Cruise Report

Blue Earth Global Expedition

(BEAGLE - 2003)

Leg 3

Valparaiso (Chile) - Santos (Brazil)

October 19th - November 2nd, 2003

Bio-optics Group

POGO Trainees **:** Ana Dogliotti (Argentina)

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Specialist in charge **:** Vivian Lutz (Argentina)

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). These are pointed out as follows: 1) 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. 2.). To estimate the amount of anthropogenic carbon uptaken by the Antarctic Ocean. 3.) To provide a training environment in which trainees could get a hand-on experience in collecting biological, optical samples and optical data.

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 reach this objective, measurements of radiation (seawater reflectance) are being measured with a variety of radiometers (Simbad, Simbada, Ocean Optics), samples are taken for the analysis of chlorophyll a concentration, and for the determination of absorption properties of particulate (phytoplankton and detritus) and coloured-dissolved-organic-matter (CDOM); P&I experiments are 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 are also being collected. Results from these analysis are expected to contribute to the validation and calibration, and probably to develop regional algorithms, for satellite-derived products (eg., chlorophyll a) by sensors such as SeaWiFS, MODIS, and MERIS.

- 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.

3. Sampling and Methods

Protocols for the sampling and methods being used for the optical measurements and analysis of biological samples can be consulted in the URL of IOCCG (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 are 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.

4. Peculiarities of Leg 3

During this leg the main focus of the expedition was on sediment analysis. There were only four stations scheduled, which were occupied for corer sampling. The survey to find a proper site and then the deployment of different types of corer in these deep areas of the ocean took several hours (almost the whole daylight). Therefore, in most cases only one sampling a day was made for the bio-optics project using a surface bucket. In the days when there were no fixed stations, two samplings a day were performed from the flow-through-system (FTS) of the ship, one around 10 a.m. and the other around 3 p.m. Occasionally an extra sample for chlorophyll a determination was taken from the FTS at noon (for the sake of matching SeaWiFS passing).

Weather conditions were not ideal for light measurements with the radiometers in this leg. During stations, when light measurements could be performed, it was mainly cloudy and foggy, even rainy. This weather is typical of this area of the Chilean Fjords, surrounded by mountains (the southern tip of the Andes) where humid air from the Pacific precipitates. Hence, a preliminary look at the few measurements obtained showed that there were not of good quality and there will not be included in this report. Nevertheless, these data could be later analysed by experts, who can better judge if there is valid information to be retrieved.

A problem encountered, and that would be the same for all legs, is that light measurements could only be done at stations with the ship stopped and from the aft area. This is because due to safety constrains you are not allowed to work on the bow of the Mirai at any time (even with the ship stopped), or at any place close to the board when the ship is sailing. Besides, the huge wake produced by the ship, making foam at the place where you are supposed to point the radiometer, would impede this type of measurements while steaming.

In this leg no CTD casts were performed, so there are no profiles of physical or chemical data available.

Sampling on this leg was restricted to the Pacific side, Chilean waters, since no authorization for sampling on the Atlantic side, including Argentinean, Uruguayan and Brazilian waters was obtained.

I. BIOLOGICAL SAMPLING

Photosynthesis v/s Irradiance (PI) Experiments

Everyday 1 or 2 experiments were carried out onboard. 42 bottles (+ 3 dark) were incubated with ^{13}C in a Larsen box for 3 hours, then filtered and dried.

Storing: filters were labelled and stored in sets of 15 envelopes.

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 are in folder JAMSTEC/CDOM/Leg3/dailyfolder

Chlorophyll Concentration

Chlorophyll-a and phaeopigments concentrations were measured onboard using a digital Turner Designs fluorometer.

Storing: no samples were stored. Results are in folder JAMSTEC/Leg3/Chl/daily files

Particulate Absorption

Two samples were collected and filtered through GF/F glass fiber filters for the 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 (Att: Dr. Venetia Stuart).

Storing: Results of samples analysed on board are in folder JAMSTEC/Absorption/Leg3/dailyfolder. Duplicate samples were frozen in liquid nitrogen into a labelled cryogenic vial and then stored in a deep freezer (-80^{o}C).

High Performance Liquid Chromatography

Two samples were collected and filtered through GF/F glass fiber filters for the determination of phytoplankton pigment composition by HPLC. These samples will be analysed in 2 different laboratories: Cape Town (South Africa) and Hobart (Australia).

