Status of optical sensors for POC and PIC concentration and Flux.

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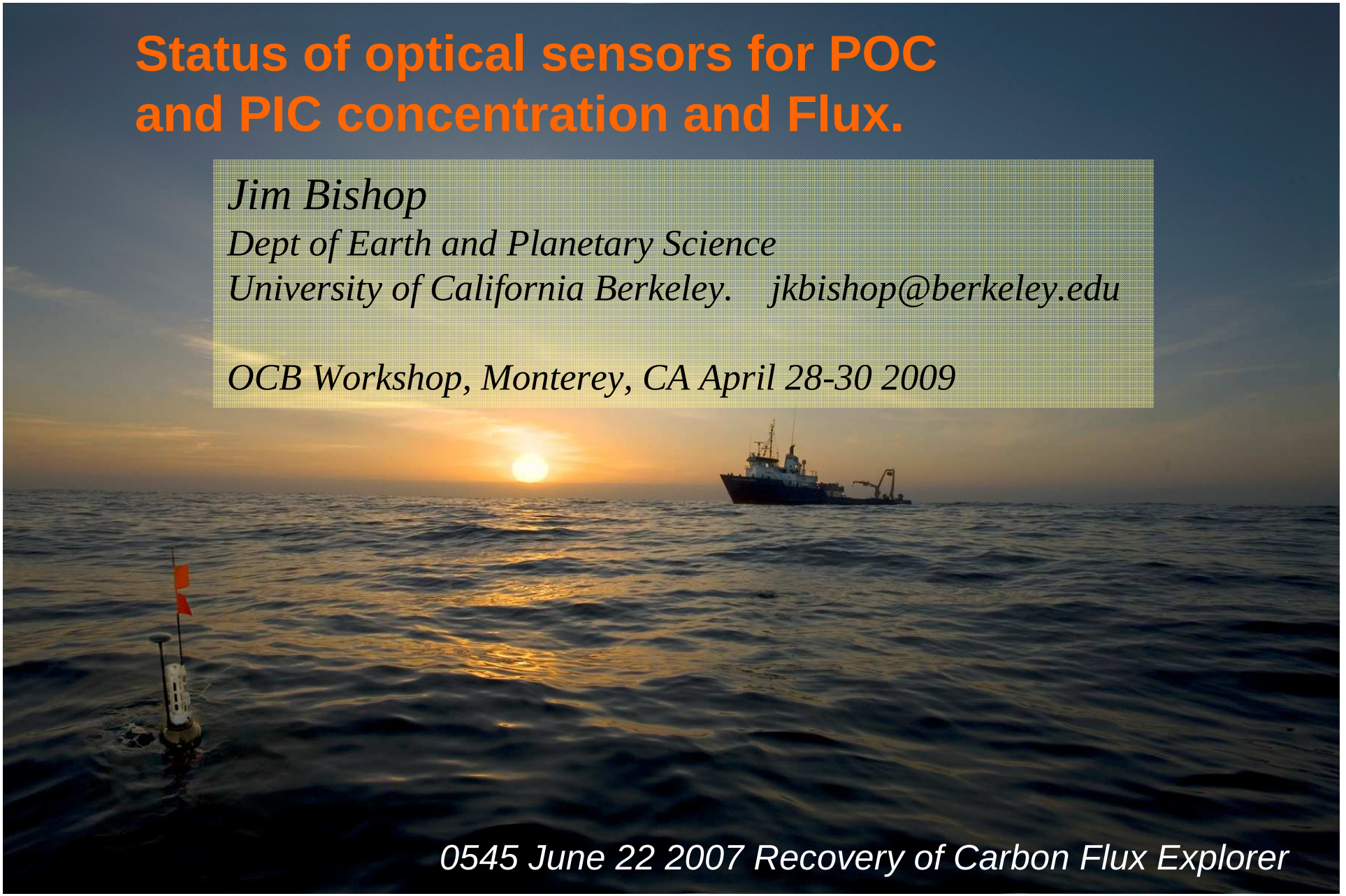
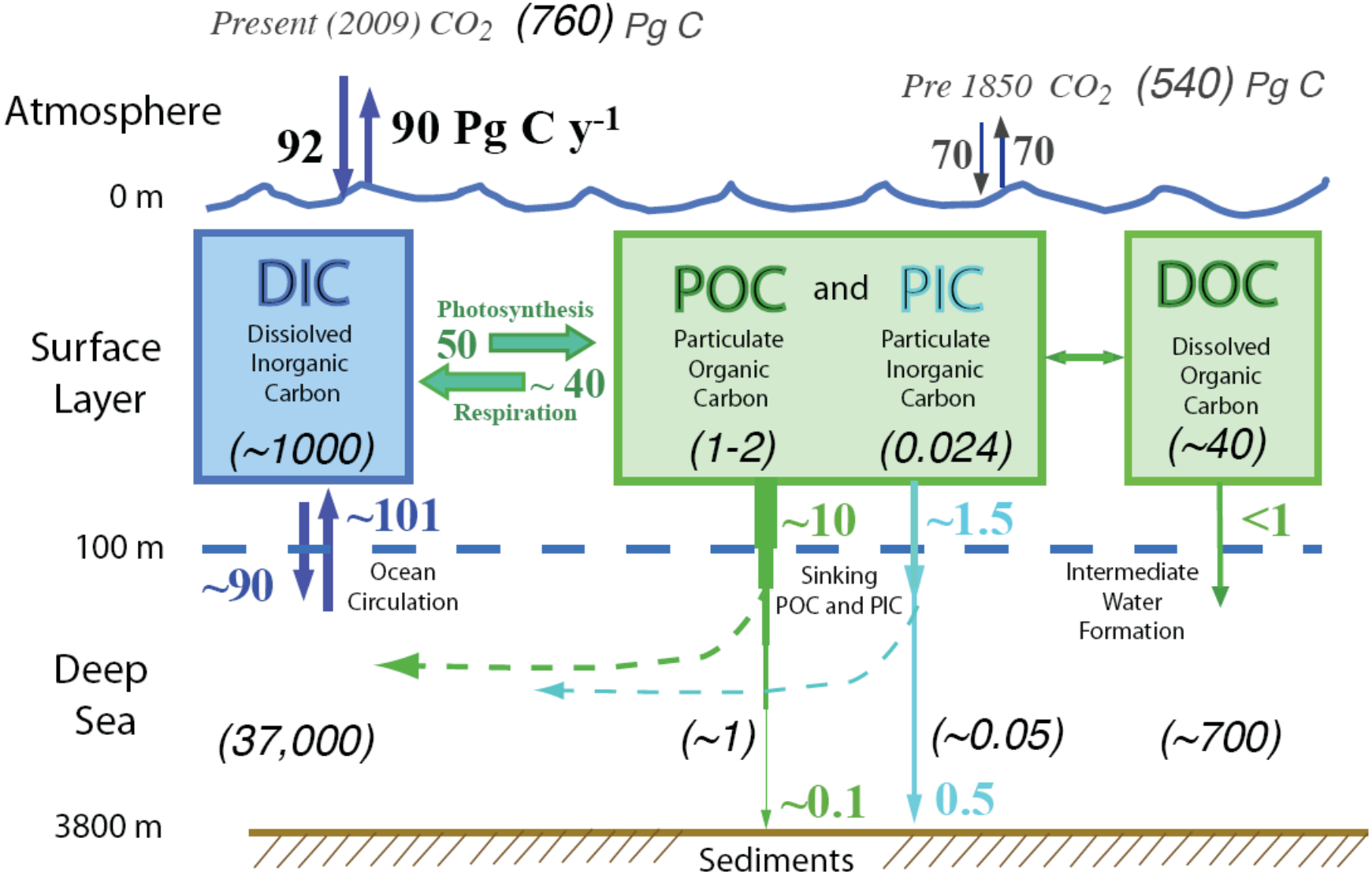
OCB Workshop, Monterey, CA April 28-30 2009



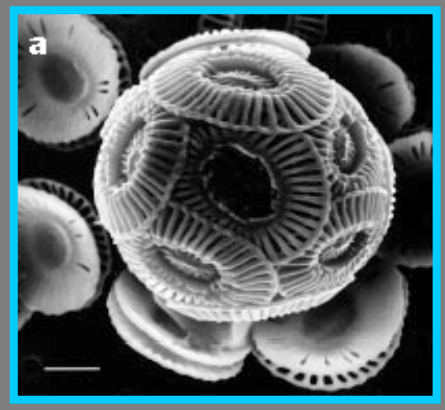
0545 June 22 2007 Recovery of Carbon Flux Explorer


