NEW VIEWS OF THE OCEANIC CARBON CYCLE FROM AUTONOMOUS LAGRANGIAN EXPLORERS

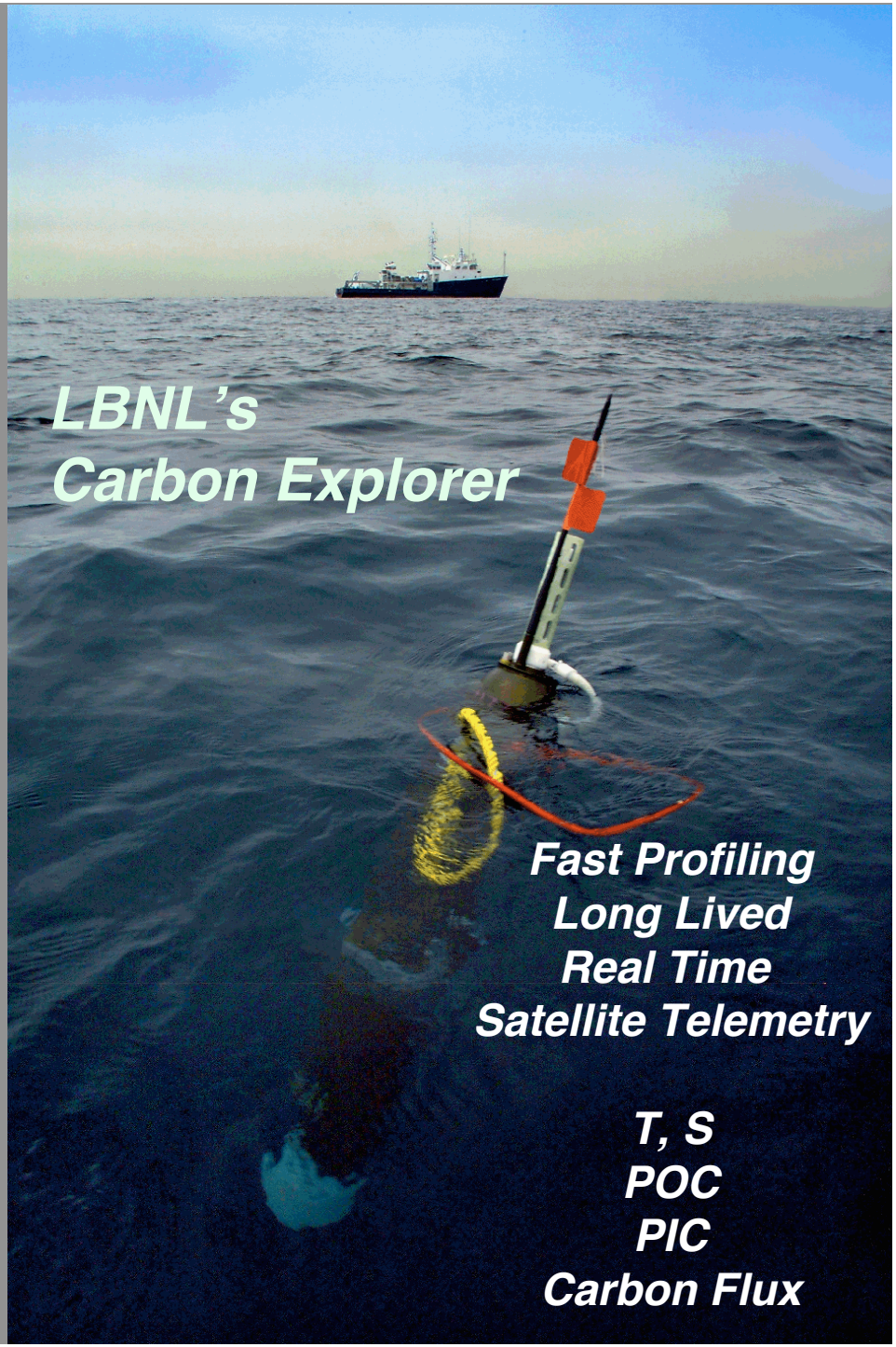
Jim Bishop

Lawrence Berkeley National Laboratory

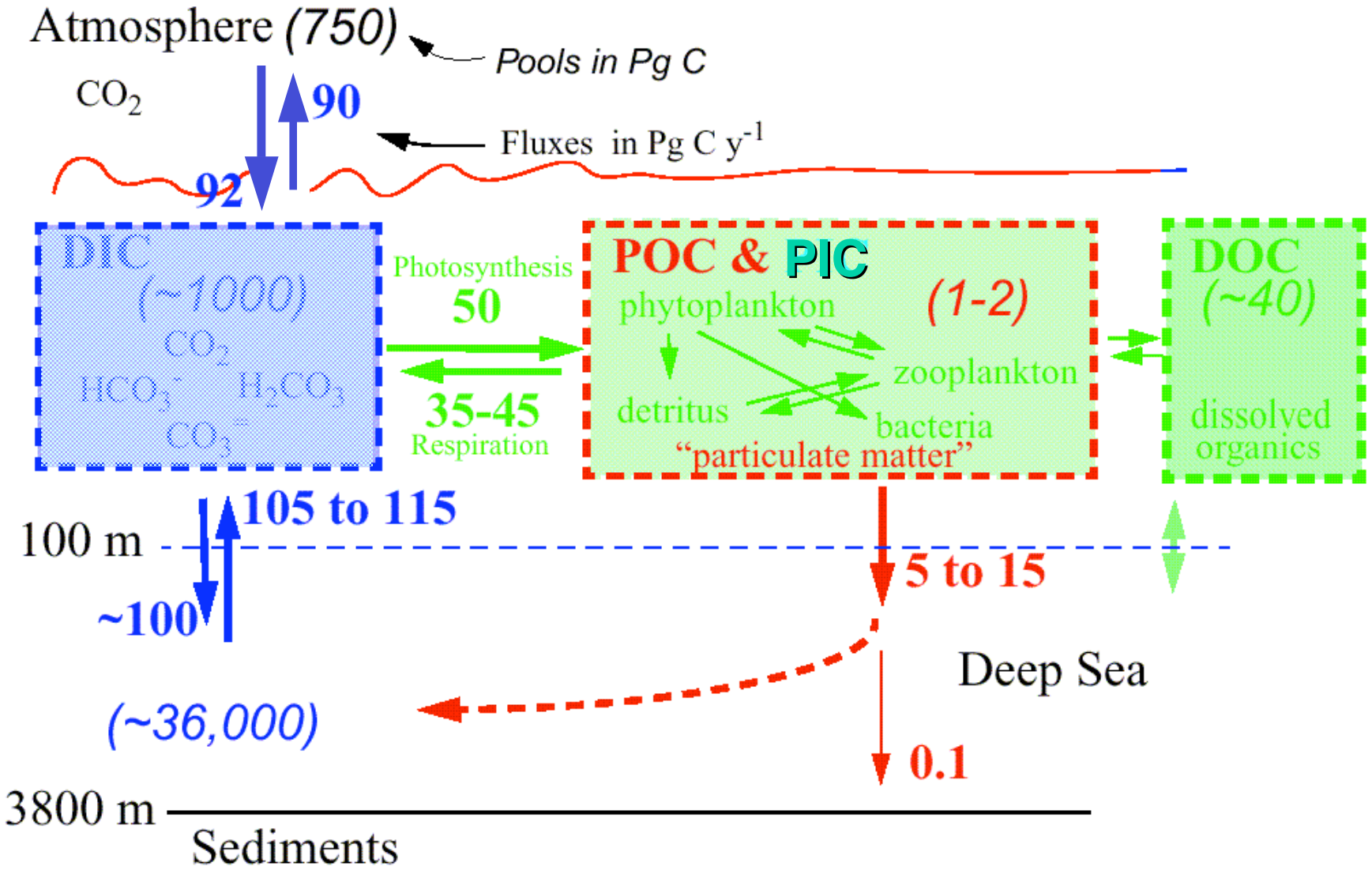
www-ocean.lbl.gov

Thanks to many, especially ….
Russ Davis and SIO IDG

Support: NOPP/DOE/NOAA

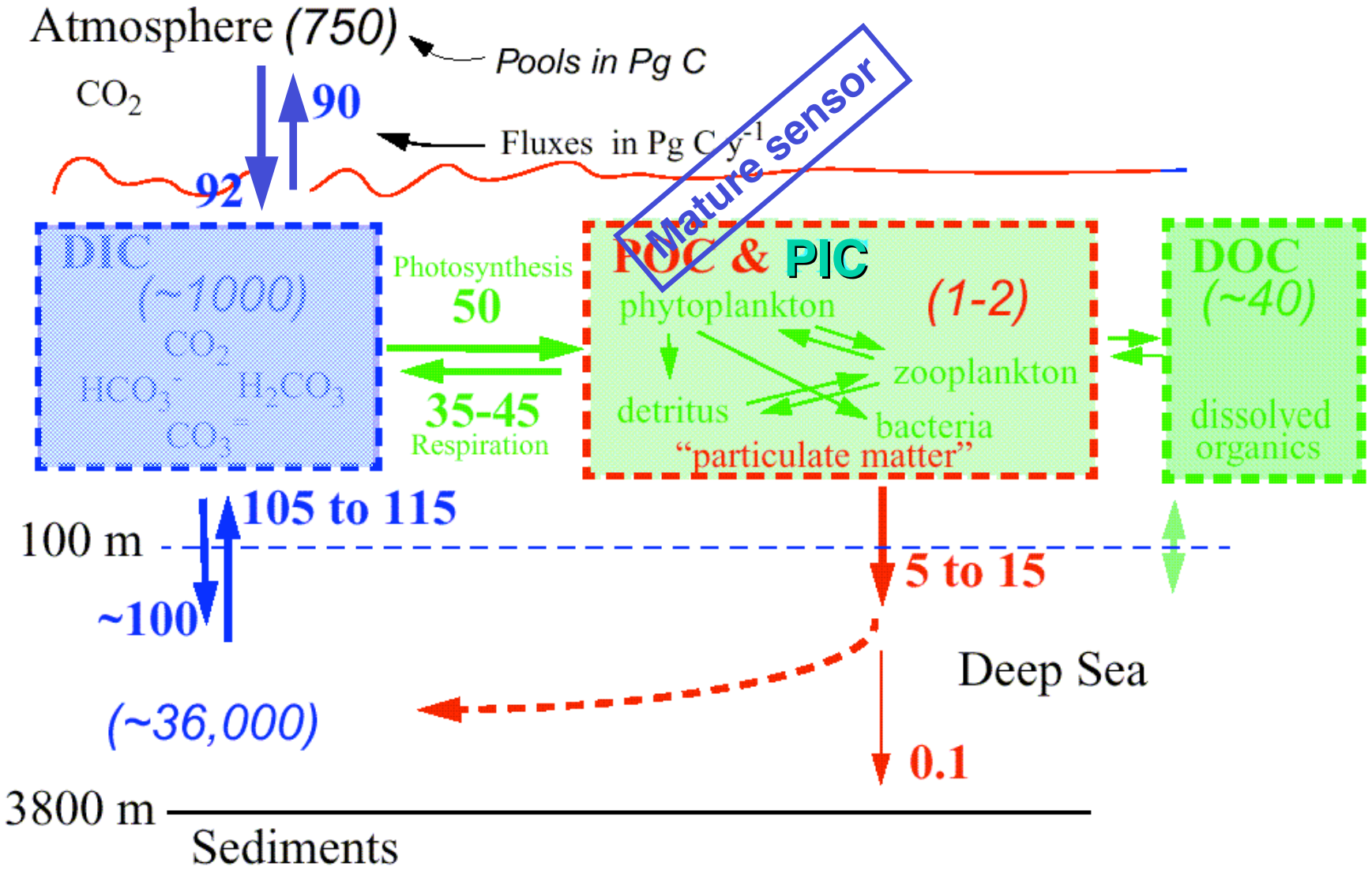


Target: Biological pump and export of C to depth



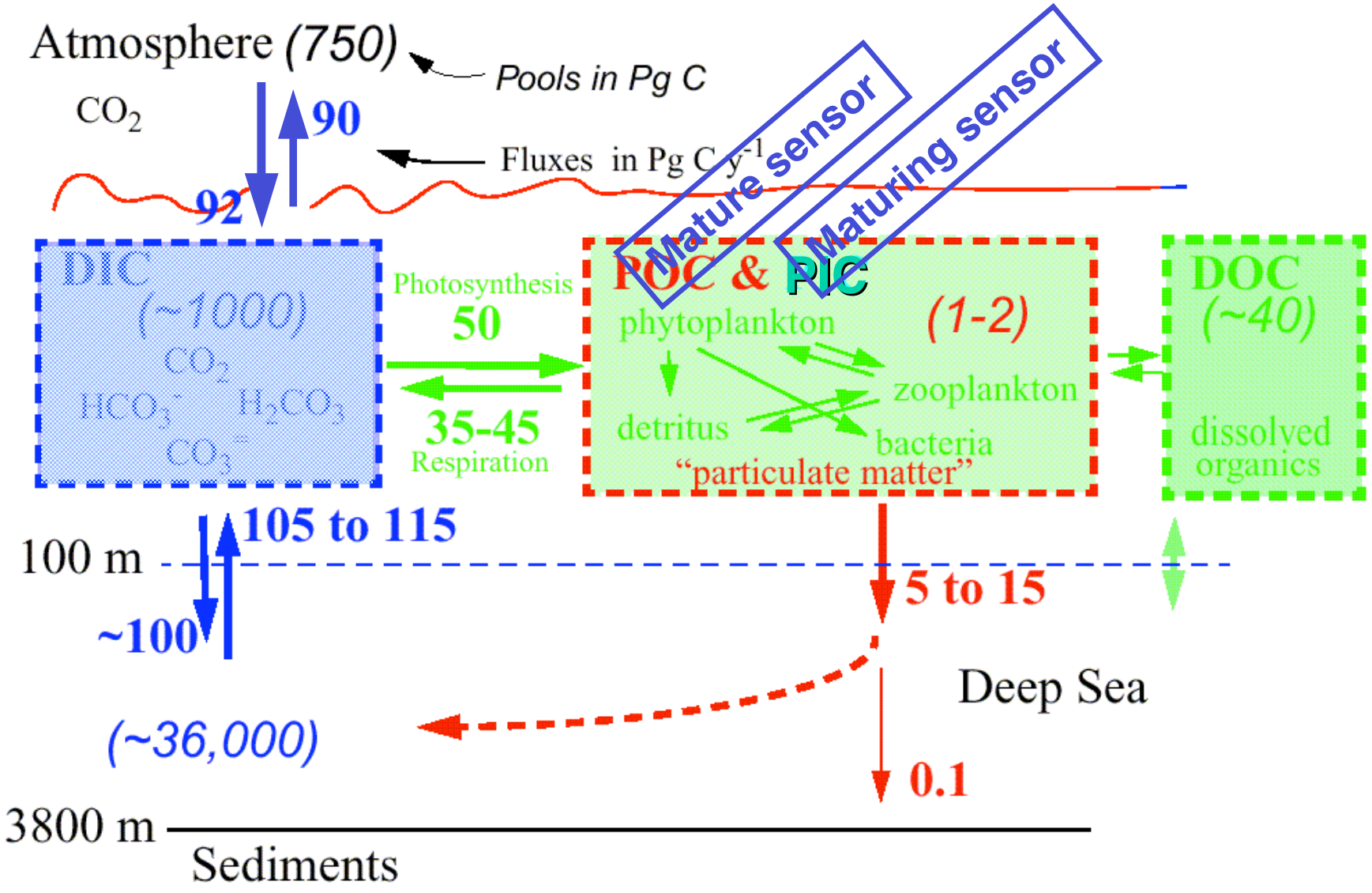
Changes in particulates easily detected

Target: Biological pump and export of C to depth



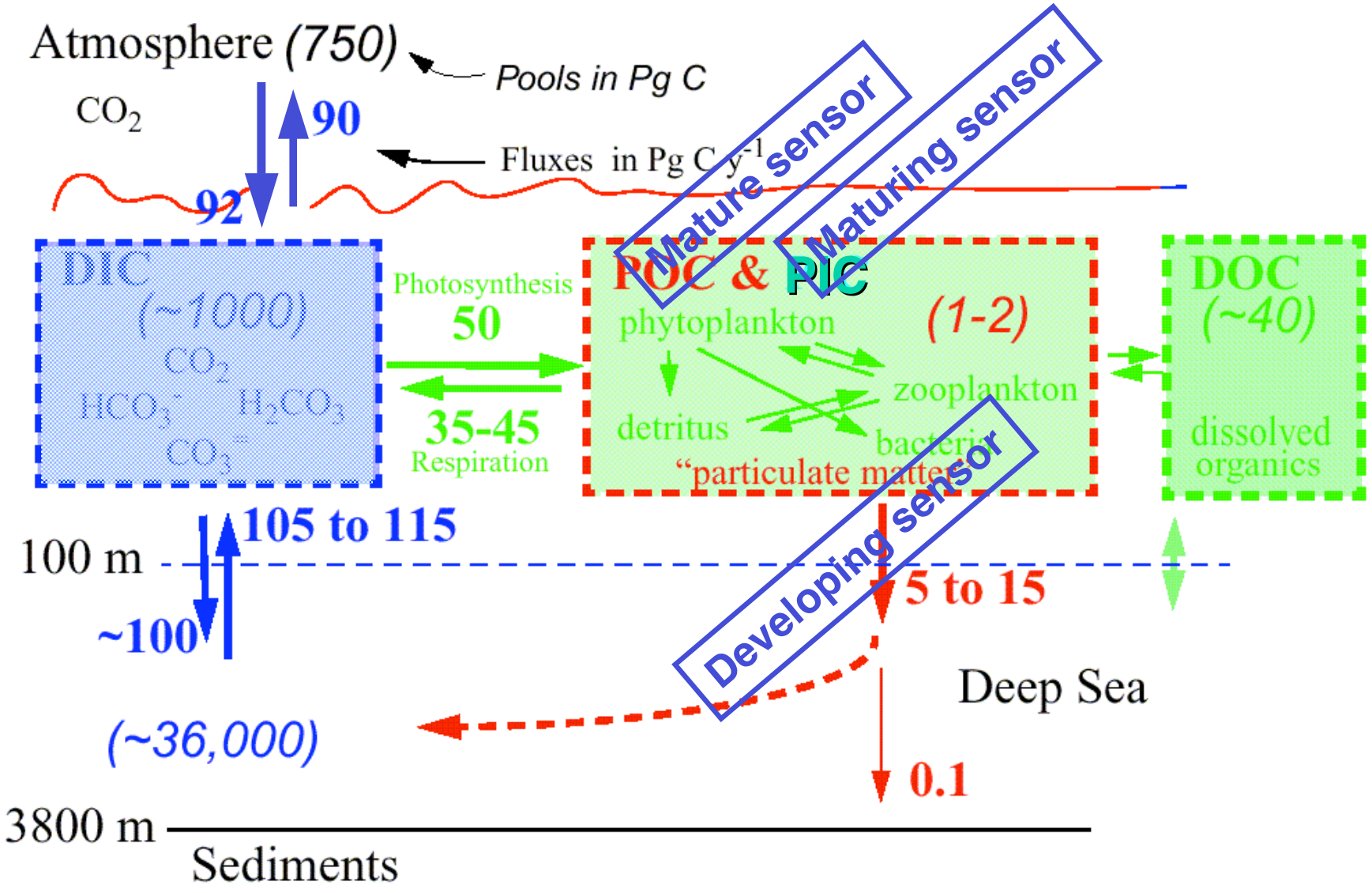
Changes in particulates easily detected

