Ocean Carbon & Biogeochemistry meeting, June 27

CAP-ICE

CARBON PRODUCTION OF UNDER-ICE PHYTOPLANKTON BLOOMS IN A CHANGING ARCTIC OCEAN

Recent changes in phytoplankton productivity and phenology in the Arctic Ocean

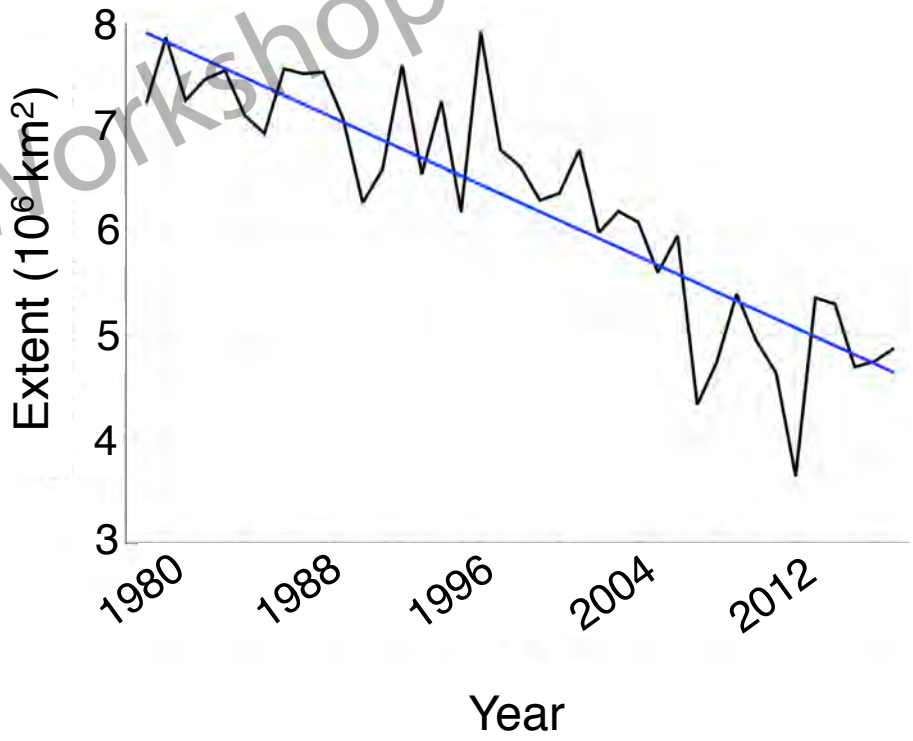
Mathieu Ardyna

Marie Skłodowska-Curie Fellow

Stanford University/Sorbonne Université

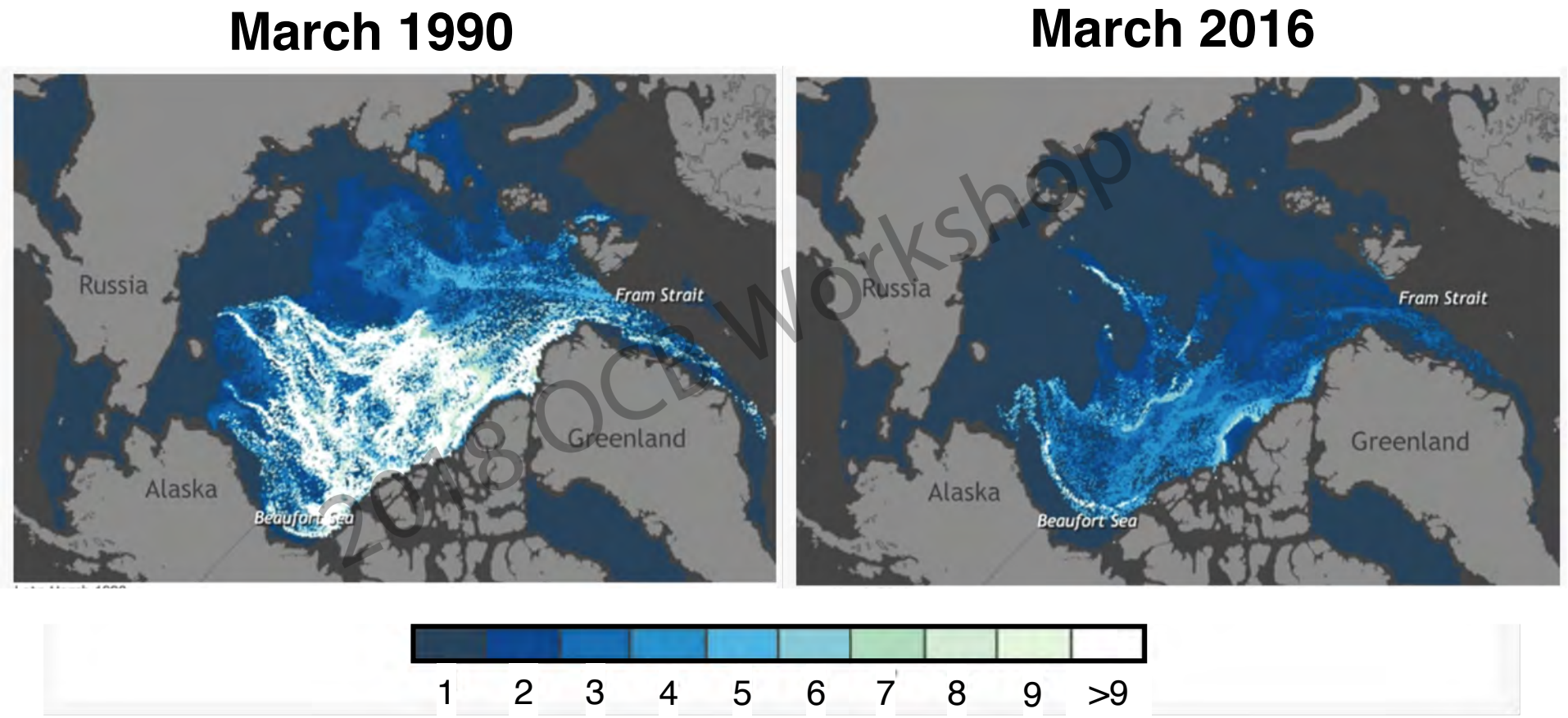
Co-financed by the Connecting Europe Facility of the European Union

Loss in sea-ice cover in September



NSIDC (2017)

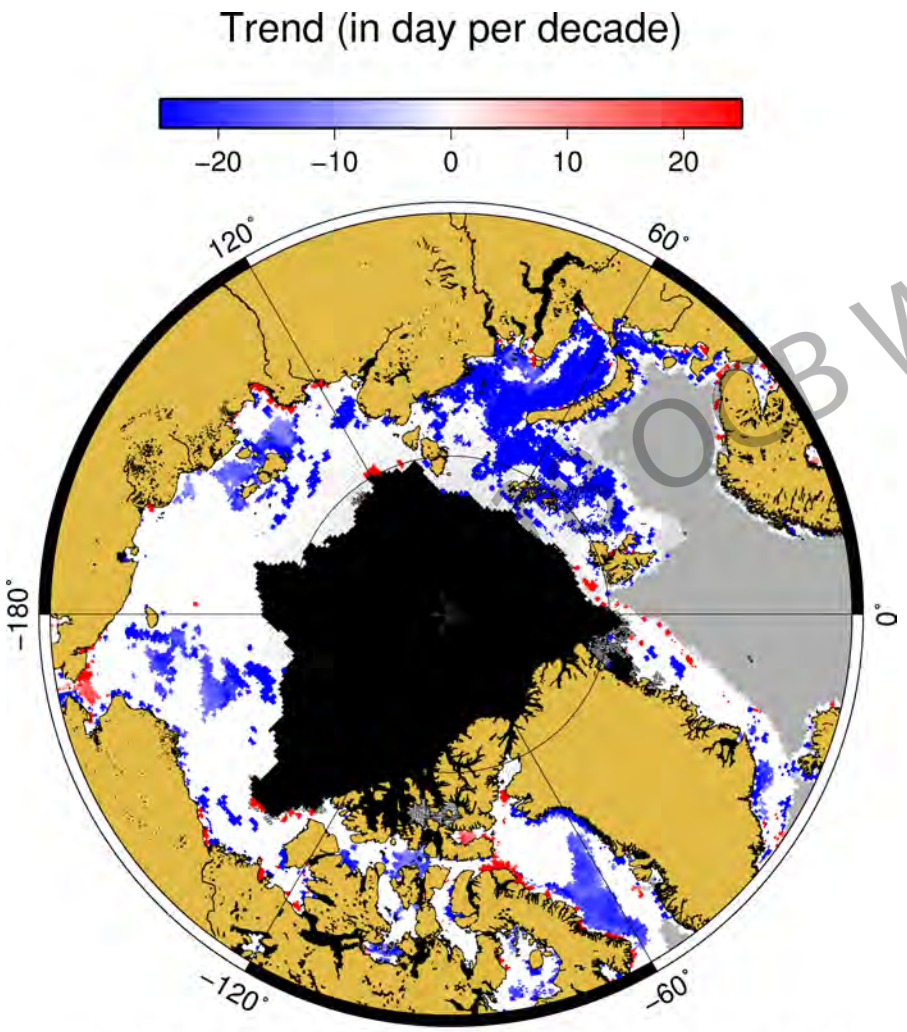
LOSS IN MULTIYEAR SEA-ICE



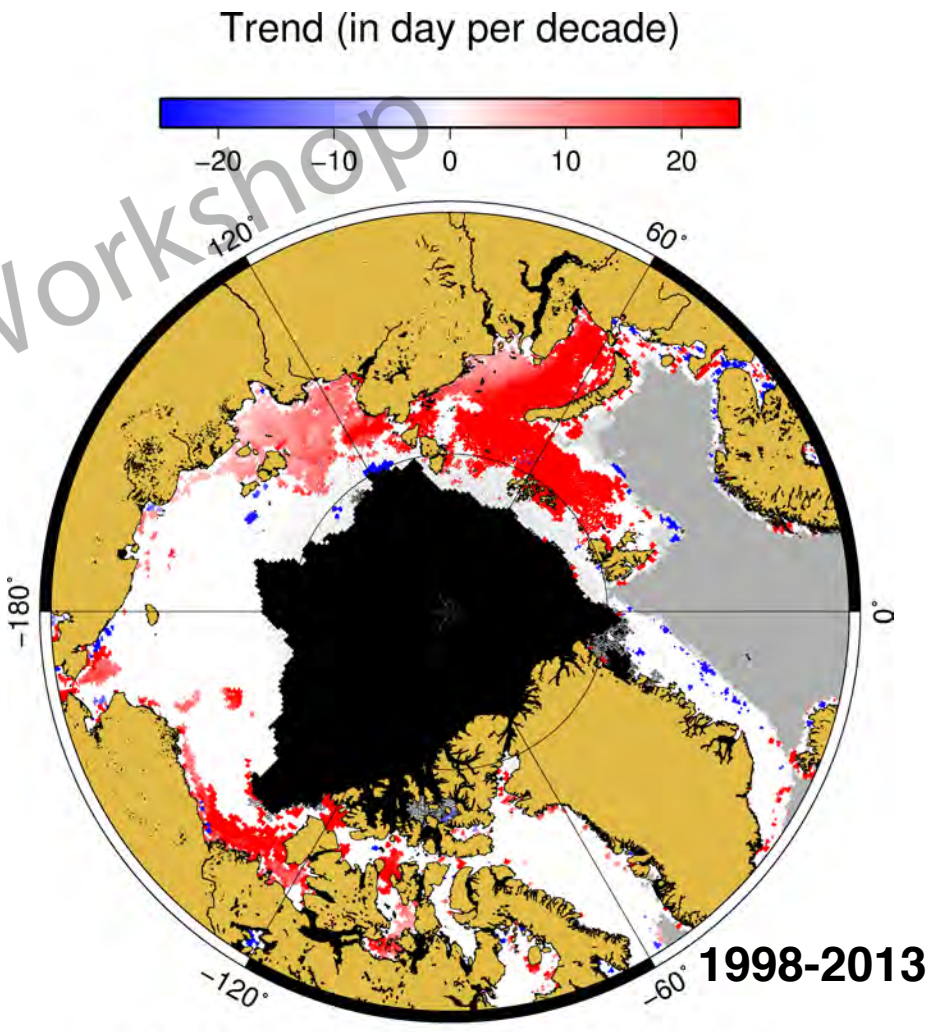
NOAA (2016)

