GLOBAL SEA LEVEL RISE

Latest scenarios and limits of adaptation

The massive Greenland and Antarctic ice sheets hold enough ice to raise sea level by 65 meters. In equilibrium, calving of icebergs and outflow of melt water into the ocean balance mass gain via snowfall. Observations now confirm that this equilibrium has been lost on Greenland, the West Antarctic Ice Sheet (WAIS) and Antarctic Peninsula; and a few portions of East Antarctica.

The Earth's climate record makes clear that warming above even 1°C over pre-industrial levels has resulted in very different coastlines in Earth's past, due to extensive melting of the WAIS, Greenland and likely parts of East Antarctica. While some of these changes occurred very slowly in the past, over thousands of years, periods of rapid sea level rise occurred at the end of the last Ice Age, raising sea levels by around 4 meters per century. This last took place around 14,000 years ago, when global sea levels rose between 15–18 meters in just 350 years, probably as part of the Laurentide Ice Sheet over Canada collapsed.

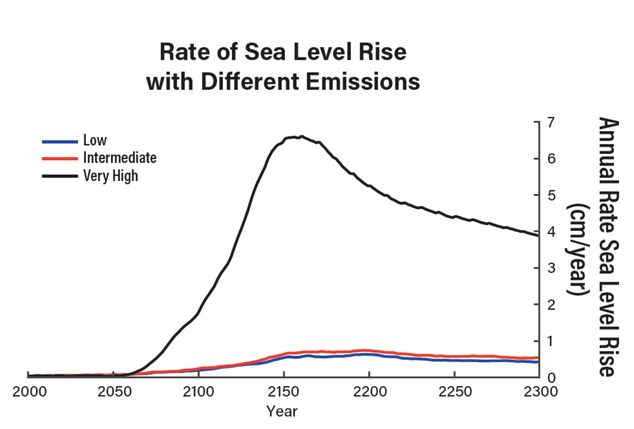
CO2 increases in the last 50 years are 200 times faster than during the end of the last Ice Age, meaning that future rates of sea level rise may increase dramatically in the next few decades.

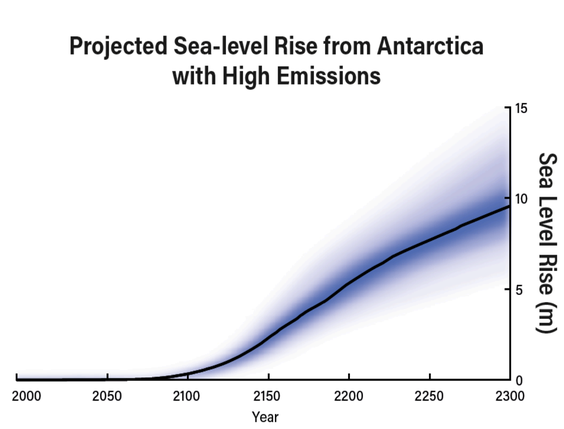
However, the observed forcing of global temperature rise over the past decades is much faster than anything documented in Earth's past. CO2 increases in the last 50 years are 200 times greater than during the end of the last Ice Age. This means that future rates of ice sheet loss and sea-level rise may be potentially more rapid than observed over the last few decades.

Some studies show that the WAIS may have already passed its threshold for collapse at around 0.8°C global warming, which would lead to about 4 meters of sea-level rise. Much of it does not really sit over land, but a vast archipelago of islands separated by extremely deep ocean basins; with ice resting on bedrock that is up to 2.5 km below sea level.

