Modeling the ecological and biogeochemical changes of the Arctic Ocean caused by the recent decline of sea-ice

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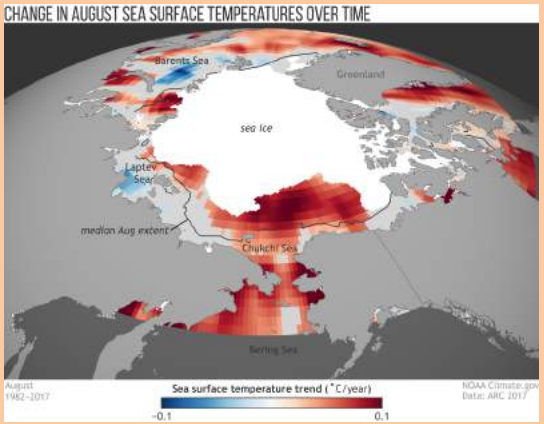
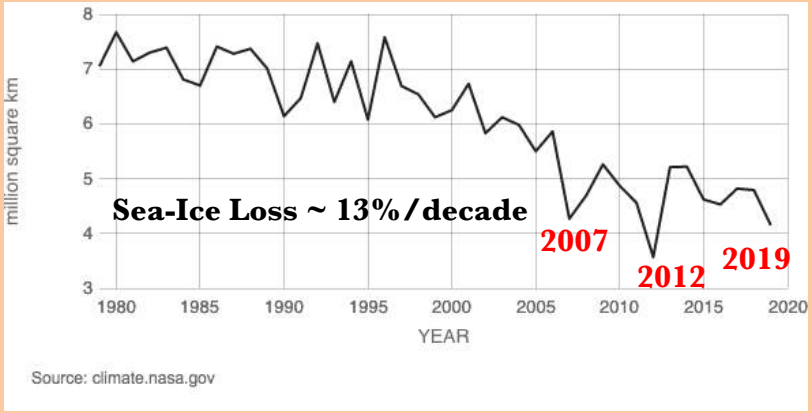
Arctic Climate Change

Summer SST warming

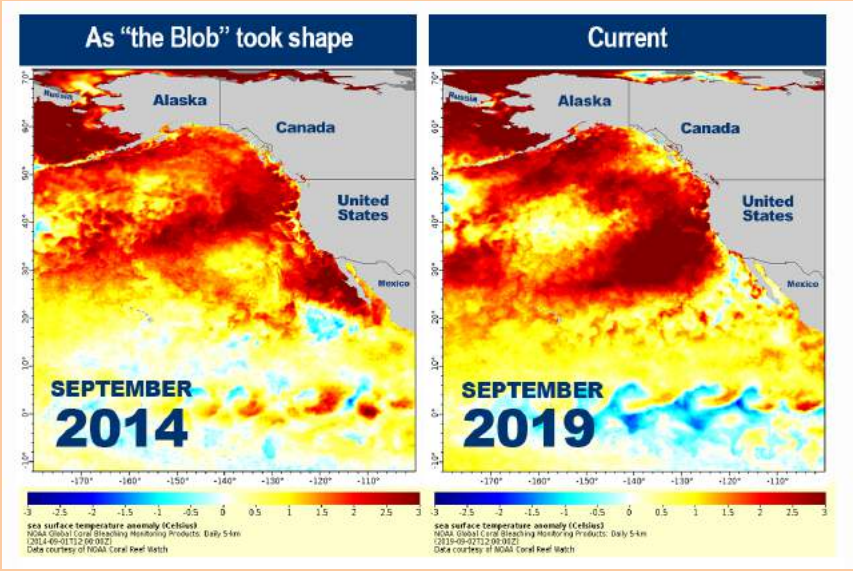


(noaa.gov)

