SNOMS STUDYING THE WORLD'S OCEANS TO PREDICT CLIMATE CHANGE

Recently an innovative partnership was established between one of the worlds major industrial groups, the Swire Group and the UK's National Oceanography Centre. The Swire Group has long taken a proactive stance on climate change issues, both in terms of measuring and attempting to mitigate the group's own carbon footprint, and also in its commitment to supporting wider initiatives that aim to tackle this problem. In 2006, the Swire Group joined forces with the UK's National Oceanography Centre, Southampton (NOCS), to launch the SNOMS (Swire NOCS Ocean Monitoring System) Project.

The Swire Group Charitable Trust has since funded the design and assembly by NOCS of a system to measure the partial pressure of CO_2 dissolved in the surface waters of the ocean. In June 2007 this monitoring equipment was installed on the Swire Shipping's vessel Pacific Celebes, which

trades out of Singapore on a five-month round-the-world service. The system was designed and developed by David Hydes (chemist) and Jon Campbell (engineer) supported by the wealth of experience in ocean science and engineering available at NOCSin Southampton.

The advantage of using large commercial vessels like Pacific Celebes to collect scientific data from the world's oceans is clear: samples can be taken over sustained time periods and long distances, at little or no cost to the scientific community, while modern communications enable the information logged by the devices to be transmitted to scientists onshore for analysis in real time.

Some recent research has indicated that the rate at which the oceans absorb CO_2 is slowing, but the information available to explain why this is so is inadequate. This is because many areas of the world's oceans have yet to be studied and where they have been studied it has not been for long enough. Man needs to gain a clearer picture of what is happening in the oceans. We need this to accurately predict future changes in atmospheric concentrations of CO_2, and hence the rate at which the earth will "warm" due to the retention of energy in the atmosphere. In addition dissolving CO_2 in water produces carbonic acid. We need to know how this increased acidity will change sensitive ecosystem such as corals.

Long-term monitoring is essential to distinguish progressive climate change from natural oscillations, which tend to have time scales in the five and ten year range. This is where liners like Pacific Celebes, which stick to well-defined routes, come in. They have huge potential to allow repeated observations over many years. SNOMS is a part of the wider International Ocean Carbon Coordination Project (IOCCP), initiated in 2003 by the International Oceanographic Commission to use so-called 'ships of opportunity' to assist with data collection in this way.

Information from the SNOMS project is made available to a network of scientific organisations linked to the United Nations via UNESCO and the World Meteorological Organisation, and to the wider public via the project's website: www.noc.soton.ac.uk/snoms. (The current position of the Pacific Celebes can be found on the website.)

Laboratory Products Focus

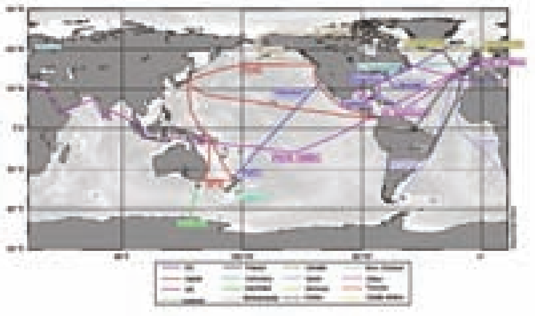

Figure 1. Map of contributions to the IOCCP by commercial ships of opportunity collecting underway data on the partial pressure of carbon dioxide at the sea surface (by Alex Kozyr CDIAC).

Climate change is now recognised as one of the most significant environmental challenges facing mankind. A major factor influencing climate change is a rapid escalation in human activity of the type that generates 'greenhouse gases' (increasing industrialisation in developing countries etc), as a result more carbon dioxide than nature can deal with is accumulating in the Earth's atmosphere. The carbon in carbon dioxide (CO_2) has a cycle; it moves between the atmosphere, living things, the soil and the seas. The role of the oceans in the cycle is very important. They soak up a third to a half of all the extra CO_2 generated each year. They do this through the physical process of chemical dissolution and the life and death cycle of surface ocean plants (plankton) the remains of which sink and carry carbon into the deep ocean.