Storing: Both samples were frozen in liquid nitrogen and then stored in 2-separated labelled aluminium foil envelopes into a deep freezer (-80^{o}C).

II. OPTICAL SAMPLING

The weather conditions were not good for collecting optics data due to high cloud cover most of the time. However, a few measurements were performed with the different radiometers available.

SIMBAD

The hand-held battery operated radiometer collects data in five spectral bands that are centred 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.

Storing: The files are in the folder JAMSTEC/Leg3/simbad03/dailyfolder.

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.

Storing: The files are in the folder JAMSTEC/Leg3/simbada21/dailyfolder.

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.

Storing: Files are in folder JAMSTEC/Leg3/HyperSp/dailyfolder.

Photosynthetic Active Radiation (PAR)

The PAR sensor is 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 are downloaded at the end of the leg to be later processed at BIO in Canada.

Storing: Files are in folder JAMSTEC/Leg3/PAR_sensor_data/PAR_Leg3.txt

5. Pogo Trainees Activities

The two trainees working on this leg, Ana Dogliotti and Gustavo Martínez, had an excellent background on bio-optics and worked hardly and with enthusiasm in all the activities developed on board not only on the practical aspects, but also on the data processing part.

5.1 Trainees Remarks

Ana Dogliotti

My experience in R/V Mirai was as extraordinary as unique. I've learned a lot about biological and optical measurements and how to work in a laboratory on board of a ship, the difficulties found when the vessel starts rolling and the precaution to be taken during sampling, filtering and measuring different variables, like absorption and chlorophyll concentration.

Even though the weather didn't help, due to the high latitudes we navigated, a few light measurements could be taken. It was hard to complete a set of measurements without having clouds covering the sun and the ship wasn't always in the correct position.

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 analyse 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. Analysing the data helped us realising problems or mistakes made during sampling and to change a little bit the protocols in order to avoid making the same mistakes in the future legs.

It was also interesting to process and analyse the absorption data on board, thanks to Vivian's experience and knowledge and Gustavo's help with programming.

It was a shame we couldn't take measurements in the Atlantic part of leg 3. It would have been interesting to sample the SouthWestern Atlantic Ocean, being a very important area and a poorly sampled one.

All the kind of measurements taken during this cruise were new to me, also being on board. It was a whole new experience that I'll probably never forget.

I would like to thank POGO for this great training opportunity and to all the JAMSTEC people for their collaboration.

Gustavo Martínez

Although I had previous experience in oceanographic sampling on board, the experience of working in the R/V MIRAI was totally different. The amplitude of the different laboratories permitted us to work comfortably and to have equipment on board that allowed obtaining data to be processed. The radiometric measurements were new for me. The sea conditions we had were not optimal for these measurements, but we could get some practice in handling and using the different sensors. For reasons already commented, we had time to do data processing. That was very important because Vivian teached us through the analysis of real data. In that way we learned the practical details that facilitate later application of the techniques. In relation with the light measurements, when we tried to process the data, we understood the relevance of respecting the conditions of sampling, mainly regarding the angles and position in relation with the sun.

The life on board the MIRAI was good. I felt a very good disposition from the crew, technical staff and other scientists, trying to help when we needed.

6. Data Processing

A series of Fortran routines were produced to process the absorption data. They can be found in the directory /JAMSTEC/leg3/data-process. These data can be later reprocessed to make any necessary adjustments, for example choosing a more appropriate Beta factor (once HPLC pigments would be available; see Stuart et al., 1998).

In the case of the particulate absorption, the first routine 'absorption_n.for' retrieves the optical density values (OD) from the ASCII files produced by the Cary spectrophotometer in a format which can be read by Fortran. The second routine 'absorption_f.for' processes the OD values following the steps described in the protocols. Basically:

1) it subtracts the value of absorption at 750 nm from the whole spectrum;
2) it averages the 10 replicates of each type of measurement;
3) it subtracts the averaged blank from the averaged sample absorption;
4) it organises the spectrum from the lower to the higher wavelength;
5) it corrects the spectrum for the Beta factor (using the equation proposed by Hoepffner & Sathyendranath, 1992; see reference in protocols);
6) it transforms OD into absorption (passing from $\log_{10}$ to $\log_e$ and considering the area and volume of filtration);
7) it subtracts the detritus from the total to retrieve the phytoplankton absorption;
8) it calculates the specific absorption coefficient of phytoplankton (dividing the phytoplankton absorption by the chlorophyll *a* concentration of the sample).

