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:

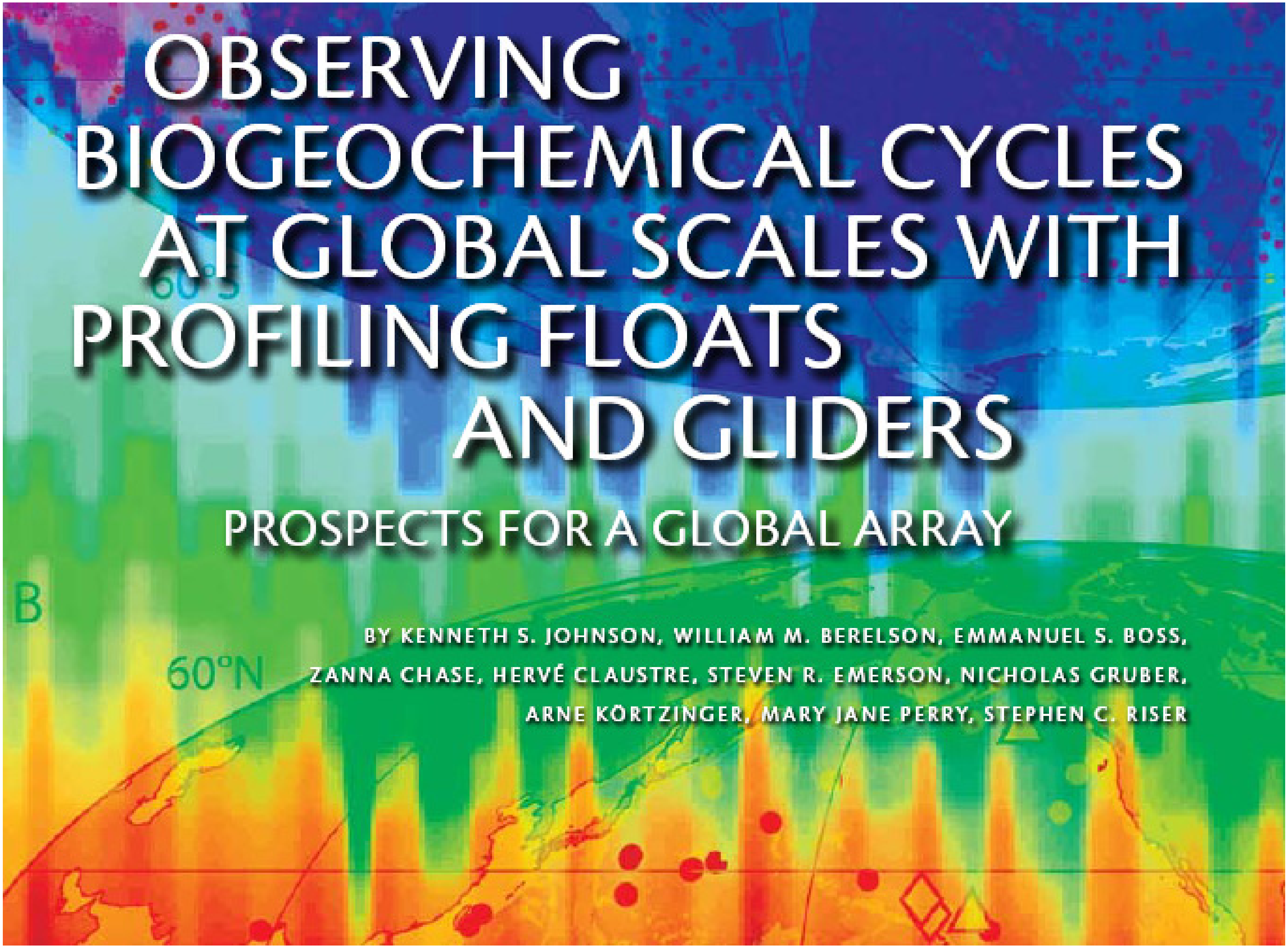
- Assess the potential to create a long-term, biogeochemical observing system based on floats and gliders capable of quantitative assessments of the ocean carbon cycle over large areas.

- 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.

Meeting summary in press, Sept. 2009 issue Oceanography



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.

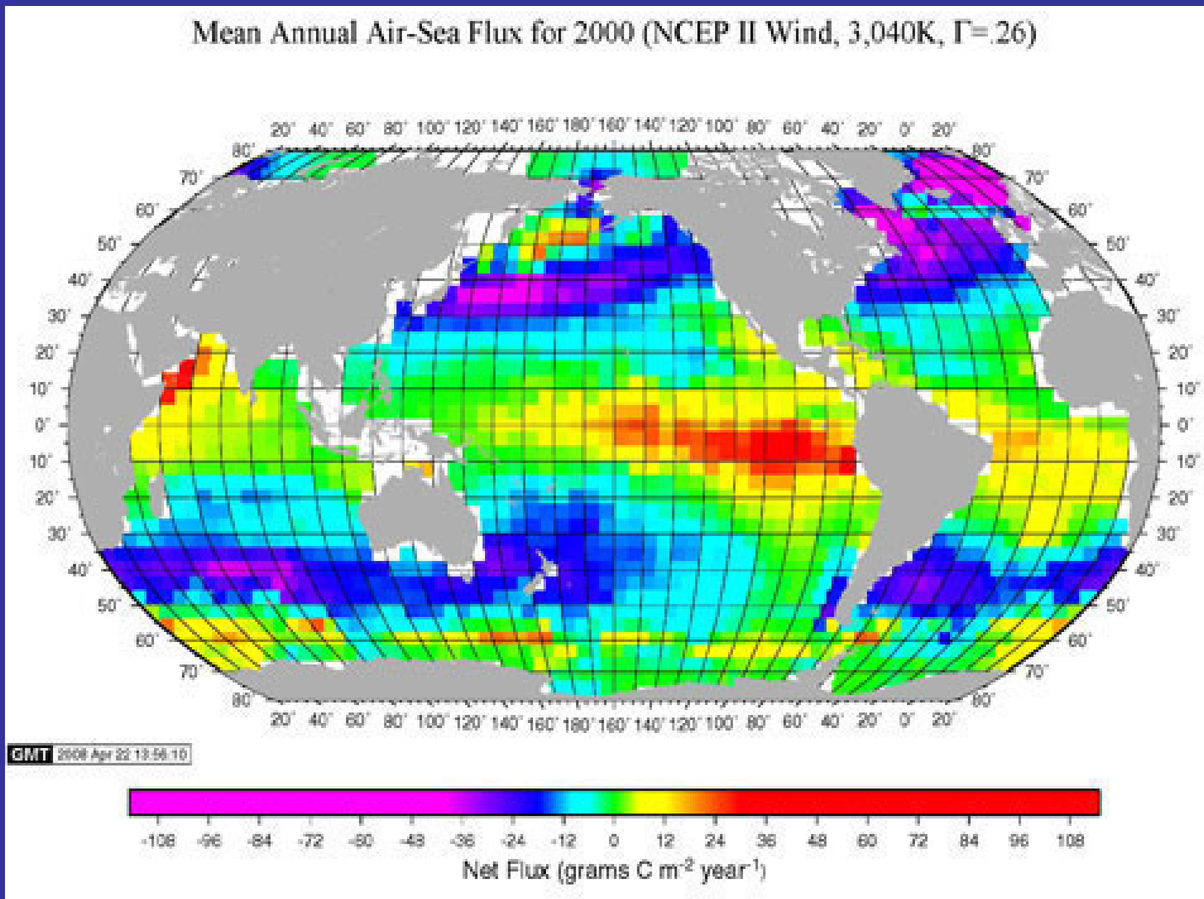
Next step –

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

- climate-reseach 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?



Mean Annual Air-Sea Flux for 2000

Taro Takahashi data base, www.ldeo.columbia.edu

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

Southern Ocean Breakout Group Report (Z. Chase, lead)

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)

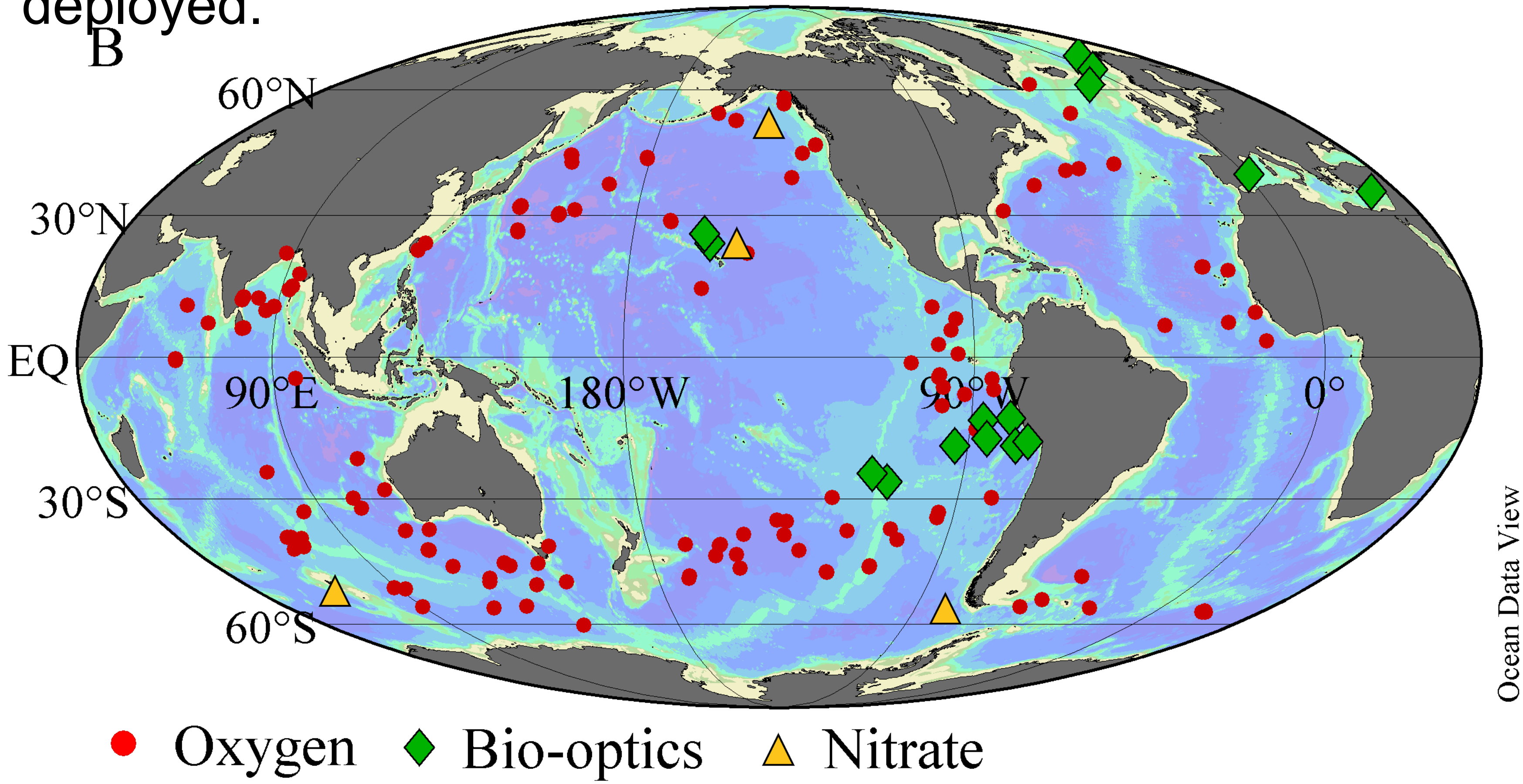
W. Berelson/M. Altabet Leads

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.

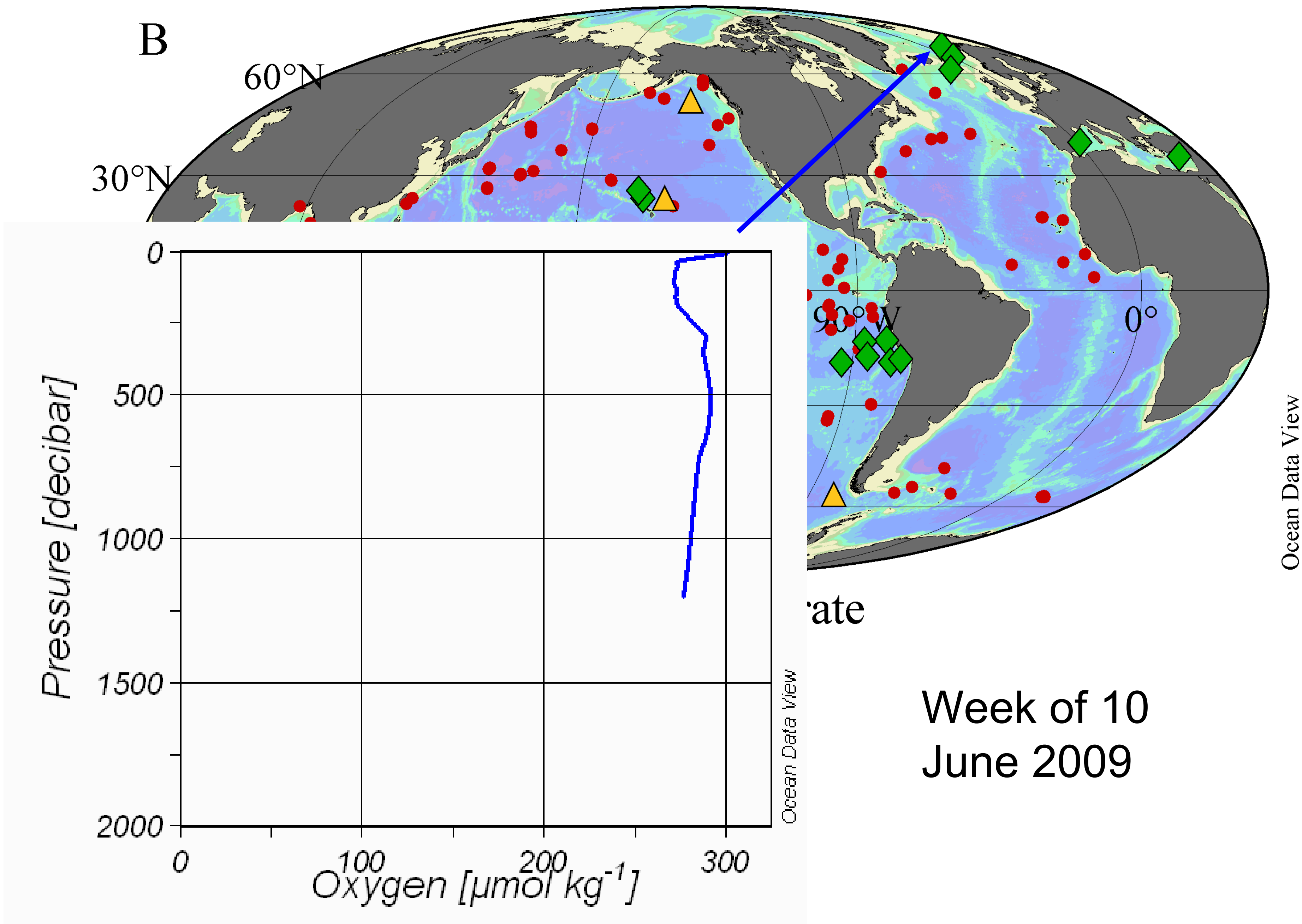
But applications really only limited by imagination and energy of science community.

