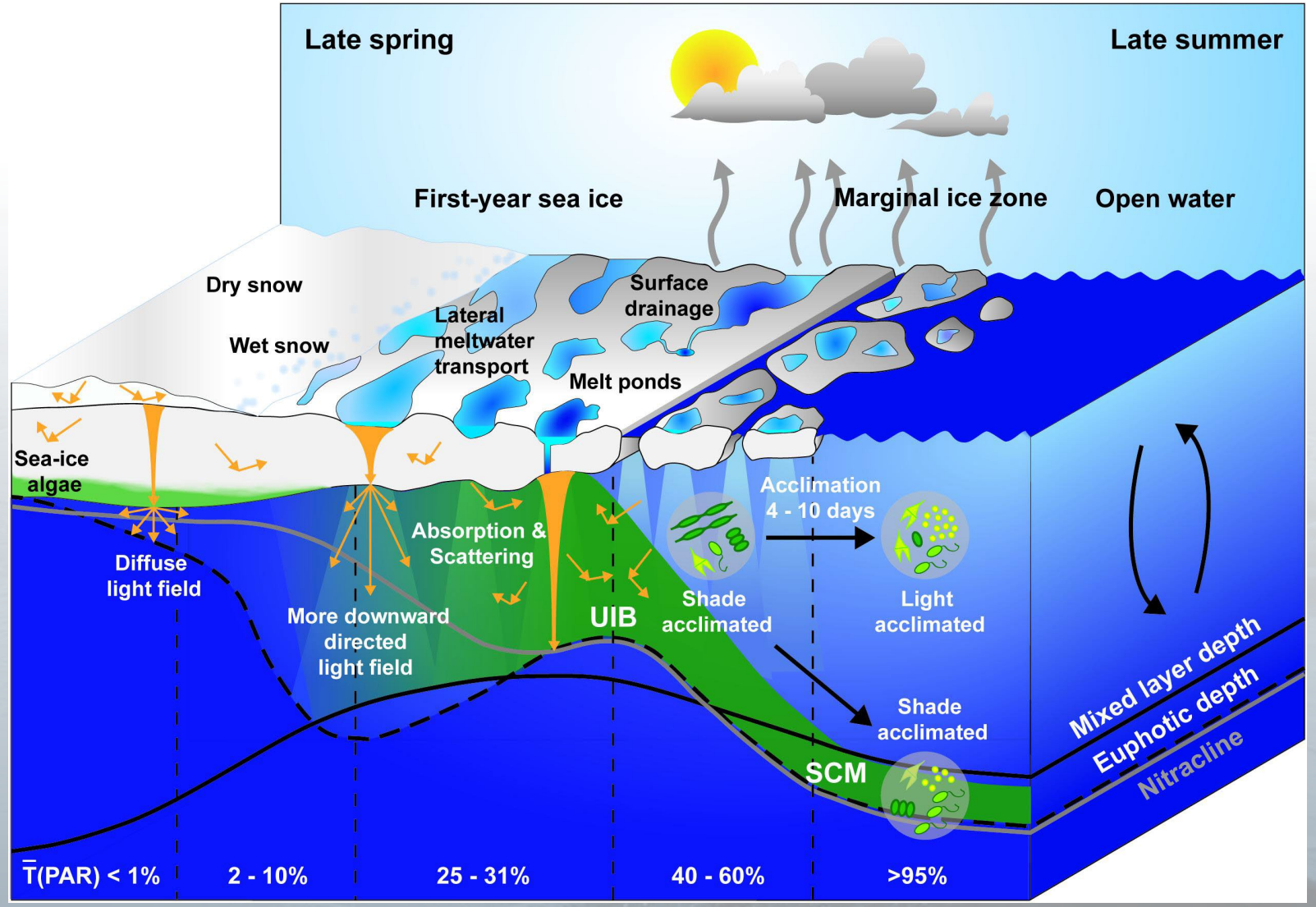
A collaborative opportunity: Combining model results and observations to reduce uncertainty in primary production beneath and within Arctic sea ice