Target: Biological pump and export of C to depth

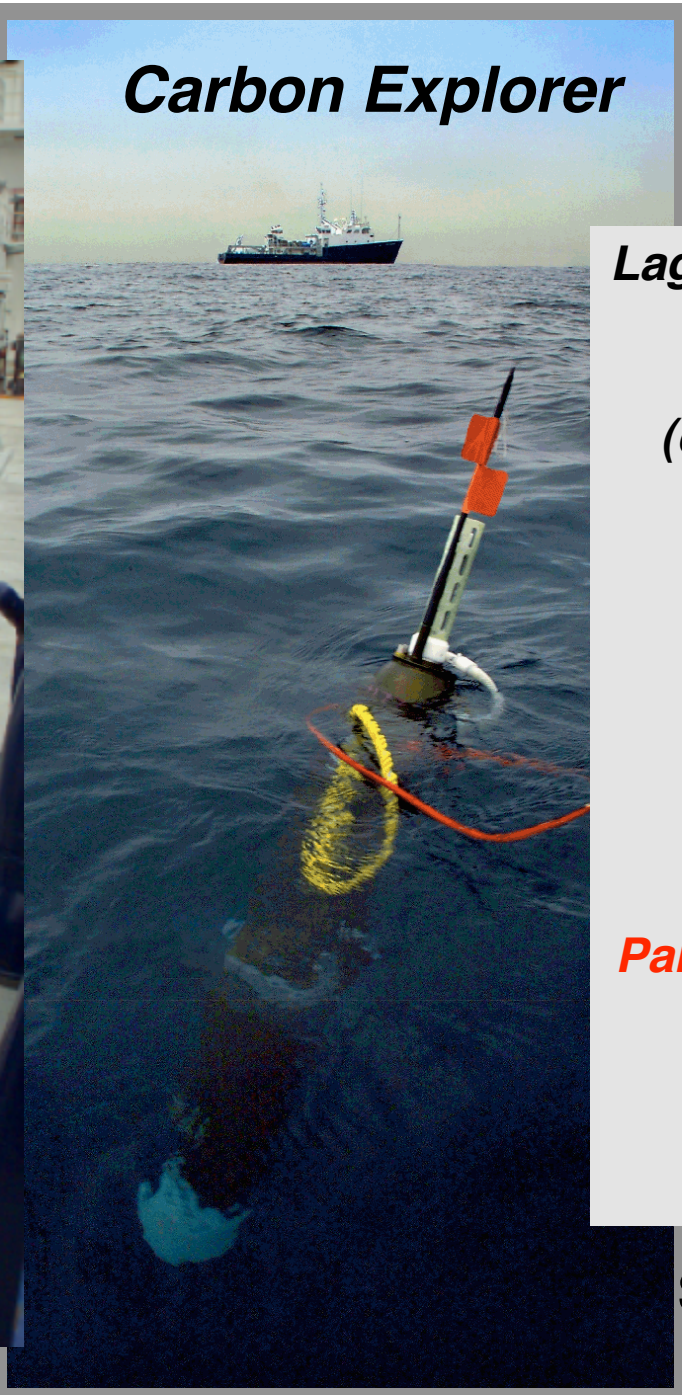


Changes in particulates easily detected

Target: Biological pump and export of C to depth



Changes in particulates easily detected



Lagrangian Profiling float

Fast Profiling
(diurnal profiles to 1000m)

Long Lived ~1 year

Real Time Bi-directional
Satellite Telemetry

T, S
Particulate Org C
Particulalte Carbon Flux Index
Scattering
Particulate Inorg C

$ per explorer = 1 ship day

Carbon Explorer observations of the ocean biological pump started in 2001

- **First obs. of natural iron fertilization of phytoplankton POC by Asian dust**

