

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

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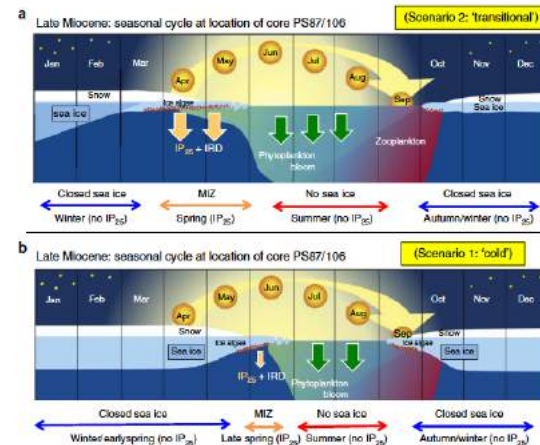
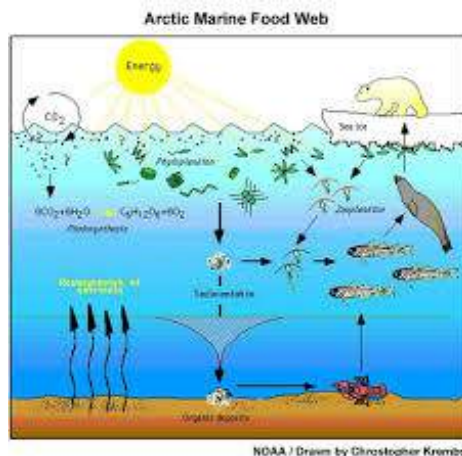
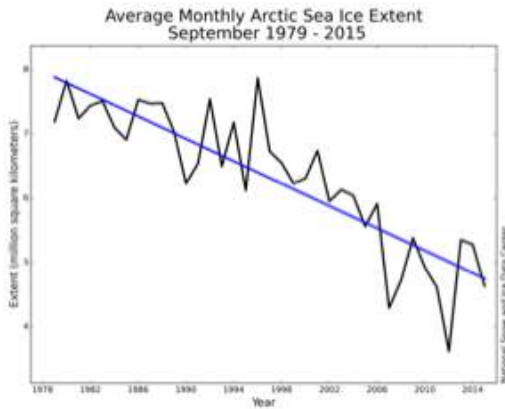
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# OUTLINE

- 1) Recent Changes in Arctic Climate and Sea-Ice**
- 2) Modeling Tools : ECCO2-Darwin**
- 3) Response of CO<sub>2</sub> 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

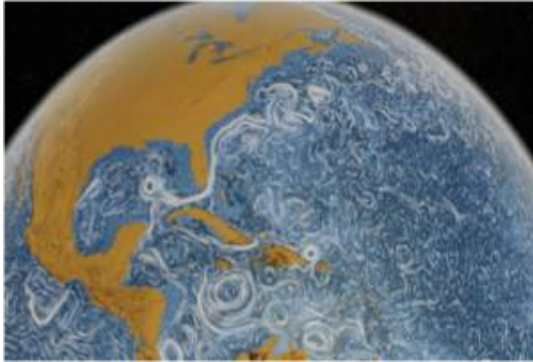
Present

Stein et al., 2016

Q1: What is the response of CO<sub>2</sub> uptake of the Arctic Ocean ?

Q2: What is the response of phytoplankton dynamics ?

