Shipboard and autonomous observations at Station ALOHA: Insights into productivity, export, and nutrient supply in the oligotrophic ocean

MATTHEW CHURCH AND THE HOT TEAM

OCEAN CARBON BIOGEOCHEMISTRY SUMMER WORKSHOP

JULY 2015

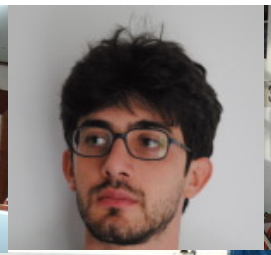
HAWAII OCEAN TIME-SERIES
SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY
H.O.T.
UNIVERSITY OF HAWAII

NSF

Mahalo to many…

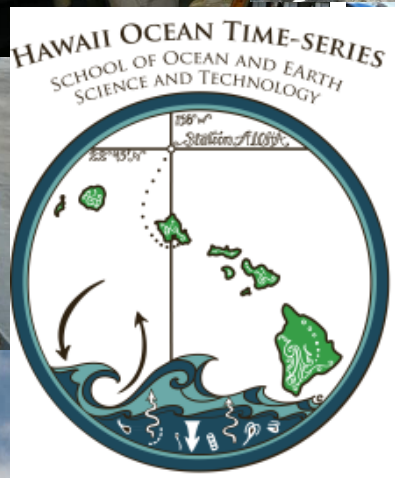
- Heather Benway and Craig Carlson
- Mary Z.
- Susanne Neuer, Angel White, Michael Lomas
- David Karl, Roger Lukas, Benedetto Barone, Sara Ferron, Fernando Santiago-Mandujano, Ken Johnson, Steve Riser, David “Roo” Nicholson
- The National Science Foundation