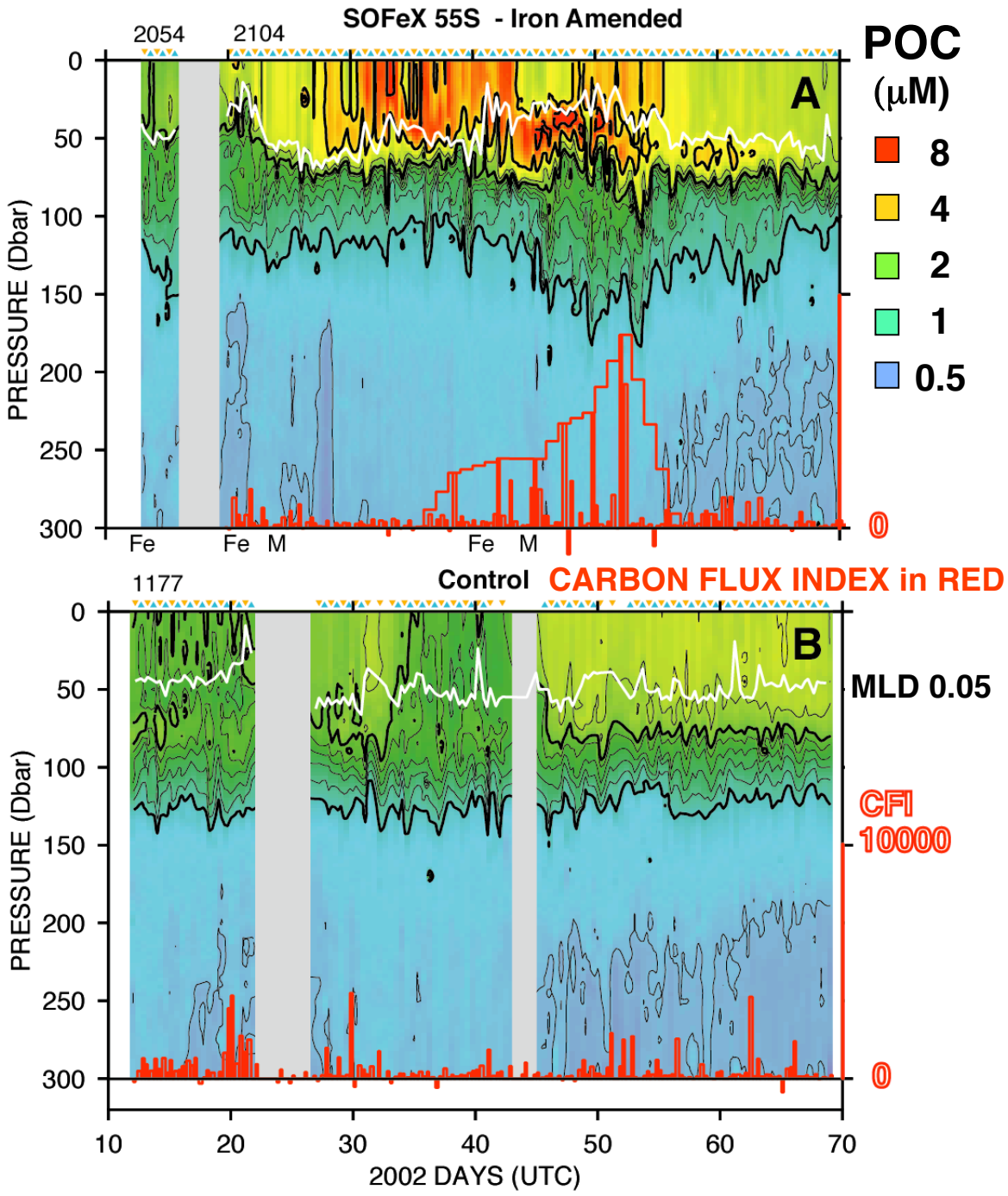
  (Bishop et al., *Science* **298, 817-821,**2002)

- **First obs. of purposeful iron-stimulation of carbon biomass and carbon sedimentation in Southern Ocean during SOFeX 2002**

  (Bishop et al. *Science*, **304, 417-420,** 2004).

Starting point for this talk

13 Carbon Explorers deployed to date



SOFeX

"North Patch" (55 S)

High NO_3 : Low Si

(22 μM : 2.5 μM)

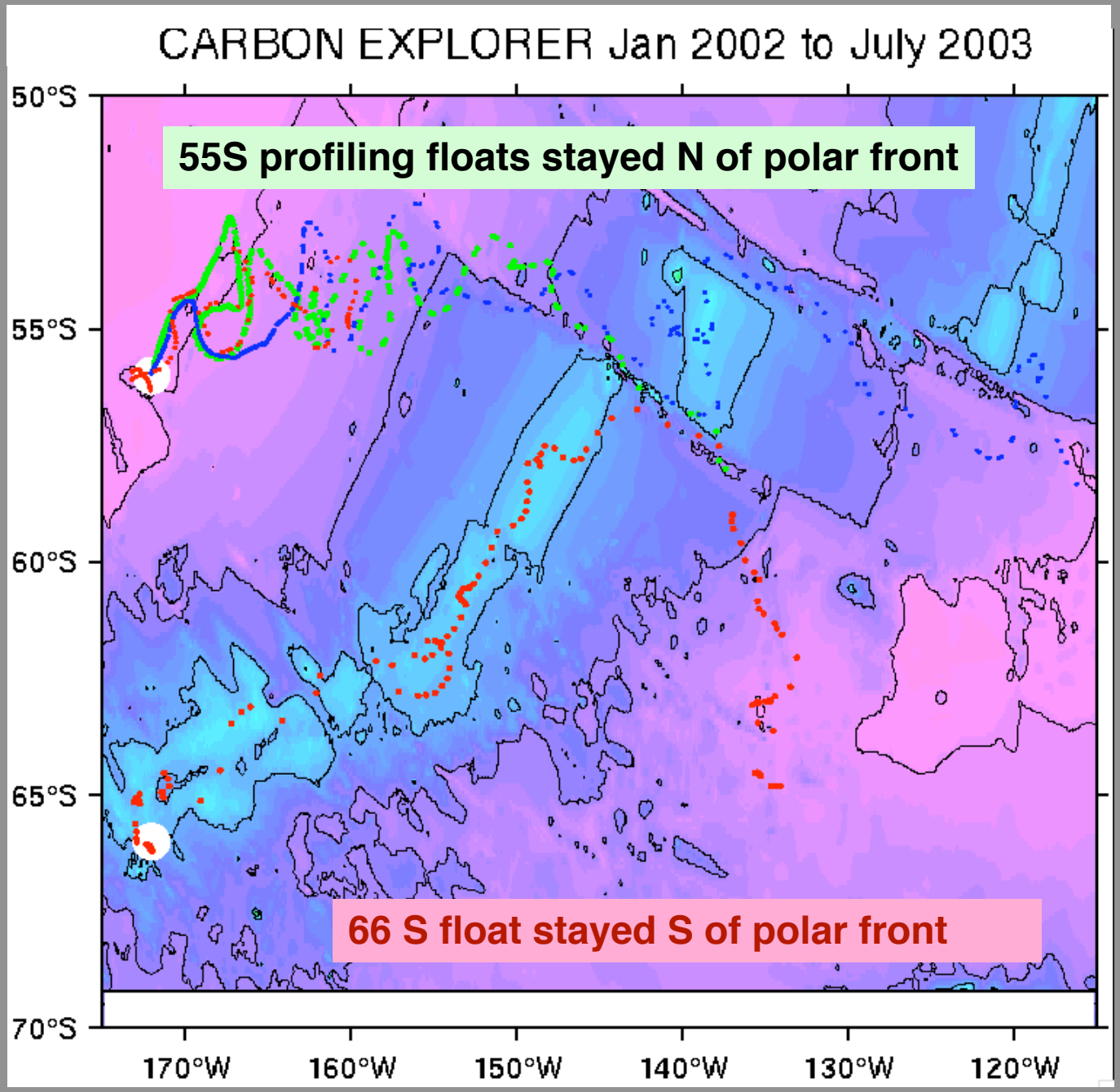
- *Measured Enhanced Carbon Export at 55S as a result of iron amendment*
- *Fe added : C Exported mole ratio >1:10^4*
- *SOFeX Hypothesis Contradicted*