# ECCO2-Darwin



+



**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)**

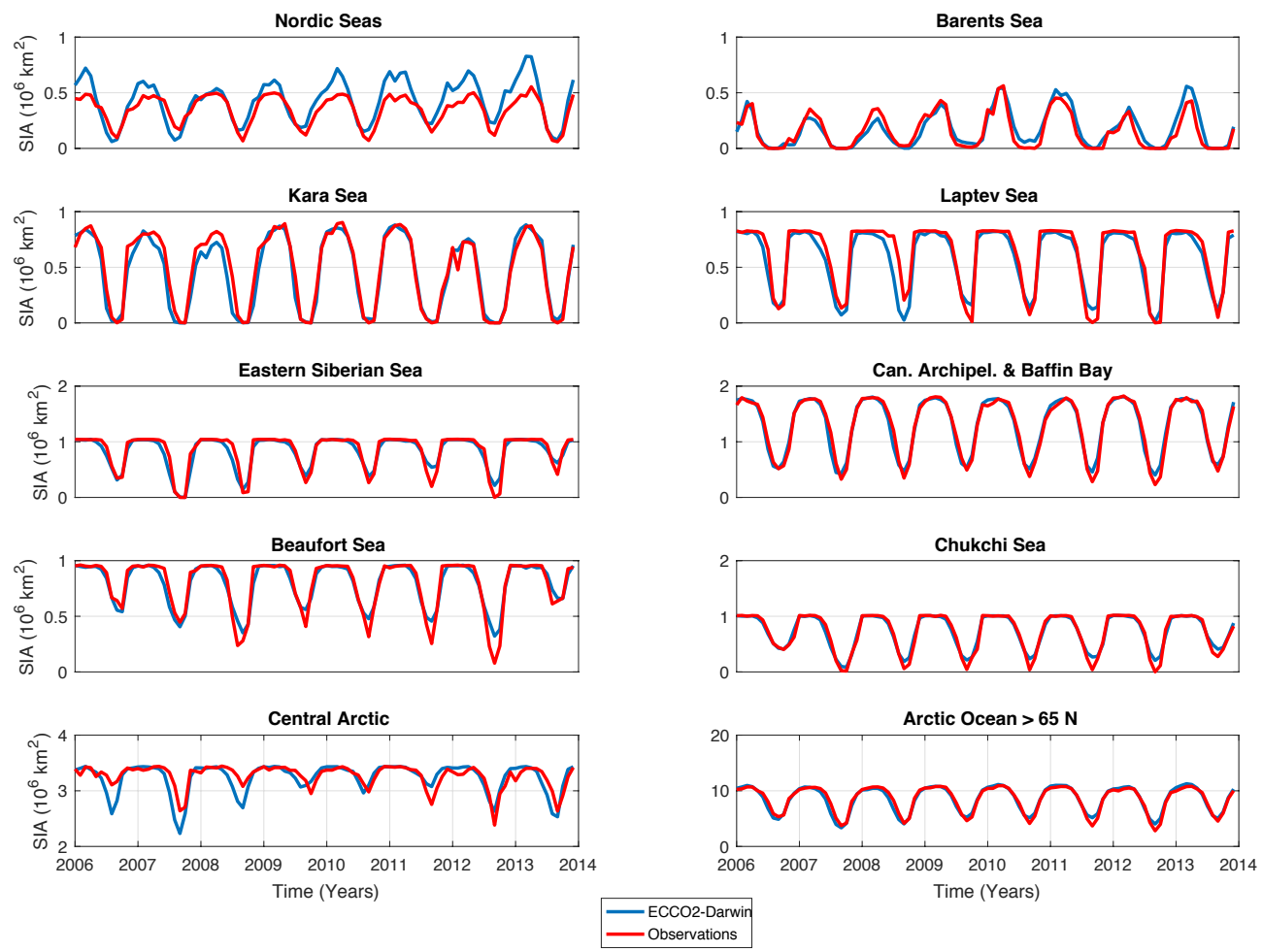
**5 phytoplankton groups  
(only 3 survive in the AO)**

**2 zooplankton groups  
(micro & meso)**

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

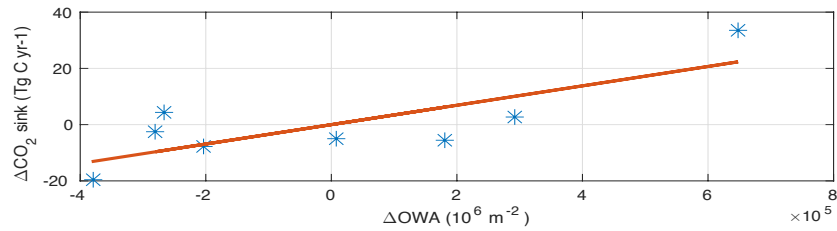
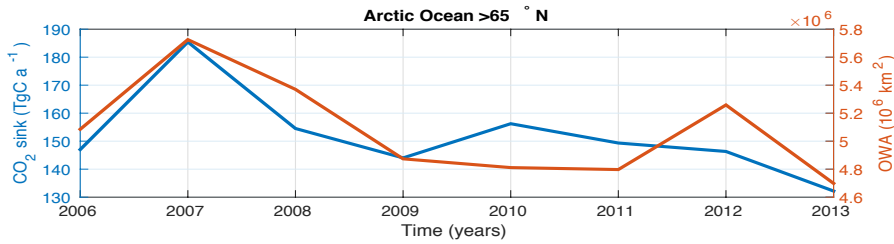
**Increasing atmospheric pCO<sub>2</sub>  
2004-2013  
“Keeling Curve”**