Present (2009) CO_2 (760) Pg C
Pre 1850 CO_2 (540) Pg C
Atmosphere
92
90 Pg C y-1
70
70
0 m
DIC
Dissiolved Inorganic Carbon
(~1000)
Photosynthesis
50
~ 40
Respiration
POC and PIC
Particulate Organic Carbon
(1-2)
Particulate Inorganic Carbon
(0.024)
DOC
Dissolved Organic Carbon
(~40)
Surface Layer
100 m
~101
~90
Ocean Circulation
~10
~1.5
Sinking POC and PIC
<1
Intermediate Water Formation
Deep Sea
(37,000)
(~1)
(~0.05)
(~700)
~0.1
0.5
3800 m
Sediments

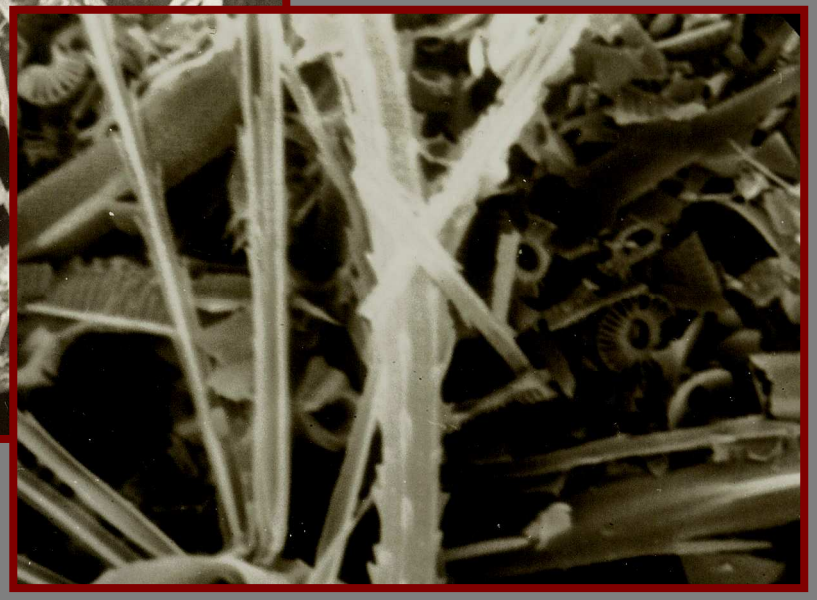
1 Pg = 10^{15}g

WHY PARTICLES?

50 µm



5 µm



5 µm

Prospects for a "Carbon ARGO" look very good

Carbon Explorer Track record

2 N Pacific OSP	2001	
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(lost on launch)		

No major biofouling problems

Transmissometers
~8 float years of data
Includes Carbon Flux Index.

PIC sensor - 1 explorer test

Orbcomm telemetry poor poleward of 55.
Irridium now implemented and gives global coverage.

Bishop, UC Berkeley

STATUS (sensors I work on)

POC

Sensor is mature. Used all platforms. Commercial.

PIC

Operational testing from CTD's. Promising. Near Commercial

POC & PIC flux:

< 2 years for fully Autonomous ops.

DOC is possible.

THANKS TO DOE-BER, NOAA-OGP, NOPP/ONR, NSF, LBNL-LDRD

Bishop, J. K. B., and T. J. Wood (2009), Year-round observations of carbon biomass and flux variability in the Southern Ocean, *Global Biogeochemical. Cycles*, doi:10.1029/2008GB003206, in press. *Carbon Explorers observe Southern Ocean N&S of polar front >1 year. High-biomass low-export.*

Bishop, J.K.B (2009) Autonomous Observations of the Ocean Biological Carbon Pump. *Oceanography, 22 (2). Personal experience with NOPP development mechanism.*

Bishop, J.K.B. and Wood, T.J. (2008) Particulate Matter Chemistry and Dynamics in the Twilight Zone at VERTIGO ALOHA and K2 Sites. *Deep-Sea Research I 55*, 1684-1706. 10.1016/j.dsr.2008.07.012 *Pumps, Bottles and Optics POC (ALOHA vs. K2).*

Bishop, J.K.B., T.J. Wood, R.E Davis, J.T. Sherman. (2004) Robotic Observations of Enhanced Carbon Biomass and Carbon Export at 55S During SOFeX - *Science*, 304, 417-420.
Carbon Explorers observe iron fertilization experiment

Bishop, J.K.B. R.E. Davis and J.T. Sherman (2002) Robotic Observations of Dust Storm Enhancement of Carbon Biomass in the North Pacific. *Scienc*e 298, 817-821. *Carbon Explorers observe biological response to dust deposition: 2001 Gobi Dust Storm Event.*

Guay. C.K. and J.K.B. Bishop (2002) A rapid birefringence method for measuring suspended $CaCO_3$ concentrations in water, *Deep-Sea Research I*, 49, 197-210. *PIC sensor method.*

Sensors for particulate inorganic carbon (PIC).

6000 m
“Cstar”
version

Laser — 25 cm open cell — Detector

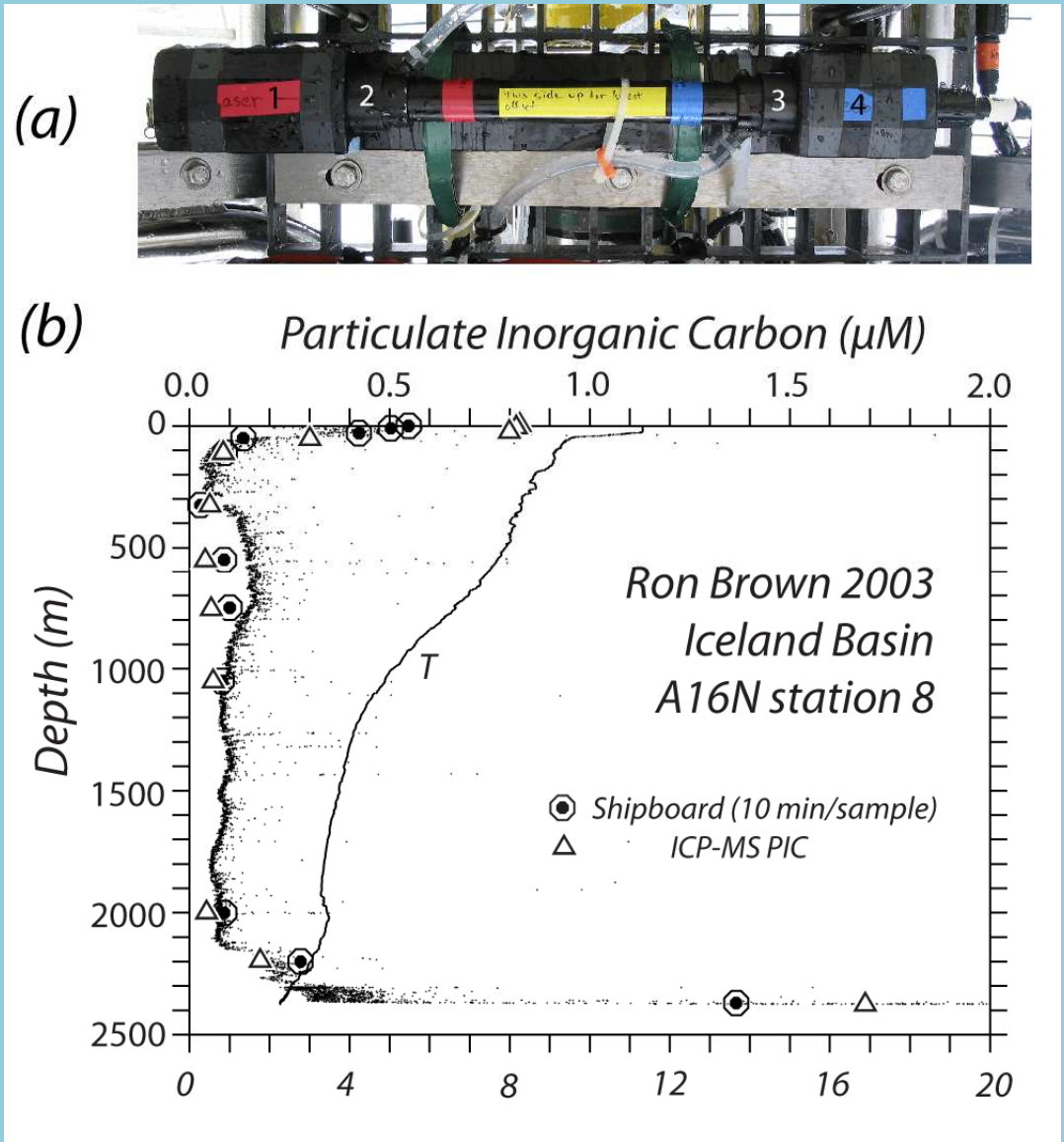
Neutrally
Buoyant
sensor

Sensors tested and reengineered multiple times.

