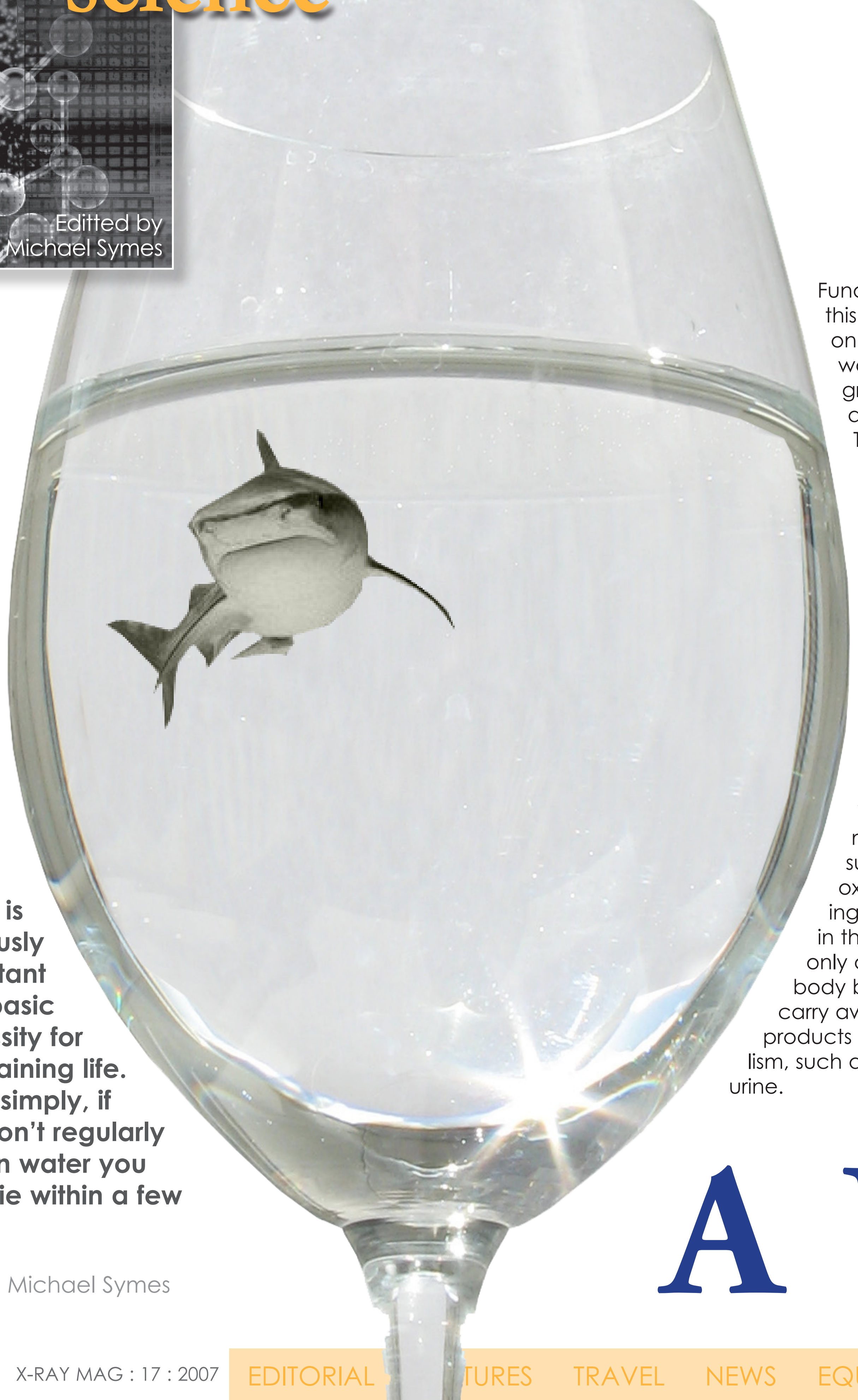