# Response of Sea-Ice to recent Climate Forcing



# Arctic Ocean Carbon Cycle Response

## Open Water Area & CO<sub>2</sub> sink



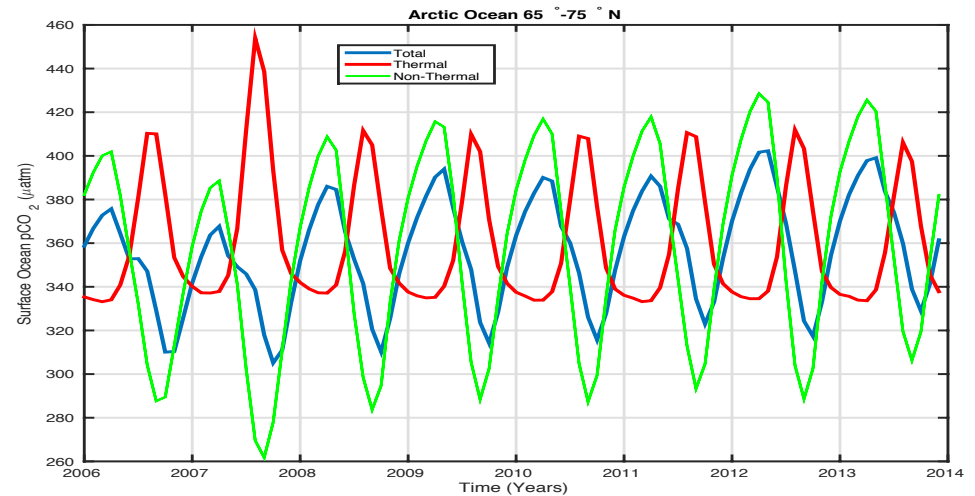
**2006-2008** : Direct relationship  
OWA and CO<sub>2</sub> sink (Bio C-pump rules !).

