California Current Ecosystem Long-Term Ecological Research Program

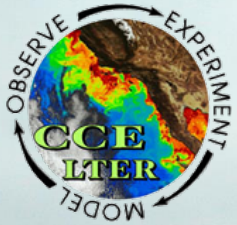
Mark D. Ohman

Scripps Institution of Oceanography

University of California, San Diego

International Research Ship Operators

La Jolla 22 Oct. 2015



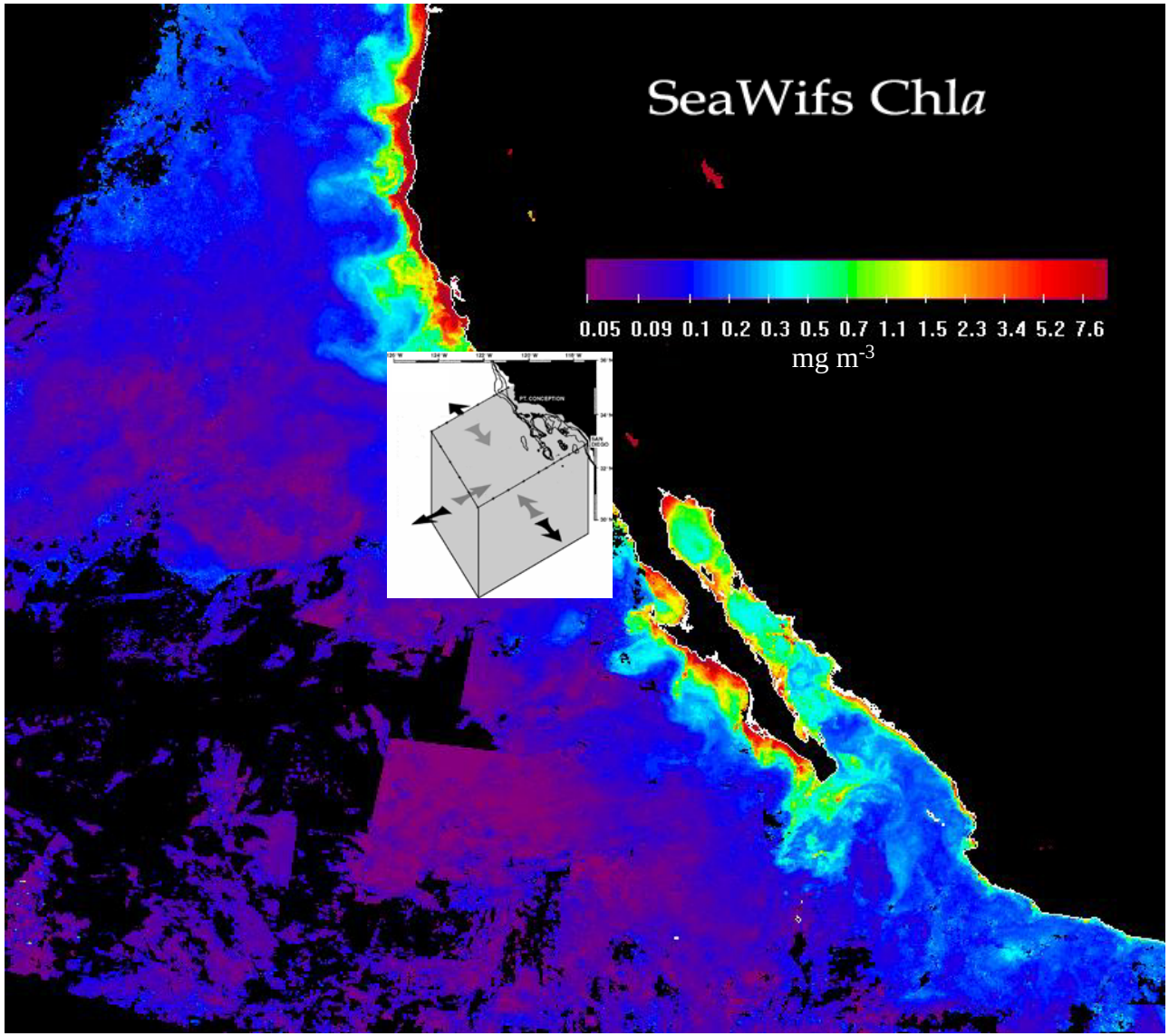
Two primary messages:

Vigorous need for global class vessels

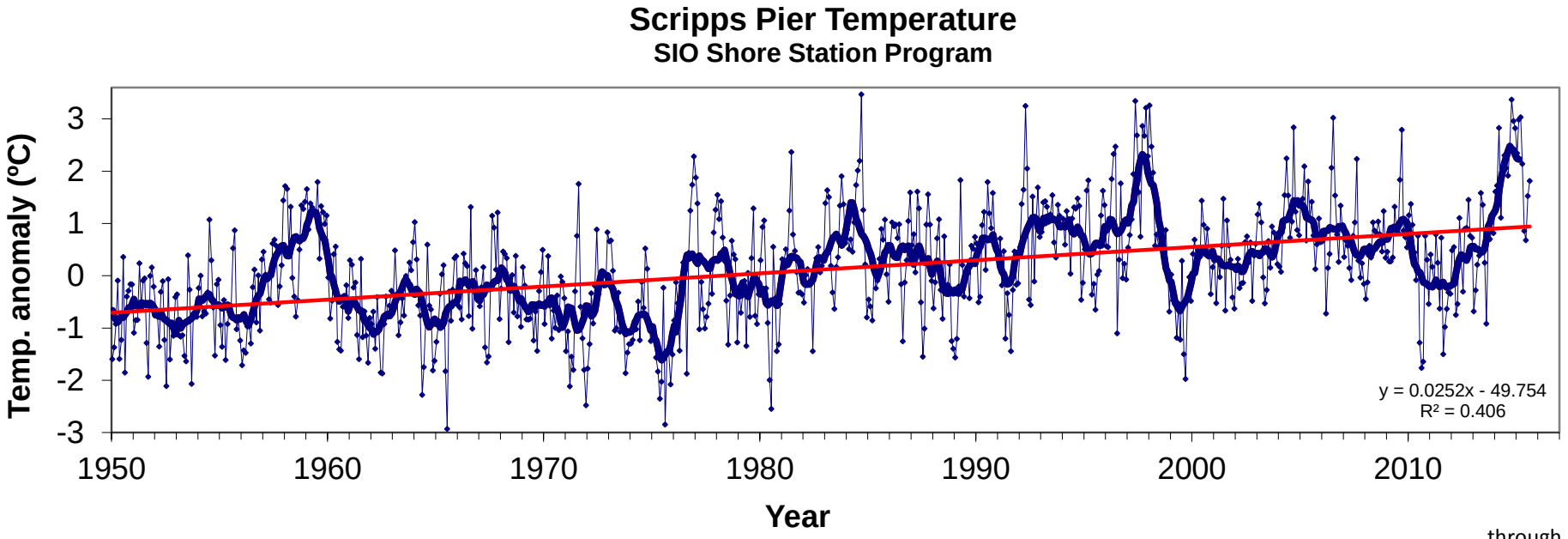
The power of integration of autonomous with shipboard research

International Research Ship Operators
La Jolla 22 Oct. 2015

California Current System
A coastal upwelling biome



M. Kahru
B.G. Mitchell
SIO



13 pt runing mean, re-centered

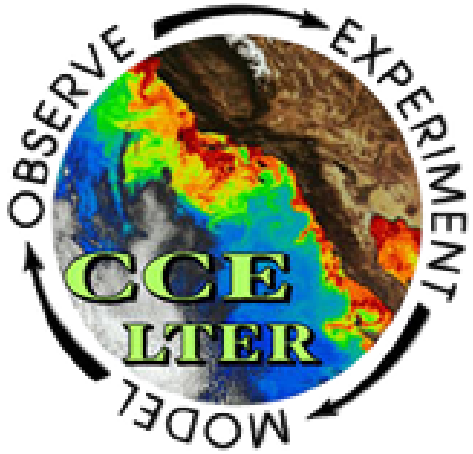
through
31 Aug. 2015

Preliminary Data

Scripps Shore Station Program

Funded by California Boating and Waterways

California Current Ecosystem
Long-Term Ecological Research



How do climate variability and climate change alter plankton production and fish production and affect the ocean's ability to sequester C in a coastal upwelling ecosystem?

Interdisciplinary Group

of Scientists, Students, Engineers, and Technicians

Biological, Chemical, Physical Oceanographers

Climate Scientists

Ocean Modelers

Resource Economist

Graduate students

Undergraduate students

Teacher-at-sea

R/V *Melville*

R/V *T.G. Thompson*

R/V *Knorr*

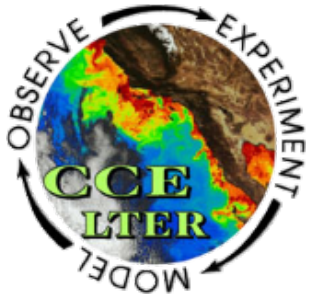
CCE-LTER Lagrangian Process Cruises

Objectives:

