Modeling the carbon cycle and ecology of the Arctic Ocean with ECCO2-Darwin

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OUTLINE

1) Recent Changes in Arctic Climate and Sea-Ice

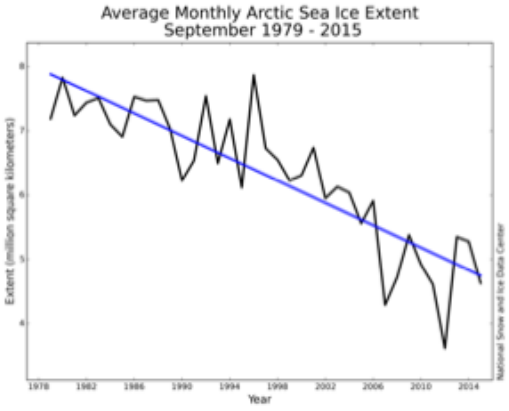
2) Modeling Tools : ECCO2-Darwin

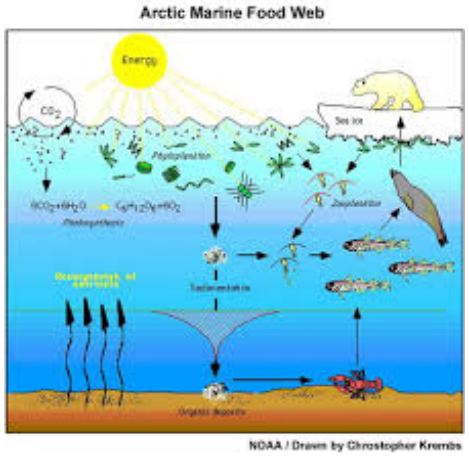
3) Response of CO_2 sink to recent Arctic sea-ice loss

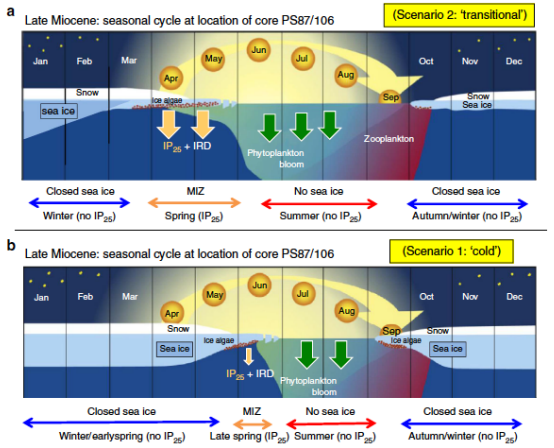
4) Response of Arctic phytoplankton seasonality

5) Conclusions & Future Directions

Arctic Climate, Sea Ice, C-Cycle & Ecology







Future

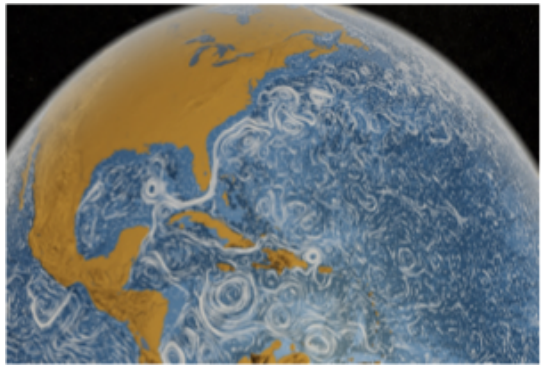
Present

Stein et al., 2016

Q1: What is the response of CO_2 uptake of the Arctic Ocean ?

Q2: What is the response of phytoplankton dynamics ?

