

# EXPORTS



EXport Processes in the Ocean from RemoTe Sensing

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EXPORTS Science Lead

UC Santa Barbara



2019 US OCB Summer Workshop

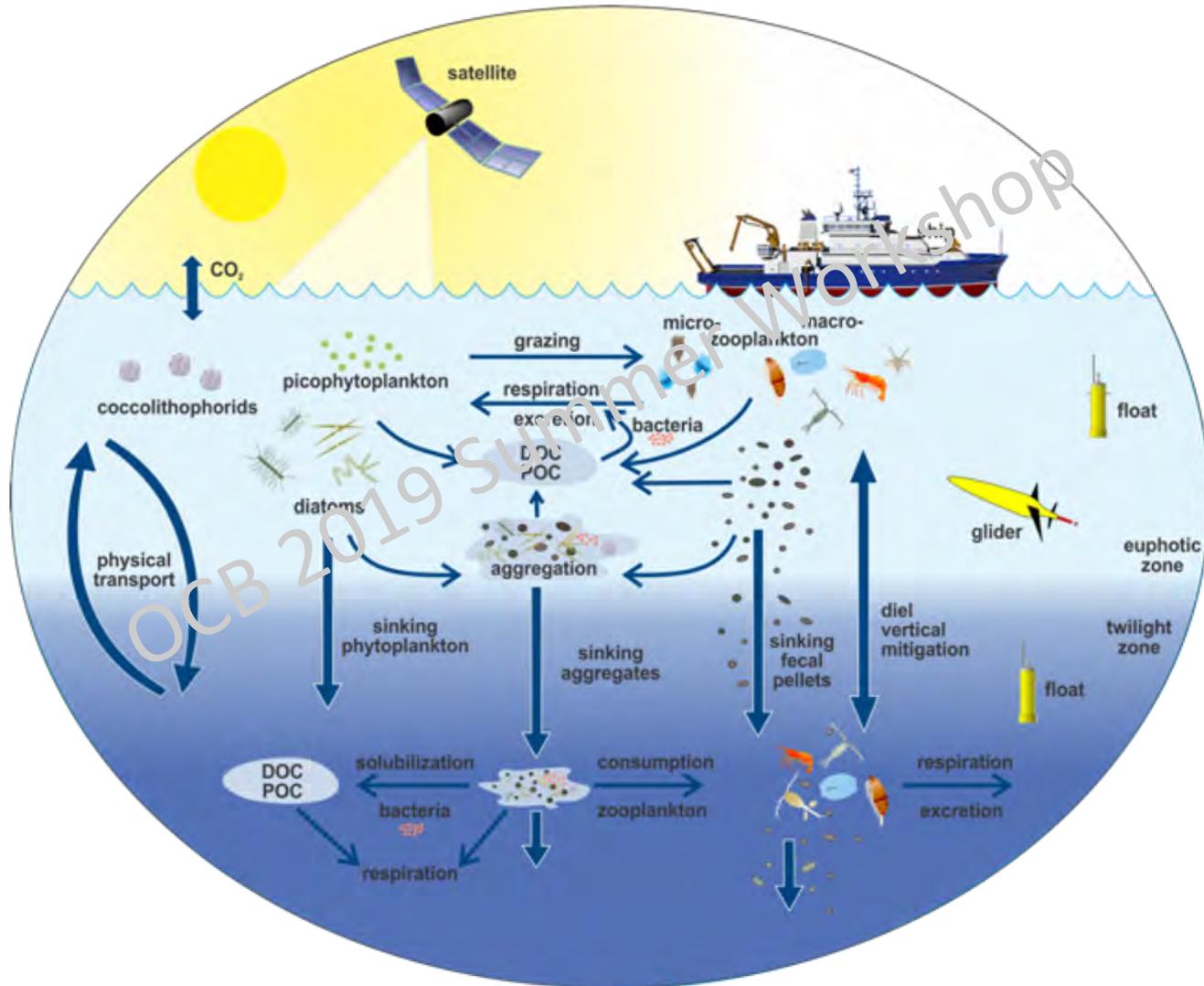


# EXPORTS Goal & Rationale

Goal: Predict export, fate & C cycle impacts of ocean NPP from satellite observations

- Focus on quantifying export pathways & NPP fates over a range of ecosystem states
- Emphasize a predictive understanding by measuring & modeling regulating processes
- Leverages advances in remote sensing, in situ imaging, genomics & autonomous tools

# Focus on Pathways...



# Three Science Questions

How do upper ocean ecosystem characteristics determine the vertical transfer of organic matter from the well-lit surface ocean?

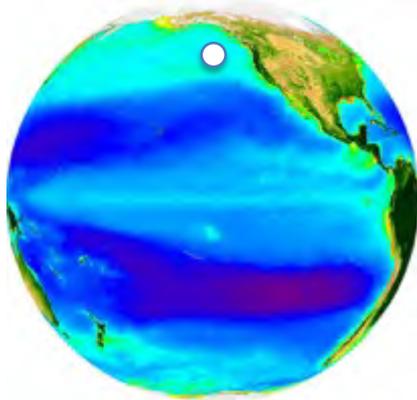
What controls the efficiency of vertical transfer of organic matter below the well-lit surface ocean?

How can the knowledge gained be used to reduce uncertainties in contemporary & future estimates of the export and fates of NPP?

# View from satellite orbit...



## Station P



**Cruise:** Aug/Sep 2018  
**Duration:** 27 d @ site  
**Leverage:** Line P & COI

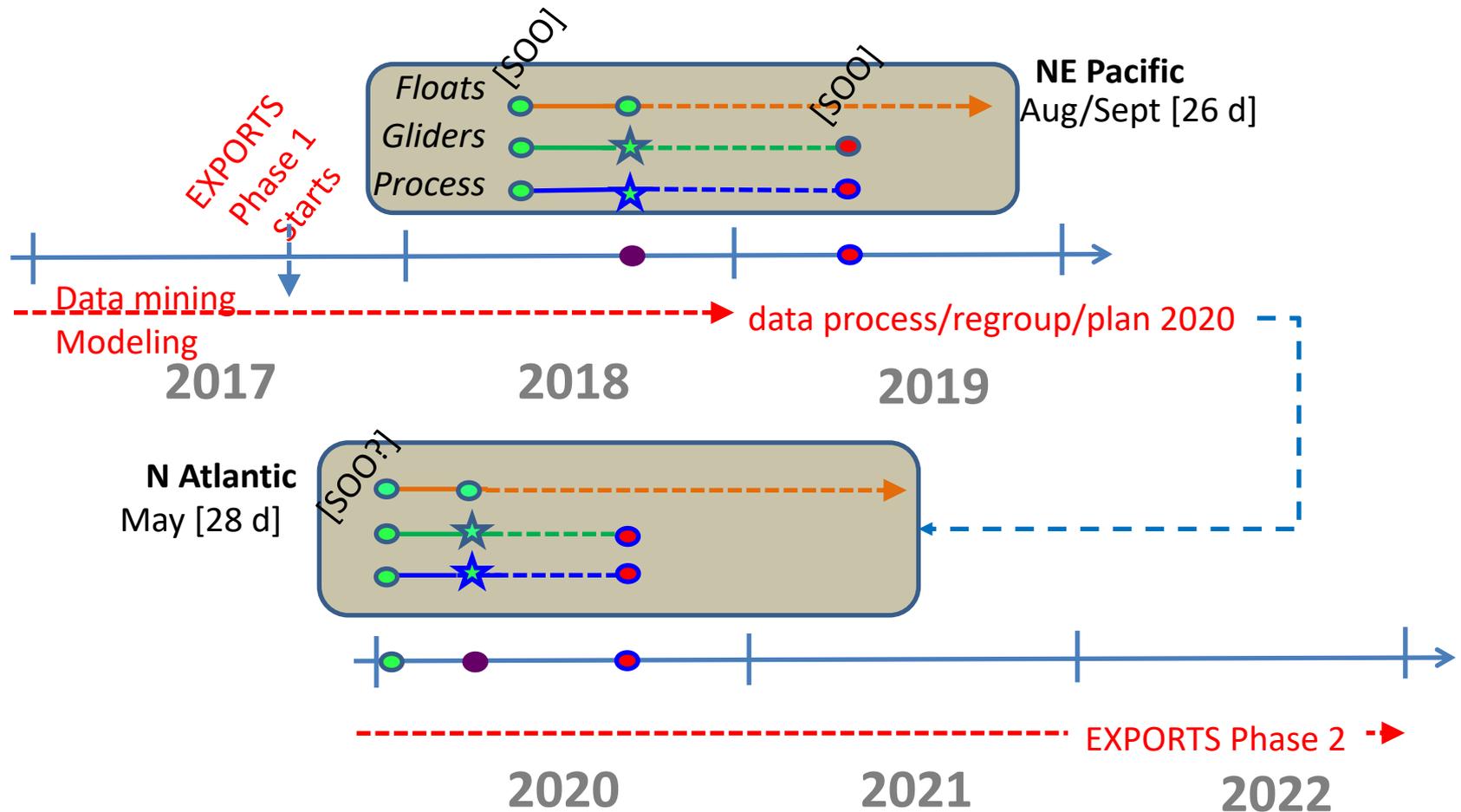
## N. Atlantic



**Cruise:** Apr/May 2020  
**Duration:** ~28d @ site  
**Leverage:** WHOI's OTZ, internationals, e.g. Biarritz

Will collect ~7 ecosystem / C cycling states  
**Also OSSE / data mining** (Pre-EXPORTS funding)  
**Phase 2 – Synthesis / Modeling** (ROSES 20??)

