briefing note
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Thwaites and Pine Island Glaciers of Antarctica and the Prospect of Rapid Sea Level Rise

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The Thwaites and Pine Island glaciers in Antarctica are flowing toward the Amundsen Sea along a 250 km wide front. Further inland, the glaciers widen into a 3 km thick mass of ice covering an area the size of Texas. Scientists are worried that the glaciers are going into irreversible retreat, meaning that no amount of climate change reversal could stop them from melting into the ocean. If both of these glaciers were to melt completely, they would raise the sea level of the world's oceans by 1 metre. What is worse, together these glaciers act as a plug holding back enough ice to raise the sea level of the world's oceans by over 3 metres— an amount that would submerge large areas of the world's coastal cities.

Figure 1. The calving front of Thwaites Ice Shelf photographed from the IceBridge research plane. Source: NASA / Jim Yunge

When in balance, the quantity of snow at the glacier's head matches the ice lost to the ocean at its front through the calving of icebergs (top of Figure 2). But Thwaites is out of balance: it has sped up and is currently flowing at over 4km per year. It is also thinning at a rate of almost 40cm a year. According to Dr Anna Hogg of Leeds University, this thinning started after 2000, spreading inland at a rate of 10-12km/year at its fastest. She suggested that on Thwaites Glacier, the increase in ice speed has coincided with a period of rapid ice thinning, and grounding line retreat, which suggests that the observed changes may have been caused by warm ocean water reaching the glacier and accelerating ice melt. The grounding line refers to the zone where the glacier enters the sea and lifts up to form a buoyant platform of ice.

If warm ocean bottom-waters are able to get under this shelf (bottom of Figure 2), the grounding line can be eroded and the glacier forced backwards even if local air temperatures are sub-zero. In the case of Thwaites, a large portion of the ice stream sits below sea level, with the rock bed sloping back towards the continent. This can produce marine ice sheet instability, in which the tall cliff that forms at the front of the glacier begins to calve in a runaway fashion. This has not yet been seen in this part of Antarctica.

