Subgrid-scale ocean mixing caused by brine rejection in lead

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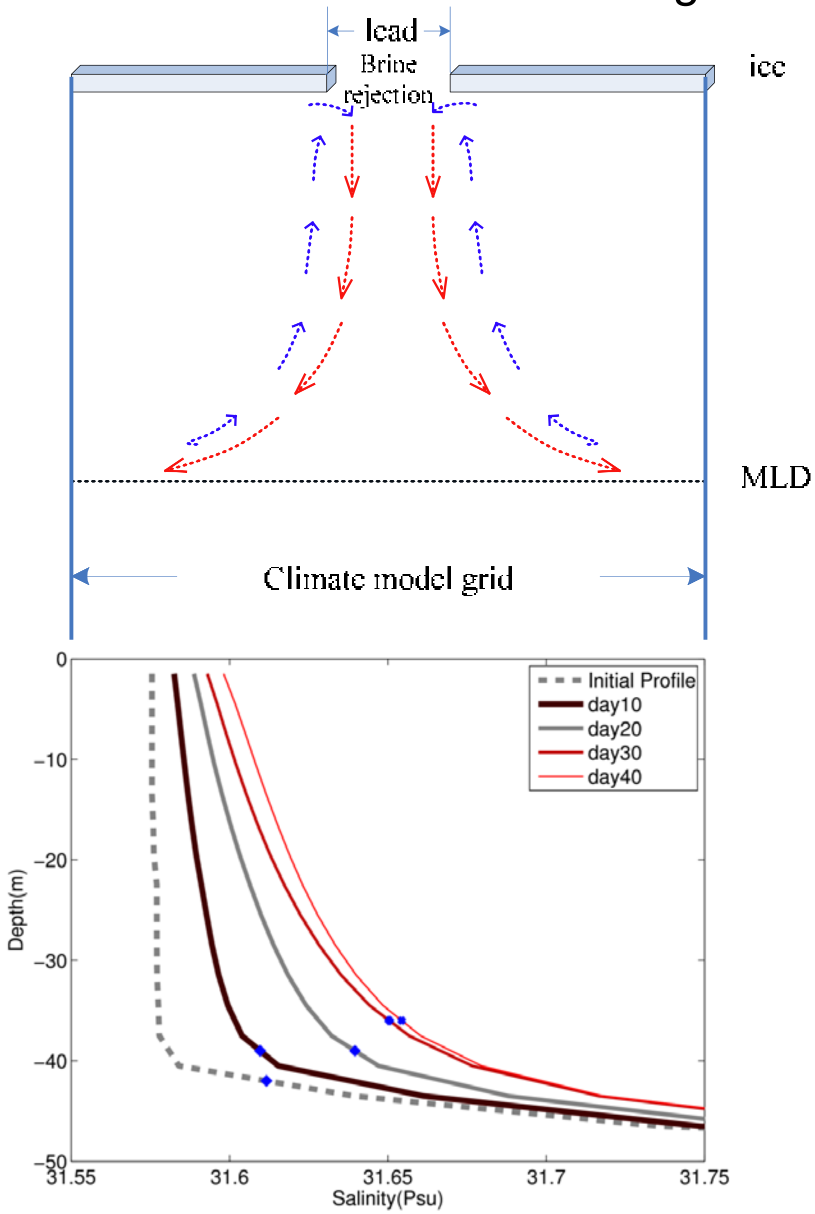
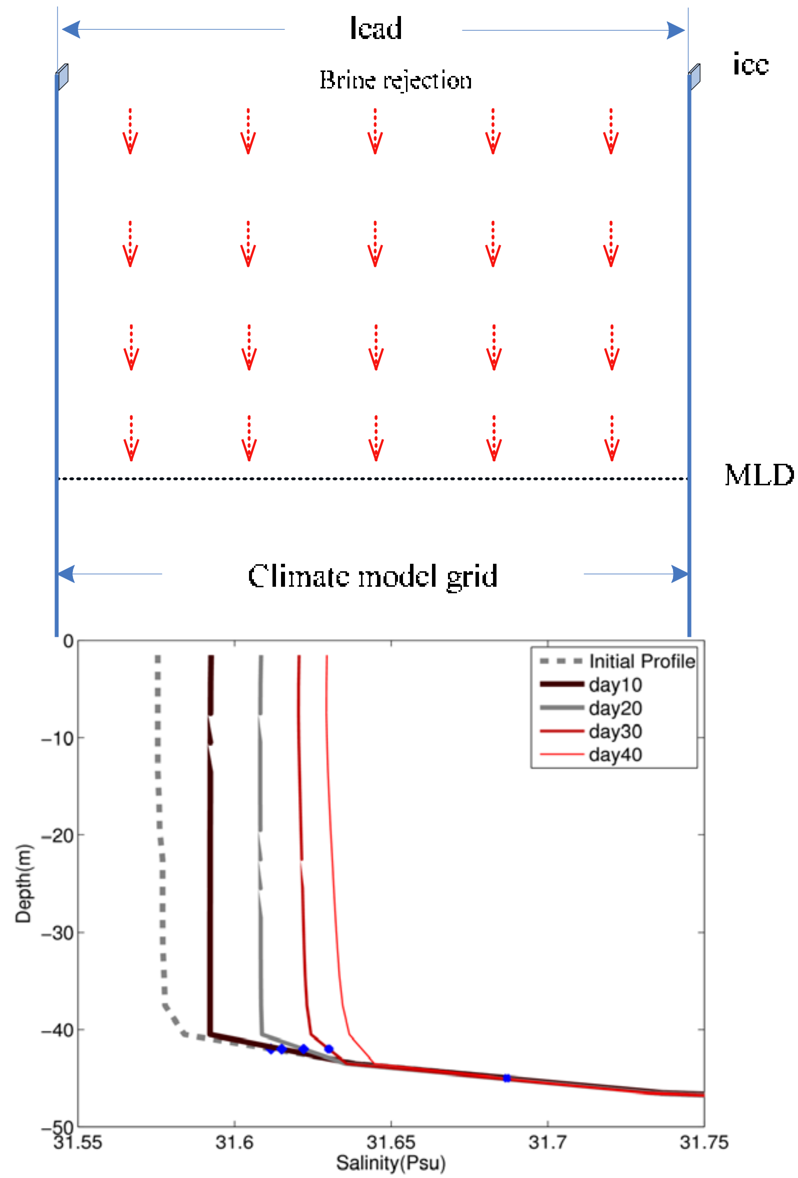
Science questions

