NOAA Station P Surface Mooring Activities

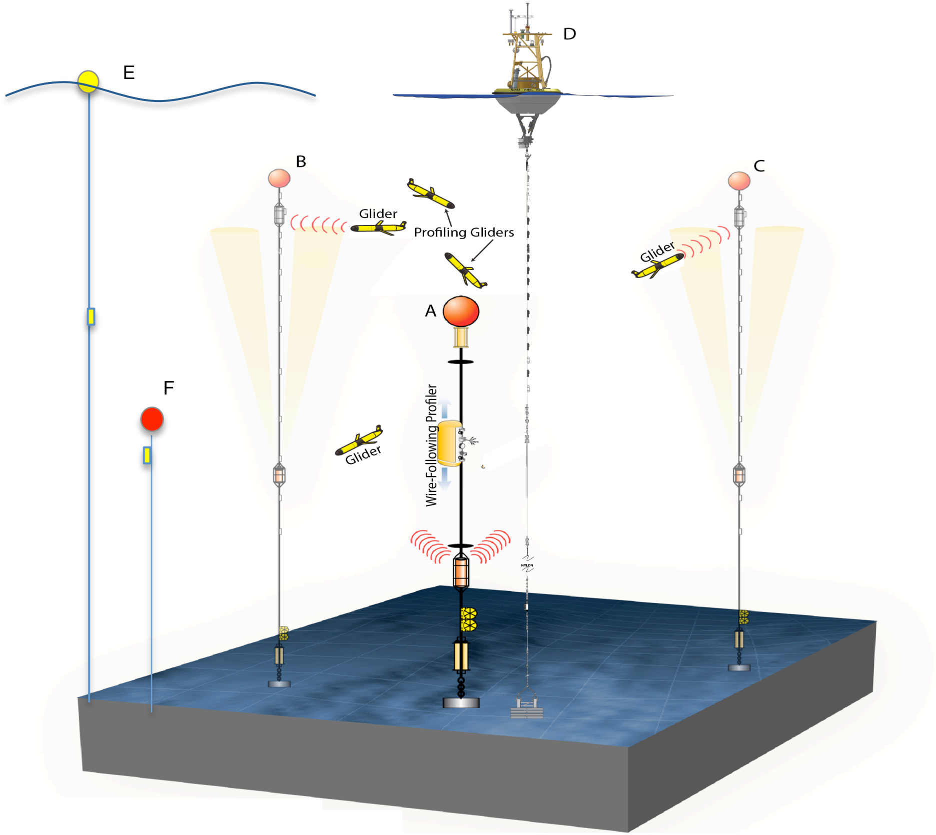
Resolving physical and biogeochemical processes across seasons, years, and into the future

Meghan Cronin

NOAA Pacific Marine Environmental Laboratory, Seattle WA USA

With input from: **Jennifer Keene** (UW JISAO), **Jim Thomson** (UW APL), **Adrienne Sutton** (NOAA PMEL), **Holger Klink** (formerly of NOAA PMEL)

Present ongoing array at Station Papa

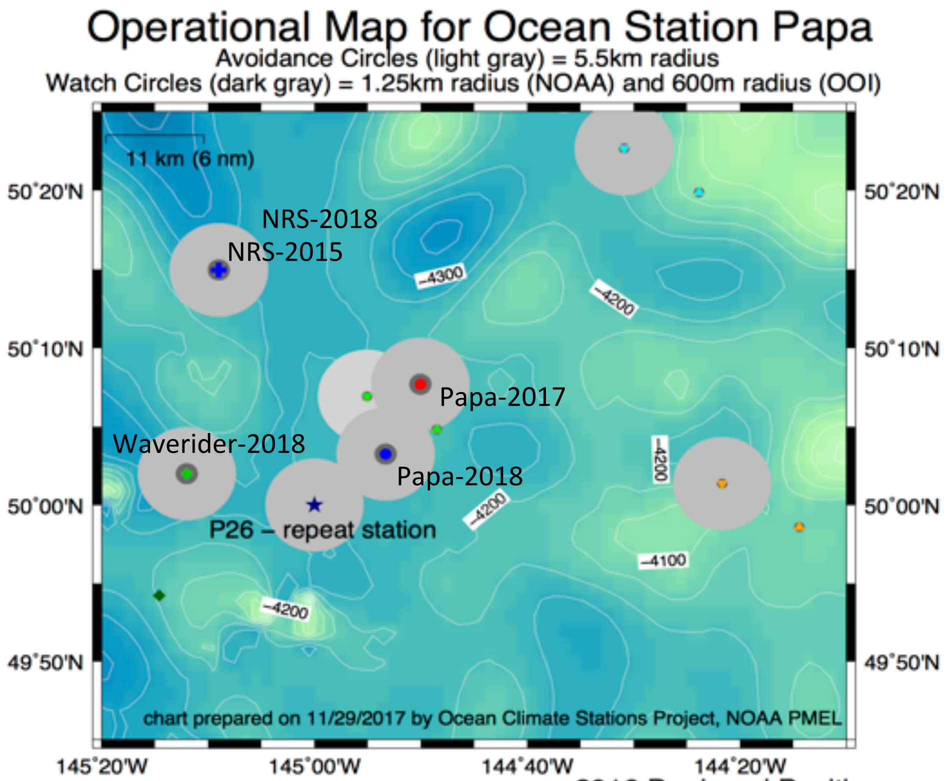


(A-C) NSF OOI *(Jul 2014–)*
Bob Weller (WHOI)

(D) NOAA Surface Mooring *(Jun 2007–)*
Meghan Cronin (NOAA PMEL),
with BGC sensors provided by
Adrienne Sutton (UW/JISAO), **Steve Emerson** (UW)

(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)



Thank you NSF OOI for providing piggy-back opportunity for mooring turnaround operations on your summer 2018 *R/V Sally Ride cruise!*

- NOAA Sfc. Mrg. – 2017 (50° 7.7' N, 144° 50.0' W)
- Planned Sfc. Mrg. – 2018 (50° 3.3' N, 144° 53.3' W)
- NRS Mooring – 2015 (50° 15.0' N, 145° 9.0' W)
- Waverider – 2014 (50° 2.0' N, 145° 12.0' W)
- Waverider – Planned (49° 54.2' N, 145° 14.6' W)