Jaclyn Clement Kinney…and others who want to join

2024 CAMAS Workshop

Under-sea ice pelagic phytoplankton blooms (UIBs)

- Previously believed to be negligible
- Limited observations and model results suggest otherwise
- UIBs develop in the late spring and early summer when the water column begins to receive more light and becomes more stratified
- UIBs can *develop* under ice or be *advected* under ice

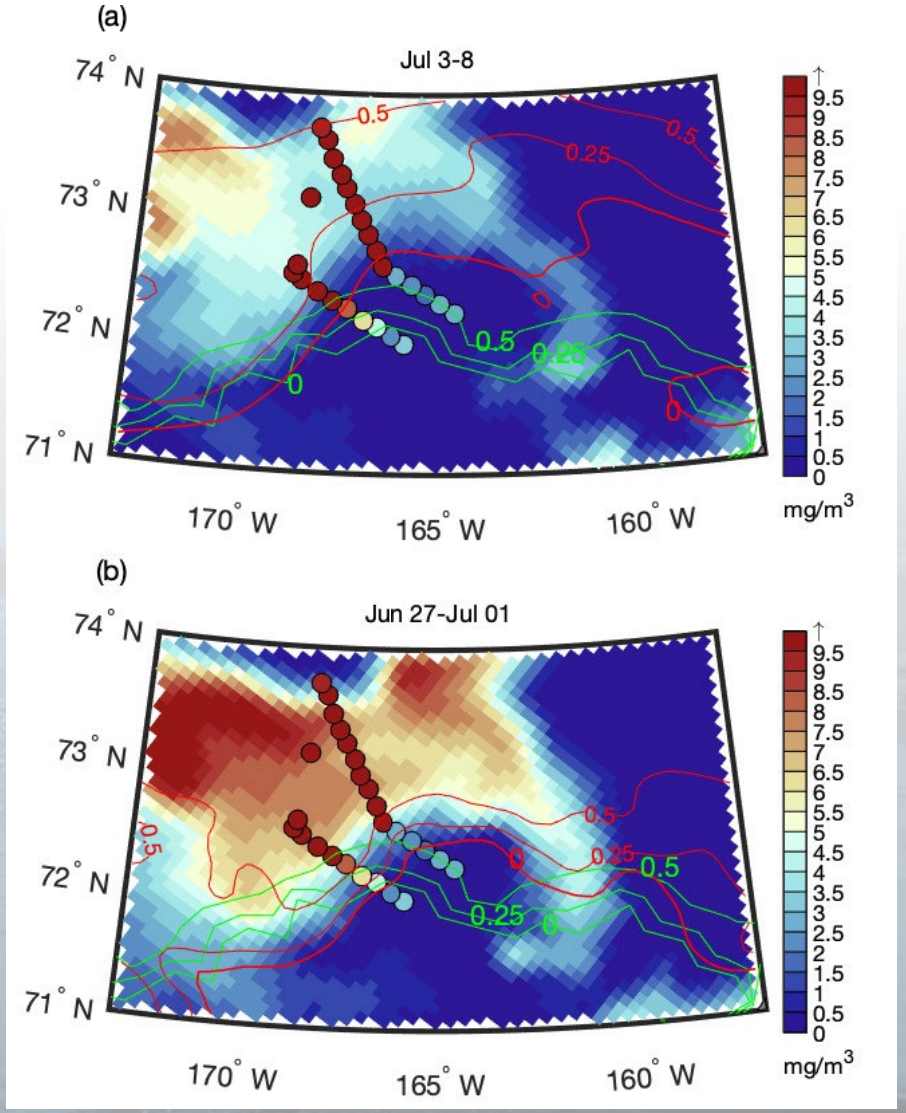


Ardyna et al. 2020

Observations of UIB in the Chukchi Sea

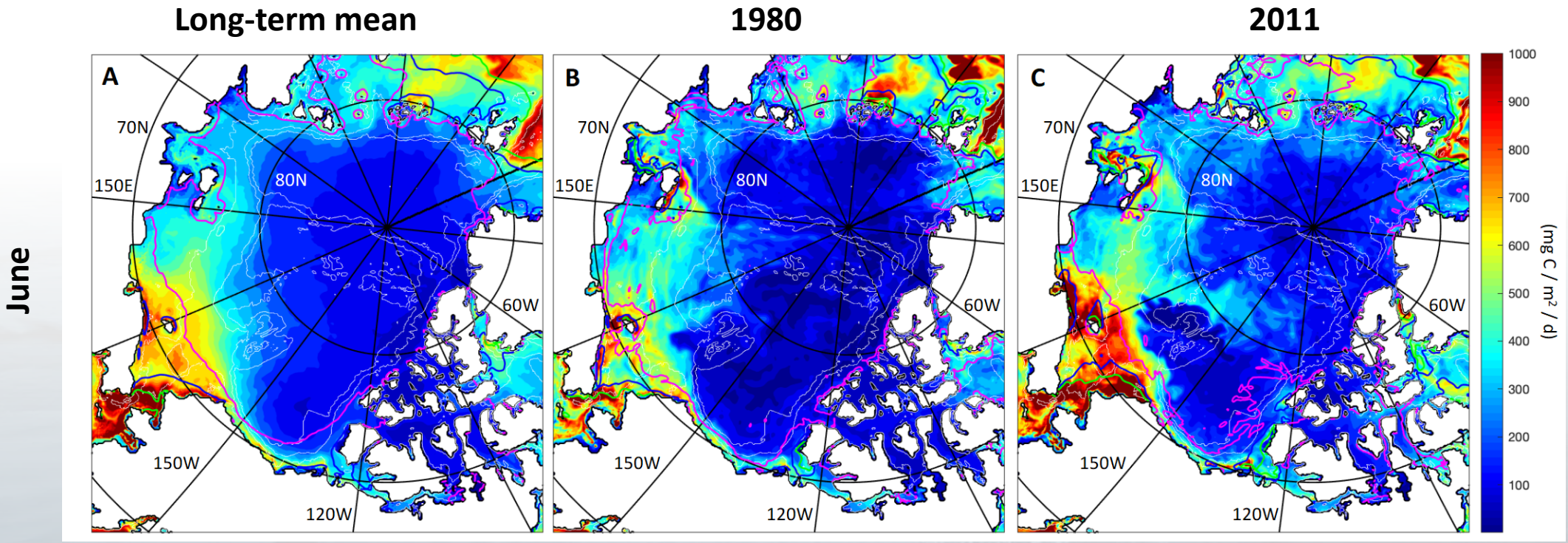
- Observations of a “massive bloom” in the northern Chukchi Sea in July 2011 (Arrigo et al. 2012) during the ICESCAPE expedition
- RASM has similar (but slightly earlier) chl-*a* distribution
- Reliable representation of sea ice is critical for the simulation of UIBs

→ 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

Importance of under-sea ice primary production



Clement Kinney et al. 2023

- 63% of the total primary production (PP) in the Arctic Ocean and marginal seas occurs under sea ice that is at least 50% in concentration
- June PP is highest on the Chukchi and East Siberian shelves, as well as in the Barents Sea
- Increasing trend over the past 4 decades

Mean primary production (mg C / m2 / d) during June (a) averaged over 1980-2018, (b) 1980, and (c) 2011. White contour lines represent bathymetry (50, 500, and 2,000 m); green, blue and magenta contour lines represent ice concentration (15, 50, and 85%, respectively).