September Sea-Ice Extent

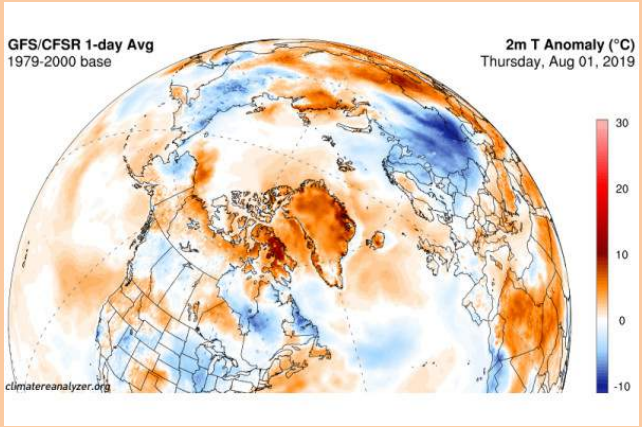


Extreme Warming Events



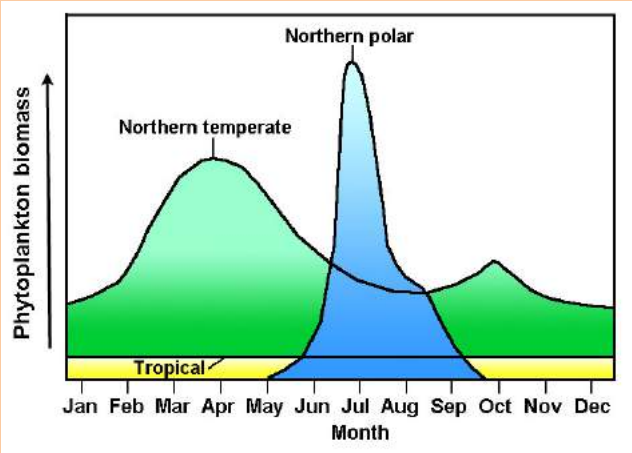
(fisheries.noaa.gov)

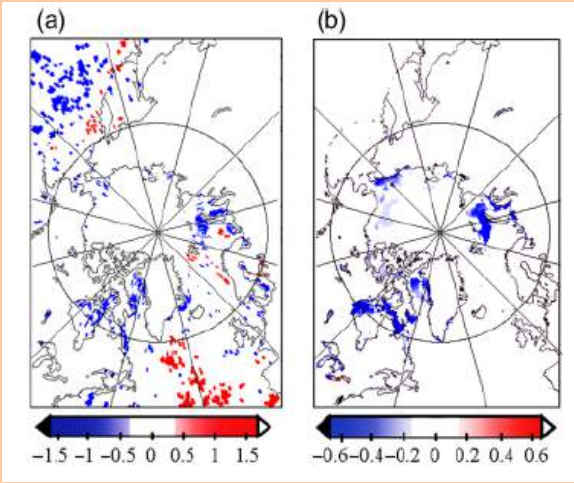
Marine Heat Waves



(Summer 2019)