To quantify and understand rates of

growth, grazing, particle export, and controlling processes

in defined water parcels in the California Current Ecosystem

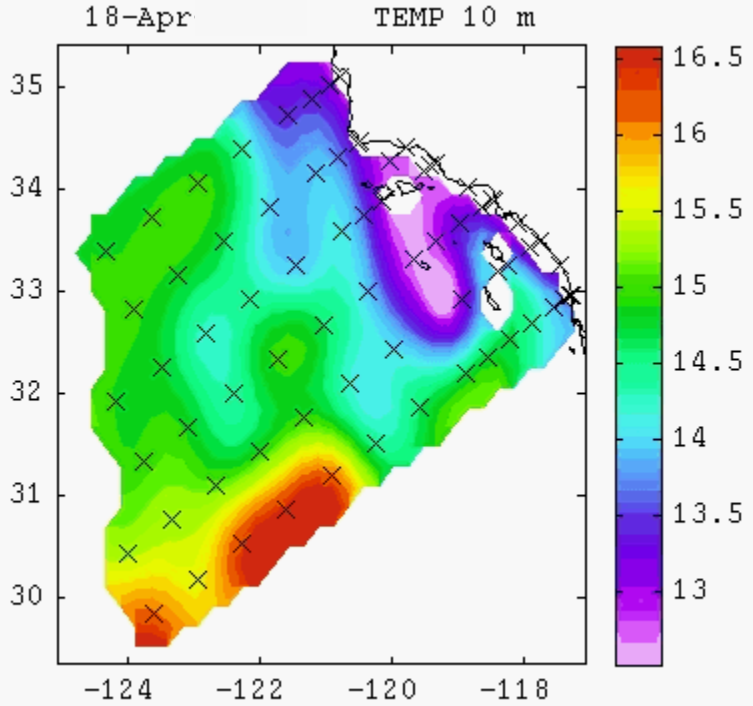


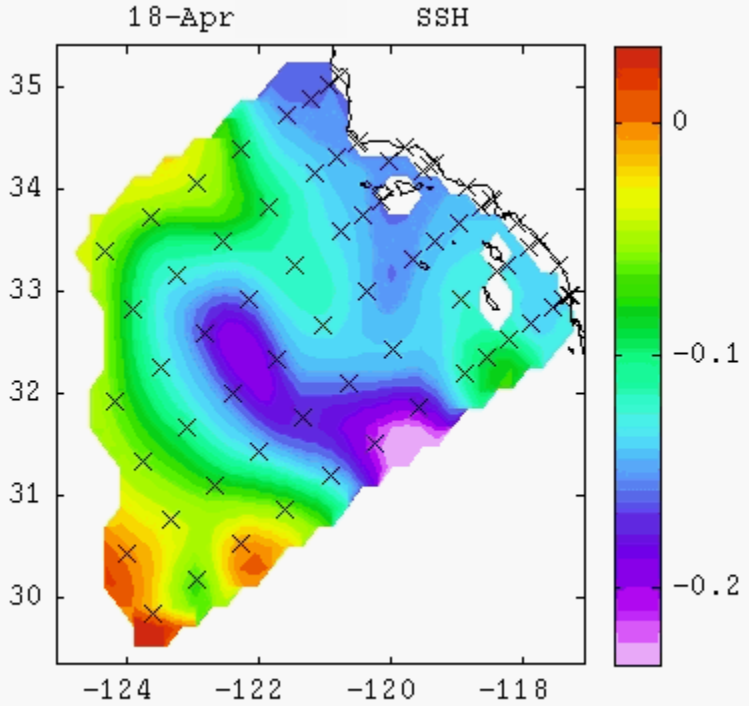
Selection of water parcels

ROMS Model Forecast

(assimilated data from CalCOFI cruise immediately preceding CCE-LTER process cruise)

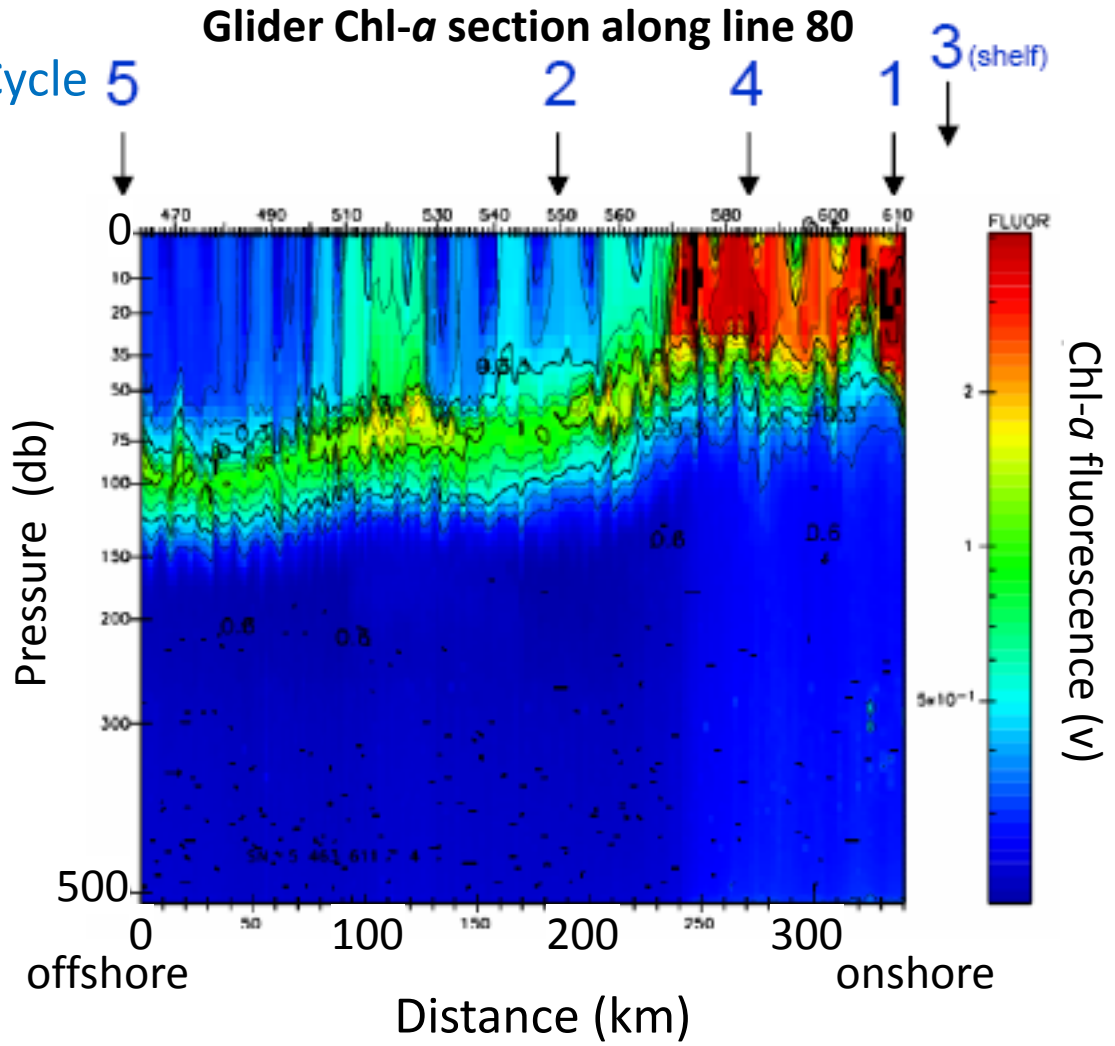
Manu Di Lorenzo





Selection of water parcels

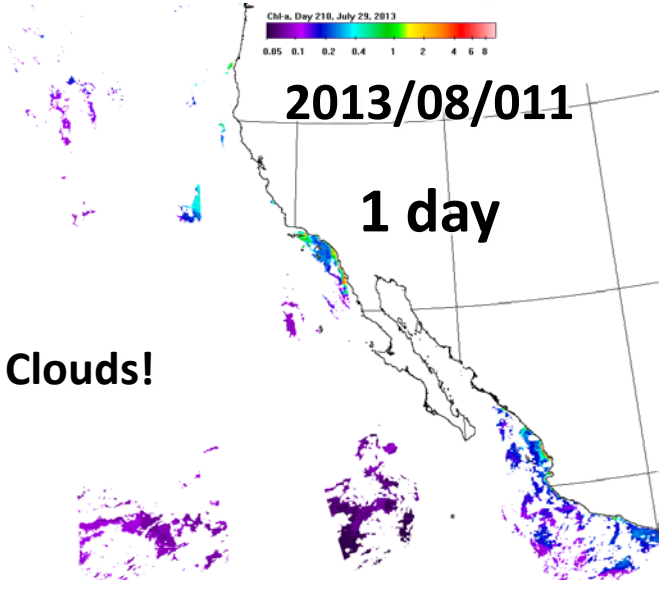
Spray gliders
(to 500 m)

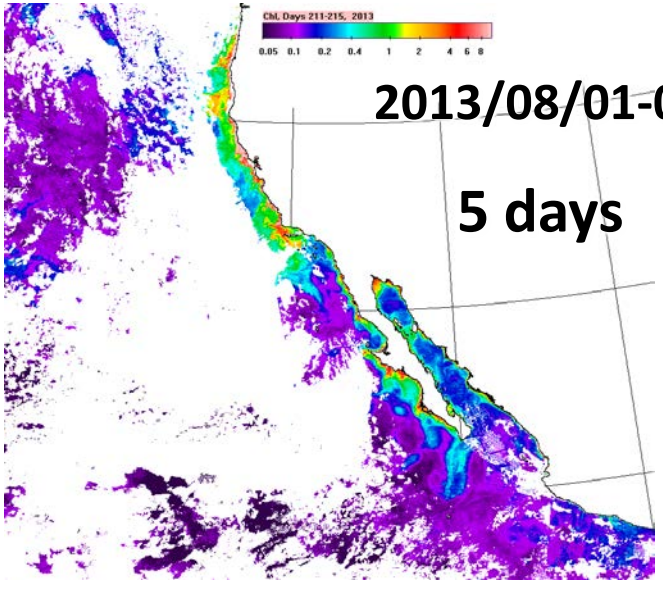


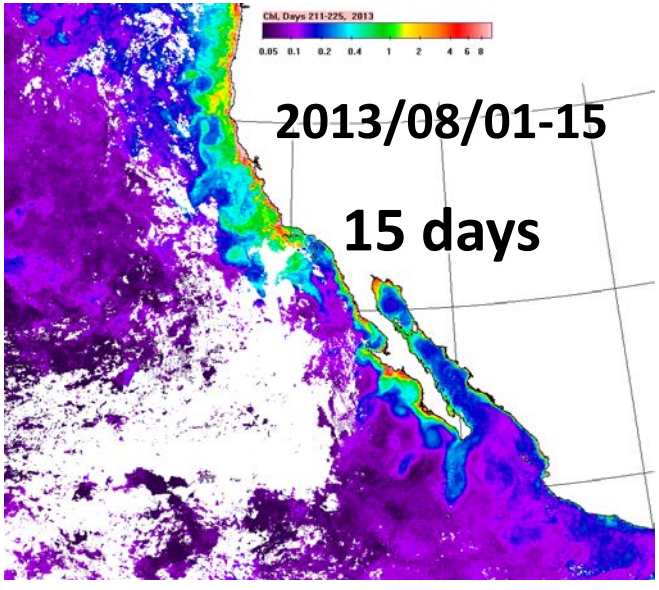
Selection of water parcels

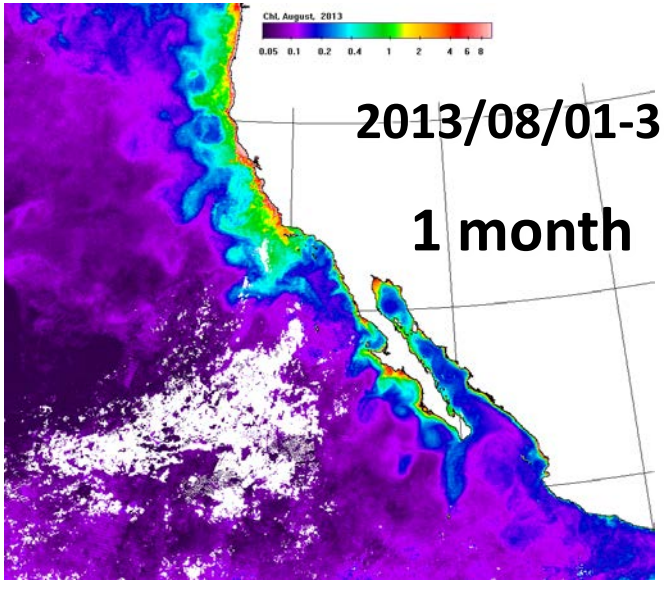
The need for compositing...the curse of the clouds