  Export surprisingly strong N of the Polar Front

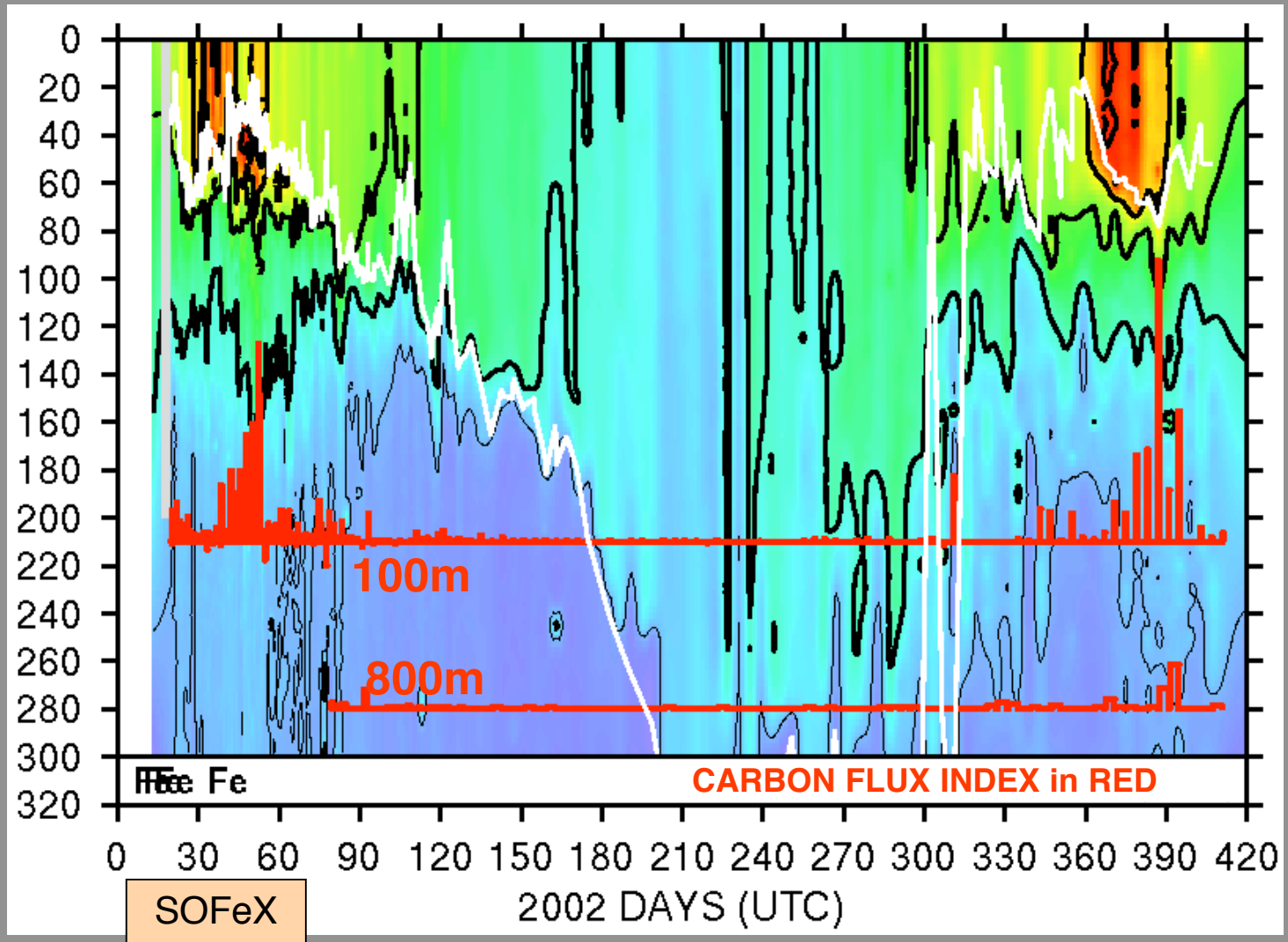
*Bishop et al. Science, **304, 417-420**, 2004*

What about the "post" SOFeX EXPLORER records?

Bathymetry



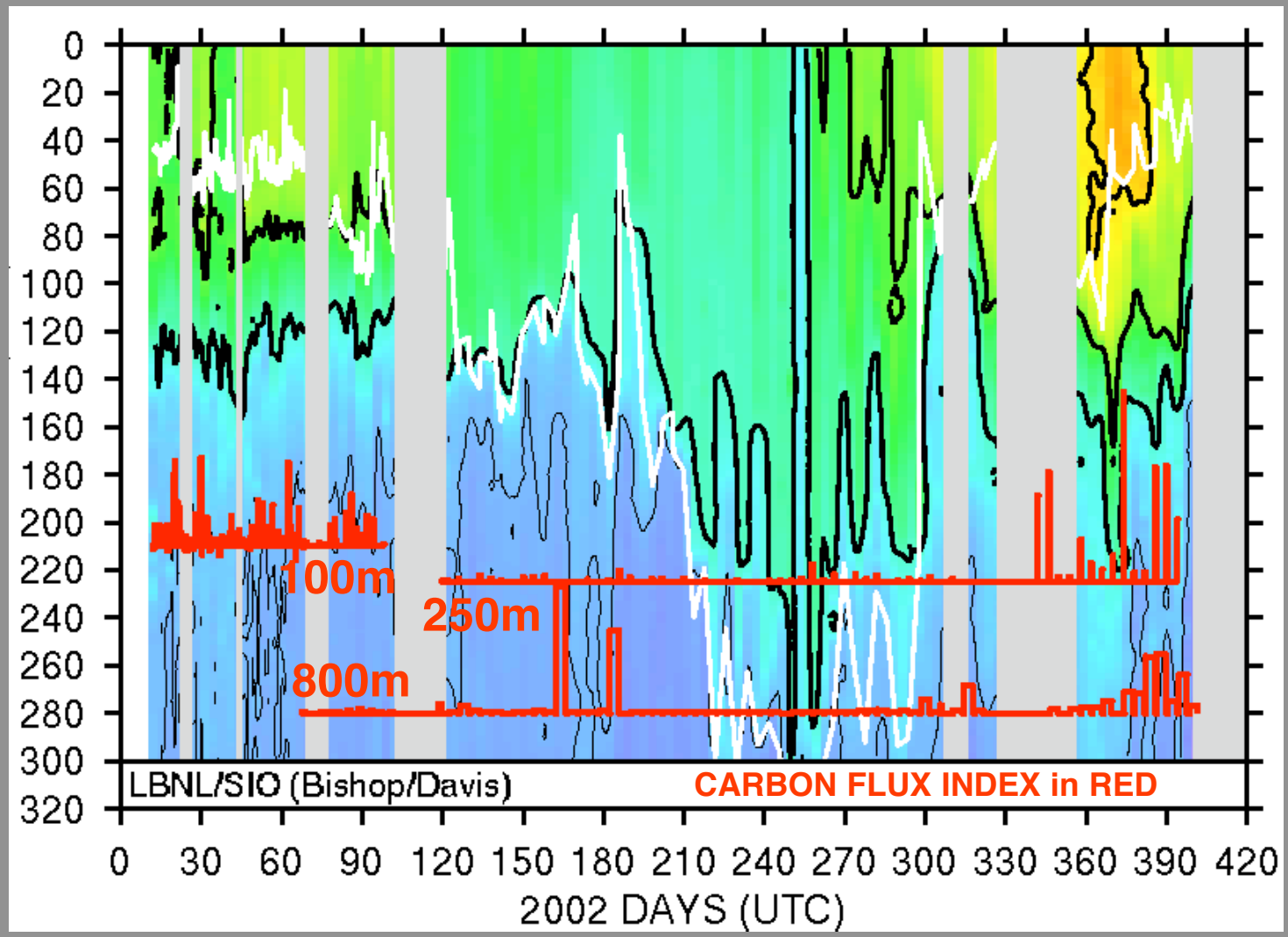
“In Patch” Explorer 2104 North of Polar Front



