To the Denmark Strait

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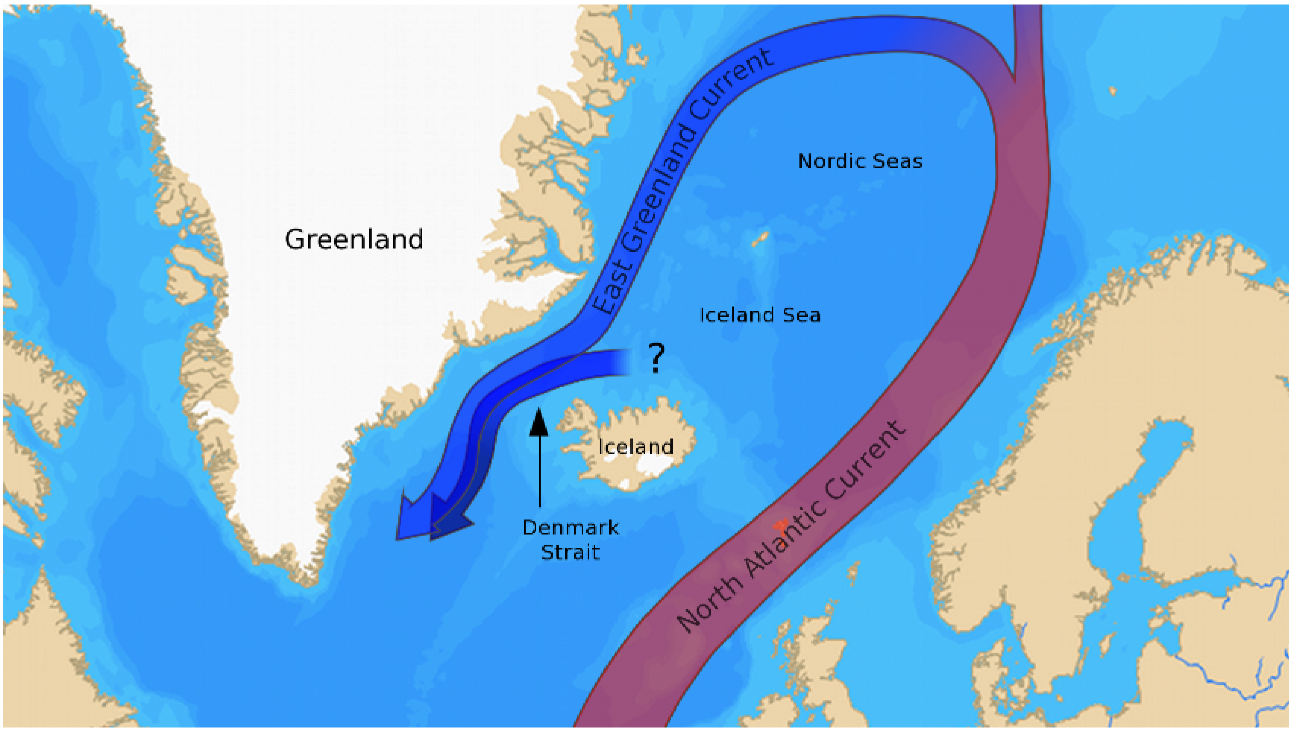
Standing on the bridge of the 279 foot research vessel Knorr I looked out on wall after wall of water. The winds were gusting over 70 knots, producing waves the size of three story buildings. The ship pitched violently, first up until all you could see was sky, then crashing down to submerge the bow in a billow of water. All around, the tips of the rollers were being ripped off by the force of the wind, creating streams of spray along the surface. Aboard, the 20 scientists and 20 crew staggered and reached for handholds. To be honest most of us were finding it exhilarating - this was the adventure that many of us, especially the young scientists, had signed up for. I had experienced this scene from exactly the same vantage point three years ago when I was starting out on my PhD. Clearly, I had not been dissuaded and part of the reason was in my fascination with where we were - the Denmark Strait.