Mati Kahru
SIO



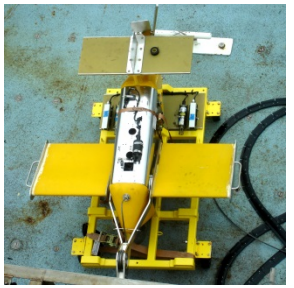


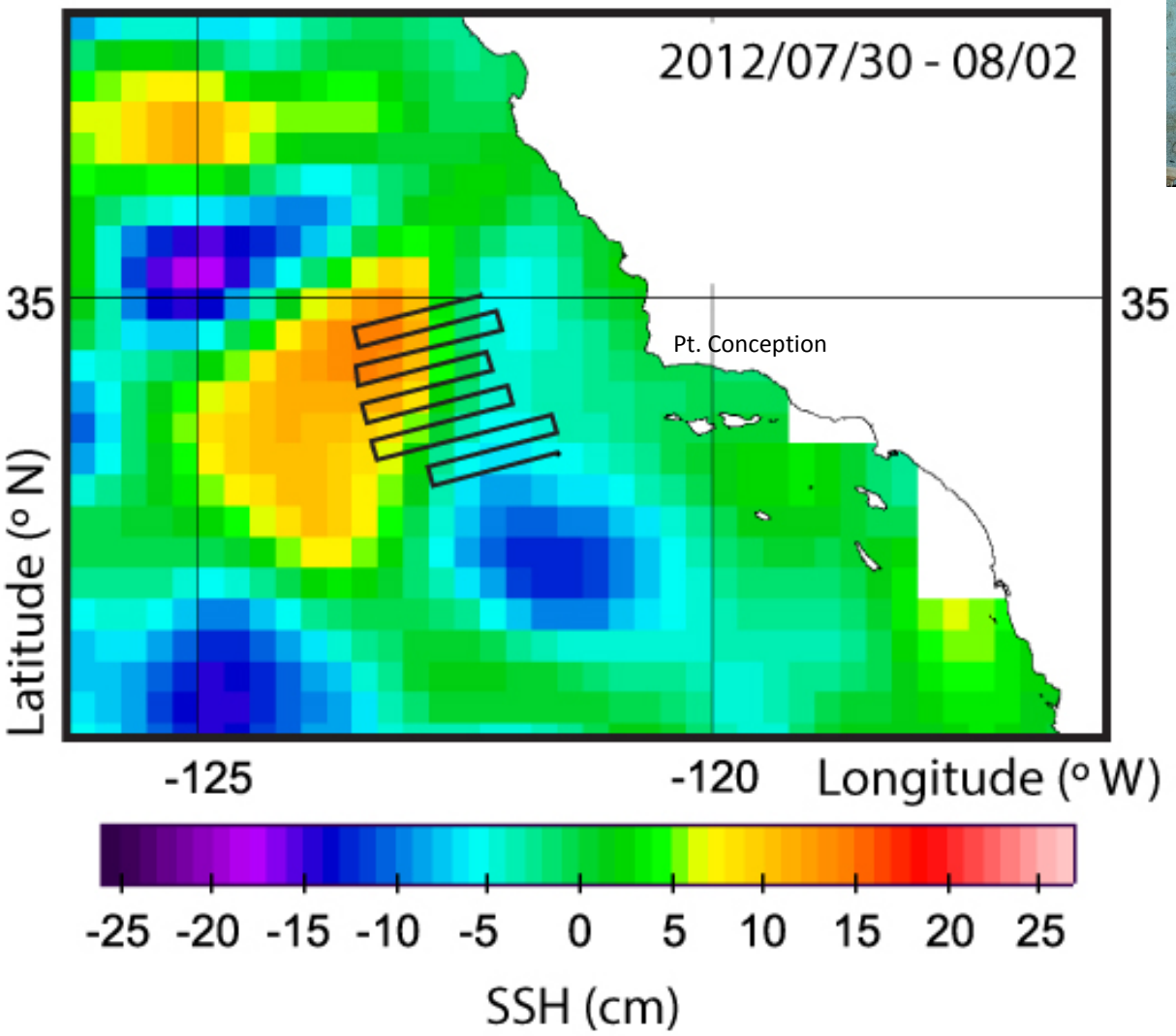




Selection of water parcels

SeaSoar Site Survey



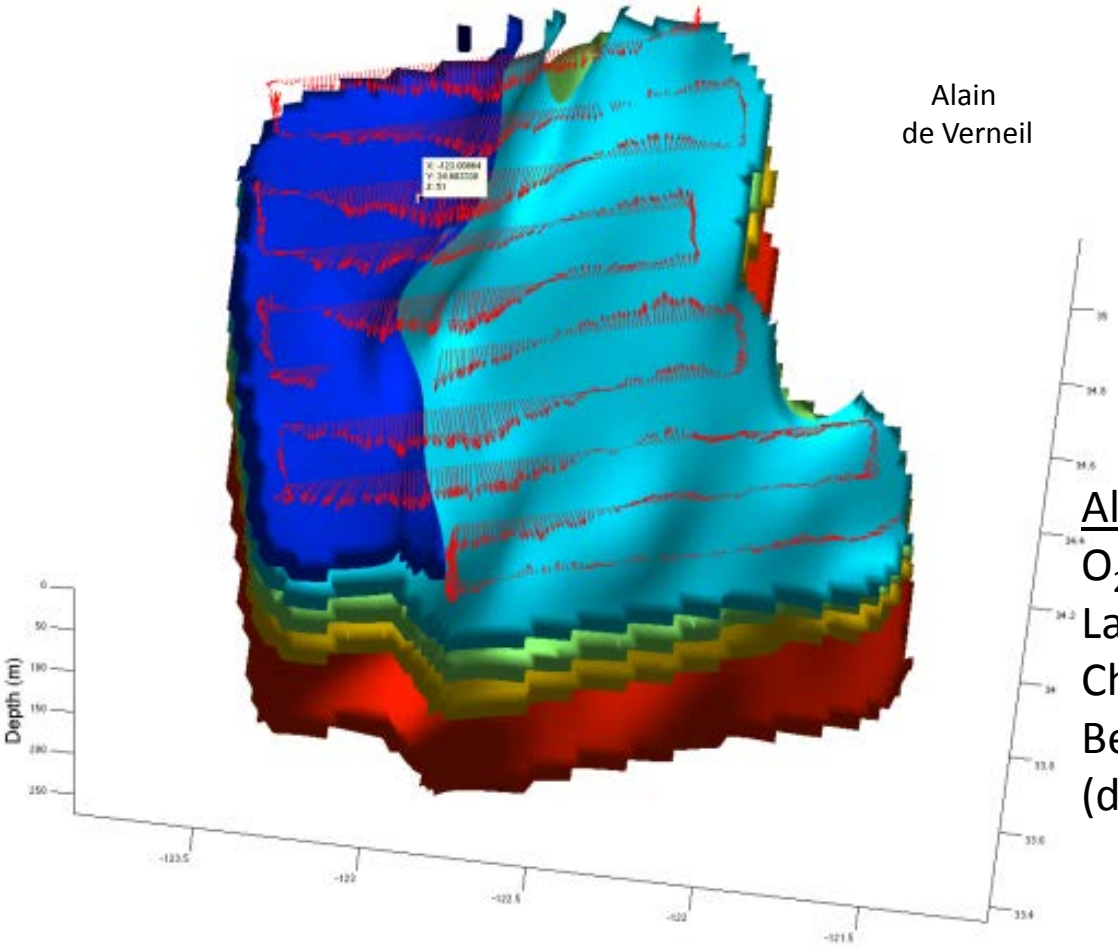


Selection of water parcels

Broad-scale surveys

SeaSoar

Density (σ_θ) + ADCP velocity



Alain
de Verneil

Also:

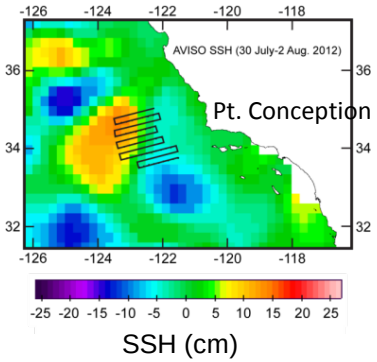
O_2

Laser Optical Particle Counts

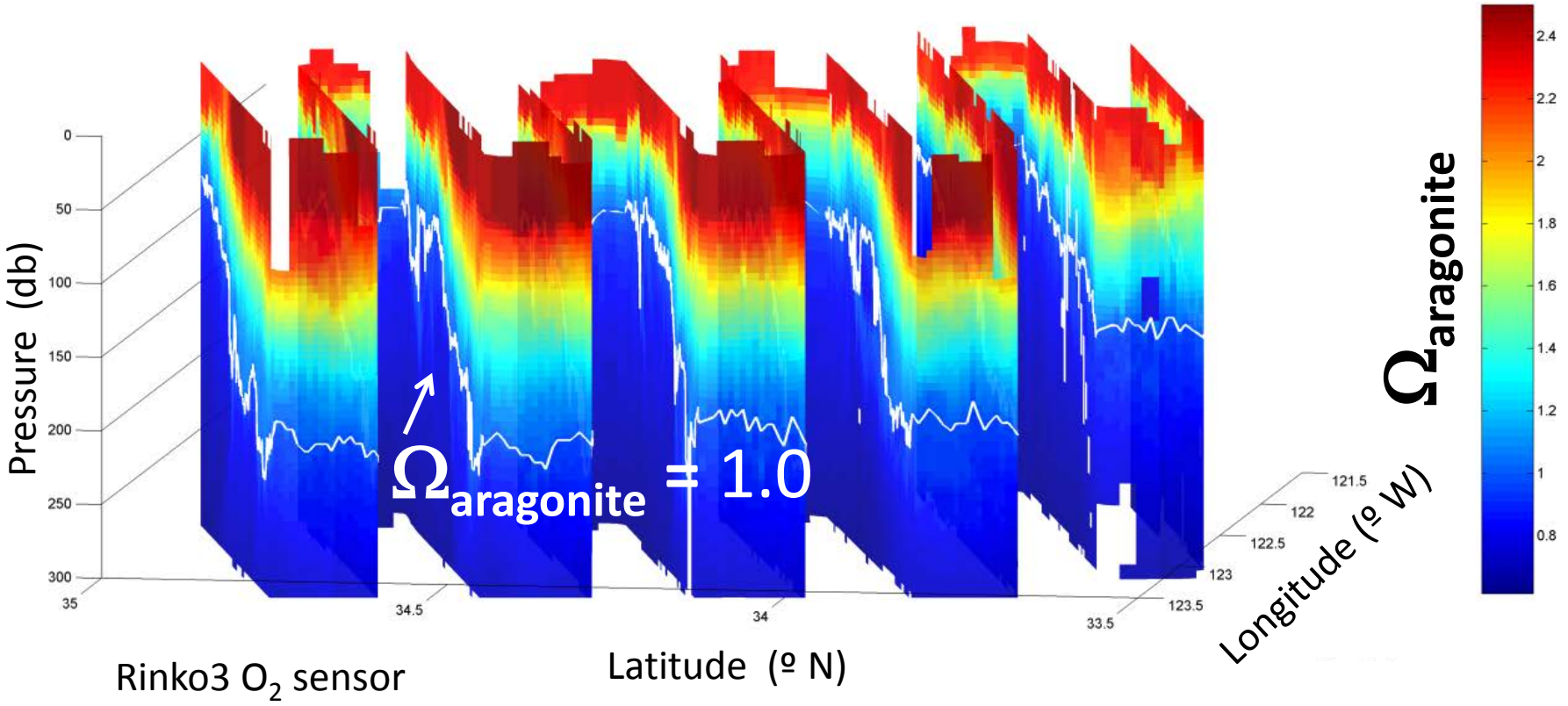
Chl-a

Beam c

(derived: $\Omega_{aragonite}$)