μM POC 0.5 1.0 2.0 4.0 8.0

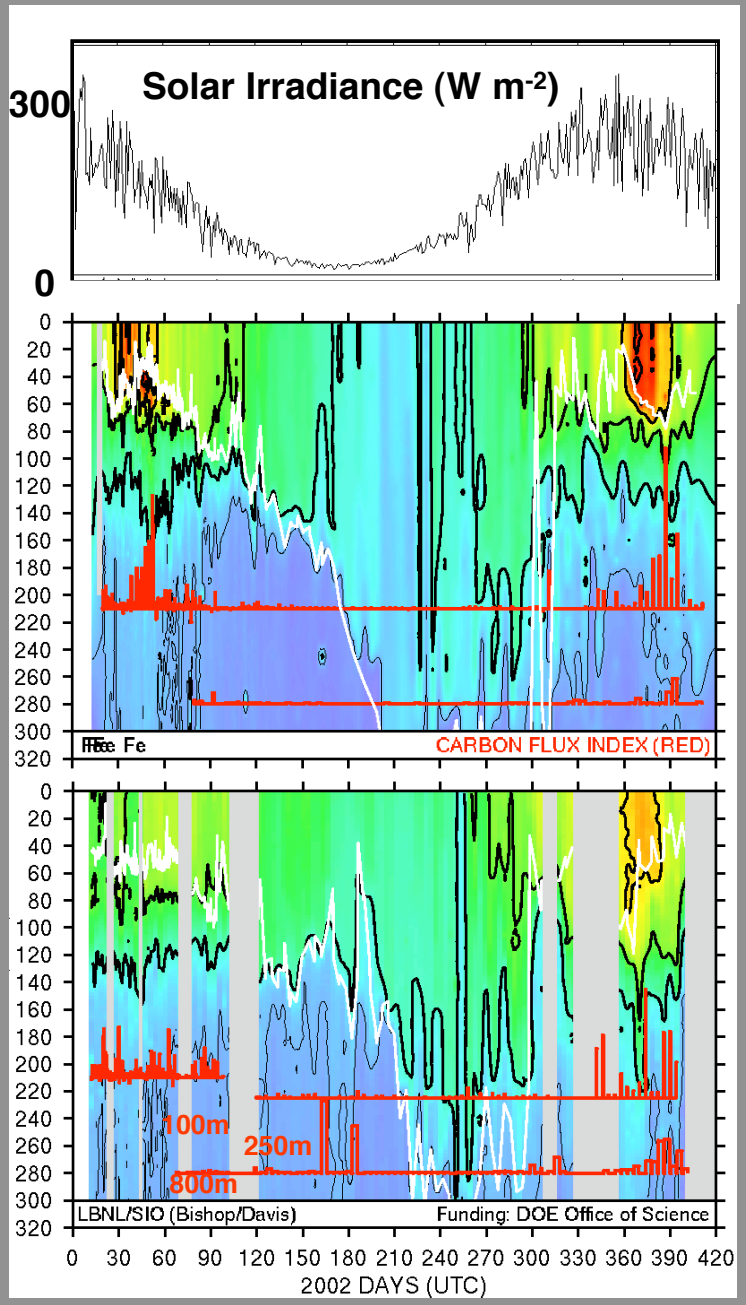
MIXED LAYER DEPTH : Δ sigth = 0.05

“Control” Explorer 1177 North of Polar Front



μM POC 0.5 1.0 2.0 4.0 8.0

MIXED LAYER DEPTH : Δ sigth = 0.05



SOFEX Carbon Explorers (II)

Continuous daily record of POC summer through winter.

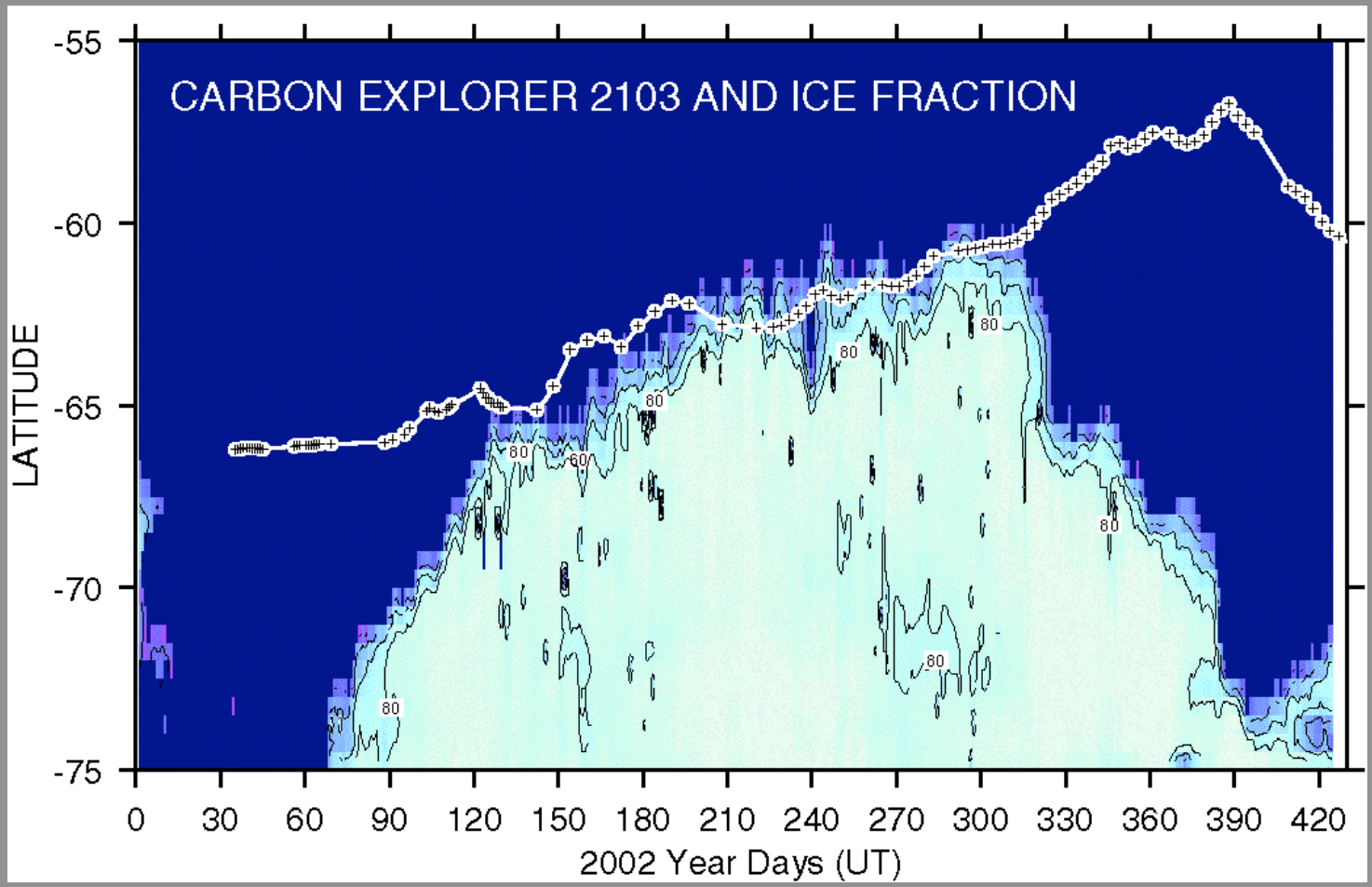
Clear link between mixed layer depth and POC.

Systematics of Carbon Flux at multiple depths.

FLUX at 800 m is <u>not</u> related to overlying biomass. Ballasting by $CaCO_3$?

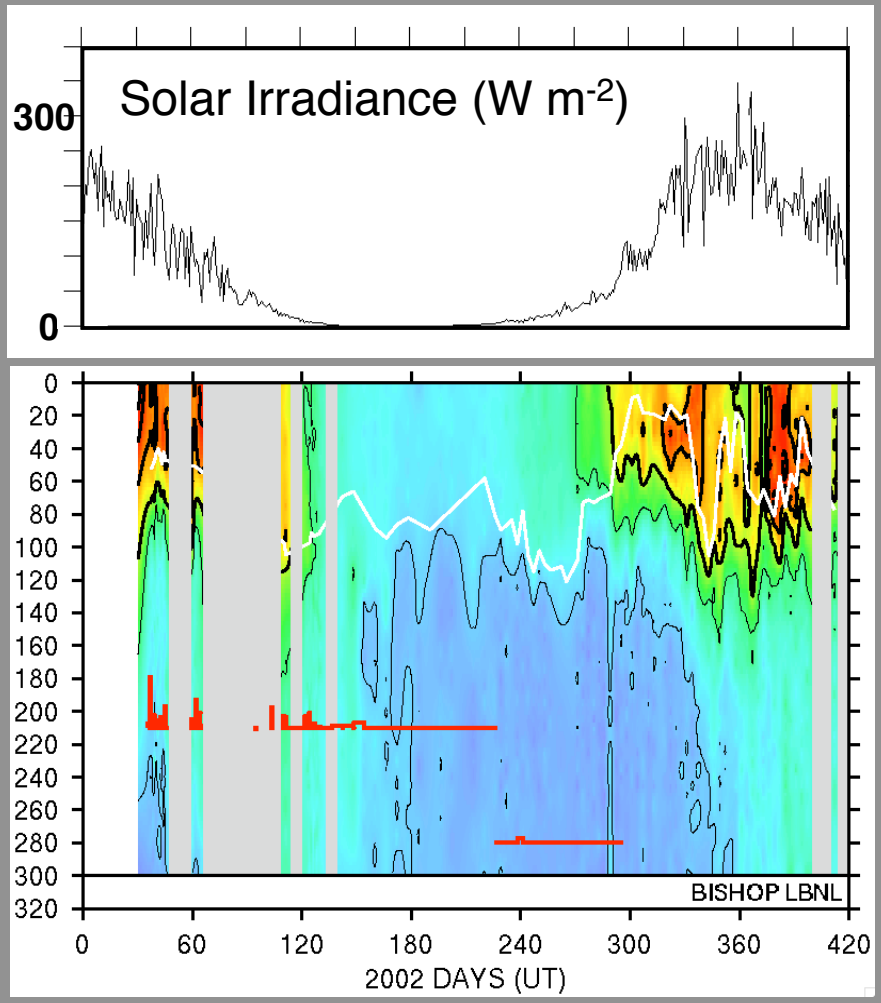
Demonstrates value of grouped deployment approach.