Earlier breakup & delayed freeze-up

Breakup



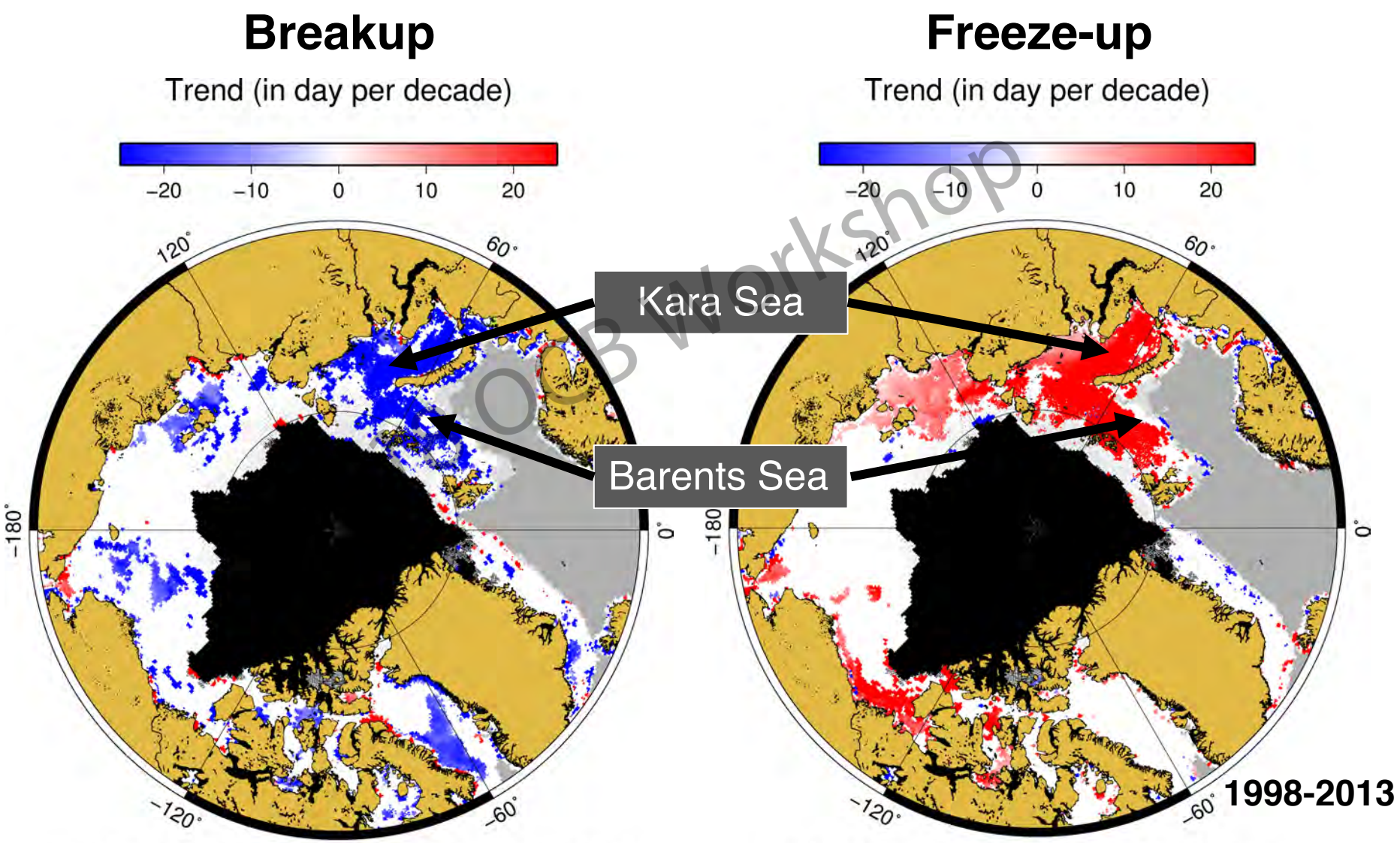
Freeze-up



1998-2013

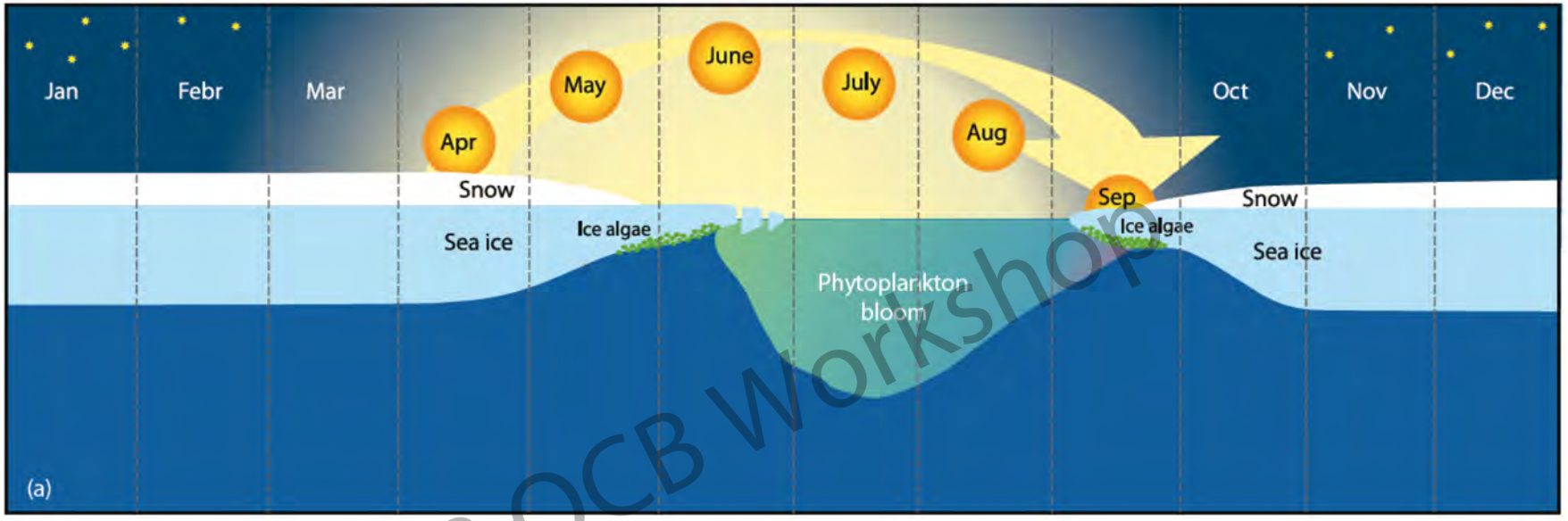
Unpublished data

Earlier breakup & delayed freeze-up



Unpublished data

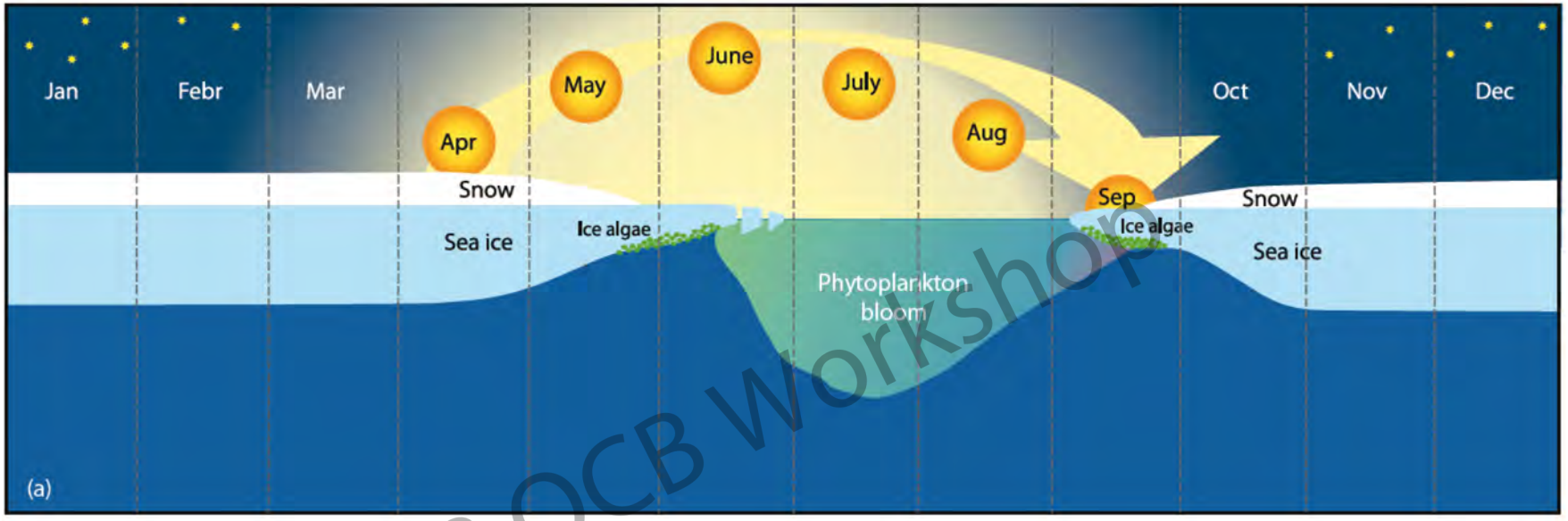
THE KEY FEATURES IN PHYTOPLANKTON PHENOLOGY



Phenology, the study of annually recurring life cycle events, can provide particularly sensitive indicators of climate change.

Wassmann & Reigstad (2011)

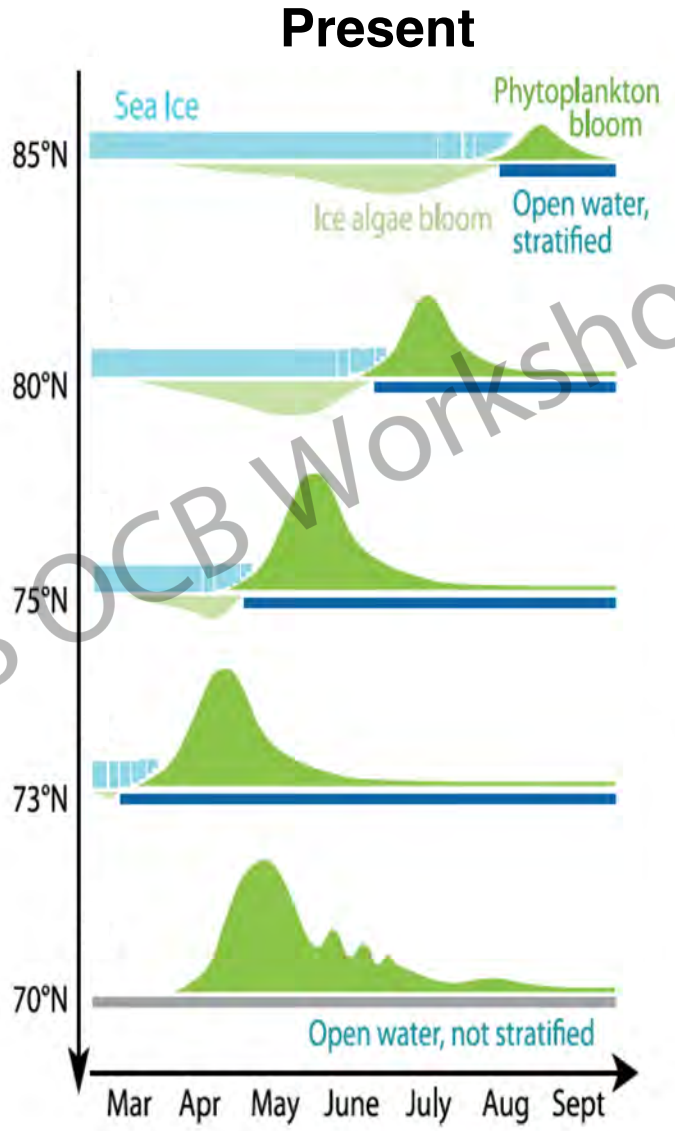
THE KEY FEATURES IN PHYTOPLANKTON PHENOLOGY



- Break-up and freeze-up time that determine the duration of the open-water period
- Seasonal light cycle
- Properties of the snow-ice system
- Nutrient dynamics
- Top-down control

Wassmann & Reigstad (2011)

ONGOING CHANGES IN PHYTOPLANKTON PHENOLOGY

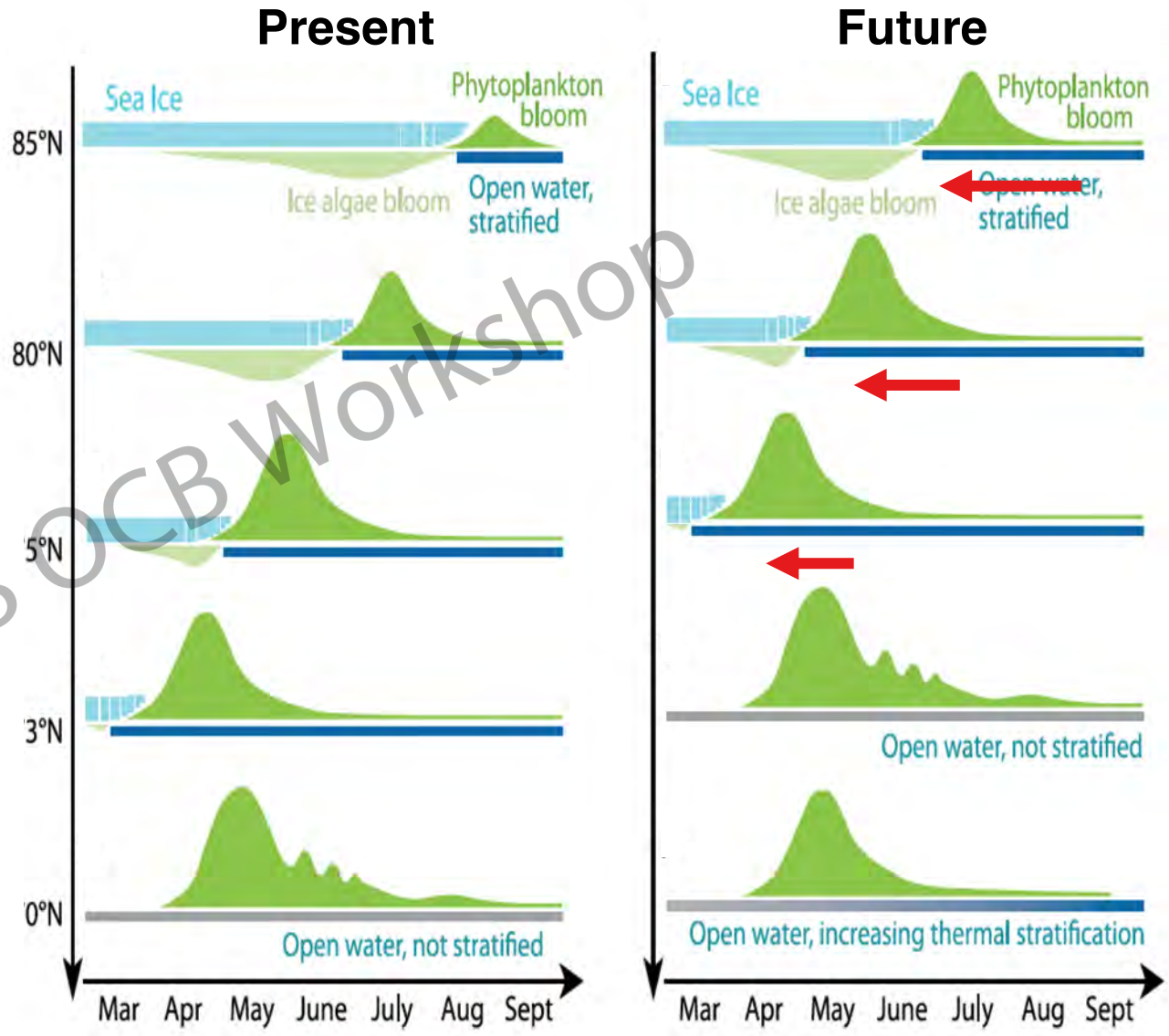


Wassmann & Reigstad (2011)

ONGOING CHANGES IN PHYTOPLANKTON PHENOLOGY

Key satellite-derived findings (2011- now):

- Earlier spring bloom in the seasonal ice zone



Wassmann & Reigstad (2011)

EARLIER SPRING BLOOM IN THE SEASONAL ICE ZONE

Key satellite-derived findings (2011- now):

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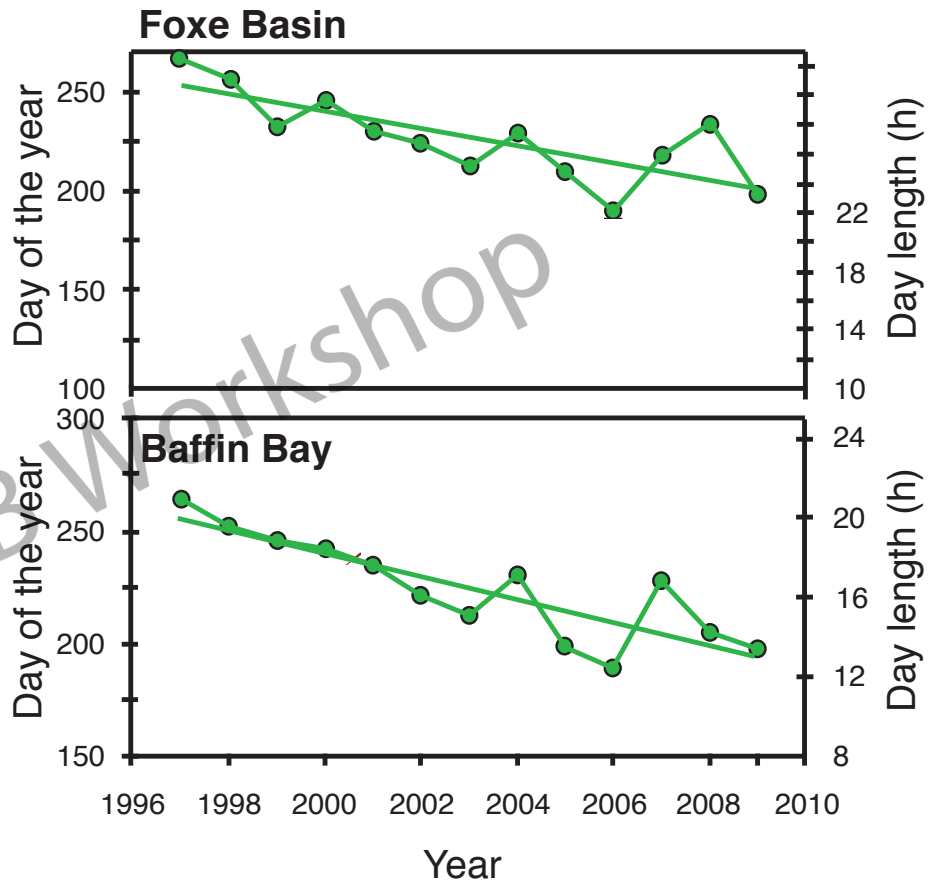

=> Due to early sea-ice break-up

Kahru et al. (2010)