# Overall Timeline



● = **Process & Survey Cruises** - includes multi depth trapping, rates, tow-yo SMS mapping, zooplankton tows, full bio-optics, etc.

● = **deploy autonomous assets**  
 ● = **recover autonomous assets**

# Phase 1 – Pls...



Genomics

Trace Metal  
Chemistry

Microbiology

Food Web  
Dynamics

Bioinformatics

Remote Sensing

Organic Matter  
Characterization

Optical  
Oceanography

Robotics

Nitrogen,  
Phosphorous &  
Silica Cycling

Carbon Cycle

Radiochemistry

Phytoplankton  
Physiology

Zooplankton  
Ecology

Particle  
Aggregation /  
Disaggregation

Numerical  
Modeling

Physical  
Oceanography

Autonomous  
Vehicles

Microzooplankton  
Grazing

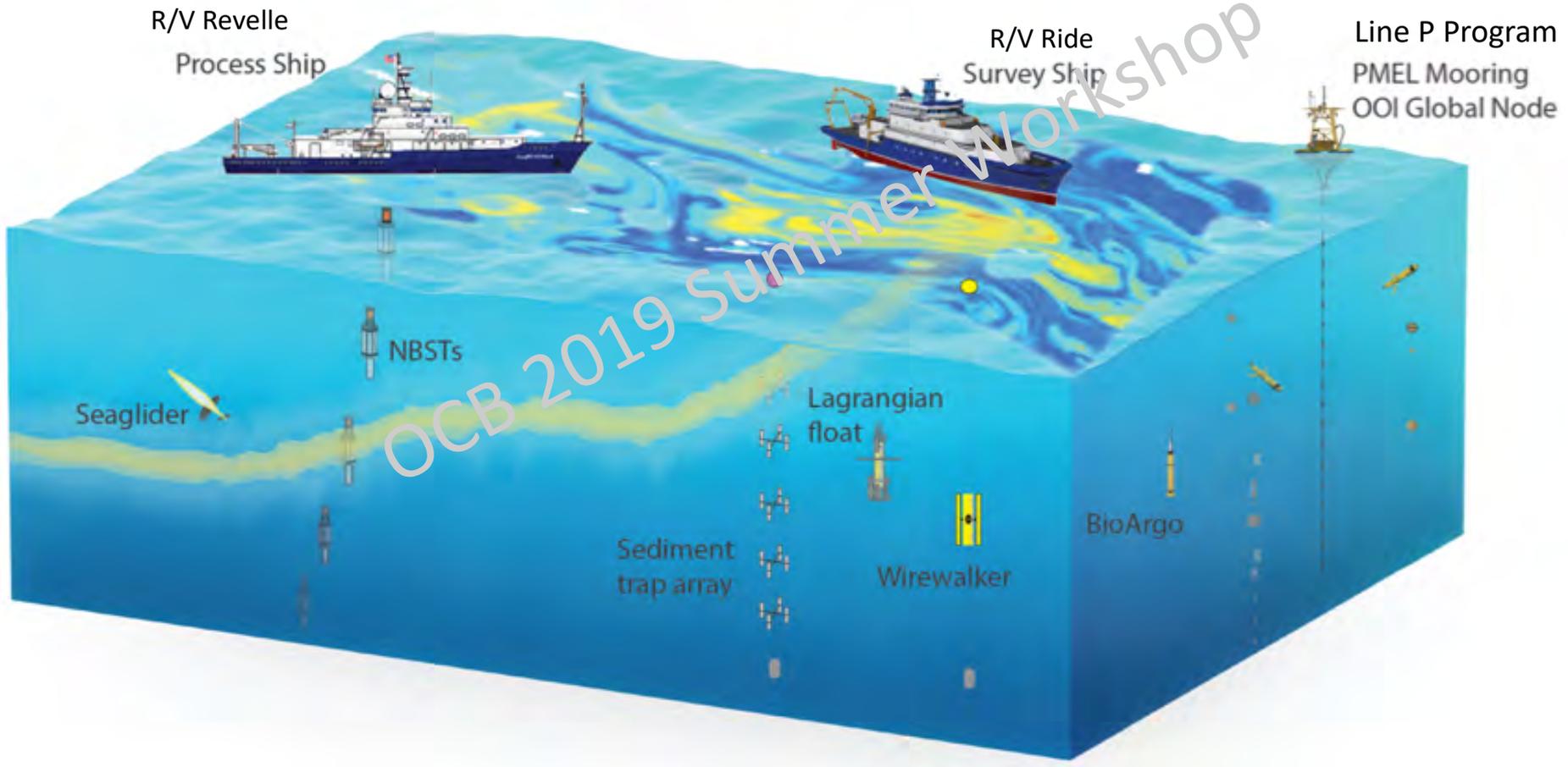
Particle  
Geochemistry

Single Particle  
Imaging &  
Characterization

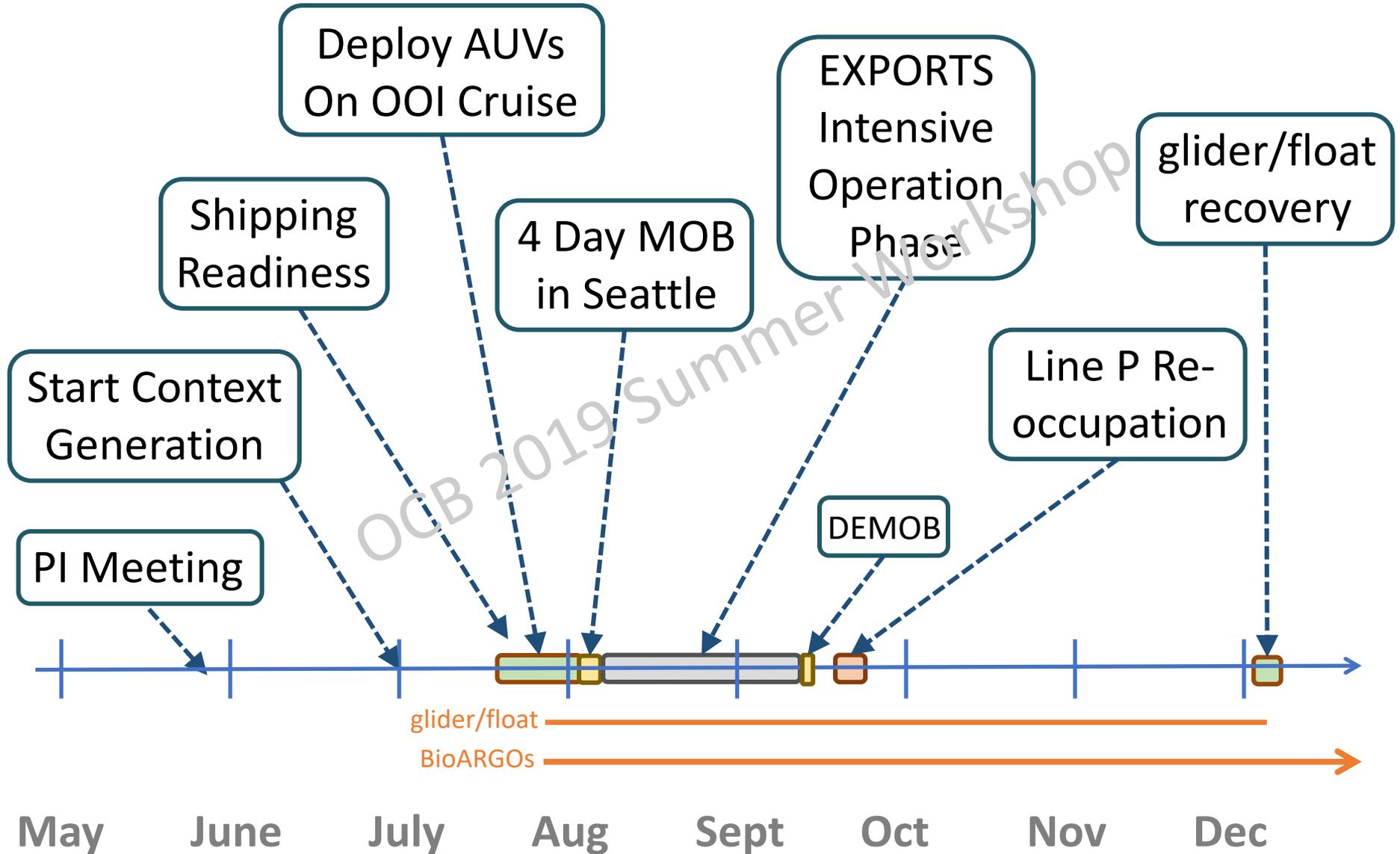
Bio-Optics

OCB 2019 Summer Workshop

