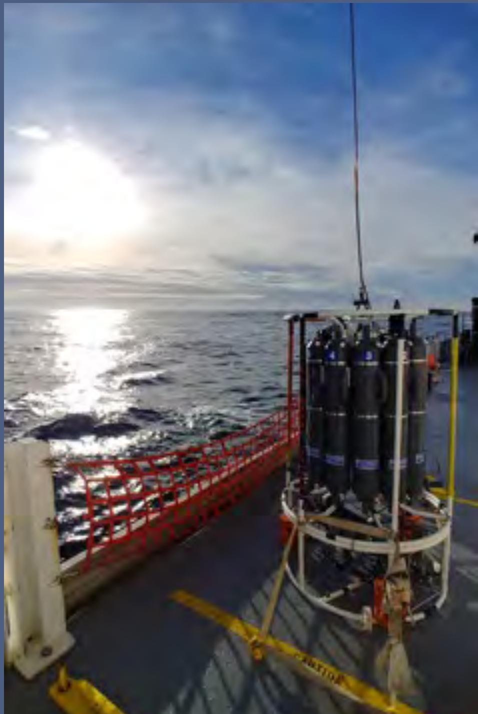
Seasonal benthic metabolism on the shelf of the northern California Current System



Oregon State University
College of Earth, Ocean, and Atmospheric Sciences

Kristen Fogaren

Postdoctoral Researcher

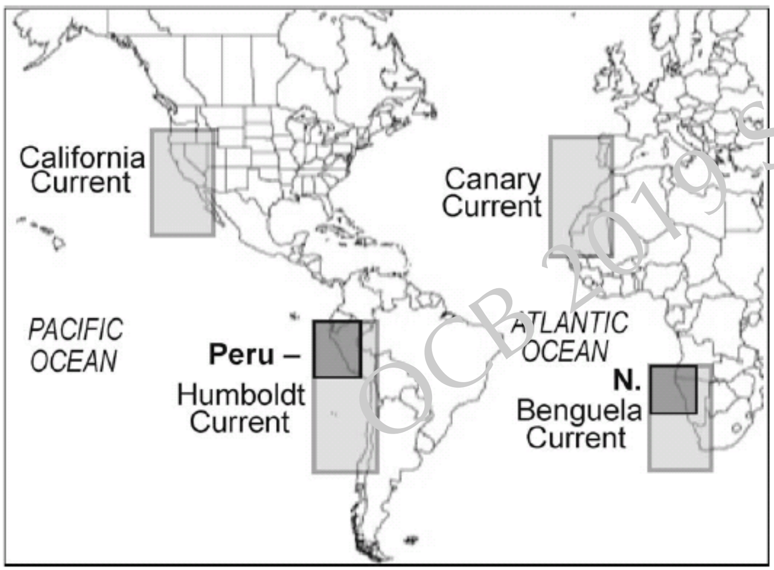
Oregon State University

OCB Workshop 2019

Research Area

Physical Domain

- Eastern Boundary Current System
- Northern California Current
- Narrow Shelf <50 km wide



Highly productive ecosystems supporting major fisheries

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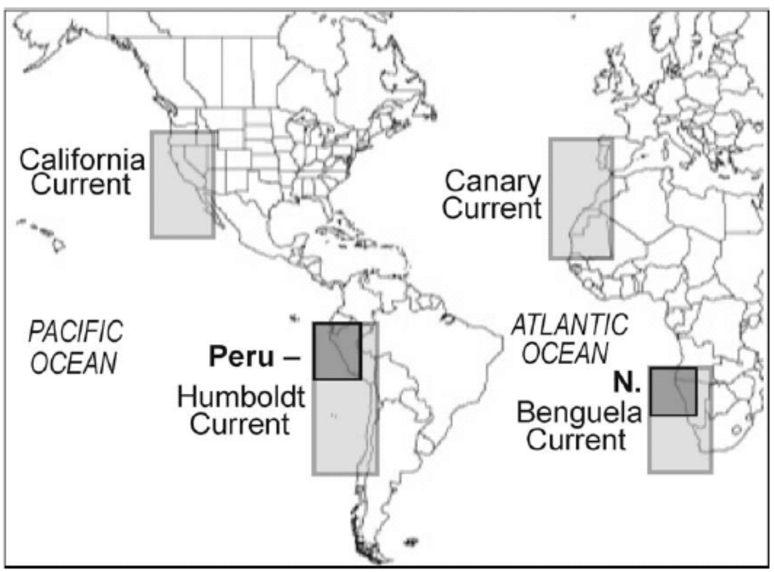

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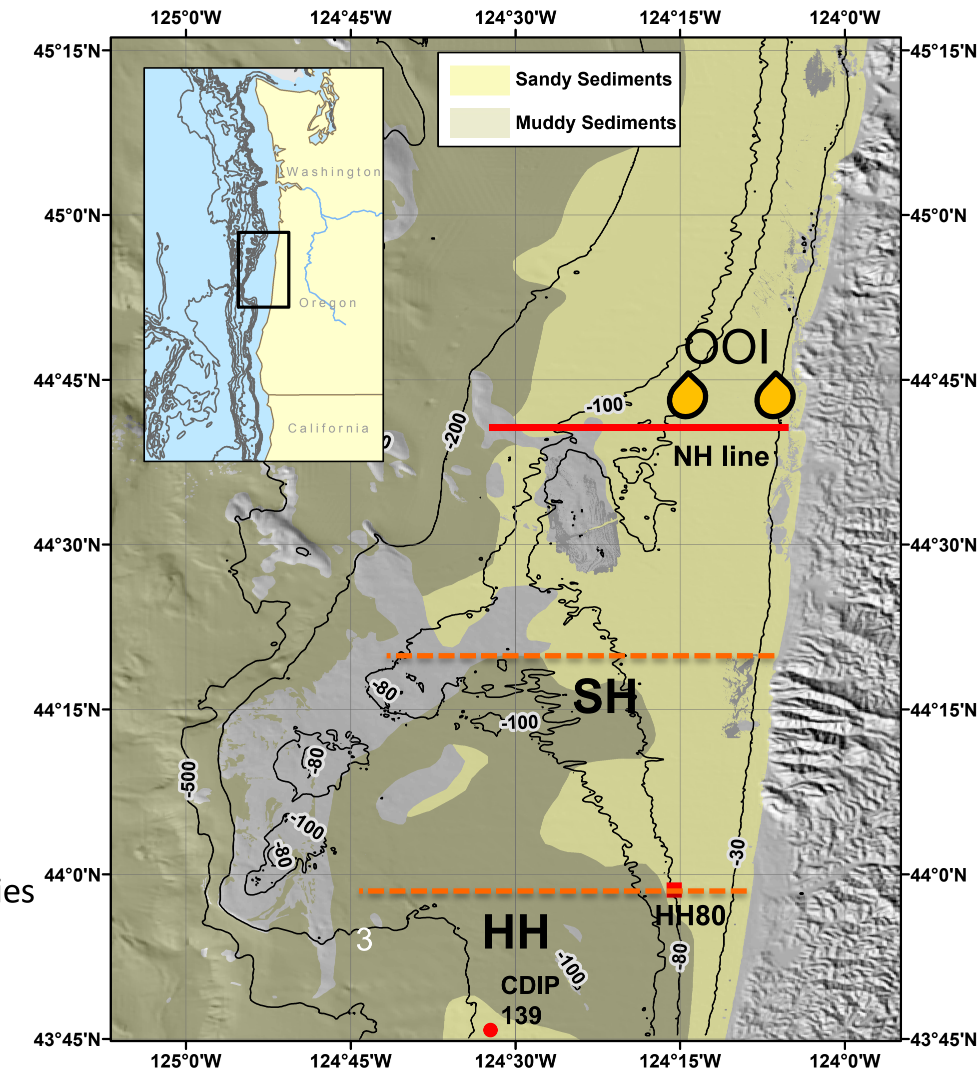
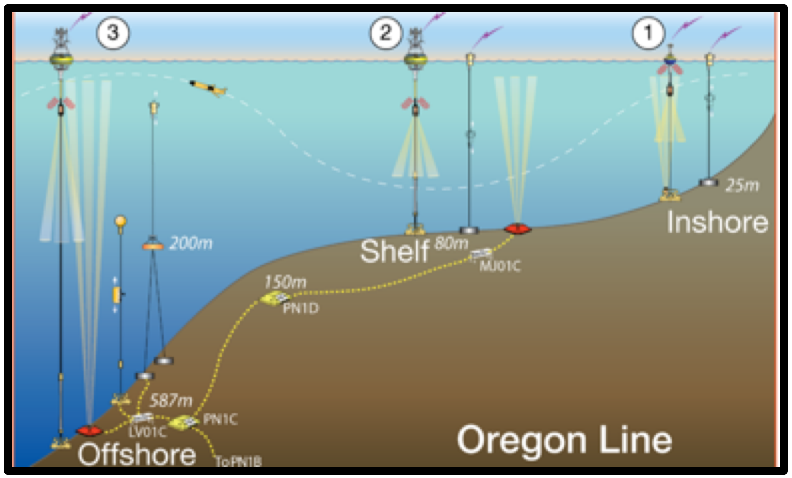
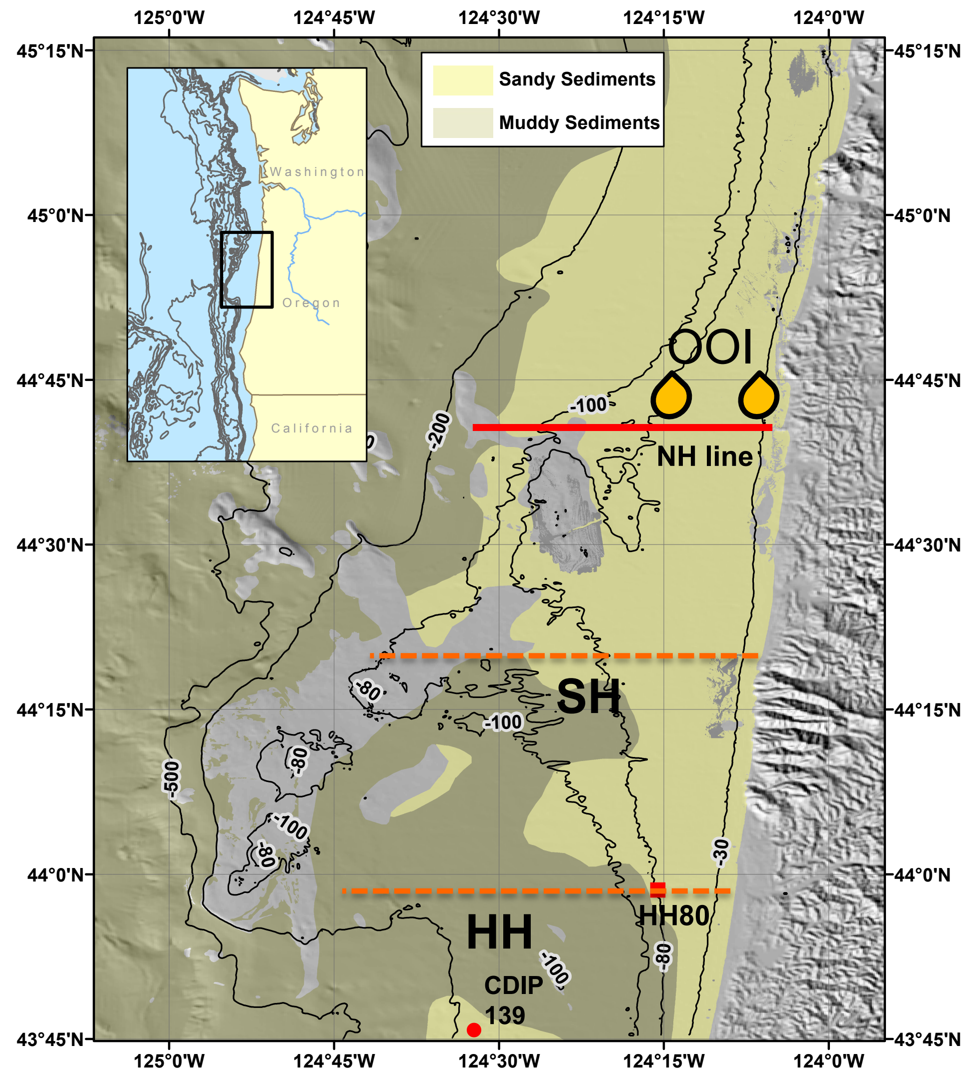


Research Area

Study Sites

- Newport Hydrographic Line
- Inner Shelf and Mid Shelf
- OOI Endurance Array





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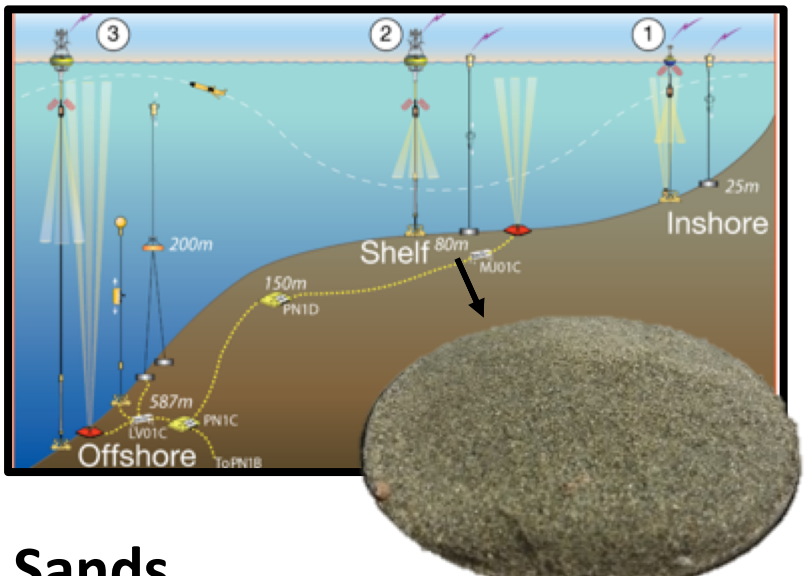
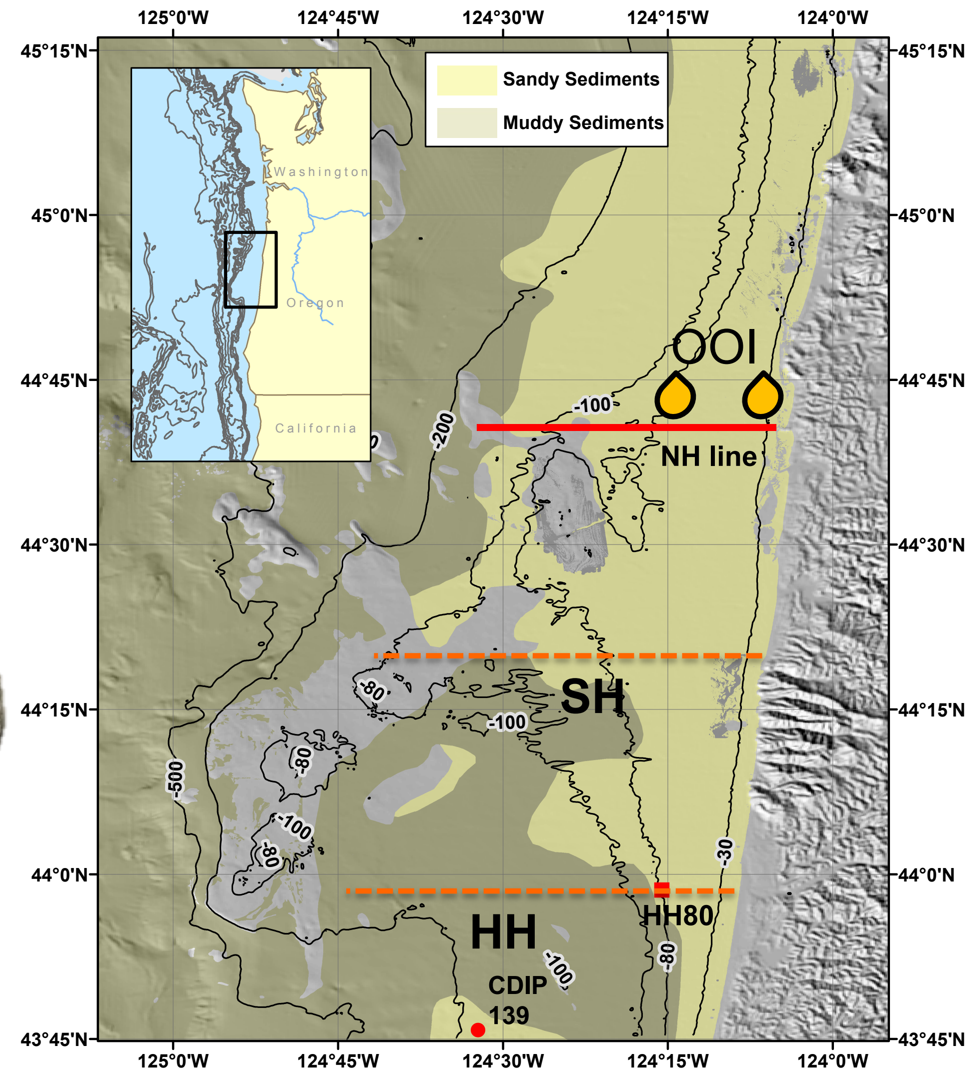
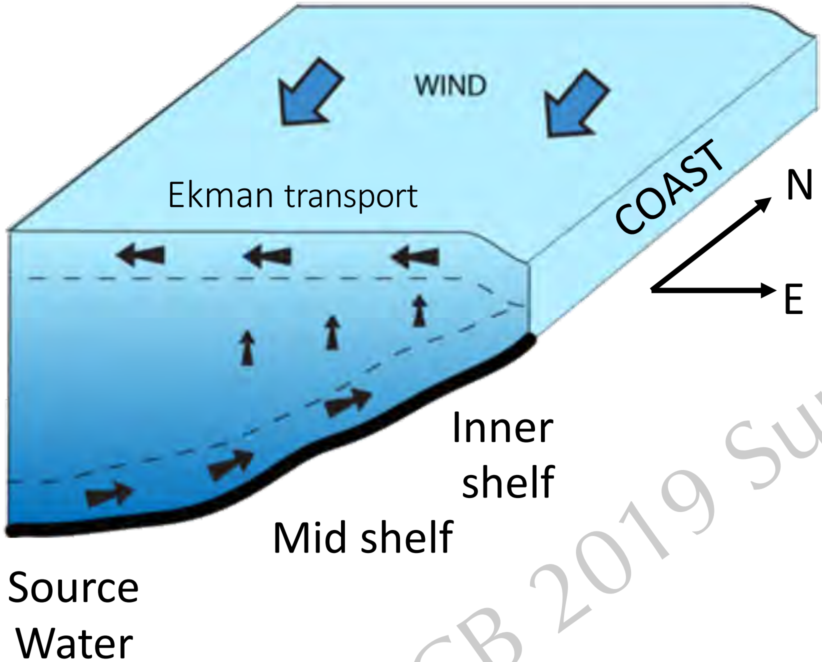