ECCO2-Darwin



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ECCO-2
PHYSICAL MODEL

Global Domain
MITgcm
Cube Sphere (CS510)
18 km resolution
Sea-ice model

Forcing period 2004-2013:

2004-2008 ERA-40 (optimized)
2009-2013 JAR-25 (optimized)

Darwin MODEL
Ocean bgc & ecology
(Follows et al, 2007)

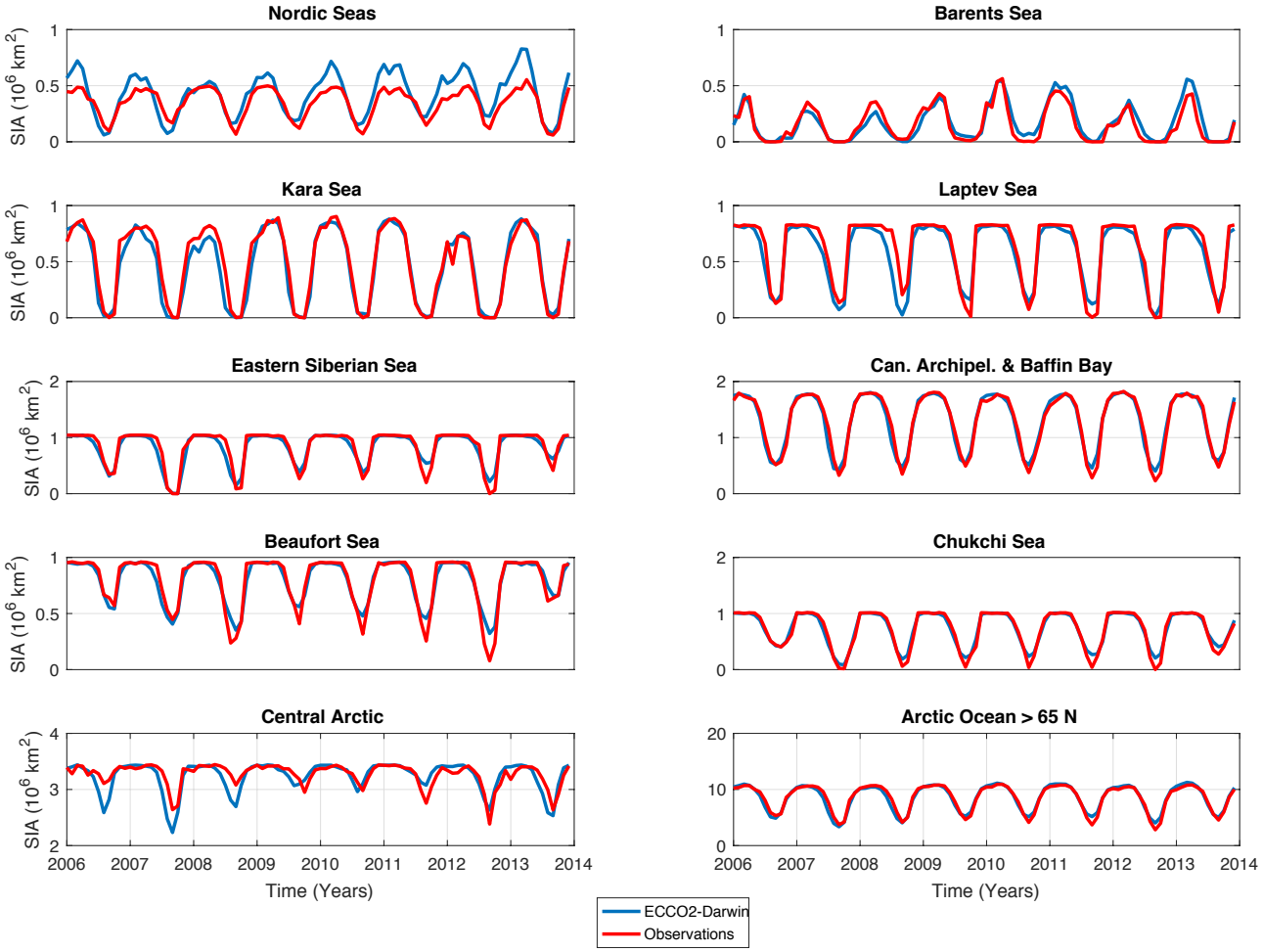
5 phytoplankton groups
(only 3 survive in the AO)

2 zooplankton groups
(micro & meso)

Carbon and Oxygen cycles
(Brix et al al, 2015)