ONGOING CHANGES IN PHYTOPLANKTON PHENOLOGY

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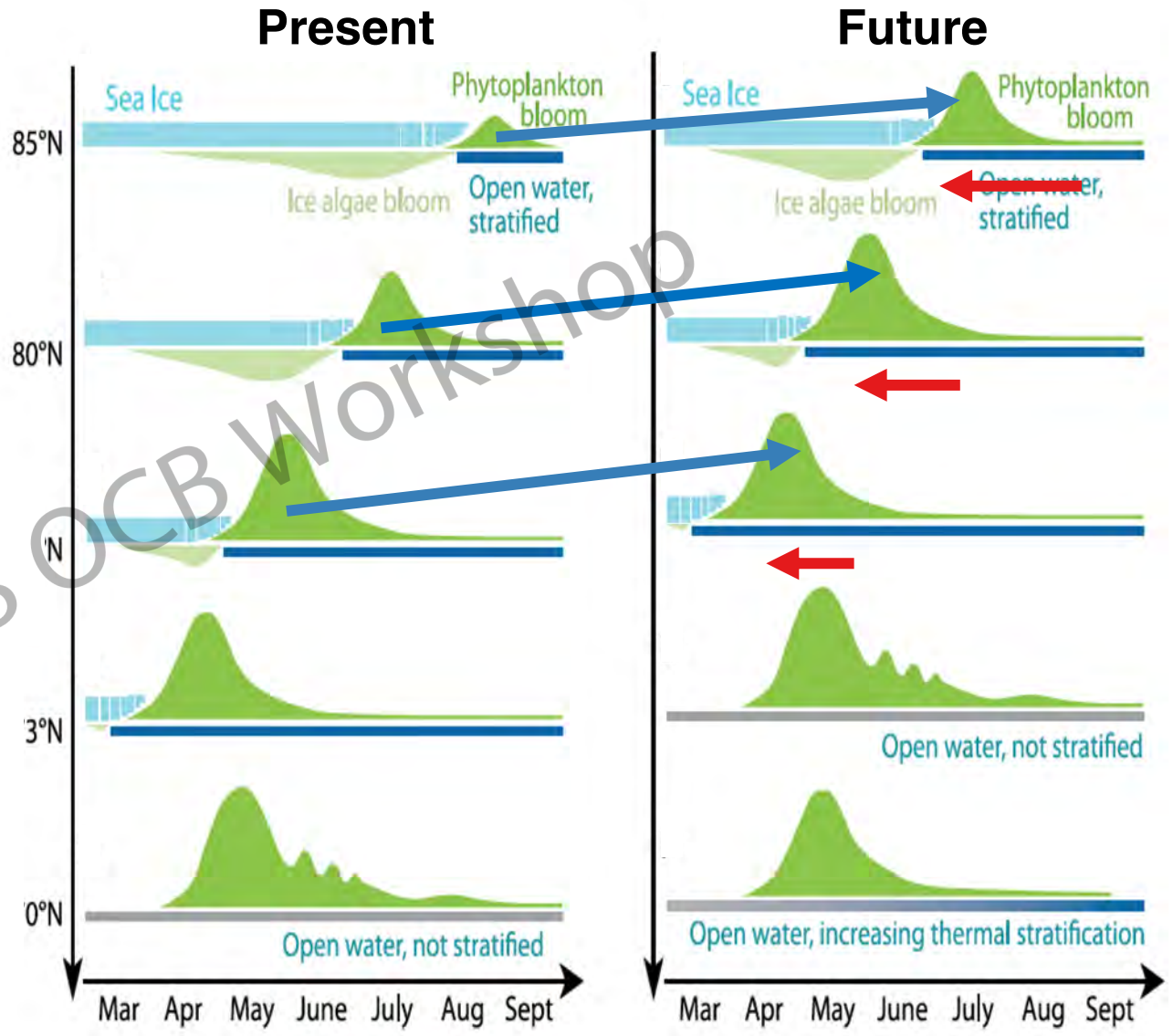
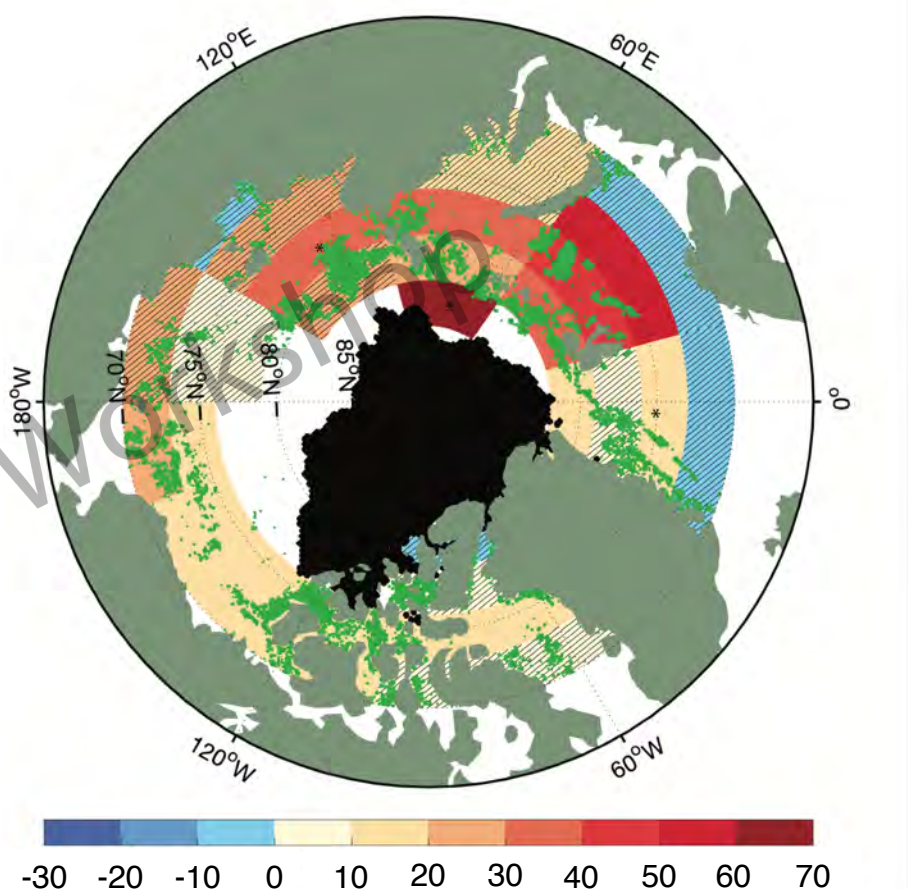


Wassmann & Reigstad (2011)

More intense bloom at high latitude

Earlier spring bloom in the seasonal ice zone

More intense bloom at high latitude



Annual increase in primary production of the spring bloom (mg C m^{-2} d^{-1} y^{-1})

Renaut et al. (sub.)

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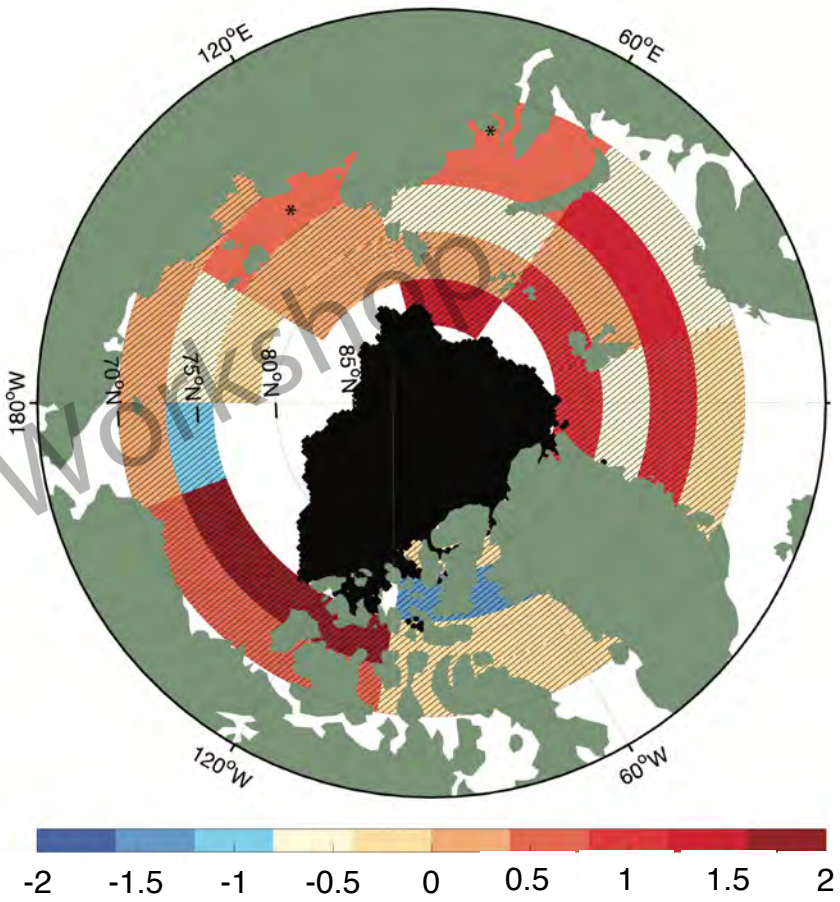

Annual increase in PAR during the spring bloom (mol photon m^{-2} d^{-1} y^{-1})

=> Due to increasing light intensity during the bloom period

Renaut et al. (sub.)

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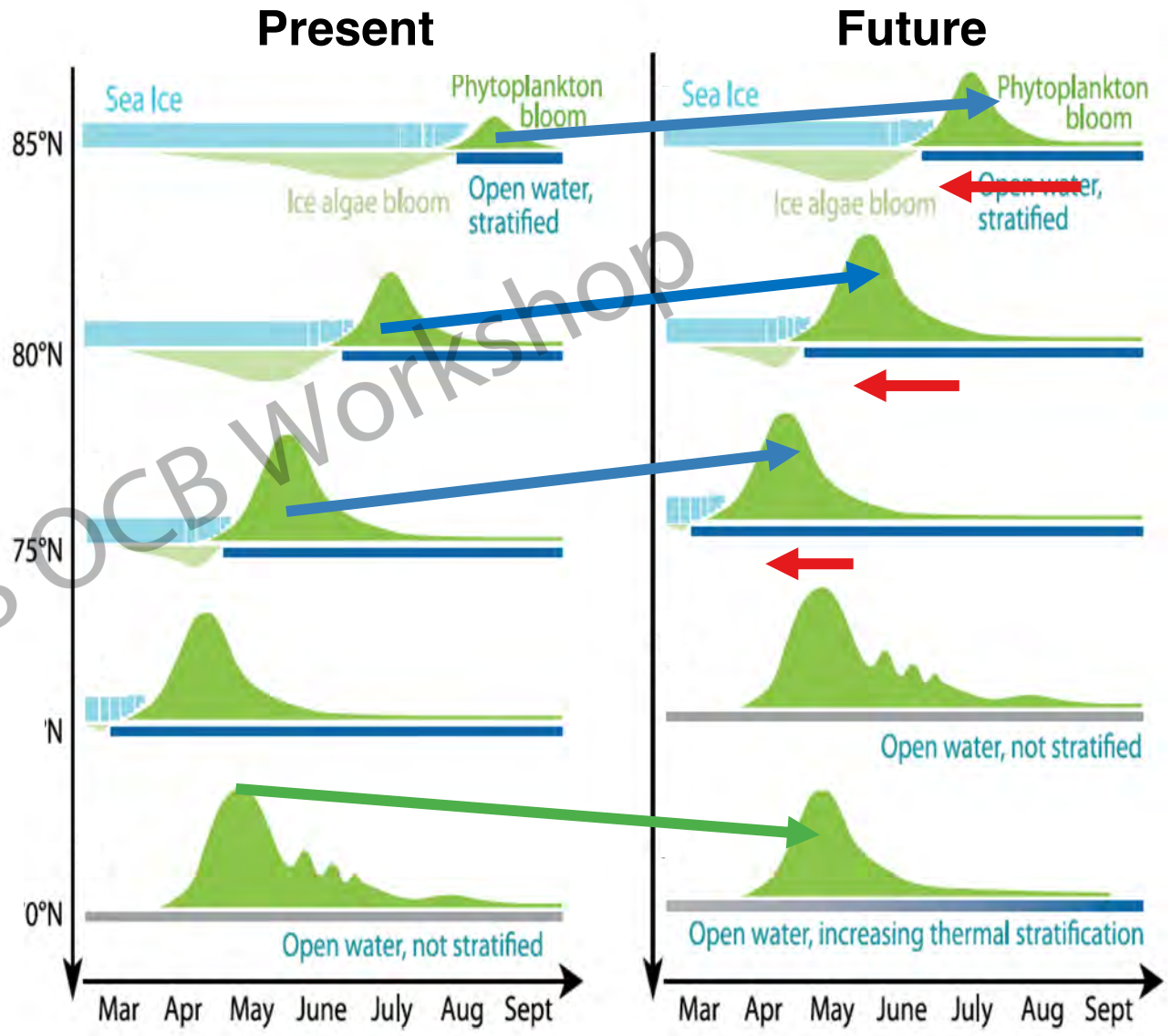


Wassmann & Reigstad (2011)

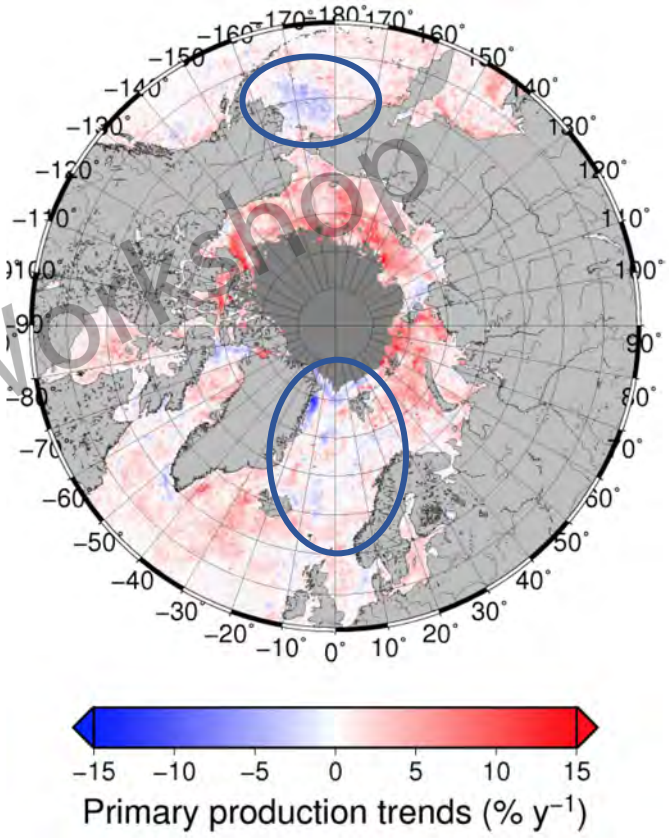
Decrease production at low latitude

Earlier spring bloom in the seasonal ice zone

More intense bloom at high latitude

Decrease production at low latitude

Inflow shelves

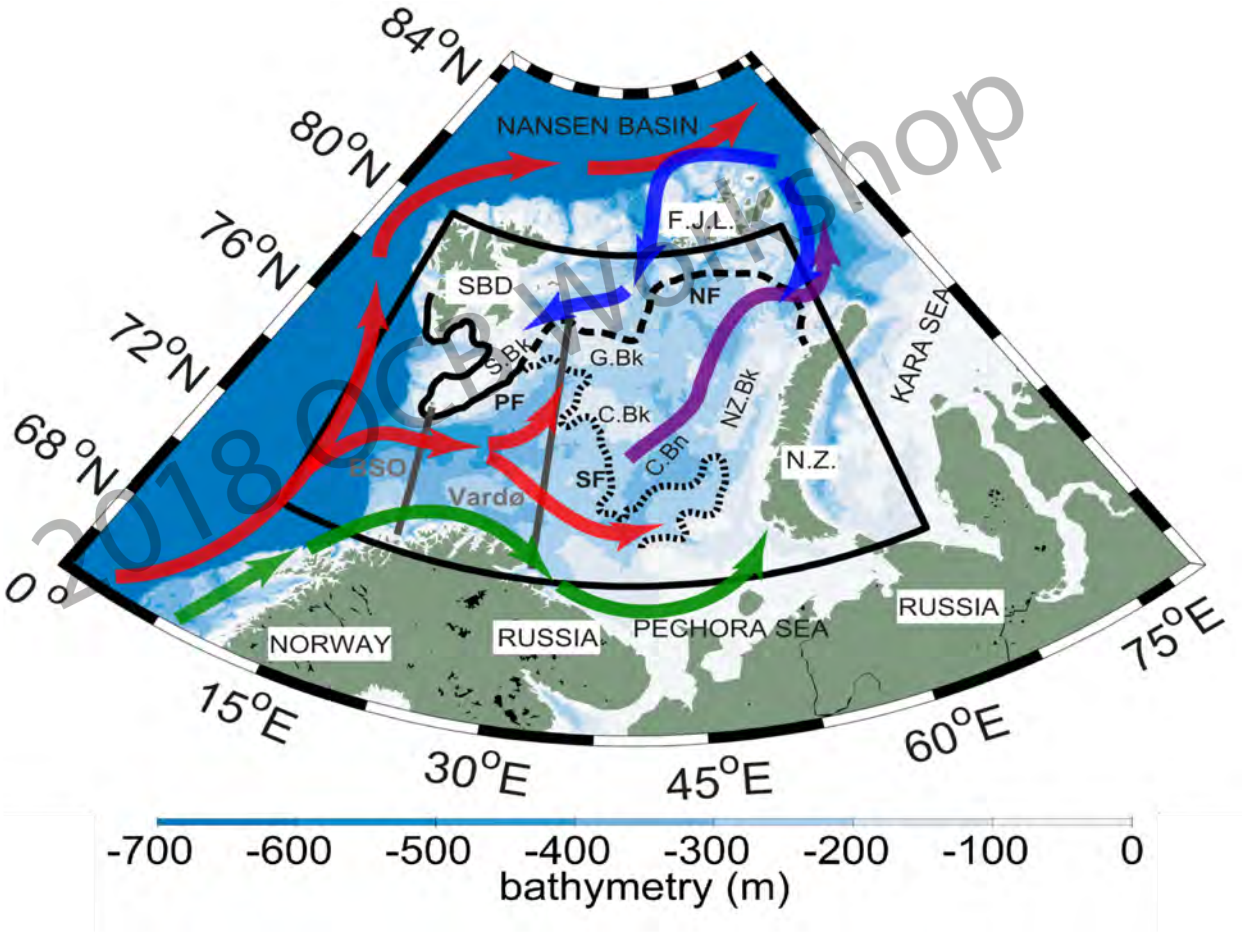


=> Due to increasing thermal stratification (and stronger nutrient limitation?) in inflow shelves

