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Welcome to IFL Science The Big Questions, the podcast where we invite the experts to explore the biggest mysteries of science, with your host, Dr Alfredo Carpineti.

Glaciers are disappearing around the planet, and the questions of how scientists monitor glaciers and how these glaciers affect global sea level rise are very important for the future. We sat down to talk with Dr Peter Davis from the British Antarctic Survey to discuss these questions and about his research on the topic of the Thwaites Glacier in Antarctica.

I: Wonderful, thank you very much for joining us. Can you please introduce yourself and tell us what you work on?

R: Yes, and thanks very much for having me on. So, I'm Peter Davis. I'm a physical oceanographer here at the British Antarctic Survey and I specialise in understanding how oceans and ice shelves interact and how the ocean is driving ice shelf melting.

I: Fascinating. So, can we start by talking about how do you monitor the changes in ice shelves and glaciers?

R: Sure, there's two or three different ways really. I guess the first and the most indirect way is through satellite automations. Whizzing around the planet way up in space there are lots of satellites that we use to observe the ice shelves. We can look at their thickness, we can look at simple imagery of them and see how they're responding in time. Then the stuff I do, which is the *in-situ* observation. So, the deep field work. We go to the ice shelves and the glaciers and we either observe them from the surface, we take observations of snow fall and weather. We use seismic, using sound essentially to understand the make up and how thick they are. Then in particular, what I do, is we understand and observe the ocean underneath. We use techniques known as hot water drilling to drill through the ice shelf, we deploy instruments in the ocean cavities underneath the floating ice shelves. We use that to monitor how the ocean is changing, how it's circulating, its temperature, it's [unclear 0:02:11] and how the ice shelf is melting from underneath. We use all that information to build a picture of how the ice shelves and glaciers are evolving over time.

I: Why is it important to understand how the glacier or ice shelf is melting from beneath? What can we gain in insight from there that we can also maybe get from sunlight observations?

R: Essentially, the key idea is that glaciers flow in off the continent of Antarctica, these massive rivers of ice. They're very slow moving but they drift towards the ocean and when that ice, that's on the ground gets into the ocean and causes sea levels to rise. Now, ice shelves, which are a floating extension of these glaciers, they act as a cork essentially that hold back the ice that's on the land. So, they prevent the ice from getting into the ocean and they control sea level rise. The problem is, when you melt an ice shelf from beneath it weakens its ability to hold the ice back on the land and it allows the sea level rise to occur more quickly. When we observe an ice shelf or glacier from the surface what we are essentially looking at is how the surface is changing, it's basically changing its height but that integrates a lot of different processes of which melt is just one part. We have to make a lot of assumptions about the other processes in order to determine how much its melting. It's a much better, although certainly harder and more logistically intense, operation to go to the ice shelf and observe its melt rate directly, either using radars we put on the surface or drilling through and essentially putting instruments looking up at it from beneath to measure the melt rate directly.

I: Thank you very much. What are the changes we are seeing in Antarctica that are affecting global sea level rise?

R: Really the changes we are seeing is that we are seeing that warm water that is offshore of the Antarctic continent is being forced onto the continental shelves and underneath the ice shelves more rapidly. When ice shelves are in balance, the amount of ice or grounded ice that crosses over the grounding line, that's the point where the ice shelf first starts floating, matches the amount of ice that's lost through melting and lost through carving of icebergs. The problem we are seeing is that we are getting more warm water that's coming onto the shelves, it's driving more melting from beneath and it's knocking these ice shelves out of balance, or these glaciers out of balance and that out of balance means that we're getting more ice from the land into the ocean causing sea levels to rise.

I: Are there specific areas in Antarctica that are more affected than others?

R: Yes, West Antarctica. I should start by saying that Antarctica is generally split into two broad areas, East Antarctica and West Antarctica. East Antarctica is much larger but West Antarctica is the area we are most concerned about, and this is because the warm water that's driving the ice shelf melting gets much closer to the continental shelf in West Antarctica than it does in East Antarctica. So, in West Antarctica its getting up onto the shelves quite readily, it's getting under the ice shelves and its driving melting. In contrast, in East Antarctica for a variety of different reasons, there's a lot of cold water on these continental shelves that essentially protects the ice shelves from the warm water that's flowing around the continent and currently our best observations show that warm water isn't readily accessing East Antarctica ice shelves. Whether that continues into the future is an open question but currently West Antarctica is the area of most concern.

I: How much have things changed in West Antarctica over the last certain period of time? I don't know how long it has been observed and documented.

R: In terms of big obvious changes, we've seen the Antarctic peninsula, which is kind of the boundary, I suppose, between East and West. We've seen a number of ice shelves collapse entirely. Larsen A ice shelf has gone, Larsen B ice shelf has gone. Essentially, the collapsing, going from the North to the South as atmospheric temperatures warm, and then further round in the Amazon C Sector where we're seeing this warm water melting feedback. We've seen grounding lines retreat very rapidly, 2 kilometres [1.2 miles] a year. We've seen big carving events from the front of these glaciers, ice fronts have retreated inland. So noticeable and significant changes.