**2009-2011** : Decoupling OWA  
and CO<sub>2</sub> sink (Barents and Nordic  
Seas dominate).

**2012** : Decoupling OWA and CO<sub>2</sub>  
sink (Wind speed).

CO<sub>2</sub> sink Trend = -3.6 TgC yr<sup>-1</sup>

## CARBON PUMPS VARIABILITY

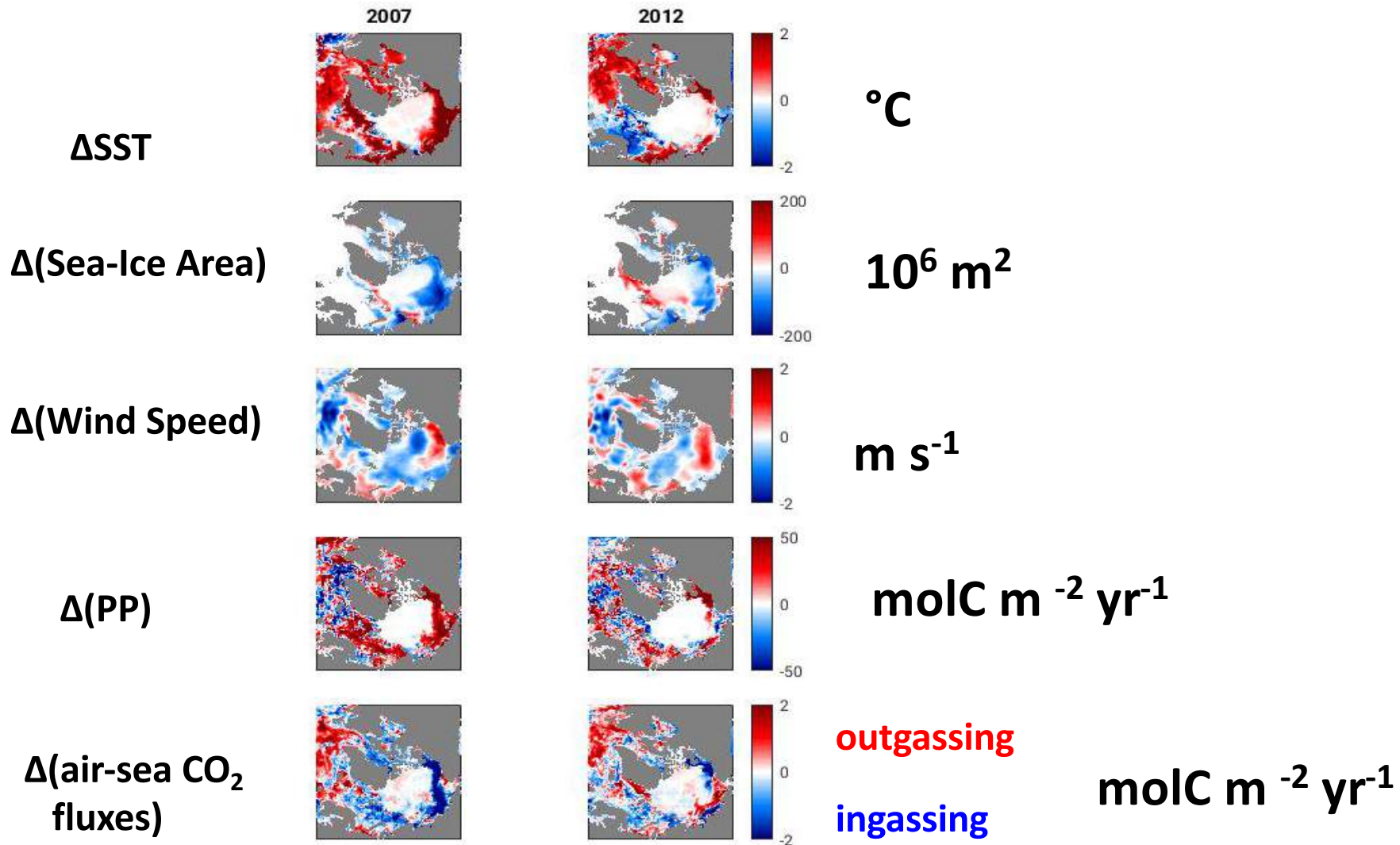


**Solubility Pump**

**Biological Pump + Winter Mixing**

# AO CO<sub>2</sub> sink response: 2007 vs 2012

Anomalies May- November Average



# Arctic Sea-Ice Area & CO<sub>2</sub> sink trajectory

## OLD ESTIMATES

CO<sub>2</sub> sink Trend = **1.4 TgC yr<sup>-1</sup>**

1996-2007 period

Manizza *et al*, GBC, 2013

## Decrease in the CO<sub>2</sub> Uptake Capacity in an Ice-Free Arctic Ocean Basin

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

(Science, 2010)

