Cruise Report

Blue Earth Global Expedition

(BEAGLE – 2003/2004)

Leg 6

Fremantle (Australia) - Fremantle (Australia)

January 27th - February 19nd, 2004

Milton Kampel

INPE, Brazil

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1. INTRODUCTION

The **B**lue **EA**rth **GL**obal **E**xpedition 2003, '**BEAGLE 2003**', is an oceanographic research program developed by Japan Marine Science and Technology Centre (JAMSTEC). The principal objective of this project is to enhance oceanographic research activities in the Southern Hemisphere, in accordance with the Sao Paulo Declaration (POGO, 2000). The specific objectives are:

- To detect and quantify temporal changes in the Antarctic Overturn System corresponding to the global ocean and the Southern Ocean warming during this century through high quality and spatially dense observation along old WHP (World Ocean Circulation Experiment Hydrographic Program 1991-2002) lines;

- To estimate the amount of anthropogenic carbon uptaken by the Antarctic Ocean;

- To provide a training environment in which trainees could get a hand-on experience in collecting biological, optical samples and optical data.

As a trainee I was requested to provide a report at the end of the leg. I kept a daily log with notes of interesting phenomena, recorded results and took pictures using the digital camera provided. This report summarises some of the results obtained and the trends observed.

2. BIO-OPTICAL OBJECTIVES

The general objectives of the bio-optical project on this expedition are:

- To generate an important database of bio-optical measurements and primary production from the under-sampled Southern Ocean;

- To provide a training environment in which trainees could get a hands-on experience in collecting phytoplankton related samples and bio-optical data. To get a first knowledge about some of the analysis and processing of bio-optical data.

To reach these objectives, measurements of radiation (seawater reflectance) were measured with different radiometers (Simbad, Simbada and Ocean Optics). Water samples were taken for the analysis of chlorophyll-*a* and phaeopigments concentration, and for the determination of absorption properties of particulate (phytoplankton and detritus) and coloured-dissolved-organic-matter (CDOM). Light – photosynthesis experiments (P&I curves) were also performed for the estimation of primary production parameters. Samples for the determination of phytoplankton pigment composition by HPLC, as well as for the quantification and identification of the small-sized phytoplankton by flow-cytometry were also collected. Results from these analyses are expected to contribute to the validation and calibration of ocean colour satellite algorithms of sensors such as SeaWiFS, MODIS, and MERIS.

3. METHODS

Protocols for the measurements and analysis of bio-optical samples can be consulted on the web at:

(http://www.ioccg.org/training/pogo_ioccg/protocols/protocols.html).

All samples are taken at the surface, or near surface, of the ocean. Analysis of chlorophyll concentrations, particulate and CDOM absorption, and P&I incubations were performed on board, while HPLC, flow cytometry and ^{13}C (for the calculations of P&I parameters), as well as a duplicate of particulate absorption samples are going to be processed in different laboratories (in Canada, Chile, South Africa, and Australia) after the end of the cruise. A preliminary processing of some of the data available is being developed onboard.

3.1. FEATURES OF LEG 6

During this leg the main focus of the expedition was on sediment analysis (similar to Leg 3). The overall sampling strategy was to sample once a day around the local noon from the flow through system (FTS). Eventually, two or tree stations a day could be sampled. There were tree stations scheduled for corer sampling, but one of those was cancelled due to weather conditions. Also, from a schedule of 17 CTD stations, only 13 could be occupied for the same reason.

Whenever possible, seawater samples were taken from Niskin bottles at the 10m depth. But in general, during CTD casts, there were not enough Niskin bottles for all the required sampling, and a bucket was used to collect surface water samples. An extra sample for determining the concentration of chlorophyll-*a* and phaeopigments was taken from the depth of the fluorescence maximum (indicated by the *in situ* fluorometer attached to the CTD).

During this leg we could take Simbad and Simbada measurements from the upper deck during navigation. But the weather conditions were not ideal for light measurements with the radiometers due to clouds, fog, rain or even snow. Nevertheless, we could get some practice in handling and using the different radiometers. Simbada was easier, lighter and faster to start operating than Simbad instrument, which took longer to find the GPS signal. But there was a specific program for SIMBAD instrument that allowed us to analyze the data, which lacked for Simbada. The hyperspectral radiometer (Ocean Optics) gives a lot of information, but it requires at least two persons to operate it and sometimes it was hard to see the computer screen to set the integration time on deck. Many times we had to use some ice to get the equipment working properly.

3.2. BIOLOGICAL SAMPLING

3.2.1. Photosynthesis v/s Irradiance (PI) Experiments

Everyday 1 experiment was carried out onboard. 42 bottles (+ 3 dark) were incubated with ^{13}C in a Larsen box for 3 hours, then filtered and dried. The filters were labelled and stored in sets of 15 envelopes.

3.2.2. CDOM

Water for the determination of coloured-dissolved-organic-matter were filtered through 0.2 μm membranes, and immediately scanned in a 10 cm quartz cuvette in a CARY spectrophotometer. Storing: No samples were stored. Results were recorded as digital files in folder JAMSTEC//Leg6/CDOM/dailyfolder (and in a CD-ROM).

3.2.3. Chlorophyll Concentration

Chlorophyll-*a* and phaeopigments concentrations were measured onboard using a digital Turner Designs fluorometer. No samples were stored. Results were recorded as digital files in folder JAMSTEC/Leg6/Chlorophyll/daily files (and in a CD-ROM).

3.2.4. Particulate Absorption

Two samples were collected and filtered through GF/F glass fiber filters for determination of particulate absorption. One sample was immediately scanned on board in a CARY spectrophotometer, and the other will be analysed at the Bedford Institute of Oceanography. Results of the samples analysed on board were recorded as digital files in folder JAMSTEC/Leg6/Absorption/dailyfolder (and in a CD-ROM). Duplicate samples were frozen in liquid nitrogen into a labelled cryogenic vial and then stored in a deep freezer (-80^{o}C).

3.2.5. High Performance Liquid Chromatography

Two samples were collected and filtered through GF/F glass fiber filters for determination of phytoplankton pigment composition by HPLC. These samples will be analysed in 2 different laboratories: Cape Town (South Africa) and Hobart (Australia). Both samples were frozen in liquid nitrogen and then stored in 2-separated labelled aluminium foil envelopes into a deep freezer (-80^{o}C).

3.3. OPTICAL SAMPLING

The weather conditions were not good for collecting optics data. However, a few measurements were performed with the different radiometers available.

3.3.1. Simbad

The hand-held battery operated radiometer collects data in five spectral bands that are centered at 443, 490, 560, 670, 870 nm. This instrument has an external GPS antenna and measures direct sunlight intensity and water leaving radiance. The GPS must first find the instruments position before readings can be made. The sequence of measurements are 1 Dark, 3 Sun, 6 Sea, 3 Sun, and 1 Dark. The digital files were recorded in the folder JAMSTEC/Leg6/simbad08/dailyfolder (and in a CD-ROM).