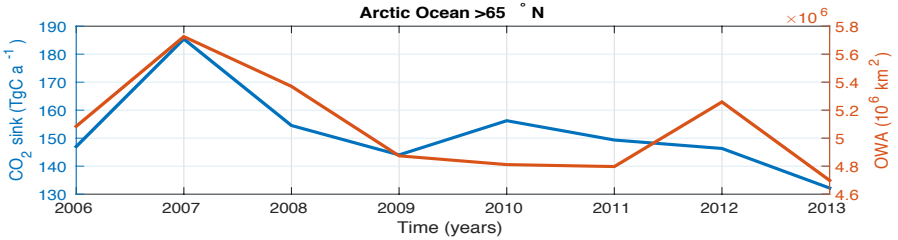
Increasing atmospheric pCO_2
2004-2013
"Keeling Curve"

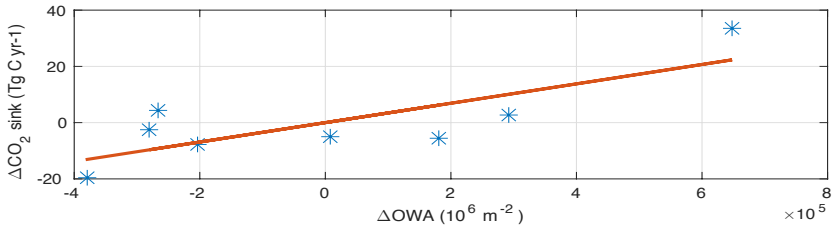
Response of Sea-Ice to recent Climate Forcing



Arctic Ocean Carbon Cycle Response

Open Water Area & CO_2 sink





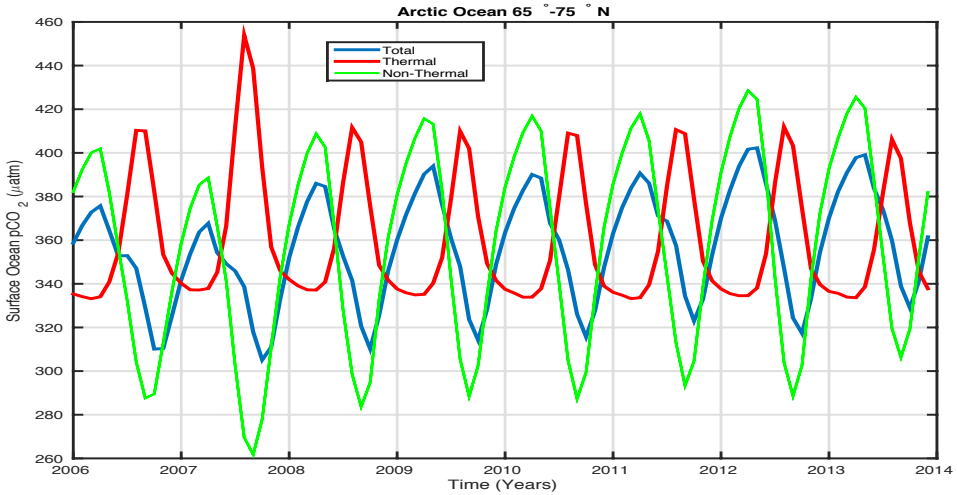
CO_2 sink Trend = -3.6 TgC yr^{-1}

2006-2008 : Direct relationship OWA and CO_2 sink (Bio C-pump rules !).

2009-2011 : Decoupling OWA and CO_2 sink (Barents and Nordic Seas dominate).

2012 : Decoupling OWA and CO_2 sink (Wind speed).