When lead << climate model grid

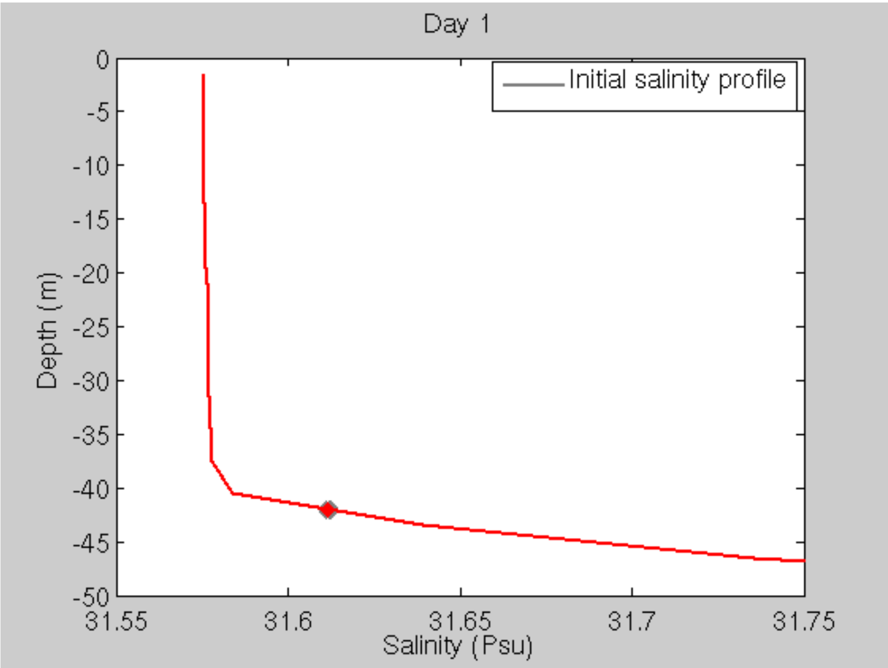


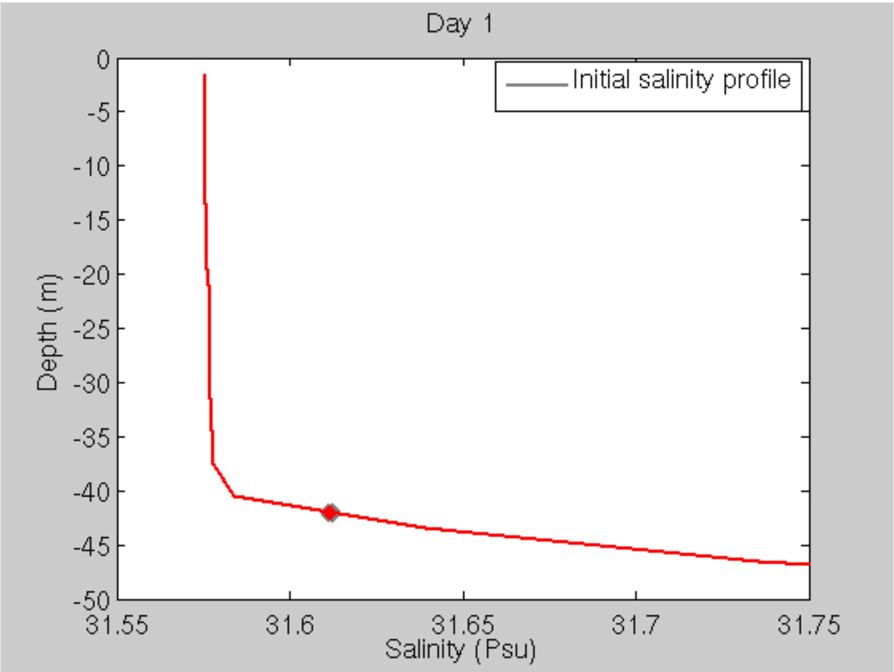
When lead ~ climate model grid



Goal of the project:

1) Identifying the model errors related to the ocean mixing process under sea ice using observations and idealized model experiments.
2) Finding optimum solutions including various parameterization schemes and implementing multi-column ocean grid (MCOG).
3) Validate the new model with observations, and conduct model inter-comparison with other Intergovernmental Panel on Climate Change (IPCC) climate models, and
4) Solicit more climate model users to participate in using and assessing the new method through workshops, web-based communications, and distribution of the new model code.


Day 1
Initial salinity profile
Depth (m)
Salinity (Psu)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
31.55
31.6
31.65
31.7
31.75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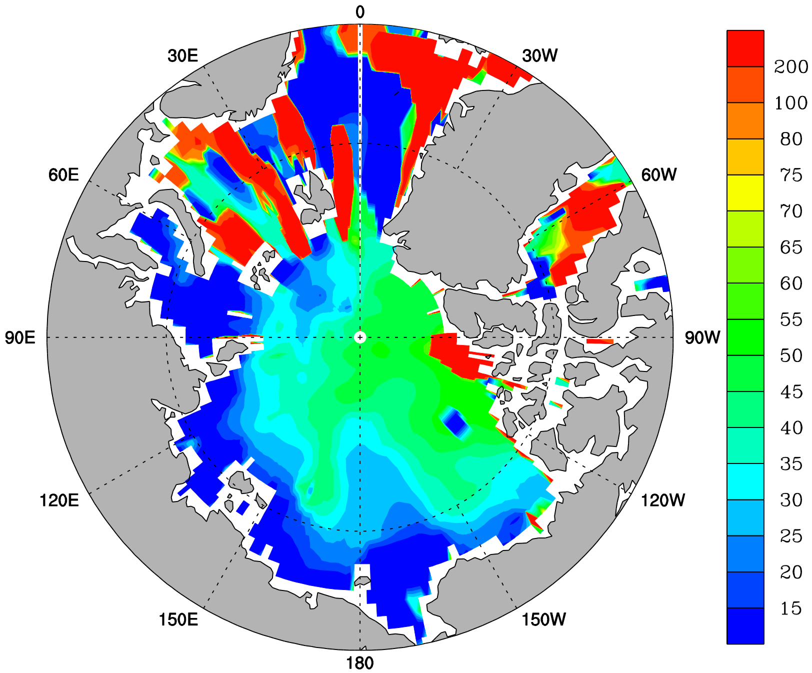
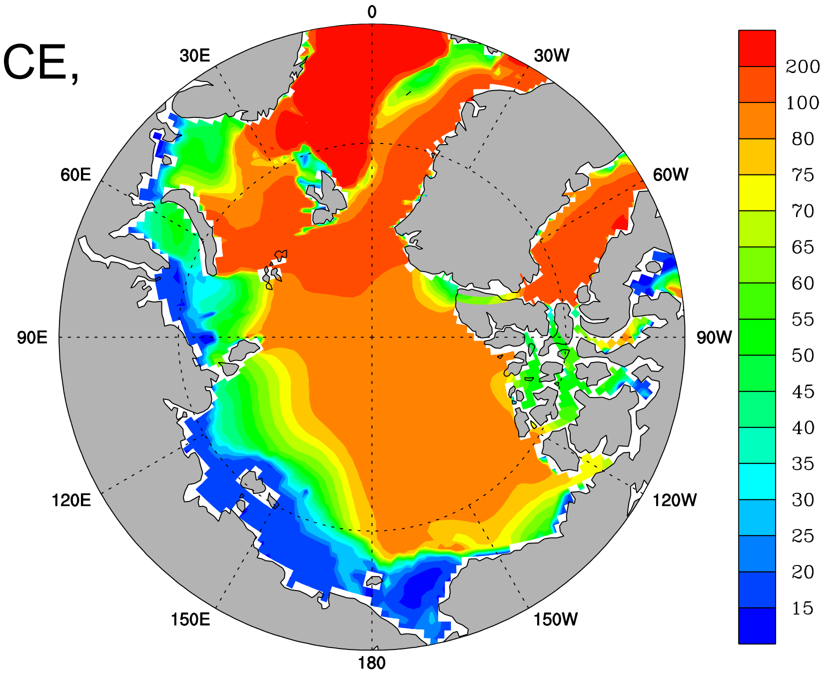
Mixed-layer depth (MLD) in March

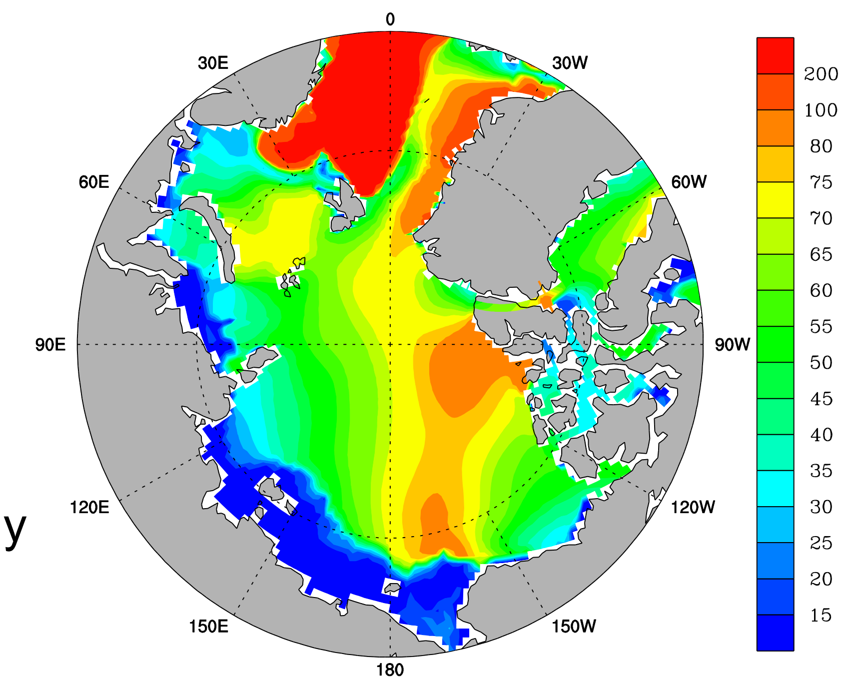
PHC 3.0



CESM POP-CICE, year 20



CESM Fully coupled, year 20



Solutions tested:

1. Parameterization of vertical distribution of brine rejection from lead.

Prescribe a vertical profile depending on the percentage of lead in a grid.
Parameters to determine: MLD and n

$$\Delta S(z) = Az^n; \qquad \int_0^{MLD} \Delta S dz = Total\ brine\ rejection$$

1.1 Idealized model experiments

Use high-resolution 'lead-resolving' model results to assess climate model errors related to the subgrid-scale brine rejection caused ocean mixing.

Derive lead-fraction dependent parameterization scheme.

