The Long-Term Consequences of Climate Change on Oceans

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Debates on mitigation and adaptation measures to adopt against climate change are based on observations and estimations over a range of less than 250 years. A recent study by Clark and his collaborators, published in Nature Climate Change, covers extremely long term (over 10,000 years[1]) climate consequences. Their scope is linked to CO_2 emissions. According to these scenarios, the temperature increase could exceed the 2 °C limit, and a 2 to 4 meters per century sea-level rise could be expected in the next millennium. These results confirm the importance of keeping a large quantity of fossil resources untouched.

A recent article published in Nature Climate Change discusses long-term climate impacts of anthropic CO_2 emissions. As did several previous studies, it sheds light on long-lasting effects, over the next 10,000 years at least. The magnitude of these effects will strongly depend on our capacity to leave unused a significant fraction of available fossil resources.

The major part of the political debate regarding mitigation and adaptation measures to take against climate change relies on observations covering the past 150 years, as well as climate projections for the next 85 years. The focus on this timeframe of less than 250 years overshadows some of the key issues linked to climate change.

The 21st century, and maybe the next one, is the period during which the majority of anthropic carbon emissions shall occur. The consequences however will be experienced for numerous millennia. In this study by Clark and his colleagues, consequences of our emissions are considered in the context of long climate timescales, going back 20 millennia (at the end of the last ice age and the start of human civilization), and looking forward over the next 10 millennia, during which expected impacts of anthropic climate change will grow and remain.

The study relies on numerical simulations of atmospheric surface temperature changes and sea-level rise for the next 10,000 years. These simulations highlight very contrasted climate destinies depending on cumulative emissions of CO_2 (carried on during 20th, 21st and possibly 22nd century). Downscaling of these results enables the authors to predict sea-level rise at a regional scale. The study takes into account 4 emissions scenarios, characterised by different cumulative CO_2 emissions into the atmosphere, from a minimum of 1280 PgC to a maximum of 5100 PgC. 1280 PgC means a 15% use of our existing resources. This is about 1.5 times the total quantity of CO_2 emitted since the beginning of industrial revolution. At the current pace of emissions, it would take 70 years to reach this, after which all emissions should cease. 5100 PgC corresponds to approximately 70% to 90% of our current fossil resources.

1 CLARK P. U., SHAKUN J. D., MARCOTT S. A., *et al.*, 2016 – *Consequences of Twenty-First-Century Policy for Multi-Millennial Climate and Sea-Level Change*. Nature Climate Change.

To burn around 5 100 PgC would lead to an increase of temperature far above 2 °C, with a very high probability that this increase would exceed 5 °C for more than 10,000 years. In parallel, a sea-level increase by 2 to 4 meters per century in the next millennium would be expected. In 10,000 years, our emissions would be still responsible for continued sea-level rise, and this level would be 25 to 50 meters above the current one, according to the study. A strong limitation of our total emissions at 1280 PgC would also lead to very long-term consequences but of much reduced magnitude, in particular with respect to increasing global temperatures. The probability to reach beyond the 2 °C limit written down in the Paris Agreement would nonetheless remain high in this scenario and human societies would face a global sea-level rise of about 10 meters. In this reduced emissions scenario, the population currently living in lands to be submerged in the future is estimated to 1.3 billion.

All of these results confirm the importance of efficient action to leave as much of the available fossil fuel as possible underground. Consequences of such actions will be felt for thousands of years. In contrast, even significant reductions of emissions rates with no cap on cumulative emissions will not solve anything in the long run.

These results on CO_2 emissions' long-term effects can be understood if we keep in mind that: *1)* a significant fraction of anthropic CO_2 we emit remains active in the atmosphere for a very long time; *2)* the Earth climate system has a very big inertia (essentially due to the ocean), so that when it is perturbed (by our emissions), it takes numerous millennia to adjust, for instance in terms of temperature. As a result, present and future generations will only endure a tiny part of the consequences of current CO_2 anthropic emissions. The major part of these consequences would be endured by the long line of our descendants for hundreds of generations. The authors recommend not to limit the presentation of climate risks to the next 85 years, in order for decisions and public debates to embrace the very long-term consequences of current emissions.