OCB Scoping Workshop report

Observing biogeochemical cycles at global scales with floats and gliders:

28-30 April 2009, Moss Landing, CA
http://www.whoi.edu/sites/OCBfloatsgliders

Ken Johnson
MBARI
Steering Committee:

• Emmanuel Boss  
• Steve Emerson  
• Dennis Hansell  
• Arne Körtzinger  
• Steve Riser  

• Hervé Claustre  
• Niki Gruber  
• Ken Johnson  
• Mary Jane Perry

65 attendees, 9 countries
Why a Float/Glider workshop?

Ocean biogeochemistry is seriously undersampled in space and time:

- Ship-based, time-series give little sense of change over broad areas, undersample events, can’t be scaled to larger numbers (too few islands with universities).

- Direct satellite observations of biogeochemistry limited to ocean color in upper ~1/5th of euphotic zone, don’t sample under clouds.
FLOAT/GLIDER WORKSHOP GOALS:

• Assess the potential to create a long-term, biogeochemical observing system based on floats and gliders capable of quantitative assessments of the ocean carbon cycle over large areas.

• Review existing technologies, their strengths, their weaknesses.

• Assess unmet needs for sensors and sensor performance, platforms, and other issues that may arise.

• Initiate planning for a near-term experiment focused on major OCB uncertainties using floats/gliders deployed for multi-year period, but also integrated with ship board operations that verify system operation.
OBSERVING BIOGEOCHEMICAL CYCLES AT GLOBAL SCALES WITH PROFILING FLOATS AND GLIDERS

PROSPECTS FOR A GLOBAL ARRAY

BY KENNETH S. JOHNSON, WILLIAM M. BERELSON, EMMANUEL S. BOSS, ZANNA CHASE, HERVÉ CLAUSTRE, STEVEN R. EMERSON, NICHOLAS GRUBER, ARNE KÖRTZINGER, MARY JANE PERRY, STEPHEN C. RISER
FLOAT/GLIDER WORKSHOP CONCLUSIONS:

We are on the verge of a revolution in biogeochemical observing:

• Sensors now exist for important biogeochemical properties that show little or no significant drift for years.
• Autonomous sensors/platforms can constrain important components of the carbon cycle such as NCP and export.
• Need to demonstrate that large arrays of sensor systems can generate climate-research quality data.
• Need to demonstrate the operation of integrated systems that combine in situ sensor data with satellite sensors and data assimilating, biogeochemical-ecological models.
• Need a common data access system, particularly for sensors on gliders.
Next step –

Implementation of a multi-year, regional scale experiment(s) that constrains a significant component of the carbon budget and which demonstrates:

• climate-research quality data from a relatively large (O(100)) array of sensors,

• integrate in situ sensor data with satellite sensors and data assimilating, biogeochemical-ecological models.

Possible experiments and carbon cycle processes (among many) that were discussed:
2. WHAT IS THE BIOLOGICAL CONTRIBUTION TO THE INTESE pCO$_2$ DRAW-DOWN AT THE PACIFIC SUBARCTIC-SUBTROPICAL BOUNDARY?

A proposed pilot project to study upper ocean oxygen production OCB
Float-Glider Workshop April 2009 Steve Emerson and friends

Mean Annual Air-Sea Flux for 2000

Taro Takahashi data base, www.ldeo.columbia.edu
A. Intermediate and mode waters of the Southern ocean: Pre-formed chemical properties and their biological determinants

Important site for anthropogenic carbon uptake by the ocean

Mechanism to supply nutrients to much of the ocean thermocline, and oxygen to low oxygen zones.

Sensitive to climate change

Perfect opportunity to piggy-back on ARGO
~100 floats with $O_2$ and nitrate
~10 including chl
Deploy in south east Pacific- near OOI mooring
Involve process cruise, possibly gliders from Chile
All it takes is money!
Low oxygen/fixed nitrogen balance in the ocean:

Two Major Questions

1. What controls the size, intensity and variability of Low Oxygen Zones? (How will they change in future)

2. What are the rates and controls of fixed N loss within these systems (How well do we understand global N, C budgets)

W. Berelson/M. Altabet Leads
Other breakouts focused on:

• North Atlantic seasonal cycle of carbon production/export (multi-year follow-on to the North Atlantic Spring Bloom Experiment).

• Influence of mesoscale processes such as eddies, fronts, lateral transport from margins on carbon cycling.

• Improved constraints on Net Community Production and Export.

But applications really only limited by imagination and energy of science community.
Why do we think we can do this? Basic components already deployed.