Why do we think we can do this? Basic components already deployed.

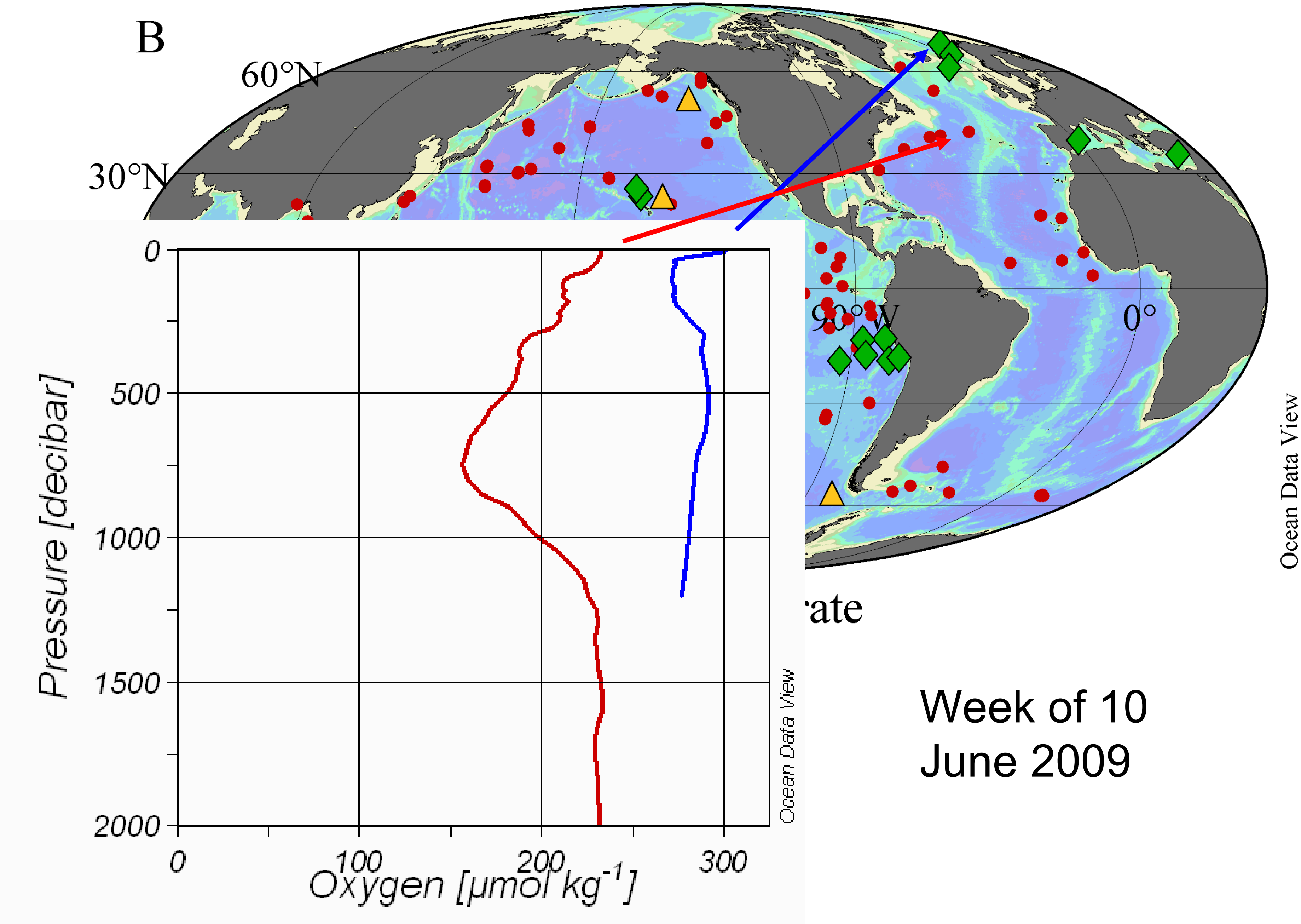


Biogeochemical sensors on floats that reported in the week of June 10. Does not show routine glider sections – many now being occupied (but no central data access location).

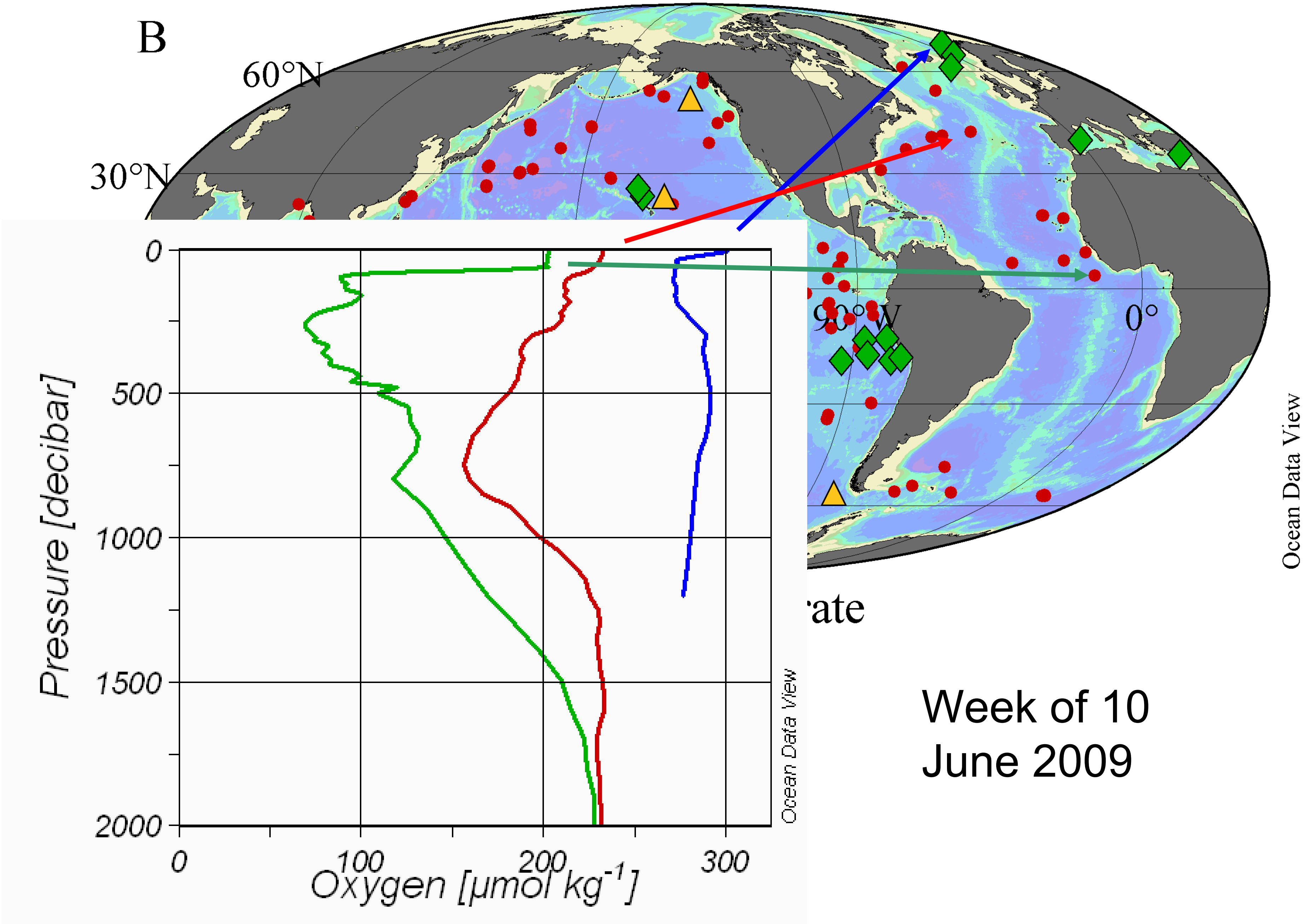
B



Week of 10
June 2009



Week of 10
June 2009



Week of 10 June 2009

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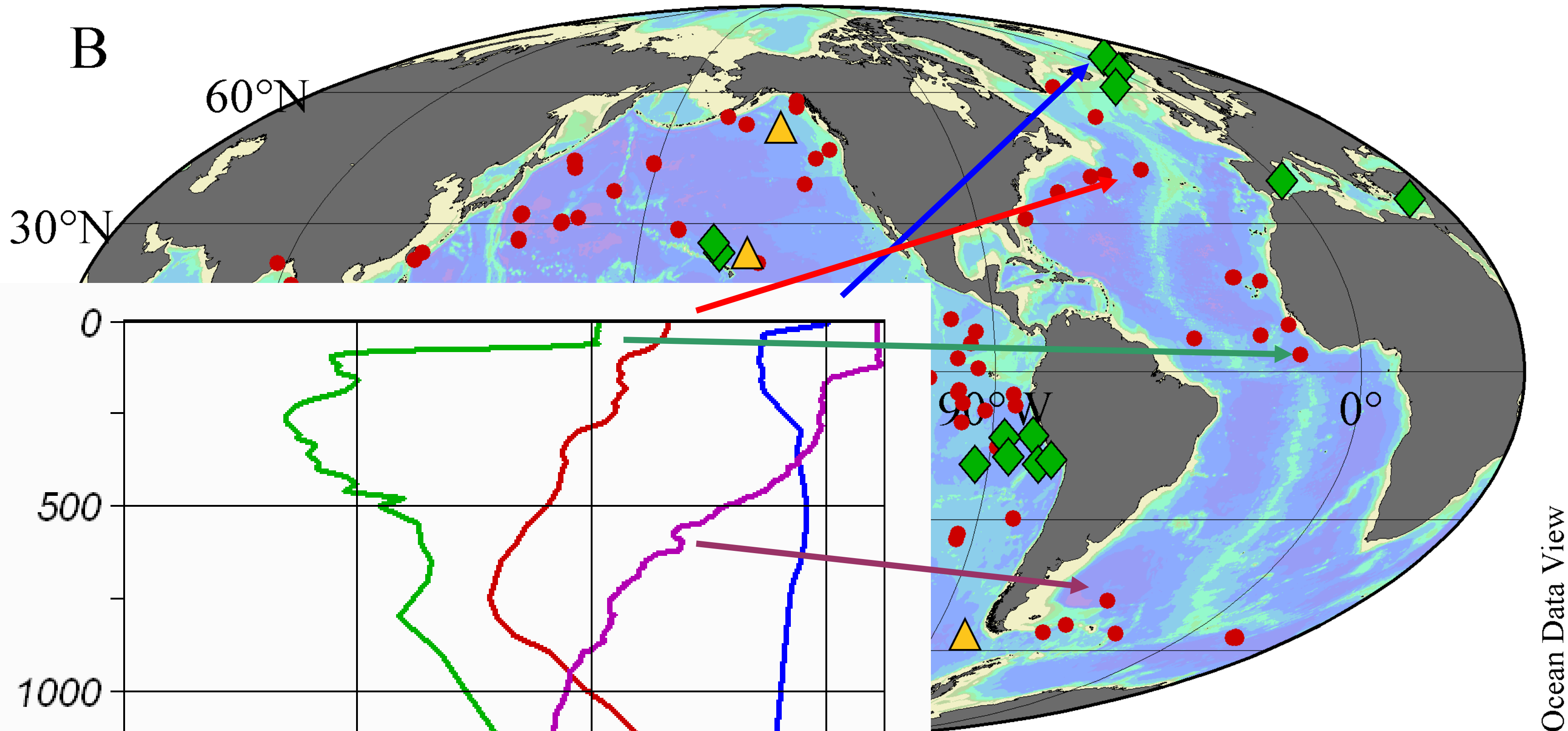

