National Oceanography Centre, Southampton

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First Annual Report on the SNOMS Project

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2008

SNOMS - (SWIRE NOCS Ocean Monitoring System)
The Swire Group and the National Oceanography Centre, University of Southampton working together to examine the role of the oceans in limiting the build up of carbon dioxide in the atmosphere

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ABSTRACT

In 2006 the Swire Group Charitable Trust funded the development and installation of a system to measure the partial pressure of carbon dioxide dissolved in the surface ocean from one of the Swire Group's ships. The system was fitted on the MV *Pacific Celebes* in June 2007. The *Celebes* trades on a global route out of Singapore. It takes about 5 months to go round the world. Measurements are made of the partial pressure of carbon dioxide in seawater and air, also of water temperature, salinity, dissolved oxygen and nitrogen, air temperature, pressure and humidity. Data are collected automatically on the ship and then transmitted to shore where they are transferred to a public web page. The data are vital to enabling the prediction of change in the ocean's ability to absorb carbon dioxide and hence the rate of climate change induced by anthropogenic release of carbon dioxide.

Key observations to date are: (1) potentially high inputs of gasses into the ocean during sustained storm conditions, (2) a substantial natural flux of carbon dioxide into the atmosphere of the western equatorial Pacific under the 'La Nina' conditions of 2007, (3) the potential of the western North Atlantic to absorb more carbon dioxide in autumn than previously predicted.

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KEYWORDS
air water exchanges, climatic changes, data acquisition, gas exchange, internet, ocean atmosphere system, *Pacific Celebes*, seasonal variations, Ships of Opportunity, SNOMS

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MV Pacific Celebes off Thailand May 2007

The Swire Group recognises that global warming is the most significant environmental problem facing mankind and is committed to assisting initiatives to tackle climate change. The Swire Group Charitable Trust is supporting the UK National Oceanography Centre (NOC), University of Southampton to improve monitoring of the changing content of carbon dioxide in the surface of the world's oceans. Equipment is fitted on the Swire ship MV Pacific Celebes and provides data from around the globe.

Global trading route of the MV Pacific Celebes

National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

SWIRE TRUST

Foreword

By absorbing carbon dioxide, the oceans play a major role in controlling the rate at which carbon dioxide from man's activities is accumulating in the atmosphere. If we are to accurately predict future changes in the atmospheric concentration of carbon dioxide and thence climate change, it is essential that we develop a better knowledge of what is happening in the oceans now. To aid the international effort towards this goal the SNOMS project was developed. (SNOMS - SWIRE NOCS Ocean Monitoring System)

In 2006, The Swire Group Charitable Trust initiated funding of the design and assembly of a system to measure the carbon dioxide content of the surface ocean and atmosphere from a ship belonging to the Swire Group. In June 2007 a system was in installed on the MV Pacific Celebes. Data from the system supports on-going projects at NOC and elsewhere including the IOCPP (International Ocean Carbon Coordination Project). Swire recognises that global warming is the most significant environmental problem and is committed to supporting climate change initiatives.

SWIRE: The Swire Group is a multinational, multi-disciplined commercial group, with interests spanning four continents. Its principal areas of operation are in Asia, and the Pacific Rim. Founded in Liverpool, England in 1816, the Group's privately owned parent company, John Swire & Sons Limited, is headquartered in London. The Swire Group's core businesses in Hong Kong are held by the publicly quoted Swire Pacific Ltd.

NOCS: The United Kingdom's National Oceanographic Centre, University of Southampton is one of the world's leading centres for research on the role of the oceans in controlling the climate of the Earth.

Summary

In 2006 the Swire Group Charitable Trust funded the development and installation of a system to measure the partial pressure of carbon dioxide dissolved in the surface ocean from one of the Swire Group's ships. These data are needed to improve our ability to predict change in the ocean's ability to absorb carbon dioxide and hence the rate of climate change induced by anthropogenic release of carbon dioxide. Data from the Swire ship supports the work at NOC and the University of Southampton and the national activities of the CASIX project, the European CarboOcean project and the international IOCPP International Ocean Carbon Coordination Project

The system was fitted on the MV Pacific Celebes in June 2007. This report describes the requirements of such a system and how it was implemented. The Celebes trades on a global route out of Singapore. It takes about 5 months to go round the world. Measurements are made of the partial pressure of carbon dioxide in seawater and air, also of water temperature, salinity, dissolved oxygen and nitrogen, air temperature, pressure and humidity. Data are collected automatically on the ship and then transmitted to shore where they are transferred to a public web page.

Even at this early stage the work from the Pacific Celebes can already be seen to be making a contribution to improving our knowledge of the role of different areas of the ocean in controlling the atmospheric concentration of carbon dioxide.

In spring 2007 trials of the system were carried out on the P&O ferry the MV Pride of Bilbao between Portsmouth and Bilbao. The measurements of concentrations of nitrogen showed that sustained winter storms can increase the saturation of dissolved nitrogen to levels only previously observed during hurricane conditions. The combination of systems used in this work* demonstrated the real progress that is now being made towards achieving linkage between new pre-operational and operational ocean monitoring techniques and technologies.

The western equatorial Pacific experienced a "La Nina" year in 2007. Large quantities of carbon dioxide rich cold water came to the surface off South America and were then transported east along the equator in the equatorial currents. The Celebes crossed this plume of cold water in July and collected data that shows for the first time that a large natural release of carbon dioxide occurs from the 600-mile wide plume. The concentration of carbon dioxide in the air above the plume was changed significantly by the release.

Data collected in the western Atlantic in September show that due to biological activity waters to the west of 40 ^{o}W have a greater potential for absorbing carbon dioxide than the

presently available maps of ocean carbon dioxide would suggest. That such differences are seen is not surprising because the maps are based on very sparse data sets.

D J. Hydes, M C Hartman, C P Bargeron, J M Campbell, MS Curé, and D K Woolf (2008) A study of gas exchange during the transition from deep winter mixing to spring bloom (2007) in the Bay of Biscay measured by continuous observation from a ship of opportunity. Paper to be published in the Journal of Operational Oceanography and presented at the Oceanology International Conference, London 12 March 2008

Introduction

Scope of the project

- The (SNOMS) system measures carbon dioxide and other essential parameters in surface seawater and the atmosphere. It was designed and built by NOC and fitted to the MV Pacific Celebes.
- Measurements are transmitted ashore in real time. They are quality controlled and made publicly and freely available using a web based data portal.
- Exploitation and scientific interpretation of the data is carried out in existing UK national and international research programmes.

Benefits to the Planet

- To manage the planet we need to know how rapidly change is taking place and to be able to distinguish permanent changes from natural oscillations.
- Well validated calculations are required to guide improved amelioration strategies.
- An improved data-base is essential for improving the accuracy of computer models accounting carbon budgets and predicting change. Without sufficient data these models cannot be tested or calibrated.
- Knowledge of how much carbon dioxide is going into the oceans and how acid the oceans are becoming is essential for the assessment of the impact on sensitive ecosystems such as corals.

Time frame required

- Long term monitoring is needed to separate out the long-term (climate) change from the noise in the earth's systems (weather). Many weather related cycles have time scales of 5-10 years so monitoring must look to decadal time scales.