Eudurance



The 66S Explorer braved ice for two winters

66S



POC to Day 300, Scattering systematics shown

SOFeX Carbon Explorers (III)

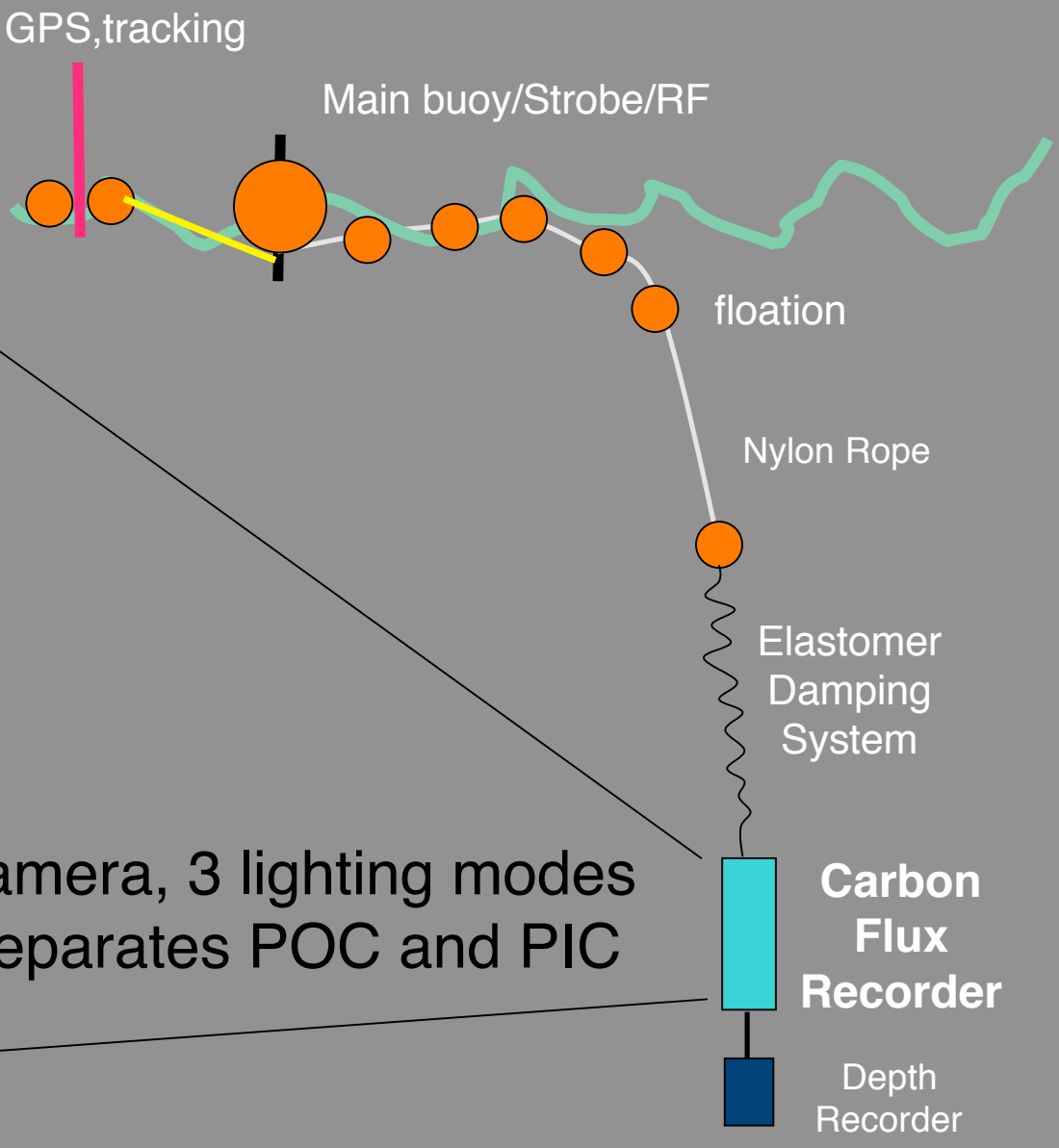
South of Polar Front

Strong PP recovery with salinity stratification as sea ice melts.

Seasonality in subsurface waters.

Carbon Flux Index: Lower sedimentation than at 55S.

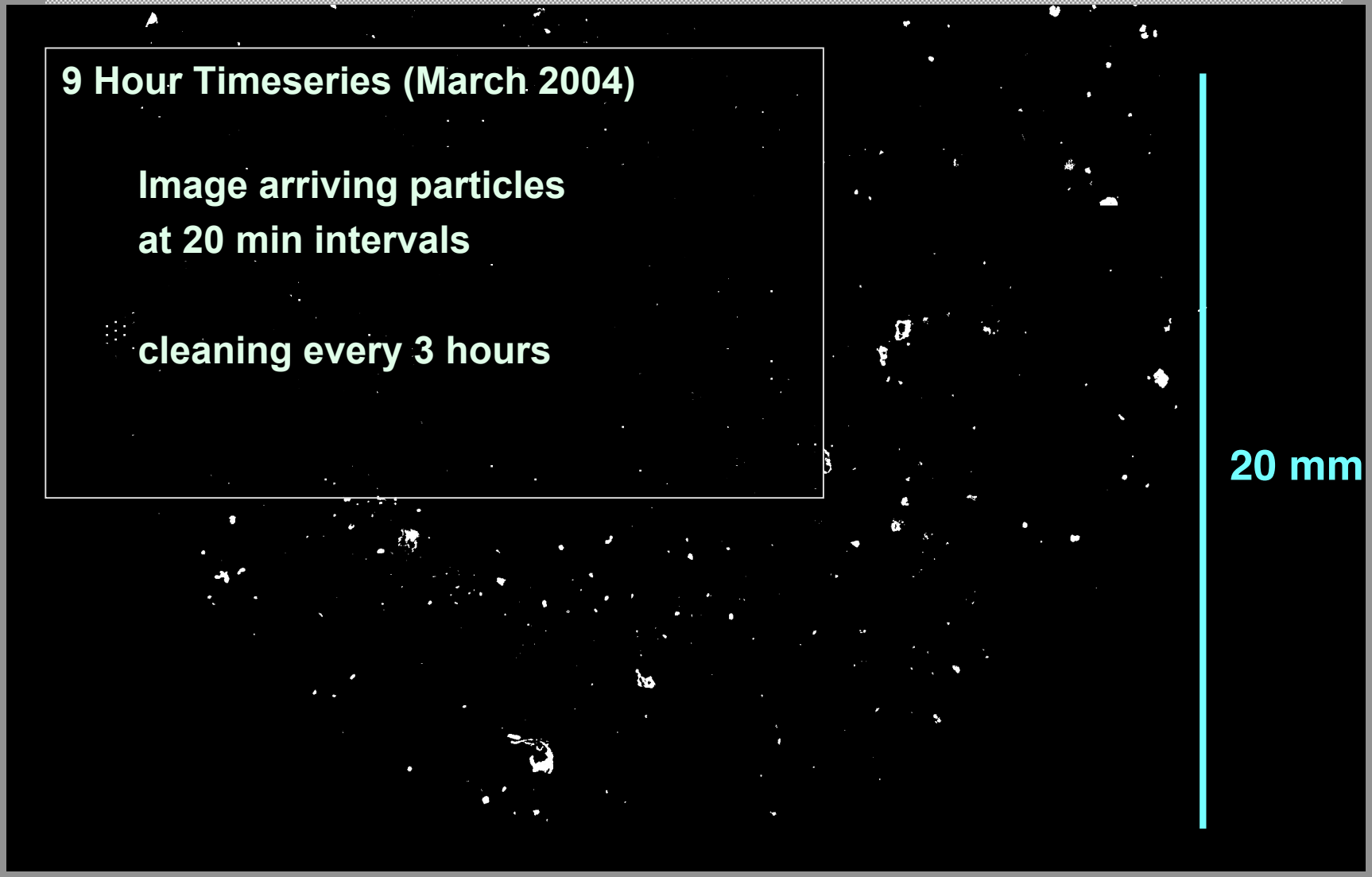
Towards a Carbon FLUX Explorer
Optical Carbon Flux Recorder



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

J Bishop LBNL

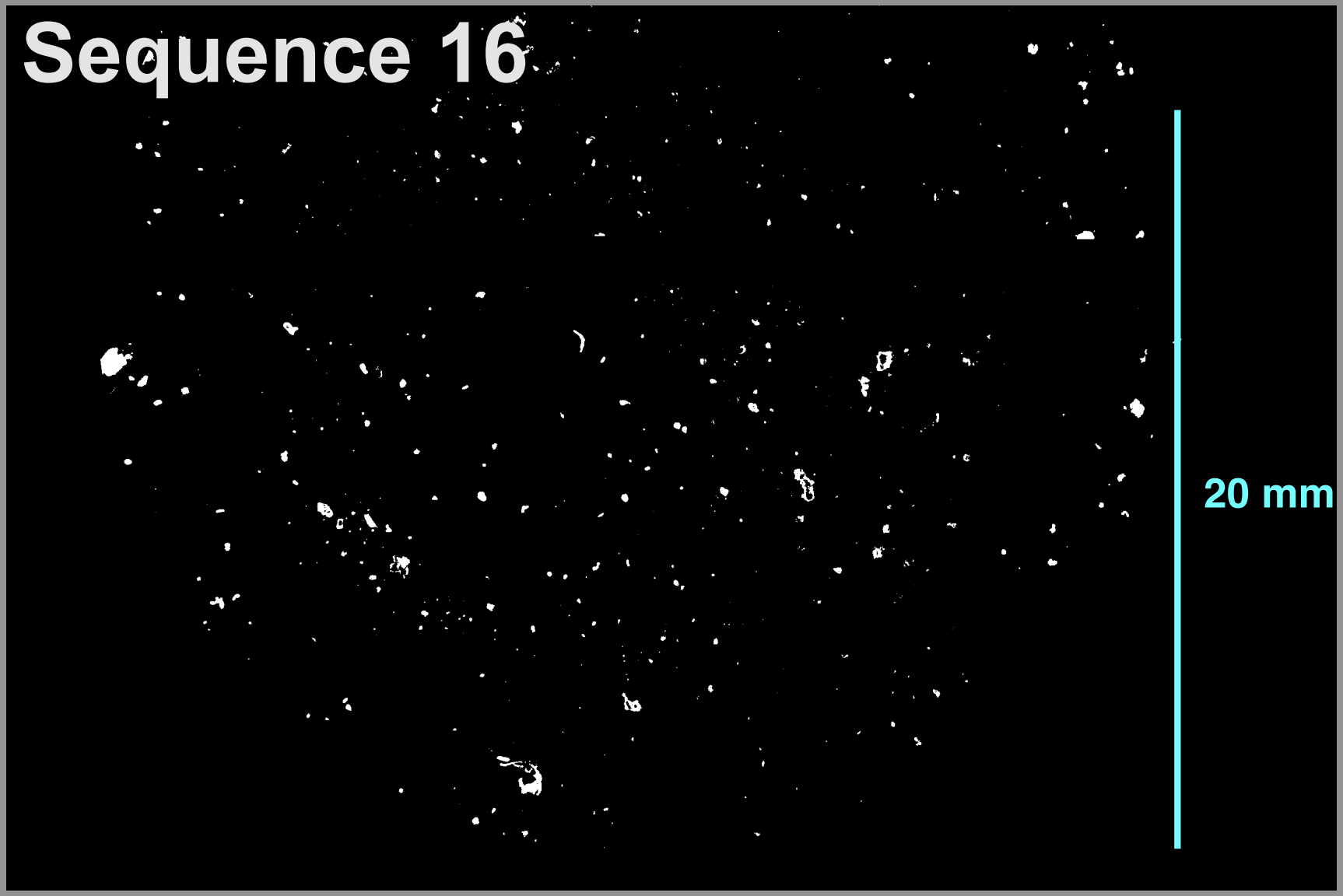
Image Processing: Particles resolved at 15 μm size