CARBON PUMPS VARIABILITY

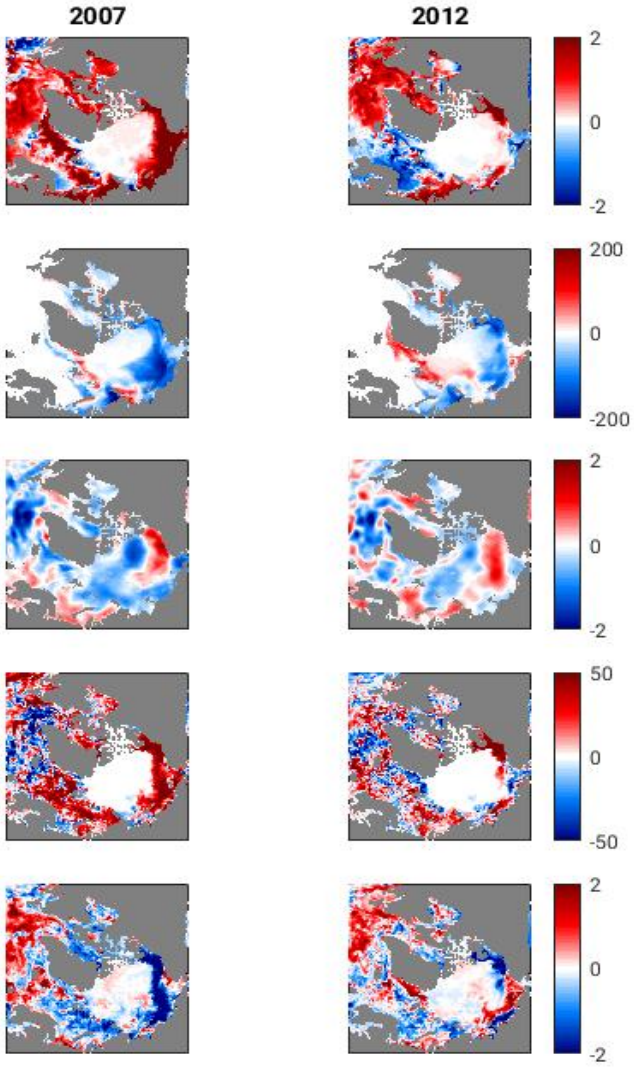


Solubility Pump

Biological Pump + Winter Mixing

AO CO_2 sink response: 2007 vs 2012

Anomalies May- November Average



Arctic Sea-Ice Area & CO_2 sink trajectory

OLD ESTIMATES

CO_2 sink Trend = **1.4 TgC yr-^{1}**

1996-2007 period

Manizza *et al*, GBC, 2013

NEW ESTIMATES

CO_2 sink Trend = **-3.6 TgC yr-^{1}**

2006-2012 period

Manizza *et al*, In Prep

Decrease in the CO_2 Uptake Capacity in an Ice-Free Arctic Ocean Basin

Wei-Jun Cai,[1*] Liqi Chen,[2] Baoshan Chen,[1] Zhongyong Gao,[2] Sang H. Lee,[3] Jianfang Chen,[4] Denis Pierrot,[5,6] Kevin Sullivan,[5,6] Yongchen Wang,[1] Xinping Hu,[1] Wei-Jen Huang,[1] Yuanhui Zhang,[2] Suqing Xu,[2] Akihiko Murata,[7] Jacqueline M. Grebmeier,[8] E. Peter Jones,[9] Haisheng Zhang[4]

(Science, 2010)

