Air-sea interaction and marine biogeochemical cycles

Rachel H. R. Stanley
Wellesley College
rachel.stanley@Wellesley.edu

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 CO₂ (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 $> 10 \text{ m s}^{-1}$
Estimating bubble flux at Ocean Station Papa

- Mean wind speed $\sim 10$ 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

![Image of experimental setup with Mass Spectrometer and 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
Marginal Ice Zone: Productivity and gas exchange

• CO₂ 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
Aerosol Solubility
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• 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/
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
21 - 25 April 2019, Sapporo, Japan

For Event Report:
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

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

From Hamme et al. 2018
Marginal Ice Zone Processes

Present

Future

Deppeler and Davidson, 2017
Frontiers in Marine Science