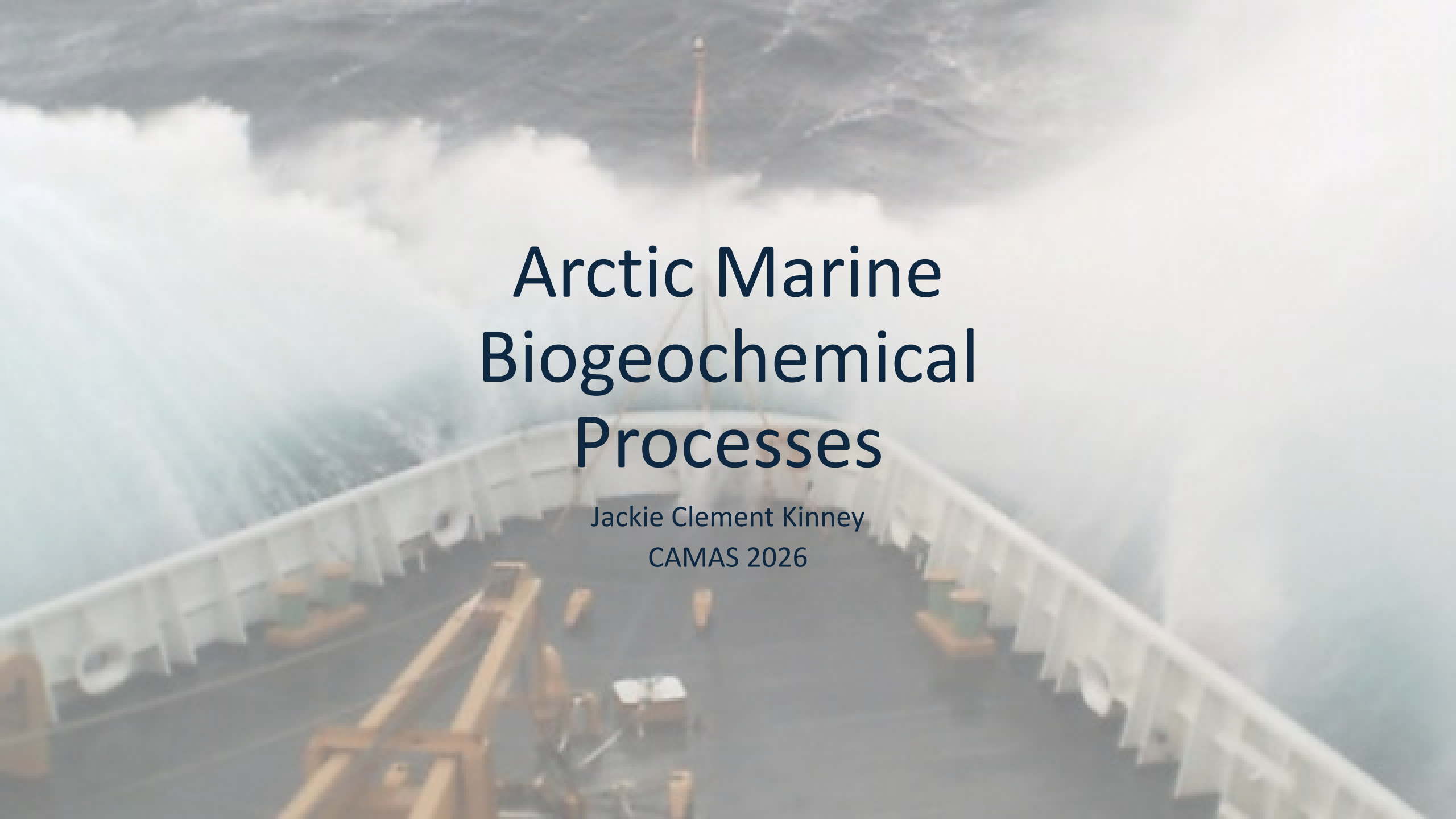
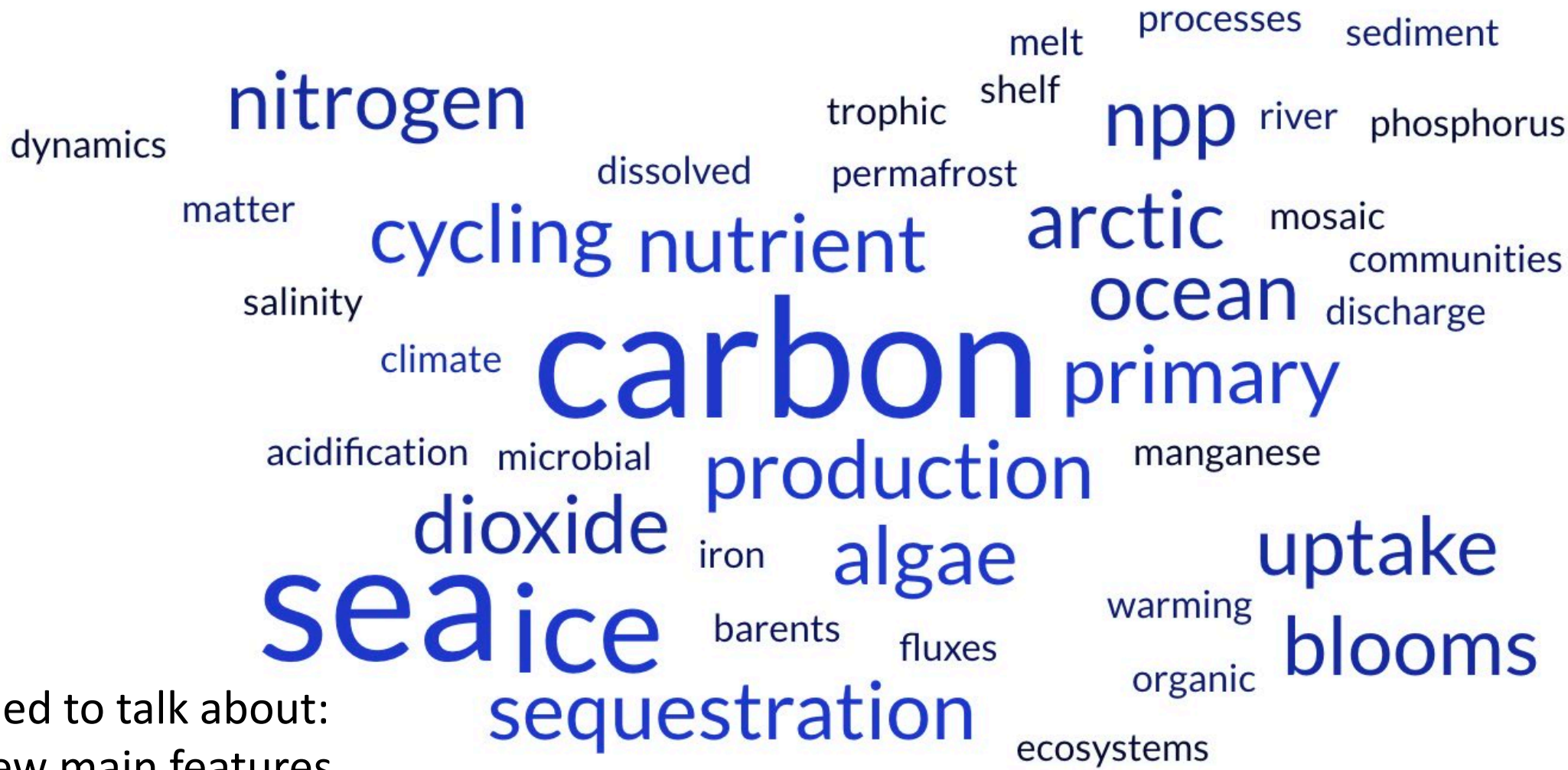


