Potential of profiling floats to enhance NASA's mission

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Outline:

What are profiling floats?

Studies to date involving optics and profiling floats.

Apex float 0005.

Collaborators: L. Taylor, P. Brickley, D. Swift, R. Zaneveld, S. Riser, C. Moore, MJ Perry, P. Strutton

'Lagrangian' profiling platforms (Davis, 90s):

Autonomous Lagrangian Circulation Explorer (ALACE)

- Global coverage without need for acoustic sources.
- At the surface, typically ½ to 1 day (ARGOS link). Improved with Irridium.
- Can obtain a profile on the way (PALACE).
- Lifetimes of 5 years or 200 cycles to 1000 m.
- full vertical control allows complex depth vs. time missions and active isopycnal following.

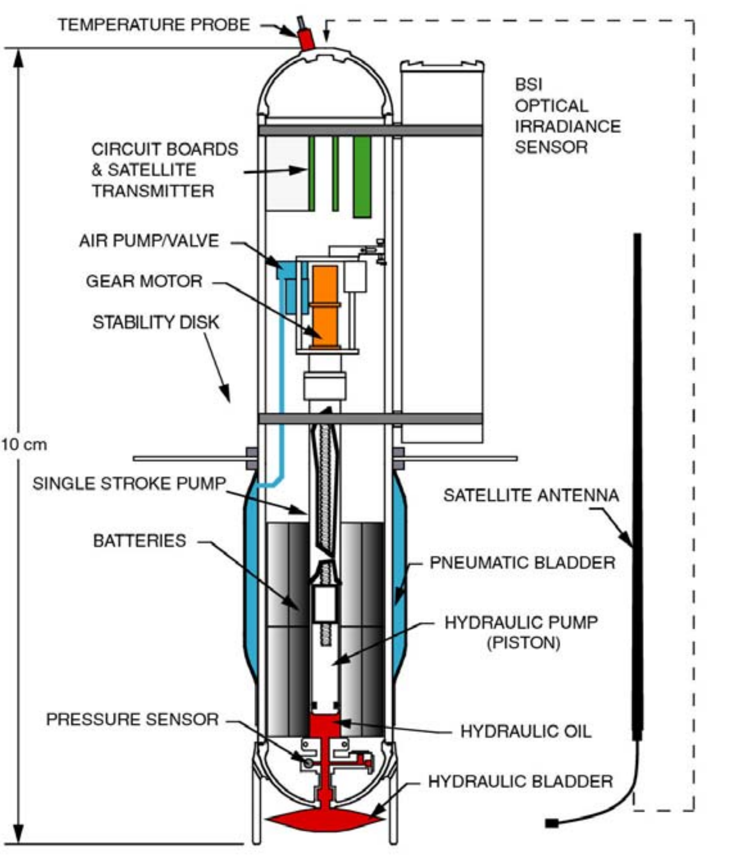
There are several domestic and foreign commercial manufacturers.

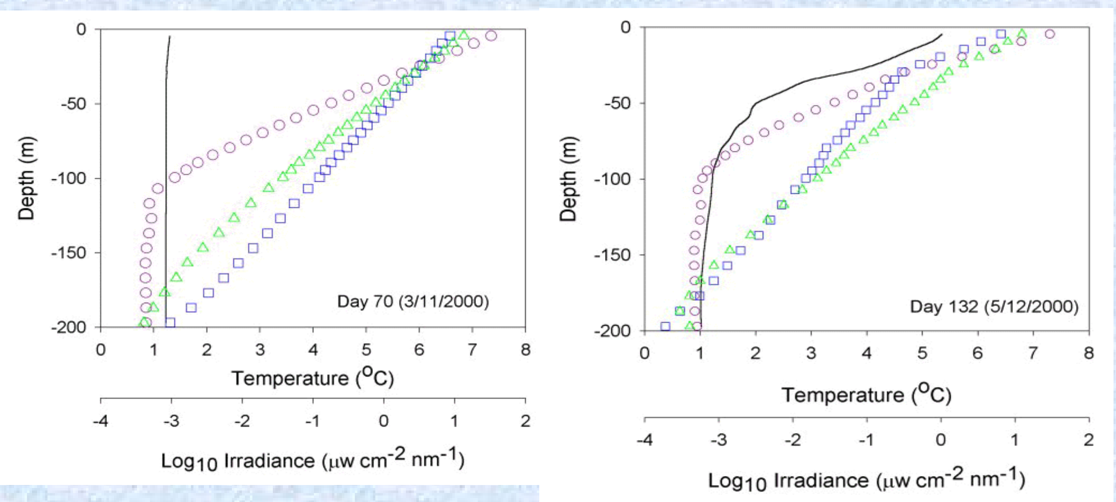
Floats with optics:

K-SOLO float (G. Mitchell, M. Kahru, J. Sherman, 2000)

3-wavelengh downwelling irradiance (Ed) sensor (380, 490 and 555 nm)

K = -1/Ed dEd/dz



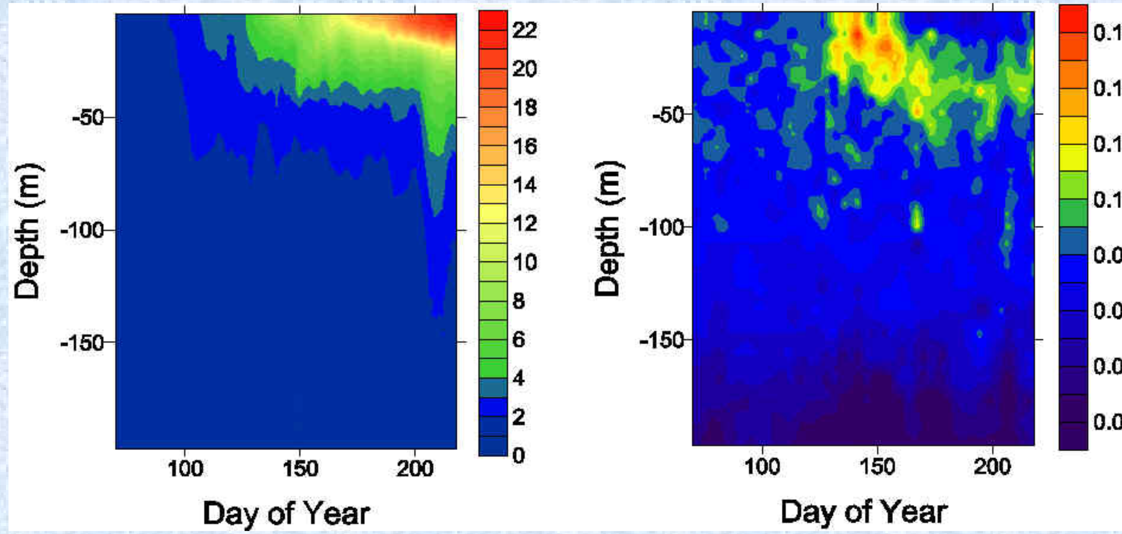


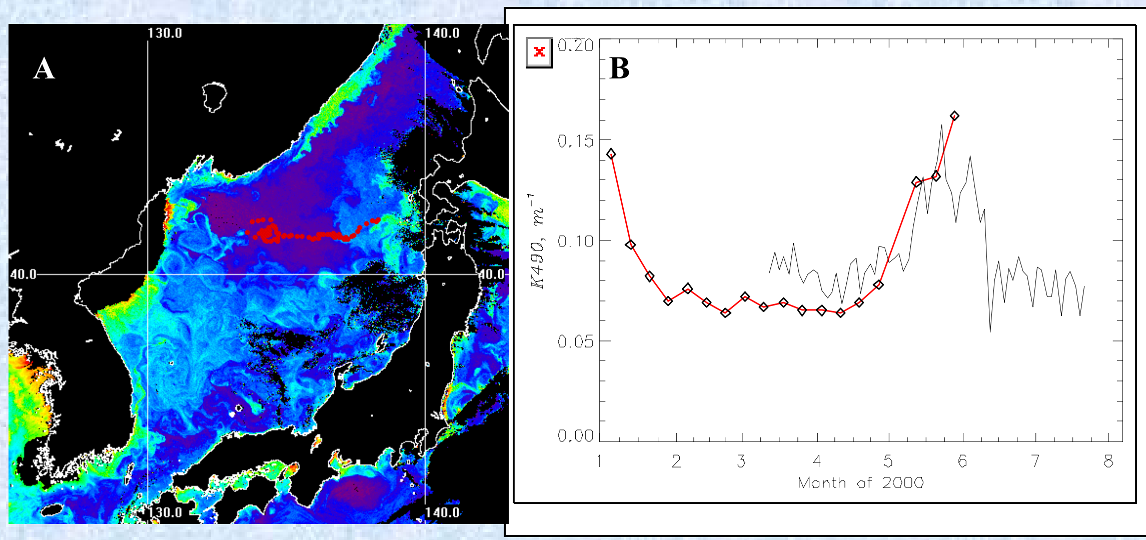
Vertical profiles of temperature (__) and irradiance at three wavelengths (380 m - ○; 490 nm - □; 555 nm - △) transmitted by KSOLO for A. March 11 and B. May 12, 2000.