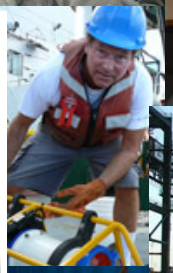
A Dedicated HOT Team



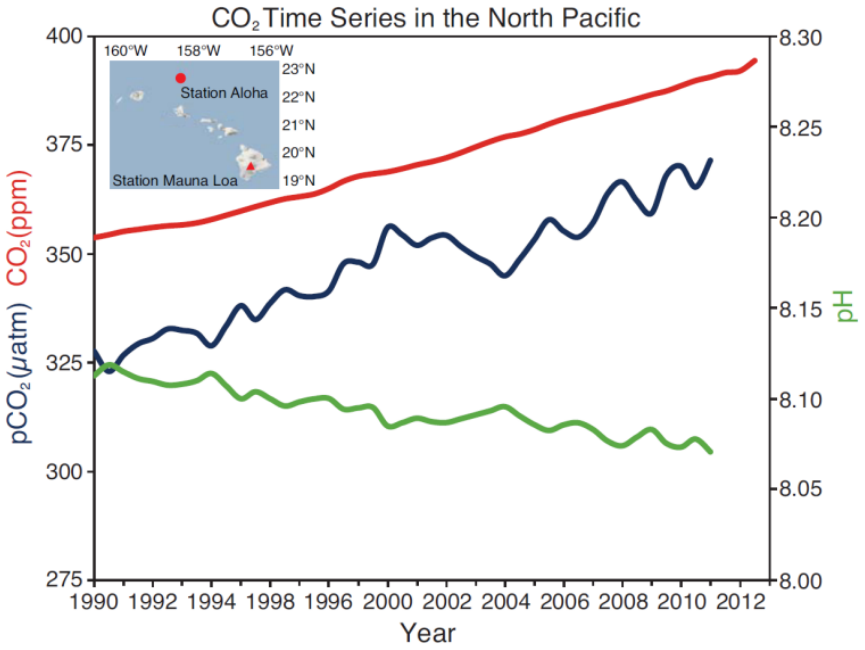


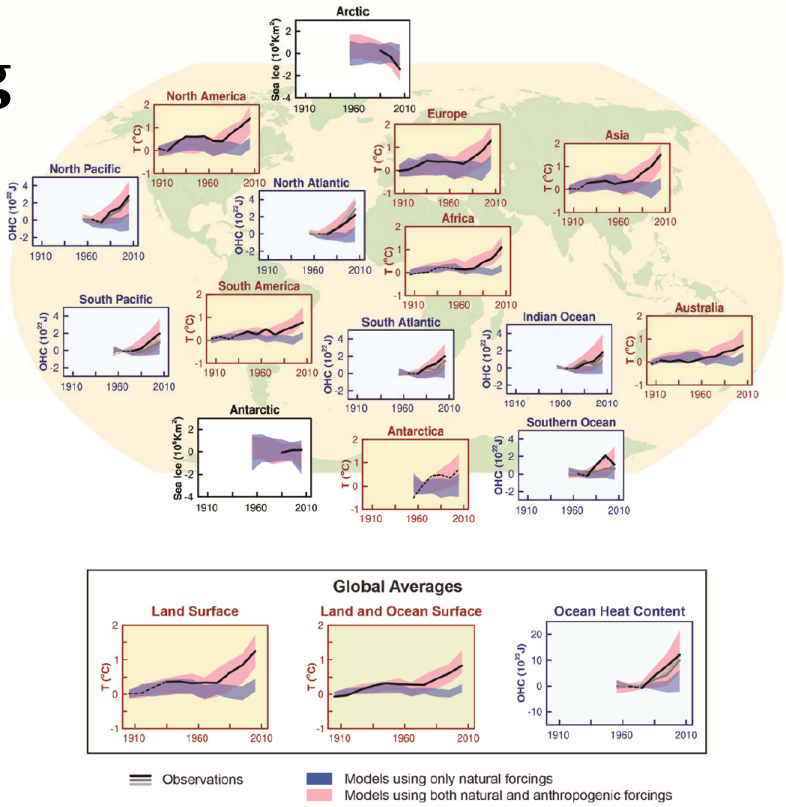







Humans are modifying the planet and our impact is growing

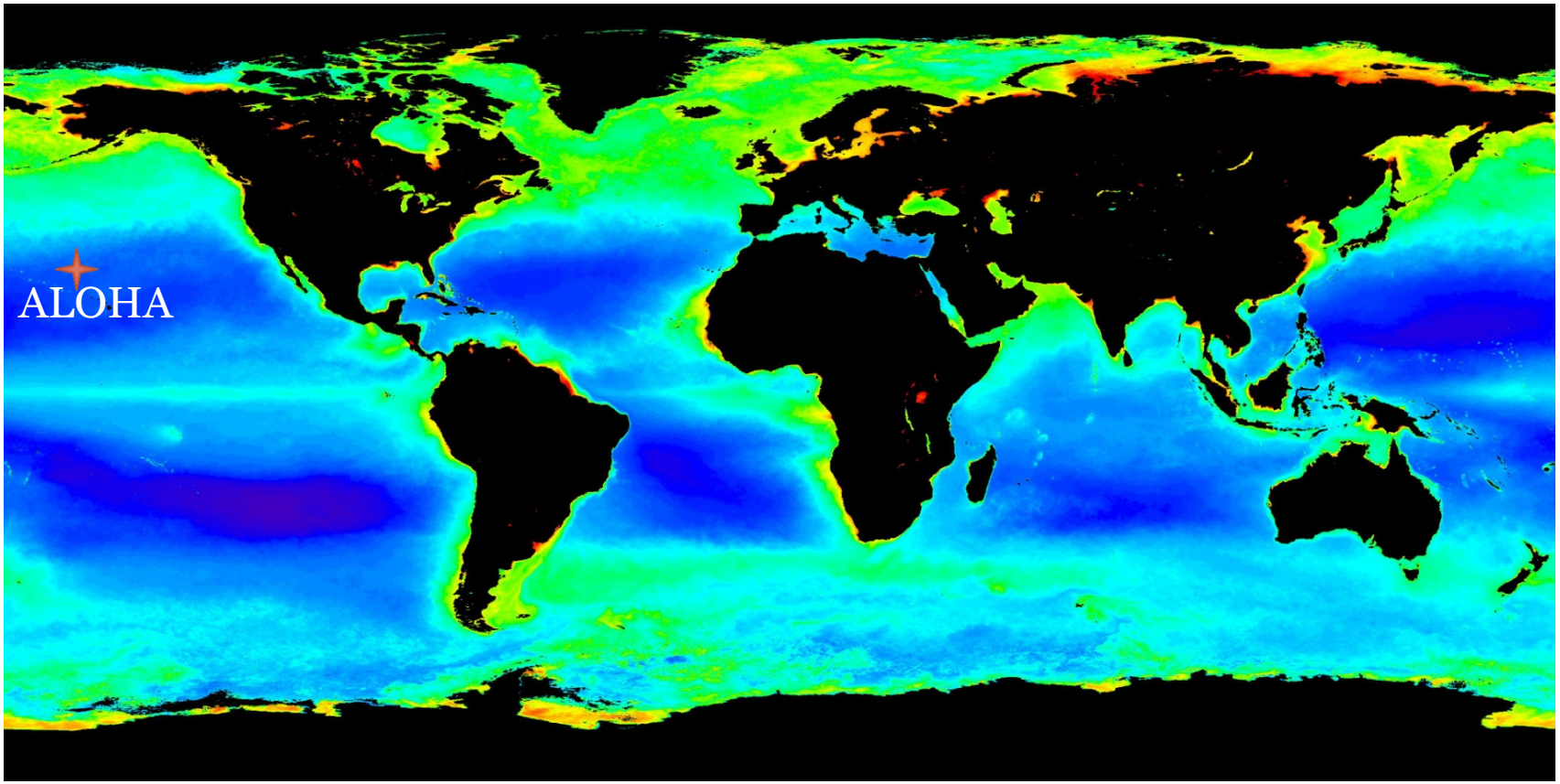




- **Time series are key tools to understanding planetary change.**

IPCC WGI AR5

27 September 2013

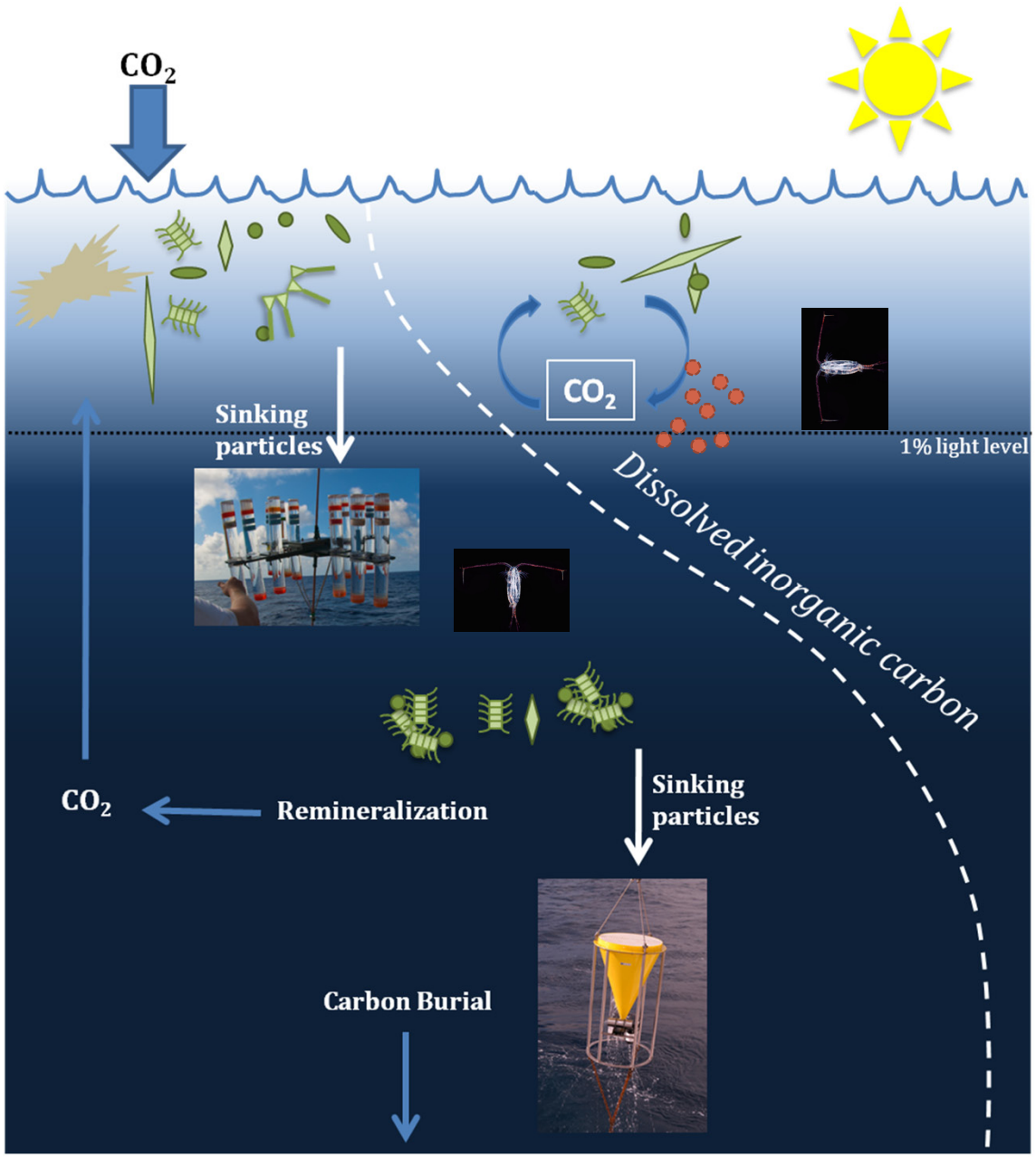


- **Subtropical gyres comprise some the largest habitats on this planet**

- **Constraining carbon production and sequestration in these regions is critical to global carbon budgets**

- **Time series programs afford unique opportunities to define the magnitude and pathways of carbon fluxes in the open sea**

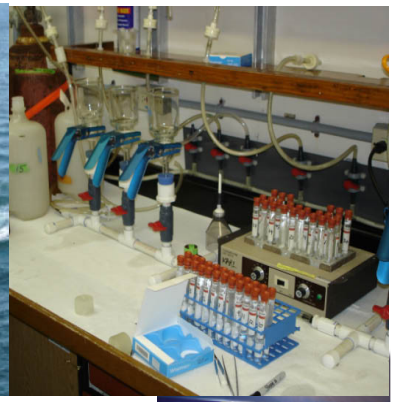
What's HOT?

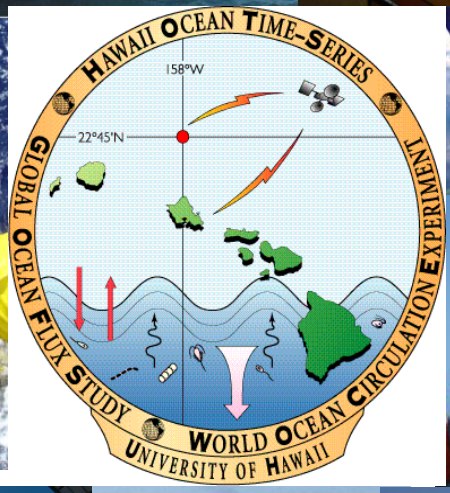


- Identify time-varying interactions between ocean-climate and ecosystem variability
- Quantify processes controlling air-sea carbon exchange, rates of C transformation through the planktonic food web, and fluxes of C into the ocean's interior
- Determine the mechanisms and rates of nutrient supply to the upper ocean

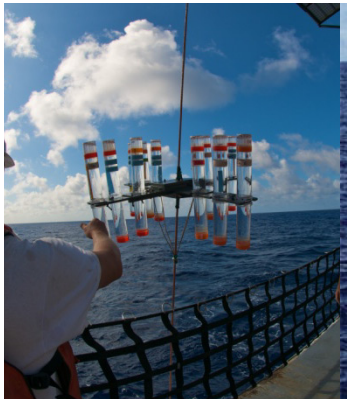
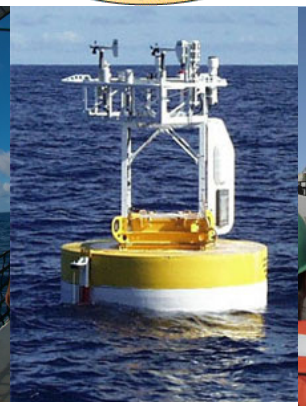
The Hawaii Ocean Time-series (HOT)

- Near monthly cruises to Station ALOHA since October 1988
- ALOHA is a deep, open ocean (~4800 m) site
- 4 day cruises, intensive sampling to 1000 m
- Shipboard and remote (moorings, gliders, floats, and satellites) measurements of ocean biogeochemistry, physics, and plankton ecology



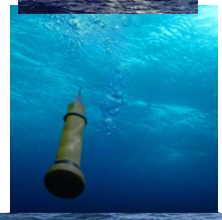


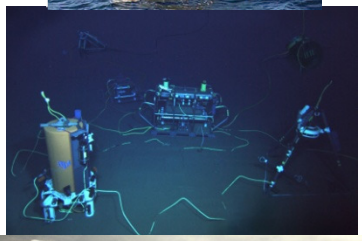




The sea of dreams…

- **Simons Collaboration on Ocean Processes and Ecology (SCOPE), Funding: Simons Foundation; E. DeLong, D. Karl, et al. 2014-2017**
- **Center for Microbial Oceanography: Research and Education (C-MORE), Funding: NSF, GBMF, Agouron Institute; D. Karl, S. Chisholm, E. DeLong, and J. Zehr; 2006-2016**
- **WHOI Hawaii Ocean Time Series Station (WHOTS), Funding: NOAA, NSF; R. Weller (WHOI), A. Plueddemann (WHOI), R. Lukas (UH); 2004-present**
- **Profiling Floats for Ocean Biogeochemistry, Funding: NSF, NOPP, MBARI. K. Johnson (MBARI), S. Riser (UW); 2007-present**
- **ALOHA Cabled Observatory, Funding: NSF; B. Howe et al. (UH); 2007-present**