Changes in AO phytoplankton blooms





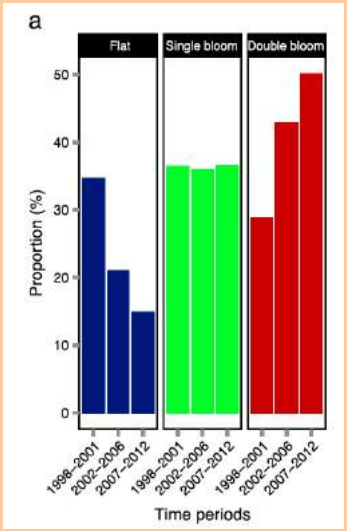
Kahru et al., 2010

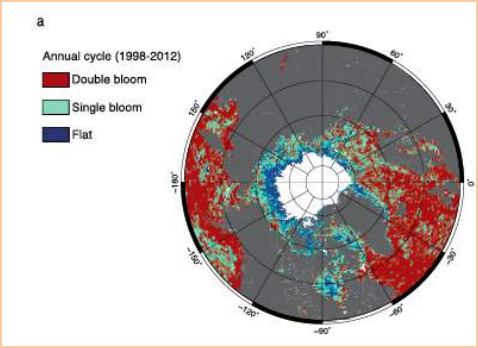
Earlier sea-ice melting

Delayed sea-ice formation

Changes in sea-ice drive changes in phytoplankton blooms

Polar ➔ Subpolar Regime

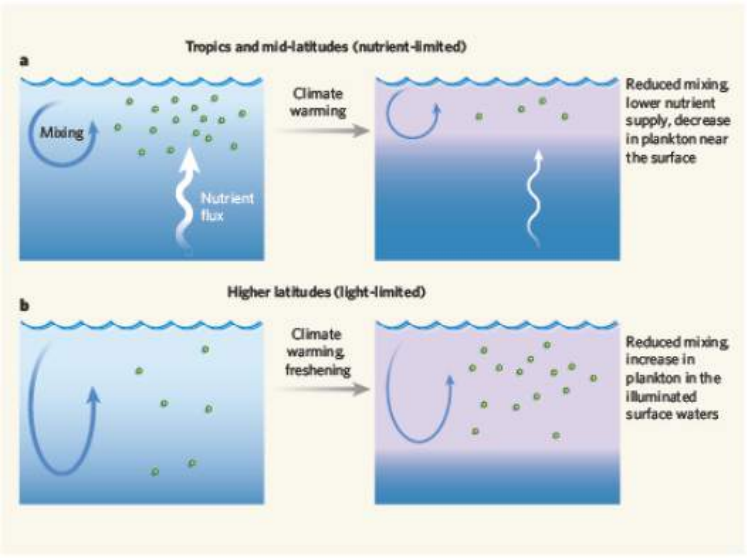




Ardyna et al., 2014

Arctic Plankton Response

Plankton in a Warmer World

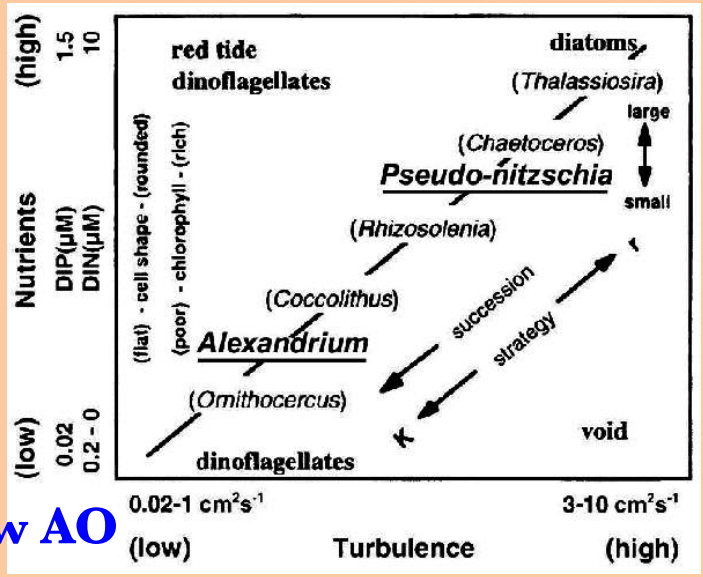


Doney (2006)

A Warmer Arctic Ocean is also a Fresher Arctic Ocean
➔ A more stratified water column

Ecological Shifts

Old AO



New AO

More Stratified

Less Stratified

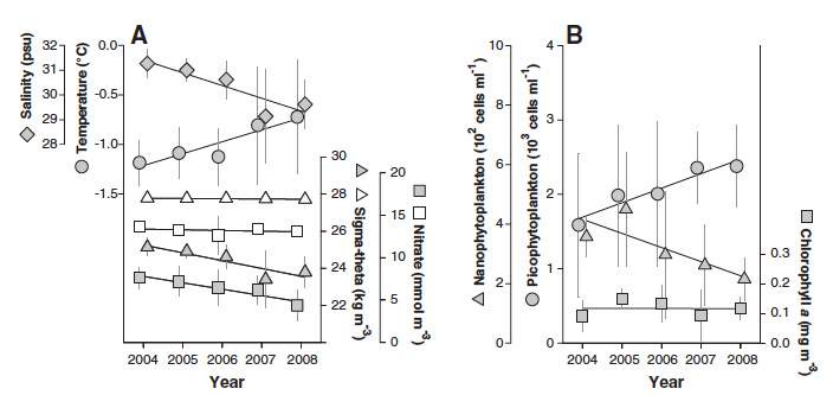
Margalef Mandala (1978)

Arctic Ecological Response

Western Beaufort Sea

Becomig More Oligotrophic

Big ➔ Small Cells

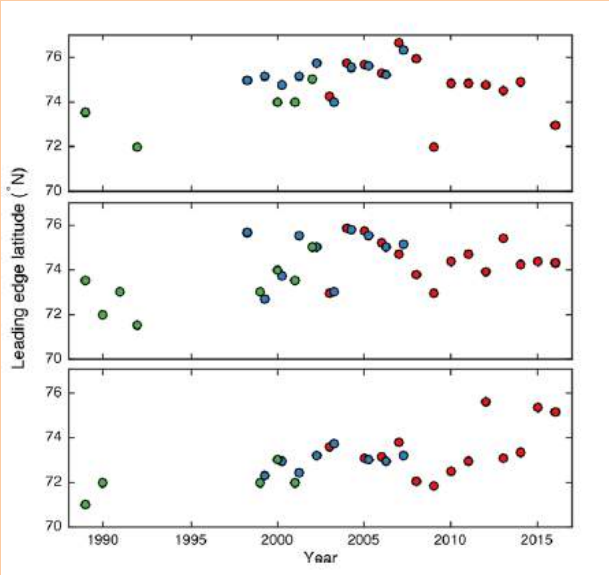


Li *et al.* (2009)

Barents Sea *"Atlantification"*

Coccolithophores

Northward migration



40-50E

30-40E

20-30E

Neukermans *et al.*, 2018

Modeling The Recent Response

ECCO-Darwin

ECCO : Sea-Ice Ocean State Estimates (ecco.jpl.nasa.gov)
Global Ocean (1/6 and 1/3 deg)- MITgcm
Multiple Obs. Constrained (ARGO floats, Satellites, etc.) via Ajdoint.

