Ocean Optics During the Southern Ocean GasEx Experiment

February 29 -April 12, 2008

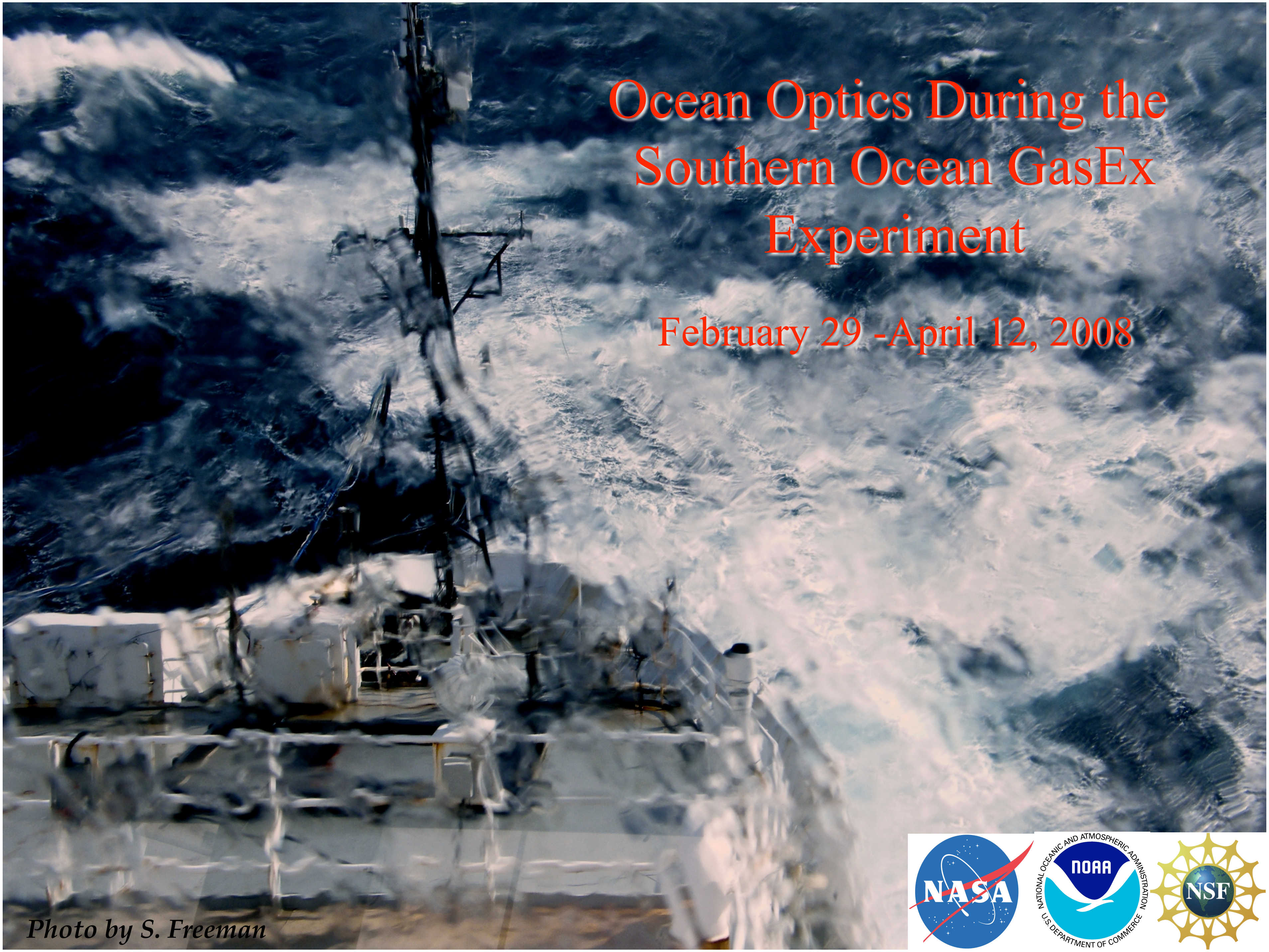


Photo by S. Freeman

R/V R. Brown

Punta Arenas, Chile

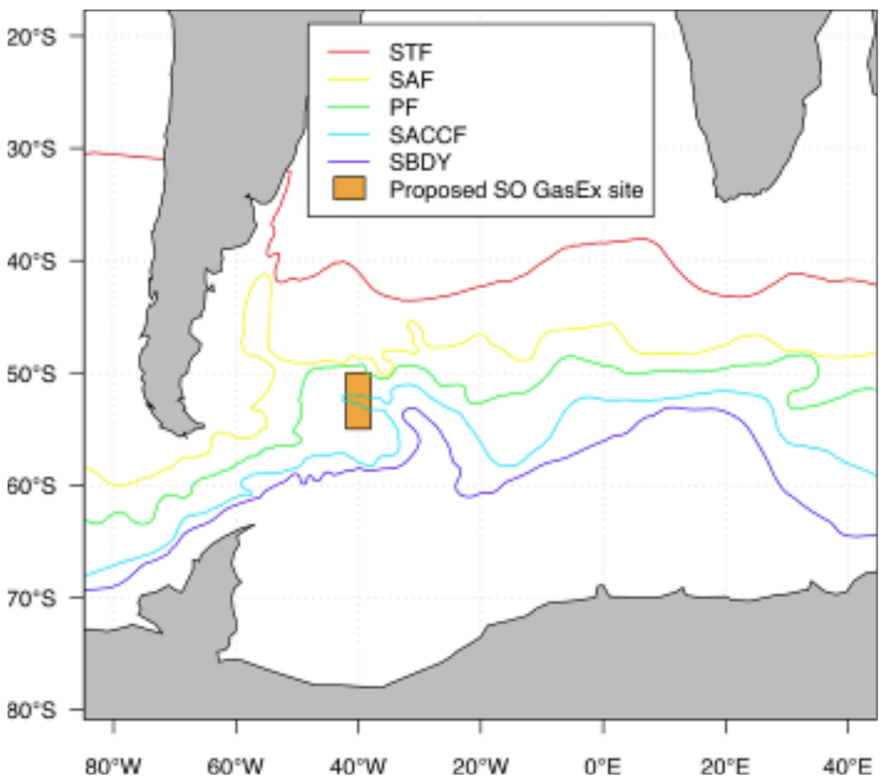
February, 28, 2008

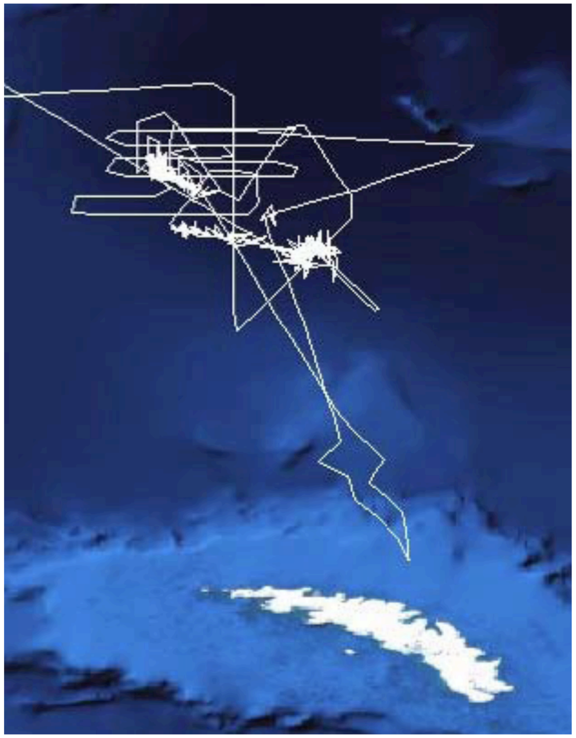
Science Questions

- **What are the gas transfer velocities at high winds?**
- **What is the effect of fetch on the gas transfer?**
- **How do other non-direct wind effects influence gas transfer?**
- **How do changing pCO2 and DMS levels affect the air-sea CO2 and DMS flux, respectively in the same locale?**
- **Are there better predictors of gas exchange in the Southern Ocean other than wind?**
- **What is the near surface horizontal and vertical variability in turbulence, pCO2, and other relevant biochemical and physical parameters?**
- **How do biological processes influence pCO2 and gas exchange?**
- **Do the different disparate estimates of fluxes agree, and if not why?**
- **With the results from Southern Ocean GasEx, can we reconcile the current discrepancy between model based CO2 flux estimates and observation based estimates?**

The study site was chosen to satisfy the following criteria...

* Delta pCO2 of at least 40 µatm to ensure a large enough signal to noise for direct eddy-covariance measurements of CO2.
* Relatively stable water mass (i.e., relatively weak currents and low mesoscale eddy variability) to allow 3He/SF6 patch to be followed for up to 25 days.
* Mixing Layer Depth less than 50 to 70 m.
* Relatively high wind speeds, long fetch and large waves.
* Proximity to Punta Arenas (Chile) to minimize transit time.





NASA Funded Research Project

Optical properties in the Southern Ocean: In situ and satellite observations in support of Southern Ocean Carbon Program

* ZhongPing Lee, Naval Research Lab
* Alan Weidemann, Naval Research Lab
* Paul Martinolich, Naval Research Lab
* Wesley Goode, Naval Research Lab

Optical properties in the Southern Ocean: In situ measurements of phytoplankton absorption using the pFPT-TR instrument in support of the Southern Ocean Carbon Program

* Bruce Hargreaves, Lehigh University

Differentiating sources of backscattering in the Southern Ocean: Calcite, bubbles, and other optical constituents

* Heidi Dierssen, University of Connecticut
* Barney Balch, Bigelow Laboratory for Ocean Sciences
* Michael Twardowski, WET Labs, Inc.
* Penny Vlahos, University of Con