3.3.2. Simbada

This instrument is an above-water radiometer and it measures water-leaving radiance and aerosol optical thickness in 11 spectral bands. The bands are centred at 350, 380, 412, 443, 490, 510, 565, 620, 670, 750 and 870 nm. The instrument has an internal GPS antenna that must home in on 3 or more satellites before readings can be taken. The sequence of measurements are 1 Dark, 3 Sun, 6 Sea, 3 Sun, and 1 Dark. The digital files were recorded in the folder JAMSTEC/Leg6/simbada21/dailyfolder (and in a CD-ROM).

3.3.3. Hyperspectral radiometer

This instrument measures irradiance from 350 to 1000 nm at 0.5 nm intervals and has a special fibre optic that collects the irradiance from the sky and the sea surface. The downwelling irradiance is measured using a spectralon that diffuses the incident irradiance. The digital files were recorded in folder JAMSTEC/Leg6/HyperSp/dailyfolder (and in a CD-ROM).

3.3.4. Photosynthetic Active Radiation (PAR)

The PAR sensor was already mounted outside, above the atmospheric observation laboratory. The Licor 1400 data logger connected to the sensor reads measurements every 60 seconds and records hourly average on the hour. Data were downloaded at the end of the leg to be later processed at Bedford Institute of Oceanography in Canada. The digital file is in folder/file JAMSTEC/Leg6/PAR_sensor_data/PAR_Leg6.txt (and in a CD-ROM).

4. PRELIMINARY RESULTS - EXAMPLES

Location of the sampling points occupied during Leg 6 is shown in Figure 1. Table 1 presents the sampling stations with its corresponding ID numbers and the type of measurements taken.

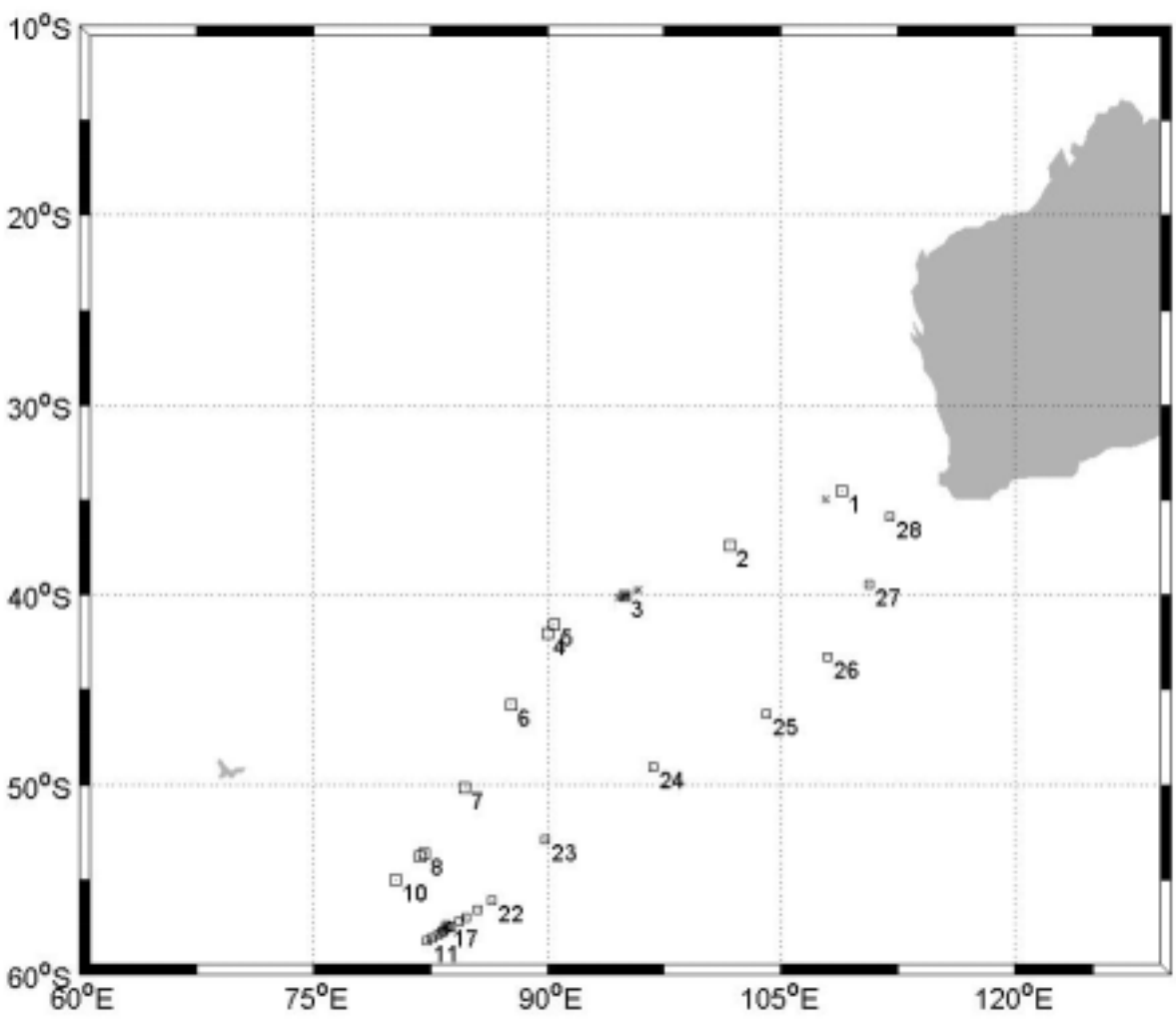

Figure 1 - Sampling points during Leg 6. Squares indicate water-sampling stations. Crosses indicate Simbad and Simbada measurements positions.

Figure 2 shows an ocean colour satellite image acquired by MODIS sensor on January 30th, 2004 processed into chlorophyll-*a* concentrations (mgm^{-3}). Blue tones indicate lower chlorophyll concentrations, and yellow to red colours denote relatively higher concentrations (see colour table in logarithmic scale on Figure 2). Even with a persistent presence of moving clouds it was possible to make a set of Simbad measurements at the same day. Black crosses around the position 40.0S and 95.0E indicate its positions.

Table 1 – Sampling stations positions, its corresponding ID numbers and the type of measurements taken.

