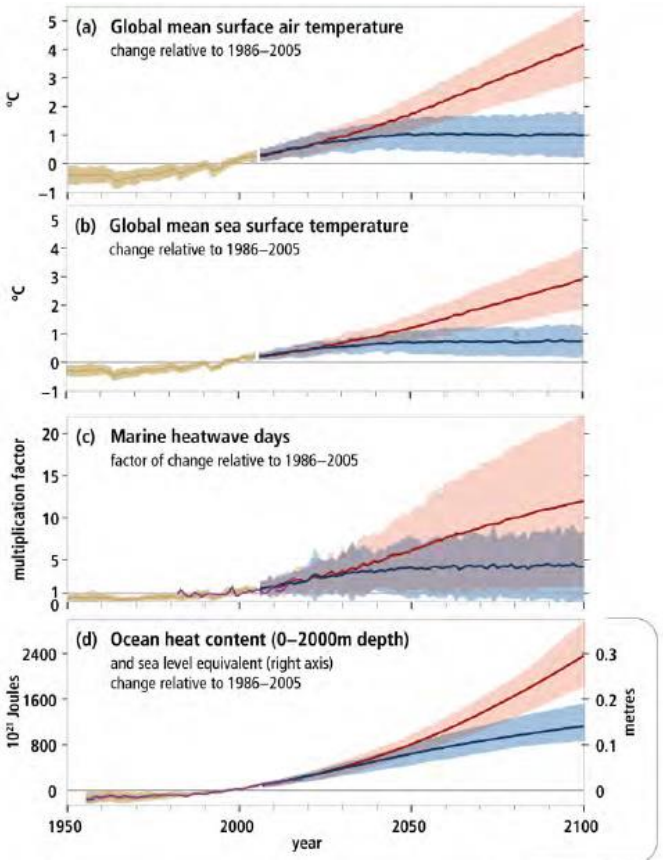
How accurate are simulations predicting the rise of water in oceans due to climate change?

Dear Roy,

This is a great question. As you might know, sea level has risen by around 21-24 cm since 1880. This number may look small, but it is significant, in particular for the susceptibility of coastal areas to floods and storms. As the planet warms, sea-level rises mainly because (1) water expands, and (2) because ice sheets and glaciers melt and release their water to the ocean. O.K. – your question was not what causes sea level changes, but how accurate predictions of future sea level rise are. Predicting sea level rise into the future is challenging, because several steps are involved in the estimate. And each step has uncertainties. I explain the estimates with graphs from "The Ocean and Cryosphere in a Changing Climate", a special report that was published by the Intergovernmental Panel on Climate Change (IPCC) in 2019. If you are really interested, you can check out the report here.

Sea level rise due to thermal expansion

I explained above that sea level can rise because water expands as the ocean warms. To predict ocean warming, we can first look at air temperatures. The increase of air temperatures until the year 2100 depends strongly on how much more CO_2 we emit. All plots below and to the right show two different scenarios. The red curve is called emission scenario RCP8.5. This scenario assumes that humans continue to emit CO_2 without any significant efforts to reduce emissions. The blue curve (RCP2.6) corresponds to what the Paris agreement aims for: A temperature rise of less than 2°C. Achieving this scenario will require significant reductions in net CO_2 emissions. In any case, you can see that, depending on how much we emit, we get a very different temperature response (panel a). Can you see shaded region around the lines? This region corresponds to the