Stakeholders who benefit from the SNOMS project

- Information from SNOMS is provided to an existing network of international projects and organisations linked to the United Nations either through UNESCO or the World Meteorological Organisation.
- SNOMS contributes to the UNESCO-International Ocean Commission - International Ocean Carbon Coordination Project (IOCCP) and the European Union's 6th Science Framework project CarboOcean.
- Use of the data in numerical models is linked to the WMO's World Climate Research Programme's (WCRP) project CLIVAR (Climate Variability and Predictability) and CASIX in the UK (NERC Centre for observation of Air-Sea Interactions & fluXes).

Benefits of the data collection and monitoring

- In many areas of the world's ocean measurements of carbon dioxide have not yet been made. Extending the marine carbon dioxide system data-base is crucial to aid improved accounting of the Earth's carbon budget.
- Data are needed to (i) determine regional differences (ii) understand the interaction of biogeochemical and physical processes (iii) validate numerical models (iv) provide input to forecast models.
- SNOMS makes a significant contribution to the existing data collecting network.

Ship of Opportunity Carbonate system measurements

The need for more observations

The oceans play a major role in reducing the rate of "warming*" of the Earth is due to increases in the atmospheric concentration of CO2. A number of recent publications in 2007 suggest that the Earth's ability to re-absorb CO2 injected into the atmosphere by man is both less than expected and slowing down (e.g. Canadell et al., 2007, Le Quere et al., 2007, Schuster and Watson, 2007). However the information base we have for clearly identifying why this is, is inadequate.

This is because although the inorganic chemistry of CO2 dissolution in seawater (at different concentrations of CO2, salinity and temperature) is well known, what happens in practice depends on for example :- (1) how rapidly the surface waters of the oceans are being renewed from the depths with water that has not been exposed to modern day levels of CO2, and (2) how effective the life and death cycle of plankton is at removing CO2 by photosynthesis into material that then sinks into the depths of the oceans taking carbon with it.

Sufficient data exists for us to be able to identify some but not all of the key regions of interest on the globe, for example high-latitude oceans are key sinks for atmospheric CO2. But little data exists in most shallow shelf seas and it is uncertain what role they play.

These processes can be reproduced in numerical models that are being developed to predict the future of the planet. However too few observations of the real world are available to both properly calibrate the equations used in these models and to test their findings.

(* *"warming" – here means more energy is being retained in the atmosphere*)

References

Canadell, J.G., C.L. Quere, M.R. Raupach, C.B. Field, E.T. Buitehuis, P. Ciais, T.J. Conway, N.P. Gillett, R.A. Houghton, and G. Marland, Contributions to accelerating atmospheric CO2 growth from economic activity, carbon intensity, and efficiency of natural sinks, Proc. Natl. Acad. Sci. USA, doi 10.1073, 2007.

Le Quere, C., C. Rodenbeck, E.T. Buitenhuis, T.J. Conway, R. Langenfelds, A. Gomez, C. Labuschagne, M. Ramonet, T. Nakazawa, N. Metzl, N. Gillett, and M. Heimann, Saturation of the Southern Ocean CO2 sink due to recent climate change, Science, 316 (5832), 1735-1738, 2007.

Schuster, U., and A.J. Watson, A variable and decreasing sink for atmospheric CO2 in the North Atlantic, J. Geophysical Res., in press, 2007

Meeting the requirement for increased observations

In response to this need for more coverage the International Oceanographic Commission, established the International Ocean Carbon Coordination Project (IOCCP) in 2003. A part of the project is the use of ships of opportunity. By installing equipment on commercial vessels the scientific community is able to collect systematic data over relatively long distances and periods of time that would be impossible to achieve using research vessels (and in conditions in which research vessels which are relatively small would not be able to operate). Modern measuring devices can be left unattended and data logging and satellite based communication systems can transfer the collected information to the scientists running the systems in real time for immediate use.

Important components of a successful contribution to the IOCCP

Any system dedicated to the collection of scientific data should provide for:-

a. the purchase and installation of sensor systems
b. equipment maintenance, calibration, repairs and (where necessary) replacements
c. quality control and data management
d. data dissemination
e. scientific analysis and interpretation,
f. promotion of public awareness

In the SNOMS project NOC and the Swire Group have worked together to implement all these requirements.

The SNOMS Project

Requirements

Measurements of the concentration of CO2 in surface seawater need to be supported by measurements of the water temperature and salinity, so the partial pressure of CO2 in the water can be calculated. If the partial pressure of a gas is greater in air than in sea water it will dissolve in the sea. The rate of exchange is determined by the size of the difference and the wind speed. When measurements are also made of both dissolved oxygen and nitrogen changes due to physical processes can be distinguished from those due to biological ones. The measurements of oxygen show the amounts of biological production and respiration taking place. Both processes remove and add CO2 to the system in a known ratio to the change in concentration of oxygen. The concentration of nitrogen is dependent solely upon physical processes.

The measurements need to be collected by a logging system which also collects navigational (GPS position) data. The logged data must to sent to shore. On shore it must be quality controlled and made available to interested parties.

After the system has been installed members of the ship's crew need to be trained to carryout physical maintenance of the equipment.

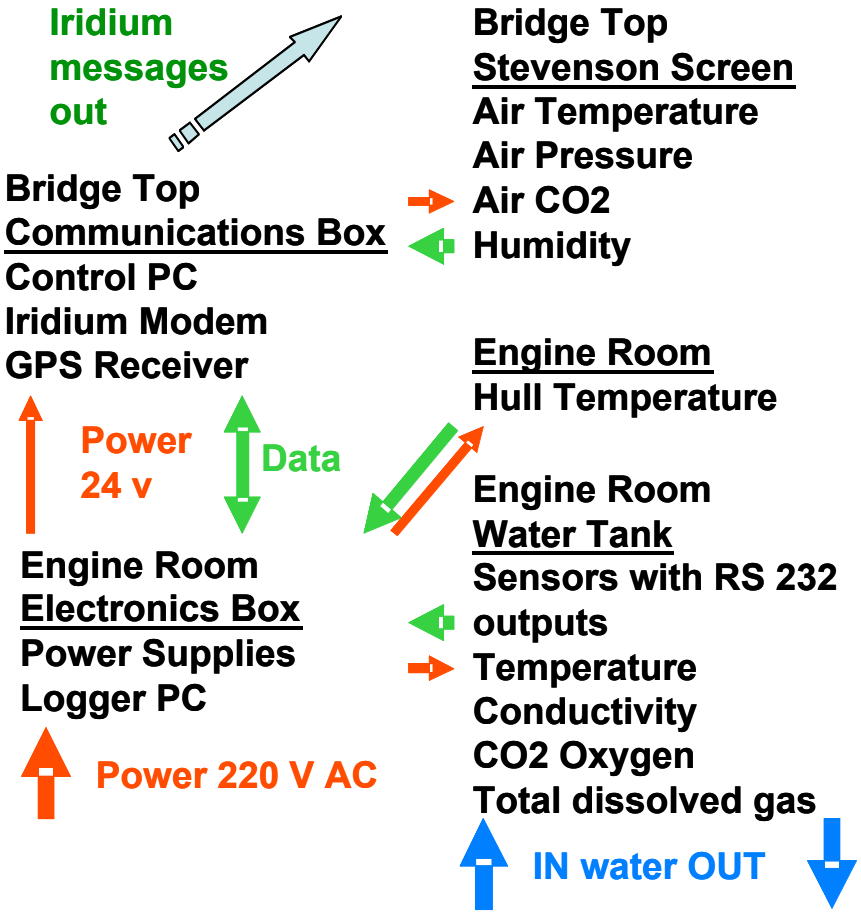
The installed system

In Singapore and Jakarta, in June 2007, NOC installed the first SNOMS system on the Swire ship the MV Pacific Celebes. (A diary of the development process from design to fitting out of the ship is presented later - see page 23.)

