Topic 1d - Large scale ocean circulation

When you look out at the ocean, it doesn't necessarily look like it's doing very much. But it's a fast, dynamic system. Tell me about your view of the ocean.

Well, the ocean really has a fundamental influence on the Earth's climate. I mean, from global to regional scales, they can store, transport, and exchange with the atmosphere a huge amount of heat, water, and gases such as carbon dioxide.

And we know, for instance, over the past 50 years they observed more than 90% of the extra heat gained by the Earth due to global warming. This is an extremely important role of the ocean as a whole to regulate the climate.

This is also due to the very large heat capacity of the ocean, which is more than 1,000 times the one from the atmosphere. So this really shows the importance of the ocean.

But the oceans, they do not only store a huge amount of heat. They transport them over a very long distance through ocean currents. This is really the dynamic part. Actually it is really the interplay between ocean dynamics on this heat storage that regulate our climates, and that also effect the regional climates in the world.

Now we've got a wonderful toy here, which is a picture of the globe that we can move around. And tell me about the black bits of the continents. Tell me what the colour of the ocean here is showing.

Yeah. The colour represents the temperature of the ocean. And we see that the temperature depends on latitude, because the ocean are getting more heat in the tropical or subtropical.

So here, this red bit.

Here, in this place, you see there's a lot of heat going.

But then we have a really important contribution of the ocean that redistributes, through the ocean current, this heat, which is stored in the tropical, subtropical region, towards high latitude. And this is part of what we call this thermohaline circulation, which is a fundamental component of the ocean circulation.

And the idea that we have current moving northwards, which carries this warm water towards high latitude. So when they move northwards, they lose heat, and they warm the atmosphere. So this is a very important effect to regulate the climate. But the water also gets denser, because colder water is denser.

So when they arrive to the high latitude, in this region, water is very cold.

There can also be salt here. Because when you have sea ice formation, you have more salt in the data. So they are much denser. So they can sink. And actually they sink to depths of up to several thousand metres.

So they sink, and then they flow back very slowly in the entire ocean. And that feeds the ocean basin.

So we have this kind of overturning circulation, which is fundamental to regulate the climate, which is very important parameter that we oceanographers want to follow.

Now, why do we want to follow it? We know from the past, analysis of past sediment, of ice cores, they show that in the past we have had a rapid variation of this meridional overturning circulation, over several decades only.

And this was associated with very important change of our climate. So this is the reason why we're really carefully monitoring this meridional overturning circulation from in situ observation, from satellites, and from models.

So we can see here. Let's go back to the detail a little bit. The reason for this bright red patch near the equator is that the sun's energy is being absorbed, and it's being taken up by the ocean.

Exactly. But this part of the ocean cannot warm indefinitely. So you accumulate water. You accumulate heat. But this needs to be transported towards a high latitude.

It's done by the ocean and by the atmosphere. But the ocean has a fundamental role through this overturning circulation.

So this is about energy distribution, not just around the oceans, but into the atmosphere as well.

Yes. A very essential point that people do not often realise is how important is the ocean for the energy of the planet. And I was mentioning before this fact that the oceans have absorbed 90% of the Earth's warming over the last 50 years, which is Earth's warming which is due to this increase of greenhouse gas concentration.

But this show that really the ocean, through the heat absorption, is a major driver of the energy system of the Earth. This is a fundamental. And without the ocean we couldn't live in this planet.

I think of the oceans as an engine. They're shunting heat around. And it's an enormous amount of heat. And it's redistributed around. And so that means there are currents. Because that's what we call moving water.

How can a satellite help you with understanding currents?

Well, actually satellite provides essential observation to monitor the ocean circulations on our different types of satellites. But the most important one for monitoring the ocean circulation are satellite altimeters.

Altimeters can provide measurement of sea level variation. And we know that sea level is directly related to ocean currents through the geostrophic approximation. So a sea level slope is associated to a current.

So thanks to satellite altimeter we can map the sea level globally. And from the slope of sea level, we can derive ocean currents. So this was actually a revolution in our way to observe the ocean from space, thanks to the satellite altimeter.

We also know that we need several of them, because we know that we need to observe the ocean at high resolution. Because we have a lot of ground surface structures, which are very important to understand the dynamics of the ocean. And this is the reason why we actually have several altimeters flying.

So we have one reference mission for climate application, with the Jason series, and later on with Sentinel 6 satellite from the Copernicus programme.

And we have, for the present time, the Sentinel 3 altimeter, which are essential to provide a complimentary sampling, and to monitor this ocean at a very fine scale.

So by using satellite altimeters you can monitor the shape of the ocean's surface. Because it's not completely flat everywhere. It's got lumps and bumps. And they can tell you where the currents are.

Yeah. Exactly. If you flew over the Gulf Stream, for instance, you would see a sea level slope of about 1 metre over several hundred kilometres. And this slope is directly related to the current.

So it just is very similar to what you have in the atmosphere with the low and highs on the winds around this. This is exactly the same phenomena.

This strong- it really is a strong value of altimeter and sea level measurement is not only for sea level. Sea level is very important, of course, for climate. But you can really get the ocean current.

In addition, we have other satellites that provide a sea surface temperature observation, ocean colour. And we also know that at a fine scale the variation of sea surface termperature and the evolution over time, they also reflect the ocean current. Because the structure advected by ocean currents.

So if you follow a sea surface temperature map from a satellite over time, you can derive ocean currents.

We also have very important satellite observations that are quite important for ocean circulation studies as well, the observations from wind. Because we know that wind is the main driver of the ocean circulation. And we can monitor wind from space as well through scatterometer emission. This is a very important observation from space for ocean circulations studies.

We have these different size scales. Then we have this very large overturning, which is due to heat redistribution. And then I think we've got a map here of some ocean currents. Suddenly when you can map these ocean currents, suddenly there's detail everywhere. Tell me about what we can see here.

Yeah. Actually there are a lot of details. And it's often, when we represent these ocean circulations, these great ocean conveyor belts, or thermohaline circulation, it's fine. But it's a very crude approximation on how the ocean works. It can actually be misleading for some aspects.

Because we know that fundamentally the ocean is a turbulent system. And its circulation, the currents, they are fed with a lot of eddies, meanders, filaments, fronts, and so on. So this is what we call the Mesocale Variability.

So it's much more complex than the visions you would get with the great ocean conveyor belt.

If you look at current from the Gulf Stream here, you will see that it has a lot of meanders. Those meanders will shed eddies. Eddies will have filament, fine scape structure.

You could say, OK, it's not important for the climate. Maybe we need the big picture with the large scale. In practise, we know that even the small scales are important if we want to understand the role of the ocean on the climate.

And, of course, it's also very important for many other applications, such as what we do, for instance, with the Copernicus marine service. We are using satellite altimeters, together with other satellites and in situ observations to analyse and predict ocean currents. This is very important for climate applications and so on, but it is also very important for a lot of practical applications, ship routing, helping the offshore operations.

If you want also to predict the fate of marine pollutants, you need ocean currents at high resolutions. So there are many requirements for these satellite observations, but these satellite observations alone will never do the job. So they need to be complemented by in situ observation to monitor the entire ocean on models to provide analysis and forecasts.