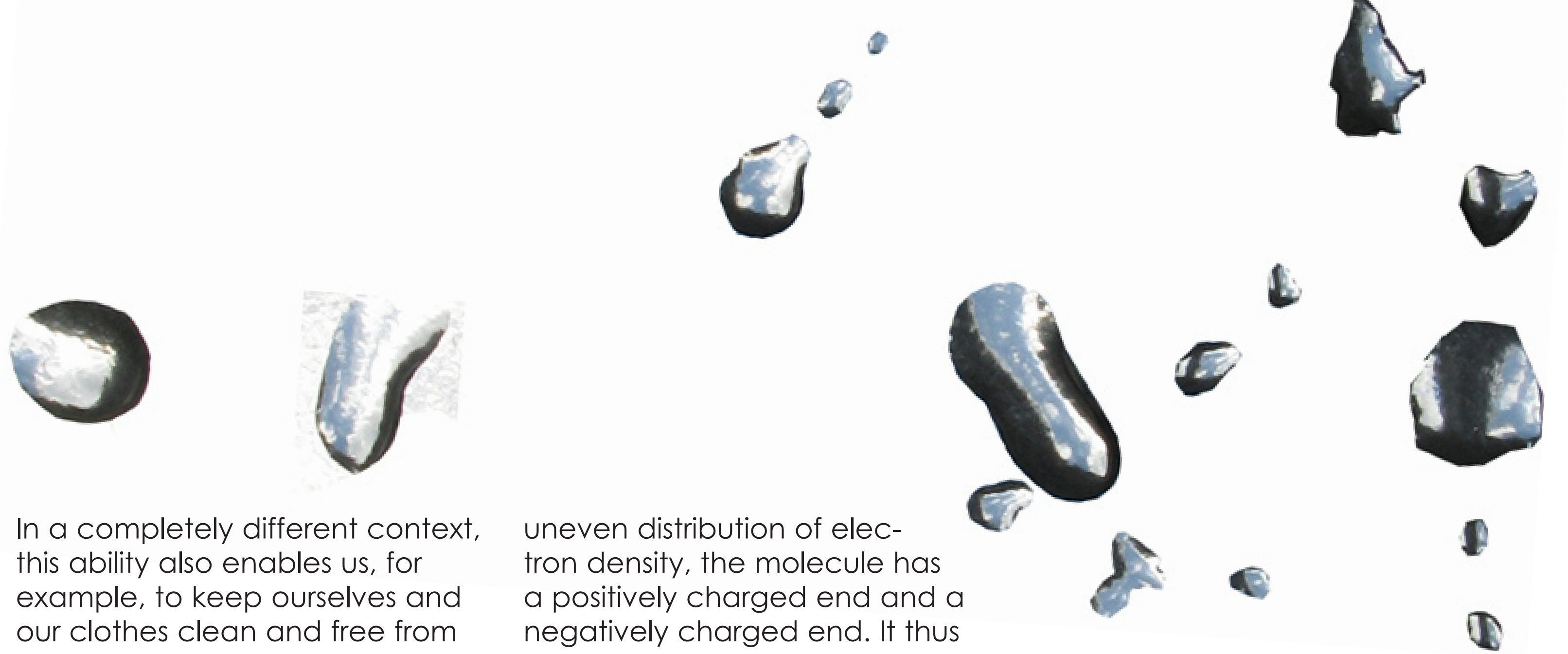