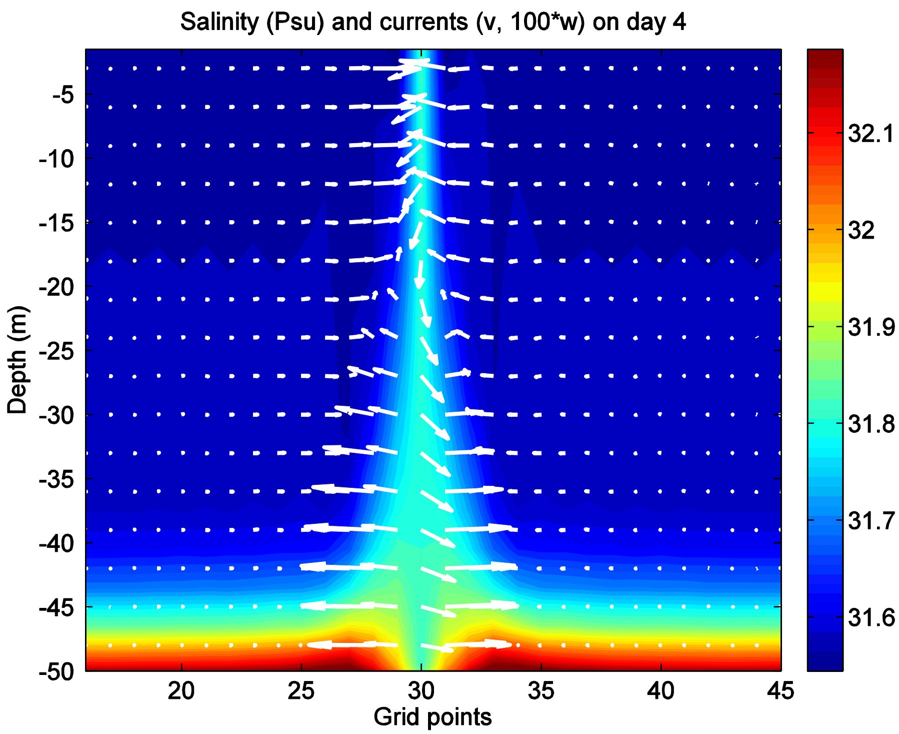
1.2 Implementation in CESM

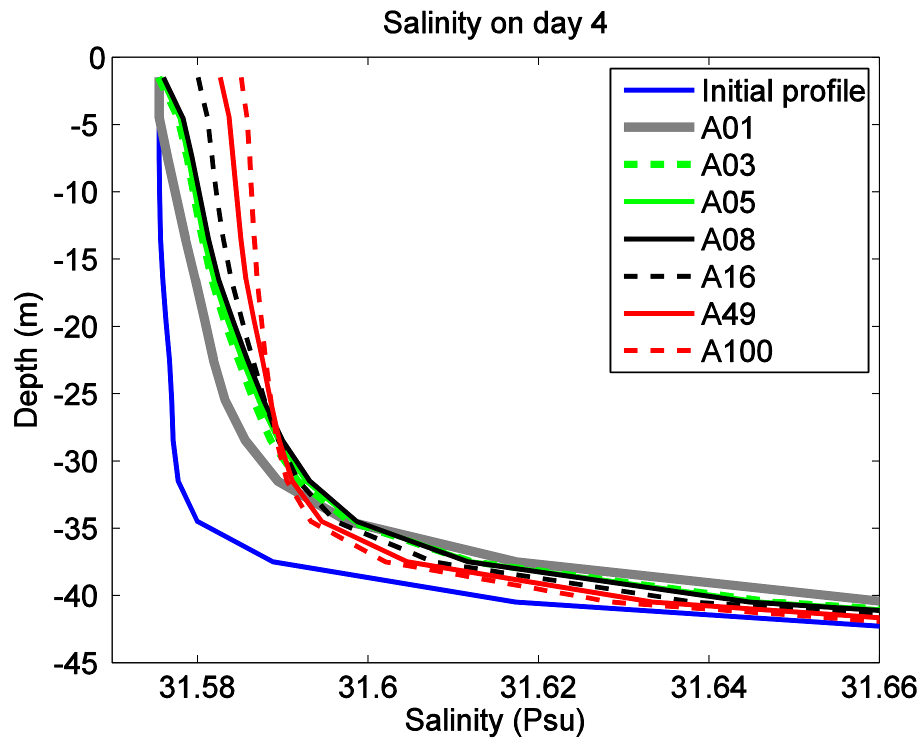
2. Multi-column ocean grid (MCOG)

Passing salt and heat flux in each ice-thickness category from CICE to POP.
Calculate separate mixing coef., and T, S in each column before average.

High-resolution lead-resolving idealized model experiments

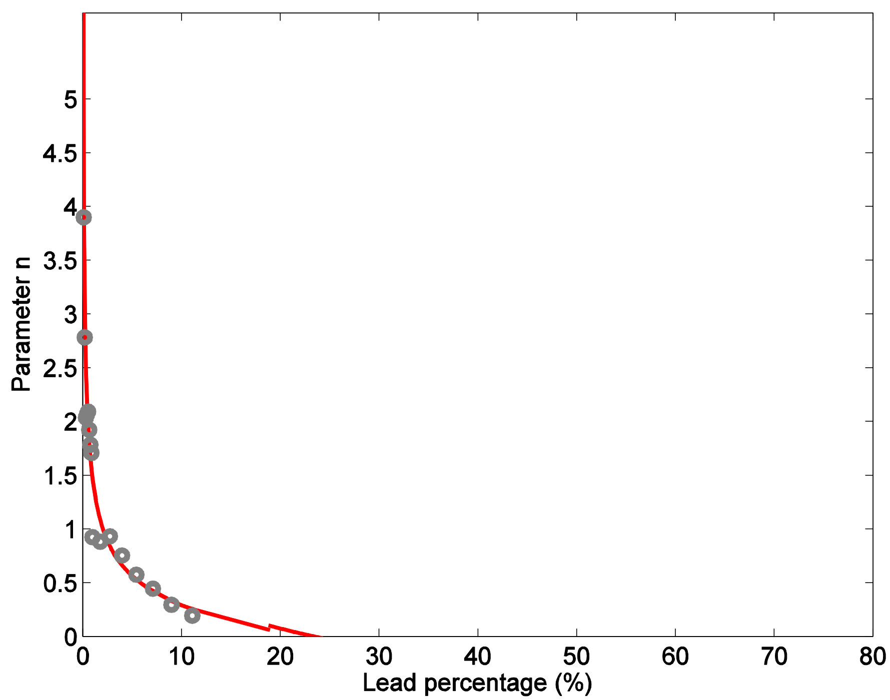
The simulated S-profile when averaged in a climate model grid is lead-fraction dependent

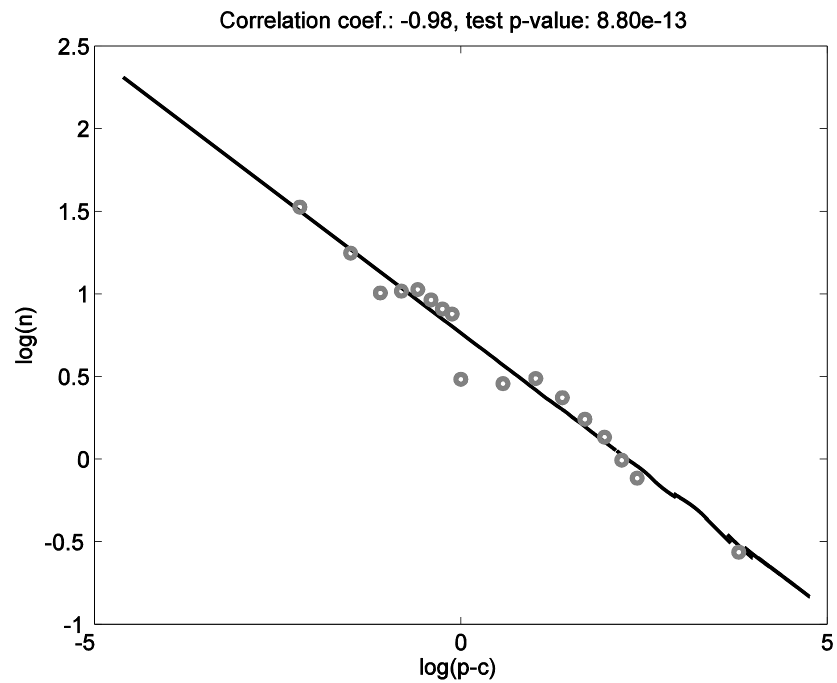




Best-fit relationship of parameter n as a function of lead-fraction p, using the idealized model results.