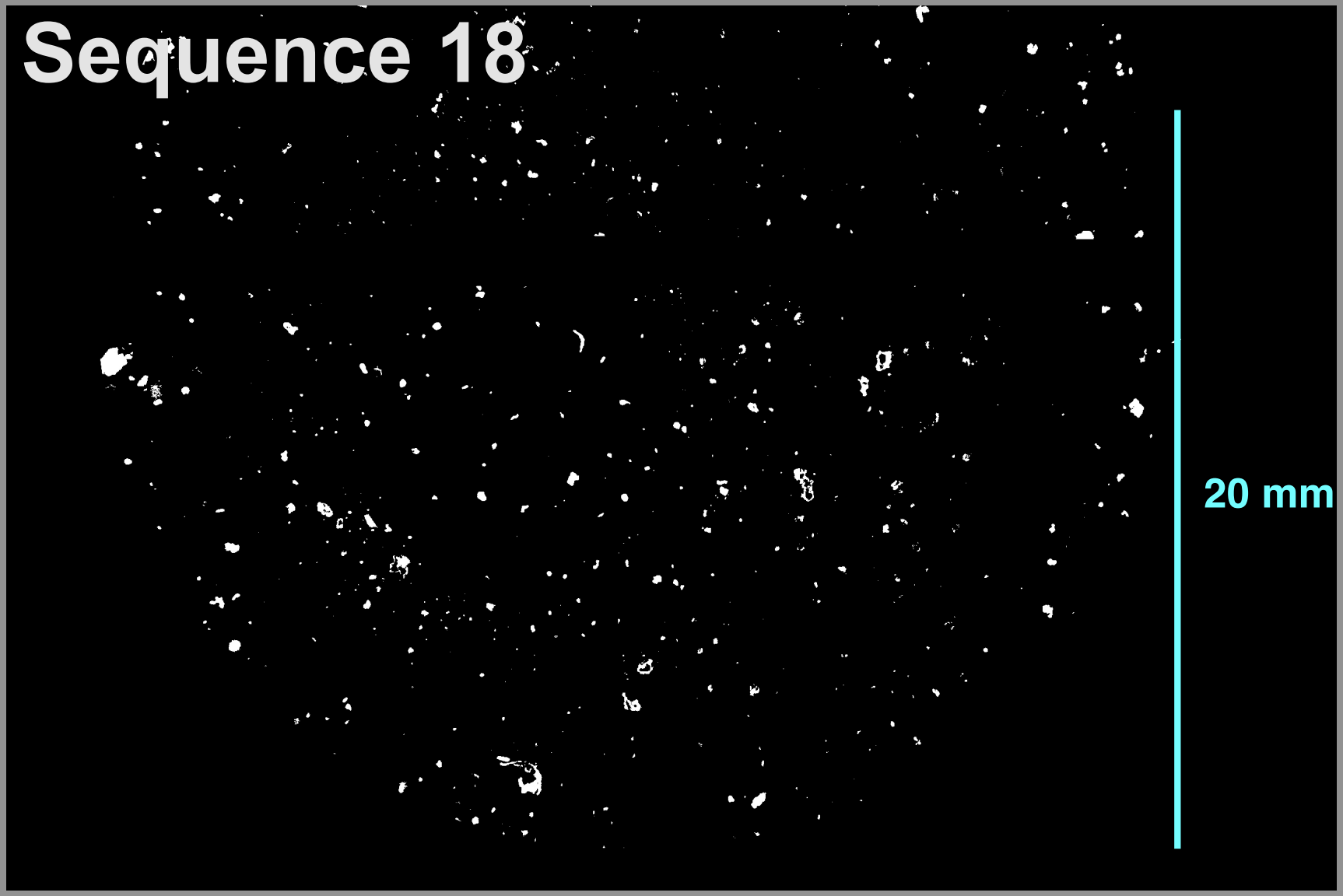
Particles are tracked in three categories and across the entire image

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

J Bishop LBNL

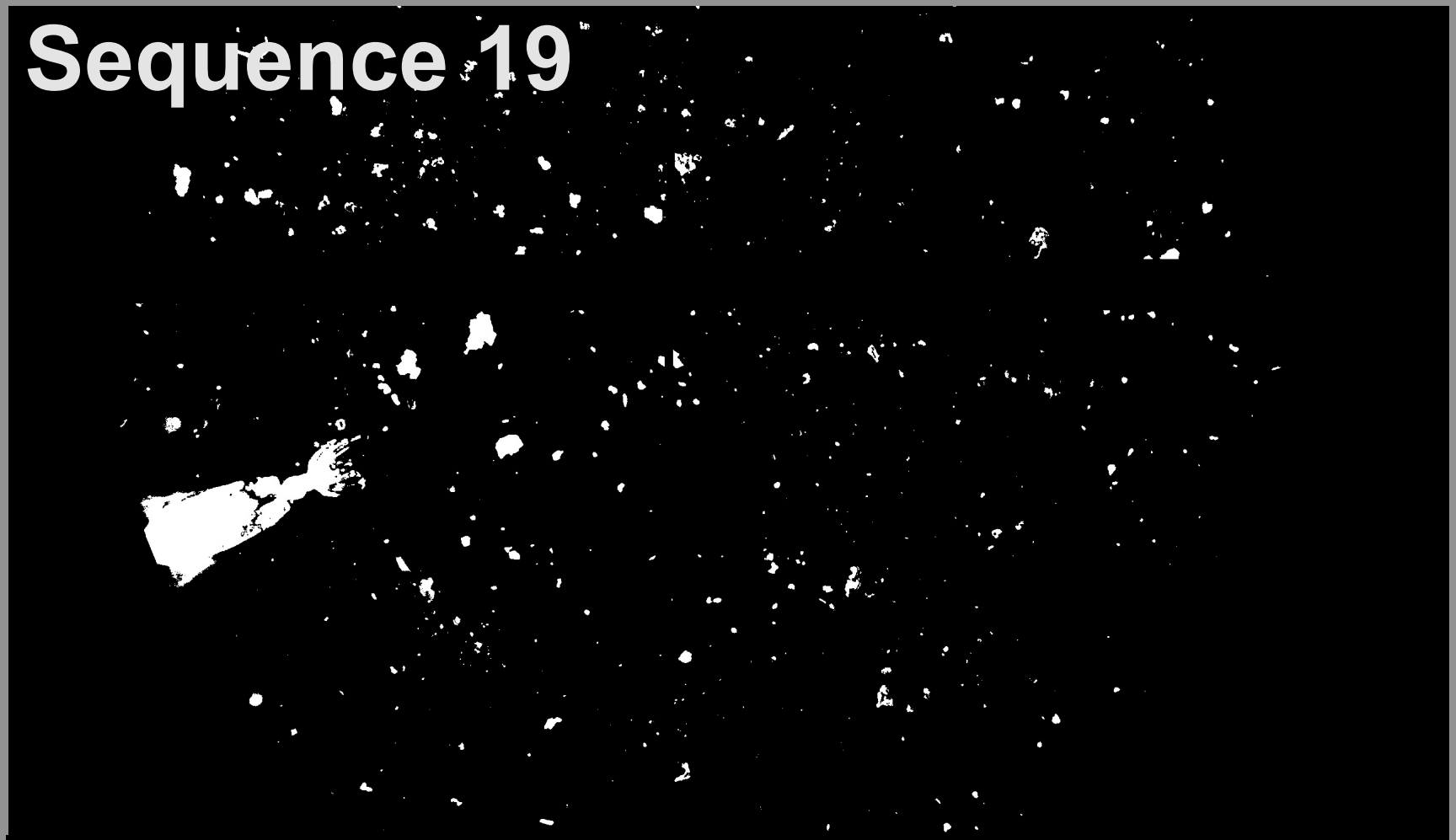


+ 2:00 hr



+ 2:40 hr

Sequence 19



Animal Arrives with many more particles. Particles are disturbed.
Animal probably feeding on the particles as they fell into the trap

+ 3:00 hr

Sequence (20 Cleaning step)

