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Off balance: the CO2 and sea level seesaw
by Katy Edgington

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Researchers based at the National Oceanography Centre (NOC), a partnership between the University of Southampton and the Natural En Research Council (NERC), have found that current carbon dioxide (CO_2) concentrations are consistent with sea levels at least nine metres higher than at present.

Although the analysis does not necessarily offer a prediction of sea levels in the immediate future, it does give an indication of the long-tern change that might be seen if the amount of CO_2 in the atmosphere remains at current levels over the coming centuries.

Dr Gavin Foster, lead author of the paper, made comparisons of reconstructions of the relationship between CO_2 concentration and sea le from the past 40 million years. The study involved the collation of more than two thousand sets of contemporary data for CO_2 concentratior and sea level from times when the climate was warmer than, similar to, or colder than it is now. In an interview with ScienceOmega.com, D Foster expounded on the link between CO_2 and the seas, and how the correlation exhibited in this study could influence our forecasts for t future.

While sea level change is arguably one of the most long-lasting and significant impacts of anthropogenic climate change, long-range predictions of the change that can be expected as the oceans warm and the continental ice sheets melt are quite uncertain.

"This is largely because the complex processes involved in the melting of the continental ice sheets are difficult to incorporate into climate models," Dr Foster pointed out. "We currently rely on semi-empirical methods to describe their behaviour; methods which remain as yet untested."

Dr Foster and his colleagues approached the problem in a slightly different way, by delving into the rich archive of the geological past to fin examples of warmer worlds that could provide an insight into how the Earth may behave in a warmer future. Focusing on the relatively rece past – the last 40 million years – they minimised the impact of changes in continental configuration, for example.

"The main advantage of looking at the geological past, and what makes it worthwhile, is that it represents a reality – a state which we can b sure the Earth system once occupied," explained Dr Foster. "It inherently includes all feedbacks involved in the system whether we currentl know about them or not; this is not the case with modelling, of course, which draws directly on the state of our current knowledge."

The inclusion of data from points at which the global temperature was increasing and decreasing allowed Dr Foster and co-author Professo Eelco Rohling – also from Ocean and Earth Science at the University of Southampton – the best chance of spotting trends and relationship

"As many people are aware, CO_2 is a potent greenhouse gas responsible for a significant portion of the greenhouse effect," stated Dr Fost "On geological timescales, the concentration of CO_2 in the atmosphere is determined by subtle imbalances in the amount of CO_2 coming o of volcanoes and the amount being removed by silicate weathering."

Over the last 40 million years CO_2 concentration has changed quite dramatically, from 1200 parts per million (ppm) 40 million years ago to 180 ppm during the last glacial maximum.

"We show here that ice volume and sea level, and hence global temperature, have changed in concert," stated Dr Foster. "Correlation does not prove causation of course, but we have known from fundamental physics for over 100 years that if you change atmospheric CO_2 concentration you change global temperature by ~1ºC per doubling. This basic response is amplified by other processes that operate in the atmosphere and the result is something like a 2–5ºC global temperature change for a doubling of CO_2."

The changes in CO_2 that have been reconstructed over the last 40 million years are capable of driving large changes in global temperature in the order of 5–10ºC, from ice-free values of 1200 ppm to ice age values of 180 ppm. While this study, appearing in the journal *Proceedings of the National Academy of Sciences* (*PNAS*), is not the first to document that the climate has been warmer in the past than it today, it is the first to describe a coherent relationship between sea level, the amount of ice on land and CO_2 concentration.

The modern climate system is experiencing change and forcing at an unprecedented rate. It is therefore out of equilibrium and playing catc up with changing climate forcing from ever-increasing CO_2 and other greenhouse gases.

In light of natural near-equilibrium situations in the past when CO_2 was similar to or higher than today, the study shows what the state of the climate system is likely to be when it reaches an equilibrium with CO_2, probably centuries to millennia from now.

"Our estimate is quite uncertain, and we can't say for sure when it will be appropriate; it could be in 500 years or 2000 years," Dr Foster sai "One way it may be useful is in performing some sort of long-range forecast. For instance, if humanity does aim to keep global warming to around +2ºC, which equates to 400–450 ppm CO_2, our study based on how the Earth has behaved in the past implies that sea level is eventually going to be at least 9 m higher than today, with a maximum possibility of a 24 m rise."

There could also be a real value to future studies of the standards set by this analysis.

"All models need testing and validating," Dr Foster remarked. "If new models of future sea level rise, be they semi-empirical or largely numerical, can match what we have shown actually happened in the past then they are probably better equipped to predict the future."

I asked if the researchers had been expecting the systematic relationships they found.

"The biggest surprise for me was when different time periods began to exhibit the same sea level for a given CO_2 concentration," Dr Foster said. "These time periods were separated by millions of years and often had continents in different configurations, different ocean circulations, and so on. This implies that CO_2 is the dominant driver of global temperature on geological timescales, because ice volume on the planet only seemed to be affected by CO_2 and not by other variables proposed as being important drivers of Earth's climate."

Although this is the first attempt at this sort of compilation and with future data a dependence on the background climate state might start to emerge, if it does exist, it appears to be of secondary importance. Based on their results, the team believe that stabilising CO_2 at 400–450 ppm is unlikely to avoid significant long-term sea level rise, as the geological records suggests a reduction of CO_2 to a value of 280 ppm would be necessary.

"If we want to avoid significant future sea level change, limiting CO_2 emissions is clearly only the first step," warned Dr Foster. "We need to start thinking seriously about not only how to slow the increase in atmospheric CO_2 but how to start reducing it to pre-industrial values."

Read about a related project in which Dr Foster is involved here.