Keck meeting

Caveat!!!
Background: biological and chemical cycles in the world’s oceans

\[
\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{CH}_2\text{O} + \text{O}_2
\]
Significant puzzles about ocean carbon fluxes
North Atlantic subtropical gyre at Bermuda: what enables DIC drawdown in the upper 50 m?

Annual cycle of dissolved inorganic carbon (mmol m$^{-3}$) at Bermuda; upper 250 m

- 7 mmol m$^{-3}$ NO$_3^-$ required for observed DIC drawdown
- Throughout growing season, [NO$_3^-$] << 1
- Where does N come from?
  - Nitrogen fixation
  - NO$_3^-$ mining by vertically migrating phytoplankton
  - Vertical mixing? But this introduces dissolved inorganic carbon
- AUV’s could examine the footprint of this process...
Influence of synoptic meteorological events on ocean carbon fluxes

- Calm weather
  - Shallow, well-lit mixed layer
  - Mature ecosystem develops
  - Grazing ~ production; low export
- Storm comes through
  - Mixed layer deepens, light and productivity fall
- Calm weather ensues
  - Mixed layer shoals
  - Productivity rises in high-light environment
  - Period of high export
  - Mature community develops...
- *Is there any validity to this scenario?*
  - AUV’s could monitor physical forcing and the biogeochemical response
- Alternative
  - Iron deposition as remote continental airmass passes over ocean region
  - Primary productivity and export production spike
Fate of carbon exported from the mixed layer or euphotic zone - 1

- Fluxes of sinking particles decrease very rapidly with depth
Fate of carbon exported from the mixed layer or euphotic zone - 2

- P1 and P3 occupied for ~5 days; productivity is very high (50-150 mmol m\(^{-2}\) day\(^{-1}\)) (Cassar et al., 2011)

- And sediment trap fluxes:

<table>
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<th>Depth m</th>
<th>Total POC flux (\mu)mol m(^{-2}) d(^{-1})</th>
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Mixed layer NCP S. of Tasmania, summer, 2007
AUV studies of shallow remineralization of sinking organic matter

• Optical studies of individual particles
  – Composition
  – Sinking rate
  – Vertical flux
  – Lateral advection
  – Change in properties with depth to characterize breakdown
Patch experiments

Objective: track an upper ocean ecosystem for 1-2 weeks and observe its biogeochemical evolution in response to physical forcing

Standard shipboard mode
- Inject a patch of $\text{SF}_6$
- Inject iron or not, depending on objectives
- Continuously measure $\text{SF}_6$ to identify THE patch
- Make physical and biogeochemical observations: $\text{O}_2$, DIC, nutrients, optical properties, flux terms (gross photosynthesis, net community production, respiration)
- Characterize evolution of ecosystem in response to physics and biogeochemical dynamics

Possible AUV modes
- Ultra mode: AUV’s inject tracer, measure tracer to track patch
- Dynamics mode:
  - Team of AUV’s identify dynamical feature (ring), tracks feature
- Minimalist mode: AUV’s identify surface feature from heterogeneity
GasEx III patch experiment, Atlantic Subantarctic
Figure 6. Time series of surface, underway \( \Delta O_2/Ar \) measurements during patch 2 from 22 March to 6 April 2008. Gray bars indicate local night. Red line segments indicate measurements inside the patch when underway SF\(_6\) concentrations were greater than 75 fmol L\(^{-1}\) during 22–27 March, greater than 25 fmol L\(^{-1}\) during 27 March to 1 April, or greater than 10 fmol L\(^{-1}\) during 1–6 April. Black points show discrete, mixed layer \( \Delta O_2/Ar \) measurements. Straight lines show linear regressions of 1 h binned averages of in-patch data with slopes and errors indicated.
Figure 2. Time series of surface, underway $\Delta O_2/Ar$ measurements during patch 1. Gray bars indicate local night. Red line segments indicate measurements inside the patch when underway SF$_6$ concentrations were greater than 30 fmol L$^{-1}$. Black points show discrete $\Delta O_2/Ar$ measurements. Straight line shows linear regression of 1 h binned averages of in-patch data with slope and error indicated. Underway $\Delta O_2/Ar$ measurements of patch 1 ended on 13 March to repair a fault in the system.
Summary of questions

- Sources of nutrients in the subtropical gyre?
- Evolution of local ecosystems in response to synoptic forcing
- Evolution of local ecosystems in response to other physical forcing and biogeochemical variability
- Seasonal net carbon production in the mixed layer and euphotic zone
- Biology and dynamics of sinking particles

Minority view: for ocean biogeochemistry, new sensors can be more important than command and control, depending on experiment

- High precision DIC, NO$_3^-$, O$_2$, total gas content
- Optical sensors for flow cytometry, fast repetition rate fluorometry...
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- **NCP** = photosynthesis-respiration
- \( C_{\text{org}} \) is not stored in euphotic zone; NCP \( \sim \) export
- \( \text{O}_2 \) flux to the atmosphere = \( \text{O}_2 \) supersat \* gas transfer velocity
- Correct for physical supersaturation based on Ar supersat
- Sea-air \( \text{O}_2 \) flux = carbon NCP and export

**Mixed layer**

- 1% light level

**Carbon export**

**Dark ocean**

Time period accessed by \( \text{O}_2 \) balance \( \sim \) 1 week
Some details regarding the calculation of net community production

- $O_2$ in the mixed layer is supersaturated as because of physical processes
  - Measure Ar supersaturation and correct $O_2$ supersaturation accordingly
- Some assumptions:
  - Steady state
  - No mixing with water below the mixed layer
- Estimate gas transfer velocity and calculate $O_2$ efflux to atmosphere
Other sources of information about rates of NCP and carbon export

- Seasonal drawdown of dissolved inorganic carbon or nutrients (seasonal timescale)
- Sediment traps
  - $^{234}$Th/C ratios and fluxes
  - $^{15}$NO$_3^-$ assimilation