2003 A16n, 2005 A16s, 2007 (San Clemente Basin),
2008 BATS and Slope Water (GEOTRACES IC I)
2009 N Pac Gyre and Santa Barbara Basin – (next month)

With WETLabs

PIC sensor



Pumped sensor promising in 2003 precision ~100 nM.

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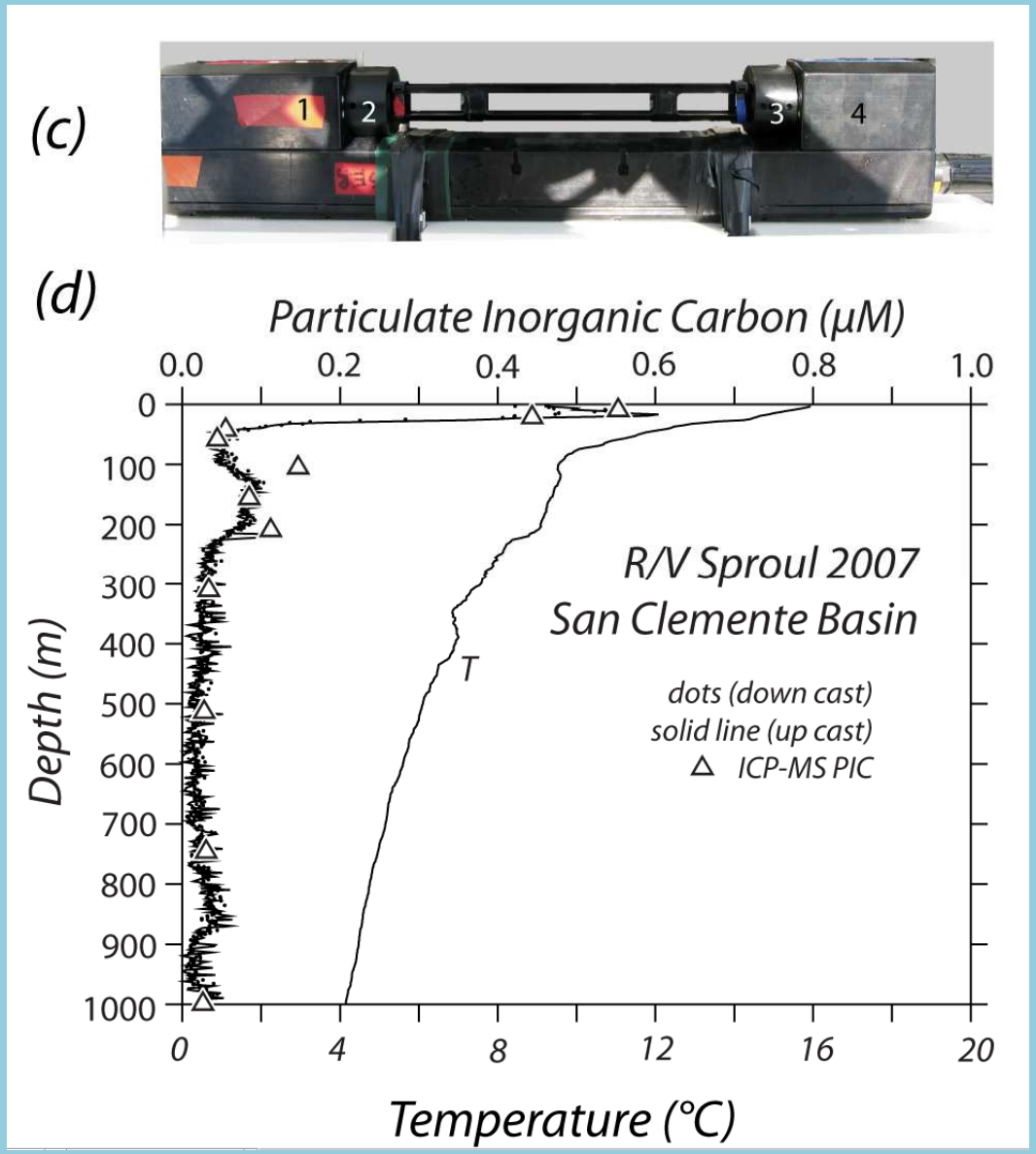
PIC sensor



Open cell sensor 2007.
Precision ~10 nM
Accuracy ~40 nM.

Up and down casts agree

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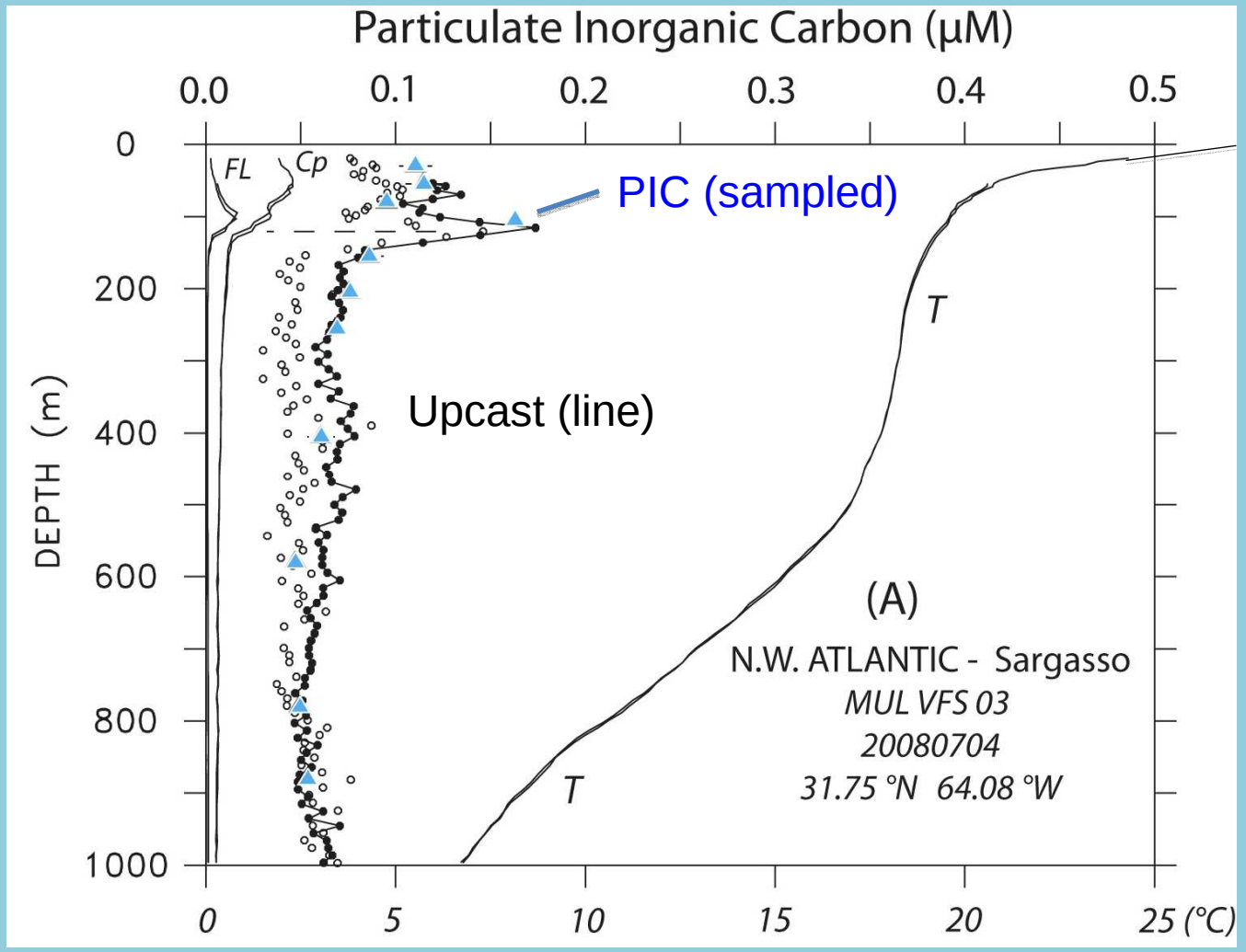
North Atlantic: 2008 near BERMUDA (NSF GEOTRACES)



Sensor baked on deck. Temp compensation routine fails down cast.
Good Upcast agreement, PIC signal is distinct from Cp, scattering, and Fl.