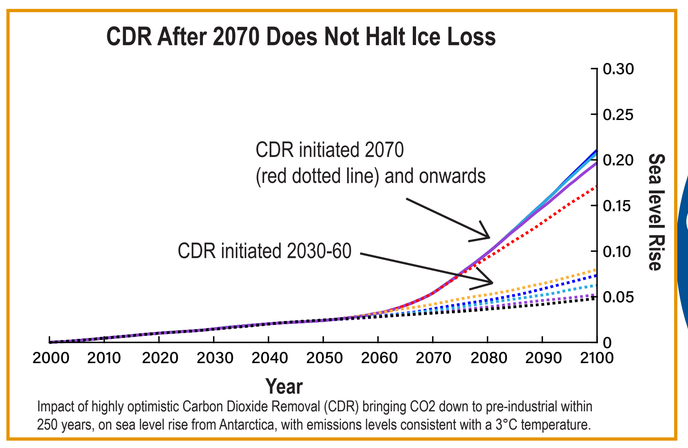
As warm water melts the edges of an ice sheet, the ice sheet retreats over these ever-deeper ocean basins. This exposes more and more of the underside of the ice sheet to warming waters, forcing further melting and eventually causing the ice sheet to become unstable. However, even if the retreat of the WAIS is now inevitable, its loss and contribution to sea level rise will be slowed to take place over many hundreds or thousands of years if temperatures remain close to 1.5° and return to below that level as soon as possible.

Scenario	Temperature peak	Impacts on sea levels
Low emissions	1.6-1.8°C …and declining	Global sea levels will continue to rise for centuries, but very slowly, reaching around 2–3 meters above today in the next 2000 years, with about half a meter occurring early in the next century. This assumes ice sheets respond to warming in a steady manner, adding to sea-level rise from land glacier loss and ocean thermal expansion.
Optimistic fulfillment of all current pledges	1.9-3.1°C	Despite a relatively slow collapse of portions of the West Antarctic Ice Sheet (WAIS), global sea levels eventually will reach 3–6 meters above today. Even higher levels cannot be ruled out: the last time temperatures exceeded the 2°C threshold, sea-level rise likely was well above 6 meters. Sea levels would reach at least 0.75 meters above today early in the next century. At this higher temperature however, a steady predictable rate of sea level rise from the WAIS is less certain, so rates and amounts could be greater already by 2100. WAIS collapse is likely to be rapid once temperatures exceed 3°C, with some involvement of portions of East Antarctica and greater loss from Greenland. WAIS collapse would be well along by 2300. Sea-level rise will continue at a relatively rapid pace for many centuries and be essentially permanent on human timescales, ending at 15–20 meters or more above today. Sea-level rise of 1–2 meters already by 2100 is possible. Greenland responds more predictably to warming atmospheric temperatures, but also reaches a significant tipping point at these temperatures once melting lowers its altitude. The Greenland ice sheet is over 3000m thick and above 3000m altitude in the interior. If its height is lowered through surface melting, it eventually becomes exposed to above-freezing temperatures for longer time periods throughout the year, leading to eventual unstoppable loss of most of the ice sheet. The first recorded rain at the highest point of Greenland occurred in August 2021, during several days with temperatures often above freezing.
Current emissions growth	4-5°C …and rising	Loss of large portions of both polar ice sheets will occur. The Earth in the past has had essentially no permanent ice at around 6°C above pre-industrial, with sea levels about 70 m (over 200 feet) above today. This last occurred over 50 million years ago. WAIS collapse will be inevitable and potentially rapid, with sea-level rise of 2 meters possible by 2100, and up to 5 meters by 2150. Rates of sea level rise from Antarctica alone may reach 5 centimeters per year. If new models including ice sheet processes are correct, 10 meters sea level rise from Antarctica alone is possible by 2300. Sea level rise will continue for many centuries even with temperature stabilization and slow decline, with complete loss of the Greenland ice sheet. Restoration of the polar ice sheets can only begin with temperatures well below pre-industrial (induction of a new Ice Age).





All figures adapted from DeConto et al., 2021



A recent study from DeConto et al., 2021, found that once temperatures pass 3°C, even aggressive carbon dioxide removal (CDR), and a return of temperatures to pre-industrial levels, would slow, but could not halt inevitable ice sheet loss.
Such peak temperatures would push ice sheets in ways not seen since the end of the last Ice Age.

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