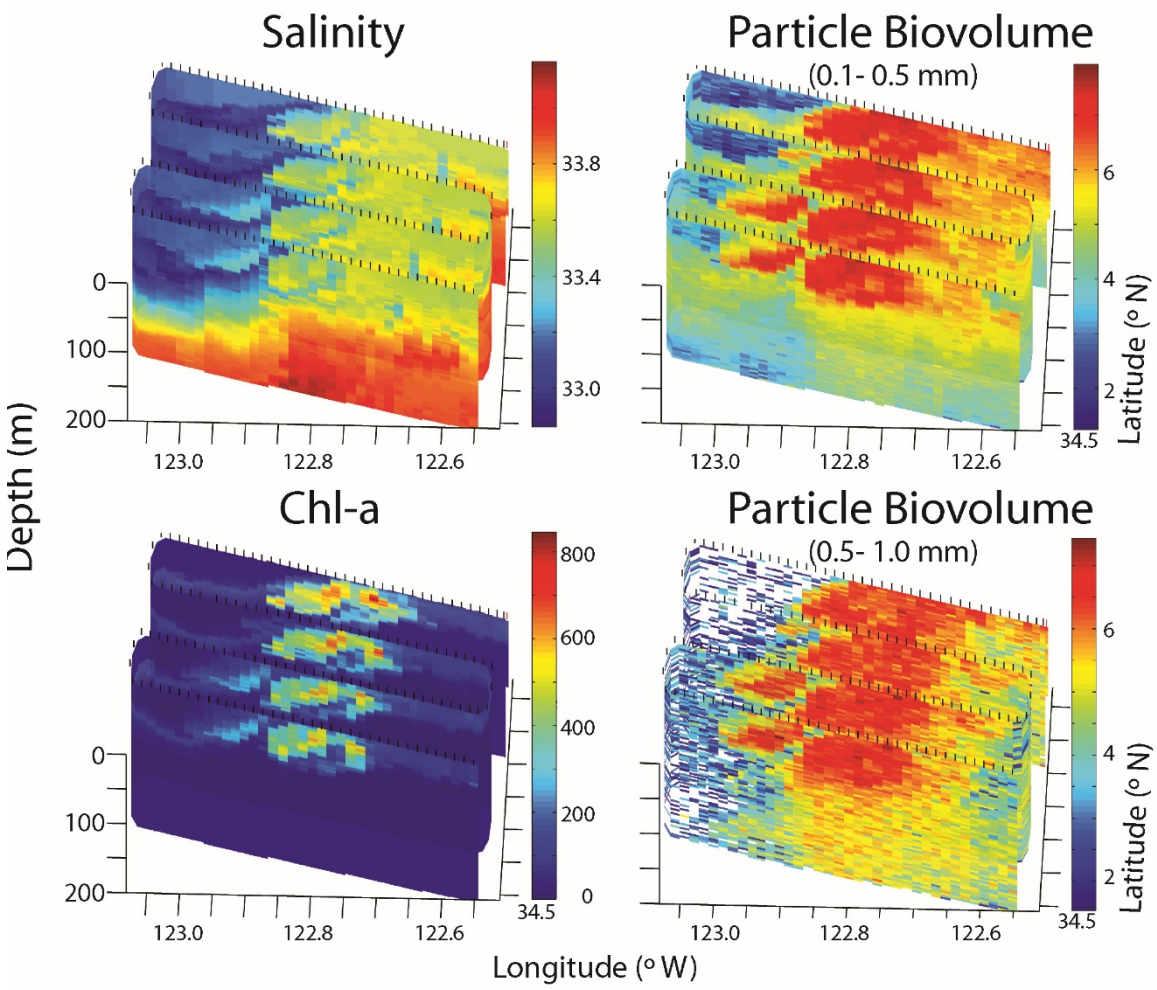
SeaSoar 3-D Ω_{arag} Surface

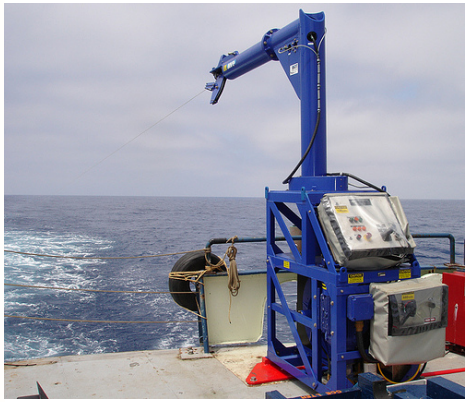


Bednaršek and Ohman (2015) *Marine Ecology Progress Series*

Definition of Frontal Region

Free-Fall Moving Vessel Profiler (MVP)

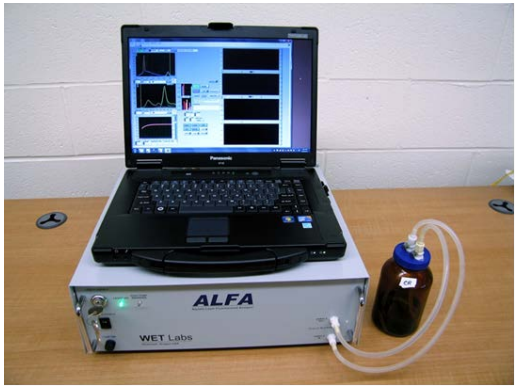


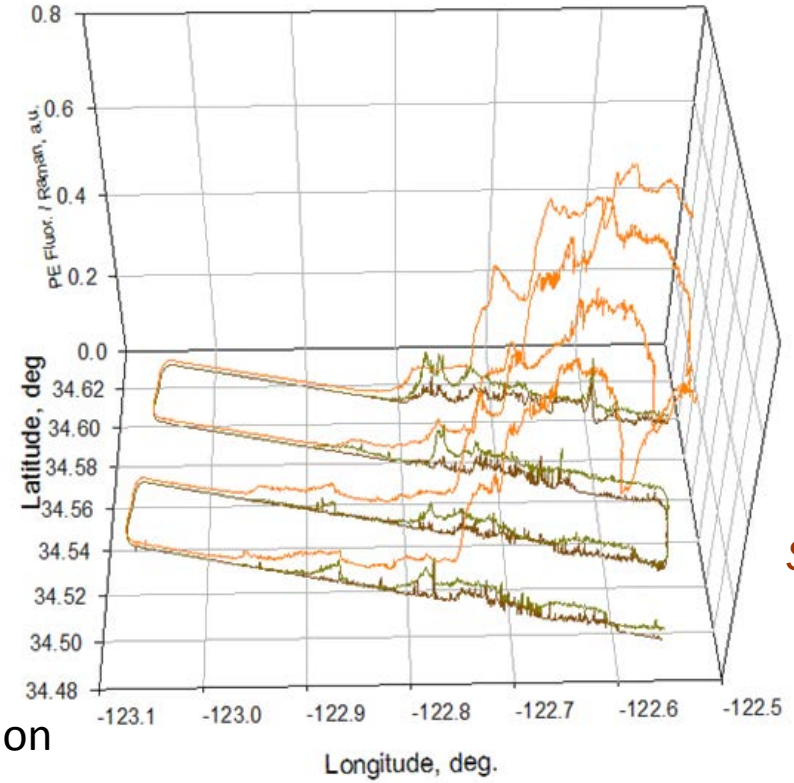


Definition of Frontal Region

Advanced Laser Fluorescence Analyzer (ALFA) continuous underway

Alex Chekalyuk
Lamont





Synechococcus
565 nm
('blue water')

cryptophytes

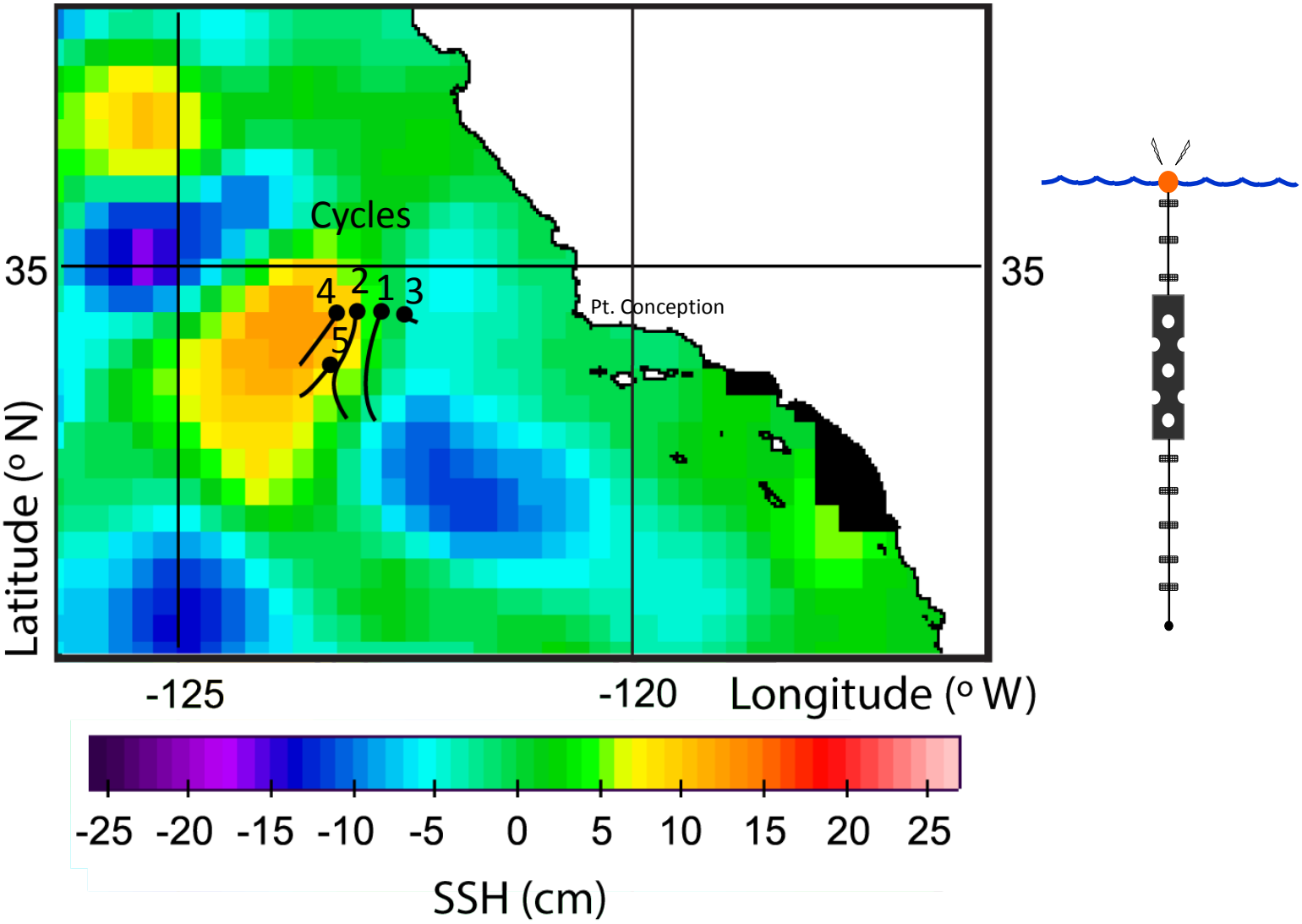
Synechococcus 578 nm
('green water')