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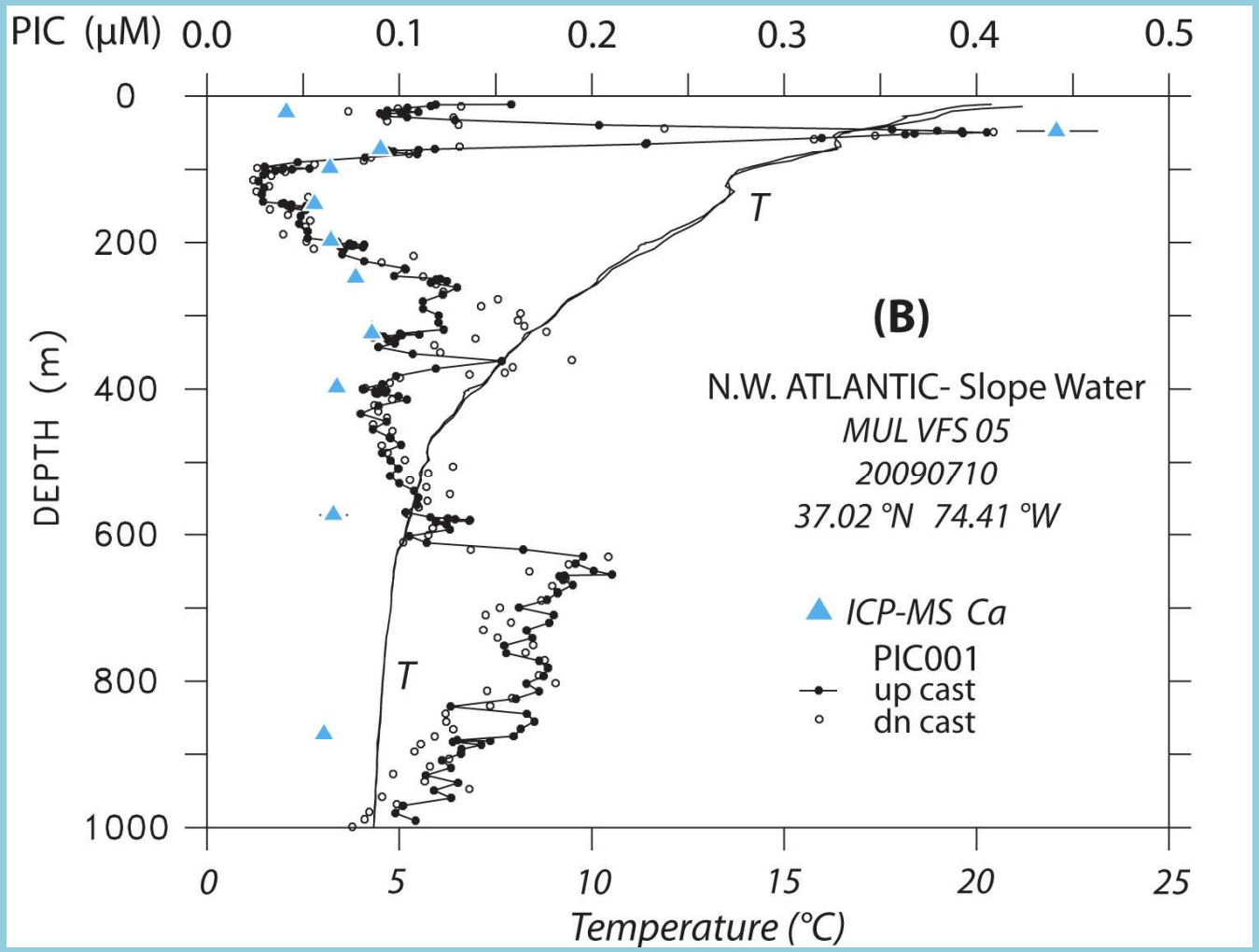
North Atlantic: 2008 Slope Water near margin.



Upper 500 m – agreement is excellent.

> 500 m, may include other birefringent particles in deep water near margins.

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PIC SENSOR

Calibration in Atlantic (2008) replicates San Clemente (2007). Some thermal/mechanical stability issues remain. Easily fixed.

Already deployed on Carbon Explorer Platform

Possible to implement on Glider platform.

PIC and POC sensor can be combined in one package

pending proposal with WETLabs, Inc. address thermal stability and simplify cell mounting.

Carbon Flux Explorer
a new concept.

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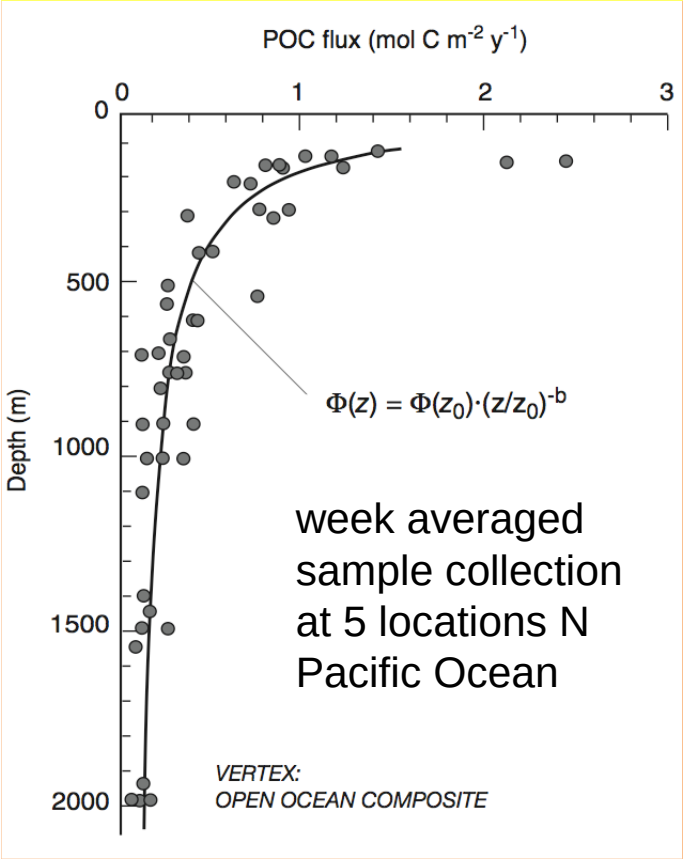
Towards improved prediction of C Sedimentation & Remineralization

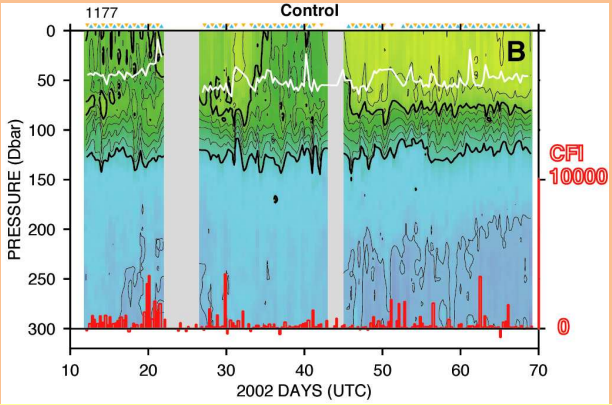
SHIP OBS

1987 Martin et al. formula globally invariant: used in all carbon cycle models



week averaged sample collection at 5 locations N Pacific Ocean

STEP (1) Carbon Explorer



Carbon Flux Index (CFI): high-frequency time series of systematic variations of carbon sedimentation in real time.

STEP (2) Carbon Flux Explorer designed to quantitatively measure daily POC and PIC flux for seasons.
First launch June 2007 a success

Instrument Development

Sedimenting particles fall into the funnel and accumulate on a glass surface and are imaged at 15 µm resolution by an upward looking digital camera. Periodically, the surface is cleaned.