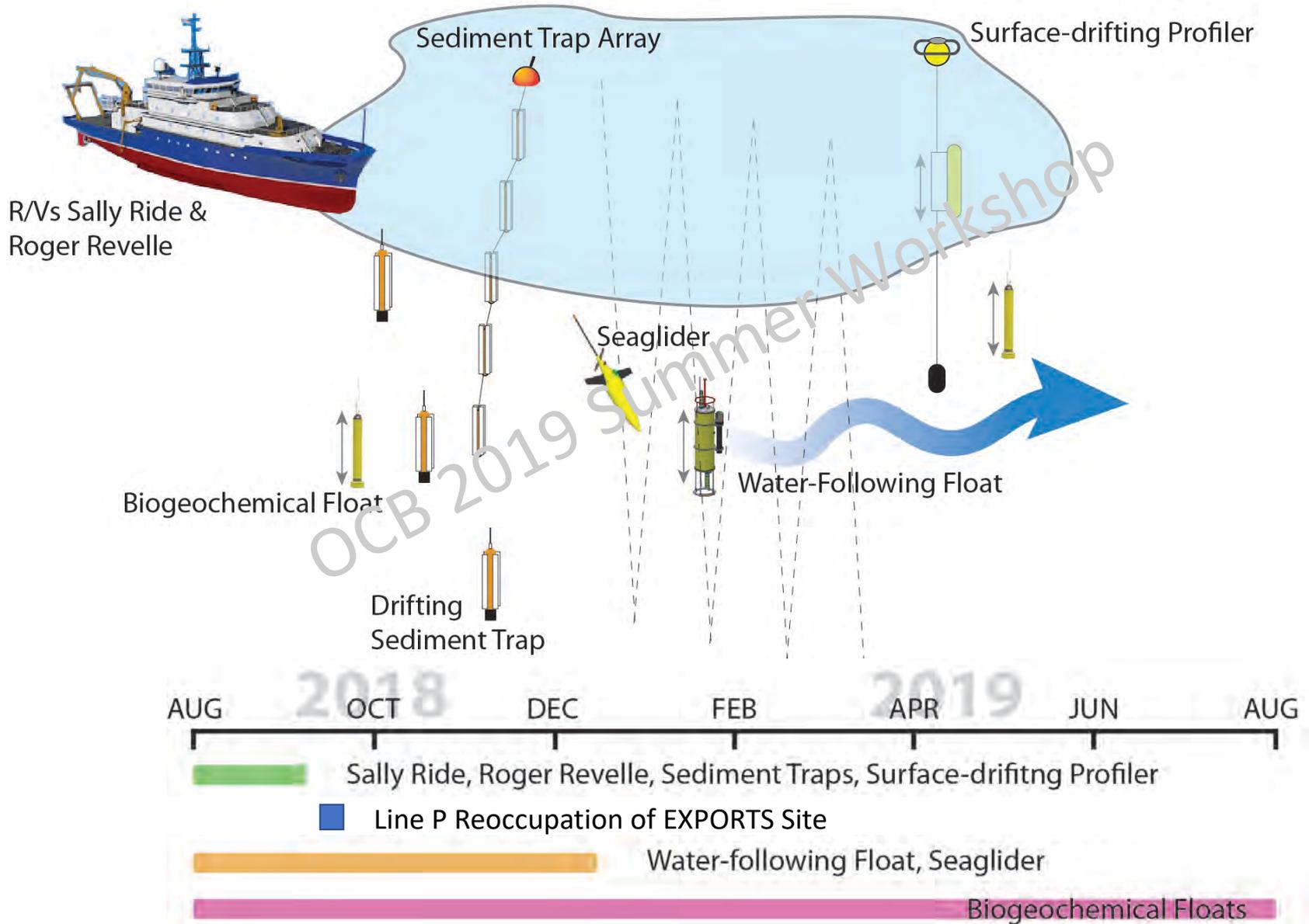
# North Pacific 2018, Station PAPA



# EXPORTS' 2018 Timeline



# EXPORTS Observational Design



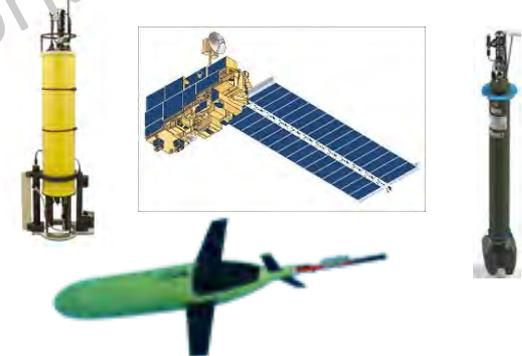
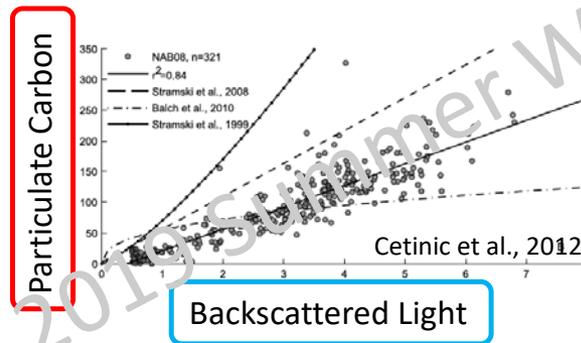
# EXPORTS Autonomous Platforms

Craig Lee, Eric D'Asaro (APL-UW), Mary Jane Perry (UMaine), Melissa Omand (URI), David Nicholson (WHOI) and Andy Thompson (CalTech)  
Andrea Fassbender, Ken Johnson, Yui Takeshita and Sophia Johannessen (MBARI)

More Variables  
Fewer Measurements



Fewer Variables  
More Measurements

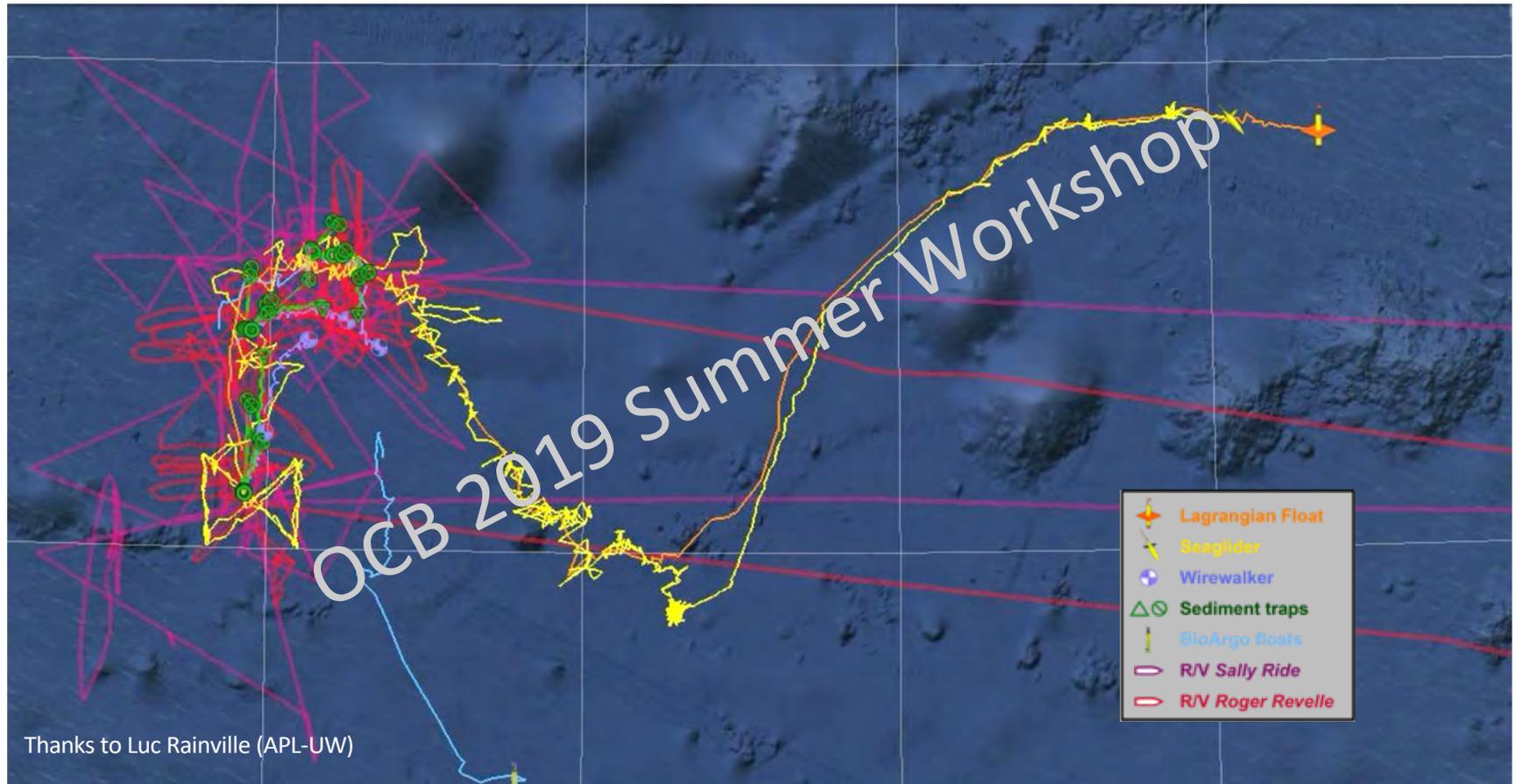


Samples, analyses, sensors

Sensors – electricity, light, sound

- Robots observe scales impractical to measure from ships
- Ships inform interpretation of measurements from robots
- Robots assist with interpretation of satellite sensors
- Lagrangian float provides the experiment's reference center

