Air-sea interaction and marine biogeochemical cycles

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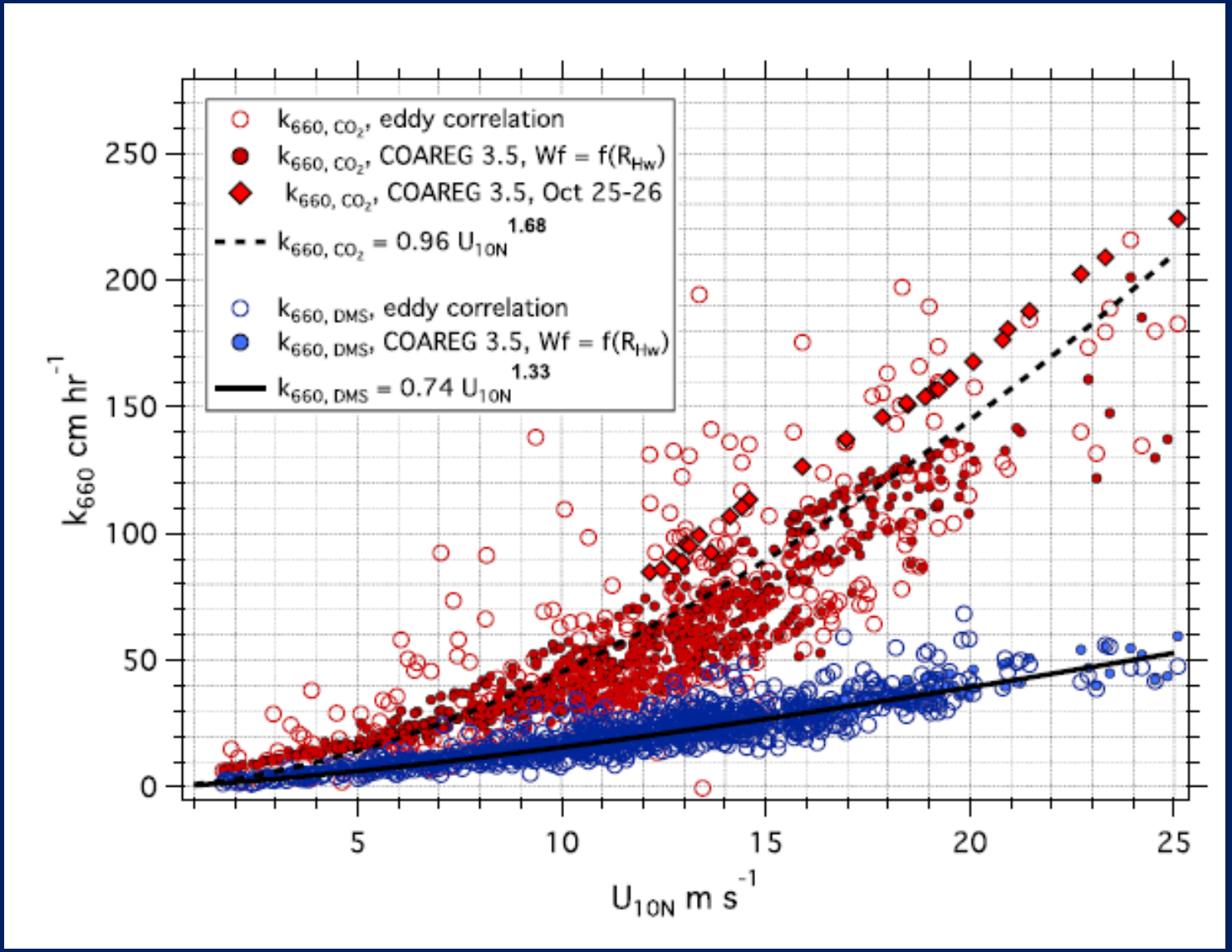
Photo by Kelly Carmody

Outline

1) Recent Advances
    a. Gas exchange and biogeochemical cycles
        - Role of bubbles
        - Processes in partially Ice-covered waters
    b. Aerosol solubility
2) Community Updates
3) Outstanding Questions

Gas Exchange and Bubbles

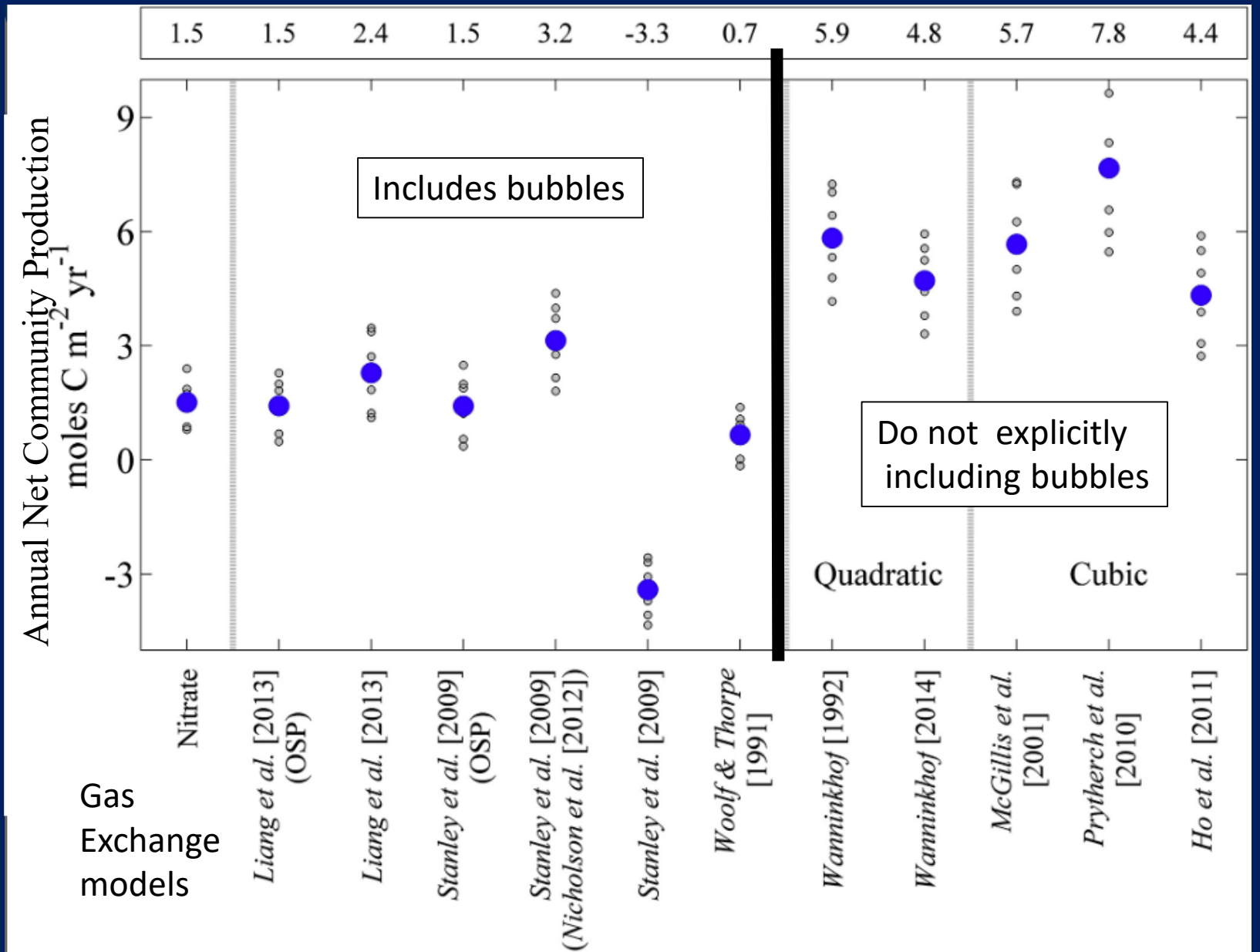
Air-sea gas exchange



- Many parameterizations exist
- Only some of them explicitly include bubbles
- Example: COAREG parameterization vs. data for CO_2 (red) and DMS (blue) during Hi-WinGS experiment