The 4 main scientific instrument packages and control units aboard the Pacific Celebes are :-

1. In the (engine room) machinery space a stainless steel tank connected to the ships pumped seawater supply containing measuring devices for dissolved carbon dioxide and oxygen, total dissolved gas pressure, temperature and conductivity.
2. In the machinery space an electronics cabinet containing the main data logging, control computer and DC power supplies. This is connected to the instruments in the tank, a temperature sensor mounted on the hull and to equipment on the Monkey Island.
3. On the Monkey Island a Stevenson screen box containing sensors measuring humidity, air temperature and pressure and atmospheric carbon dioxide content.
4. On the Monkey Island an electronics cabinet containing an Iridium satellite communications modem, two GPS receivers and a data logger.

The arrangement of these units is shown diagrammatically on the next page



Schematic diagram of the installed system

The following more detailed reports on the system can be down loaded as PDF files from Southampton University's e-prints website.

Hydes, D.J. and Campbell, J.M. (2007) Report on the SNOMS Swire NOCS Ocean Monitoring System. System description and inventory for the MV Pacific Celebes system fitted June 2007. Southampton, UK, National Oceanography Centre Southampton, 15pp. (National Oceanography Centre Southampton Internal Document, 8)
http://eprints.soton.ac.uk/48809/

Hydes, D.J. and Campbell, J.M. (2007) Report on the SNOMS Swire NOCS Ocean Monitoring System. Maintenance and underway sampling protocols and safety information for the MV Pacific Celebes system fitted June 2007. Southampton, UK, National Oceanography Centre Southampton, 27pp. (National Oceanography Centre Southampton Internal Document, 9)
http://eprints.soton.ac.uk/48810/

Hydes, D.J. and Campbell, J.M. (2007) SNOMS Swire NOCS Ocean Monitoring System: Diary of the system development and installation on the MV Pacific Celebes in 2006 and 2007. Southampton, UK, National Oceanography Centre Southampton, 22pp. (National Oceanography Centre Southampton Internal Document, 10)
http://eprints.soton.ac.uk/48812/

Machinery Space

The SNOMS tank stands 1.2 m high and weighs approximately 85 kg when empty. The tank is bolted down to a solid 10mm steel floor plate and two bracing hoops welded to the bulkhead prevent vibration. Seawater is fed into the bottom of the tank and out through the top using flexible hosing.

The lid of the tank contains 9 sensors measuring temperature, oxygen and conductivity. Suspended inside the tank are the instruments for measuring dissolved gas pressure and carbon dioxide. The crew collect calibration samples each day the ship is underway and clean the inside of the tank each time she reaches port. All the instruments are powered from the electronics cabinet, which also contains the control electronics and the computer that records the data from the sensors.

Photographs of equipment and work in the machinery space

Top Left: Electronics cabinet and sensor tank.

Top Right: Inside lid of tank showing the 9 Aanderaa sensors, 2 inner connectors to GTD and ProCO2 units.

Bottom Left Inside the tank showing the GTD (top) and the ProCO2 instruments the SBE48 temperature sensor is seen attached to the hull plate.

Bottom Left Ship's engineers being trained in collection and preservation of samples

Monkey Island Atmospheric Data Collection and Satellite communications systems

A frame has been welded to the deck above the forward port side of the bridge to hold the Stevenson Screen and Iridium/GPS communications box. The Stevenson screen contains sensors for atmospheric CO2, and air temperature pressure and humidity. The telemetry system comprises an Iridium satellite modem, two GPS receivers, control and data logging computers.

Photographs of the Monkey Island frame

Left: Monkey Island frame containing the Stevenson Screen with the communications box mounted on top.

Right: Open screen with the Vaisala GMP 343 atmospheric CO2 senor at front being pointed out.

SNOMS WebPages

The SNOMS web pages have been established to provide both effective contact to the scientific community (who make use of the data) and a wider audience.

The web pages make available the data collected by the project, show work in progress and the details of the effort that has gone into making the SNOMS project a reality.

Below is the SNOMS home page

The home page links the home web page to ten other “tabbed” pages.

Why: Why provides a brief statement of the rational for the project

Diary: Diary provides an illustrated listing of key stages in the development of the SNOMS project, taking it from the drawing board to latest activities.

Route: Route provides a map of the route and an example schedule from the first global voyage of the SNOMS system on board the MV Pacific Celebes. From this page the most up to date schedules published by Swire Shipping can be down loaded.

Partners: Partners who are located close to the route and have an immediate interest in the data are listed.

System: System provides a schematic introduction to the instrumentation that we use and links to information available on the instruments on the manufacturer’s web pages.

Graphs: Graphs provides a graphical display of the data from the sensors. All the data sent back to NOC from the Celebes via the Iridium link, from the first measurements to the latest data is shown in series of graphs.

Position: Position uses an active link to “Google Earth®” to show the position of the Celebes on its most recent circumnavigation. The starting port is Singapore. This page also shows the last set of data points received at NOC over the Iridium link. Data are transferred from the ship every 6 hours

Data: This page is still under development. It will be possible to select and down load the digital data via this page.

Links: Links provides links to activities relevant to the SNOMS project

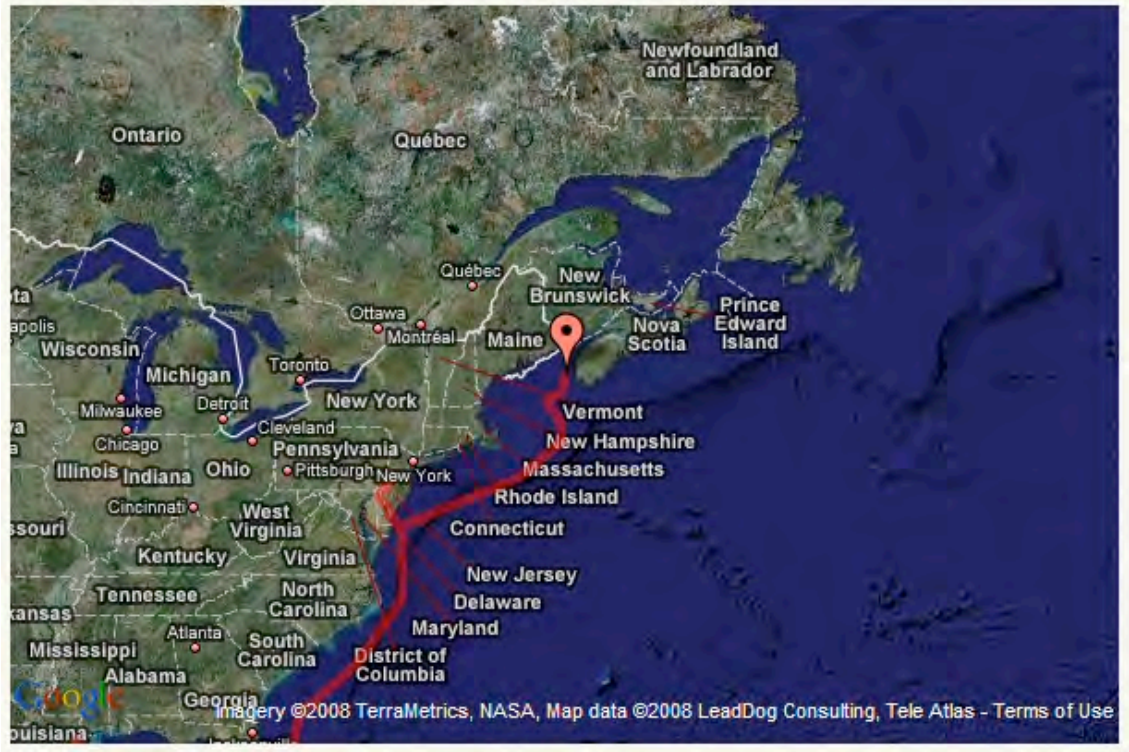
Contact: Contact provides the addresses of David Hydes and Jon Campbell - the NOC team leaders on the project.