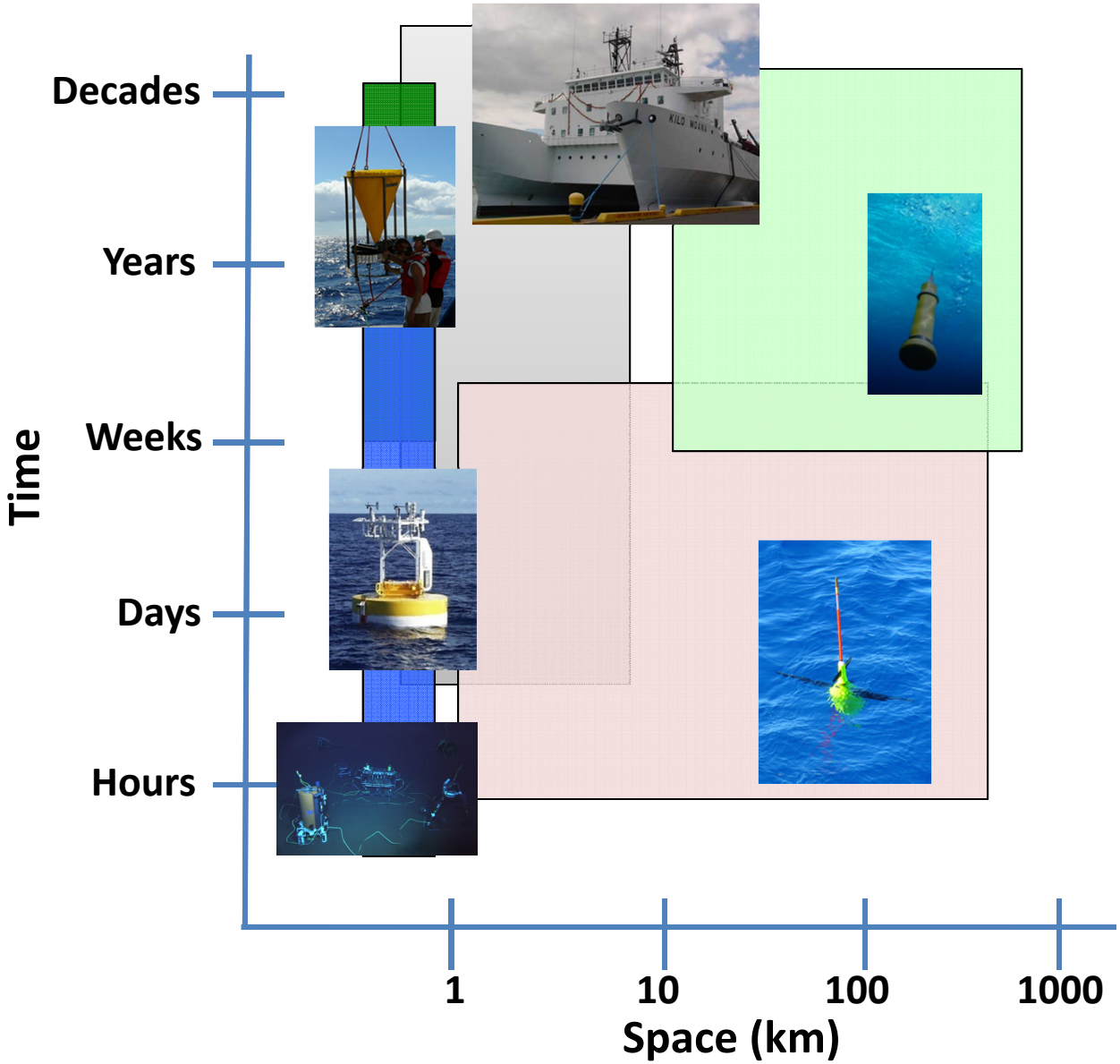




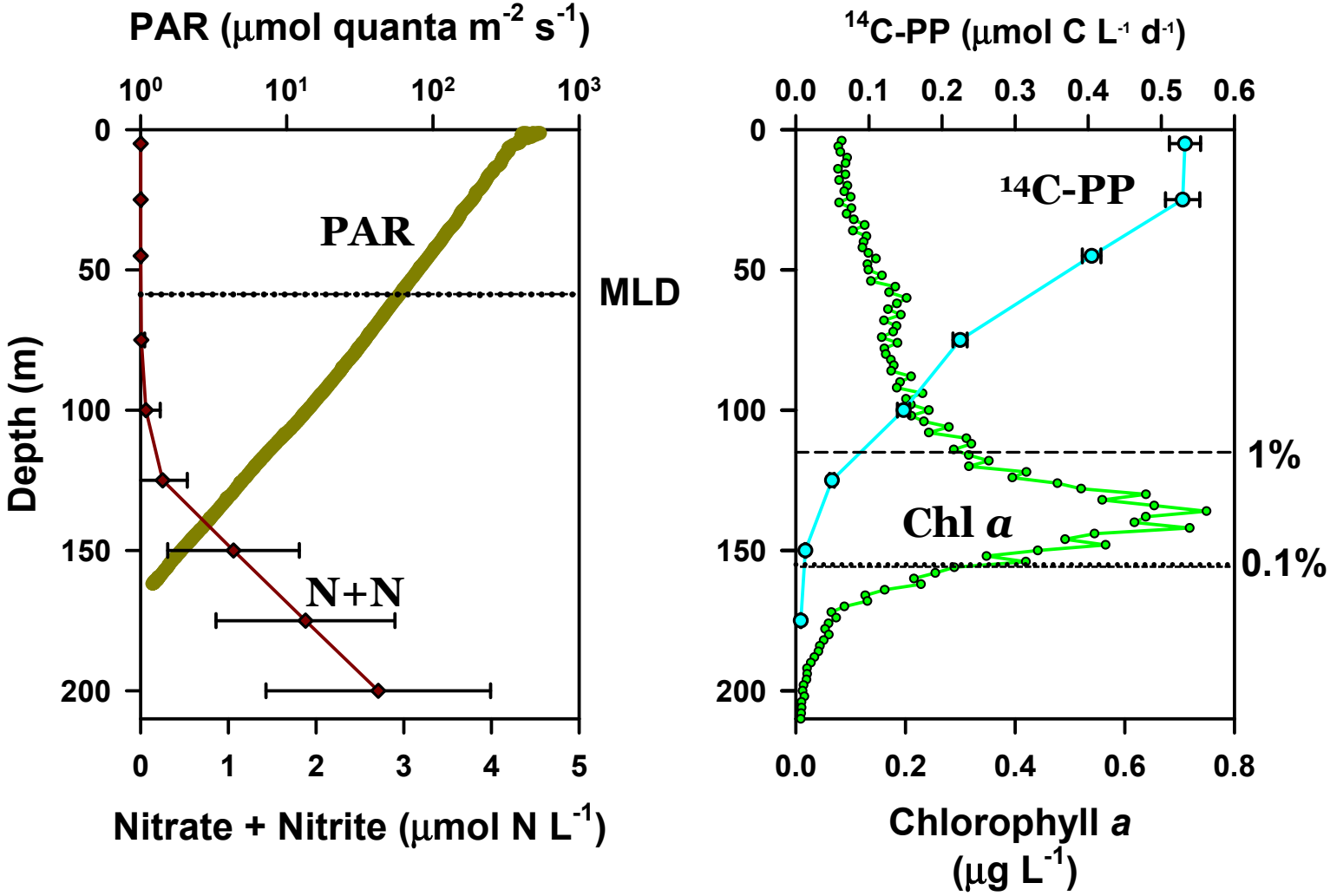



HOT forms the cornerstone for ocean research in the central Pacific

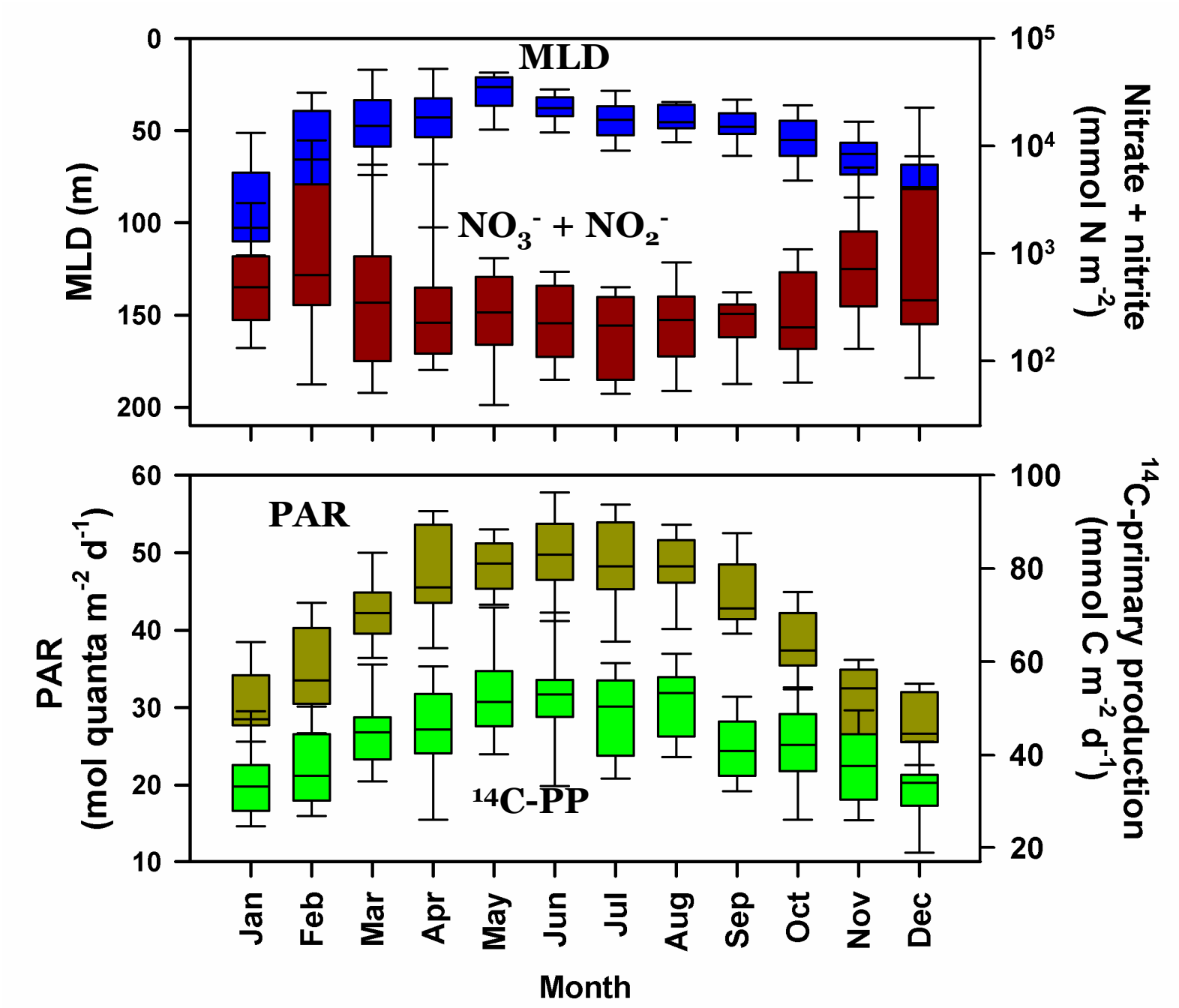
Spatiotemporal coverage of sampling platforms at Station ALOHA



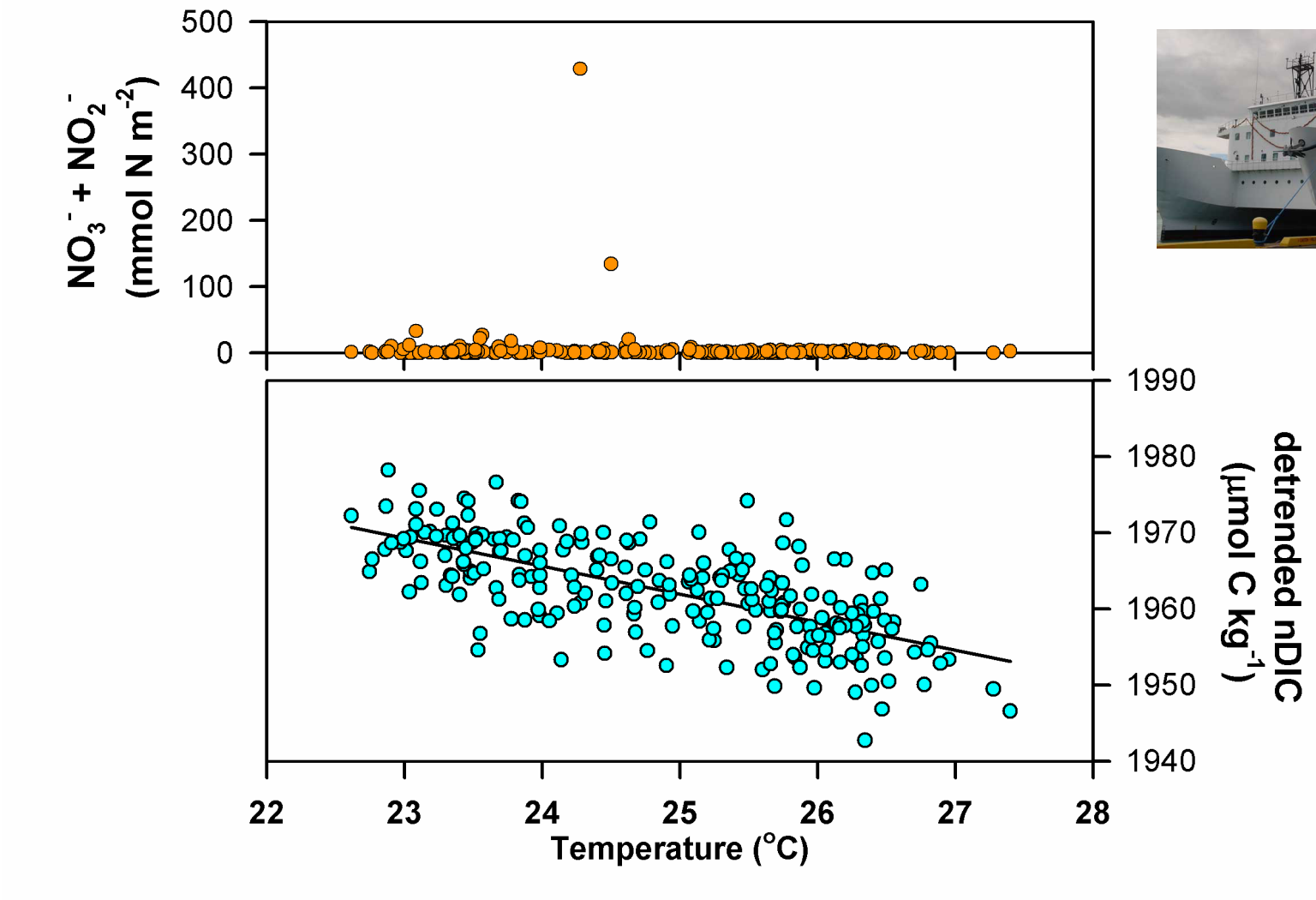
The upper ocean habitat



- Mixed layer ~30-100 m, euphotic zone ~100-125 m
- >65% of the daily carbon fixation occurs in the nutrient-deplete mixed layer