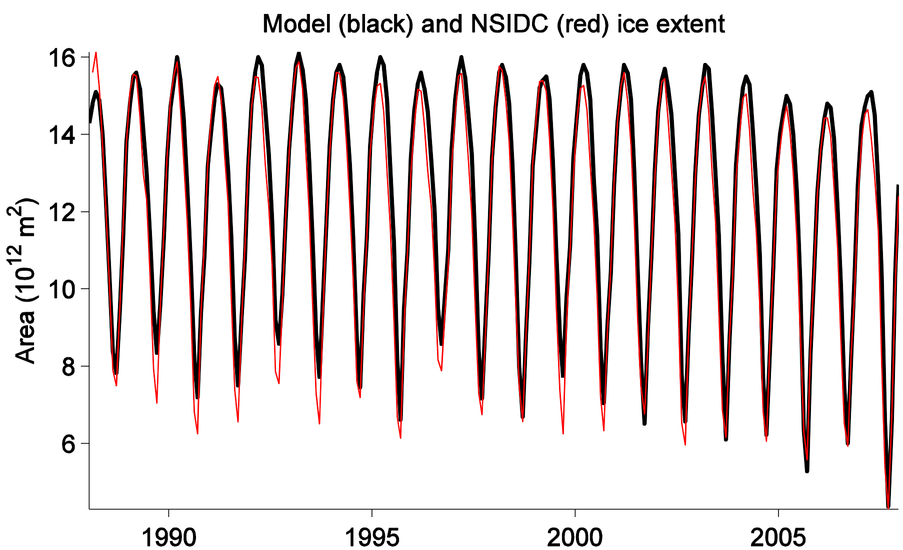
$$n = a \cdot p^b + c$$

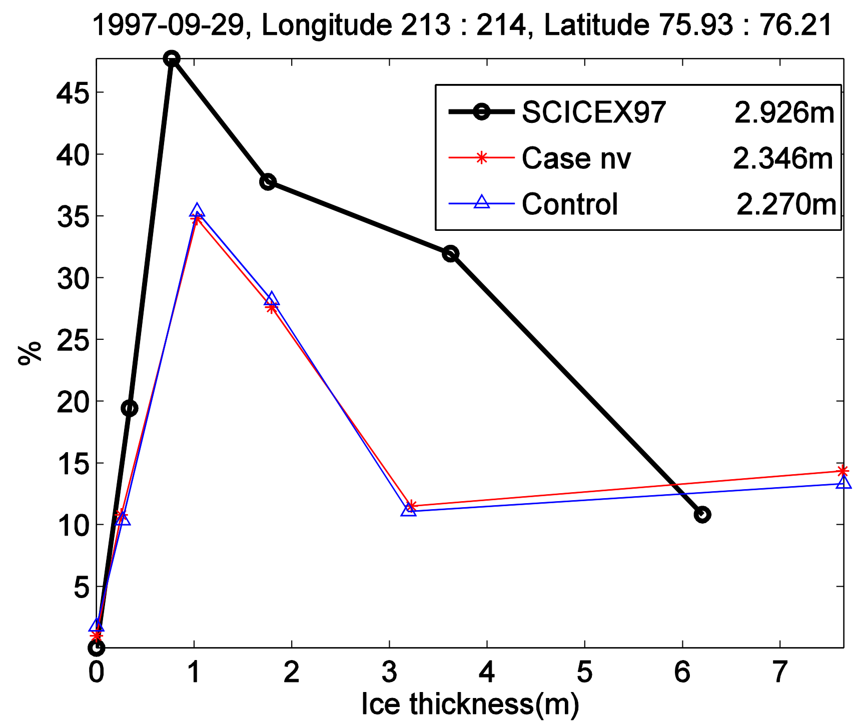




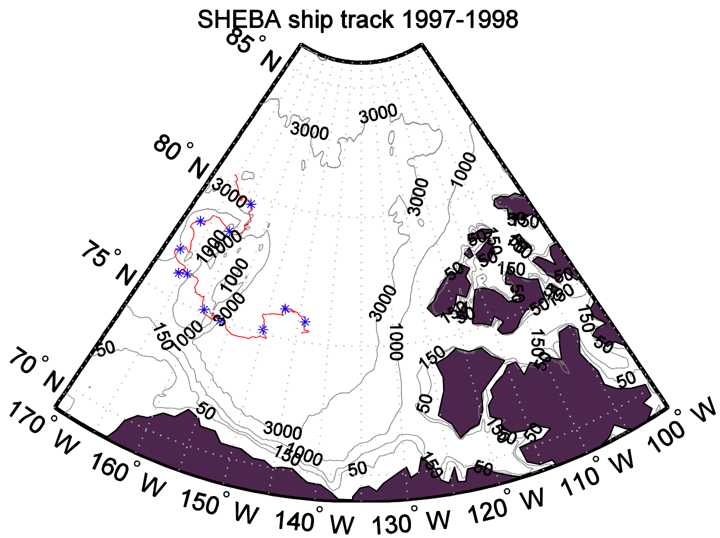
Forced CESM (POP-CICE) runs for parameterization
1) control, 2,3,4) n=0, 5, and lead-fraction dependent: case n0, n5, nv.