Interactive Sea-Ice model

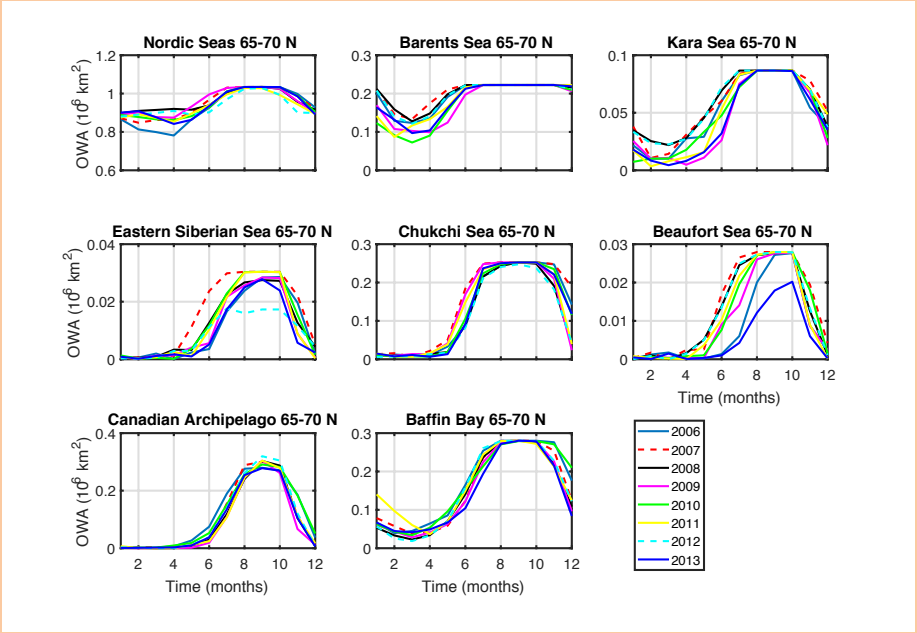
Darwin Code for Ocean Carbon Cycle/Ecology studies
(Manizza et *al.*, 2019, Carroll *et al.*, In Press)

5 Phytoplankton & 2 Zooplankton groups:
1 – Diatoms (*)
2 - Large Eukaryotes (*)
3 – Picophytoplankton (**)
4 , 5 – Prochlorococcus (**)
(High and Low Light affinity)

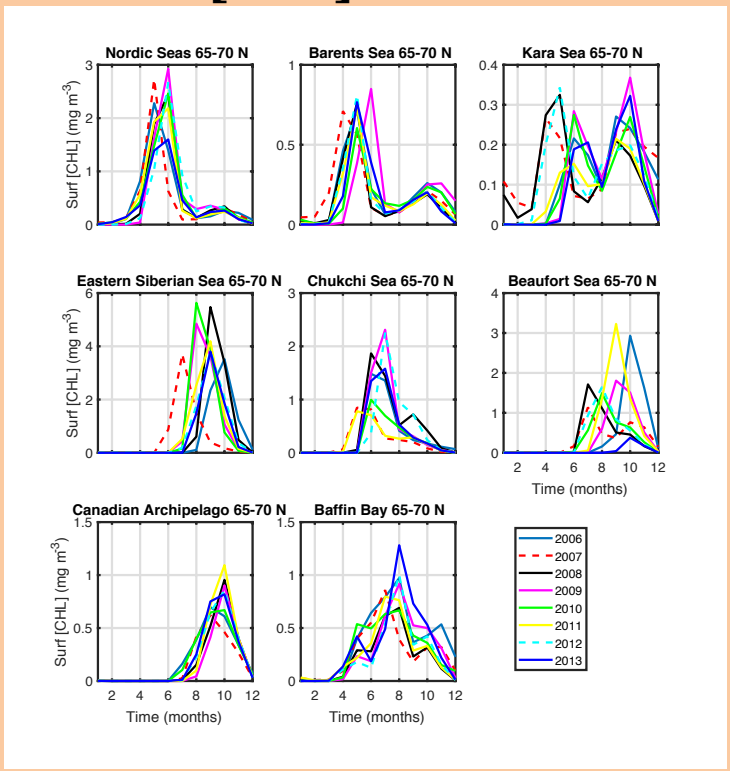
(*) Traits fit for High Lat. Oceans
(**) Traits fit for Mid-Lat. Oceans

Modeling Blooms Phenology

Open Water Area



Surface [CHL]



