbulent closure scheme)

$$A^{vT} = A^{vm} / P_n \qquad A^{vm} = C_k l_k \sqrt{\bar{e}}$$

$$\frac{\partial \bar{e}}{\partial t} = \frac{A^{vm}}{e_3}\left[\left(\frac{\partial u}{\partial k}\right)^2 + \left(\frac{\partial v}{\partial k}\right)^2\right] - A^{vT} N^2 + \frac{1}{e_3}\frac{\partial}{\partial k}\left[\frac{A^{vm}}{e_3}\frac{\partial \bar{e}}{\partial k}\right] - c_\varepsilon \frac{\bar{e}^{3/2}}{l_\varepsilon}$$

  - DDM (double diffusion mixing)
  - Item caused by choosing horizontal mixing scheme

$$D^{lt} = \nabla \cdot (A^{lt} \Re \nabla T)$$

iso-level

iso-neutral

$$\Re = \begin{pmatrix} 1 & 0 & -r_1 \\ 0 & 1 & -r_2 \\ -r_1 & -r_2 & r_1^2 + r_2^2 \end{pmatrix}$$

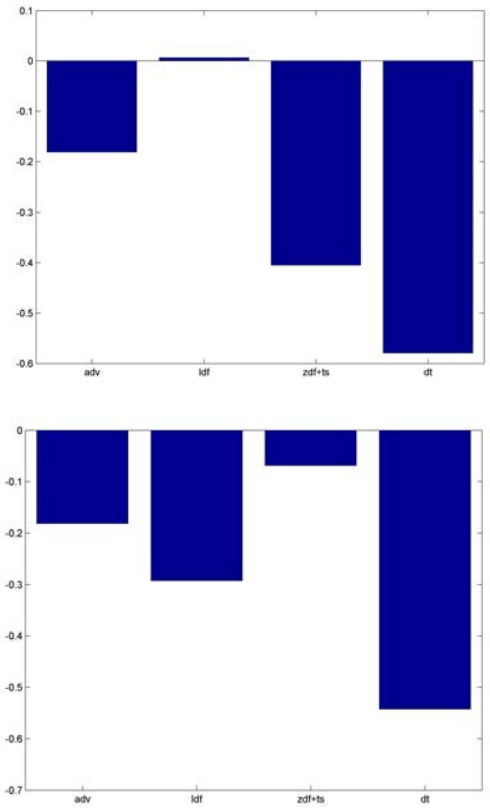
$$\frac{\partial}{\partial k}\left(A^{lt}(r_1^2 + r_2^2)\frac{\partial T}{\partial k}\right)$$

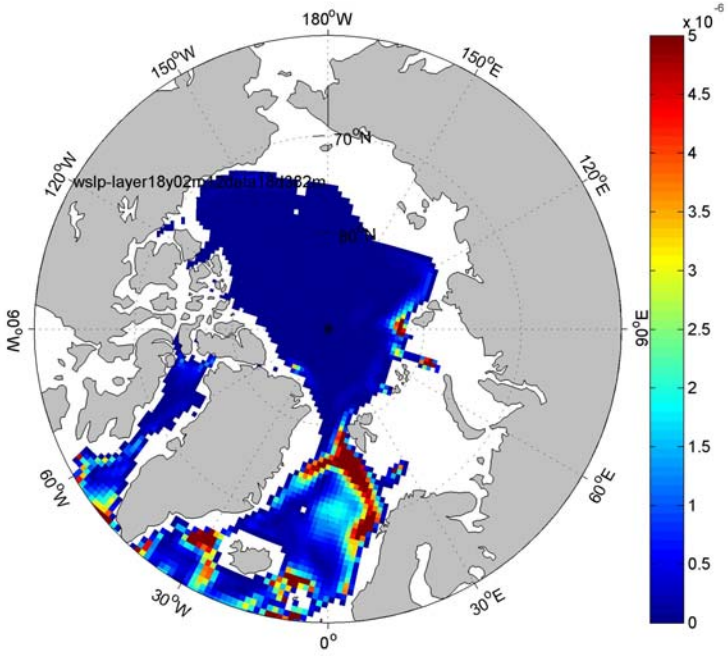
$$r_1 = \left(\frac{\partial \rho}{\partial i}\right)\left(\frac{\partial \rho}{\partial k}\right)^{-1}$$

$$r_2 = \left(\frac{\partial \rho}{\partial j}\right)\left(\frac{\partial \rho}{\partial k}\right)^{-1}$$