Arctic Marine Biogeochemical Processes

Jackie Clement Kinney

CAMAS 2026

Arctic Marine Biogeochemical Processes…



Decided to talk about:

1) a few main features
2) interesting recent work
3) proposed future directions

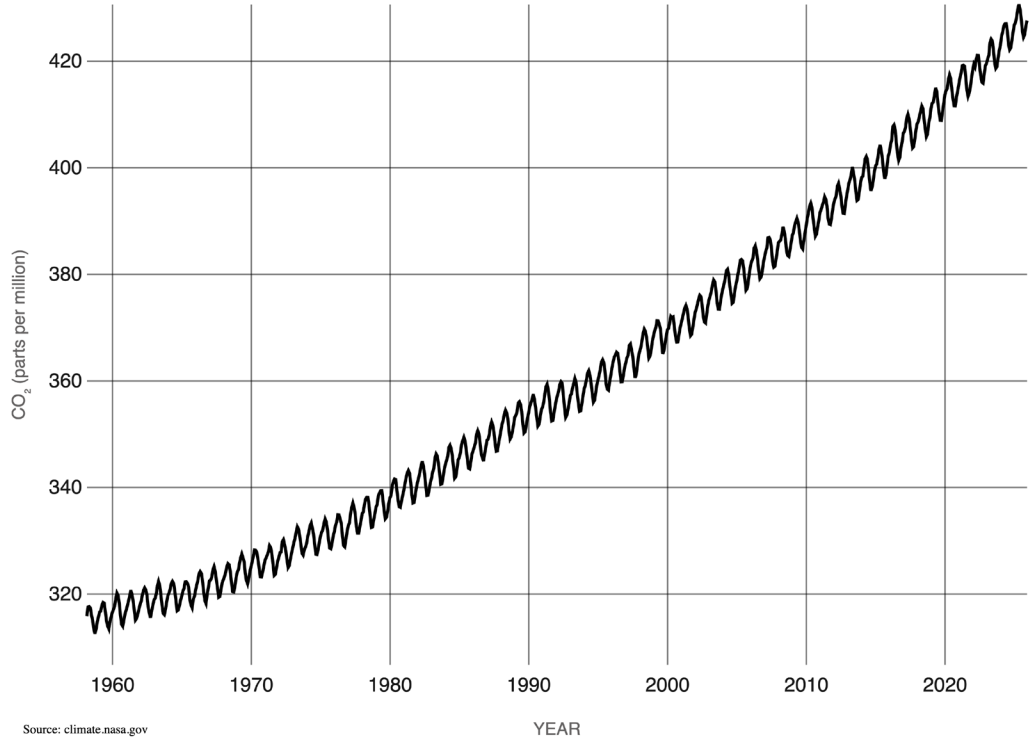
BGC can has a role in climate change

Every day the ocean takes up and stores CO^2 from the atmosphere through two related processes collectively referred to as the ocean carbon "sink." This includes:

1) ocean plants and phytoplankton taking in CO^2 and converting it into organic matter
2) the ocean absorbing and dissolving CO^2 from the atmosphere

The ocean is a major net carbon sink, absorbing approximately **25-31**% of all human-induced CO^2 emissions (Gruber et al., 2019, Science).