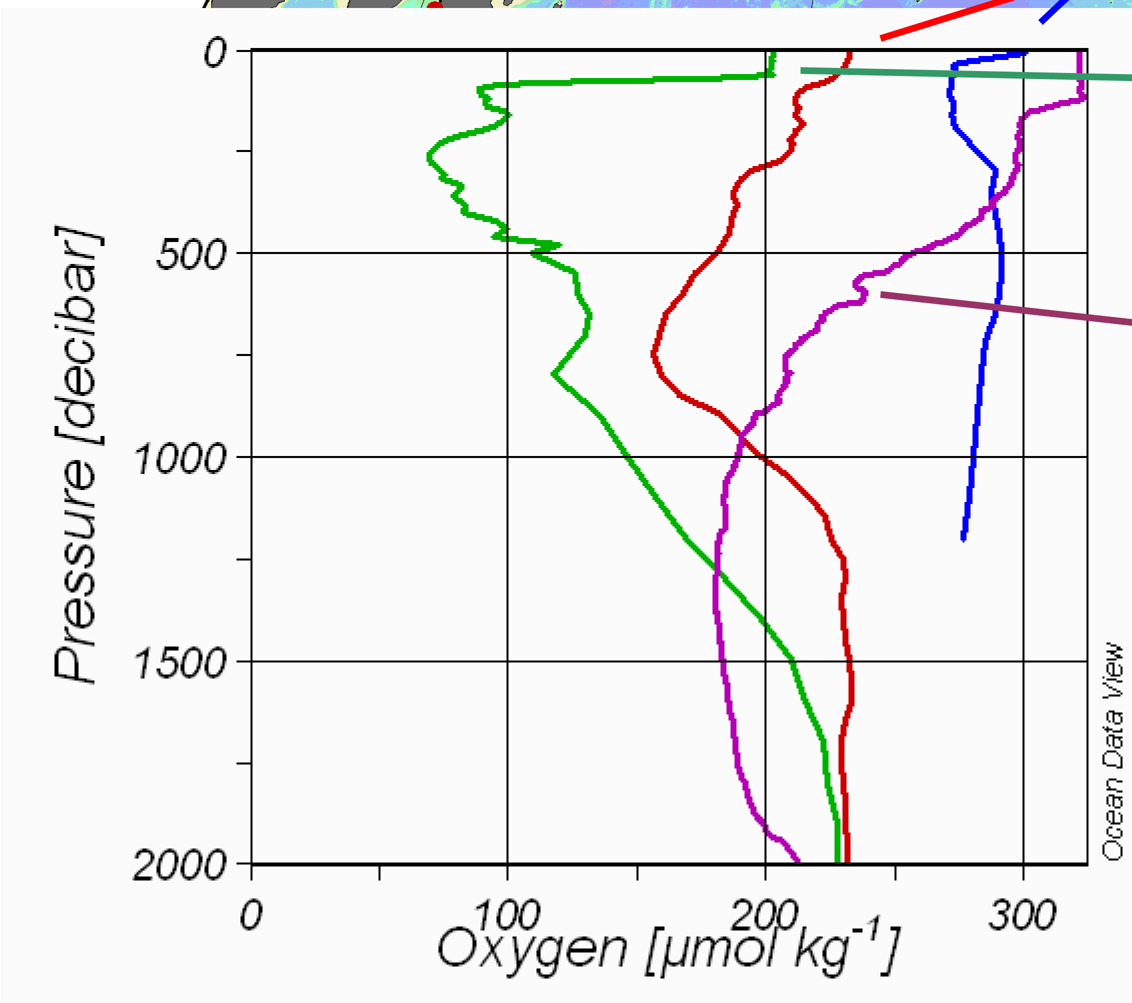

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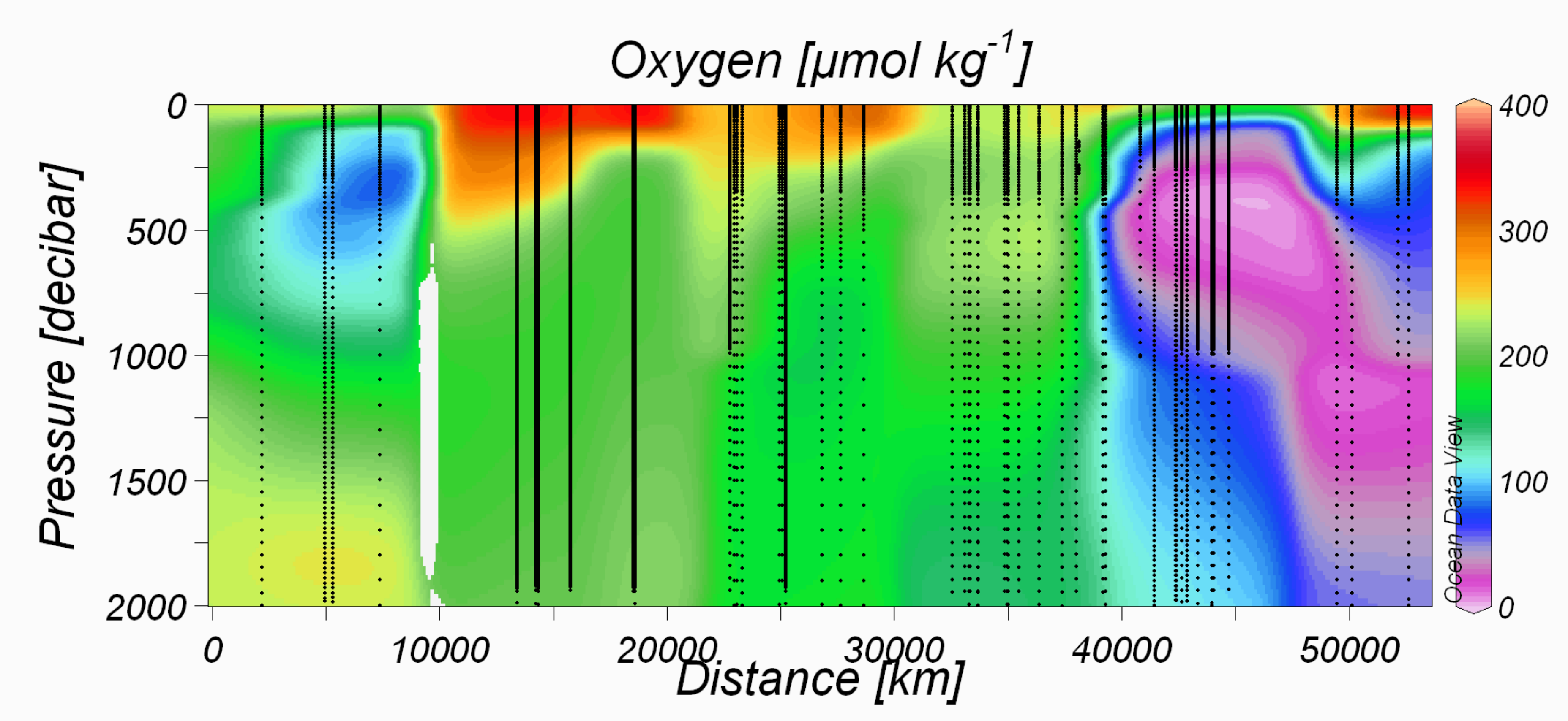
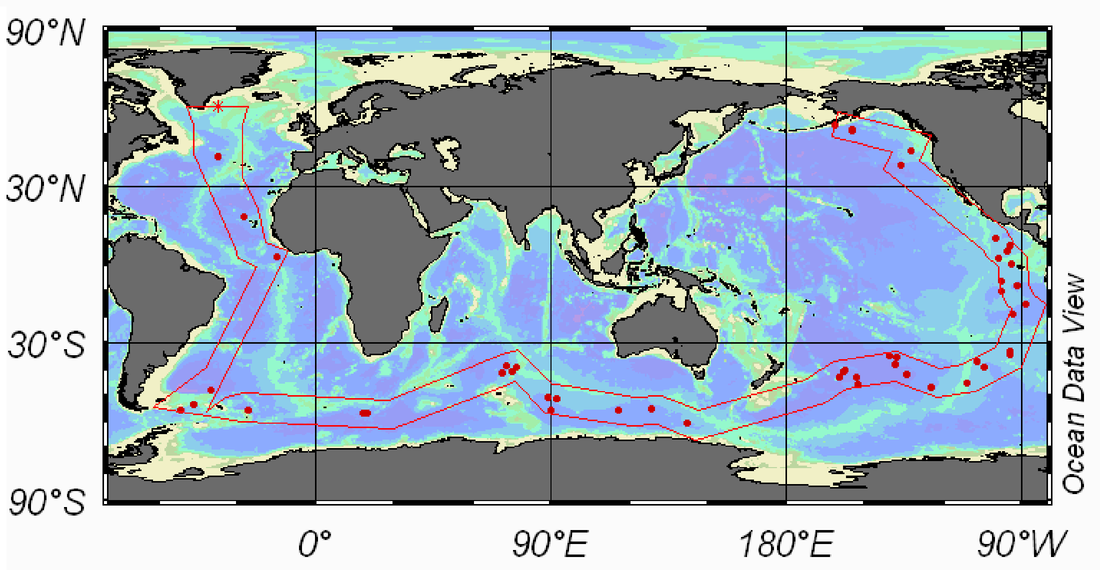
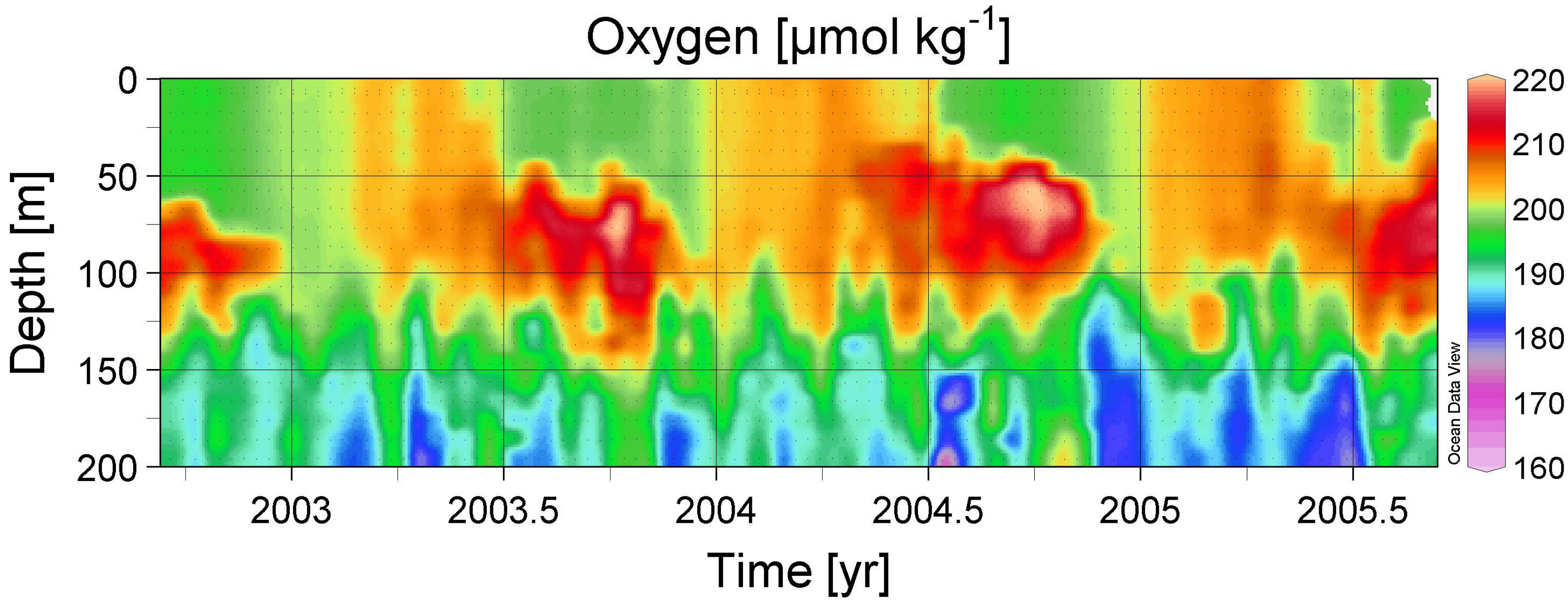
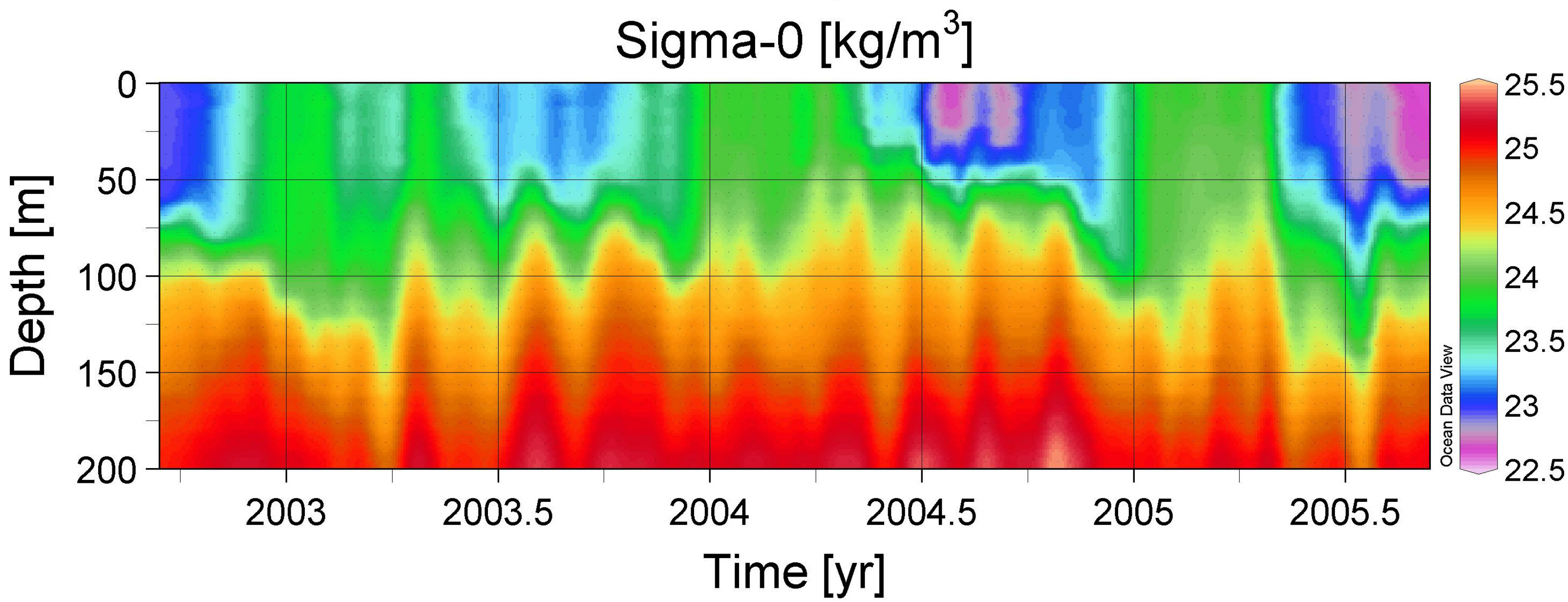


