OC3570 Operation Oceanography Paper
LT Erica A Museler
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Comparison of In-Situ and Remotely Sensed Ocean Optical Properties.

Introduction

During the Operational Oceanography cruise a preliminary experiment to compare the in-situ to satellite measured horizontal visibility was conducted on July 15th, 18th, and 28th. Dive number 3 was a hull dive and not used to record optical data. Dive 4 and 5 were the last two recorded dives of the experiment, hence the numbering system of Dive 1, 2, 4, and 5 as written in this paper. Using the RV Pt Sur's CTD information, diver observation and composite satellite retrieved radiation values for the month of August, a simple comparison of the underwater horizontal visibility was established. Four dives were conducted within a two-week time frame located nearshore at Moss Landing, Port San Luis and Santa Barbara. The preliminary results were recorded and are compared in this documentation.

Equipment

The device used on the Pt Sur's CTD is a 25 cm transmissometer. Transmission of a collimated 670 nm wavelength of light is measured using a Light Emitting

Diode (LED) and a synchronous detector. The data is output from voltage is in values ranging from 0 to 100% which is conversely related to a beam attenuation coefficient ‘c’. In general the transmissometer measures the particulate concentration in the water column, but this experiment was to relate the beam attenuation with what a diver sees under water as his or her visibility.

Diver measurements were conducted within the first 10 meters of the water column, ~ 10,20 and 30 feet. Two divers descended to ~30 feet, one diver held a 12 inch secchi disk marked with a black ‘X’ for contrast and the other diver swam away until the secchi disk was lost out of sight. The horizontal distance was recorded and then the divers ascended 10 feet to repeat the same process. Because the satellite data is only comparable to 10 meters, which was the depth chosen to record diver measurements.

The satellite used for value comparisons is the Sea Viewing Wide Field of View Sensor (SeaWiFS) on the OrbView 2 Satellite. SeaWiFS is an ocean color observing satellite with 8 channels to observe high-resolution reflectance characteristics of seawater. (Specifically in this experiment channels 3-5 were used to observe the green/blue spectrum of the ocean, which is the wavelength at which the human eye sees objects underwater.) Approximately 90% of the world's oceans are observed with SeaWiFS each day. A brief cartoon in figure 1 clearly displays what the satellite measures from the ocean. The irradiance values calculated are for K only, a and b were not observed in this experiment. Clouds sevearly limit daily composites of the California Coastal region in the summer due to the persistent low-level stratus. The week of July 8th and July 29th were clear sky days, unfortunately not during the diving operations on the cruise. The first assumptions in this paper is that the optical properties on or about the time of the diving and CTD measurements were nearly the same as a composite image of July/Aug for the Satellite images or approximately equal to a clear day image 4 to 5 days earlier. The measurement from SeaWiFS is then process and the outputs are diffuse attenuation (K) at the 490 & 532 nm wavelengths, absorption (a) and backscatter (b). The significance of K, a and b will be discussed in the following paragraphs.

Environment

The meteorological conditions for the days of the four dives were overcast, low winds (~<4 knots) and low waves. The overcast weather hinders both the satellite retrievals of radiances and also limits the true visual measurement of the divers. With that being stated, there is one possible cause in the disparity between the satellite's observed measurements with the in-water diver measurements.

The oceanographic conditions off the coast of California are near perfect for optical measurements with its relatively clear waters. Measurements of chlorophyll concentration and K at the 532 and 490 wavelengths from the satellite, transmissometer measurements and diver visibilities are all very distinct with variability in cloud coverage for the satellite, and transmissometer instrument inconsistencies being the only limitations on results due to oceanographic climatology.

Data Results and comparison

Transmissometer results are displayed in figures 2 through 6. The tables associated with figures 2 through 5 are transmissometer percentage measurements converted to c via the logarithmic relationship:

$$c = -\ln(\%\text{Transmission})/[z] \quad (1)$$

Equation 1 represents the fact that light approximately attenuates in water exponentially with depth. The variable c is also an inherent optical property of water and is routinely measured with a 670 nm wavelength to determine the percentage of suspended particulate matter over a distance z. Beam attenuation is highly dependent on the scattering and absorption of particles, which is difficult to model optically because of large deviations from particulate matter concentration to optical parameters of natural waters.

The tables also have a column that represents the relationship of the horizontal visibility measurement:

$$R \sim 4.0/[c] \quad (2)$$

It is well known in optical oceanography that light, as seen underwater, is seen at 4 to 5 times the distance $1/(c-K\cos\theta)$. Where θ is the viewing angle with respect to zenith, and because in this experiment the view is horizontal the term is dropped leaving equation 2 above.

Using the transmissometer and diver observations and with the exception of Dive 5, there is a distinct increase in visibility at the 9.14 m depth. Dive 5 shows the opposite with a decrease in visibility with depth. This is indicative of a surface phytoplankton layer in dives 1, 2 and 4 and a mid phytoplankton layer in dive 5. Figure 6 illustrates this nicely with contour plots produced. Figure 6a and 6b are for dives 1, 2 and 4, while figure 6c represents dive 5 and its mid phytoplankton layer.