Number [No]	**ID** [No]	**Date** [UTC]	**Time UTC** [hour]	**Latitude** [deg]	**Longitude** [deg]	**PI** [Y/N]	**HPLC** [Y/N]	**ABS** [Y/N]	**Chl** [S/F]	**FC** [Y/N]	**CDOM** [Y/N]	**SIMBAD** [Y/N]	**SIMBADA** [Y/N]	**OceanOptics** [Y/N]	**System** [FS/B/R]
1	264417	01/28/04	3:22	-34.52	108.87	Y	Y	Y	S	Y	Y	Y	Y	N	FS
2	264418	01/29/04	4:42	-37.41	101.74	Y	Y	Y	S	Y	Y	N	N	N	FS
3	264419	01/30/04	6:00	-40.05	94.96	Y	Y	Y	S	Y	Y	Y	Y	N	FS
4	264420	01/31/04	1:54	-42.00	90.00	Y	Y	Y	SF	Y	Y	Y	Y	Y	BR
5	264421	02/01/04	5:38	-41.55	90.42	Y	Y	Y	S	Y	Y	Y	Y	Y	B
6	264422	02/02/04	5:15	-45.81	87.70	Y	Y	Y	S	Y	Y	Y	Y	N	FS
7	264423	02/03/04	6:00	-50.20	84.70	Y	Y	Y	S	Y	Y	N	N	N	FS
8	264424	02/04/04	1:16	-53.67	82.08	Y	Y	Y	SF	Y	Y	Y	Y	Y	BR
9	264425	02/05/04	13:00	-53.80	81.88	Y	Y	Y	S	Y	Y	Y	Y	Y	B
10	264426	02/06/04	4:55	-54.99	80.25	Y	Y	Y	S	Y	Y	N	N	N	FS
11	264427	02/07/04	1:32	-58.24	82.32	N	N	N	SF	N	N	Y	Y	N	R
12	264428	02/07/04	4:00	-58.05	82.62	Y	Y	Y	SF	Y	Y	Y	Y	N	BR
13	264429	02/07/04	7:45	-57.87	83.00	N	N	N	SF	N	N	N	N	N	R
14	264430	02/07/04	12:00	-57.75	83.25	N	N	N	SF	N	N	N	N	N	R
15	264431	02/08/04	0:50	-57.68	83.38	N	Y	Y	SF	Y	Y	N	N	N	BR
16	264432	02/08/04	5:40	-57.58	83.62	Y	Y	Y	SF	Y	Y	Y	Y	N	BR
17	264433	02/09/04	5:36	-57.41	83.51	Y	Y	Y	S	Y	Y	N	N	N	FS
18	264434	02/10/04	0:15	-57.46	83.86	N	Y	Y	SF	Y	Y	Y	Y	N	BR
19	264435	02/10/04	5:40	-57.22	84.34	Y	Y	Y	SF	Y	Y	Y	Y	Y	BR
20	264436	02/10/04	11:05	-56.98	84.81	N	Y	Y	SF	Y	Y	Y	Y	N	BR
21	264437	02/11/04	0:10	-56.60	85.53	N	Y	Y	SF	Y	Y	N	N	N	BR
22	264438	02/11/04	7:30	-56.10	86.43	Y	Y	Y	SF	Y	Y	N	N	N	BR
23	264439	02/12/04	4:49	-52.89	89.89	Y	Y	Y	S	Y	Y	N	N	N	FS
24	264440	02/13/04	4:46	-49.06	96.77	Y	Y	Y	S	Y	Y	N	N	N	FS
25	264441	02/14/04	4:50	-46.28	104.03	Y	Y	Y	S	Y	Y	N	N	N	FS
26	264442	02/15/04	5:06	-43.27	107.98	Y	Y	Y	S	Y	Y	N	N	N	FS
27	264443	02/16/04	4:52	-39.413	110.60	Y	Y	Y	S	Y	Y	N	N	N	FS
28	264444	02/17/04	3:23	-35.892	111.97	Y	Y	Y	S	Y	Y	N	N	N	FS

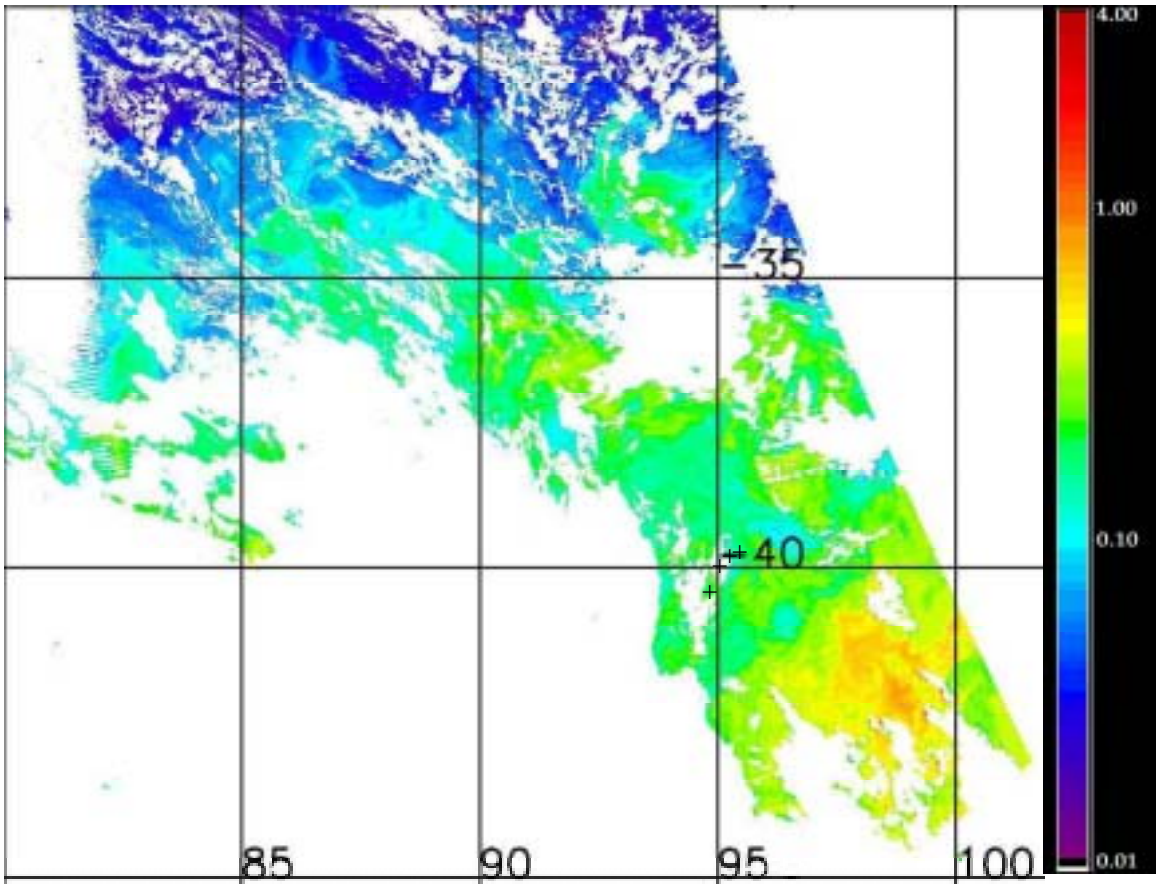

Figure 2 – MODIS image acquired at 01/30/04 and processed into chlorophyll-*a* concentrations (mgm^{-3}, colour table in log scale). Black crosses indicate Simbad measurements positions.