Some results:

- Vernal bloom

- Satellite validation $k_d(490)$

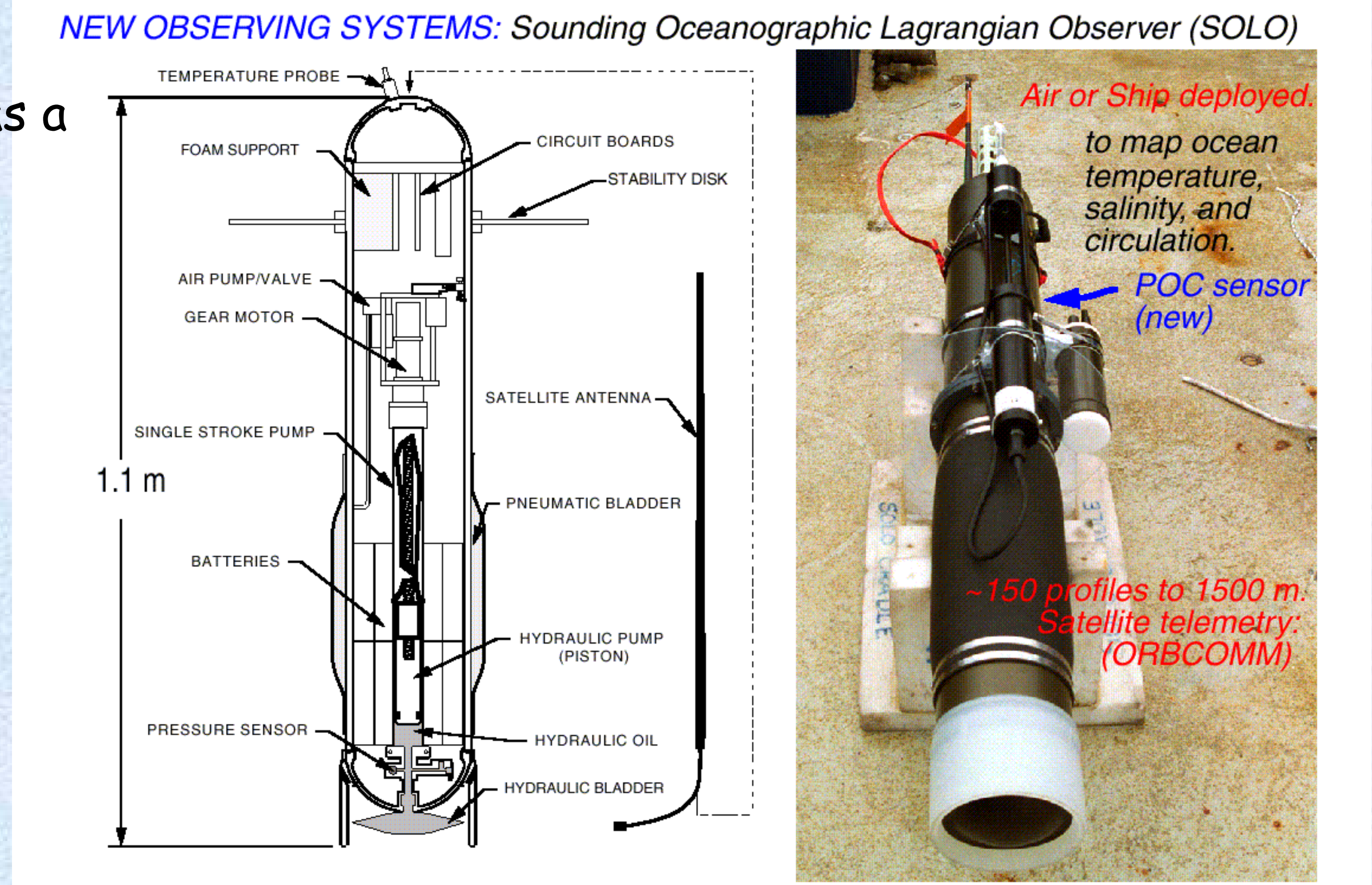




Floats with optics:

SOLO float (J. Bishop, R. Davis, J. Sherman) – Carbon explorers

Beam-c used as a proxy of POC.

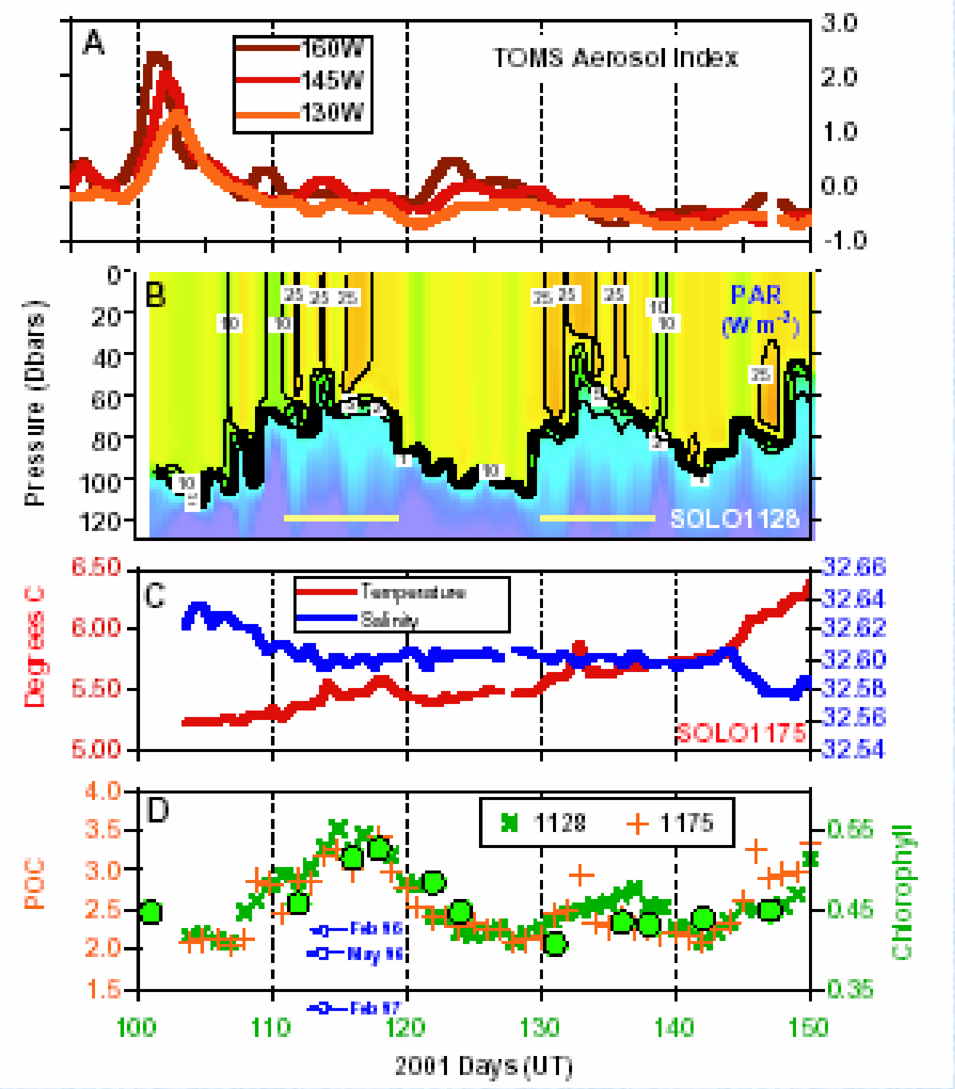


(Davis et al., 1999)

Results:

Two blooms of phytoplankton in North Pacific following dust deposition event.

SeaWIFS [chl] and POC covary.



Bishop et al., Science, 2002

SOLO floats (J. Bishop, R. Davis, J. Sherman) – Carbon explorers

Measure beam-c in and out of an Iron seeded patch.

Use the transmission due to particles that settled on optical window at depth to quantify carbon flux.