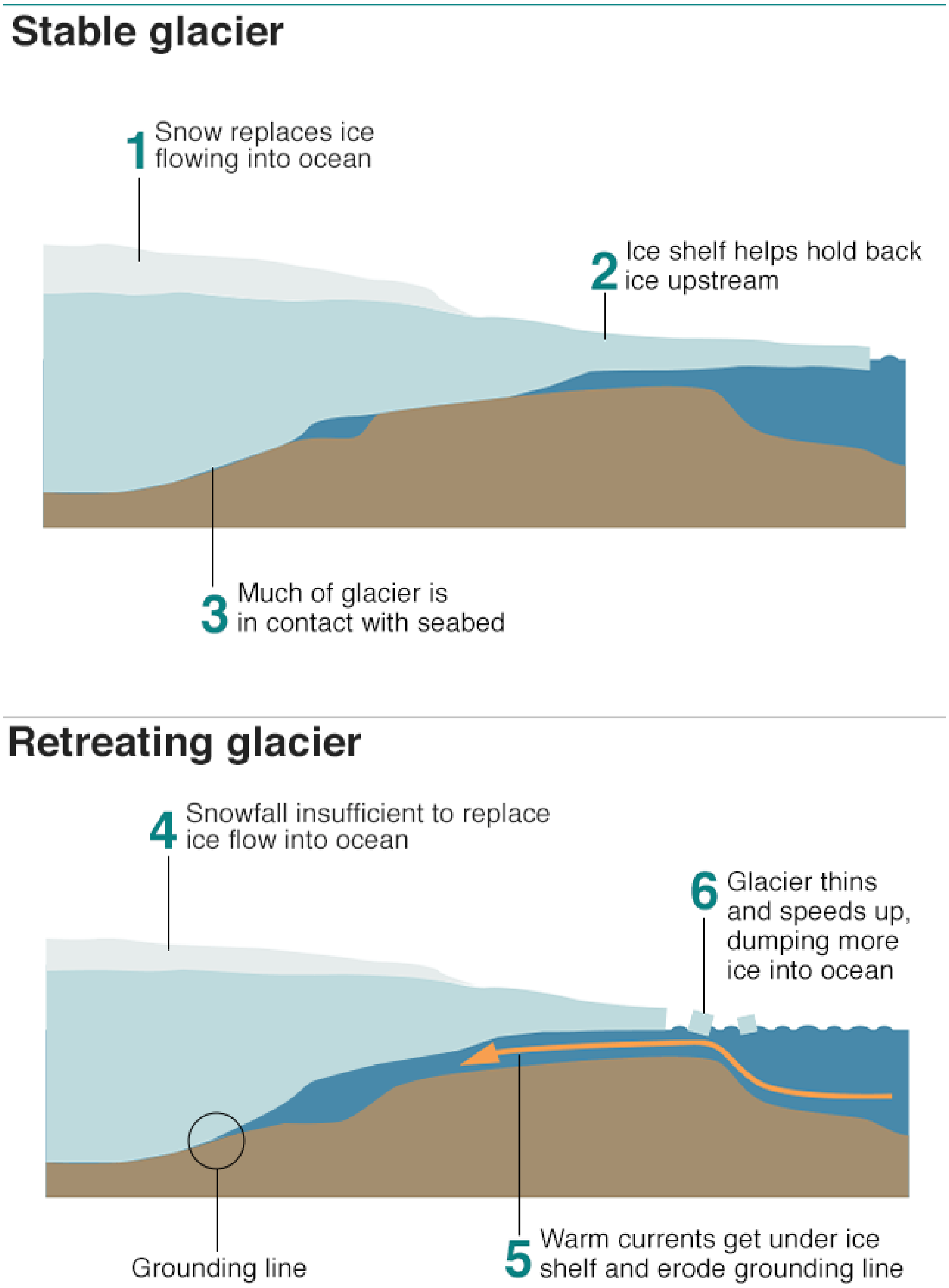

Figure 2. Schematic diagram of stable and retreating glaciers. Source: BBC

Speed of collapse

It is unclear how long it would take for the glaciers to melt completely - it may take decades or centuries. Scientists have been looking back to the end of the last ice age, about 11,000 years ago, when global temperatures stood at roughly their current levels. There is growing evidence that the glaciers collapsed rapidly back then, flooding the world's coastlines. Unfortunately, as indicated above, the ocean floor on which the glaciers rest gets deeper toward the interior of Antarctica (Figure 2), so each new iceberg that breaks away exposes progressively taller and taller cliffs. When the cliffs become so tall that they cannot support their own weight, they may collapse catastrophically.

Scientists funded by the U.K. National Environment Research Council and the U.S. National Science Foundation are planning to go to the field to try to find out how quickly these glaciers might collapse. They will monitor the way in which ocean water moves beneath the floating shelf, drill sediments from under and just in front of the glacier to find out what it did during past warming events on Earth, and use a submersible to explore the cavity under the buoyant sections of Thwaites.

Such massive ice sheet collapses have occurred in the past, but the climate effect of a huge freshwater input into the Southern Ocean, in the form of ice sheet melt, is far from certain. In the Northern Hemisphere, there is evidence to suggest that past periods of rapid ice sheet melt have actually led to periods of climate cooling, called Heinrich events, after the paleoclimatologist Hartmut Heinrich. Scientists have hypothesised that these freshwater dumps reduced ocean salinity enough to slow deepwater formation in the Arctic and the ocean circulation that relies on seawater density differences (in the form of salinity and temperature) to operate. Since the 'thermohaline' circulation plays an important role in transporting heat towards Europe, a slowdown would cause the North Atlantic to cool. Such deepwater formation also occurs around the rim of Antarctica.

The U.S. National Oceanic and Atmospheric Administration reports that, globally, sea level has risen about 6.6 cm above the 1993 average level, and it continues to rise by about 3 mm per year. Meltwater streaming into the Amundsen Sea from Antarctica's Thwaites glacier accounted for about 4 percent of total global sea level rise in recent years — twice its contribution from the mid-1990s.

