海洋生態系モデリングシンポジウム@東大大気海洋研

Nov. 17, 2016

北極海生態系モデリングの現状と課題
～FAMOSプロジェクトの紹介～

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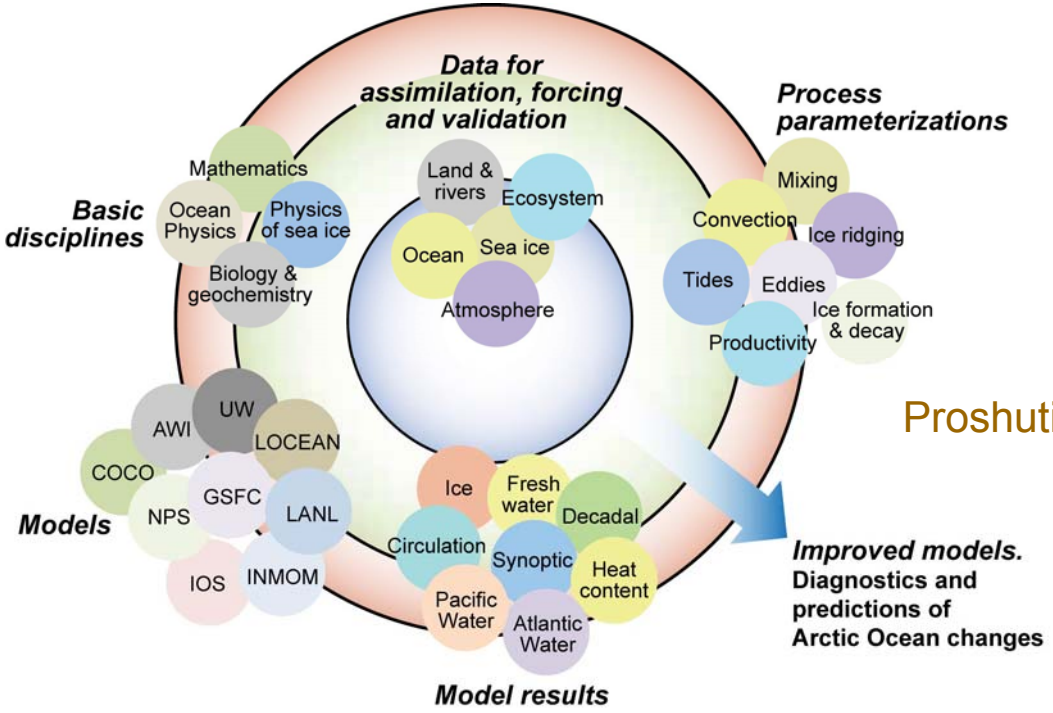
AOMIP Project

AOMIP (Arctic Ocean Model Intercomparison Project)

Phase 1 : 1999 ~ 2007 (JGR special issue)
Phase 2 : 2008 ~ 2012 (JGR special issue)



Proshutinsky et al. [2011]

FAMOS Project

FAMOS (Forum for Arctic Modeling and Observational Synthesis)

Phase 1 : 2013 ~ 2016 (JGR special issue)
Phase 2 : 2017 ~

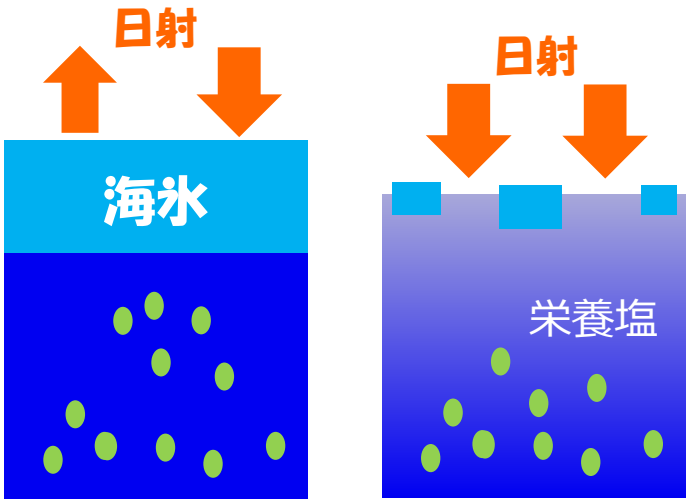
Working Group [Phase2]
1. Arctic Climate Response Functions
2. Bio-Geo-Eco
3. Eddies / Mixing / Internal Waves
4. Greenland & Gyres
5. Sea Ice
6. General Circulation
7. Regional-scale Oceanography and Ice-Ocean Interactions

Proshutinsky et al. [2016]

Impact of Sea Ice Decline

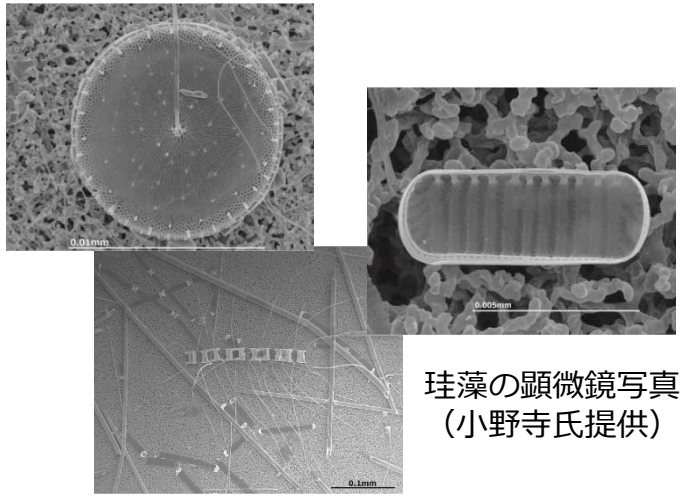
植物プランクトンの生産を支配する条件

- 光
  海氷が減ると日射が直接海面に入る
- 水温
  日射が入ることで海水が暖まる
- 栄養塩
  海氷の融け水によって濃度が低下する



植物プランクトンが増えるかどうかは
海域によって大きく異なる

動物プランクトンや魚にとっても
餌環境がどうなるのかが重要



珪藻の顕微鏡写真
（小野寺氏提供）

Model

Arctic Marine Ecosystem Modeling

北極海生態系に焦点を充てた３次元モデリング研究

Reference	Model Domain	Exp. Period	Keyword
Popova et al. [2010]	Global	Decade	Total PP
Zhang et al. [2010]	Arctic	Decade	Total PP
Jin et al. [2012]	Global	Decade	Ice algal PP
Dupont [2012]	Arctic	Decade	Ice algal PP
Popova et al. [2012]	Global / Arctic	Decade	Total PP (MIP)
Watanabe et al. [2012]	Arctic	Season	Eddy
Zhang et al. [2014]	Arctic	Decade	Cyclone
Watanabe et al. [2014]	Arctic	Season	Biogenic flux
Watanabe et al. [2015]	Arctic	Season	Ice algal flux
Jin et al. [2016]	Global / Arctic	Decade	Under-ice PP (MIP)
Steiner et al. [2016]	Global / Arctic	Decade	Subsurface Chl (MIP)

Model

Primary Productivity

Marine ecosystem models analyzed in Popova et al. [2012]

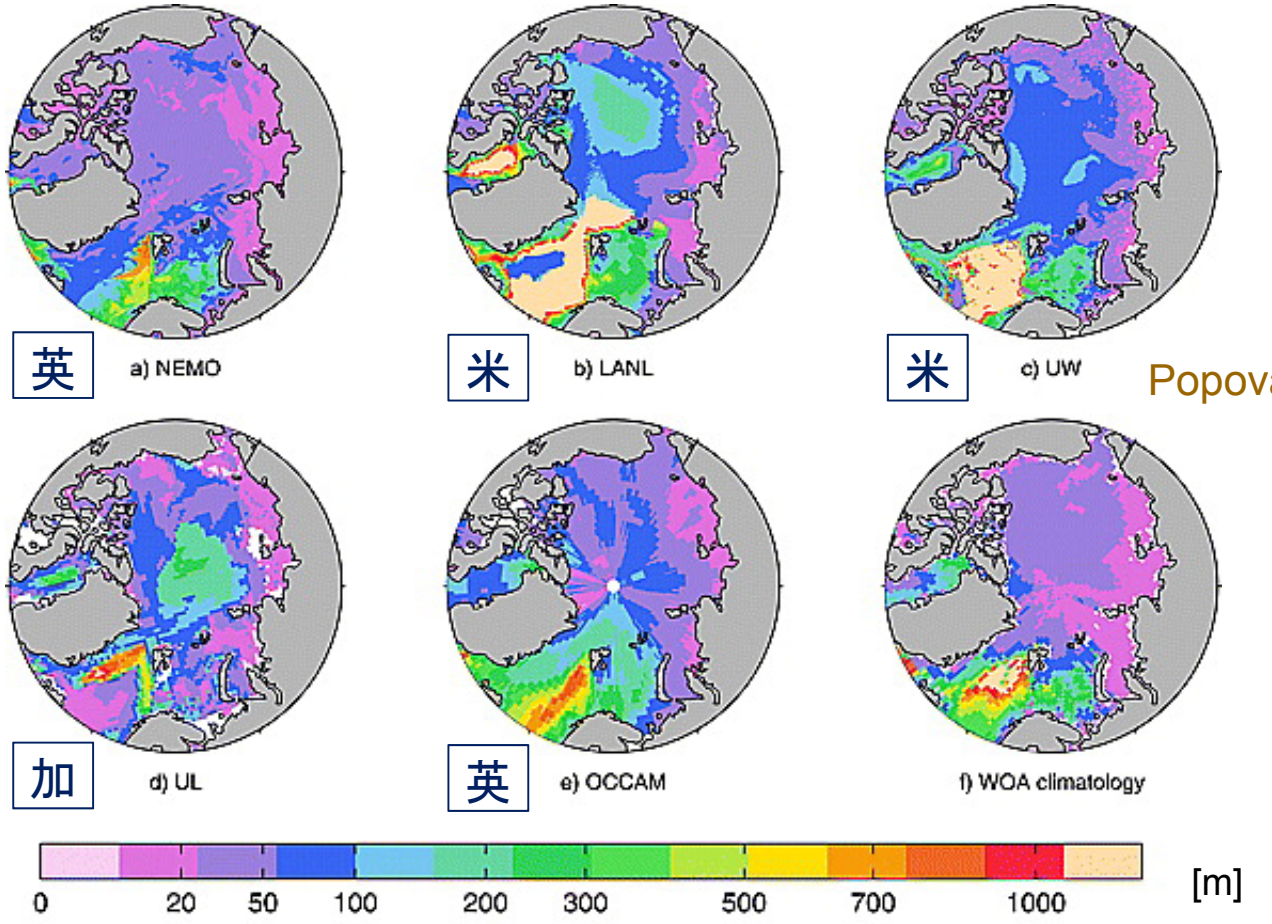
Model	Nation	Domain	Grid Size	Ecosystem		Nut Cycle
NEMO	UK	Global	5 ~ 15 km	MEDUSA	11	N, Si, Fe
LANL	USA	Global	23 ~ 62 km	BEC	24	N, Si, P, Fe
UW	USA	Arctic	5 ~ 30 km	NEMURO	11	N, Si
UL	Canada	Arctic	55 km	NPZD	4	N
OCCAM	UK	Global	111 km	NPZD	4	N

まずは北極海全域の基礎生産量をとにかく比較してみた

- モデル間のバラつきを知っておくことは改良の参考になる
- 混合層深度の違いが有光層の栄養塩濃度や基礎生産量に反映されている
- 海洋物理モデルの成層構造の再現性を高める必要がある