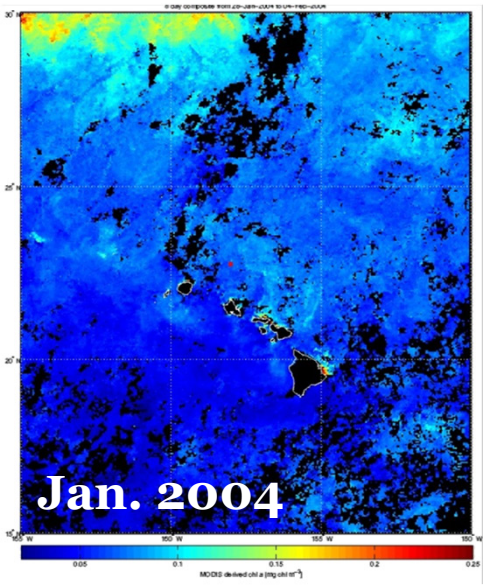

MLD
$NO_3^- + NO_2^-$
MLD (m)
Nitrate + nitrite (mmol N m^{-2})
PAR
^{14}C-PP
PAR (mol quanta m^{-2} d^{-1})
^{14}C-primary production (mmol C m^{-2} d^{-1})
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

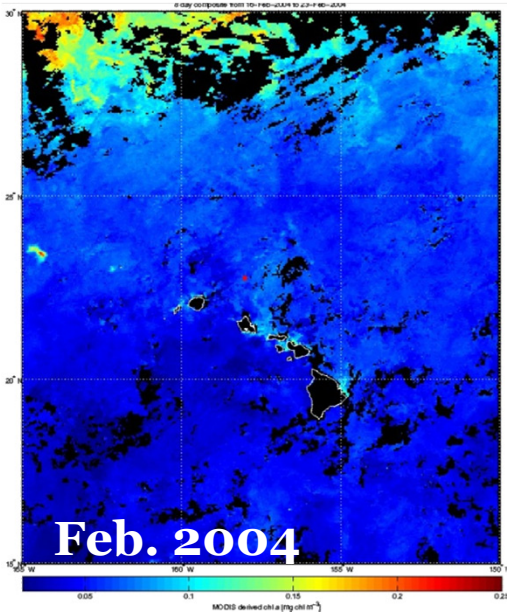
Spring ➔ Fall drawdown of mixed layer DIC in the absence of nitrate is a common feature of the subtropical gyres

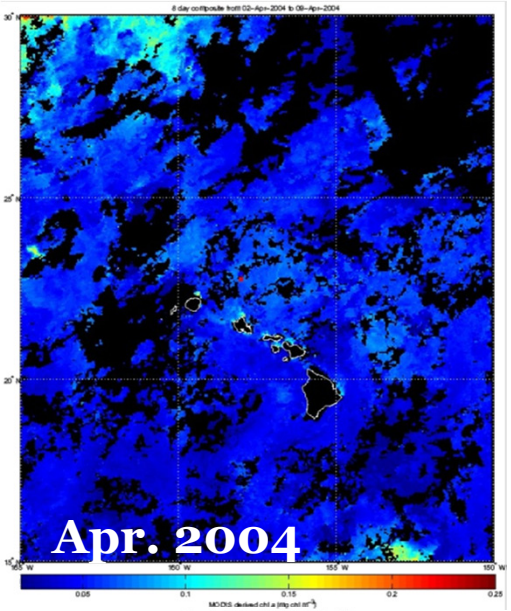


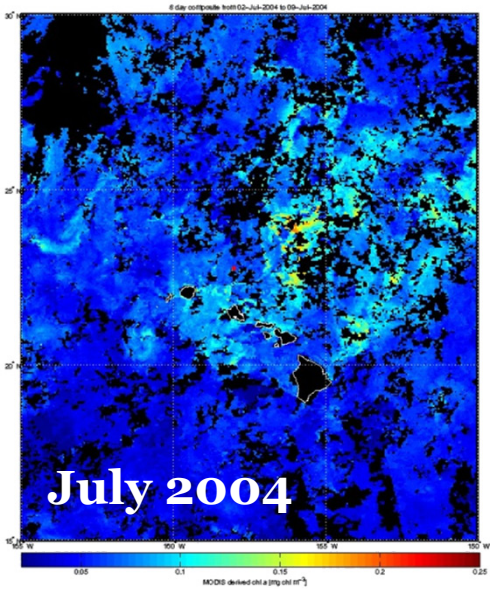
Michaels et al. 1994, Bates et al. 1996, 1998, Gruber et al. 1998, Lee et al. 2000, Karl et al. 2003

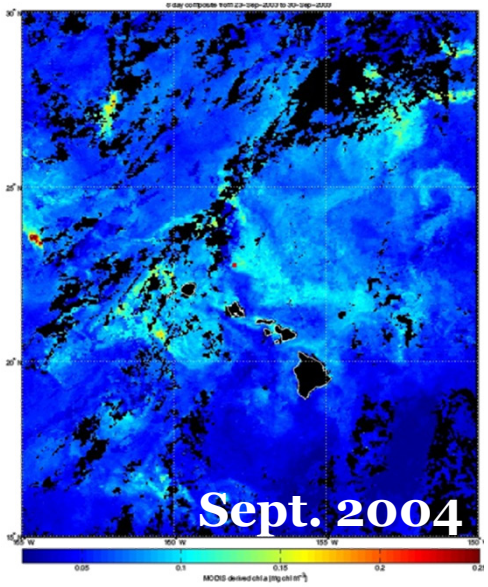
The many faces of Station ALOHA

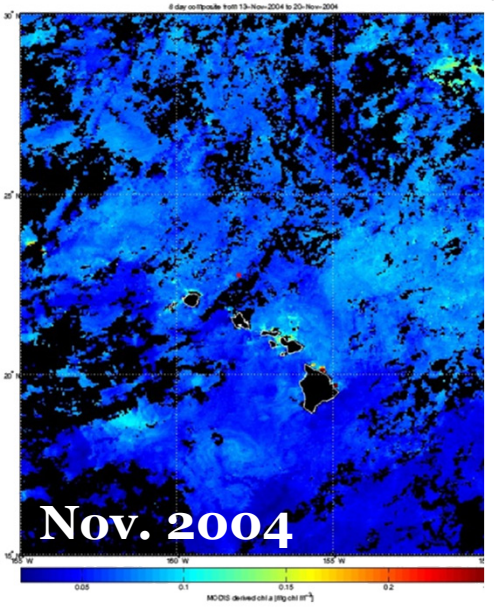






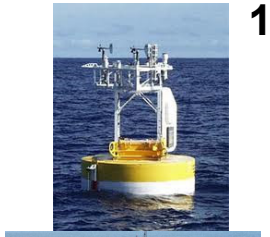


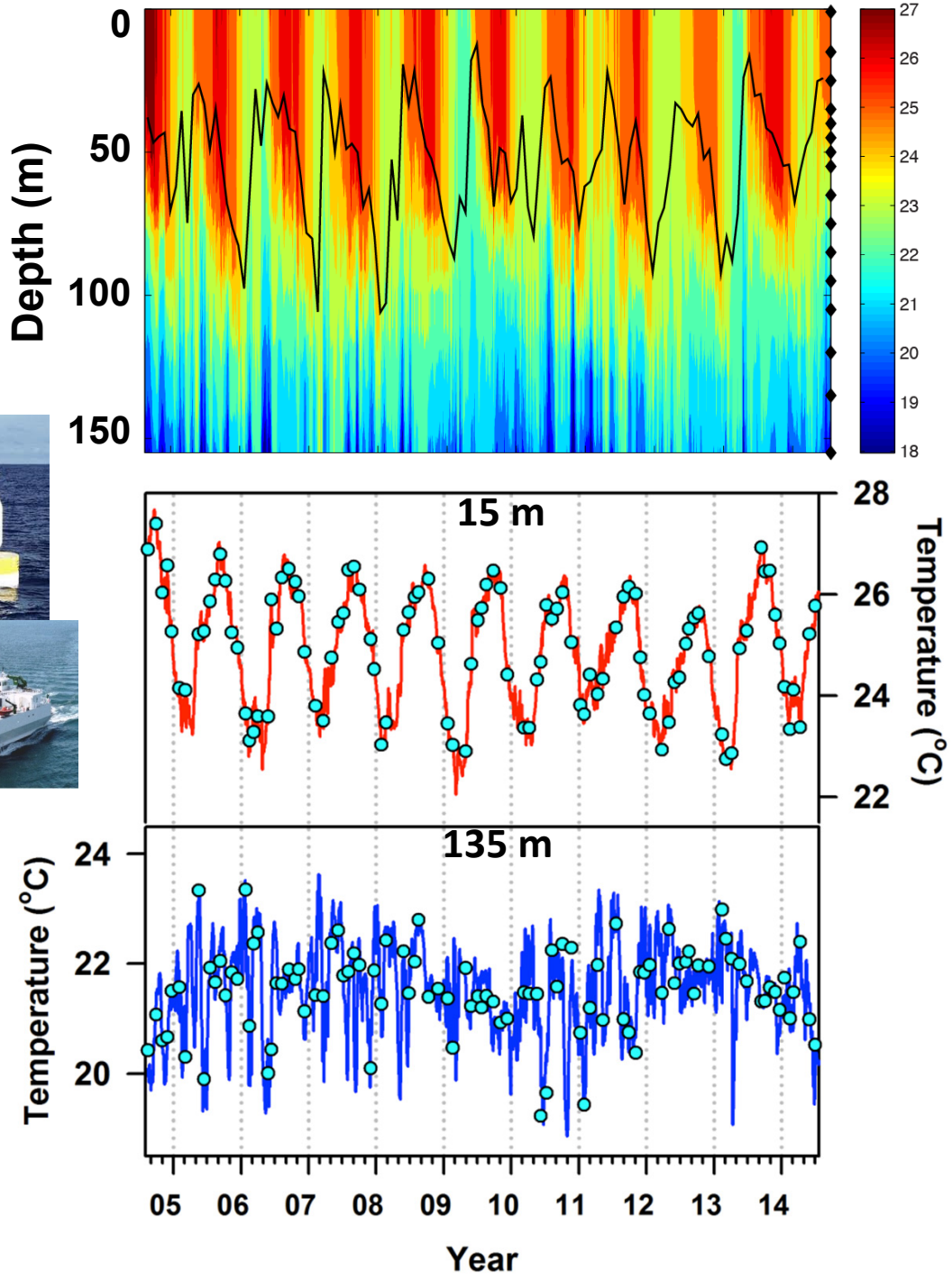




Ricardo Letelier and Angel White (OSU)