Limited satellite data retrieval was possible due to clouds resulting in only two images used for study. An

August composite image for the NRL derived SeaWiFS K532 product at the Santa Barbara Bight (Dive 5) and a daily composite of a clear day (July 23rd) NPS terrascan K490 product located near Monterey Bay (Dive 1) [Figure 7a and 7b respectively] were chosen because of the best clarity of the images. Both images can be interpreted as the rate at which light at 532 or 490 nm can be attenuated with depth. Typically attenuation length is similar to that of the secchi depth and can be used to estimate the visibility throughout the water column. Note: since the comparison is for a diver's visibility, it is assumed that a diver can see only approximately one attenuation length (1/c) which on average is ~10 meters. For Dive 1 the K490 value was approximately 0.5 which corresponds to a range of ~3 meters, coinciding with the transmissometer measurement. The K532 measurement for Dive 5 yielded a parallel result with the value being ~0.1 and a range of ~10 meter, again matching the transmissometer value.

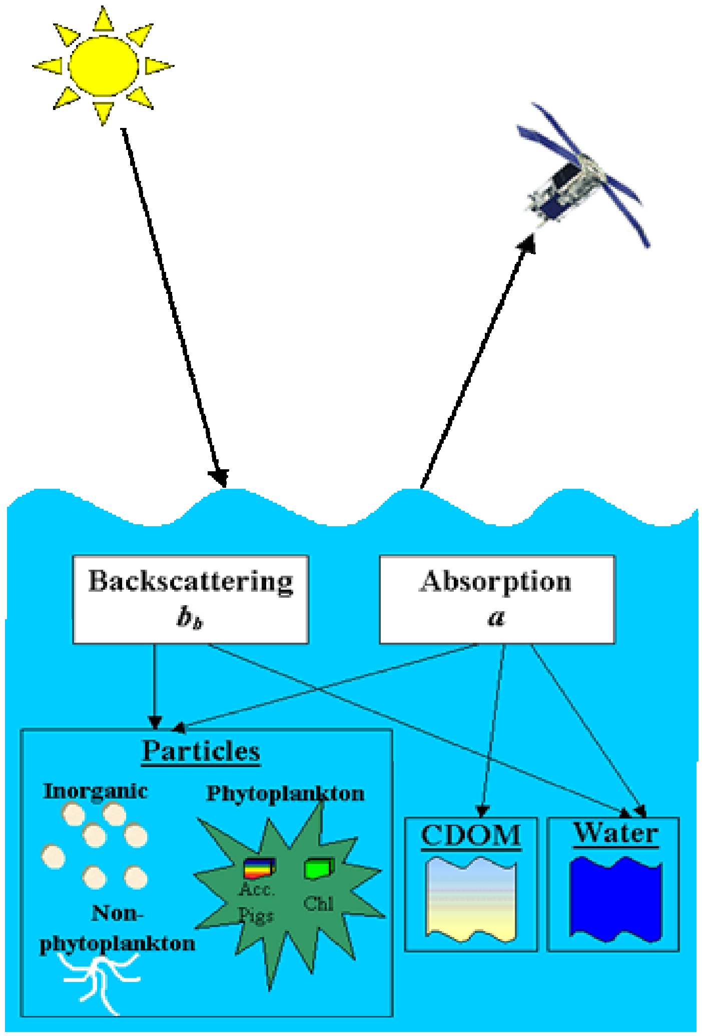
The diver visibility results are represented in figure 8. The transmissometer and SeaWiFS measurements underestimate the divers observations by 2 to 5 meters but follow a similar trend.

Conclusion and Further Investigation

Obviously in each measurement taken there must be a translation between wavelengths and the inherent verses apparent optical property used in the observations. The 670 nm collimated beam of light of the transmissometer is sufficient for determining the magnitude of particulate concentration in the water column but only gives a poor c value for an underestimated range in visibility. Having a transmissometer that uses a wavelength in the green/blue spectrum would be a better comparison with the diver and satellite measurements. The satellite derived K490 and K532 products give similar comparisons to that of the transmissometer, which underestimates the actual visibility of the diver.

In an operational view this is a less than satisfactory result but the ability to extract the water clarity/visibility anywhere in the world remains a driving force for reducing the error in measurements. The world wide accessibility of this product for the Navy’s operational use cannot be stressed enough. The impact on time and monetary assets in the planning phase of operations that deal with determining water clarity is invaluable. Future study in reducing the satellite derived error from the measured error will increase the credibility of this remotely sensed oceanographic parameter with the hope that horizontal visibility products will become a trusted ‘norm’ in the planning stages of military exercises and operations.