+ 3:20 hr

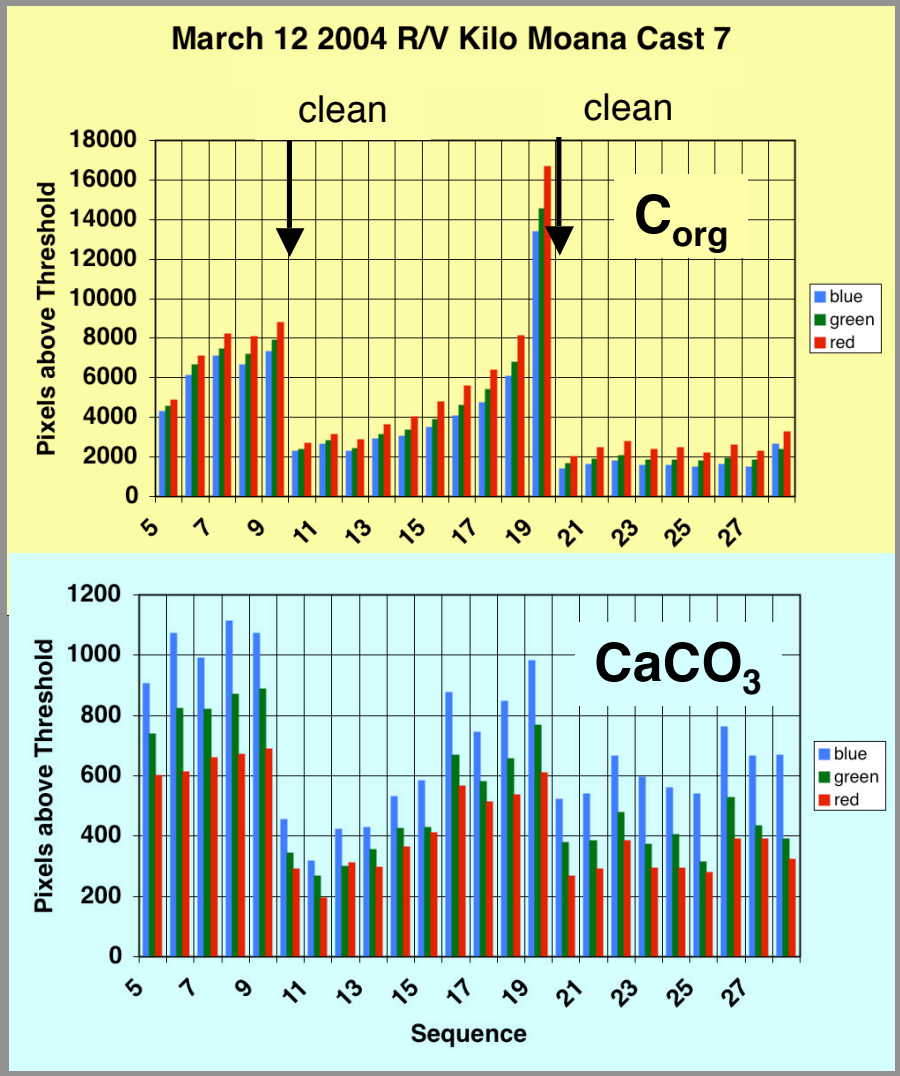
Carbon Sedimentation Flux through 180 m easily detected in a low productivity environment.

First autonomous measure of $CaCO_3$ sedimentation

So Far: 17 days of experience with twin buoy instruments

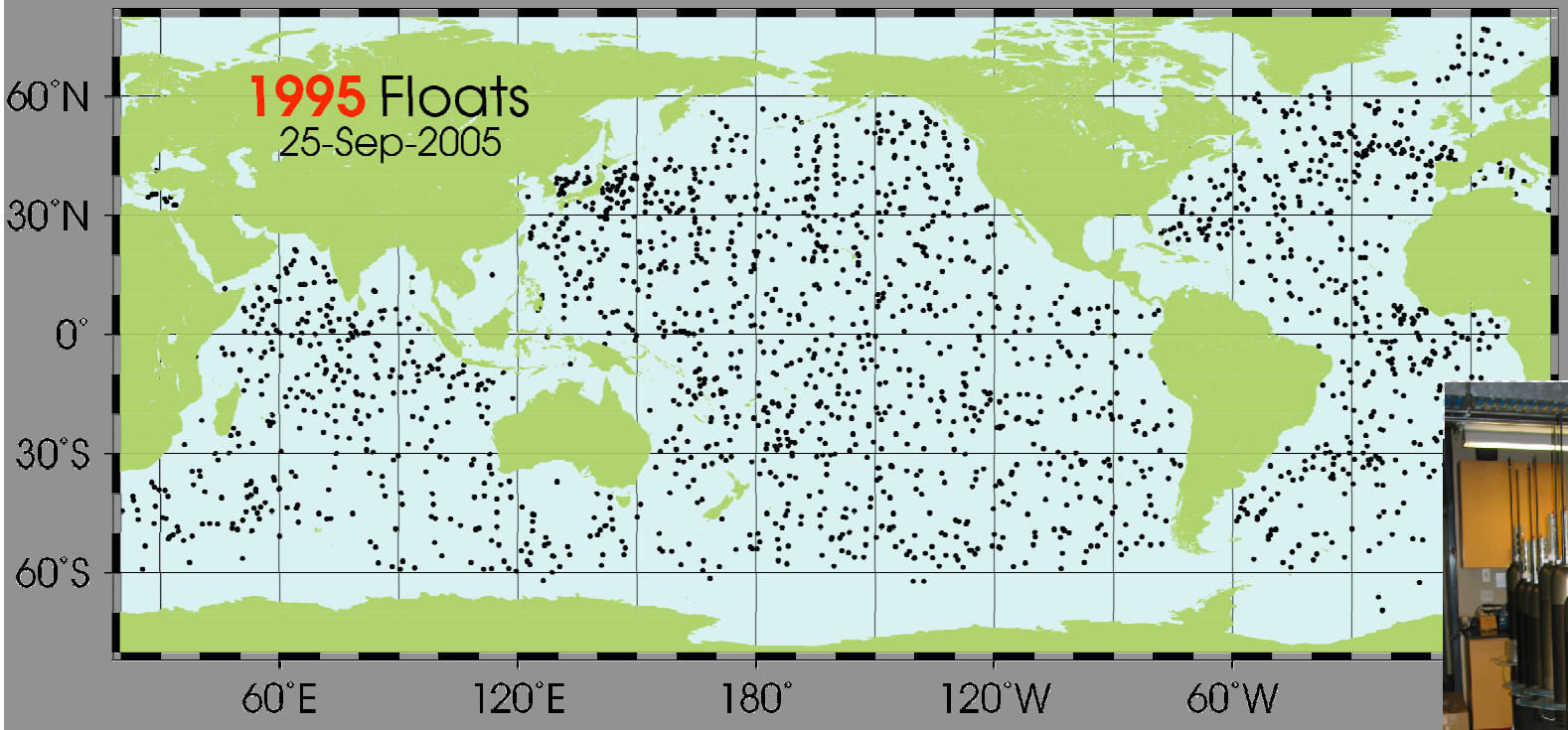
recently: July-August 2005
North Pacific (Oyashio)
near Japan

.



30 min frequency for 3-4 weeks.
expect to get to seasons

Can we have a Carbon - ARGO?

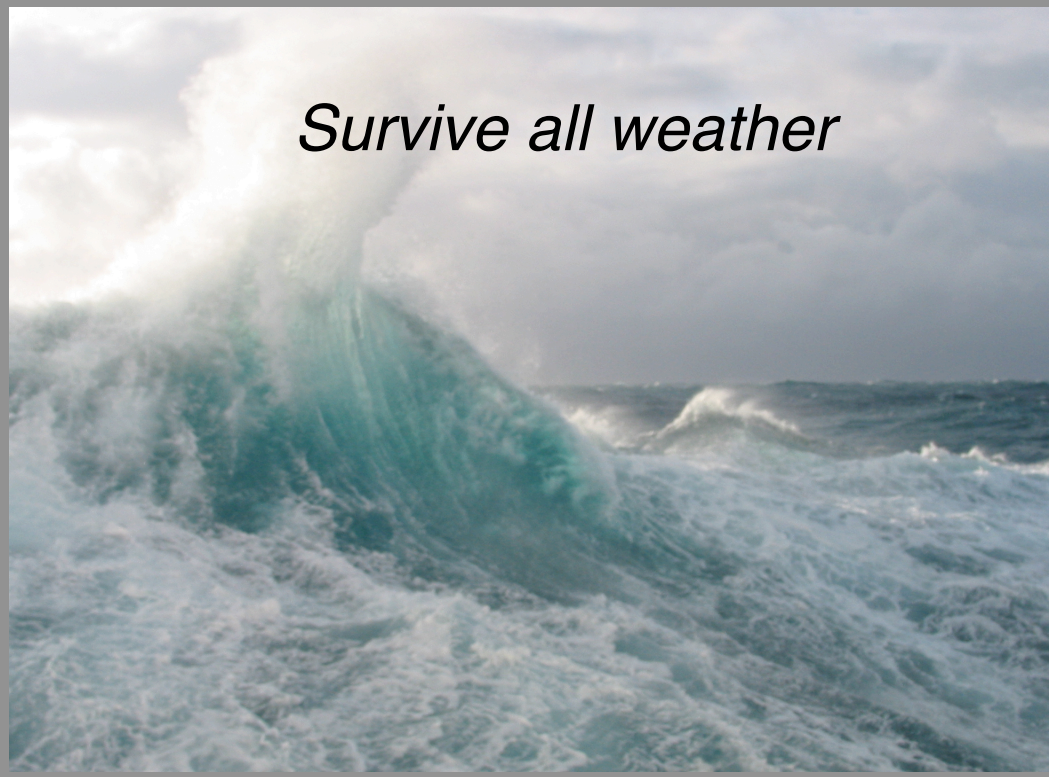


~1300 Floats
Jan 2005

Prospects for a Carbon ARGO look very good

Carbon Explorer Track record

2 N Pacific OSP	2001
1 Cal current	2001
4 SOFeX	2002 - 1 at 66S
2 N Pacific OSP	2003
3 N Atlantic A16N	2003 - 1 at 60 N
1 HOT	2004
(lost on launch)	



No major biofouling problems

POC sensor / scattering sensor
~8 float-years of data

Sensors outlive battery life of float

PIC sensor - 1 test on Carbon Explorer

Orbcomm telemetry saves power but was poor poleward of 55. Irridium will fix

Sensor STATUS

POC

Sensor is mature.

PIC

Operational validation on CTD's [CLIVAR A16N, S]

POC & PIC flux:

1-2 years for fully autonomous float ops.

DOC components:

Possible

pCO_2, TCO_2, NO_3, O_2…

June 22 2005

Sensor STATUS

POC

Sensor is mature.

PIC

Operational validation on CTD's [CLIVAR A16N, S]

POC & PIC flux:

1-2 years for fully autonomous float ops.

DOC components:

Possible

pCO_2, TCO_2, NO_3, O_2…

We are now ready for an enhanced ocean carbon observing system that is …

Fast
Real Time
Robotic
High Frequency
Free Ranging
Low Cost