A set of Simbad measurements was processed using the software available onboard. Figure 3 shows an example of raw Simbad sun-data acquired on 01/30/04. Despite ship was steaming it was possible to record stable data which demonstrate how this equipment compensates for the motion of the ship. While steaming there was some foam generated by the ship. To properly process the data it is necessary to eliminate this contaminated signal. This should not be difficult because of the high contrast between “good” data and the contaminated one (Figure 4).

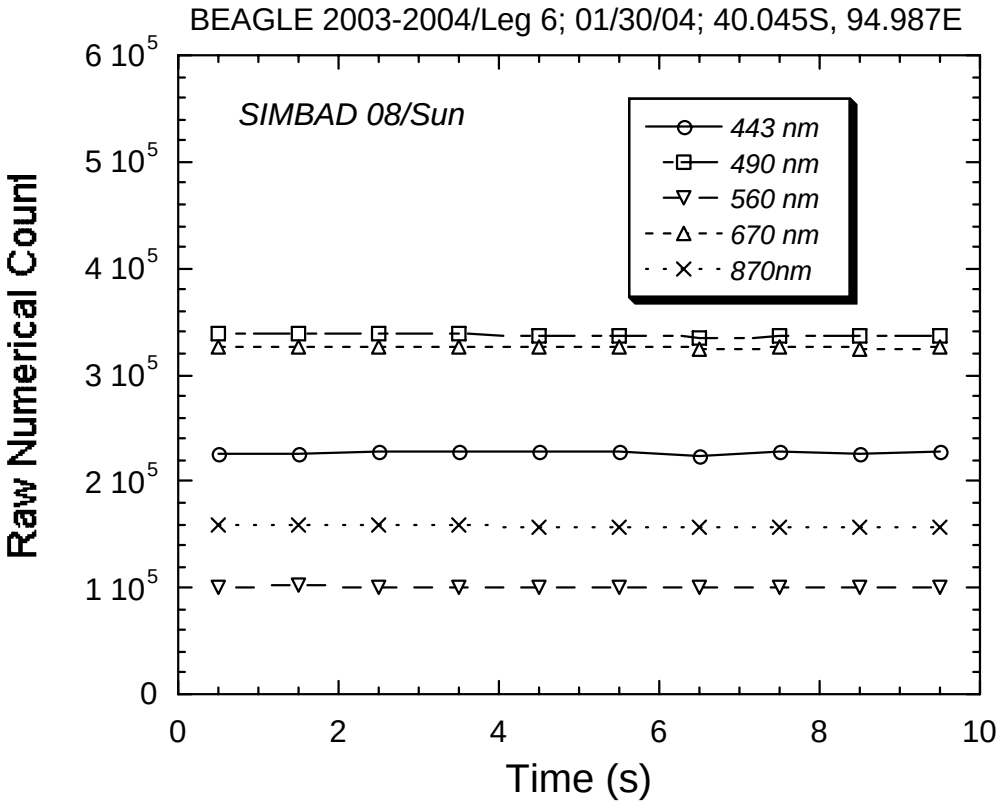

Figure 3 – Raw Simbad sun-data acquired at 01/30/04.

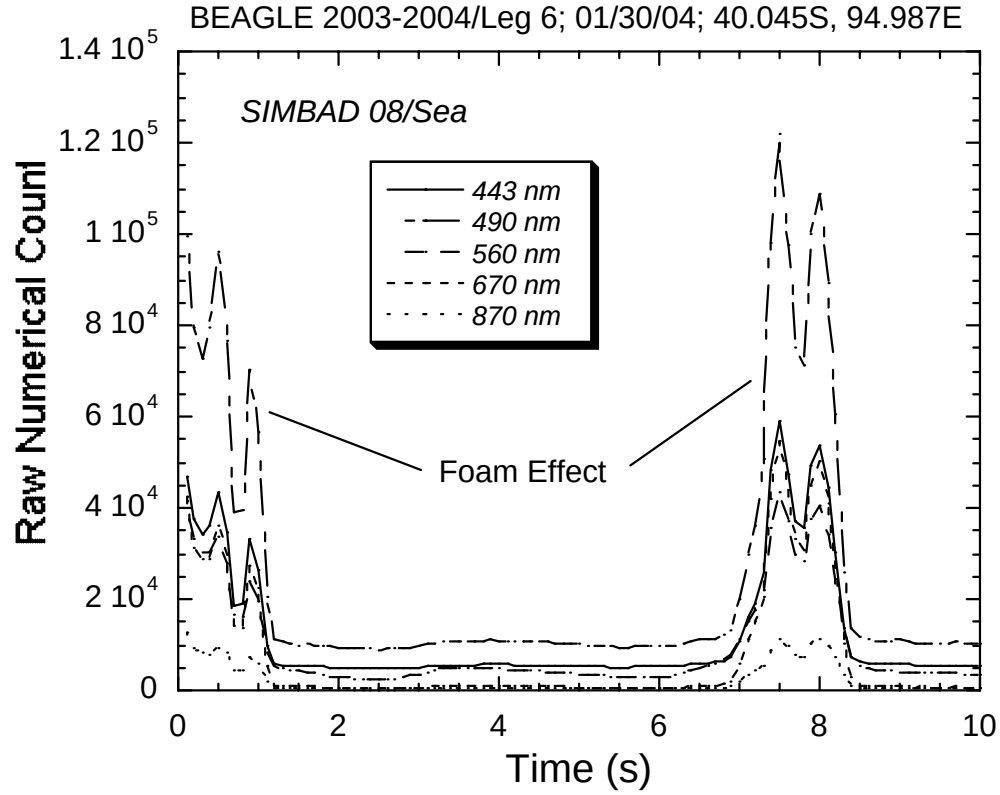

Figure 4 – Raw Simbad sea-data acquired at 01/30/04.

The aerosol optical thickness retrieved from Simbad data indicates that the spectral dependence is very small (Figure 5). With the series of one minute of measurements (Figure 6) it is possible to see that averaging the data minimize the errors.