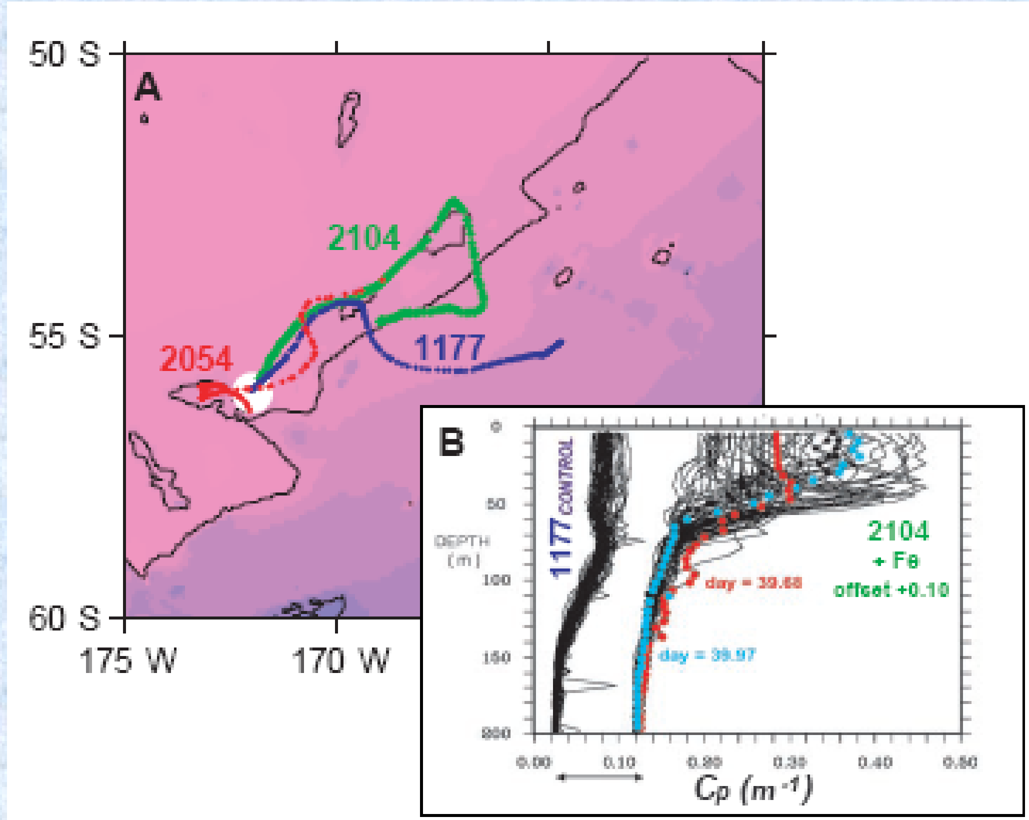


Fig. 1. (A) Trajectories of Carbon Explorers for the first 60 days of deployment superimposed over bathymetry of the Southern Ocean. Blue, red, and green tracks denote trajectories for Explorers 1177 (control), 2054 (in-patch #1), and 2104 (in-patch #2), respectively. (B) Carbon Explorer POC sensor data (beam attenuation coefficient) from the control (1177) and in-patch (2104) Explorers during the first month of observations of the North Patch. Three profiles per day were transmitted in real time. The highlighted profiles from the in-patch Explorer on universal time coordinated (UTC) day 39 were collected 6 hours apart at the time of the RV *Revelle* survey and indicate variable sampling of waters below 80 m that were enriched in POC. Both 1177 and 2104 went on to operate for another year in the Southern Ocean.

Bishop et al., Science, 2004

Upcomming Project: PROBIO

12 ARGO floats + radiometer + transmissiometer

+ (Chla & CDOM) fluoresence + bb meter + irridium

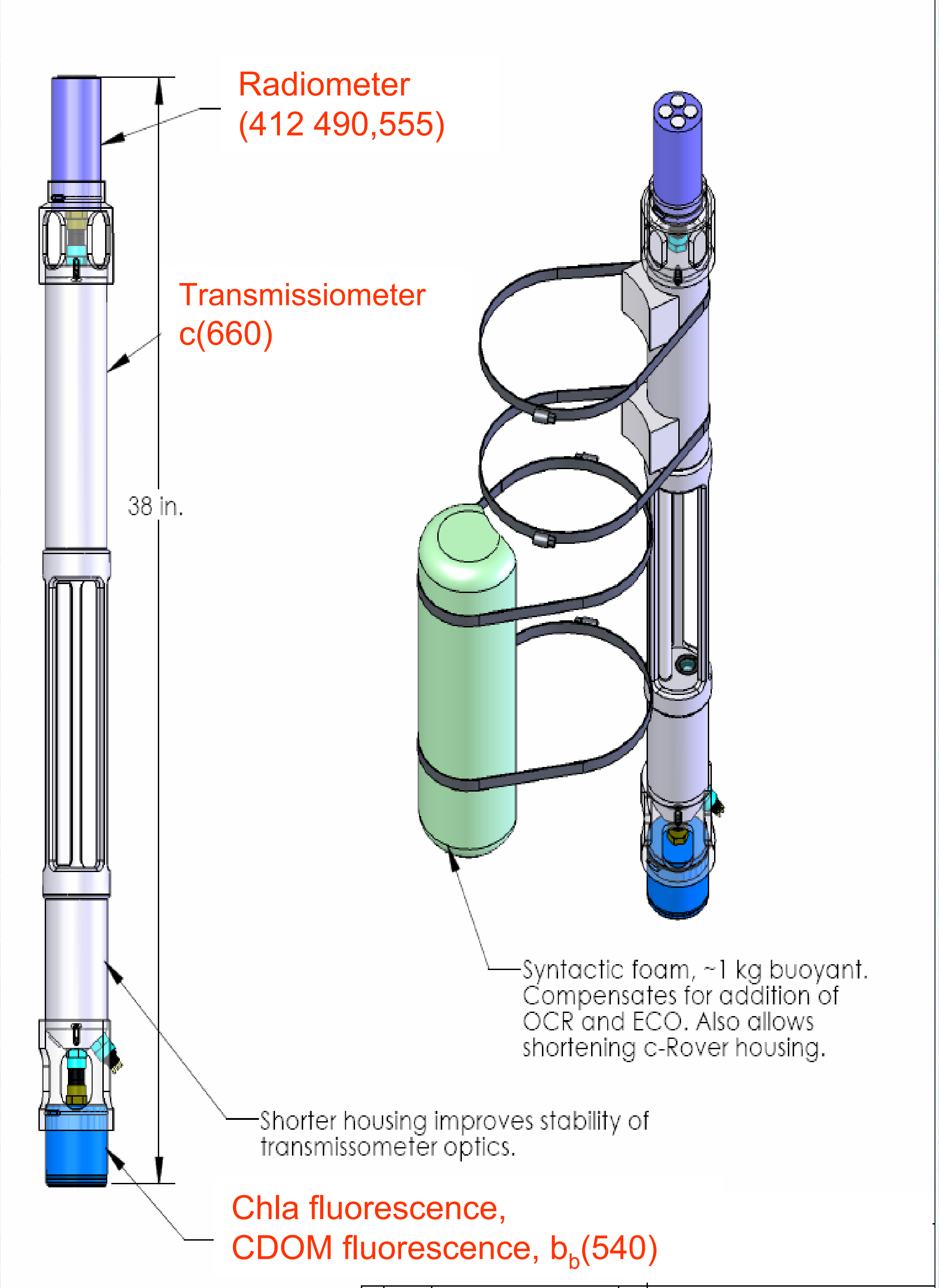
- Iridium capability : two-way communication (dialogue) :

to adaptively sample in time, and as well along the vertical, in order to resolve some events (e.g. storms, bloom, matchups with sensors…) as accurately as possible.

- Deployment planned in 2007:
- Med Sea, South Pacific Gyre, North Pacific Gyre, North Atlantic

Funding by CNES, Operational Agency (Coriolis), and ANR

(Hervé Claustre, PI)



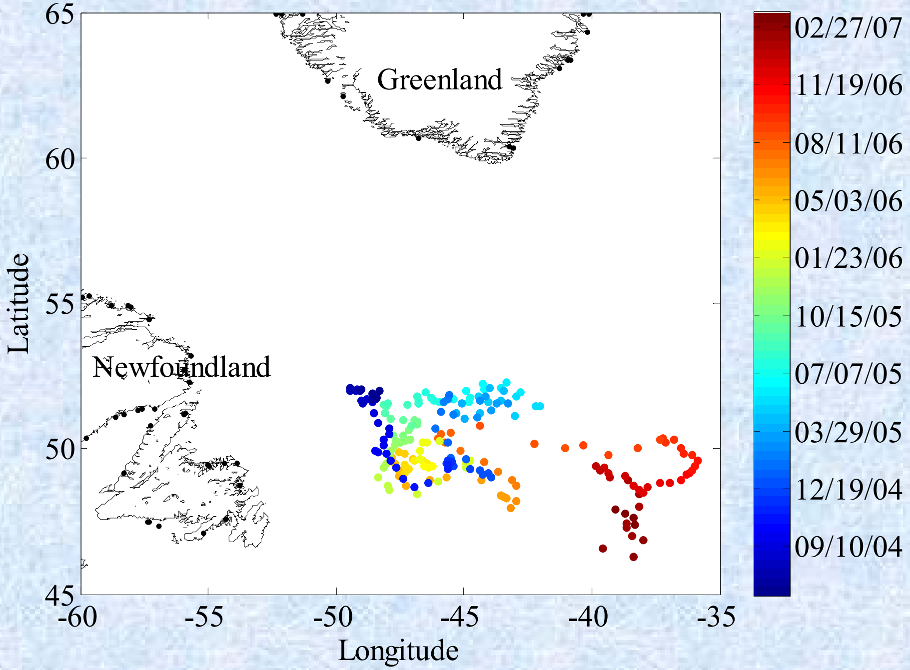
For PROBIO

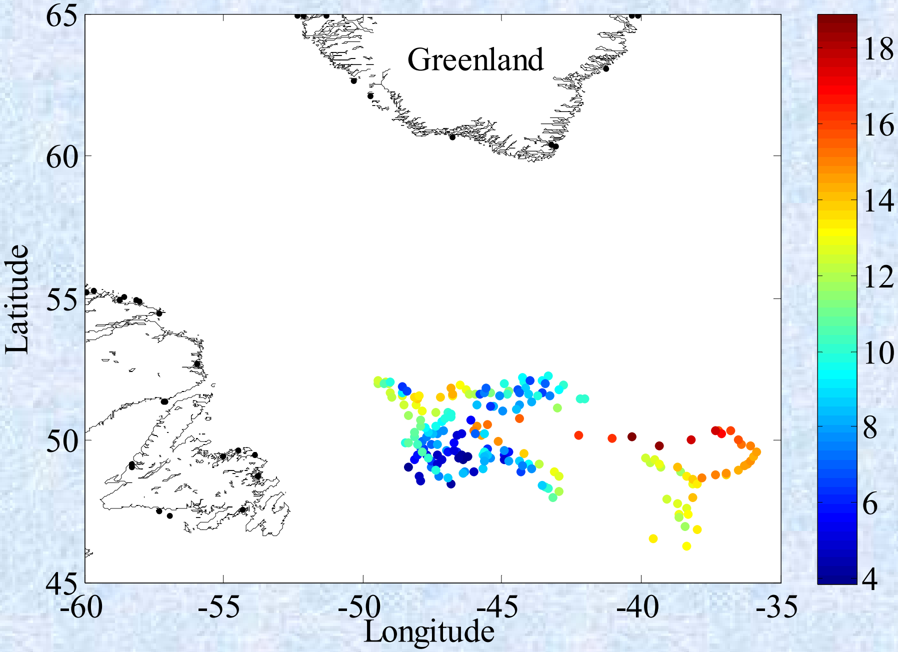
Added bio-optical sensors

Radiometer (3λ)
C-meter
Chla fluorescence
CDOM fluorescence
bb-meter

APEX Float 0005:

New auxiliary board.
New (Lithium) batteries.
Chl-LSS combined sensor
O_2 (failed after 6 months).
To date: 206 profiles, one every 5days.