Oxygen along the conveyor – 12 to 21 June 2009

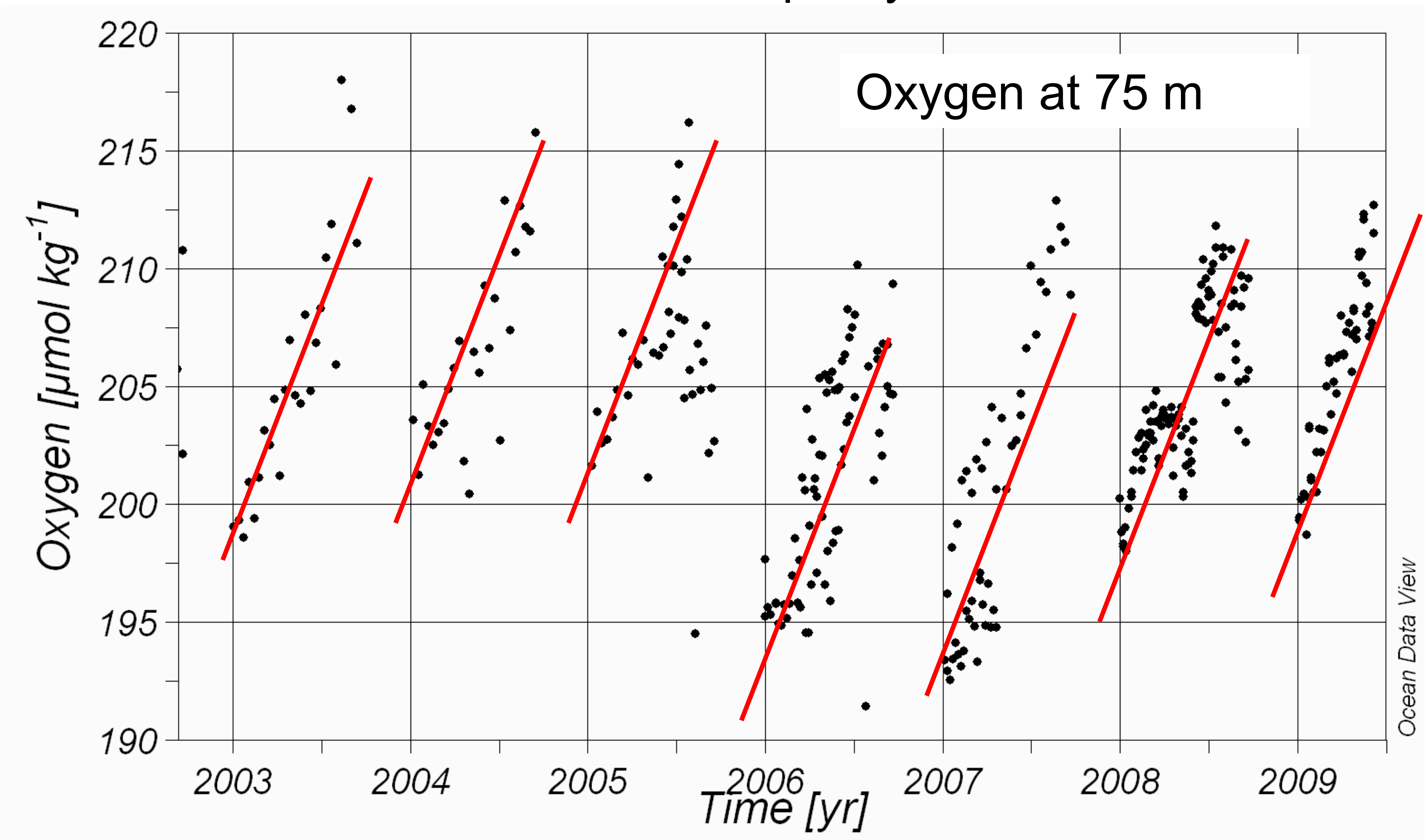


3 years of O_2 data near HOT.
From Riser and Johnson, Nature
2008





Seven years of O_2 data near HOT from floats. Biggest challenge – make data from each float consistent – climate-research quality.



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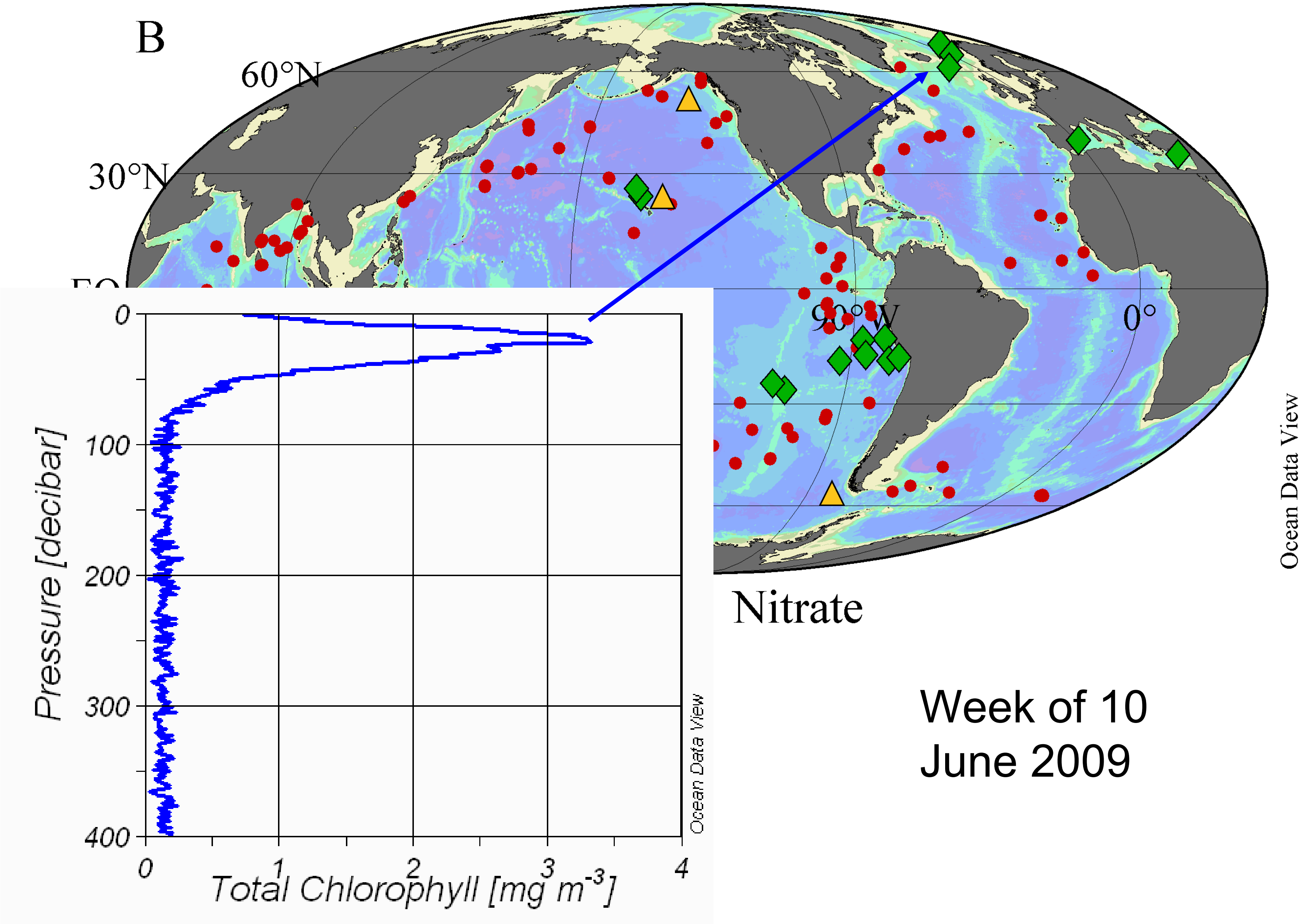
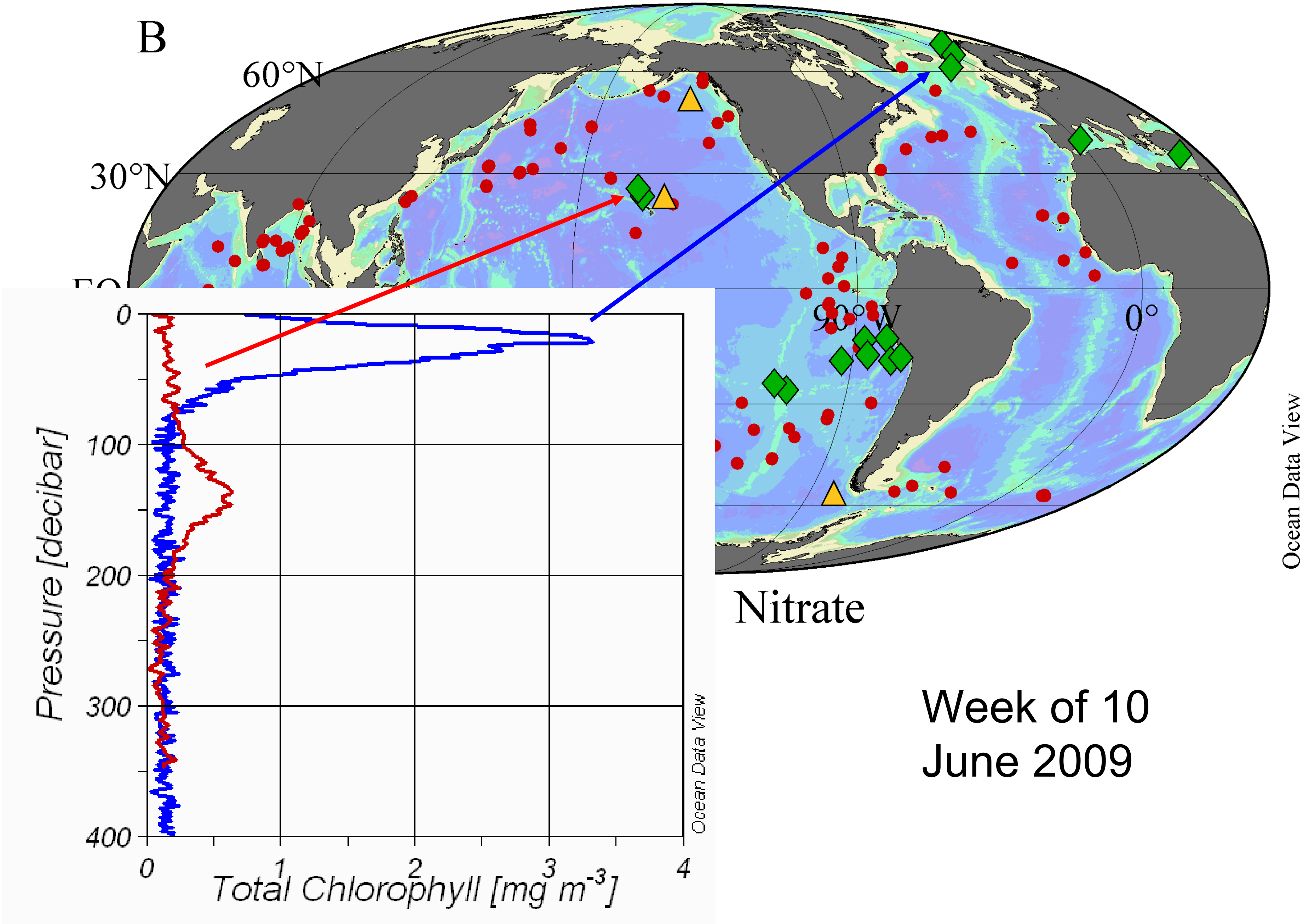