Instrument integrated with float

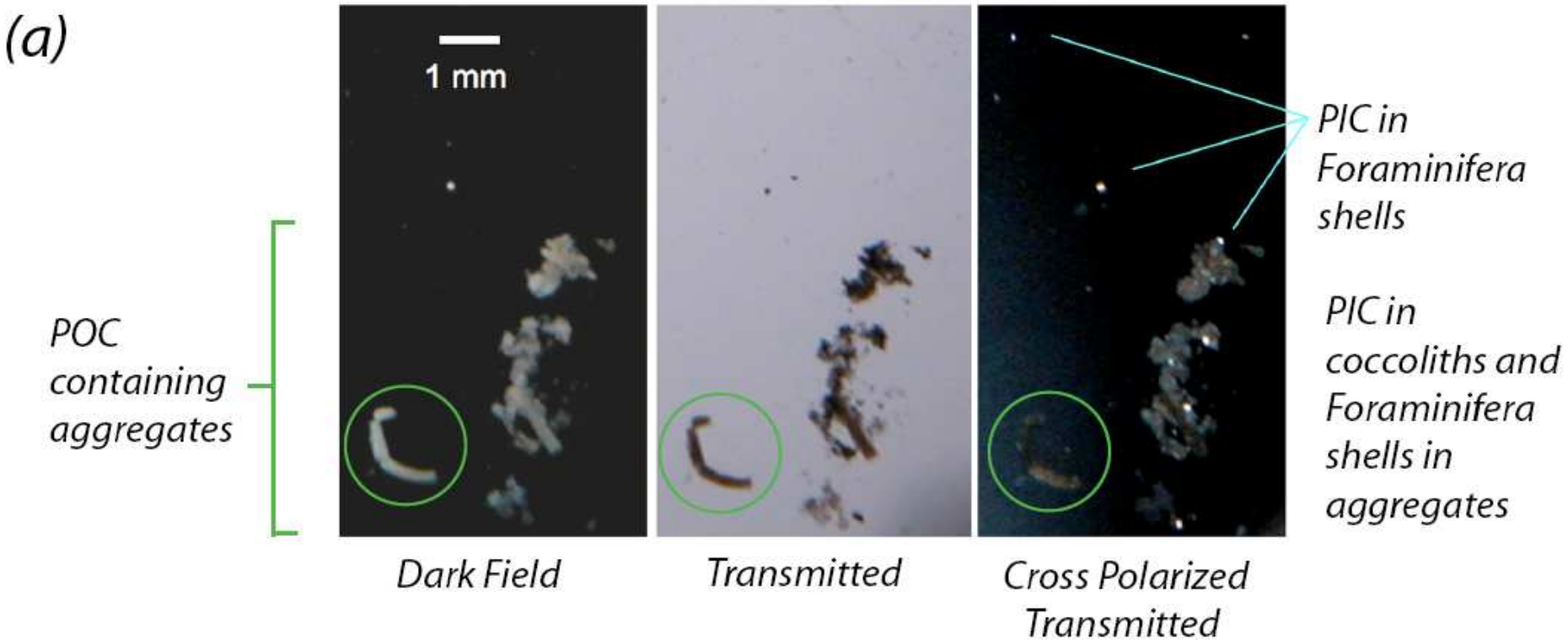
Carbon Flux Explorer

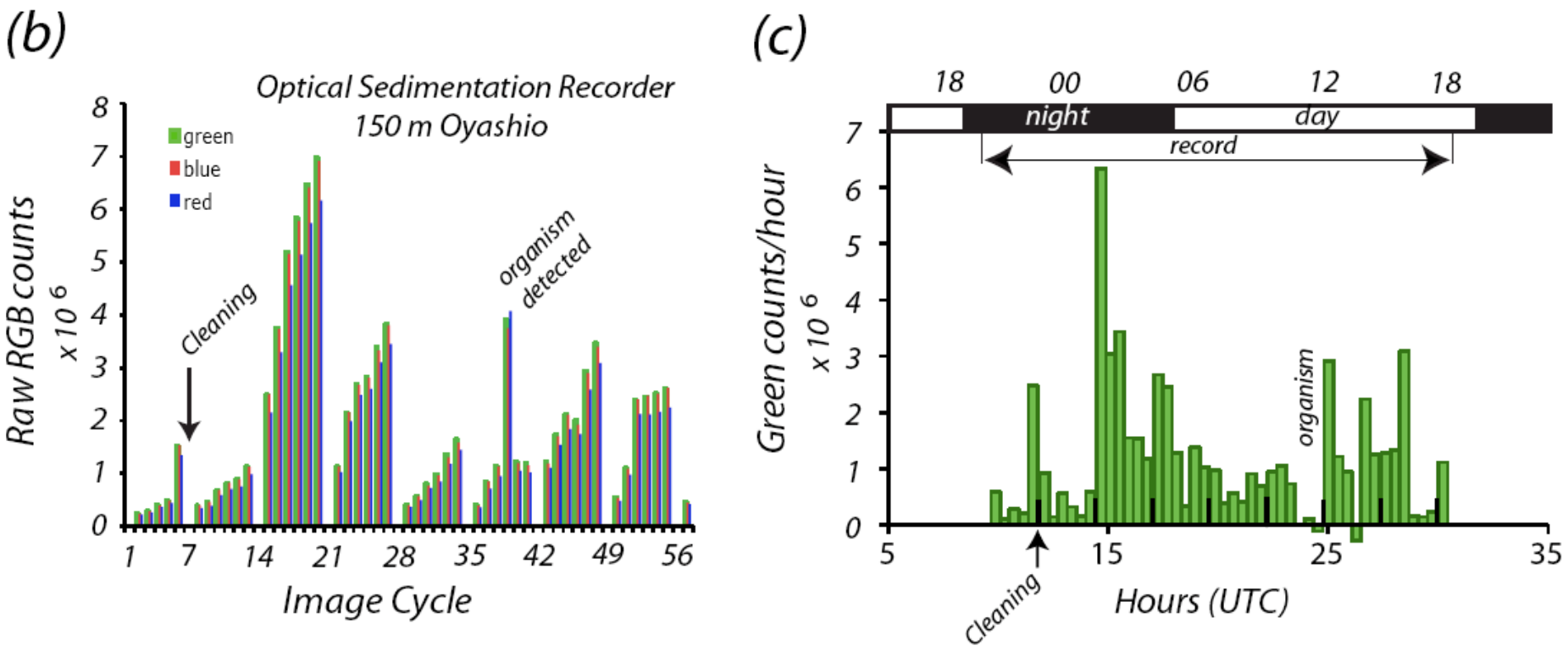
Instrument and ballasting design for free vehicle achieved at LBNL

Support DOE Office of Science, Office of Biological and Environmental Research

J Bishop UCB/LBNL

Three ***calibrated*** lighting modes – separate organic C from Inorganic C





OSR instrument lights/parts now stable, CFE integration looks good, now address issues of seasonal to year scales – organism invasions, fouling.