Sands

- Permeable sediments
- Subject to advective flows
- Act as filters
- Enhanced solute exchange

Oregon Shelf Coastal Upwelling & Oxygen



Hypoxia Defined

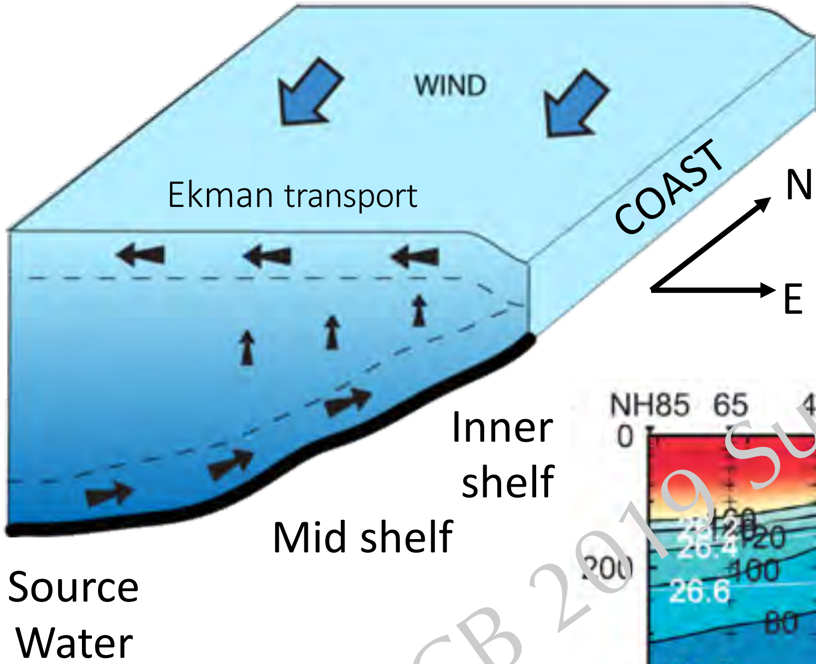
2 mg L^{-1}

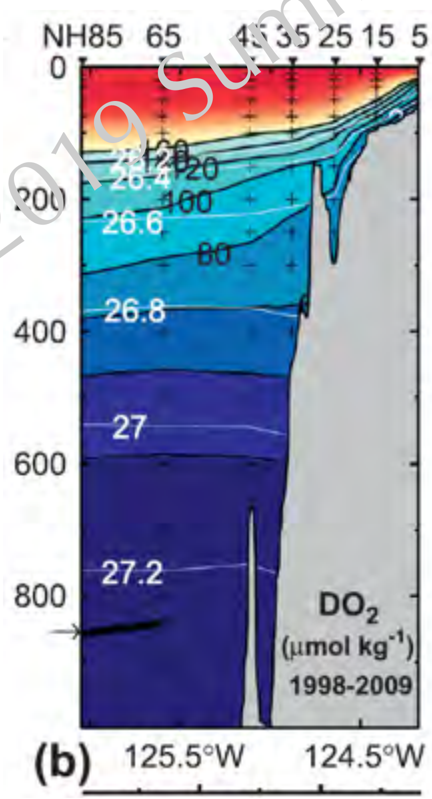
1.4 ml L^{-1}

62.5 µM

60 µmol kg^{-1}

Oregon Shelf Coastal Upwelling & Oxygen





Pierce *et al.*, 2012

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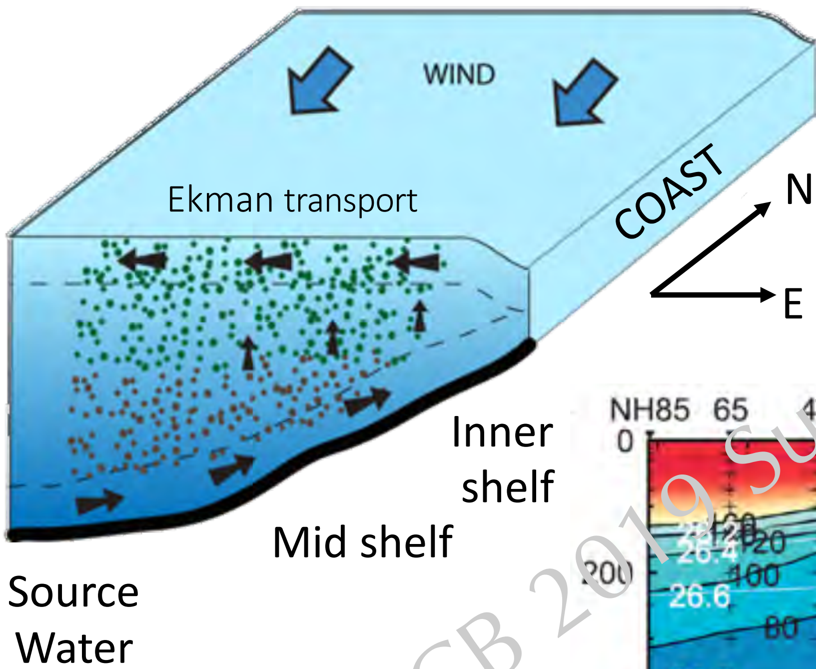

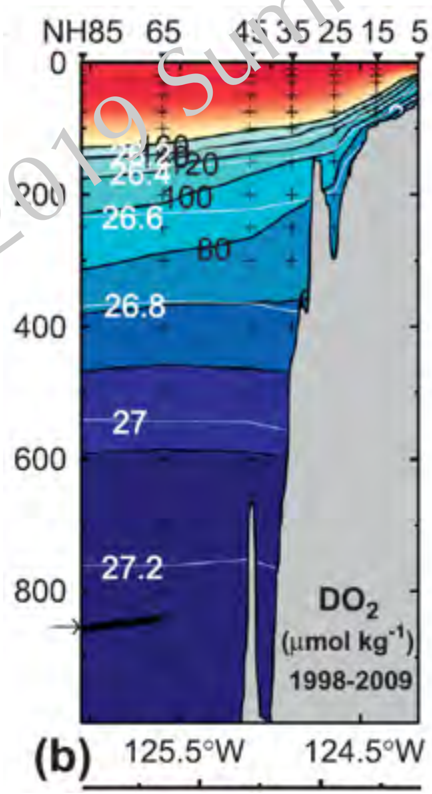

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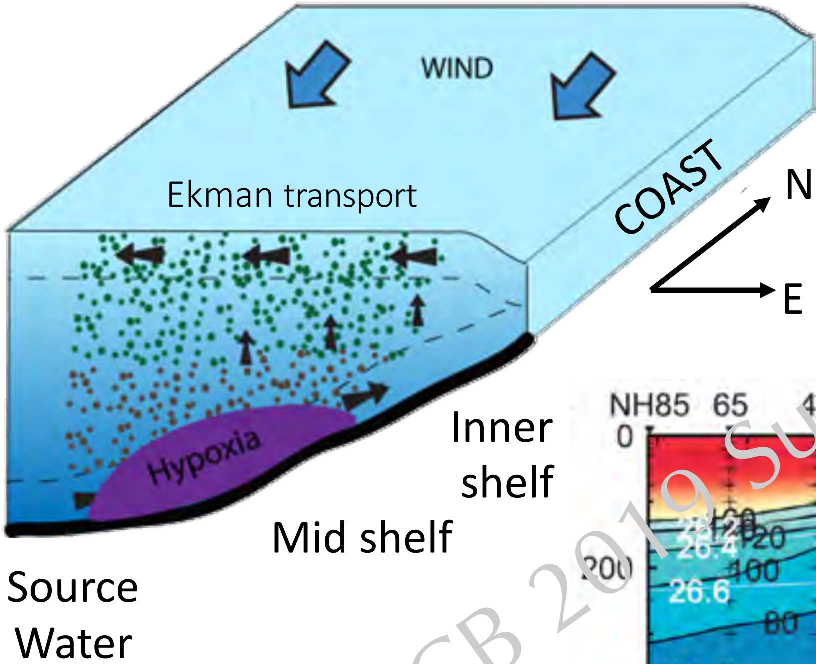

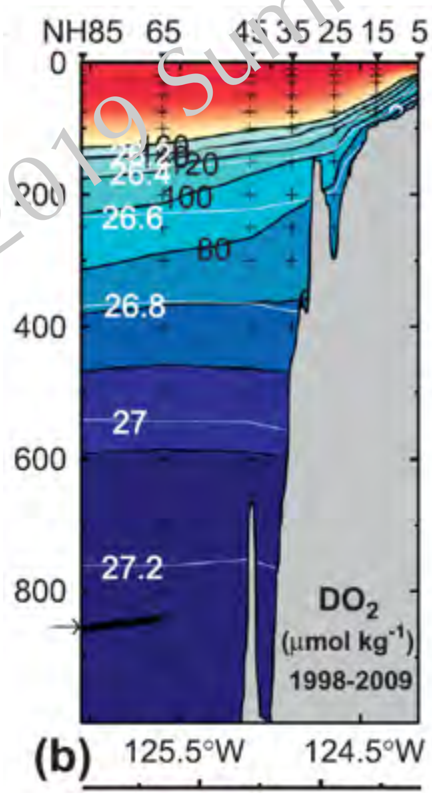

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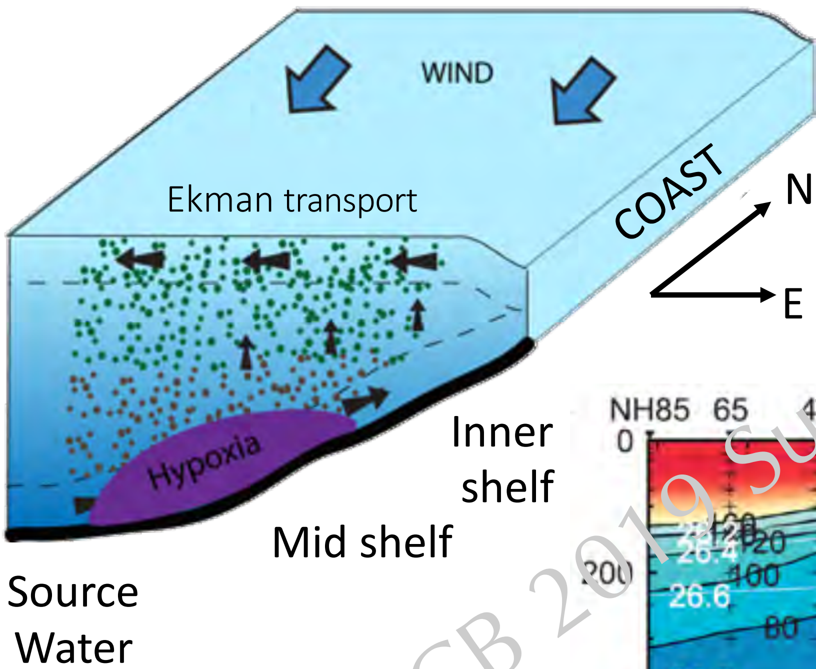

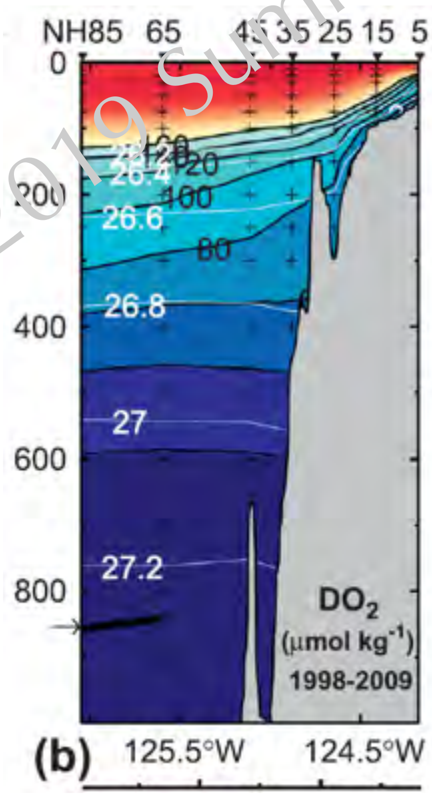

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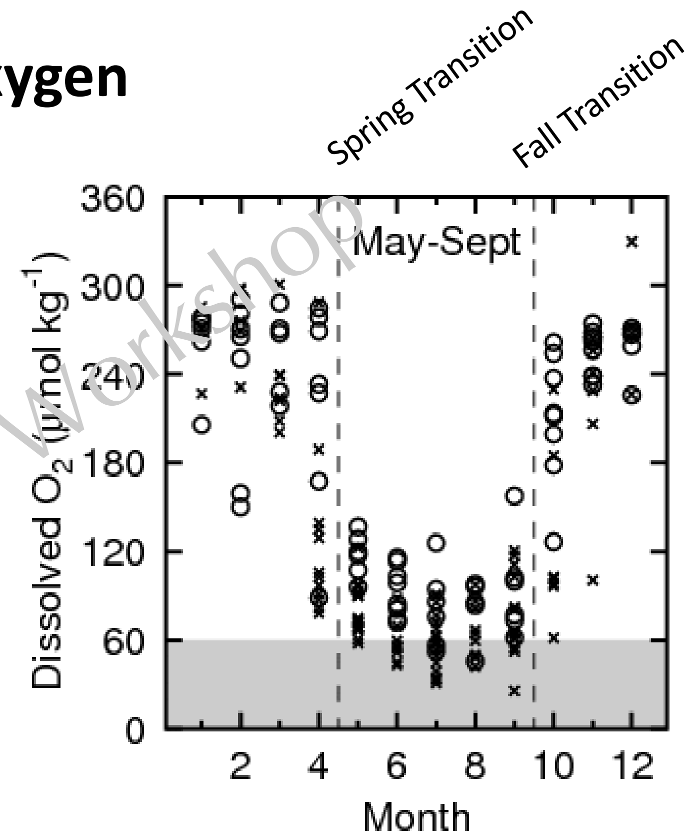