Week of 10
June 2009



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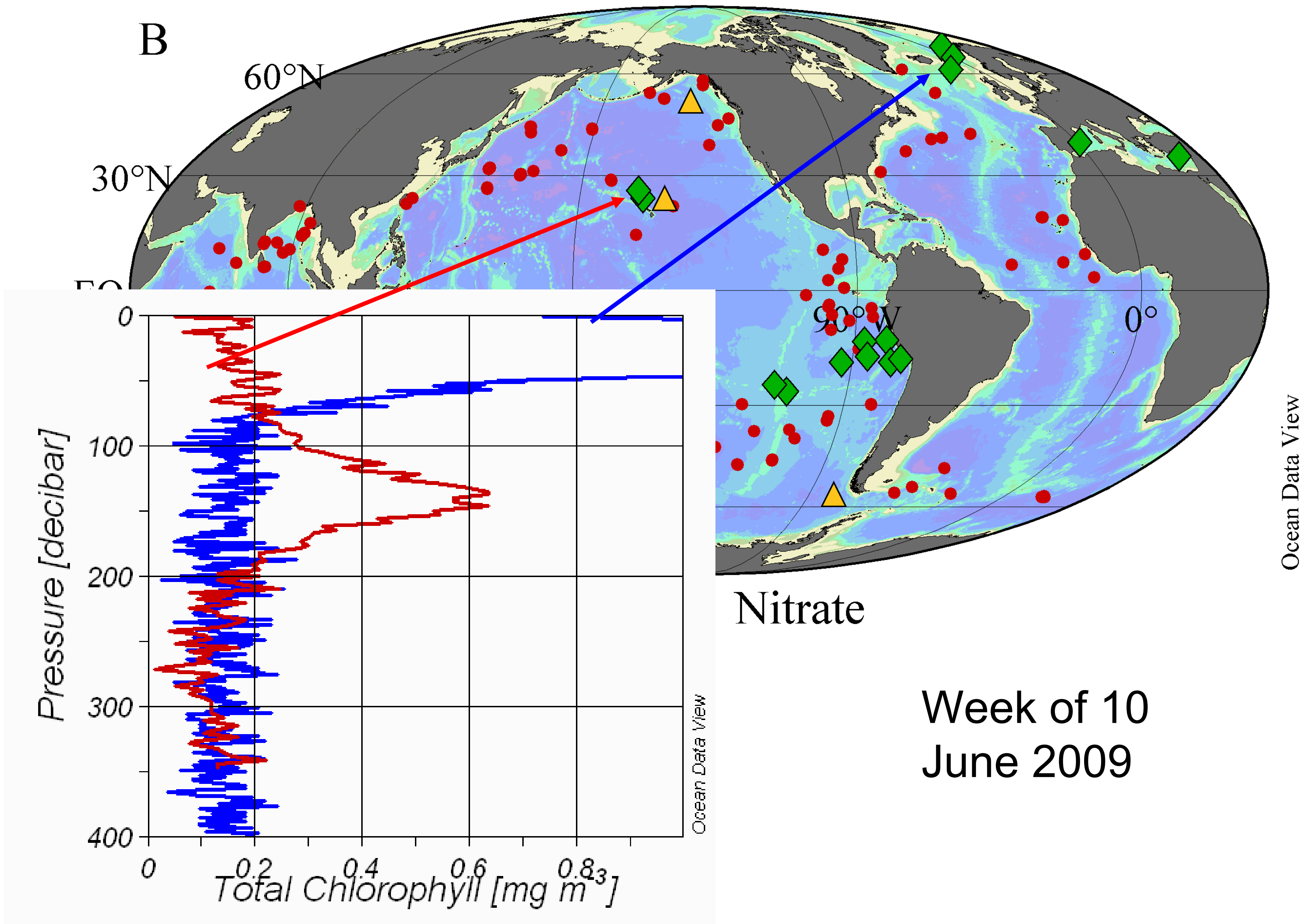
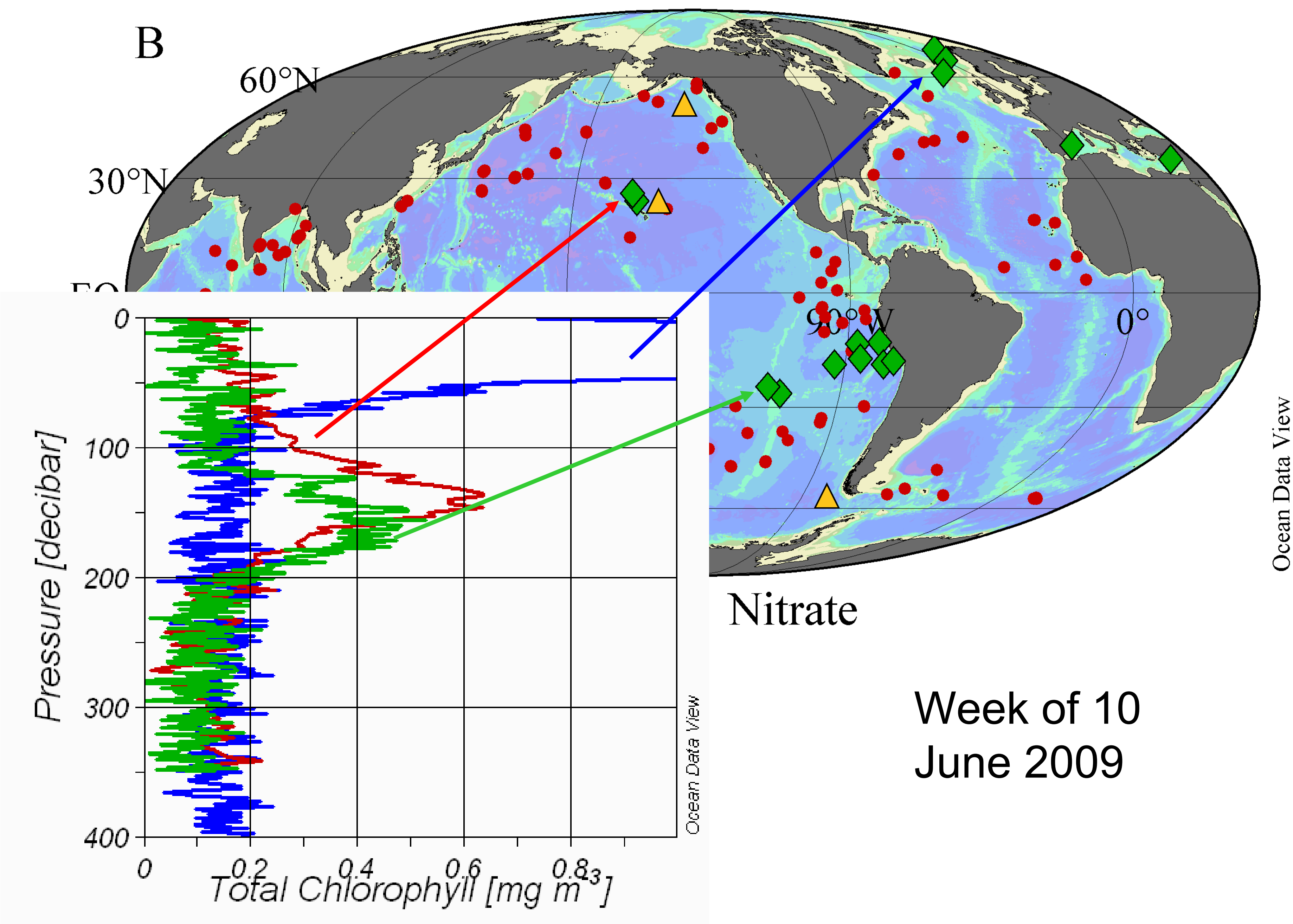