Future Directions

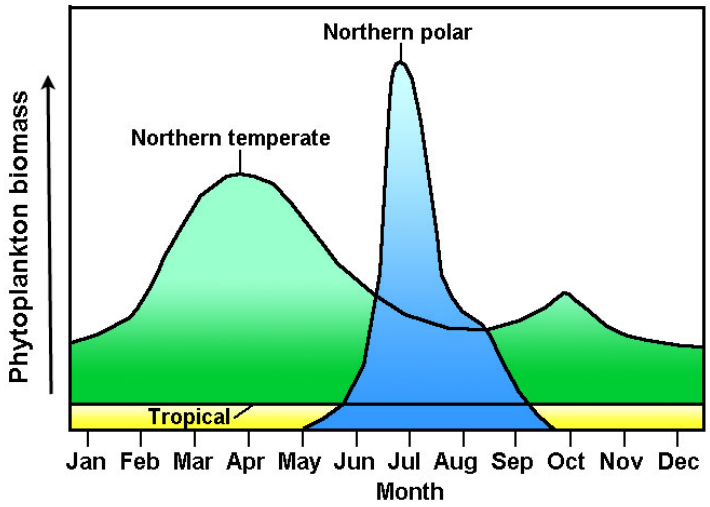
New ECCO-Darwin

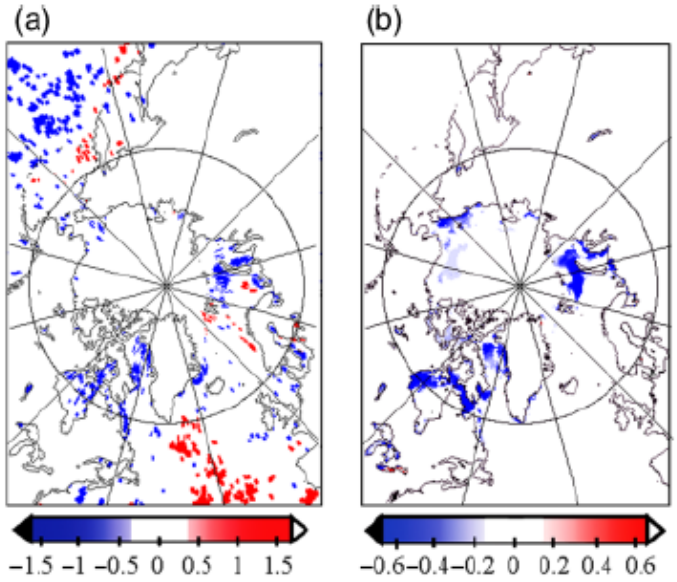
LLC270 1992-2015

>2 decades of CO_2 sink

Long term trend

Changes in AO phytoplankton blooms

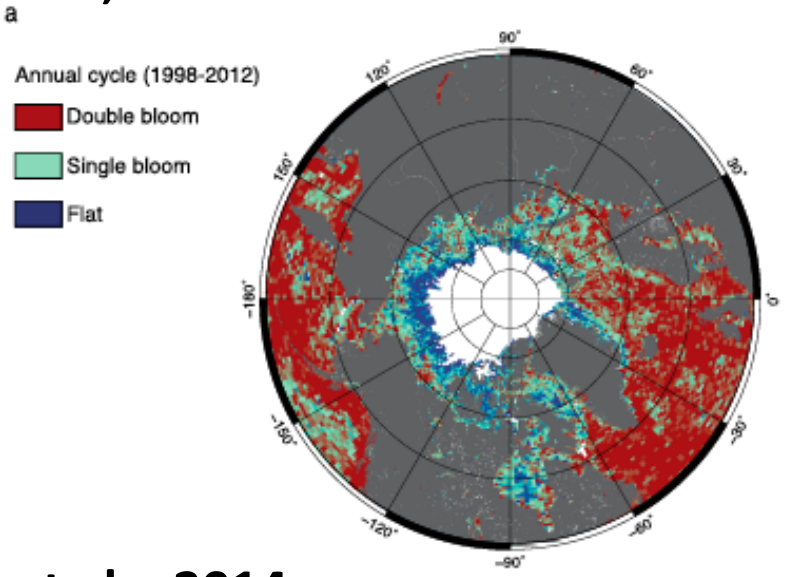




Kahru et al., 2008

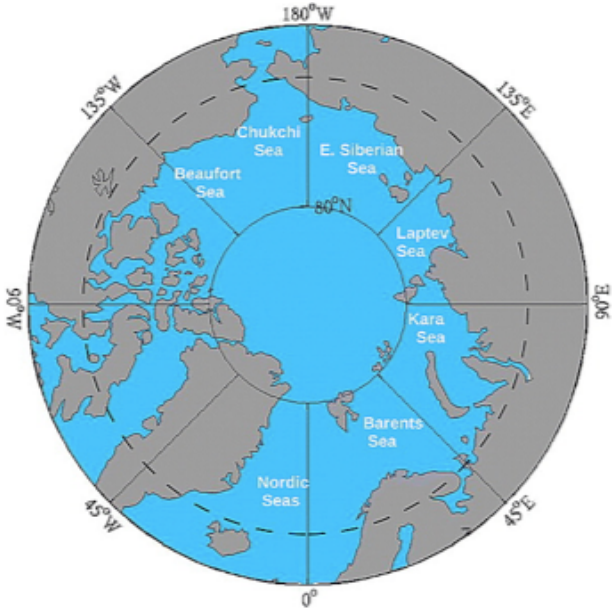
Earlier sea-ice melting
Delayed sea-ice formation