2007 Warming event
Earlier Sea-Ice break-up: ➔ Early Bloom

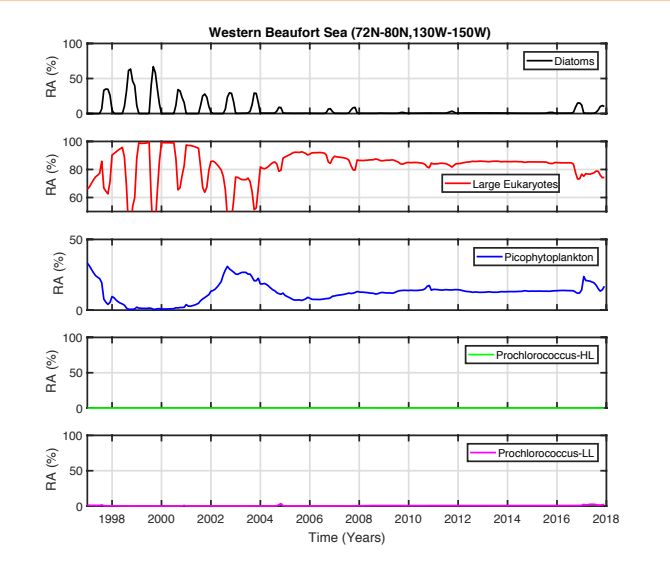
Some sectors show second fall bloom

ECCO2-Darwin 2004-2013 run
1/6 degree

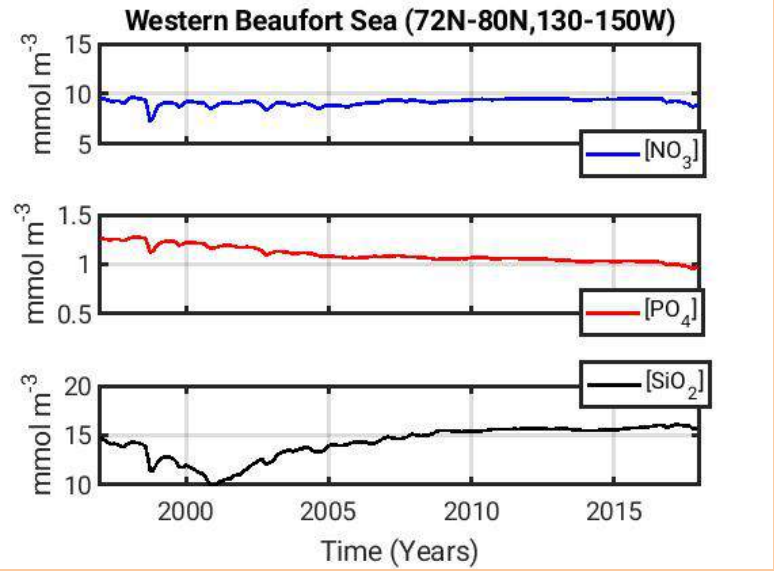
Manizza *et al.*, In Prep.

Western Beaufort Sea

Relative Abundance (%)



