Brine

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Non Fiction

The oceans are a chemical cocktail, mixed from the residue of the planet's rivers, grinding and dissolving the earth since its beginning. This residue, salinity, enters a rough equilibrium, essentially what goes in balances what precipitates out. But it's not a constant throughout the oceans, either in form or amount. Differences at molecular scales drive flow and circulation that encompass the planetary scale and set the scene for life on earth.

We can follow two intersecting journeys driven in part by these differences in chemistry. One is taken by the oceans as they circulate over millennia. The other journey is comparatively instantaneous and far more modern: this is the journey taken by an Argo float, a small instrumented droid designed to capture basic seawater properties as it drifts around the global oceans.

The oceanic blanket that envelopes the globe soaks up heat, sunlight, gas and, in return, provides a buffer and a habitat for life on earth. The top few metres of the ocean has as much thermal heat capacity as the entire atmosphere above it. The majority of the sun's radiation is captured in the top thirty metres of the ocean. Climate and ecosystems are intertwined in the ocean.

An apocryphal fact states that as many measurements are made in the atmosphere in a day as exist for the entire history of oceanography. A development over the last fifteen years has seen a dramatic change in this: little droids, numbering 3200, are now floating throughout the world's oceans. Programmed to rise and fall through the ocean layers at timed intervals, they send data home via satellite whenever they surface. They carry remarkable instruments designed to measure ocean properties to accuracies undreamt of even in the most ordered laboratories only a few decades ago. That these instruments remain stable over their three year lifetime, in the ocean depths, is something of a miracle of applied electro-chemistry.

Birth

One journey starts near the poles. From polar plateaus, unimaginably cold and powerful winds blow, so cold that the surface of the ocean freezes – despite seawater freezing several degrees below zero degrees Celsius. And despite the need for the salt in seawater to be squeezed out before the water can actually freeze. The katabatic wind is so strong that it simply blows the nascent sea ice away, allowing still more ice to form. These ice factories are also ice exporters. But more than that, the cold extra-salty water formed by this process - this coldest and saltiest of seawater - sinks to the sea bed and flows equator-ward, starting the great arterial flow that drives our planet's oceans. This earth-sized picture emerged when in 1875 the first truly global oceanographic mission, the *Challenger* Expedition, recovered seawater samples from the depths beneath the equator, only to discover the water to be near-freezing and very salty. The ocean deep is no inert abyss; it has a global passport.

As with people, my birth is a time of great vulnerability. Dropped or lowered from a ship, or an aircraft. Smashing against the hull as I go in is my greatest challenge – even greater than breaking waves. Rudely dumped into the ocean, a few minutes to *equilibrate, and then my mission begins. I can puff myself up or suck in air. Just like a toddler. This changes my density by pushing oil in and out of a small rubber bag – smaller than a hot water bottle. This tiny change in volume means I must be perfectly balanced for the ocean into which I enter. Tiny adjustments are made and away I go.*

The very first attempts to measure how much salt the ocean contains involved nothing more clever than boiling away the water to leave a residue. This was inaccurate, as the residue itself could burn off, or conversely not be entirely emptied of water. Methods developed; by adding particular chemicals the salts would precipitate out and be separable from the liquid that way. These were manual, sample-based approaches to global chemistry.

Oceanography took an astounding leap forward in the 1970s when it became possible to routinely record the seawater electrical conductivity using delicate glass tubes and early digital electronics. This meant instruments could record continuously through depth or time – simplistic paradigms of ocean behaviour morphed before our eyes into complexity. Some four decades later new breeds of conductivity sensors remain stable for years and measure to accuracies beyond belief. It's absolutely fundamental – instrumental you might say – to our understanding of how the earth system works. Can you imagine justifying to the tax-payer the need to travel the world with a series of glass jars in 1876 aboard the Challenger with the promise that in a century's time it will all be worth it? The connections between start and end points in science are intricate and non-linear.

Going from conductivity to salinity is not all beer and skittles. Temperature, the chemical mix and even pressure all affect the conversion. And with the incredible accuracy of the instruments comes the need to take a step forward and have the conversion vary with ocean basin. Only last year, 2010, a new improved international convention for converting conductivity to salinity was developed. The corrections due to this new approach are tiny, but necessary as we seek to better describe the earth system to ever greater detail and with ever more ambitious predictive desire.

Life

After drifting for days at a depth of a kilometre it's time to go to work. First, I suck in again and drop to two kilometres depth, then I huff and puff to make myself bigger and less dense and I rise. Slowly, perhaps only ten metres every minute - it takes a long time to reach the surface two kilometres away. But as I go, the chemistry of the ocean flows through my sensors. The elements pass through a glass tube that is - literally - electrified.