blue & green laser excitation

Hyperspectral emission

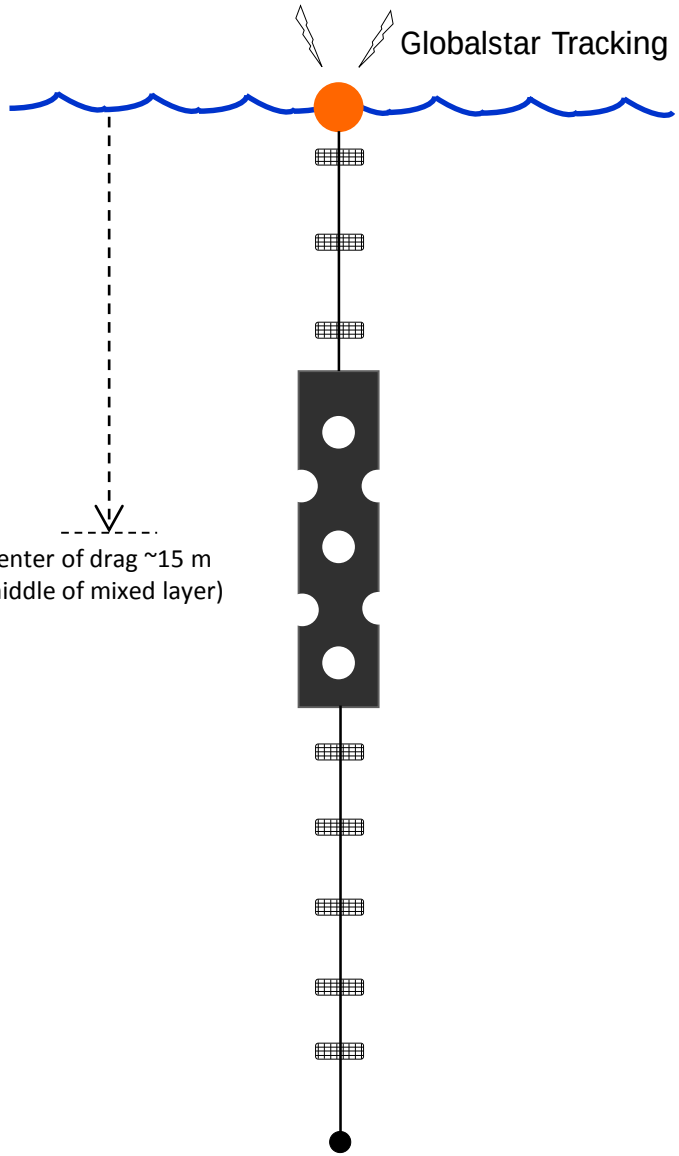
Variable fluorescence

Lagrangian Experimental “Cycles”



WOCE holey sock drifter design

Sybrandy and Niiler 1992



Dilution experiment driftarray

Sediment trap

A day in the life of a CCE-LTER Process Cruise…

7 July – Experimental Cycle #4 (coastal/east side)

0000 Sediment trap deployment, begin CYCLE 4

0100 Wirewalker deployment

0200 CTD cast, UVP5, CYC 4-1

0300 TM cast, experiments

0430 Deploy drift array #57

0500 CTD, thorium

0600 TM cast, experiments

0700 Ring net, plankton isotope size-fractions

0830 Bongo live tows

0930 Bongo, Zooplankton net tow, gut fluorescence

1030 CTD, ^{14}C-Primary Production, biooptics

1130 MOCNESS

1400 Oozeki trawl

1800 McLane pump, C:thorium

1900 CTD, UVP5, full dilution, zooplankton experiments

2100 Bongo, Zooplankton net tow, gut fluorescence

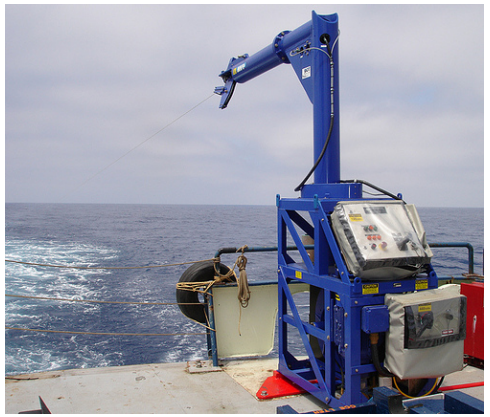
2300 MOCNESS

Survey Instrumentation

Spray gliders

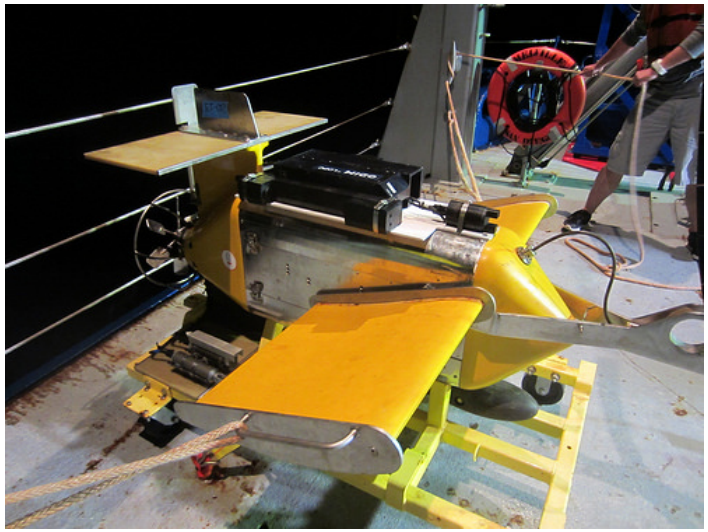
EK60 Acoustic pole

Moving Vessel Profiler



SeaSoar

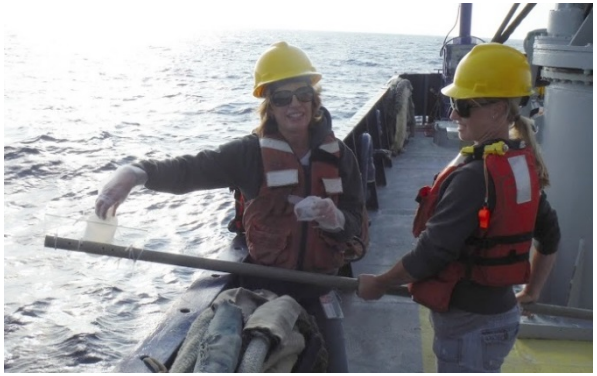
w/ LOPC and Rinko O_2 optode



ALFA

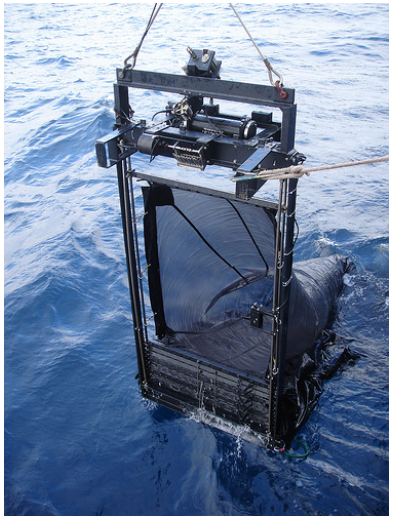
Sampling Devices

Trace Metal Pole



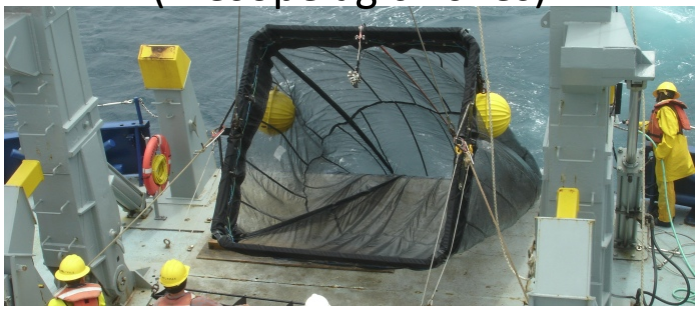
Sediment Traps

MOCNESS



Oozeki Trawl

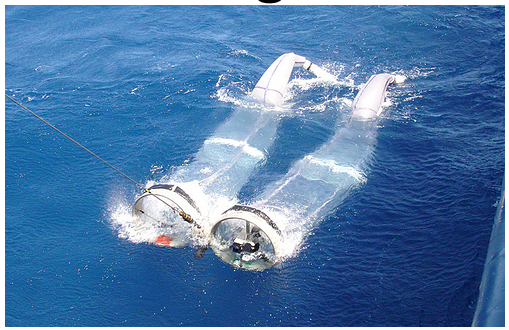
(mesopelagic fishes)



SOLOPC

Dave Checkley

Bongo

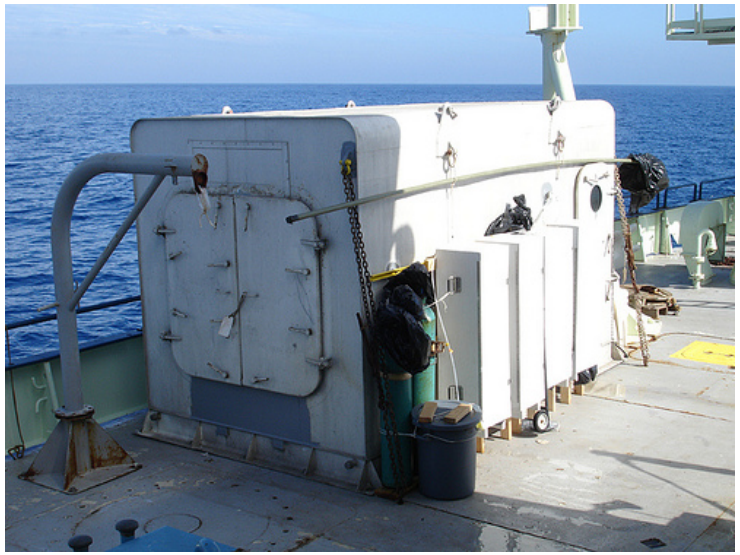


UVP5

(in situ plankton camera on CTD-rosette)