From Blomquist et al., 2017
In JGR oceans

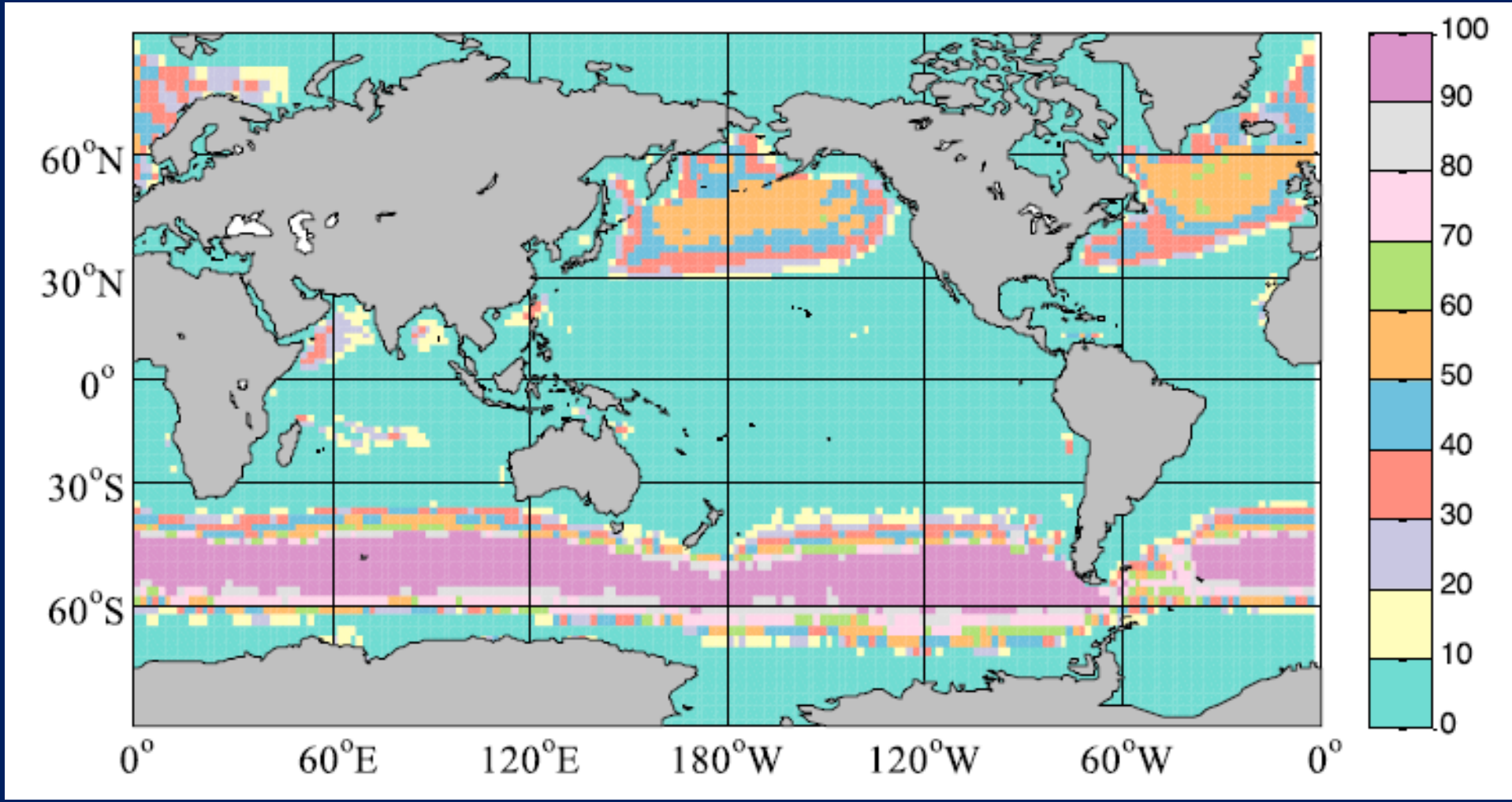
Bubbles: Crucial for estimating biological production from O_2



- Net Community Production (NCP) calculated from bio-Argo floats
- NCP calculated without explicit bubbles are factor of 2 higher

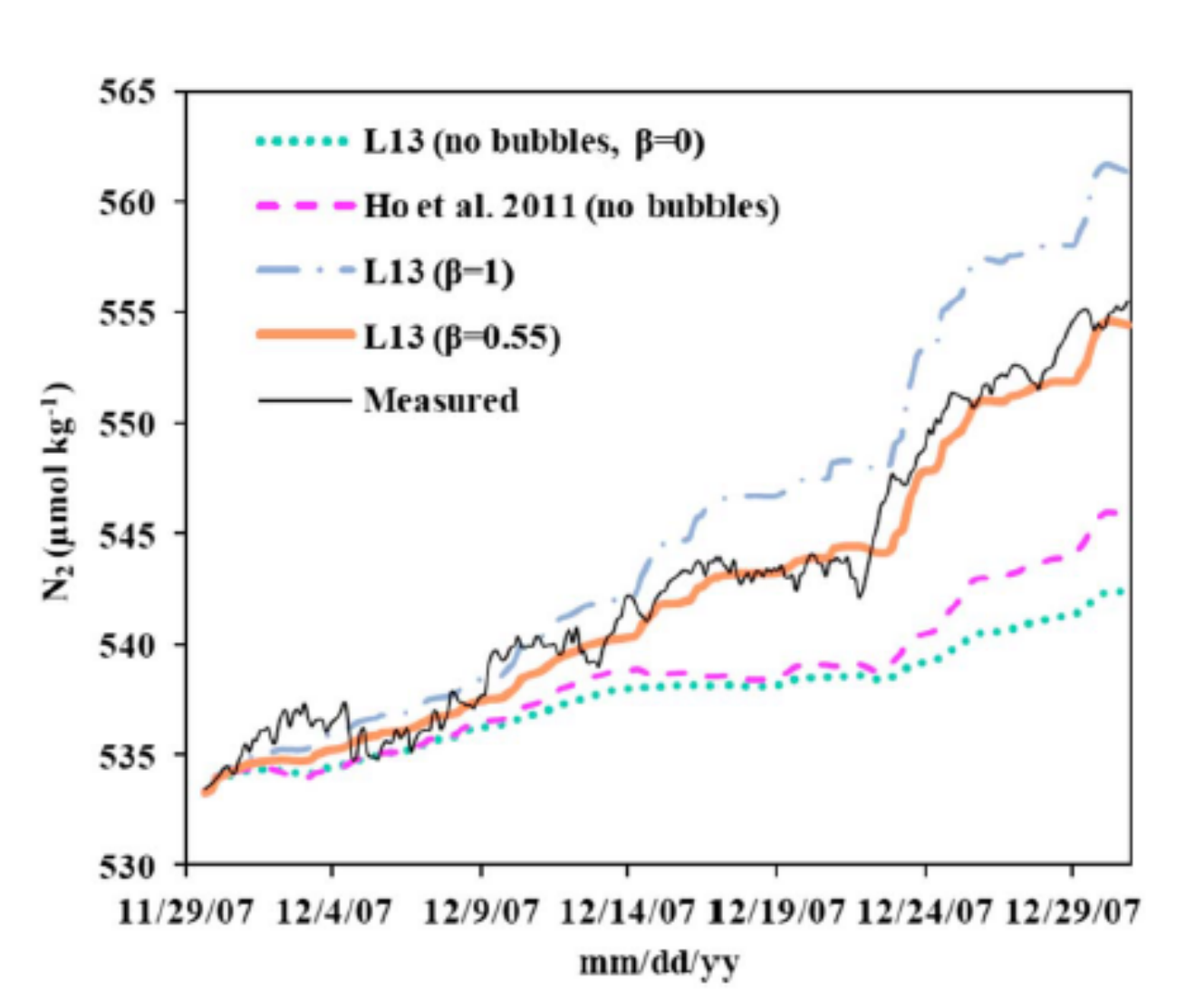
Plant et al., 2016
Global Biogeochemical Cycles