O = 1960–1971
X = 1998–2009

Pierce *et al.*, 2012

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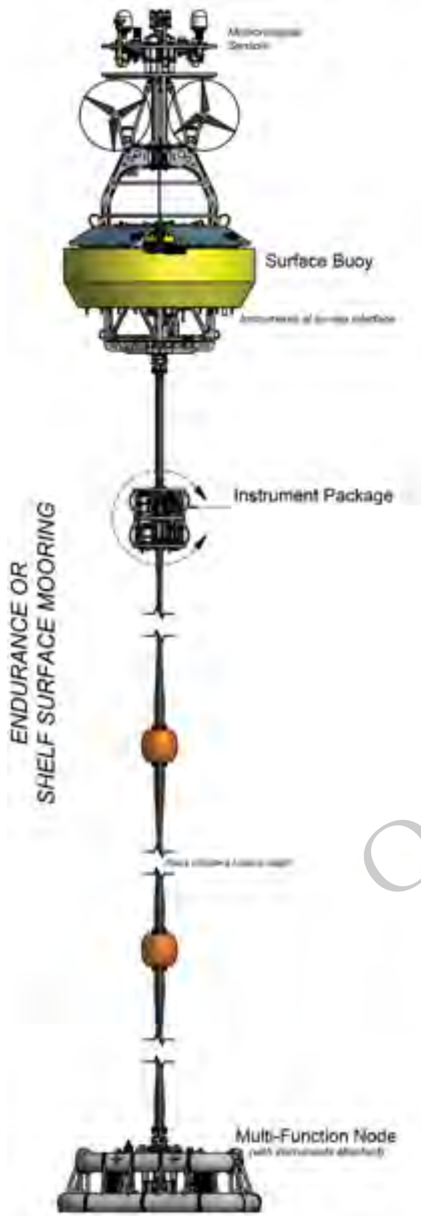
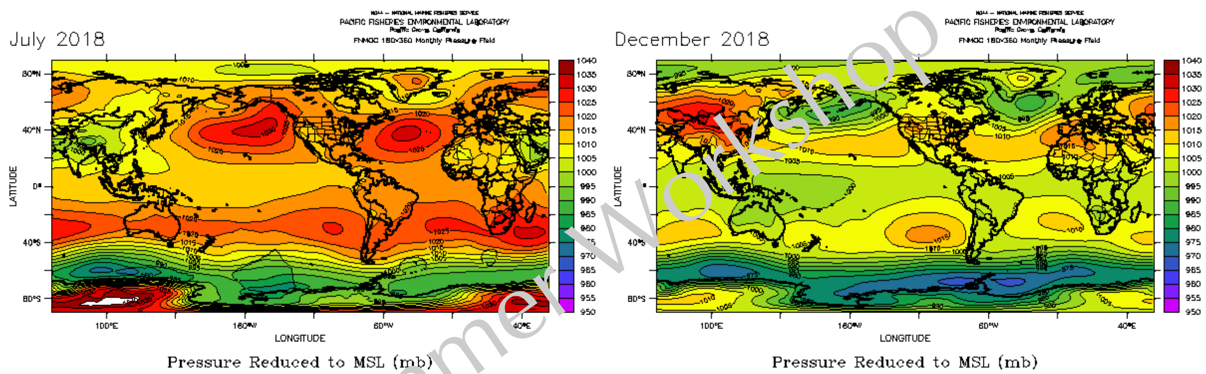
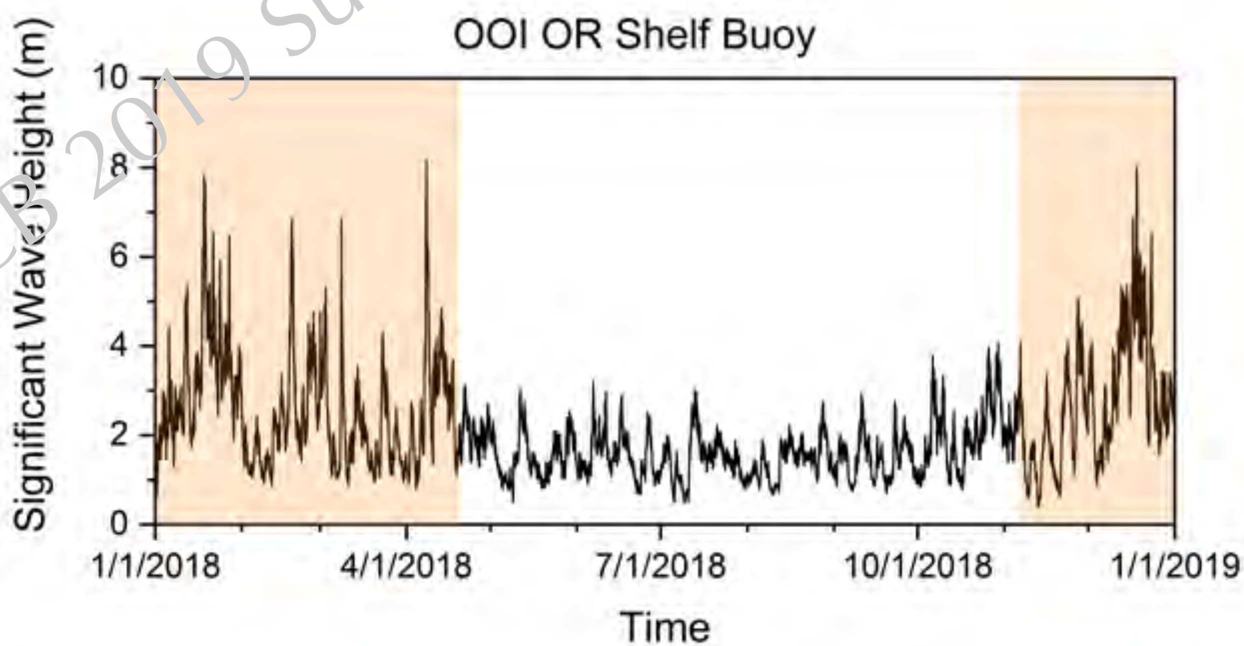
Seasonal Wave Energy



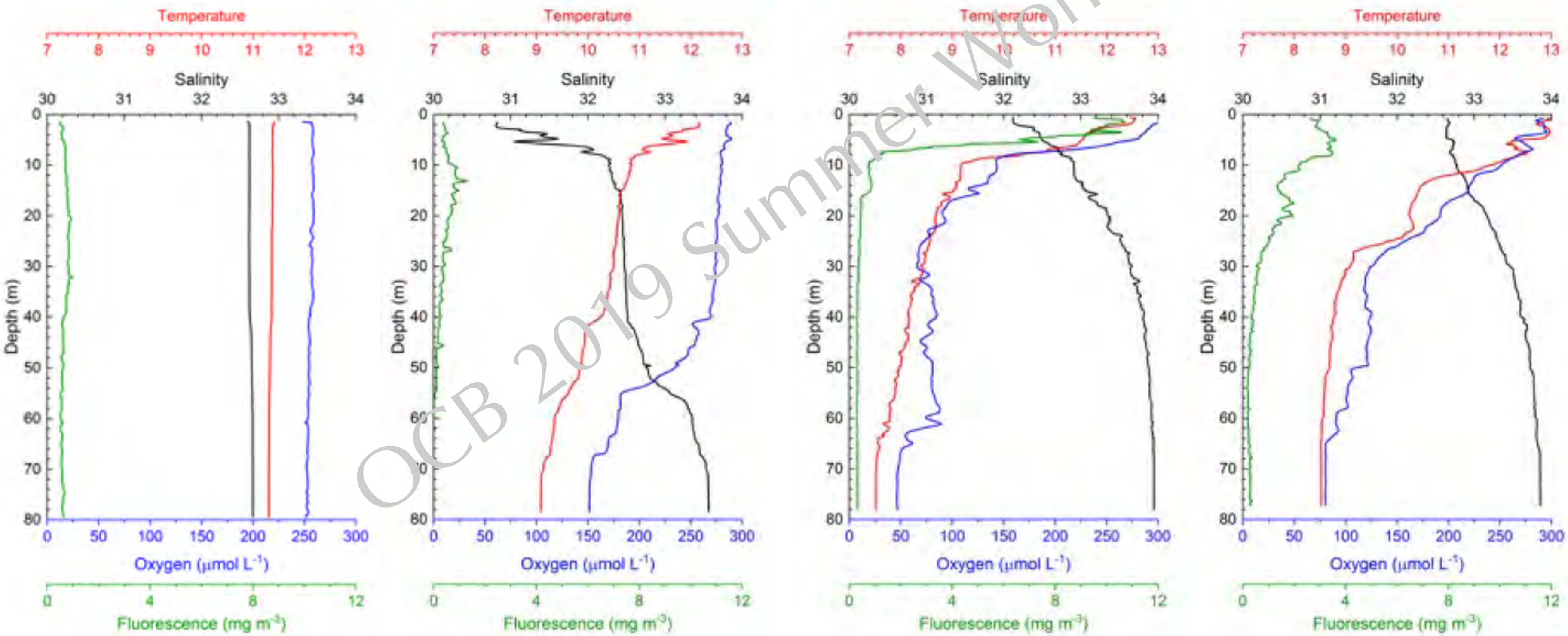




Water Column Signatures of Seasonal Dynamics

2018-2019

WINTER (JAN) SPRING (APR) SUMMER (JUL) FALL (OCT)



Effects on marine life: Dead Zones

Healthy rockfish

'Dead Zone' Causing Wave Of Death Off Oregon Coast
ScienceDaily 14 Aug 2006

Dead rockfish & crabs

Grantham *et al.* 2004

Summary of effects of reduced oxygen concentrations on marine organisms

Type of organism	Effect	Conc. (mg l^{-1})
Actively swimming fish	Growth	6
Actively swimming fish	Metabolism	4.5
Bottom-living fish	Metabolism	4
Most fishes	Mortality	2
Crabs, shrimps, lobsters, isopods	Growth	2–3.5
Bottom-living isopods	Mortality	1–1.6
Bivalve molluscs	Growth	1–1.5
Annelids	Growth	1–2
Mudskippers	Mortality	1

Gray *et al.* 2002

OREGON Fish & Wildlife

Research Questions

1. Is there seasonal variability in benthic oxygen utilization?

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2. What is the contribution of sediment oxygen utilization to conditions of hypoxia on the Oregon Shelf?
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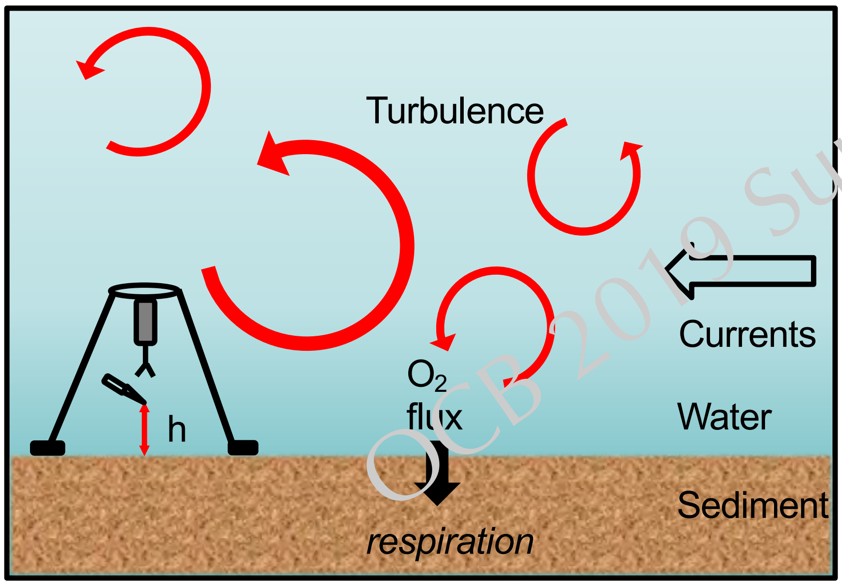
2017-2019 Field Program

Ten cruises on R/V Oceanus

Sampling in Jan (2), Feb, Apr, May, July (2), Aug, Oct, Dec

Approach for Oregon's Shelf

Aquatic Eddy Covariance
a water-side approach to flux measurements



$$\overline{Flux} = \left(\overline{w'c'}\right)_h$$

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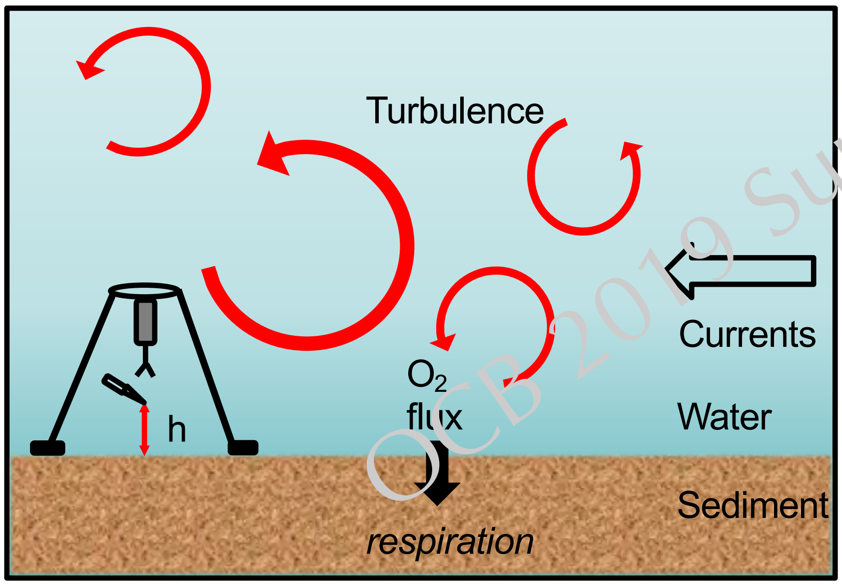

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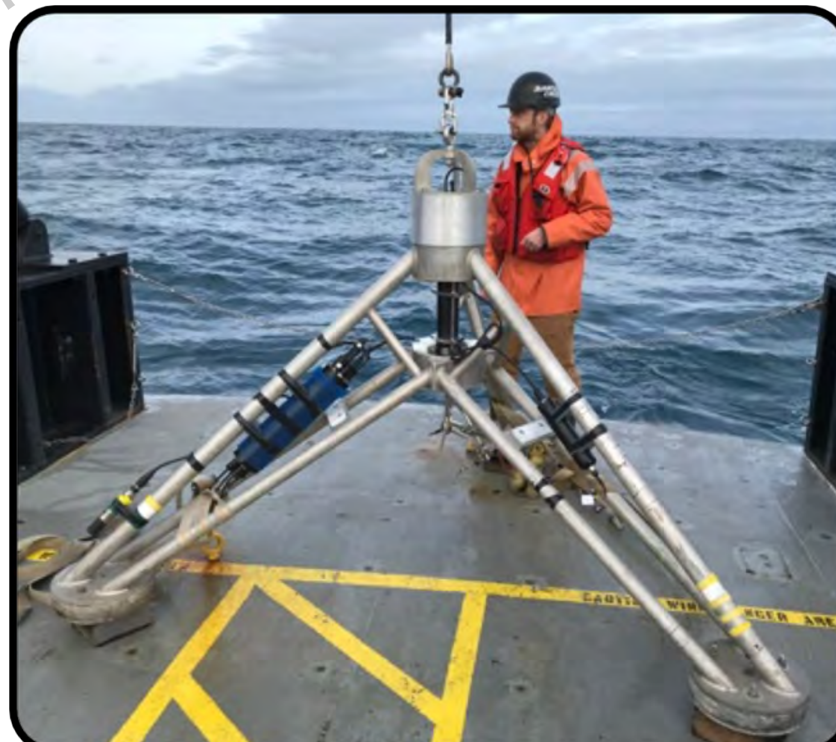