The Denmark Strait is a 300km wide stretch of water that separates Iceland from Greenland. This thin strait, although tiny in the context of the Atlantic Ocean, just so happens to be one of the most important ocean channels in the world. In order to appreciate its significance it is important to expand ones view point and look at the entire North Atlantic Ocean. The UK owes it's relatively balmy climate to an offshoot of the Gulf Stream called the North Atlantic Current. This transports warm surface water northwards from the Caribbean, across the Atlantic and up the west coast of Europe. This warm water heats the air and keeps our climate that little bit more hospitable than that of places that share our latitudinal band - Moscow for example.

But what is the fate of these waters? The water is flowing towards the Arctic, an essentially enclosed basin with no exit routes. Therefore, what goes up must come back down; conservation of mass states that an equal quantity of water as flows north in the North Atlantic Current must return towards the equator. This return flow can be found not at the surface, but deep in the ocean as a stream of very cold, dense water flowing southward along the east coast of North America. For the surface waters to reach this deep current they have to sink in the seas to the north of the UK. The accepted view is that the warm water flows anticlockwise around the Nordic Seas between Scandinavia and Greenland and is subjected to cold and strong winds. This removes heat and moisture from the ocean surface waters making them colder and saltier, increasing their density. As the water progresses around the Nordic Seas it eventually becomes dense enough to sink to the deep ocean.

There is one final obstacle this dense water faces. To leave the Nordic Seas it has to navigate an ocean ridge that runs all the way between Greenland and Scotland via Iceland and the Faroes. This ridge essentially dams the dense water behind it and only allows the water to flow through a few gaps. The Denmark Strait is one such gap. In fact, it is the gap which allows the majority of the water to leave.

To study the flow of dense water through the Denmark Strait is therefore to investigate the circulation of the entire Atlantic Ocean and by extension to appreciate why the UK is so climatically mild. By developing a more complete knowledge of this system our ability to then predict how it will alter under a changing climate is enhanced. If the return flow were modified, reduced or increased, this will have an impact on how much warm water can pass northwards past our shores. This is why my colleagues and I were braving some of the roughest conditions on the planet aboard the research vessel Knorr.

Earlier in the expedition we had experienced calmer seas and had been close aboard the wall of mountains that constitute the south coast of Greenland, on the north side of the Strait. It is a cliché, but words really cannot do justice to the scene. The coastline of Greenland consists of steep sided mountains that shoot up from the ocean to lofty heights of 1000 meters plus. These are cut with graceful glaciers that descend into the sea and supply to the ocean the litter of icebergs that drifted around us. Some were the size of apartment blocks making a home for a myriad of seabirds.

The sky was piercingly blue (as it is commonly over Greenland - one of the least cloudy places in the world) but as far as the science was concerned we were only interested in what was going on beneath us. The water that had previously circulated around the Nordic Seas was now hugging the Greenland coastline, fast approaching the Denmark Strait from the north in a current called the East Greenland Current. Once it arrives in the centre of the Strait, it can pass over the ridge and cascade down in to the depths in what is known as the Denmark Strait Overflow. This is one of nature's great wonders, an underwater cascade that descends 1500 metres and transports as much water as 2000 Niagara falls' down in to the deep ocean. All of this was occurring right beneath our feet, only 600 meters down. This knowledge was as exhilarating as the scenery above the water.

We were not to stay here long though, for our expedition was to head back to the other side of the strait and search for a related flow of dense water, a brand new current that was only discovered at the turn of the century. This had been named the North Icelandic Jet and, as the name suggests, it flows along the north coast of Iceland, westward towards the Denmark Strait.