Calibration:

•Vicarious calibration with of F_{chl}-LSS sensor with three Fchl and $b_b(440)$ sensors deployed by P. Strutton on a mooring at the same time as the float.

•The mooring drifted away from its anchor and we used 2.5months of the deployment for the calibration.

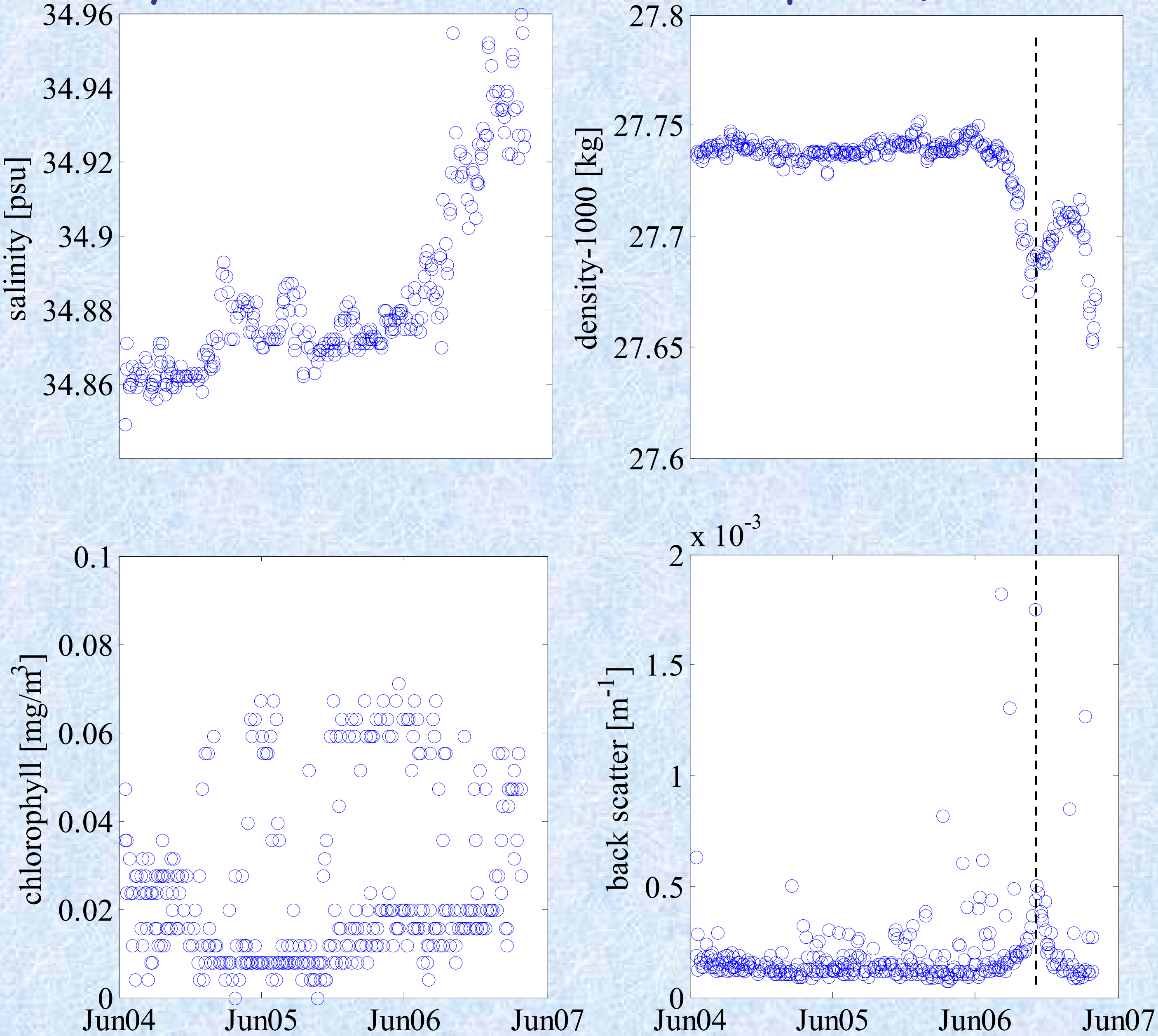
•Strutton's F_{chl} calibration was done with local in-water samples (factor of 3 difference relative to laboratory phytoplankton culture).

Note:

•F_{chl} while an IOP varies with species composition, light history, amount of pigment per cell.

•Float data used here was taken around midnight to avoid NPQ.

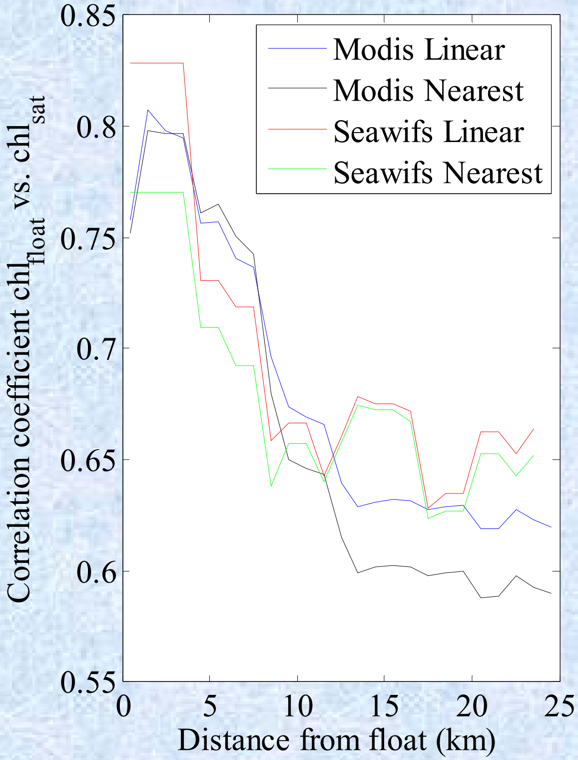
Stability of sensors, values at depths (975-1000m):

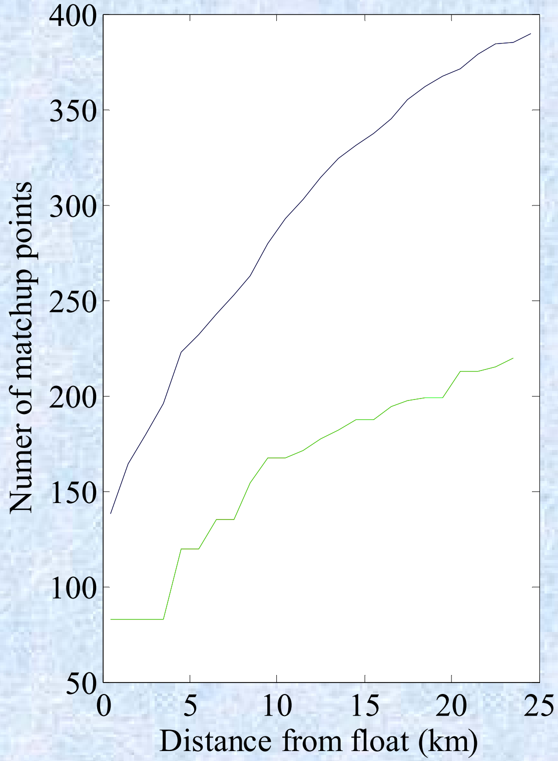


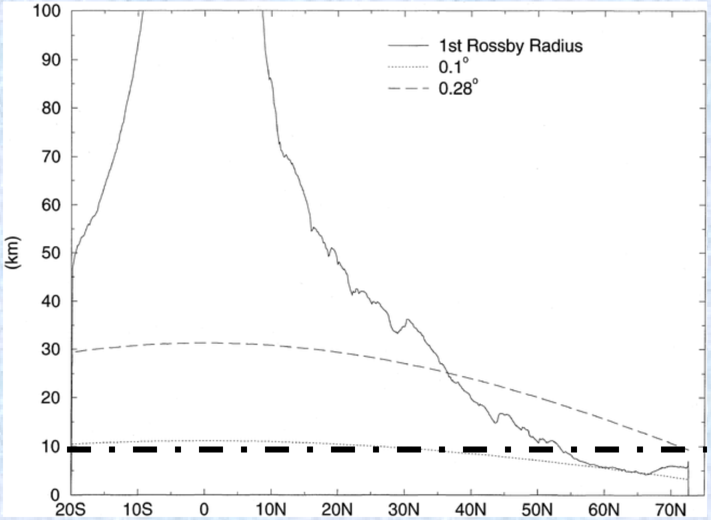
For reference: $b_{bsw}(440)$~$2.2{\times}10^{-3}\ m^{-1}$

What is the appropriate horizontal scale to compare the satellite and float data over?