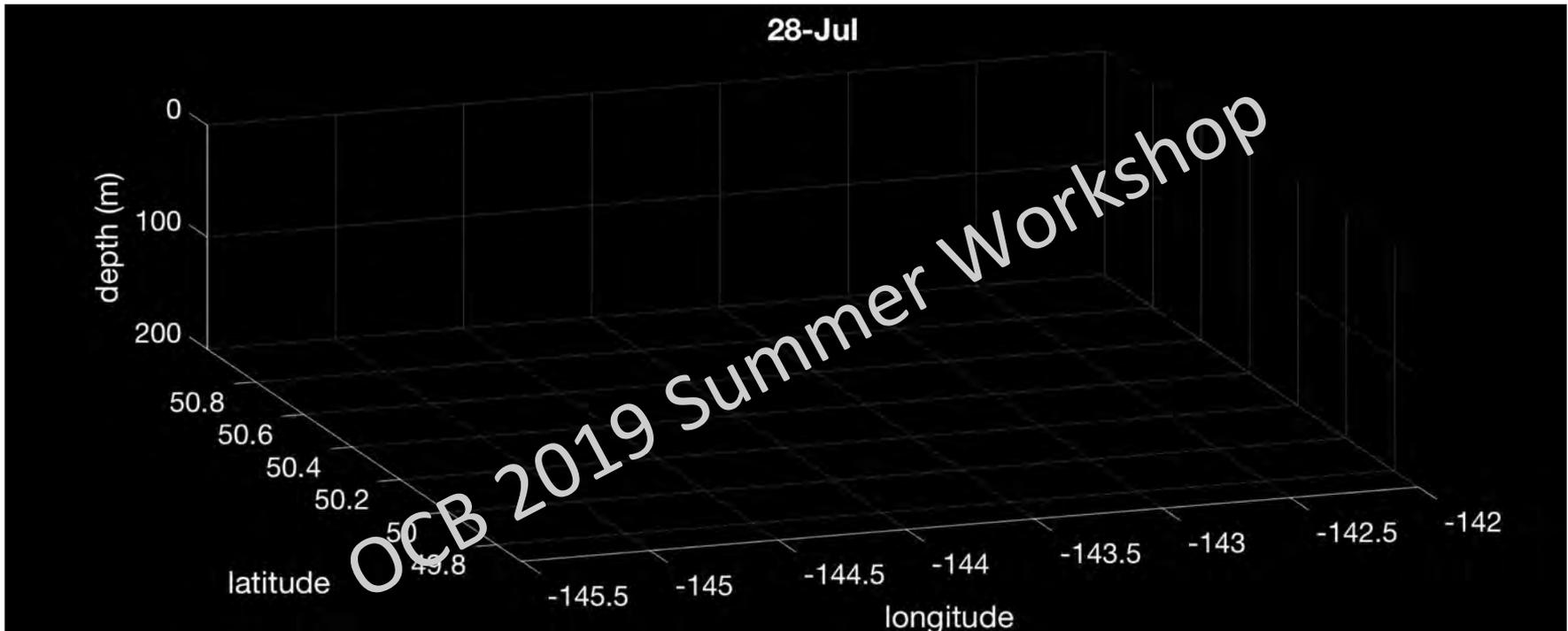
# EXPORTS NE Pacific Program – 1 Aug–30 Nov 2018



R/V Roger Revelle  
R/V Sally Ride  
5 NBSTs + 1 surface-drifting trap  
Wirewalker

**Long-term Autonomous Measurements**  
2 BioArgo Float  
1 Lagrangian Float  
1 Seaglider

# Chlorophyll Fluorescence (Seaglider)



- Lagrangian float tracks water parcels below euphotic zone.
- Seaglider collects profiles in butterfly pattern around drifting float.
- Float and glider pair resolves 1D dynamics plus advective contributions at scales larger than the mesoscale (tens of kilometers).
- Two BioArgo floats provide broader context.

# Process Ship

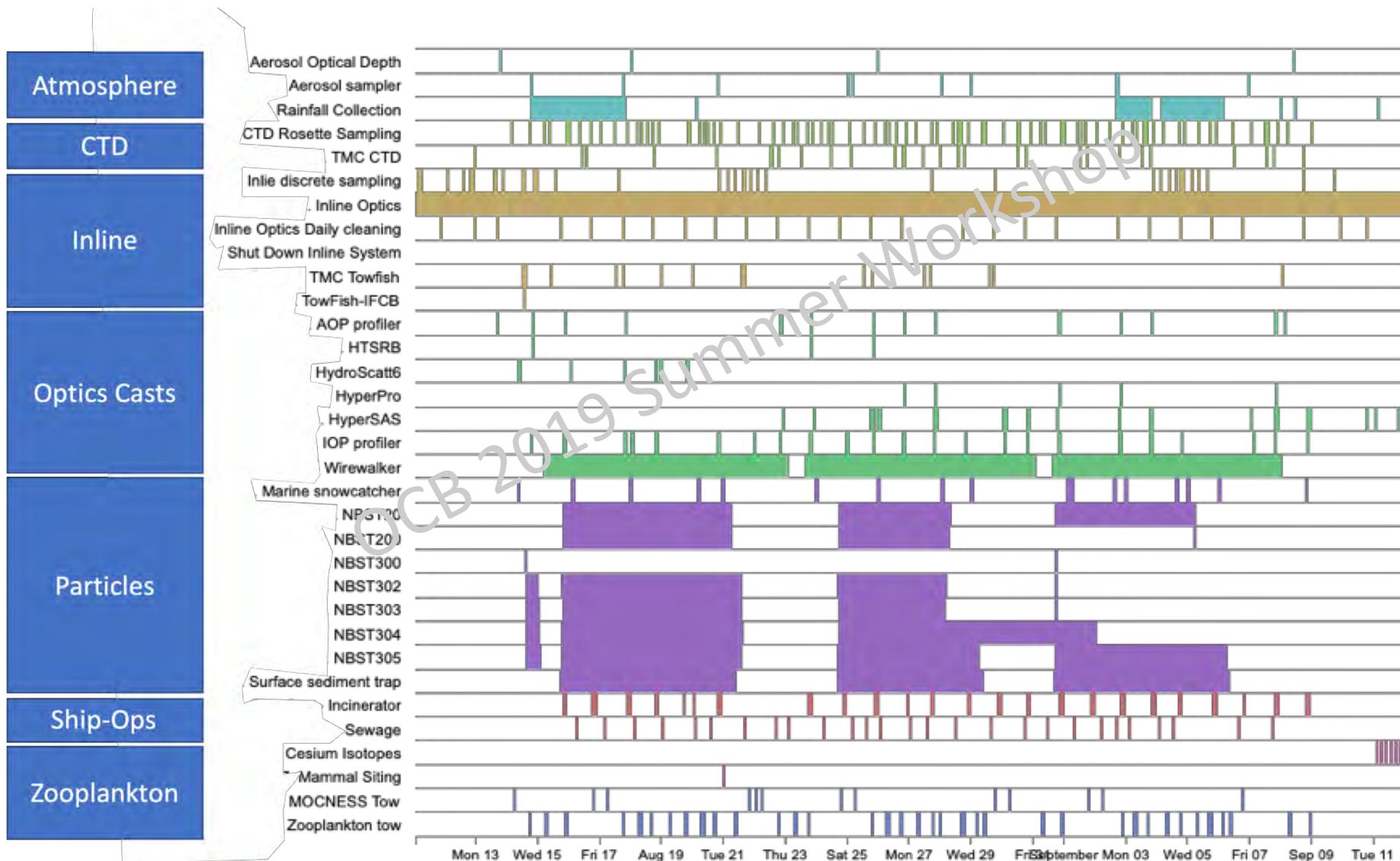
- Optics
  - Profiling & UW IOPs (incl. discrete), C-OPS & HyperSAS reflectance, LISST-Deep PSD, ...
- NPP / Rates
  - NPP ( $^{14}\text{C}$  &  $^{15}\text{N}$ ), NCP ( $\text{O}_2/\text{Ar}$ ), Community resp, Phyto growth / grazing, Zoop resp/grazing, bacterial prod, ...
- Taxa & Particle Characteristics
  - MOCNESS, HPLC, iFCB, UVP, FloCam, genomics for Pro's & Euk's, ...
- Export pathways
  - Sediment traps, DOM/POM remin, aggregate char, diel zoop migration, ...
- BGC stocks
  - Nuts, Chl/HPLC, DOM, POM, Fe,  $\text{O}_2$ , BSI, PIC, PSD, ...