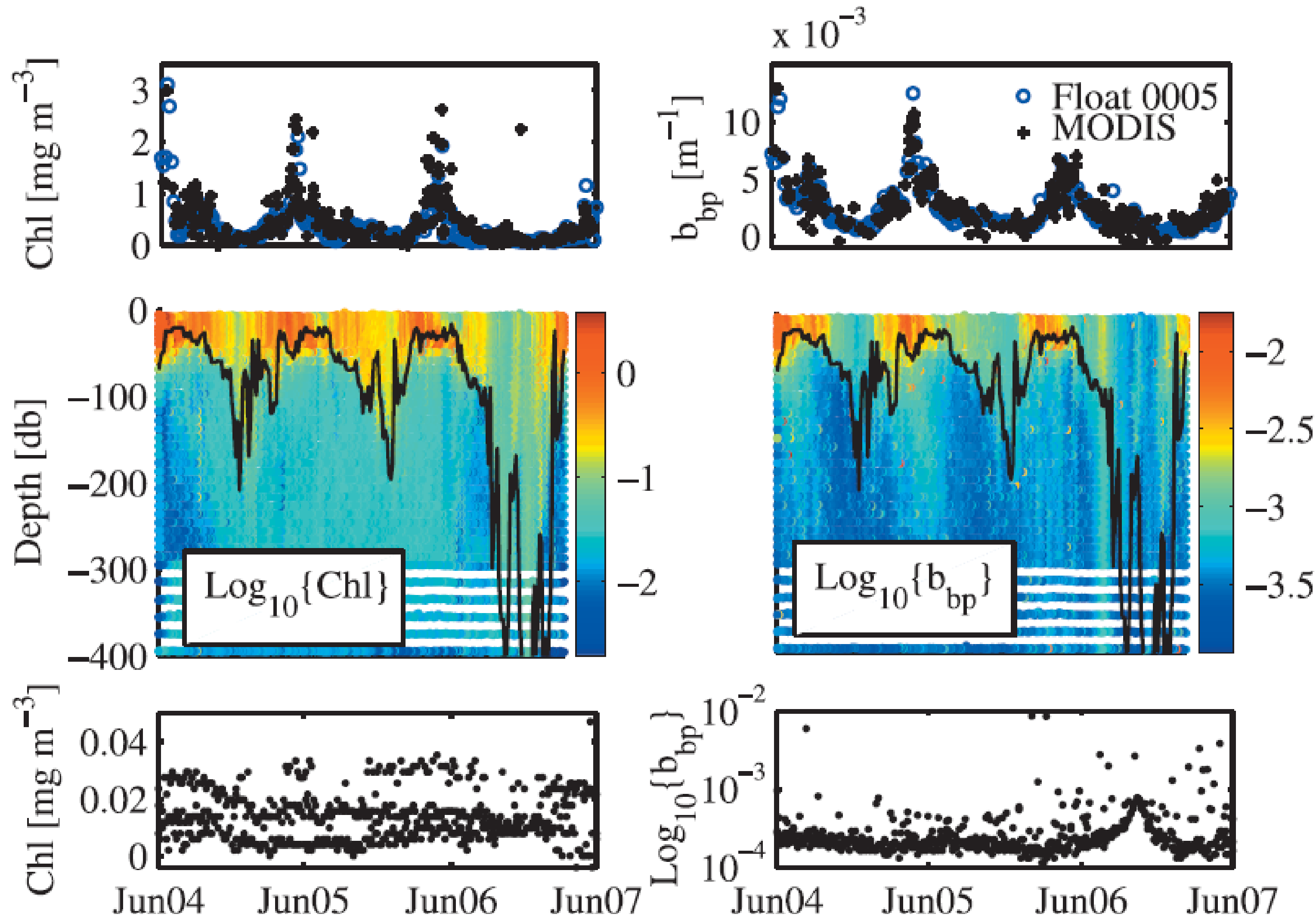
Week of 10
June 2009



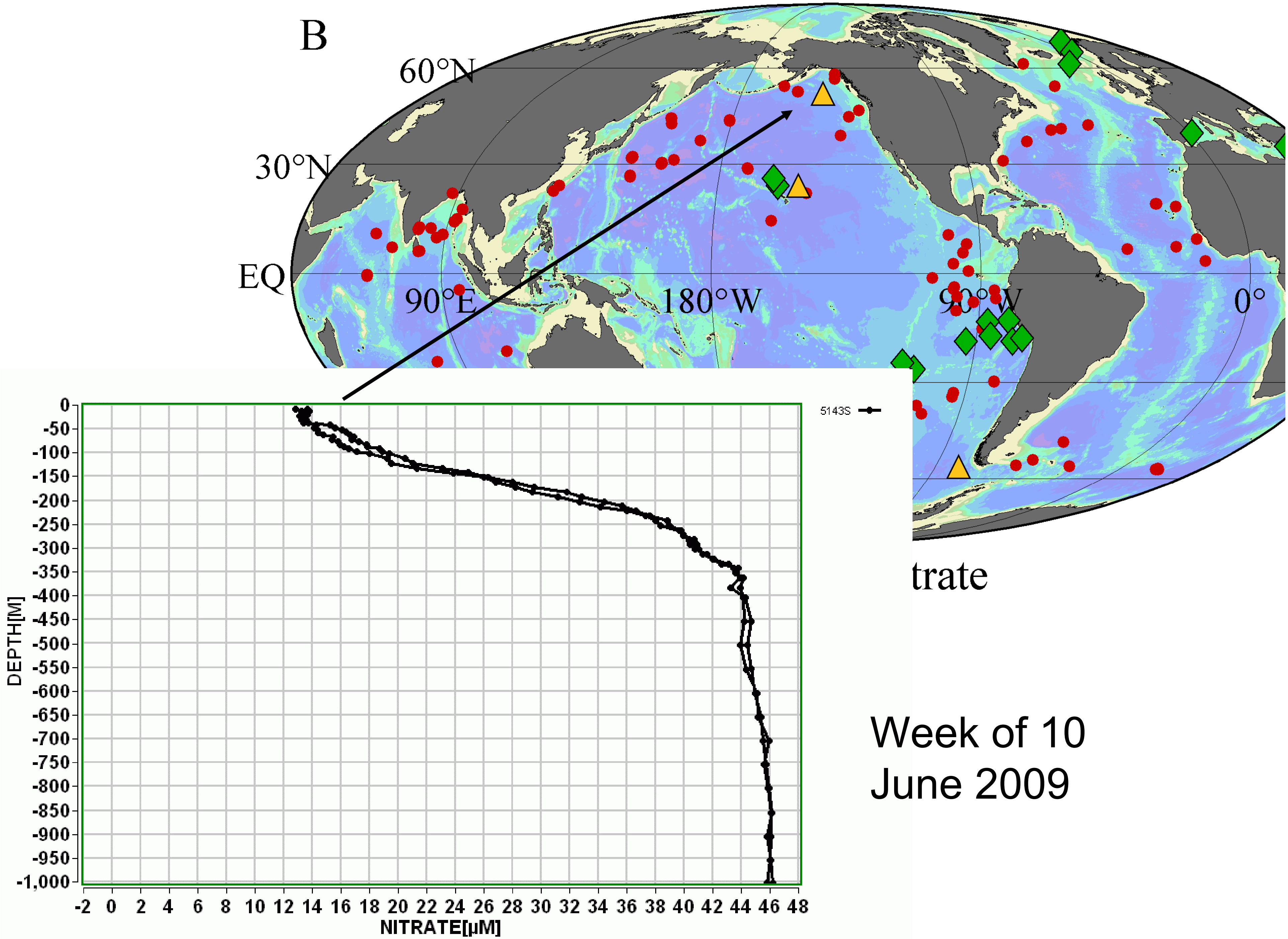
Week of 10
June 2009

Surface time-series

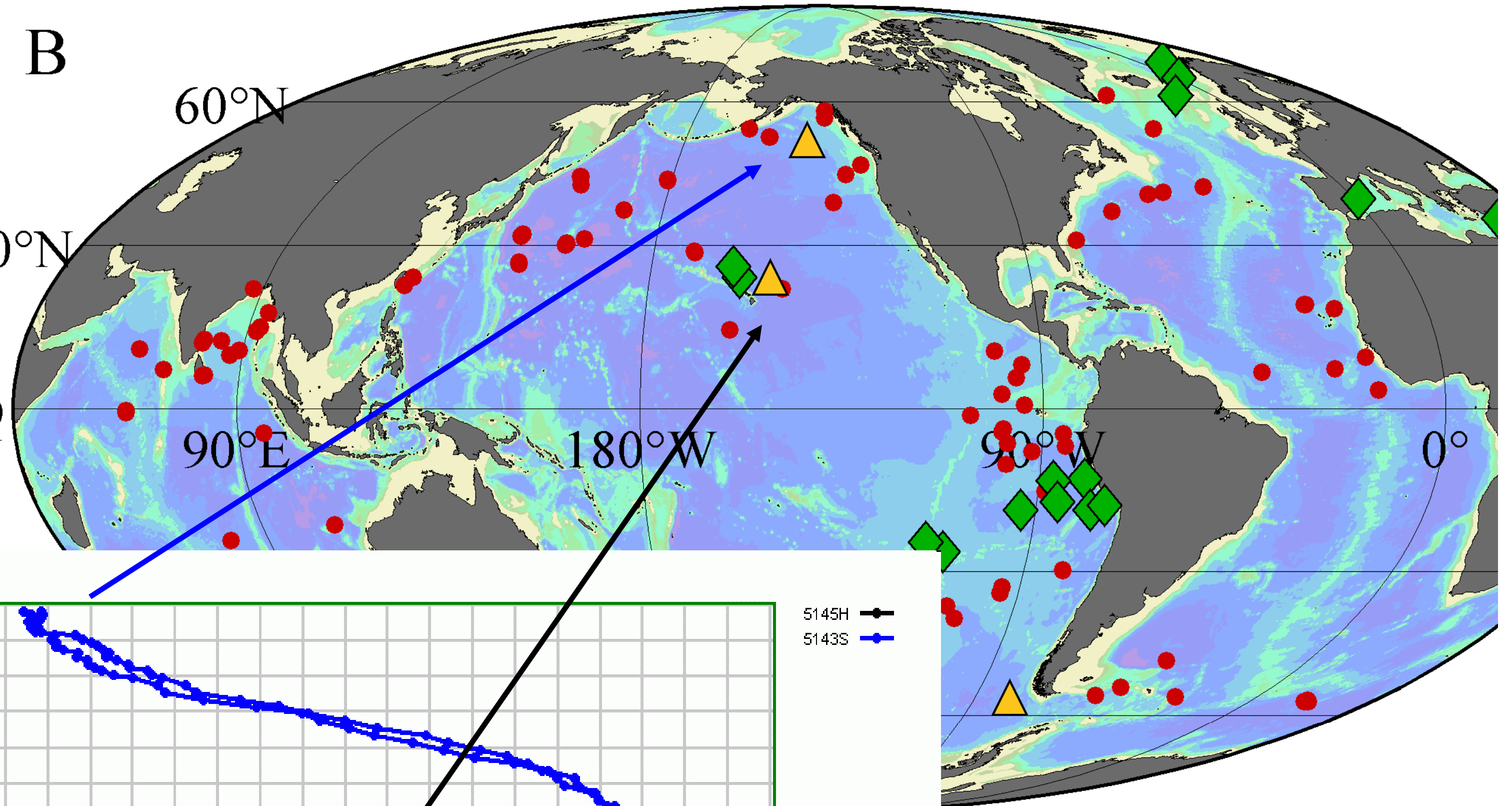
1000 m time-series

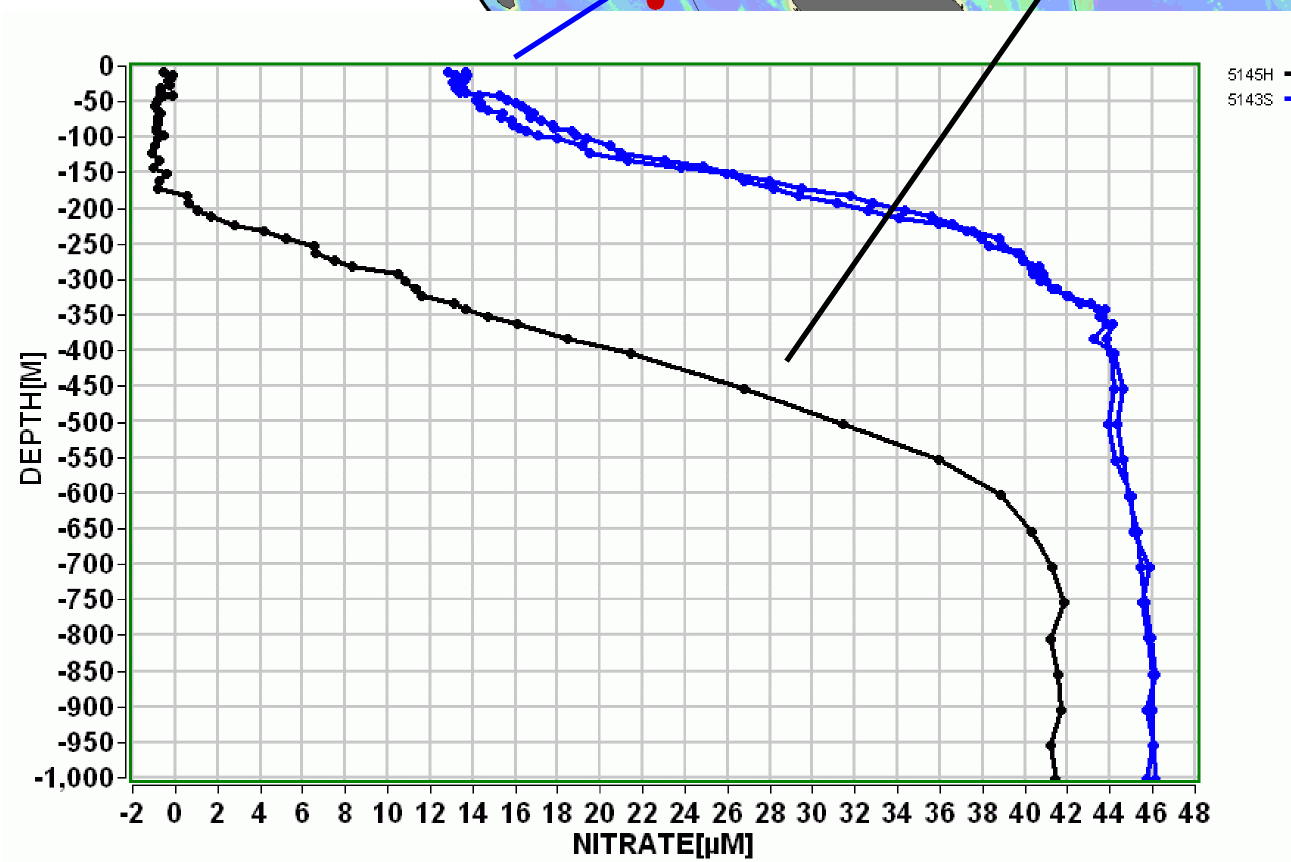


E. Boss et al., 2008 (EOS and L&O). Three yrs of data for a fluorometer on a profiling float in the Labrador Sea. No sensor drift.



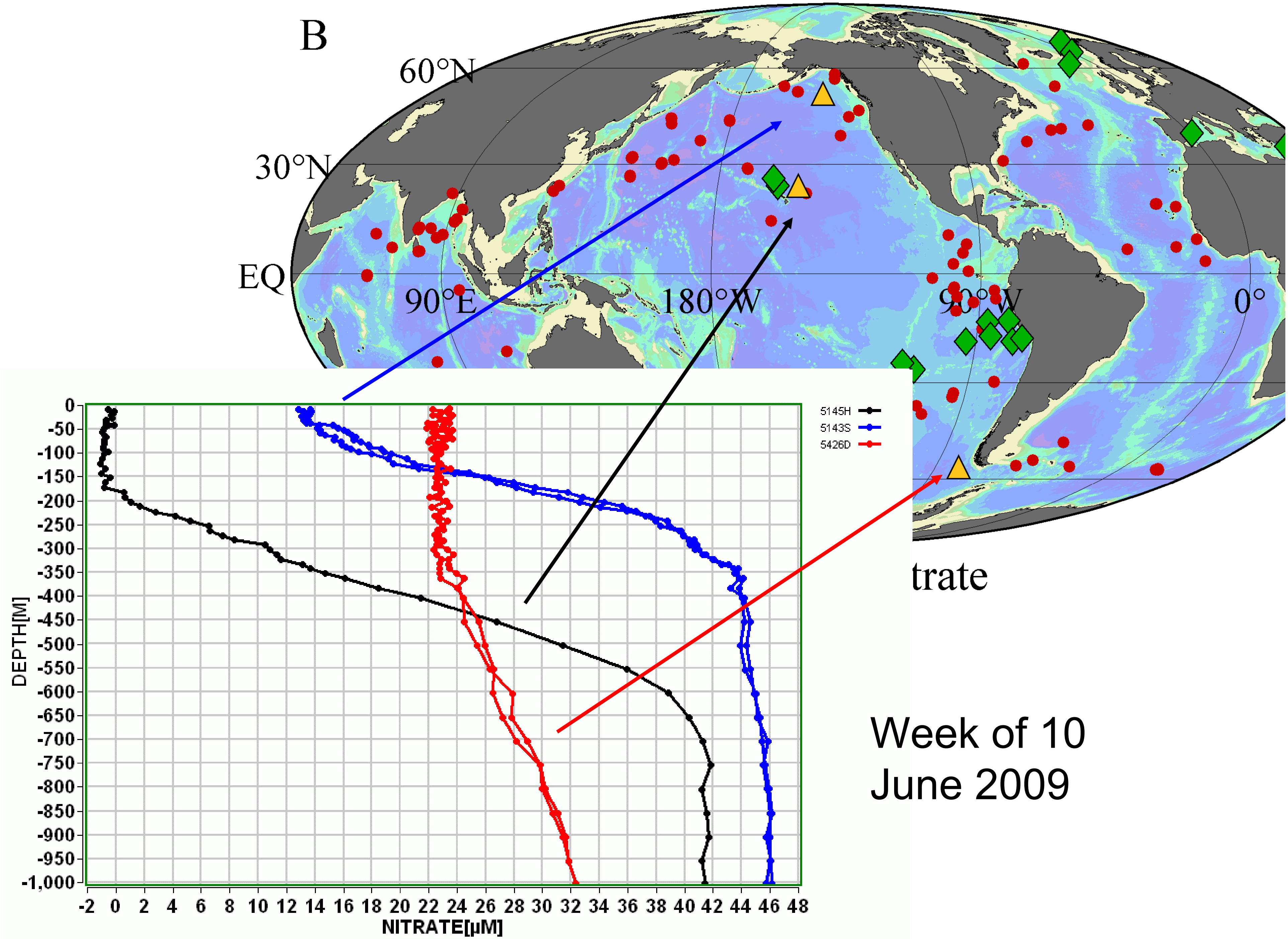
Week of 10
June 2009





trate

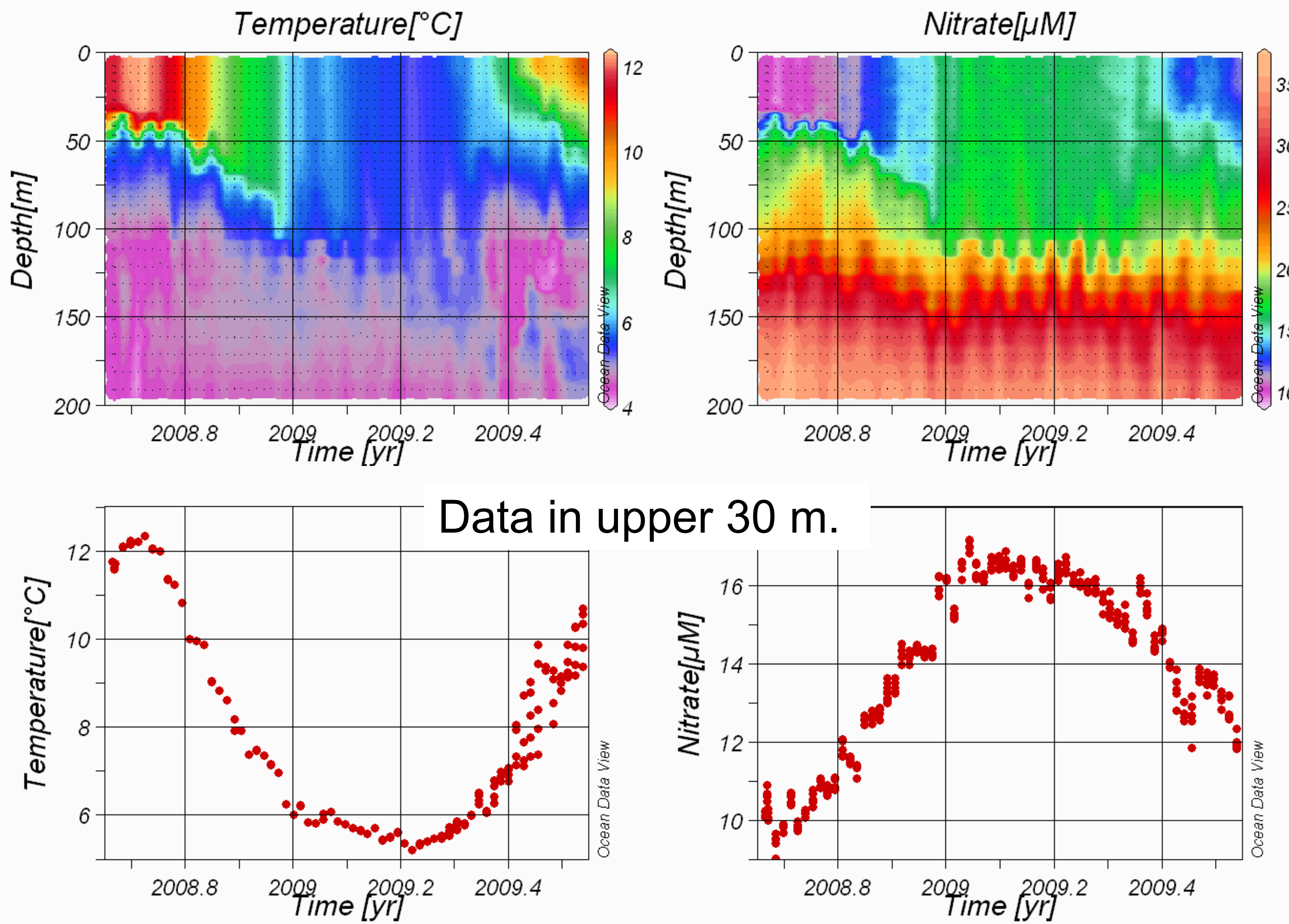
Week of 10
June 2009



trate

Week of 10 June 2009

Ocean Station Papa – Apex Float/ISUS Nitrate



Science 2002, 2 mon. data

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

James K. B. Bishop,[1*] Russ E. Davis,[2] Jeffrey T. Sherman[2]

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.