Result

Mixed Layer Depth

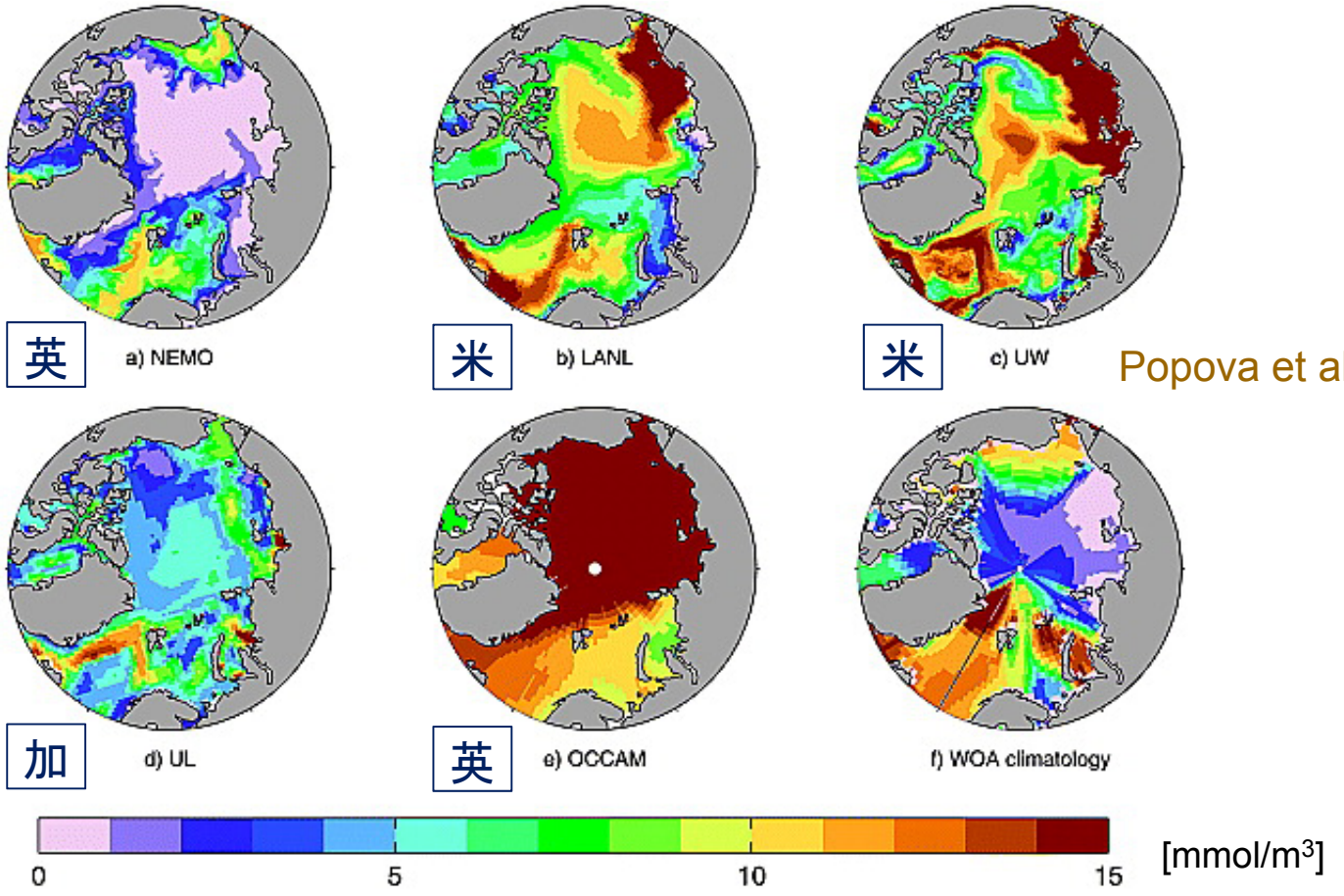


Popova et al. [2012]