Figure (1)



Backscattering
b_b
Absorption
a
Particles
Inorganic
Phytoplankton
Acc. Pigs
Chl
Non-phytoplankton
CDOM
Water

Figure (2)

Dive 1

Dept	%	c	R
3.05	77.5	1.02	3.92
6.1	77.4	1.02	3.92
9.14			

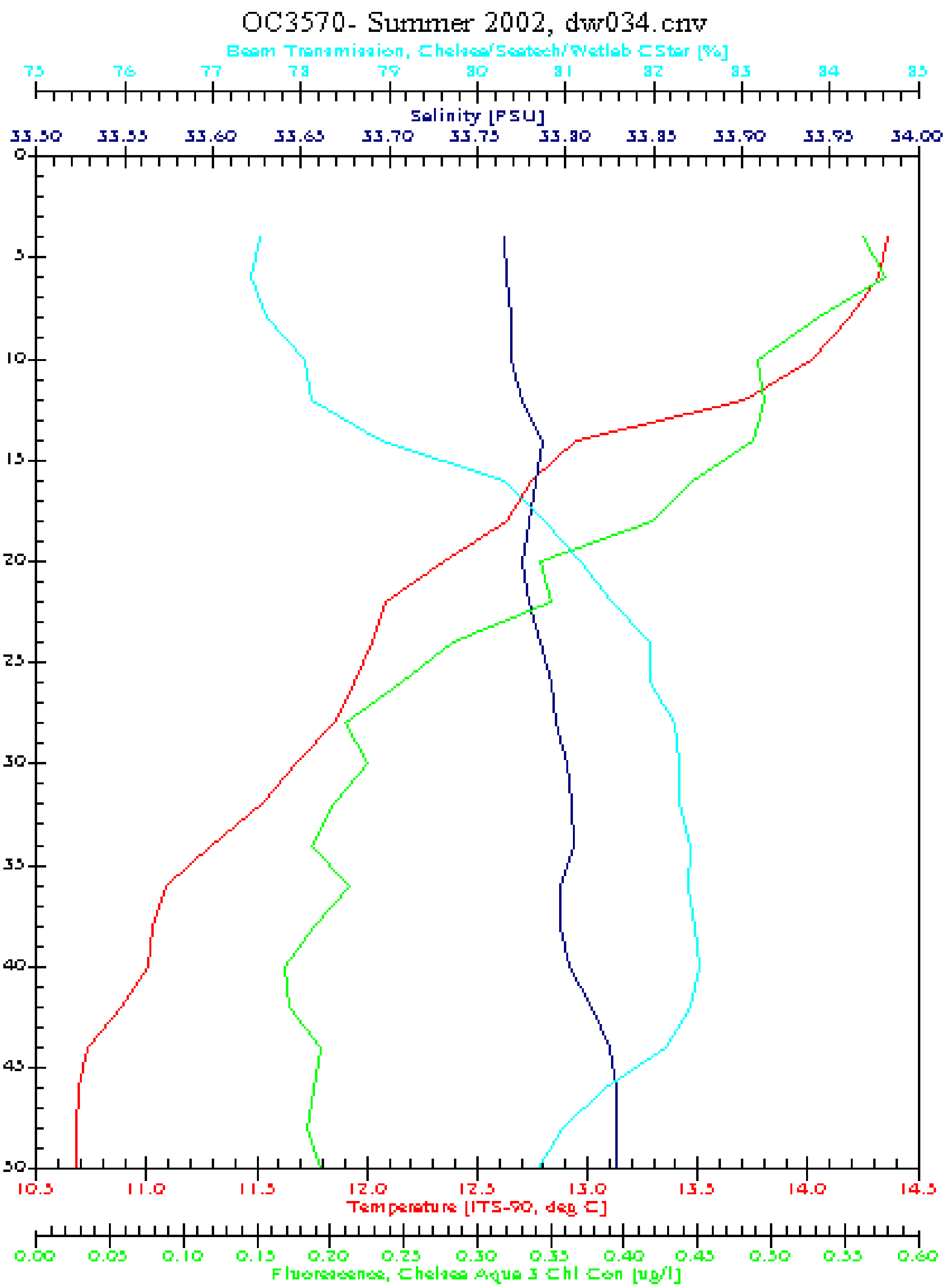


Figure (3)