2016 Deployed Positions:

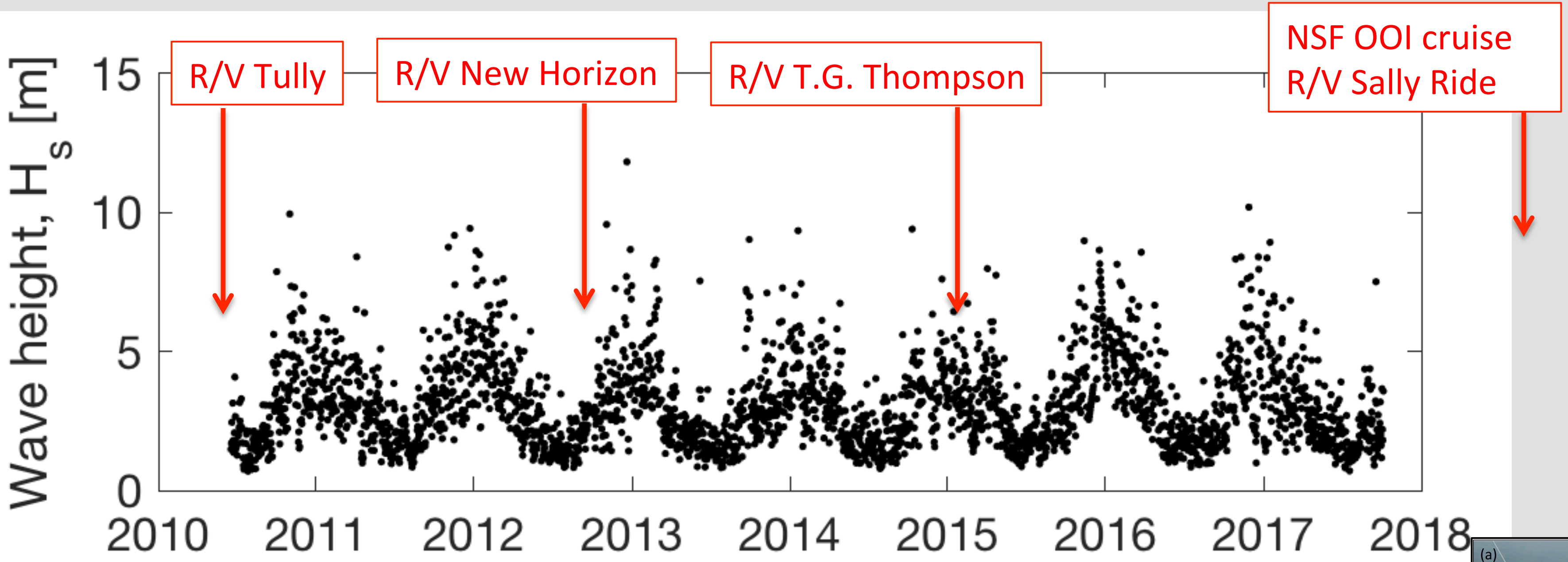
- OOI Flanking Mooring A (49° 58.6' N, 144° 14.4' W)
- OOI Flanking Mooring B (50° 19.9' N, 144° 23.9' W)
- OOI Profiler – 2016 (50° 4.8' N, 144° 48.5' W)

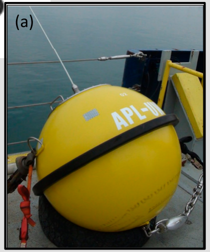
2017 Deployed Positions:

- OOI Flanking Mooring A (50° 1.4' N, 144° 21.7' W)
- OOI Flanking Mooring B (50° 22.7' N, 144° 30.9' W)
- OOI Profiler – 2017 (50° 6.9' N, 144° 55.1' W)