Marine phytoplankton biomass is replaced, on average, once every 1 to 2 weeks (*1–3*). Carbon products of photosynthesis (*4*), i.e., particulate organic carbon (POC), particulate inorganic carbon (PIC), and dissolved organic carbon (DOC), are exported below 100 m at a rate of

iencemag.org SCIENCE VOL 298 25 OCTOBER 2002 817

Science 2004, 2 mon. data

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

James K. B. Bishop,[1*] Todd J. Wood,[1] Russ E. Davis,[2] Jeffrey T. Sherman[2]

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 subducted 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.

The Ocean Takes a Deep Breath

Arne Körtzinger,* Jens Schimanski, Uwe Send, Douglas Wallace

Science 2004, 10 mon. data

Vol 451 | 17 January 2008 | doi:10.1038/nature06441 nature

Nature 2008, 36 mon. data

LETTERS

Net production of oxygen in the subtropical ocean

Stephen C. Riser[1] & Kenneth S. Johnson[2]

ASLO: Limnology and Oceanography - Mozilla Firefox

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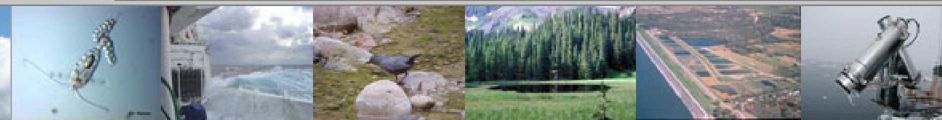

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Table of Contents, Vol. 53(5, part 2), September 2008

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

Mary Jane Perry and Mark Moline, coordinating editors
Tommy D. Dickey and Eric C. Itsweire, issue editors

This issue is devoted to recent developments of Autonomous and Lagrangian Platforms and Sensors (ALPS) and their uses for solving a broad range of interdisciplinary aquatic problems that span a continuum of spatial and temporal scales. ALPS platforms in this issue include: surface drifters, profiling and other types of sub-surface floats, gliders, unmanned boats, autonomous underwater vehicles (AUVs), and instrumented animals. These types of platforms provide access in difficult environments (e.g., under ice and in high sea states). They are also important for emerging networked ocean and lake observing systems that require continuous measurements and near real-time data.

We thank all of the authors and reviewers of the papers that appear in this issue. Editor-in-chief, Everett Fee, was an invaluable resource and Lucille Doucette greatly facilitated the editing of the manuscripts. Financial support for the publication of this Special Issue was provided by the National Science Foundation and the Office of Naval Research through a grant to Mark Moline (OCE-0737167). Tommy Dickey, Mark Moline, 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 Observing System (WOOS) program that would send gliders on missions from the Slocum Mission Control Center on Nonamesset 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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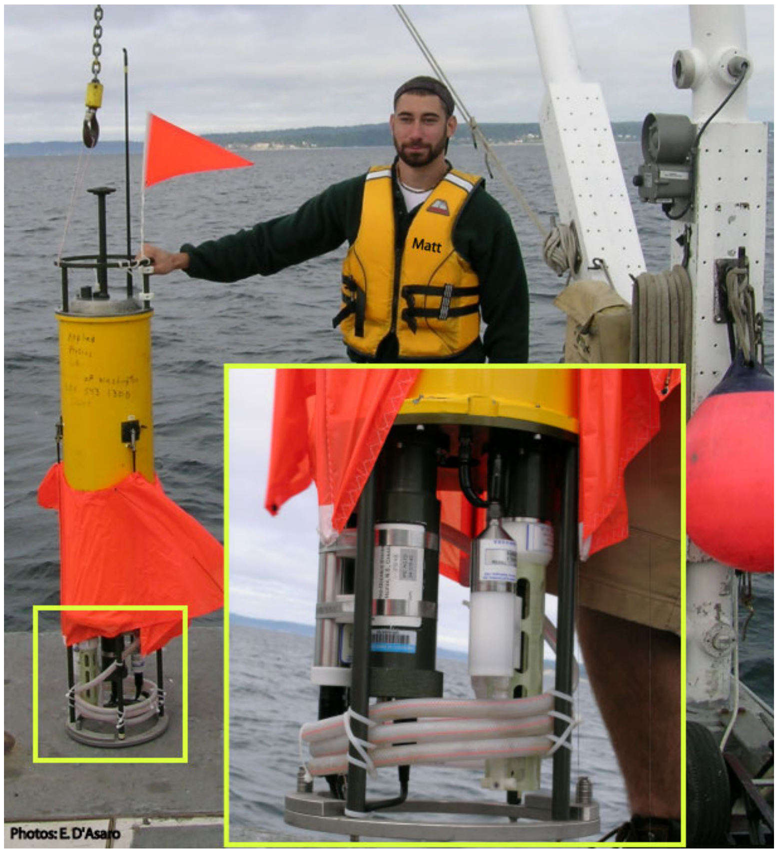
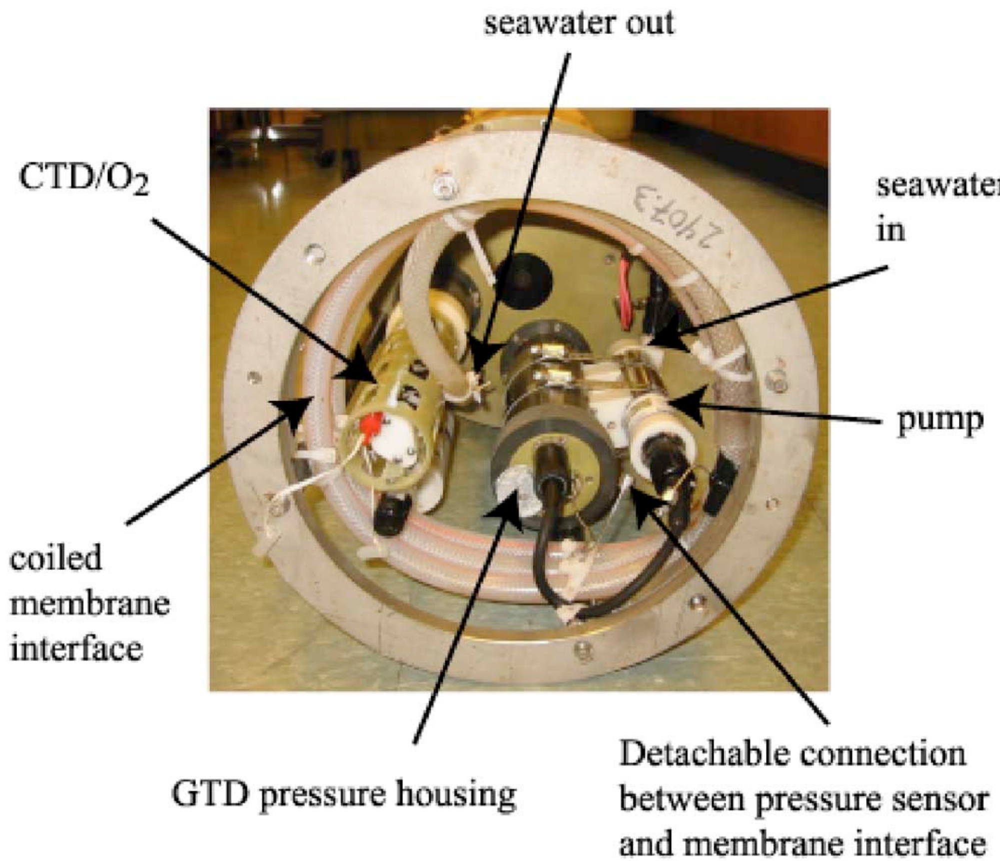
Right-click on the link below to save this Table of Contents to a text file suitable for importing into EndNote. An EndNote filter (ASLO.enf) to interpret the file is available for download here.

EndNote File

- Gas Tension Device deployed on Float – C. McNeil, UW/APL



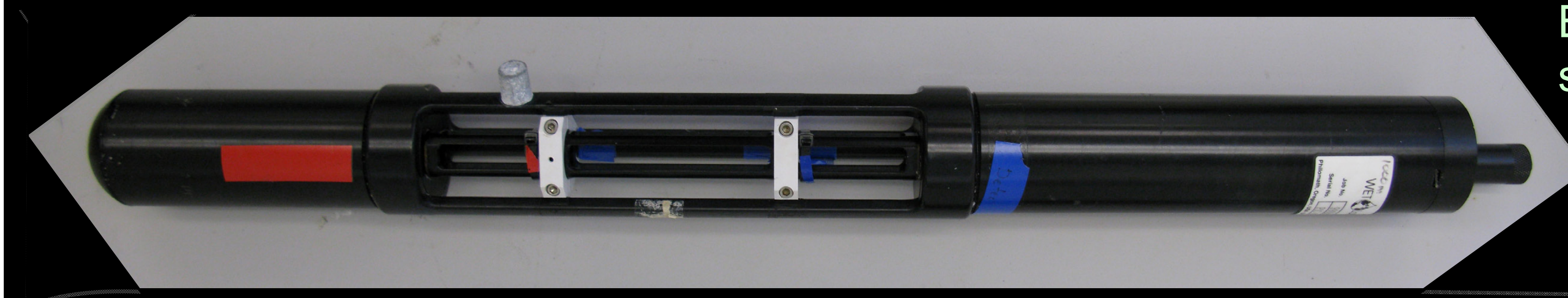


τ ~ 2 min at surface
τ ~ 10 min at 60 m

Sensors for particulate inorganic carbon (PIC).

6000 m
"Cstar"
version

Laser — 25 cm open cell — Detector



Neutrally
Buoyant
sensor

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)

With WETLabs

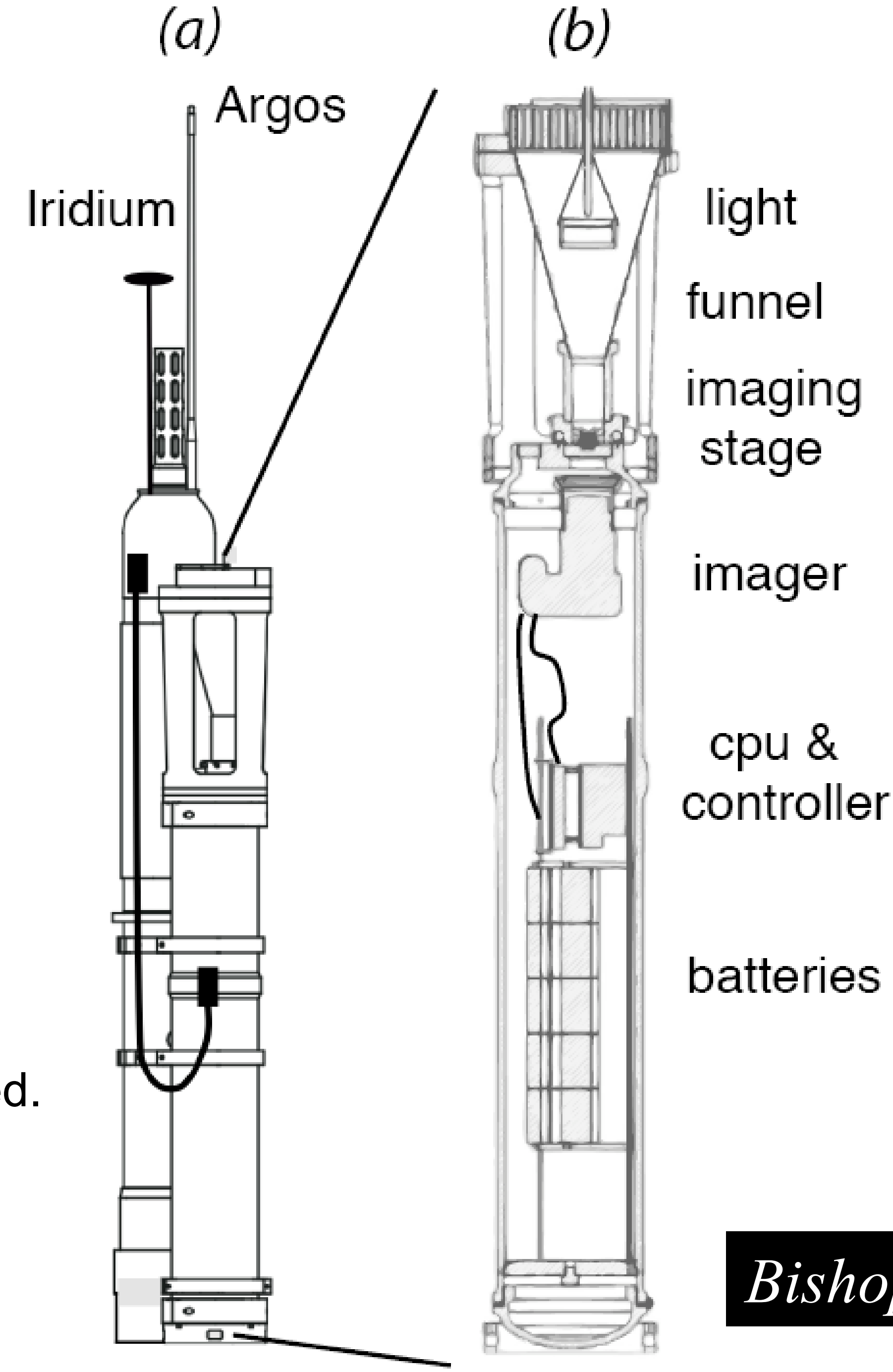
Bishop, UC

Carbon Flux Explorer:

An example of independent and complex platform/sensor Integration.

