AN OCEAN LIKE NO OTHER

8.2 SOMALIA UPWELLING: WHAT DRIVES THE WORLD'S STRONGEST SEASONAL UPWELLING?

VIDEO DURATION – 7:18

Off the coast of the Horn of Africa runs the fastest current of the global ocean – the seasonally reversing Somali Current. From June to September, when the monsoonal winds blow to the north-east, the world's strongest seasonal upwelling occurs along the coastline of Somalia, bringing cool, nutrient-rich water to the surface.

In this lecture, we will take a closer look at this Somali upwelling system using a combination of satellite remote sensing and ocean modelling. This lecture was written by myself, Dr Zoe Jacobs, an ocean modeller at the National Oceanography Centre in the UK.

Little is known about this ocean region. Somalia's turbulent history combined with issues of maritime security have resulted in limited ship-based research expeditions, meaning there are very few *in situ* data available.

However, modelling and remote sensing data provide us with powerful tools to begin unravelling the dynamics of this upwelling system.

We are trying to address the following questions:

- When and where does this upwelling occur and is it observable from space?
- how variable is it or how much does it change from season to season and from year to year and what actually drives this upwelling, which sustains regional fisheries.

First, let's take a look at the remotely sensed surface chlorophyll during July, which is at the peak of the southwest monsoon shown here as an average from 1998-2018. We can see that large chlorophyll concentrations, which indicate high productivity, exist along the Somali coast, with the greatest concentrations occurring further north.

If we look at sea surface temperatures, you can see a similar pattern, with the coolest waters occurring along the coast and north of 10°N. Comparing the two monsoon seasons, it is clear that the southwest monsoon is the most productive. This is all down to the Somali upwelling.

So what drives the upwelling at this time of year? During the southwest monsoon, strong winds blow along the Somali coast in a north-eastward direction. This results in a narrow band of upwelling along the coast, which we refer to as Ekman upwelling. In contrast, when the winds blow in the opposite direction toward the southwest during the northeast monsoon, the upwelling is shut off. The Somali Current is also very fast at this time of year and flows northwards along the coast, in alignment with the winds.

However, it isn't as straightforward as that. In this image of modelled currents, averaged in July from 1990-2015, we see two separate deviations of the Somali Current away from the coast. These deviations form the northern limbs of two important features. The Southern Gyre, and the Great Whirl.

As these branches of the fast-flowing Somali Current deviate away from the coast, cold, nutrient-rich water is upwelled to the surface, leading to the initiation of large phytoplankton blooms. This, is the Somali upwelling.

Let's look at the Somali upwelling in motion, using our model. Here, we can see the seasonal changes in sea surface temperature associated with the Somali upwelling. During the summer months the temperature is much cooler than during other times of year. You can also see the seasonal pulse of chlorophyll, with high concentrations, shown as green, occurring during the summer alongside the cool temperatures, indicating high productivity. This is able to occur due to the large quantities of nutrients brought to the surface by the upwelling, providing food for phytoplankton. You can see the high nutrient concentrations here in red.

Now we would like to understand how stable the Somali upwelling is. Does it occur every year with the same strength, or does it change from year to year in a similar way to the neighbouring North Kenya Banks upwelling?

These time series graphs show the mean sea surface temperature and chlorophyll averaged over the two main upwelling sites for each month from 1998-2018. We see both seasonal and year-to-year variability. The peaks in chlorophyll and troughs in temperature occur during the southwest monsoon season. This is the productivity induced by the Somali upwelling. In contrast, the peaks in temperature and troughs in chlorophyll are associated with the northeast monsoon, when the Somali upwelling is not active. While there is some year-to-year variability, the relatively small range indicates that the Somali upwelling is fairly stable, and occurs every year.

The Somali upwelling may be a fairly stable feature over recent years, but what is expected to happen with future climate change? Around the world, upwelling systems are expected to become more powerful in future, in line with faster winds. However, this is working against the increased stratification due to warming. Because of these

competing factors it is unclear how productivity will be impacted, so we need to use models to improve our understanding.

Because climate models are now sufficiently advanced to assess what may happen if large quantities of carbon dioxide keep entering our atmosphere, we can use them to understand what may happen to the Somali upwelling. In addition to a much warmer ocean, climate change is projected to lead to a more stable stratification with fewer nutrients and reduced productivity, deoxygenation, ocean acidification, sea level rise, sea ice loss and changes to the ocean circulation.

Upwellings are also "windows into the deep ocean" – they are the places where acidification and deoxygenation will manifest themselves first. Under the high emission scenario, nutrient availability and primary production is expected to decline in this region by the end of the century, especially in the vicinity of the Great Whirl.

Dissolved inorganic nitrogen, which is needed to sustain phytoplankton, declines by half by the end of the century. Primary production also declines by about 20%. Despite this, the Somali Upwelling will remain active right through to the end of the 21st century, and carry on its important role as a highly productive and relatively cool feature of the region.

What this means for fisheries is a big unknown. Being so close to the equator, the sea surface temperature in the Somali waters is likely to be higher than currently observed anywhere in the tropical ocean by the end of the century. How marine species will adapt is unclear as it will be compounded by other factors like reduced productivity and acidification. However, this is an upwelling system, and its immediate vicinity will still be cooler and more productive than the surrounding ocean and could become a refuge for various species.

In this lecture we have learned about the most powerful seasonal upwelling system in the world, the Somali upwelling. We found out that it occurs every year during the southwest monsoon season from peaking in July, bringing cold, nutrient-rich water to the surface. While its productivity is expected to slowly decline over the course of the century under the impact of climate change it will carry on playing its important role as one of the most productive features of the region.