As is so common in science, the North Icelandic Jet was discovered by accident by two Icelandic oceanographers who were analysing routine ocean measurements. They established that the current was, like the East Greenland Current, moving dense water below the surface towards the Denmark Strait from where it could enter the deep ocean, but in this case the water was coming from the east, not the north. In fact they found that half of the dense water that makes up the return flow in the Atlantic Ocean (and the densest half at that) comes through this current and not from the north via the East Greenland Current. Evidently the description of the circulation of the entire Atlantic thus far was missing a vital component and importantly one that could affect how the ocean responds to a changing climate. Aboard the Knorr the biggest question for us was to find out where the dense water in the North Icelandic Jet came from. No one had previously gone out to answer this question, but that was the task that we had set ourselves and like all good scientists we set off with a hypothesis and the tools with which to test it.

The hypothesis was simple – the source of the North Icelandic Jet will be in the Iceland Sea, just upstream of where the current had been previously measured. This explanation came from a series of numerical studies conducted in advance of the cruise. If this were true than as we followed the current it would eventually die out much as a river would do if you were to follow that upstream. The notion is that the dense water in the North Icelandic Jet is formed very locally to the Denmark Strait in stark contrast to the formation of the dense water for the East Greenland Current which forms around the entire rim of the Nordic Seas.

The tools of oceanography are exceptional in being a blend of fine instrumentation and heavy industry. A point often overlooked is that the ship itself is one of, if not the, key pieces of kit. If you can't get out over the water you want to measure then how are you going to measure it? We rely heavily on the skill and expertise of the captain and the crew of the Knorr to keep the ship operational, navigate to our next way-marker and then, importantly, keep the ship static whilst we take our measurements. None of these tasks is trivial and none of the oceanography would function without them.

Once in the correct location we lower the instruments. In our case, the instruments are mounted on a two-ton package that has to be lowered on an industrial winch to depths at times exceeding 3000 meters. This is where the crew's deckies and instrument technicians flex their muscles and show us their skills, deploying and recovering this package without damaging it against the ship or sea floor whilst also protecting the ship and indeed any of the hapless scientists who are stood on deck rubber necking. Finally, after all of this heavy industry, we come to the specific tools we need to measure the current. The instruments we use measure the currents unique temperature and salinity fingerprint along with it's velocity. With these pieces of information in hand we can work out the location and strength of the current and we can follow it upstream to work out where it comes from. To do this successfully all of these components have to perfectly come together; scientists working in close communication with the crew; delicate instruments operating next to industrial power; and each individual drawing on experiences from wildly different areas of expertise.

And so we set off. Like an aquatic bloodhound we searched out the current and traced it back to it's origin along the north coast of Iceland. Slowly, as we moved eastwards, it started to fade out and by the time we got to the northeast corner of Iceland it had vanished. We had reached the source - the Iceland Sea. The hypothesis was confirmed. Dense water forming locally in the Iceland Sea was flowing out in the North Icelandic Jet and supplying half the dense water to the Denmark Strait. We had filled a key hole in our knowledge of the circulation of the Atlantic.

This discovery has significant implications for our understanding of how the ocean will respond to climate change. The formation regions for dense water in the North Icelandic Jet and the East Greenland Current are very different and so it may be expected that they will be affected by climate change in different ways. One major concern for the formation of dense water is the increase in the amount of freshwater flowing off the Greenland ice sheet. Freshwater essentially caps the ocean and restricts the production of dense water.

Changes in how much freshwater is produced and where and how it is distributed will therefore effect the formation regions of each current differently and hence how effectively the circulation of the Atlantic functions. It will be intriguing to learn just how important this new current will be for the resilience of the Atlantic to climate forcing.

Standing on the bridge looking out at the stormy seas I began to reflect on the cruise and oceanography in general. In my opinion, this mission is completely exemplary of how intriguing and satisfying a science oceanography is. Yes, it is the adventure that maybe draws people in (and who would blame them), but that slowly fades in comparison to the wonders that are to be found when you look hard enough at the water beneath your feet. The tools, teamwork, planning and raw intelligence that goes in to making a discovery such as the origin of the North Icelandic Jet constantly leaves me astounded. Best of all, there is still so much out there that is yet to be discovered, and exciting new tools, ships and techniques constantly developing to help us in this quest.