Examples of position plots from the “Position “ tab.

Global track since leaving Singapore 20 October 2007

Progress of Pacific Celebes along eastern seaboard December 2007 January 2008.

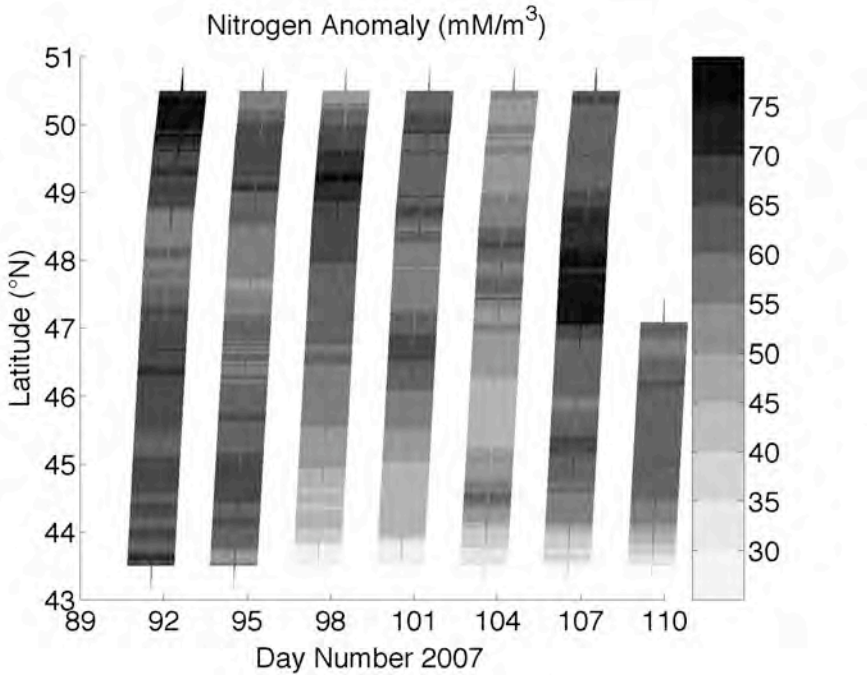
The latest position shown is off St John, Canada ,10 January 2008.



Three examples of key findings from the SNOMS system

High inputs of gasses into the ocean during sustained storm conditions

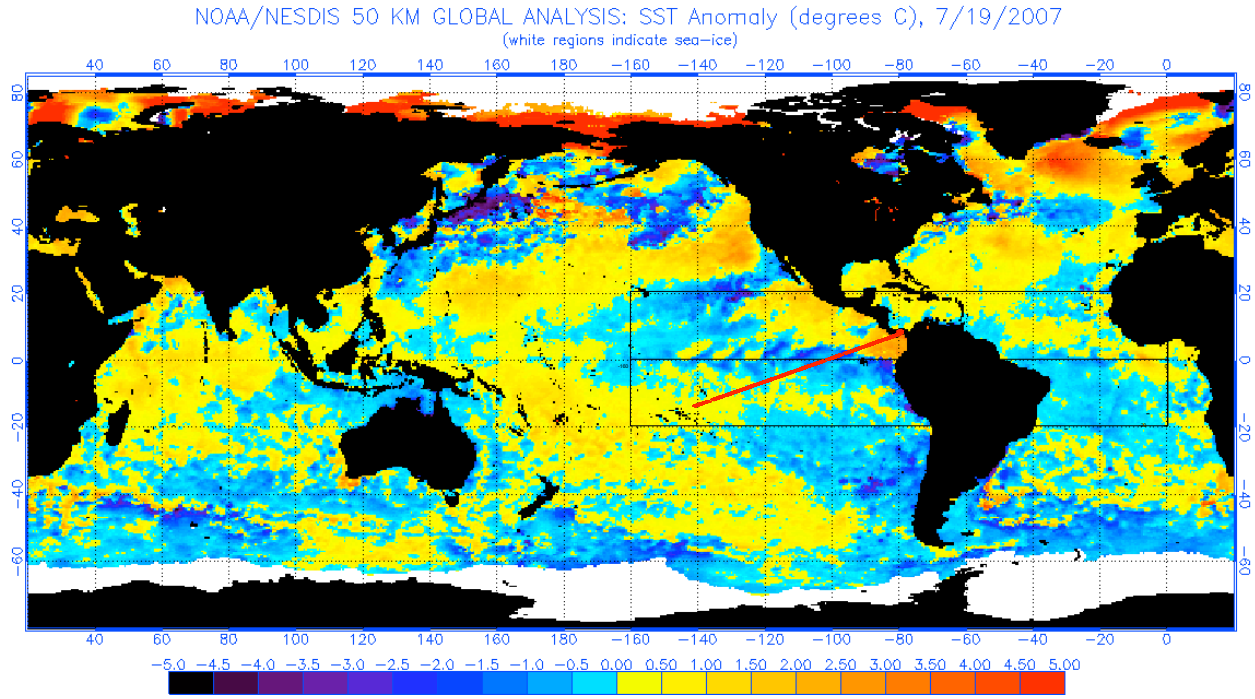
In spring 2007 trials of the system were carried out on the P&O ferry the MV Pride of Bilbao. The measurements showed that sustained winter storms can increase the saturation of dissolved nitrogen to levels only previously observed during hurricane conditions. This knowledge of gas exchange helps to improve our ability to predict how all gasses move between ocean and atmosphere under different conditions. The map below shows the nitrogen anomaly - the difference between observed concentrations of nitrogen and the saturation concentration at the temperature and salinity of the water. One data point every 30 seconds and is plotted for the 7 trips from Bilbao to Portsmouth between days 90 and 110.



Very few other such observations of the concentration of nitrogen are available.. These data provide a measure of the super saturation of dissolved gas, which can occur when bubbles of air from breaking waves are injected, up several meters below the sea surface and dissolved under pressure. This work will be published as *D J Hydes, M C Hartman, C P Bargeron, J M Campbell, MS Curé, and D K Woolf . A study of gas exchange during the transition from deep winter mixing to spring bloom (2007) in the Bay of Biscay measured by continuous observation from a ship of opportunity.* This paper demonstrates the real progress that is now being made in achieving linkage between new pre-operational and operational ocean monitoring techniques and technologies.

