# Underwater Rivers: From the Bosphorus to Ocean Floors

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Until the late 1940s, deep-ocean floors were considered to be smooth surfaces with the exception of fracture-zones and relict volcanoes. Since then, we have become aware that ocean floors are covered in lines, some almost straight, others highly sinuous and contorted. These lines can run for hundreds and in some cases many thousands of kilometres, and they are formed by underwater rivers. The lines typically start in shallow water (200–300 metres deep) and extend to abyssal depths of 4–5 kilometres; occasionally they initiate just off the coastline. Intriguingly, there is a global variation in the sinuosity (wiggliness) of these lines, with highly tortuous ones observed in equatorial regions, and virtually straight channels present in polar regions. These underwater channels carry flows of mud and sand formed from collapses on ocean slopes (Fig. 1), close analogues to snow avalanches and to pyroclastic flows from volcanic eruptions such as those that destroyed Pompeii. Flows are infrequent and extremely powerful and destructive, largely restricting detailed measurements. Much of what is known about these flows instead comes from the destruction of seafloor fibre-optic cables, which enable us to measure the speed of these currents, up to tens of metres per second in their steepest parts, and 7–8 metres a second even on deep ocean floors – about the speed of elite male distance runners. Such cables carry 95% of all trans-oceanic voice, data and internet traffic and their periodic destruction has caused some major regional reductions in internet capacity.

Figure 1. View of flow through a laboratory underwater river. Flow is towards the viewer, and can be seen to be spilling over the sides of the channel. The channel is approximately 20 cm wide.

We still know remarkably little about our ocean floors, which make up two thirds (71%) of our planet. For instance, we know the surface of the far side of the moon to a resolution almost 100 times greater than most of the ocean floor. However, we do know that: underwater rivers can cause small but destructive tsunami; can damage underwater infrastructure such as pipelines, data cables and other sub-sea engineering; are important for the burial of organic carbon and therefore global carbon cycles; and that their deposits can subsequently host hydrocarbons. Because of the difficulty of studying these infrequent flows at depths of kilometres, the detailed understanding of underwater rivers has largely been derived from laboratory experiments and numerical models (Fig. 1). These laboratory and numerical approaches have suggested that flows in underwater channels behave very differently from their cousins, land-based rivers. However, what has been needed is a natural underwater river that could be studied in detail.

The Bosphorus connects the Mediterranean, via the Marmara Sea, to the Black Sea. Sailors have long been aware that water at the bottom of the Bosphorus moves in the opposite direction to that at the top, forming an unusual flow type known as an exchange flow. The lower flow is composed of denser (saltier) water from the Mediterranean and as this exits the Bosphorus into the Black Sea the flow hugs the bottom and travels through a remarkable and spectacular network of underwater channels that have only been discovered and imaged since the mid-1990s (Fig. 2). The underwater river initiating from the Bosphorus is the equivalent of the sixth largest river on land, based on the estimated amount of water flowing through it. Since 2008, three research cruises have used a remote-controlled submarine, yellow of course, to study the Black Sea channels, in order to understand the processes that occur in deep ocean-floor channels. The submarine is fitted with a range of instruments that enable it to measure in detail how fast the underwater river is moving, and to image the three-dimensional shape of this underwater system (Fig. 2). Analysis of the data from these instruments has revealed that flows in the underwater river are moving at up to one metre per second, and that the flow moves in a spiral (helical) pattern, much like a stretched out Slinky (the children's toy). Surprisingly, the direction of this spiral is opposite to that in rivers, with flow at the bottom of the channel directed towards the outer bank, at the middle (apex) of the bend, confirming previous results from small-scale laboratory experiments. In turn, these changes in flow will affect the evolution and development of underwater river channels.