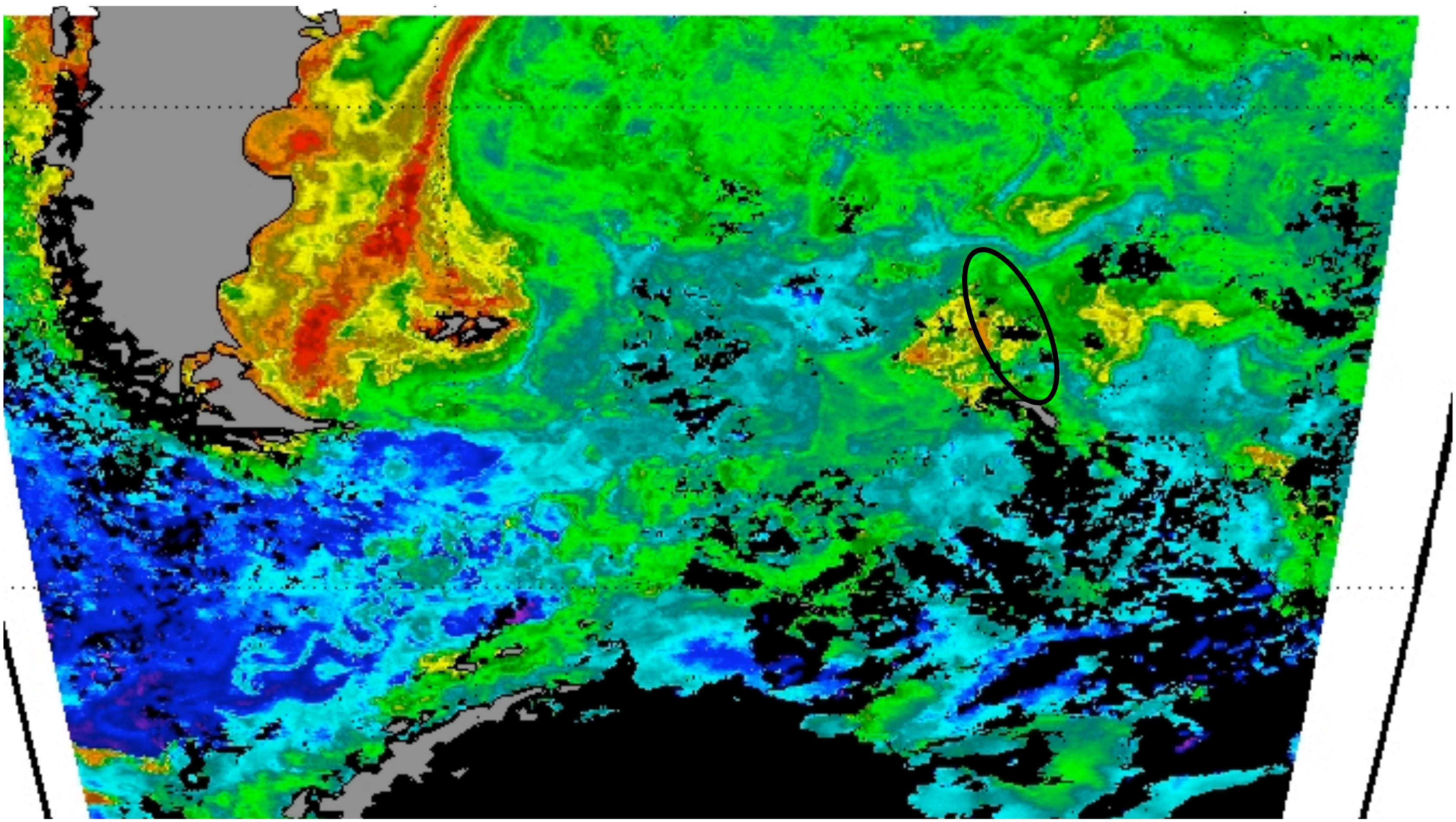
Phytoplankton absorption and carbon dioxide drawdown in the Southern Ocean: A consortium of observations

* John Marra, Lamont-Doherty Earth Observatory
* Bob Vaillancourt, Lamont-Doherty Earth Observatory
* Ajit Subramaniam, Lamont-Doherty Earth Observatory

On the distribution of colored dissolved organic matter in the Southern Ocean and the potential for photoproduction of CO_2 and CO

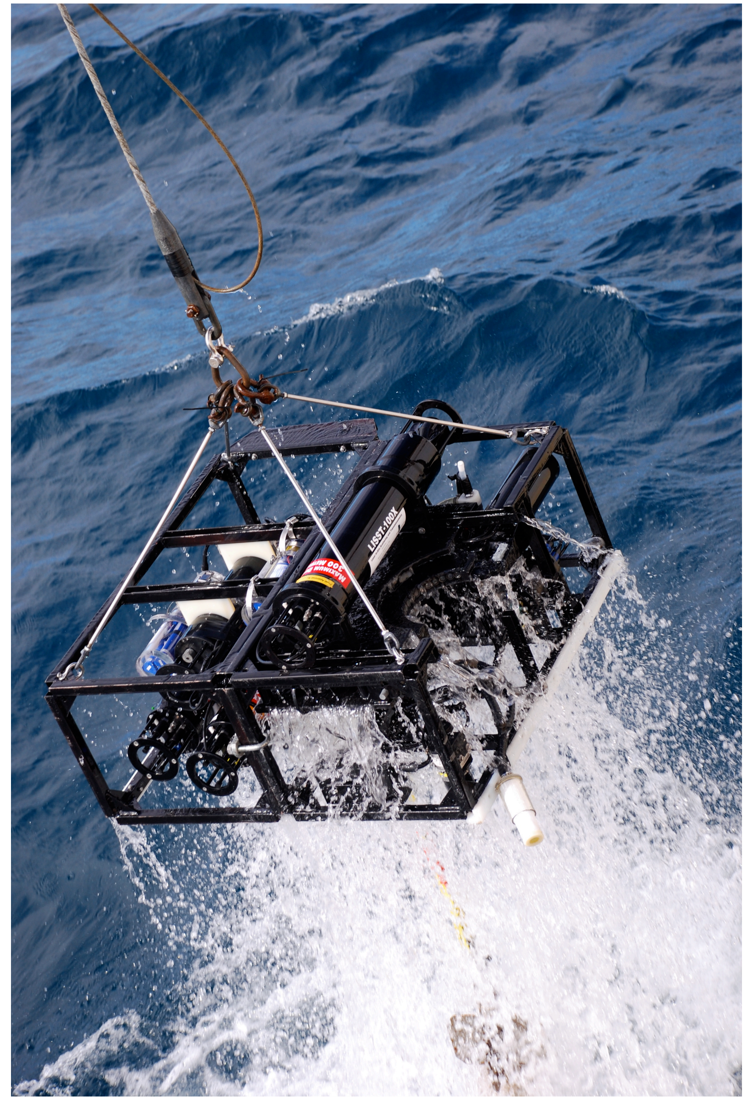
* Carlos Del Castillo, Johns Hopkins University
* Richard Miller, NASA Stennis Space Center
* Watson Gregg, NASA Goddard Space Flight Center
* Tom Haine, Johns Hopkins University
* Francis Monaldo, Johns Hopkins University
* Donald Thompson, Johns Hopkins University

Chlorophyll March 2008



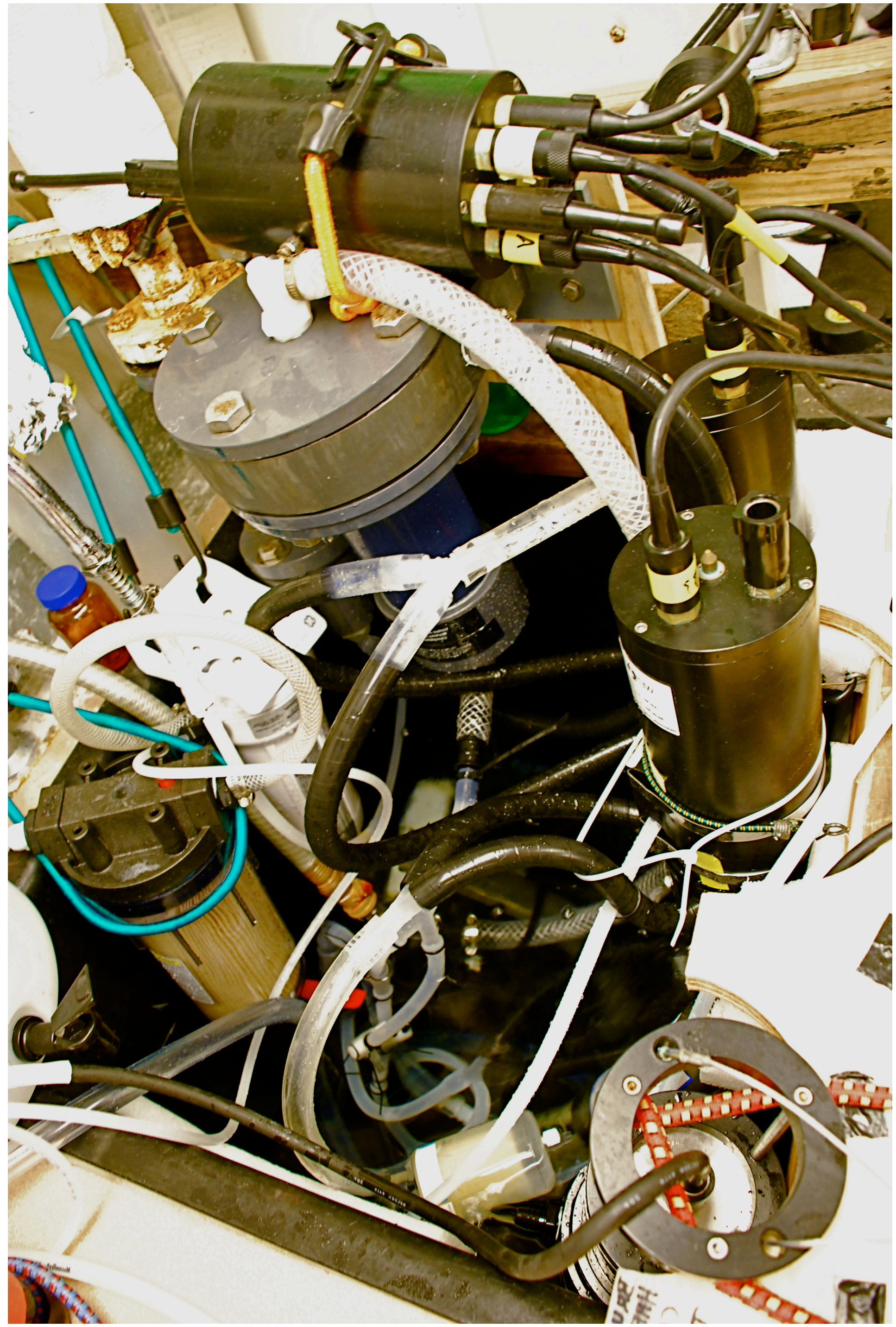
Optical package

Instrument	Number	Measurements
CTD	1	Conductivity, temperature, and pressure
LISST	3	Near-forward scattering and particle size distribution
ac9	1	Light absorption and attenuation at 9 wavelengths
ECO-VSF	1	Volume scattering function to obtain b and bb
ECO-bb3	1	Scattering at 3 wavelengths
AUV-b	1	Total scattering
MASCOT	1	Scattering at 17 angles from 10 to 170