Dive 2

Dept.	%	c	R
3.05	72.5	1.29	3.1
6.1	72.0	1.31	3.05
9.14	75.8	1.11	3.6

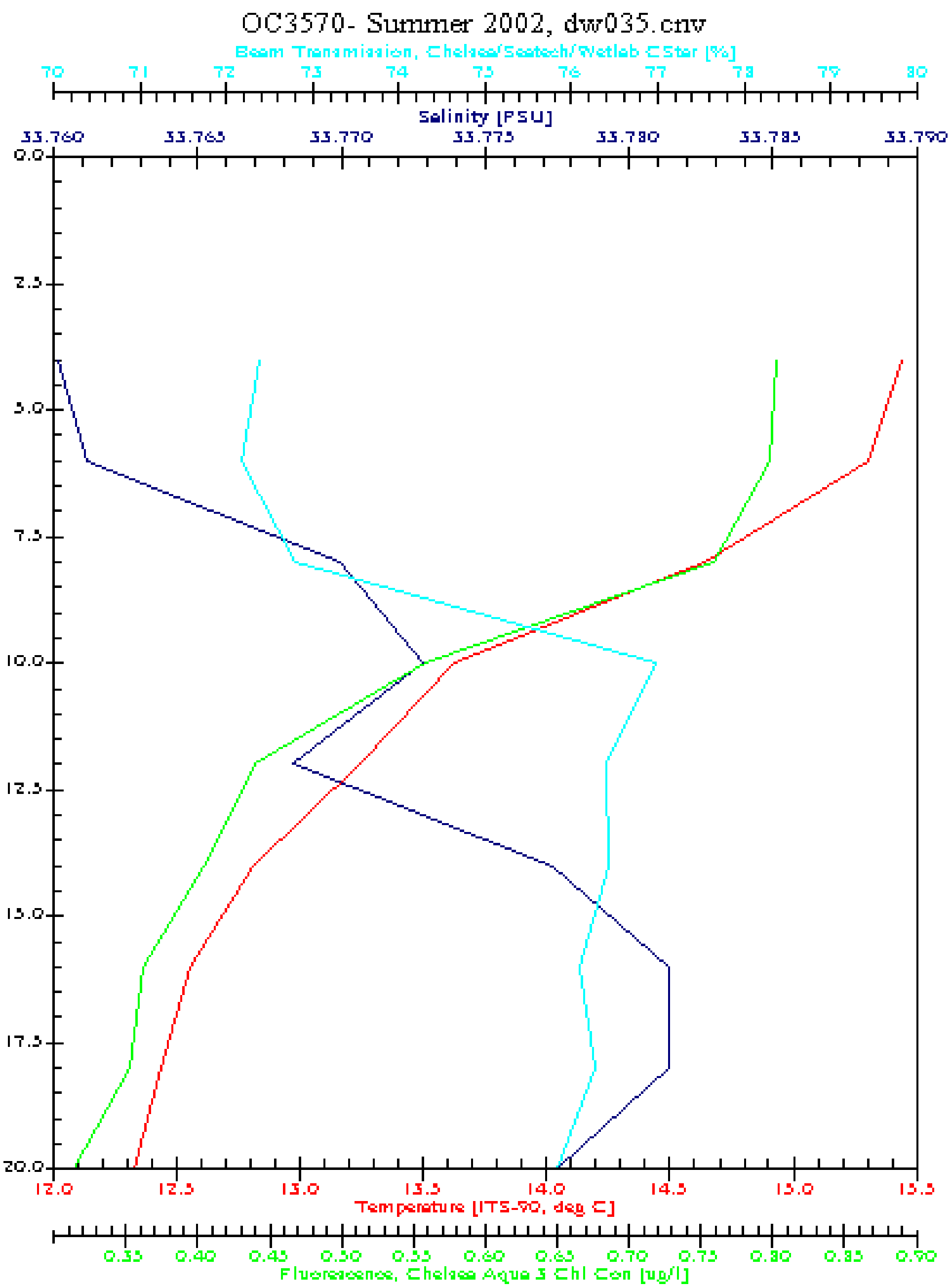


Figure (4)