Excessive vertical mixing is an important factor for model biases

Result

Nutrient Availability

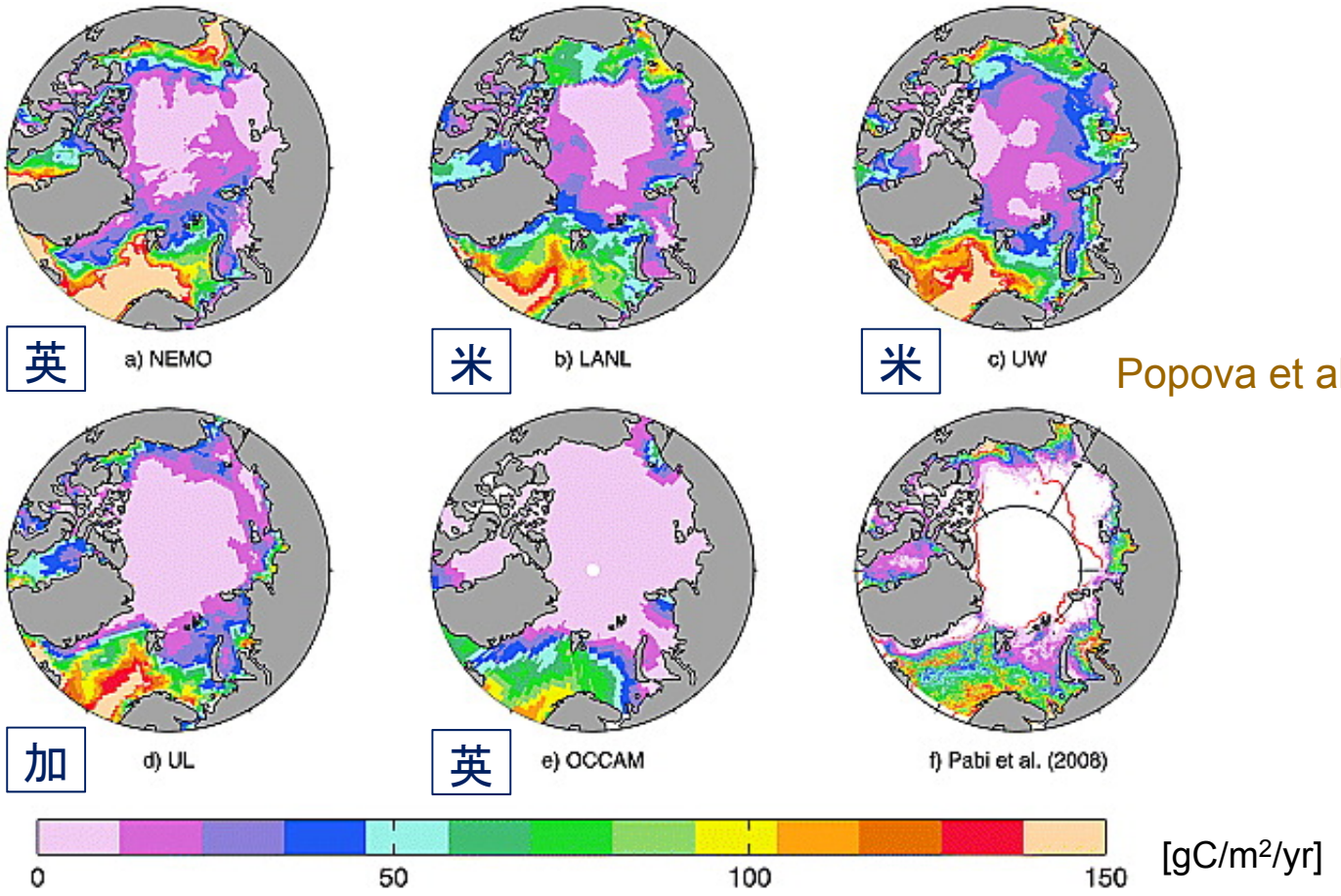


Popova et al. [2012]

Nitrate maximum is unrealistically simulated in the central Arctic basin

Result

Annual Primary Production



Popova et al. [2012]

Primary productivity in shelf region widely differs between models

Model

Under-Ice Phytoplankton Bloom

Marine ecosystem models analyzed in Jin et al. [2016]

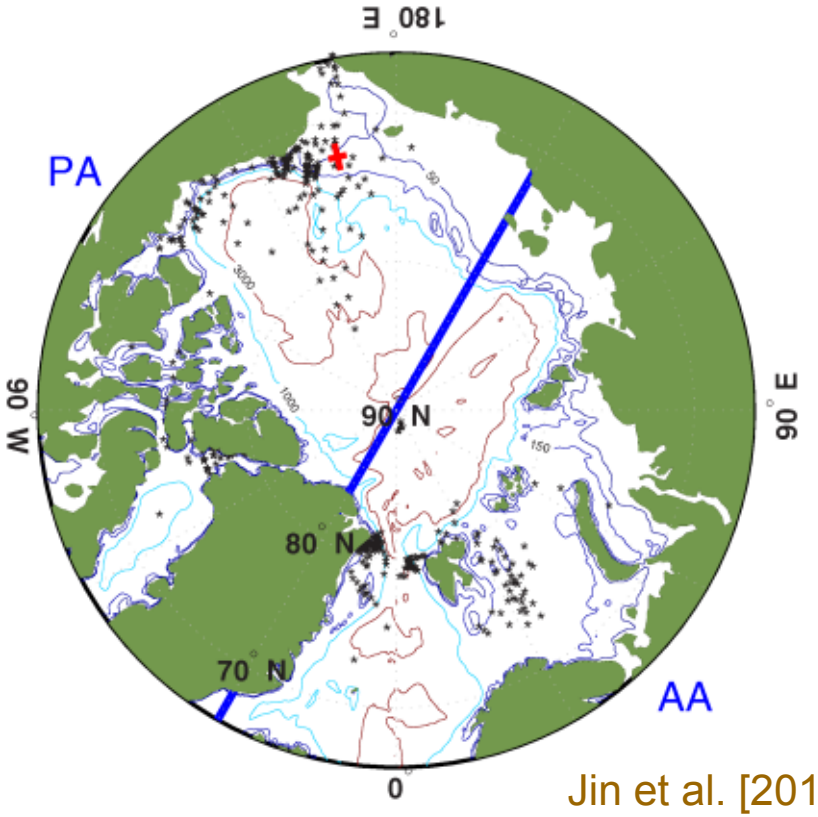
Model	Nation	Domain	Grid Size	Ecosystem		Nut Cycle
NEMO	UK	Global	30 km	MEDUSA	11	N, Si, Fe
LANL	USA	Global	30 ~ 50 km	UAF	12	N, Si, P, Fe
UW	USA	Arctic	2 ~ 100 km	NEMURO	11	N, Si

海氷下の基礎生産量を比較してみた

- 海氷縁後退前に植物プランクトンブルームが始まっている
- 海氷域での光の透過率の違いも基礎生産量のバラつきに反映される
- メルトポンドによるアルベド変化も精度良く計算する必要がある
- 人工衛星からの推定値を上方修正する必要がある

