Seeing Antarctica's future more clearly

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Do you love to lose yourself in little things? To read every footnote of a book, watch ants in a patch of grass, memorise every mole on a lover's skin?

I'm undecided. I often fall into the rabbit hole of nitty gritty, and nit picking. Other times I enjoy the hazy view of the bigger picture in life, ideas, and work.

When it comes to Antarctica, details matter. That's because the ice sheet is super-sensitive to the lumps and bumps in the bed that lies beneath it, whether it is hard bedrock or soft sediment, and how slippery or rough.

Turns out the vast, ancient Antarctic ice sheet is restless like the Princess and the Pea.

The wrinkles and soft patches in Antarctica's bed affect how the edges of the ice react to changes around it in the ocean and air, especially when the bed lies underwater (as it does for much of West Antarctica). If warm waters approach the coast, melting the ice from underneath, the edge of the ice can either retreat inland – potentially adding to sea level rise – or else hold firm. It all depends on the small-scale features of the bed. In this coldest of places, the devil is in the detail.

A study published this week – led by my friend and colleague Steph Cornford, with contributions by me and many others – predicts the future of Antarctica with greater detail, for a larger part of the continent, than ever before. That means we think they're the most reliable predictions yet for how much sea levels might rise in future, in response to human-caused and natural climate change.

It all comes down to the ice sheet model (a description in computer code of how ice flows and changes) and in particular its 'resolution': how small the pixels are. Just like a digital camera, the finer the resolution, the greater the clarity with which we see the pictures.

In this study the smallest pixels are 250 metres across. A human can jump that far.

You can see the simulation here.

This extra clarity comes at a price: we can only simulate part of the ice sheet at a time, because the calculations are so slow. The study looks at four parts of the West Antarctic ice sheet: above is a simulation of the Amundsen Sea Embayment, with the two great ice streams Pine Island Glacier and Thwaites Glacier. The large dividing lines are 128 km (80 miles) apart, roughly the distance from Bristol to Reading, so that's about how wide the mouth of Thwaites Glacier is now.

Last year we saw more evidence that this coastline is changing fast. The glaciers are losing ice; the thin blue line that divides ice resting on the bed from floating ice is retreating inland. They're showing signs of instability, which means they might keep losing ice for some time. We're not completely sure if the trigger was natural or man-made, but we know they are contributing to sea level rise, and that human-caused warming could make this worse. And we think other areas of West Antarctica might be vulnerable too, because they also lie on an underwater bed.

In the ice sheet interior the pixels (faint grey boxes) are fairly large (4 km, about the width of Manhattan) but at the coastline—where the interesting stuff is happening—they are so tiny the lines are a blur. This is called an 'adaptive mesh': the pixel size adapts in real time, picking out more detail where the changes are happening fastest.

This means the ice sheet model can capture far more detail about the valleys in the bed that guide ice towards the ocean, the downward slopes that make the ice sheet unstable, and the spikes and hills that snag and drag the ice sheet and stop or slow the retreat. All these crucially determine how sensitive the ice sheet – and therefore sea level – is to global warming.

As co-author Dan Martin put it, it's akin to transforming a blur into a flock of birds.

That's why the study is special. What did we find?

We looked at two scenarios of human activity – business-as-usual (called A1B) or strong reductions in greenhouse gas emissions (E1) – and the results were quite surprising. Strangely the second scenario seems to have more sea level rise.

That's because there's a balancing act between the loss and gain of ice. While ice can be lost from Antarctica because the coastline retreats inland, at the same time warmer air means more snowfall. This adds ice, compensating for some of the retreat.

The melting by the ocean is similar in both scenarios, so they lose about the same amount of ice from retreat. But in the cooler E1 scenario there is much less snowfall to compensate than in the warmer A1B.

So in this study mitigation gives a couple of centimetres sea level contribution from Antarctica by 2100, and five or more by 2200; business-as-usual gives about a centimetre by 2100, and one to five by 2200.

Inevitably – as I often write about on this blog – there are uncertainties in these predictions. Two important ones come from climate models: the predictions of snowfall and melting by the ocean, which give the range of results at 2200 for A1B.

More importantly still, there is uncertainty about what Antarctica is doing today. Snowfall is hard to measure, especially over large areas of an inaccessible continent, so it also comes from modelling. Starting off with a different plausible version of today's snowfall means the ice sheet model reacts very differently: Thwaites Glacier is much more unstable, and contributes two more centimetres by 2100 and ten more by 2200. That's the simulation above.

So that flock of birds is still a little fuzzy. But we hopefully now have greater clarity about which parts of our climate matter most to West Antarctica, the restless Princess at the bottom of the world.

More information: "Century-scale simulations of the response of the West Antarctic Ice Sheet to a warming climate." *The Cryosphere*, 9, 1579-1600, 2015 DOI: 10.5194/tc-9-1579-2015

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