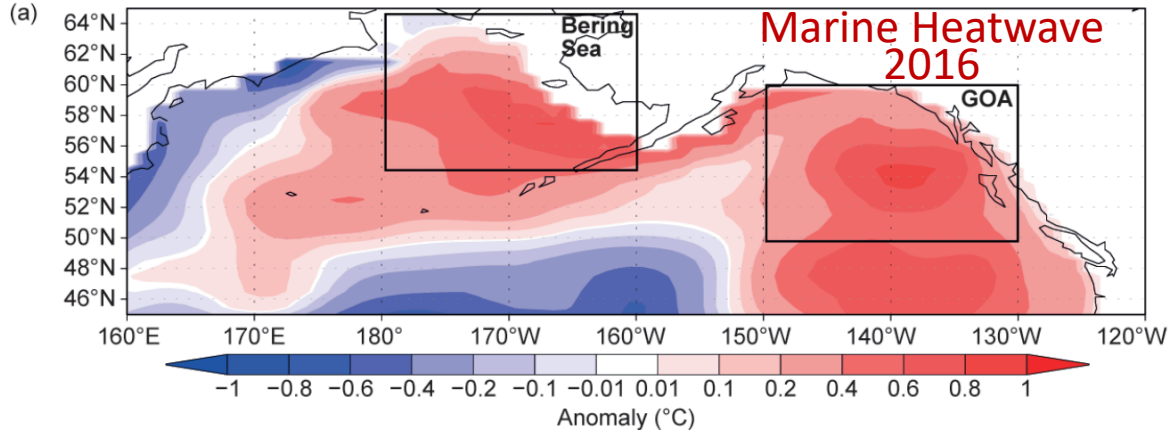
The Arctic Ocean is relatively small but still accounts for **5-14**% of the global ocean's CO^2 uptake (Manizza et al. 2013, Global Biogeochemical Cycles).

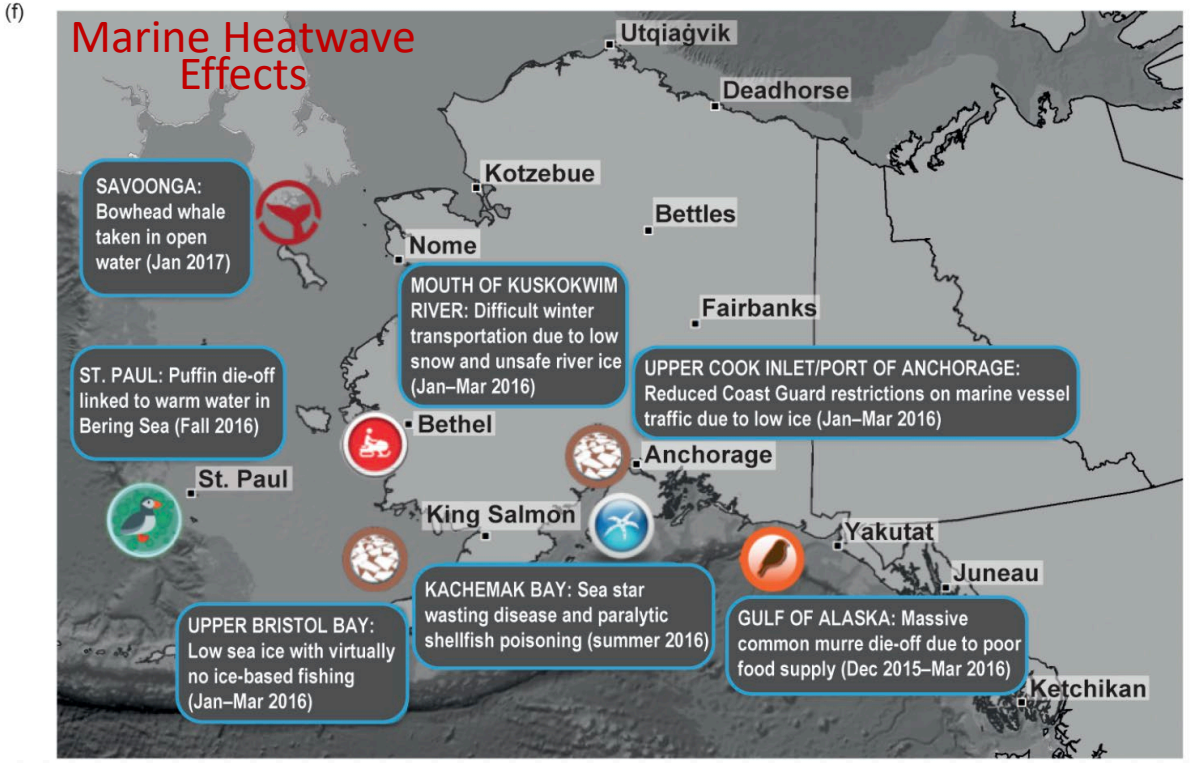


Atmospheric CO^2 levels measured by NOAA at Mauna Loa Observatory, Hawaii

BGC can has a role in climate change

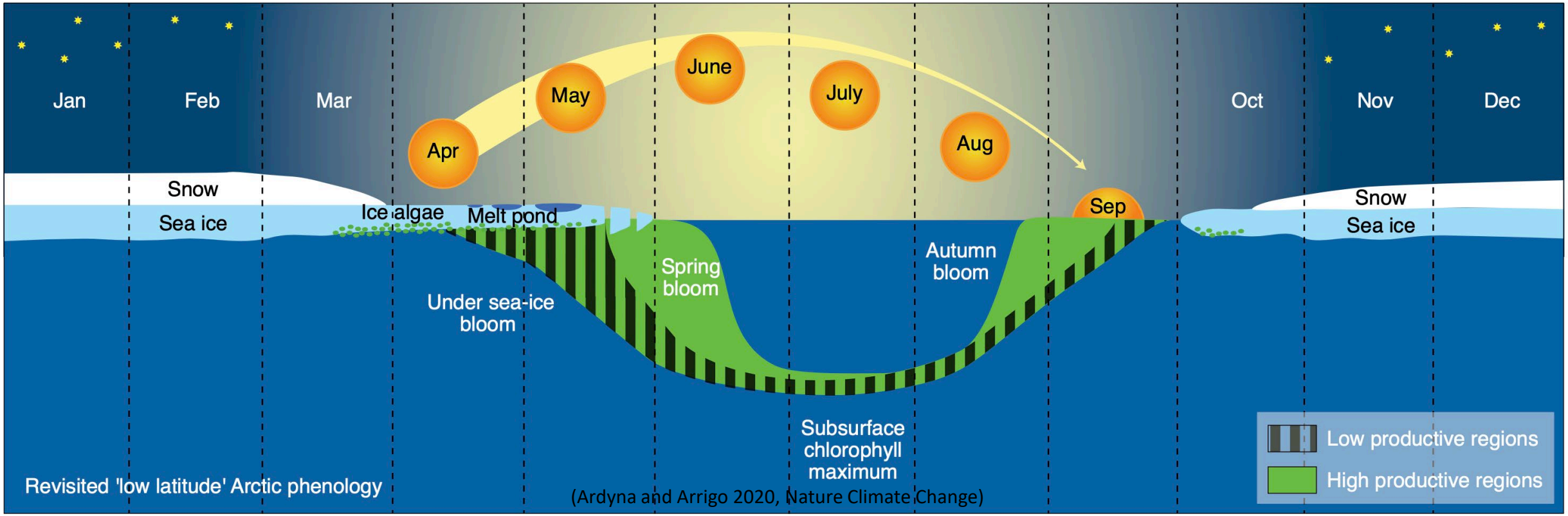
- **Biological Pump**: Phytoplankton and marine microorganisms use CO^2 for photosynthesis, forming organic matter that sinks, effectively removing carbon from the atmosphere and storing it in the deep ocean.
- **Carbon Sink/Source Dynamics**: Biogeochemical factors like temperature, pH, and nutrient availability alter seawater's capacity to absorb CO^2, shifting it between a carbon sink and source.
- **Trace Gases**: Marine biogeochemistry influences the emission of gases like dimethyl sulfide (DMS), which affects aerosol formation and cloud cover, impacting atmospheric reflectivity.
- **Marine Heatwaves & Acidification**: Warming and acidification stress marine ecosystems, impacting calcifying organisms and phytoplankton communities that drive the biological pump, potentially reducing carbon sequestration.