Waverider mooring at Station Papa

Funded through NSF research grants



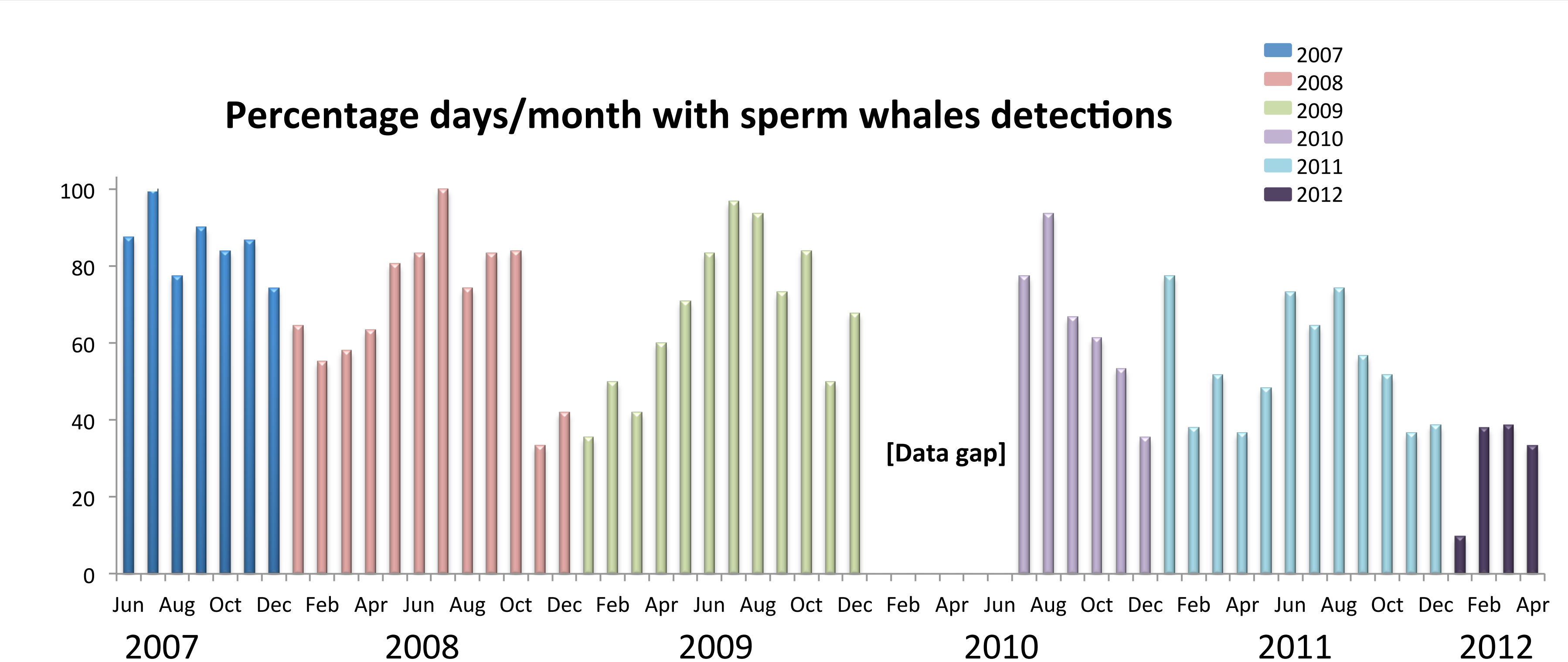


Data: CDIP 166 / NBDC 46246

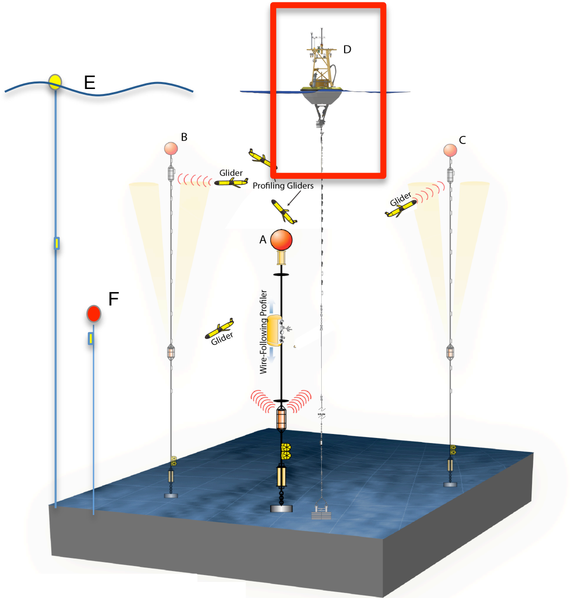
Contact: Jim Thomson <jthomson@apl.uw.edu>

Station Papa Ambient Noise data

(1) PAL on Waverider (2) NOAA Noise Reference Station Mooring



From N. Diogou, H. Klink, J. Nystuen (2013)



www.pmel.noaa.gov/ocs/Papa/

Ocean Climate Stations

Pacific Marine Environmental Laboratory

Research

- Overview
- Kuroshio Extension Observatory
  - KEO Background
- Ocean Station Papa
  - Papa Background
  - Other Research at Papa
- Agulhas Return Current
  - ARC Background
- Air-Sea Fluxes

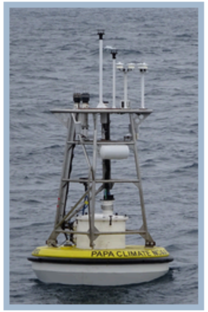
Related

Data Overview
It is the OCS project policy that timely, free, and unrestricted access shall

Moorings

Measurement Heig...
The tables below describe the nominal heights of meteorological measurements,