The program generates four output files with the results of the processing:

SampleID+ABT.txt
SampleID+ABD.txt
SampleID+ABPHY.txt
SampleID+ABSPHY.txt

The OD values of CDOM were first retrieved by the routine 'cdom_n.for'. Then the routine 'cdom_f.for' process the data following these steps:

1) it subtracts the value of absorption at 700 nm from the whole spectrum;
2) it transforms OD into absorption (passing from $\log_{10}$ to $\log_e$ and considering the pathlength of the cuvette).

The output of the program is a file with the name 'AC+sampleID.csv'.

7. Preliminary Results

This is just a preliminary analysis of some of the results obtained on Leg 3. Location of the sampling points is shown in figure 1.

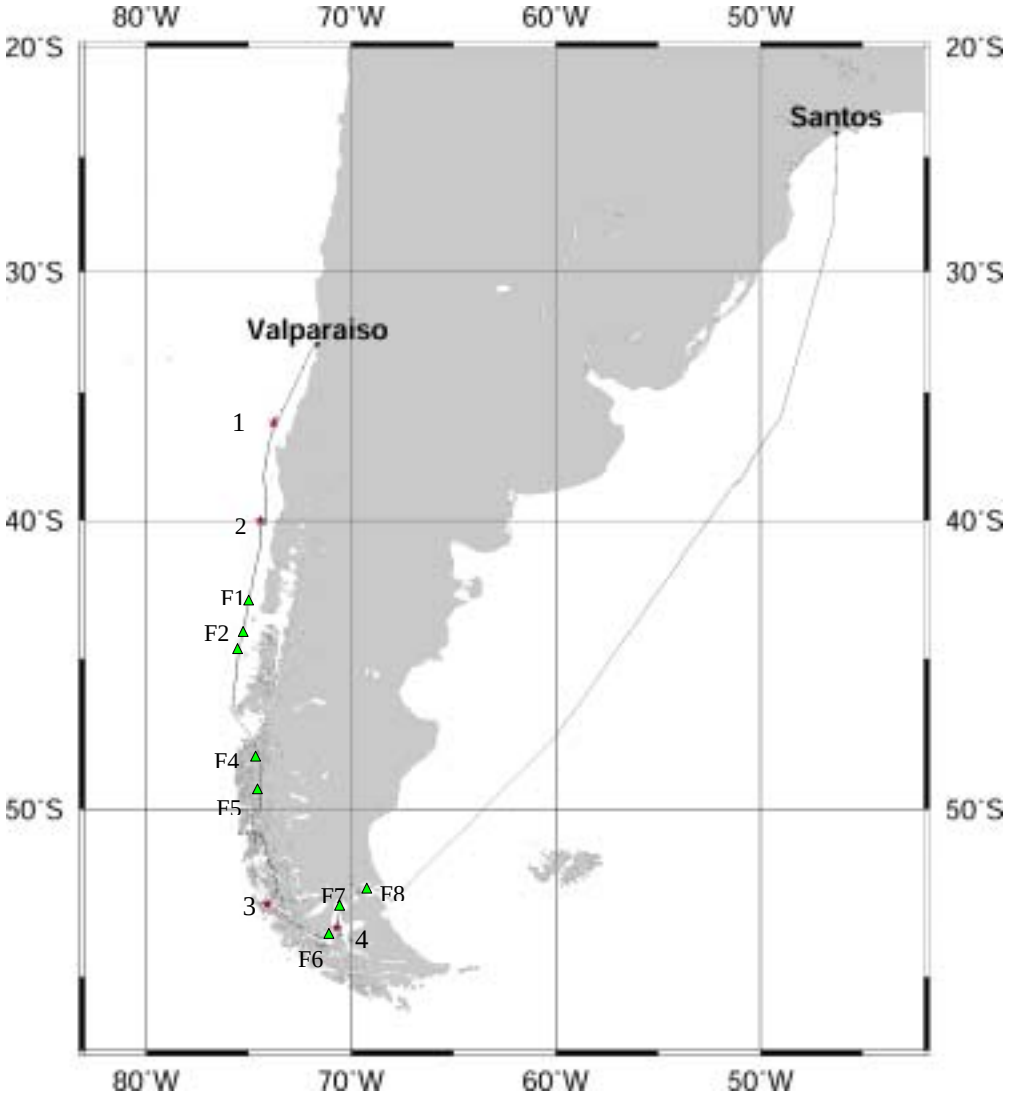

Figure 1. Sampling points during Leg 3. Numbers alone correspond to the corer stations, and F+number correspond to sampling points from the flow-through-system.

Table 1. Chlorophyll a concentrations in the samples of Leg 3.

Sample ID	Station #	Chla (mg m^{-3})
264302	1	0.418
264303	2	0.249
264304	F1	1.125
264305	F2	0.654
264306	F3	0.708
264307	F4	2.048
264308	F5	2.947
264309	3	0.739
264310	F6	5.925
264311	4	7.669
264312	F7	4.417
264313	F8	1.026