Pabi et al. (2008), Bélanger et al. (2013), Arrigo and van Dijken (2015)

FAVORING POLEWARD SHIFT OF COCCOLITOPHORE BLOOMS

Inflow shelf: Barents Sea



Oziel et al. (2017, 2018), Neukermans et al. (2018)

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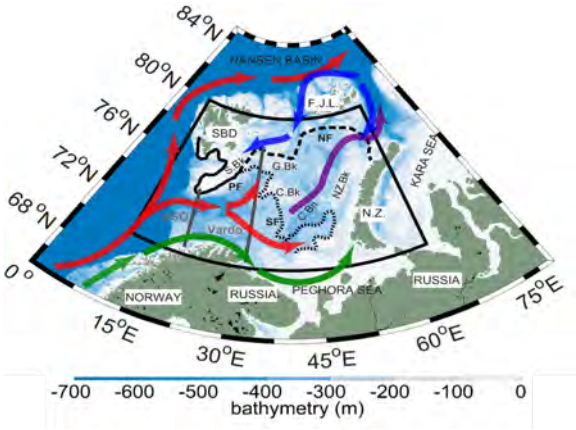

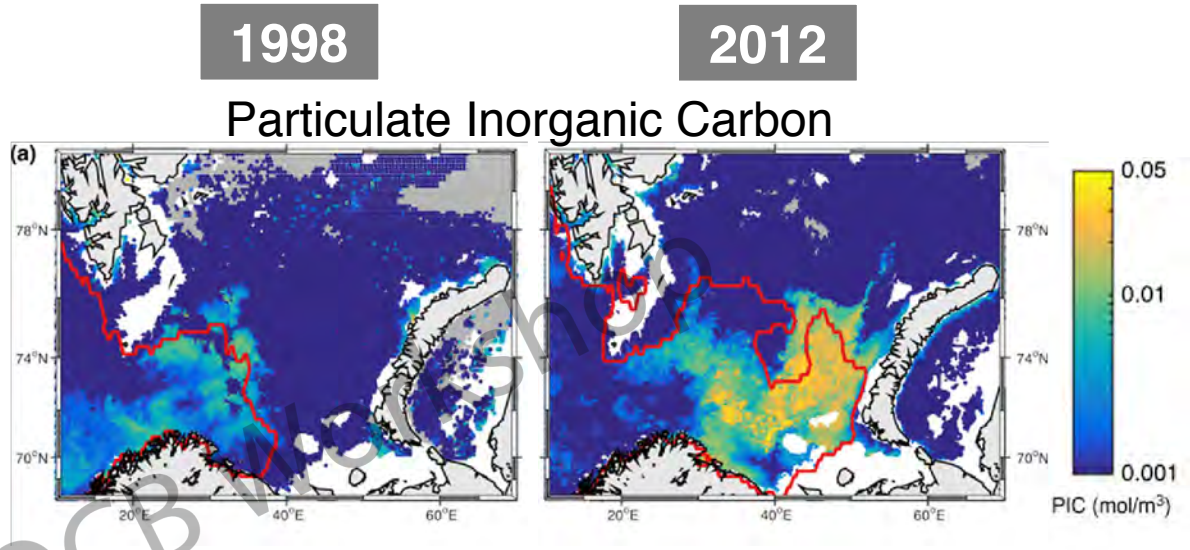

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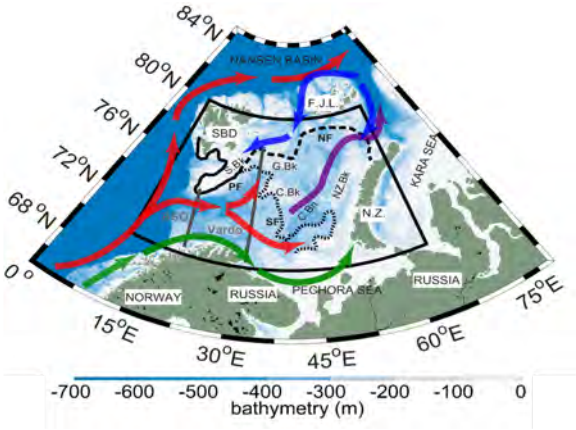
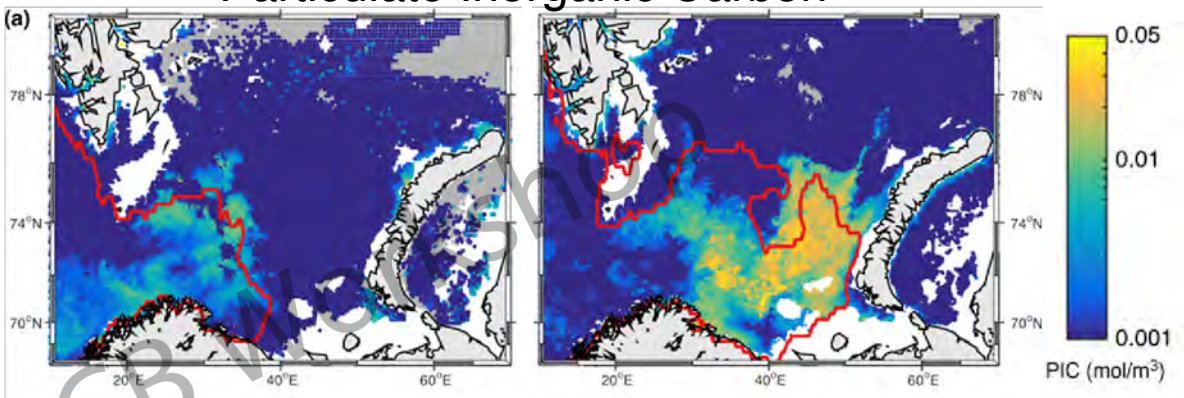


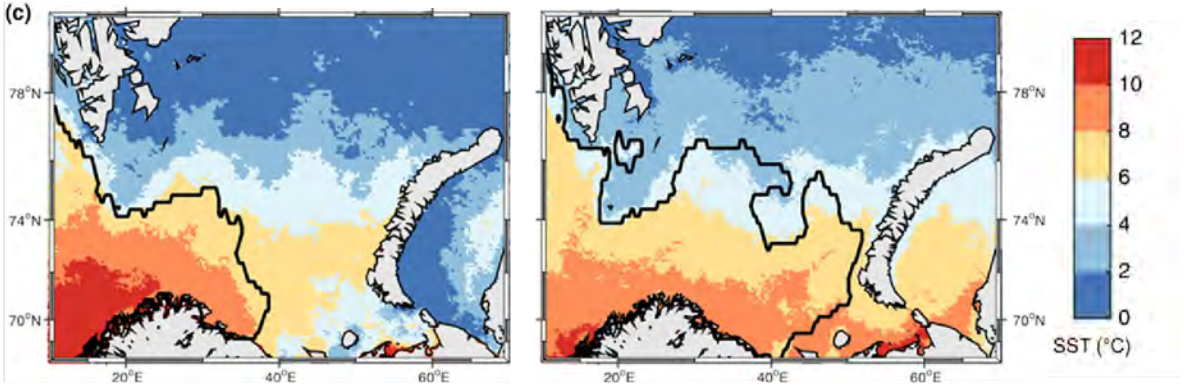
Increased intrusion of warm Atlantic water leads to the expansion of coccolithophore blooms in the Arctic

1998 **2012**

Particulate Inorganic Carbon



Sea Surface Temperature



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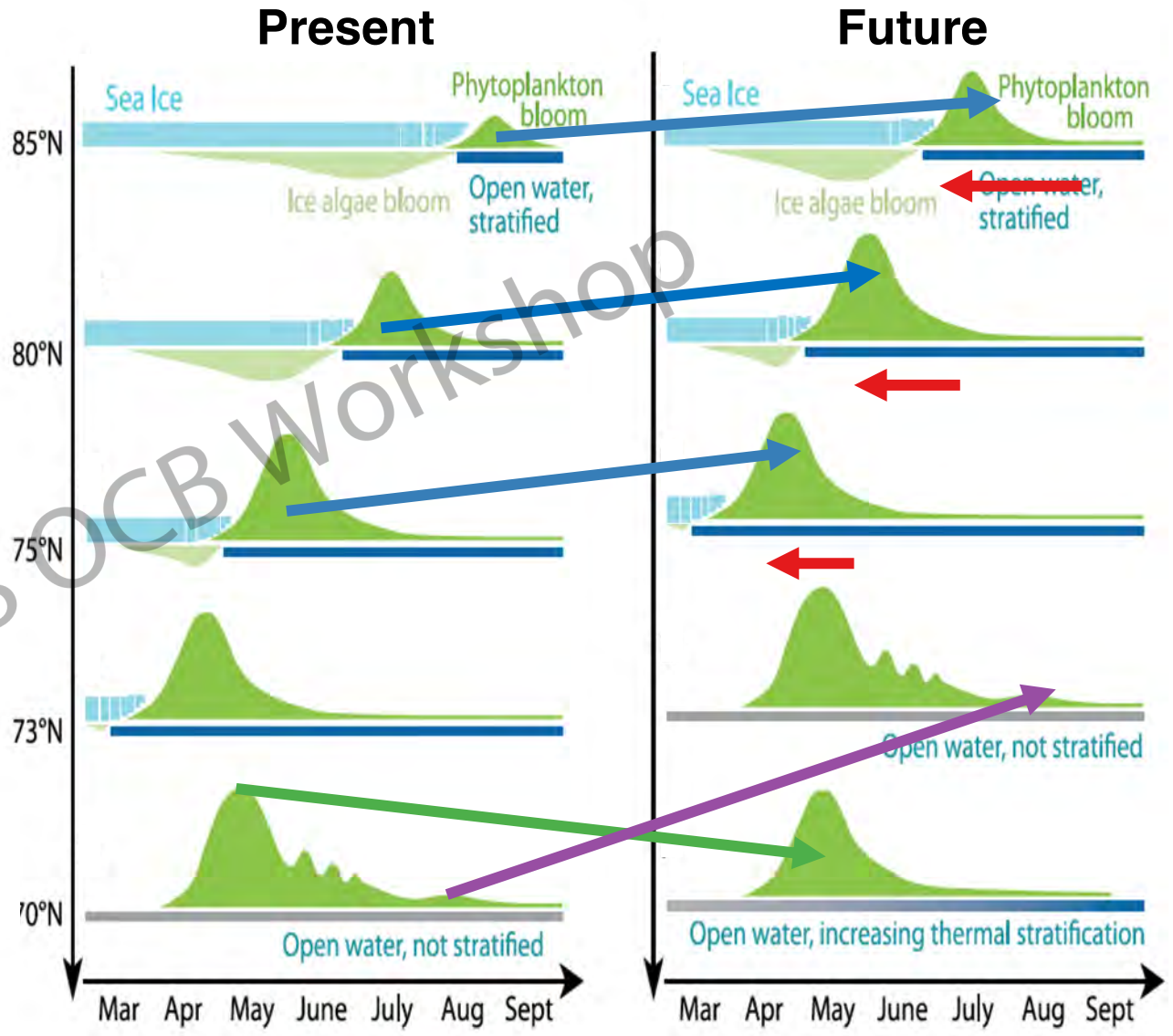


Wassmann & Reigstad (2011)

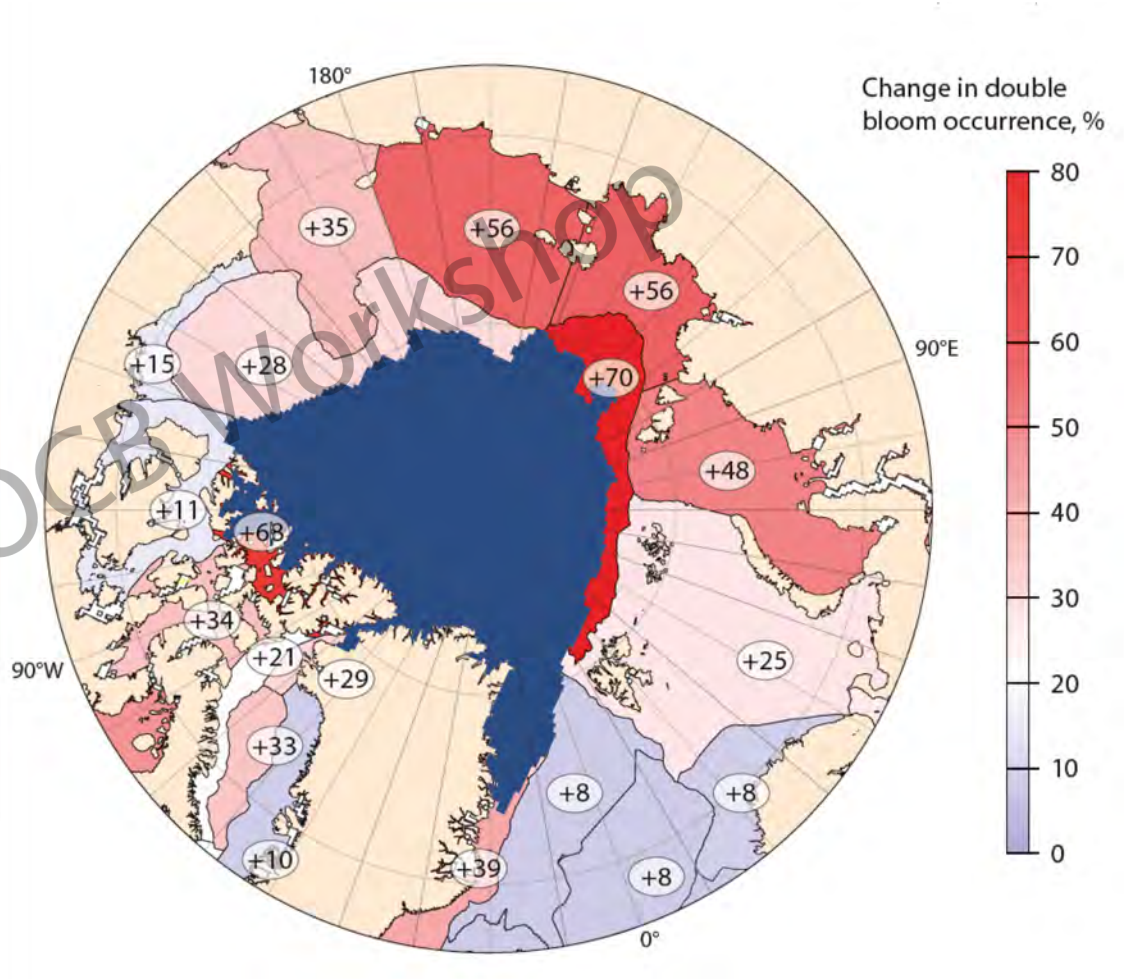
INCREASING OCCURRENCE OF FALL BLOOMS

Earlier spring bloom in the seasonal ice zone

More intense bloom at high latitude

Decrease production at low latitude

Increasing occurrence of fall bloom



Ardyna et al. (2014), SWIPA (2017)