Water
A Unique Solvent

Water is obviously important as a basic necessity for maintaining life. Quite simply, if you don't regularly take in water you can die within a few days.

Text by Michael Symes



Fundamentally, this all depends on the fact that water has a great ability to dissolve things. These solvent properties of water are vital in human biology, because many biochemical reactions take place only within aqueous solutions. Water is also used to transport the resulting biological molecules, such as the oxygen-carrying haemoglobin in the blood, not only around the body but also to carry away the waste-products of metabolism, such as urea in urine.

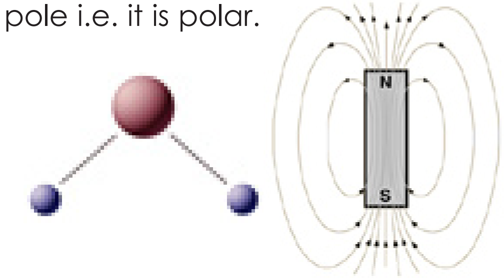
In a completely different context, this ability also enables us, for example, to keep ourselves and our clothes clean and free from pathological bacteria, thus helping us to maintain good health.

Water can, in fact, dissolve more substances than any other solvent—that's what makes it unique. It has often been called the universal solvent, although this is something of an exaggeration. But what is it that makes water such a good solvent?

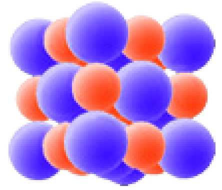
The solvent properties of water

To put it briefly, water is a good solvent due to its polarity. This polarity arises from the shape of this relatively small molecule. As we have shown in previous articles, the shape of the water molecule is non-linear.

The significance of having 2 hydrogen atoms on one side of the water molecule is that oxygen, being a stronger attractor for electrons than hydrogen, is able to pull the shared electrons towards it. This results in an unequal sharing of the electrons. It will be seen that, due to this uneven distribution of electron density, the molecule has a positively charged end and a negatively charged end. It thus acts like a small electromagnet having a north pole and a south pole i.e. it is polar.



The ability of ions and other molecules to dissolve in water is due to this polarity. Take, for example, the ionic NaCl molecule (sodium chloride, or salt). The solid NaCl crystal consists of a lattice of positively charged Na ions and negatively charged Cl ions. They are held together by attractive electrostatic forces, otherwise known as van der Waal forces.



When a crystal of NaCl comes into contact with water the small water molecules can penetrate between these ions and thereby eliminate the effect of the van der Waal forces, allowing the ions to separate. On dissolving, the positive sodium ions then become surrounded by water molecules where the negative end of the polar water molecule is attracted to the positive sodium ion. And similarly, the positive end of the water molecule is attracted to the negative chloride ion. The relatively small size of the water molecule allows many water molecules to surround one molecule. An ionic or polar compound in water is thus surrounded by water molecules to give a stable solution of solute.

An example of a non-ionic solute is table sugar, where the water dipoles hydrogen-bond (see X-RAY MAG no. 7) to the dipolar regions of the sugar molecule thereby allowing it to be carried away into solution.

In general, ionic and polar substances such as acids, alcohols and salts are easily soluble in water, and non-polar substances

such as fats and oils are not. Non-polar molecules stay together in water because it is energetically more favourable for the water molecules to hydrogen bond to each other than to engage in van der Waal interactions with non-polar molecules.

Salinity of the Oceans

For a diver, one of the most obvious facts about the water of the oceans is its salinity, due of course to the ability of water to easily dissolve all ionic salts. The salinity, as all divers know, has a great effect on buoyancy.

Salinity is a measure of the amount of dissolved salts in seawater, and is calculated as the amount of salts in grams dissolved in 1 kg of seawater. In the case of common salt, NaCl, for example, the maximum solubility is 357 grams in 1000 grams of water at 0 °C.

About 70 percent of the Earth is covered with water, with about 97 percent of that water in the oceans. The oceans contain about 3.5 percent of dissolved minerals, so it is nowhere near a saturated solution. However, the Dead Sea has a salinity of about 30 percent, which is getting close to saturation.

The following elements make up 99.99 percent of the total mass of Earth's ocean water.

Element	%	Element	%
Oxygen	85.84	Sulphur	0.091
Hydrogen	10.82	Calcium	0.04
Chlorine	1.94	Potassium	0.04
Sodium	1.08	Bromine	0.0067
Magnesium	0.1292	Carbon	0.0028

It will be seen that, apart from water of course, the major component of sea water is NaCl, some 85 percent of the total salts. This is because sea life has a strong influence on the composition of sea water. Crustaceans take out large amounts of calcium salts to build their shells, and diatoms remove silica to form their shells. Some elements, however, are not affected to any real extent by plant or animal life. For example, no known biological process removes the element sodium from the sea, thus allowing it to accumulate.