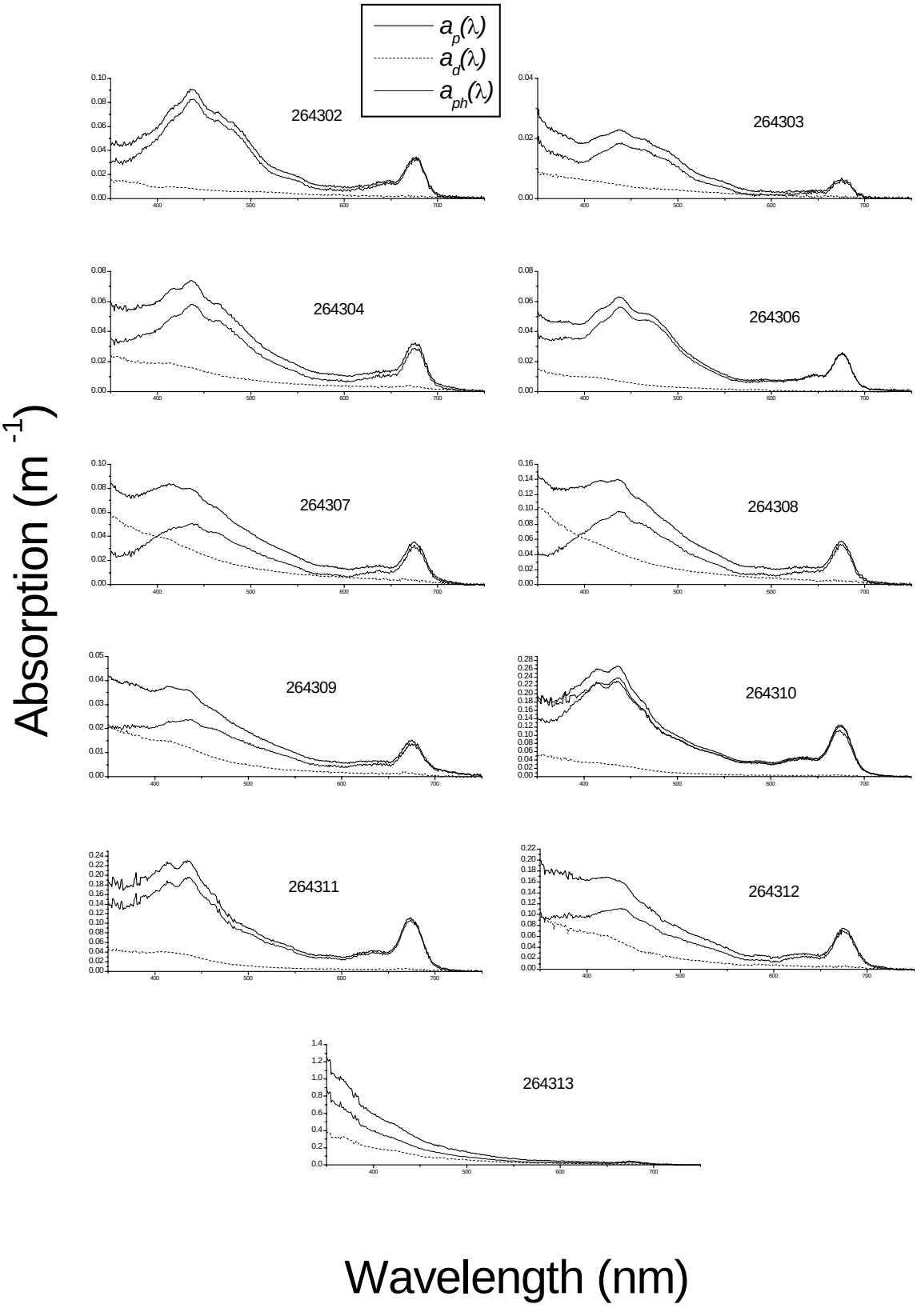

Figure 2. Absorption coefficients of total particulate material, $a_p(\lambda)$, detritus, $a_d(\lambda)$, and phytoplankton, $a_{ph}(\lambda)$, in