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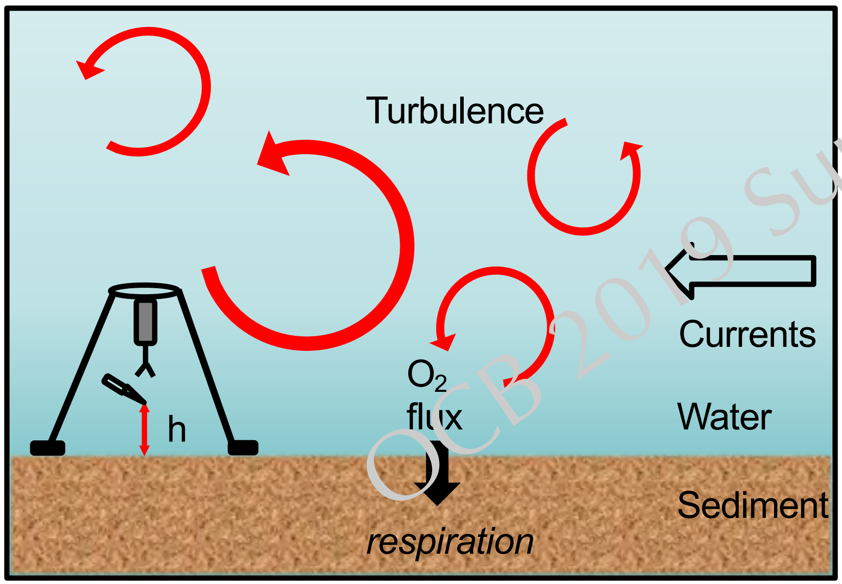

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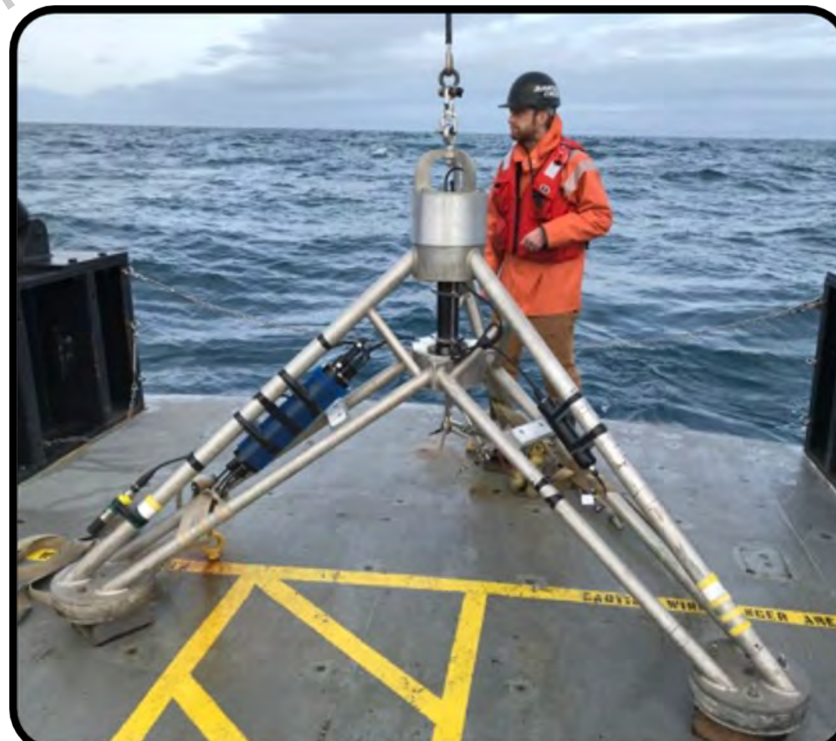
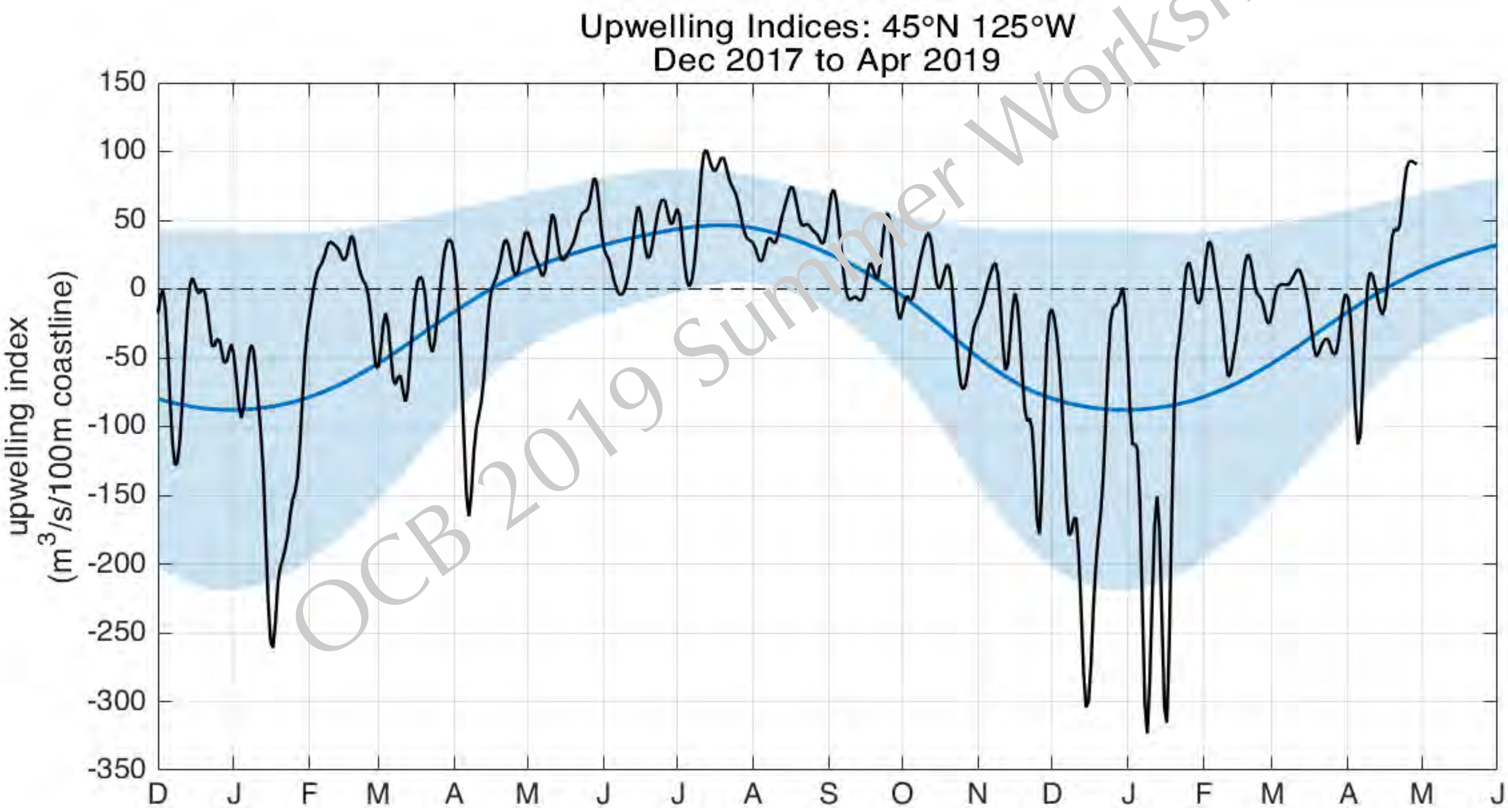
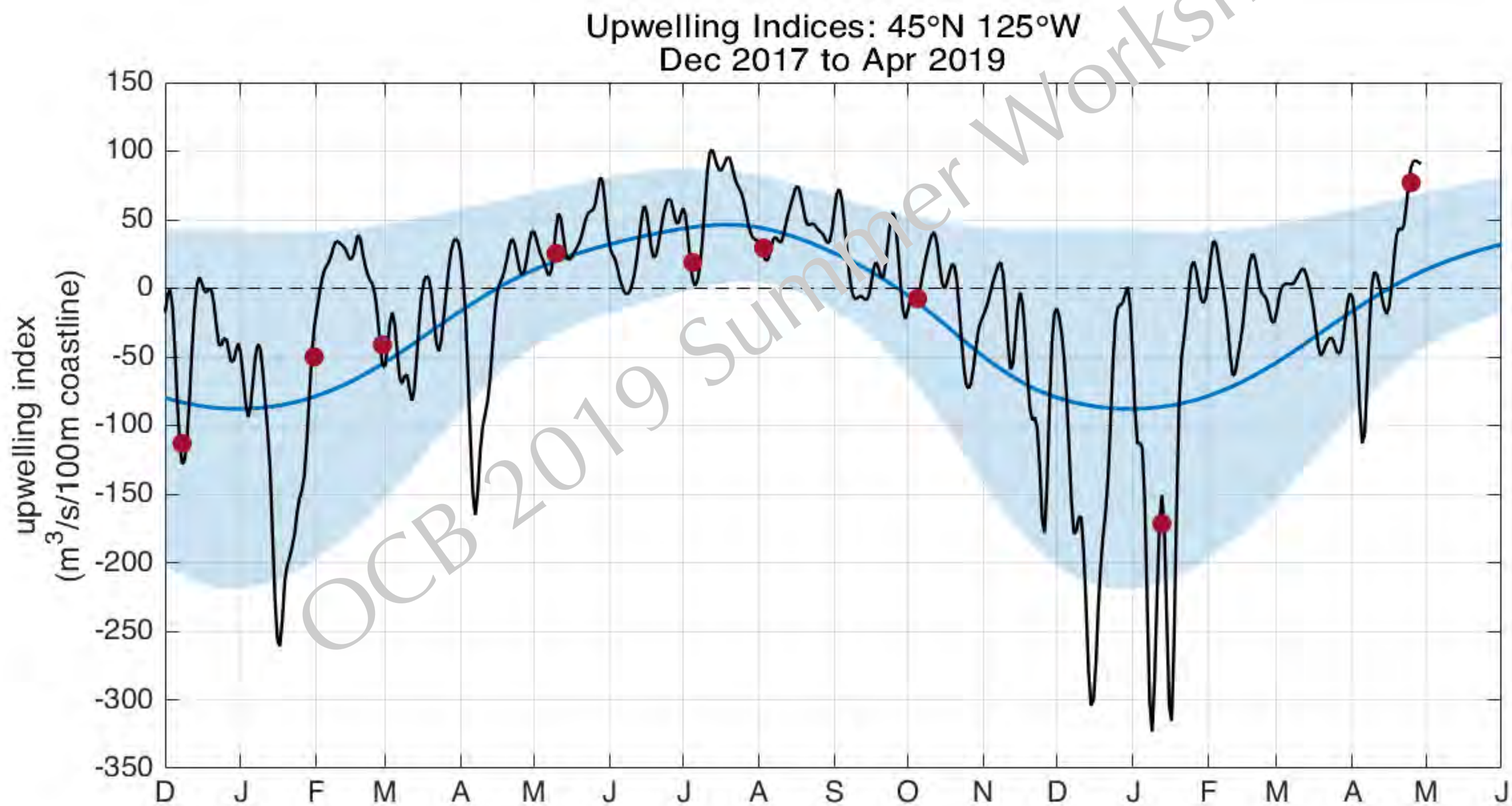


Oregon Shelf Coastal Upwelling



Data from Pacific Fisheries Environmental Lab

Oregon Shelf Coastal Upwelling



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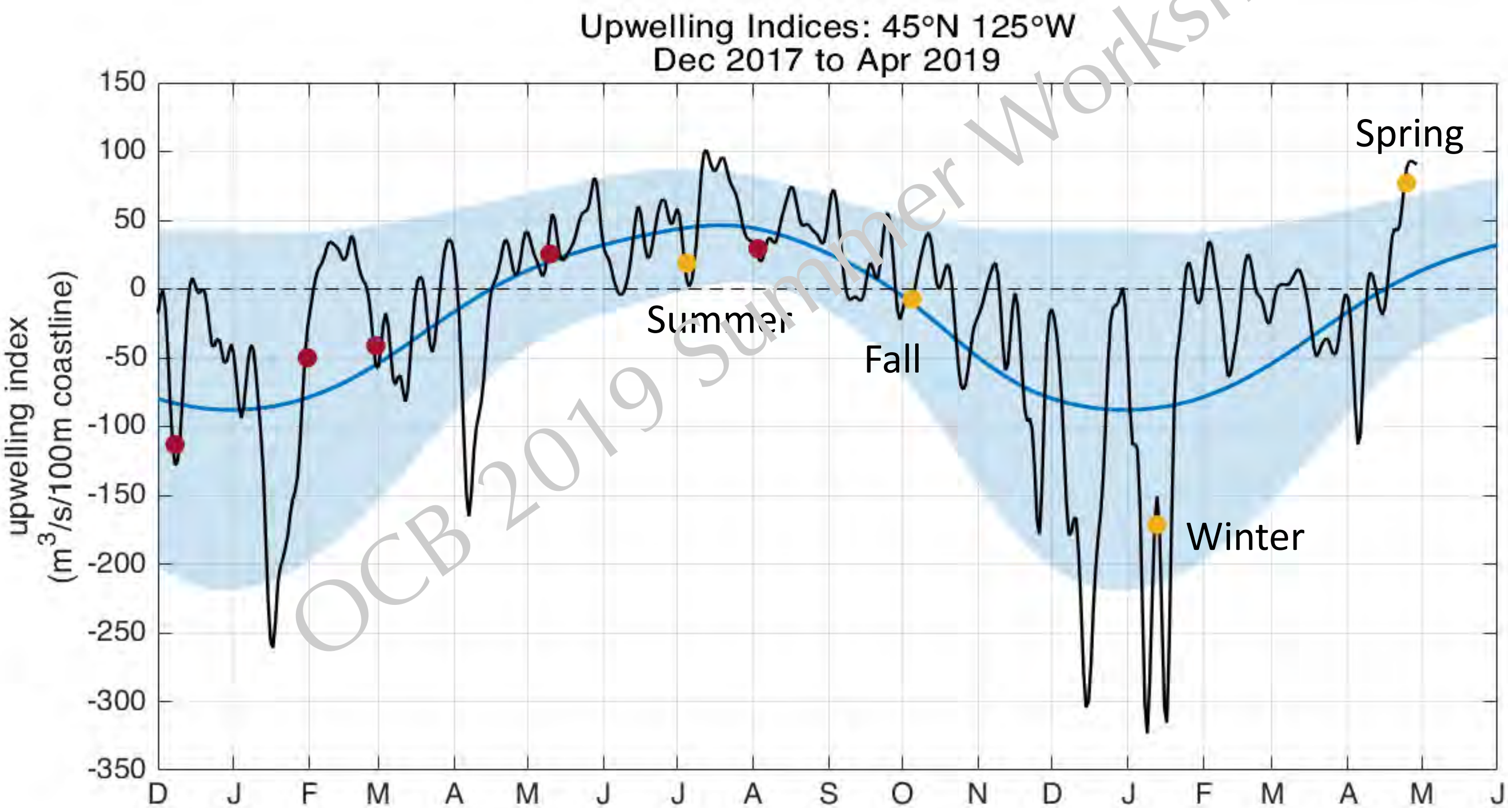