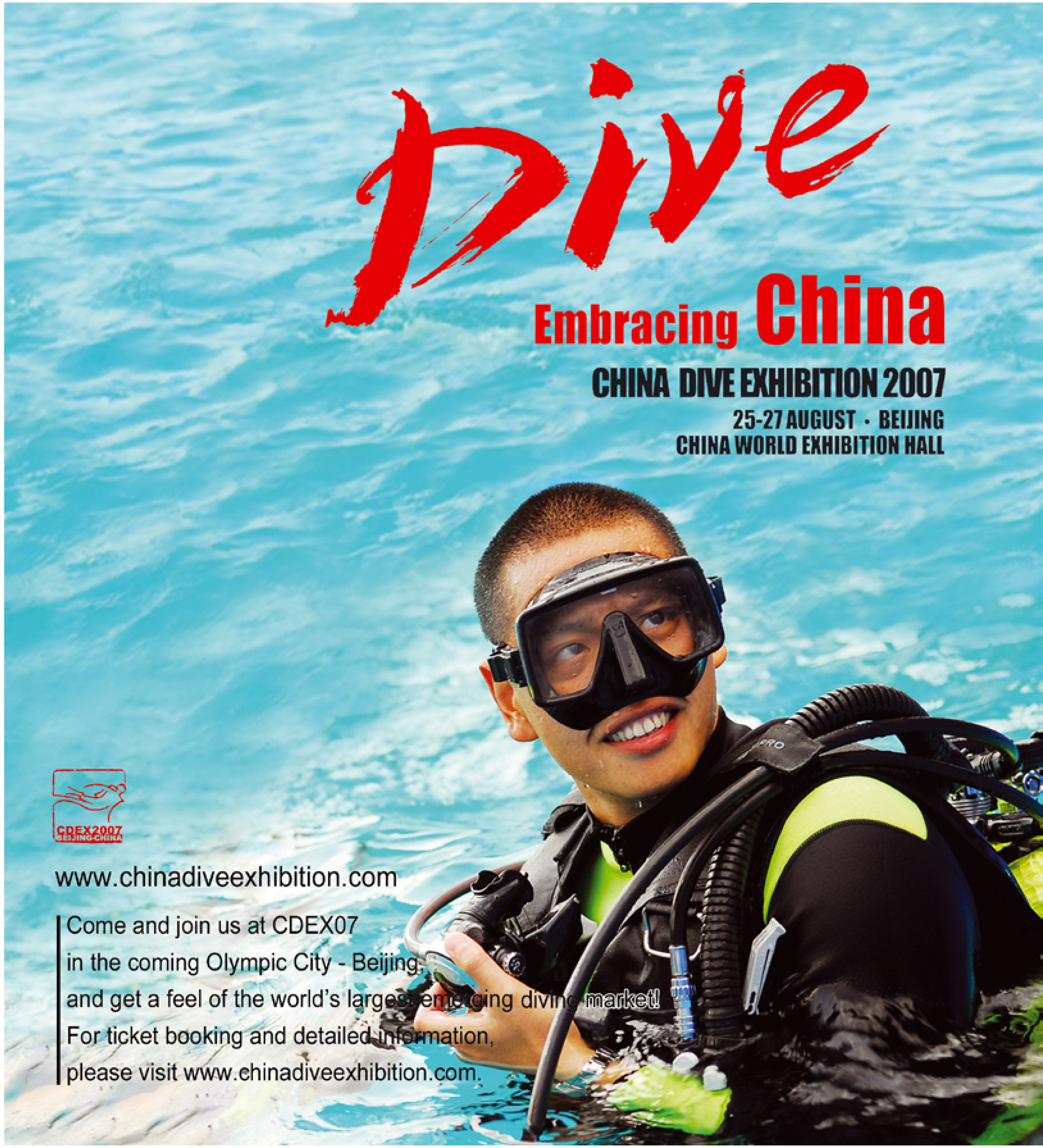
YANN SAINT-YVES

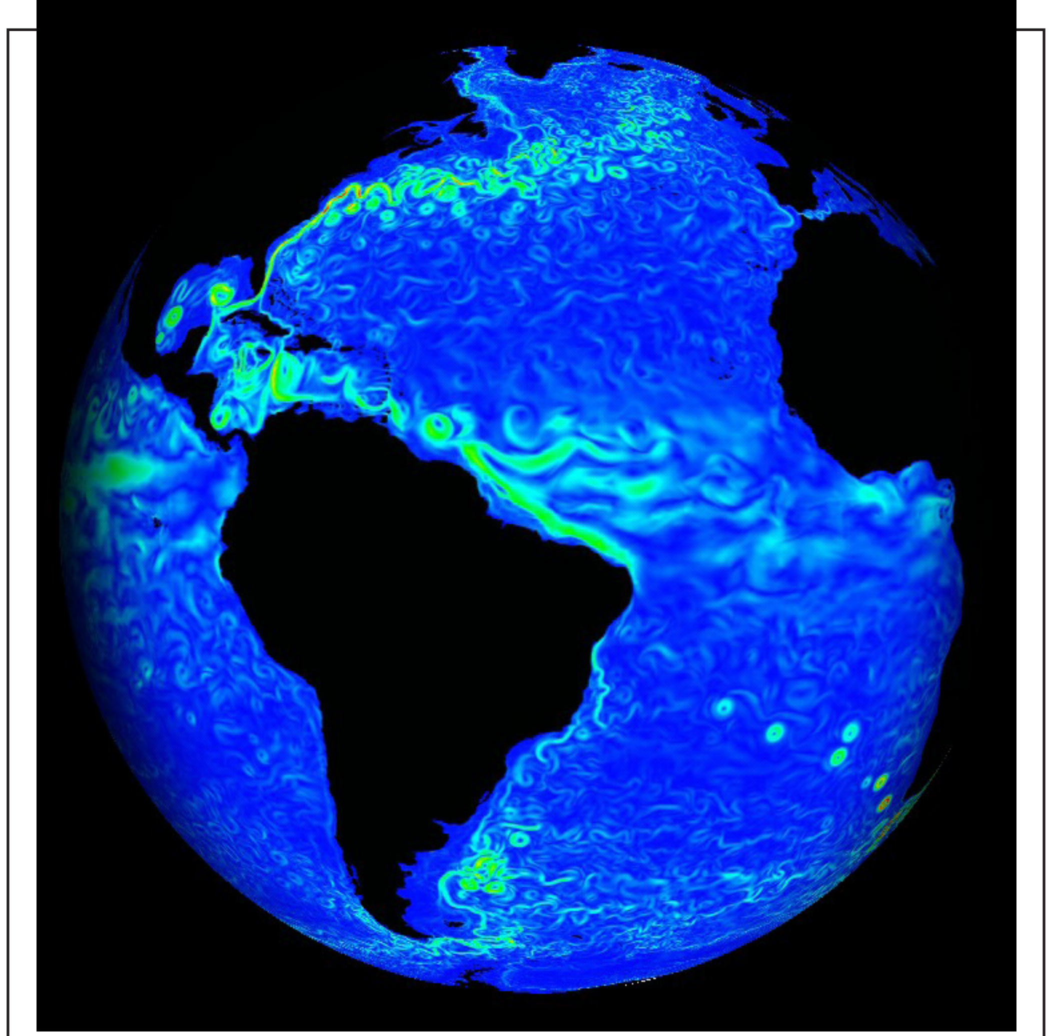
The Dead Sea

Now, while the average salinity of the oceans is about 3.5 percent, varying from about 3.2 to 3.7 percent, there can be great differences in salinity between different bodies of water. For example, The Black Sea, which is greatly diluted by river run-offs, has an average salinity of only 1.6 percent, while the Caspian Sea has a salinity of only 1.2 percent. This is still quite salty, though, when compared to fresh water with a salinity less than 0.05 percent.

Not only are there slight differences between the oceans regarding their salinities, in much of the Earth's oceans there is a marked difference in salinity between the surface zone and the deep zone, with the salinity increasing with depth. Although salinity generally increases with depth, there is a distinct layer where salinity increases sharply, called the halocline. These sharp differences in salinity can be due to several causes, e.g. an excess of evaporation over precipitation which leads to surface water being saltier than deeper water. This again can lead to some strange oceanic effects, both physically and biologically.