the samples of Leg 3.

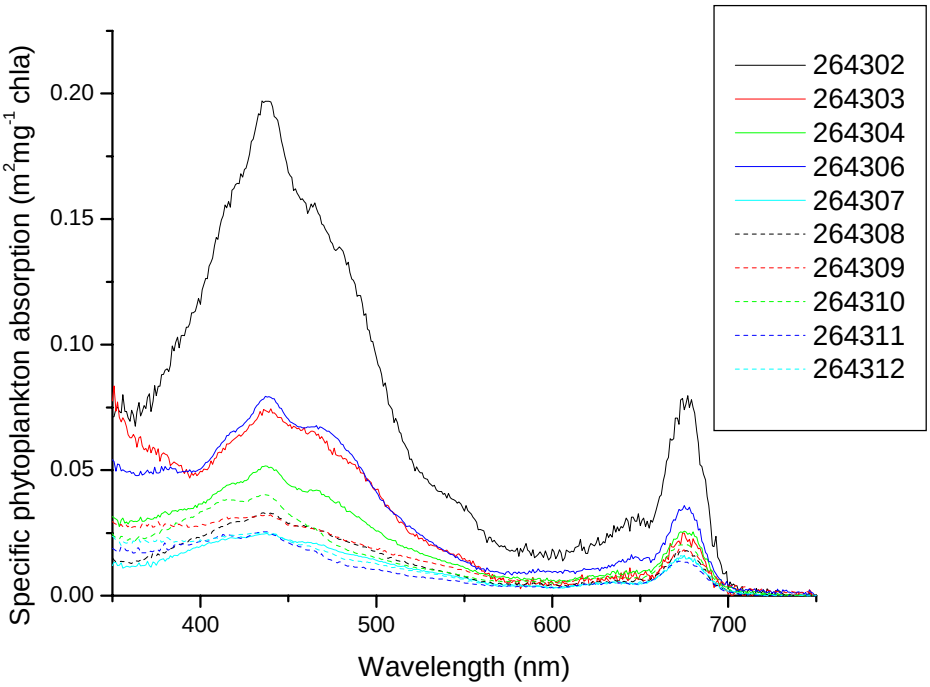

Figure 3. Specific absorption coefficient of phytoplankton, $a^*_{ph}(\lambda)$ in the samples.