Fraction of year when wind speed > 10 m s^{-1}



Emerson et al. 2019
JGR: Oceans

Estimating bubble flux at Ocean Station Papa

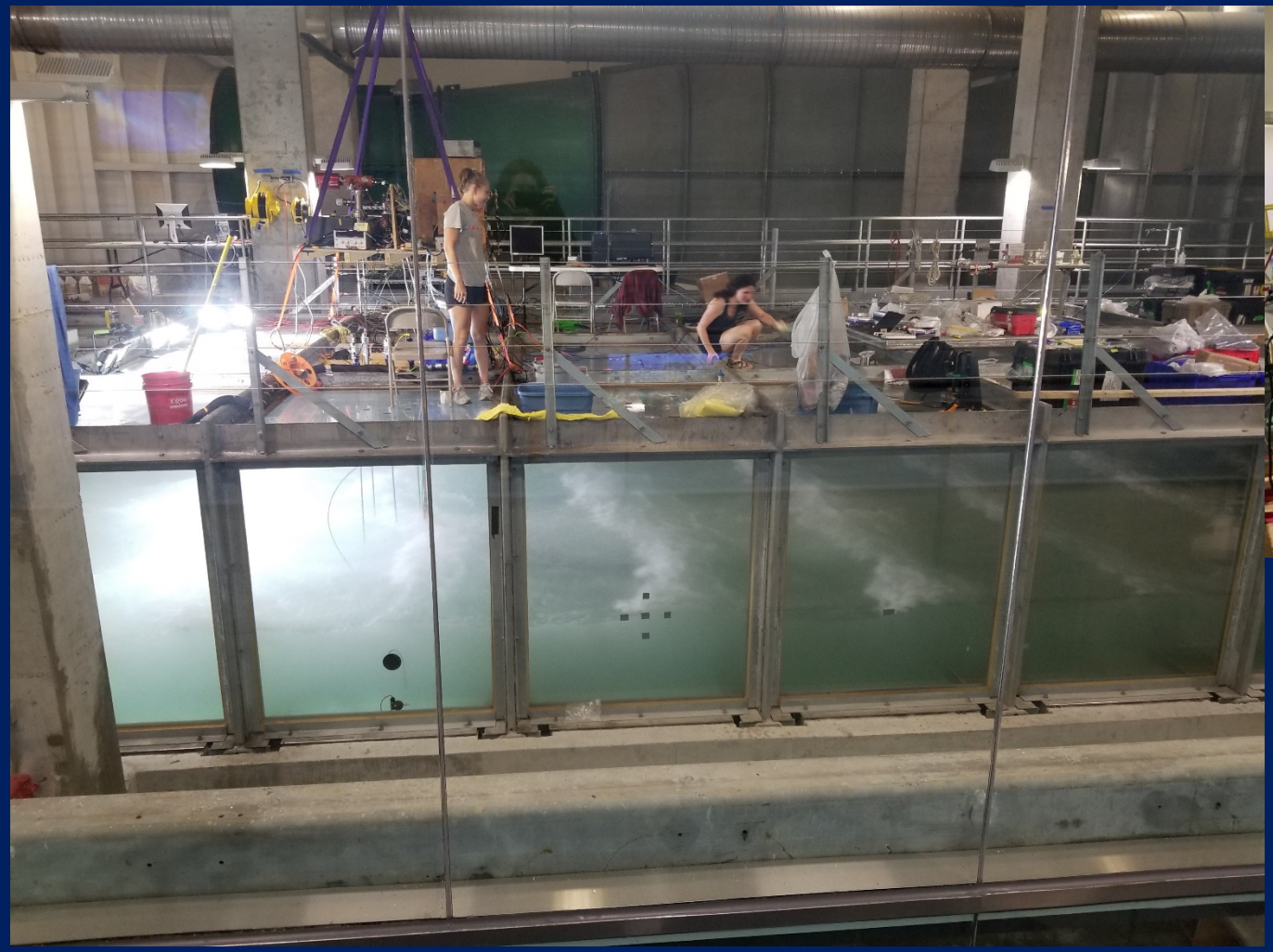


- Mean wind speed ~ 10 m s^{-1}
- Measured N_2 on mooring, 10 month-long periods within 10 years
- Data matched parameterization best when 30 to 50% of expected Liang et al. 2013 bubble flux included

Emerson et al. 2019
JGR: Oceans

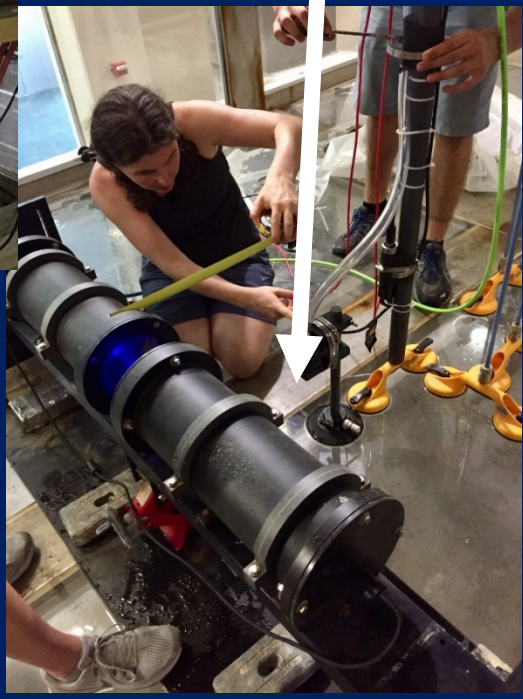
What about higher wind speeds? U_{10}> 20 m s^{-1}