The salinity of the oceans is thus a very interesting and complex subject due mainly to the unique solvent properties of water. ■





Short-circuit found in ocean circulation

A *short-circuit* in the circulation of the world's oceans has been discovered that could aid predictions about future climate change. This process in the Southern Ocean allows cold waters that sink to the abyss to return to the surface more rapidly than previously thought.

This affects the Southern Ocean circulation, which links all the other oceans, and is also relevant to uptake and release of carbon dioxide by the sea; transport between the deep and surface waters in the Southern Ocean is particularly important for this process.

The researchers made use of a unique signal—the spread of helium released naturally from the Earth's interior at deep vents in the Pacific. The helium dissolves in the deep sea and a plume of this marked water travels down the coast of Chile. It is injected at depth into the Antarctic current on the Pacific side of Cape Horn. It then streams through into the Atlantic with the current, but in the process is spread, shifted and diffused by the circulation. Measurements of this spreading of the helium were used to deduce the short-circuit. ■

Striking deep current reversal in the tropical Pacific Ocean

The near-surface currents of the Pacific Ocean are generated essentially by the winds, whereas the deeper ones (known as thermohaline currents) result from water-density variations induced by differences in temperature and salinity between the distinct masses. The prevailing winds in the tropical Pacific, the trade winds, blow from the American continent towards Asia, causing the warm surface waters to drift in a general East-West direction. As they approach the Asian continent, these waters accumulate, then change direction, part of them turning North, part going South, while another portion flows at depth, feeding the Equatorial Undercurrent (EUC), which runs between 100 and 150 m below the surface. The EUC flows along the Equator, from Papua New Guinea to the Galapagos Islands, counter to the trade winds, and extends over a width of nearly 300 km at a maximum velocity of around 3.6 km/h.

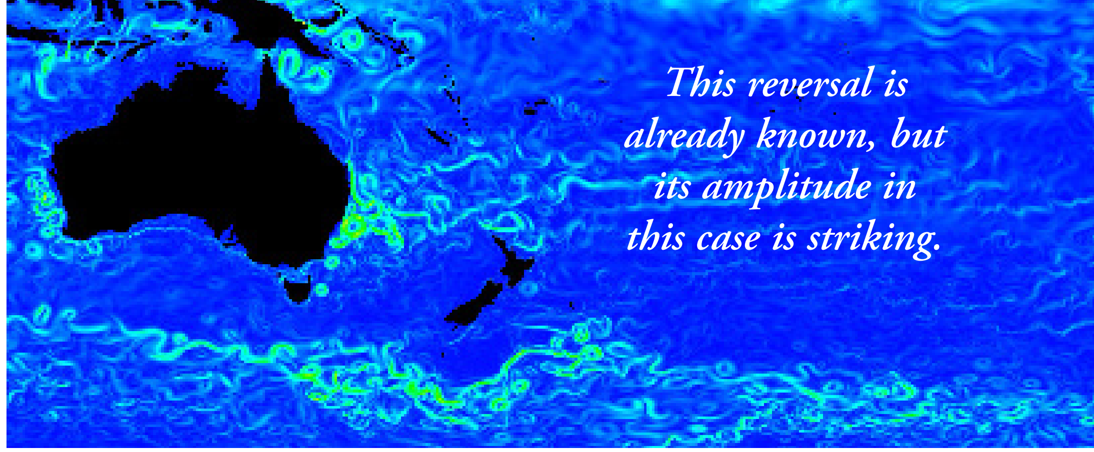
In two oceanographic cruises run in October 1999 and April 2000 as part of the IRD's ECOP programme, the Institute's researchers were able to study this region and, in particular, the El Niño-Southern Oscillation. The latter has a determinant effect on the distribution of ocean water masses, ocean/atmosphere exchanges in the tropical southern Pacific and many anomalies of climate that occur on the continents that border the Pacific. Physical determinations of currents and masses of water under transport were made from the surface down to 1200 m over a large area, 1700 km in length.

These series of measurements give a well-defined picture of the tropical circulation in this zone, but they also reveal a surprising variability of intermediate equatorial currents, which plunge at the Equator under the Equatorial Undercurrent and flow in the same direction between about 300 and 1200 m depth.