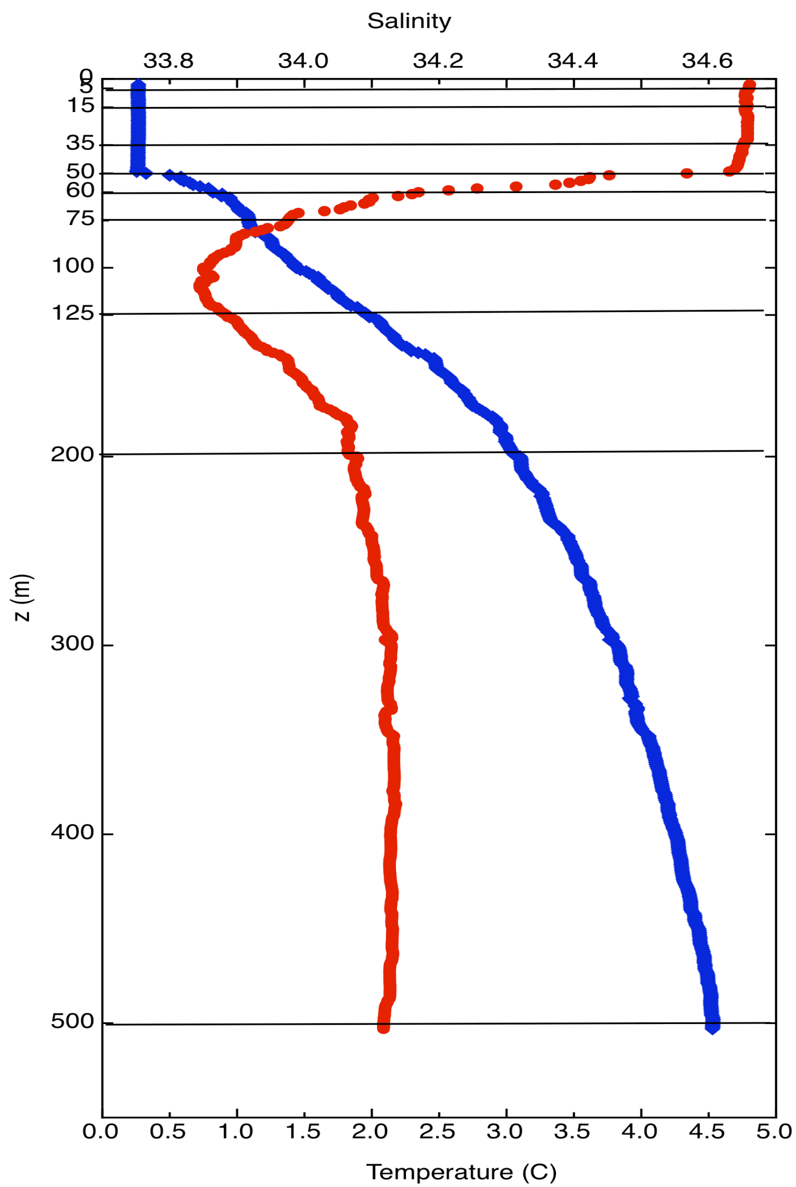


Underway Systems

- 2 x **acs**
- **CTD**
- **Turner designs C-6 fluorometer**
- **EcoVSF - acid labile back scattering**
- **Solar Radiometers (PAR, multi-spectal)**
- **Satlantic SeaWiFS Aircraft Simulator (MicroSAS)**
- **Above water radiance**
- **Cameras**
- **GPS, wind**

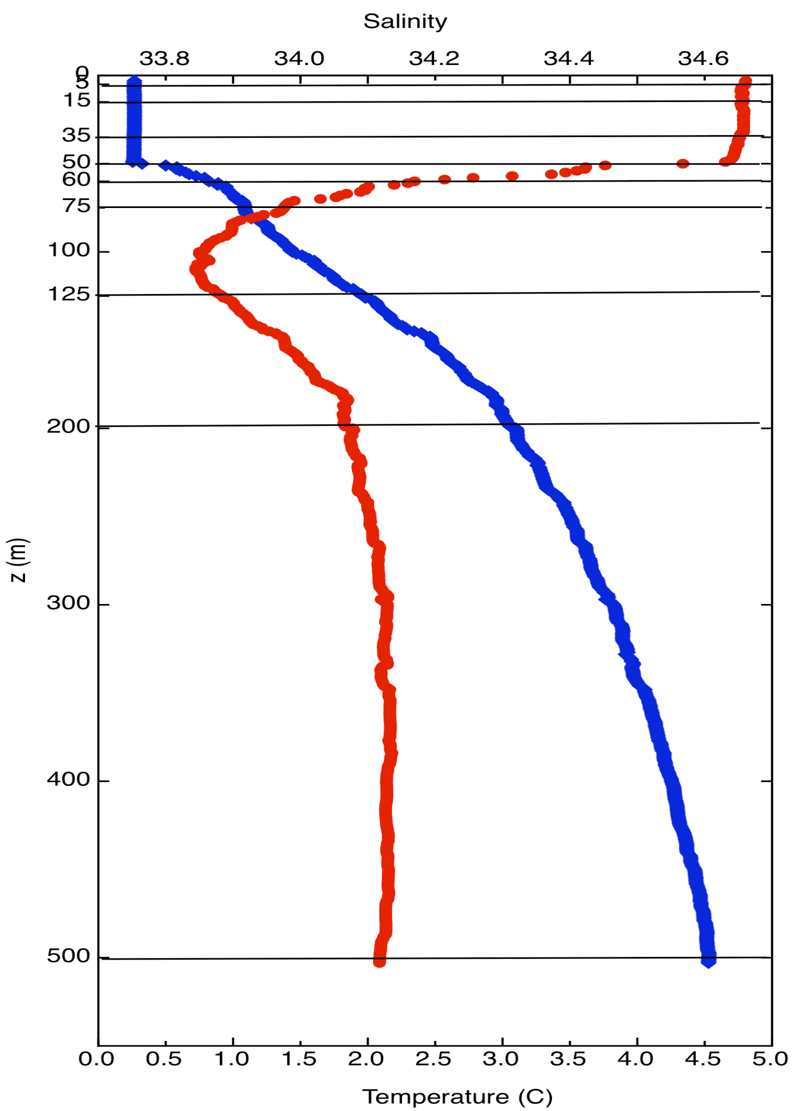


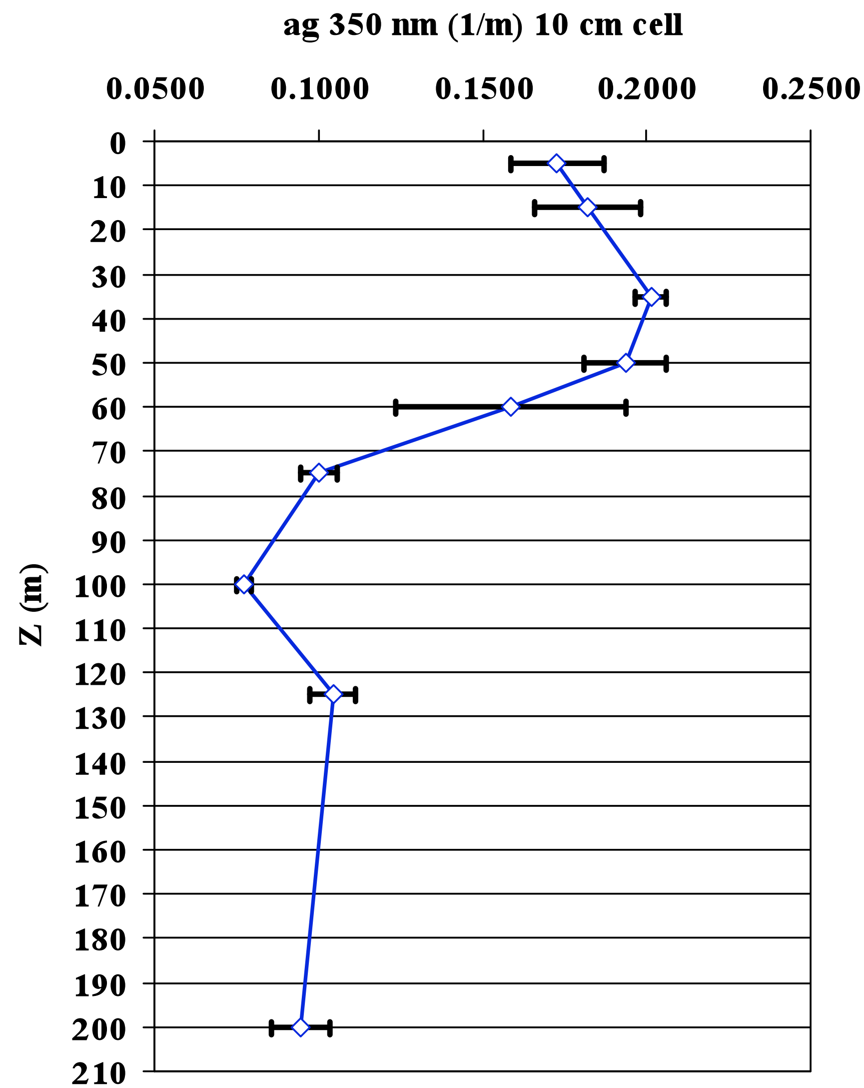

SOLAR
LIGHT CO
MICROTOPS II
On/Off
Sun Target
N00173731289000

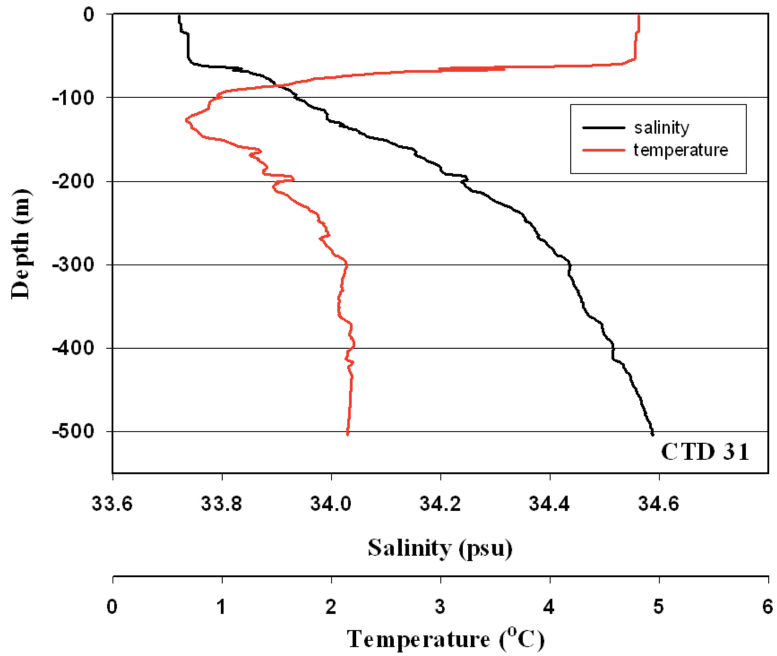


- **51 CTD hydrocasts**
- **R_{rs}**
- **CDOM**
- **aph, ap,**
- **DOC and TOC**
- **POC**
- **PIC (4-5 /day)**
- **Coccolith cell counts**
- **BiSi**
- **Fluorometric and HPLC Chl, and size fractioned Chl.**
- **PP**
- **TSM**

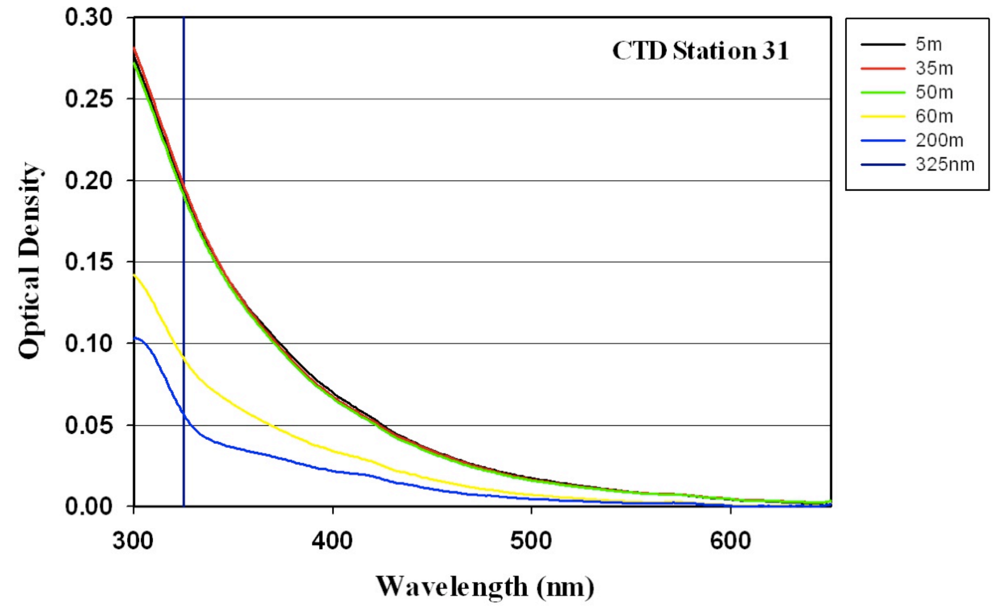
Some Preliminary Results



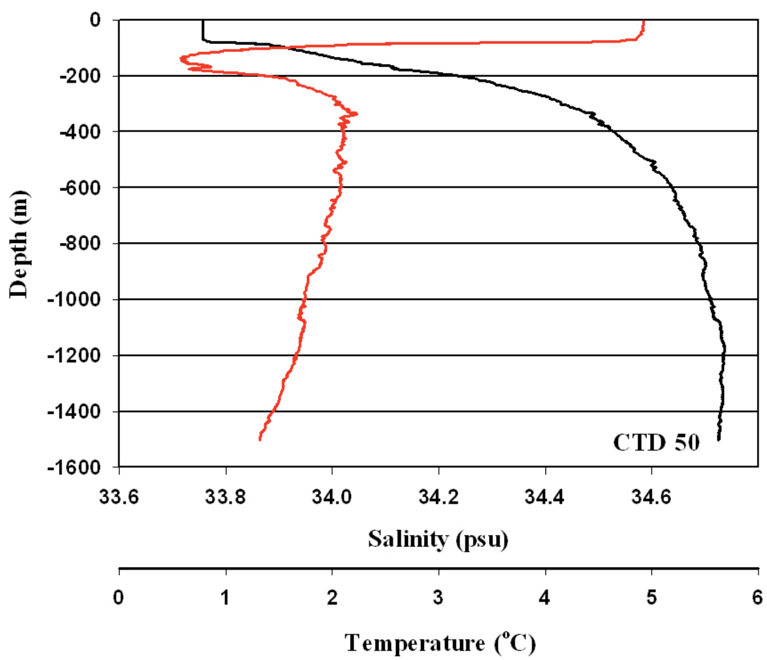




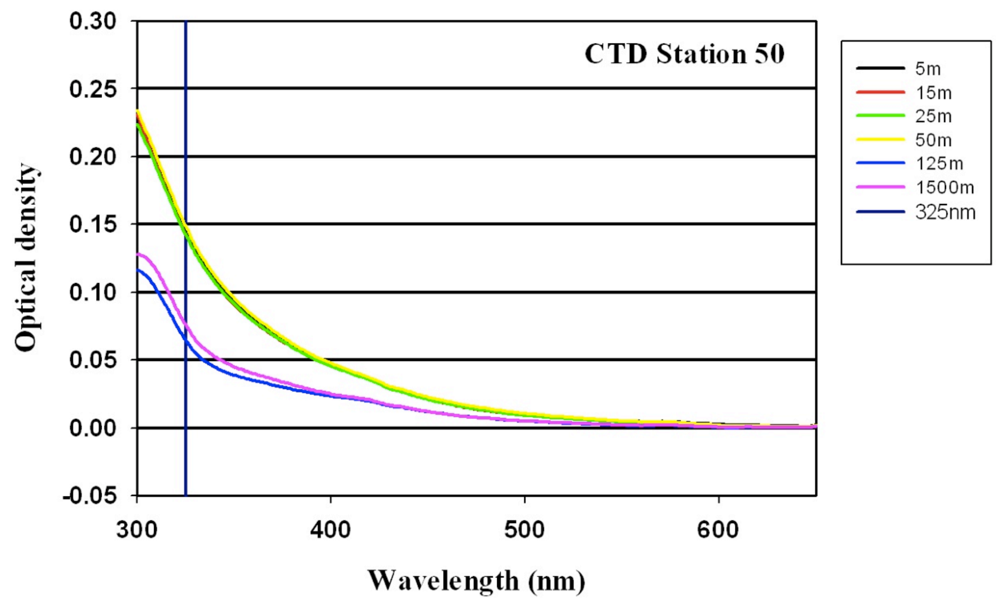
0
-100
-200
-300
-400
-500
Depth (m)
salinity
temperature
CTD 31
33.6
33.8
34.0
34.2
34.4
34.6
Salinity (psu)
0
1
2
3
4
5
6
Temperature (°C)



0.30
0.25
0.20
0.15
0.10
0.05
0.00
Optical Density
CTD Station 31
5m
35m
50m
60m
200m
325nm
300
400
500
600
Wavelength (nm)



0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
Depth (m)
CTD 50
33.6
33.8
34.0
34.2
34.4
34.6
Salinity (psu)
0
1
2
3
4
5
6
Temperature (°C)

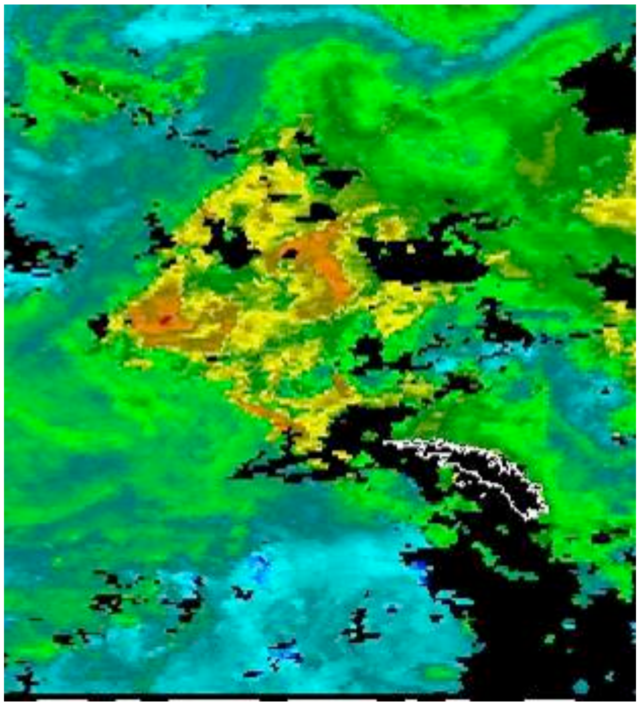


0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
Optical density
CTD Station 50
5m
15m
25m
50m
125m
1500m
325nm
300
400
500
600
Wavelength (nm)

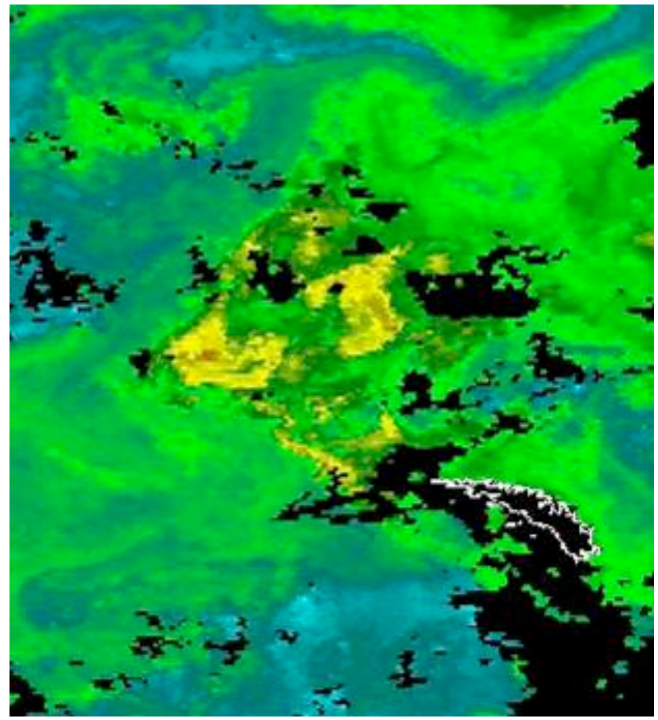
What causes high backscattering in Southern Ocean?

- Particulate Inorganic Carbon (PIC)
  - Highly backscattering phytoplankton Coccolithophores
- Enhanced bubbles due to breaking waves
- Incorrect Atmospheric Correction
  - Whitecap and glint correction
- Combination of the above