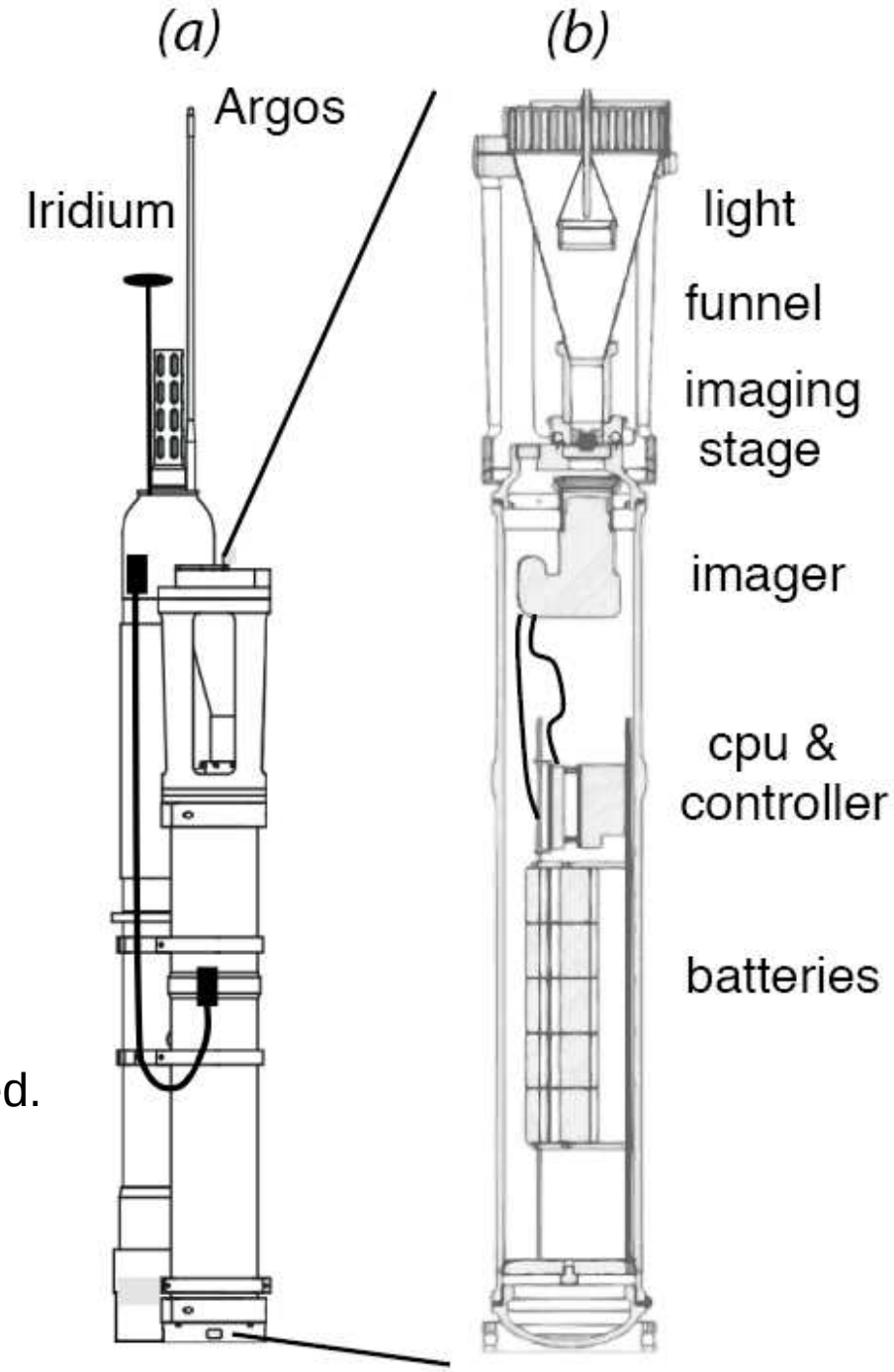
Bishop (2009) Oceanography

Carbon Flux Explorer:

An example of independent and complex platform/sensor Integration.

Platform provides queues to sensor.

Sensor responds with data when asked.



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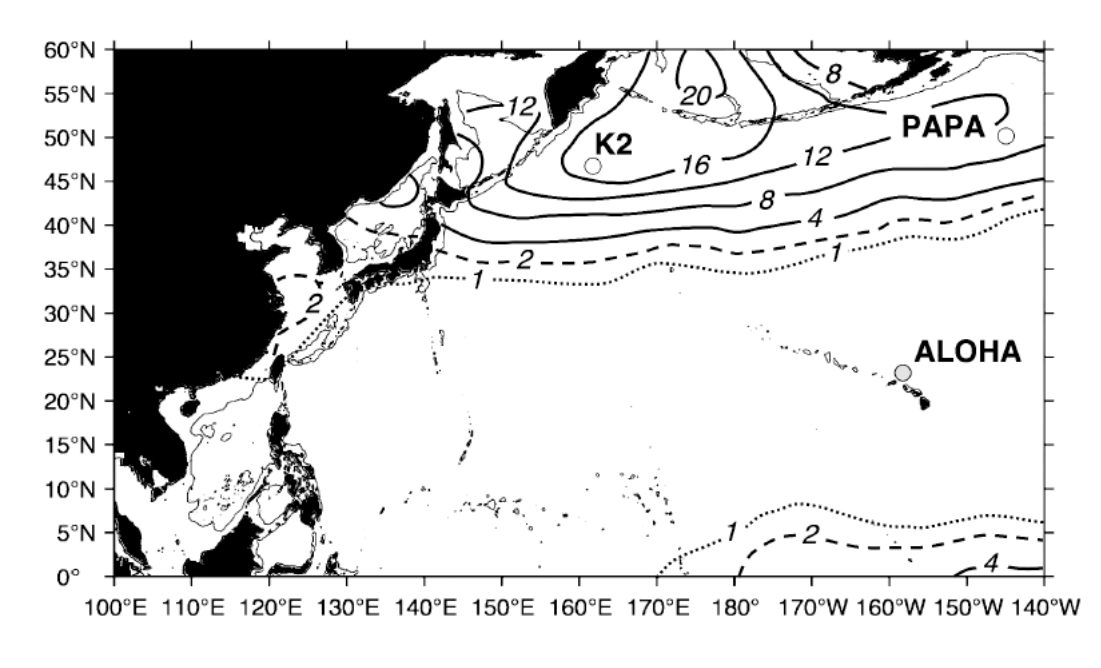
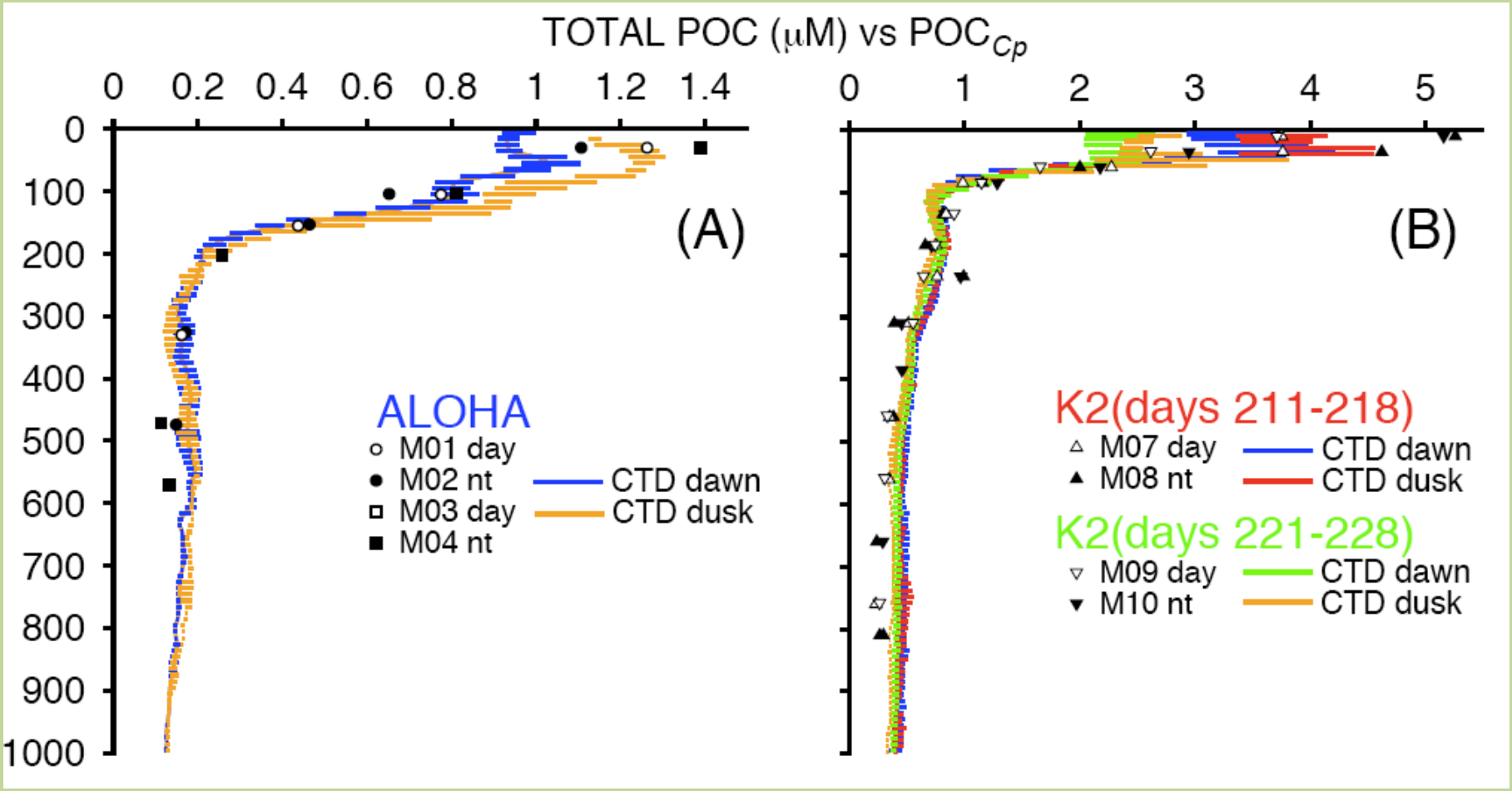
POC – c_p and scattering VERTIGO K2 and ALOHA



Bishop and Wood (2008); Deep-Sea Res. I 55 – 1684-1706

POC vs. Transmissometer (660 nm)