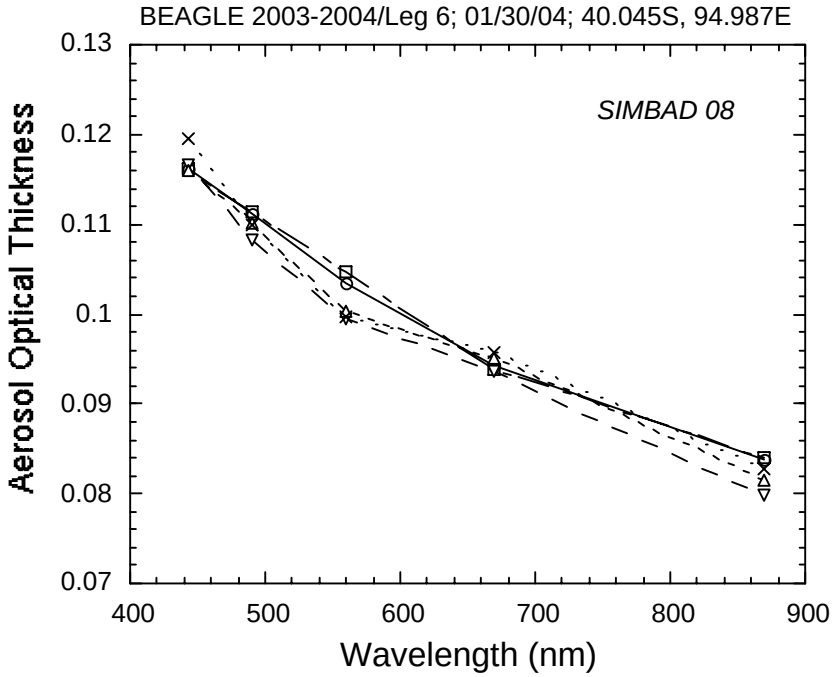

Figure 5 – Aerosol optical thickness retrieved from Simbad data acquired at 01/30/04.

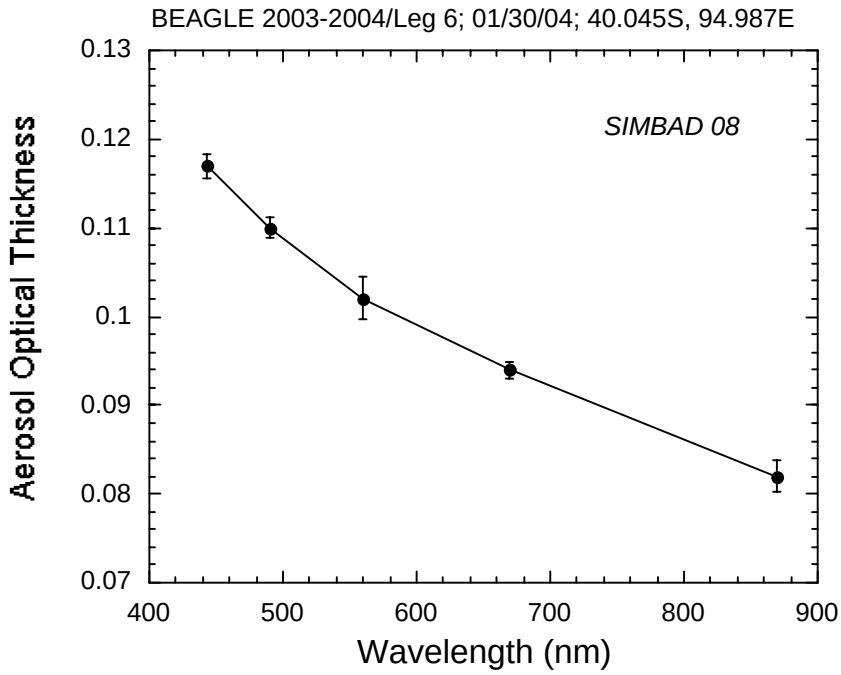

Figure 6 – Averaged (1 minute) aerosol optical thickness retrieved from Simbad data acquired at 01/30/04.

Also, from Simbad data it is possible to retrieve marine reflectance data (Figure 7). A few differences among scans can be observed (Figure 7a). The average plot is typical of clear waters (Figure 7b). With the ratio of wavelengths the chlorophyll concentration can be estimated (0.16 mgm^{-3}).

