Ocean mixing under sea ice with multi-column ocean grid in CESM and its impact on ecosystem dynamics

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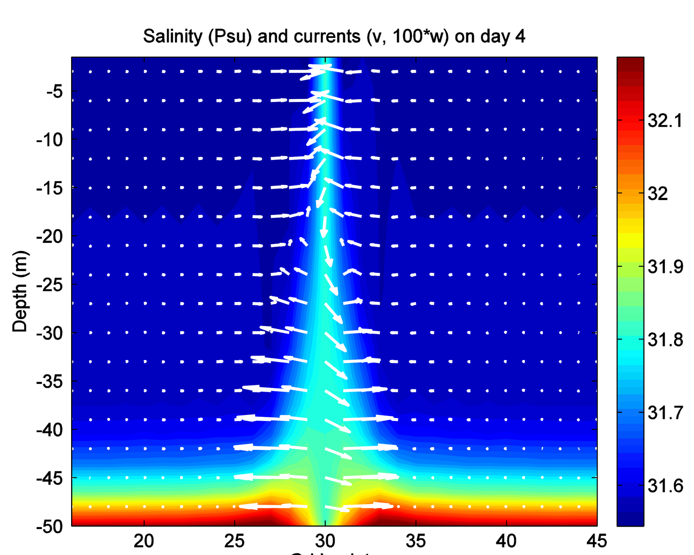
Abstract

Brine rejection from sea ice formation is an important driver of upper ocean mixing and therefore influences ecosystem dynamics in the Arctic Ocean. The sea ice is spatially heterogeneous and the horizontal scale and amount of brine from ice formation is understudied due to difficulties in field observations. Climate models is only designed to catch the mean brine flux over a large area (model grid area). By ignoring details of the brine rejection, such as its spatial scale and amount relative to a model grid average, climate models tend to overestimate ocean mixing and have deeper mixed layer depth (MLD). We have implemented two kinds of parameterizations of the subgrid scale ocean mixing by brine rejection in the CESM climate model: 1) lead fraction-based parameterization of vertical distribution of brine within mixed layer (Jin et al., 2012); 2) two-column ocean grid to separately compute the vertical mixing coefficients with/with brine rejection before merged into normal single column. The parameter in the second scheme is the fraction of grid area with brine rejection, that is tested to be a small number, either equal to the lead fraction or a number << 1%. Both schemes achieved significant improvements of simulated MLD when compared with observations. Here we presented the model comparison with a number of ITPs at the same time and location from 2005 to 2009. The ecosystem response to the changes of MLD are dynamic due to its different seasonal cycle than the MLD. With parameterization, MLD becomes shallower, NO3 decreased in the surface but increased in subsurface; primary production rate changes are confined to certain time in the surface; Chl fluctuated in the surface but generally increased in the subsurface; surface pCO2 has increased most time and locations due to less biological pump in the surface.

1. Introduction

A visual look at the sinking process of rejected brine

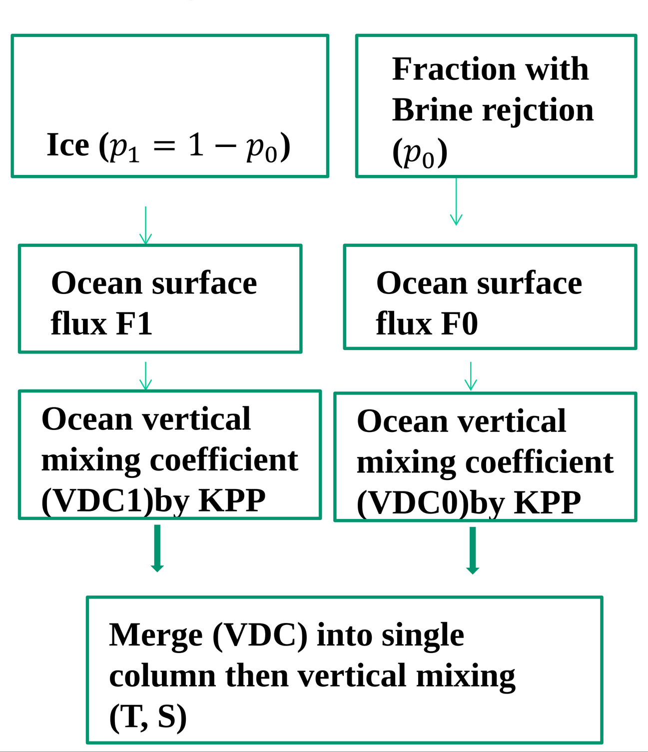
1) Lead fraction based parameterization of vertical distribution of brine in mixed layer



$$s(z) = \begin{cases} Az^n & if\ |z| \le |D_{sp}| \\ 0 & if\ |z| > |D_{sp}| \end{cases} \qquad n = a \cdot p^b + c$$

Fig. 1. Idealized model show the vertical distribution of brine sinking in a stratified field. The distribution is parameterized with a predefined curve depending on lead fraction.

