Taking the oceans' pulse

Dr John Gould

Planet ocean

When Arthur C Clarke saw photographs of our planet taken by the Apollo astronauts he exclaimed that the earth had been mis-named; it should, he said, be called planet ocean. Indeed from above the Pacific all one can see from space is white clouds and blue oceans revealing the two fluids that govern our weather and climate. The case for Clarke's pronouncement is even stronger when one knows that the oceans hold 97% of earth's water and land accounts for only 29% of its surface.

Earthrise from Apollo 11 (NASA, GSFC)

The oceans' influence gives Britain its mild winters and temperate summers, over-simplistically attributed to the Gulf Stream. Indeed the entire earth's climate - past, present and future – is intimately tied to the behaviour of the oceans.

Exploring the oceans

Britain's close association with the oceans has been the stimulus for exploration aboard ships with such evocative names as *Endeavour*, *Challenger* and *Discovery* - names appropriately chosen for the US space shuttle fleet. The global voyage of *HMS Challenger* in the 1870s started an era of scientific exploration, first to describe the oceans, then to learn how they "work" , and most recently to focus on their role in climate.

Ocean scientists face huge obstacles in gathering their information; obstacles brought into focus by the fact that while anyone can see features on the moon a quarter of a million miles away only a select few have glimpsed the deep sea floor. This is because as well as the oceans being deep and remote, sea water is corrosive and largely impenetrable to light and radio waves. How those obstacles were overcome is the focus of a recent book, "*Of Seas and Ships and Scientists*", describing the establishment, following World War II, of the UK's National Institute of Oceanography. Thankfully, since the 1980s new observational tools have been developed that are starting to match the enormity of the task.

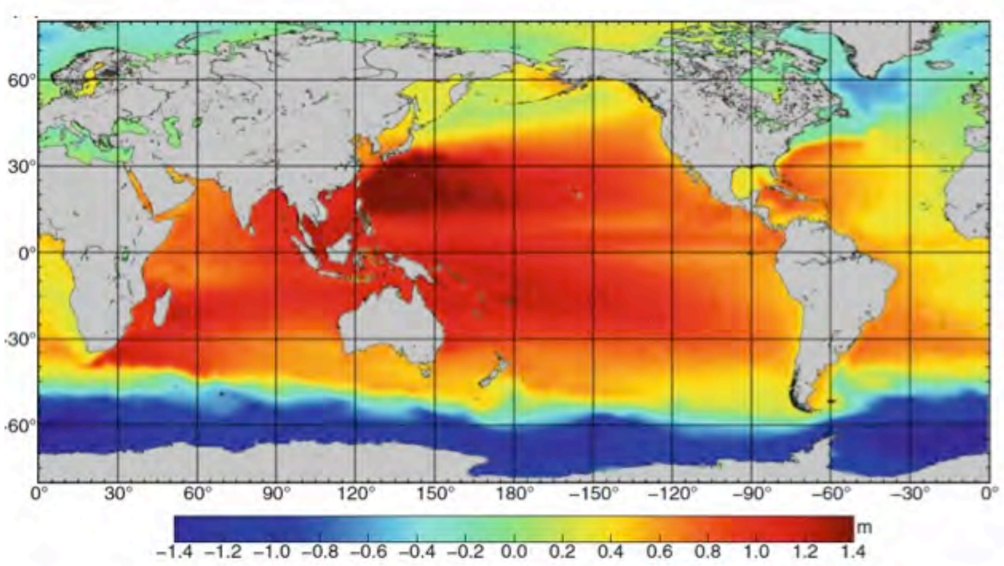
How are the oceans important for our climate?

Seawater's physical properties govern the oceans' role in climate. Most obviously the oceans are wet and evaporation from their surface produces the moist atmosphere that gives the rain that sustains life. Sea water's high heat capacity - a slab 3 metres thick holds as much heat as the entire atmosphere above it - makes the oceans very effective at storing heat and transporting it around the planet. Sea water's density depends on both temperature and salinity and the interplay of these factors means that water moves both horizontally and vertically in the global thermohaline circulation. This circulation allows the oceans to absorb properties from the atmosphere (notably heat and carbon dioxide) and lock them away in the depths for hundreds of years so buffering earth from rapid climate fluctuations.

New technologies

To understand how our climate might change we need to collect ocean observations to match the records we have in the atmosphere and to feed them into state-of-the-art computer models. Research ships are still a mainstay but there are few of them and they cannot make all the measurements needed.

A new era of ocean observing started in 1978 with the launch of the first satellite devoted to the oceans. SeaSat's radar sensors could see through clouds and allowed round-the-clock monitoring. Since then similar satellites have measured the ups and downs of the oceans' surface, not just due to waves and tides but the changes in sea level across currents like the Gulf Stream and the subtle changes as the oceans warm and cool - amazingly to an accuracy of just a few millimetres.



The shape of the sea surface. Red areas are high, blue are low. The biggest slopes are found across major currents (NASA, JPL)

Satellites, though powerful, can only measure the external "symptoms" of what is going on inside the oceans. To look below the surface, robotic probes now complement ship-based observations and routinely measure temperature and salinity. Most are in the 3000-strong fleet of Argo profilers; each one drifting with the deep currents and regularly rising and sinking through the oceans' top 2 km and beaming their data to climate-monitoring centres. Others are underwater gliders capable of navigating themselves and probing the important but difficult-to-access regions between the deep ocean and the continental shelves and around and under ice-covered areas.

Near the equator, where interactions between the warm ocean and the atmosphere are most energetic, a network of 120 fixed buoys monitors the upper ocean and weather conditions to detect changes that, at their most extreme, manifest themselves as El Niño, a disruption to normal climate patterns that affects weather not just near the equator but around the world.