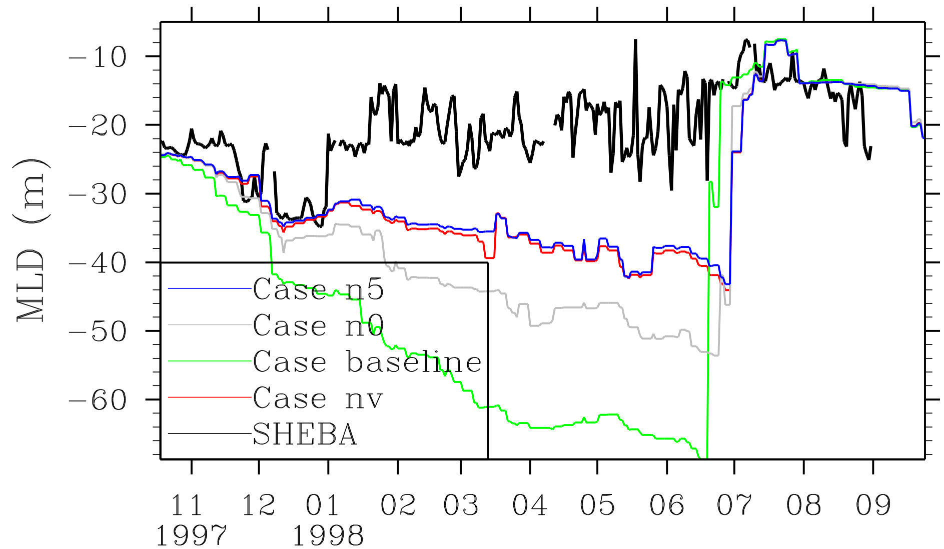
--- Sea ice results

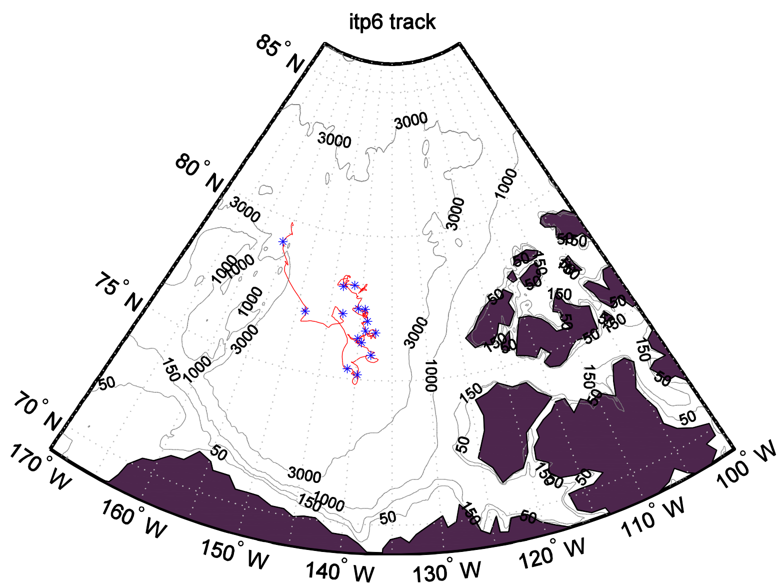


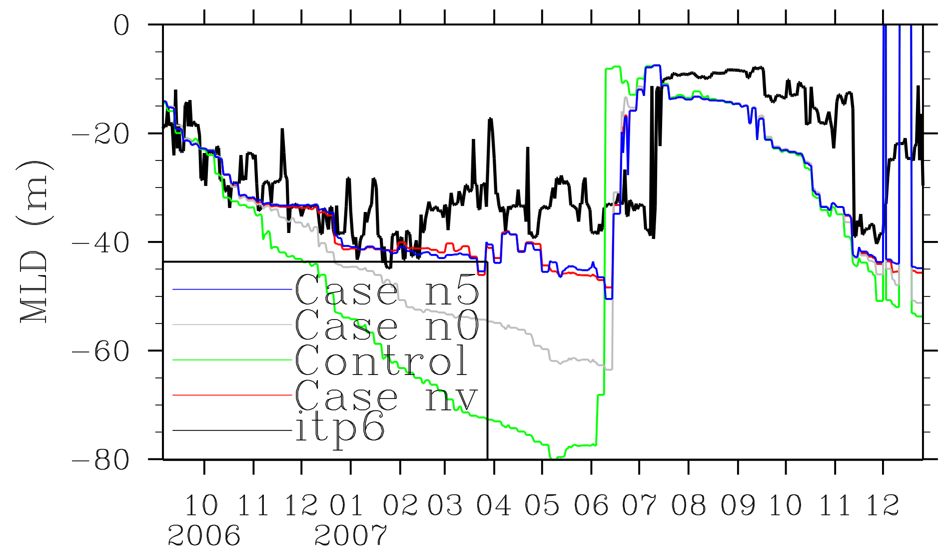


Forced CESM (POP-CICE) runs for parameterization:
--- Ocean results

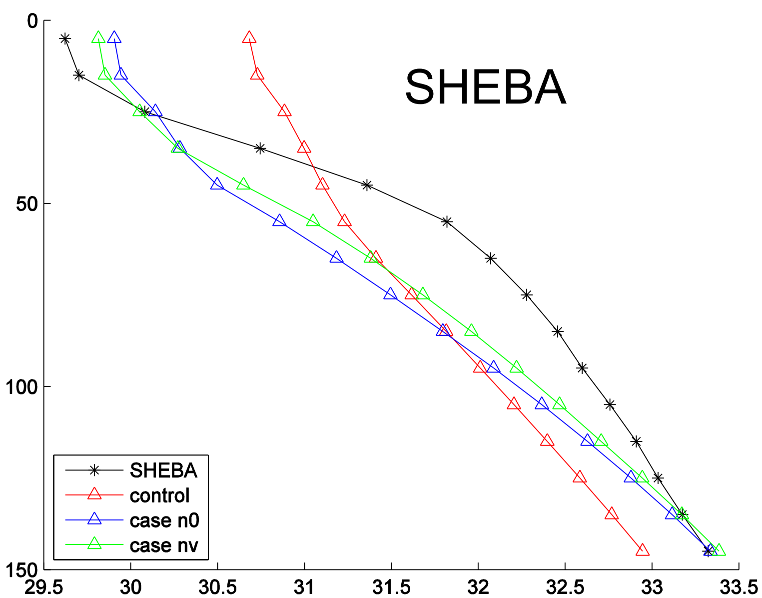


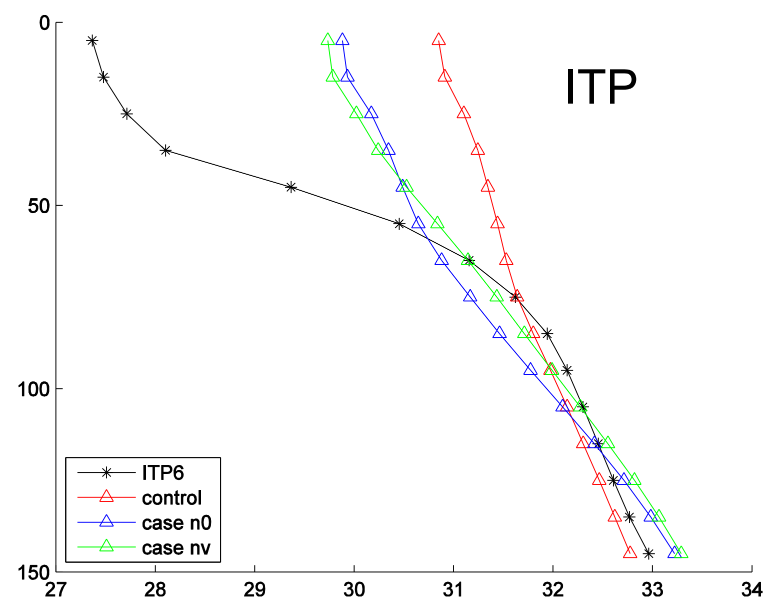






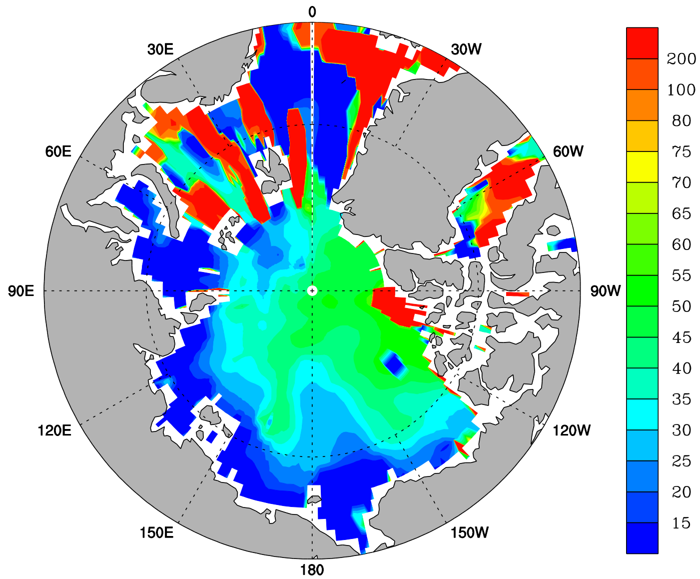
Forced CESM (POP-CICE) runs for parameterization --- Ocean results: annual mean salinity profiles



