Towards Modeling The Contemporary Carbon Cycle of the Arctic Ocean

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INTRODUCTION

The **Arctic region** is the Earth's most sensitive area to anthropogenic climate change. Understanding the functioning of its carbon cycle is vital if we are to predict its response .

Arctic Rivers represent a crucial **link** between terrestrial and marine carbon cycles through the runoff of **Dissolved Organic Carbon (DOC)**.

Estimation of air-sea CO_2 fluxes in the Arctic Ocean at basin scale is one piece of missing information for closing the budget of the contemporary global carbon cycle. We present here some modeling results on DOC dynamics and a strategy for filling this gap.

REGIONAL ARCTIC MODEL

For this project we will use different moduels of MITgcm :

[1] Sea-Ice-Ocean Model : 3-D MIT ocean general circulation model (MITgcm) based on primitive equations. The model is eddy-resolving (~20 Km of horizontal resolution) and has 50 vertical levels). This set-up is forced by re-analyzed forcing fields (NCEP) such as wind stress, solar heat and freshwater fluxes for present climate. It is also coupled to a thermodynamical and dynamical sea-ice model.
This regional Arctic ocean model has been developed in the framework of the ECCO2 project (ecco2.org).

[2] Idealized Tracer Model : We aim to assess the decay time scale of riverine DOC entering in the Arctic basin from rivers. We implement a climatological seasonal cycle of major rivers DOC discharge as tracer source for the Arctic basin.
With this tracer model we can set different time scales of remineralization (**τ**) of our DOC-like tracer (**C**) to compare with estimates from field data (Hansell *et. al*., 2004, Fig. 2) :

$$\frac{\partial C}{\partial t} = u \cdot \nabla C + K \nabla^2 C$$ ***PASSIVE TRACER***

$$\frac{\partial C}{\partial t} = u \cdot \nabla C + K \nabla^2 C - \lambda \cdot C$$ ***DECAYING TRACER***

$$\lambda = \tau^{-1}$$

[3] Ocean Carbon Cycle Model : To compute **the air-sea fluxes of CO_2** we will use an ocean biogeochemical model that solves the full ocean carbon chemistry equations.

PRELIMINARY RESULTS

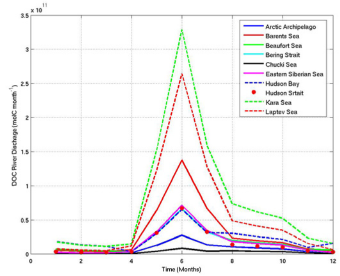


Figure 1 - Seasonal cycle of DOC discharge of rivers implemented in MITgcm in this study.

DOC River Discharge Climatology

Discharge of DOC in the Arctic Ocean is strongly influenced by the marked seasonal cycle of discharge of freshwater from land (Fig. 1). We constructed a climatological seasonal cycle for the major Arctic rivers combining direct [DOC] measurements at the mouth of the rivers and modeled freshwater fluxes due to river runoff (Lammers *et al*., 2001). Results from multi-year numerical simulations carried out with climatological circulation fields shown here use for each year the same climatological seasonal cycle of DOC river discharge shown in Fig. 1.

DOC-Salinity Relationship from data

Field data (Hansell et al., 2004) suggest that there is a robust relationship between DOC and Salinity in the Western Arctic Ocean (Fig. 2). They also imply that this relationship can be used to distinguish between different sources of DOC coming from different rivers entering the Arctic basin.

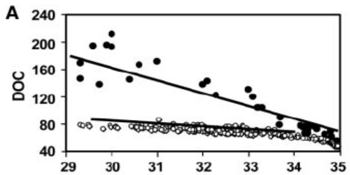


Figure 2 - DOC-Salinity relationship in the Western Arctic Ocean (figure from Hansell *et al*., 2004).

a)

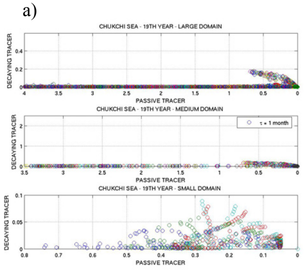
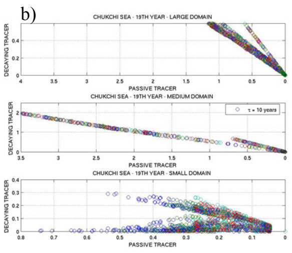


Figure 3 - Decaying tracer-passive tracer relationships in the Western Arctic Ocean simulated by MITgcm.

b)



DOC-Salinity Relationship in the Arctic model

We used our idealized tracer model with different values of **τ** in order to explore the sensitivity of the DOC-Salinity relationship (DSR) to liability of riverine DOC. Our passive tracer is considered to have a salinity-like behaviour and the decaying tracer represents riverine DOC. Here we show results with experiments of extreme cases with τ equal to (Fig. 3a, top) **1 month** and (Fig. 3b, bottom) **10 years**.

Results refer to 19th simulated year. Each figure represents modeled tracer values sampled at the surface of the ocean model and they refer to domains of different size (Fig. 4) in the western Arctic Ocean to distinguish on the importance of rivers for DOC supply to the ocean.

Preliminary results shown here **FIRST** highlight the high sensitivity of the DSR to the value of τ. Plots in Fig 3a **SECONDLY** show that **1 month as value for τ is probably too small** to have a DSR that can be compared to that as shown in Figure 2. However results with τ set to 10 years would suggest that to simulate a DSR comparable to field data we have to explore **values of τ in the range from one to several years**.

HIGHLIGHTS & GOALS

With this project we aim to :

[1] constrain the decay timescale of DOC in the Arctic Ocean and clarify its fate inside the basin due to ocean dynamics.

[2] use constrained DOC model set-up to help provide for the first time **basin-scale information on CO_2 sea fluxes** resolving seasonal cycle variations and interannual variability.

[3] integrate our results with model-derived terrestrial carbon fluxes and atmospheric inversions **to budget the carbon cycle of the Arctic domain**.

SAMPLING IN THE ARCTIC

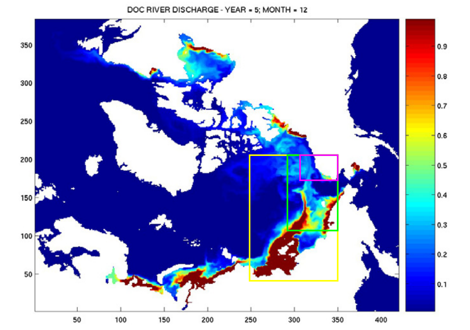


Figure 4 - Sampling boxes and surface passive [tracer].

ONGOING & FUTURE WORK

[1] Use of new version of regional Arctic MITgcm to repeat experiments shown here for constraining the lifetime of DOC using modeled salinity**.**

[2] Activation of ocean biogeochemical component embedded in MITgcm to estimate the air-sea fluxes of CO_2 with interannual atmospheric forcing.

[3] Exploring the response of both ocean circulation and ocean carbon cycle to positive and negative phases of North Atlantic Oscillation (In collaboration with A. Condron and P. Winsor, WHOI).