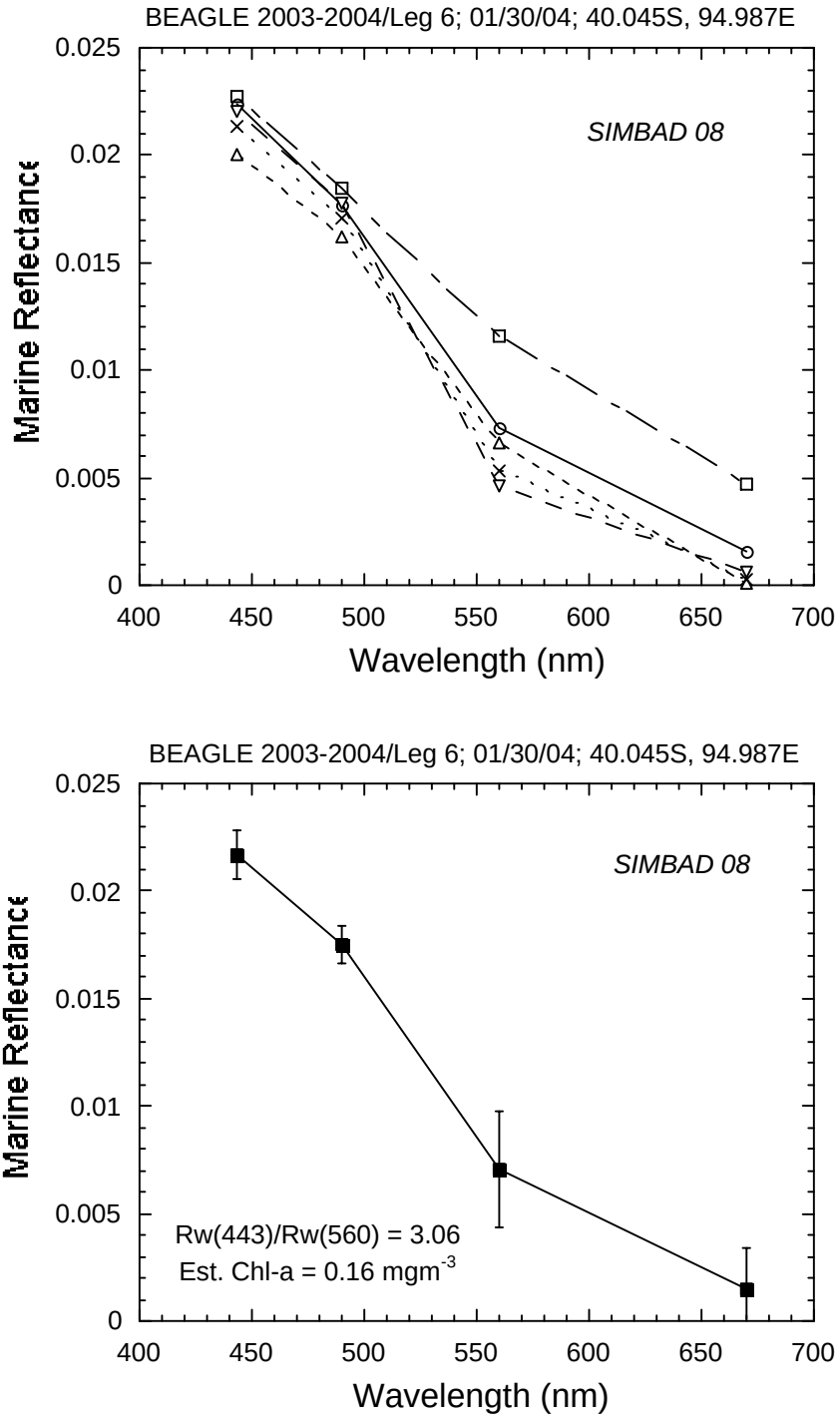

Figure 7 – (a) Marine reflectance estimated from Simbad data acquired on 01/30/04 (above); (b) Average values (below).

Ocean optics data were processed to show an example of hyperspectral data (Figure 8) acquired onboard. From the raw signal plots (Figure 8a) we can see how sky data is important. Remote sensing reflectance (corrected and nor corrected) was estimated from the hyperspectral data (Figure 8b). At shorter wavelengths the signal is more noise, maybe due to the sensitivity of the instrument at these wavelengths. A noticeable peak could be observed around 680 nm.

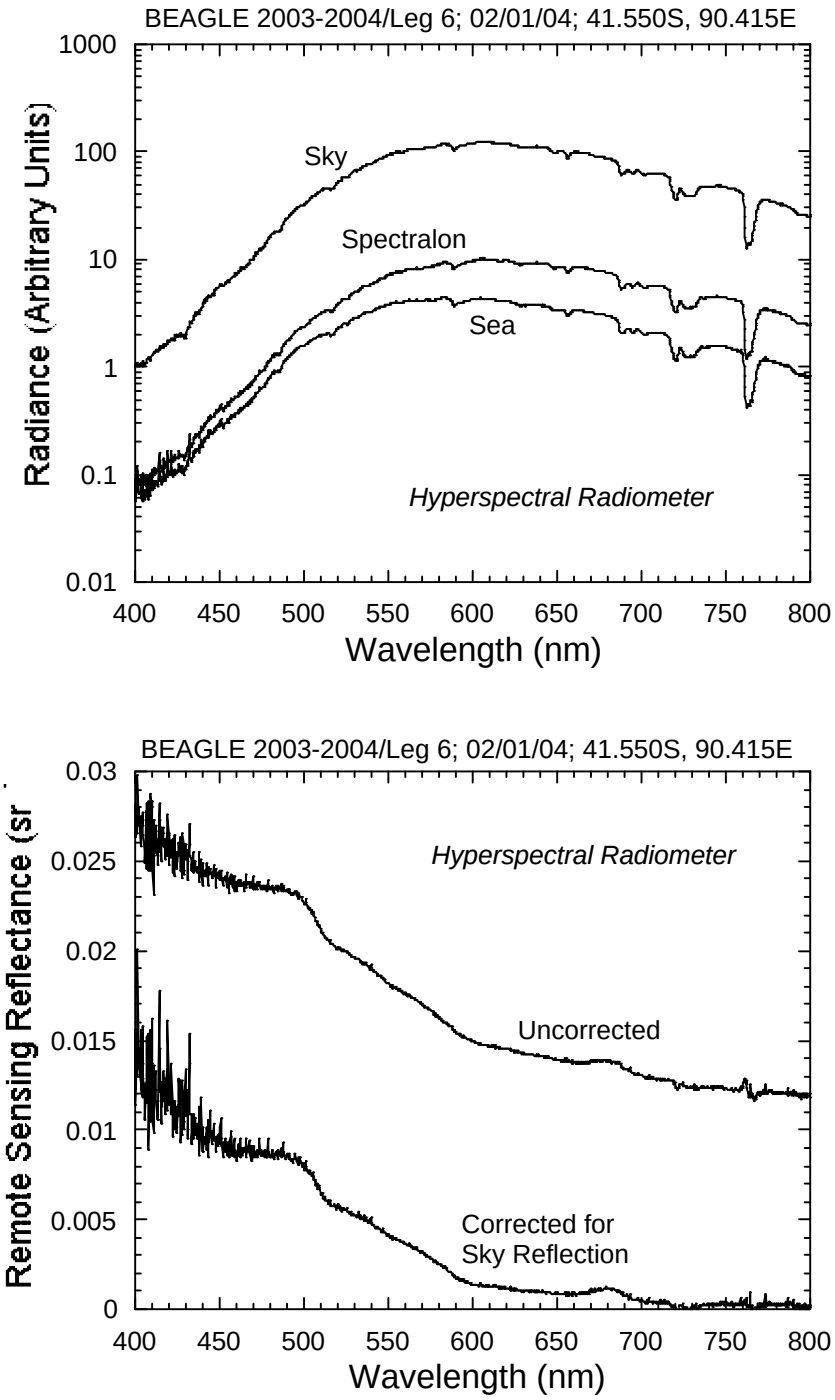

Figure 8 – (a) Raw sky, sea and spectralon hyperspectral data (above) acquired on 02/01/04 (above); (b) Remote sensing reflectance (sr^{-1}) estimated from hyperspectral data corrected and uncorrected fro sky reflection.

Particulate absorption plots show two prominent peaks around 680 nm and 440 nm probably associated with phytoplankton (Figure 9a). The de-pigmented curve is a typical example of phytoplankton detritus. Specific absorption coefficient of phytoplankton for the same sample is shown on Figure 9b.