Ocean Station Papa



Current Anchor Position: 50° 3.3'N, 144° 52.4'W

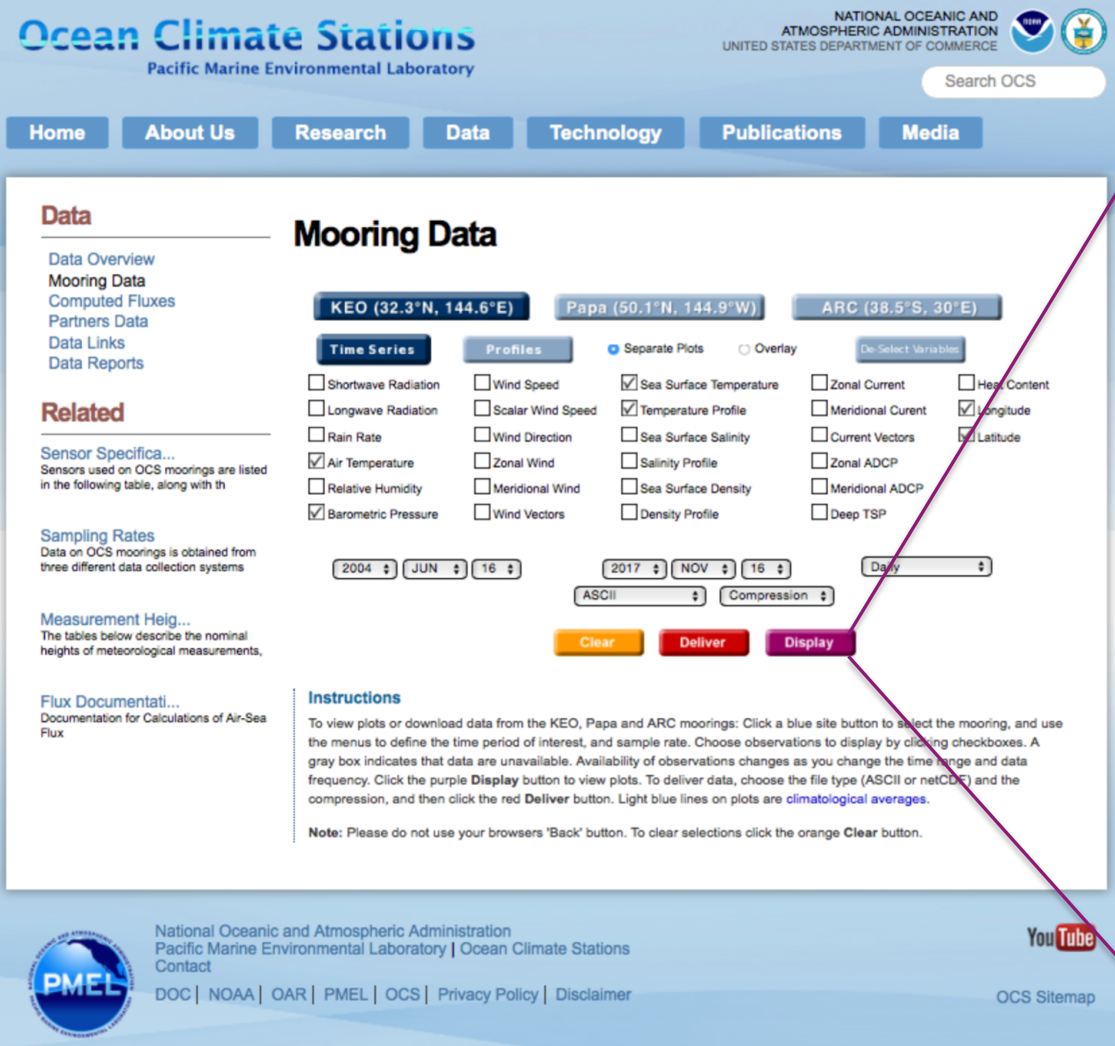
Nominal Location: 50.1°N, 144.9°W

Mooring Type: Taut-Line

Scope: 0.965 (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.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Sensors used on OCS moorings are listed in the following table, along with th
Sampling Rates
Data on OCS moorings is obtained from three different data collection systems
Measurement Heig...
The tables below describe the nominal heights of meteorological measurements,
Flux Documentati...
Documentation for Calculations of Air-Sea Flux
Mooring Data
KEO (32.3°N, 144.6°E)
Papa (50.1°N, 144.9°W)
ARC (38.5°S, 30°E)
Time Series
Profiles
Separate Plots
Overlay
De-Select Variables
Shortwave Radiation
Longwave Radiation
Rain Rate
Air Temperature
Relative Humidity
Barometric Pressure
Wind Speed
Scalar Wind Speed
Wind Direction
Zonal Wind
Meridional Wind
Wind Vectors
Sea Surface Temperature
Temperature Profile
Sea Surface Salinity
Salinity Profile
Sea Surface Density
Density Profile
Zonal Current
Meridional Curent
Current Vectors
Zonal ADCP
Meridional ADCP
Deep TSP
Heat Content
Longitude
Latitude
2004 JUN 16
2017 NOV 16
Daily
ASCII
Compression
Clear
Deliver
Display
Instructions
To view plots or download data from the KEO, Papa and ARC moorings: Click a blue site button to select the mooring, and use the menus to define the time period of interest, and sample rate. Choose observations to display by clicking checkboxes. A gray box indicates that data are unavailable. Availability of observations changes as you change the time range and data frequency. Click the purple Display button to view plots. To deliver data, choose the file type (ASCII or netCDF) and the compression, and then click the red Deliver button. Light blue lines on plots are climatological averages.
Note: Please do not use your browsers 'Back' button. To clear selections click the orange Clear button.
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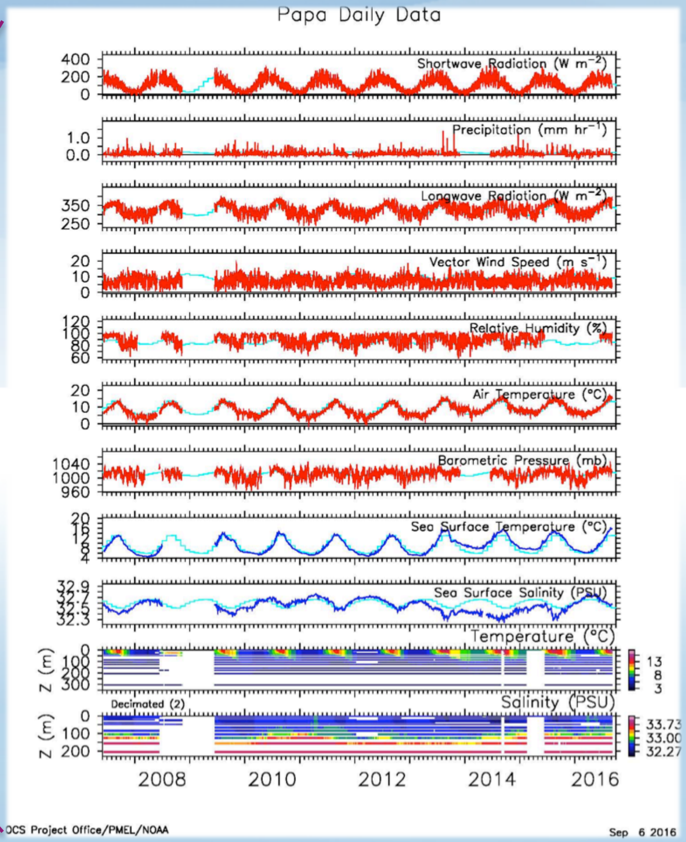
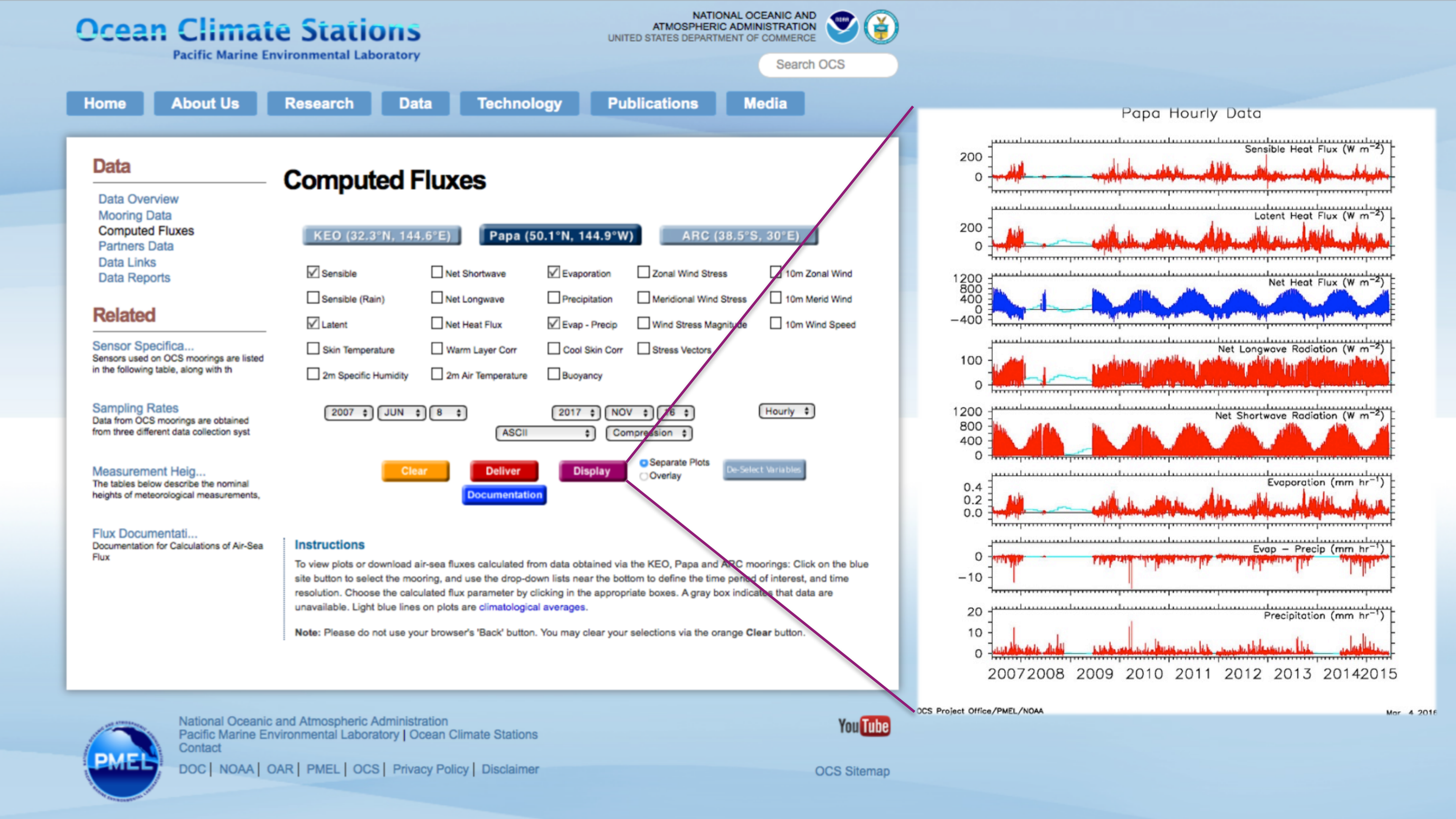