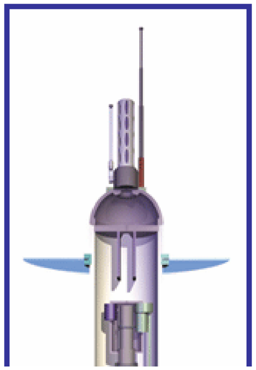
Platform provides queues to sensor.

Sensor responds with data when asked.

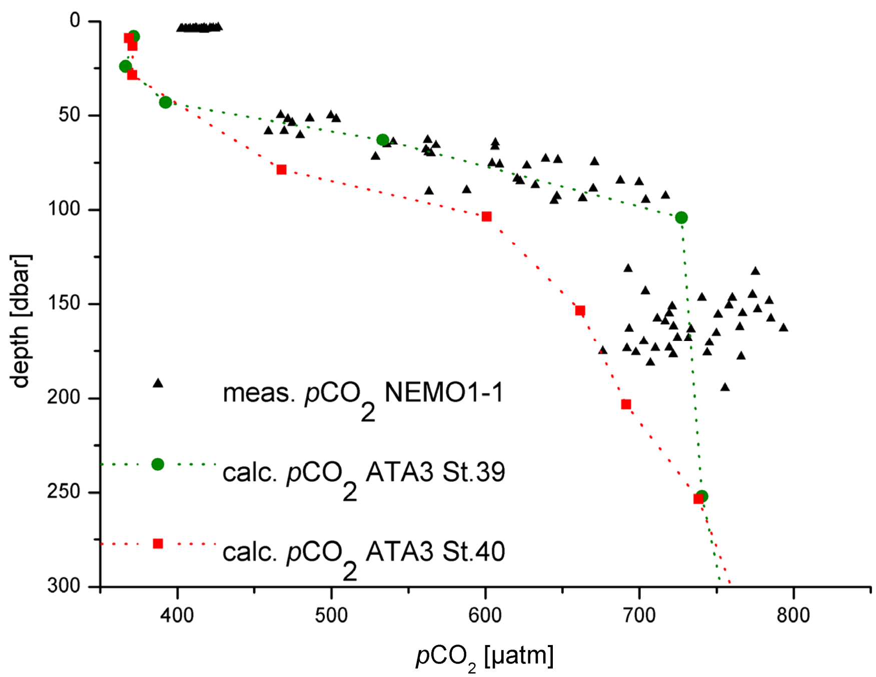


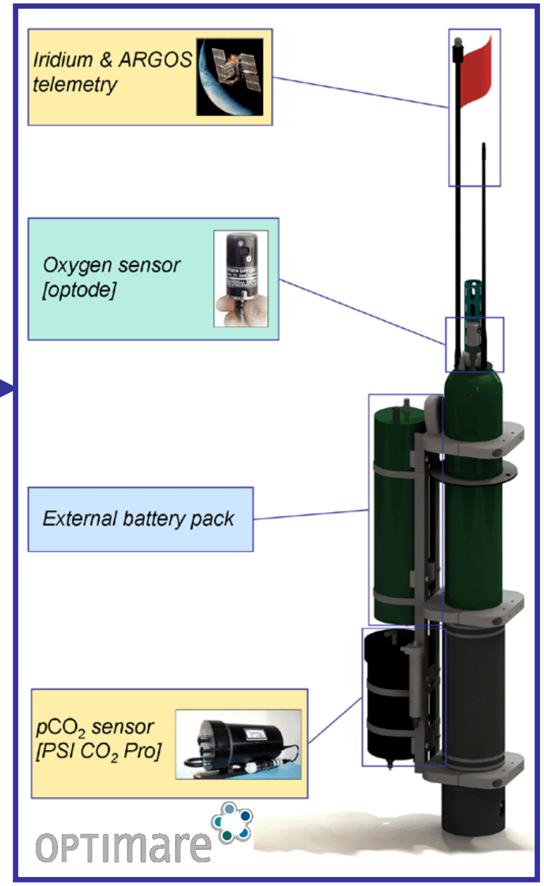
Bishop, UC

Experimental Float Design and Development - A. Kortzinger



PSI CO_2 Pro



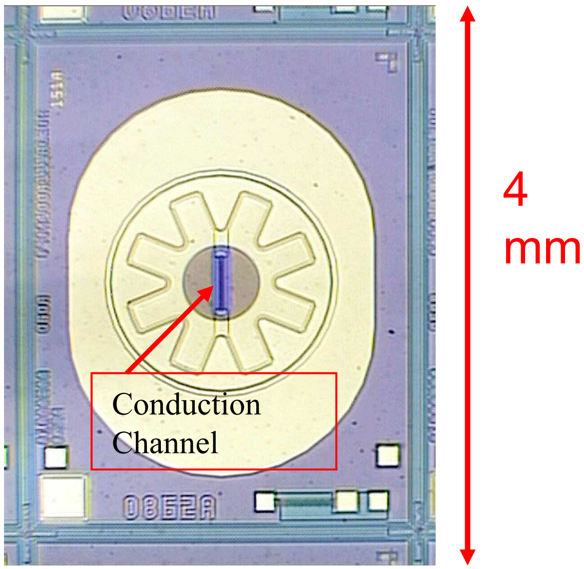


Design

Field Testing

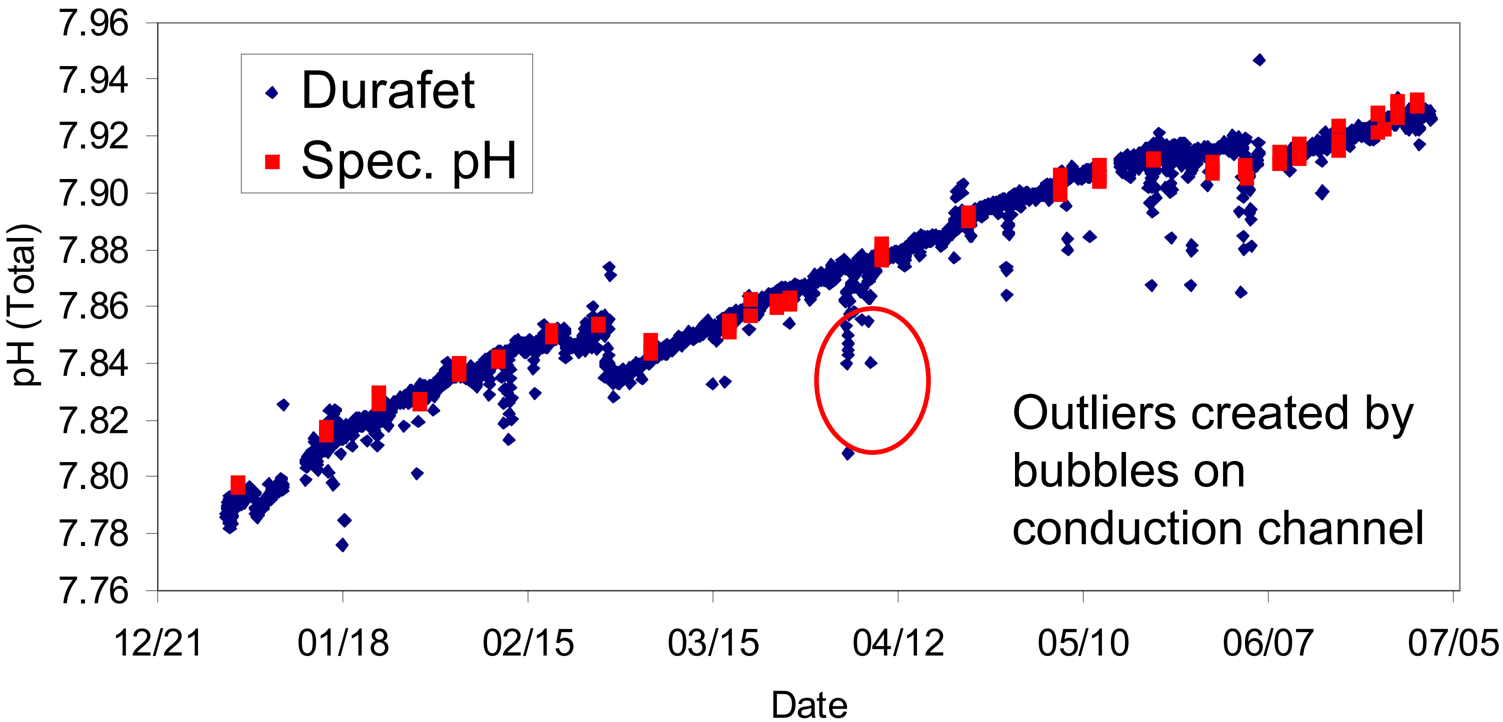
IFM-GEOMAR
Leibniz-Institut für Meereswissenschaften an der Universität Kiel

SOPRAN, Sub-project 3.5 (Körtzinger & Heimann)
Sea-Air fluxes of CO_2 and O_2 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 CO_2)

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 <u>much</u> easier to adapt (more batteries, big sensors)
6. Floats are relatively immune to fouling – better for long duration

<u>Map with L/T (of signal) > 25 cm/s:</u> array of floats

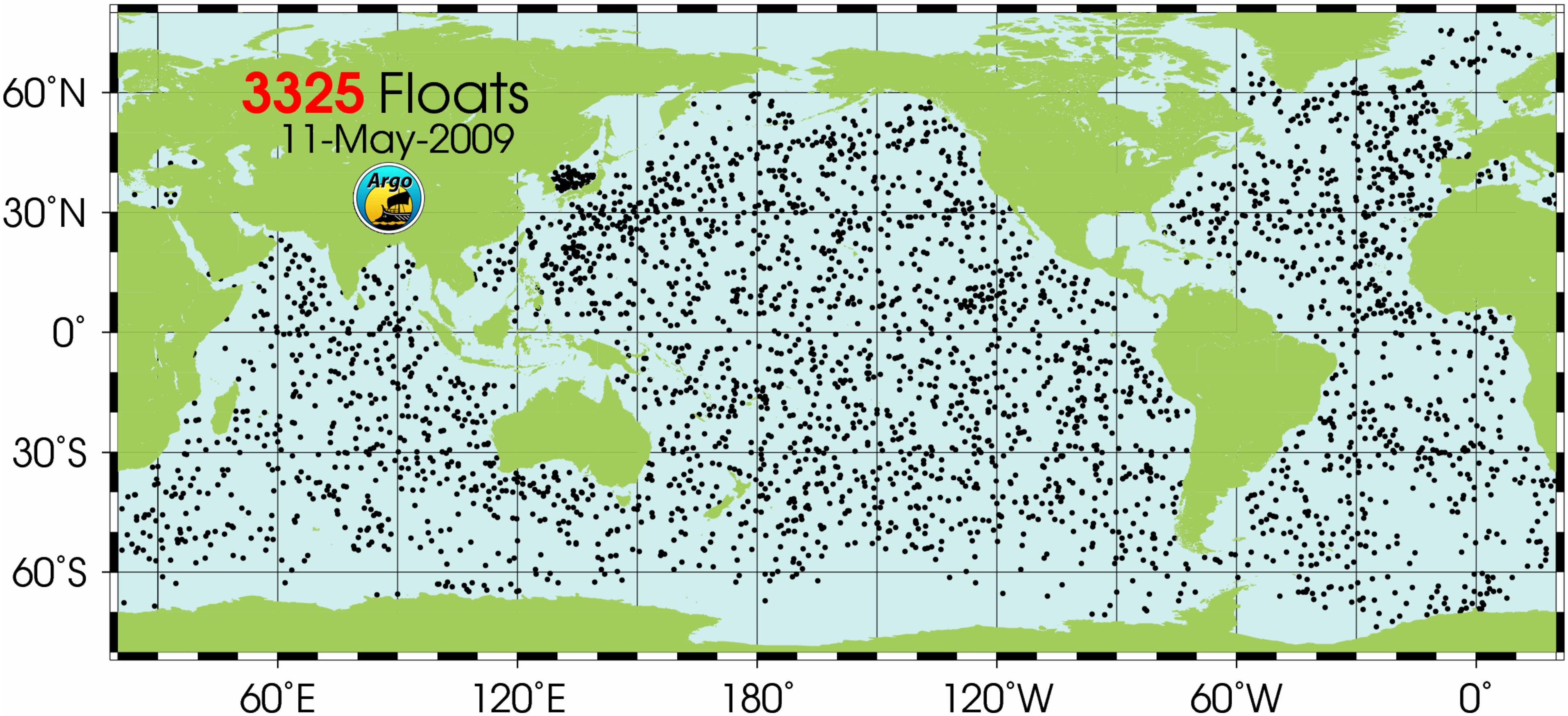
<u>Map with L/T < 25 cm/s:</u> glider(s)

<u>Quasi-Lagrangian time series:</u> floats

<u>Many big co-located sensors: floats</u>

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.