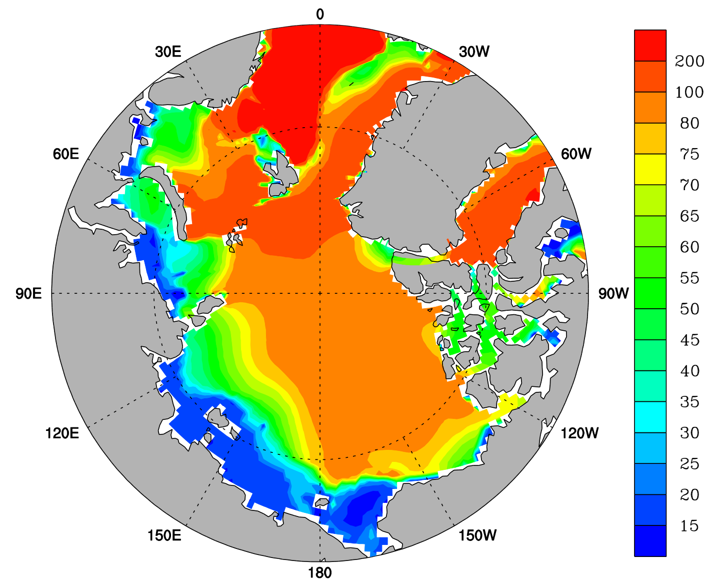


Forced CESM (POP-CICE) runs for parameterization:
--- Ocean results

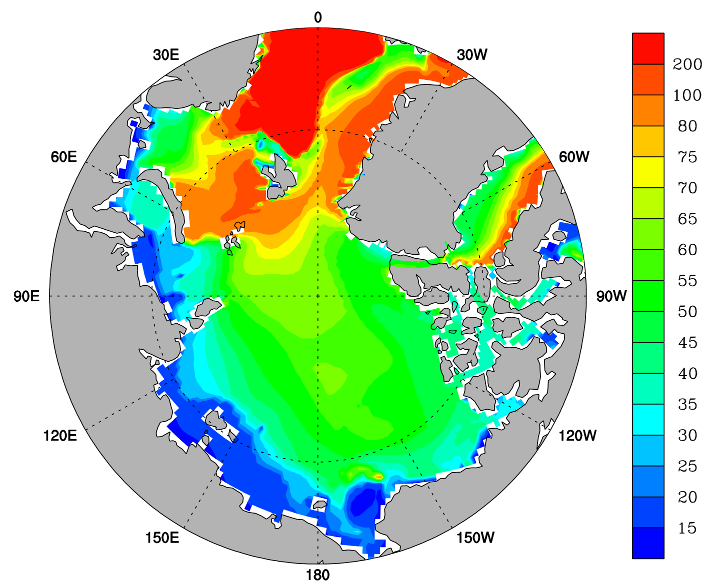
PHC3.0



Control



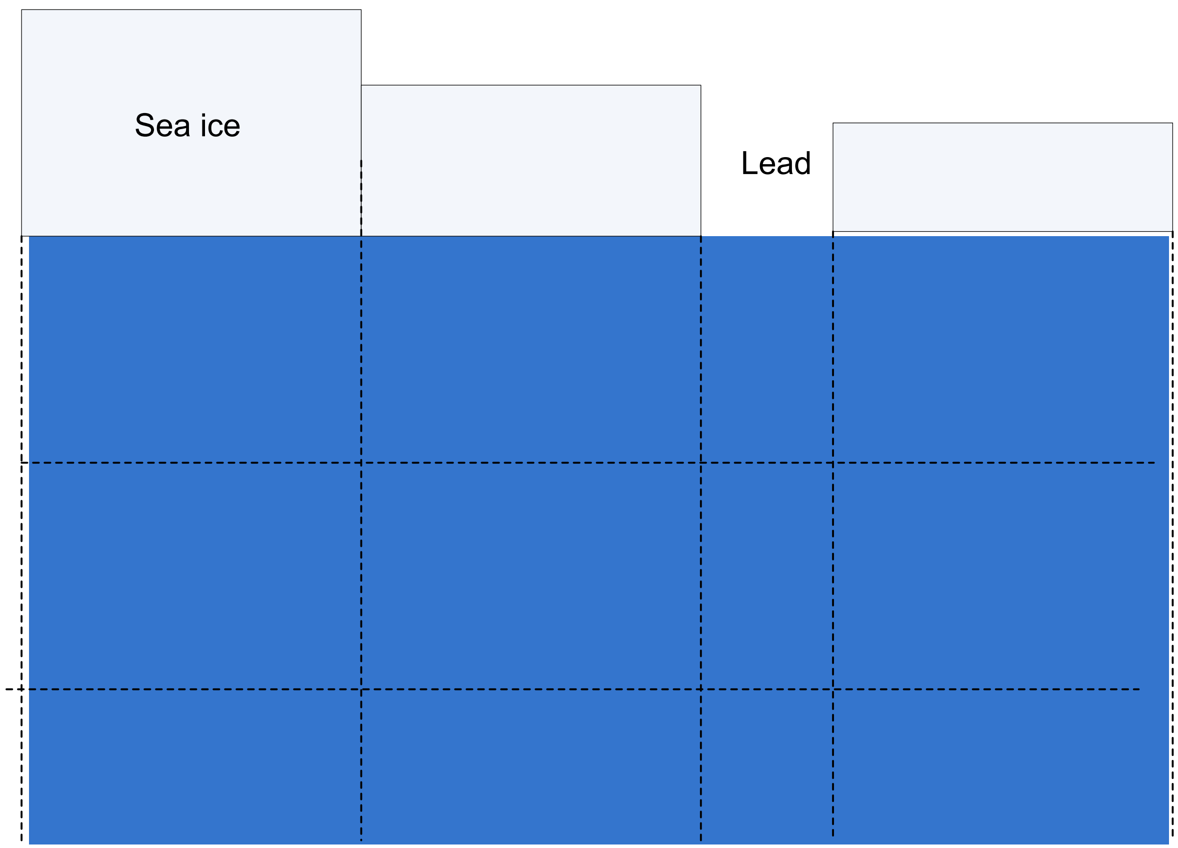
Case nv



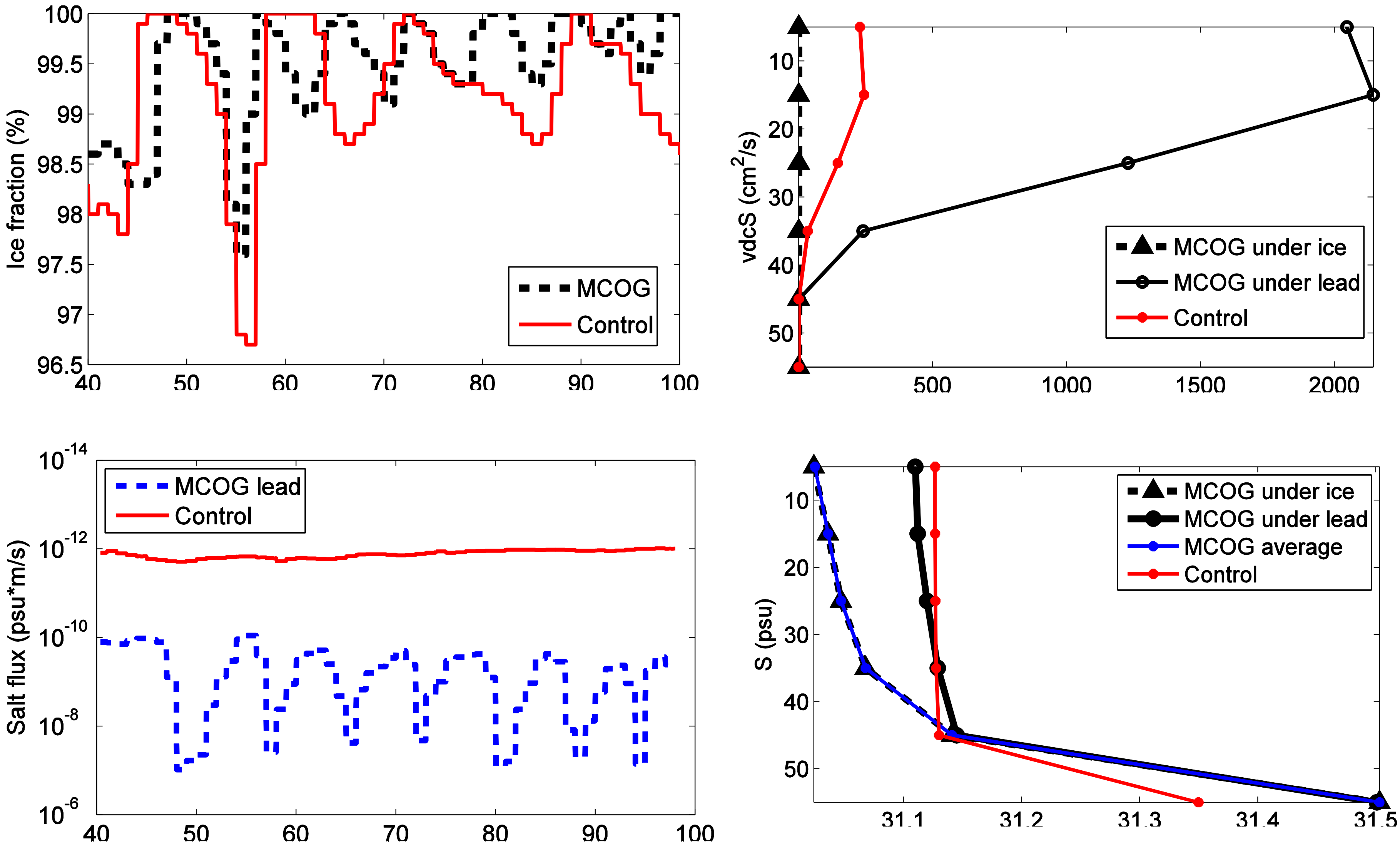
Forced POP-CICE and fully coupled CESM runs for MCOG

Control run and MCOG run

MCOG is multi-column ocean grid associated with sea ice thickness categories from CICE. To reduce computational cost, here, we used only two columns: lead and ice. The separate computation of ocean mixing in each column are merged every time step due to consideration of computational cost (memory) and limited changes to POP code structure.



Forced POP-CICE and fully coupled CESM runs for MCOG:
--- Results of the two columns from one grid point output