Note: we use 4km SeaWIFS data and 1km MODIS data





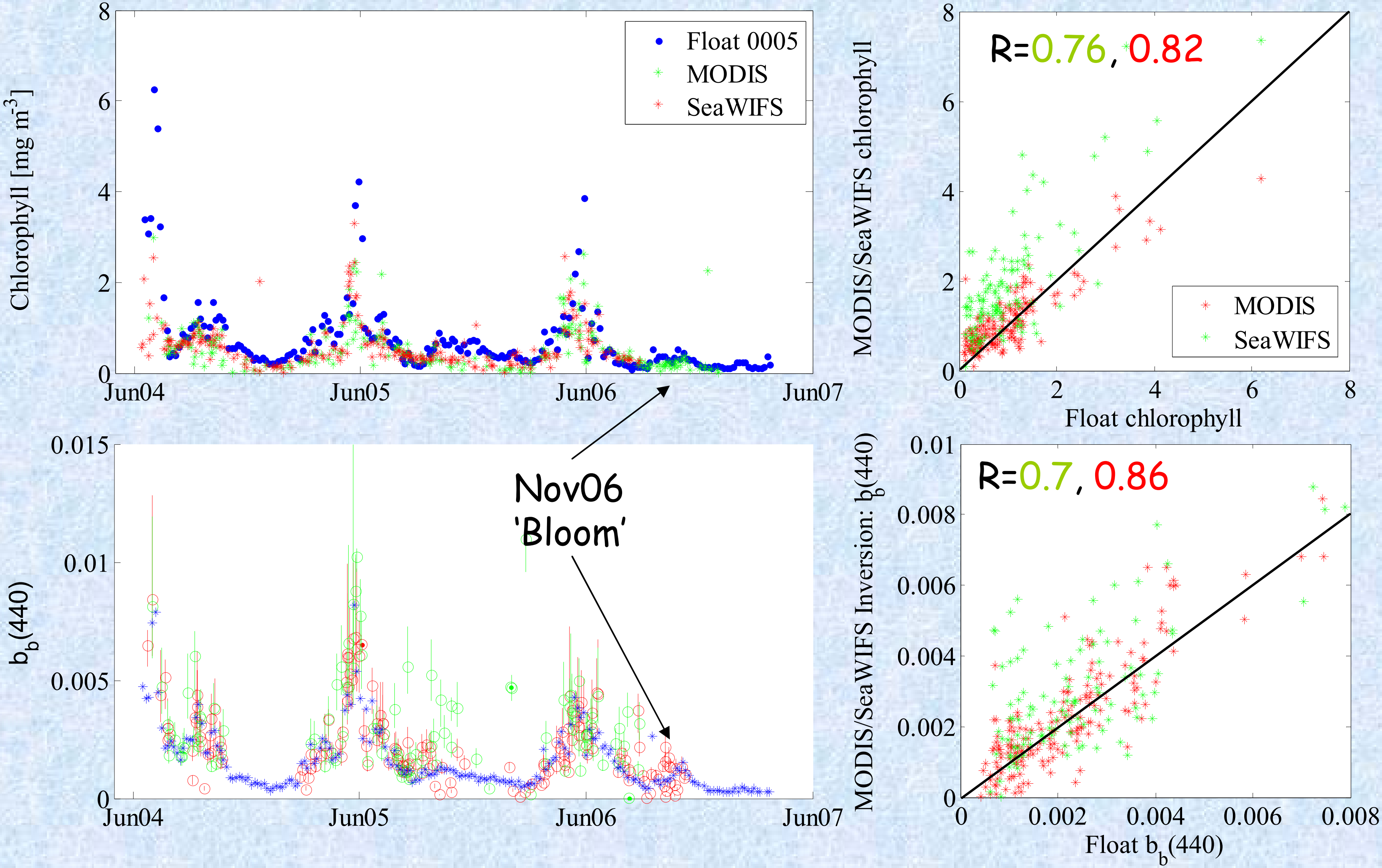


Smith et al., 2000, JPO

Consistent with the (Rossby) deformation radius.

Hereon we use L<7.5km averaging for all comparison of remote-sensing with float.

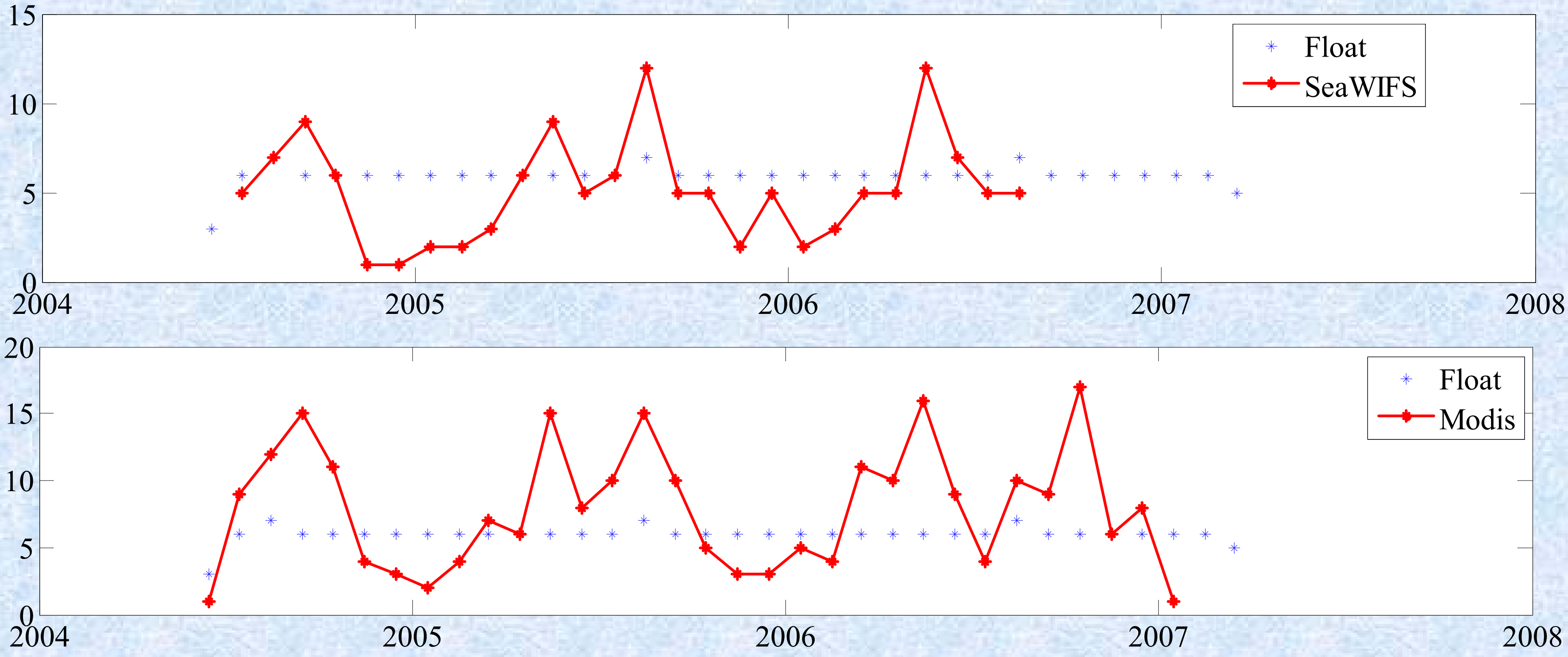
Stability of sensors: comparison with remotely derived surface IOPs.



b_b based on semi-analytical inversion (IOCCG, 2006, ch. 8)