Biogeochemical sensors on floats that reported in the week of June 10. Does not show routine glider sections – many now being occupied (but no central data access location).
Week of 10 June 2009
Oxygen along the conveyor – 12 to 21 June 2009
3 years of $O_2$ data near HOT.
From Riser and Johnson, Nature 2008
Seven years of O$_2$ data near HOT from floats. Biggest challenge – make data from each float consistent – climate-research quality.

![Oxygen at 75 m](image)
Week of 10 June 2009
E. Boss et al., 2008 (EOS and L&O). Three yrs of data for a fluorometer on a profiling float in the Labrador Sea. No sensor drift.
Week of 10 June 2009
Ocean Station Papa – Apex Float/ISUS Nitrate

Temperature[°C]

Nitrate[µM]

Data in upper 30 m.
Science 2002, 2 mon. data

Robotic Observations of Dust Storm Enhancement of Carbon Biomass in the North Pacific

James K. B. Bishop, Russ E. Davis, Jeffrey T. Sherman

Two autonomous robotic profiling floats deployed in the subarctic North Pacific on 10 April 2001 provided direct records of carbon biomass variability from surface to 1000 meters below surface at daily and diurnal time scales. Eight months of real-time data documented the marine biological response to natural events, including hydrographic changes, multiple storms, and the April 2001 dust event. High-frequency observations of upper ocean particulate organic carbon variability show a near-doubling of biomass in the mixed layer over a 2-week period after the passage of a cloud of Gobi desert dust. The temporal evolution of particulate organic carbon enhancement and an increase in chlorophyll use efficiency after the dust storm suggest a biotic response to a natural iron fertilization by the dust.

Nature 2008, 36 mon. data

The Ocean Takes a Deep Breath

Arne Körtzinger, Jens Schimanski, Uwe Send, Douglas Wallace

Science 2004, 2 mon. data

Robotic Observations of Enhanced Carbon Biomass and Export at 55°S During SOFeX

James K. B. Bishop, Todd J. Wood, Russ E. Davis, Jeffrey T. Sherman

Autonomous floats profiling in high-nitrate low-silicate waters of the Southern Ocean observed carbon biomass variability and carbon exported to depths of 100 m during the 2002 Southern Ocean Iron Experiment (SOFeX) to detect the effects of iron fertilization of surface water there. Control and “in-patch” measurements documented a greater than fourfold enhancement of carbon biomass in the iron-amended waters. Carbon export through 100 m increased two- to sixfold as the patch subsided below a front. The molar ratio of iron added to carbon exported ranged between $10^4$ and $10^5$. The biomass buildup and export were much higher than expected for iron-amended low-silicate waters.

Science 2004, 10 mon. data

Net production of oxygen in the subtropical ocean

Stephen C. Riser & Kenneth S. Johnson
Table of Contents, Vol. 53(5, part 2), September 2008

Limnology and Oceanography Special Issue on Autonomous and Lagrangian Platforms and Sensors (ALPS)

Mary Jane Perry and Mark Moore, coordinating editors
Tommy D. Dickey and Eric C. Isaken, issue editors

This issue is devoted to recent developments of Autonomous and Lagrangian Platforms and Sensors (ALPS) and their use for solving a broad range of interdisciplinary aquatic problems that span a continuum of spatial and temporal scales. ALPS platforms in this issue includes surface drifters, profiling and other types of sub-surface floats; gliders, unmanned boats; autonomous underwater vehicles (AUV); and instrumented animals. These types of platforms provide access to difficult environments (e.g., under ice and in high seas) they are also important for emerging connected ocean and space observation systems that require continuous measurements and near real-time data.

We thank all the authors and reviewers of the papers that appear in this issue. Editor-in-chief, Everett Fei, was an invaluable resource and Lucio Bousette greatly facilitated the editing of the manuscripts. Financial support for the publication of this Special Issue was provided by the National Sciences Foundation and the Office of Naval Research through a grant to Mark Moore (OCE-0737167), Tommy Dickey, Mark Moore, and Mary Jane Perry acknowledge support by the National Science Foundation, the Office of Naval Research, the National Aeronautics and Space Administration, and the National Ocean Partnership Program.

This special issue is dedicated to Henry Stommel who understood the challenge and necessity of sampling a turbulent ocean across a continuum of space and time scales, and who envisioned solutions using autonomous platforms. His vision was crystallized as the mythical World Ocean Operating System (WOOS) program that would send gliders on missions from the Sogun Mission Control Center on Nantucket Island, one of the Elizabeth Islands near his Cape Cod home. Stommel continues to be an inspiration to generations of aquatic scientists and the papers in this special issue are a tribute to his ideas.