Surface Nutrients

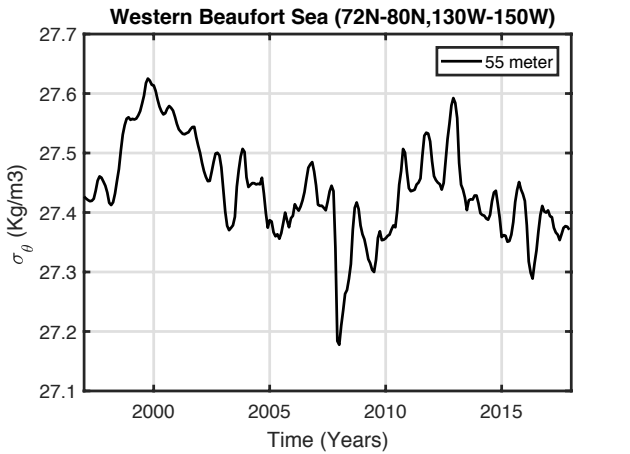


ECCO-Darwin 1996-2017
1/3 degree

Stratification increase

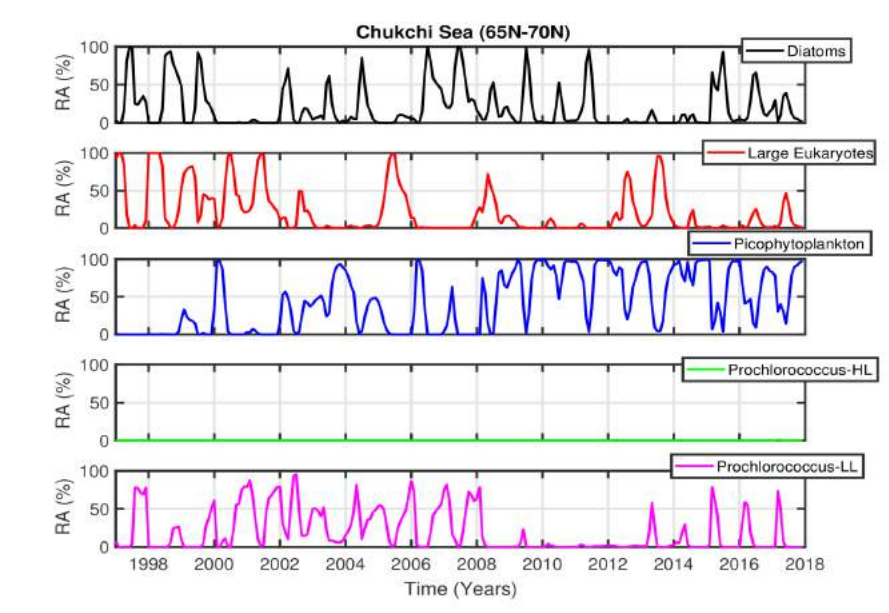
Onset of oligotrophic regime

Ecological shift as data show

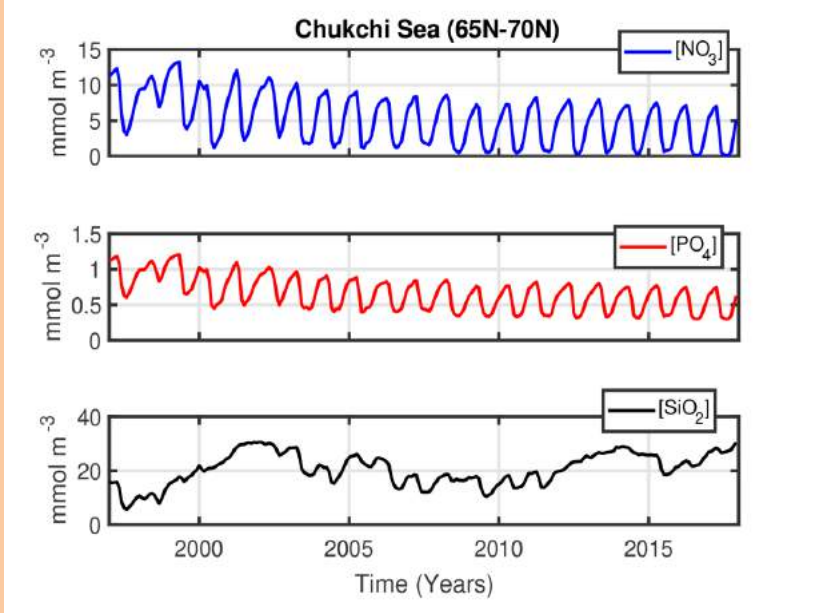


Southern Chukchi Sea

Relative Abundance (%)