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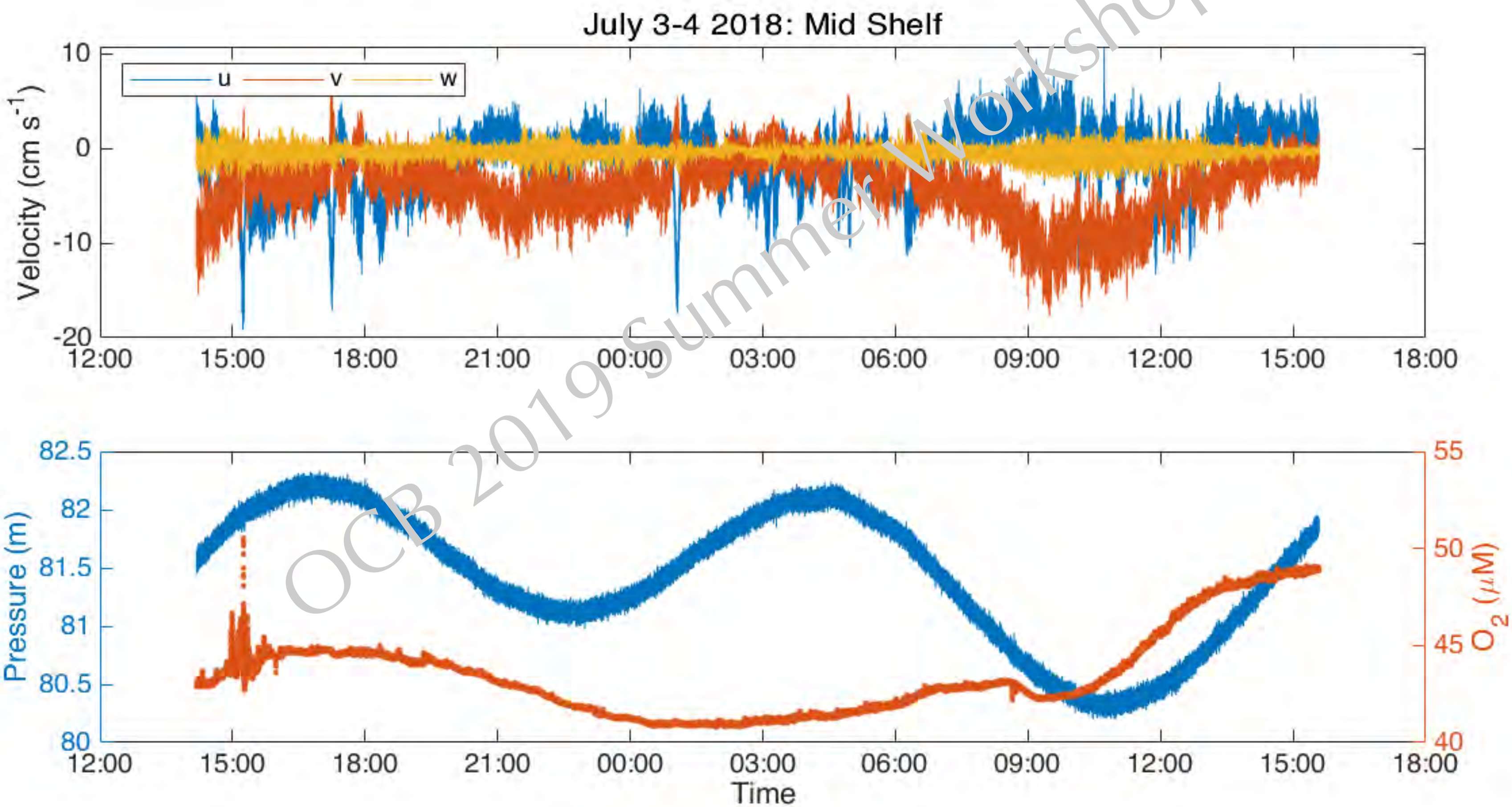
Benthic Metabolism during Hypoxia



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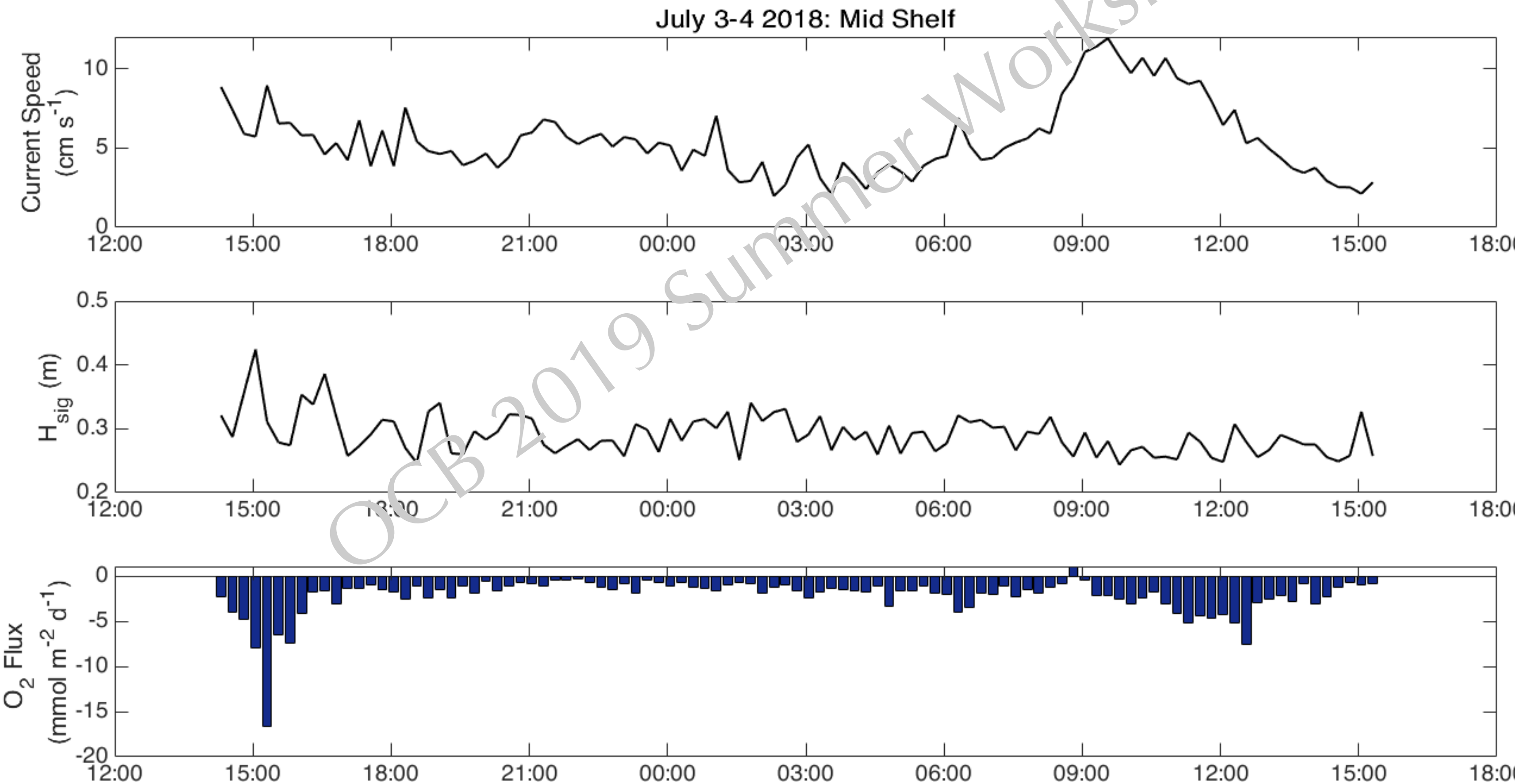

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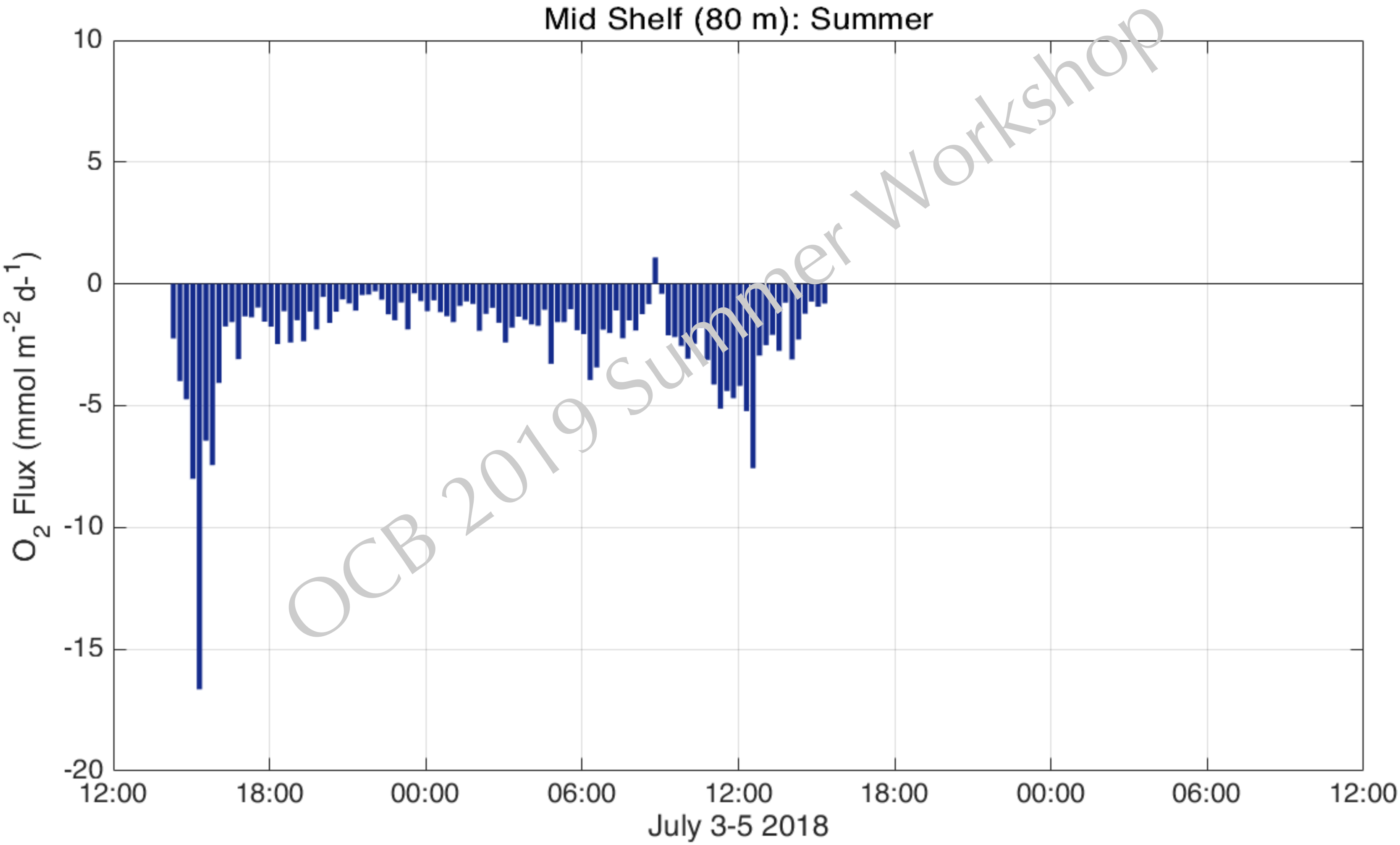

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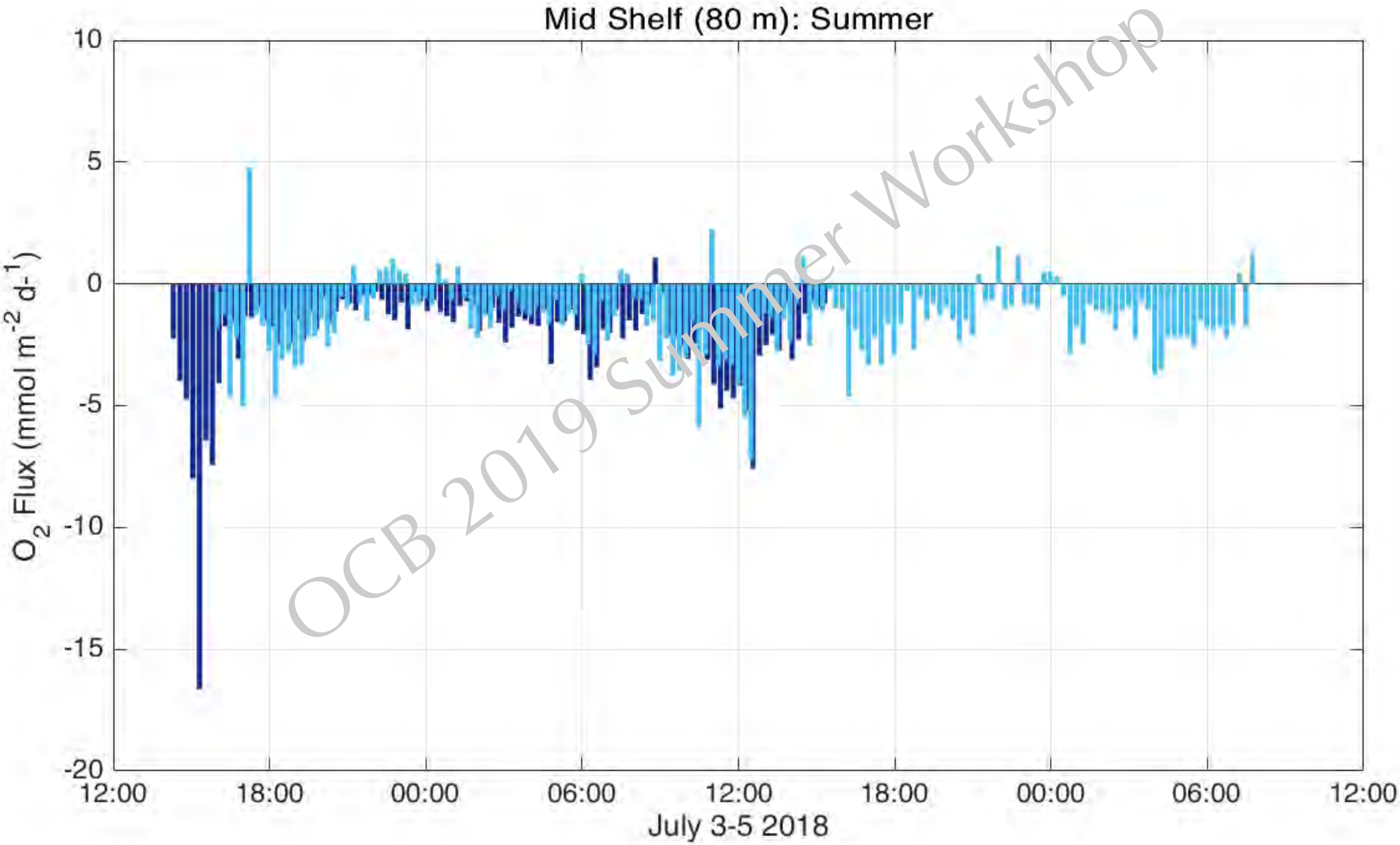
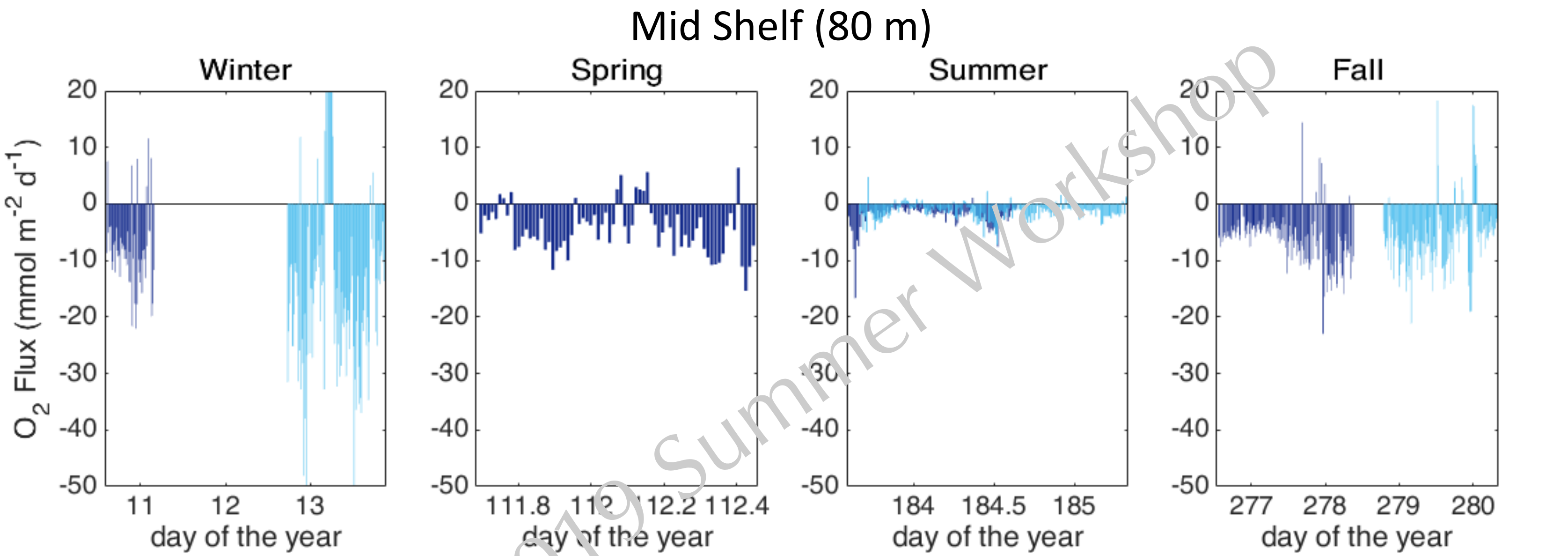