Experimental work

Trace Metal Van

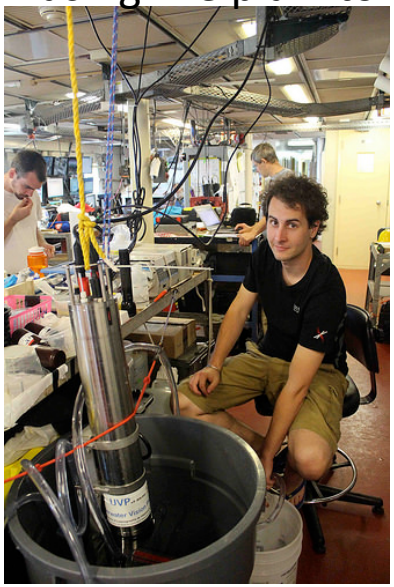


Kathy Barbeau lab

Experimental work

Single cell isolation for DNA extraction

Instrument calibration using live plankton



Silica uptake and cycling

Zooplankton grazing experiments

Lessons Learned

Global Class Vessels are essential

- Interdisciplinary teams
- Many people with diverse skills are needed onboard
- Stable platforms to accommodate experimental work
- Adequate deck space for specialized vans, multiple winches, diverse sampling gear
- Large interior lab space that can be partitioned to accommodate different (and sometimes incompatible) work

Uninterrupted internet communications are mission critical

- Tracking drift arrays, sediment traps
- Glider updates
- Satellite updates

Teacher-at-Sea

Carmina Ramirez
Calexico School District, CA

Brief vignettes, illustrating the importance of *integration* of:

Autonomous

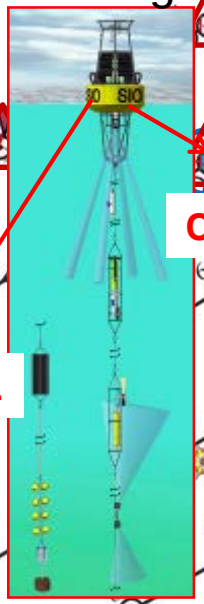
Semi-autonomous

Attended Shipboard measurements

CalCOFI shipboard, 4X yr^{-1}

Deep-sea benthos
Sta. M (K. Smith)

Moorings



CCE1

CCE2

SCCOOS
Southern California Coastal Ocean Observing System

1504NH CALCOFI
& Sampling

Ocean Institute

Scripps pier

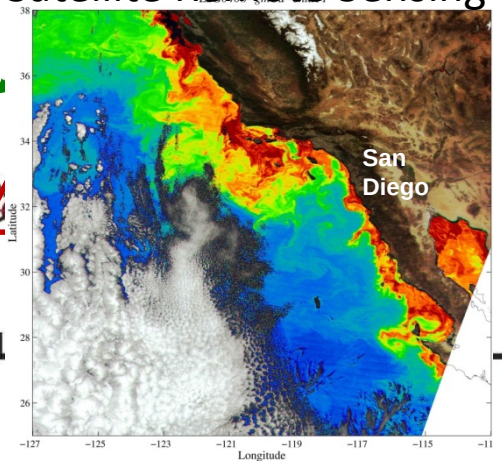
s underway
CO_2

CalCOFI
LTER-Augmented

ckson lab
artz lab

Spray gliders

Satellite Remote Sensing



30°N

'Seasonal' variations

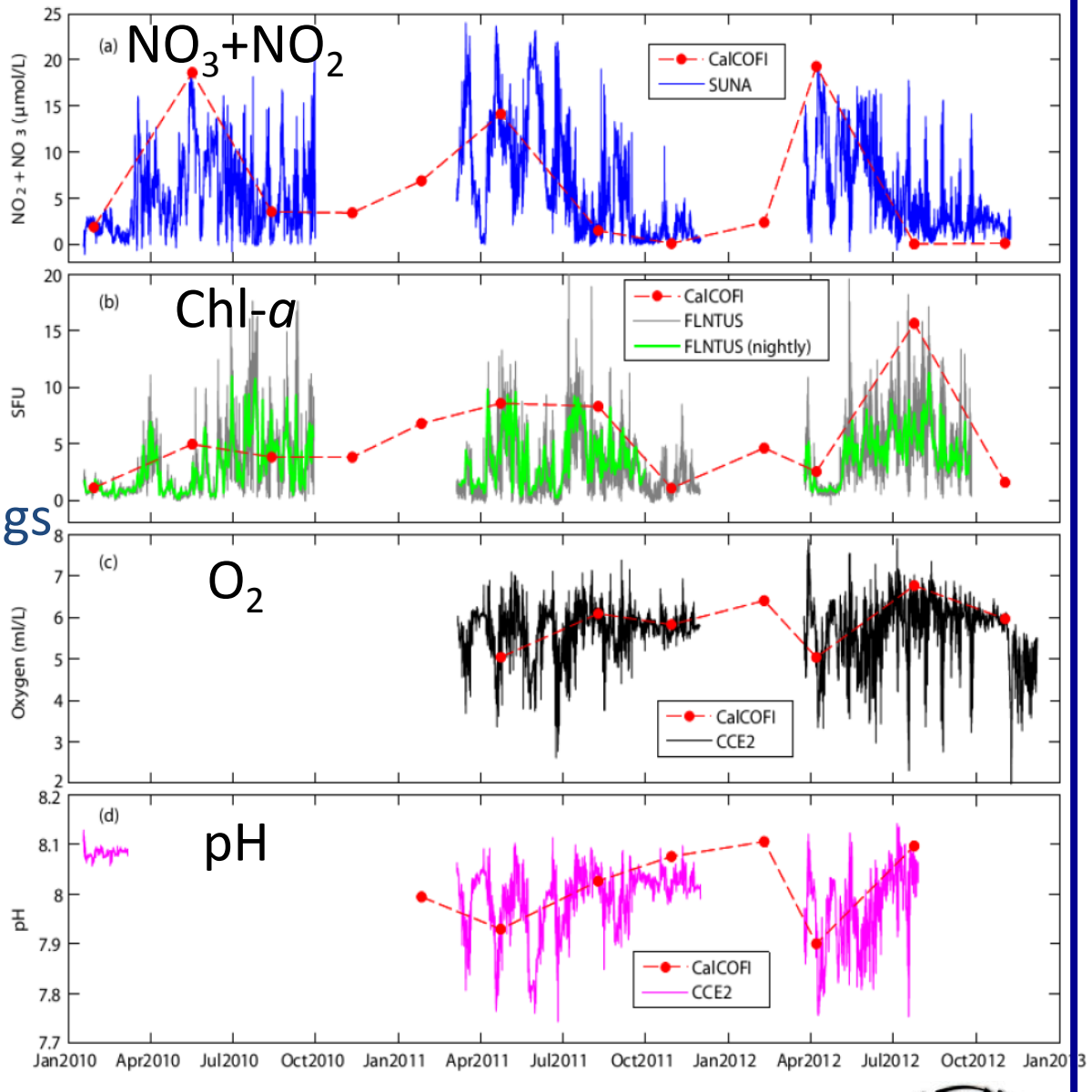
shipboard sampling

(CalCOFI, 4 times year^{-1})

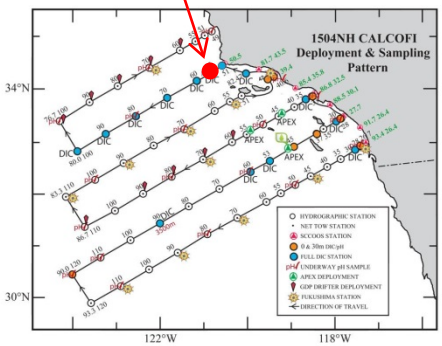
'Event-scale' variations

multi-disciplinary moorings

(continuous)



CCE2 mooring

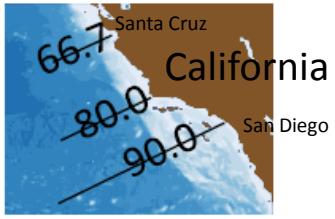


U. Send, M. Ohman, T. Martz (unpubl.), SIO

Katherine Zaba and Dan Rudnick, SIO

Pacific Anomalies Workshop, SIO, May 2015

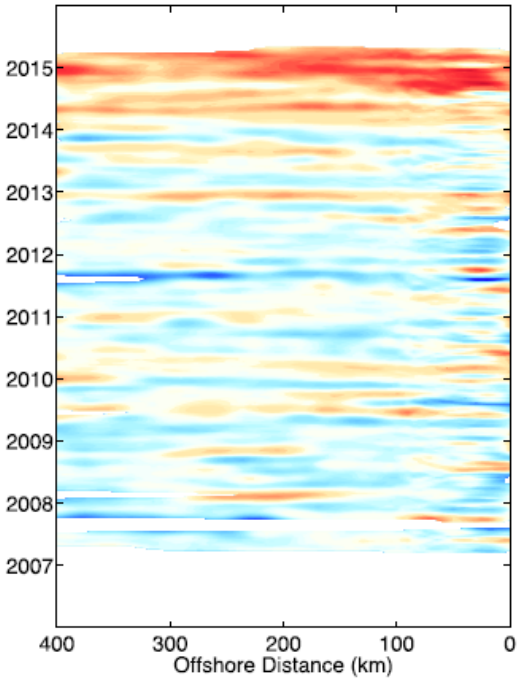
Interannual Anomalies



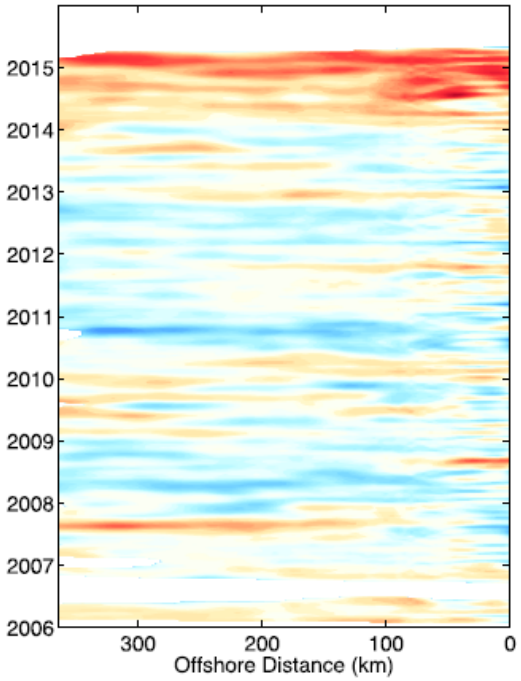
Spray gliders

10 m Temperature (º C)

