A slippery situation: surface melt on Antarctic ice shelves

Imagine an area the size of Greater London collapsing in the ocean; the Houses of Parliament disintegrating and the Olympic Park floating off into the sea, all in less than a month. Luckily the UK is a stable land mass so this is not a realistic scenario, but if London were built on an ice shelf (ice shelves are the huge slabs of ice that flow off of the land and are left floating on the ocean in areas such as Greenland and Antarctica) the story may be a little different.

In 2002 the Larsen B Ice Shelf on Antarctica collapsed spectacularly. An area of ice twice the size of Greater London was lost in less than a month. This occurred in the northernmost region of Antarctica - the Peninsula - which has warmed by more than five times the global average over the last century[1]. A result of this is that in certain parts of the Peninsula the surface of the ice is starting to melt. The water from this melting can accumulate to form lakes up to 4km long. Larsen B was covered in these lakes, but just before the ice shelf collapsed, the lakes started to drain. First one drained, then those around it, then those around them in a chain reaction that is suggested to have been key to the sudden collapse of the ice shelf[2].

Figure 1: NASA satellite images taken of the Larsen B Ice Shelf during its collapse. The zoomed in area shows the dark coloured lakes that were present at the time.

We don’t know what caused this sudden drainage, or exactly how it links to the ice shelf’s collapse. Various hypotheses have been suggested as triggering the collapse, including the forces that the weight of the water in the lakes exert on the ice shelf[2] and melting of the ice shelf from below by heating from the ocean[3]. However, it is clear from the sudden drainage of the lakes that their role needs investigation, especially as they are beginning to appear further south on the Antarctica Peninsula.
The loss of ice shelves such as Larsen B can mean a loss of habitat for creatures such as penguins. It can also cause changes in ocean circulation, temperature and salt content, due to the addition of cold, fresh water that the ice from the collapsed ice shelf provides as it floats away into the ocean and melts.

It may seem that all this ice being added to the ocean would contribute to sea level rise but this is not the case, or at least not directly. Due to Archimedes' principle (he's the one with the 'Eureka' moment in the bathtub), as ice shelves are floating on the water they have already displaced their own weight in the ocean and therefore their disintegration or melting won't change the level of the water.

However, ice shelves are key in regulating the speed of glaciers on Antarctica. Ice shelves can act to hold glaciers back but take the ice shelf away and the glaciers are free to speed up and flow straight into the ocean, and all the ice and water that they take with them will contribute to sea level rise.

Recently lakes similar to those seen on Larsen B have been observed on the Larsen C Ice Shelf, which is situated next to Larsen B. The reason for this area warming so rapidly and therefore surface melt occurring in increasingly southern locations on the Peninsula is not certain but it is thought that changes in atmospheric circulation and human influences (such as those due to greenhouse gas emissions and ozone depletion) on the belt of westerly winds that circle Antarctica have played a role.

In order to investigate the ways in which these lakes are forming computer simulations of the way that heat is transferred through the surface of the Larsen C Ice Shelf can be run. The snow on Larsen C that sits on top of the ice is many metres deep and water from snow melting at the surface will just drain away downwards into the remaining snow. For a lake to form the snow below it needs to be fully saturated with water and for snow this deep this would take a lot of water, likely much more than would be provided just by the melting snow at the surface of the ice shelf. This suggests that something else must be playing a part. Scientists need to understand if the water accumulates in certain areas due to the shape of the ice shelf’s surface, providing enough water to make a lake, or if processes involving the refreezing of water are having an effect.

However, investigating this is not straightforward. In addition to the difficulties in taking year round measurements of a location as remote as Larsen C, there is also a lack of good satellite observations because the area is often very cloudy. Creating a computer simulation allows scientists to combine the information that they do have, such as weather station data (which can be collected automatically once a weather station has been set up) and information from ice cores taken during one off expeditions, with physical equations in order to simulate how these lakes form and change with time, without someone having to actually be there to observe this.

The results of this work will provide information that will allow ice shelf and climate models to be improved in the future. In particular, knowing how the lakes are forming will give new insights into the role of surface melting in ice shelf collapse and therefore the fate of Larsen C- is it headed for a similar fate to Larsen B?
References: