OCEAN SCIENCE IN ACTION

9.6 A TALE OF TWO UPWELLINGS

VIDEO DURATION– 06:56

In this lecture we will introduce you to some applications of the modelling and remote sensing you have learned about during the second week of the MOOC.

This lecture was written by Dr Fatma Jebri, who will take you on a fascinating journey of the analysis of fisheries data, model output and remotely sensed parameters. Fatma is on a quest to understand what environmental factors drive the abundance of small pelagic fish along the Tanzanian coastline, and if there a chance that we can predict it.

First of all, let's have a look at the yearly Tanzanian catch of herrings, shads and anchovies, superimposed with remotely sensed chlorophyll. As you can see, the year-to-year variability is highly correlated, which is a good sign.

If we can explain what drives the variability of chlorophyll along the Tanzanian shelves, we may gain some predictive capability for the small pelagics. Or at the least, we will be able to anticipate good and bad years.

As you remember from our food security lectures, stability is one of the four pillars of food security, and small pelagic fish are renowned for variability and instability of its stocks.

Chlorophyll is a good proxy for phytoplankton biomass, which lies at the base of all marine food webs and is also a proxy for primary production. It can be observed from space and modelled with a high degree of realism.

Also, as you may remember from our modelling lectures, the vertical supply of nutrients is the key factor that controls the growth of phytoplankton in tropical waters and, therefore, the amount of chlorophyll we observe. The key factor that controls the growth of phytoplankton in tropical waters and, therefore, the amount of chlorophyll we observe.

The key process which brings nutrients to the surface in these waters is upwelling. What drives the upwelling along the Tanzanian coast? During which season does it occur?

First of all, let's look at the seasonal cycle of the chlorophyll over the Tanzanian coastline from remote sensing. It has high values during both monsoon periods: in boreal summer, during the peak of the Southeast monsoon, and one in boreal winter, during the Northeast monsoon.

If you remember from our lecture about upwelling, the explanation for the Tanzanian upwelling during the Northeast monsoon is pretty straightforward; We are in the Southern hemisphere. Wind blowing from the north along the coastline will cause the coastal waters to deviate to the left under the influence of the Coriolis force. This off-shore movement will bring the nutrient-rich deep water to the surface and cause a phytoplankton bloom which we will detect in the elevated chlorophyll signal. But in summer, during the south east monsoon, the wind blows in the opposite direction. And it is not an upwelling-favourable direction.

So what causes the upwelling during this season?

There is another mechanism at play, called Dynamic Uplift Upwelling. It occurs when a boundary current flowing along the shelf break accelerates.

In our case, we have the strong East African Coastal Current flowing along the whole of the Tanzanian coastline, and when it accelerates during the southeast monsoon, it brings nutrient-rich waters to the surface.

Let's go back to our graph of small pelagic fish catch and chlorophyll. As you can see, in this time series there are two extreme years. One in 2002 where we see an abnormally high chlorophyll concentration and high small pelagic fish catch. And one in 2011 when the situation was reversed to a minimum. Now, with our knowledge of two different types of upwelling at play, can we find out what was different about these two years?

The answer lies in both the local and large-scale wind fields, with both monsoon seasons experiencing anomalous conditions.

During the winter, there were stronger than normal alongshore local winds, and during the summer, there was an unusual large-scale wind pattern over the tropical Western Indian Ocean, which accelerated the South Equatorial Current and East African Coastal Current.

Here is what the upwelling looked like in September 2002 in the model and in remotely sensed Chlorophyll relative to the climatological averaged values. You can see a band of unusually high values along the coast.

Further analysis of the model discovered the additional role that the South Equatorial current plays in elevating the productivity of Tanzanian waters. It connects the Tanzanian shelf to the areas upstream, near the tip of Madagascar, in the vicinity of Aldabra and Cosmoledo islands and the Mascarene plateau.

These features are right on the path of the south equatorial current and trigger topographically-induced upwelling, which enriches its waters with deep nutrients that are brought to the surface.

Horizontal advection of nutrients in the subsurface waters provides a powerful additional source that fuels primary production along the coast when the dynamic uplift upwelling kicks in.

You may ask "What gives us confidence in the model?"

Good agreement with the remotely sensed chlorophyll and ocean currents derived from altimetry do not give us the whole picture of the system. In situ observations are not very common in these waters. But luckily for us, a cruise taking lots of measurements of nutrients has taken place during one of the strong upwelling events in 2004. Also, in summer 2019 major fieldwork including marine robotics and biogeochemical surveys was carried out in the Pemba Channel by an international team of scientists from the SOLSTICE project.

A wealth of information about the structure of the current, nutrients, phytoplankton and zooplankton have become available to further interrogate our model and to learn about its strengths and weaknesses.

Also, the model performance in other upwelling systems of the Western Indian Ocean have proven that under different conditions and in different locations the model performs really well.

A growing collection of such case studies puts our models under stringent tests. And if proven successful, we gain confidence to use such models not only for the present or recent past events, but also for the future projections under various climate change scenarios. Such studies also give us new information and new insights into the dynamics of ecosystems and allow us to further improve model parameterisations.

In this lecture, we showed you an example of how analysis of remotely sensed information together with modelling and in-situ data allows us to begin to understand the driving mechanisms of the fisheries along the Tanzanian coast.

This lecture, as well as Kenyan and South African case studies also showed that ocean upwelling is a common mechanism driving blooms of phytoplankton in many areas.

Manifestations of the upwelling, its driving mechanisms and consequences for ecosystems, fisheries and societies are unique in every region and requires data from many platforms and sensors, and multiple methods of analysis to begin to understand and predict.