Changes in sea-ice drive changes in phytoplankton blooms

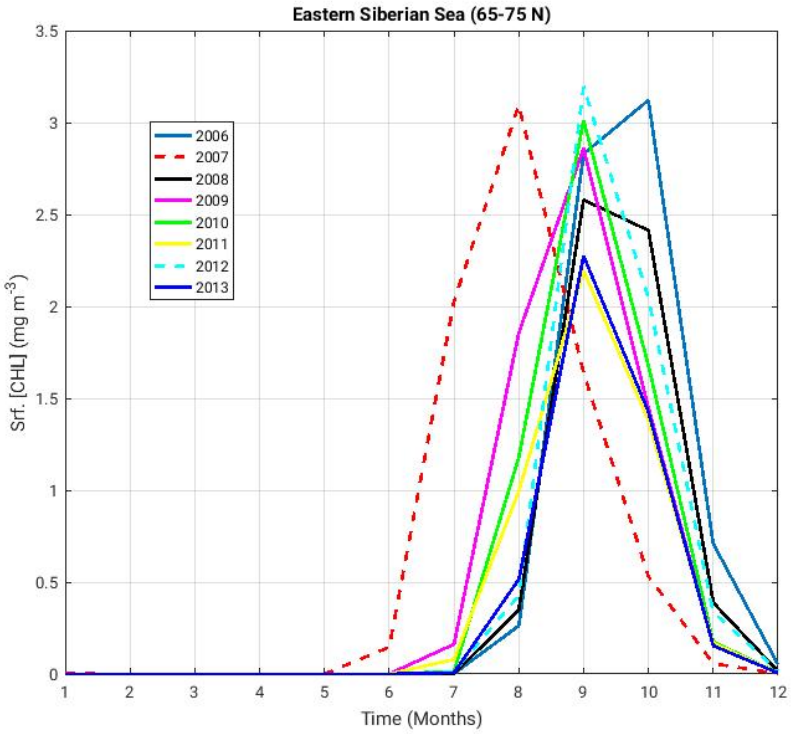


Ardyna et al., 2014

Simulated changes in AO phytoplankton blooms

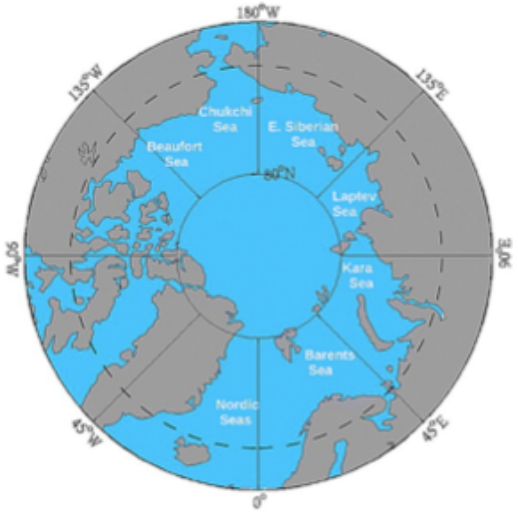


Earlier Phytoplankton Bloom

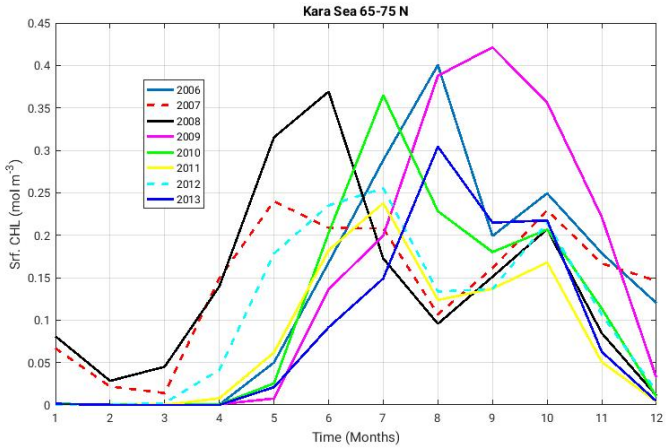


ECCO2-Darwin

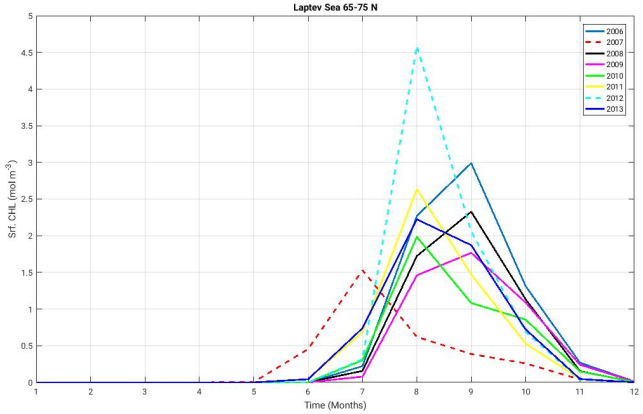
New fall phytoplankton blooms in AO

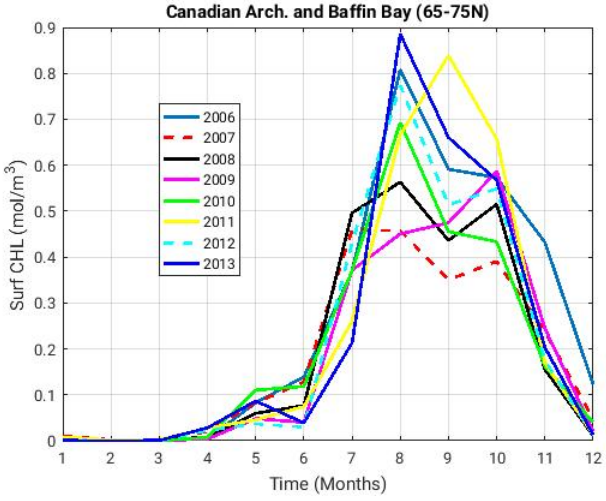


Kara Sea

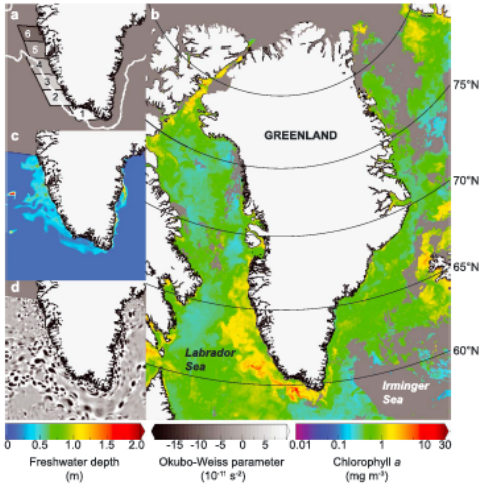


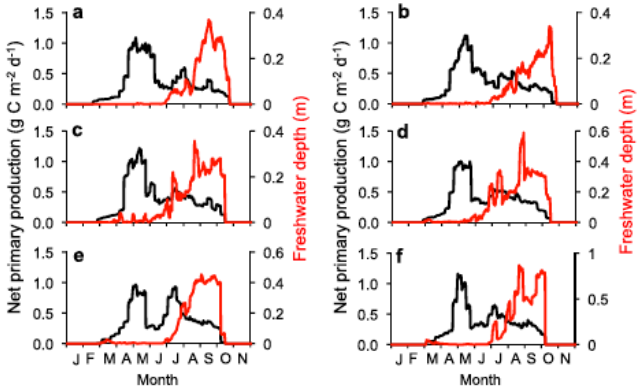
Laptev Sea





Future Work (Interaction with ice-sheets)





AGU PUBLICATIONS

Geophysical Research Letters

Melting glaciers stimulate large summer phytoplankton blooms in southwest Greenland waters

Kevin R. Arrigo[1], Gert L. van Dijken[1], Renato M. Castelao[2], Hao Luo[2], Åsa K. Rennermalm[3], Marco Tedesco[4,5], Thomas L. Mote[6], Hilde Oliver[2], and Patricia L. Yager[2]

Conclusions

Recent simulations show unexpected response of the AO CO_2 sink to severe sea-ice loss (2007 vs 2012).

ECCO2-Darwin captures main biogeochemical & ecological processes occurring in the AO.

Longer simulated periods are needed in order to compare to the observed changes in CO_2 sink and phytop. blooms
➔ New runs with Darwin coupled to LLC270 for the 1992-2015 period (link to I. Fenty's work).

Future coupling polar oceans and icesheets to explore the response of bgc and ecology to increasing freshwater and chemical forcing driven by climate change.