# Process Ship

Process Ship Day	State 1 0	State 1 1	State 1 2	State 1 3	State 1 4	State 1 5	State 1 6	State 1 7	State 1 8
0000-0100		SIO CTD - 1000 m (UVP n, uz, expts)	SIO CTD - 1000 m (UVP n, uz, expts)	Mocness	SIO CTD - 1000 m (UVP n, uz, expts)	zoo tow (fp, resp)	SIO CTD - 1000 m (UVP n, uz, expts)	zoo tow (fp, resp)	Mocness
0100-0200		TMC Towfish	TMC CTD 1	Mocness	TMC CTD 1	TMC CTD 1	TMC CTD 1	SIO CTD - 150 m uz	Mocness
0200-0300									SIO CTD - 150 m uz
0300-0400									SIO CTD - 150 m uz
0400-0500			TMC CTD 2		TMC CTD 2	TMC Towfish	TMC CTD 2		TMC CTD 1
0500-0600									TMC CTD 2
0600-0700		Deploy Traps & wire walker		zoo tow (63 um-day)			Poop run	zoo tow (fp)	Poop run
0700-0800			SIO CTD 150m (NC,expt) TMCCTD-150m BJ	zoo tow (fp)	zoo tow (graze)	SIO CTD - 1000 m (UVP d)	SIO CTD 150m (NC,expt) TMCCTD-150m BJ		
0800-0900									
0900-1000			TMCCTD-150m KH	Mocness	TMCCTD-150m BJ	zoo tow (fp, resp)	SIO CTD 150m (NC,expt) TMCCTD-150m BJ	Mocness	TMCCTD-150m BJ
1000-1100			Optics	Optics	Optics	Optics	Optics		Optics
1100-1200	NBST test deploy		Mocness					Mocness	
1200-1300		zoo tow (fp)	Mocness	SIO CTD - 1000 m (UVP d)	SIO CTD - 1000 m (UVP d)	SIO CTD - 1000 m (UVP d)	SIO CTD - 1000 m (UVP d)	Mocness	SIO CTD - 1000 m (UVP d)
1300-1400									
1400-1500		SIO CTD - 500 m (trap water)	SIO CTD - expts	Mar snow catchr	Poop run	TMCCTD-150m KH	Mar snow catchr		
1500-1600		(trap water)	SIO CTD - 1000 m	SIO CTD - 1000 m		Poop run		SIO CTD - 1000 m	Recover Wire walker
1600-1700		(expt. water)							
1700-1800		NBST test recover	Mar snow catchr						SIO CTD - 500 m (trap water)
1800-1900				poop run	poop run	SIO CTD - 500 m (expt)	zoo tow (MSC)	Poop run	(expt. water)
1900-2000					Recover 3-day traps	Recover 4-day traps	Recover 5-day traps		
2000-2100									
2100-2200	zoo tow (fp, resp)	Poop run	Mocness	zoo tow (63 um-night)			(includes STT)	Mocness	zoo tow (fp, resp)
2200-2300				zoo tow (fp, resp)					
2300-2400									

<b>SIO CTD - 500 m (trap water)</b>	To fill sediment traps (500 L from 500m). Could use Marine Snow catcher instead, or combo of the two; also collect incubation water for expts
<b>SIO CTD - 150 m (uz)</b>	Water for microzooplankton grazing incubations
<b>SIO CTD - expts</b>	water needed for incubations/experiments- quick CTD casts to get mixed layer water (Steinberg), also some water needed at 10m and 200 m (Carlson, Gifford); some of these can be done on existing casts
<b>TMC CTD - 150 m - TMC TMCCTD-150m BJ/KH</b>	w/ TMC rosette- morning PP cast, plus water for many people (see CTD water budget list); 2 casts likely needed to get enough water
<b>SIO CTD - 1000 m</b>	to bottom of euphotic zone (light dependent gene expression)- B. Jenkins group and Kim Halsey; TMC rosette
<b>Mar snow catchr</b>	Water for many people (see CTD water budget list); also Day vs. night deployments of UVP and ADCP; sometimes water for experiments too
<b>zoo tow</b>	3 casts per state, @same time of day, 3 depths per cast: mixed layer, at depth of export flux (below the mixed layer, trap depth) and deep – e.g. 500; request prior to CTD cast that will have bacteria respiration & production
<b>zoo tow (63 um)</b>	tows for live animals for experiments day vs. night; usually 200 um mesh; fp=fecal pellet production; resp=respiration&excretion; graze=added bottles to S M-D expt; MSC= marine snow grazing
<b>Mocness</b>	small mesh zoo tow (for 63-200 um size fraction)
<b>Trap recoveries</b>	paired Day vs. night; beginning and end of state
<b>trap/WW deploy/rec</b>	best at night so can see the light when they pop up
<b>optics casts</b>	at beginning and end of state
<b>Towfish</b>	mostly hand-lowered instruments
<b>NBST test deploy</b>	water collection for Jenkins large volume incubations (this done 2x in any two states)
<b>Poop run</b>	do earlier in day if get there in time
	dump sewage, gray water from ship's tanks away from traps; once traps are recovered, don't have to run as far ; need 1x every 24 hr.

# Process Ship

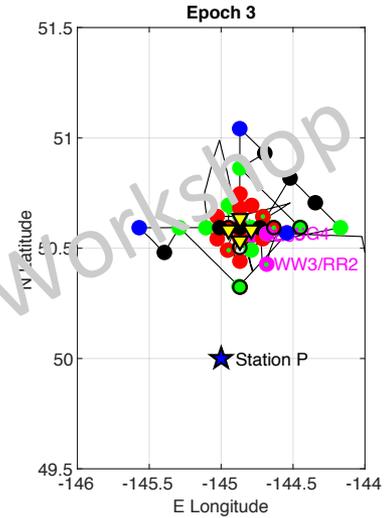
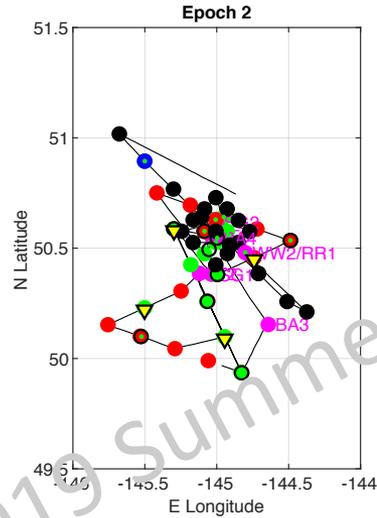
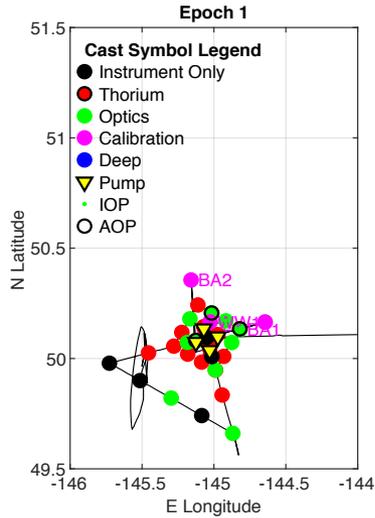


# Survey Ship

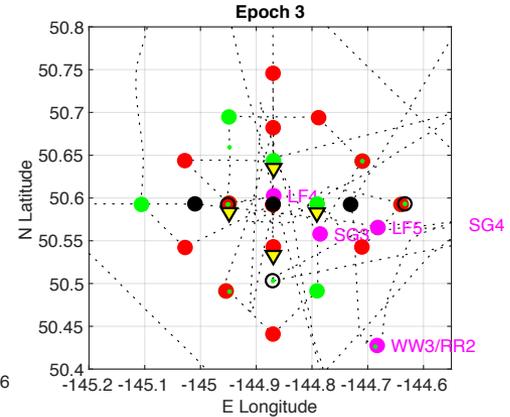
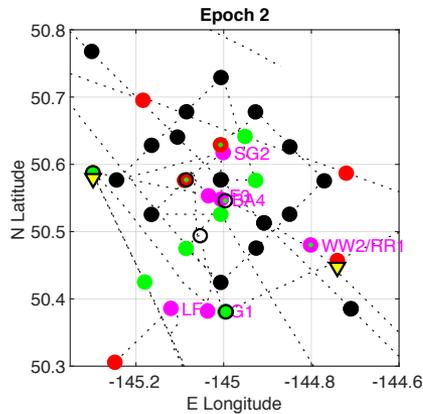
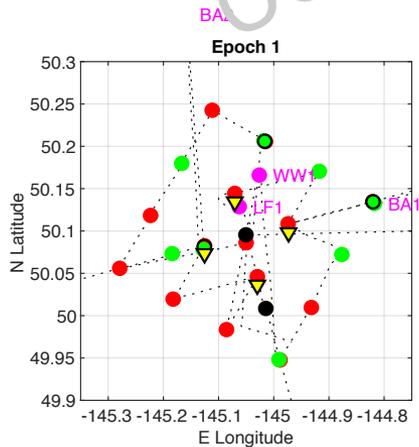
- Optics
  - Multispectral / multi angle scattering, nanoparticle PSD, profiling & UW IOPs (incl. discrete & size frac), HyperSAS reflectance, submicron PSD, C-OPS & LISST-Deep, ...
- NPP / Rates
  - NCP (by O<sub>2</sub>/Ar)
- Taxa & Particle Characteristics
  - iFCB, UVP, HPLC, acoustics for zooplankton, genomics for Pro's & Euk's, ...
- Export pathways
  - <sup>234</sup>Th export, UVP-sinking flux
- BGC stocks (also act as the calibration link to AUVs...)
  - Pump & Niskin POC/N/PIC/Bsi/etc. profiles, Nuts, Chl/HPLC, DOC/N, O<sub>2</sub>, PSD, ...