- Experiment at SUSTAIN wind-wave tank at University of Miami



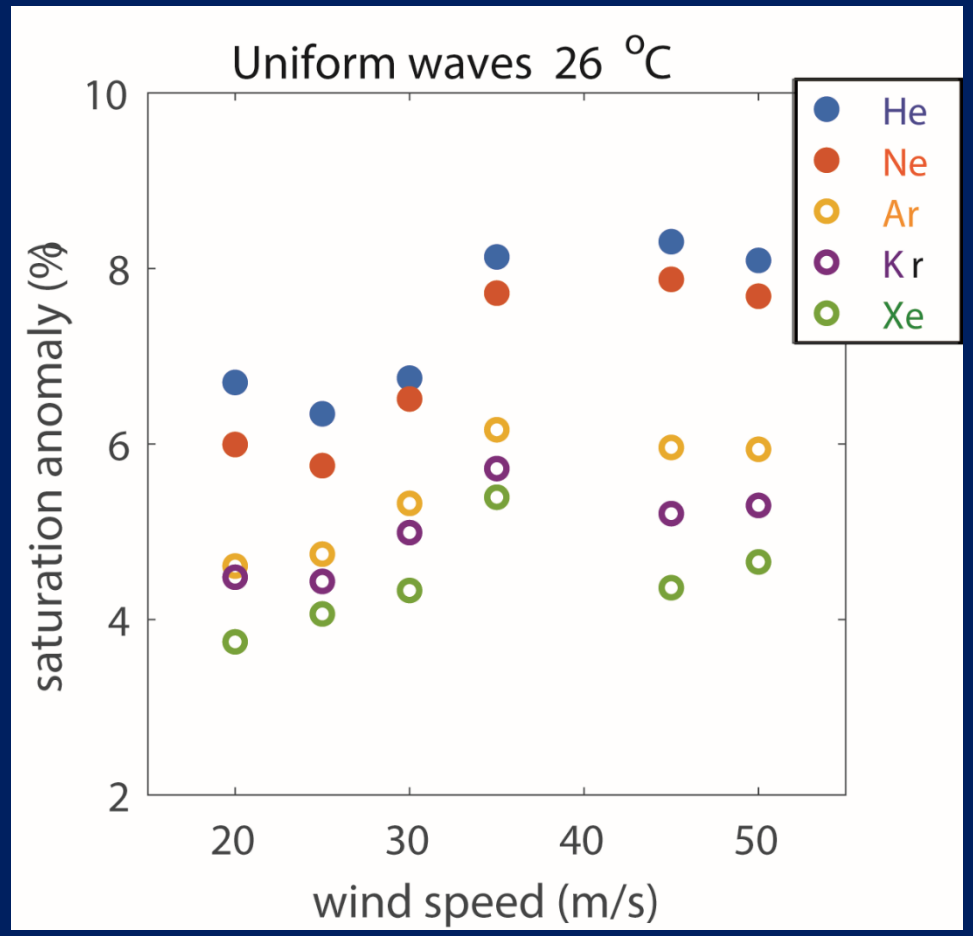
Mass Spectrometer

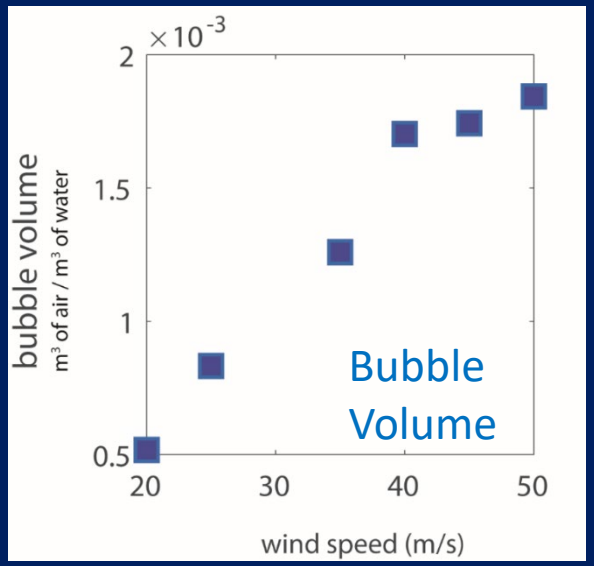
Bubble Imager

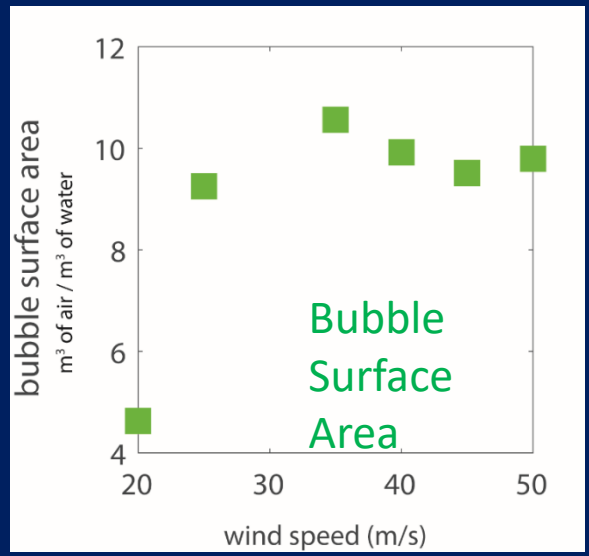


Effect of bubbles on gas saturation anomalies

- Experiment at SUSTAIN wind-wave tank at University of Miami
- Flattening off of bubble supersaturation at high wind speeds