Dive 4

Dept.	%	c	R
3.05	75.1	1.15	3.49
6.1	75.1	1.15	3.49
9.14	75.4	1.13	3.54

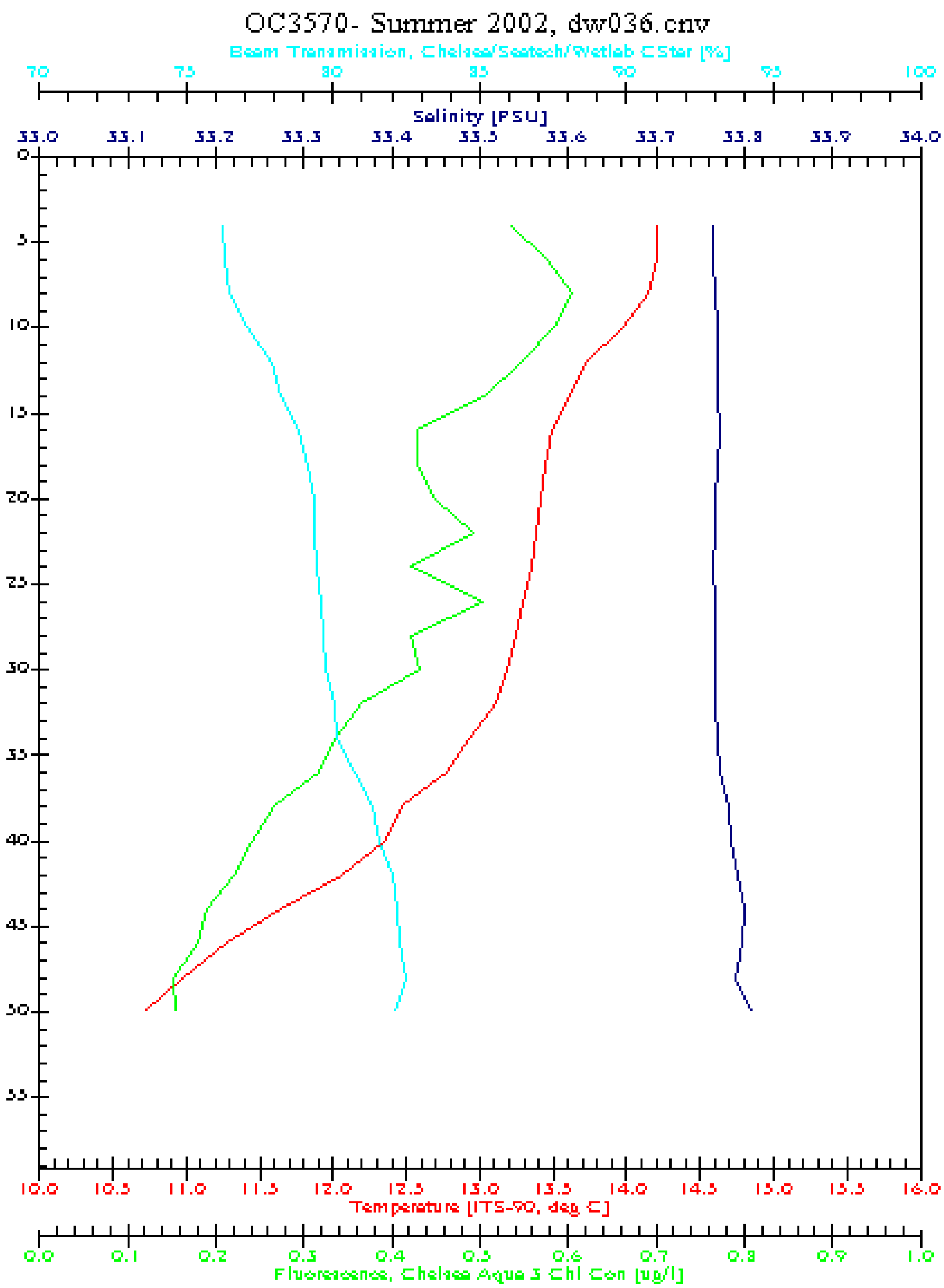


Figure (5)