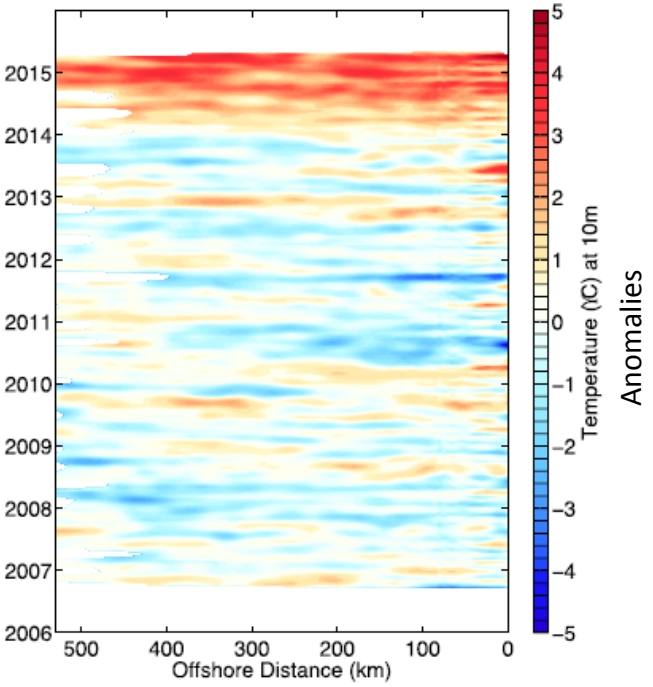
Line 66.7



Line 80.0



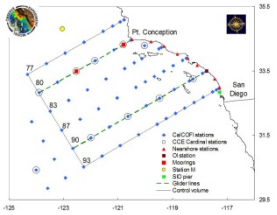
Line 90.0



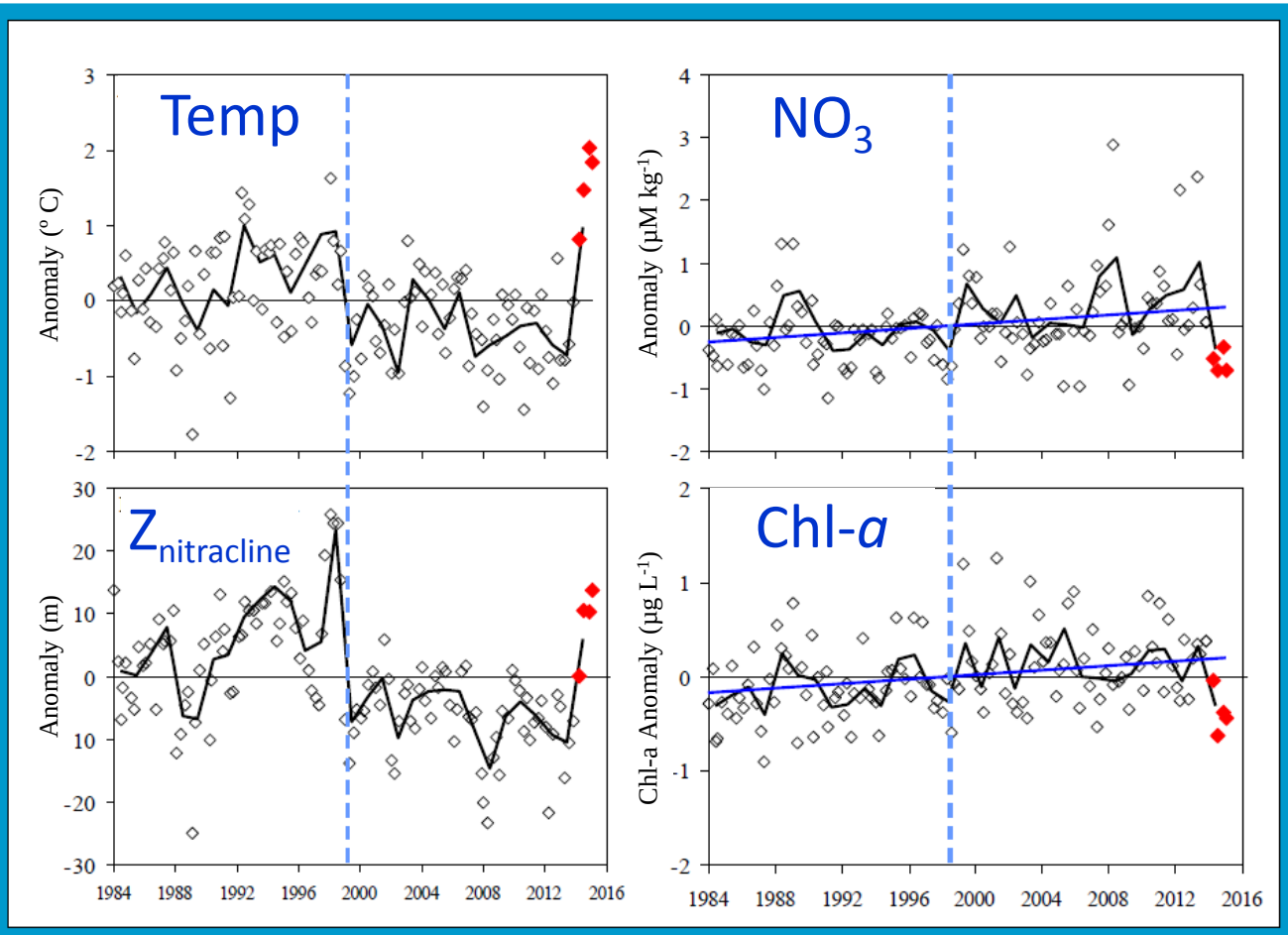
Ralf Goericke, SIO

Pacific Anomalies Workshop, SIO, May 2015

CalCOFI



Phytoplankton and Nutrients



Phytoplankton biomass was controlled by the availability of inorganic nitrogen

Mixed layer anomalies

Combining ship-derived proxy relationship

with Gliders and Moorings to resolve

both Space and Time

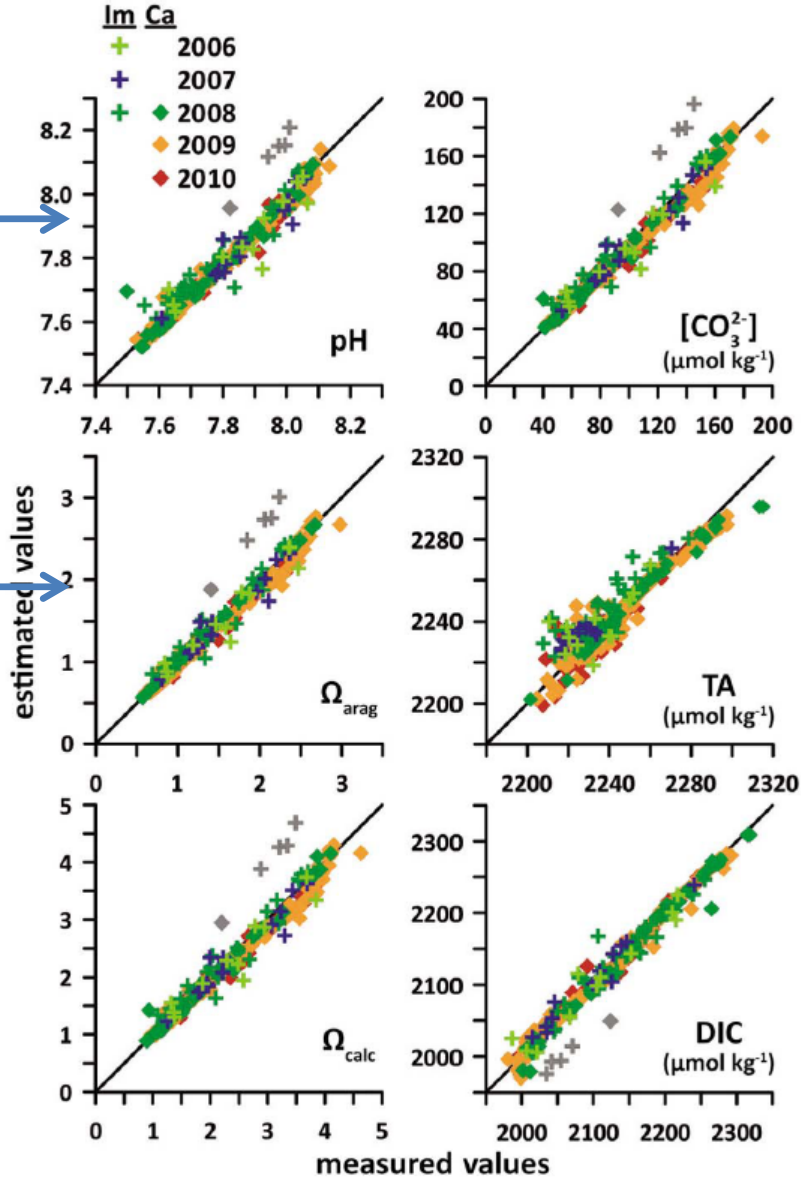
Proxy relationships for Carbonate System Variables

from shipboard samples, Southern and Baja CA regions

Alin et al. (2012)