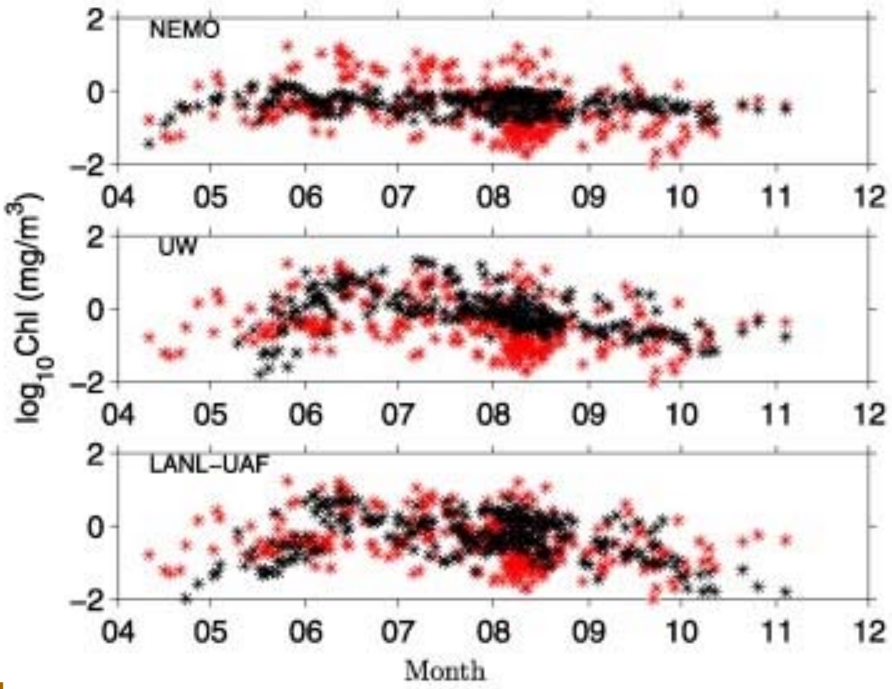
Result

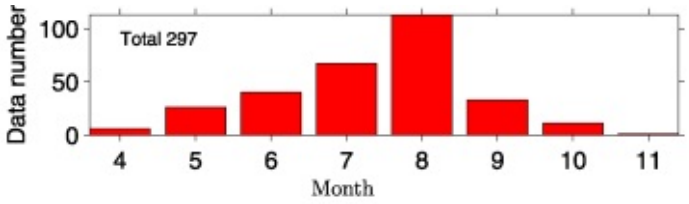
Under-Ice Chlorophyll



Jin et al. [2016]

Chlorophyll at sampling locations

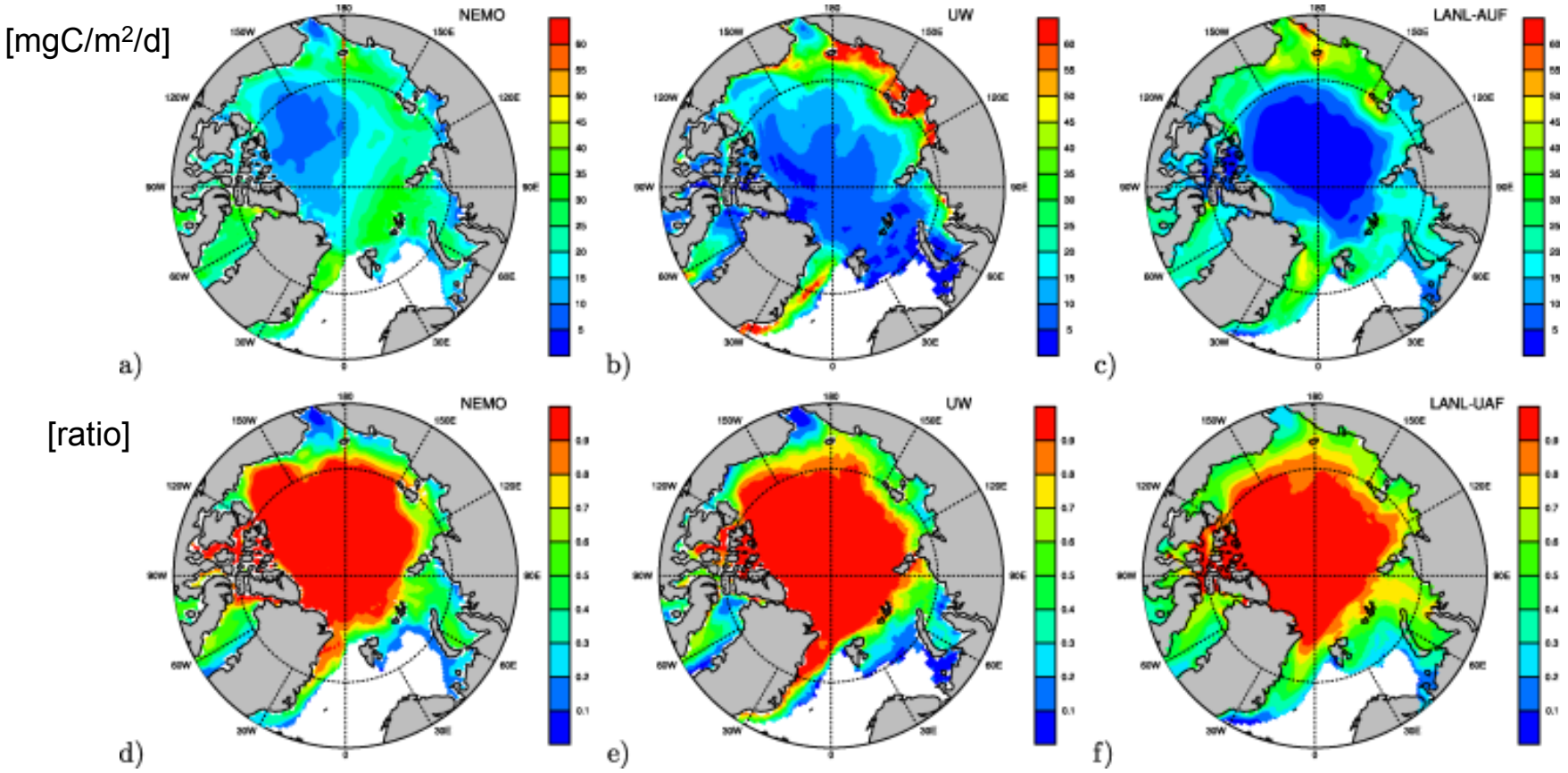




Modeled chlorophyll has smaller variability

Result

Under-Ice Primary Production



Jin et al. [2016]

Primary productivity in shelf region depends on ice-covered period

Model

Subsurface Chlorophyll Maximum

Marine ecosystem models analyzed in Steiner et al. [2016]

