The Station P mooring array

Resolving physical and biogeochemical processes across seasons, years, and into the future

Meghan Cronin

NOAA Pacific Marine Environmental Laboratory, Seattle WA USA
Ocean Weather Stations
1940 – 1980

ATLANTIC

<table>
<thead>
<tr>
<th>Sta.</th>
<th>Position</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>62°00'N 33°00'W</td>
<td>U.S. &amp; Neth.</td>
</tr>
<tr>
<td>B</td>
<td>59°30'N 31°00'W</td>
<td>U.S.</td>
</tr>
<tr>
<td>C</td>
<td>52°45'N 29°30'W</td>
<td>U.S.</td>
</tr>
<tr>
<td>D</td>
<td>41°30'N 41°00'W</td>
<td>U.S.</td>
</tr>
<tr>
<td>E</td>
<td>35°00'N 48°00'W</td>
<td>U.S.</td>
</tr>
<tr>
<td>H</td>
<td>36°00'N 70°00'W</td>
<td>U.S.</td>
</tr>
<tr>
<td>I</td>
<td>41°00'N 75°00'W</td>
<td>U.S.</td>
</tr>
<tr>
<td>J</td>
<td>52°30'N 29°00'W</td>
<td>U.K.</td>
</tr>
<tr>
<td>K</td>
<td>45°00'N 16°00'W</td>
<td>France</td>
</tr>
<tr>
<td>M</td>
<td>56°00'N 62°00'E</td>
<td>Norway</td>
</tr>
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PACIFIC

<table>
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<tr>
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<th>Position</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>13°N 140°W</td>
<td>U.S.</td>
</tr>
<tr>
<td>P</td>
<td>50°N 143°W</td>
<td>Canada</td>
</tr>
<tr>
<td>V</td>
<td>14°N 154°E</td>
<td>U.S.</td>
</tr>
</tbody>
</table>
A worldwide system of deep water reference stations providing:

- Realtime data access
- High resolution measurements
- The full depth of the ocean
- Multi-year time scales
- Dozens of variables

www.oceansites.org
Present ongoing array at Station Papa
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(A-C) NSF OOI (Jul 2014–)

Ed Devers (OSU), Bob Weller (WHOI)
Present ongoing array at Station Papa

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(D) NOAA Surface Mooring (Jun 2007–)
Meghan Cronin (NOAA PMEL),
with BGC sensors provided by
Adrienne Sutton (UW/JISAO), Steve Emerson (UW)
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(E) UW APL Waverider (Jun 2010– )
Jim Thomson (UW APL),
with passive acoustic sensors provided by
Jie Yang, Jeff Nystuen (UW APL)

(F) NOAA Noise Reference Station
(Jan 2015– )
Holger Klinck, Bob Dziak (NOAA PMEL)
Ocean Station Papa

Current Anchor Position: 50° 3.3'N, 144° 52.4'W
Nominal Location: 50.1'N, 144.9'W
Mooring Type: Tau4-Line
Scope: 0.985 (2015 - ), 0.985 (2007 - 2014)
Watch Circle: 1.25km Radius
Avoidance Area: Ships working in the area are requested to observe an avoidance area of at least 3NM radius (5.5km) from the stated anchor position.
Change in mixed layer due to surface forcing

horizontal advection

Entrainment across base of mixed layer

turbulent diffusion (residual)

Residual of Heat Budget = $w' T'$

Journal of Geophysical Research: Oceans

Estimating diffusivity from the mixed layer heat and salt balances in the North Pacific

Meghan F. Cronin1, Noel A. Pelland2, Steven R. Emerson3, and William R. Crawford4

1NOAA Pacific Marine Environmental Laboratory, Seattle, Washington, USA, 2School of Oceanography, University of Washington, Seattle, Washington, USA, 3Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney, Canada