I: And over what time period have we seen these changes?

R: That's a good question. Probably easier if I just say over the last 10 or 20 years. I think the problem is that we see a lot of individual events and then attribution is actually quite a difficult…but certainly it's been a slowly evolving process. Probably triggered around the 1970's or 1980's when we first began to sense that this warm water was coming onto the shelf. We've seen these successive events and excessive record retreats, but I don't think you can really point to one particular period of time where something changed and happened. It's a very ongoing process and really, what complicates a lot of this is we know the region has these natural long-term cycles, cycles that maybe take 10 years to go from one state the next and then back to the original state. So, when we've only been observing for 20 years and not much *in-situ* when you've got this natural cycle going on, its quite difficult to pick out from the observations exactly what started when. Of course, we have the models as well that give us the much bigger picture, that tell us why its changing and how its going to change, but picking out the attribution of those changes is more difficult.

I: I understand. So, are you using the model to try and work out what are the changes that just happen naturally to the Antarctic Continent and the glaciers and West Antarctica and those that might be attributable to anthropogenic climate warming?

R: Yes definitely. There's colleagues here working [unclear 0:08:26], they're working on that exact question. So, the great thing about computer models is you can run many, many, many different simulations with many, many, many different initial conditions and the way that we force the model. Some of things that they do is they run the models using historical climate forcing without greenhouse gas emissions, many, many, many times and that tells us something about the natural variability in the system that we see and the benefit of that is what we see in the real world is only one instance of all possible cycles. It's a chaotic system. Then they can re-do all the simulations with greenhouse gas forcing and begin to look at the differences between all the different simulations but because they haven't just done it once, they've done it hundreds of times, they can begin to pick out what's natural and what's not natural and start attributing change to greenhouse gas emissions and what's change to natural variation and natural forcing.

I: Wonderful. You work specifically on Thwaites Glacier. What kind of changes have you seen there in the last decade or so?

R: Thwaites is essentially split into two separate dynamic regions really. We have the Thwaites main trunk and we have Thwaites Eastern Ice Shelf. What we've seen is the main trunk has disintegrated quite rapidly into more of a loose melange of these blocks of ice, whereas the Eastern Ice Shelf has retained more of an ice shelf structure. It has a more classical floating tongue that's out over the ocean, but what we're seeing now on Eastern Ice Shelf is even that now is beginning to break up. We're seeing big rifts and cracks in the ice, across the ice shelf's surface and all the evidence is pointing to a collapse of that ice shelf in the next 10, 15, 20 years.

I: **Do you know why there is a difference between these two parts? Is it clear that one is more exposed the warm water or…?**

R: I think the answer is really to do with the seabed topography. So, the ice shelves, once they float off the continent can come into contact with what is known as "pinning points". So, this is where you get shallow seabed topography that intersects with the ice base and it creates a place for the ice to grip onto. Now, in front of the Eastern Ice Shelf there remains still a pinning point. The ice shelf is still thick enough that it can hold onto that seabed and it can retain its shape whereas on the main trunk there is no longer a pinning point. So, essentially, what was the ice shelf has become unconstrained and it's just flown out into these big blocks.

I: **If the collapse of this glacier happens in the next 15 or 20 years, what are we looking at in terms of short term and longer-term consequences, for both the glacier in West Antarctica and global sea levels?**

R: I should make sure to clarify that we're talking about the collapse of the ice shelf in 15 to 20 years, this is the floating bit. The collapse of the glacier, of Thwaites Glacier, the grounded bit, whilst possible, certainly it's not something we are expecting to happen within 100, 200, 300 years. It's a multi century to millennial timescale. However, if we saw the ice shelf collapse, what we would immediately see is a greater flux of ice from the ground into the ocean. That would immediately cause the rate of sea level rise to increase. If, in the worse case scenario, that triggered some sort of unstable collapse of the glacier that played itself out over many centuries, the sea level rise could be on the order of feet, as the glacier, the grounded part, continues to flow into the ocean. There are suggestions that if you lose the Thwaites Glacier that may destabilise wider parts of West Antarctica, the whole [unclear 0:12:21] they become unstable and then you're looking at really catastrophic rates of sea level rise. But, to stress again, this is not a decade process, this is centuries to thousands of years.

I: **So, in the short term with the breaking of the ice shelf, we just would expect more ice from the continent to flow into the ocean.**

R: Exactly.

I: **Okay, thank you very much for taking the time and talking to us about glaciers in Antarctica.**

R: Thanks very much for having the opportunity.

Thank you for listening to The Big Questions. Head over to iflscience.com for the latest and greatest science headlines. The music in this episode is credited to Audioblocks.com. See you next time.

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