Model	Nation	Domain	Ecosystem	
CanESM	Canada	Global	ESM2	NPZ
GFDL	USA	Global	ESM2	N4P3
HadGEM2	UK	Global	ES	N3P2Z
IPSL	France	Global	CMSA	N5P2Z2
MPI	Germany	Global	ESM	N3PZ
MIROC	Japan	Global	ESM	NPZ
LANL	USA	Global	UAF	N4P3Z2
NEMO	UK	Global	MEDUSA	N3P2Z2
NAA	Canada	Arctic	CMOC	NPZ

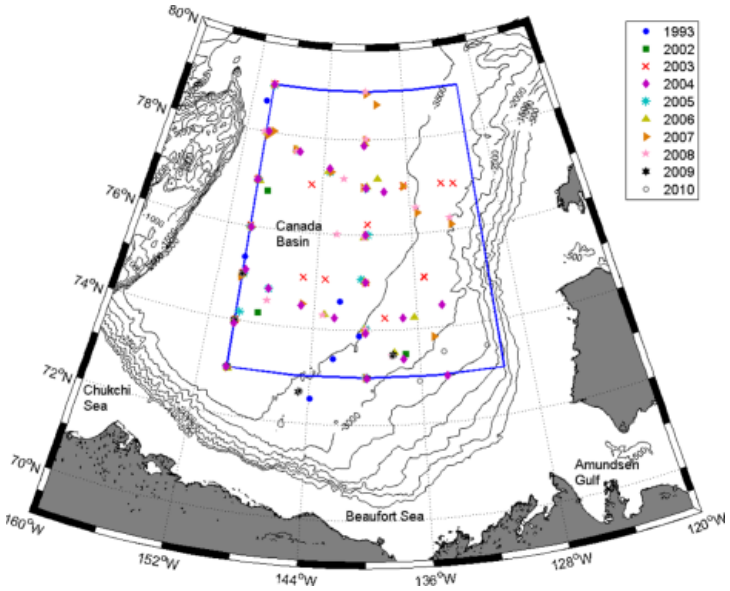
亜表層クロロフィル極大を比較してみた

- 光と栄養塩に対する依存性がうまくバランスしなければ再現できない

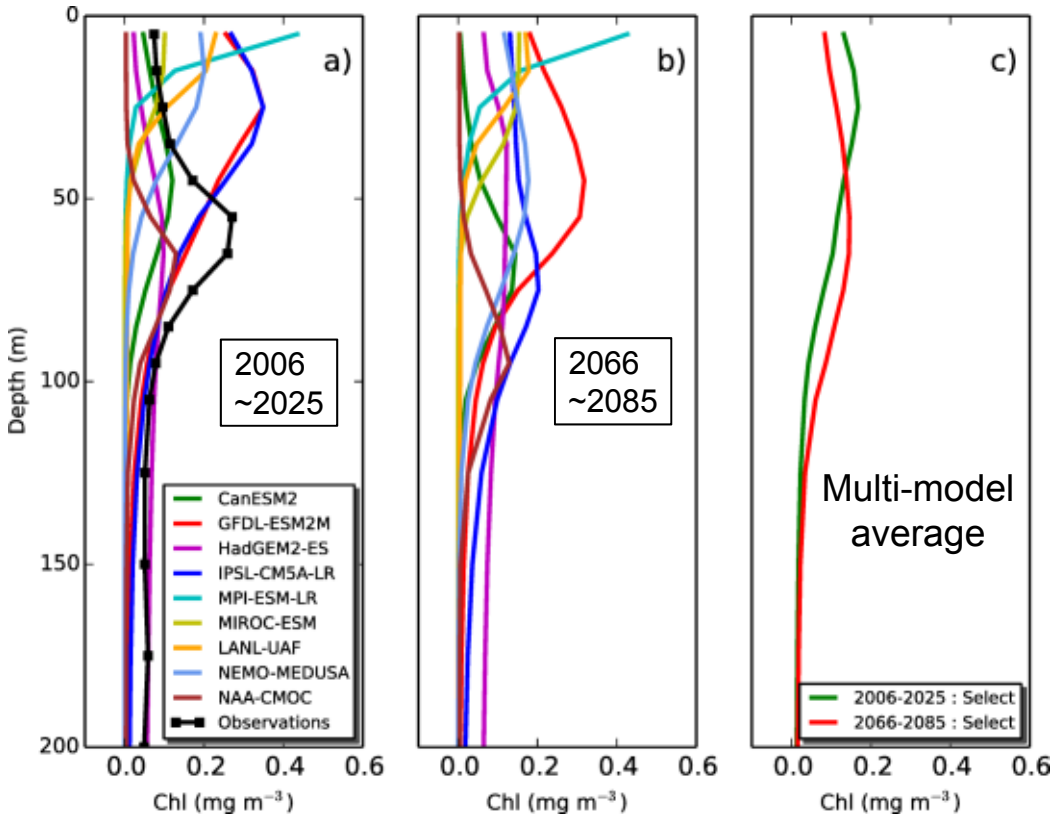
Result

Subsurface Chlorophyll Maximum

Vertical chlorophyll profile averaged in the Canada Basin



Steiner et al. [2016]

