



The BEAGLE Cruise in the Southern Hemisphere: Science and Oceanographic Training



The Blue Earth Global Expedition (BEAGLE*) was organized by the Japan Agency for Marine-earth Science and Technology (JAMSTEC); <http://www.jamstec.go.jp>) to commemorate its 30th anniversary. This international circumpolar cruise in the Southern Hemisphere took place on board the R/V *Mirai*, one of the world's largest research vessels. The cruise was designed to enhance marine research and research training activities in the Southern Hemisphere, in accordance with the São Paulo Declaration of the Partnership for Observation of the Global Oceans (POGO: <http://ocean-partners.org>).



Why focus on the Southern Hemisphere?

Two-thirds of the earth's oceans are in the Southern Hemisphere. This vast region is much less observed and monitored than the ocean basins of the Northern Hemisphere. Opportunities to study the Southern Hemisphere are limited by difficult access and by the concentration of financial, scientific, and technological resources in the north.

The Southern Ocean is the only ocean where water can circulate around the globe without being obstructed by the continents. The complex three-dimensional hydrography of the Southern Ocean is called the Antarctic Overturn System. Cold bottom water is formed here, feeding all other oceans. Thus, the Southern Ocean functions as an environmentally sustainable giant air conditioner, keeping all oceans cool and transferring heat to the air. The only other place where large amounts of deep ocean water are being formed is in the North Atlantic Ocean. The entire Antarctic Overturn System is again an important part of the global thermohaline conveyor belt of large current systems, connecting the waters of all four oceans at the sea surface, in intermediate water layers and along the ocean floor.



Specifications of the RV *Mirai*

Length :	130 m
Width :	19 m
Depth :	10.5 m
Draft :	6.9 m
Gross Tonnage :	8,687 tons
Crew members :	34 persons
Observation Staff :	18 persons
Scientists :	28 persons



Why focus on Climate Change?

In the Southern Ocean, the water column between 100m and 700m has shown a 0.2°C warming since the start of the compilation of modern hydrographic data. Also, at the northern end of the Antarctic Overturn System in the North Pacific, the bottom water got warmer.

- Are these phenomena natural variations or are they caused by the burning of fossil fuels?
- How does the ocean take up the heat from the air and transport it to the deep?

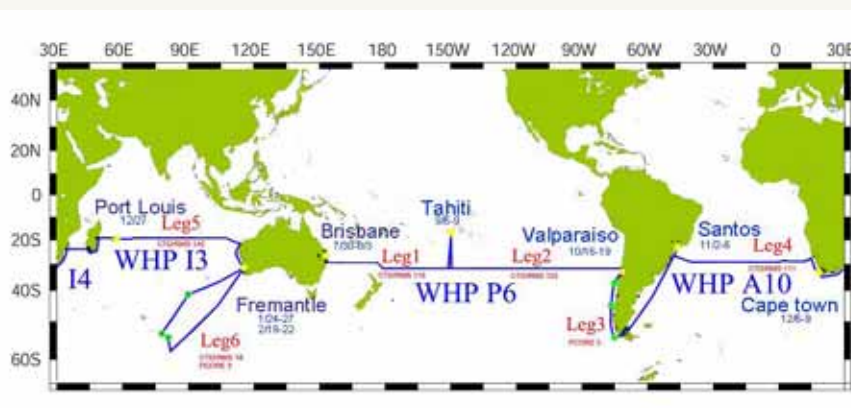
* The acronym 'BEAGLE' also refers to the name of the ship that took Charles Darwin around the world, which finally led to the foundation of evolutionary theory in his famous standard work "On the Origin of Species".

- Can we forecast the future of our marine environment with enough certainty to act in a timely and sensible manner?

These questions urgently need answers and the BEAGLE Cruise was set-up to make a significant contribution

What were the Scientific Objectives of the BEAGLE Cruise?

- To study the changes in the temperature of the surface and the deep waters of the Antarctic Overturn System through high-quality observations along the lines of the Hydrographic Programme of the World Ocean Circulation Experiment (WOCE).
- To estimate the amount of anthropogenic carbon dioxide (CO₂) taken up by the surface ocean and its transport to the deep sea. CO₂ can be taken up by the sea in two ways: by cold surface water sinking down, *the physical pump*, and by the growth and subsequent decay of algae, *the biological pump*.
- To characterize the bio-optical properties of phytoplankton along the BEAGLE track. Such measurements are needed for large-scale computations of primary production and also to improve the interpretation of ocean colour data from satellites.



Tracks of the six legs BEAGLE Cruise.