Papa Daily Data
Shortwave Radiation (W m⁻²)
400
200
0
Precipitation (mm hr⁻¹)
1.0
0.0
Longwave Radiation (W m⁻²)
350
250
Vector Wind Speed (m s⁻¹)
20
10
0
Relative Humidity (%)
120
100
80
60
Air Temperature (°C)
20
10
0
Barometric Pressure (mb)
1040
1000
960
Sea Surface Temperature (°C)
Sea Surface Salinity (PSU)
Temperature (°C)
Z (m)
0
100
200
300
13
8
3
Decimated (2)
Salinity (PSU)
Z (m)
0
100
200
33.73
33.00
32.27
2008
2010
2012
2014
2016
OCS Project Office/PMEL/NOAA
Sep 6 2016



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Computed Fluxes
KEO (32.3°N, 144.6°E)
Papa (50.1°N, 144.9°W)
ARC (38.5°S, 30°E)
Sensible
Net Shortwave
Evaporation
Zonal Wind Stress
10m Zonal Wind
Sensible (Rain)
Net Longwave
Precipitation
Meridional Wind Stress
10m Merid Wind
Latent
Net Heat Flux
Evap - Precip
Wind Stress Magnitude
10m Wind Speed
Skin Temperature
Warm Layer Corr
Cool Skin Corr
Stress Vectors
2m Specific Humidity
2m Air Temperature
Buoyancy
2007 JUN 8
2017 NOV 16
Hourly
ASCII
Compression
Clear
Deliver
Display
Documentation
Separate Plots
Overlay
De-Select Variables
Instructions
To view plots or download air-sea fluxes calculated from data obtained via the KEO, Papa and ARC moorings: Click on the blue site button to select the mooring, and use the drop-down lists near the bottom to define the time period of interest, and time resolution. Choose the calculated flux parameter by clicking in the appropriate boxes. A gray box indicates that data are unavailable. Light blue lines on plots are climatological averages.
Note: Please do not use your browser's 'Back' button. You may clear your selections via the orange Clear button.
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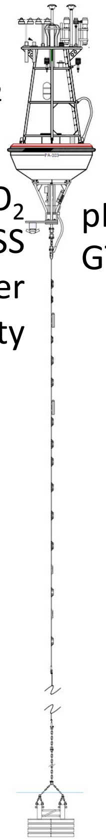
Papa Hourly Data
Sensible Heat Flux (W m^{-2})
200
0
Latent Heat Flux (W m^{-2})
200
0
Net Heat Flux (W m^{-2})
1200
800
400
0
−400
Net Longwave Radiation (W m^{-2})
100
0
Net Shortwave Radiation (W m^{-2})
1200
800
400
0
Evaporation (mm hr^{-1})
0.4
0.2
0.0
Evap − Precip (mm hr^{-1})
0
−10
Precipitation (mm hr^{-1})
20
10
0
2007 2008 2009 2010 2011 2012 2013 2014 2015
OCS Project Office/PMEL/NOAA

https://www.nodc.noaa.gov/ocads/oceans/Moorings/Papa_145W_50N.html



pCO_2 (air and sw), pH, Fluorometer-Turbidity -- A. Sutton

GTD-O_2-CTD -- S. Emerson

http://www.pmel.noaa.gov/co2/story/Papa

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OCADS > Access Data > Time-series and Moorings Project > Mooring PAPA_145W_50N

CO_2 Moorings and Time Series Project

Mooring: Papa_145W_50N (Buoy Position: 50.12°N, 144.83°W)

