AN OCEAN LIKE NO OTHER

6.2 MODELLING TO THE RESCUE! WHAT DRIVES NORTH KENYA BANKS UPWELLING?

VIDEO DURATION– 07:33

In the last lecture, we learned that the offshore fisheries over the North Kenya Banks are seen as the new frontier for food security for Kenya's growing population. Yet, they remain largely unexploited.

In this lecture, we will take a look at the latest scientific research that employs a combination of remote sensing and ocean modelling to answer the following questions:

- how much of the high productivity of the North Kenyan Banks is sustained by the upwelling?
- Does this productivity hotspot vary from year-to-year and occurs in the same place?
- And how will this productivity be impacted by climate change?

First, let's take a look at the remotely sensed chlorophyll, shown here as an average during the southeast monsoon, in boreal summer, and during the northeast monsoon, in boreal winter, over the period from 1998 to 2016.

Here, we can see that the chlorophyll, and hence the productivity, is enhanced over the North Kenya Banks during the winter.

Looking at different examples from January and February reveals that the productivity is highly variable. Examples of highly productive years include 2002, 2003, 2007 and 2015 where chlorophyll concentrations exceed 1milligram per meter squared over the North Kenya Banks.

The exact position and extent of this feature varies every year. The strength of the signal is also different, with some years experiencing high productivity over a large area, while some years there is no signal at all, like in 1998 and 2006.

To investigate the variability and importance of the North Kenyan Banks upwelling, we use our high-resolution, biogeochemical ocean model you've seen many times in our lectures.

Just like in the satellite-derived chlorophyll, we see the same elevated chlorophyll signal over the North Kenya Banks in the model; here is an example in 1997. The model also reveals cool sea surface temperatures and high nutrient concentrations over the same region, which are indicative of upwelling.

Let's have a look at how ocean characteristics are changing with depth. This is something we can do only with the model, as remote sensing fields give us only surface information.

Taking a cross-section through this signal shows the cold, nutrient-rich water being upwelled to the surface waters, leading to increased primary production. Like in remote sensing, the position, strength and extent of the enhanced productivity in the model varies from year to year.

However, there are multiple upwelling features here.

If we take a closer look at one of these images, we can see a thin band of high productivity along the entire coast. This is caused by wind-driven upwelling, as the North-easterly winds that blow at this time of year induce an offshore Ekman transport, which causes surface waters to flow away from the coast, and the cooler, nutrient-rich waters to be brought up from the deep to replace it. This occurs every year during the Northeast Monsoon.

You can also see further enhanced primary production over the North Kenya Banks, which provide additional topographic enhancement as the current flows over them. Again, this is seen every year.

But in some years, we see wider productivity over the North Kenya Banks – this is the signature of the upwelling we are looking for.

As we have seen in the previous lectures, during the winter, the Somali Current reverses to flow southwards, and meets the still northward-flowing East African Coastal Current to form what we call the Somali Zanzibar Confluence Zone, which resides near the North Kenya Banks.

After the currents converge, they are deflected away from the coast into the open ocean to continue flowing eastwards to the South Equatorial Counter Current. This deflection causes the deeper, colder water that is full of nutrients to be upwelled to the surface. This availability of nutrients leads to the enhanced productivity that we see in some years.

The exact location of the confluence of these two powerful currents depends on the strength of each of them in a particular year. It is influenced by many factors of the Western Indian Ocean dynamics. However, when it occurs in the vicinity of the North Kenyan Banks, a large hotspot of elevated productivity is formed in this area.

The position of this confluence zone acts as a control on the strength of upwelling, and therefore the amount of primary production that occurs every winter.

There is one year that doesn't conform to this trend, and that was 1998, which was the year immediately after a strong El Nino occurred, which caused major changes in the Indian Ocean. It led to widespread warming of up to 2C more than normal in the Western Indian Ocean and caused a large gyre to form. This meant that the confluence zone was found much further south than usual, to the south of Zanzibar.

This caused the North Kenya Banks upwelling to completely collapse and led to a temporary upwelling cell to develop in Tanzanian waters instead, by Dar es Salaam.

In summary we have seen three upwellings at play in the Kenyan waters – a coastal, wind driven upwelling; a topographically constrained upwelling driven by the rough topography of the Banks; and a large shelf break upwelling driven by the highly variable Somali-Zanzibar confluence zone. It is the confluence zone upwelling which brings the largest variability and largest uncertainty to the amount of productivity the banks can sustain.

How fish stocks respond to this variability is the next critical piece of information we urgently need to obtain in order to manage the stocks sustainably.

The critical importance of this information is difficult to overestimate, for example during an unusually strong upwelling in 2019 the fishery was hitting the newspaper headlines.

That brings us to the final question: What will the impact of climate change be on this productive system?

Climate models are now sufficiently advanced to show indications of what might happen to the oceans if the amount of CO_2 entering our atmosphere continues to increase.

Let's have a look at the High Emission Scenario, or RCP8.5.

Under this scenario, tropical Western Indian Ocean is expecting to see a rise of the averaged sea surface temperature by about 4 to 5C by the end of the century. In the background of this averaged temperature rise, we will see extreme events, such as marine heatwaves, increasing in frequency, duration and intensity.

Model projections also show a reduction of winter primary production of about 30% by 2100.

Without a doubt, the impact of these climatic stressors on marine ecosystems combined with the ocean acidification and reduction in oxygen concentrations will be severe. However, some major uncertainties remain as the resolution of climate models is not yet good enough to be confident about the fate of the Confluence Zone, the key feature driving the North Kenya Banks upwelling. Changes in its future dynamics are also tightly link to the future fate of the Indian Ocean Monsoons, one of the major uncertainties of the climate change projections in the region.

Understanding how these climatic stressors will evolve in the next two decades and how the ecosystems will respond to them is the key scientific challenge we need to address to ensure we can manage these ecosystems sustainably under the accelerating impact of climate change.