2) Two-column ocean grid scheme



2. Comparison of MLD in March

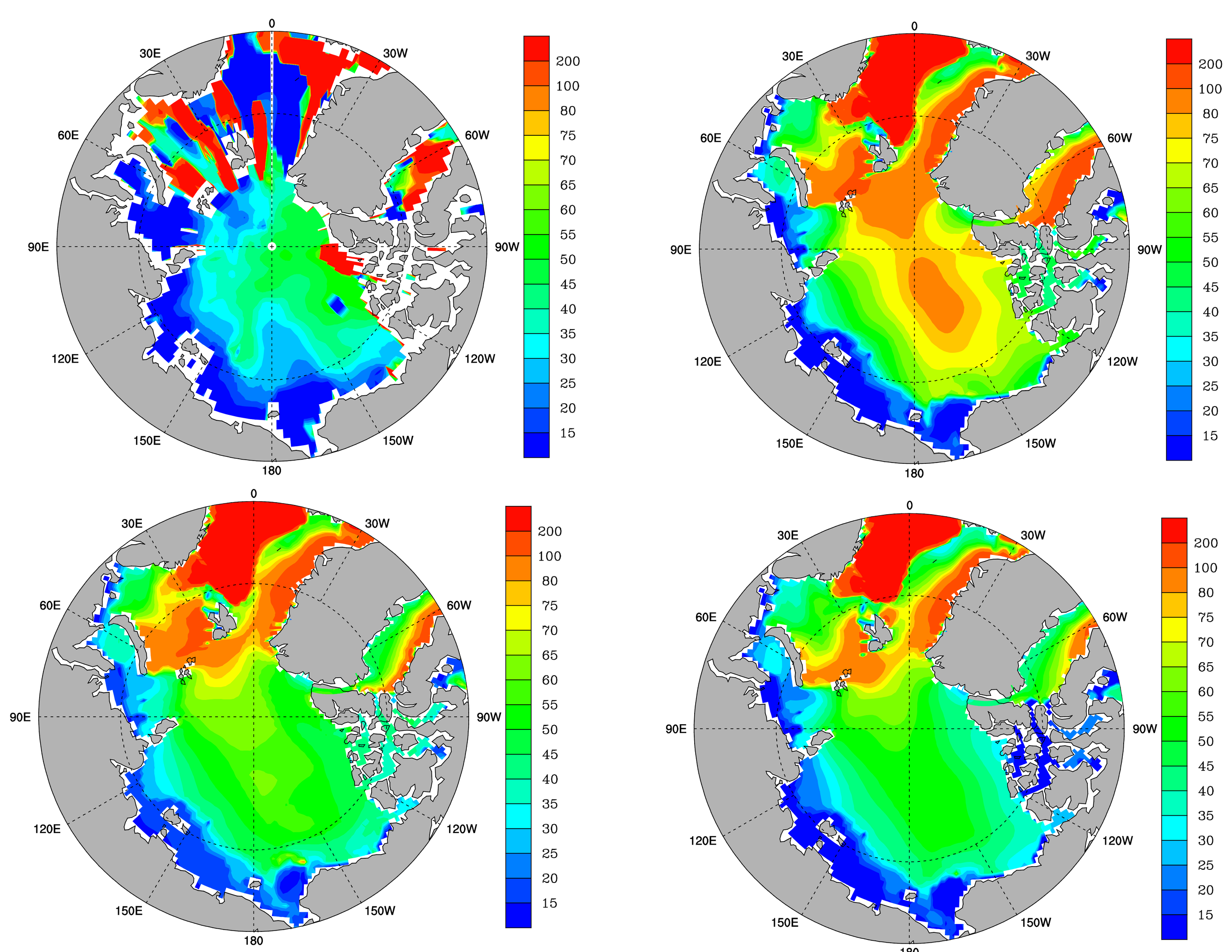
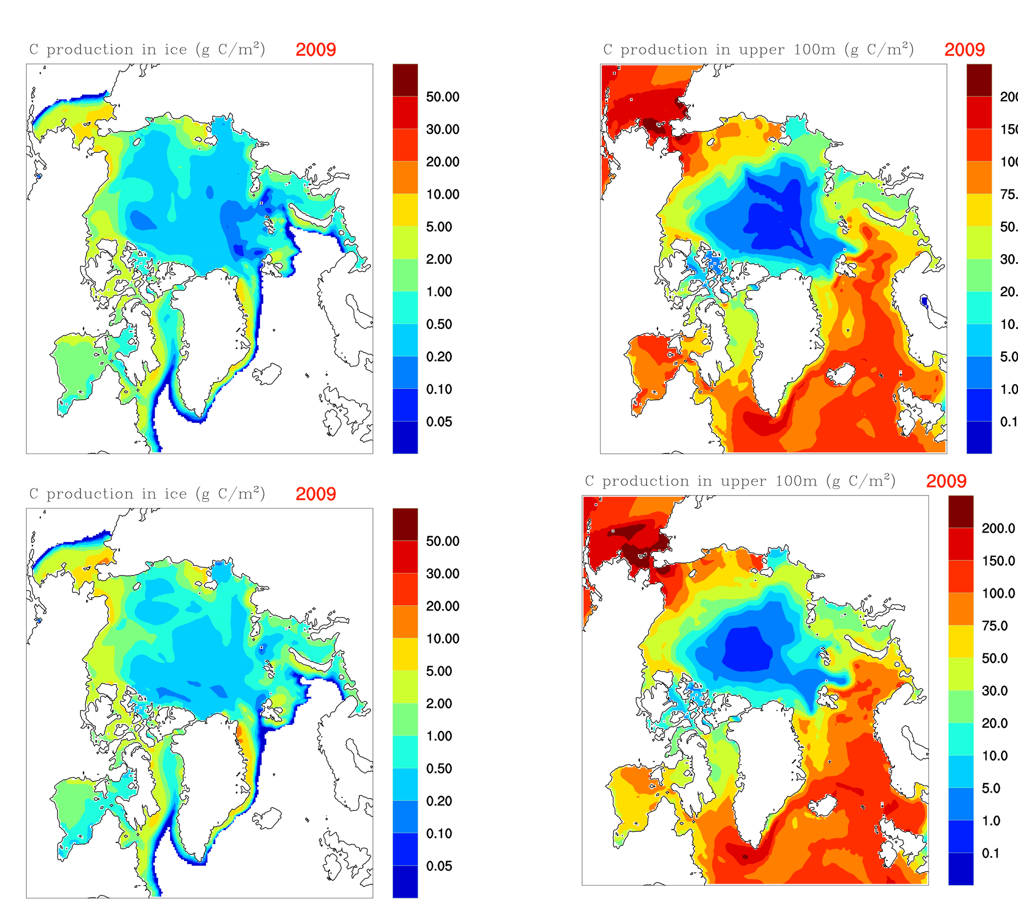