DATA SET NAME	GRAPHICS	PLATFORM	PLACE	DEPLOYMENTS	CARBON-RELATED DATA CONTRIBUTOR	VARIABLES IN DATA SET	DATA	PROJECT LINK
Papa_145W_50N_Jun2007_Jun2008; Papa_145W_50N_Jun2008_Nov2008; Papa_145W_50N_Jun2009_Mar2010; Papa_145W_50N_Jun2010_Jun2011; Papa_145W_50N_Jun2011_Apr2012; Papa_145W_50N_Jun2012_Mar2013; Papa_145W_50N_Jun2013_Jun2014; Papa_145W_50N_Jun2014_Jun2015	See real time data graphics for this mooring	Papa_145W_50N	Pacific Ocean	Jun2007_Jun2008; Jun2008_Nov2008; Jun2009_Mar2010; Jun2010_Jun2011; Jun2011_Apr2012; Jun2012_Mar2013; Jun2013_Jun2014; Jun2014_Jun2015	Adrienne Sutton / PMEL	SST, SSS, Atm. press, xCO_2 water, xCO_2 air, fCO_2 water, fCO_2 air	Data files Metadata	PMEL Buoys and Autonomous Systems
Papa_145W_50N_Jun2007_Mar2008_O2_N2; Papa_145W_50N_Jun2009_Jun2010_O2_N2; Papa_145W_50N_Jun2010_Dec2010_O2_N2; Papa_145W_50N_Jun2011-Jun2012_O2_N2; Papa_145W_50N_Jun2012-Jun2013_O2_N2; Papa_145W_50N_Jun2013_Dec2013_O2_N2; Papa_145W_50N_Jun2014_Feb2015_O2_N2		Papa_145W_50N	Pacific Ocean	Jun2007_Mar2008; Jun2009_Jun2010; Jun2010_Dec2010; Jun2010_Jun2011; Jun2011-Jun2012; Jun2012-Jun2013; Jun2013_Dec2013; Jun2014_Feb2015	Steve Emerson, Mariela R.T. White/ University of Washington	SST, SSS, GTD, ATM_PRE, N_2, O_2, O2 saturation (%), N2 saturation (%)	Data files Metadata	

Time Series Line P (underway measurements)

VESSEL	COUNTRY	MAP	PORTS	DATES OF OPERATION	FREQUENCY OF REPEAT	PI/CHIEF SCIENTIST	MEASUREMENTS	DATA	PROJECT LINK
CCGS *John P. Tully*, R/V *Quadra*, R/V *Vancouver*, CCGS *Parizeau* See cruise table	Canada	See map	Sidney BC - Station P (50° N, 145° W)	1973-2003	3/year	C.S.Wong, S. Johannessen/IOS, Canada	pCO_2, SST, salinity, atm pressure, atm CO_2, wind speed	Data files Metadata	Line P link

CLIVAR Repeat Section Line P (discrete measurements)

DATA SET NAME	COUNTRY/STATUS	RESEARCH VESSEL	PLACE	PERIOD	CHIEF SCIENTIST	CARBON-RELATED DATA PI(S)	VARIABLES IN DATA SET	DATA/AVAILABILITY NDP NO.
Line P (See map)	Canada / Completed	CCGS *John P. Tully*	Northeast Pacific Ocean	1985-2001, 2003-2008	IOS / Canada	Jim Christian, Lisa Miller, Marty Davelaar, Joe Linguanti / Institute of Ocean Sciences / Canada	Temp, salinity, nutrients, TCO_2, TALK, pH	Data files Metadata

R/V *John P. Tully* 1989 Cruise

VESSEL	COUNTRY	MAP	PORTS	DATES OF OPERATION	FREQUENCY OF REPEAT	PI/CHIEF SCIENTIST	MEASUREMENTS	DATA	PROJECT LINK
CCGS *John P. Tully*	Canada	See map	Sidney BC - Beaufort Sea - Sidney BC	1989		C.S.Wong/IOS, Canada	water pCO_2, air pCO_2, water fCO_2, air fCO_2,SST, SSS, atm pressure, wind speed	Data files Metadata	Line P link

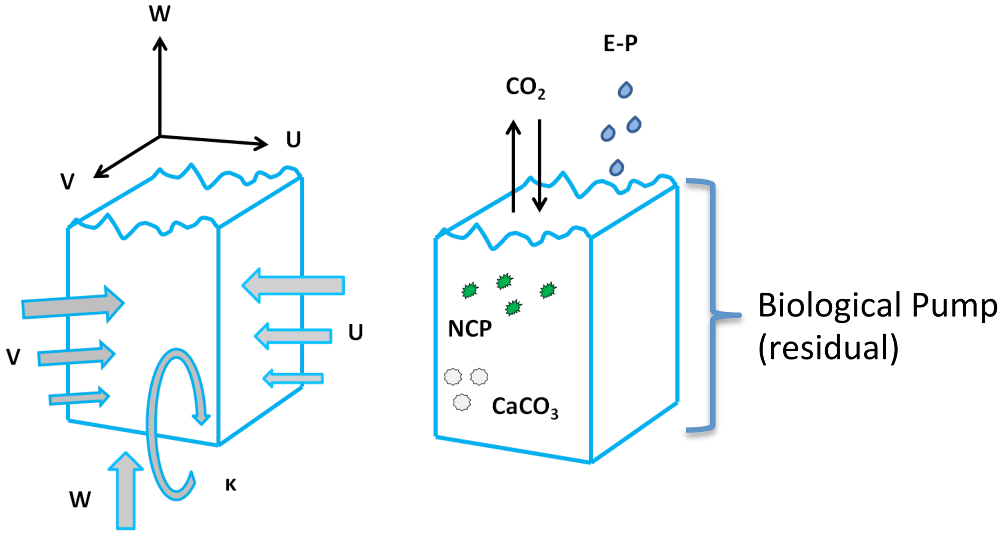
Last Modified: 2017-10-02 20:05 UTC

Biological Pump
(residual)

$$\frac{\partial TA}{\partial t} = \left.\frac{\partial TA}{\partial t}\right|_{E-P} + \left.\frac{\partial TA}{\partial t}\right|_{Phys} + \left.\frac{\partial TA}{\partial t}\right|_{NCP} + \left.\frac{\partial TA}{\partial t}\right|_{CaCO3}$$

$$\frac{\partial DIC}{\partial t} = \left.\frac{\partial DIC}{\partial t}\right|_{gas} + \left.\frac{\partial DIC}{\partial t}\right|_{E-P} + \left.\frac{\partial DIC}{\partial t}\right|_{Phys} + \left.\frac{\partial DIC}{\partial t}\right|_{NCP} + \left.\frac{\partial DIC}{\partial t}\right|_{CaCO3}$$

Biological Pump
(residual)



AGU PUBLICATIONS
Global Biogeochemical Cycles

RESEARCH ARTICLE

10.1002/2015GB005205

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

Andrea J. Fassbender[1,2], Christopher L. Sabine[2], and Meghan F. Cronin[2]

[1]School of Oceanography, University of Washington, Seattle, Washington, USA, [2]NOAA Pacific Marine Environmental Laboratory, Seattle, Washington, USA

Key Points:
- Significant seasonality found in NCP including fall and winter heterotrophy
- Elevated PIC:POC ratio relative to the global average
- Continuous in situ observations are required to develop a robust carbon cycle baseline

Supporting Information:
- Text S1, Figure S1, and Tables S1 and S2
- Text S2

Correspondence to:
A. J. Fassbender,
andrea.fassbender@noaa.gov

Citation:
Fassbender, A. J., C. L. Sabine, and M. F. Cronin (2016), Net community production and calcification from 7 years of NOAA Station Papa Mooring measurements, *Global Biogeochem. Cycles*, *30*, doi:10.1002/2015GB005205.