Dive 5

Dept.	%	c	R
3.05	90.0	.42	9.5
6.1	91.0	.38	10.5
9.14	90.5	.40	10.0

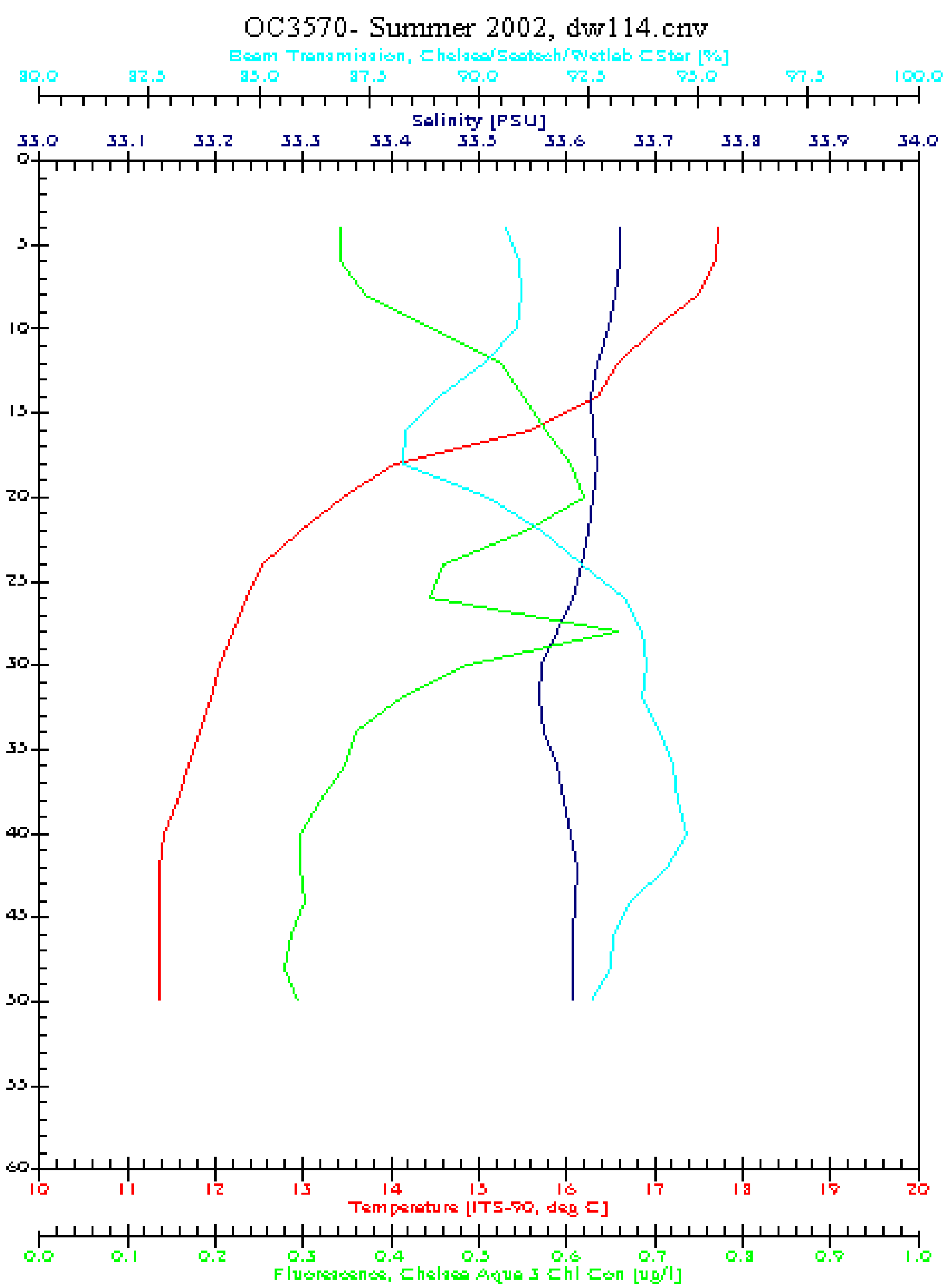


Figure (6)