UIBs in the literature

UIBs have been reported many times in the literature from observations and are beginning to be modeled

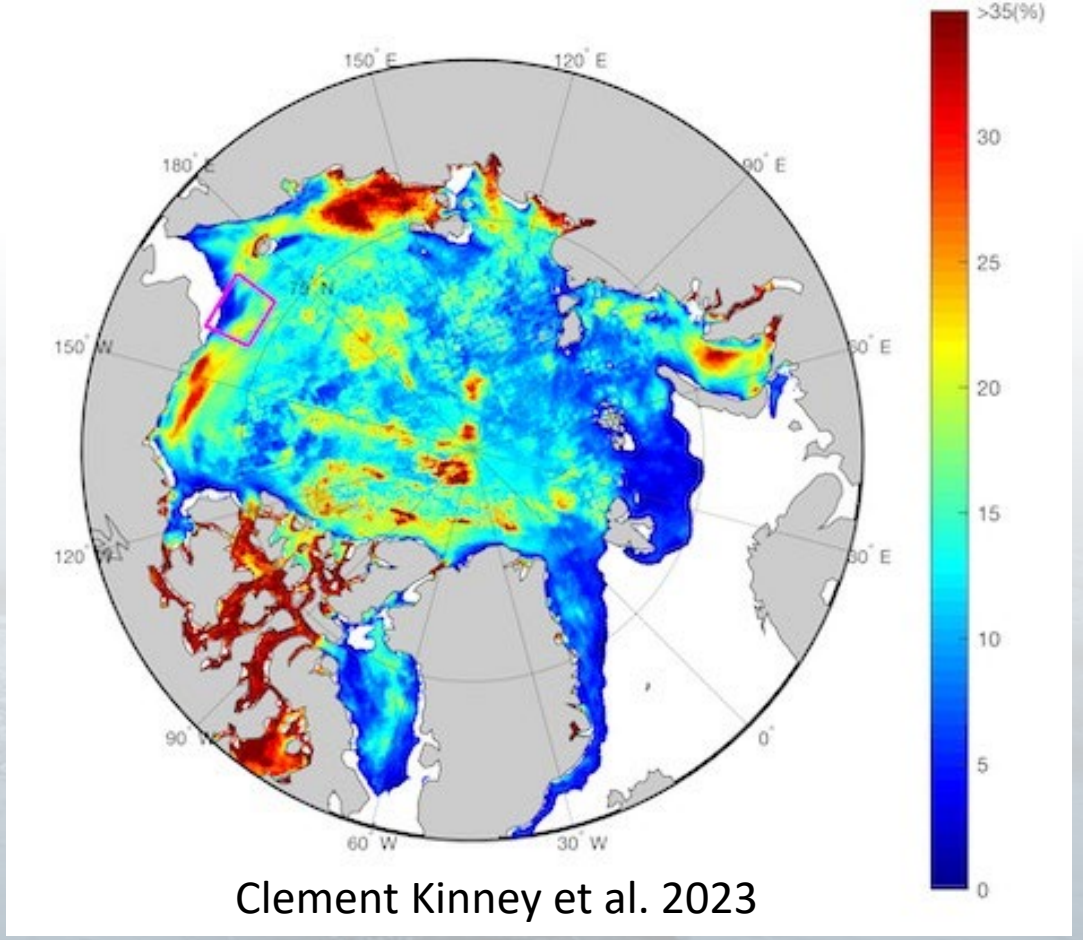
A few examples from observations:
Arrigo et al. 2012
Boles et al. 2020
Ardyna et al. 2020

A few examples from models:
Jin et al. 2016
Clement Kinney et al. 2020
Gao et al. 2022

Can we combine observations and model results to reduce uncertainty and provide a better estimate of the pan-Arctic under sea ice primary production?