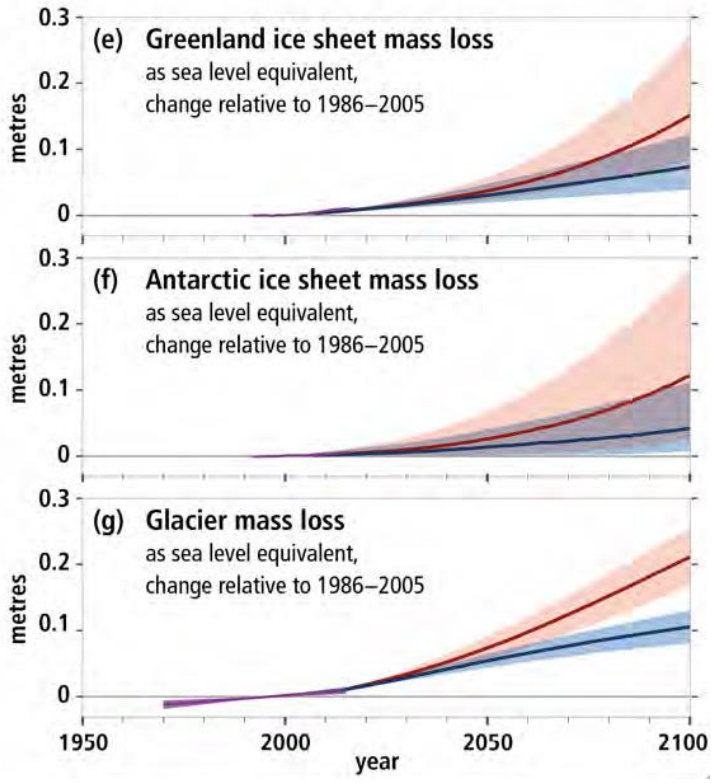


uncertainty in the prediction. So, we can see that even for a path of CO_2 emissions, the uncertainty in the temperature evolution is several degrees large.

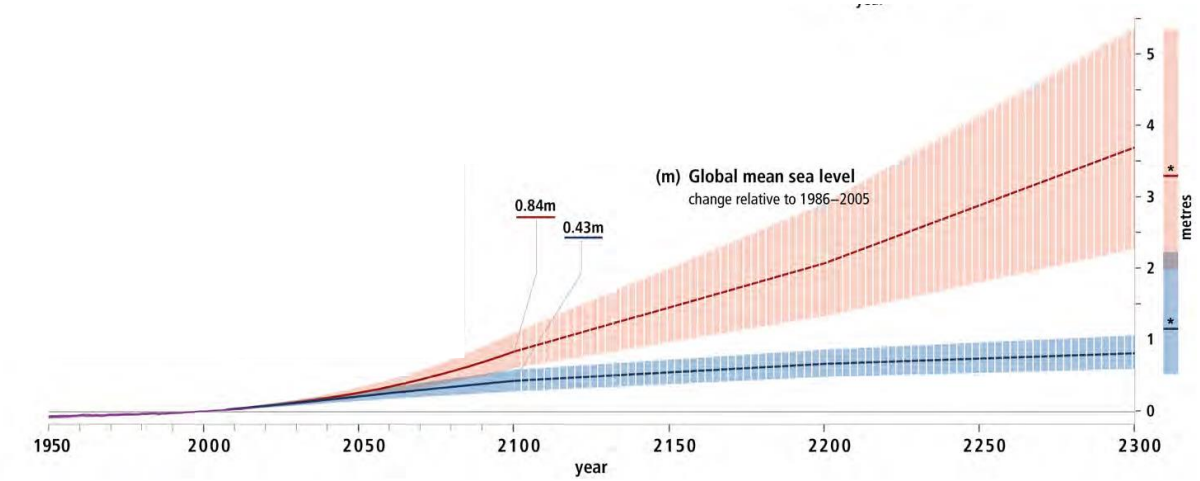
Now, we can look at how the ocean warms, nicely shown in panel (d) above. On the left y-axis you have the heat content of the ocean. On the right y-axis, you have the sea level rise that corresponds to the given heat content. You can see that sea level may rise an additional 10-40 cm due to warming of the water. How much, will depend on the emissions of CO_2. Again, even if we exactly know how much CO2 we emit, the uncertainty of sea level rise until 2100 is still about 10 cm (the shaded region around the lines). O.K. This was the easy part.

<u>Sea-level rise due to ice melting</u>

Predicting how ice sheets melt is hard. In fact, models have been corrected many times over the last years. Unfortunately, it looks like the melting is going faster than we thought. Panels e-f show the predictions of how many meters of sea-level change we might get from melting of the two big ice sheets (the Greenland and the Antarctic ice sheet) as well as glaciers. Again, there is a difference between emission scenarios, but now you can see that the uncertainties (the shaded regions) are so large, that the two emission scenarios (red: continue emitting as before or blue: implementing strong reductions in CO_2 emissions) overlap in their predictions – at least for the Greenland and Antarctica ice loss.



Now, let’s look at everything together and projected until the year 2300. Below, we are looking at meters of predicted sea level rise! The answer to your question is the range in the prediction.



So, you can see that we probably need to work on improving the models and data. Nevertheless, we can clearly say that sea level will rise with warming temperatures, and that there is a significant impact of either achieving the Paris agreement (blue curve) or not.