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Pliocene sea level snapshots

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ABSTRACT

Geological evidence from a Mallorcan coastal cave in the western Mediterranean Sea shed new light on past sea level. The results indicate that sea level was up to 16 m higher than present during a time when the Earth was 2-3 degrees warmer than the pre-industrial era. These findings have significant implications for predicting the pace of current-day sea level rise.

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How much are the seas ultimately going to rise is a question scientists are still struggling to answer. To understand the polar ice sheets' sensitivity to current global warming, we draw on evidence from periods in the geologic record when Earth's climate was warmer than today. The mid-Piancenzian Warm Period (3.26 to 3.02 million years ago) is a good analog for what future holds. During that period, the temperatures were 2-3ºC higher than pre-industrial levels, and atmospheric CO_2 concentration was as high as today.

Cave deposits help us to unravel past sea-level changes by providing valuable evidence to assess the models used for future predictions. In this work, we studied carbonate encrustations on preexisting speleothems. These deposits are ideal sea-level indicators since their elevation can be precisely measured. Furthermore, their age can be determined using absolute radiometric dating. These deposits form at the water/air interface in littoral caves each time sea-level oscillations flood these caves. Since their growth covers the full tidal range, they have an explicit relation to past sea levels. The caves are located within 300 m from the coast. Thus, the water table in them is (and was in the past) coincident with sea level. By performing 70 U-Pb analyses on such deposits from Artà Cave on Mallorca Island, we provide six snapshots of Pliocene sea level.

To translate these local observations into a global mean sea level, we thoroughly quantified the corrections (and their uncertainties) that need to be applied due to processes that may alter the elevation of sea level indicators after their formation. These processes include: the deformation of the solid Earth accompanying the waxing and waning of land ice and changes in the size/volume of ocean basins hosting seawater.

Our results indicate that during the mid-Piancenzian Warm Period the global mean sea level was as high as 16.2 m (with an uncertainty range of 5.6-19.2 m) above present. This result means that if current emissions and warming continue, the global mean sea level could rise that high.

We acknowledge that this sea-level rise would not happen overnight. It would take hundreds to thousands of years to melt such large amounts of ice. Another important finding of our study is that, under temperatures ~4°C higher than pre-industrial values and elevated CO_2 during Pliocene Climatic Optimum, the global mean sea level reached 23.5 m (with an uncertainty range of 9.0-26.7 m) higher than present. This indicates that significantly more ice will melt if temperatures stabilize at this level. This estimate can serve as a target for future ice sheet model calibrations.

Collectively, our data contribute to a better understanding of the ice sheets response in a warmer climate. This knowledge will help to generate more accurate predictions of future sea-level trends. We also highlighted the need for further work to reduce uncertainty in Pliocene's global mean sea level estimates. That would be a critical step in forecasting the effects of future global warming.