Atmospheric CO_2 has a varying solubility in seawater depending on the water temperature, level of salinity, and difference in its concentration between the atmosphere and in the surface of the ocean. These factors in turn depend on how rapidly the warmer surface waters are renewed from the ocean depths with cooler, water that has not been exposed to modern levels of CO_2, and on how much growth of marine plants has also reduced the concentration of CO_2 in the surface water.

The SNOMS monitoring equipment installed on Pacific Celebes centres around an enclosed stainless steel tank located at the bottom of the engine room. The tank is connected to the ship's seawater supply and contains sensitive devices for measuring dissolved carbon dioxide and oxygen, total dissolved gas pressure (for estimating dissolved nitrogen), temperature and conductivity. The information is collected by a data-logging control computer, which also receives input from a temperature sensor mounted on the ship's hull and from measuring equipment on the "monkey island" - the highest deck on the ship. This includes a Stevenson screen with sensors for measuring humidity, air temperature and atmospheric CO_2 content, and a cabinet housing a data logger, two GPS receivers (to accurately pinpoint the ship's position) and an Iridium satellite communications modem for transmitting the information to NOCS in the UK.

The partial pressure of CO_2 is measured in the surface water and in the atmosphere - the difference is measure of the ocean's ability to absorb CO_2. Gases always flow from a region of high partial pressure to one of lower pressure, so if the partial pressure of CO_2 is greater in the air than in seawater, it will dissolve - the greater the difference, the faster the flow. Sea temperature and salinity will also affect the solubility of the gas. To better understand why these differences exist the SNOMS equipment additionally measures dissolved oxygen and nitrogen, enabling the NOCS scientists to distinguish changes due to physical (chemical) processes from those due to biological ones. The measurement of oxygen indicates the amount of biological production (such as photosynthesis) and respiration taking place in the surface water, since both processes add and remove CO_2 at a known ratio to the change in concentration of oxygen. The concentration of nitrogen is solely dependent upon physical processes and indicates how much the system may be out of equilibrium following events such as storms.

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Figure 2. Swire Shipping's MV Pacific Celebes off Thailand in May 2007

Chief Engineers Valeri Didenko and Chris Wilson, (who operate on a back-to-back regime on Pacific Celebes), and their engine room staff are responsible for maintaining the SNOMS system, a job that involves collecting daily samples, cleaning the tank, (known affectionately on board as 'R2D2'), and reporting back to NOCS. Chris comments: "The system is hardly any trouble at all to maintain. The tank monitors seawater fed from the fresh water generator ejector pump.

Daily at sea, we take two water samples from the ejector pump discharge line - one salinity, and one alkalinity sample - and fill out a simple log sheet with the times of sampling. The whole thing only takes about ten minutes. On reaching port, depending on the time of arrival, the tank is shut off and drained. Sometimes this occurs earlier if we expect muddy river or estuary waters. After draining, the tank is then opened for cleaning. The Aanderaa oxygen, temperature and conductivity sensors in the lid are cleaned with soap and water; The ProOceanus CO_2 and GTD (total dissolved gas) sensors suspended in tank are cleaned with a fresh water spray - these two sensors are never touched by hand. We take a few photos of the inside of the tank before and after cleaning and email them to Southampton. Times of shut off and cleaning are recorded in the log sheet. It takes about 20 minutes to do this job. Other than that, we have only done some quick tests or checks when the CO_2 sensor has been playing up and Valeri and I have each changed out the CO_2 sensor." The Vaisala atmospheric sensors on the Monkey Island are checked when NOC staff visit the ship in Livorno, Italy. Also in Livorno the full bottles of water samples are exchanged for new "empties".

There is genuine enthusiasm for this project both ashore and on board. Valeri and Chris have established a close and fruitful relationship with the team in Southampton. All those actively involved - particularly the ship's Second Engineers, who do the majority of the sampling - are aware of how important a role Pacific Celebes is playing in international climate change research. Just how important was illustrated during Celebes' very first voyage with the SNOMS equipment on board: 2007 saw a very intense 'La Niña' event in the eastern tropical Pacific. La Niña is an oceanic-atmospheric phenomenon marked by a significant fall in sea surface temperature in the tropical Pacific Ocean. It is the opposite of the more common 'El Niño', but whereas during El Niño, winds blowing from areas of high to low atmospheric pressure cause ocean currents to flow eastwards towards South America from the western Pacific and Indian Ocean, resulting in a rise in sea surface temperatures; during La Niña, a reversal of these conditions carries warmer surface waters further west than normal. This induces an upwelling of dense, cold water from the ocean depths to the surface off South America.

