A NEW OCEAN MONITORING TOOL FOR CLIMATE RESEARCH

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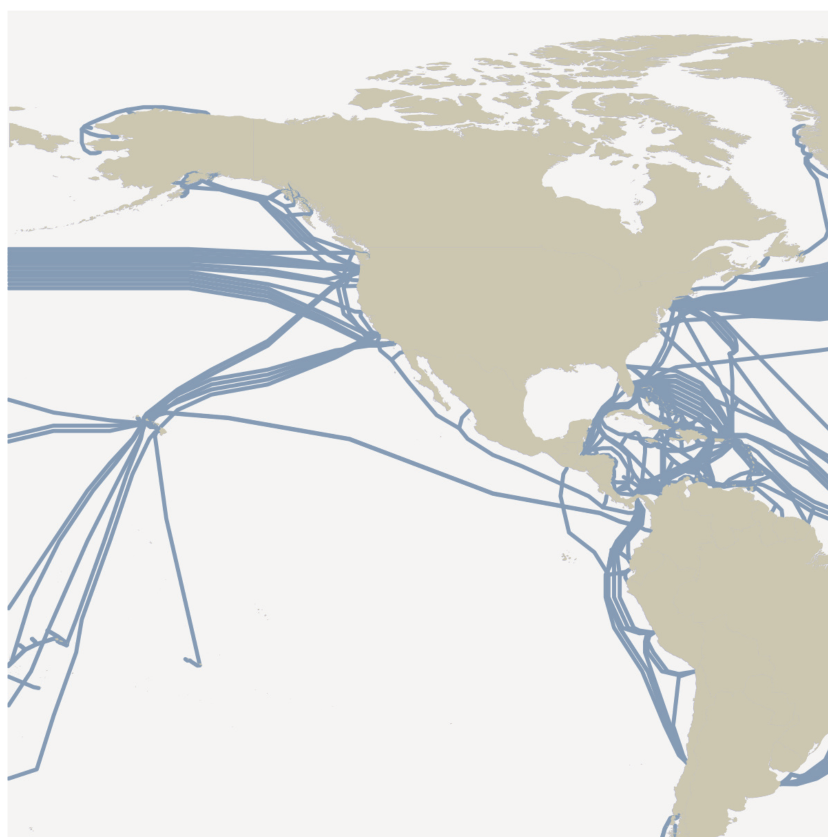
Earth monitoring is essential to understand the effects of climate change. However, whilst the ocean plays a fundamental role in regulating the world's climate, it is still mostly unmonitored. New research led by the National Physical Laboratory (NPL) in Teddington shows that seafloor telecommunication cables could play a fundamental role in reducing this data gap.

Climate change is one of the greatest challenges that the world is currently facing. Unprecedented temperatures and extreme weather events have dominated the headlines in several countries this summer, and more can be expected in future. In this changing climate, a fundamental role is played by the ocean and its complex circulation. Changes in these water conveyor belts can in fact have a dramatic impact on the world's climate and a full understanding of their behaviour is crucial to predict, and possibly mitigate, their effect. Over several decades, scientists have been equipping land and space with increasingly advanced monitoring capabilities, delivering crucial data for climate change research. However, whilst more than 70% of the Earth's surface is covered by water, it might be surprising to learn that the oceans are still largely unmonitored. Indeed, it is technically and economically very challenging to install and maintain a network of permanent sensors on the seafloor on a global scale. As a result, environmental data from the seafloor is scarce and available only from deployments with temporary sensors in specific areas of the world and a handful of permanent ocean-bottom scientific observatories, limiting our understanding of the overall dynamic ocean behaviour.

Results from our recent research show a possible new way to start filling the large gap in ocean data, without requiring any additional seafloor installation. We showed that in the future, a network of ocean-bottom environmental sensors could be deployed by using the existing subsea telecommunication infrastructure that already lies on the seafloor and enables internet traffic across the world.

By launching ultra-stable laser light into the optical fibres inside a 5,860 km-long seafloor cable connecting the UK and Canada and performing precise measurements of the time it takes for the light to travel through it, we were able to detect ocean currents at the



The existing network of seafloor telecommunication cables enabling global connectivity.

bottom of the Atlantic Ocean[1]. Under the action of ocean currents, the seafloor cable is "strummed" like a guitar string, causing changes in the time of travel of the light in the optical fibre. These are very small changes which do not normally have any impact of the internet traffic transmitted over the optical fibre cables. However, by employing high-precision optical measurements, they can be detected so that the optical fibre becomes a sensor for deep-ocean currents. In seafloor optical cables, optical amplifiers are installed typically every 50 to 90 kilometres along the cable. This is because, whilst optical fibre inside the cables is made of very transparent glass, the intensity of the light still weakens significantly after travelling tens of kilometres through it. Thus, "light boosters" (the optical amplifiers) are employed at regular intervals to enable transmission over thousands of kilometres. In our experiments, each cable span between optical amplifiers acted as an individual environmental sensor, thus achieving up to 20 sensors every 1,000 km. Expanding this technique to multiple cables, a network of hundreds, or even thousands of sensors could be achieved without changes to the seafloor infrastructure.

In the future, the same principle could potentially be used to monitor long-term changes in ocean-bottom water temperatures, currently unmonitored. Research in this direction has only recently started, but if successful, this novel way of monitoring the thermal changes in deep ocean could add crucial information to global warming research.

After enabling the digital revolution of the last 30 years, the web of optical cables that criss-crosses seas and oceans might be the key to a new revolution, this time in Geophysics and climate research, by enabling a unique new way of detecting deep ocean currents and, potentially, temperature as well. Today 1.4 million kilometres of optical fibre, across 550 cables, are already installed on the seafloor. With the ever-increasing demand for more connectivity, the number and geographical coverage of these cables can be expected to increase substantially over the coming decades. Consequently, the coverage of this seabed infrastructure will expand, reducing the number of areas of the oceans not crossed by cables. By applying the environmental sensing technique developed at NPL, crucial data could be collected to better monitor changes in the ocean, enhancing our understanding of ocean circulation and climate change research.

It is interesting to note that this potentially game-changing monitoring technique was derived from research on ultra-precise time and frequency distribution over optical fibre links that NPL has been developing over the last two decades. Once again, by pushing the boundaries of precision measurements in research laboratories like NPL, new innovative outcomes and applications are achieved. Just as the improved resolution of the James Webb Space Telescope is now allowing us to discover details of space we couldn't see before, pushing the precision of measurement provides a fundamental tool to set the landscape for new discoveries and applications, with huge potential benefits to society.

Reference

1 Marra G. et al., "Optical interferometry-based array of seafloor environmental sensors using a transoceanic submarine cable", Science, 376 (2022)