Topic 3f - Ice: in-depth case study - monitoring ice thickness

The loss of Arctic sea ice is perhaps one of the most iconic examples of our changing climate. People will have heard about it in the news over the past 10 or 20 years. And the sea ice the Arctic region has been retreating inexorably over the past 20 or 30 years. The Arctic sea ice occupies, in winter, most of the Arctic Ocean basin here. It's not seen in this image because the images have it stripped away.

But in summertime it retreats to a small area. This is a picture of some investigators from the Alfred Wegener Institute in Germany, collecting really, really important, and, as you can see, tough measurements of how thick the Arctic sea ice is in the middle of winter in Antarctica. Very, very hostile environment. We rely heavily upon these sort of ground based measurements to correctly interpret the satellite measurements that we collect more routinely, and with a lot less effort. Without these measurements, we just wouldn't be able to study the Arctic region from space as we do.

The sea ice that's in the Arctic region is a really important part of the climate system. People believe that it affects the thermohaline circulation in the oceans south of the Arctic region, because it controls heat and input in the Northern Arctic. People believe it affects patterns of atmospheric circulation as well. There's been some suggestion that Hurricane Sandy, for example, was influenced by the pattern of Arctic Sea ice when that event took place.

And of course, many people are interested in the prospect of an ice-free Arctic region for the advantages that that might offer in terms of shipping, or access to the Arctic region. For example, mineral and oil exploration. So it's a really important part of the climate system, not just because of the way it's changing, but because of the opportunities that may be presented if the region becomes ice free.

And unlike the ice sheets, where we can spot and tell with some confidence where the ice is going to be from time to time, the sea ice drifts around on the ocean surface. And we can see that here in this animation. It's a stop-motion animation filmed for over about 10 or 20 years of how the Arctic sea ice rotates over time. And it doesn't stay in one place at all.

What I'm showing you here, though, is the image that we would have from a conventional set of satellite instruments that weren't designed to look at the polar regions. And you can see, the important thing that you can see about it is that most of the area of the Arctic sea ice is actually not surveyed. And that's really problematic, because we're not sure whether we're losing that sea ice. It could be entering a region that the satellite can't see.

Now CryoSat is designed to look at the entire polar region. And so we have a very, very small area that's no longer seen by the satellite. And we see all of that sea ice mobility as it progresses over time. And so, we're not losing any of the signal. And that's really important, because what people really want to know is how much sea ice is left in the Arctic region.

And that matters, not just the extent of the sea ice, but also the thickness. So really briefly, how do we calculate the thickness of sea ice from space? We take measurements along the satellite's ground track of the height of the earth beneath the satellite as it flies around the planet. And we take the measurement of the height of the sea ice flow itself, difference it from the height of the ocean, and we can calculate this thickness of ice that's popping up above the water. We call that the Freeboard, and we can use that to estimate the total thickness of the ice.

But we can only do that because of the estimates of snow thickness that we've got from those ground observations that I showed you earlier. The Freeboard can then give us an estimate of the thickness. And then we can chart changes in thickness over time. Just for comparison, this is how we used to be able to see the thickness of the sea ice flows with the old ocean designed altimeter missions, really coarse resolution and not accurate in terms of the thicknesses itself.

This is how we now see it from CryoSat. So you can imagine you're looking at the sea ice flows, swimming in the Arctic Ocean, which is not an advisable thing to do. And this is the thickness of the ice. And we can see the gaps between the individual ice flows themselves. And they're really critical, because if we can't see the ocean between the ice, then we can't measure the Freeboard.

CryoSat can detect 10 times as many leads between the sea ice flows of the last class of altimeters, which means it's really well suited to mapping changes in the polar regions in terms of the sea ice itself. This movie is a collection of measurements from the last four years of CryoSat. And it shows how the Arctic sea ice has changed over the four seasons of growth since the mission was launched in 2010.

So the satellite collects measurements of sea ice thickness every month. In fact, it flies around in the repeat orbit of 369 days. And we can map out the thickness of the sea ice in each month where the sea ice doesn't have melt ponds on its surface. That's about seven months in the year. And we can take those measurements and chart how thick the sea ice is over time, and how that thickness is changing.

And this map is showing the waxing and waning of the Arctic sea ice pack. So it extends and grows wider and thicker in winter. And then in summer it starts to shrink and retreat again, each year. We can't measure the thickness from CryoSat in summer, because the melt ponds on the surface cause problems. But we can measure, for seven months of the year, the growth season. And this gives a really good handle on how much ice is present, and whether that's changing over time.

So the thickest ice is up to about five metres thick. And that's concentrated around the northern coasts of Greenland and Canada. And the thinnest ice is at the edges of the ice pack as it spreads out to touch the northern coasts of Siberia, for example, as it drifts down into Baffin Bay and other parts of the Arctic Canada. So over time, CryoSat measurements here shows that the sea ice grows each winter at a rate that's very similar to that predicted by the models.

What I'm showing here are the CryoSat measurements in yellow, the actual measurements of sea ice volume as it evolves over time. This is in 2011, and we're now going into 2012. We will see shortly 2013 and 2014. And what we have to rely on prior to CryoSat, these model estimates of the sea ice thickness after the event. That's not really helpful, because those models can't tell us anything about the future in the first instance. But also, you can see that there are some uncertainties in the models that are not reproduced by the actual observations themselves.

First of all, we can see that the rate of growth of sea ice in the models is slower than it ought to be, and that's very clear from this plot here. This is the rate of growth of sea ice in the Arctic region during the early winter seasons. And the models are not growing enough sea ice, and so they can't reach the maximum sea ice volume, which is about 25,000 cubic kilometres. We can also see in the first three years of the mission, a slight decline in the winter volume of sea ice, and also in the summer volume of sea ice.

And this is consistent with the picture that people are familiar with that the Arctic sea ice is in retreat. But actually, there's been a change over the past year, which has outstripped all of that gradual decline. And there's been a recovery in the volume of Arctic sea ice that's outstripped all of the changes over the past three years. This is really important, because it shows you that the Arctic climate system is affected by weather, as well as long-term climate change.

This growth of sea ice last year is a consequence of the relatively mild, and by mild I mean relatively cool arctic summer in 2013. And more ice survived through that summer, and so more ice now exists in 2014. It's very likely to be just a temporary retrieve. It's a weather event. It's not a climate-related event, but it shows you that you need very, very long-term records in order to pick out the trend of climate change from the short term variability that you have in weather.

So even with four full years of measurements of Arctic sea ice, we still can't tell people reliably what the rate of loss is in terms of the volume of sea ice over time, because of these weather events which interrupt the signal. So we need to fly the mission for a longer time period.

Unfortunately, we can't fly the mission back in the past. There were no measurements before 2011 of most of the Arctic region. But we have enough full on board to continue the mission for many years into the future. And so we hopefully will be able to take a long-term signal of climate change pretty soon.