Potential sources of uncertainty:

- Light field
  - Snow and ice
  - Cloudiness
  - Melt ponds
- Nutrient concentrations
  - Probably replete at the beginning of the growing season
- Phytoplankton assemblages
- Depth of the euphotic zone and mixed layer
- Spatial and temporal heterogeneity
- …

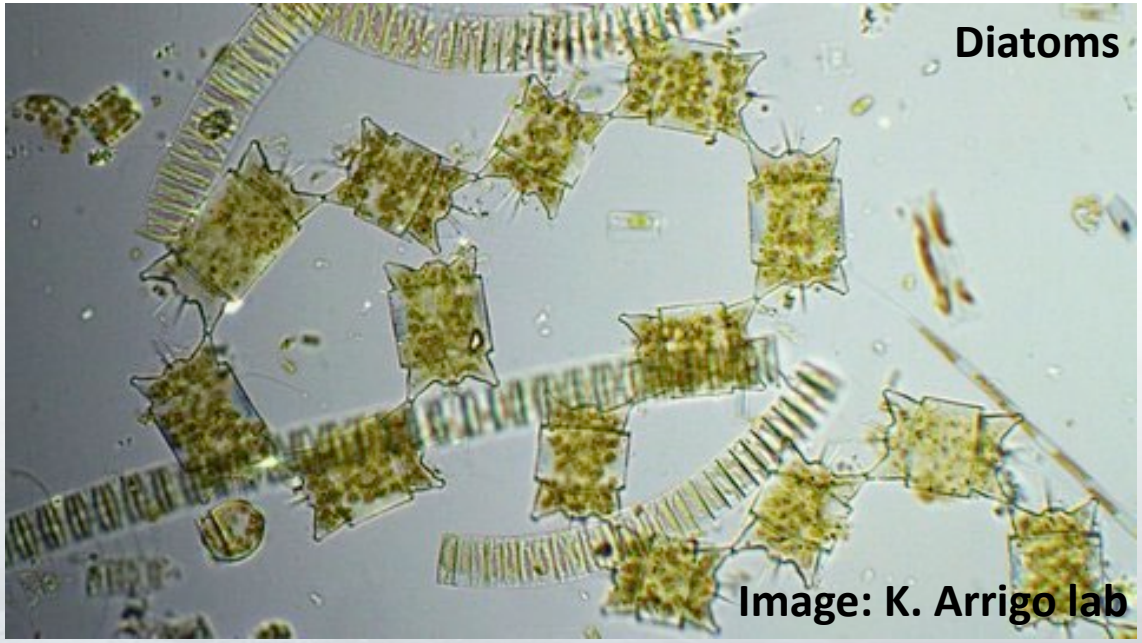


Clement Kinney et al. 2023

RASM melt pond fraction in June 2011.