Enhanced Radiance consistent with chlorophyll patches

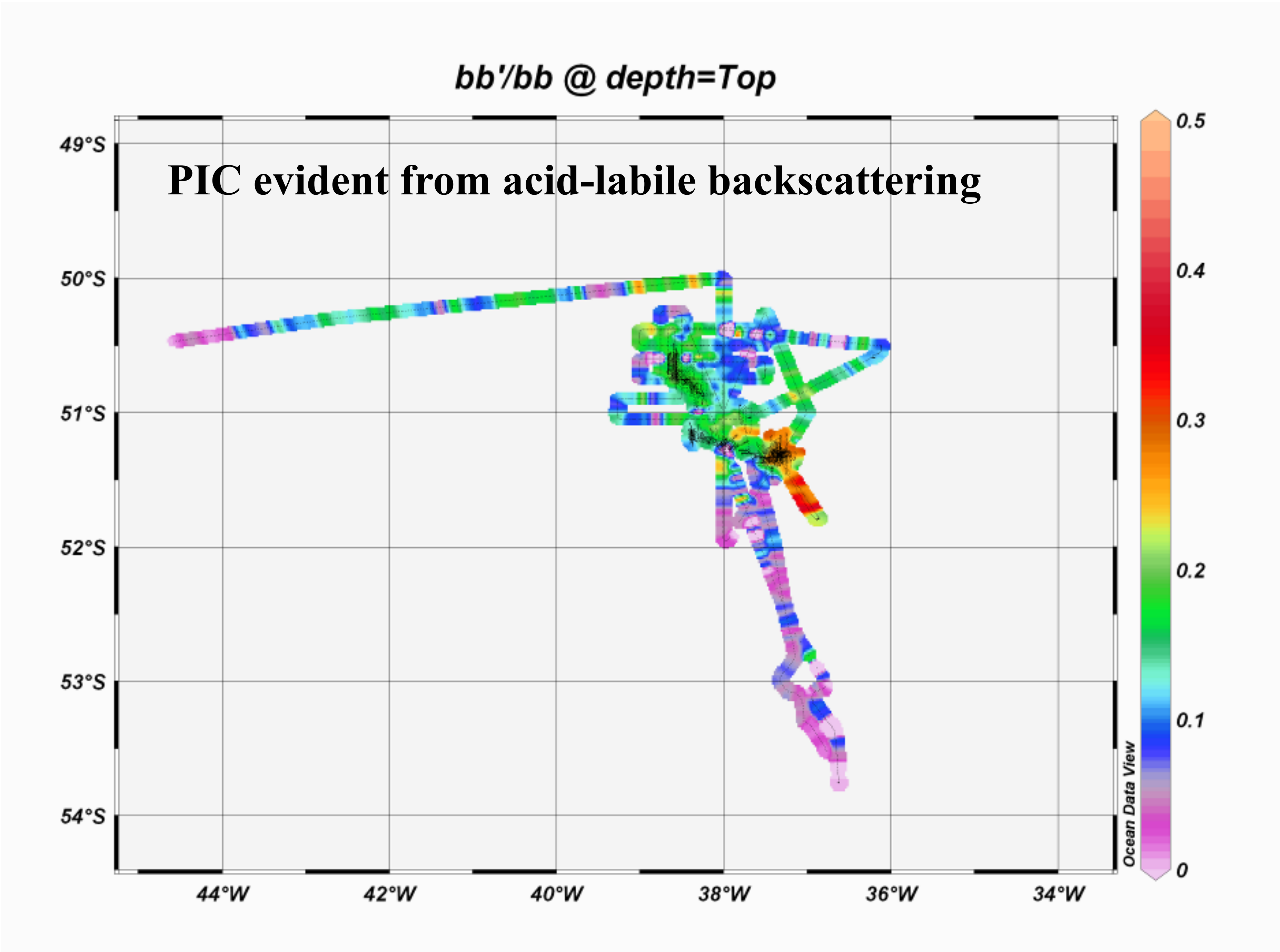


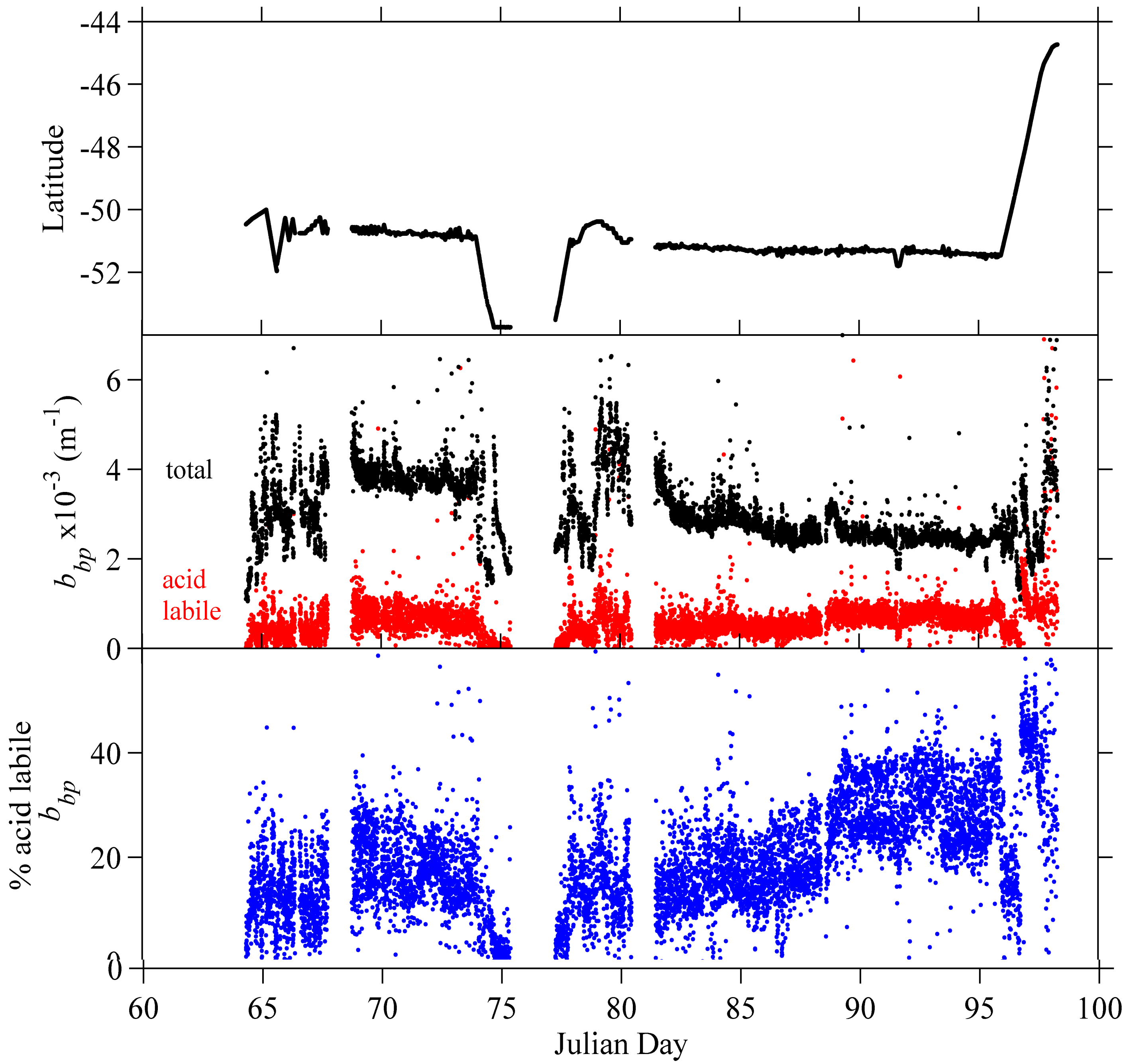
Chlorophyll (mg m^{-3})



Normalized Radiance

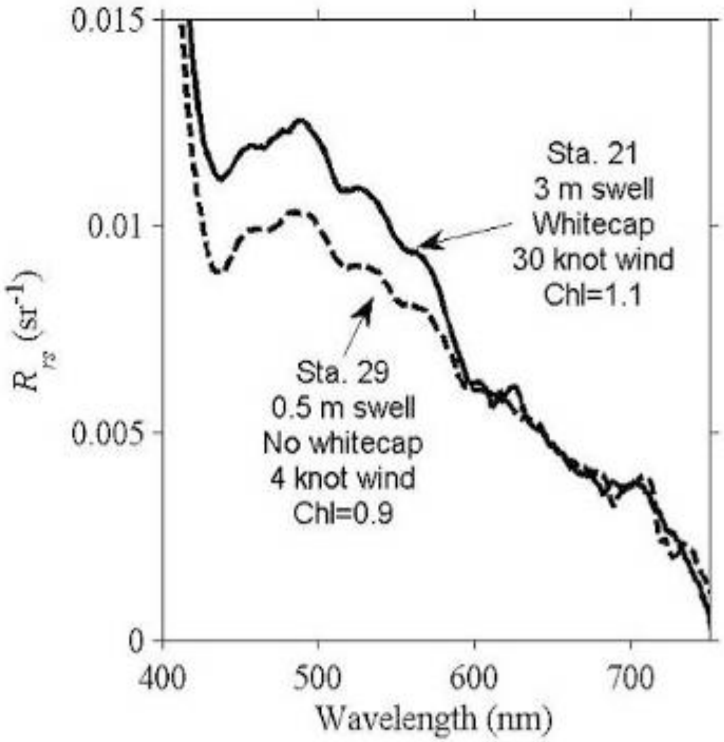
Lw551 (mW cm^{-2} mm^{-1} sr^{-1})

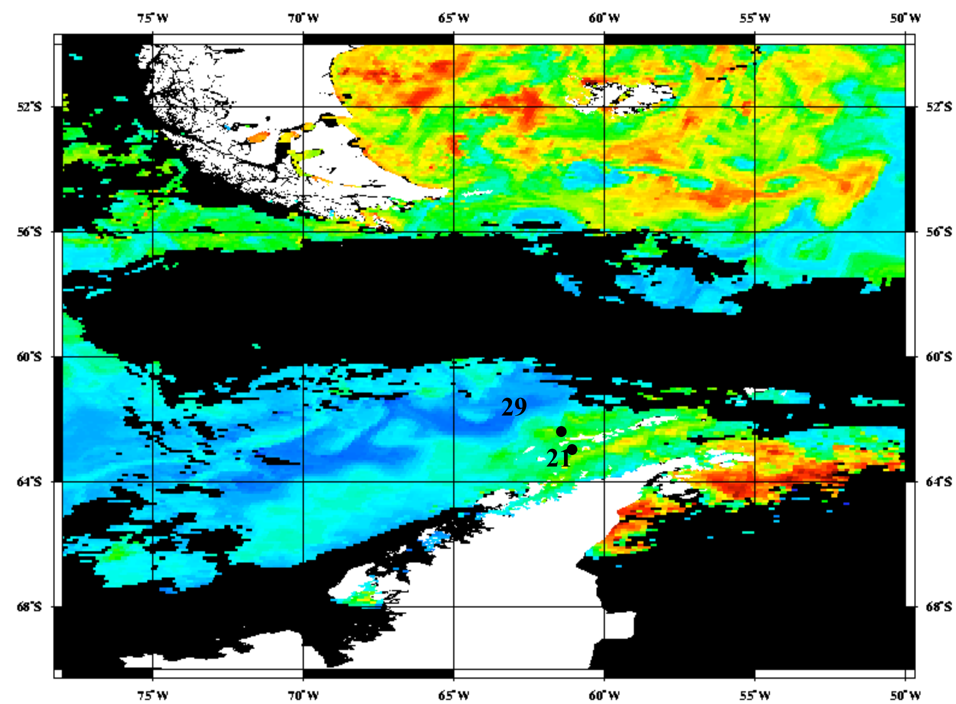

bb'/bb @ depth=Top
PIC evident from acid-labile backscattering
49°S
50°S
51°S
52°S
53°S
54°S
44°W
42°W
40°W
38°W
36°W
34°W
0.5
0.4
0.3
0.2
0.1
0
Ocean Data View