Implications for sea level rise

Glaciers like Thwaites matter a great deal to sea level because they are large masses of landlocked ice that hold back even larger masses of ice, keeping them from sliding into the sea. Landlocked ice changes sea level because when it melts, it introduces new water to the ocean. Sea ice, on the other hand, like the ice cap in the Arctic, can have major effects on climate when it melts, but it is basically water that is already in the ocean, and whether it is liquid or solid does not directly affect sea level around the world.

The current suite of projections of sea level rise are derived from a range of global climate models and a range of future carbon emission scenarios (Representative Concentration Pathways, RCPs) by the IPCC – thus inter-scenario and intra-model uncertainty is not insignificant. The range of uncertainty for global sea level rise to 2100 is largely shaped by the uncertain contributions of the Antarctic Ice Sheet and Greenland Ice Sheet, and thermal expansion of the oceans.

On the east coast of Australia, sea level rise to 2030 is expected to be on the order of 0.09 – 0.19 m, and between 0.22 – 0.88 m by 2090 (change relative to 1986 – 2005, taking the 95 % confidence limits of RCP 2.6, 4.5 and 8.5). A typical, convenient horizon for most coastal planning is to consider sea level rise of 0.9 – 1.0 m by 2100.

Over the past four years, Risk Frontiers has been developing a coastal risk visualisation tool, in association with the Office of Environment and Heritage, to help State Government entities and Local Governments visualize impacts of sea level rise on assets and infrastructure over planning timeframes in NSW. Figure 3 shows an example of the amount of expected seawater inundation around Newcastle with 0.5 to 1.5 m sea level rise, using the tool. As can been seen, inundation even to this level impacts critical infrastructure and residential areas with potential significant costs to asset owners, insurance and the local community.

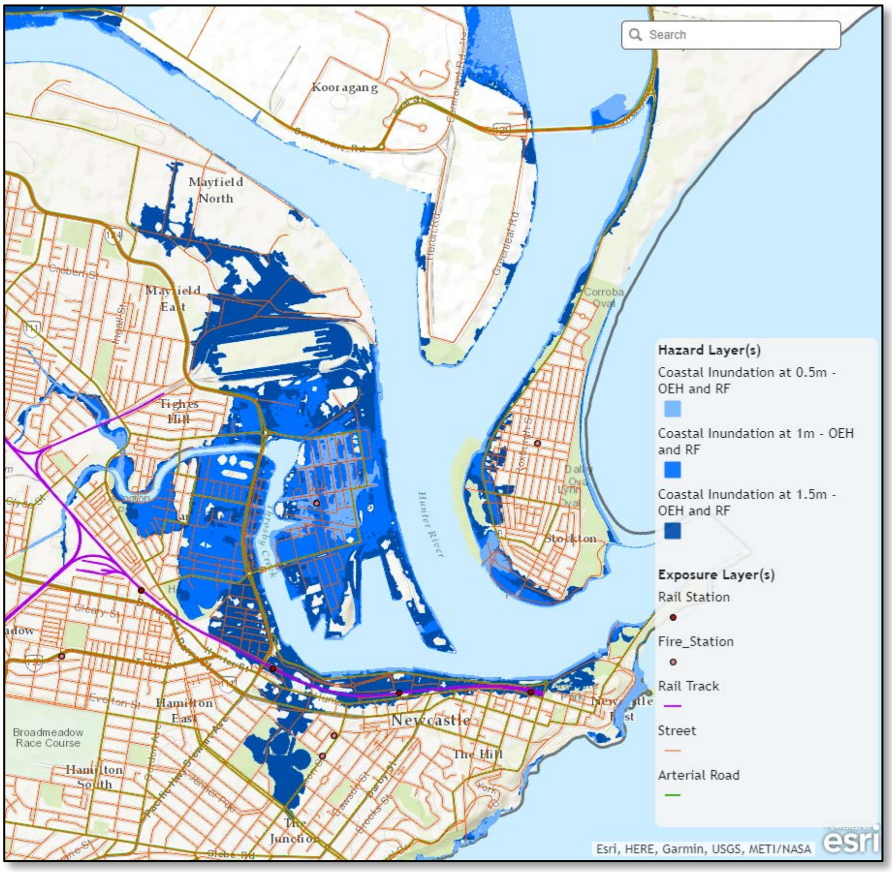

Figure 3. Potential seawater inundation as a result of sea level rise between 0.5 to 1.5 m above the present-day high tide level in Newcastle using the Risk Frontiers / OEH coastal risk visualisation tool.