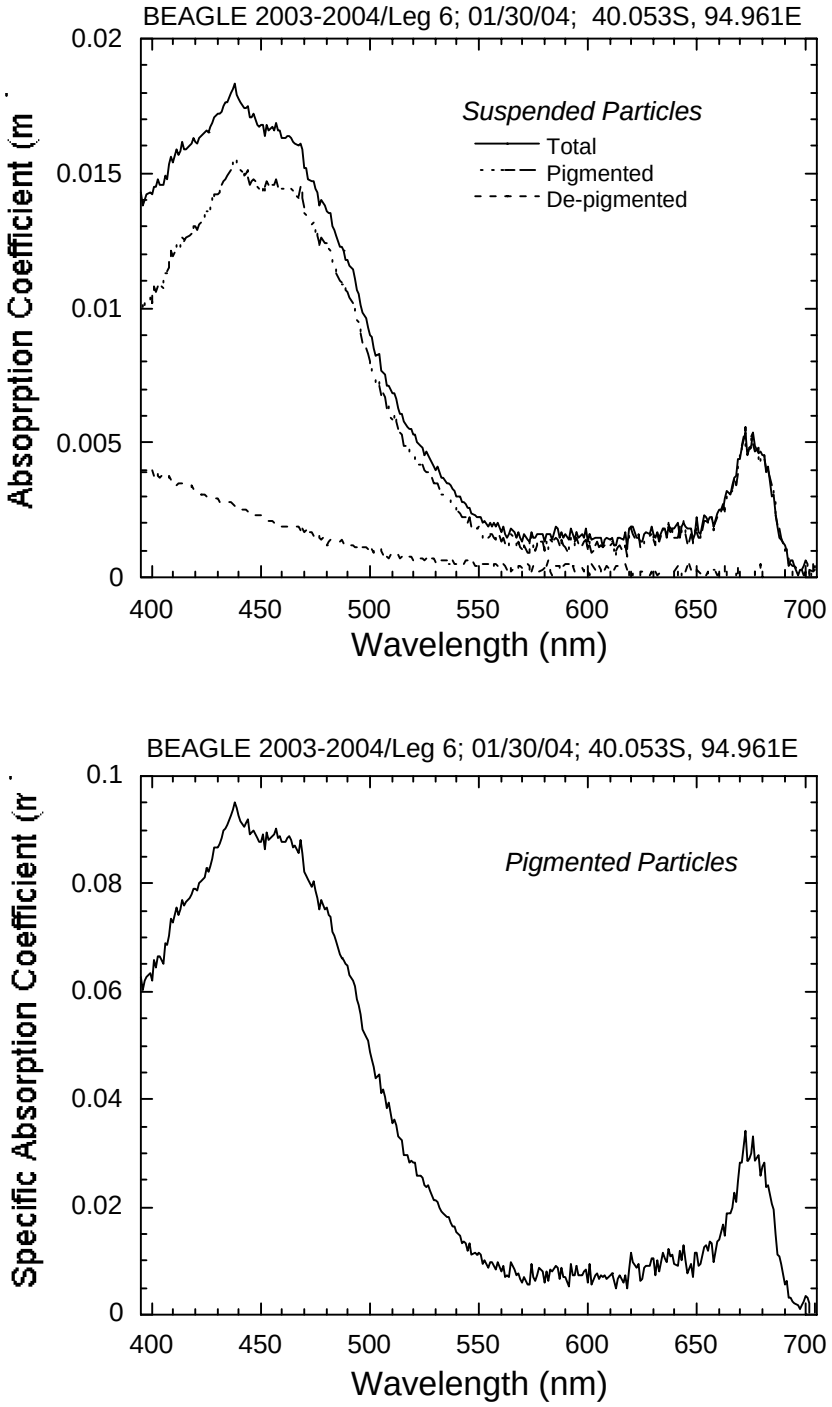

Figure 9 – (a) Absorption coefficients of suspended particles, total, pigmented and de-pigmented in the sample collected on 01/30/04 (m^{-1}, above); Specific absorption coefficient of phytoplankton for the same sample (m^{-1}, below).

A typical exponential shaped curve was obtained for the absorption coefficient of CDOM in the sample collected on 01/30/04 (Figure 10).

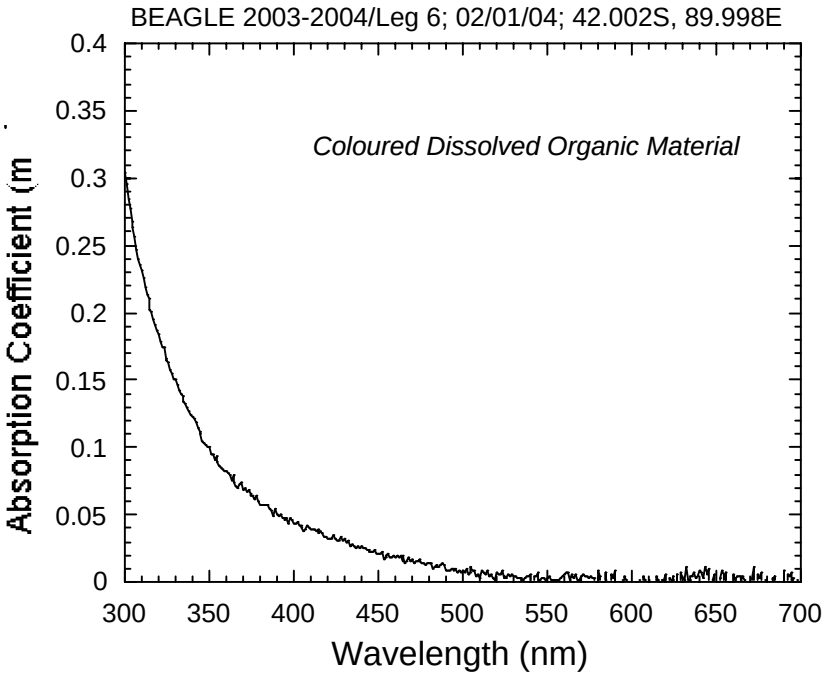

Figure 10 – Absorption coefficient of CDOM (m^{-1}) in the sample collected on 01/30/04.

On Figure 11 we have surface chlorophyll concentrations and sea surface temperatures plotted against latitude for both North to South (Figure 11a), and South to North (Figure 11b) transects samples during leg 6 (see map on Figure 1). The most prominent feature in both transects is the gradients observed around the Antarctic Convergence zone (around 40 – 45S). During the South to North transect, a higher resolution set of CTD stations were occupied between 56 and 58.5S. The chlorophyll and temperature v/s latitude plots indicate also another region of relatively intense surface gradients, probably associated with a polar front in this region of the Southern Indian Ocean. It is interesting to note a peak of maximum chlorophyll at the southernmost side of this front. Such features will be examined later.

5. FINAL REMARKS

I believe that the hands-on training on bio-optical measurements received onboard the *R/V Mirai* would permit further enhancements of the research activities in the Southern Hemisphere if we could multiply the knowledge and techniques acquired during the cruise with other colleagues. I have no doubts that the primary production experiments and bio-optical data collected during the cruise would provide an invaluable database for the under-sampled Southern Ocean. The results obtained are expected to contribute to the validation of ocean-colour satellite-derived products from different sensors (e.g., SeaWiFS, MODIS, MERIS), and to assist in the development of regional algorithms for remote sensing estimate of phytoplankton

standing stocks and primary production. I also believe that the training received onboard would be very helpful to the understanding of the biophysical interactions and relationships between oceanic variability and observed ecosystem changes in the Southern Oceanic region.