INCREASING OCCURRENCE OF FALL BLOOMS

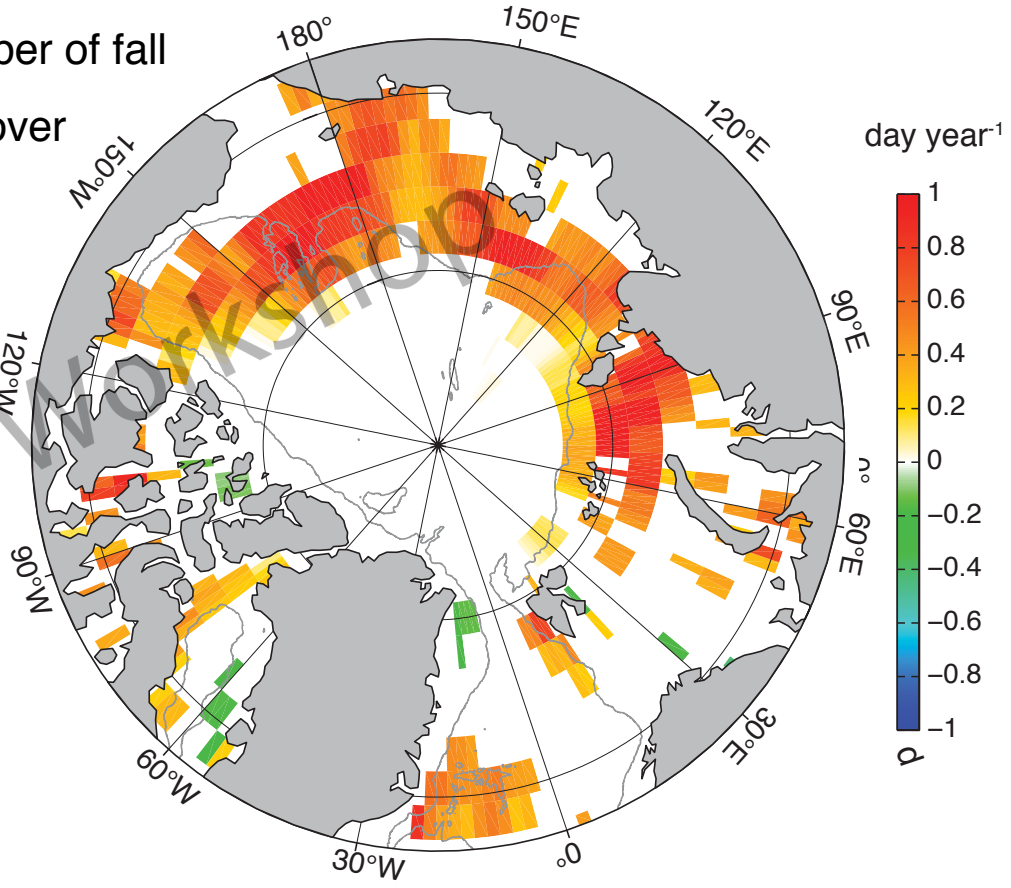
Earlier spring bloom in the seasonal ice zone

More intense bloom at high latitude

Decrease production at low latitude

Increasing occurrence of fall bloom

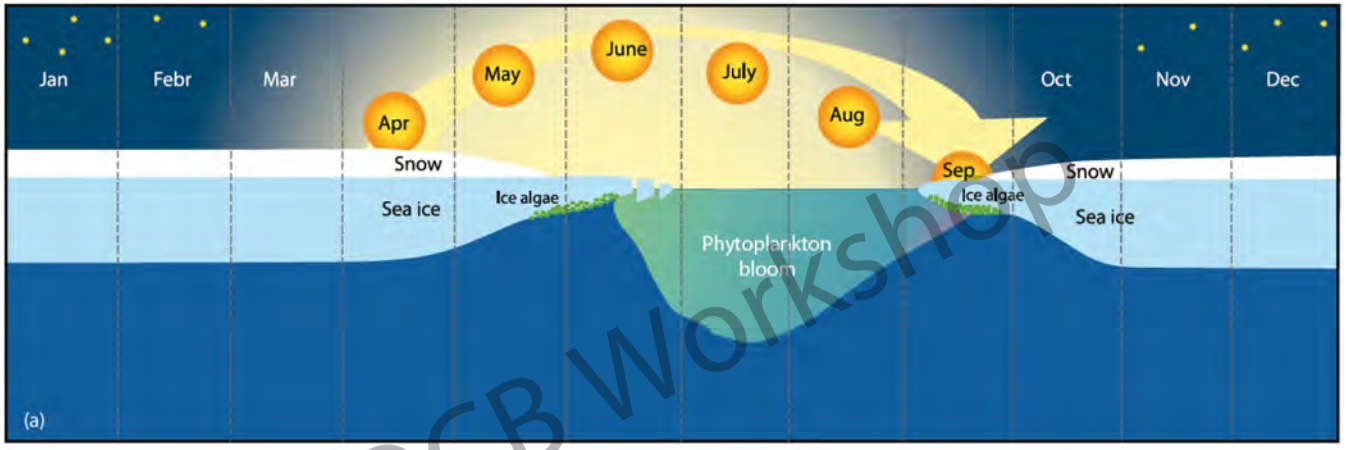
Trend in number of fall stormy days over open water



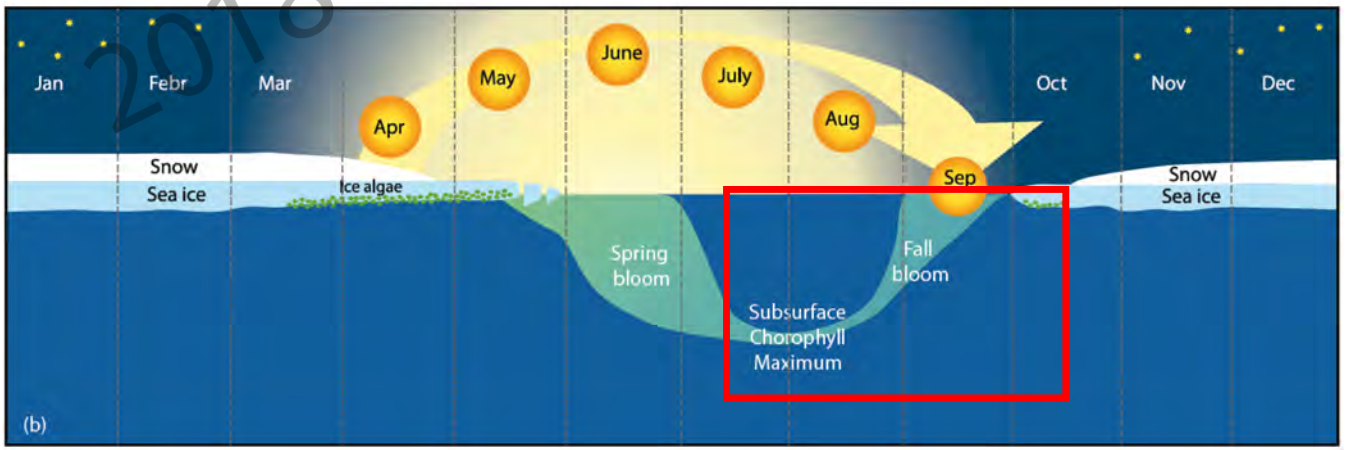
=> Due to both more storms and more sea-ice free areas

Ardyna et al. (2014), SWIPA (2017)

Changing Arctic paradigms

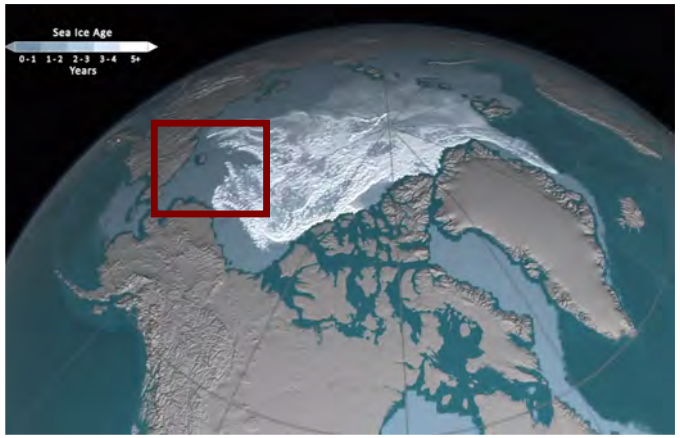


To the "borealization" of the Arctic Ocean:



Ardyna (2013,2015), Wassmann & Reigstad (2011)

MASSIVE UNDER SEA-ICE BLOOMS: UNDETECTABLE BY SATELLITE



Phytoplankton bloom beneath ponded-ice due to increased light transmittance.

The highest values reach up 30 mg Chl m^{-3} and dominated by centric diatoms.

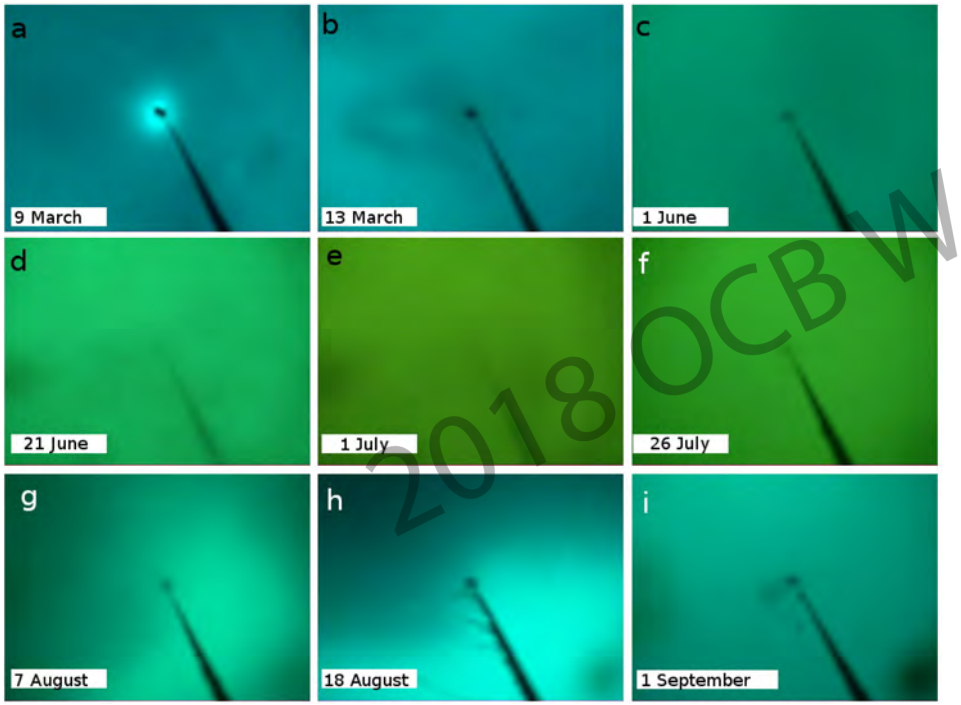
Melt-ponded sea ice

Under-ice bloom

Arrigo et al. (2012, 2014)

MASSIVE UNDER SEA-ICE BLOOMS: PAN-ARCTIC DISTRIBUTION ?

In the Chukchi Sea
captured by Ice-Tethered Profilers.



Hill et al. (2017)

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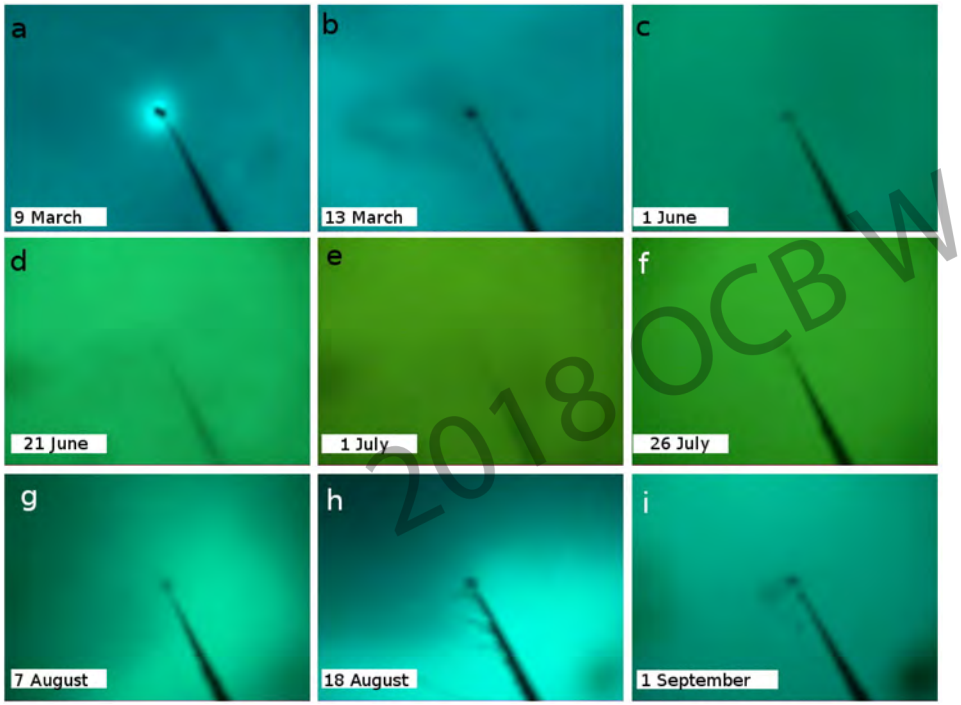
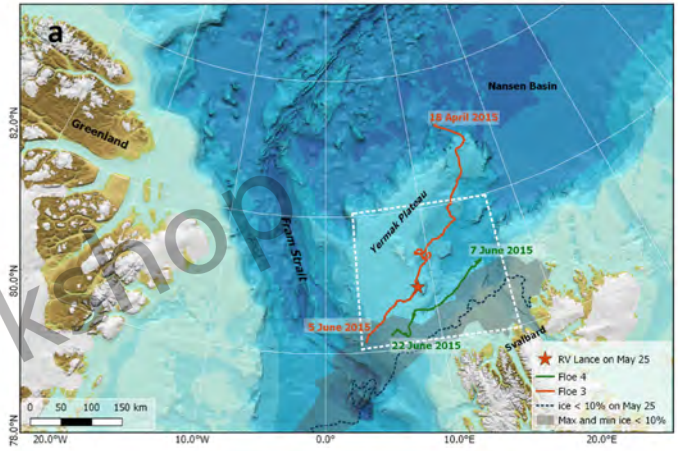
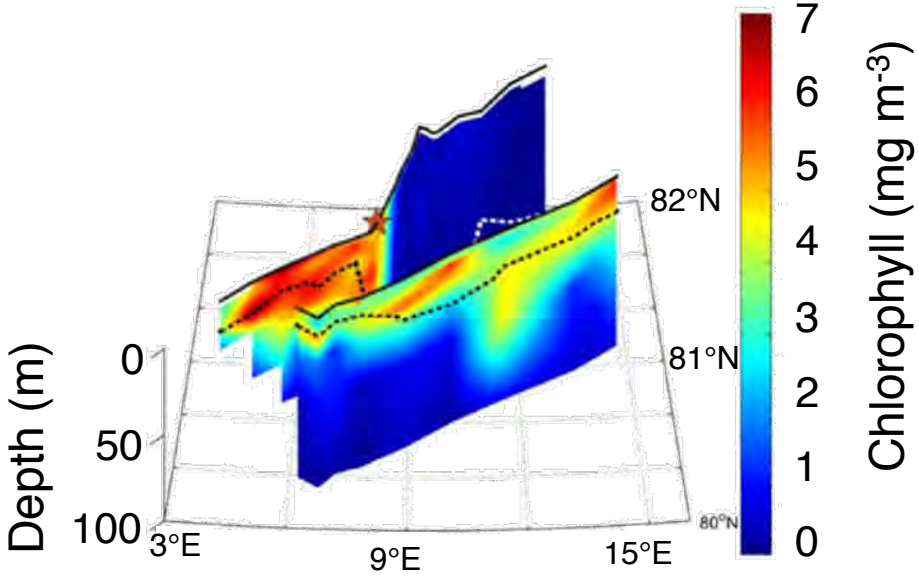