Surface Nutrients

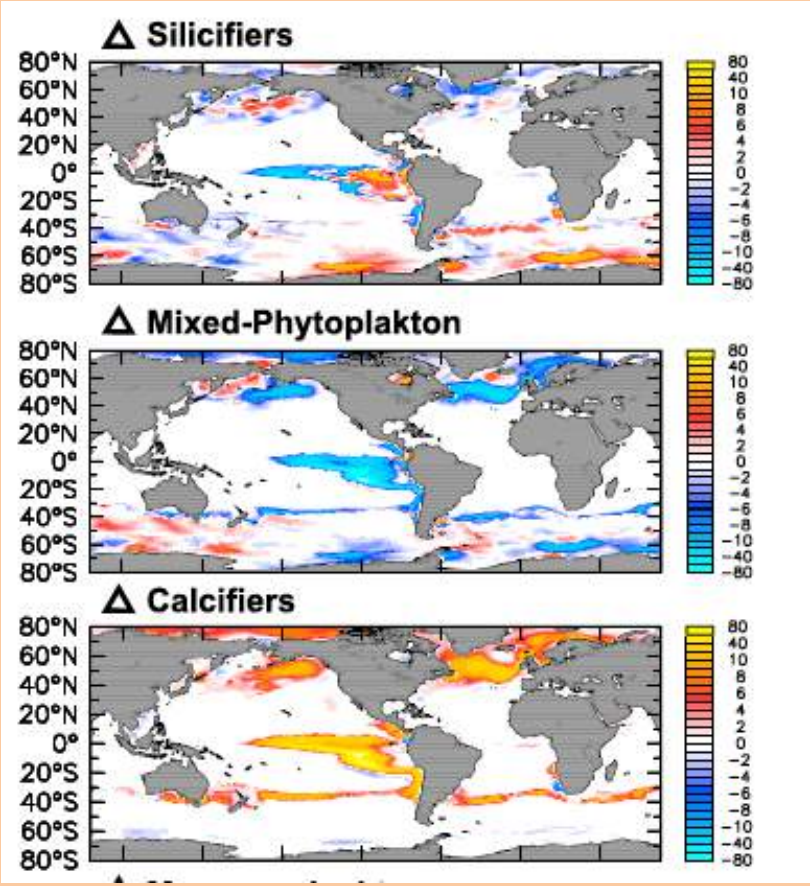


ECCO-Darwin 1996-2017
1/3 degree

Similarities with data
of Neeley et al., GRL, (2018)
Ecosystem Shifts

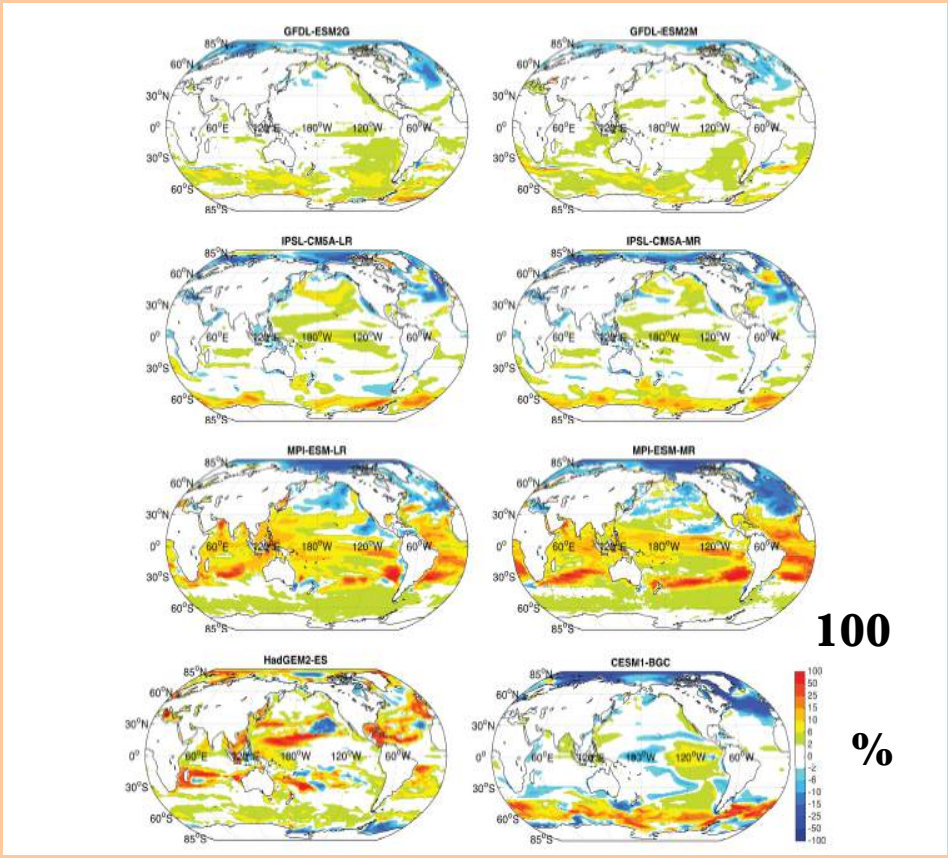
Ecological Future Response

Relative Abundance (%)



Manizza *et al.* (2010)

ΔNPP due to diatoms only



100

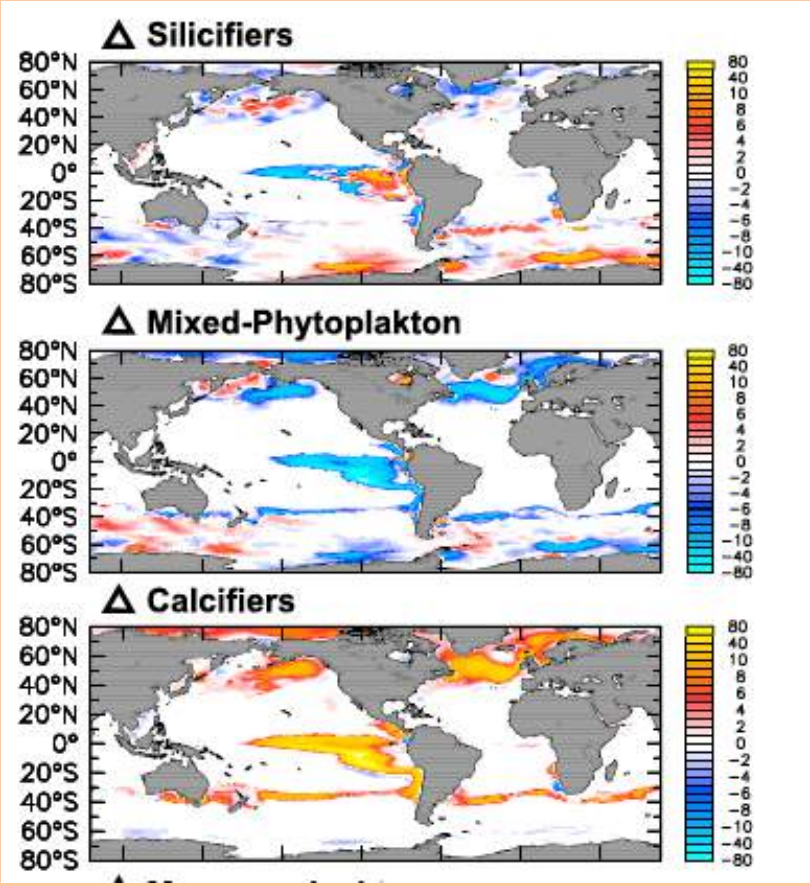
%

-100

CMIP5 models RCP8.5 - Fu *et al.* (2016)