Abstract Data from two National Oceanographic and Atmospheric Administration (NOAA) surface moorings in the North Pacific, in combination with data from satellite, Argo floats and glider (when available), are used to evaluate the residual diffusive flux of heat across the base of the mixed layer from the surface mixed layer heat budget. The diffusion coefficient (i.e., diffusivity) is then computed by dividing the diffusive flux by the temperature gradient in the 20 m transition layer just below the base of the mixed layer. At Station Papa in the NE Pacific subpolar gyre, this diffusivity is $1 \times 10^{-3}$ m$^2$/s during summer, increasing to $4 \times 10^{-3}$ m$^2$/s during fall. During late winter and early spring, diffusivity has large errors. At other times, diffusivity computed from the mixed layer salt budget at Papa correlates with fluxes from the heat budget, giving confidence that the results are robust for all seasons except late winter-early spring and can be used for other tracers. In comparison, at the Kuroshio Extension Observatory (KEO) in the NW Pacific subtropical recirculation gyre, somewhat larger diffusivities are found based upon the mixed layer heat budget: $3 \times 10^{-3}$ m$^2$/s during the warm season and more than an order of magnitude larger during the winter, although again, winter-time errors are large. These larger values at KEO appear to be due to the increased turbulence associated with the summertime typhoons, and weaker winter-time stratification.

Cronin et al. (JGR 2015)
Residual of Heat Budget = $w'T''$

Residual of Salt Budget = $w'S'$

Cronin et al. (JGR 2015)
Change in mixed layer due to surface forcing

horizontal advection

Entrainment across base of mixed layer

turbulent diffusion (residual)

If Assume

\[
\text{Residual of Heat Budget} = \overline{w'T'} = -\kappa_T \frac{\partial T}{\partial z} \bigg|_{z=-h}
\]

\[
\text{Residual of Salt Budget} = \overline{w'S'} = -\kappa_S \frac{\partial S}{\partial z} \bigg|_{z=-h}
\]

Then, what is \( \kappa \) value? “diffusivity”

Cronin et al. (JGR 2015)
If Assume
\[ \text{Residual of Heat Budget} = \bar{w} \bar{T}' = -\kappa_T \left( \frac{\partial T}{\partial z} \right) \text{,} \]
\[ \text{Residual of Salt Budget} = \bar{w} \bar{S}' = -\kappa_S \left( \frac{\partial S}{\partial z} \right) \text{,} \]

Then, what is $\kappa$ value? “diffusivity”

Cronin et al. (JGR 2015)
Residual of Heat Budget: \( \bar{w}'T' = -\kappa_T \frac{\partial T}{\partial z} \bigg|_{z=-h} \)

Residual of Salt Budget: \( \bar{w}'S' = -\kappa_S \frac{\partial S}{\partial z} \bigg|_{z=-h} \)

If Assume \[
\begin{aligned}
\end{cases} \\
\kappa_S &\sim \begin{cases} 10^{-6}, & 2007-2008 \\ 10^{-5}, & 2009-2010 \\ 10^{-4}, & 2011-2012 \\ 10^{-3}, & 2013-2014 \\
\end{cases}
\end{aligned}
\]

Then, what is \( \kappa \) value? “diffusivity”

Cronin et al. (JGR 2015)
In order to identify changes in the efficiency of the biological pump and quantitatively assess the climate efficiency, it is essential to develop a robust carbon cycle baseline required to develop a robust carbon cycle baseline.

Global Biogeochemical Cycles

Net community production and calcification from 7 years of NOAA Station Papa Mooring measurements

Andrea J. Fassbender1,2, Christopher L. Sabine3, and Meghan F. Coste1

1School of Oceanography, University of Washington, Seattle, Washington, USA
2TechLab Pacific Marine Environmental Laboratory, Seattle, Washington, USA

Abstract

Seven years of near-continuous observations from the Ocean Station Papa (OSP) surface mooring were used to evaluate drivers of marine carbon cycling in the eastern subarctic Pacific. Processes contributing to mixed layer carbon inventory changes throughout each deployment year were quantitatively assessed using a time-dependent mass balance approach in which total alkalinity and dissolved inorganic carbon were used as tracers. By using two mixed layer carbon tracers, it was possible to isolate the influence of net community production (NCP) and calcification from time series sites, such as Bermuda Atlantic Time-series Study (BATS).