# Survey Ship

EXPORTS 2018 Survey Overview



Zoomed on Small Scale Survey



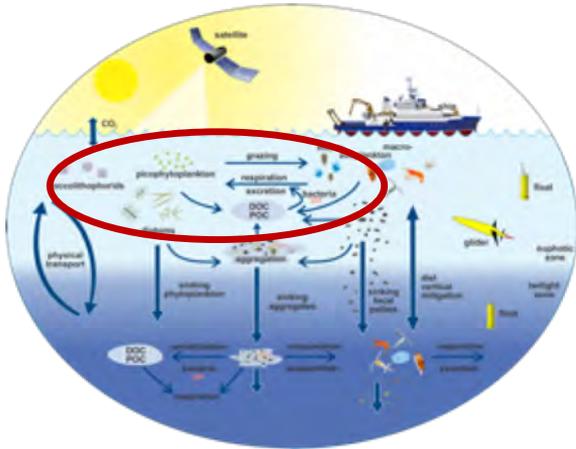
# May 2019 Science Meeting – Williamsburg VA



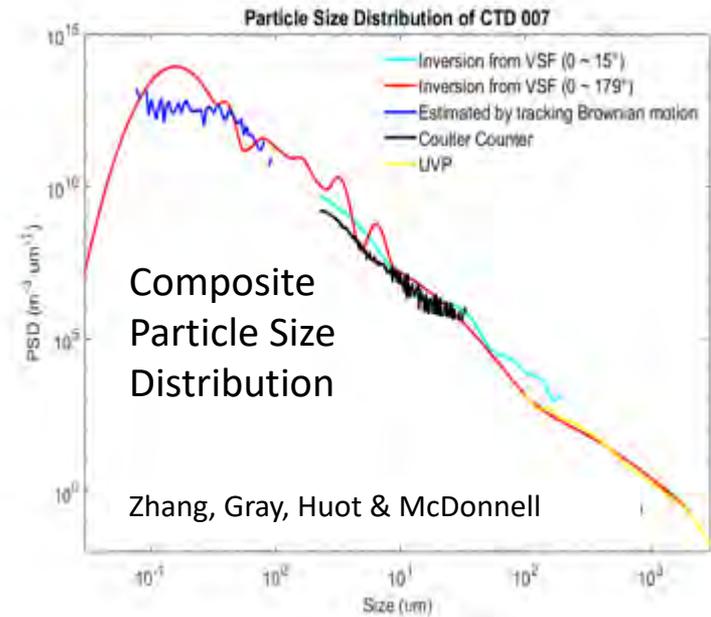
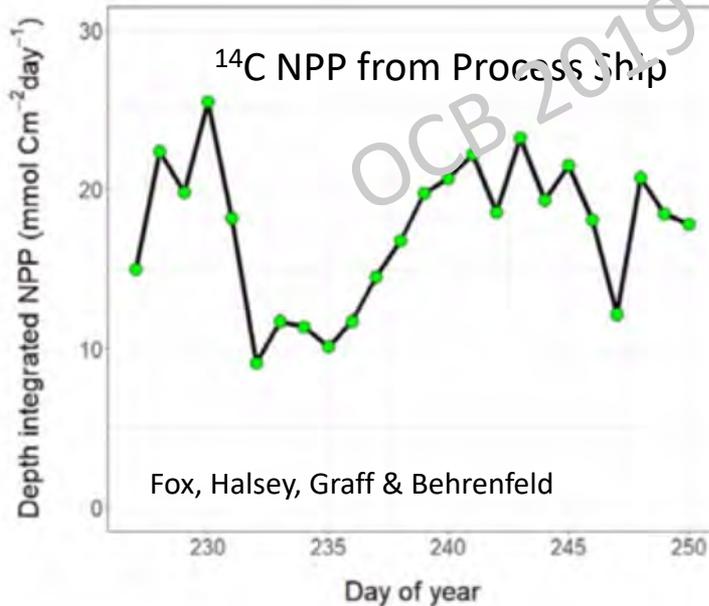
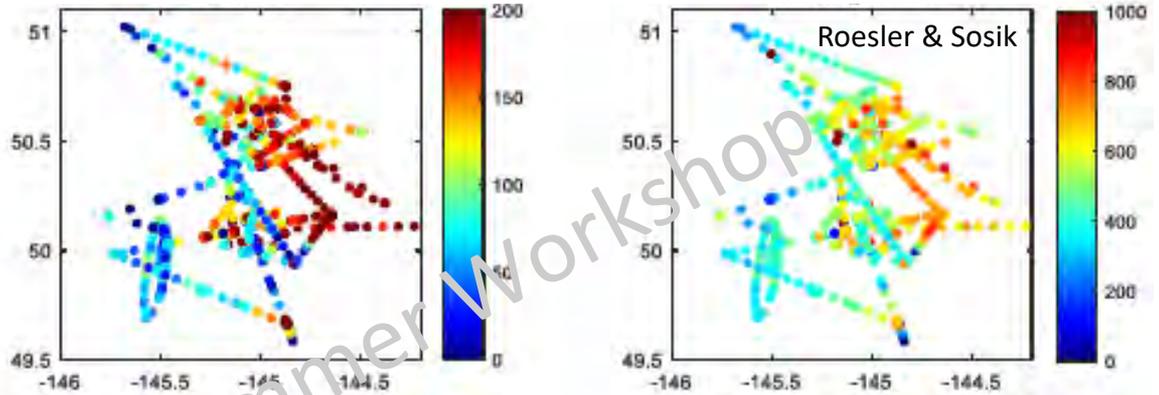
## Focus:

- Synthesis WGs (Pathways, Food Webs, BGC Budgets, Optics & BGC & Time/Space Attribution)
- Data management & synthesis products
- North Atlantic Planning

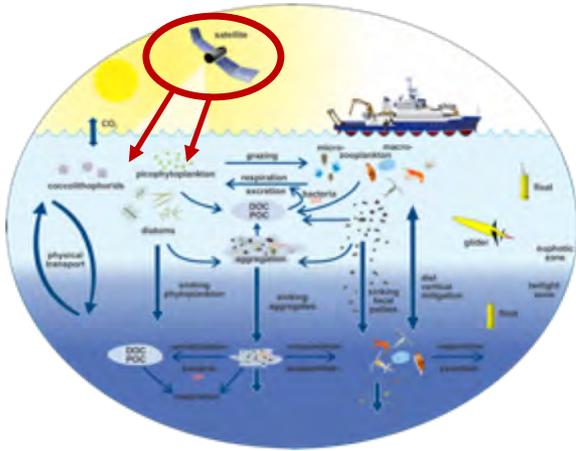
# Primary Production and Composition of Producers



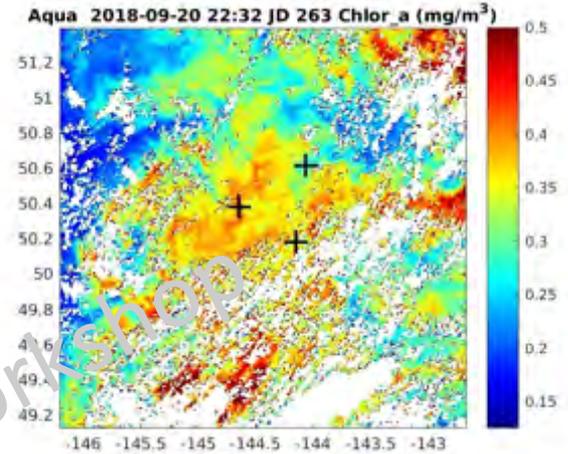
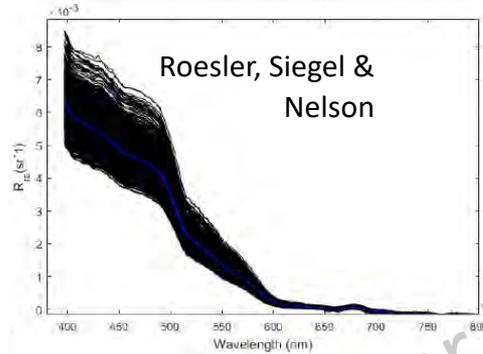
IFCB Diatom & Dinoflagellate Carbon from Survey Ship