$pH = f(Temp, O_2)$

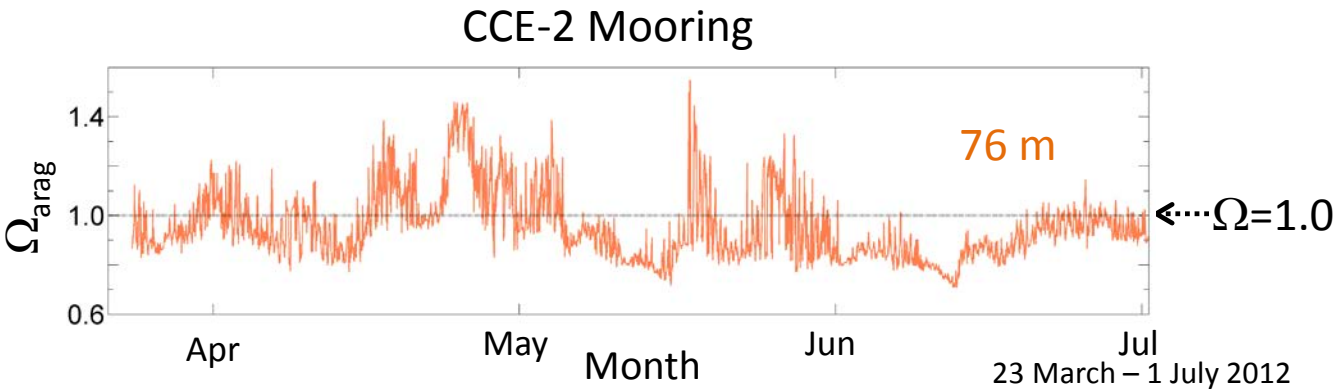
$\Omega_{arag} = f(Temp, O_2)$



Applicable to autonomous sensors
> 15 m depth

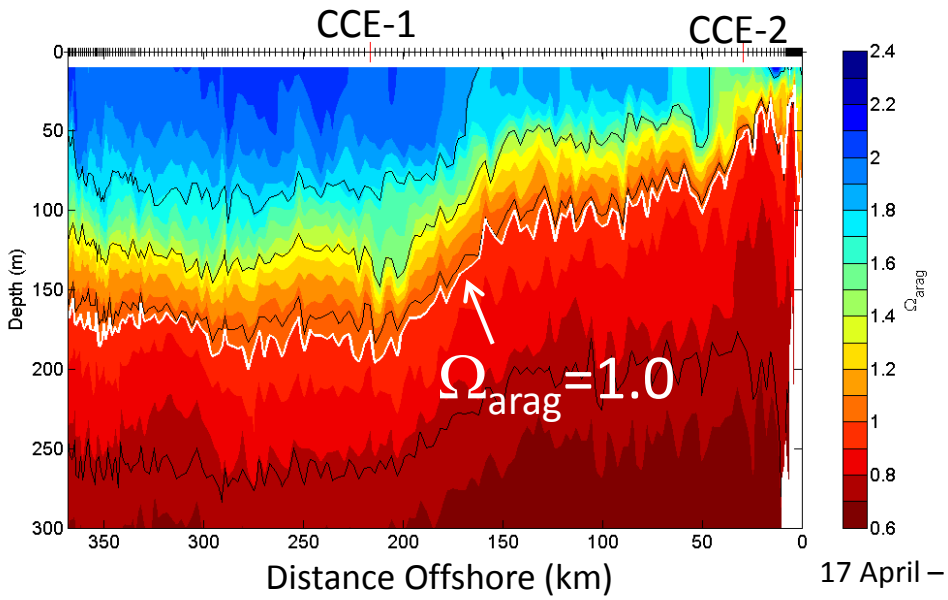
Upwelling/Acidification Events

Temporal variations



Spatial variations

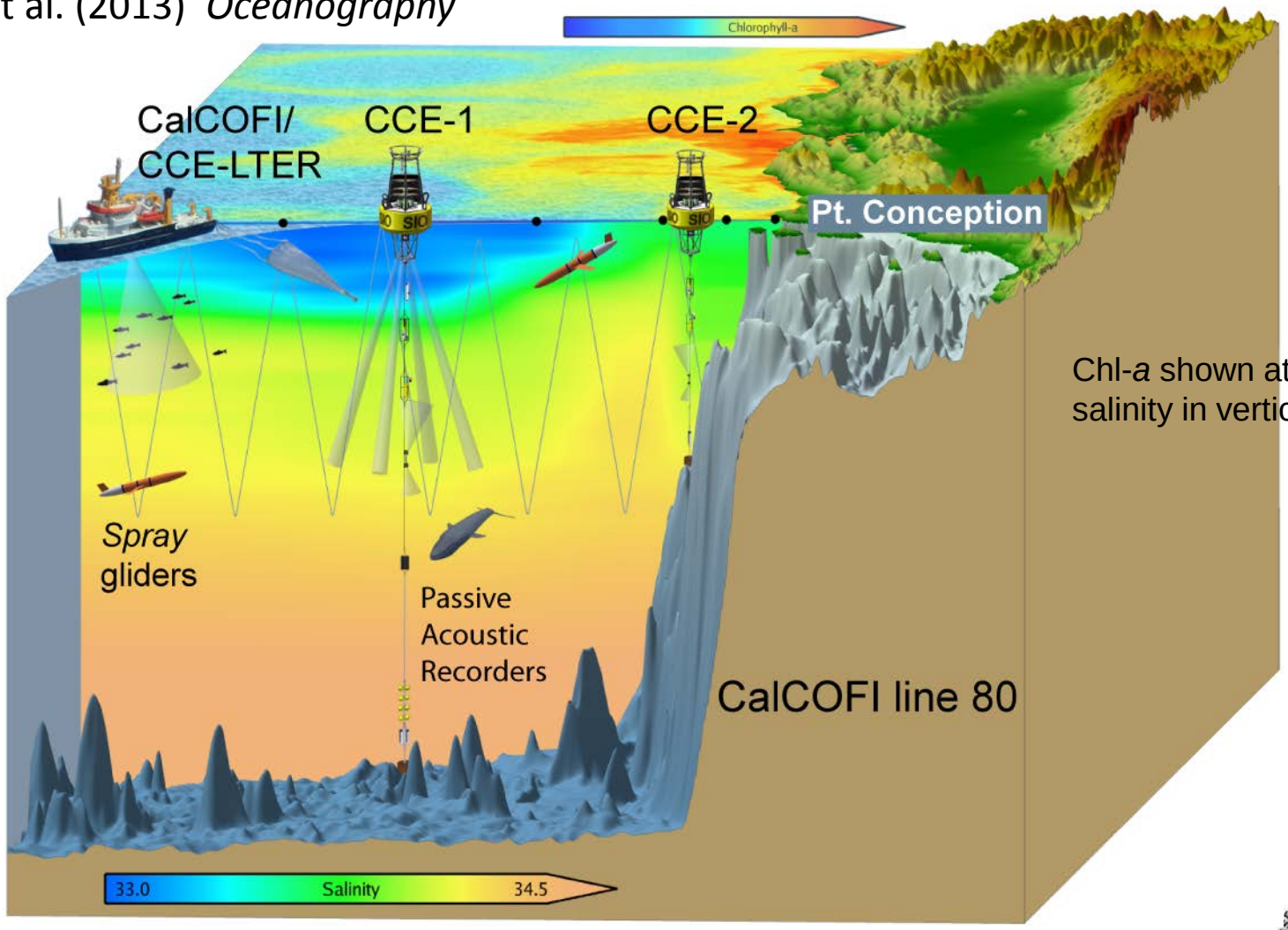
Ohman et al. (2013)



End-to-end Observing System

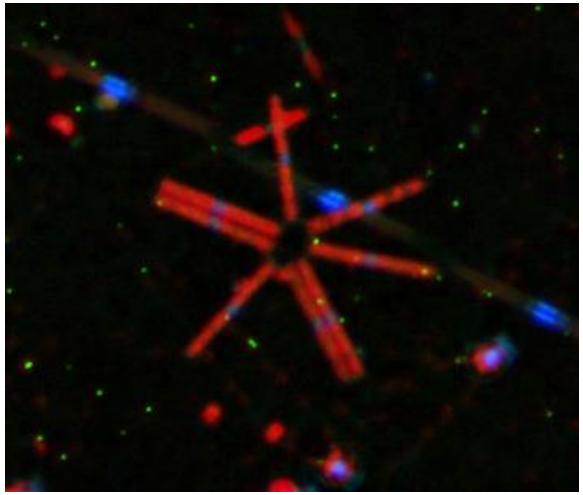
pCO_2 to marine mammals, integrated with 4D ocean modeling

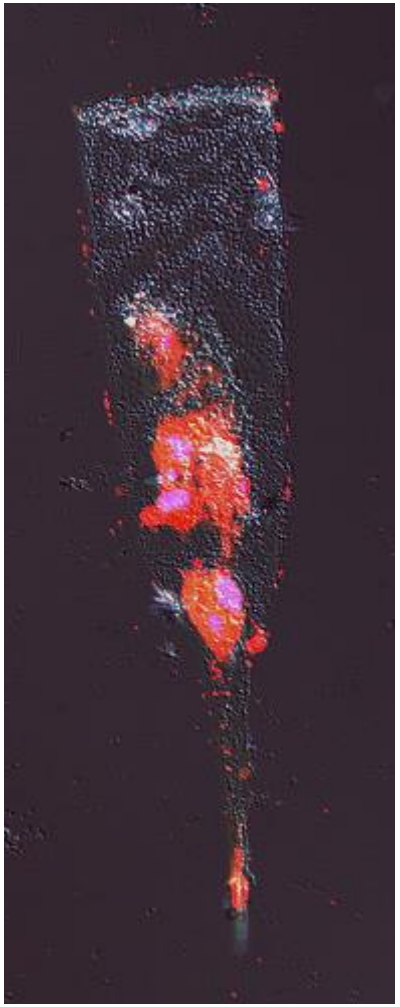
Ohman et al. (2013) *Oceanography*

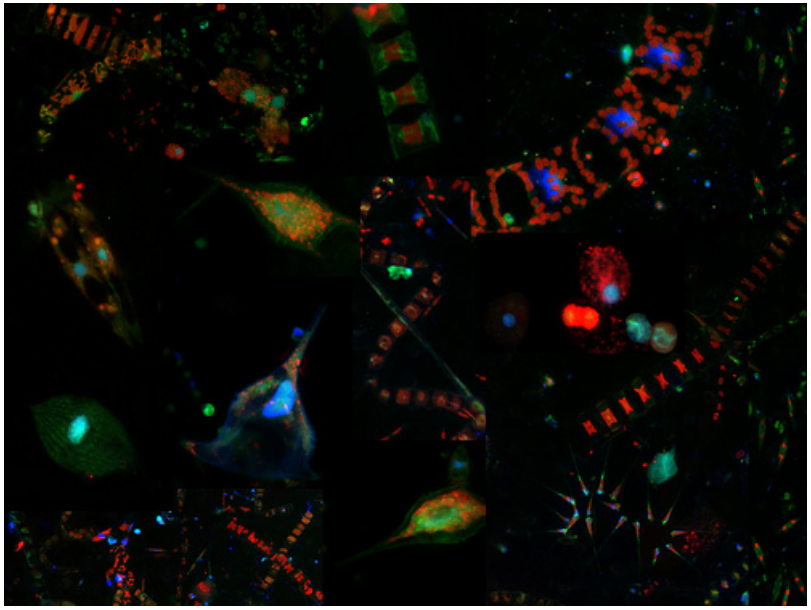


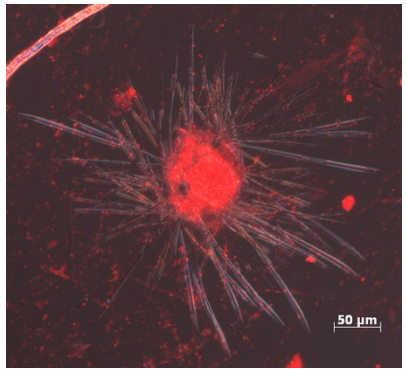
Chl-*a* shown at surface;
salinity in vertical section

figure design: U. Send lab

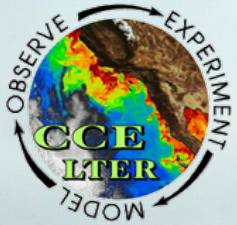







50 µm


© Rasmus Swalethorp



Two primary messages:

Vigorous need for global class vessels

The power of integration of autonomous with shipboard research

International Research Ship Operators
La Jolla 22 Oct. 2015