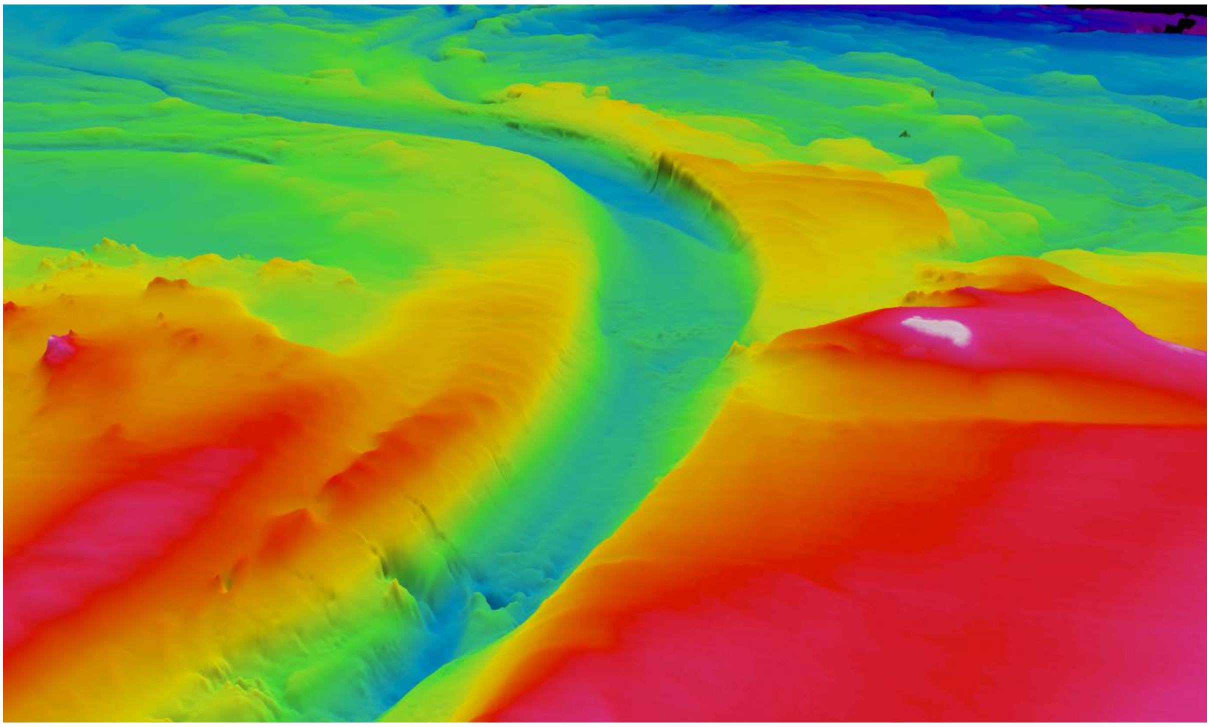

Figure 2. View of the underwater river on the floor of the Black Sea, downstream from the exit of the Bosphorus. Flow is moving away from the viewer, and blues and greens are low points, whilst oranges and reds are high points. The channel imaged has a maximum width of around 1.3 km and a maximum depth of about 25 m.

The Black Sea channels are also enabling us to look at the controls on these flows, and to understand why they differ from normal river channels. The vertical and lateral variations in density and velocity are very different from rivers; for instance, highest velocities in rivers are always towards the top of the flow, whilst in underwater rivers they can often be close to the bottom.

As we understand more about underwater rivers, we are realising just how different these systems are from normal river channels. In particular, recent work has shown that not only is there a global variation in the wiggliness of these sea-floor lines, but that this is reflected in their deposits, with those in polar regions being very different from those closer to the equator. There is still much to learn about these giants of the deep, and many aspects remain mysterious and poorly understood. However, the work undertaken to date reveals a rich range of flow behaviour and associated deposit patterns that are in many ways far more complex than in river systems. Strangely, given their ubiquity and importance here on Planet Ocean, these channels have received less popular science coverage than those on other planets such as the great Martian outflow channels, and even the channels on Venus, or Saturn’s largest moon Titan. Whilst the allure of channels on other planetary bodies remains as strong as ever, it is to be hoped that these giant and mysterious channels on our own planet may draw much wider attention.