Meticulous sea-level research at Southampton University's School of Ocean and Earth Science (SOES) suggests that large long-term sea-level rise is coming our way unless we take drastic action soon. Eelco Rohling tells us what this projection is based on.

The rise and rise of the SEA

You don't have to delve far into the climate science literature to spot that predicting sea-level rise is difficult. But it is becoming increasingly apparent that the numbers don't look good.

In its most recent (2007) report, the Intergovernmental Panel on Climate Change (IPCC) projected a rise in sea level of up to 70cm by 2100. That sounds a lot, but this figure is probably too low and the IPCC knows it. The report clearly states that the responses of the world's great ice sheets to warming were not included in the projections, and that such reductions in ice volume will cause significant additional rise.

The total volume of ice on Earth is equivalent to roughly 70m of sea-level rise, but ice decay lags behind global warming. So the IPCC projections serve as baselines to which scientists must add realistic projections of the rate of contribution from melting ice sheets. The problem is that the size of these rates remains poorly understood.

Our project has shown that the last time Earth was as warm as it is predicted to be later this century, sea level rose by 1-2m per century. We also found that, even if CO_2 emissions were stabilised now, similar rates may be expected to continue over many centuries until global mean sea level reaches 15-25m above the present level. This far exceeds most recent predictions – so how did we arrive at these numbers?

Since the 2007 IPCC report, other researchers have estimated total sea-level rise in the next century, using statistical projections based on observations from the last few centuries and coastal geology going back two millennia. This work suggests that sea levels may rise twice as quickly as the IPCC's worst-case prediction, or even faster. Estimates of the potential sea-level rise contributions from the great ice sheets support this possibility. A recent report suggests that the sea-level contribution from Antarctic ice alone could reach up to 1.5m by the end of this century.

These are very big numbers. They mean that significant planning and construction work will be needed to protect our current way of life in the coastal regions, especially when you add in the impacts of tides and storm surges.

But how realistic are they? Predictions are all very well, but is there actually any evidence that Earth has experienced similar rates of sea-level rise in the recent geological past?

To find some answers, our team at SOES produced the first ever continuous record of sea-level change through the last 520,000 years. This period covers five complete ice-age cycles, with global sea-level fluctuations between -130m and +10m, relative to the present-day level. The record we produced with our new method is based on evidence taken every 100–200 years from sediment cores from the Red Sea. It provides real-world data that let us test the reality of sea-level projections for the future, by revealing whether different climate conditions in the past actually resulted in similarly large and fast sea-level fluctuations.

Our new data came from studying changes in conditions in the Red Sea. This land-locked sea receives hardly any rainfall or river inflow from outside, and has some of the highest rates of evaporation in the world. The Red Sea's only natural connection with the open ocean, which prevents it from becoming ever saltier, is through the narrow and shallow (137m deep) Bab-el-Mandab Strait.

Because there's a limit to the amount of water that can be 'squeezed' through such a small passage, the Red Sea's salt content is highly sensitive to changes in sea level in the very shallow strait. And so is the ratio of the stable oxygen isotopes ^{16}O and ^{18}O in the water. The lighter ^{16}O isotope is more likely to evaporate, so when sea level is lower and there is less water moving through the strait the water contains a higher proportion of the heavier ^{18}O isotope. These properties are recorded in the shells of tiny marine creatures found in sediment cores from the Red Sea floor, letting us reconstruct past changes in sea level.


A corer in action.

Together with researchers from Tübingen University, Germany, we used this method to look in particular at the last interglacial, 125,000-117,000 years ago. At that time, the Earth was a few degrees warmer than today because of variability in its orbit around the Sun, and sea level reached 6-10m above the present. We found that the rate of sea-level rise, from present levels to these maxima, was on average 1-2m per century.

Think of it like standing in front of a freight train – it's travelling slow enough for you to be able to avoid it, but if you stand still you can be sure that it will hit you.

These results provide important context to the proposed high rates of sea-level rise for the future, and they should not be ignored. Even though rates of up to 2m every hundred years seem alien to our (human) experience, they are not at all alien to our planet. In fact, we have found that these kinds of rates are very common in the geological record.

Next, we compared the entire sea-level record with records of past temperature and CO_2 concentrations, from Antarctic ice cores. On the scale of ice-age cycles, the sea-level record closely matches temperature, as one might expect. When the temperature goes up, sea levels rise. When the climate cools down, ice caps expand and sea level drops. We can assume that these observed natural relationships give us a reasonable model for a future with sustained global warming.

The relationships we've seen clearly indicate that, for current CO_2 concentrations, sea level may eventually (over several thousand years) creep up towards almost 25m above the present. It's hard to imagine, but geological studies tell us that around three million years ago, this was reality. At that time, atmospheric CO_2 concentrations were about the same as today (due to differences in the balance of the geological release and removal of CO_2) and sea level stood between 15 and 25m above the present level.

Modern CO_2 changes are dominated by anthropogenic emissions, but the greenhouse-gas properties of CO_2 remain the same. Our results therefore suggest that – given a sufficiently long period of time – even stabilisation at current CO_2 concentrations would lead to a big enough loss of global ice for sea level to rise to similar heights of 15-25m above the present.

How inevitable is this? Think of it like standing in front of a freight train – it's travelling slow enough for you to be able to avoid it, but if you stand still you can be sure that it will hit you.

It now looks very likely that we will see significant (1m or more) sea-level rise during the next century. Already, tide-gauge and satellite observations show that sea level is rising at or above the fastest rate proposed by the IPCC in 2007. For the longer term, stabilising and then reducing CO_2 concentrations within the next century or so will allow us to dodge the freight train. Alternatively, we could close our eyes and ears, stay in the middle of the tracks, and hope for the best.

MORE INFORMATION

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www.soes.soton.ac.uk/staff/ejr/ejrhome.htm

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