Experiments on vertical turbulence problem

1 2 3 all





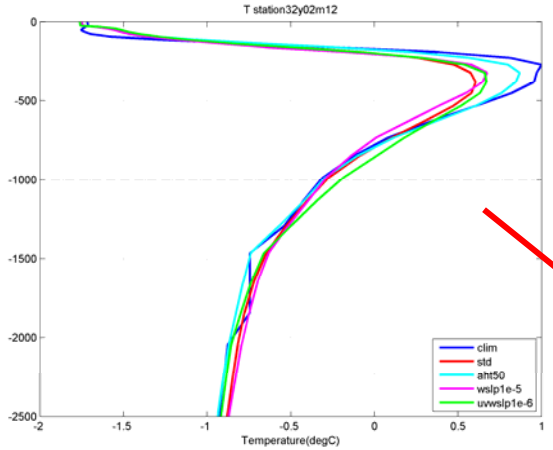
$$\Re = \begin{pmatrix} 1 & 0 & -r_1 \\ 0 & 1 & -r_2 \\ -r_1 & -r_2 & r_1^2 + r_2^2 \end{pmatrix}$$

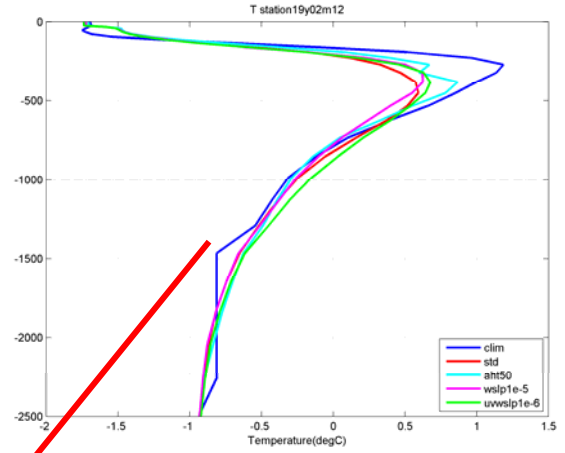
Exp1:limit wslp to 1e-5

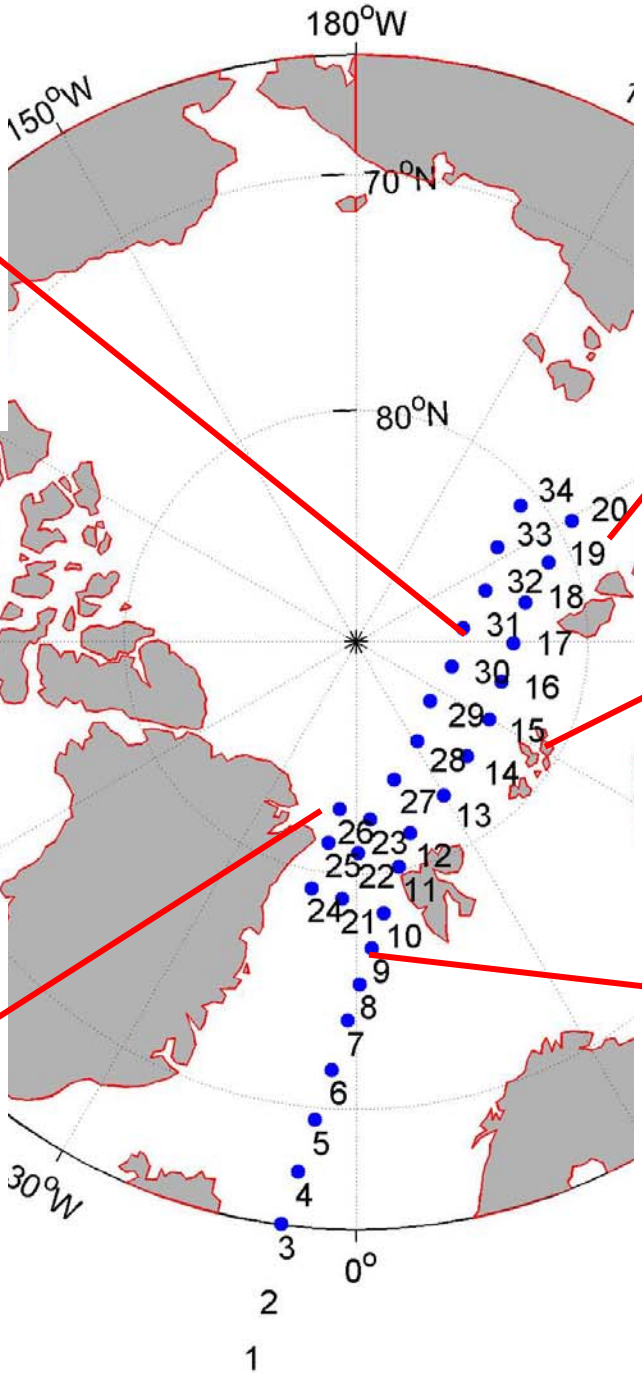
Exp2:limit r1,r2 to 1e-6

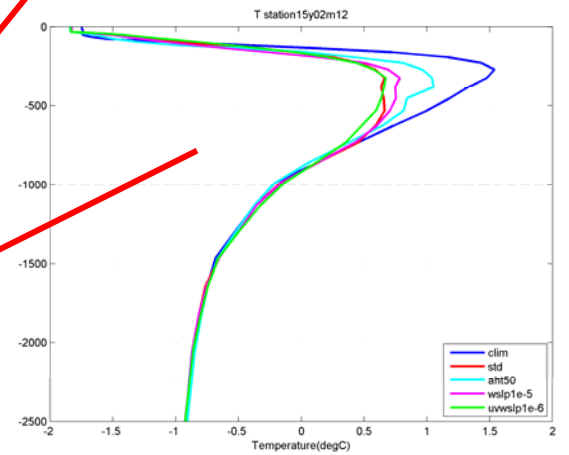
Exp3:limit Alt (under ice) to 1e-7

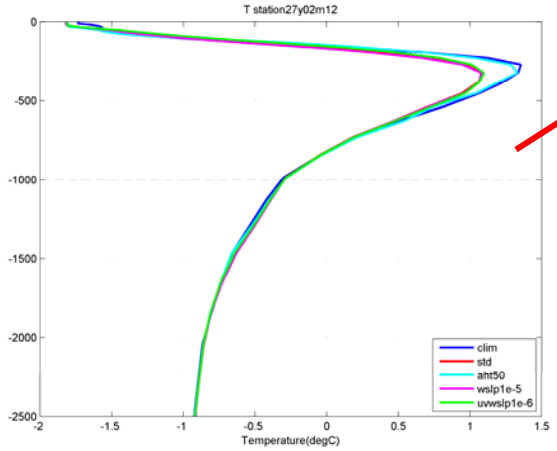
Two years experiments

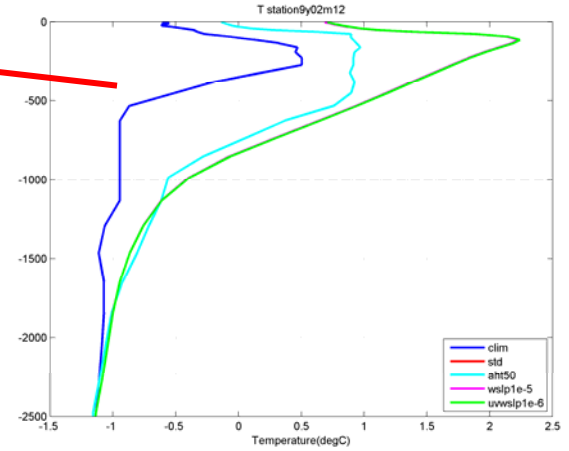












Summary and discussion

- The modeled sea ice results can represent the seasonal cycle of Arctic sea ice in basic pattern. Ice area agrees well with those calculated by SSMR-SSMI ice concentration.
- The Beaufort gyre and the transpolar drift are showed obviously in the modeled ice drift and upper 100m current field.
- 10y run fails to reproduce the Atlantic layer in ice covered region, especially in Euro-Asian Basin. This problem can be solved by enhance model resolution.
- Using a coarse model, the problem of Atlantic layer is possibly caused by too weak transport though Fram Strait and too strong vertical diffusion which caused by iso-neutral horizontal mixing scheme. Limit the advection diffusion coefficient can partly improve the results.

Thank you for your attention!

Any Question?