# Optics & Remote Sensing



Remote Sensing Reflectance



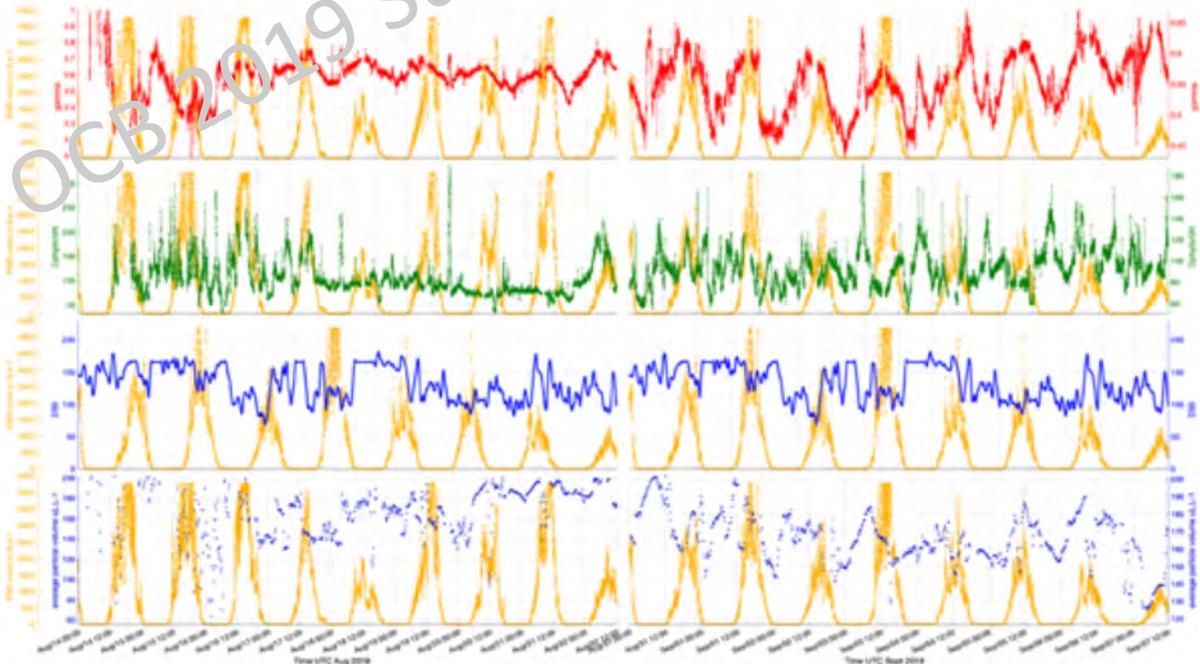
10 days after EXPORTS left!!!

$C_p$  slope

$C_{ph}/Chl$

Median Biovolume

Mean Biovolume



Small particles



Large particles

Large particles



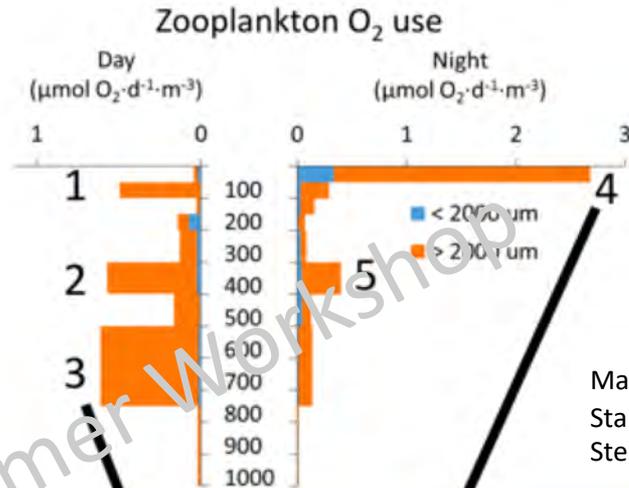
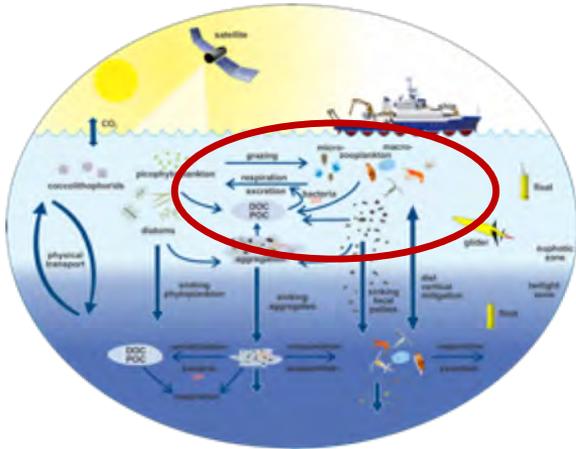
Small particles

Large particles

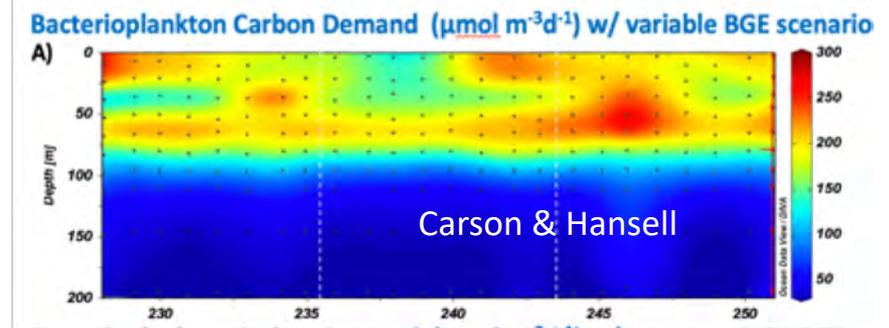
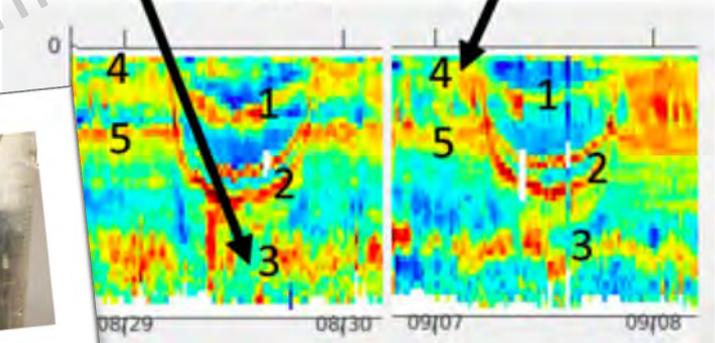
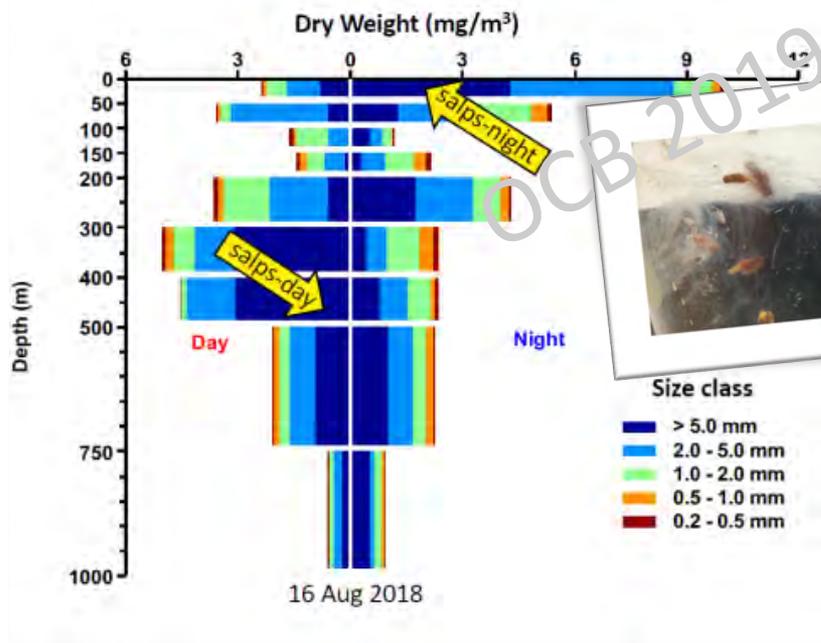


Small particles

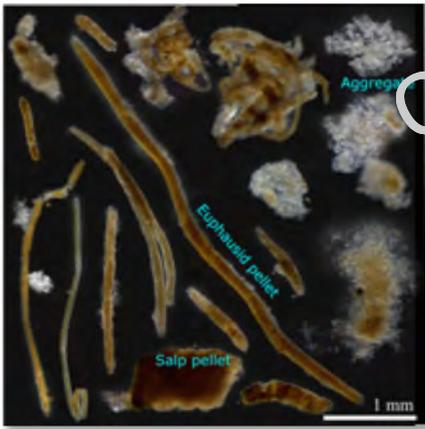
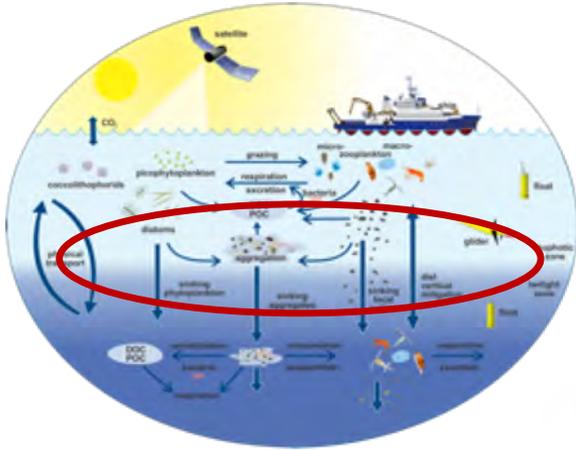
# Secondary Production and Producers