## NEW ESTIMATES

CO<sub>2</sub> sink Trend = **-3.6 TgC yr<sup>-1</sup>**

2006-2012 period

Manizza *et al*, In Prep

## Future Directions

New ECCO-Darwin

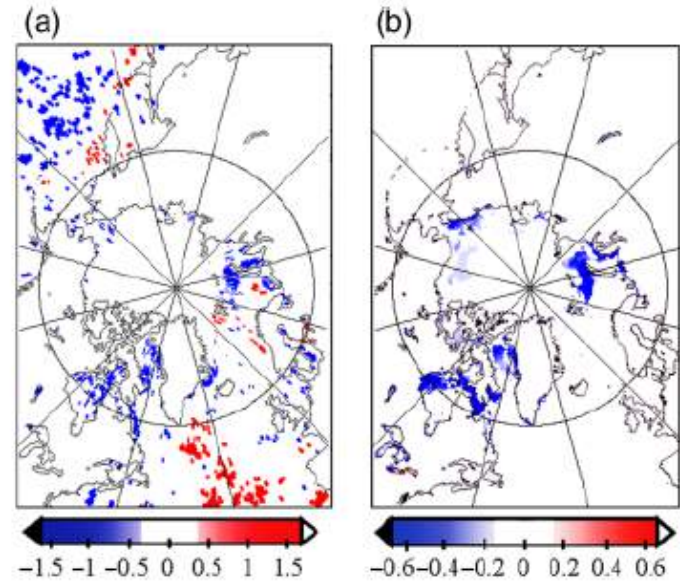
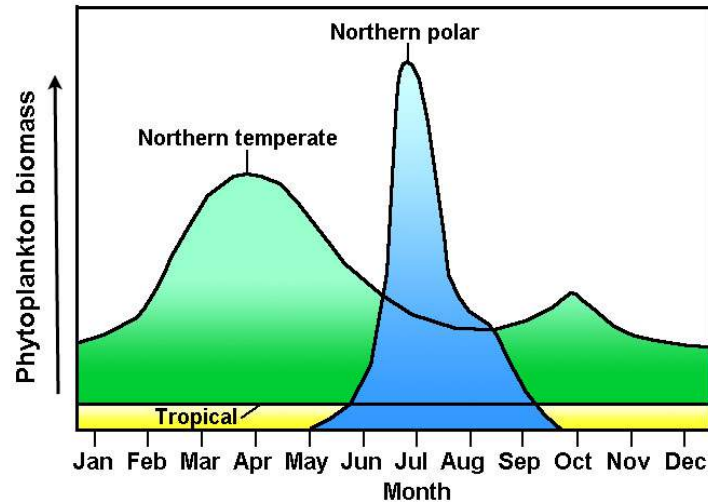
LLC270 1992-2015

>2 decades of CO<sub>2</sub> sink

Long term trend



# Changes in AO phytoplankton blooms

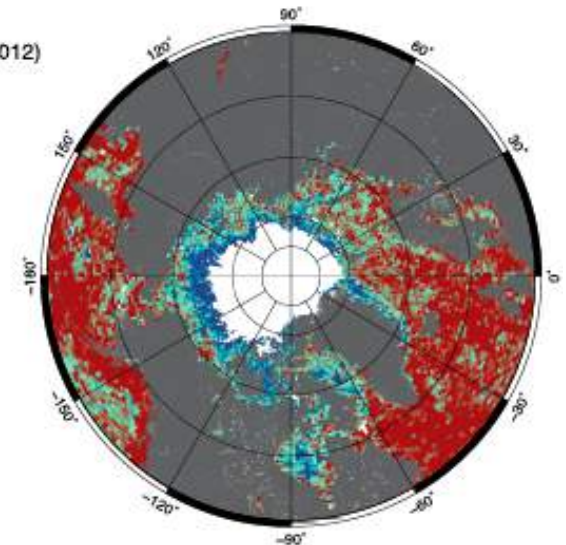


Kahru et al., 2008

a

Annual cycle (1998-2012)