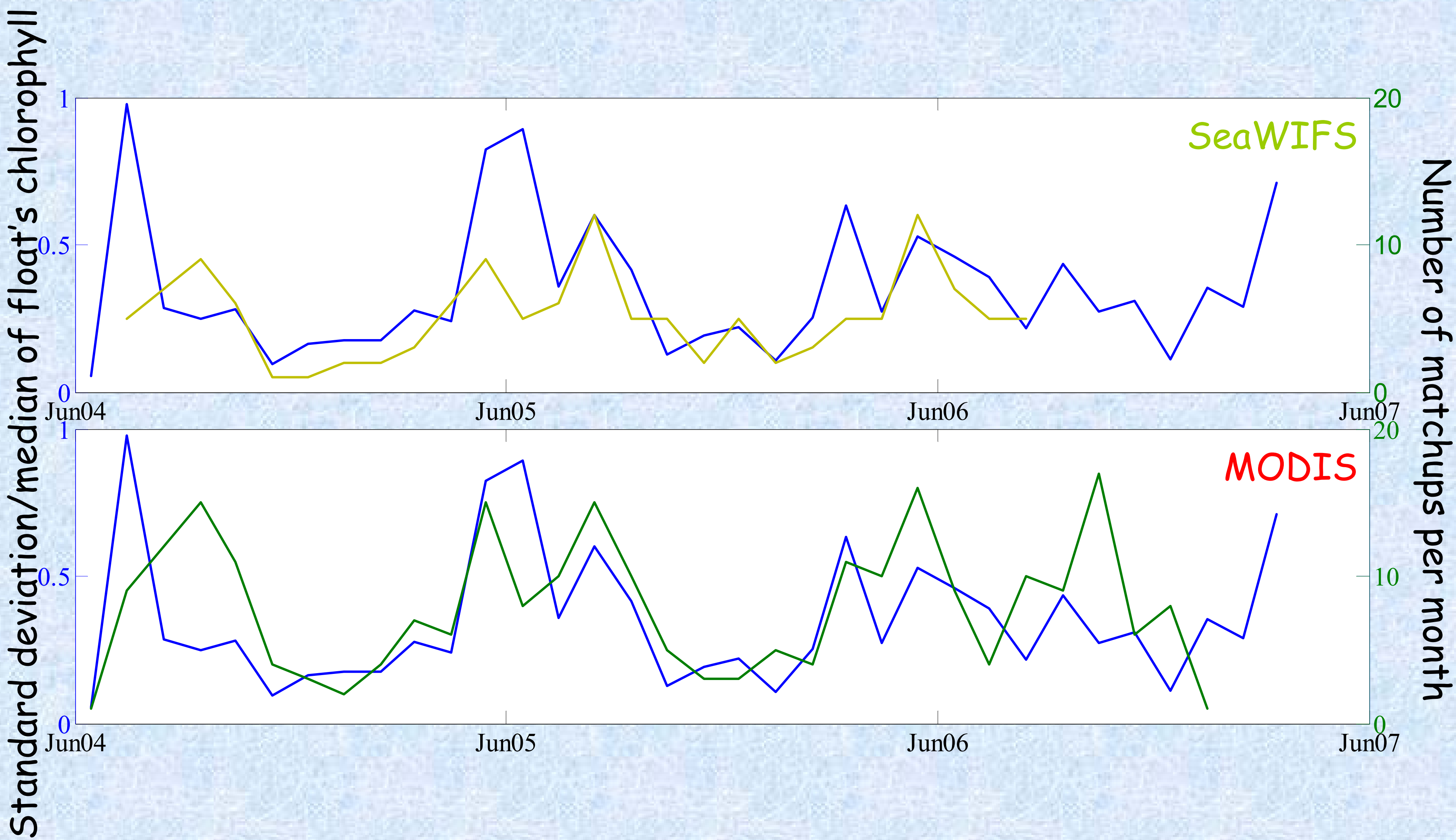
An attractive feature of floats is that they can sample under clouds.

How important is it for the region under consideration?



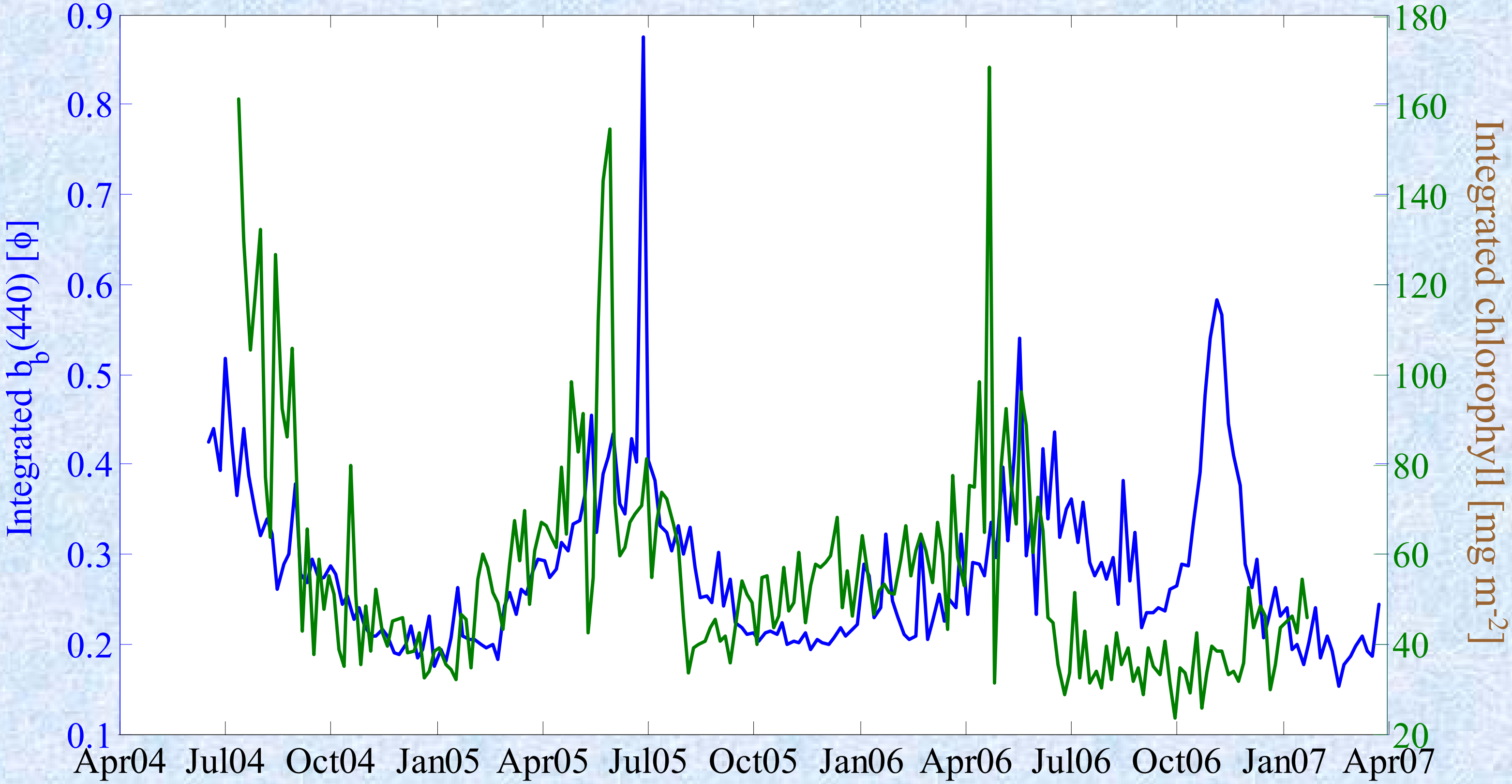
Clouds mask the region over extensive periods each year.

Indeed, coverage from space correlates with normalized variability:



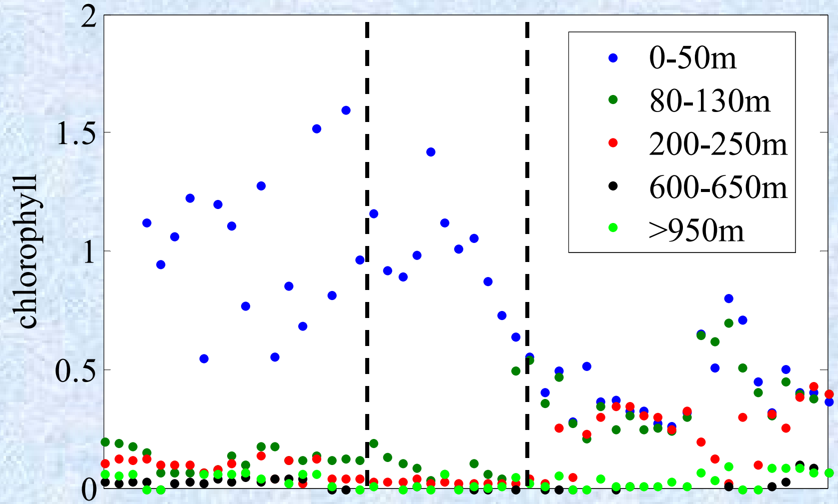
The 'November 2006 event':

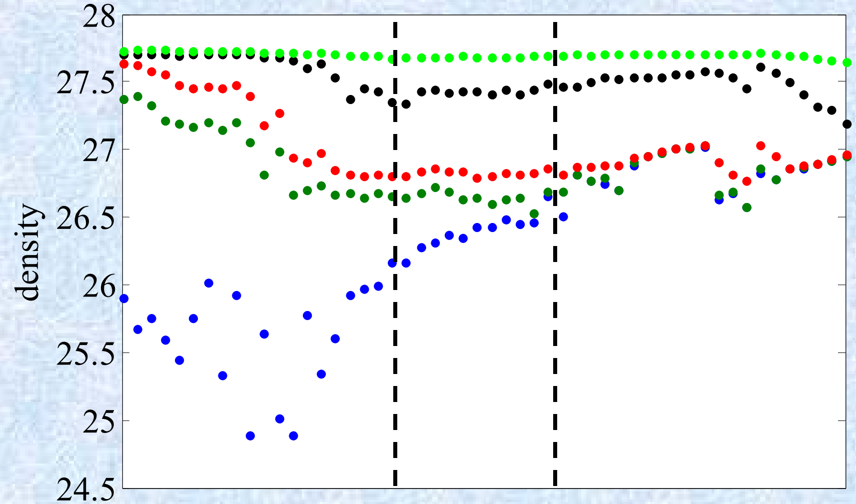
Within a month following the float's passage to subtropical gyre an coherent increase is observed in b_b at depth associated with a small surface bloom.



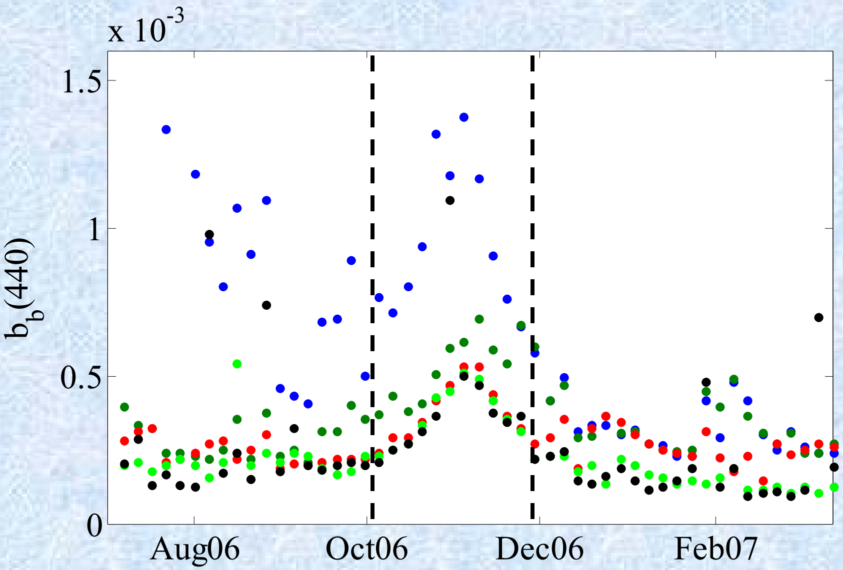
Note: integrated properties vary by a factor < 4 between summer and winter.

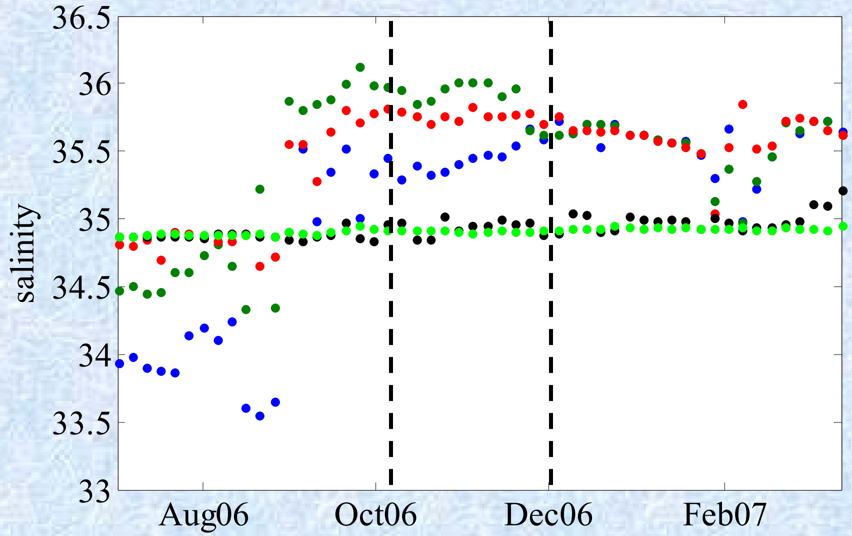
Surface data suggests small 'bloom':





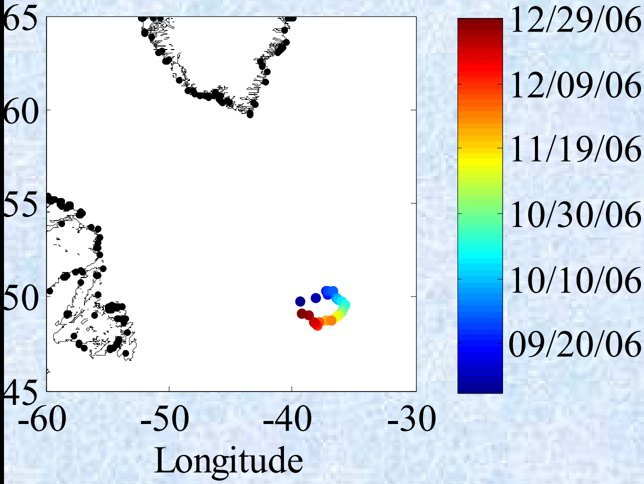
Deep data suggests LARGE 'flux':





Anticyclonic, low density eddy with enhanced b_b down to depth.

Altimeter data (surface anomaly) suggests float is caught in eddy:



Float moves in association with an anticyclonic (light) eddy

Hypothesis:

1. E. huxleyi bloom (But liths need to be repackaged to provide depth coherence).

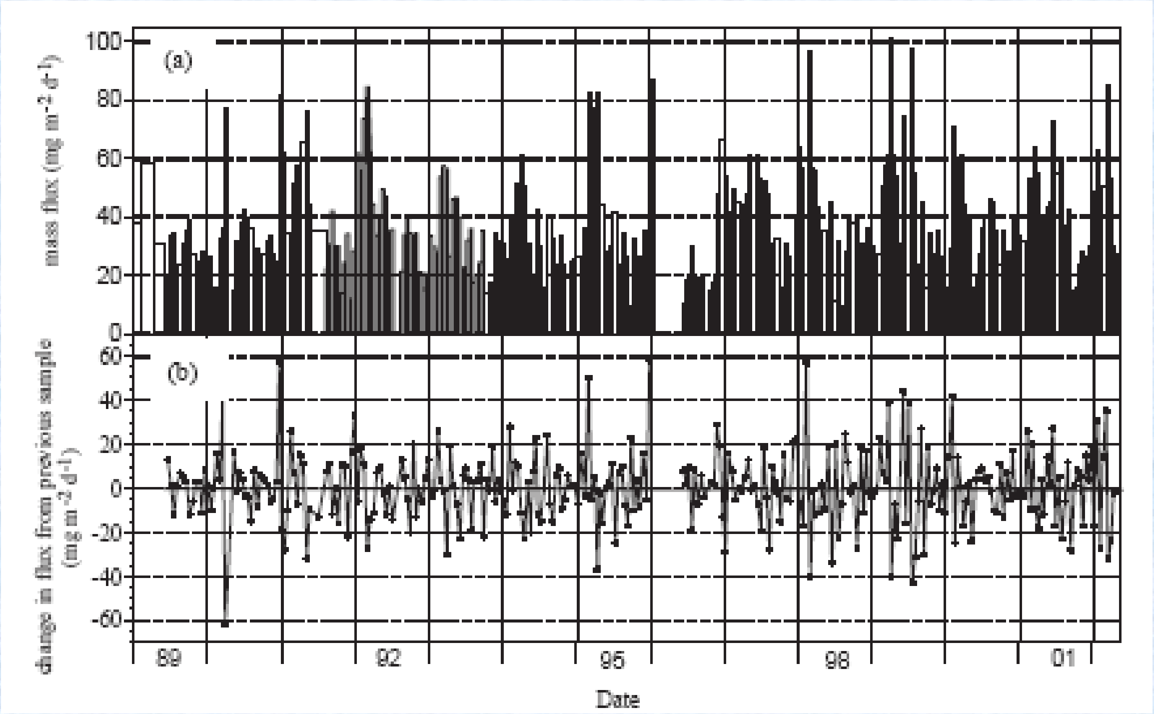
2. Lateral input (not consistent with T/S).

3. Concentration by eddy. (How?)

4. Aerosol deposition (No anomalous τ observed).

Association of flux events with mesoscale processes (eddies) has been observed before.