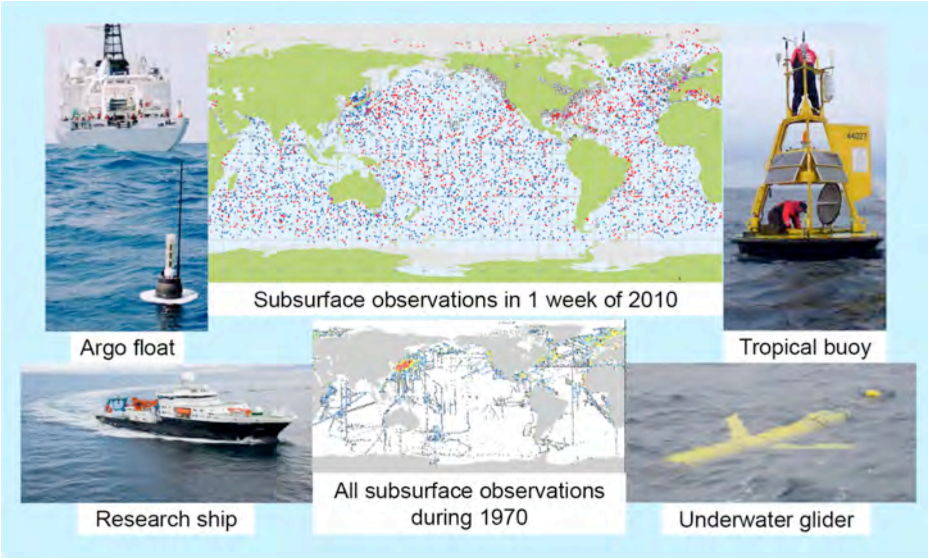
Designing and launching satellite missions and maintaining global in-water observing systems is beyond the capability of any single nation. International collaboration, as exemplified by the Argo fleet of profilers maintained by 30 nations (at a total annual cost of £26 million), is the way ahead. Argo data are freely and openly shared.

Ocean observations - What they show? Why they matter?

Satellite measurements confirm the accelerating rate of sea level rise in tidal records extending back to the 19th century but, most importantly, can now show where sea level rise (and fall) is greatest. The average rise of 30 cm since the pre-industrial era is largely due to the oceans' warming and to melting and freezing of icecaps and glaciers. Worldwide, 150 million people live less than 1 metre above the present high tide level. For them and for people in Britain with homes that are vulnerable to coastal flooding and erosion, rising sea level is a matter of great concern. Steps to reduce coastal flooding and erosion cost £745m for England and Wales in the year to March 2011.

The same satellites have measured changes in the strength and position of ocean currents like the Gulf Stream that transport vast quantities of heat around the globe and redistribute it away from the equator towards the poles (1000 million megawatts in the North Atlantic). Since 2004 a joint UK-USA network of sensors has revealed unexpected large variability in this transport. Major changes in ocean heat transport have been implicated in the onset of ice ages and interglacial periods such as the one in which we now live.

Just as the atmosphere has warmed since the industrial revolution so have the oceans, most rapidly near the surface (around 0.1°C per decade) and less deeper down. Over 90% of the heat associated with earth's recent warming is stored in the oceans; they have also absorbed a quarter of the carbon dioxide released by our modern life-style. These two factors have greatly limited the impact of human-induced global warming. But there is a down-side; increasing temperatures and ocean acidity (dissolved carbon dioxide is acidic) threaten living organisms and particularly coral reefs.



40 years of progress in ocean observations

The moisture that falls as rain has evaporated from the oceans and the salinity at the ocean surface reflects the exchange of water between the atmosphere and the ocean and can be used as a type of rain gauge. While the patterns of salinity are unchanged over the past 40 years the fresh areas have freshened and the salty areas become more saline. This suggests that evaporation and precipitation have increased implying a strengthening of the global water cycle consistent with an increase in both floods and droughts. We also now have a better understanding of the mechanisms that cause El Niño events and using advanced computer models can now predict their onset 6 months in advance. These predictions are used by farmers, planners, the emergency services, commodity traders and the insurance industry.

In 40 years we have moved from an era of curiosity-driven research to one in which the understanding we have gained and the observations we have made are serving society in an enormous number areas; fisheries, oil and gas exploration, search and rescue, coastal protection, oil spill tracking, merchant shipping and naval operations, as well as climate applications. Ocean forecasts are now being made routinely.

Everyone's oceans

The BBC's iconic Blue Planet series showed fascinating images of life below the ocean surface. But how can we convey to non-specialists the wider importance of the oceans?

Fortunately in parallel with the revolution in ocean observations has come the revolution in communication; the internet is now an integral part of our lives.

Cyclone clouds over the Indian Ocean (Herman Ridderinkhof, NIOZ)

Capitalising on these two strands, space agencies post stunning images of the oceans on their web sites and open access to data from, for example, the tropical buoy array (http://www.pmel.noaa.gov/tao/elnino/nino-home.html), provides an insight into the ocean world. Moreover, the free and open access to Argo data means that anyone can now "see" the conditions deep inside the remotest parts of the ocean from the comfort of their office or home and be guided on a tour of the oceans' interior (http://www.noc.soton.ac.uk/o4s/euroargo).

The advances in understanding that have come from new observations herald an era in which the oceans will play a bigger role in all our lives. Climate is just one aspect with useful seasonal forecasts a key objective – "Will the coming winter be wet/dry, cold/warm, windy/calm?". In addition to providing food the oceans are also becoming a source of energy, minerals and pharmaceuticals and changes such as an ice-free Arctic would have profound impacts.

Despite the progress, more remains to be done and to be discovered and will require continued commitment by governments and further international collaboration. Making the public aware of the oceans' role in their lives is a key step towards that goal.