- Double bloom
- Single bloom
- Flat

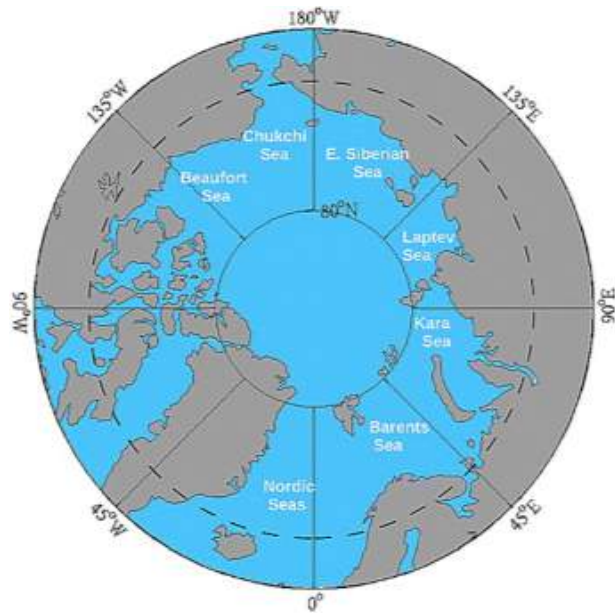


Earlier sea-ice melting  
Delayed sea-ice formation

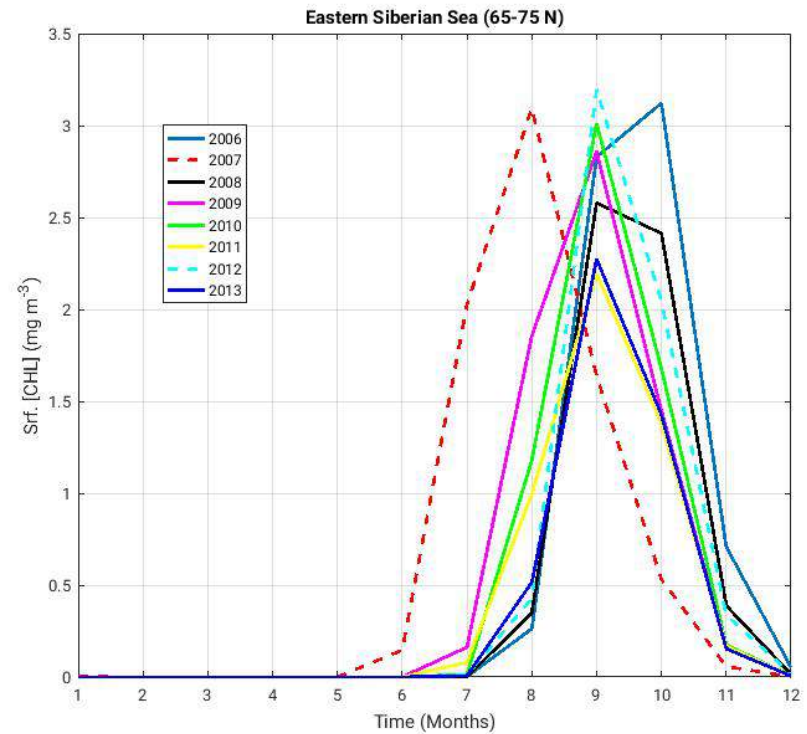
Changes in sea-ice drive changes  
in phytoplankton blooms