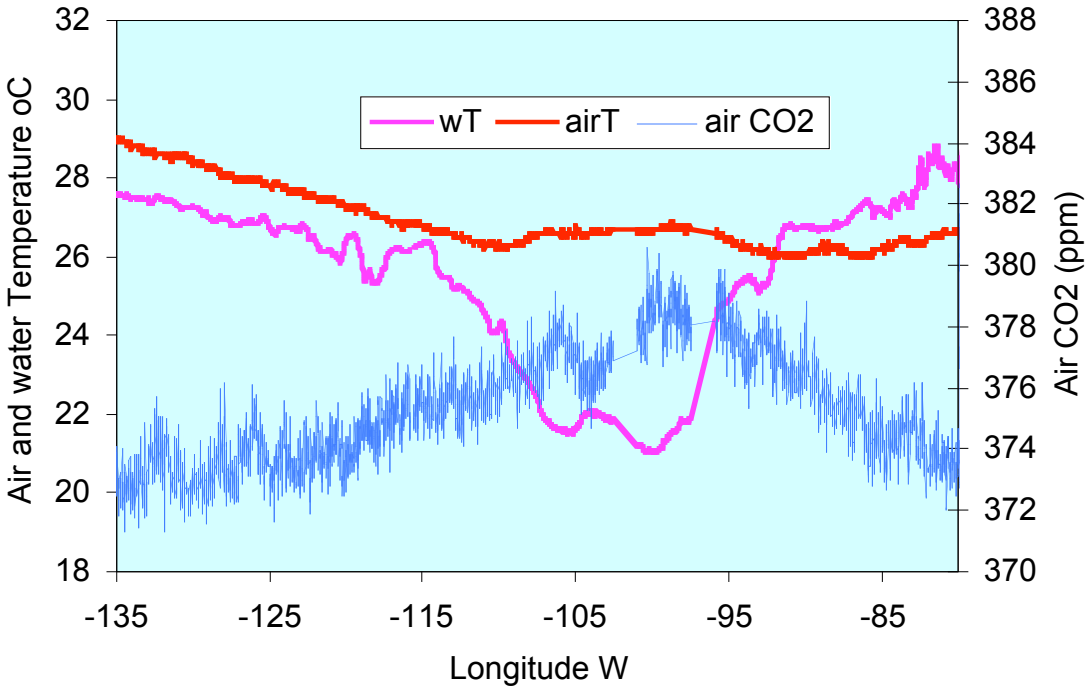
First observation of an increase in atmospheric CO2 during a La Nina event

Summer 2007 was marked by intense "La Nina" activity in the eastern tropical Pacific. This produced extensive up welling of cold water off the western seaboard of South America and an unusually intense plume of cold water which moved west along the equator. This activity fed back into the world's weather system and was one of the causes of the record levels of rain recorded in the UK in June and early July 2007. The Celebes crossed through the 600 mile wide plume of cold water between the 19 and 23 July and from 133.7 to 93.1 ^{o}W.
The picture below is an analysis of the difference between mean surface temperatures (measured by earth observing satellites) for the 5 days up to 19 July 2007 and temperatures averaged over the same period in 1985 through to 1993.



Temperature anomaly plot from the NOAA web page http://www.osdpd.noaa.gov/PSB/EPS/SST/climo.html. Red line track of MV Pacific Celebes 14 to 25 July 2007.

During this part of the voyage the SNOMS system was able to record the temperature and salinity and concentrations of total dissolved oxygen and nitrogen in the water. The atmospheric sensors for temperature humidity and CO2 were also working well.
The data for atmospheric CO2 is shown in the plot below in comparison to the data for air and water temperature. This plot clearly demonstrates that concentrations of CO2 above normal oceanic air concentrations were observed while crossing the plume of La Nina cold water.



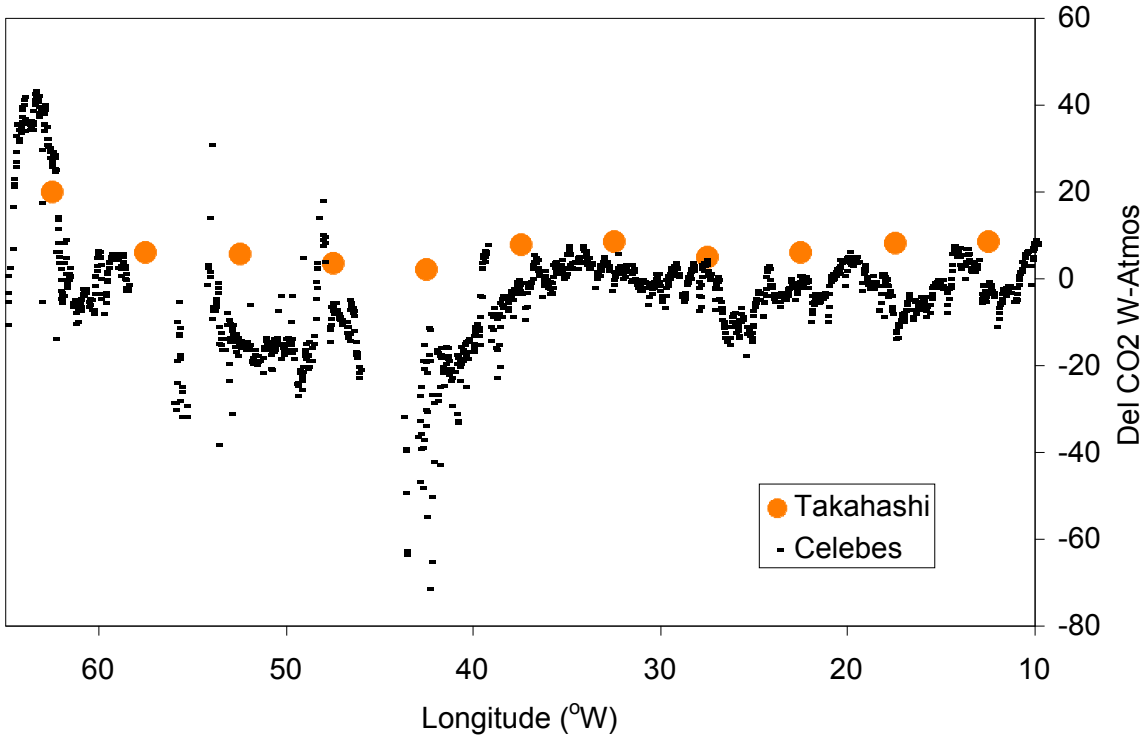
Plot of data collected by the SNOMS system crossing the La Nina plume in July 2007 on the track shown in the preceding plot.

Although the theory of the release of CO2 from the upwelling of CO2 water is well known, this is the first time that evidence has been collected that the release can at times be sufficiently intense to be detected as a change in the atmospheric concentration of CO2. Upwelling is a process by which cool water from below is advected to the surface. Typically these subsurface waters are enriched in inorganic carbon particularly off the western seaboard of South America. Newly upwelled water has a partial pressure of CO2 that is in excess of that of the atmosphere is therefore a natural source of CO2 to the atmosphere. The exchange of CO2 between ocean and atmosphere is a function of the concentration difference between the surface layer of the ocean and the atmosphere.