Seasonal and event scale forcing of the euphotic zone

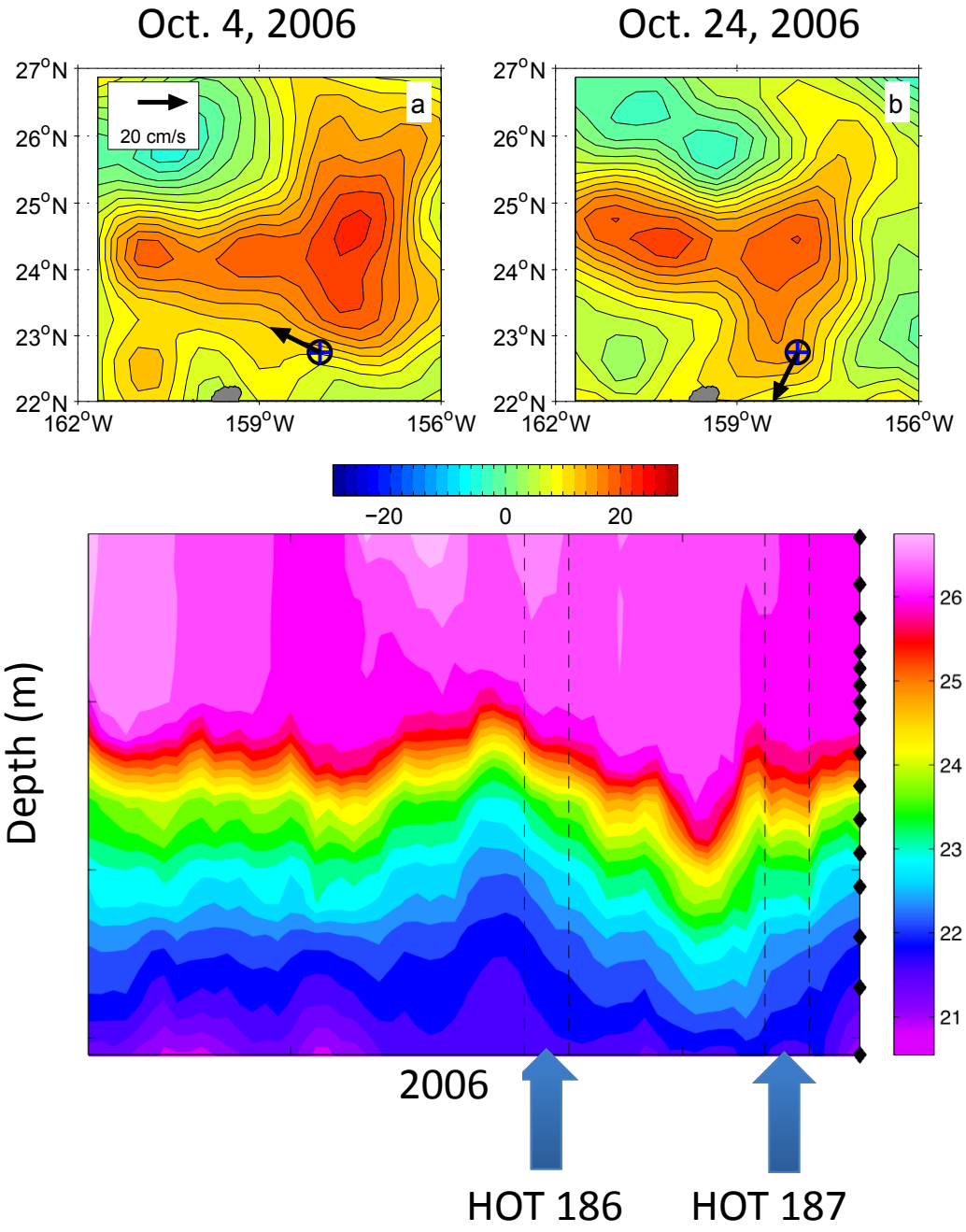


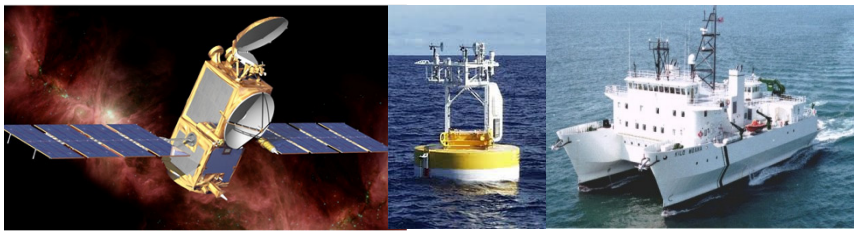


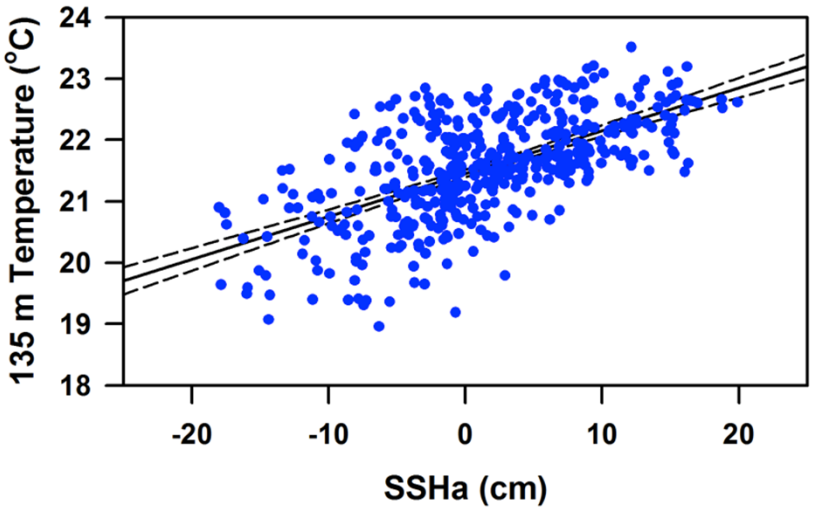
- **Seasonality dominates variability in mixed layer temperatures**

- **Lower euphotic zone dominated by higher frequency physical forcing, *e.g.* mesoscale and submesoscale processes = undersampled at monthly scales.**

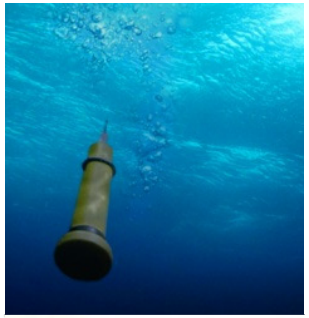
Eyes on and in the water







The WHOTS mooring provides a continuous record of mesoscale perturbation to the upper ocean.

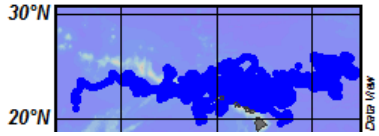


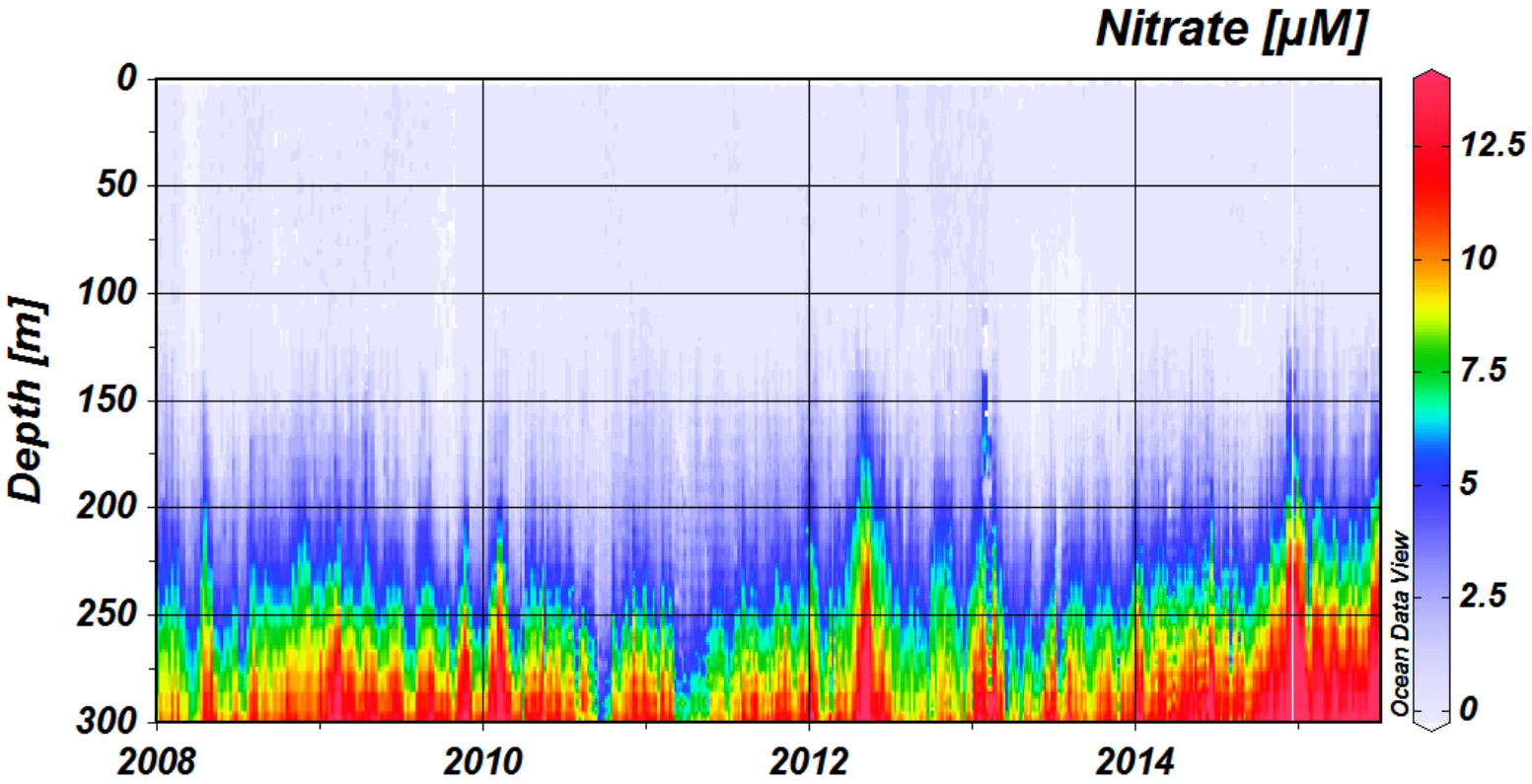
nature Vol 465|24 June 2010|doi:10.1038/nature09170