Hill et al. (2017)

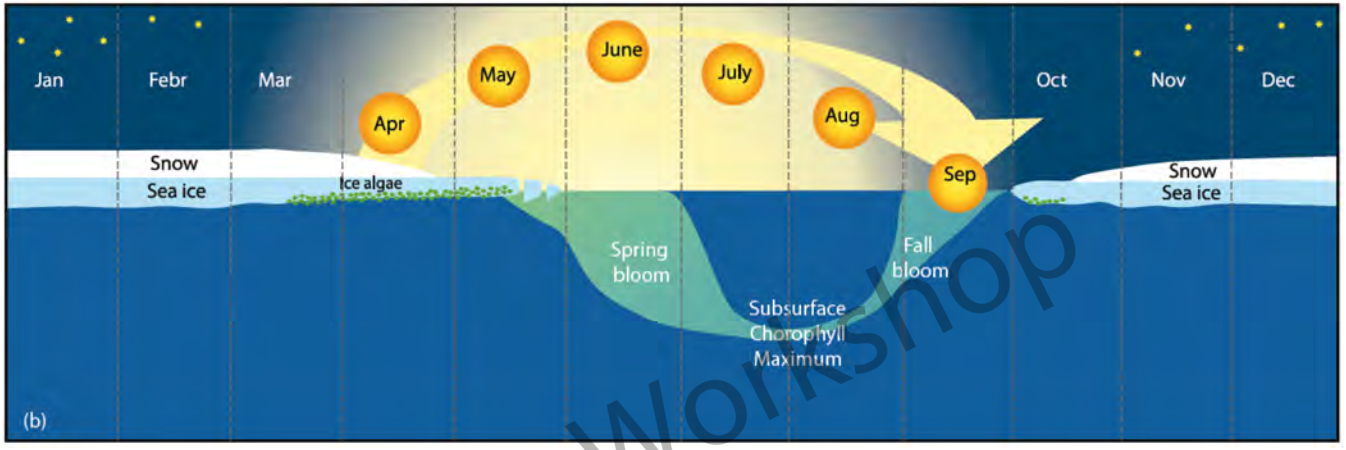
North of Svalbard: N-ICE program



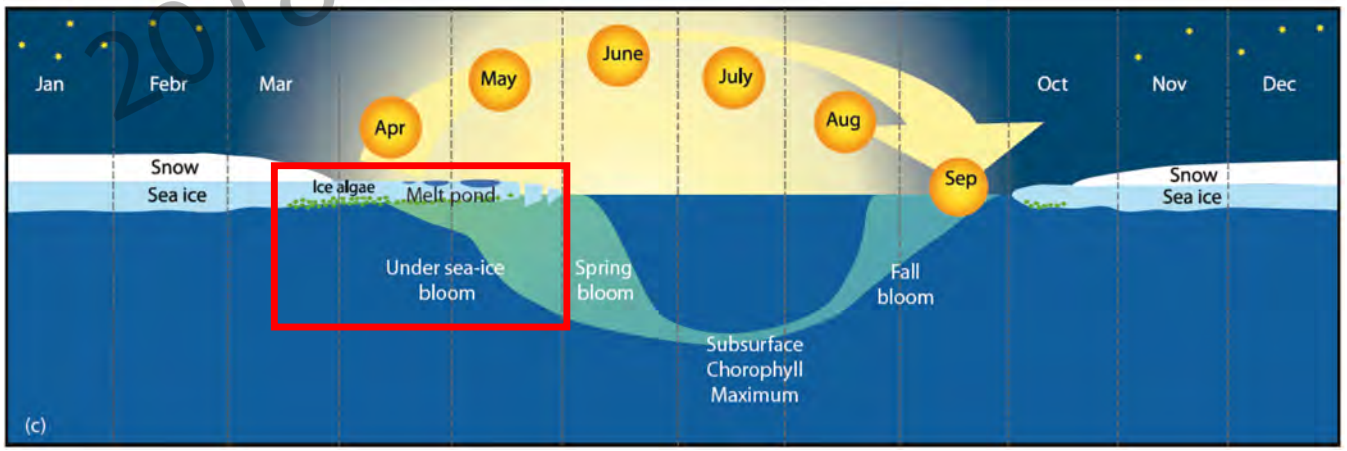


Assmy et al. (2017)

CHANGING ARCTIC PARADIGMS

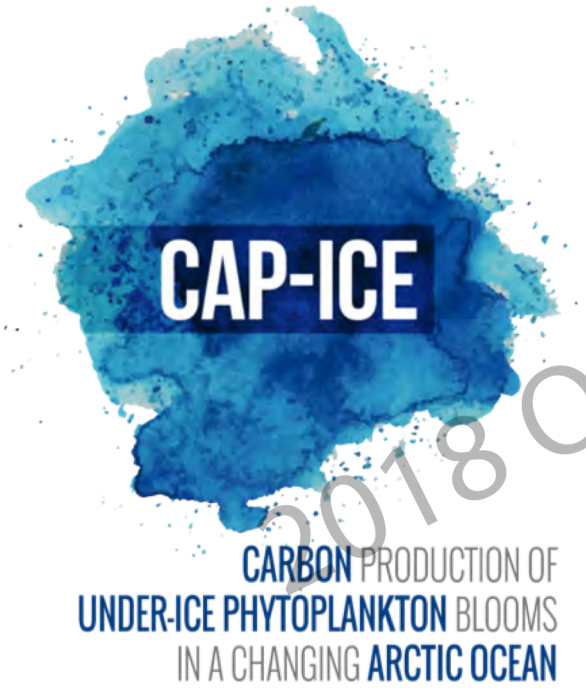


To an **uncertain future** for the sea-ice algae and under-ice phytoplankton blooms



Ardyna (2015), Wasmman & Reigstad (2011)

CAP-ICE: MARIE SKLODOWSKA-CURIE FELLOWSHIP



The primary objectives are to:

(i) Determine the spatial importance of under-ice blooms in the Arctic Ocean.

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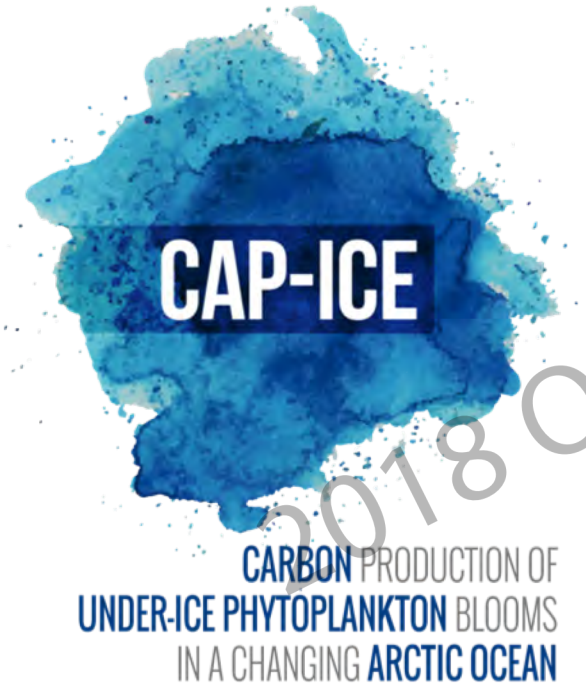

The primary objectives are to:

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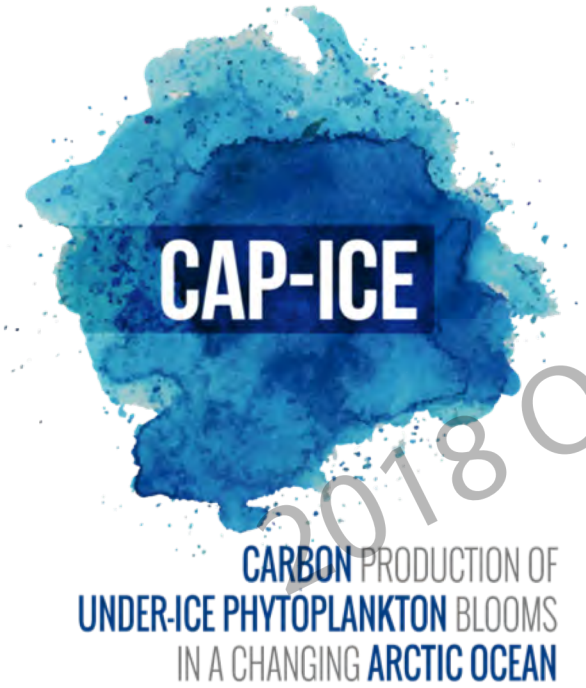
(ii) Reveal the environmental drivers of the initiation, magnitude and structure

Co-financed by the Connecting Europe Facility of the European Union

CAP-ICE: MARIE SKLODOWSKA-CURIE FELLOWSHIP



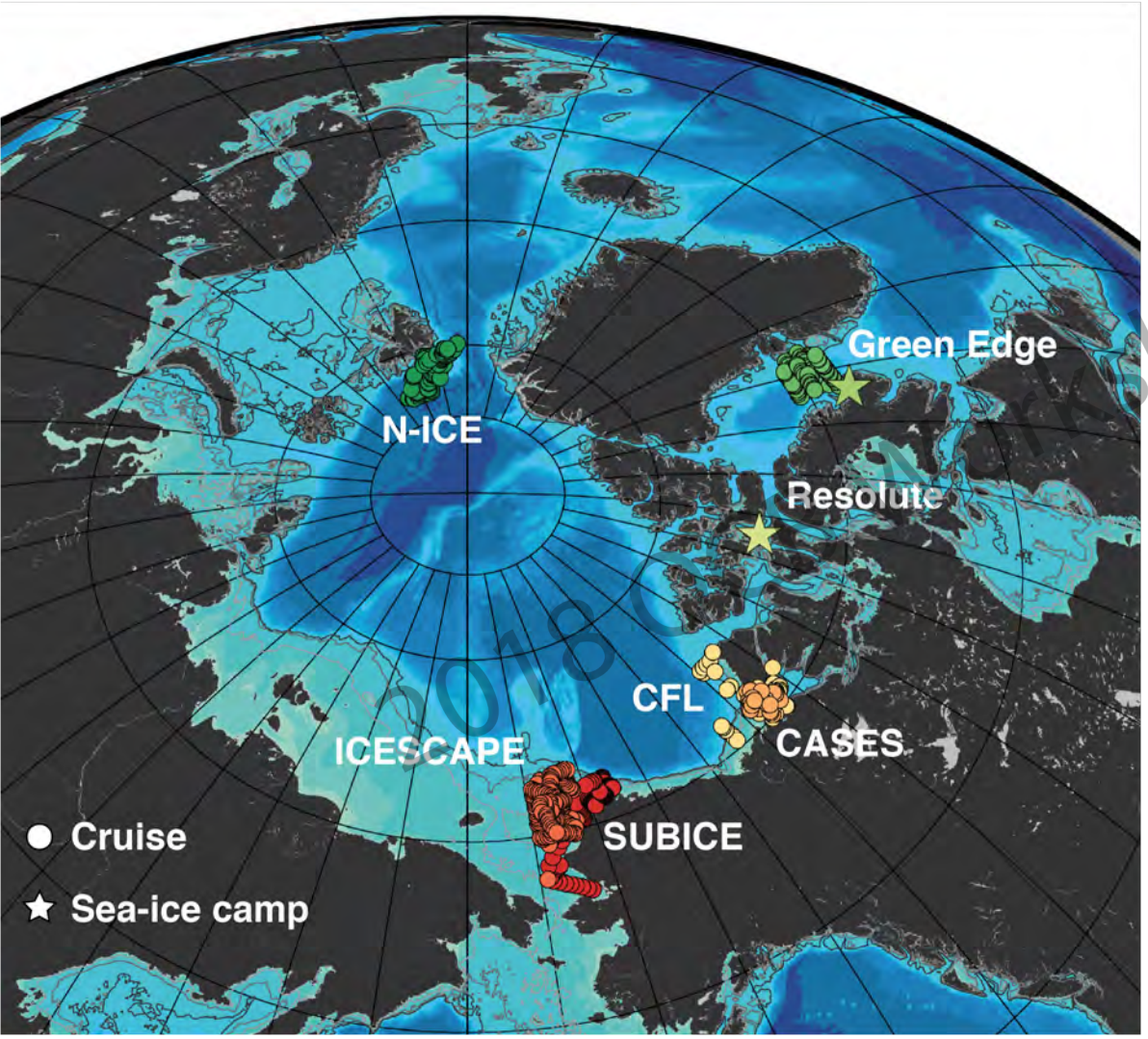
The primary objectives are to:

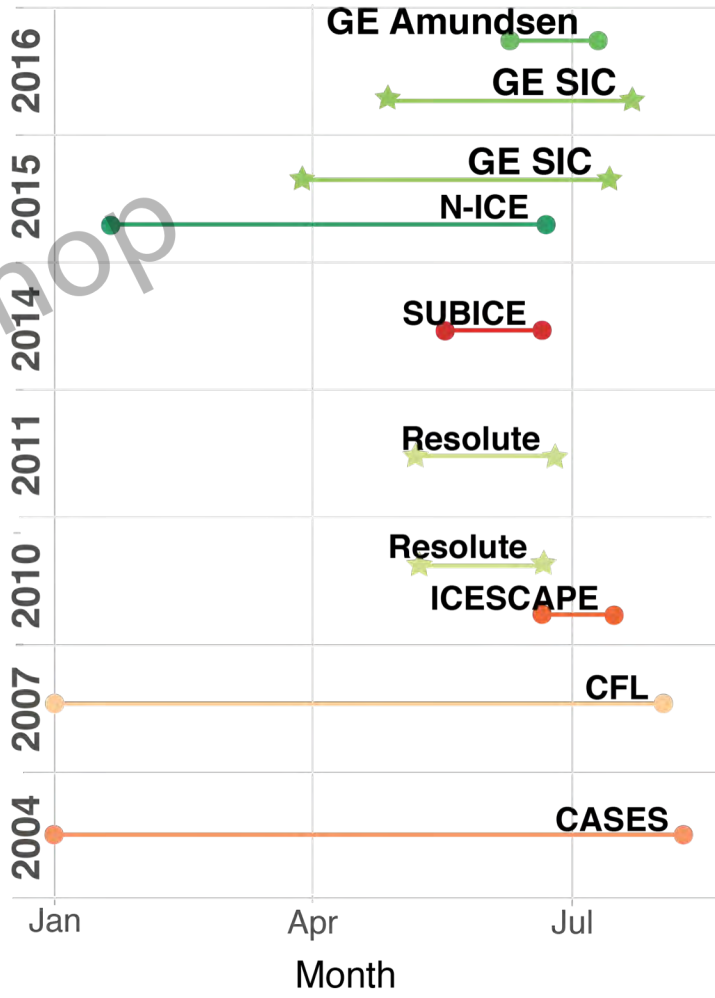
(i) Determine the spatial importance of under-ice blooms in the Arctic Ocean.