The excellent opportunity for training and collaborative work with Dr Robert Frouin and researchers from other countries and institutions is also another topic I would like to point out. Undoubtedly this onboard training represented a great opportunity for those interested in increasing their knowledge about bio-optical and other oceanographic measurements. I expect that we would be able to continue working together contributing to the success of POGO and IOCCG initiatives.

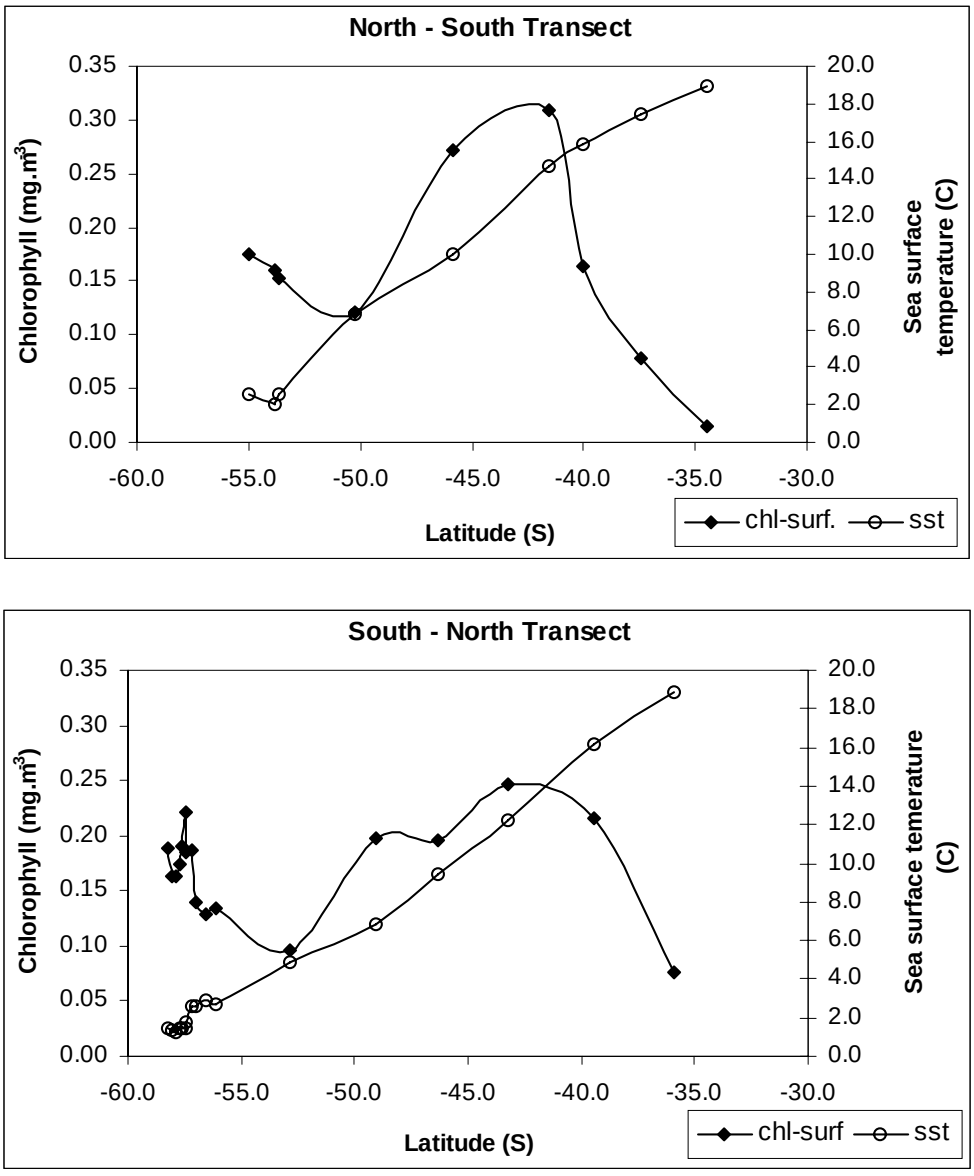

Figure 11 – Surface chlorophyll concentrations and sea surface temperatures v/s latitude in a: (a) north to south (above); and (b) south to north transect (below).

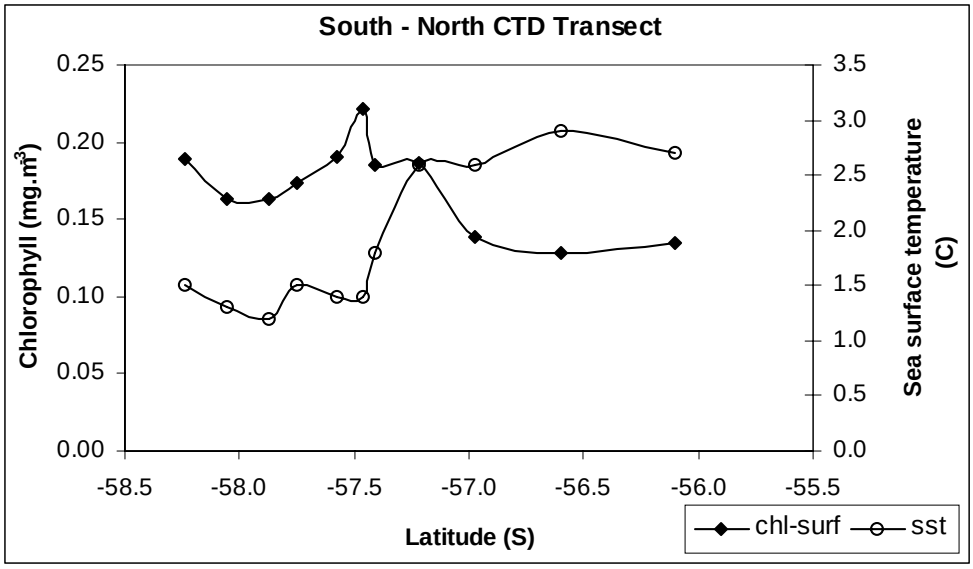

Figure 11 – Surface chlorophyll concentrations and sea surface temperatures v/s latitude in a higher resolution south to north transect.

6. ACKNOWLEDGEMENTS

I would like to thank people at POGO, IOCCG and JAMSTEC, also the Director and staff of INPE for giving me the opportunity of being able to participate in the BEAGLE 2003-2004 expedition, getting a hand-on training in collecting and processing biological, optical samples and optical data onboard the *R/V Mirai*. The experience will be very useful in my future work. Special thanks go to Robert Frouin, Vivian Lutz, Venitia Stuart, Pru Bonham, Shubba Sathyendranath, Tony Payzant and previous participants in legs 1, 2, 3, 4 and 5 for their direct or indirect support. I appreciate the collaboration received onboard from Shuichi Watanabe chief scientist, the scientific and sampling team from JAMSTEC, as well as the captain, the officers and crew of the *R/V Mirai*.