Observations across the Atlantic Ocean in September 2007

The ProOceanus instrument measuring the partial pressure of CO2 in seawater was refitted into the SNOMS tank when the Celebes was in St John, Canada at the end of August 2007. Between St John and arriving in Livorno, Italy we have data for the partial pressure of CO2 across the surface of the Atlantic. This can be compared to an atlas that has been produced by Taro Takahashi of the Lamont Doherty Observatory in America (and many colleagues around the world). Takashashi's work is of fundamental importance because it draws together all available observation to provide a global view of how CO2 potentially exchanges between the oceans and the atmosphere through the year. To generate this atlas the available data has had to be extrapolated into areas for which no data exist. A touchstone for new observations is to compare them with expectations based on the Takahashi's atlas.

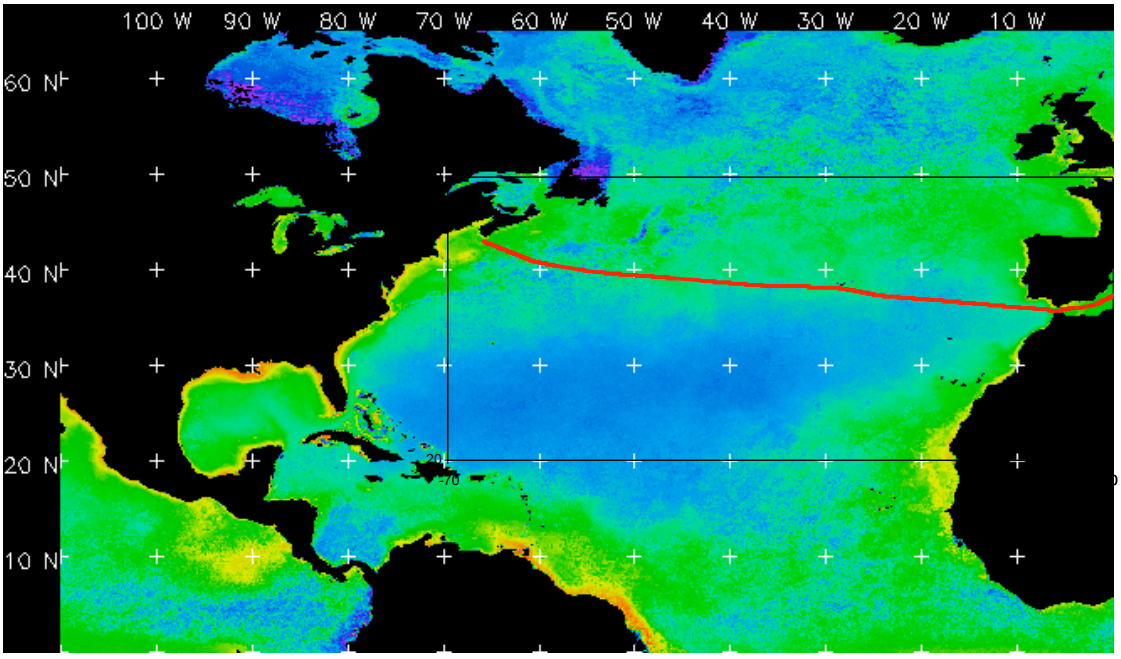
From the atlas we can extract data which has been assembled on a grid of squares 4 by 4 degrees latitude and longitude in size and fitted to a pattern of monthly change calculated to represent global conditions in a model year which is 1995. In the figure below we compared the data observed form the Pacific Celebes with data from Takahashi's atlas for the grid cells closest to the track of the Celebes.



Plot of the difference (Del CO2 W-Atmos) between the partial pressure of CO2 in the air and at the sea surface measured crossing the on the Celebes in September 2007 and the equivalent data in the climatology developed by Taro Takahashi.

East of 40 °W the figure above shows good agreement between the observations from the Celebes and what might be expected on the basis of the Taro Takahashi's climatology. Data to the west between 40 and 55 °W agrees less well. Here the partial pressure of CO2 in the water is lower than expected on the basis of the climatology. This can be explained by the likely higher biological productivity west of 40 °W suggested by estimates of biological production based on satellite measurements of ocean colour. The higher biological production would remove more CO2 from solution as it was converted into organic compounds by photosynthesis in plankton cells.

This comparison clearly demonstrates the value of new observation made from the Celebes and the limitations of the currently available best estimates.



Map of the annual relative photosynthetic production in different areas of the Atlantic Ocean derived from satellite based measurements of the colour of the surface ocean compared to the track of the Pacific Celebes in September 2007 (red line). The production map was generated by Tim Smyth of the Remote Sensing Group, PML Plymouth. The production map follows Sathyendranath S., Longhurst, A.R., Caverhill, C.M. and T. Platt 1995- Regionally and seasonally differentiated primary production in the North Atlantic. Deep-Sea Research ***42****: 1773-1802. http://www.ioccg.org/software/Ocean_Production/index.html*

Diary of the system development and installation

March 2006

A contract was signed between NOC and the Swire Group Charitable Trust for the development of an OceanBox system for the scientific study of ocean concentrations of carbon dioxide, making use of a China Navigation Company ship as a scientific platform. The acronym SNOMS was chosen representing **S**wire **N**OCS **O**cean **M**onitoring **S**ystem.

Procurement and assembly of the SNOMS system

March & April

Final specification of the instruments to be used was completed and an order was placed with ProOceanus in Canada for instruments to measure total dissolved gas pressure and the dissolved concentration of carbon dioxide. The instruments for measuring conductivity, temperature and concentration of dissolved oxygen were ordered from Aanderaa in Norway.

May

A conversation with John Grace from Edinburgh University alerted David to the existence of the Vaisala GMP343 sensor for atmospheric CO2. The design of the SNOMS system was extended so that atmospheric concentrations of CO2 could be monitored using this device. The GMP343 is used along with sensors for air temperature, pressure and humidity.

June

David Hydes and Jon Campbell visited tSingapore to see the MV Pacific Celebes (then called the Indotrans Celebes) to arrange the installation of the Ocean Box later in the year. David and Jon worked with Francis Cheung the technical manager for the Pacific Celebes and the ship's engineers to work out the optimum position for the equipment and to arrange the necessary fitting out and cables runs.

Group photograph on the bridge wing of the Celebes of David and Jon with the Ship's Captain, Chief Engineer and Technical Manager, from left to right David, Valeri, Jon, Norman and Francis.

July

David worked with Peter Stephenson at NOC on a design for a flow-through tank that would house all the sensing devices, and that could be opened easily for cleaning. A number of possible manufacturers were contacted to discuss a final design

July & August

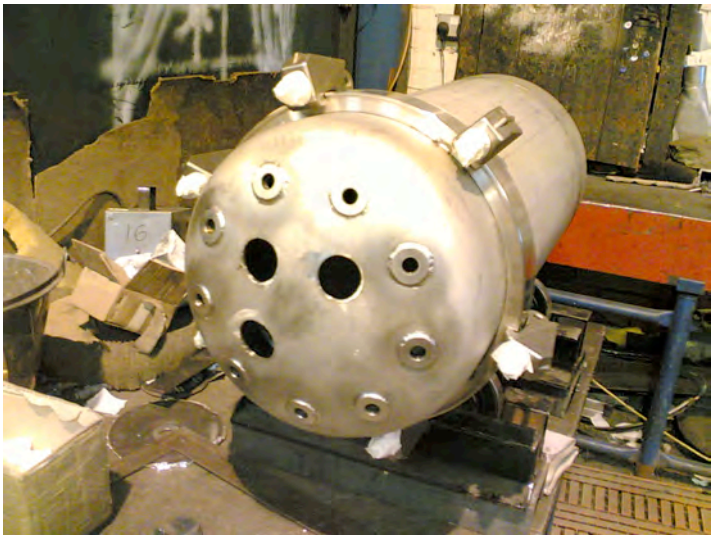
The instruments to be used in the system from Aanderaa in Norway, ProOceanus in Canada and Vaisala in Finland were delivered to NOC.