LETTERS

Nitrate supply from deep to near-surface waters of the North Pacific subtropical gyre

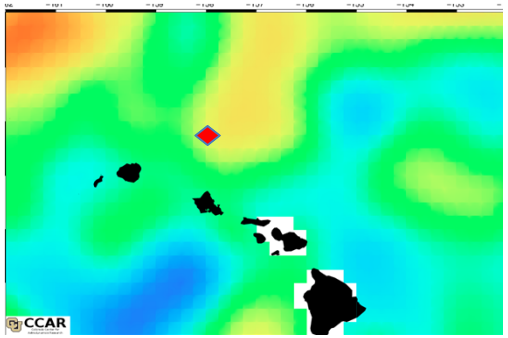
Kenneth S. Johnson[1], Stephen C. Riser[2] & David M. Karl[3]

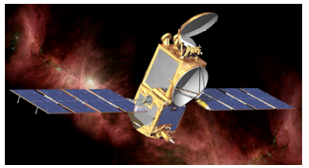


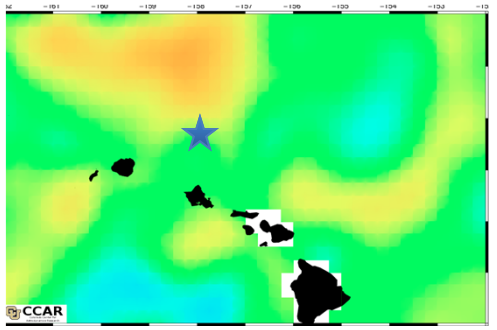


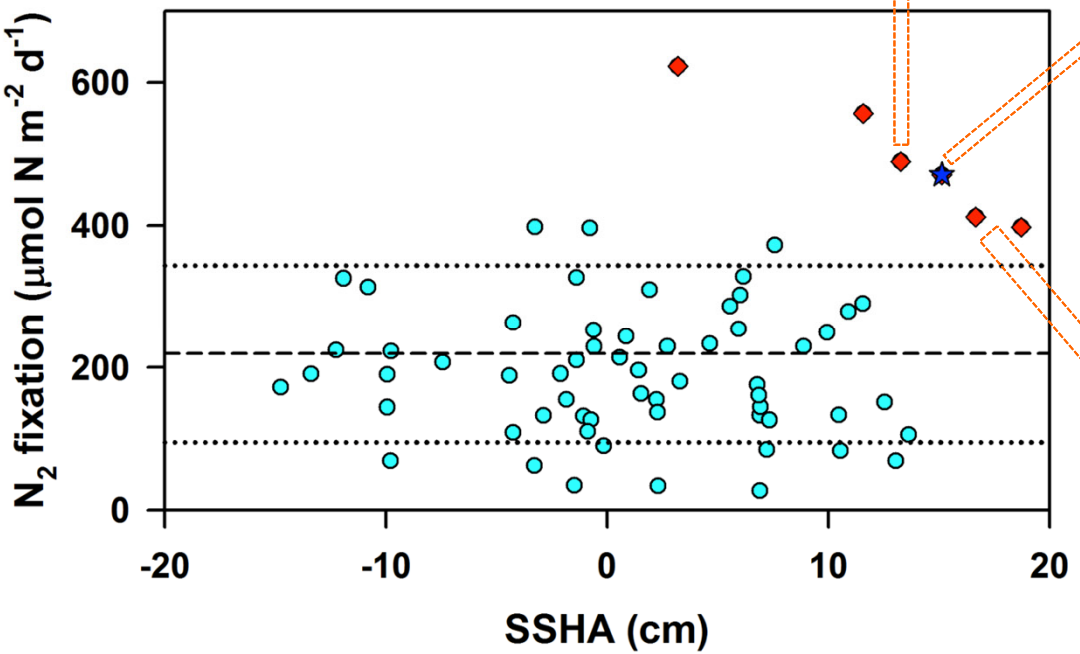
Annual N supply: >88 mmol N m^{-2} yr^{-1} (0.6 mol C m^{-2} yr^{-1})

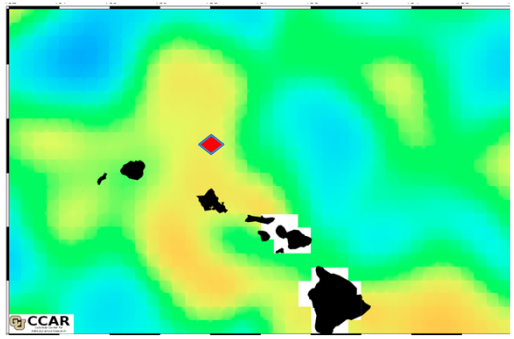
Courtesy of Ken Johnson, MBARI Chemical Sensor Lab







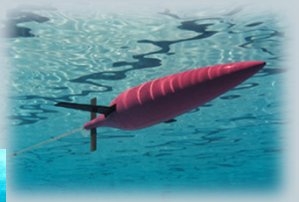
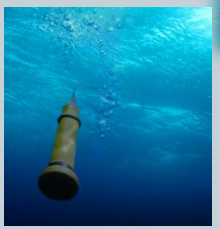


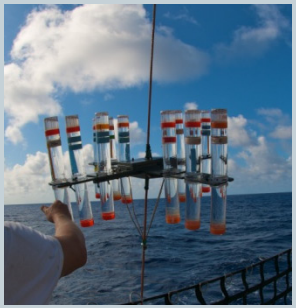


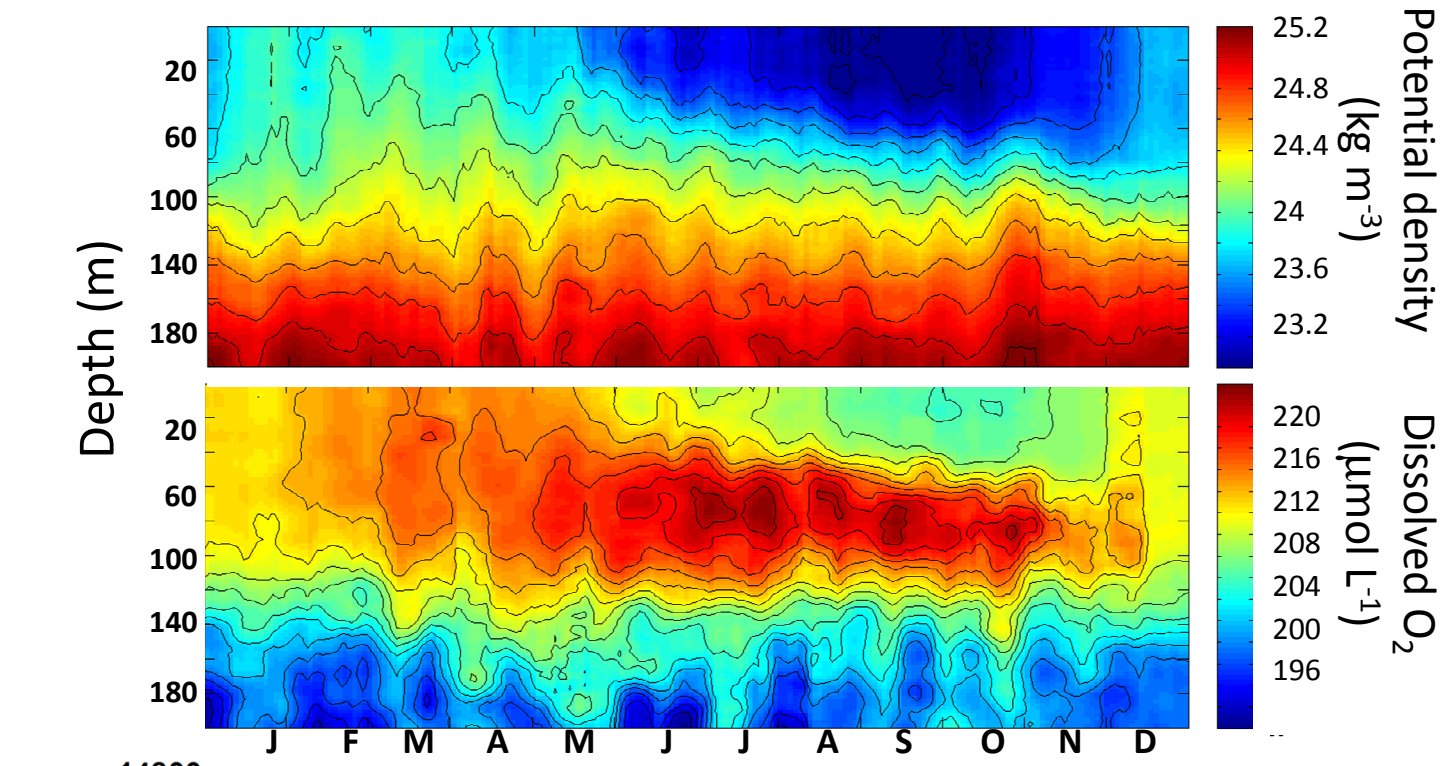
- **Annual N supply by N_2 fixation = 75 ± 45 mmol N m^{-2} yr^{-1} (0.5 mol C m^{-2} yr^{-1})**
- **Mesoscale (and submesoscale) processes influence new production in unexpected ways**