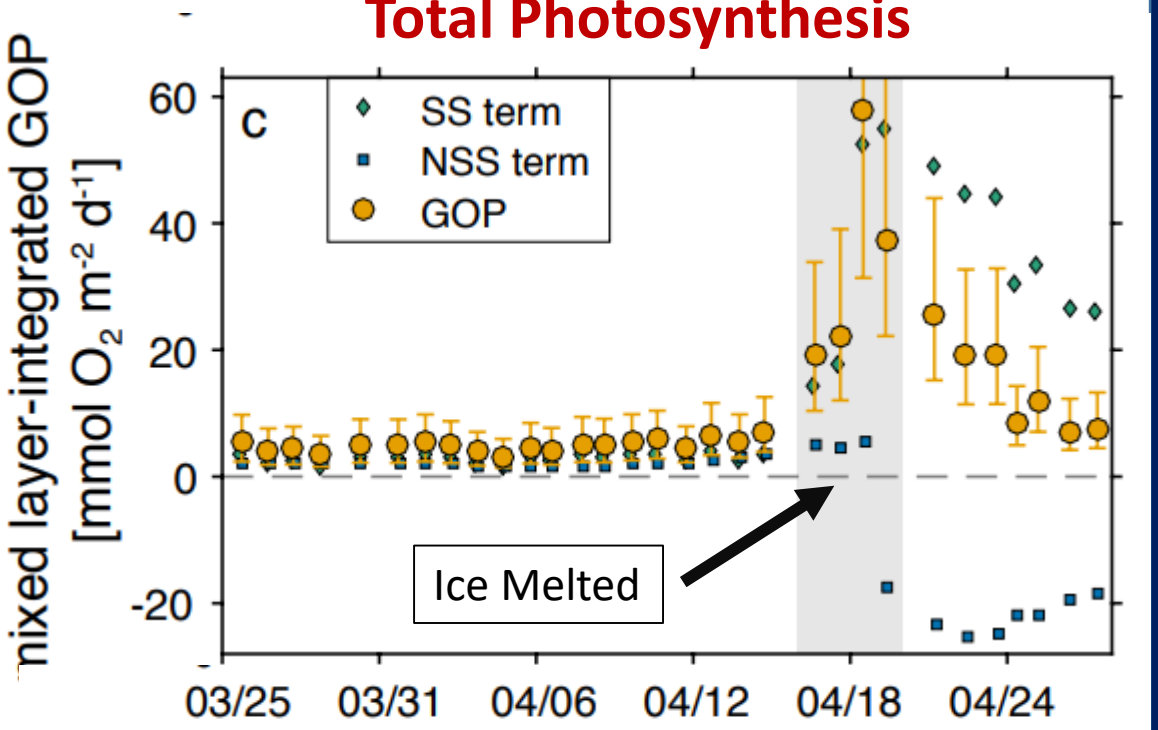
Stanley et al.
In prep

Effects of Ice Melt

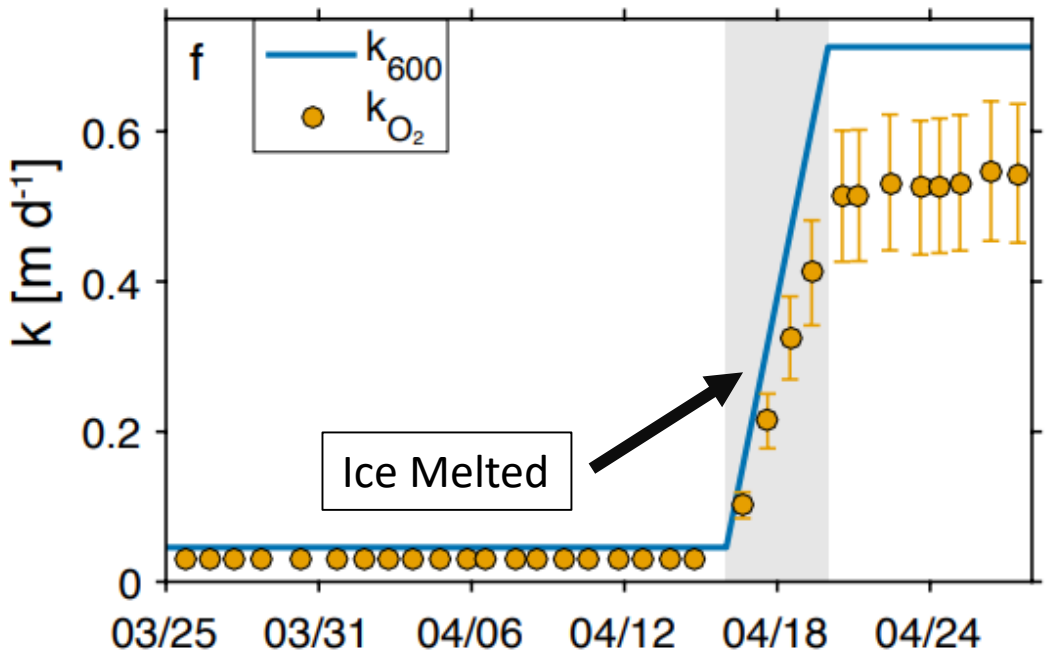
Biological production and gas exchange as ice melts

- Study in Bras D'Ors Estuary, Canada shows peak in Gross Oxygen Production (GOP), due to photosynthesis, as sea ice melts.
- Gas exchange increases dramatically as ice melts

Total Photosynthesis



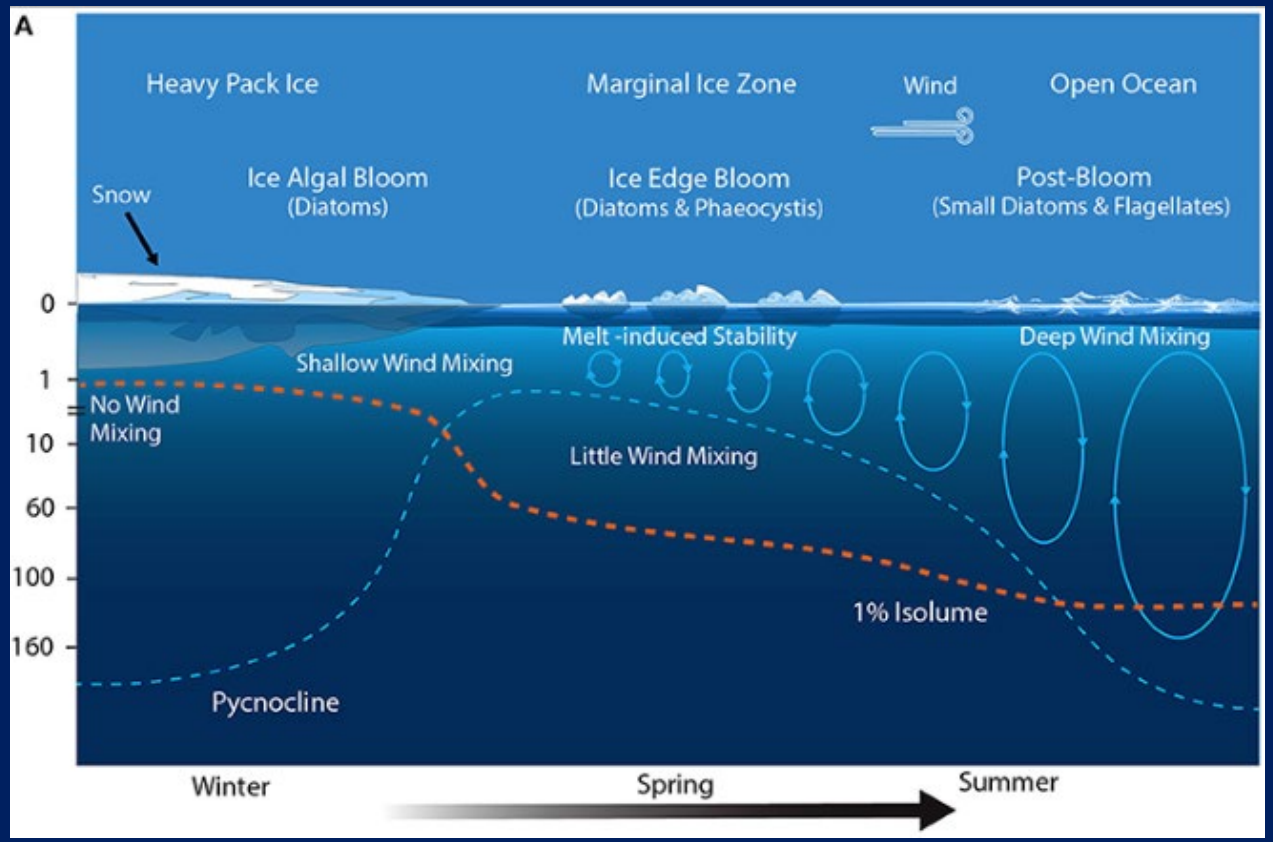
Gas Exchange



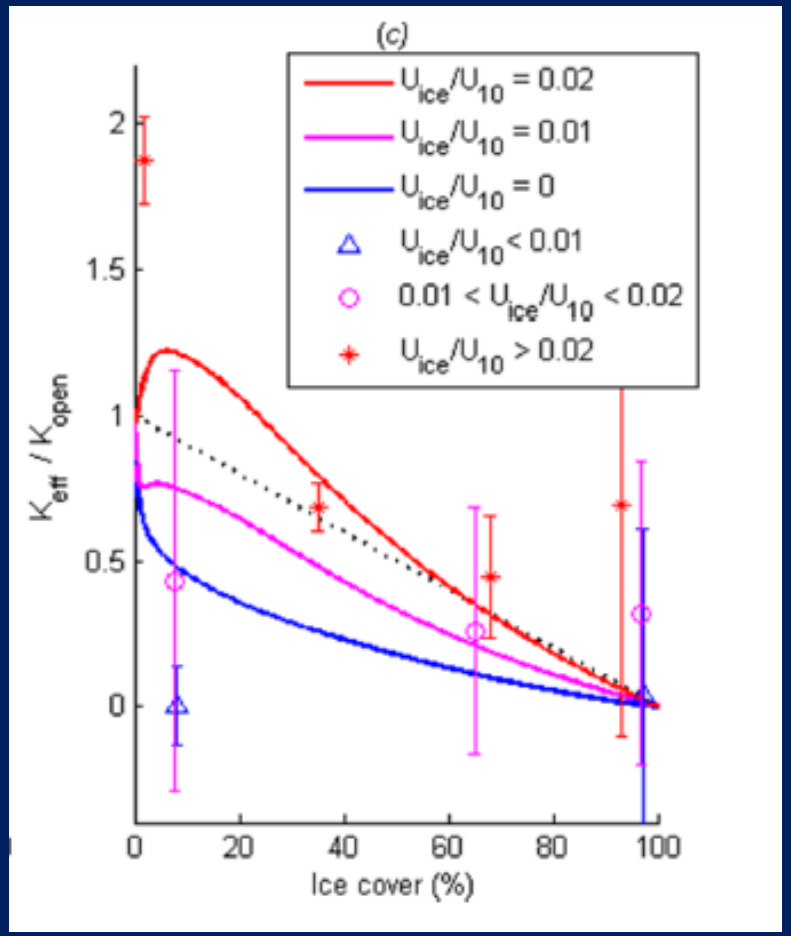
Manning et al., Biogeosciences, in press