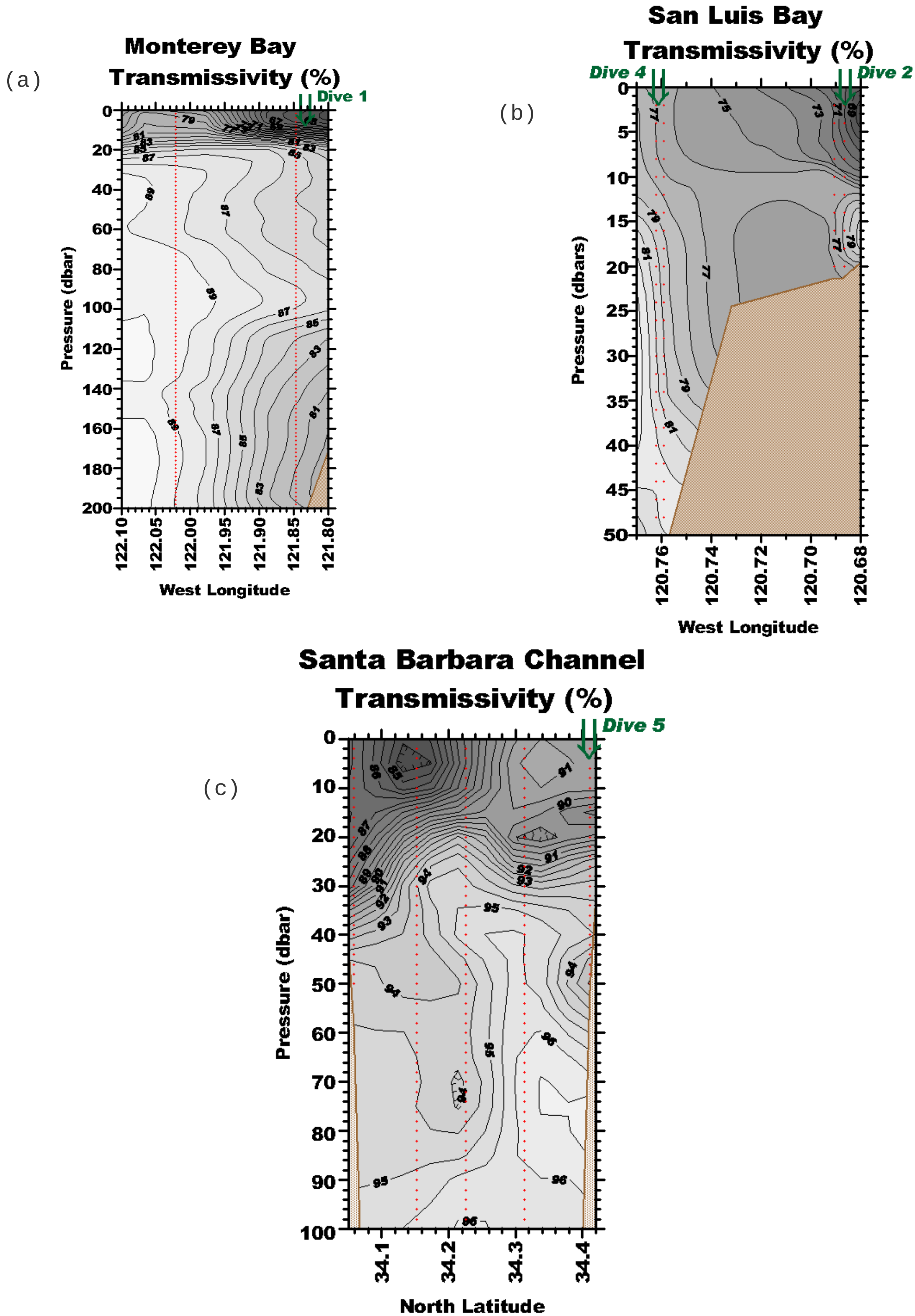

(a)
Monterey Bay
Transmissivity (%)
Dive 1
Pressure (dbar)
0
20
40
60
80
100
120
140
160
180
200
122.10
122.05
122.00
121.95
121.90
121.85
121.80
West Longitude
(b)
San Luis Bay
Transmissivity (%)
Dive 4
Dive 2
Pressure (dbars)
0
5
10
15
20
25
30
35
40
45
50
120.76
120.74
120.72
120.70
120.68
West Longitude
(c)
Santa Barbara Channel
Transmissivity (%)
Dive 5
Pressure (dbar)
0
10
20
30
40
50
60
70
80
90
100
34.1
34.2
34.3
34.4
North Latitude

Figure (7a)

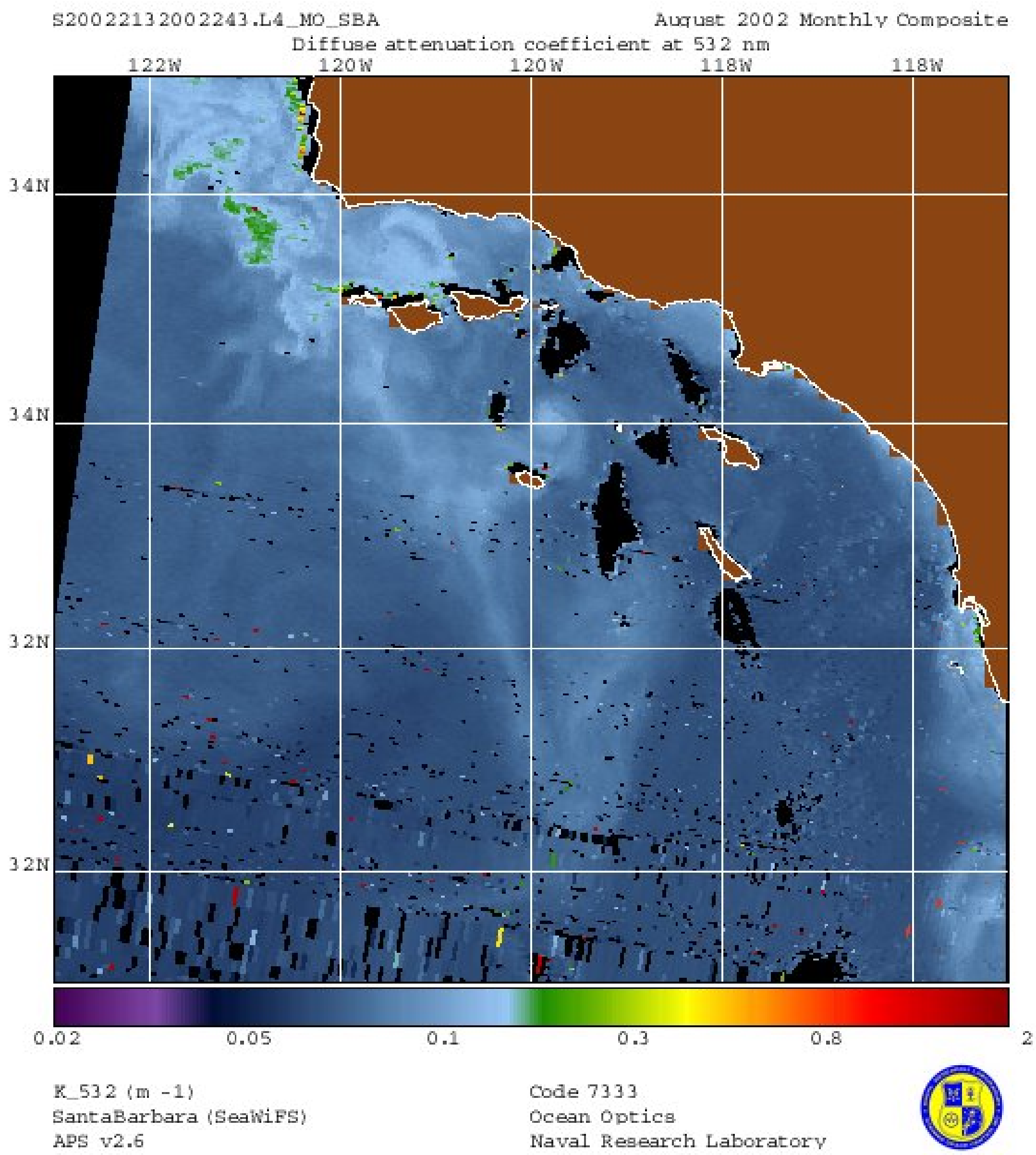
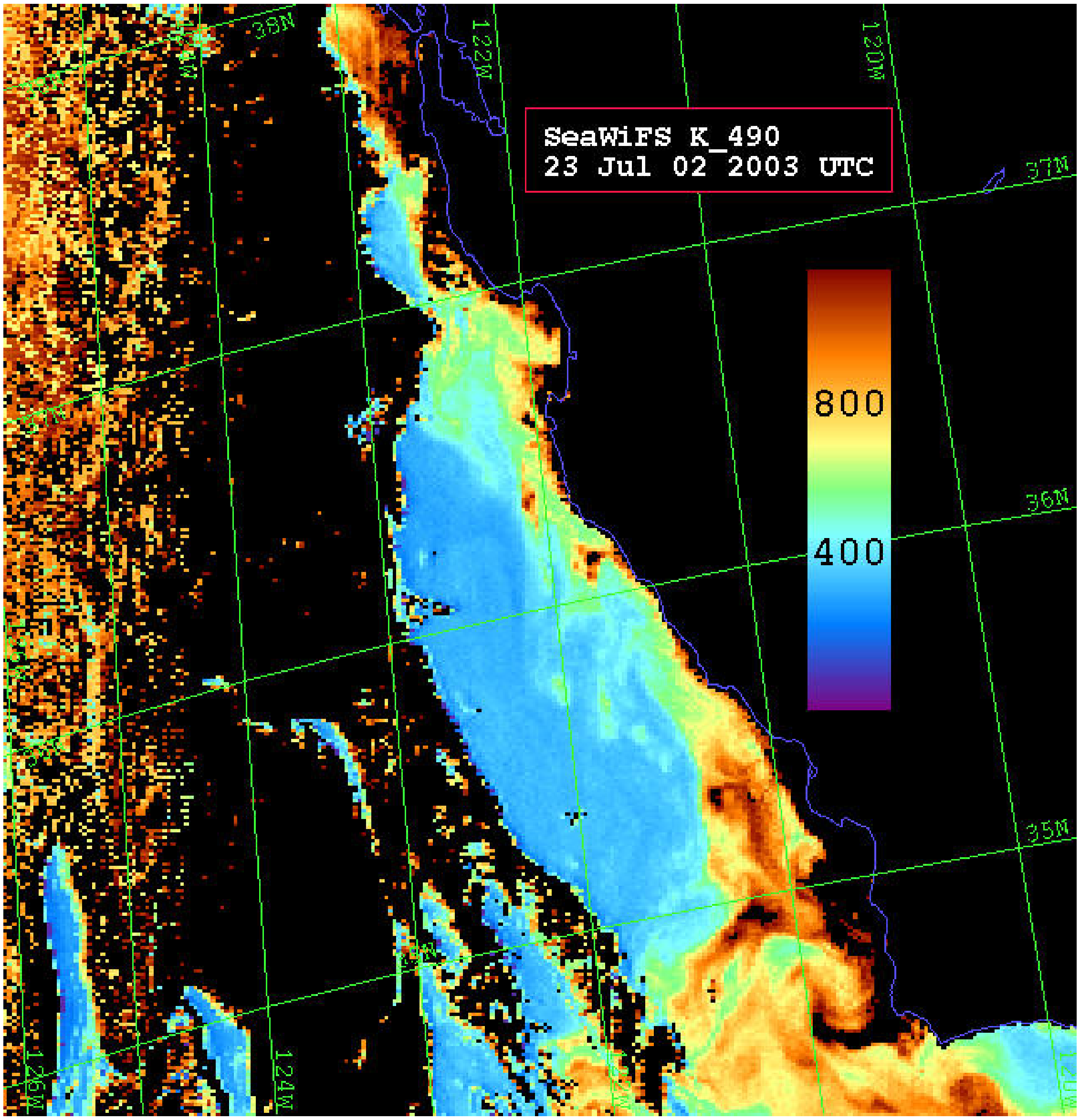

S20022132002243.L4_MO_SBA
August 2002 Monthly Composite
Diffuse attenuation coefficient at 532 nm
122W
120W
120W
118W
118W
34N
34N
32N
32N
0.02
0.05
0.1
0.3
0.8
2
K_532 (m -1)
SantaBarbara (SeaWiFS)
APS v2.6
Code 7333
Ocean Optics
Naval Research Laboratory

Figure (8)

Dive	Location	Depths(m)	Visibilities(m)
1	~ Monterey Bay **36 46.7** **121 50.4**	3.05 6.1	2.08 4.32
2	~ Port San Luis **35 07.9** **120 41.156**	3.05 6.1 9.14	4.57 4.7 6.15
4	~ Port San Luis **35 05.9** **120 45.7**	3.05 6.1 9.14	7.36 7.62 7.62
5	~ Santa Barbara **34 24.6** **119 57.1**	3.05 6.1 9.14	7.62 7.62 6.25

Figure (7b)


SeaWiFS K_490
23 Jul 02 2003 UTC
800
400
38N
37N
36N
35N
122W
120W
124W

REFERENCES

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Mr. Kurt Neilsen

Mr. Tarry Rago