These phenomena have a very significant, and essentially opposite, impact on the world's weather systems: 2007's La Niña produced an unusually intense plume of cold water that moved west along the equator and was one of the causes of the record levels of rain recorded in the UK in June and early July.

Pacific Celebes crossed this 600-mile-wide plume between 19-23 July last year, between longitudes 133.7° and 93.1° W. David Hydes and his team were excited to find that during this leg of the voyage, the SNOMS equipment recorded concentrations of CO_2 in the air above the cold La Niña water that were significantly higher than normal. Whilst it was well known that the cold subsurface waters that upwell off South America during a La Niña event are rich in inorganic carbon, this was the first time that evidence has been collected that the event could be so intense as to be detected as a change in the atmospheric concentration of CO_2.

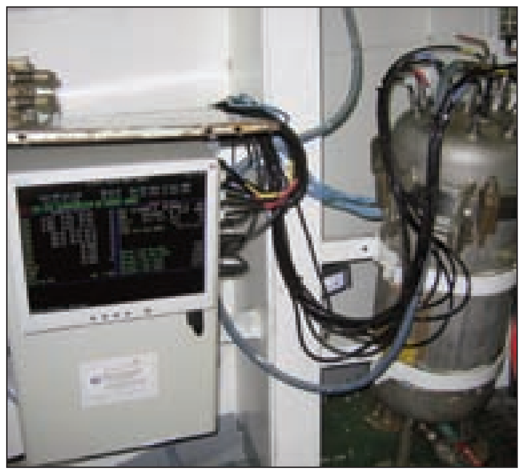

Figure 3. The SNOMS sensor tank and data logging unit in the machinery space of the MV Pacific Celebes

The scientists at NOCS were able to make further useful comparisons between predicted and real conditions as the Pacific Celebes continued her round-the-world voyage. As the ship travelled east across the Atlantic between St. John and Livorno in Italy during September, the Southampton team compared the actual partial pressure of carbon dioxide in the ocean's surface recorded by Celebes with expectations modelled in an Atlas produced by a team led by Taro Takahashi of the Lamont Doherty Observatory in America. The Atlas is major resource for the world's climate scientists as it synthesises all the available data into a global view of how CO_2 potentially exchanges between the oceans and the atmosphere through the year. As David explains: "To generate a global Atlas, Taro had to extrapolate the available data into areas for which no data existed, so a touchstone for new observations is to compare them with expectations based on Taro's Atlas. Each new observation we make will make the next version of the Atlas better".

What SNOMS found was that east of longitude 40°W the data collected by Celebes agreed quite closely with what was expected; however, between 40°W and 55°W there was more deviation between reality and prediction. The actual partial pressure of CO_2 was lower than anticipated. The reason for this would seem to be higher biological productivity west of 40°W, indicated by satellite imaging of ocean colour - higher biological production means the removal of more CO_2 through plankton photosynthesis. In order to manage the planet, we need to know how rapidly changes are taking place and to be able to distinguish permanent changes from natural oscillations. David Hydes comments, "More data will continued to be needed for some time yet to help us determine regional differences, and understand the interaction of biogeochemical and physical processes through time. Extending the marine CO_2 system database is crucial to aid improved accounting of the Earth's carbon budget and ultimately to guiding improved amelioration strategies. Even at this early stage the SNOMS project has been very impressive in showing how well commercial and research organisations can work together to reduce the serious short fall in human knowledge about our small green planet. SNOMS provides a perfect example of how the aims of the IOCCP Ship of Opportunity project can be met very effectively when cross sector partnerships such as SNOMS evolve."

Figure 4. Jon Campbell (NOC) showing the atmospheric CO2 sensor to Tony Baker (Master), Chris Wilson (Chief Engineer) Francis Cheung (Technical Officer)

Figure 5. David Hydes training the engineering team on the Pacific Celebes in the collection and preservation of the water samples collected for shore based analysis. Jakarta June 2007.

Figure 6. Chief Engineer, Valeri Didenko opening the SNOMS tank for inspection

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