Marginal Ice Zone: Productivity and gas exchange

- CO_2 build-up due to respiration during ice-covered months
- Enhanced gas exchange when ice melts
- Enhanced primary production – heat fluxes affecting ice & light penetration



Deppeler and Davidson, 2017, Frontiers in Marine Science

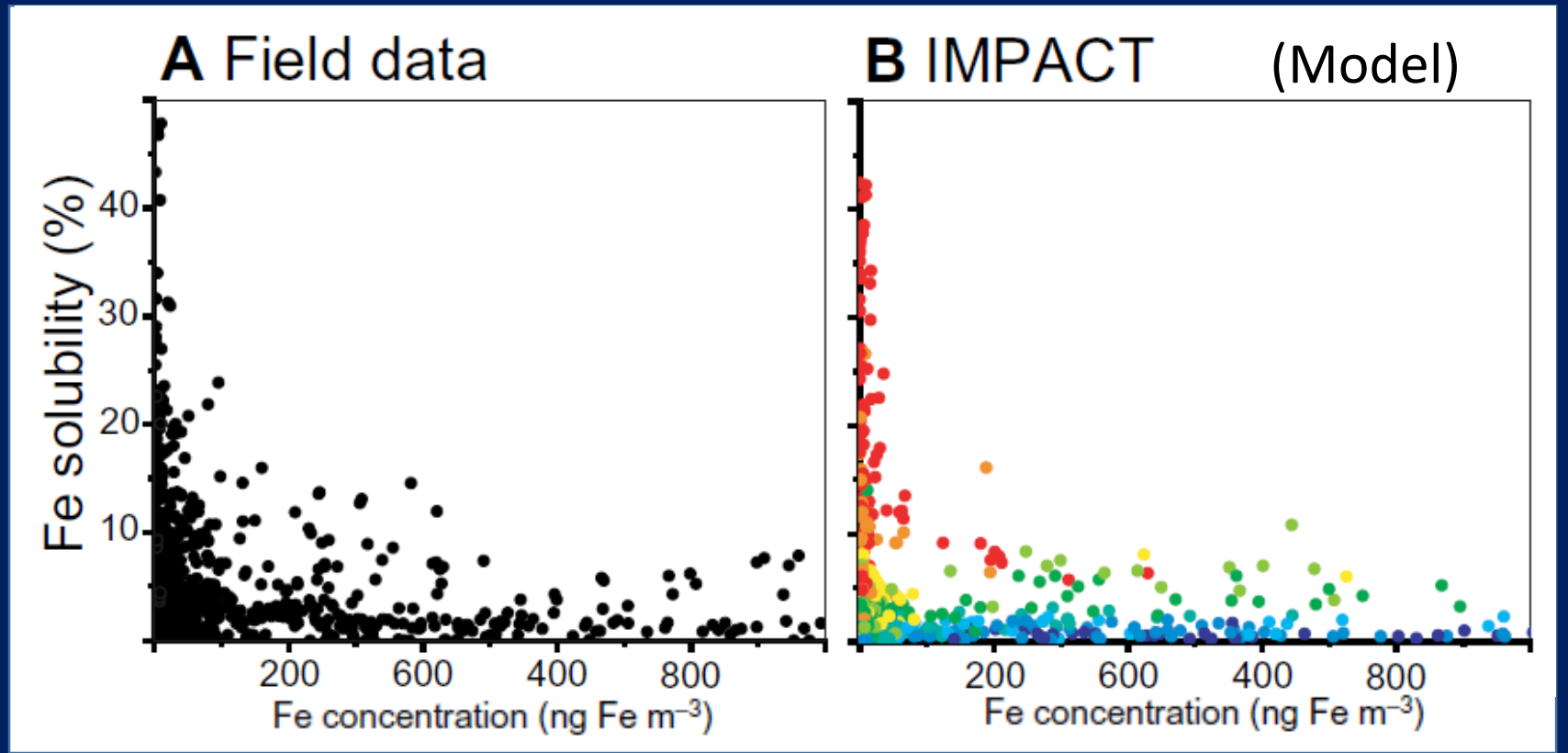


Bigdeli et al. 2018 JGR Oceans

Aerosol Solubility

Aerosol Solubility

- Aerosol iron solubility depends on pyrogenic iron fraction and iron concentration
- But even including those factors, models underestimate by factor of 15 in the Southern Ocean (better match other basins)



From Ito et al., 2019 Science Advances

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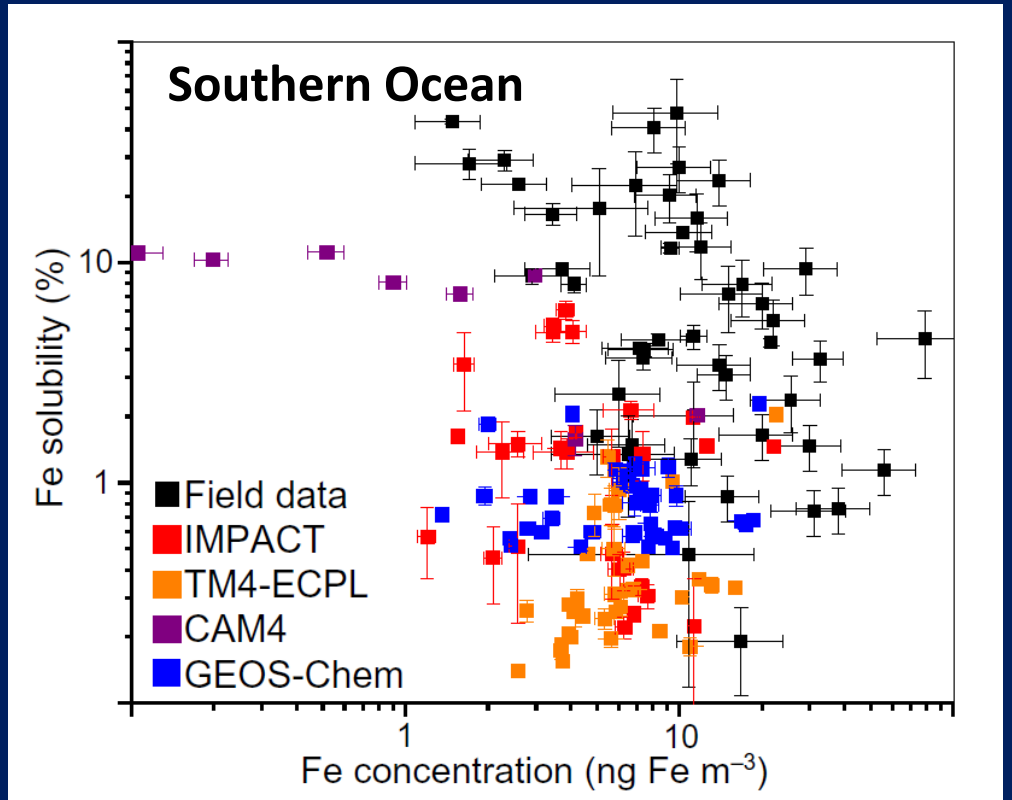