Walsh et al. 2018, BAMS

Many BGC processes have a strong seasonal cycle

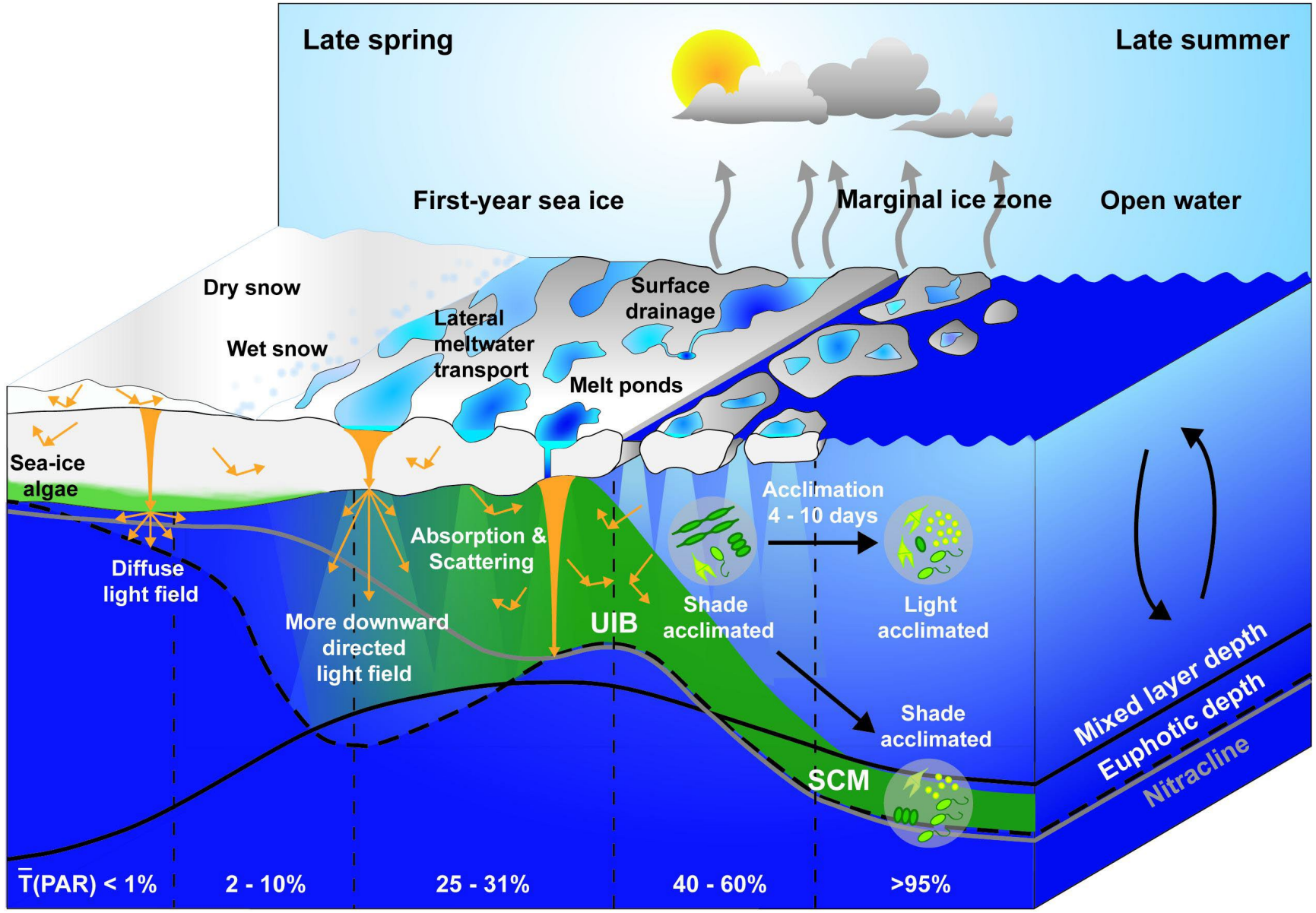


'Borealization' of Arctic phytoplankton phenology

- start of the growing season is earlier
- end of the growing season has been delayed
- Will the disappearance of the summer sea-ice barrier enhance atmospheric forcing and increase nutrient supply and carbon production?