Seasonal Benthic Metabolism



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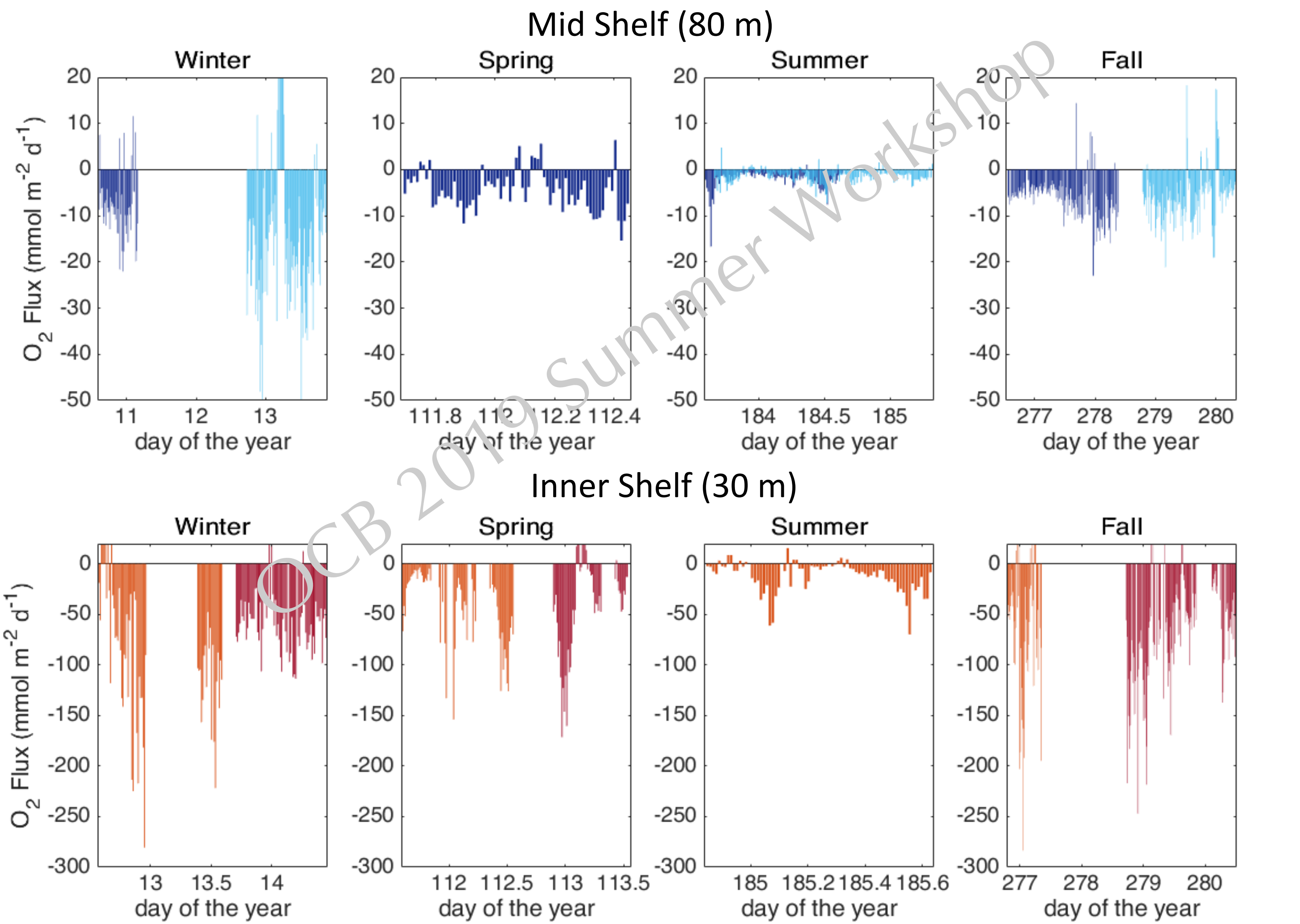
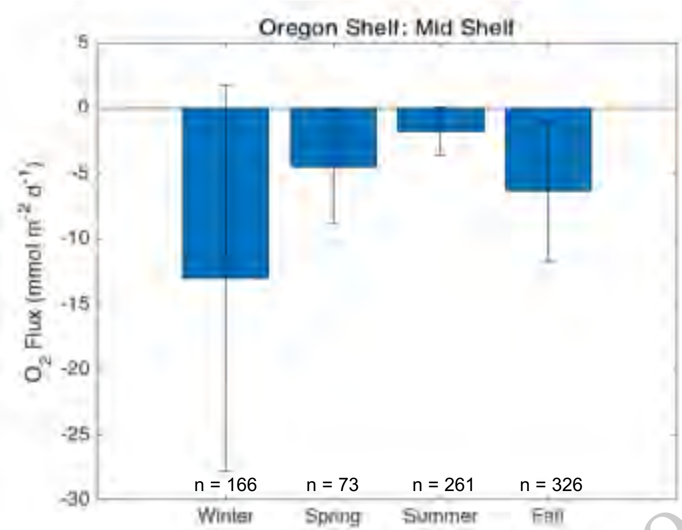
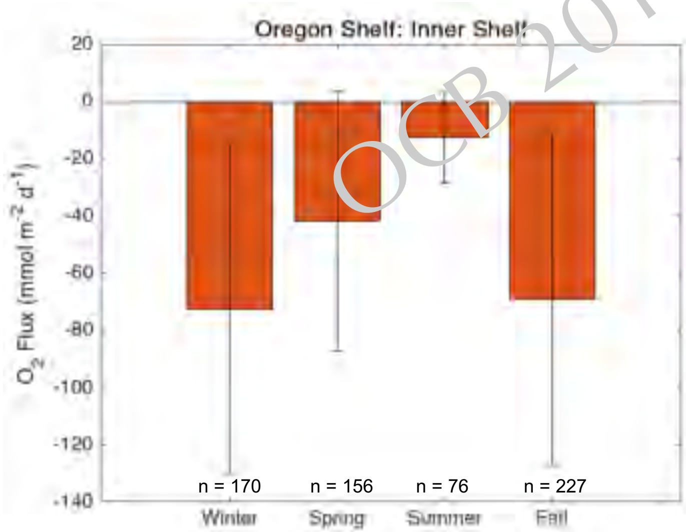
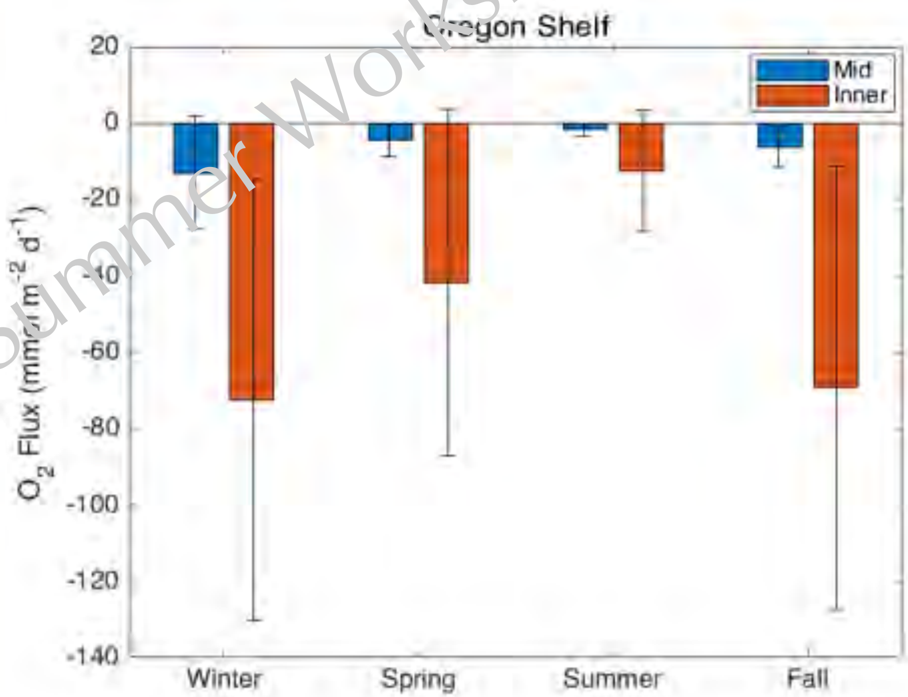


Is there seasonal variability in benthic oxygen utilization?







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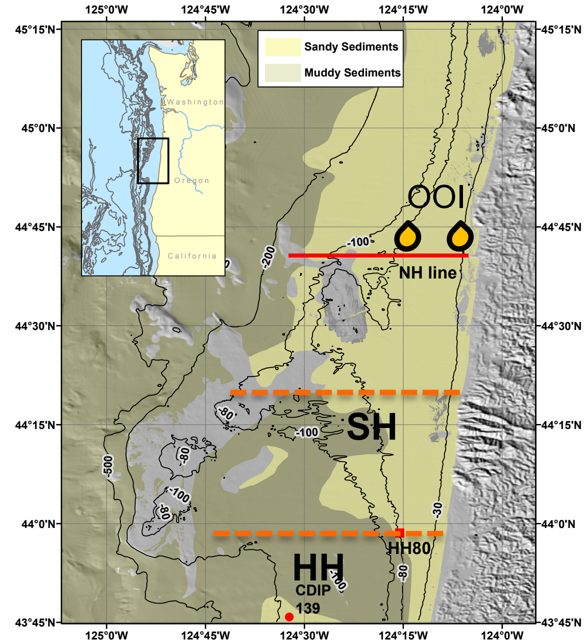

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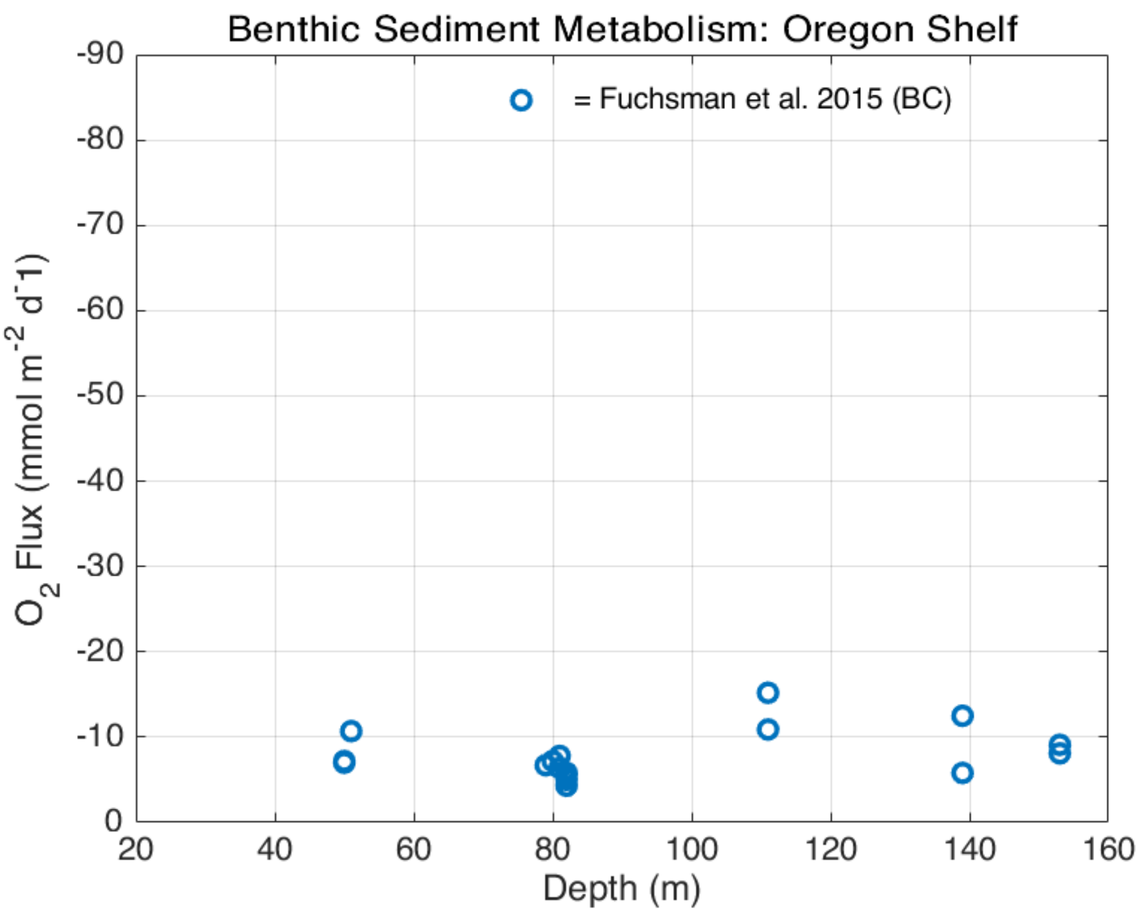

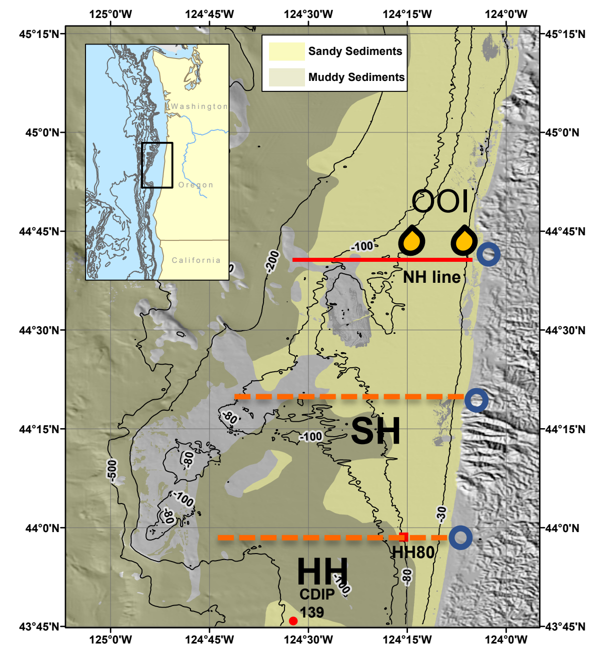

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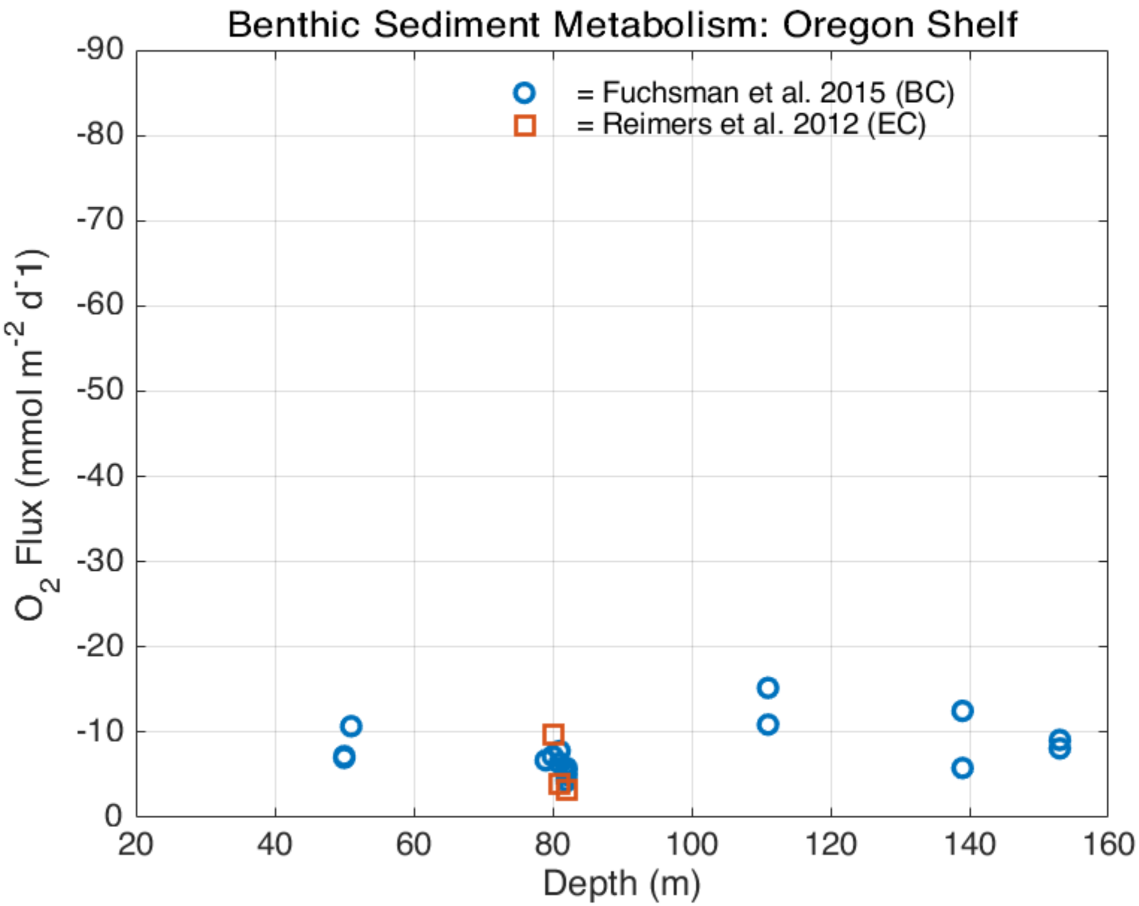