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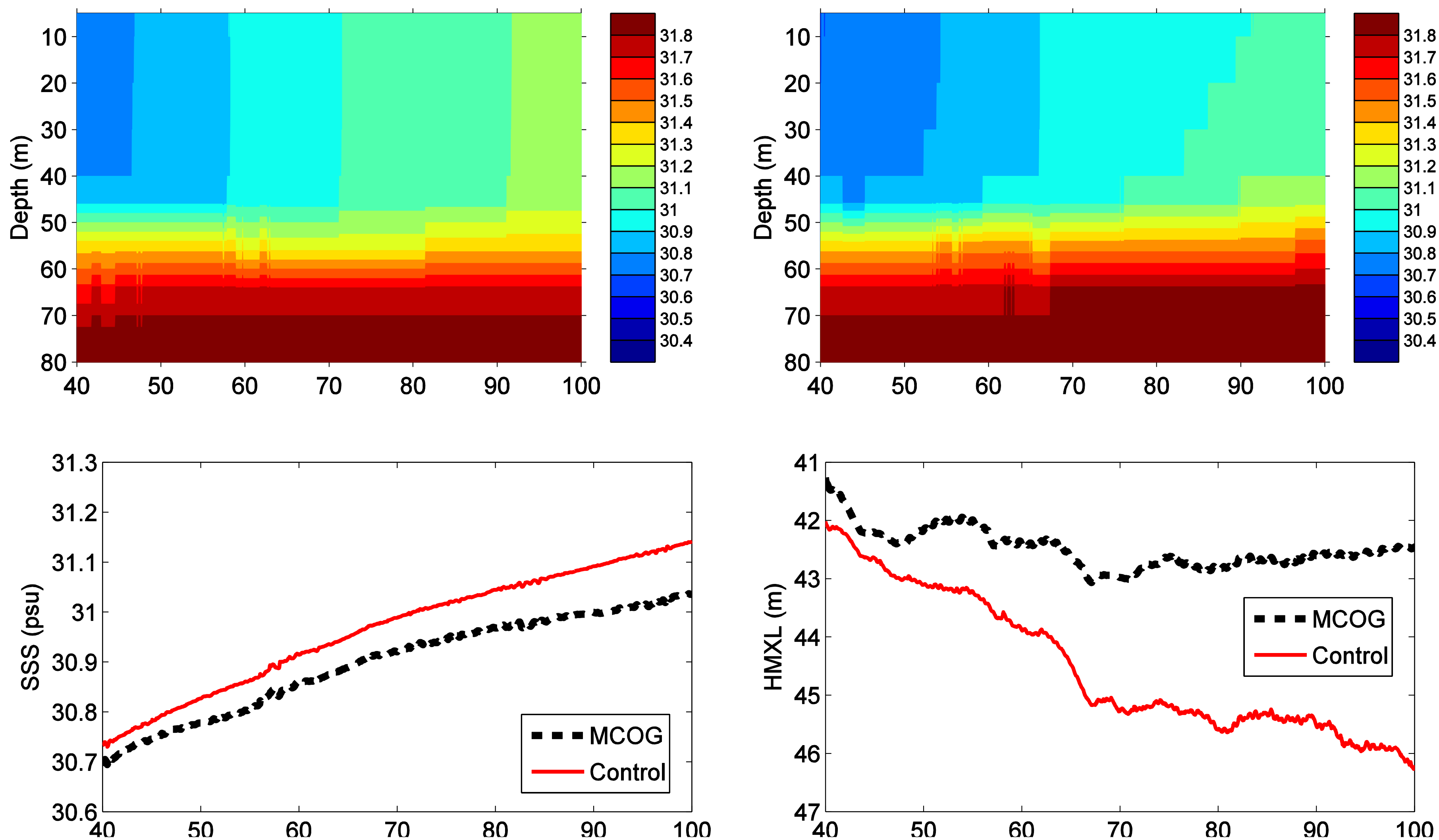
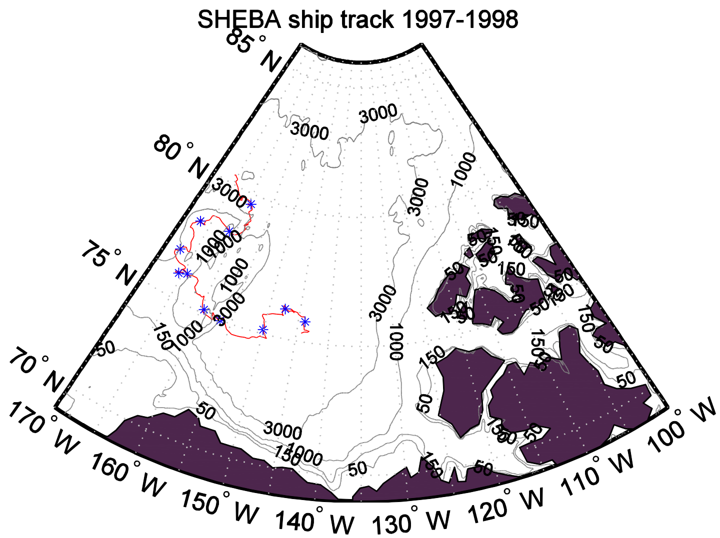
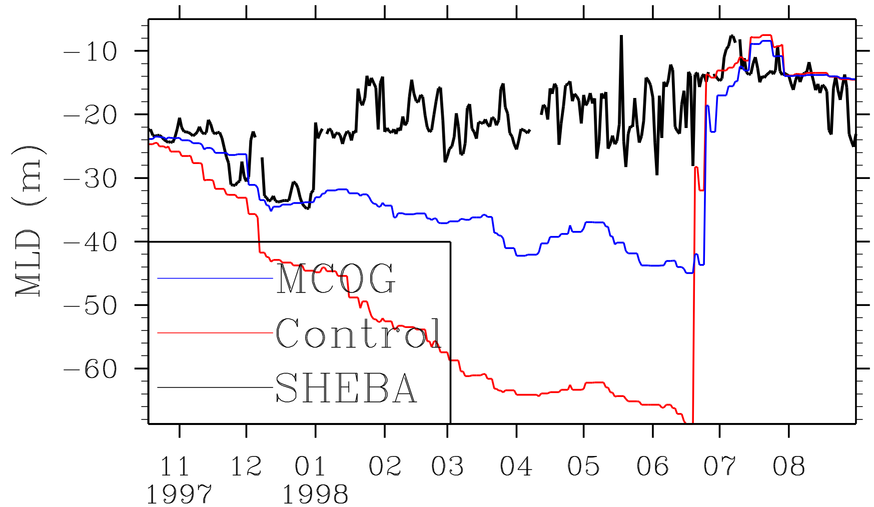
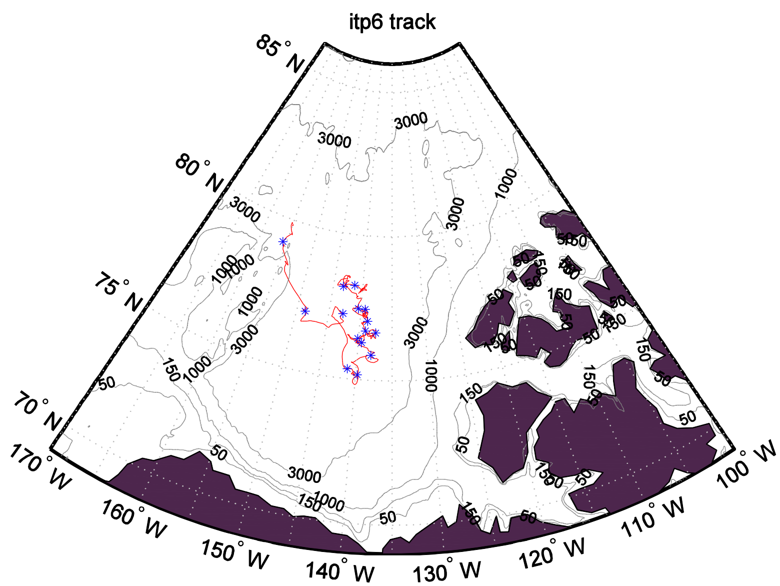
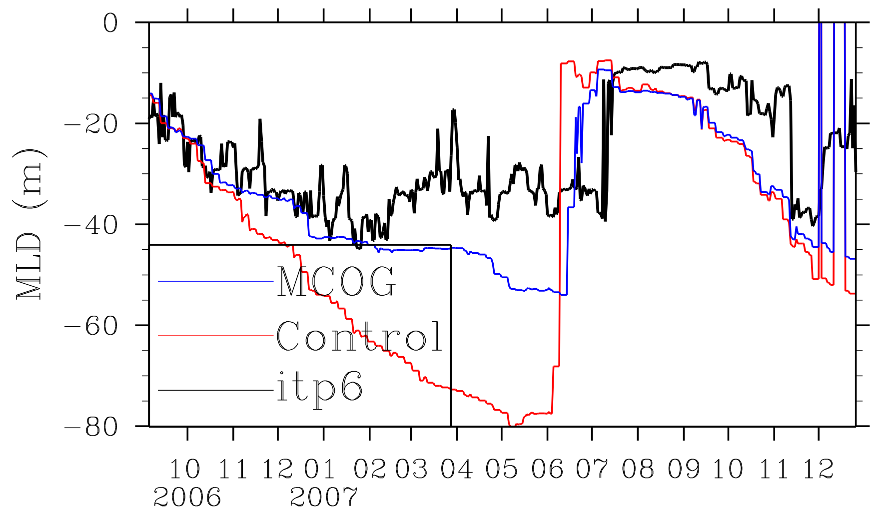