Between October 1999 and April 2000, these equatorial intermediate currents changed direction, between 2° S latitude and the Equator, over the 1700 km of the zone investigated. This reversal is already known, but its amplitude in this case is striking. The resulting variation in water mass transport is considerable.

What causes this reversal?

One hypothesis put forward involves the passage of an oceanic instability wave, but no disturbance of the EUC was detected during the research cruises and the reversal remains unexplained. Further current measurement campaigns in the future should shed light on this event and bring clues for unravelling the dynamics of these currents. ■



This reversal is already known, but its amplitude in this case is striking.

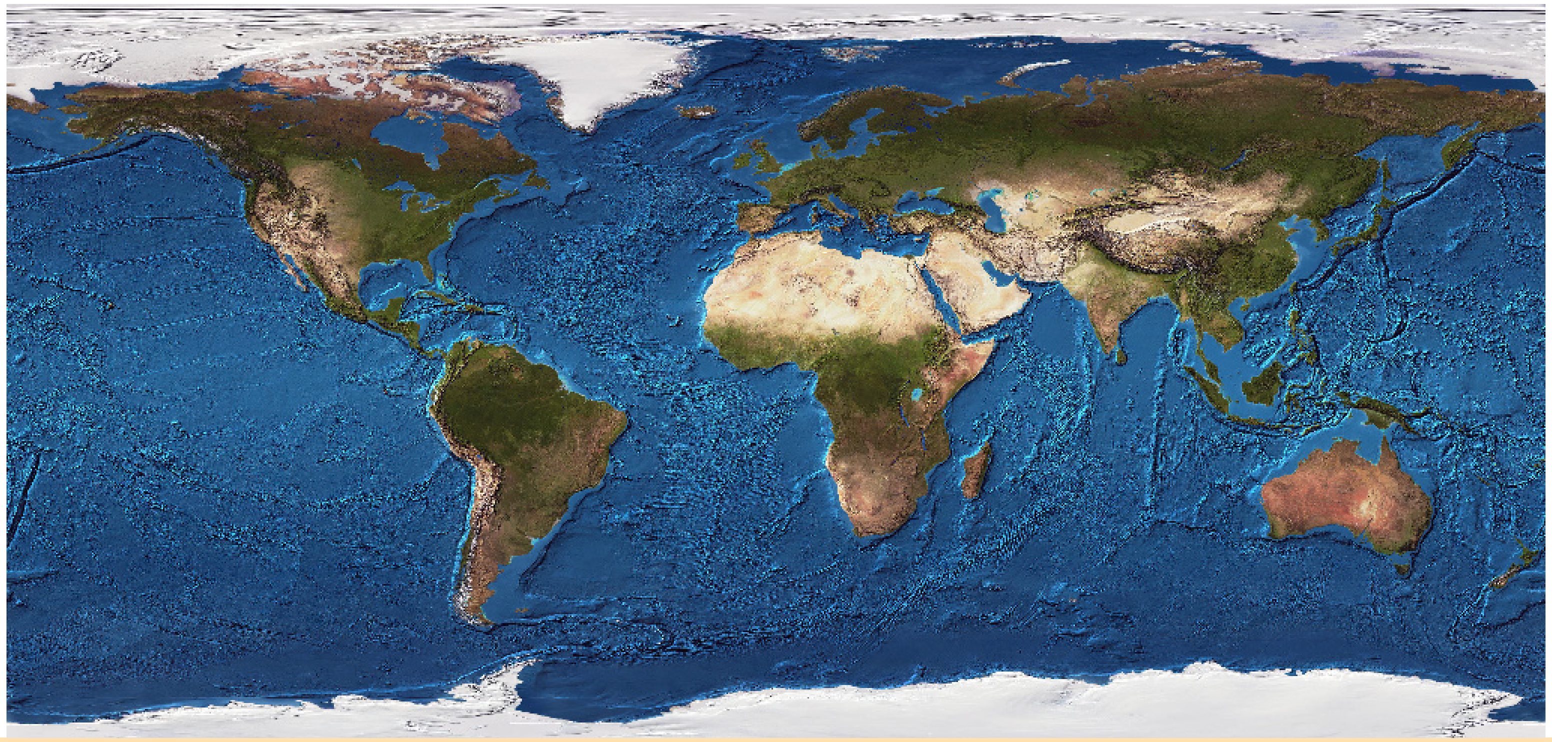
NZ scientists study Antarctic currents

New Zealand scientists have been getting close to the world's biggest ocean current in a bid to shed light on some unanswered questions about climate change.