- To investigate historical changes in:
 - (a) The transport rates of carbon from the sea surface to the deep ocean by means of sinking debris from the biological production of the food-web in the photic zone (biological pump). Currently, the high latitudes of the Indian Ocean show high biological productivity for an open ocean environment.
 - (b) The sea-surface temperature.
 - (c) The ventilation rate of the intermediate water since the last interglacial period.
 - (d) The release of carbon dioxide from the sea surface with changes in the expansion of Antarctic sea ice.

For more information on the geological programme, please contact Dr. Naomi Harada of JAMSTEC (haradan@jamstec.go.jp), or Dr. Carina Lange of COPAS and the University of Concepción (clange@udec.cl).

What was Measured?

Water temperature, salinity, oxygen, carbon dioxide, nutrients, and other chemicals were measured at 493 stations from sea surface to the bottom. Phytoplankton concentrations, optical properties and photosynthetic rates were measured in the surface layer. More than 80 Argo floats were launched along the cruise track. Sea birds were counted daily at the stations during the entire cruise, since birds tend to flock where the food is. For the geological programme, sediment cores were collected with piston-, gravity-, and multi-core equipment during leg 3 on the Chilean continental margin and Magellan Strait and during leg 6 in the Indian Ocean.



What Were the Key Scientific Results?



IOCCG
International Ocean Colour Coordinating Group

Physical Oceanography Programme

All temperature and salinity data measured during the BEAGLE cruise were compared to the data of the WOCE cruises between 1992 and 1995. As an average over the entire BEAGLE cruise track, sea water temperature increased by 0.036°C, even within the water column below 0.5 km depth, where no seasonal influence is expected. The temperature of the Lower Circumpolar Deep Water increased by 0.012°C in the Southern Pacific, although the mean temperature of this water mass is only 0.7 – 0.8°C. On the other hand, Antarctic Intermediate water above this layer had become cooler by 0.01°C in the eastern portion of the Southern Pacific. At the same time, the salinity of this water layer had decreased with 0.02×10^{-3} . Although these temperature differences appear small at first sight, the amount of energy involved is large, because of the vast water volumes involved. To heat the entire water volume by the observed 0.036°C would take 1×10^{12} tons of oil, or the equivalent of 3,000,000 of the world's largest tanker vessels of 300,000 tons, even for the water mass between the BEAGLE track and the Antarctic continent.



The volume of the entire Antarctic Overturn System was estimated to have shrunk by 10 per cent to 40×10^6 m³/sec. Detailed data analysis is still ongoing. For more information on the physical aspects of the BEAGLE cruise, contact Dr. Masao Fukasawa of JAMSTEC (fksw@jamstec.go.jp).

Biological Oceanography Programme

A unique dataset over a large ocean area has been collected during the BEAGLE cruise with standardized methods for the calibration of satellite data on ocean colour (i.e. the plant pigment chlorophyll a), using a suite of shipboard measurements on phytoplankton.

A major new insight is that the same processes that determine the concentrations and distribution of phytoplankton species over the vertical water column at a single geographical location are also responsible for differences in plankton physiology, ecology and genetics between entire ocean basins (see also Bouman, H.A. et al., *Science* 312, pp. 918-921 (2006)).

For more information on the biological aspects of the BEAGLE cruise, please contact Dr. Heather Bouman (heather@profc.udec.cl) or Dr. Trevor Platt (tplatt@dal.ca).

Why a Training Programme on BEAGLE Cruise?

It is of extreme importance that young and promising marine scientists are educated now.

Three trainees were accommodated on each leg of the cruise. Accordingly, POGO, the International Ocean Colour Coordinating Group, IOCCG: <http://www.ioccg.org>, and the Intergovernmental Oceanographic Commission, IOC: <http://ioc.unesco.org>, awarded a number of scholarships for young scientists to participate and to receive hands-on training on board the RV *Mirai*. All on-board expenses and berth fees for the trainees and bio-optical specialists were covered by JAMSTEC.

Milton Kampel, a trainee from INPE in Brazil says in his cruise report: "I believe that the hands-on training on bio-optical measurements received onboard the RV *Mirai* would permit further enhancements of the research activities when we share our experiences from the cruise with other colleagues. I have no doubts that the primary production experiments and bio-optical data collected during the cruise will provide an invaluable database for the under-sampled Southern Ocean. Our results will contribute to the validation of ocean-colour satellite-images from different sensors and to assist in the development of regional algorithms for remote sensing estimates of phytoplankton standing stocks and primary production. I also believe that the training received onboard is very helpful for our understanding of the relationships between the variability in physical oceanographical parameters and ecosystem changes in the Southern Ocean."



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More information: <http://ocean-partners.org>



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