And what changes I see – the oceans at two kilometres depth are around three degrees Celsius and filled with layers, sliding in like smoke creeping under a doorway. The saltiest waters of all have come from the polar reaches, formed by freezing winds squeezing the very salt from the sea ice. This heaviest of water sinks to the seafloor – bottom water - and pools until it has nowhere to go but equator-ward. Traces of these waters are found far to the north. My rise continues and I start to see layers of intermediate conditions, waters that are a playground mix of different water masses.

These layers circulate on something like a millennial cycle as they move from the poles to the equator and back to the poles again. But this doesn't mean things are slow-moving and still. Eddies swirl so that the local flow is much faster than the time-average. And waves – internal waves - bounce around within the ocean, formed at undersea ridges when the layers of differing heat and salt are driven over the ridge by tides. Once formed they are free to propagate and carry energy for thousands of kilometres, just like ocean swell, until broken on submerged shores, dissipated to viscosity or turned in on themselves by the earth's rotation – like a kid stumbling on a playground roundabout.

A curious thing can happen when layers originating from different sources slide across one another. Molecular diffusion is the process whereby vibrations in molecules cause material to spread. Imagine you have a gaggle of blindfolded school children initially in a huddle in a school yard. They won't stand still of course. They'll fidget, kick and generally goof around. In doing so they'll slowly spread through the school yard. Molecules do the same thing. Except heat travels at a different rate to salt – it's like the boys goof off at a different rate to the girls. Double diffusion results. So even though a light layer of seawater will flow over a heavy layer, with the right conditions the two layers will start to "fizz" and form strange layers and tendrils. The ocean is alive with more than plankton and fish.

As I rise I encounter steps in salt and heat, each step maybe only a few metres thick, but extending horizontally for hundreds of kilometres. I ascend this double diffusive staircase that mixes the ocean in a way that was totally unknown to science 50 years *ago. My electrochemical sensors must feel these layers so they need to rapidly respond – despite also having to last for five years. Everything is demanded of them.*

Then a few hundred metres beneath the surface things begin to heat up. I hit the seasonal thermocline – the remnant of the deepest mixing from last winter's storms. This surface layer tends to encompass all the water illuminated by the sun and so it contains the majority of the ocean's productivity. But left quiescent, this layer quickly uses up its resources of oxygen and nutrients. It needs oxygen to be injected at the surface and nutrients to be mixed in from deeper waters below. Nothing is static.

I quickly pass through the surface layer and at the last moment before surfacing I cross the diurnal thermocline – the daily fluctuations of the surface influence of the winds, heating and cooling – perhaps the thinnest layer in my journey but with the biggest variations in heat and salt.

The very skin of the ocean is also the only layer of the oceans that satellites can see. We can look at global images from space in a routine fashion now, beyond the dreams of even five decades ago, but we lose sight of the fact that we are just seeing the very surface and a very different surface it can be. Just as the *Challenger* turned understanding inside out by finding cold water at the equator so too do Argo floats through their sheer number and ability to explore the limits of natural variability.

Hitting the surface and it is action stations. I inflate a little collar with air to help me get my aerial as far out of the water as possible and then I talk. I talk to other droids – space droids orbiting the planet. They tell me where I am and I tell them what I've *measured and how I'm feeling. But I cannot linger for this is a dangerous time – ships, waves, sea ice, marine life, all present dangers. While the chances of any unfortunate encounter are small, the result will be the end. There's no careful technician out here to tighten my seals, straighten my aerial, replace my glass conductivity sensor. So, data shared, I quickly suck in once more and shrink, back to my kilometre-deep travelator.*

Thousands of these droids patrol the oceans – deployed from ships on long tedious voyages where nothing happens, except for a slowing of the engines at noon every day, and the launch of another droid.

Death

Ignominy really is the only way to put it. My passing is rarely understood because I'm lost from the world of light when batteries drain or seals finally leak or I drift under sea ice. Cycling through pressures ranging from zero to two kilometres of water and temperatures from -2 to 25 degrees for years are serious mechanical challenges as the molecular structure within my body expands and contracts. With ten days between each profile I capture around 35 profiles a year and with luck I might last five years – 175 precious profiles.

My passing may not be understood but it is noticed. Those who sent me off follow fading signals and missed transmissions, hoping for re-contact. I finally close out with silence.

You can follow these droids yourself. Go to argo.net. In a geek-tragic way you can even check out the “Float of the Month”. The curves on display here follow the beauty of fluid motion where planetary forces push, pull and heat our oceans. The floats can get squeezed through Drake Passage – the real action passing the Cape Horn - or entrained into the Gulf Stream, or stuck beneath ice for years before emerging bursting with data. They can get caught in the doldrums of the Tasman Sea, or rocket around the roller-coaster of the Antarctic Circumpolar Current, or get spat out of the Mediterranean through the Straits of Gibraltar.

Media reports like to call me a robot – an autonomous machine doing its master’s bidding. But I have two masters, one of whom lets go control when I’m released, so I prefer sentinel *– silently patrolling, recording and obeying the complexity of the global ocean.*

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