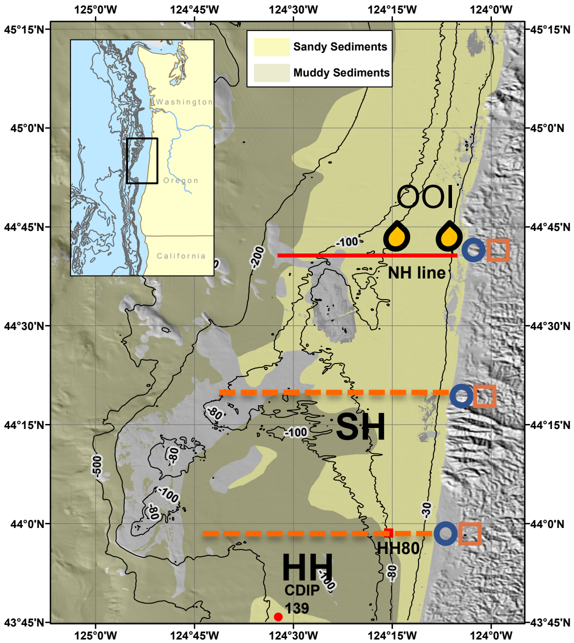

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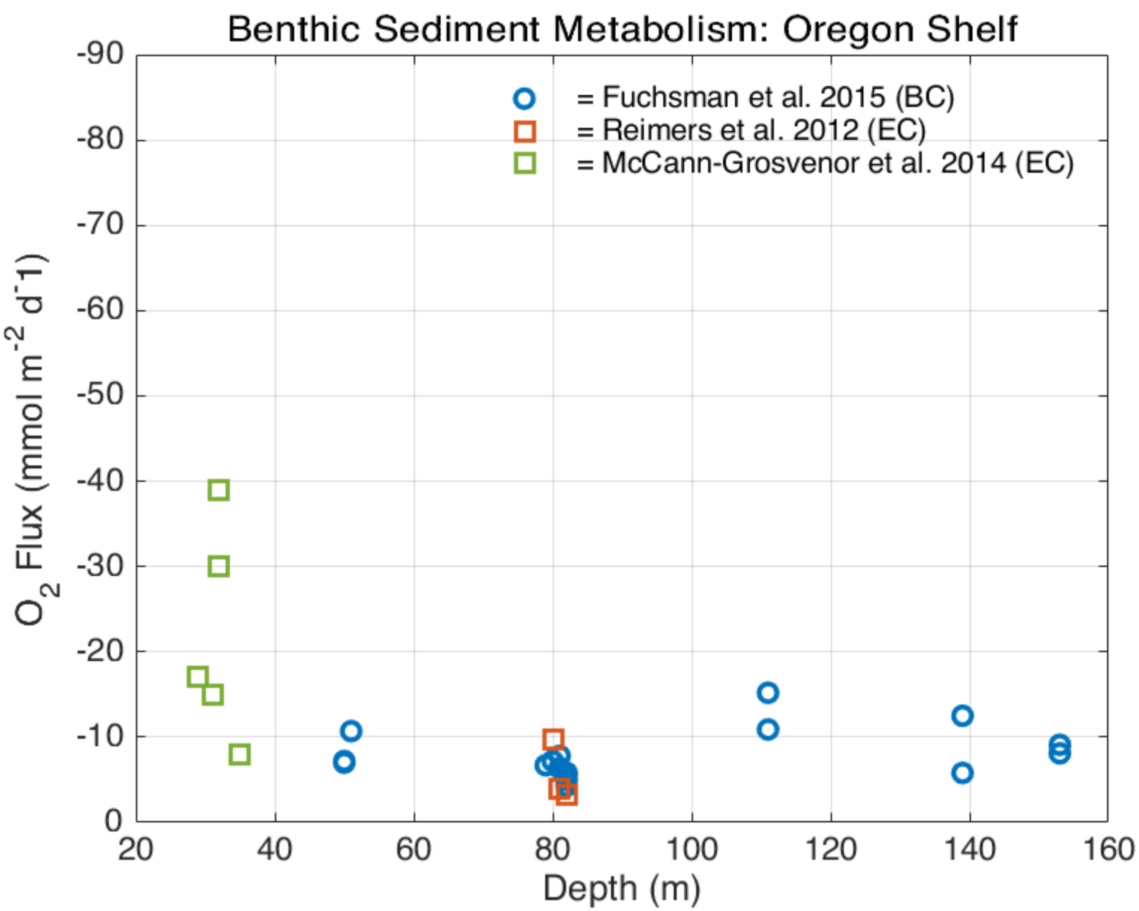

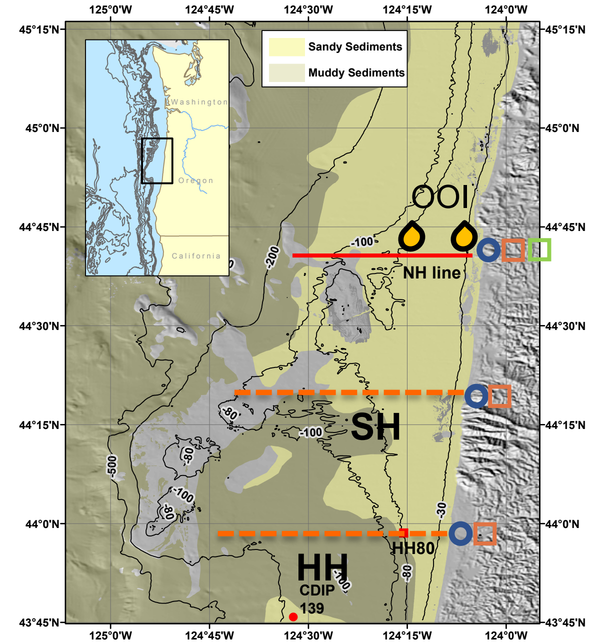

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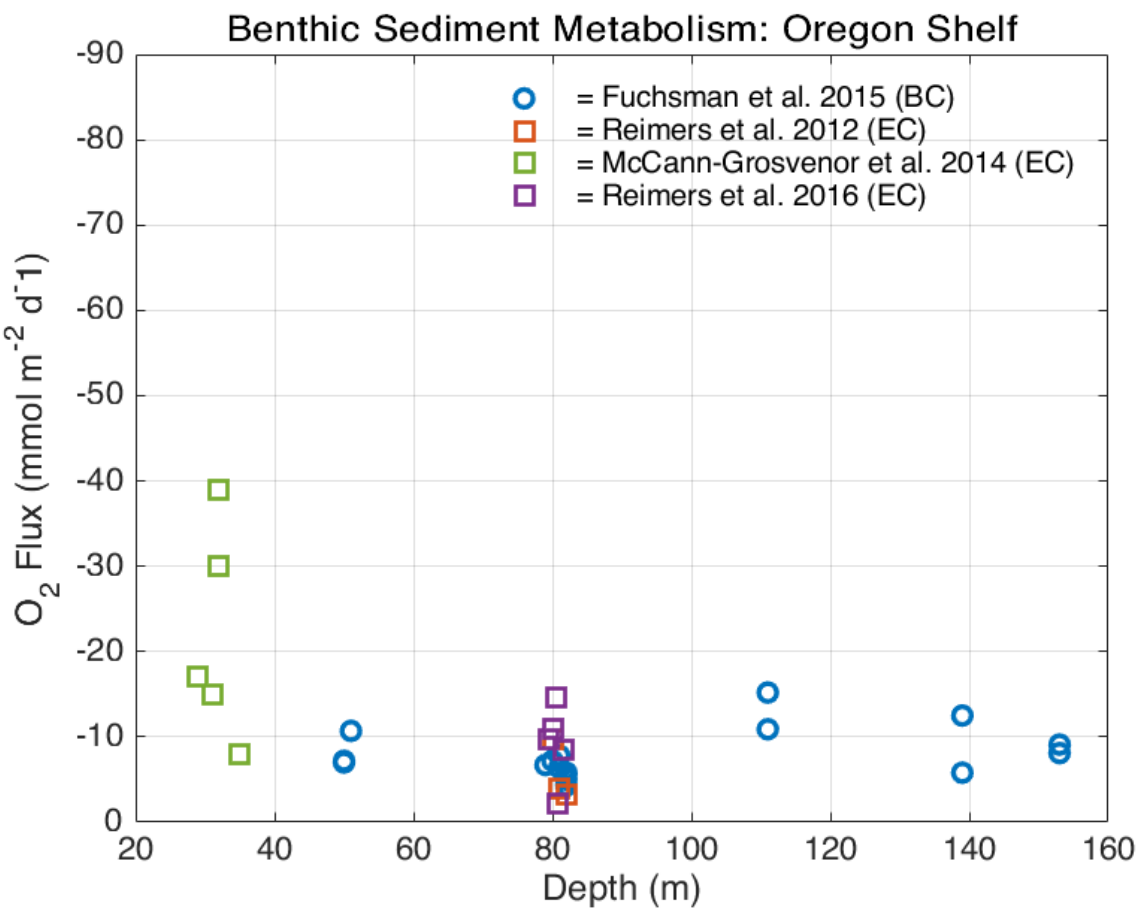

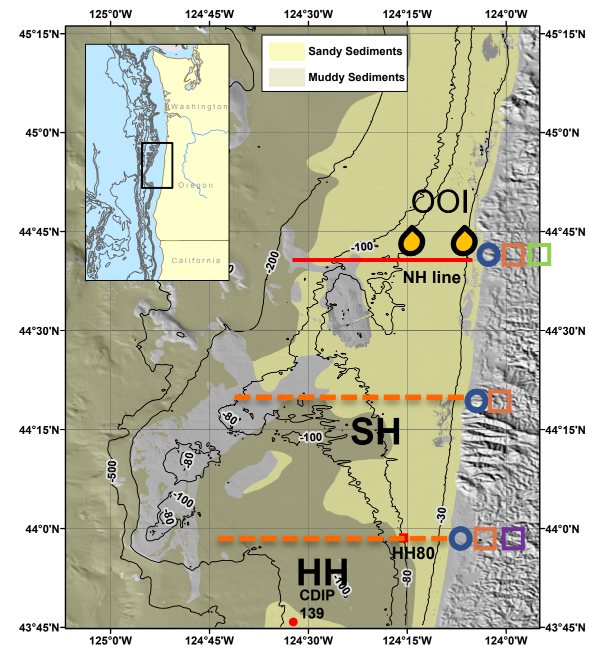

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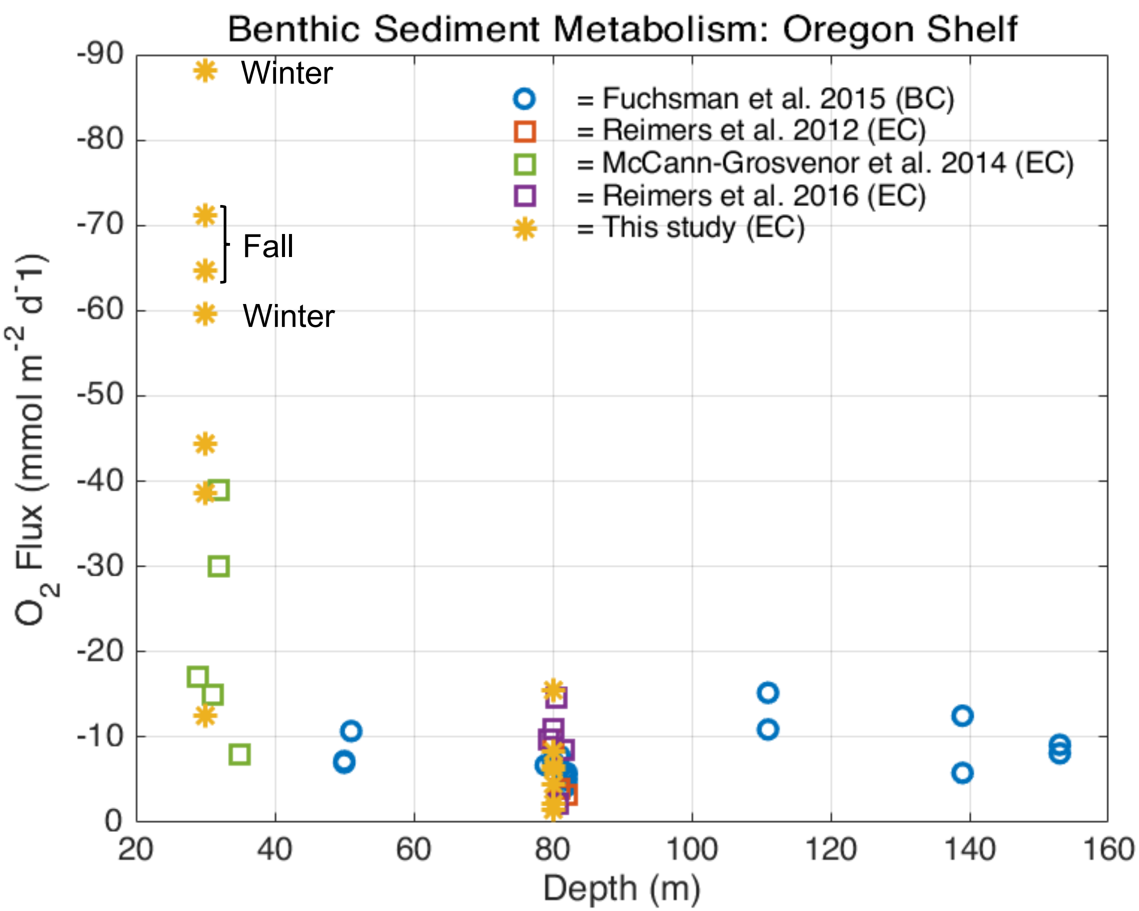