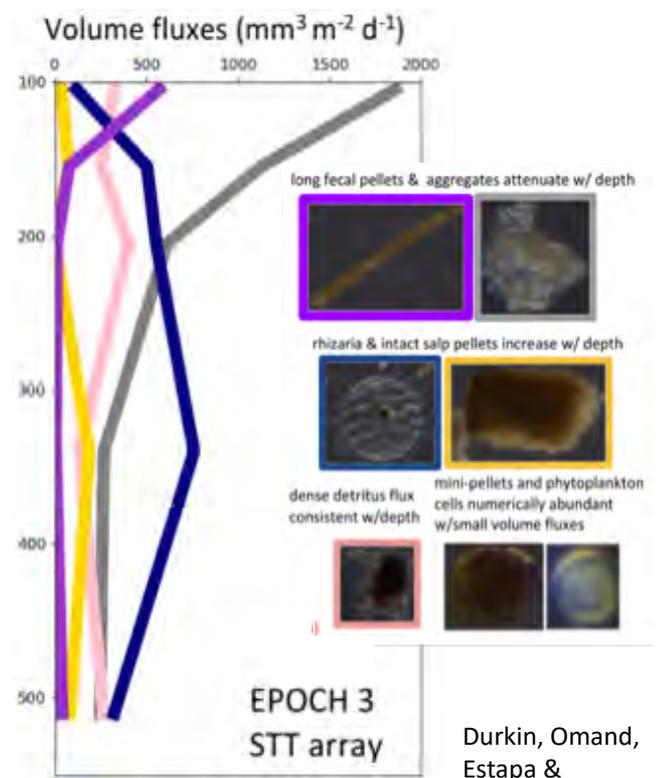
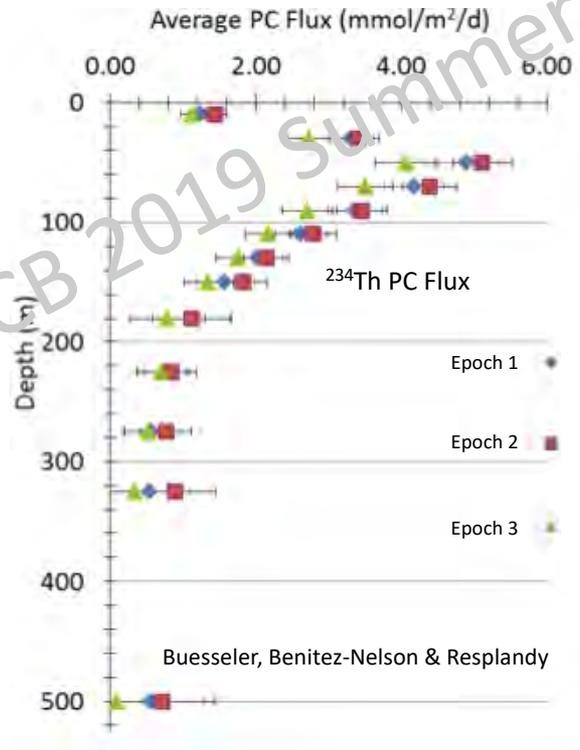
Maas,  
Stamieszkin &  
Steinberg



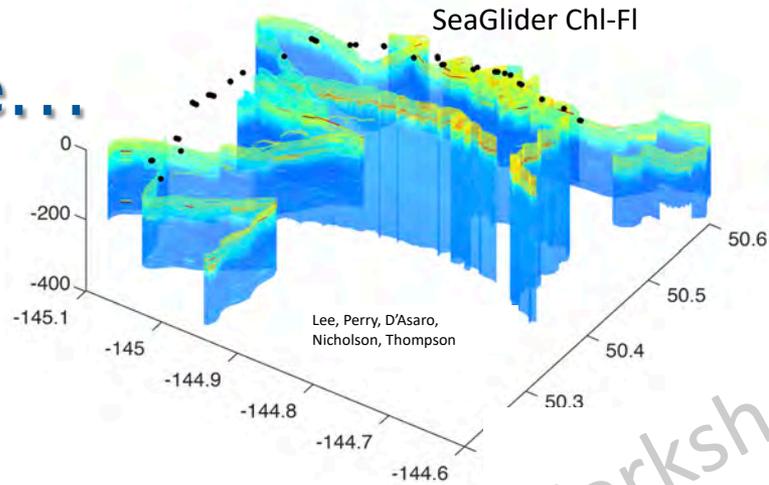
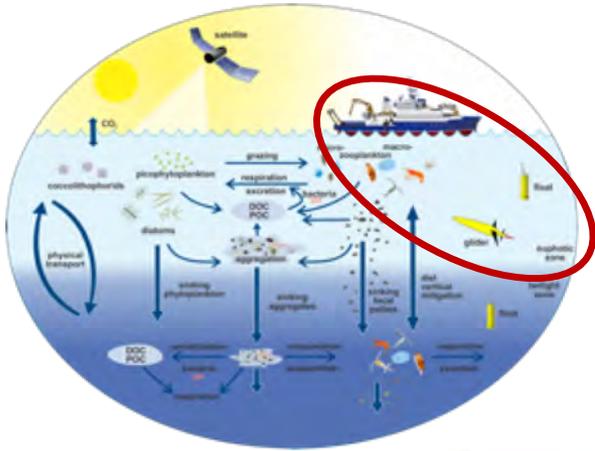
# Export and Export Pathways



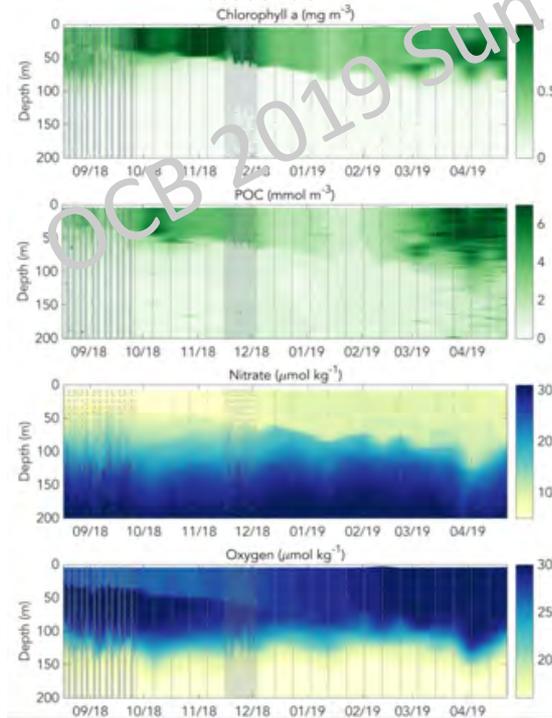
View of sinking flux



# Variability in Time...



BioArgo Profiles  
 Fassbender

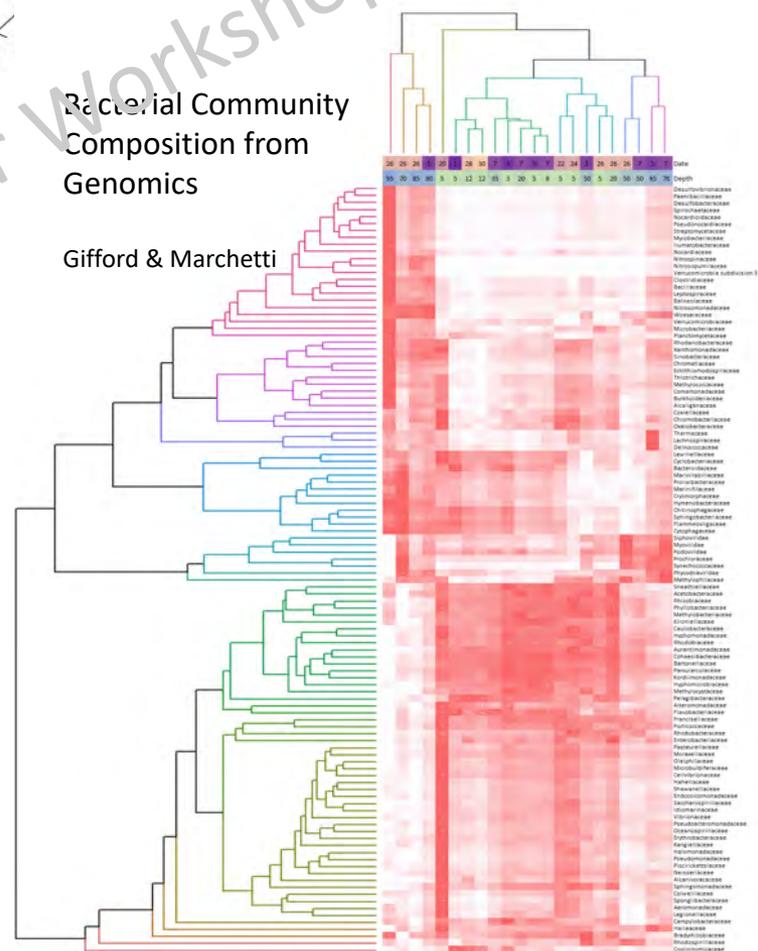


Time ->

Bacterial Community  
 Composition from  
 Genomics

Gifford & Marchetti

<- Sequence Variants ->



- Contrasting endmember to the 2018 NE Pacific Cruise
  - Big signals in biomass, export & low flux attenuation
  - Focus on assessing post-bloom C cycle fates
  - Larger phytoplankton types & diatoms?
  - High mesoscale & sub-mesoscale energy driving patchiness in biomass & NPP and advective C fluxes
- Working on schedule for NAtl 2020 cruise
  - Request for two ships on station for 28 days (3 epochs with 4 weather days with MOB & DeMOB at same port)
  - Schedule of the moment: R/Vs Atlantis & Armstrong for spring 2020 (mid April to end May)
  - Collaboration with WHOI's OTZ group (a 3<sup>rd</sup> ship...)



Patrick Dougherty – “A Passing Fancy”

Highfield Hall (up the hill from the Bus Station)



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EXPORTS 2018 STATION PAPA