Other Issues in Volume 53
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EndNote Import File
Right-click on the link below to save this Table of Contents to a text file suitable for importing into EndNote. An EndNote file (ASLO.ent) to interpret the file is available for download here.
- Gas Tension Device deployed on Float – C.
  McNeil, UW/APL

\[ \tau \approx 2 \text{ min at surface} \]
\[ \tau \approx 10 \text{ min at 60 m} \]
Sensors for particulate inorganic carbon (PIC).

Sensors tested and reengineered multiple times.
2003 A16n, 2005 A16s, 2007 (San Clemente Basin),
2008 BATS and Slope Water (GEOTRACES IC I)
2009 N Pac Gyre and Santa Barbara Basin – (next month)
Carbon Flux Explorer:

An example of independent and complex platform/sensor Integration.

Platform provides queues to sensor.

Sensor responds with data when asked.

Bishop, UC
Experimental Float Design and Development - A. Kortzinger

**Experimental Float Design and Development - A. Kortzinger**

**NEMO Float** (Optimare, Germany)

**CO2 & Oxygen Sensors**

**PSI CO₂ Pro**

**Field Testing**

**Iridium & ARGOS telemetry**

**Oxygen sensor (optode)**

**External battery pack**

**pCO₂ sensor (PSI CO₂ Pro)**

**Design**

**Depth (dbar) vs. pCO₂ [µatm]**

- ***meas. pCO₂ NEMO1-1***
- ***calc. pCO₂ ATA3 St.39***
- ***calc. pCO₂ ATA3 St.40***

**SOPRAN, Sub-project 3.5 (Körtzinger & Heimann)**

Sea-Air fluxes of CO₂ and O₂ in the eastern tropical Atlantic: a combined atmosphere-ocean perspective
Honeywell Durafet Ion Sensitive Field Effect Transistor pH sensor – a potential float/glider sensor

- Long-term stability – months at ±0.006 pH in seawater
- High temperature stability – weeks of cycling 5 to 35°C in equimolar buffers (pH=pK(T)) show >0.01 pH stability
- Low power (µWs), low weight (grams), fast (<1 s)
- Pressure tolerance is now limiting factor. Re-engineering packaging to be pressure tolerant – possible, but not easy.

MBARI Seawater Test Tank – Std. dev. of difference from Spec. pH values is 0.006 over 6+ months (pH going up as tank outgases CO₂)

Outliers created by bubbles on conduction channel
A vision for the future: the Riley (or NPZ) float
Boss et al., 2008, EOS

N: ISUS
P: FL-NTU
Z: LOPC/Gorsky/novel cheap acoutic b_b
+PAR & O_2

Minimum sensor-suite to constrain ecosystem models.

Our current vision is constrained to be 'bottom-up' by the lack of cheap zooplankton sensors

The age of exploration is not over!
Floats or Gliders?

1. Gliders provide spatial structure (slowly) and simplify recovery
2. Glider measurements can (to some extent) be positioned
3. Floats provide (very approximate) Lagrangian time series
4. Floats are less expensive (purchase 15K$ vs 90K$)
5. Floats are much easier to adapt (more batteries, big sensors)
6. Floats are relatively immune to fouling – better for long duration

Map with L/T (of signal) > 25 cm/s: array of floats
Map with L/T < 25 cm/s: glider(s)
Quasi-Lagrangian time series: floats
Many big co-located sensors: floats

Russ Davis, SIO
The take home message: it’s now possible to instrument the world ocean with a reasonably low-cost biogeochemical sensor network for nitrate, oxygen, biomass, and (perhaps) pH. This will transform ocean observing.
What would it cost? First some background:

- US Deep-Sea Drilling Program was order of $55 million/year
- Academic research fleet order of $80 million/year
- OCO Orbiting Carbon Observatory order of $30 million/year during construction (lost on launch).
- Ocean color satellite – order of $300 to $500 million/10 year lifetime.
- OOI - $300 million/?? year lifetime.
What would it cost per year?

- Current US Argo cost $10,000,000/year; world is probably double that = $20,000,000/year.
- Adding oxygen to Argo estimate in Friends of Oxygen on Argo Floats report (Gruber et al., 2007) to increase operating costs <50% = $10,000,000/year.
- Adding bio-optics is probably a similar cost = $10,000,000/y.
- Adding pH is probably a similar cost = $10,000,000/y.
- Adding nitrate would probably be order of $20,000,000/y (or more). Think hard about how many.
- Total is $70,000,000/y and assume US share is $35,000,000 per year to support a global ocean observing system.
- A system can be done in small increments focused on regions. Each component will do good science.