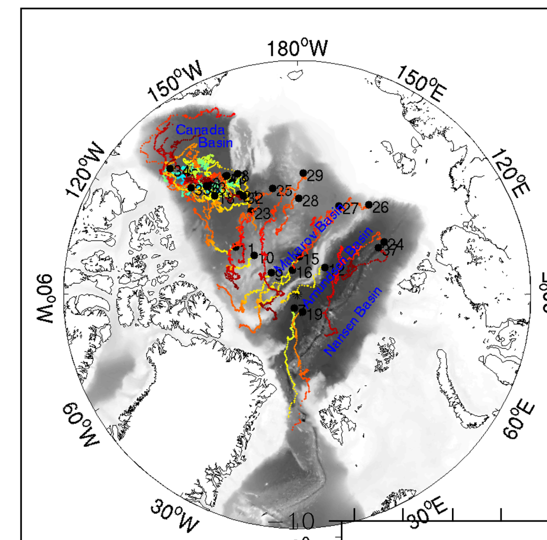
Figure 7: MLD in March 2009: a) PHC 3.0, b) Control c) Scheme 1 parameterization, d) Two-column ocean grid case..

2. Comparison of Annual primary production in 2009

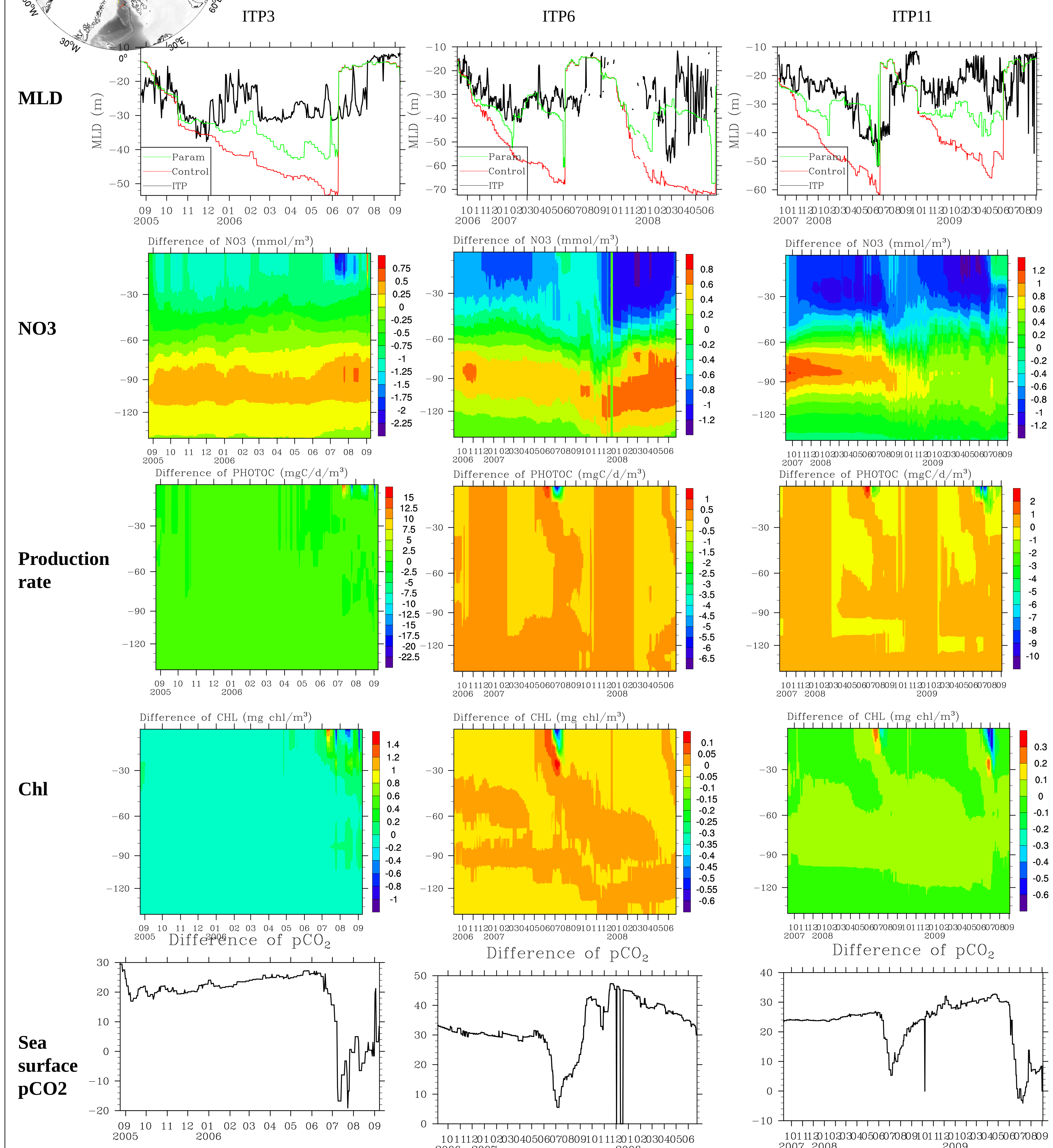
Control run

With parameterization





2. Comparison of MLD and differences of NO3, Chl a and production rate and sea surface pCO2 between the control case and parameterization case along the track of ITPs in the Arctic Basin area from 2005-2009.



Acknowledgements. This work was funded by NSF ARC-0652838, also supported by International Arctic Research Center through JAMSTEC-IARC Research Agreement.