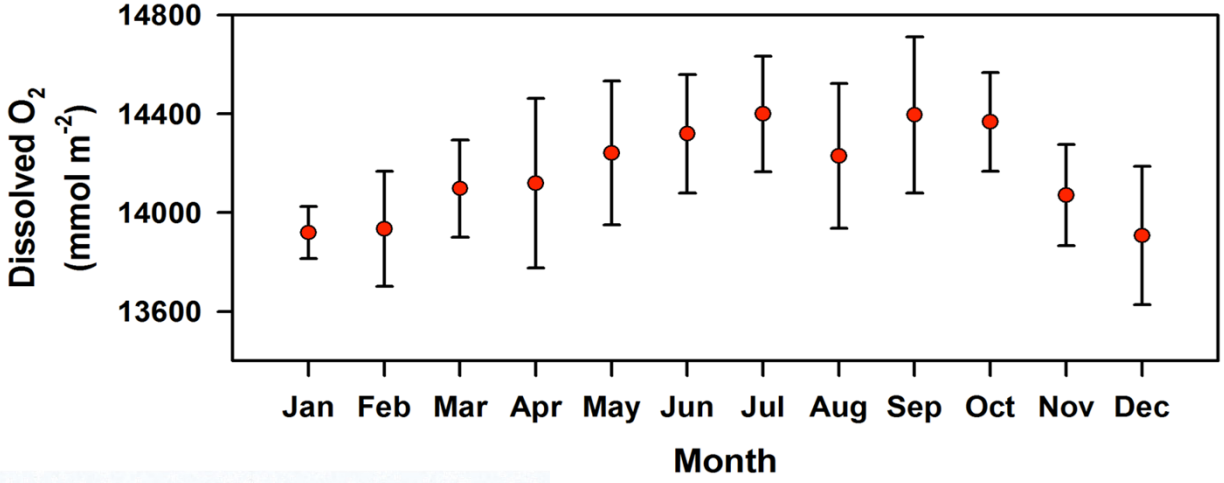
Measurements of productivity at Station ALOHA

- ^{14}C-PP
  (HOT core measurement)
- Mixed layer DIC and $^{13}C/^{12}C$ (HOT core + P. Quay, R. Keeling, etc.)
- Time-varying O_2:Ar (P. Quay, S. Ferron, D. Karl, etc.)
- Diel to seasonal-scale evolution of dissolved oxygen (K. Johnson, D. Nicholson, S. Emerson, etc.)
- O_2 isotopes (L. Juranek, P. Quay)







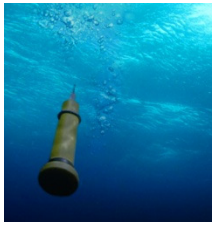
Seasonal buildup of submixed layer O_2

NCP: 2.8 mmol O_2 m^{-2} d^{-1}

The Pacific shallow oxygen maximum, deep chlorophyll maximum, and primary productivity, reconsidered

ERIC SHULENBERGER* and JOSEPH L. REID†

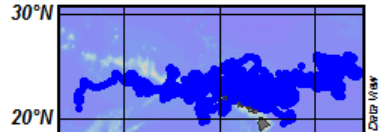
1981 Deep Sea Res. 28: 901-919

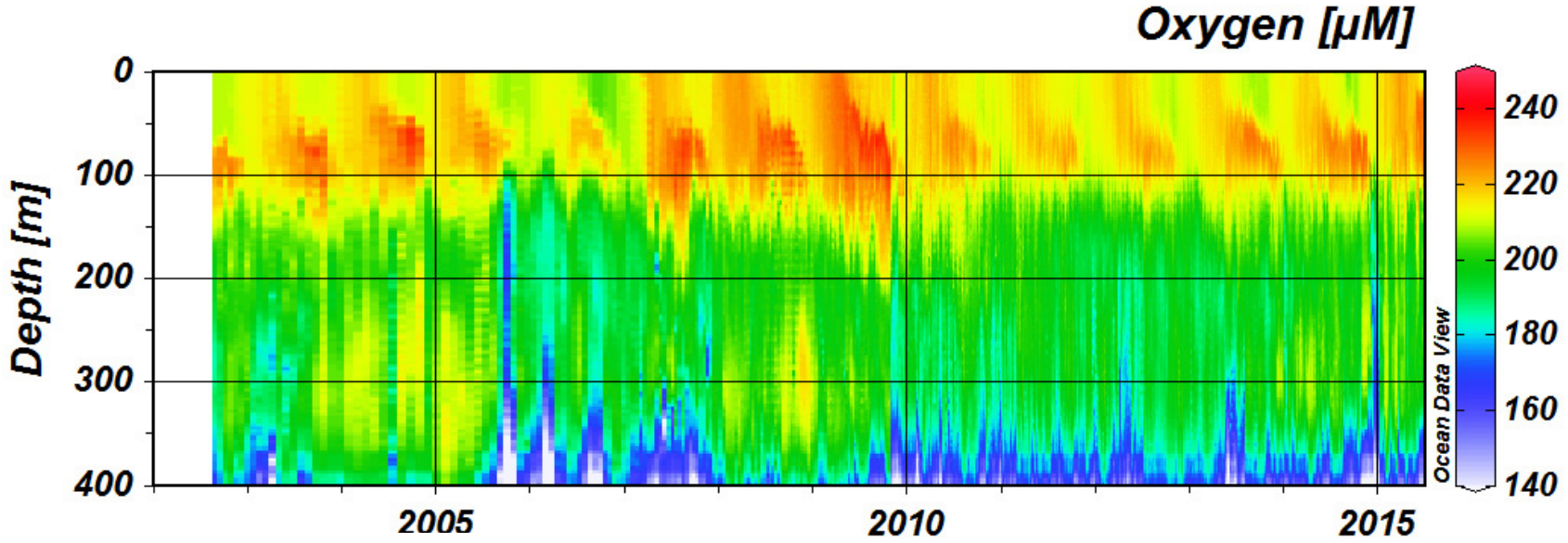


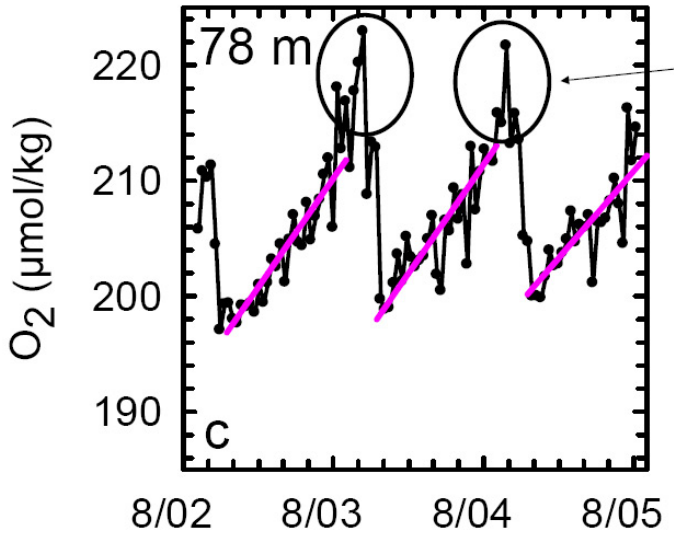
Vol 451|17 January 2008|doi:10.1038/nature06441 nature

Net production of oxygen in the subtropical ocean

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







Late summer primary production event.

Riser and Johnson (2008) - Floats

NCP: 5.4 ± 2.3 mmol O_2 m^{-2} d^{-1}

Nicholson et al. (2008) - Gliders

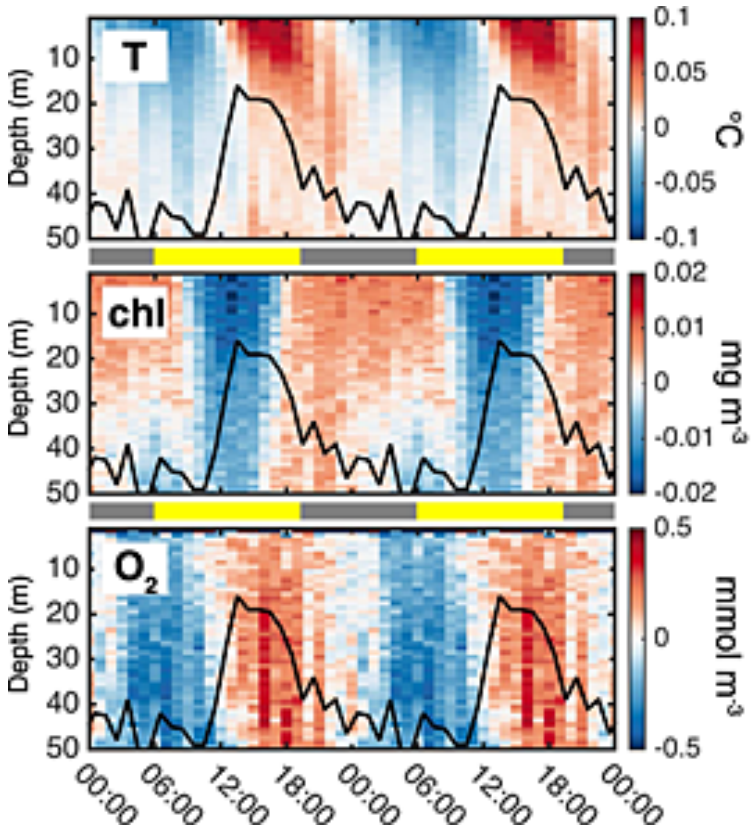
NCP: 3.5-5.8 mmol O_2 m^{-2} d^{-1}

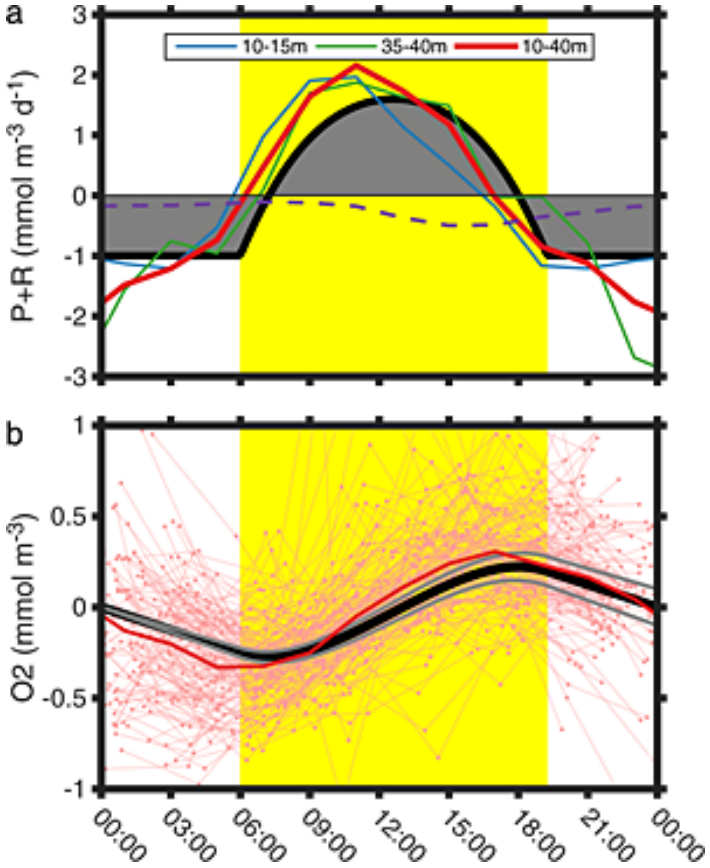
Limnol. Oceanogr., 53(5, part 2), 2008, 2226–2236

