Shipboard and autonomous observations at Station ALOHA: Insights into productivity, export, and nutrient supply in the oligotrophic ocean
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
Humans are modifying the planet and our impact is growing.

- Time series are key tools to understanding planetary change.

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**IPCC WGI AR5**

27 September 2013
Subtropical gyres comprise some of 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...


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

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.
LETTERS

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

Kenneth S. Johnson¹, Stephen C. Riser² & David M. Karl¹

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 $\text{N}_2$ fixation = $75 \pm 45 \text{ mmol N m}^{-2} \text{ yr}^{-1}$ ($0.5 \text{ mol C m}^{-2} \text{ yr}^{-1}$)

• 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 by Eric Shulenberger and Joseph L. Reid. 1981 Deep Sea Res. 28: 901-919
Riser and Johnson (2008) - Floats
NCP: $5.4 \pm 2.3$ mmol O$_2$ m$^{-2}$ d$^{-1}$

Nicholson et al. (2008) - Gliders
NCP: 3.5-5.8 mmol O$_2$ m$^{-2}$ d$^{-1}$

Net production of oxygen in the subtropical ocean

Stephen C. Riser & Kenneth S. Johnson

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

David Nicholson, Steven Emerson, and Charles Eriksen
School of Oceanography, University of Washington, Seattle Washington 98195
Quantifying mixed layer primary productivity from Seaglider observations of diel oxygen cycles

Summer 2012
NCP = 4.5 ±3.6 mmol O₂ m⁻² d⁻¹
GPP = 102.6 ± 39.9 mmol O₂ m⁻² d⁻¹

Geophysical Research Letters
Volume 42, pages 4032-4039
Diel changes in mixed layer 
$O_2$/Ar saturation ratios

Spring 2014

$NCP = 9.2 \pm 9.6 \text{ mmol } O_2 \text{ m}^{-2} \text{ d}^{-1}$

$GPP = 96 \pm 10 \text{ mmol } O_2 \text{ m}^{-2} \text{ d}^{-1}$

Ferron, Wilson, Martinez-Garcia, Quay, and Karl (2015)
Geophysical Research Letters
Volume 42, Issue 9, pages 3421-
Daily-scale variability in mixed layer $\text{O}_2$ concentrations used to constrain net and gross productivity

Spring 2014
NCP = 6 mmol $\text{O}_2$ m$^{-2}$ d$^{-1}$
GPP = 66 mmol $\text{O}_2$ 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