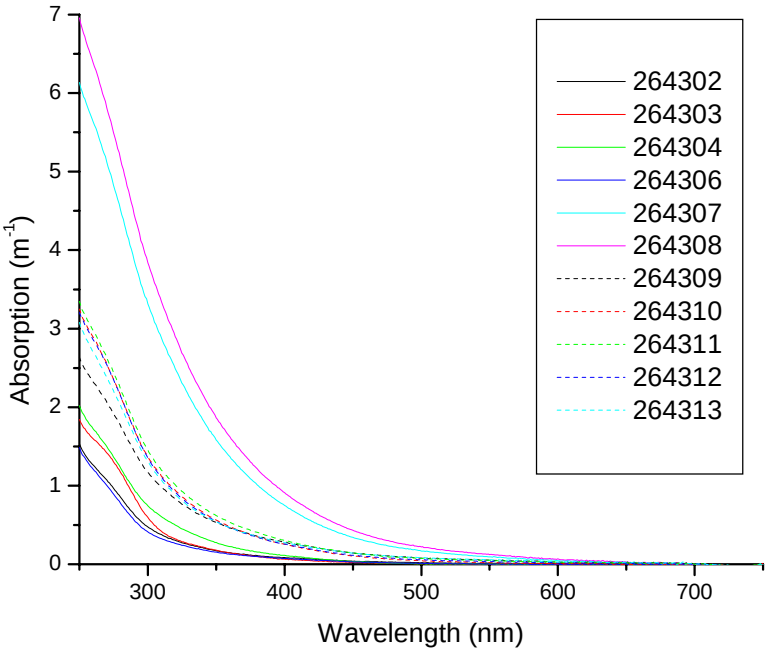

Figure 4. Absorption coefficient of CDOM, $a_y(\lambda)$ in the samples.

Although there were not many samples taken in this leg, only eleven, they showed a large variability in chlorophyll concentrations and absorption characteristics. This is because the cruise track covered a large latitudinal range, from about 36 to 53 degrees S (Figure 1). Even more, some of the samples in the North were taken (although close to the coast) in open deep waters, while others in the South were well within the Chilean Fjords and the Magellan Strait.

According to the specific absorption coefficients of phytoplankton, $a^*_{ph}(\lambda)$ (Figure 3), and the absorption coefficients of CDOM, $a_y(\lambda)$ (Figure 4), we can make a first division of the samples into two groups. The first one includes stations in open waters (stations 1, 2, F1, and F3), and the second corresponds to stations within the channels and the strait (F4, F5, 3, F6, 4, F7, and F8).

The first group showed in general low chlorophyll concentrations (Table 1), low detritus absorption, $a_d(\lambda)$ (Figure 2), relatively high $a^*_{ph}(\lambda)$, and low $a_y(\lambda)$ typical conditions of clear waters. Station 1 on this group corresponded to the CONCEPCION time series study, and showed an extremely high $a^*_{ph}(\lambda)$, probably due to the presence of small phytoplankton (Figure 3). These cells would be less affected by the packaging effect, and probably having high concentrations of photoprotective pigments as evidenced by the sharp peak at 440 nm. Station 2, had a somewhat lower $a^*_{ph}(\lambda)$, but showed a conspicuous increase in the absorption towards the UV (Figure 3). This feature coincided with a bump around 280 nm in the $a_y(\lambda)$. This might be due to the presence of UV absorbing compounds in the phytoplankton, which could also be exuded to the water.

The second group showed in general high chlorophyll concentrations (Table 1), higher $a_d(\lambda)$ (Figure 2), low $a^*_{ph}(\lambda)$, and higher $a_y(\lambda)$ characteristic of land influenced waters. This low $a^*_{ph}(\lambda)$ may be explained by the presence of large phytoplankton more affected by the flattening effect. Stations F4 and F5, which were located inside narrow channels (Figure 1), showed extremely high $a_y(\lambda)$. This may be the result of organic matter washed by numerous narrow streams coming down from the mountains, covered by forests, and carrying water from the ice caps. Station 3 had the general characteristics of group 2. Stations within the Magellan Strait showed a marked increase in $a_d(\lambda)$ from the Pacific entrance (Stations 4 and F6), middle (Station F7), towards the Atlantic end (station F8). The extremely high values of detritus absorption at this last station impeded to filter enough volume of water to obtain a clear phytoplankton absorption signal. This clogging of the filters resulted in very long filtration times, which wouldn't have been adequate to treat samples incubated for the P&I experiments. This huge amount of thin sediment (clay- like) in the samples may have its origin in airborne dust brought by the strong winds sweeping the dry Patagonian terraces surrounding the strait at this end.

8. Acknowledgements

We would like to thank people at POGO, IOCCG and JAMSTEC for giving us the opportunity of being able to participate in this exciting BEAGLE-2003 expedition. The experience will be most useful to us in our future work. We want to thank Kathleen Peard and Bronwen Currie from Namibia, who helped us in different occasions with the sampling on board. Special thanks go to Shubbha Sathyendranath, Venetia Stuart, Tony Paysant, Marie Helene Forget, Robert Frouin and previous participants in legs 1 and 2 for their long distance support. We appreciate the collaboration received on board from Naomi Harada chief scientist, and Shuichi Watanabe and his team, as well as the captain and crew of the R/V Mirai.