(ii) Reveal the environmental drivers of the initiation, magnitude and structure

(iii) Upscale their survey and predict their occurrence by combining autonomous platforms and satellite

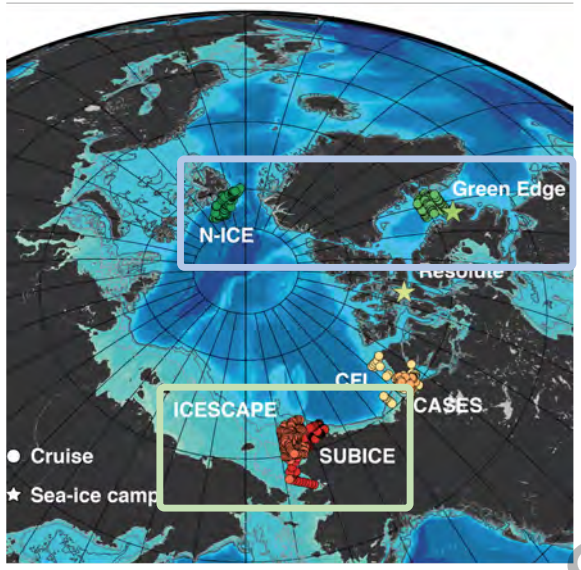
PAN-ARCTIC CONSORTIUM: EXPEDITION & SEA-ICE CAMPS

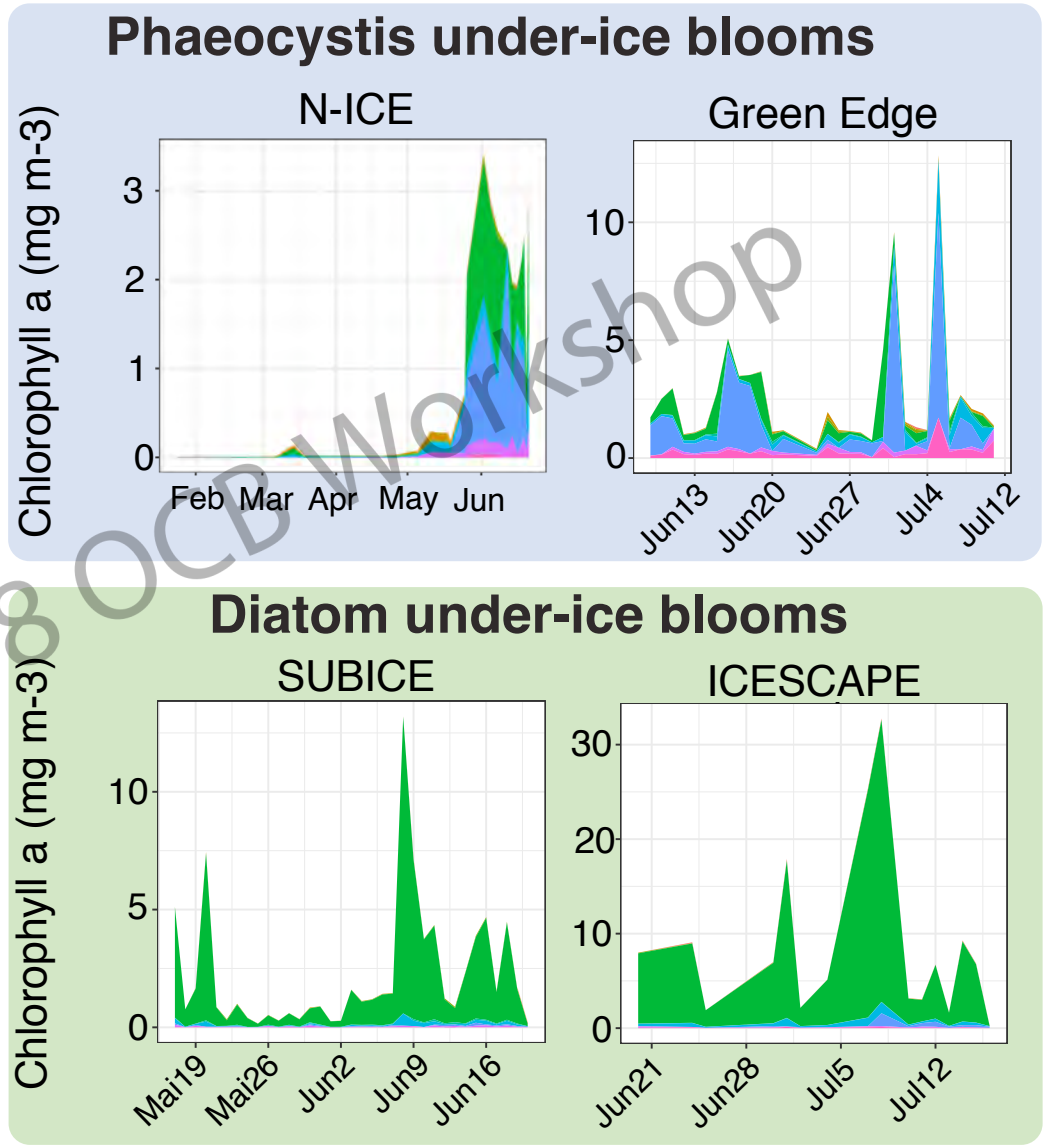




Ardyna et al. (In prep.)

DIATOM VERSUS *PHAEOCYSTIS* UNDER-ICE BLOOMS





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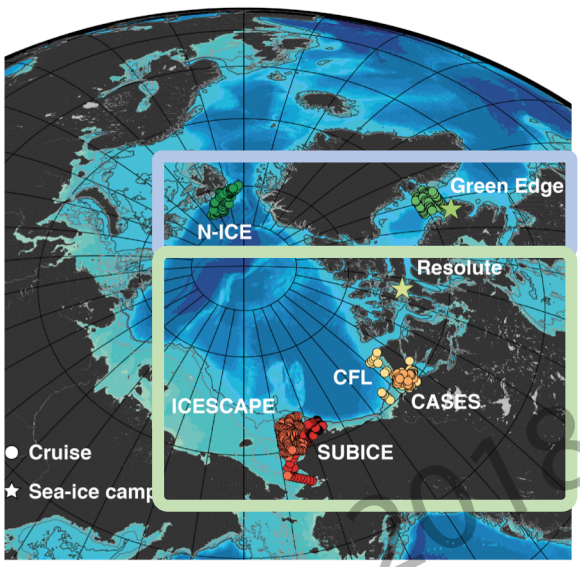
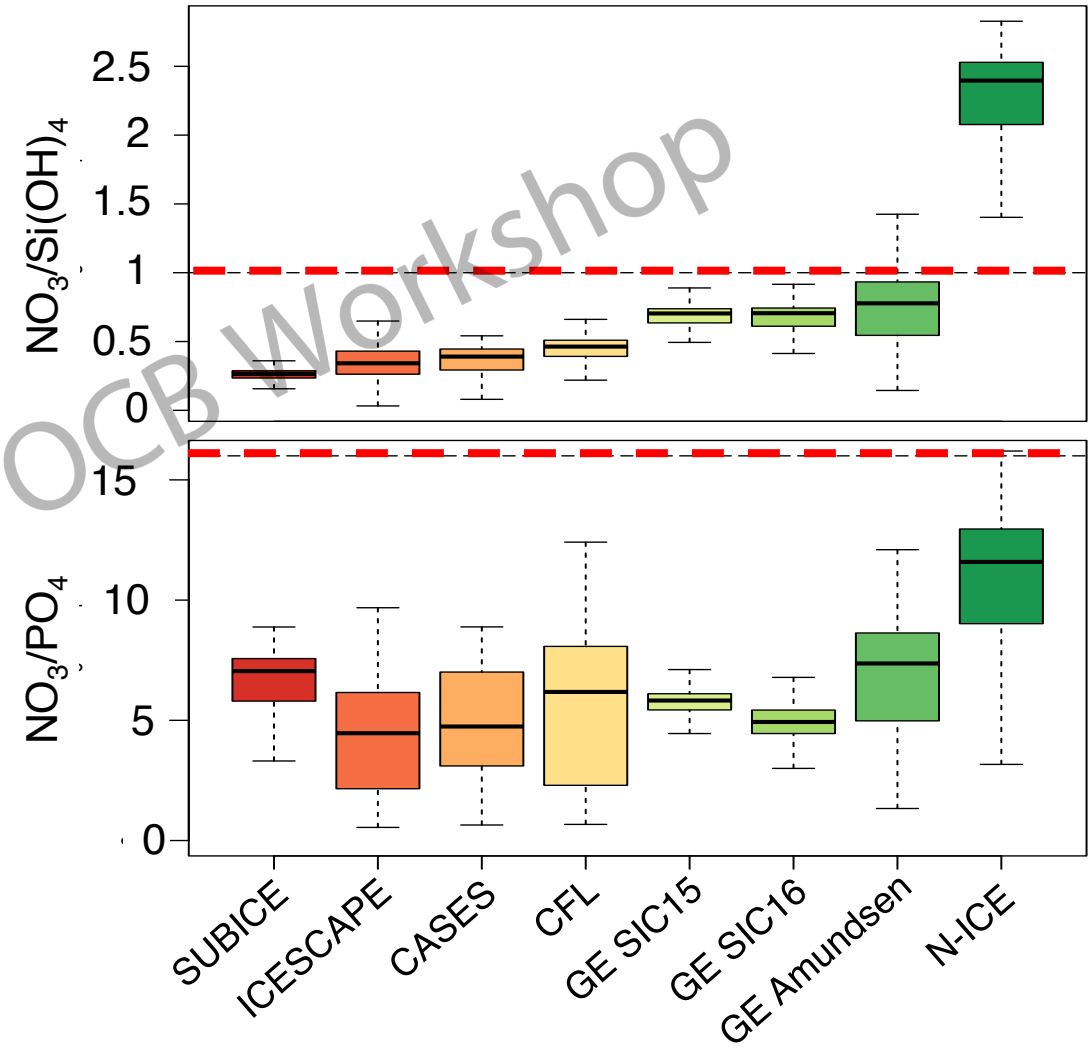


Phaeocystis

Diatoms



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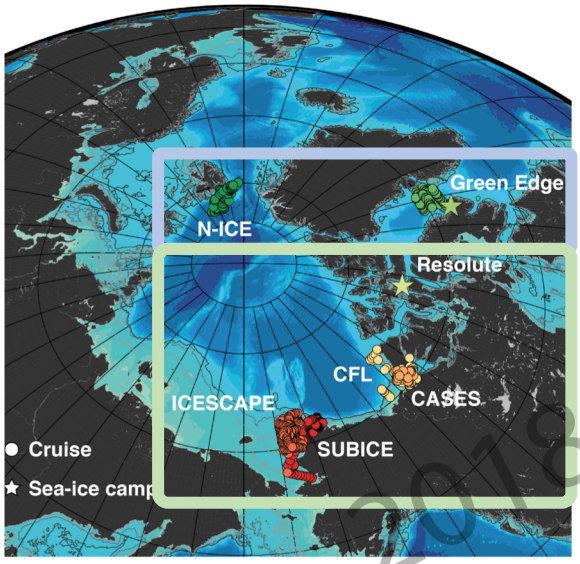
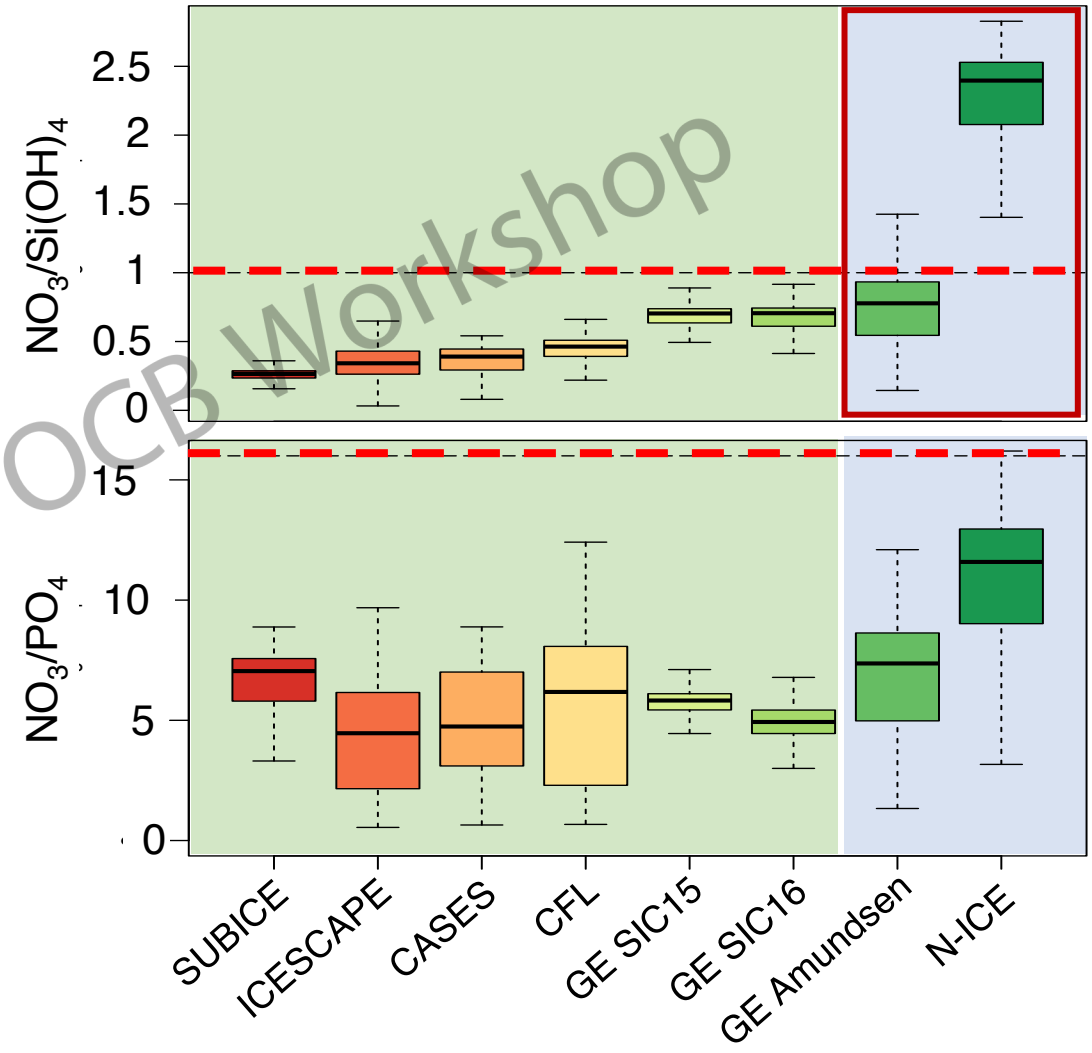


Phaeocystis

Diatoms

Silicate limitation



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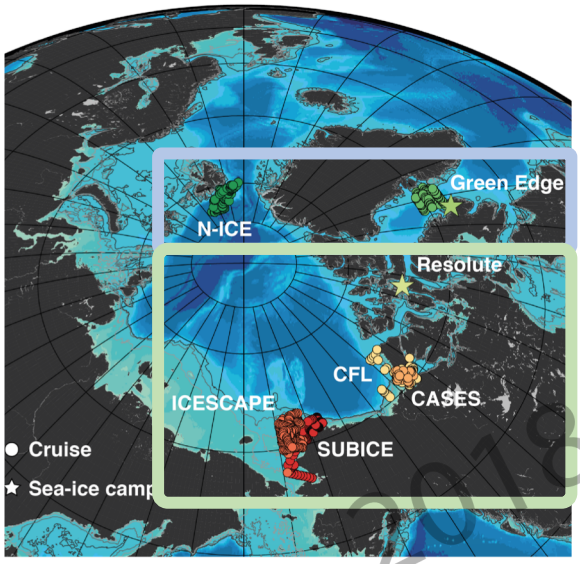