Ecological Future Response

Relative Abundance (%)



Manizza *et al.* (2010)

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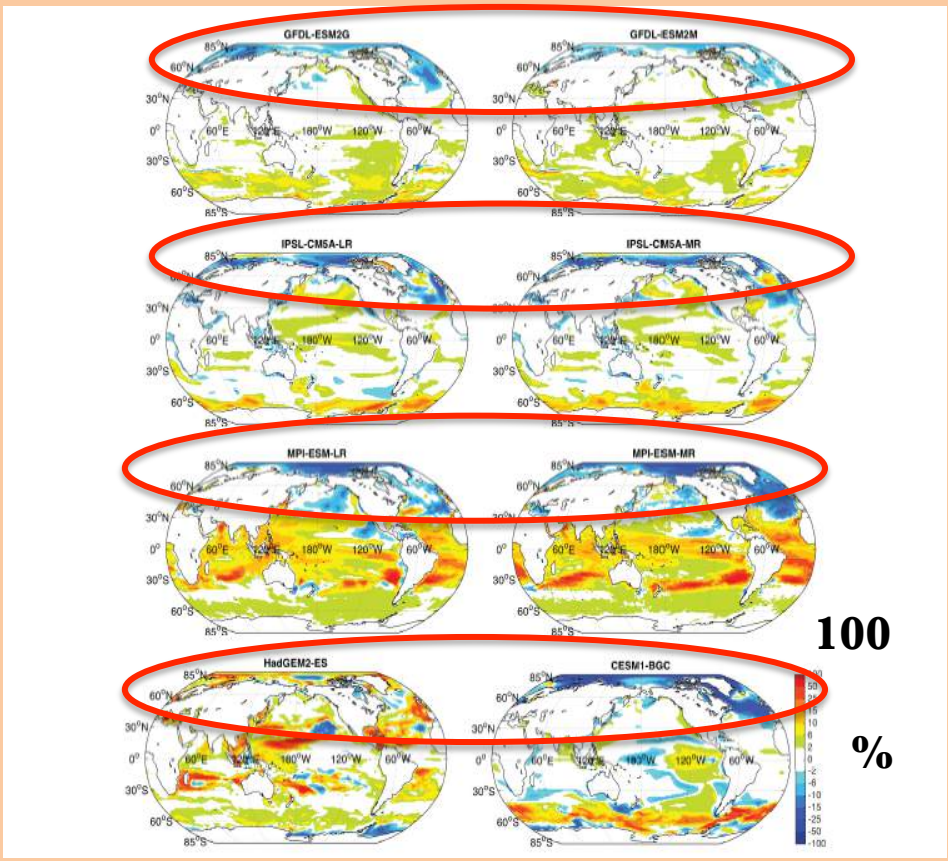
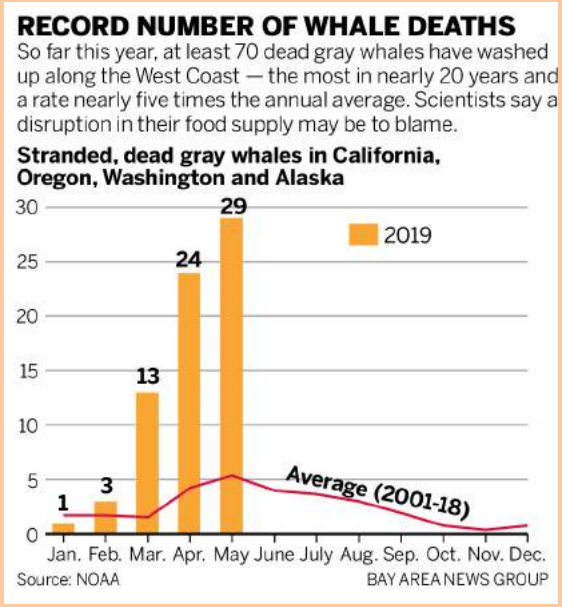


CMIP5 models RCP8.5 - Fu *et al.* (2016)

What happens in the Arctic….

Grey Whales



Stranded Grey whales with very low body fat

Less nutritious food? ←→ Planktonic shifts

Lack of food? ←→ Earlier blooms

….(maybe) does not stay in the Arctic

Conclusions

The planktonic AO ecosystem is changing due to climate perturbation: Data and Models converge.

Future predictions also consistent with ECCO-Darwin response and data. Is the Future AO already here?

Expansion of data collection vital to monitor the changes and build appropriate models for AO ecosystems.

NEXT: Impact of future marine heat waves/extreme warming events (NP Warm Blob-like) on AO ecosystems?

Cascading effects for upper trophic levels in an Arctic Ocean where phytoplankton larger cells ➔ smaller cells?