Under sea ice pelagic phytoplankton blooms (UIBs)

- Phytoplankton growth is strongly constrained by light availability
- UIBs were previously believed to be negligible
- Melting of snow and melt ponds enhance light availability

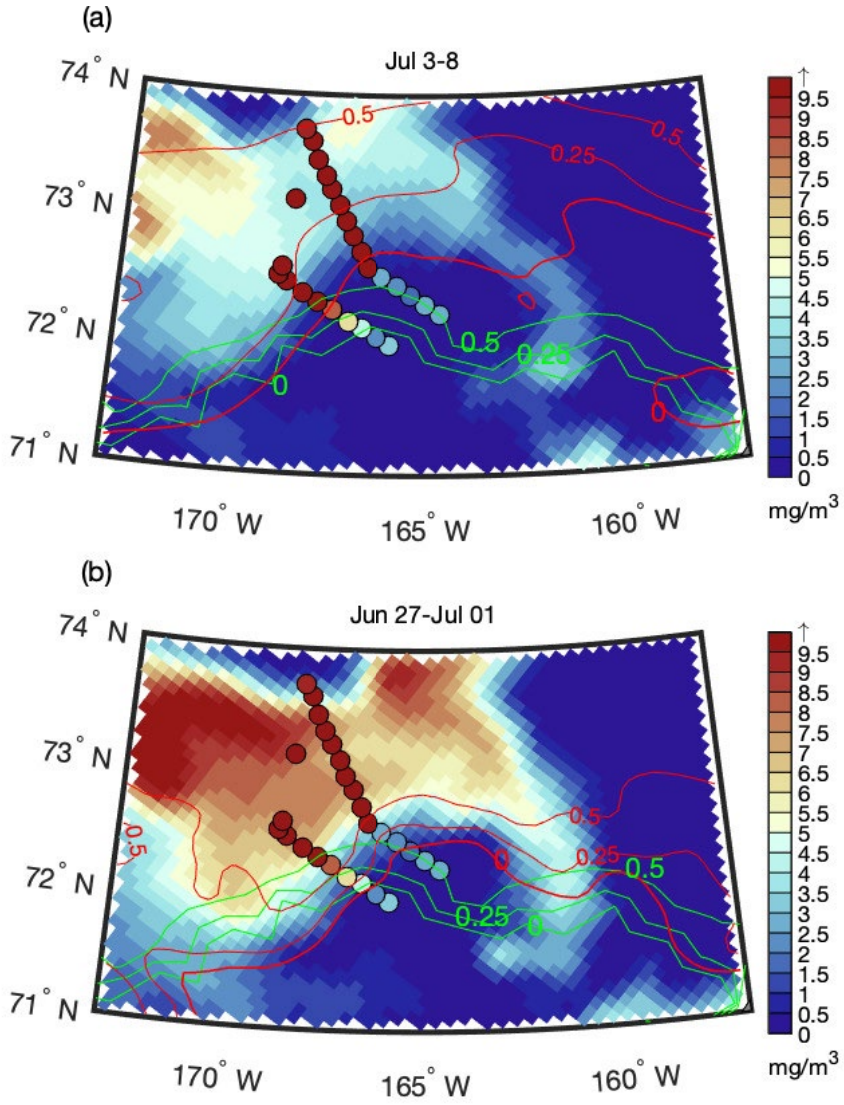


(Ardyna et al. 2020)

Under sea ice pelagic phytoplankton blooms (UIBs)

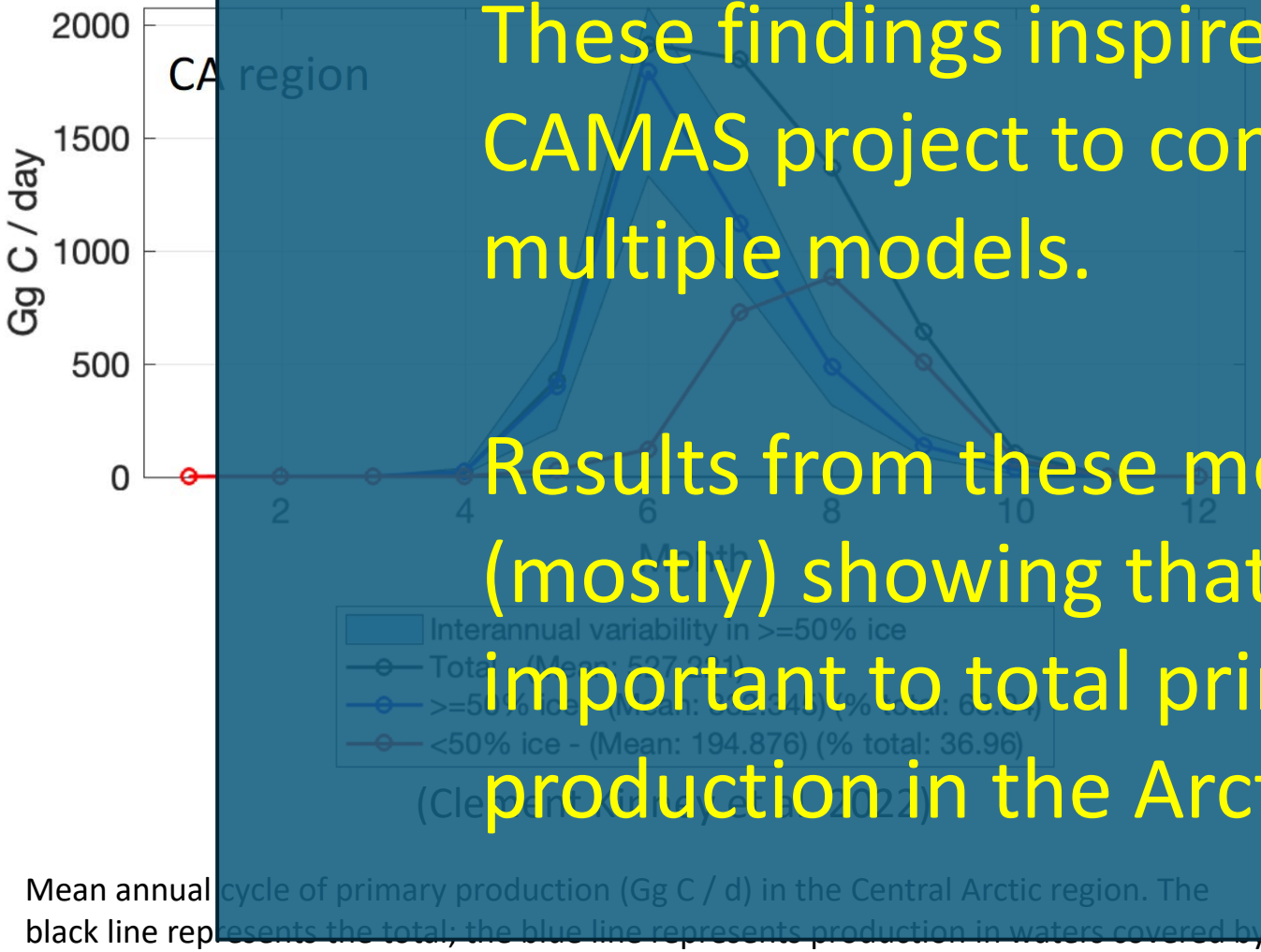
- Observations of a “massive bloom” in the northern Chukchi Sea in July 2011 (Arrigo et al. 2012) during the ICESCAPE expedition
- RASM has similar (but slightly earlier) chl-*a* distribution
- Reliable representation of sea ice is critical for the simulation of UIBs