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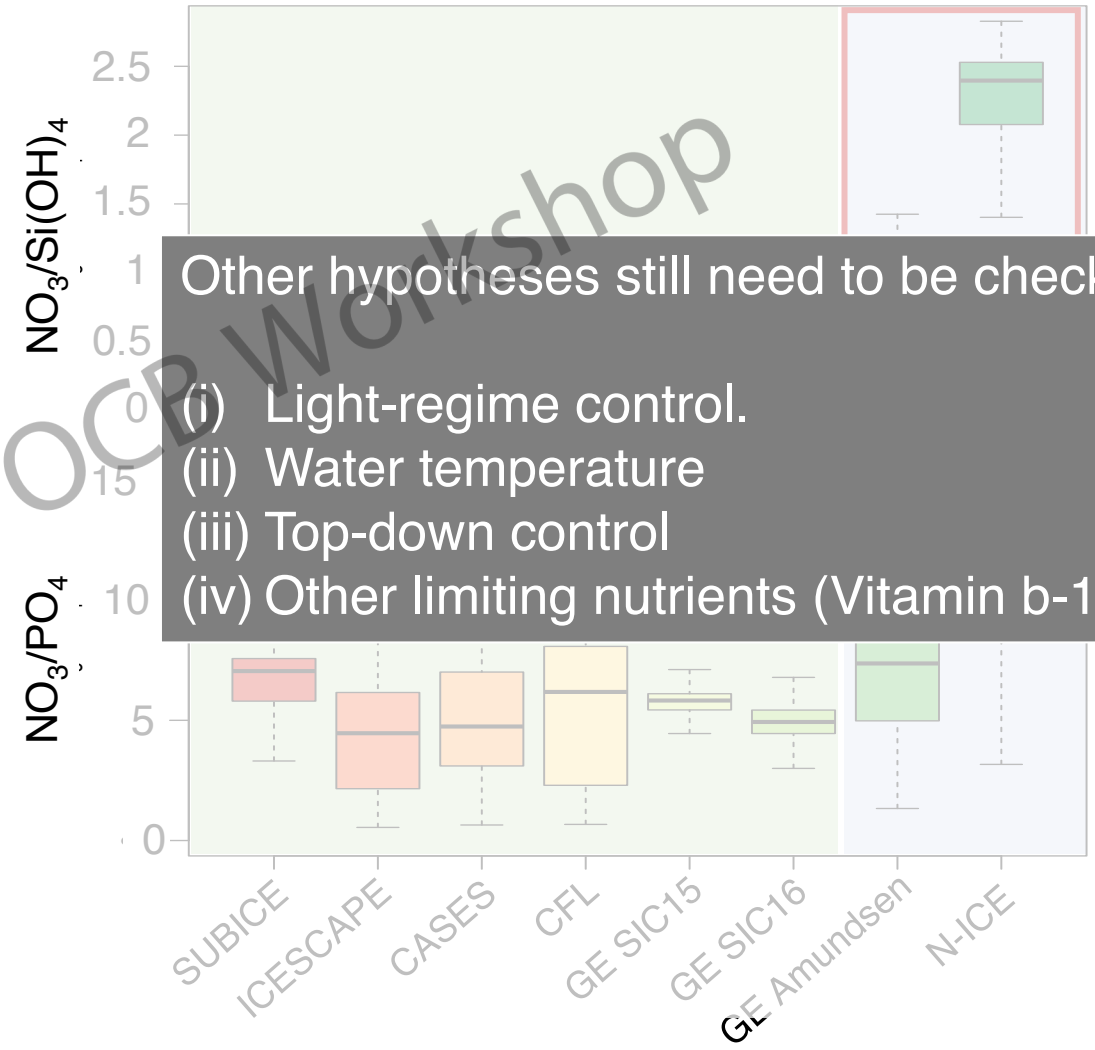
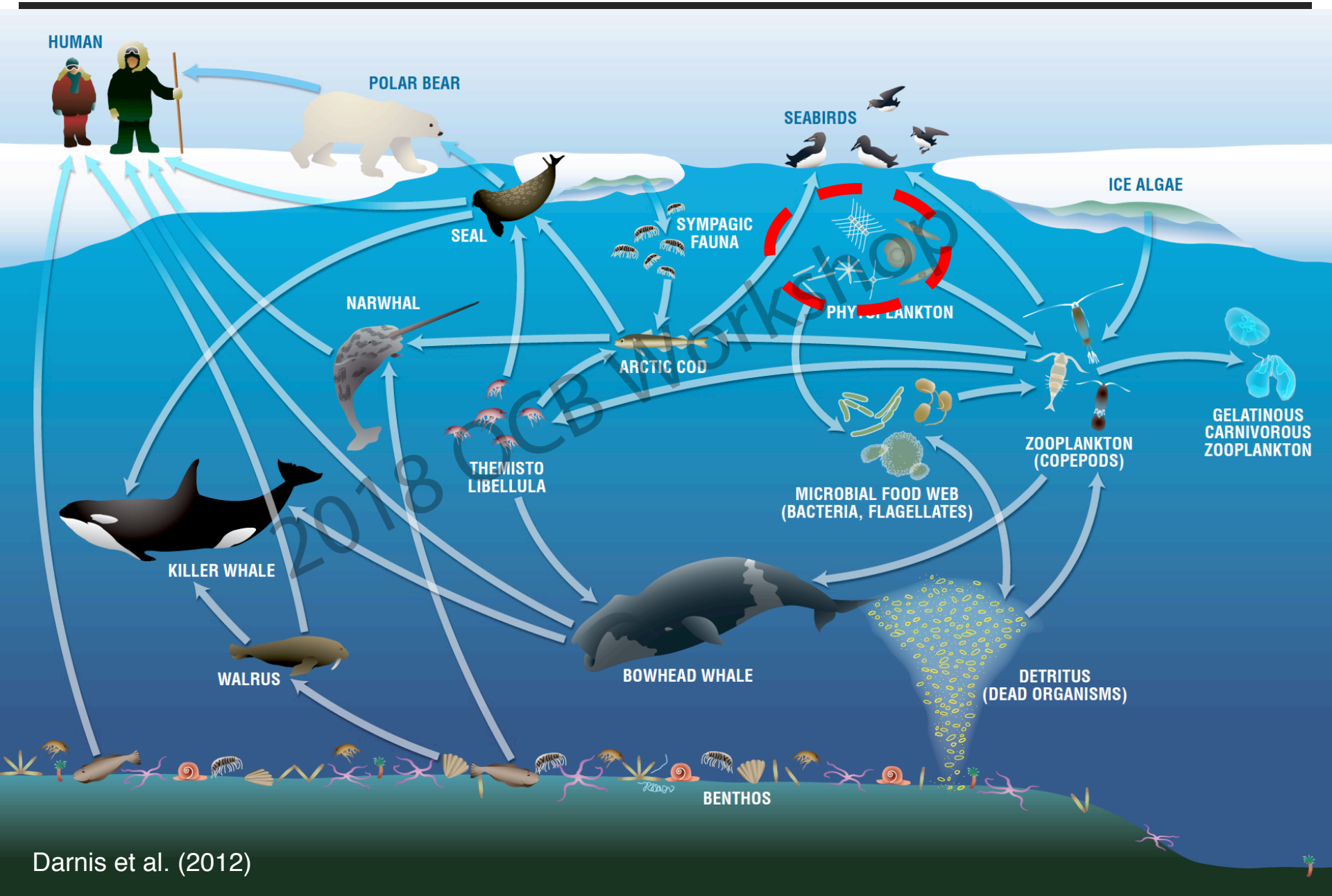


Other hypotheses still need to be checked:

(i) Light-regime control.
(ii) Water temperature
(iii) Top-down control
(iv) Other limiting nutrients (Vitamin b-12…)

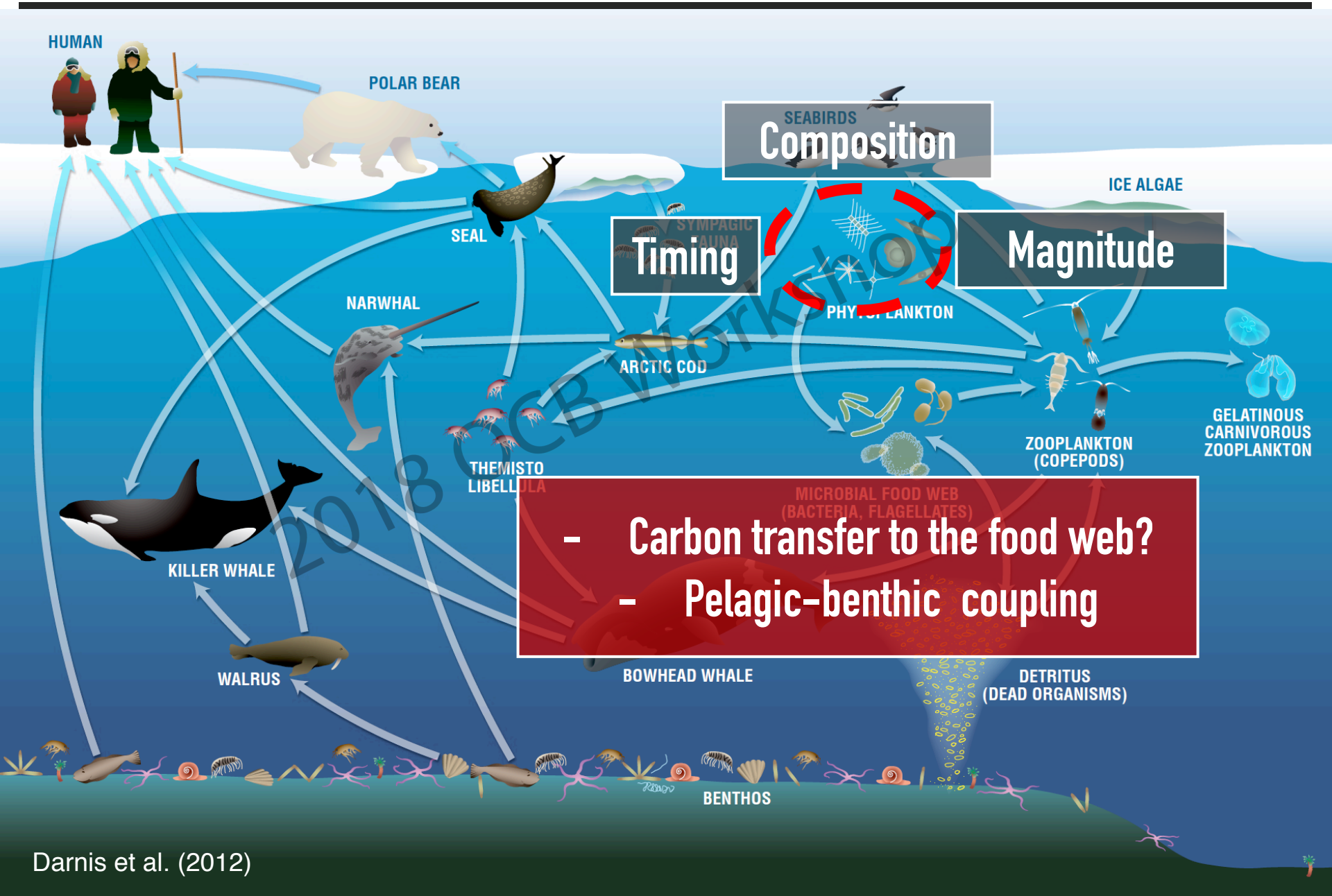
Ardyna et al. (In prep.)

IMPLICATIONS FOR ARCTIC MARINE ECOSYSTEMS ?



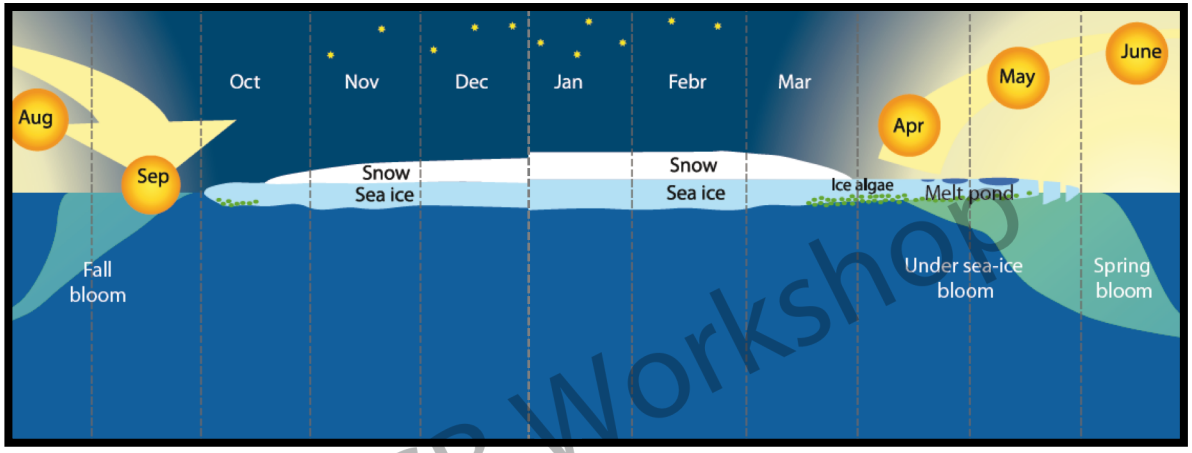
Darnis et al. (2012)

IMPLICATIONS FOR ARCTIC MARINE ECOSYSTEMS ?



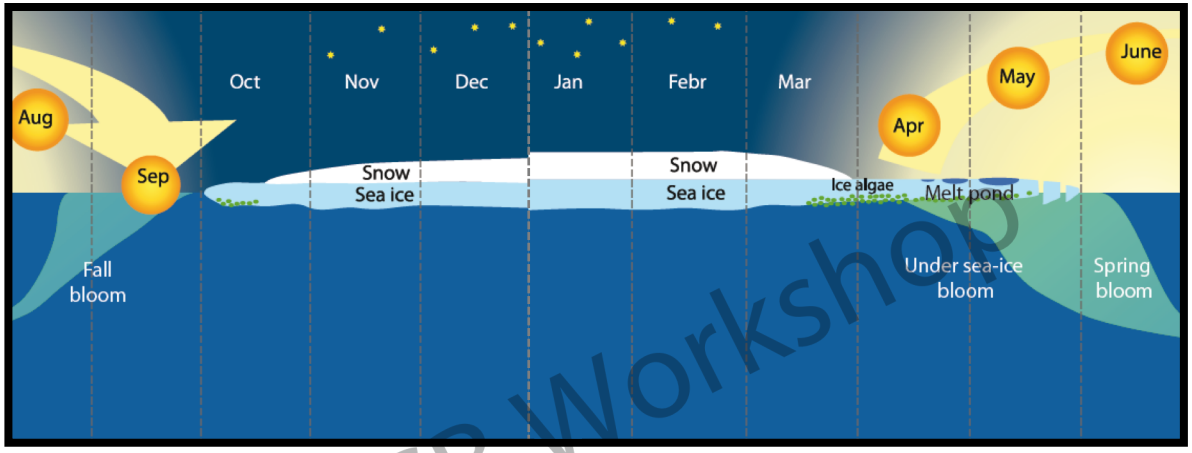
Darnis et al. (2012)

FUTURE PERSPECTIVES



How are the changing sea-ice dynamics modifying under-ice biogeochemistry and carbon cycle?

Future Perspectives



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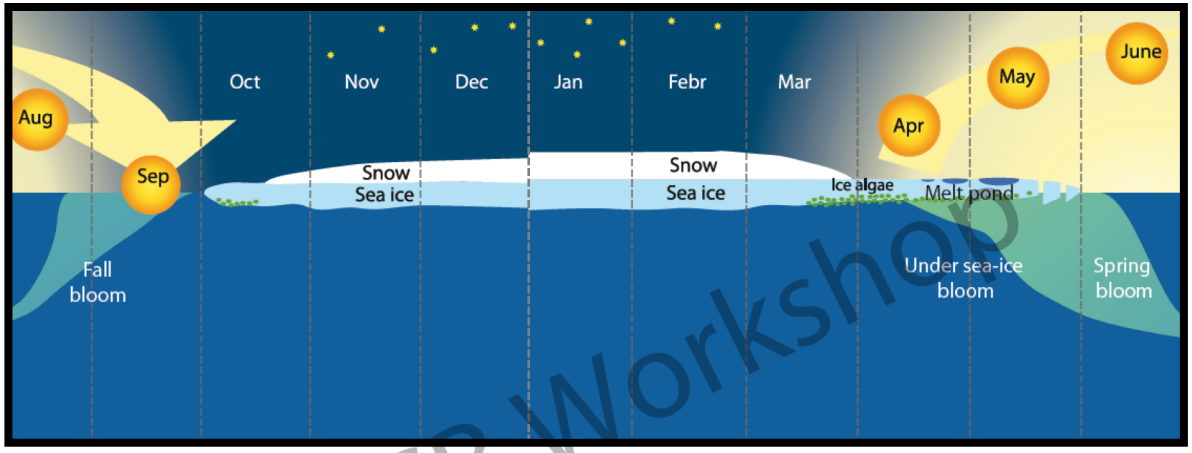

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The polar night and under-ice environments need more attention!!!

CAP-ICE

CARBON PRODUCTION OF UNDER-ICE PHYTOPLANKTON BLOOMS IN A CHANGING ARCTIC OCEAN

Questions???

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