Cycles of net marine carbon uptake and pH declines have been primarily controlled by CO2 solubility and the annual calcification. Our results indicate that the annual NCP at OSP is -2 ± 1 mol C m⁻² yr⁻¹ and the annual calcification is 0.3 ± 0.3 mol C m⁻² yr⁻¹. Piecing together evidence for potentially significant dissolved organic carbon cycling in this region, we estimate a particulate inorganic carbon to particulate organic carbon ratio between 0.15 and 0.25. This is at least double the global average, adding to the growing evidence that calcifying organisms play an important role in carbon export at this location. These results, coupled with significant seasonality in the NCP, suggest that carbon cycling near OSP may be more complex than previously thought and highlight the importance of continuous observations for robust assessments of biogeochemical cycling.

1. Introduction

The biological consumption and export of carbon from the ocean surface to the abyssal sediments, commonly referred to as the biological pump, is a major pathway for long-term carbon sequestration from the atmosphere. Changes in the efficiency of the biological pump and quantitatively assess the climate efficiency are critical for understanding and predicting future carbon cycle responses to anthropogenic and natural forcing.
\[
\frac{\partial TA}{\partial t} = \left( \frac{\partial TA}{\partial t} \right)_{E-P} + \left( \frac{\partial TA}{\partial t} \right)_{\text{phys}} + \left( \frac{\partial TA}{\partial t} \right)_{\text{NCP}} + \left( \frac{\partial TA}{\partial t} \right)_{\text{CaCO}_3}
\]

\[
\frac{\partial DIC}{\partial t} = \left( \frac{\partial DIC}{\partial t} \right)_{\text{gas}} + \left( \frac{\partial DIC}{\partial t} \right)_{E-P} + \left( \frac{\partial DIC}{\partial t} \right)_{\text{phys}} + \left( \frac{\partial DIC}{\partial t} \right)_{\text{NCP}} + \left( \frac{\partial DIC}{\partial t} \right)_{\text{CaCO}_3}
\]

Fassbender et al. (GBC 2016)
\[
\frac{\partial TA}{\partial t} = \frac{\partial TA}{\partial t}_{E-P} + \frac{\partial TA}{\partial t}_{\text{phys}} + \frac{\partial TA}{\partial t}_{\text{NCP}} + \frac{\partial TA}{\partial t}_{\text{CaCO}_3}
\]

\[
\frac{\partial DIC}{\partial t} = \frac{\partial DIC}{\partial t}_{\text{gas}} + \frac{\partial DIC}{\partial t}_{E-P} + \frac{\partial DIC}{\partial t}_{\text{phys}} + \frac{\partial DIC}{\partial t}_{\text{NCP}} + \frac{\partial DIC}{\partial t}_{\text{CaCO}_3}
\]

Fassbender et al. (GBC 2016)
Future Studies
Station Papa Ambient Noise data

Percentage days/month with sperm whales detections

[Data gap]

See Niki Diogou (OSU) poster
Special Collections:
Midlatitude Marine Heatwaves: Forcing and Impacts
Persistent, midlatitude marine heatwaves (MHWs), such as the 2013-2014 extreme warming of the Northeastern Pacific (aka “the Blob”), can have dramatic and widespread impacts on ecosystems, fisheries and weather. MHWs have been observed in both hemispheres (e.g., the Ningaloo Niño in Western Australia), including in semi-enclosed basins such as the Mediterranean Sea. MHWs can be caused by a combination of atmospheric and oceanographic processes. It is also expected that they will become more frequent and intense under anthropogenic climate change. This Special Collection welcomes papers investigating the causes, evolution, and impacts of persistent midlatitude MHWs.

Joint with: JGR-Oceans, GRL, JGR-Atmosphere, JGR-Biogeosciences

February 2014 SST anomaly. Courtesy K. Karnauskas.
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PMEL Engineering Division, led by: Christian Meinig
And to our partners:
Marie Robert (IOS).... DFO Line P program
Steve Emerson (UW).... O₂, pH sensors
Adrienne Sutton (UW/JISAO/PMEL) .... air and sea pCO₂, Chl sensors
Jim Thomson (UW APL).... Waverider mooring
Ed Devers (OSU) and NSF OOI .... Papa Global Node moorings and gliders
Holger Klinck, Bob Dziak (NOAA PMEL).... NOAA Noise Reference Station Mooring
Jie Yang, Jeff Nystuen (UW APL).... Passive Acoustic Listening Device sensor