From Ito et al., 2019
Science Advances

Community Updates

Ocean Atmosphere Interaction Subcommittee

- Subcommittee of Ocean Carbon Biogeochemistry (OCB)
- Focus is on ocean-atmosphere interactions and their role in marine biogeochemical cycles

https://www.us-ocb.org/about/ocb-subcommittees/subcommittee-on-ocean-atmosphere-interactions/

OCB Ocean Carbon & Biogeochemistry

solas

Upcoming workshop

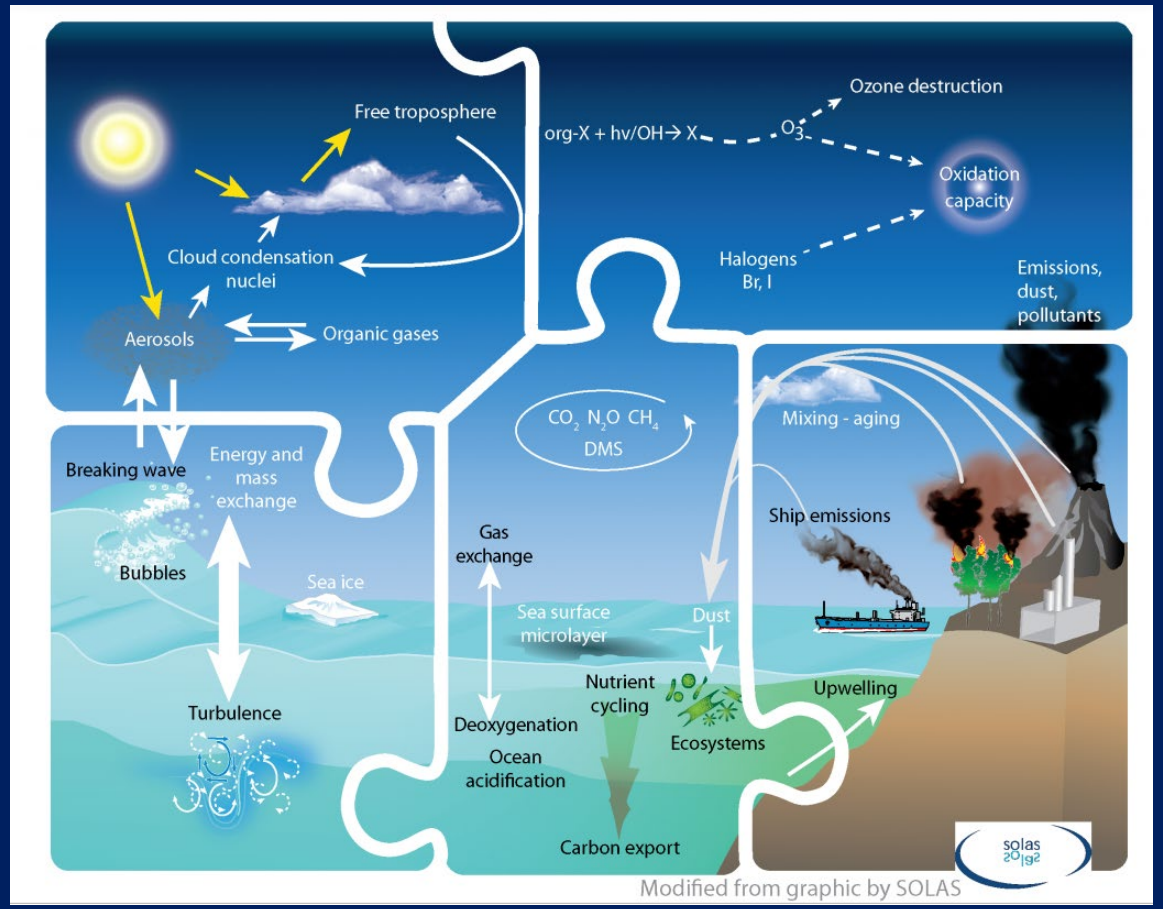
OCB Ocean-Atmosphere Interactions: Scoping directions for U.S. research

October 1-3, 2019 (Sterling, Virginia, USA)

- Workshop will identify research priorities, produce US-SOLAS science plan, and facilitate communication
- Registration closed but we would still like your input!

https://web.whoi.edu/air-sea-workshop/

Email rachel.stanley@wellesley.edu or hbenway@whoi.edu with your ideas



SOLAS Open Science Conference, April 2019

For Event Report:

http://solas-int.org.customers.tigertech.net/files/solas-int/content/downloads/Activities/OSC/OSC%202019/SOLAS%20Event%20Report_Issue%2014_OSC2019.pdf

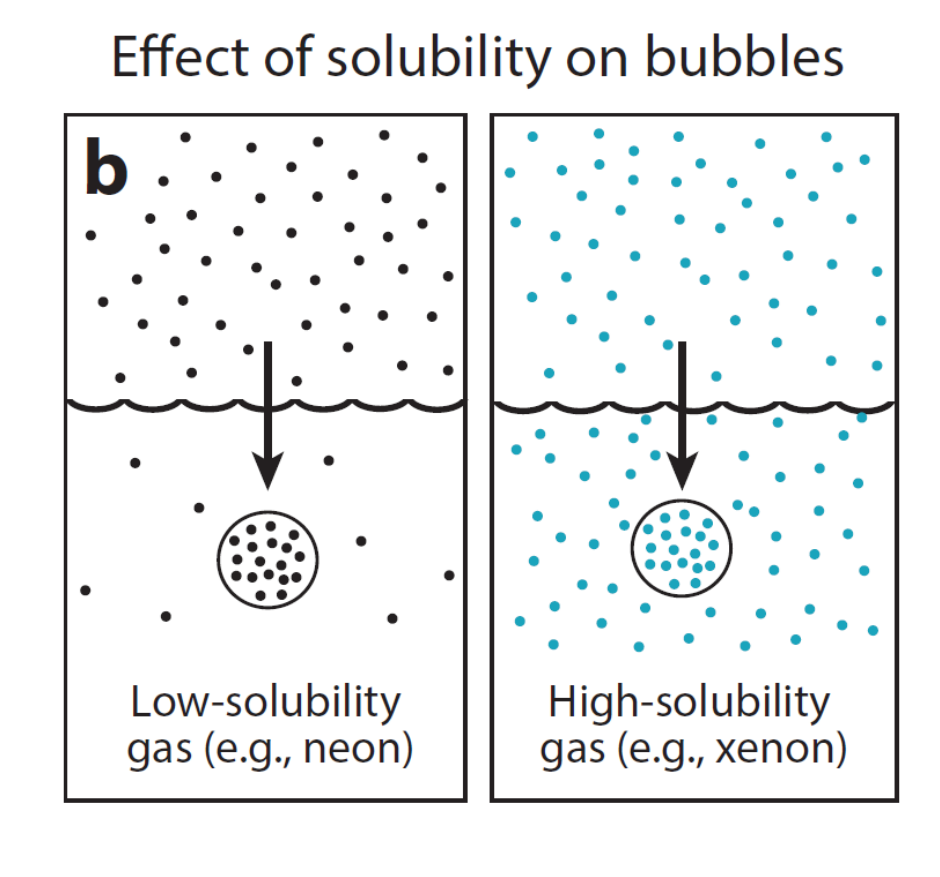
Outstanding Questions on Air-Sea Interactions and Biogeochemical Cycles

- How best to model fluxes of gas exchange for bioactive gases in non-standard environments – coastal systems, with surfactants, high winds, etc.?
- What properties of marine aerosols are important for modulating oceanic primary production and biogeochemical cycles of carbon and other elements?
- What will the effects of ocean deoxygenation be on biogeochemical cycles of carbon and nitrogen and on marine biota?
- How will changes in stratification – driven by changes in heat flux – affect upper ocean primary productivity in different regions?
- For many processes: What are expected changes? important feedbacks? tipping points?