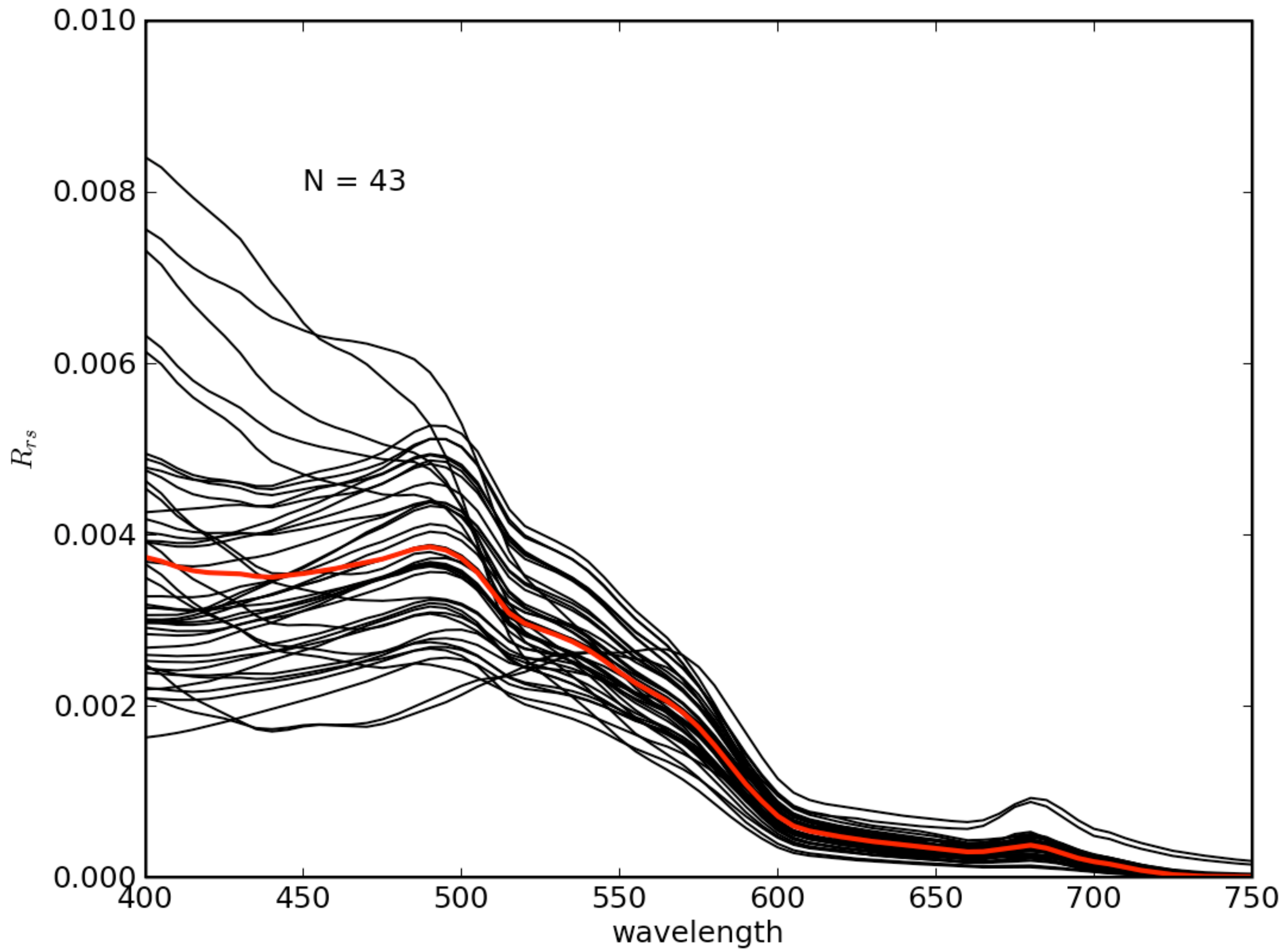
-44
-46
-48
-50
-52
Latitude
6
4
2
0
b_{bp} x10^{-3} (m^{-1})
total
acid
labile
40
20
0
% acid labile b_{bp}
60
65
70
75
80
85
90
95
100
Julian Day