Forced CESM (POP-CICE) runs for MCOG:
--- Ocean results

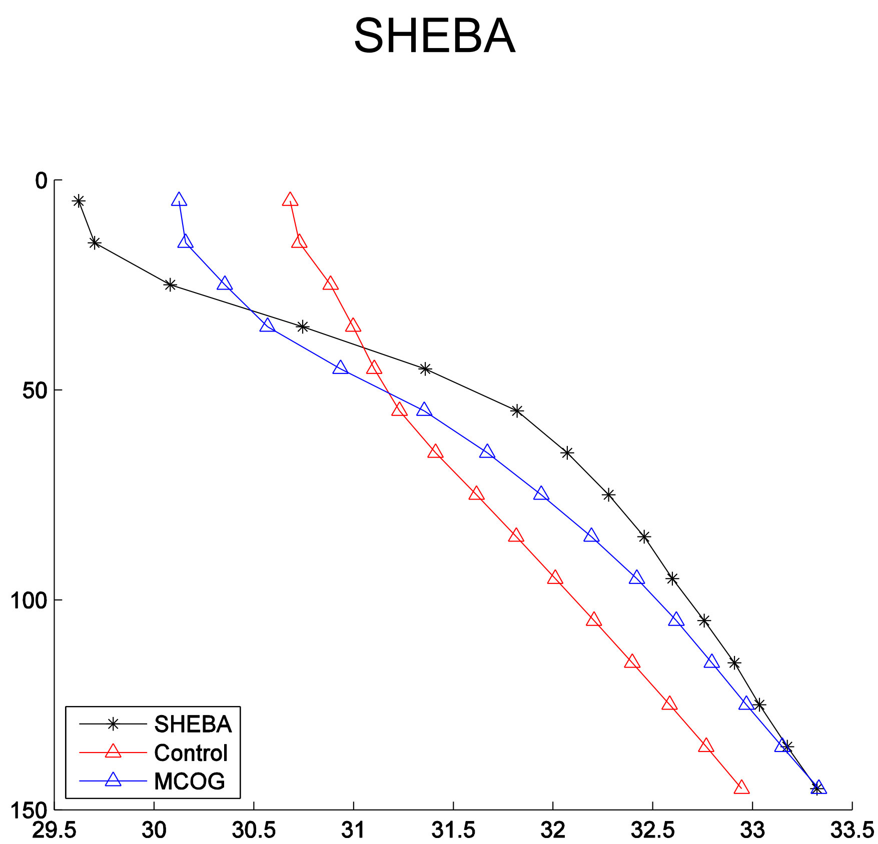


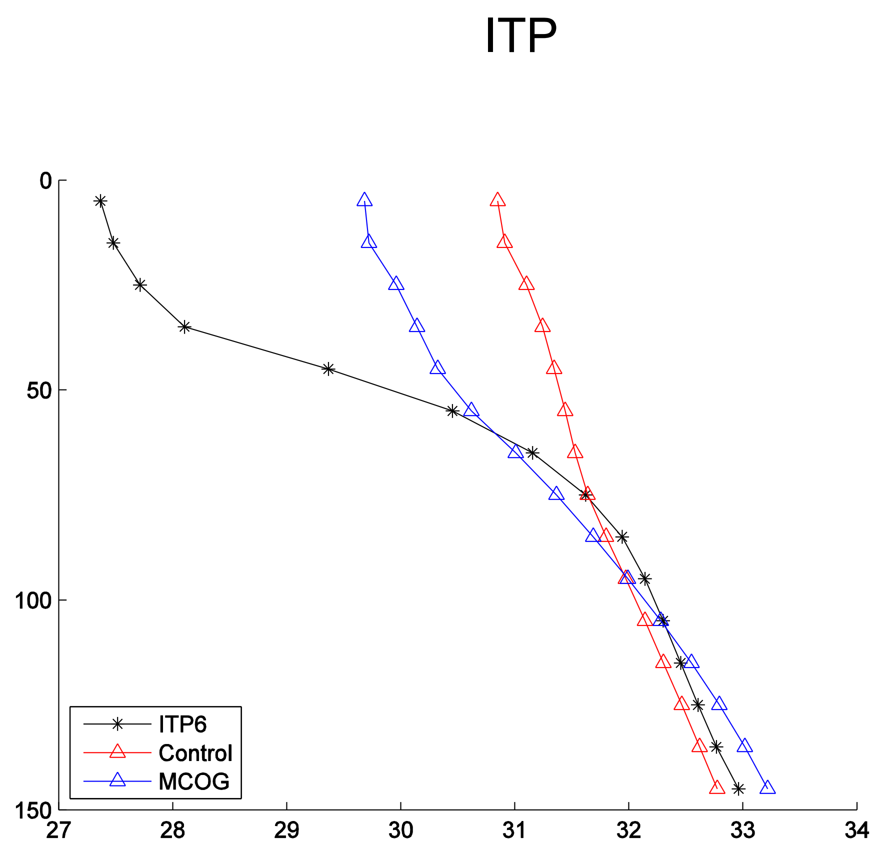






Forced CESM (POP-CICE) runs for MCOG
--- Ocean results: annual mean salinity profiles





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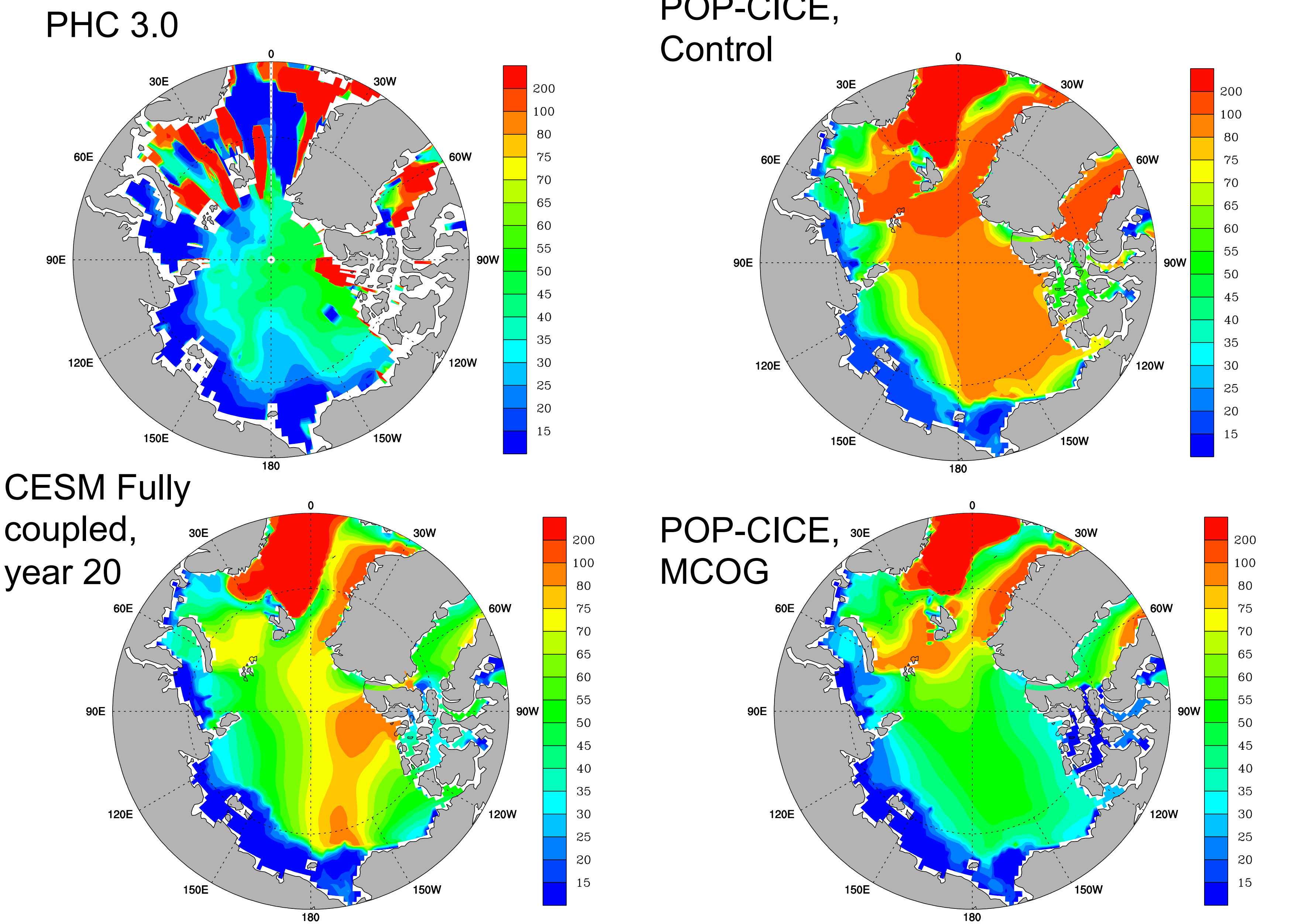

Completed works, challenges and future directions

Completed works:

- Identifying the model errors related to the ocean mixing process under sea ice using observations and idealized model experiments.
- Finding optimum solutions including various parameterization schemes and implementing multi-column ocean grid (MCOG).

Challenges:

- Computational cost.
- Conflict of new code and existing software structure.

Future works:

- Reorganize/ standardize model code implementation in CESM for broad community users. Besides the 3-D fully coupled code, we will also develop a vertical 1-D CESM for testing as many CESM user demanded.
- Conduct fully coupled CESM runs.
- Have the schemes tested and compared with GFDL model

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