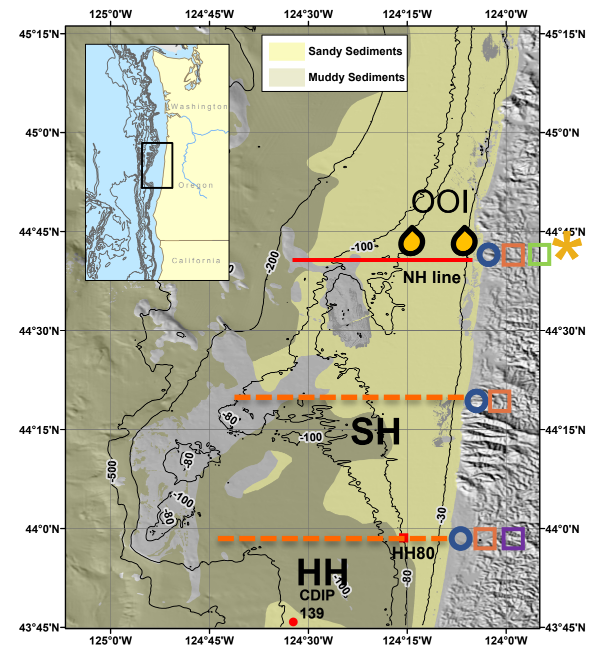

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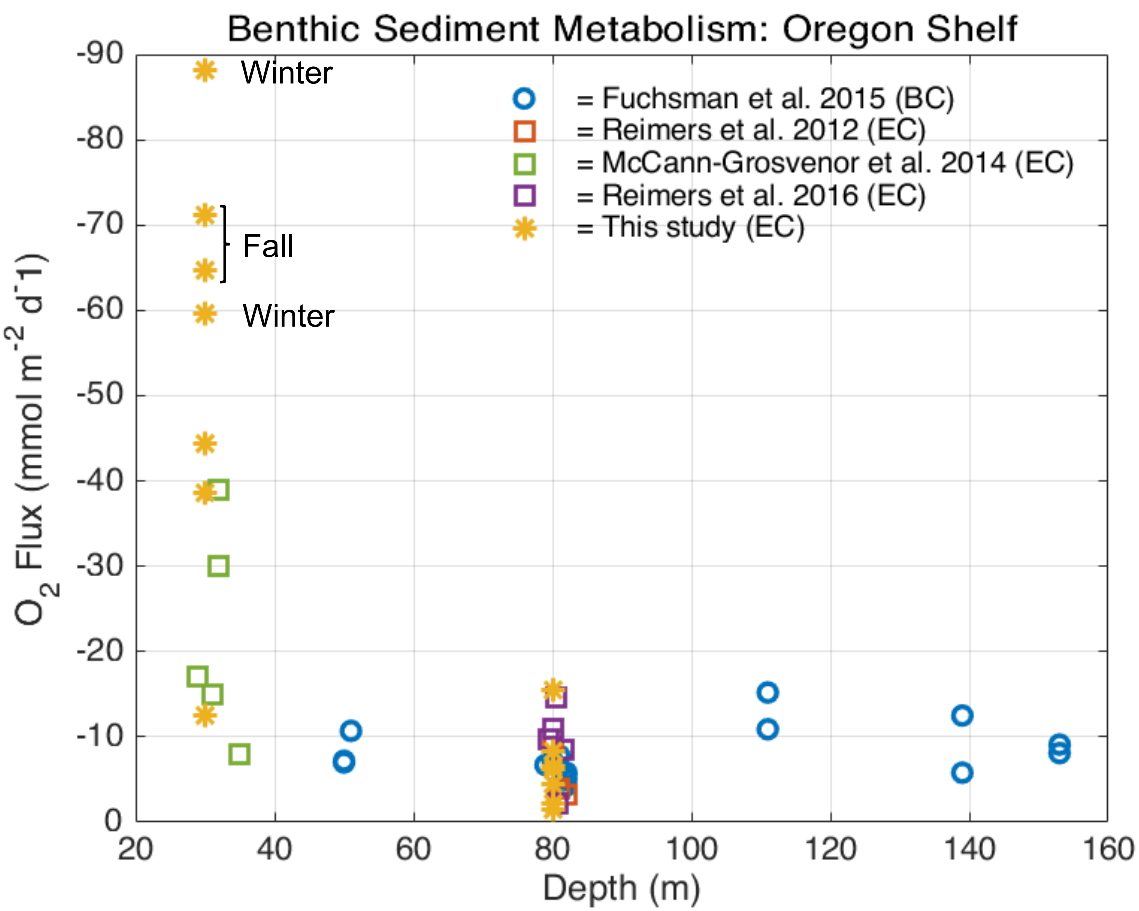

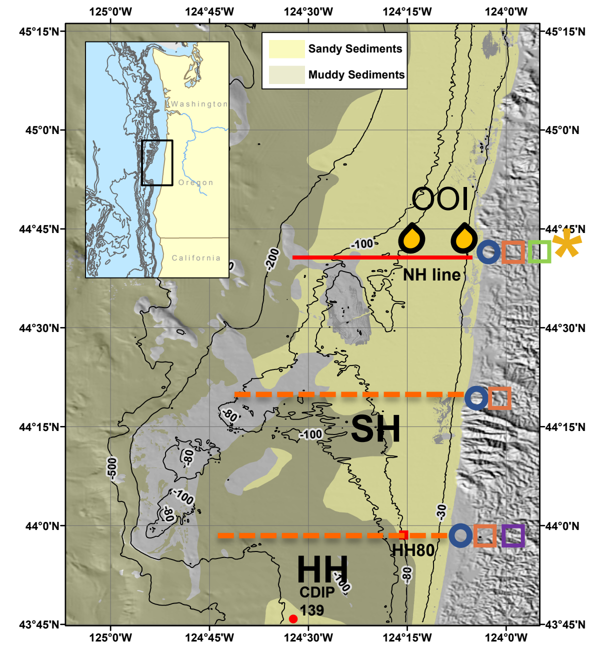

Discussion Idea:
What do these fluxes indicate about organic C fluxes and retention vs. export of organic C from the shelf environment?

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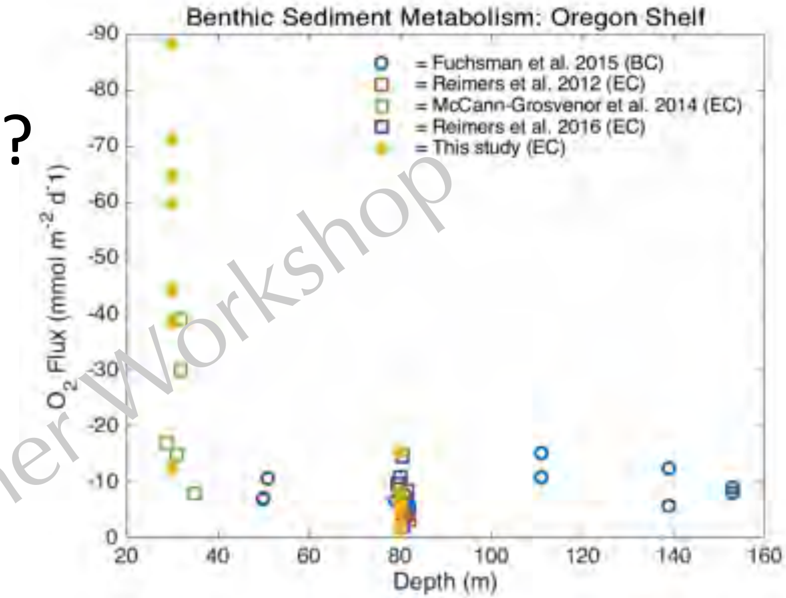


<u>Summer Fluxes</u>

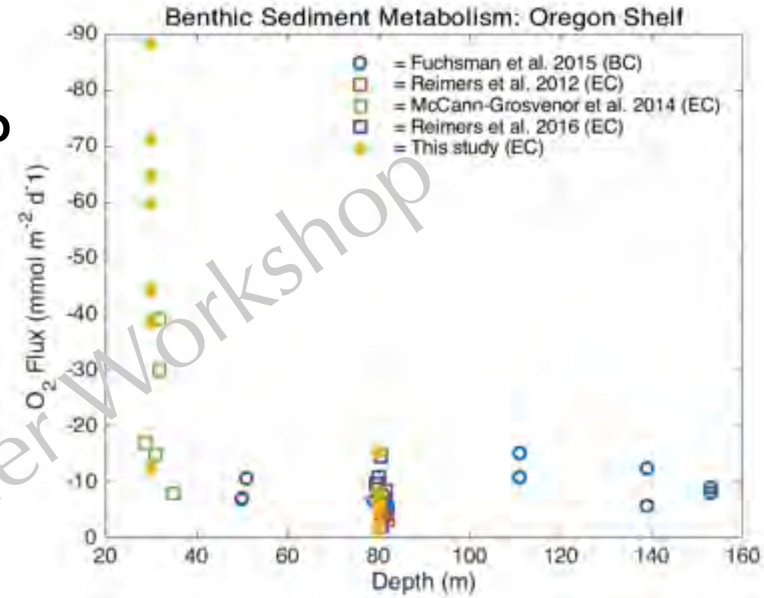
Inner Shelf: -12.5 mmol m^{-2} d^{-1}

Mid Shelf: -1.8 mmol m^{-2} d^{-1}

Oregon shelf	Budget Term	Averaged Over 2005 Upwelling Season	Std Dev (2005)	Averaged Over 2006 Upwelling Season	Std Dev (2006)	Averaged Over 2007 Upwelling Season	Std Dev (2007)	Average (2005–2007)	Interannual Variability (Std Dev)	Percent of (Prod-dO/dt)	Heceta Bank (44–45N,HB) Avg Only (2005–2007)	HB Interannual Variability (Std Dev)
	Primary production	72	18	91	26	94	25	86	12		88	13
	Air-sea gas exchange	−33	16	−33	28	−43	29	−36	6	−31%	−39	5
	Divergence	5	103	3	98	−10	61	−1	8	−1%	0	9
	Total Respiration	−67	11	−85	18	−90	21	−81	12	−69%	−83	12
	Consumption in Water Column	−60	11	−78	16	−83	19	−74	12		−74	11
	Sediment Oxygen Demand	−7	1	−7	2	−8	2	−7	1		−9	1
	Temporal Change (dO/dt)	−23	103	−24	99	−49	70	−32	15		−32	13
	Summer Average 8 day Wind Stress	7.3		7.2		2.4						
	Winter Average 8 day Wind Stress	−25.5		−22.2		−23.2						

From Siedlecki et al. 2015

How do these fluxes compare?



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From Siedlecki et al. 2015

Water column respiration dominates (~90%) oxygen utilization on the Oregon shelf in the summer.

Do levels of wave energy and turbulence dictate oxygen utilization?

Turbulent Kinetic Energy (TKE)

Significant Wave Height (H_{sig})

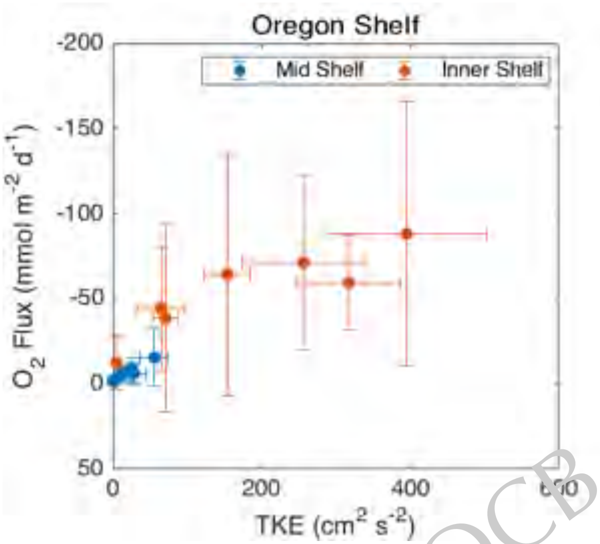
Current Speed

Correlation coefficients for physical parameters and O_2 fluxes

Physical Parameter	Inner Shelf (30 m)	Middle Shelf (80 m)
TKE		
H_{sig}		
Current Speed		

Do levels of wave energy and turbulence dictate oxygen utilization?

Turbulent Kinetic Energy (TKE)



Significant Wave Height (H_{sig})

Current Speed

Correlation coefficients for physical parameters and O_2 fluxes

Physical Parameter	Inner Shelf (30 m)	Middle Shelf (80 m)
TKE	R^2 = **0.79**	R^2 = **0.94**
H_{sig}		
Current Speed		

Do levels of wave energy and turbulence dictate oxygen utilization?

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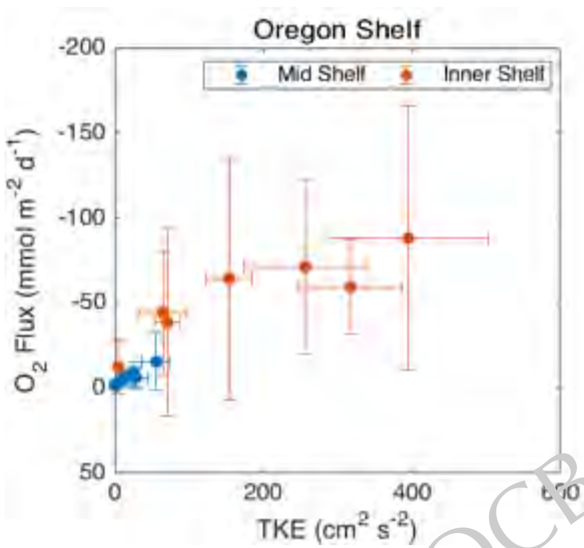
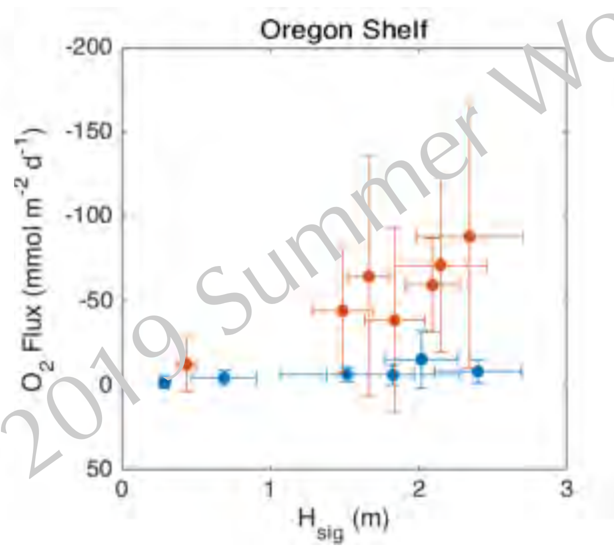


Significant Wave Height (H_{sig})



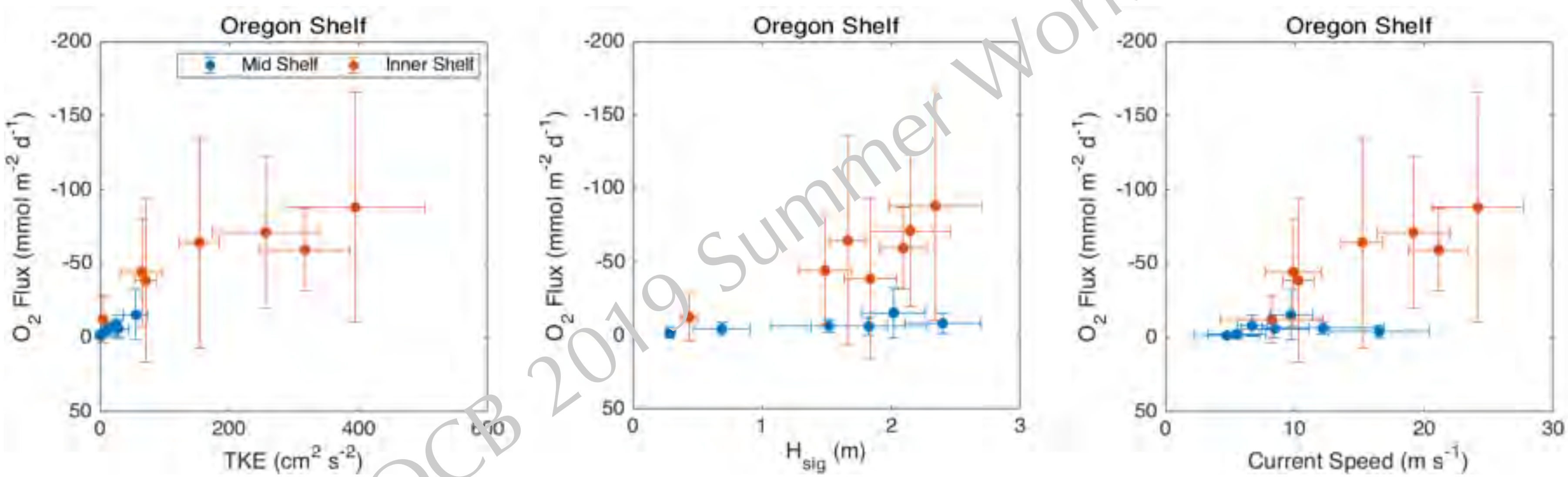
Current Speed

Correlation coefficients for physical parameters and O_2 fluxes

Physical Parameter	Inner Shelf (30 m)	Middle Shelf (80 m)
TKE	R^2 = **0.79**	R^2 = **0.94**
H_{sig}	R^2 = **0.79**	R^2 = **0.61**
Current Speed		

Do levels of wave energy and turbulence dictate oxygen utilization?

Turbulent Kinetic Energy (TKE) | Significant Wave Height (H_{sig}) | Current Speed



Correlation coefficients for physical parameters and O_2 fluxes

Physical Parameter	Inner Shelf (30 m)	Middle Shelf (80 m)
TKE	R^2 = **0.79**	R^2 = **0.94**
H_{sig}	R^2 = **0.79**	R^2 = **0.61**
Current Speed	R^2 = **0.80**	R^2 = 0.04

Summary and Implications

- Both seasonal and spatial variability in benthic metabolism on the shelf
- Highest benthic oxygen consumption in fall and winter
- Lowest sediment oxygen utilization in the summer under hypoxic conditions
- Summer fluxes compare well with model results
- Non-winter/fall fluxes compare well with previous measurements
- Strong relationships between benthic oxygen utilization and turbulent kinetic energy and significant wave height at both sites

- The margin may not be slope dominated
- Tighter coupling of carbon production and remineralization on the shelf
- Greater importance of non-summer sediment oxygen utilization