Net community production in the deep euphotic zone of the subtropical North Pacific gyre from glider surveys

David Nicholson, Steven Emerson, and Charles C. Eriksen
School of Oceanography, University of Washington, Seattle Washington 98195

Quantifying mixed layer primary productivity from Seaglider observations of diel oxygen cycles





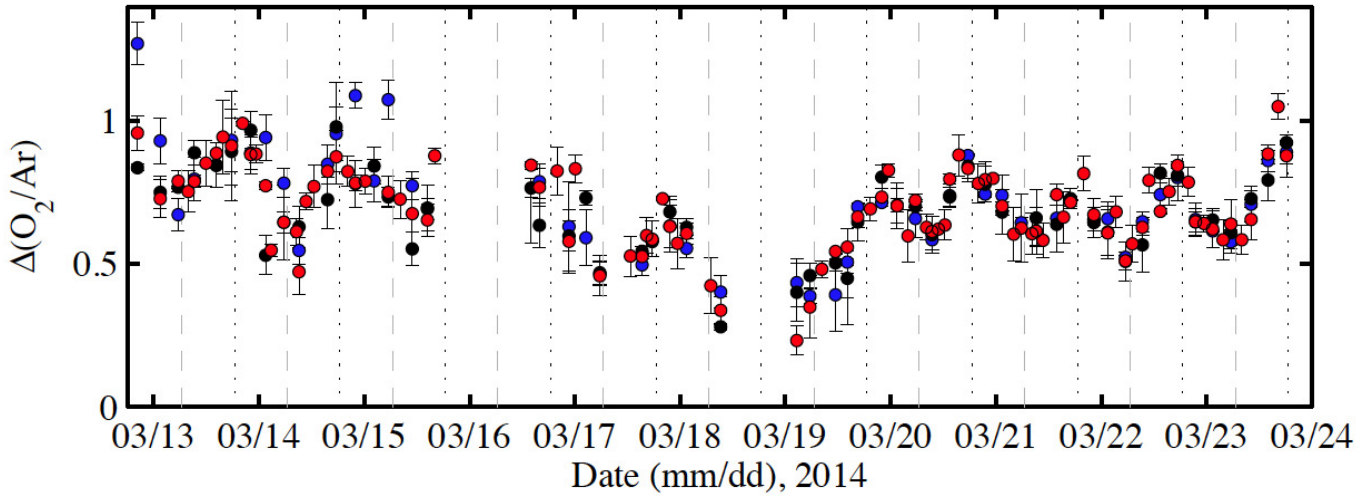
<u>Summer 2012</u>

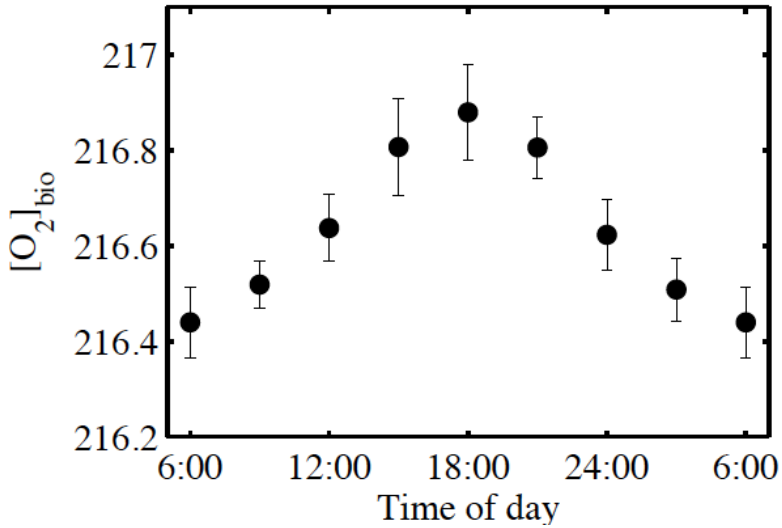
NCP = 4.5 ±3.6 mmol O_2 m^{-2} d^{-1}

GPP = 102.6 ± 39.9 mmol O_2 m^{-2} d^{-1}

Nicholson, Wilson, Doney, Karl (2015)
Geophysical Research Letters
Volume 42, pages 4032-4039

Diel changes in mixed layer O_2/Ar saturation ratios





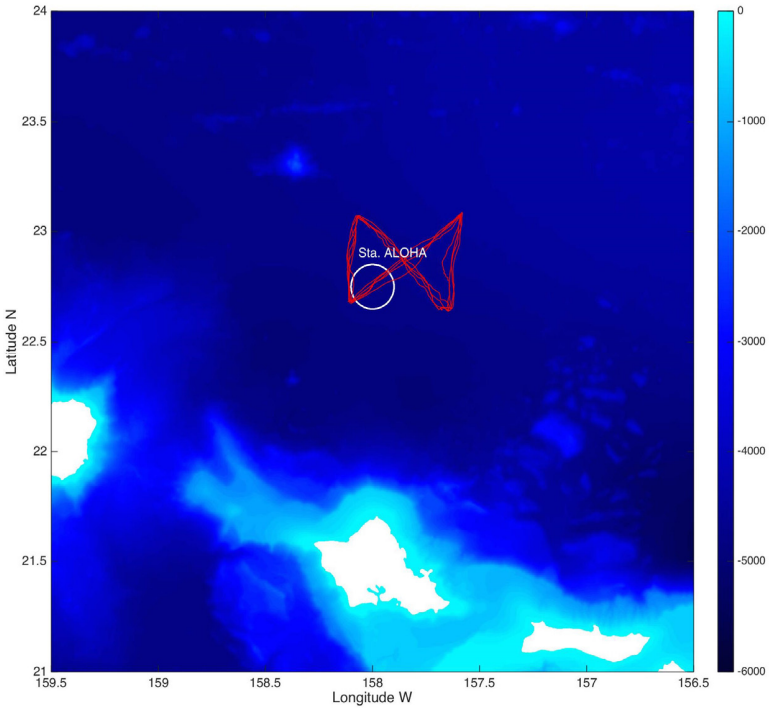
Spring 2014

NCP = 9.2 ± 9.6 mmol O_2 m^{-2} d^{-1}

GPP = 96 ± 10 mmol O_2 m^{-2} d^{-1}

Ferron, Wilson, Martinez-Garcia, Quay, and Karl (2015)
Geophysical Research Letters
Volume 42, Issue 9, pages 3421-

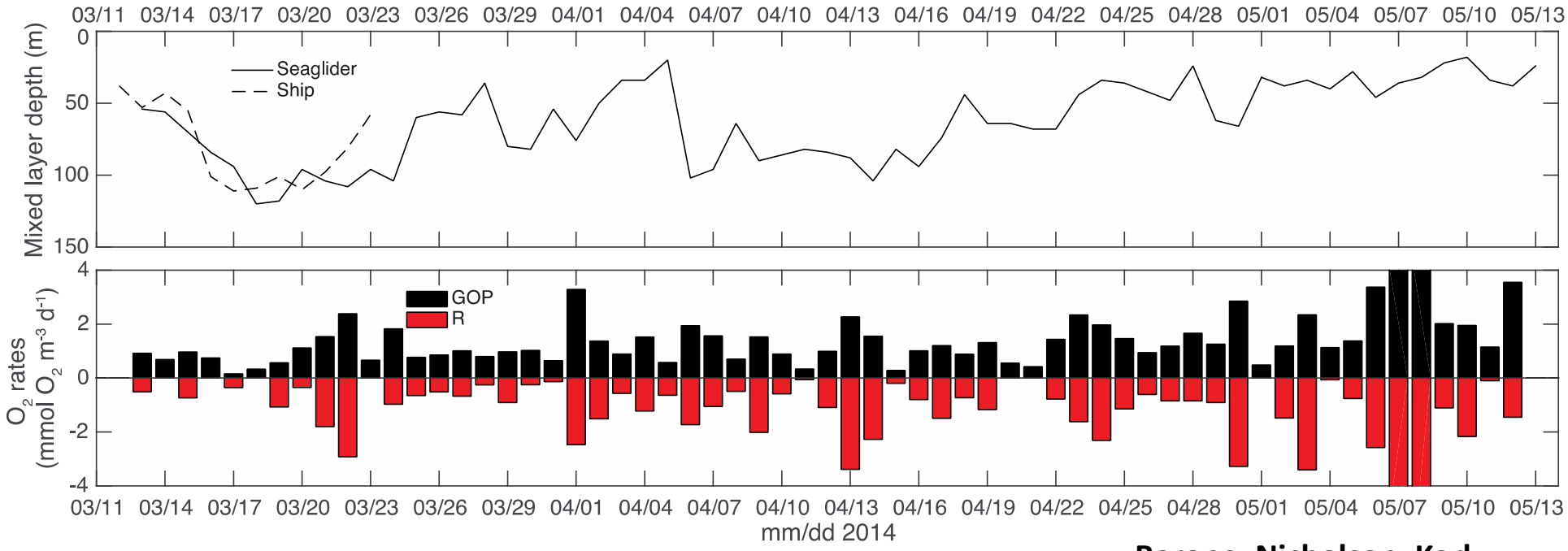
Daily-scale variability in mixed layer O_2 concentrations used to constrain net and gross productivity



Spring 2014

NCP = 6 mmol O_2 m^{-2} d^{-1}

GPP = 66 mmol O_2 m^{-2} d^{-1}



Barone, Nicholson, Karl

Summary

- The complexity of ecosystem dynamics, even in “stable” systems, demands multi-disciplinary, sustained observations.
- The suite of shipboard, remote, and autonomous sampling strategies at Station ALOHA continues to provide new insights into elemental cycling and plankton ecology in one of Earth’s largest ecosystems.
- Separating spatial and temporal dynamics remains challenging, even with a diverse suite of autonomous sampling assets.
- Net community production and nutrient supply vary annually, seasonally, and over daily scales.
- Time series programs (augmented by autonomous technologies) continue to improve our ability to constrain the magnitude and variability in carbon fluxes in the open sea.

THANK YOU