Received 3 JUN 2015
Accepted 5 JAN 2016
Accepted article online 7 JAN 2016

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 influences of net community production (NCP) and 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 [*Ciais et al.*, 2013]. Each year, approximately 11 Pg C is exported from the ocean surface to the interior as sinking

Note: Given any two carbon parameters (pCO_2, TA (use salinity as proxy), pH, DIC), can estimate other two. **Measure pCO_2 & Salinity to get DIC.**

Fassbender et al. (GBC 2016)

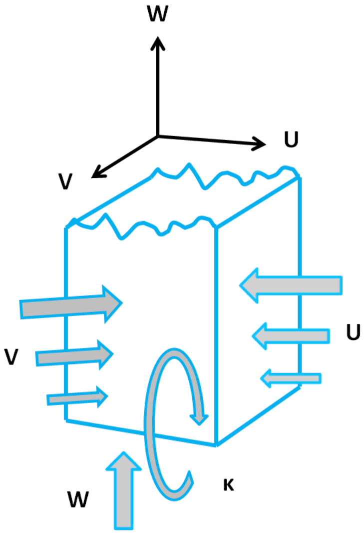
Biological Pump at Papa

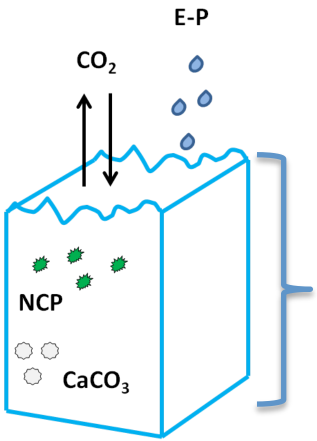
Biological Pump (residual)

$$\frac{\partial TA}{\partial t} = \left.\frac{\partial TA}{\partial t}\right|_{E-P} + \left.\frac{\partial TA}{\partial t}\right|_{Phys} + \left.\frac{\partial TA}{\partial t}\right|_{NCP} + \left.\frac{\partial TA}{\partial t}\right|_{CaCO3}$$

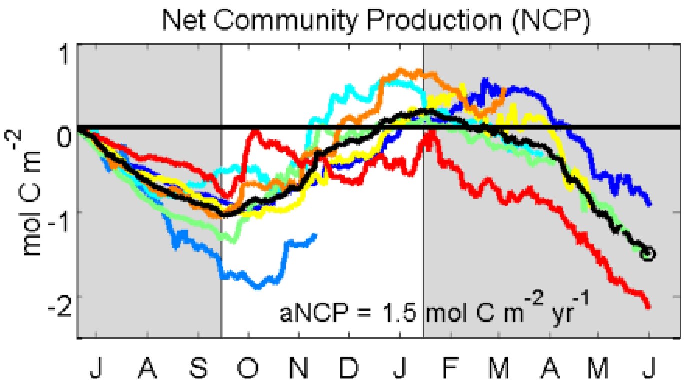
$$\frac{\partial DIC}{\partial t} = \left.\frac{\partial DIC}{\partial t}\right|_{gas} + \left.\frac{\partial DIC}{\partial t}\right|_{E-P} + \left.\frac{\partial DIC}{\partial t}\right|_{Phys} + \left.\frac{\partial DIC}{\partial t}\right|_{NCP} + \left.\frac{\partial DIC}{\partial t}\right|_{CaCO3}$$

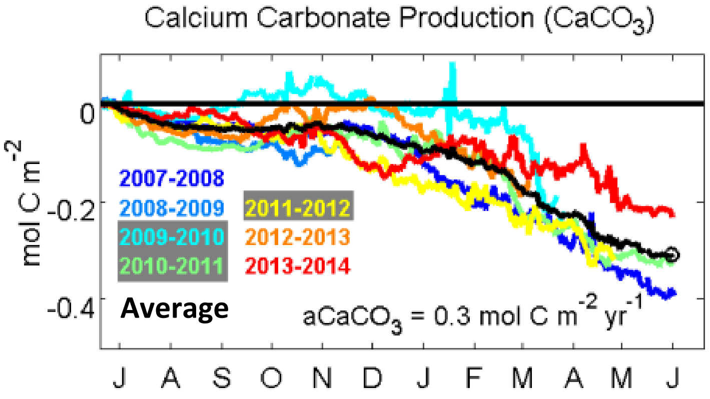
Biological Pump (residual)





Biological Pump (residual)





Large!

Fassbender et al. (GBC 2016)