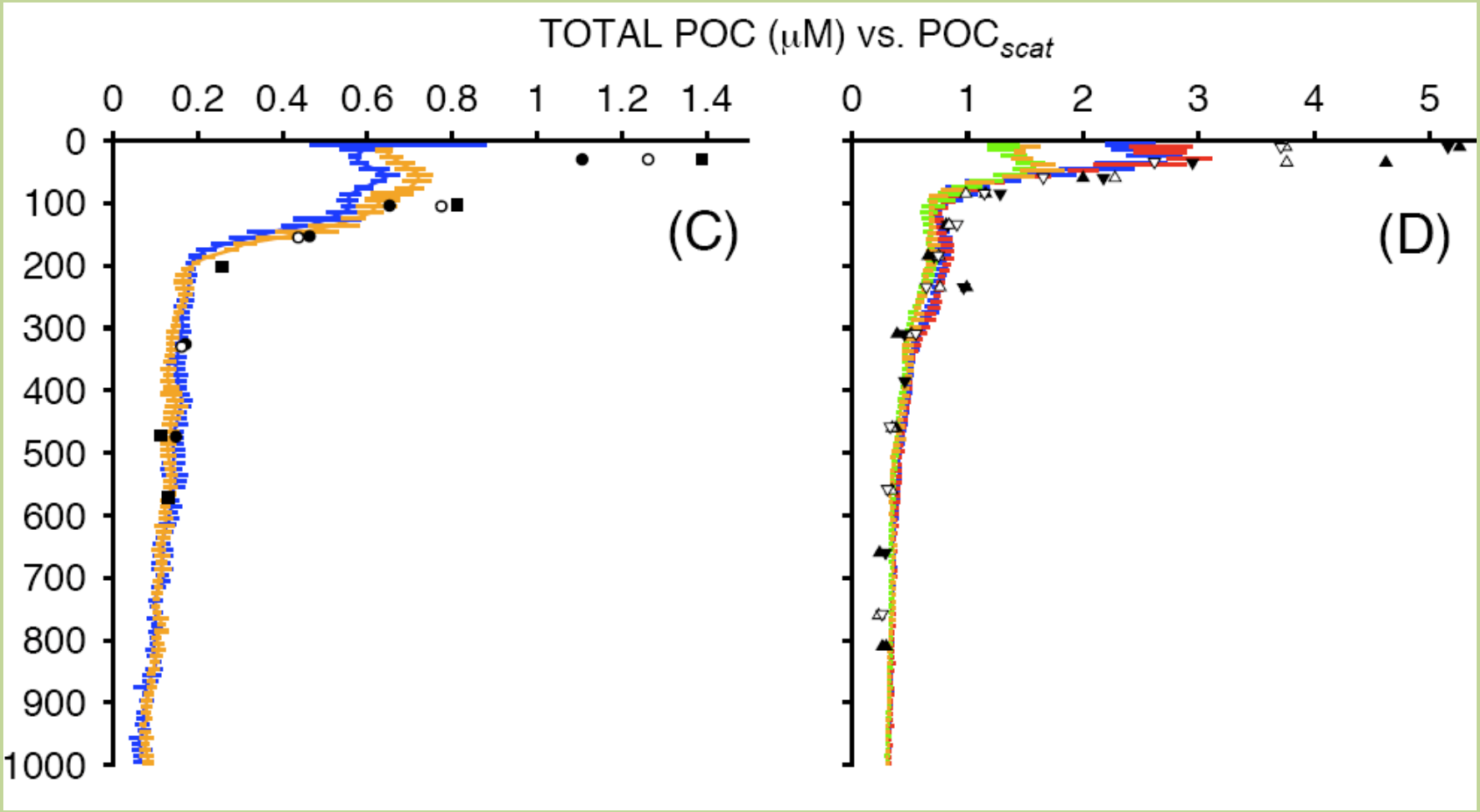


POC from the Multiple Unit Large Volume in-situ Filtration System (MULVFS)

Bishop and Wood (2008); Deep-Sea Res. I 55 – 1684-1706

Bishop, UC Berkeley

POC vs. Scattering (880 nm)



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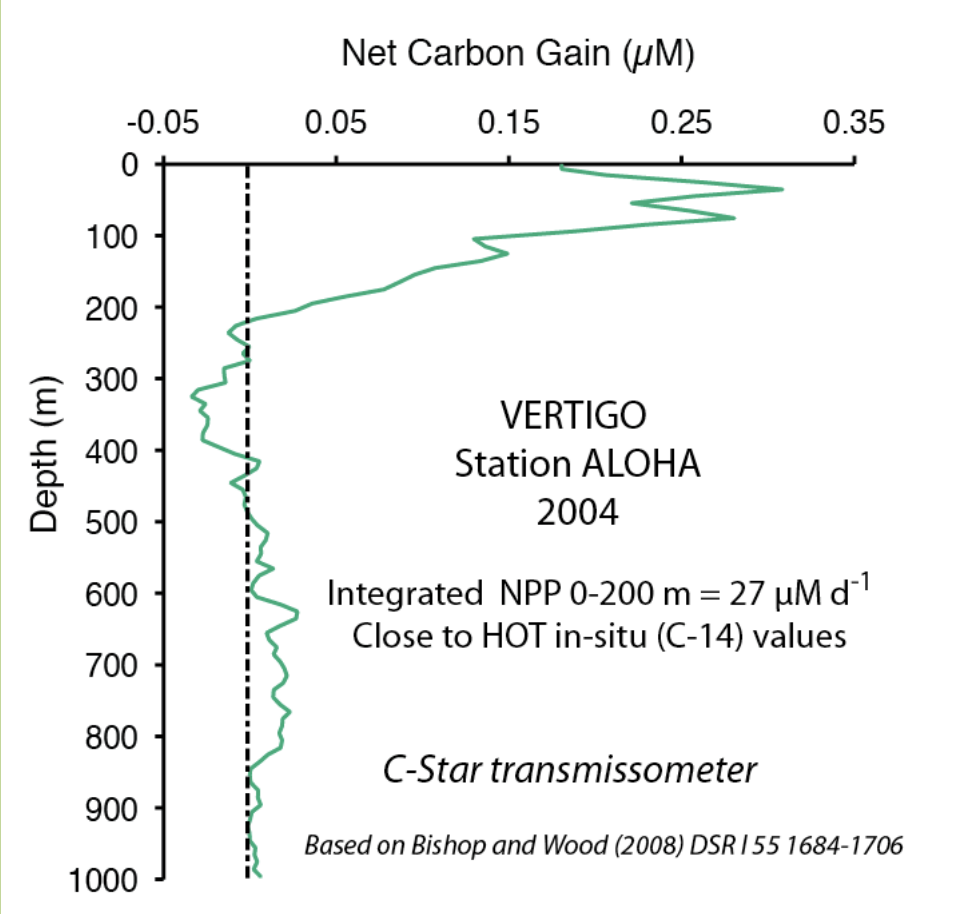
Transmissometer based estimates of POC production in good agreement