Ardyna et al., 2014

# Simulated changes in AO phytoplankton blooms

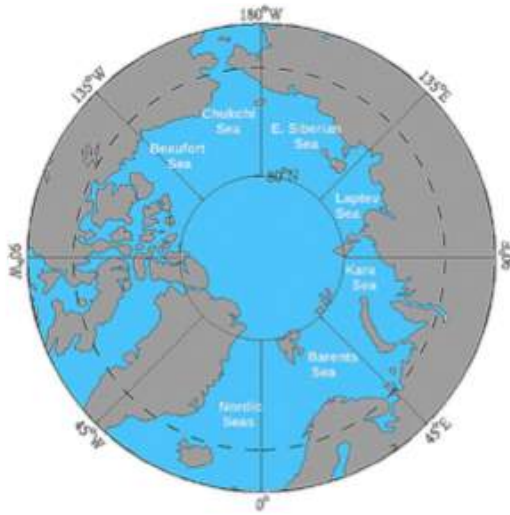


## Earlier Phytoplankton Bloom

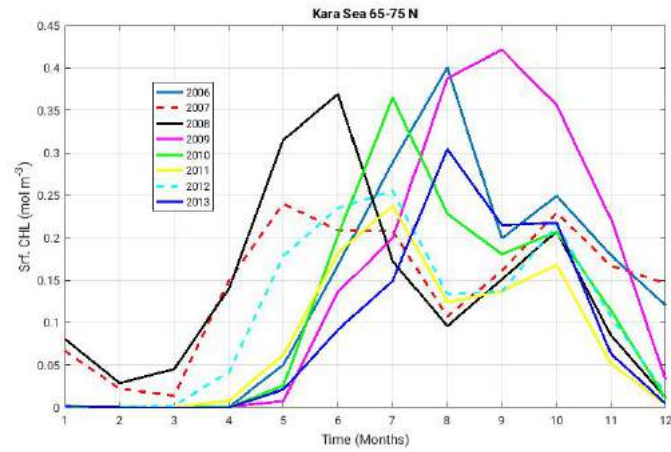


ECCO2-Darwin

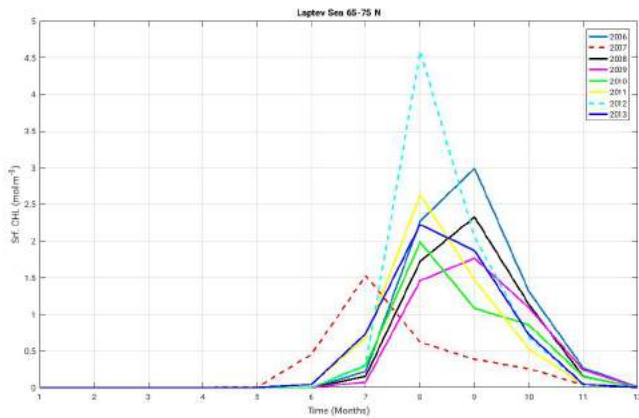
# New fall phytoplankton blooms in AO



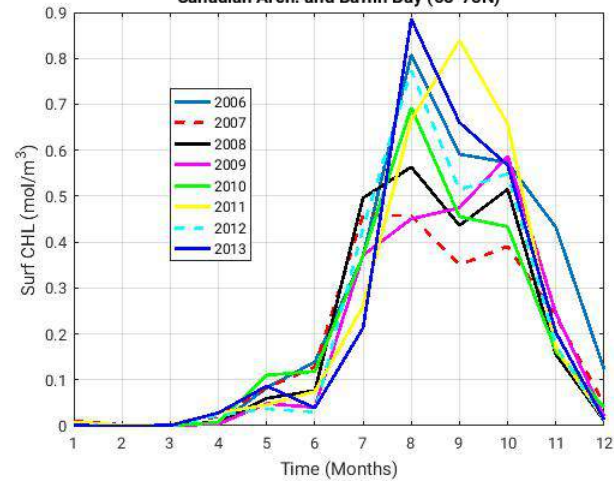
## Kara Sea



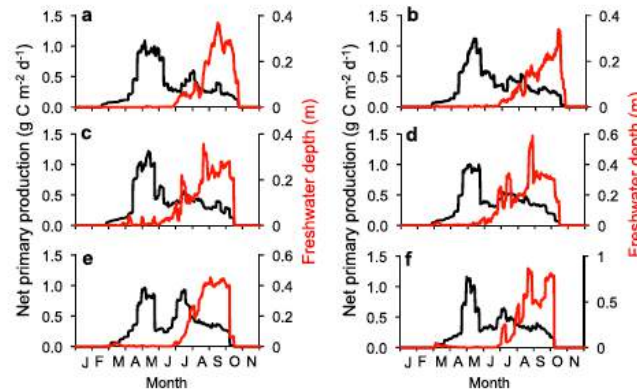
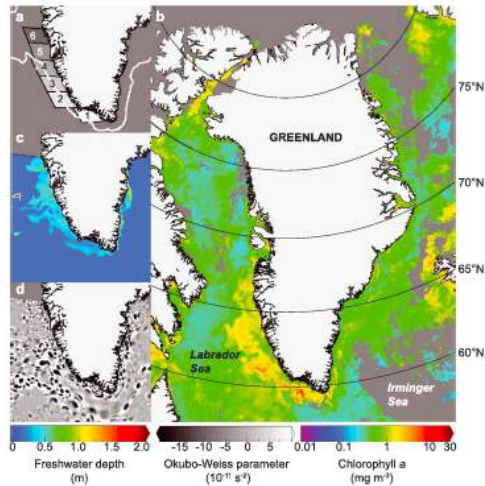
## Laptev Sea



## Canadian Arch. and Baffin Bay (65-75N)



# 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<sup>1</sup>, Gert L. van Dijken<sup>1</sup>, Renato M. Castelao<sup>2</sup>, Hao Luo<sup>2</sup>, Åsa K. Rennermalm<sup>3</sup>, Marco Tedesco<sup>4,5</sup>, Thomas L. Mote<sup>6</sup>, Hilde Oliver<sup>2</sup>, and Patricia L. Yager<sup>2</sup>

# Conclusions

Recent simulations show **unexpected response** of the AO CO<sub>2</sub> 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<sub>2</sub> 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.**