August

The final design of the water flow through system to hold the instruments was completed and an order was placed with Abbfab Services, Bolton UK.

September

Work on tank was well underway at Abbfab Services



The SNOMS tank on the work bench at Abbfab on 19 September 2007

The SNOMS tank nearing completion at Abbfab services 21 September 2007

October

The SNOMS tank arrived at NOC and was pressure tested with the external fittings that would be used in the full SNOMS OceanBox system on the Pacific Celebes.

The SNOMS tank under leak testing at NOC

Tests of the system at NOC and on the Pride if Bilbao in 2006

October

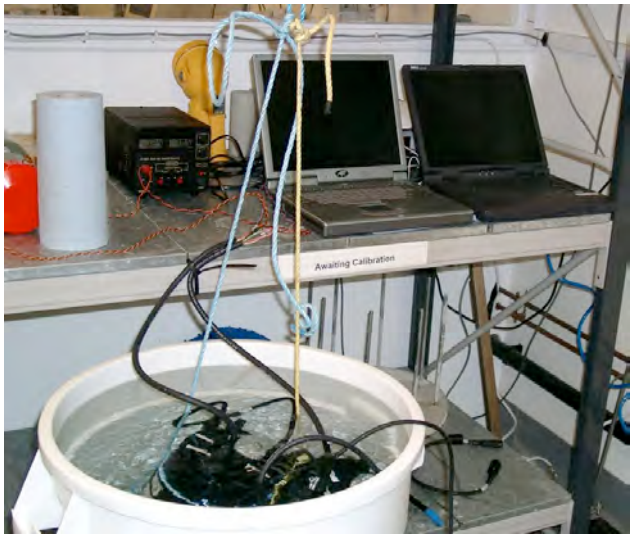
Calibration of the Aanderaa sensors in-situ on the SNOMS tank was carried out working with the NOC Calibration Facility.

The Aanderaa sensors for temperature, conductivity and dissolved oxygen newly fitted into the lid of the SNOMS tank

Dave Childs collects a sample to of the seawater being pumped through the tank so he can measure its salinity to compare with the output from the Aanderaa sensors

October

Laboratory tests of the performance of the two ProOceanus ProCO2 units were carried out.



The two ProCO2 units were suspended in a large tubs of continuously aerated seawater and the output logged over several days.

November

The plan in June had been to fit out the Celebes in Singapore in the autumn. The delayed design and delivery of the tank prevented this ambitious plan happening and encouraged a more detailed set of evaluations to be carried out.

On 23 November the first field tests of the SNOMS OceanBox were done on the P&O ferry the MV Pride of Bilbao. [NOC has been working with P&O and the Pride of Bilbao since 2002.] David Hydes sailed with the system to collect an extensive set of calibration samples during the 3 day round trip between Portsmouth and Bilbao back to Portsmouth.

SNOMS OceanBox tank and electronic cabinet in the forward pump room of the P&O Pride of Bilbao 23 November 2006

The ProOceanus ProCO2 unit being lowered into the SNOMS tank prior to the test cruise on the Pride of Bilbao.

December

At this stage fitting out of the Celebes had been seen as being in Houston in January.

The results from the tests on the Pride of Bilbao indicated that some modification might improve the system. The enclosed design of the ProCO2 unit's manifold made it difficult to be sure how clean the surfaces of the exchange membrane were. In discussion with Bruce Johnston of ProOceanus an idea for more open design was developed. The unit used on the Pride of Bilbao was then returned to Halifax for it to be modified. It was therefore decided to delay fitting out of the Celebes until after a test of at least two months duration had been conducted on the Pride of Bilbao. This was considered necessary to check the stability of the sensors and how effectively they could be maintained in a clean condition. The date of fitting out was now moved to May when the Celebes would return to Singapore after being refitted in Thailand.

December

David Hydes and Charlie Bargeron attended the 2nd CarboOcean Annual Science meeting on Gran Canaria, and presented a poster that showed some of the results from the trial of the OceanBox tank on the Pride of Bilbao in November.

2007

Tests on the Pride of Bilbao in 2007

February

2/2/07 The SNOMS OceanBox tank and electronics control unit were fitted in the P&O Ferries MV Pride of Bilbao along with the standard FerryBox system. The GTD was not fitted at this stage as corrosion round the membrane retaining plate was found when the plenum chamber was removed. The GTD was shipped to Canada for repair.

On 5/2/07 the Pride of Bilbao sailed on its first crossing after refit.

23/2/07 the system was cleaned for the first time (due to logistics problems including the weather severely delaying the ship's arrival in Portsmouth). The SNOMS tank was found to be very muddy (see photograph below). The levels of sediment collecting in the FerryBox units was higher than seen at any time in the proceeding four years due to stirring up of bottom sediments by the very stormy condition experienced in 2007 up to mid April. The mud did not attach to surfaces and cleaned off easily.

Before cleaning photograph showing the high levels of sediment contamination experienced in 2007

March

Comparison of the data from the ProCO2 SNOMS system and the equilibrator CO2 system showed that the two data sets agreed well immediately after cleaning. On 9/3/07 before the system was cleaned the amount of respiration taking place in the mud in the tank was looked at by turning off the flow through the tank. Turning the flow off for 30 minutes resulted in an xCO2 increase from 600 to 1200 ppm and a decrease in oxygen from 290 to 210 micro mole/L.

The system stopped receiving data from the ProCO2 during these tests. It didn't prove possible to diagnose the fault on board Pride of Bilbao. On 23/3/07 ProCO2 and SNOMS logger were removed from ship for tests at NOC. The fault was found to be a loose connection and chip inside the ProCO2.

Interior of OceanBox tank after cleaning. Tank contains the ProOceanus ProCO2 and GTD units. The Seabird 38 thermometer(used for comparison with the Aanderaa 4050 thermometers in the lid of the tank) can be seen at "5 o'clock".

On 30 March the complete SNOMS system with the ProCO2 unit and the repaired GTD were refitted in the tank. In addition a high accuracy Sea Bird 38 thermometer was also set up in the tank.

April

The complete SNOMS system then ran well. It was removed from the ship on 20/4/07. The system was cleaned on April 5,11 & 17th. The GTD output was found to settle faster after cleaning and refilling the tank if efforts were made to remove the air bubble that got trapped on the interface when the tank was filled. For work on the Celebes where conditions were expected to be cleaner, it was decided that the GTD should be mounted with the interface at the top (a) So bubbles would not be trapped and (b) so that it could be cleaned without the need to remove it from the tank. On 20/4/07 a blanking plug in the base of the tank began to leak and the crew turned off the system

On 20/4/07 the system is removed from the Pride of Bilbao as planned. It was returned to NOC to be cleaned and checked ready for shipping to Singapore in May.