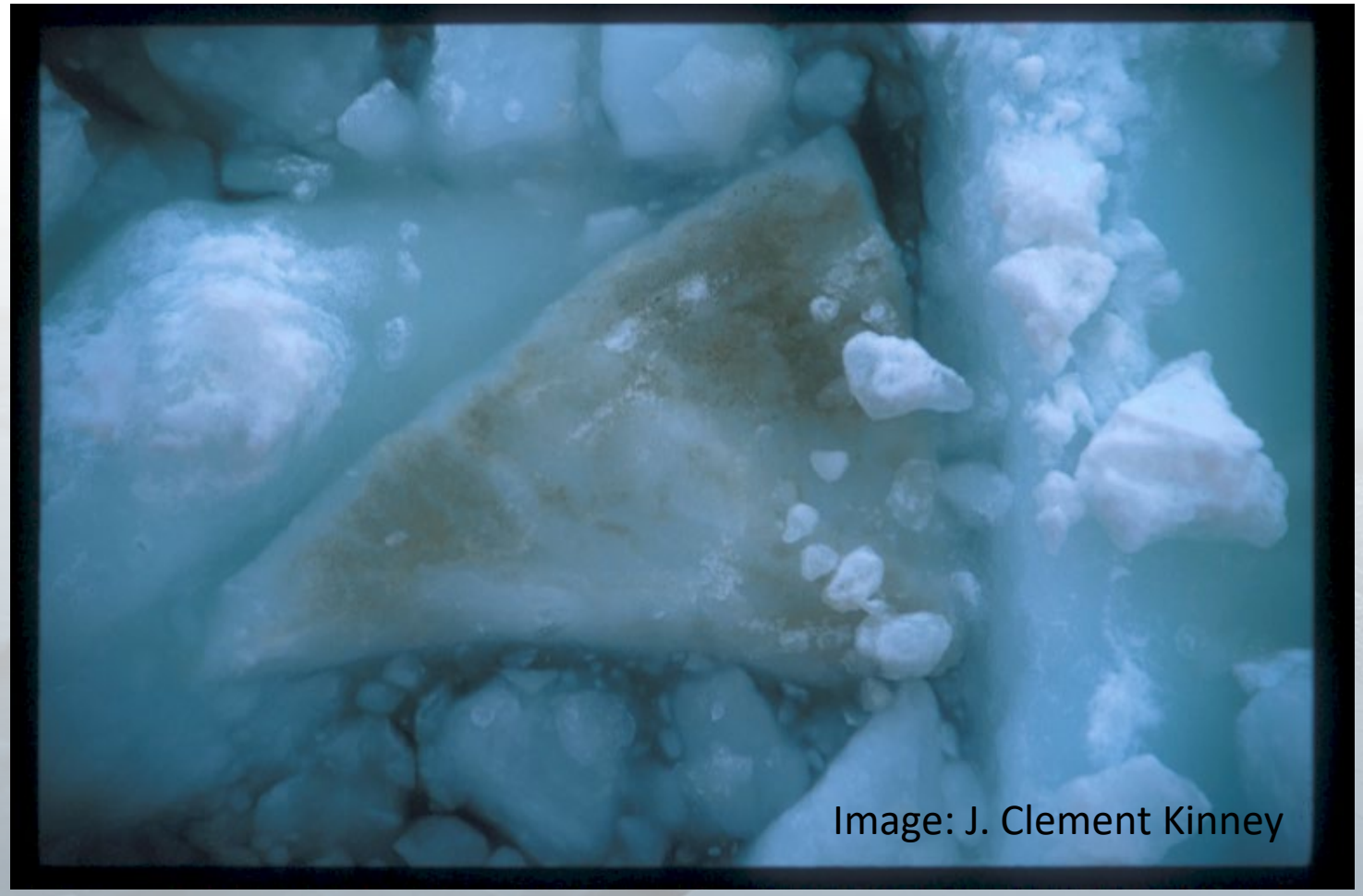
How to reduce uncertainty?

- More observations
  - Increased spatial and temporal coverage
  - Satellites cannot see beneath the sea ice
  - Autonomous sampling could help
  - …



- Model intercomparisons
  - Does resolution matter?
  - Are we representing functional groups well?
  - Do the PAR and nutrient fields compare well with (limited) observations?
  - What about stratification?
  - Is zooplankton grazing important?
  - …

We could also look at primary production *within* sea ice



- This talk has mostly focused on *pelagic* under ice primary production, but primary production also occurs within and on the underside of sea ice…
- Ice algae is thought to make up only about 3-25% of the total…are we sure about that?

Conclusions

- UIBs are difficult to observe and challenging to model
- UIBs are important for ecosystem functioning in the Arctic and may contribute more carbon to the system than open water blooms
- Can we combine observations and model results to review what we know and reduce uncertainty in estimates of pan-Arctic under sea ice primary production?
- Could we also reduce uncertainty in estimates of sympagic primary production?

Clement Kinney, J., et al. (2020). Hidden production: On the importance of pelagic phytoplankton blooms beneath Arctic sea ice. Journal of Geophysical Research - Oceans, 125, 9, https://doi.org/10.1029/2020JC016211

Clement Kinney, J., et al. (2023). Investigation of under-ice phytoplankton growth in the fully-coupled, high-resolution Regional Arctic System Model. Journal of Geophysical Research: Oceans, 128, e2022JC019000. https://doi.org/10.1029/2022JC019000