High winds may cause elevated reflectance

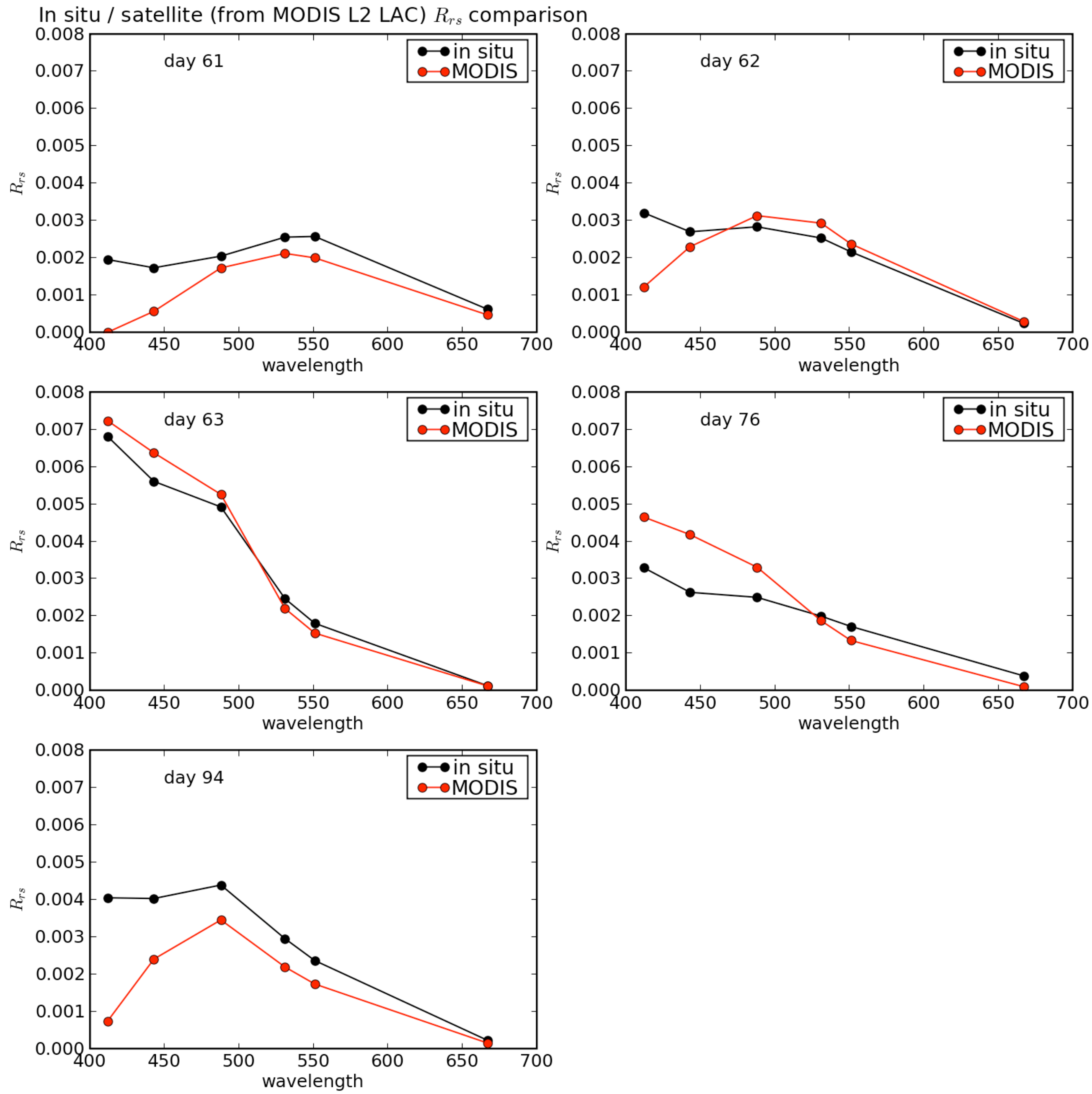




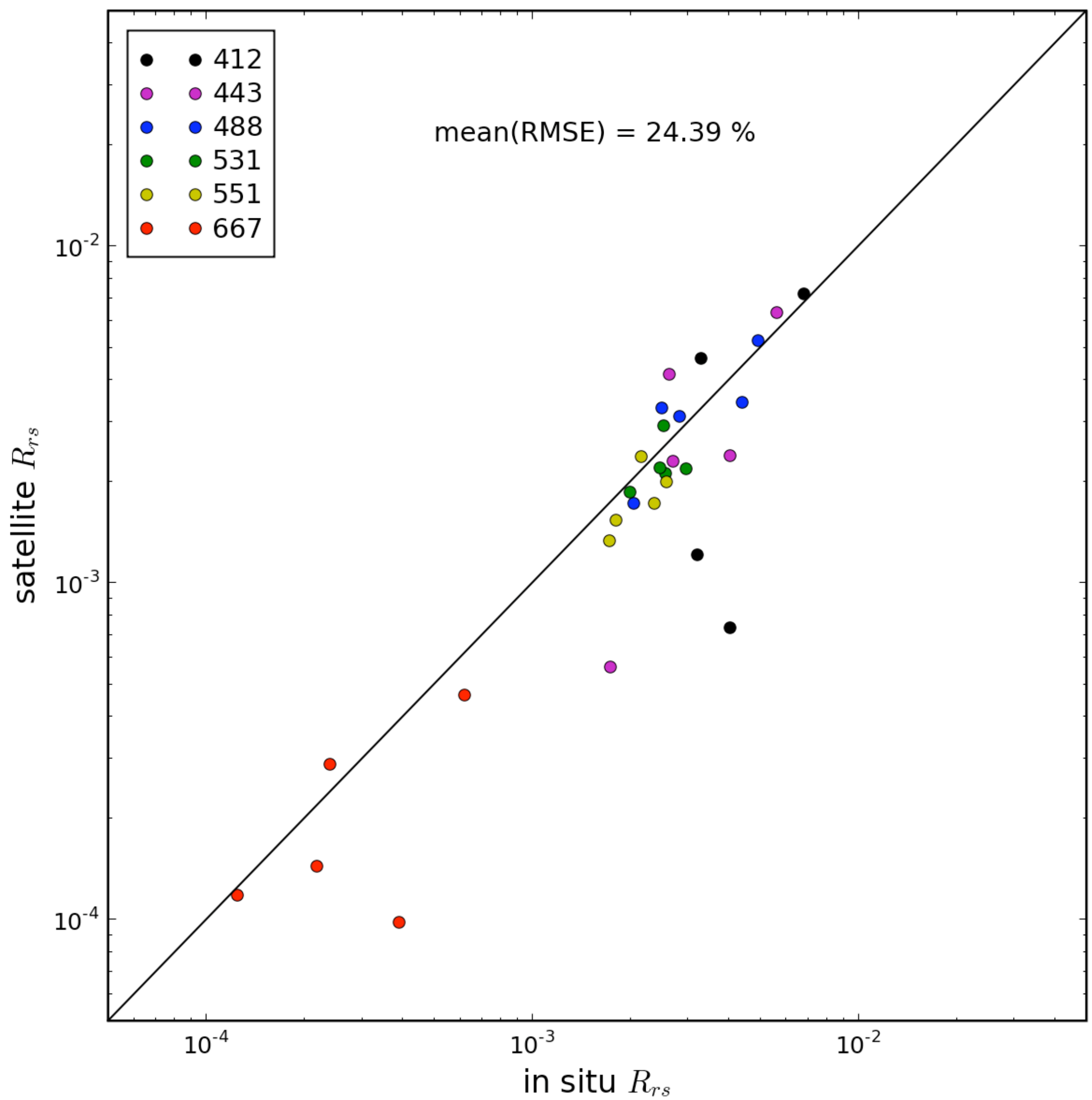
Results of in situ measurements



In situ Rrs vs MODIS Rrs

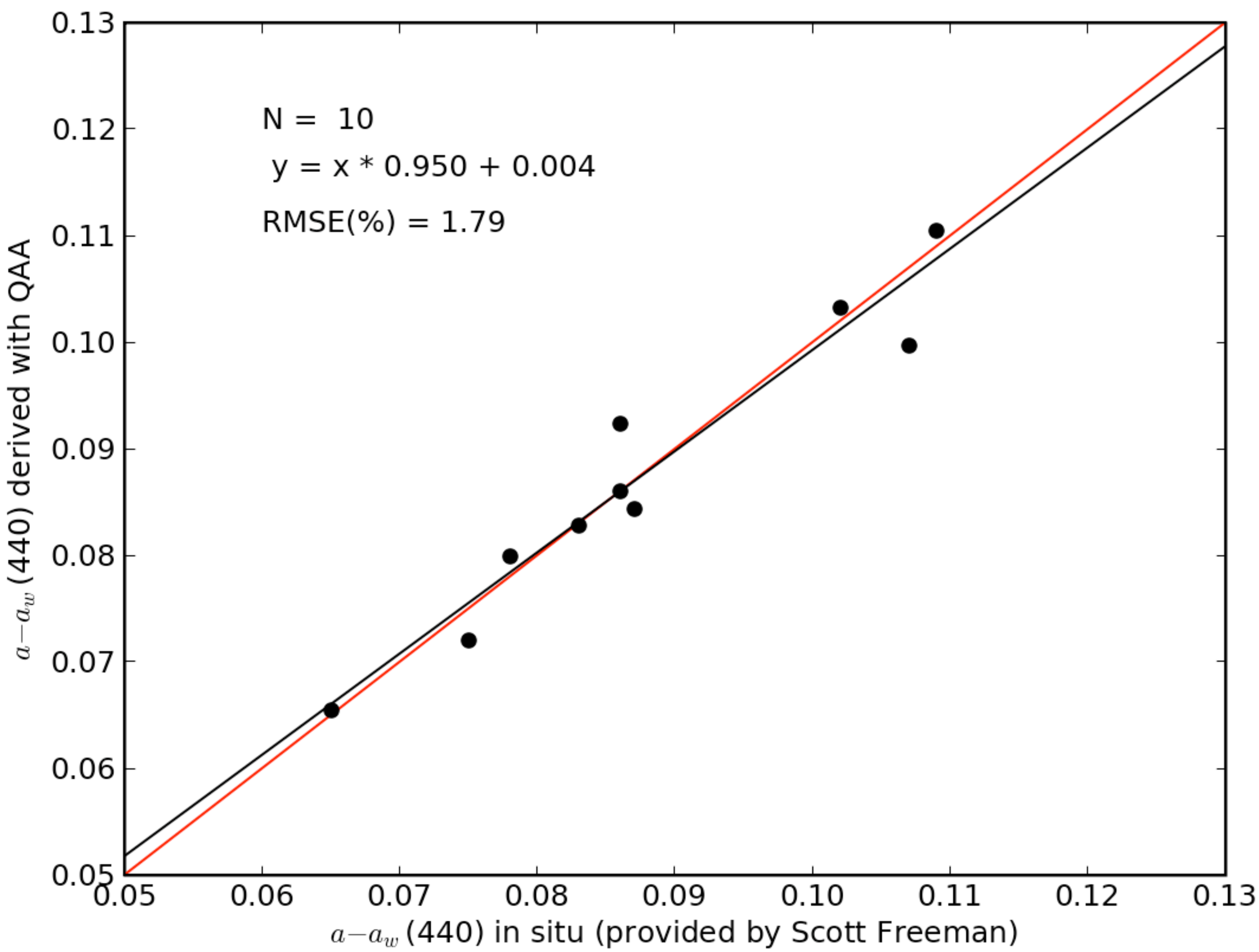


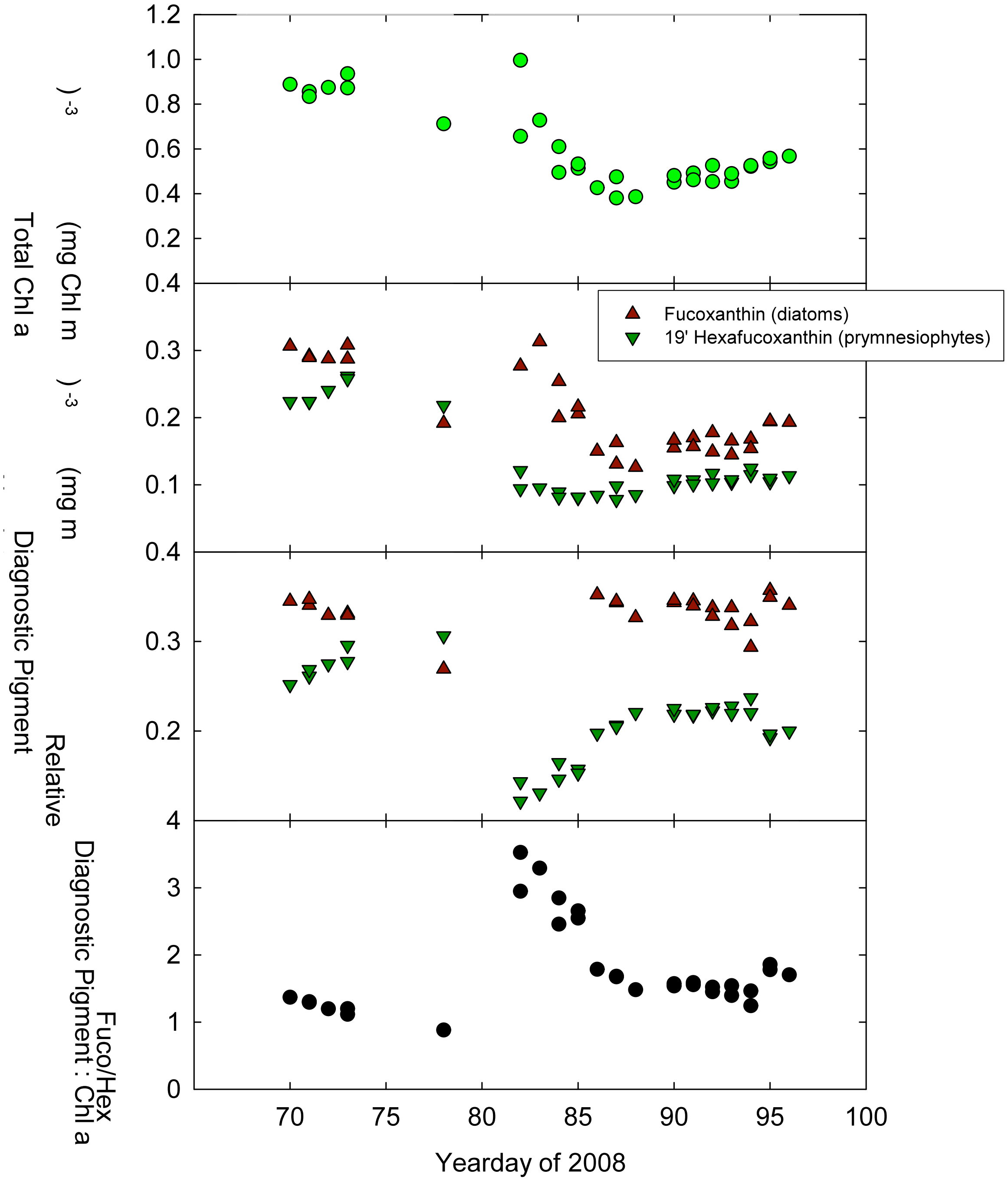
In situ Rrs vs MODIS Rrs



Rrs inverted IOPs compared with in situ measurements

1. Total absorption coefficient

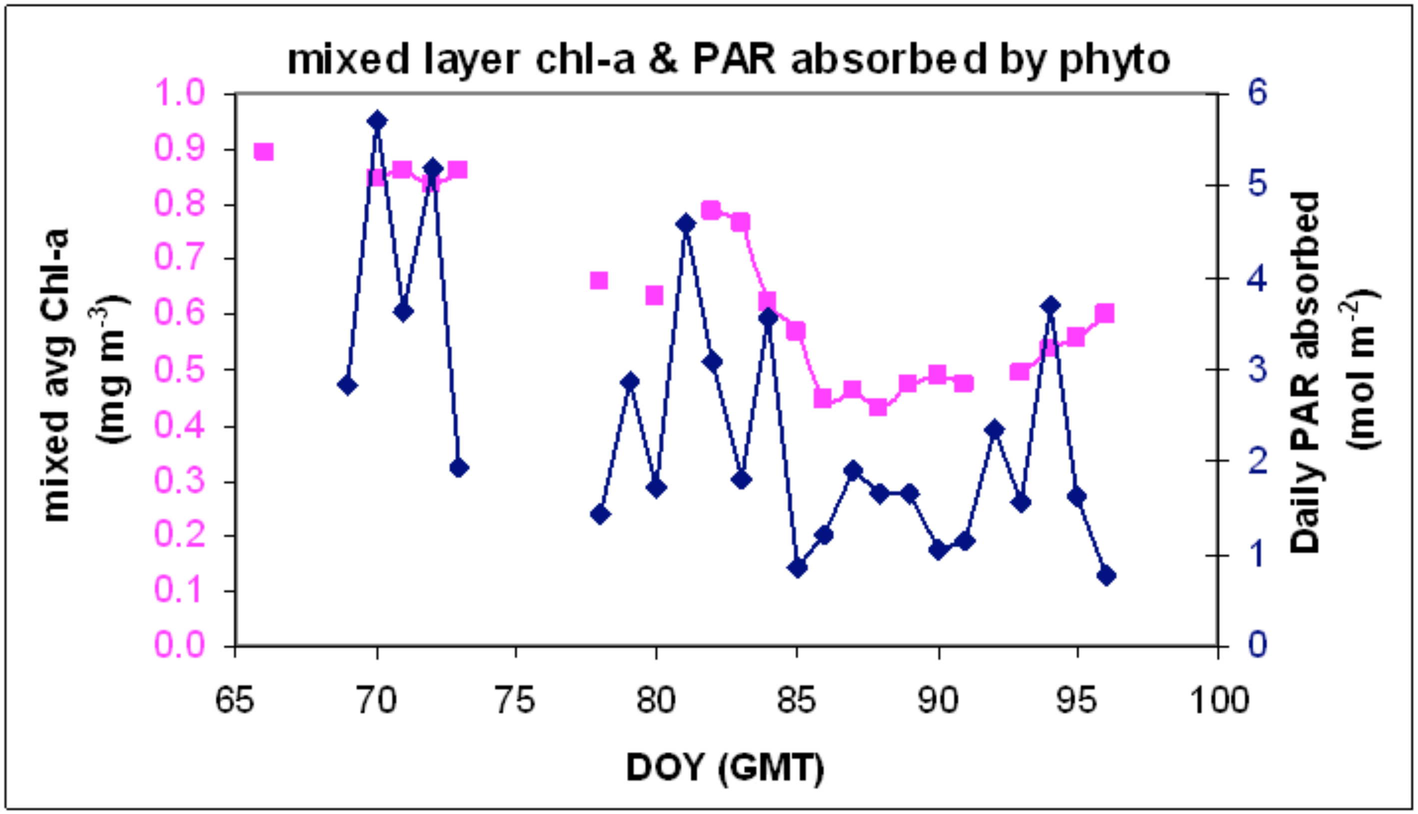




Total Chl a (mg Chl m^{-3})
Diagnostic Pigment (mg m^{-3})
Relative Diagnostic Pigment
Fuco/Hex Diagnostic Pigment : Chl a
Fucoxanthin (diatoms)
19' Hexafucoxanthin (prymnesiophytes)
Yearday of 2008
1.2
1.0
0.8
0.6
0.4
0.2
0.3
0.1
4
3
2
1
0
70
75
80
85
90
95
100