→ Modeled surface chl-a distribution in the northern Chukchi Sea (shading) and observations (circles). Red lines indicate modeled ice concentration; green lines indicate observed ice concentration from satellite during the ICESCAPE cruise.



Clement Kinney et al. 2023

Under sea ice pelagic phytoplankton blooms (UIBs)



Mean annual cycle of primary production (Gg C / d) in the Central Arctic region. The black line represents the total; the blue line represents production in waters covered by >= 50% ice; the red line represents production in waters with <50% ice. The shaded blue area represents the interannual variability in production in waters covered by >= 50% ice.

These findings inspired a current CAMAS project to compare UIBs in multiple models.

Results from these models are (mostly) showing that UIBs are very important to total primary production in the Arctic!

- Most primary production (63%) in the Arctic Ocean and marginal seas occurs under sea ice that is at least 50% in concentration
- Annual cycles of primary production show there is a peak in June for the under sea ice component
- Environmental conditions in spring are conducive for a bloom
- Current observational estimates of the primary production in the Arctic Ocean may be significantly underestimated, due to the importance of under-sea ice production

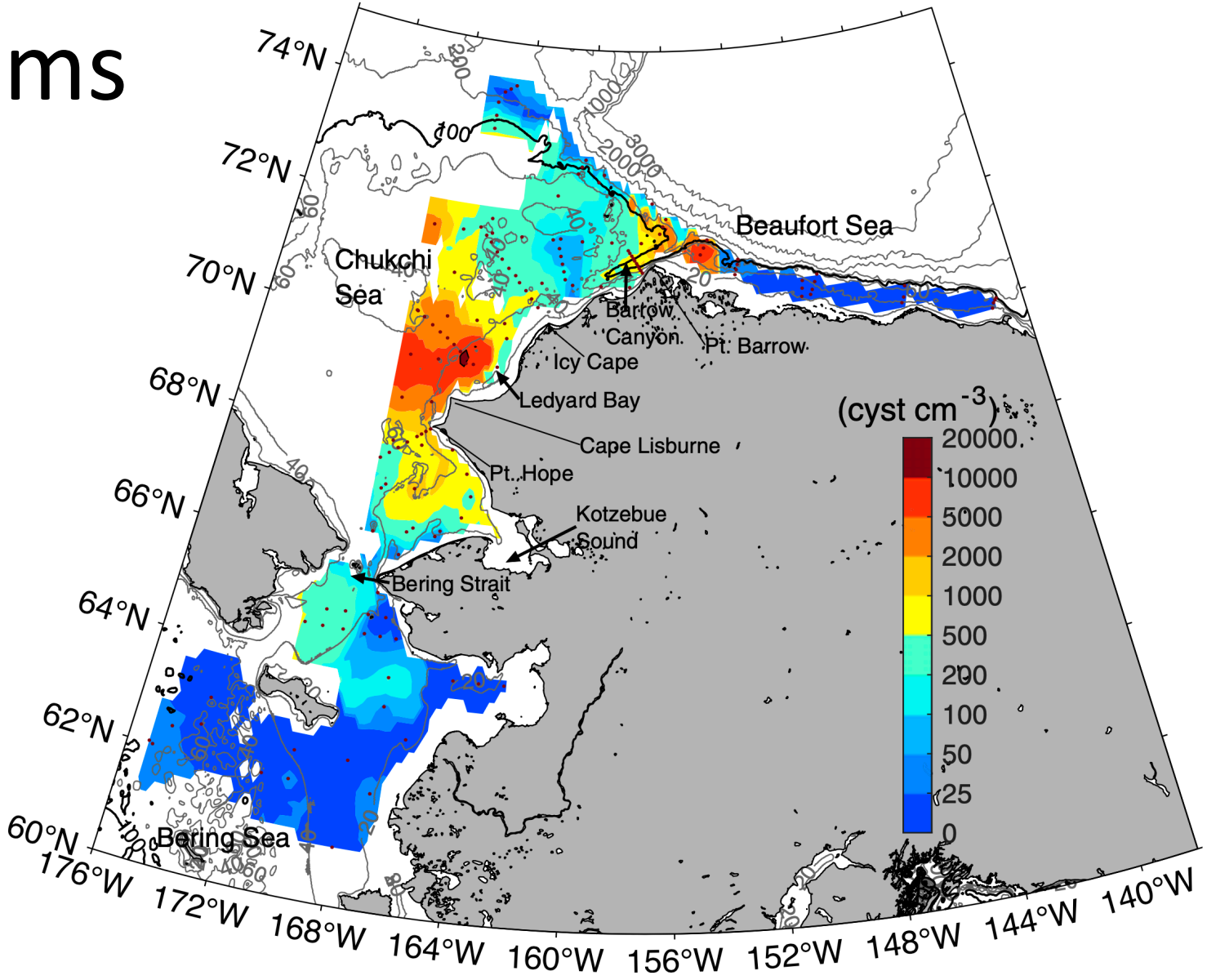
Harmful Algal Blooms

- **Harmul algae:** *Pseudo-nitzschia* spp., *Dinophysis* sp., Cyanobacteria, and ***Alexandrium catenella***
- ***Alexandrium catenella***: most problematic species in the Pacific Arctic
  - Paralytic Shellfish Poisoning due to the powerful saxitoxin that can be produced
  - Can be lethal to high trophic organisms, including humans
  - Have a benthic resting stage
  - Germinate when temperature, light, and oxygen are optimal
  - Temperatures of bottom waters are increasing in areas that were previously too cold for germination
  - Increasing threat with warming water

(Fachon et al. 2026)

Harmful Algal Blooms

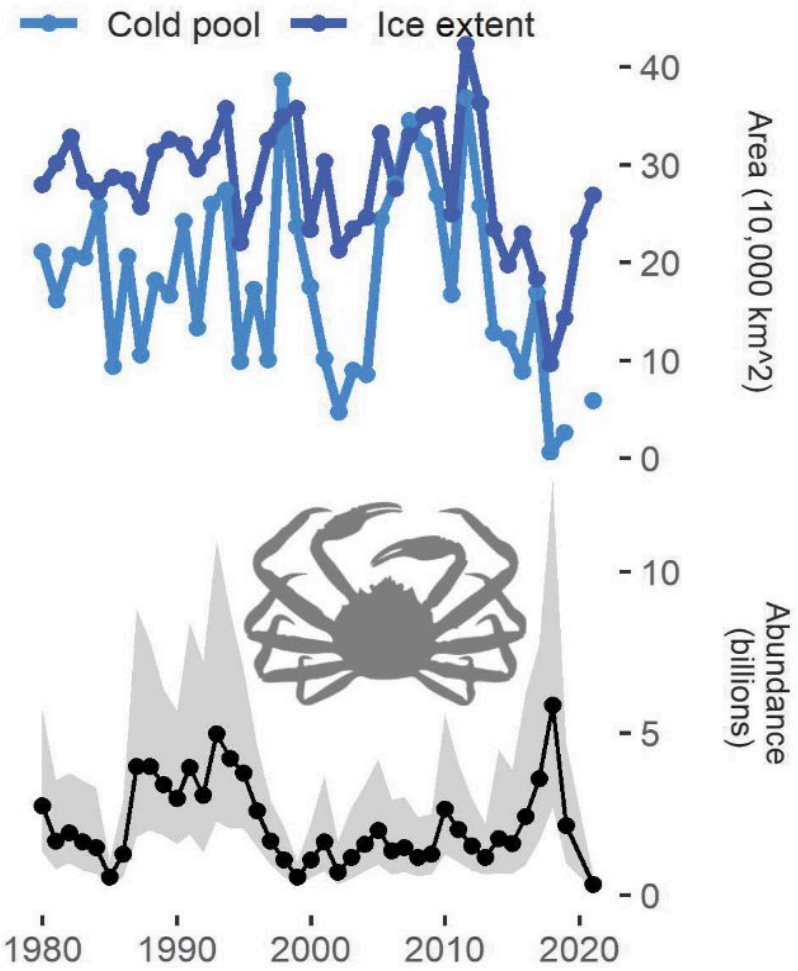
- The largest and most highly concentrated *A. catenella* cyst bed ever measured in the global ocean is in the Chukchi Sea
- Temperatures of bottom waters are increasing in areas that were previously too cold for germination
- Increasing threat with warming water
- More observations and understanding is required
- A need for predictive capability

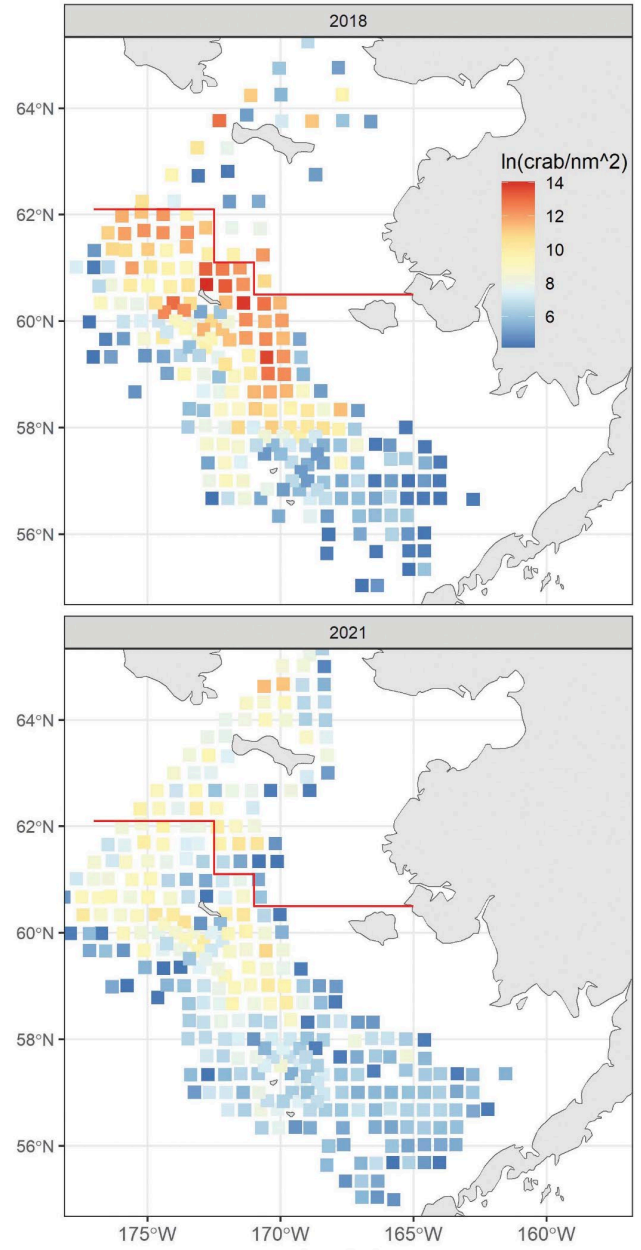


Composite *A. catenella* cyst distribution and abundance in surface sediments (0 to 3 cm) for 2018 and 2019. Data points are indicated by black dots, black lines are the 100-m isobath, and gray contours are bottom depth in meters from ETOPO-2. (Anderson et al. 2021)

Marine Heatwaves Effects

- Very little sea ice in the Bering in 2017-2018
- Drastic reduction in the size of the Bering Sea Cold Pool in 2018
- 10 billion snow crab disappeared from the eastern Bering Sea
- One of the largest losses of motile marine macrofauna to marine heatwaves globally
- Also an economic loss to Alaskans

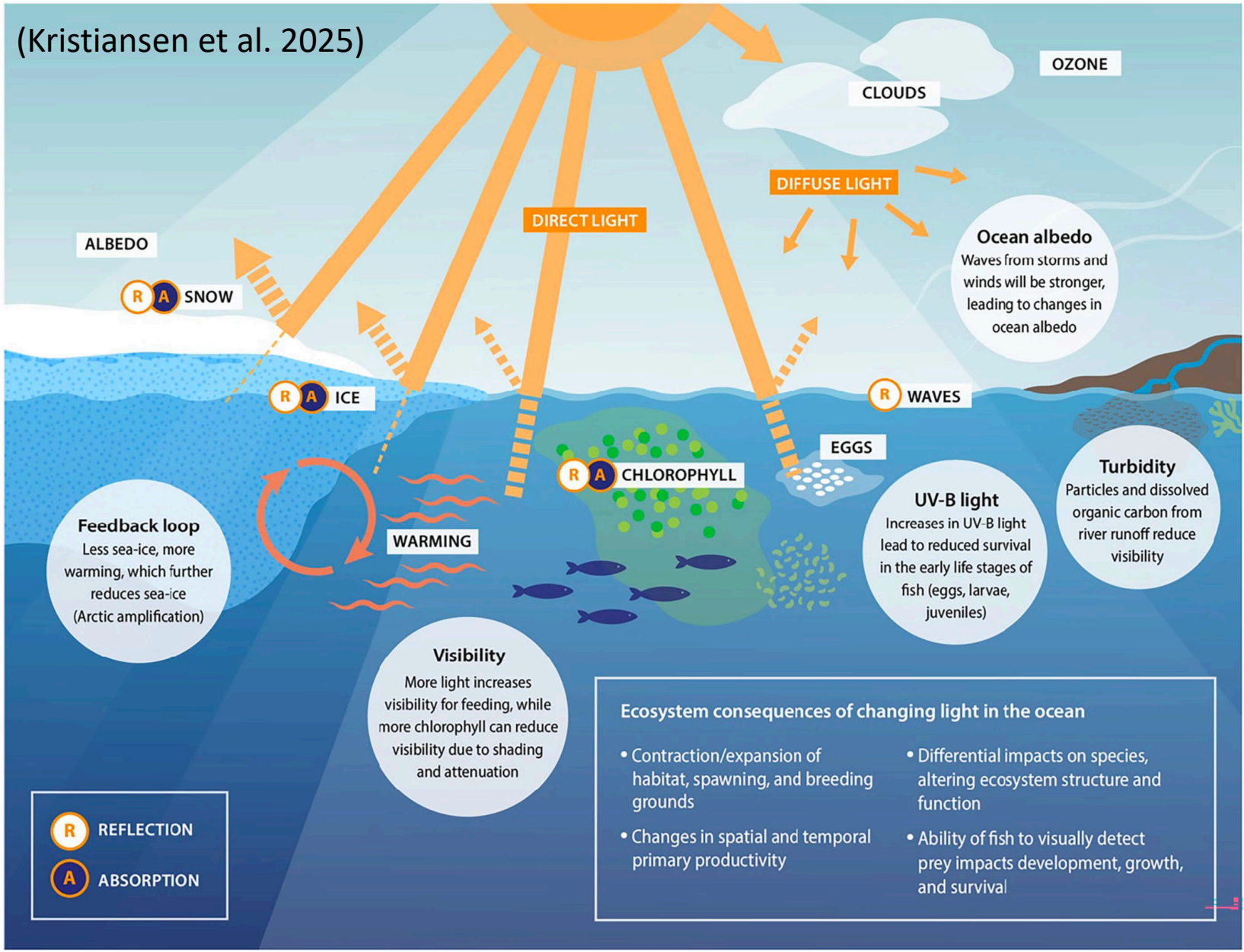




(Szuwalski et al. 2023)

Impacts of Increased Light Availability

- Sea ice loss is leading to increased light availability
- Warming may outpace the adaptive capacity of many Arctic fish species (e.g. polar cod in the Bering and Barents seas)
- Increased levels of UV-B can cause DNA damage that can be detrimental to egg survival and embryonic development
- Allow for the northward expansion of boreal species



Future Challenges

under ice observation

computational resources

New/better technology and methodology

responsible use of AI/ML

integrated observational programs

Marine BGC

Future Challenges

coastal/riverine processes

nutrient cycling

Process understanding and coupled effects

benthic-pelagic coupling

benthic and sediment processes

Marine BGC

Future Challenges

extreme events

HABs

primary production

marine mammals

Predictive capability

marine heatwaves

sea ice

fisheries

Marine BGC