For more, see white paper that will be produced by the upcoming OCB Ocean Atmosphere Interaction Workshop!

Extra Slides

Effect of bubbles on gas saturation anomalies

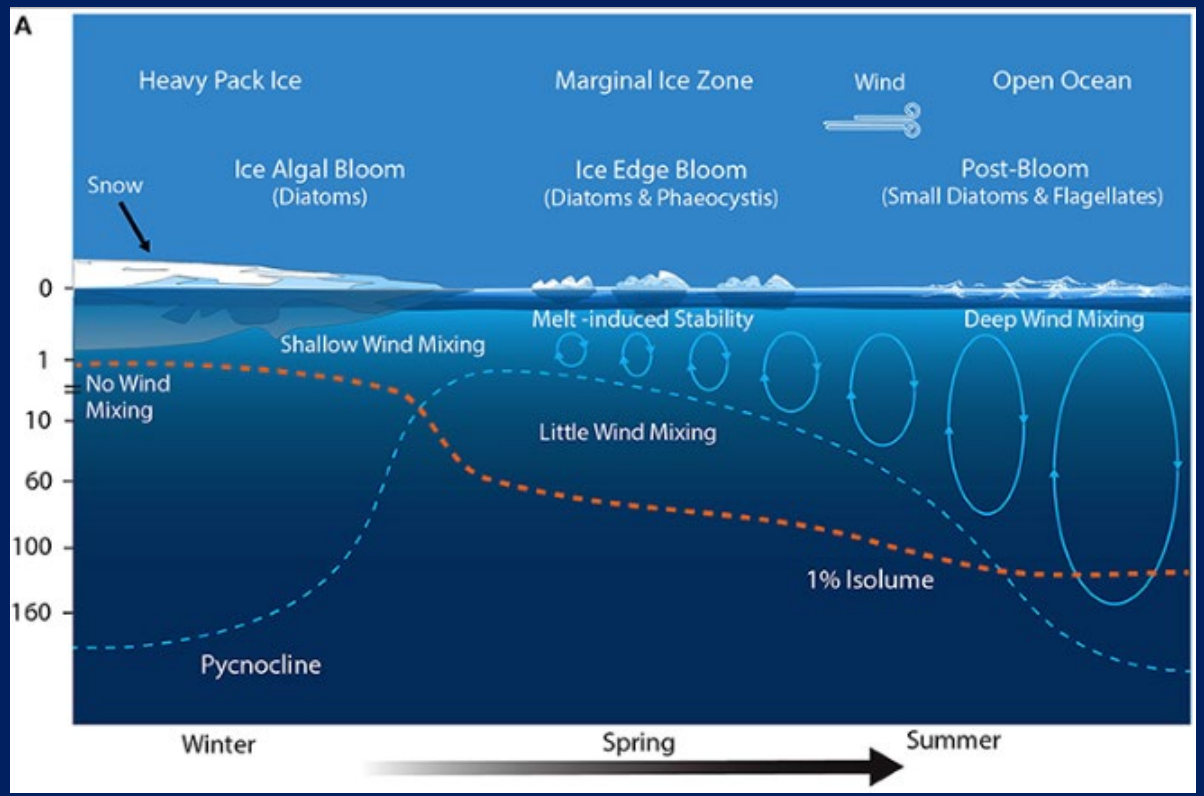


From Hamme et al. 2018

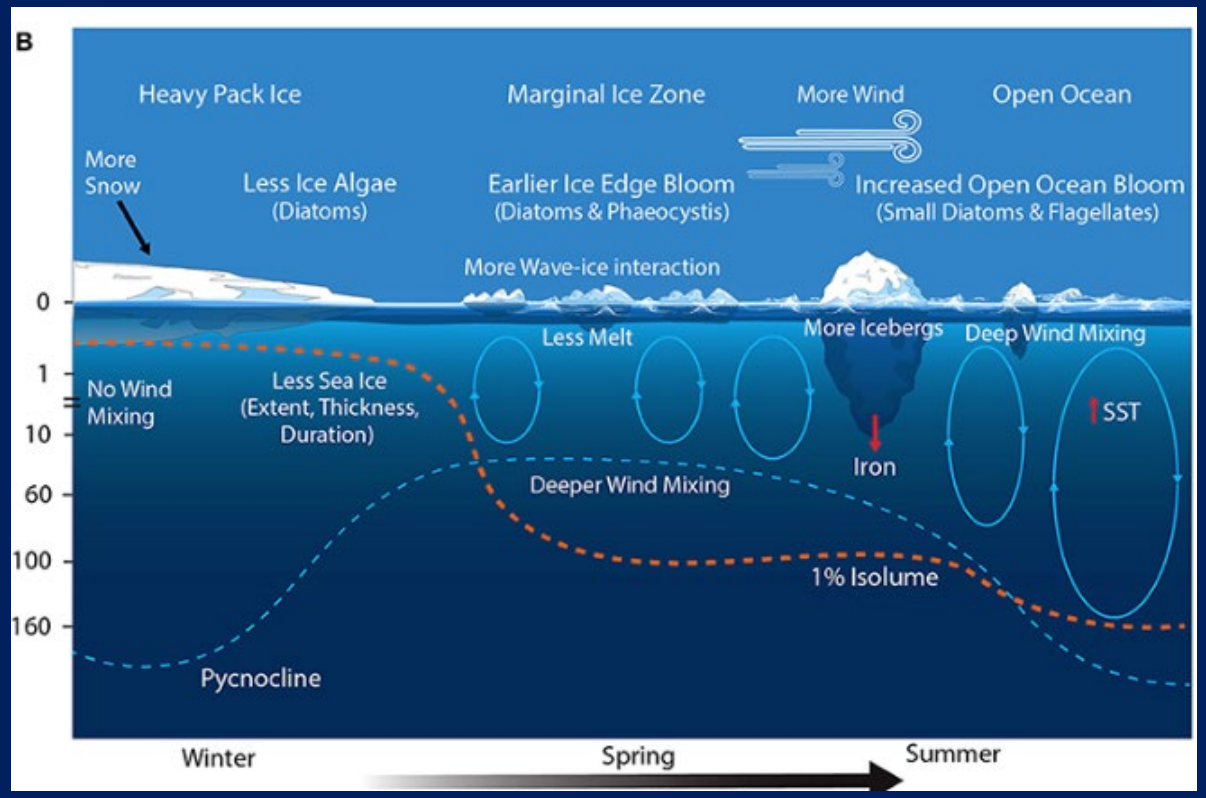
- Bubbles serve as direct conduit for gas exchange, especially for lower solubility gases (O_2, noble gases, sometimes CO_2)

Marginal Ice Zone Processes

Present



Future



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Frontiers in Marine Science