However, there is great uncertainty in the standard IPCC projections related to the West Antarctic Ice Sheet (WAIS), of which Thwaites is a small part. A recent publication by Bakker et al. (2017) presents a set of probabilistic sea-level projections that approximates the deeply uncertain WAIS contributions. "Deep" uncertainty in this context refers to sea-level rise uncertainty that is hard to probabilistically quantify. Figure 4 compares these projections to the standard IPCC sea-level rise projections (IPCC AR 5, Chapter 13).

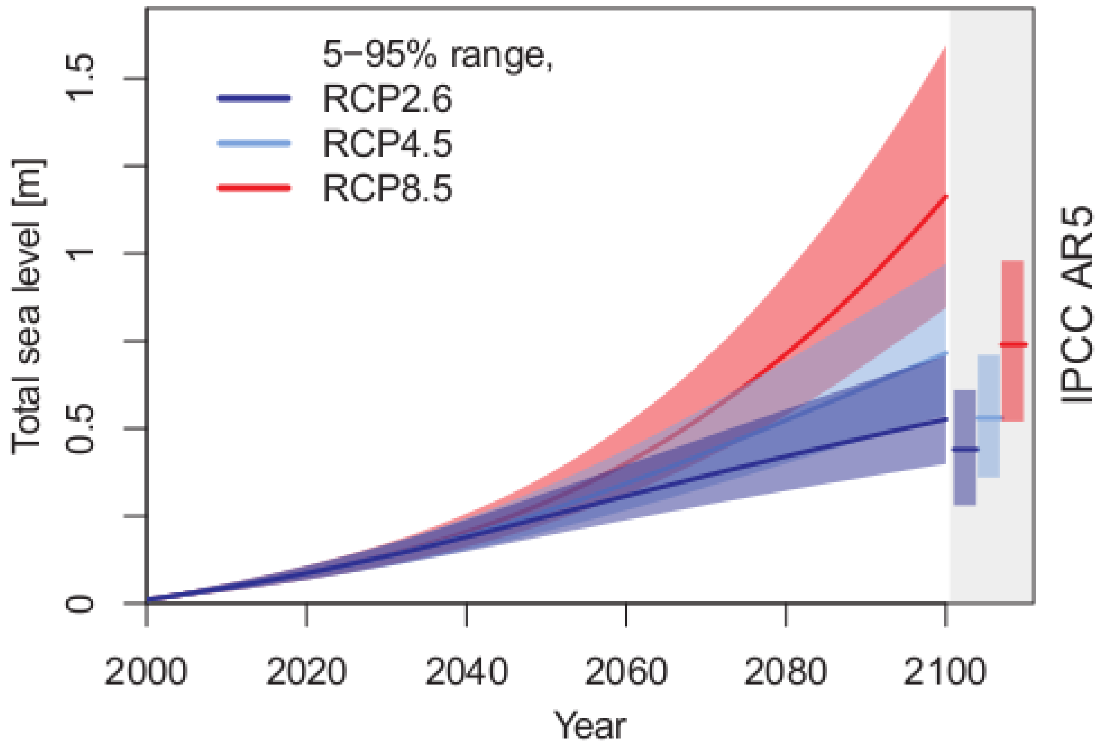

Figure 4. Future probabilistic global sea-level projections for the 21st century under RCP2.6 (dark blue), RCP4.5 (light blue) and RCP8.5 (red) from modelling by Bakker et al. (2017), compared to the conventional IPCC AR5 projections (right-hand side). IPCC projections are the 2100 values, not those averaged over 2081-2100, so they are comparable to the endpoints of the Bakker et al. (2017) projections. This plot was produced by T. Wong and represents a modified version of Figure 2 in Bakker et al. (2017).