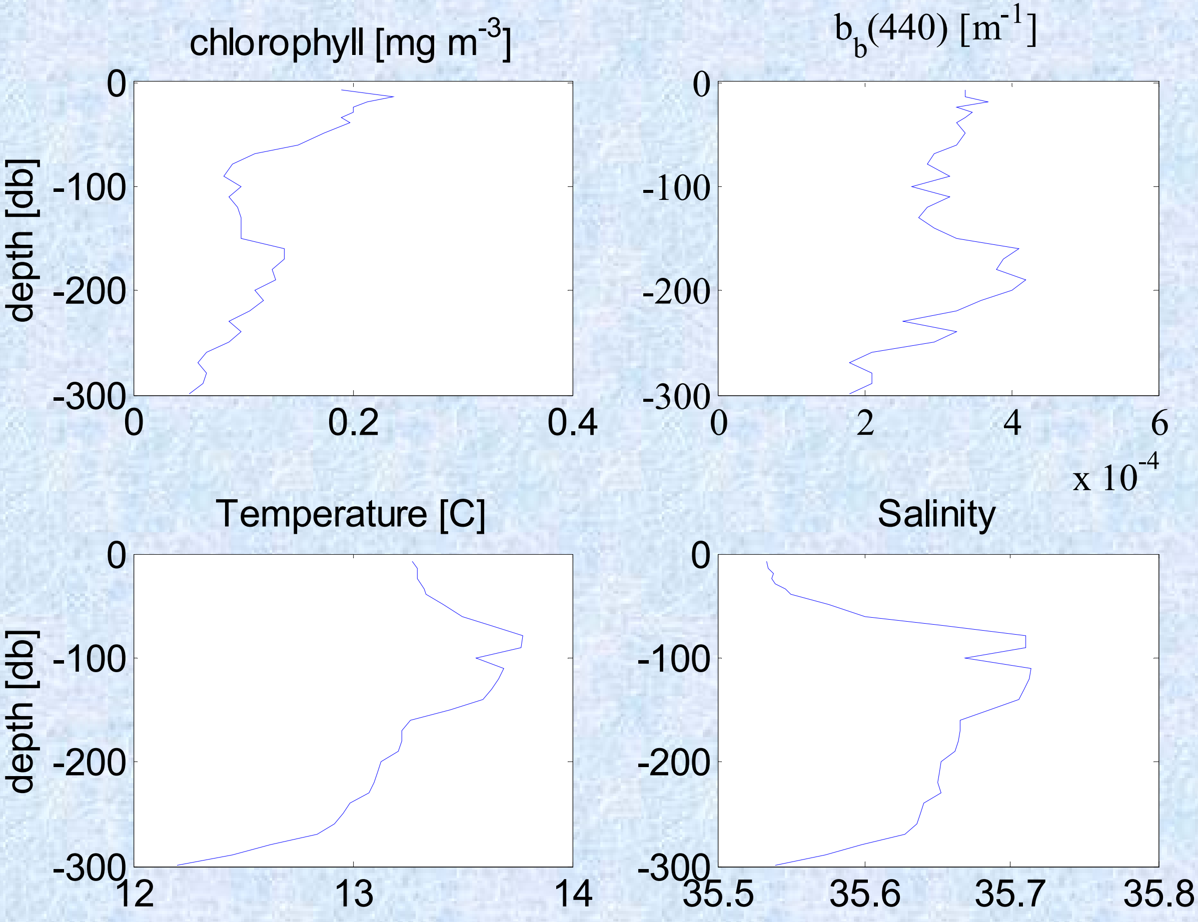
Similarities with the 'Christmas bloom' at BATS (Conte et al., 2003):



Evidence on 2-D processes in floats profiles:

~10% of the profiles show chlorophyll profiles that cannot be explained by 1-D models (e.g. multiple chl peaks).

Likely processes: slantwise convection and interleaving of water masses.



Value of floats consistent with NASA's mission:

1. Sampling under cloud (is it a problem?).

2. Sub-surface structure (in particular when lateral processes are at work).

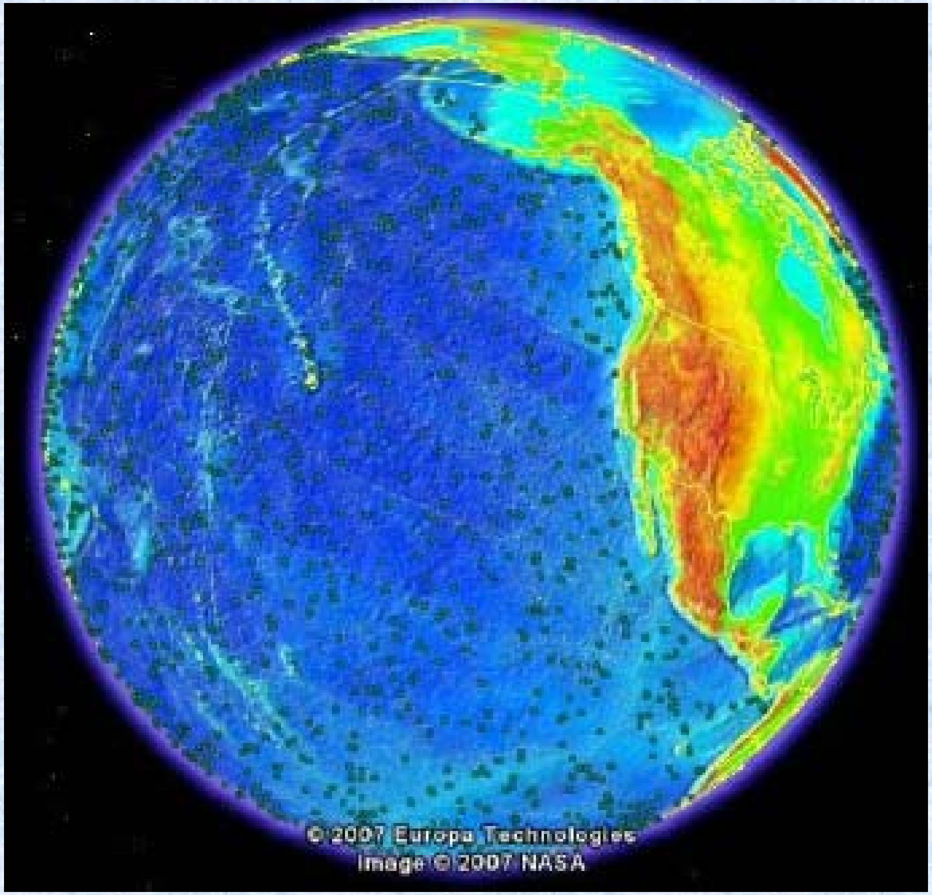
3. Validation – magnitude of uncertainties in products for given horizontal scales.

4. Ability to collect cheaply independent data to be used in for improvement of algorithms.

Where do we go from here:

Currently a strong community push of addition of O_2 sensors (N. Gruber).

We (NASA (?)) should spearhead the push to add optical sensors.

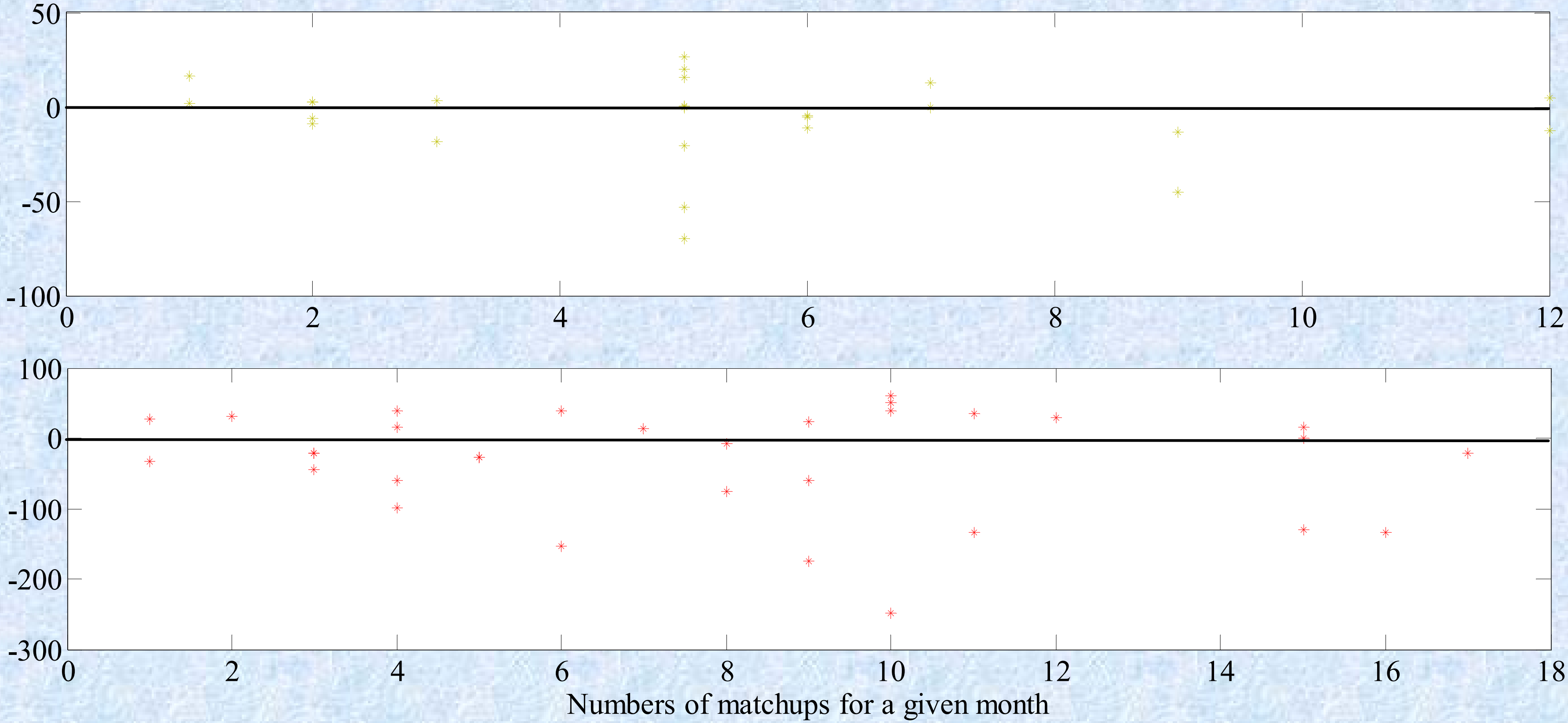


As of April 9th 2007, 2820 floats are profiling the oceans.

Imagine how much we could learn if 10% of them had biogeochemical sensors…

How biased are averages obtained from space at the location of the float and during its 3yrs deployment due to clouds?

% bias in monthly median value of $(chl_{float}-chl_{sat})/chl_{float}$:



In months when clouds are significant there is little variability → little bias.