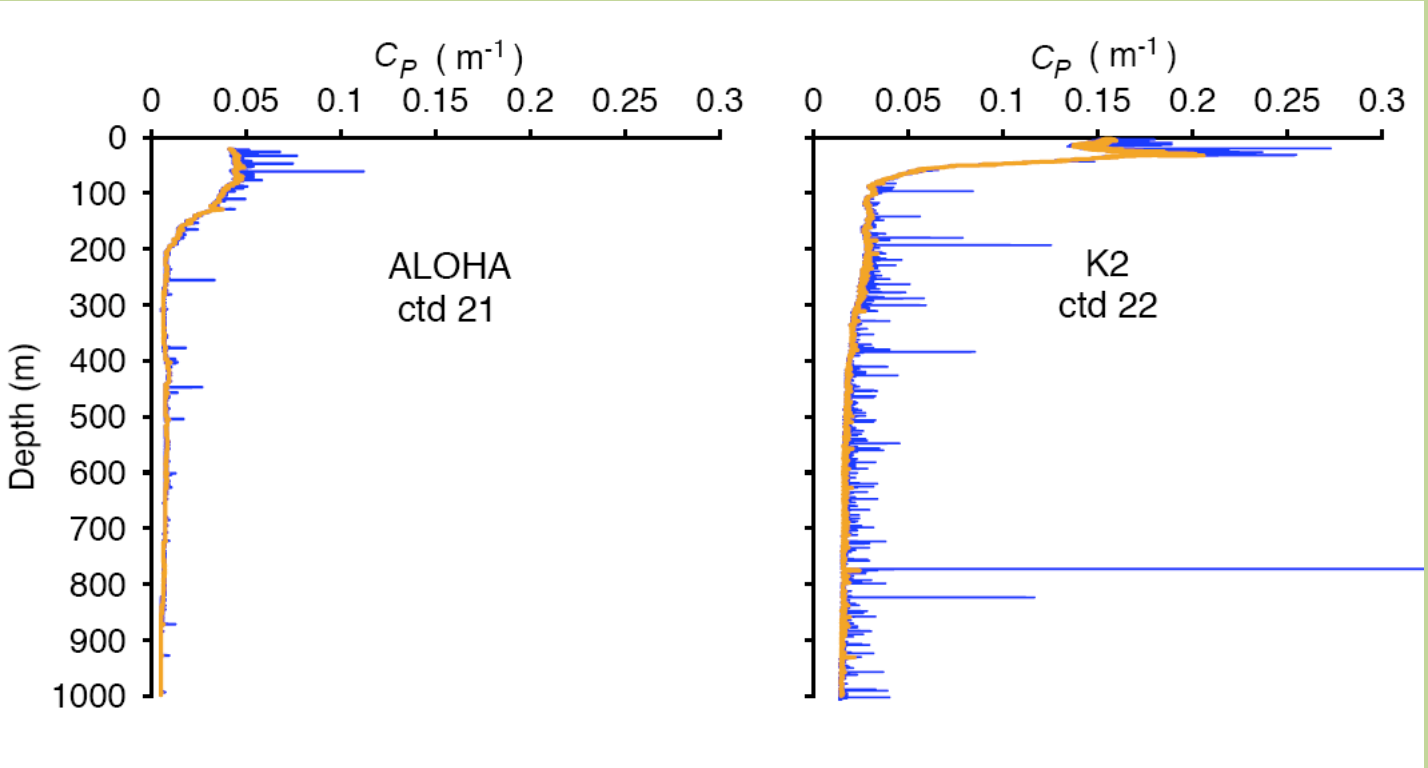
Dusk minus Dawn c_p profile changes

Bishop and Wood (2008); Deep-Sea Res. I 55 – 1684-1706

Bishop, UC Berkeley

There is Value in High Frequency data

What do spikes in transmissometer and scattering sensor profiles mean?



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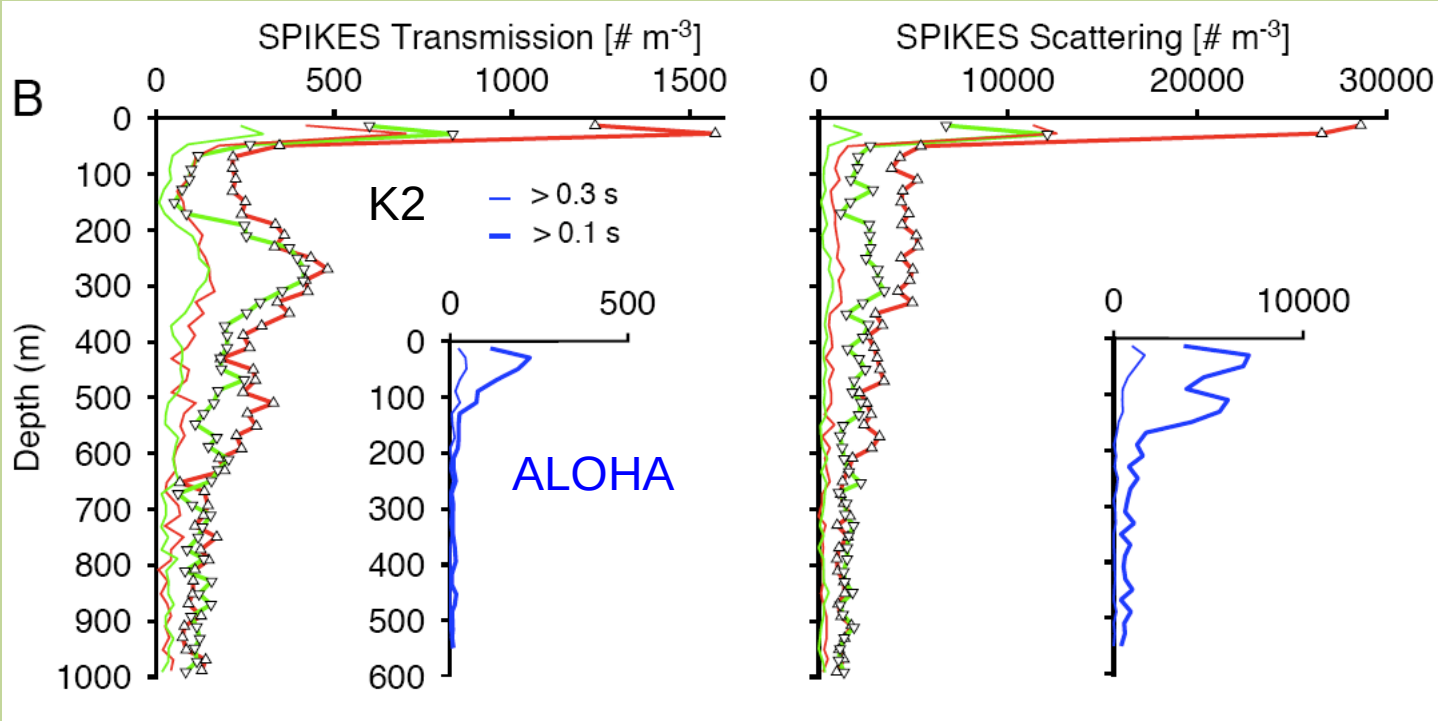
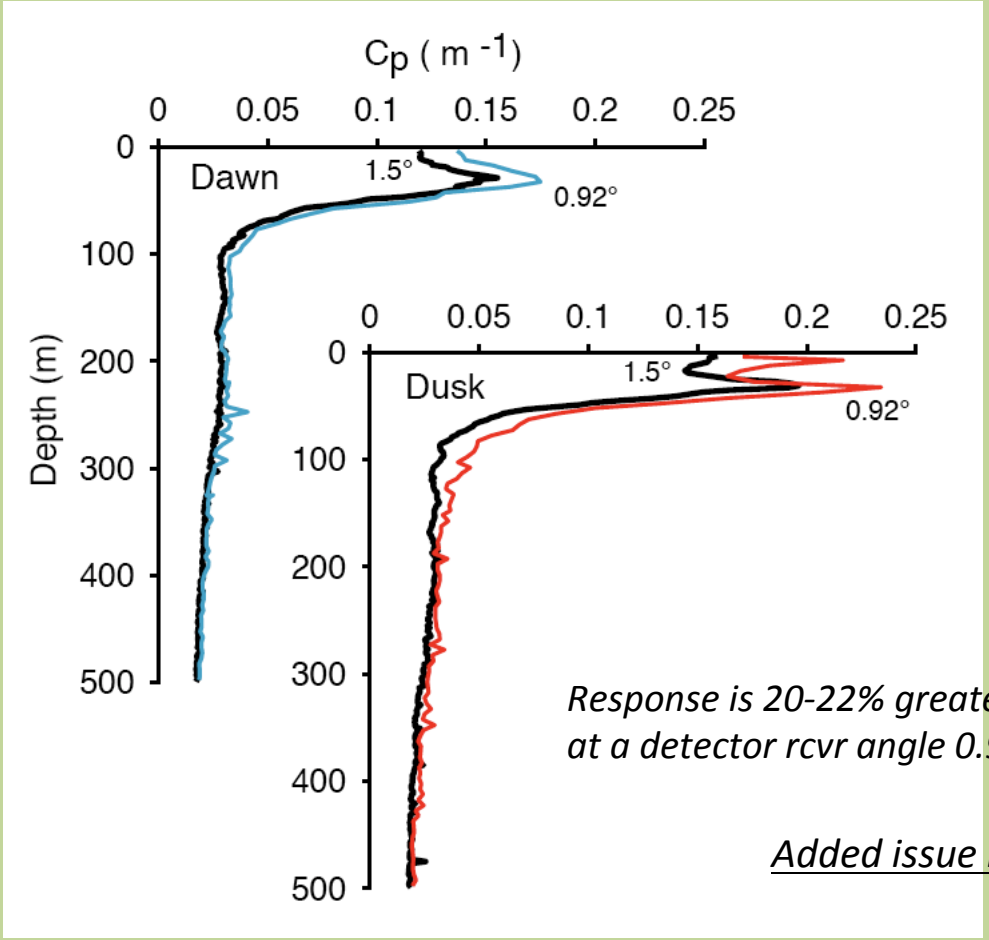


Transmissometer spike abundances reflected zooplankton abundances
Scattering spikes – larger phytoplankton and microzooplankton and possibly aggregates

Bishop and Wood (2008); Deep-Sea Res. I 55 – 1684-1706

Bishop, UC Berkeley



Transmissometer beam attenuation coefficient follows POC quite well (to within ~10%)

N Atlantic calibrations similar to N Pacific (ALOHA and K2 and PAPA) if one takes into account beam and detector geometry effects.

Response is 20-22% greater at a detector rcvr angle 0.92°

Added issue is beam geometry

C-Star vs. C-Rover (POC meter)

Recommendation: Standardization of specifications would be very useful at this time

Bishop and Wood (2008); Deep-Sea Res. I 55 – 1684-1706

Bishop, UC Berkeley