The SNOMS OceanBox tank being winched out of the engine room of the P&O Pride of Bilbao

April

David Hydes and Charlene Bargeron attended the meeting on Surface Ocean CO2 Variability and Vulnerabilities,) April 11-14 2007 hosted by IOC/UNESCO, Paris. A report of the meeting can be found at - http://ioc.unesco.org/ioccp/LatestNews.htm#Article1

A poster was presented which introduced the work then underway on the Pride of Bilbao.

May

MV Pacific Celebes was dry docked and refitted in Thailand

The newly repainted bow of the MV Pacific Celebes before the ship left dry dock in Thailand

Stern of the Pacific Celebes showing her single screw

Installation of the SNOMS system on the MV Pacific Celebes in Singapore and Jakarta

18 May

549 kg of equipment was shipped from NOC to Singapore to meet the Pacific Celebes on its arrival

The SNOMS OceanBox Tank on its pallet prior to wrapping and shipping

Gear and bottle crates on their pallet already wrapped ready for labelling

27 May

David Hydes and Jon Campbell flew from Heathrow.

28 May

David and Jon arrived Singapore 17:15 local time, and sign on Pacific Celebes.

Location of equipment is checked out – all gear appears to have arrived in good condition.

29 May

All fittings and cabling installed on ship were checked out. Equipment was moved down into machinery space or the fitter's workshop. OceanBox tank and electronics cabinet were installed in machinery space adjacent to seawater purifier ejector pump.

30 May

Rahmon started work on the Monkey Island frame. Electrical power was wired into Machinery space electronics cabinet. Sensors were fitted into the OceanBox tank.

First view of machinery space electronics control box data screen

31 May

Completion of installation of OceanBox tank and electronics unit in machinery space

First down load of test data. Frame delivered to Monkey Island. Finishing delayed by rain

June 1

Ejector pump which provides seawater supply turned on for first time. It provides a flow >30 litres per minute and there are no significant leaks. Data from Ocean Box tank starts to be recorded. Work on the Monkey Island is completed. Stevenson Screen containing the Met sensors installed and the Iridium GPS box mounted.

Rahmon and Roberto putting the final touches to the Monkey Island frame built by Rahmon

Roberto, Rahmon, Luis and Perfecto. The fitting & wiring team

Stevenson Screen and Iridium GPS box on the frame on the Monkey Island

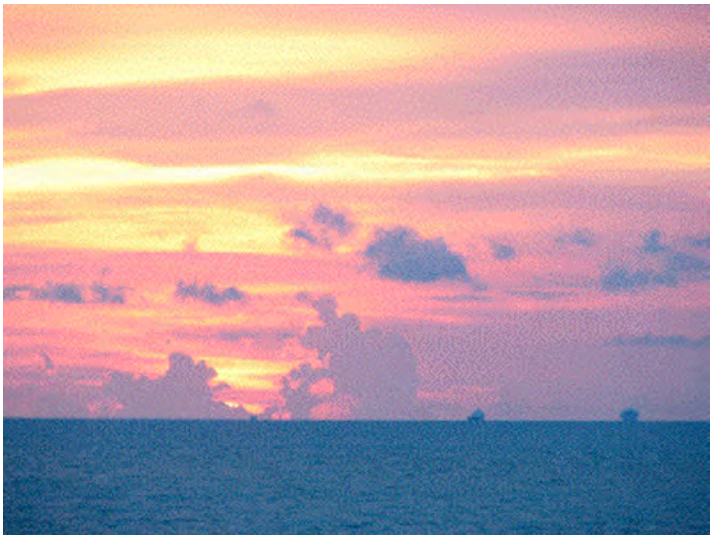
June 2

Bridge GPS checks out OK. First Iridium message sent. Photo call on bridge and Monkey Island

Jon shows Tony, Chris and Francis the contents of the Stevenson screen

Adjustments were made to the system.

Work on the training manual and the system description were underway and the first footage for training video was shot. Pacific Celebes sailed from Singapore for Jakarta.



Sunset off Singapore 2 June 2007

June 3

Data and system checking continues.

First versions of the training manual and videos for cleaning the OceanBox tank and the collection of samples completed.

The training manual containing job descriptions and risk assessments is available as NOC Internal Document No. 9 as PDF file from the University of Southampton e-print service (see page 12 for details)

The tools of the trade for cleaning the OceanBox tank

June 4

Pacific Celebes docks in Jakarta

Engineers trained in cleaning and sampling procedures

Final versions of system descriptions and training videos prepared

Tidy up and prepare box for shipping

Team photo of the OceanBox maintenance and sampling squad with their coach

A demonstration of how to use the pipette when preserving the alkalinity and Total CO2 sample that will be collected each day the ship is underway.

June 5

The SNOMS system and documentation was finished and handed over to the ship.

The SNOMS tank and electronics box in the machinery space on the Pacific Celebes

June 6

David Hydes and Jon Campbell left Jakarta on 6 June.

June 10

Chief Engineer (Chris Wilson) e-mailed to say the Pacific Celebes had sailed from Jakarta at 18:00 local time and that the ship had entered clean water and the system was restarted 12:24 GMT.

Immediate Users of the data

CASIX

CASIX is an inter UK institution partnership. UK Natural Environment Research Council funds CASIX as a NERC "Centre of Excellence". The CASIX partnership comprises: the Met Office, 3 NERC centres (NOC, Southampton, PML, Plymouth & POL, Liverpool), and 6 UK universities (U. East Anglia, U. W. Bangor, U. Plymouth, U. Leicester, U. Edinburgh, U. Reading). It has an annual budget of £523k in 2005/6, about one quarter of which funded research at NOC. CASIX will assimilate data into circulation models with coupled biology of the open ocean and shelf seas. Modelling will provide simulated fields of phytoplankton biomass, productivity and ultimately CO2 concentrations and air-sea fluxes of CO2.

Observations of actual concentration of CO2 are vital for validation of model-generated pCO2 climatologies and CO2 fluxes. The pCO2 observation data gathered in the NOC-Swire project will also be used directly in calculations of the climatology of CO2 fluxes. The climatology component of CASIX is supervised from NOC by Peter Challenor.

CarboOcean - Marine carbon sources and sinks assessment

CarboOcean is funded by the European Commission with 14.5 million € (2005-2009) within the 6th Framework Programme. It is the main task of the CarboOcean Consortium to determine the ocean's quantitative role for uptake of CO2. The CarboOcean Consortium consists of 47 international groups who started an integrated research activity on 1 January 2005. The participating countries are Belgium, Denmark, France, Germany, Iceland, Morocco, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland, United Kingdom and the USA. CarboOcean operates the SOO (Ship Of Opportunity) systems in the Atlantic Ocean contributing data to the IOCPP (see below). Data from the Celebes route crosses other CarboOcean routes in the Atlantic. This will provide a valuable resource for comparison and validation of the data collected by the different systems.

IOCPP International Ocean Carbon Coordination Project

(http://ioc.unesco.org/ioccp/) is supported by IOC and SCOR who provide financing, in-kind assistance, and stewardship for the IOCCP. IOCCP has been organized to gather information about ongoing and planned ocean carbon research and observation activities; to help optimise resources for international ocean carbon research. It promotes the integration of ocean carbon research with appropriate atmospheric and terrestrial carbon activities. IOCPP ship of opportunity activities are co-ordinated by Chris Sabine of US-NOAA and Bronte Tilbrook of CSIRO in Australia.