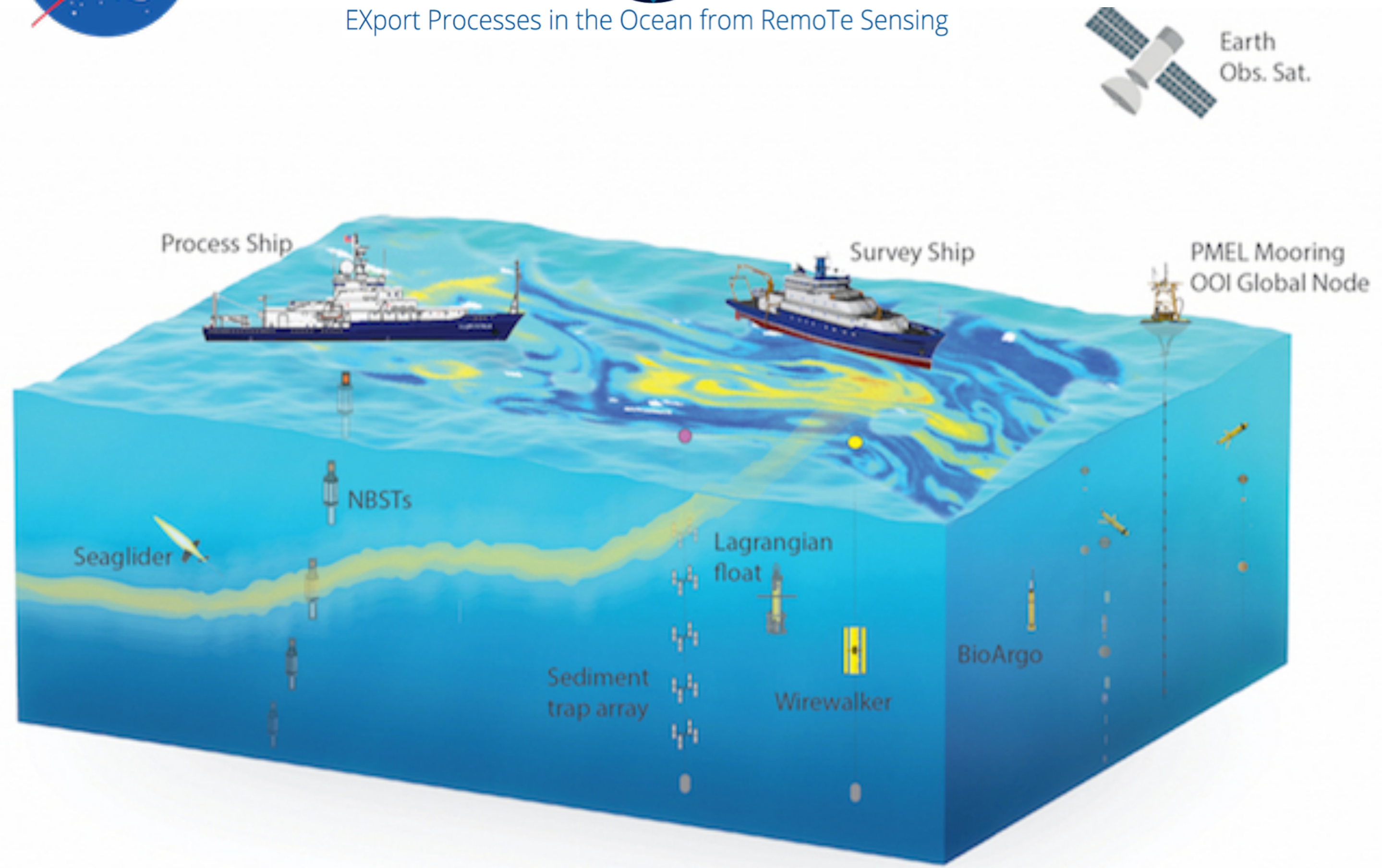
Unanswered questions:

- How do upper ocean ecosystem characteristics determine the vertical transfer of organic matter from the well-lit surface ocean?
- What controls the efficiency of vertical transfer of organic matter below the well-lit surface ocean?
- How can the knowledge gained be used to reduce uncertainties in contemporary & future estimates of the export and fates of NPP?

NASA Goal: Predict the export and fate of ocean Net Primary Production (NPP) from satellite and other observations.

EXPORTS

EXport Processes in the Ocean from RemoTe Sensing



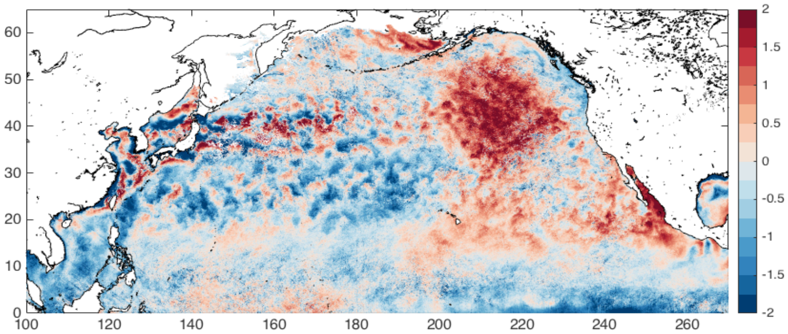
Geophysical Research Letters
AN AGU JOURNAL

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

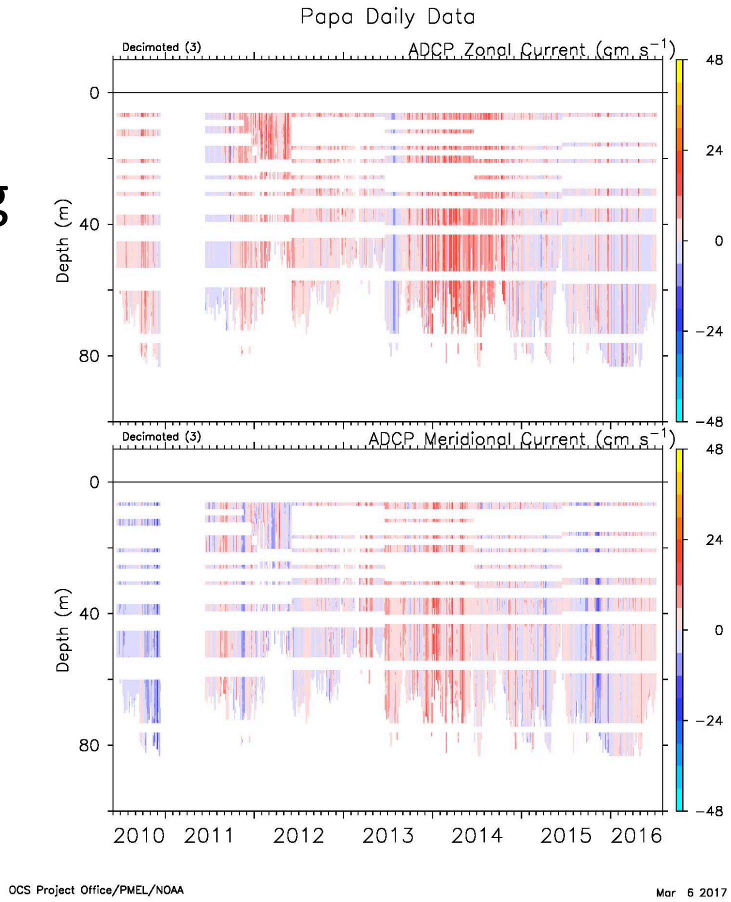


February 2014 SST anomaly. Courtesy K. Karnauskas.

END

Thank you.

Returns from downward-looking ADCP show reflection from sensors mounted on mooring line. These depths are masked out.



Met and physical sensors – Cronin

http://www.pmel.noaa.gov/ocs/