Topic 3a - Looking at our oceans

The oceans are critical in determining the Earth's weather and climate. We receive more energy from the sun at the equator than at the poles, and both the atmosphere and the oceans act to distribute some of that energy towards the poles. The oceans do that by the vast overturning circulation, where water sinks to the deep ocean in the North Atlantic travels all the way down the Atlantic to the Southern Ocean, where it ventures up towards the surface again, completing the overturning circulation.

The oceans also soak up a significant amount of the carbon dioxide that we put into the atmosphere each year. About 25% of our carbon emissions end up being soaked up by the ocean, reducing the amount of carbon dioxide in the atmosphere. We also see other important influences of the ocean on the El Nino phenomenon, for example, which is critical coupling at the atmosphere and ocean, which ends up influencing weather patterns throughout the world. Oceans are also critical to other extreme weather events, such as hurricanes, and they help to determine our daily weather patterns.

Satellite data can provide a host of critical information to help us understand the oceans and their interaction with other parts of the Earth system. They tell us about the winds that blow across the surface of the ocean, about the ocean currents themselves, about the temperature of the ocean, and about the composition of the ocean. We're able to determine the amount of chlorophyll, for example, at the surface of the ocean from satellite data.

All this data can help us to understand the dynamical relationship between the ocean and the atmosphere. That's critical for understanding some key aspects of our weather. The El Nino phenomenon, for example, is something that depends on, both changes in the atmosphere and changes in the ocean, and how they connect together. So to be able to predict future El Ninos, we need to have information, both from the atmosphere and the ocean.

Remote sensing offers a number of different ways of acquiring information about the coastal and open oceans. Scatterometers provide information about the wind speed and direction at the surface of the ocean. Altimetry tells us about the height of the ocean surface, which enables us to get information about the currents and the waves. Synthetic aperture radar tells us about the roughness of the surface between the ocean and the atmosphere. And scanning radiometers and microsounders give us information about the sea surface temperature.

The satellite altimeter's actually, in principle, a very, very simple instrument. All it's actually doing is measuring the distance between a satellite and the ocean surface, or the surface, whatever it happens to be. We're interested in the oceans. And it bounces a microwave signal, emits a microwave signal, bounces off the sea surface, measures the time that it takes to get back to the satellite. We convert that time, using the speed of light, into a distance.

Fundamentally, that's all an satellite altimeter does. The interesting bit is what that tells us about the ocean. Because what we actually do is to convert that distance to the height of the sea's surface above a reference. We need to know the reference. And our reference is where the sea surface would be if there were no ocean currents.

Because ocean currents make the surface of the ocean bump up. If you imagine a pressure chart for the atmosphere, so if you're looking at a weather forecast and you have the charts with all the lines that show you the pressure in the atmosphere, then you can work out where the winds are blowing. Satellite altimetry works in exactly the same way. If you have an ocean current, it makes the sea surface rise up. We measure that change in height, and from that, we can determine the ocean currents.

So that's what we're after in principal, and in principle, it's very simple. The next set of missions being launched by ESA are the Sentinel missions. Sentinel One is up and it's just gone operational. That gives us synthetic aperture radar data. That gives us amazingly fine resolution views of the ocean surface, and the land surface, and of ice.

There are other missions planned for launch this year and next year that have new optical sensors to give us ocean colour, new temperature sensors to give us a new view of high-resolution sea surface temperature. There's another altimeter mission that will continue the measurements that were taken from the previous ERS I, the ERS II, Envisat missions. So we get a continuity of those data that give us very important time series for climate research.

Global climate change is a global problem. And as such, you need to tackle it with global means. You need to look at the whole picture, things that are happening around the entire globe, and make sure that the measurements that you take are representative of the global picture.

In the top three metres of the ocean, there's exactly the same amount of heat as you have in the whole atmosphere from 0 altitude to the top of the atmosphere. And yet, the oceans, on average, they are 3,000 metres deep. So the quantity of heat that there is in the ocean is enormous. And those are really the regulators of the climate on our planet. That's why it is important to look at the ocean as an important factor in climate change.

Satellites give us a very good vantage point to look at our planet in it's entirety. And it's possible, with satellites to measure a huge number of parameters. And what you see here is a plot that we get from satellites in particular, from radar altimeters of the global mean sea level. You measure the sea level all around the globe, and you average, and you get just one number, which will tell you the average sea level in that particular instant around the globe.

This is very important to tell us how climate is changing, because it's like the blood pressure in a patient. It will tell you where it is going, and what is the result of many things going on at the same time on our planet. And it is the result, of course, of water getting warmer. But even more importantly, it is the result of more water getting into the ocean because glaciers are melting over land and over the ice sheet.

And what you see here, the end of 1992, when the modern altimeter either started to nowadays, you see a very steady increase, about 3 millimetres per year. This has been possible by just looking at data from satellite. And another thing that you see on this plot is that, on the very short time scale, there are variations, even rapid variation of the sea level of a small amount. So that may depend on a number of different things, like changing weather around a particular region, or atmospheric phenomena, or more rain over another particular region, and so on.

But what we are really interested in, from a climate perspective, is the long-term trend of this curve. And it's clear that, in between some inter-annual variability, you've got a long trend that is a clear sea level rise. Projection of sea level rise for the future, point in some cases, and for so many models, to an acceleration of this rate of sea level rise that could lead to another sea level rise of 1 metre, perhaps, by the end of this century.

If you look at this plot, we have already over 20 years of data, 6 centimetres, but some models predict that it is going to accelerate because of global warming, and so more water flowing into the ocean from melting of the ice. This is the global mean, but what I can show to you from space is really a map of how this varies from region-to-region, which brings up a very nice map. And this is a map of the trend of sea level rise on the globe, so you can see how it varies from region-to-region.

What you see here in red are regions where the sea level is rising faster than the average. Again. the global average is about 3 millimetres per year, and we've seen it in the line plot before. But from region-to-region, it varies quite a lot. And indeed, there are regions like the West coast of the United States, and the Eastern Pacific, where it's not rising much. There are other regions, like the Indonesian region, where we've seen rise rates in excess of 1 centimetre per year.

This is important for oceanographers, because it points to changes in the global ocean circulation, the larger scale currents. So these changes and these differences map into changes in the currents over long periods of time, or changes in the way that, locally, the ocean is storing heat. There are places, perhaps, where the ocean is up-taking more heat than in other places.

Of course, one of the reasons that we see so many differences is that, so far, we've looked for 20 years. Because, perhaps, if we could see this very same map in a 100 years from now, it would be much more uniform, because eventually, many of those differences will have to even out. And everything will follow the global sea level rise rate that we saw in the line plot.

And there are interesting features that I should point out. How the various big currents are changing, like the Gulf Stream in the North Atlantic, or the Agulhas Current here, or the Kuroshio Current in the North Pacific. This map really shows the capability of altimetry as a global means of monitoring sea level. Because from tide gauges, you would only get a measurement in many dots along the coast. And from from Argo floats, you can get a very smooth picture of how this is varying across the whole ocean.

But from space, from the vantage point of a satellite, you get a very detailed picture that covers the entire globe. And the good thing is that space agencies have recognised the usefulness of these, and there's a long lineup of altimetry missions planned for next 20 years by the European Space Agency, by other space agencies. At the moment, they have been integrated in Europe within the Copernicus Project run by the European Space Agency in connection with the European Union.