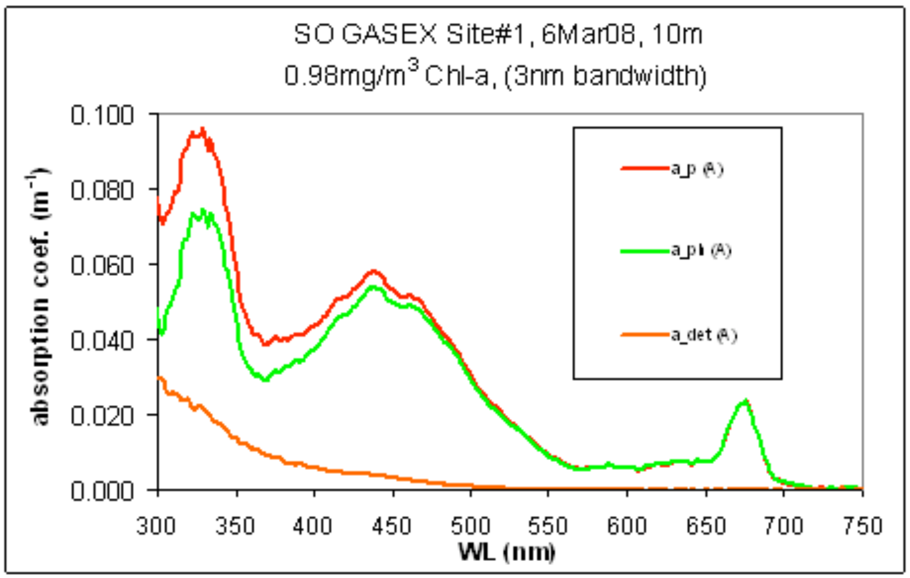
Daily PAR absorbed by phytoplankton pigments in mixed layer (AGU 12/08)

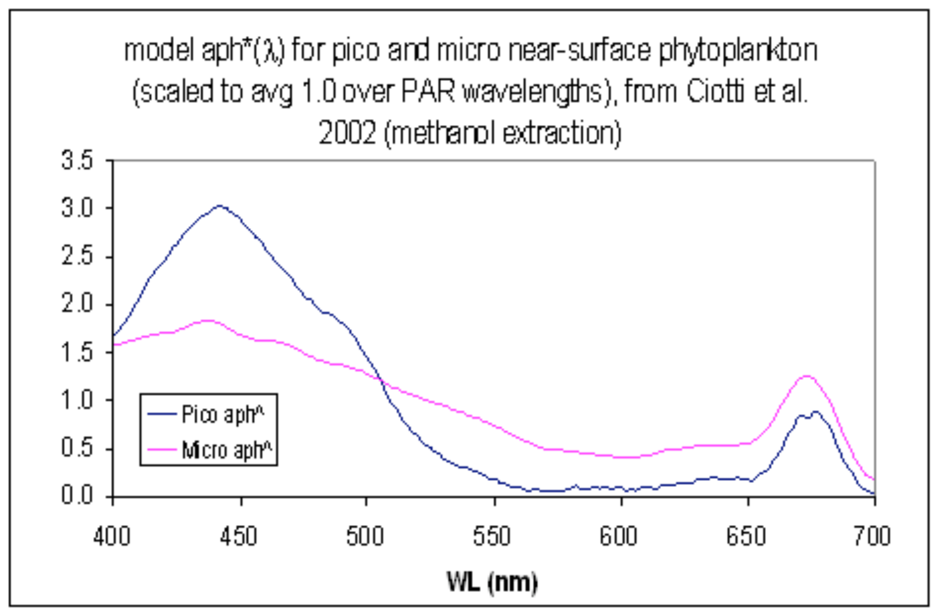
- **Underwater spectral PAR from**
  - **Measured Incident PAR**
  - **Kd from IOPS (30 ac9 profiles, filterpad ap spectra, ultrapath CDOM)**
- **a_{ph} measured via filterpad method on ship (>300 samples)**



Daily average phytoplankton cell size (likely to influence rates & efficiency)

- **a_{ph} measured (>300 samples on SOGASEX)**
- **Size estimated from phytoplankton pigment spectrum (after Ciotti et al., 2002); interpolate pico⇔micro**

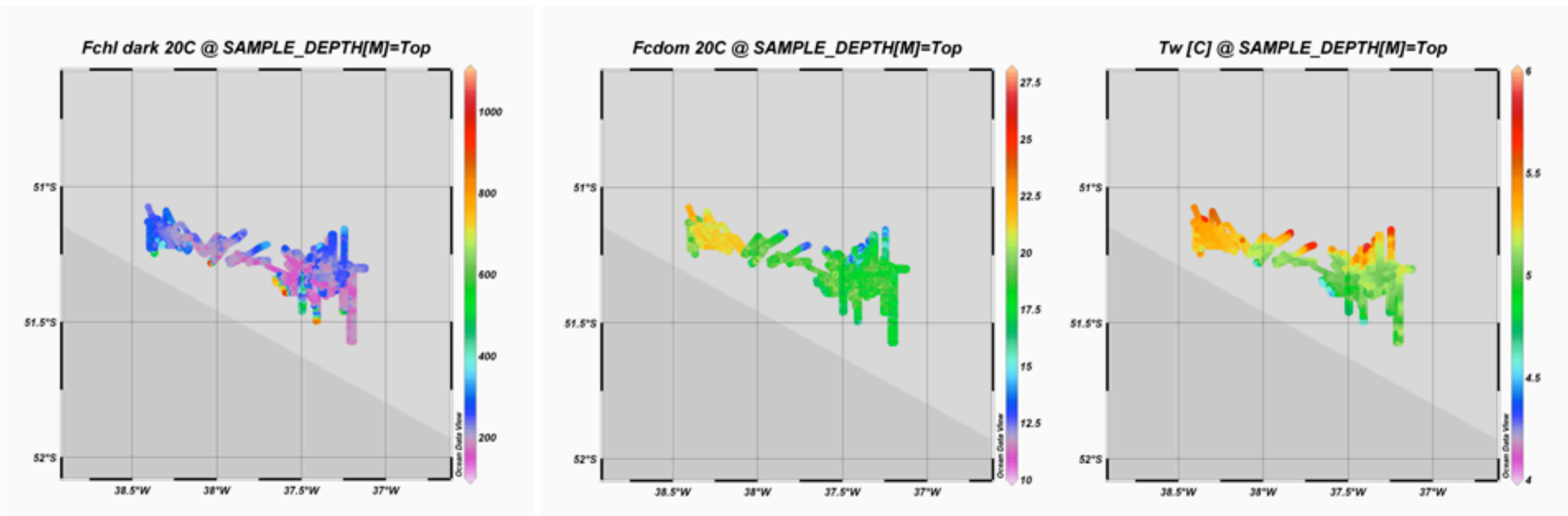




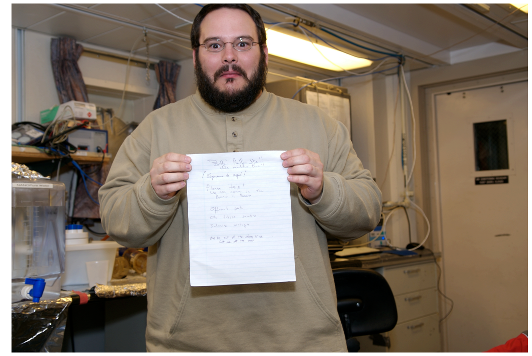
Spatial & temporal patterns of Chl-a and CDOM via refined fluorescence (see Hargreaves' poster; Turner Designs Cyclops7 sensors and C6 instrument)

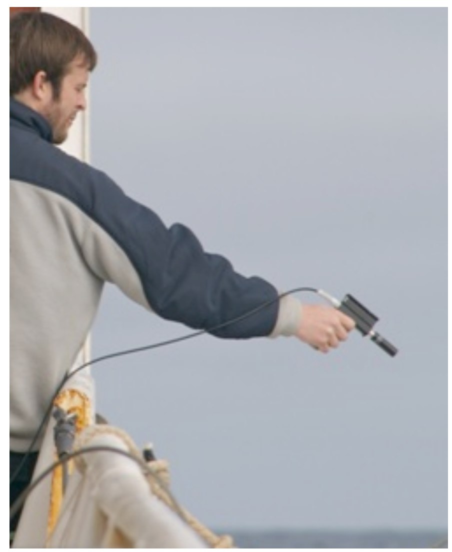
- **Continuous underway data plus fluorescence depth profiles 30Mar-5Apr08**
- **Correction for turbidity errors in pigment channels**
- **Correction for CDOM errors in pigment channels**
- **Incident PAR correction for non-photochemical quenching of phytoplankton**

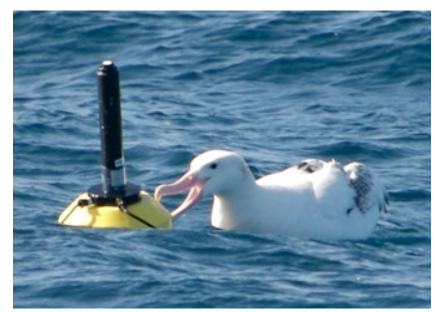
EXAMPLE: 21-30 MARCH 2008 (PATCH 2 started 20March, at left; Fchl adjusted to dark equivalent using incident PAR relationships)



A few problems:







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Dispatches from the Southern Ocean Gas Exchange Experiment

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April 2008

M T W T F S S

« Last Cast (Cor)relation for Air-Sea fluxes »

Tiny Bubbles

Posted by sogasex on April 7, 2008

By Carlos Del Castillo, The Johns Hopkins University-APL

The loud popping sound was immediately followed by pressurized 4°C seawater being sprayed all over the room. We are working inside the wet lab on board the NOAA Ship Ronald H. Brown (see **Richard's blog entry**) and one of the clean seawater lines that feeds our instruments just burst. A high-pressure water line does not just burst and calmly spills water. The line swings left and right, up and down, squirting water on everything and everyone. But no worries, we are in the wet lab. It is supposed to be wet. Before the indoor shower, we had settled into an easy, boring routine for our long transit to the proposed research site, so the burst line was almost a welcomed distraction. Almost welcomed because a busted line means some data will be lost, and the inevitable invasion of air bubbles into our system. We do not like bubbles in the wet lab. Air bubbles dramatically change the optical properties of water and create a lot of noise in our data. Bubbles must be dealt with. Bubbles are the enemy. We battle bubbles along three fronts. The water that flows through our optical instruments enters the boat through an intake that is several meters below the sea surface. There are not many bubbles at this depth unless the weather is bad. Weather is almost always bad in the Southern Ocean. The second line of defense is a "debubbler." This plastic contraption uses a vortex to trap bubbles and send them back to the ocean – where they belong- while tunneling bubble-free water to our instruments. Bubble-free water is good. In our quest for bubble free water we keep all the lines that feed the instruments submerged in a water bath as our third line of defense. By doing this, we keep the water inside the lines very cold to avoid degassing- or the formation of un-welcomed bubbles that will eventually migrate to our instruments. In this case, the water bath is a large sink where we also keep the instruments to avoid temperature fluctuations. The water in the bath is the same 4°C seawater that flows through the instruments.

In this expedition we encountered our first un-welcomed bubbles in bottled water. As in most countries, bottle water in Chile can be found in two varieties, sparkling water and regular water, or "agua con gas y agua sin gas." Sparkling water seems to be the most popular and the default offering unless otherwise specified. So, if one does not add the "sin gas" modifiers, one may get bubbles. Agua con gas is not all that

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