Figure 5 shows that the deeply uncertain WAIS contribution can dominate other uncertainties within decades, and by 2100 are very different from the IPCC projections. These high-end projections have been the focus of many of the semi-empirical modeling community's efforts lately. **Much of the work by Alexander Bakker and Tony Wong suggests that coastal managers should seriously be considering global sea level rise of > 2 m.**

Some studies (Bakker et al, 2017, Pollard et al., 2015) entertain the scenario of whole WAIS collapse, it could contribute a further 3 - 4 m to global sea levels (Figure 5).

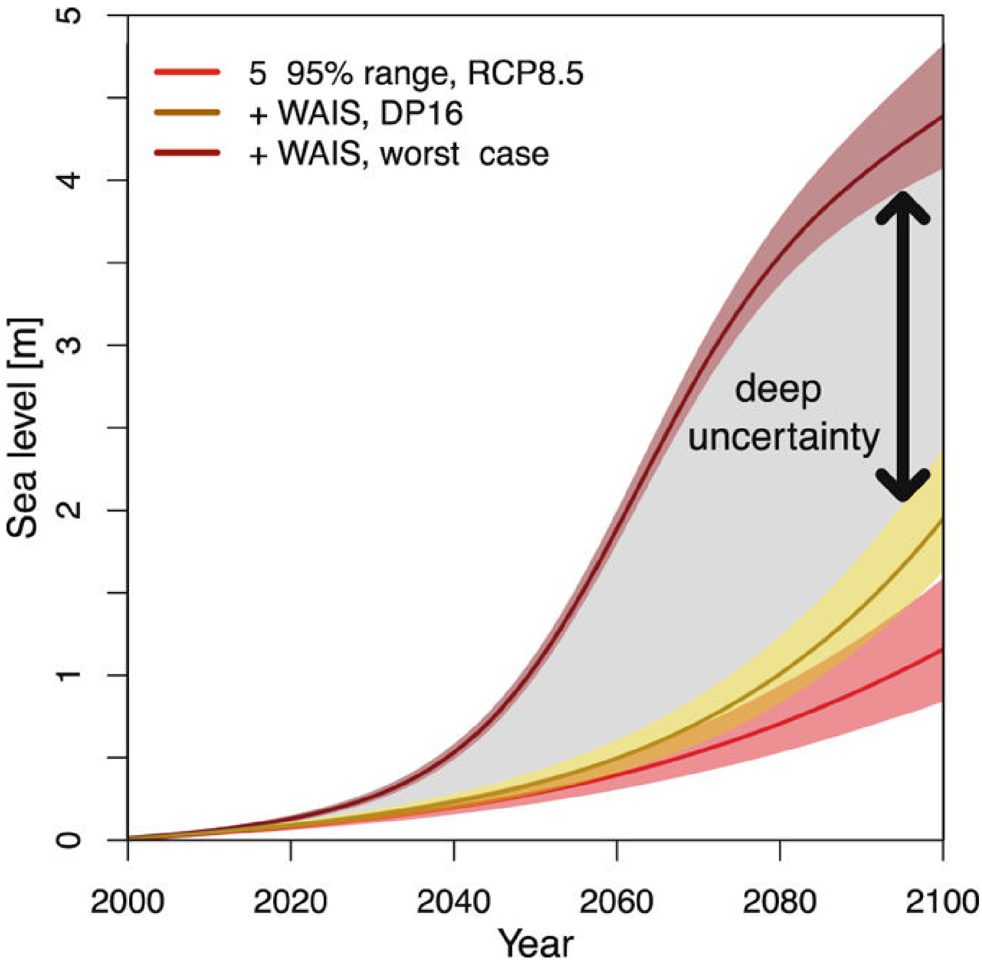

Figure 5. Future sea-level projections including very uncertain contribution of the WAIS. Red line shows most extreme RCP scenario considered by the IPCC, and yellow and brown shaded areas demarcate different WAIS collapse scenarios, with deep uncertainty in probability in between. Source: Bakker et al (2017).

Obviously, these levels of sea level rise would be catastrophic for the ~ 80 % of Australian population that current lives within the coastal zone and well beyond planning capabilities. While Government deliberates over how best to plan for sea level rise of 1 m by 2100, we perhaps should also be thinking about what provisions should be in place if sea level rise of 4 m + were to occur. For the time being, all eyes are on Thwaites.

Acknowledgements

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References

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