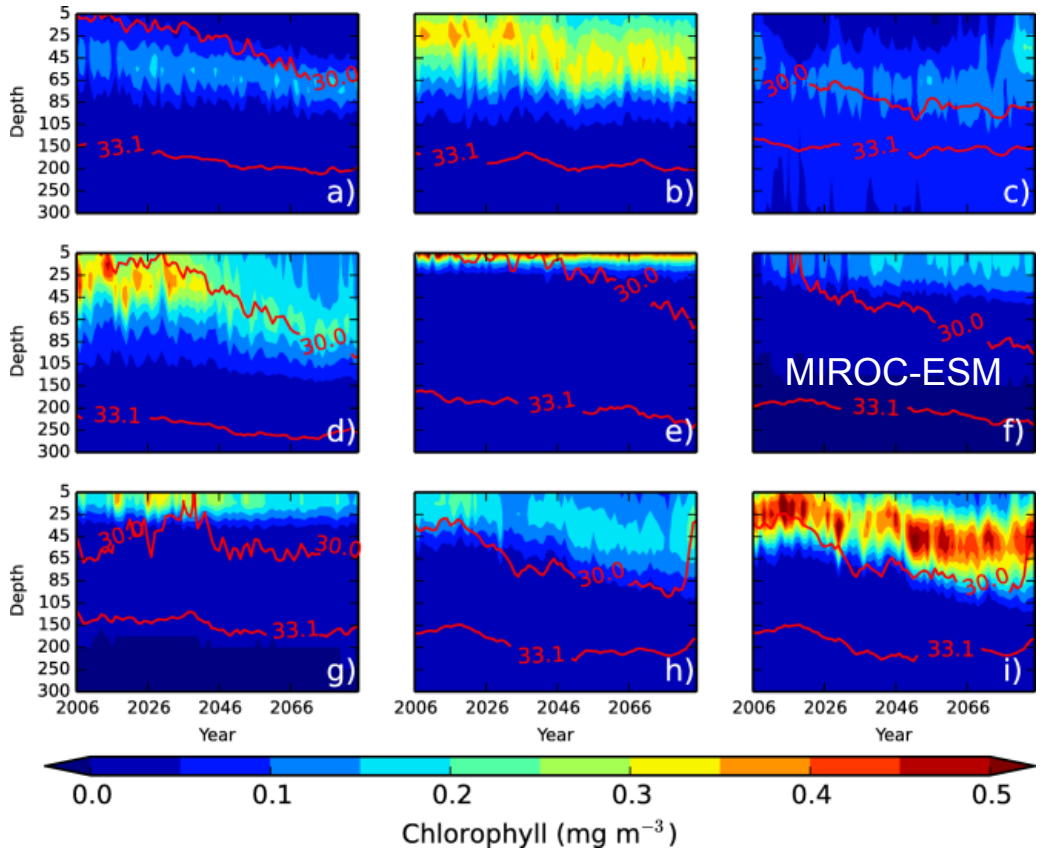


Modeled SCM is located at shallower depths or missing

Result

Subsurface Chlorophyll Maximum

Decedal trend in the modeled chlorophyll in the Canada Basin



Steiner et al. [2016]

Enhanced sea ice melting and Ekman pumping will deepen the SCM

Model

Ocean Acidification

Marine ecosystem models analyzed in Steiner et al. [2014]

Model	Nation	Domain	Ecosystem	
CanESM	Canada	Global	ESM2	NPZ
GFDL	USA	Global	ESM2M	N4P3
HadGEM2	UK	Global	ES	N3P2Z
IPSL	France	Global	CM5A	N5P2Z2
MPI	Germany	Global	ESM	N3PZ
MIROC	Japan	Global	ESM	NPZ

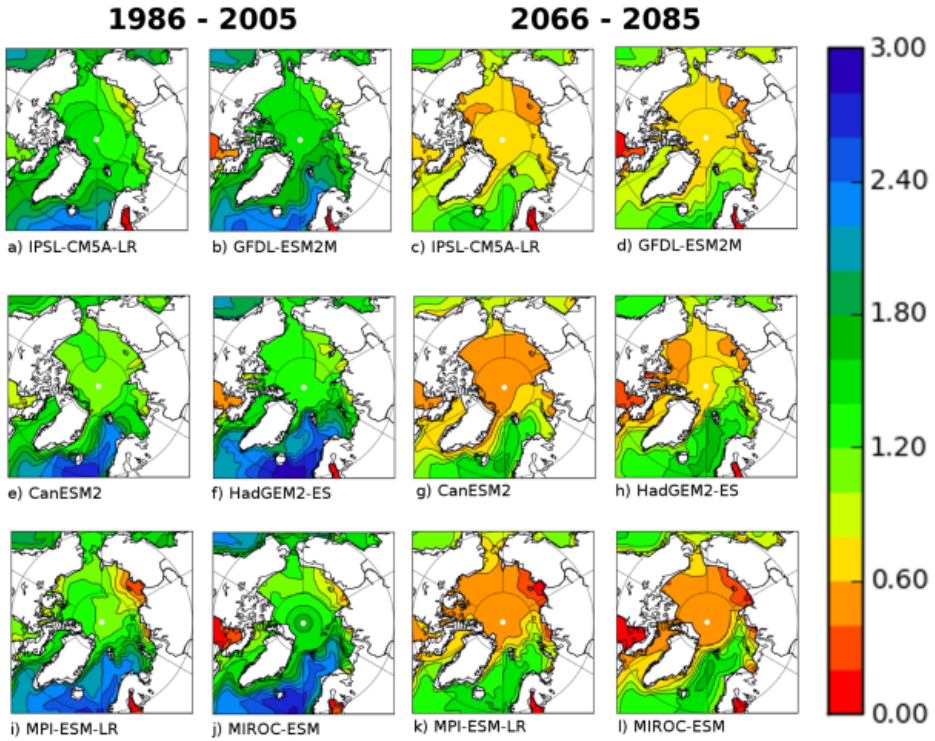
炭酸カルシウム飽和度を比較してみた

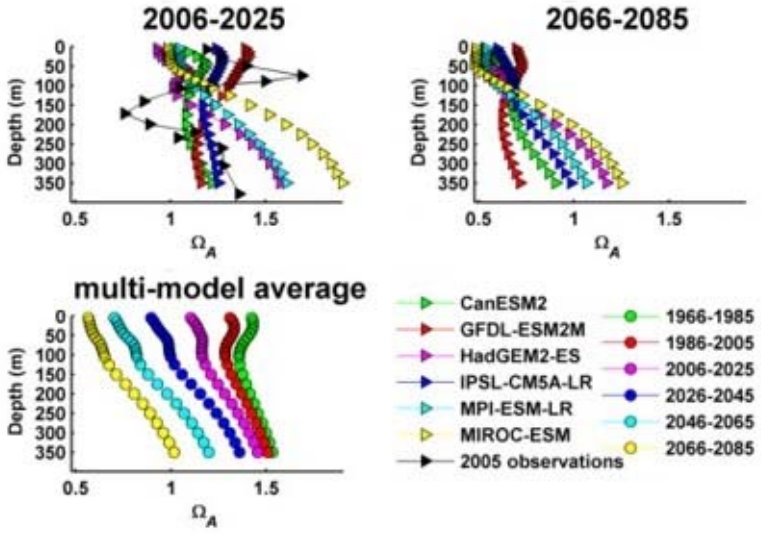
- 北極海は世界で最も酸性化が進行している海域の１つ
- 冬季陸棚水が流入する亜表層で深刻なバイアスが生じている
- 格子間隔の粗い地球システムモデルでは陸棚海盆間輸送の再現性が鍵を握る

Result

CMIP5 Future Projection

CMIP5 future projection of calcium carbonate saturation rate (Ω_{arg})



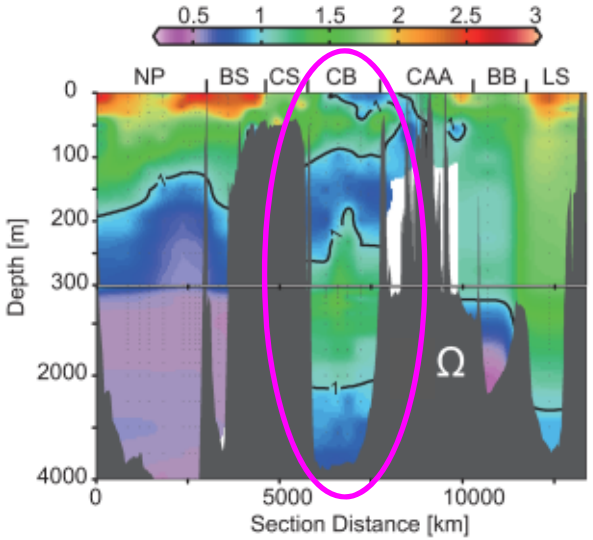


Steiner et al. [2014]

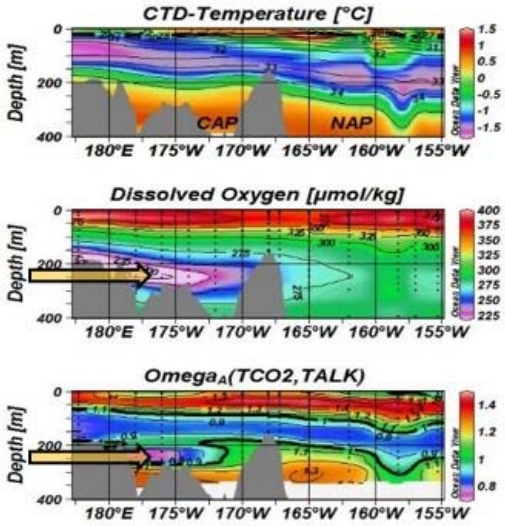
Reasonable trend in ocean surface Ω_{arg}, but crucial bias in vertical profile

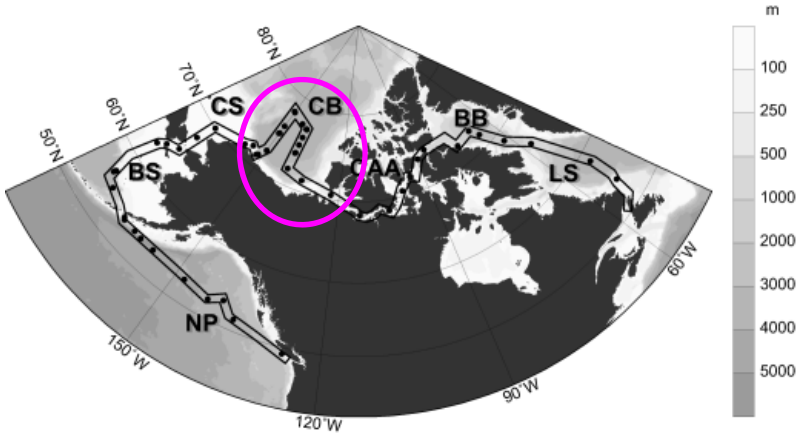
Discuss

Dense Shelf Water Intrusion



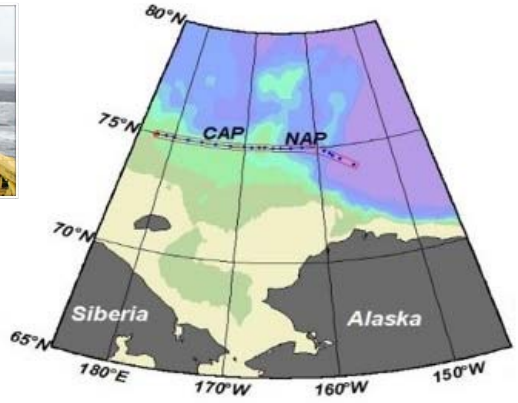
Intrusion of DSW (low Ω_{arg}) is important





Yamamoto-Kawai et al. [2013]

R/V Mirai



Nishino [per. comm.]

New Project in FAMOS-2

1. Multiple ecosystem models in same physical model (N. Steiner)
2. Same ecosystem model in multiple physical models (G. Castellani)
3. Ice PP model intercomparison 3-D (E. Watanabe)
4. Ice PP feedbacks on ice physics (TBD)
5. Ice PP model intercomparison 1-D (L. Tedesco)
6. Different resolution in same physical-ecosystem model (K. Popova)
7. F-ratio, export production (A. Randelhoff)
8. Under-ice production with ice-tethered profilers (N. Steiner)
9. Parameterization of light transparency (TBD)