The Role of Sea Level Rise and the Greenland Ice Sheet in Dangerous Climate Change and Issues of Climate Stabilisation

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Abstract

Sea level rise is an important aspect of future climate change because, without upgraded coastal defences, it is likely to lead to significant impacts. Here we report on several aspects of sea level rise that have implications for the avoidance of dangerous climate change and stabilisation of climate. If the Greenland ice sheet were to melt it would raise global sea levels by around 7m. We discuss the likelihood of such an event occurring in the coming centuries and the possibility that it might be irreversible. We also discuss the time scales controlling sea level rise and estimate how long after atmospheric greenhouse gas concentrations or global temperature have been stabilised that coastal impacts will stop increasing.

Introduction

Sea level is reported to have risen during the 20th century by between 1 and 2 mm per year. At the same time there has been considerable growth in the coastal populations and the value of assets within the coastal zone. Presently, there is a concern that future increases in sea level will lead to sizeable coastal impacts.

The causes of increased global average sea level during the coming few centuries will be the thermal expansion of the ocean, melting of small glaciers and the melting of the Greenland and Antarctic ice sheets. Here we focus on thermal expansion and the melting of the Greenland ice sheet. Results are presented from a range of physical models, including: simple climate models; complex climate models with detailed representation of the atmosphere, ocean and land; a high resolution model of the Greenland ice sheet; and a coastal impacts model. The results have been generated for a number of future emissions scenarios that eventually lead to stabilisation of the atmospheric greenhouse gas concentrations.

Likelihood and irreversibility of a deglaciation of Greenland

If the Greenland ice sheet were to melt it would raise global average sea level by around 7 m. Previous studies of the Greenland ice sheet have shown that for a local warming of more than 2.7 °C the ice sheet is likely to contract. We have used a range of climate models, and emissions scenarios leading to stabilisation of atmospheric carbon dioxide at levels between 450 ppm and 1000 ppm, to show that there is a significant possibility that this trigger point will be reached in the next few centuries (Figure 1).

We have also considered the question of whether Greenland deglaciation is irreversible, or whether, if greenhouse gas concentrations were returned to either present day or pre industrial levels, it could be restored. Recent results suggest that a complete deglaciation of Greenland would be irreversible. We are now trying to establish at what point in the deglaciation the change becomes irreversible.

Timescales of sea level response

The rate at which Greenland could melt and the consequences for regional and global climate have been investigated for a pessimistic, but plausible, scenario in which atmospheric carbon dioxide concentrations were stabilised at four times pre-industrial levels (around 1100 ppm). The simulation indicates that the ice sheet would almost totally disappear over a period of 3,000 years, with more than half of the ice volume being melted during the first millennium. In the Hadley Centre climate model the freshwater provided by the melting of Greenland ice had a small but noticeable effect on the model's ocean circulation, temporarily reducing the thermohaline circulation by a few percent. The time scale associated with the thermal expansion component of sea level rise has also been studied. This depends on the rate at which heat can be transported from near the surface into the deep ocean. The thermal expansion response time in the Hadley Centre coupled climate model was found to be around 1500 years, which is much greater than the time needed to stabilise temperature (Figure 2). Therefore, rising sea levels and increasing coastal impacts would continue for a considerable amount of time after the atmospheric greenhouse gas concentrations and surface air temperatures have been stabilised.

Conclusions

Simulations of sea level rise and the Greenland ice sheet have highlighted several issues that are relevant to the stabilisation of climate at a level that would avoid dangerous changes. In particular:

- Deglaciation of Greenland may be triggered for even quite modest stabilisation targets.
- Deglaciation of Greenland may be irreversible.
- Sea level is likely to continue rising for more than 1000 years after greenhouse gas concentrations have been stabilised, so that with even a sizeable mitigation effort adaptation is also likely to be needed.

Finally, we note that the large uncertainty on sea level rise predictions implies that, if sea levels were used to define a “safe” stabilisation level, the uncertainty on the emissions leading to that level would also be very large.

Figures

Figure 1: Predicted warming for CO_2 stabilisation levels of 450 ppm, 550 ppm, 650 ppm, 750 ppm and 1000 ppm. The threshold for deglaciation is shown as a dotted line.

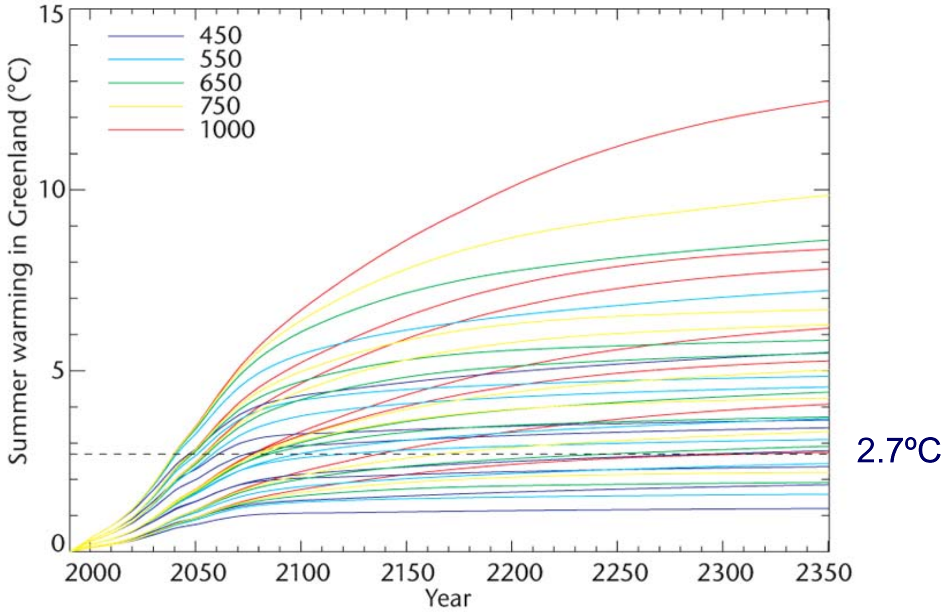

Figure 2: Simulated temperature rise and thermal expansion for a 4xCO2 experiment.