A NZ research vessel is back in the country after travelling more than 3000 kilometres in rough southern seas, on a mission to anchor scientific recording gear in the sub-Antarctic ocean. The deepest mooring is in 4500 metres of water. The equipment will help study just how much water flows in the Antarctic circumpolar current, which is estimated to be 110 times bigger than all the water in all the world's rivers.

It will be a while before the initial data is analysed, and it is the next sail south that will reveal more about the world's biggest current. The data obtained will tell us about how currents vary and how the ocean temperature varies over a year, and that allows us to understand whether there are sudden changes, or whether things just change with the seasons. ■

The Antarctic circumpolar current is estimated to be 110 times bigger than all the water in all the world's rivers.



Ocean eddy observed off northern Baja California

Eddies are important because these giant swirling areas of seawater are frequent in the world's oceans. Passing eddies can accelerate local currents, retain and transport plankton and nutrients, enhance open water productivity and stimulate fast, deep sinking. Quasi-permanent eddies can retain larvae in the lee of an island, for example. Important vertebrates like sea turtles, elephant seals, blue whales and sperm whales seem to track these pelagic features, presumably because they aggregate prey species.

Eddies are easily detectable by satellites, although a recent article in Geophysical Research Letters reports that some deep eddies can go undetected by satellite, because they remain submerged. The authors conducted a 21-day hydrographic survey in the southern region of the California Current, and observed for the first time a subsurface anticyclonic (warm core) eddy off northern Baja California with the same water mass characteristics as the California Undercurrent. The core of the eddy was quasi-circular with radii of 35 km and thickness of 250 m. ■

Giant cold water eddy off Sydney lowers sea level

Australian oceanographers have discovered a giant cold water eddy off Sydney, which has lowered sea levels by almost one meter and impacted a major ocean current.

The eddy, which has a diameter of about 200 km and reaches to depth of 1 km, lies about 100 km off Sydney. It was stated that the eddy was so powerful, it had pushed out to sea the strong East Australian Current, although shipping traffic and fishing have not been affected.

The sea surface was lowered by 70cm at its centre

The cause of the giant eddy was a mystery. The sea surface was lowered by 70cm at its centre, although the dip in the surface of the ocean was invisible to the eye, it had been accurately measured by European and U.S. satellites.

Ocean eddies can have a life of up to three weeks, although similar eddies off South Australia and Western Australia are known to have survived several months. ■

Arctic Deep Sea May Hold World's Largest Fuel Supply

The energy source of the future may lie beneath the ocean floor and under Arctic permafrost. Both places are sources of gas hydrates, strange ice-like substances that trap methane—the primary component of natural gas.

The hydrates were discovered in 1983, and no one knows how much of them exist. But there appear to be enough hydrates to represent a larger energy source than all of the word's gas, oil and coal combined. Because each cubic meter of hydrate releases 225 cubic meters of natural gas they are a very good storage system for methane.

Efforts to extract the methane are focusing on the Arctic, where tests have shown that gas can be produced from hydrates using conventional drilling and production technology. Rather than mining solid hydrates, scientists are working on ways to melt the deposits underground. This would free the gas from the ice, allowing the methane to be captured in the same way ordinary natural gas is collected.

Because methane is a powerful greenhouse gas, some experts wonder if massive methane releases from melting seabed hydrates might have contributed to past epochs of global warming, while others are concerned that current global warming may heat the oceans enough to melt the hydrates, causing similar methane releases today.

Unstable hydrates could also cause underwater landslides, which could damage offshore drilling equipment and possibly create surges large enough to generate tsunamis, according to some models. ■