PALAEOCLIMATE

The past is not the future

During the last interglacial period, summer temperatures were warmer and the Greenland ice sheet smaller than today. Modelling suggests that the low ice-sheet volume was not simply a consequence of high ambient temperatures.

Andrey Ganopolski and Alexander Robinson

The last interglacial period, or Eemian, was characterized by warmer summer temperatures in the high latitudes of the Northern Hemisphere[1] than in the Holocene epoch. This was accompanied by a sea-level highstand at least four to six metres above present[2]. Because the higher ambient temperatures are in line with those predicted for the end of this century, the palaeoclimate conditions of the Eemian are often used as an analogue for future climate change. However, the cause of Eemian warmth was fundamentally different from that of anthropogenic climate change: unlike today, the concentration of greenhouse gases during the Eemian was essentially the same as in the preindustrial period[3]. Instead, the warmth was related to the configuration of the Earth's orbit, which resulted in more incoming solar radiation in the high northern latitudes during the summer than at present. Writing in *Nature Geoscience*, van de Berg and colleagues[4] report that the direct effect of this insolation change on the surface mass balance of the Greenland ice sheet is of comparable importance to temperature changes, and thus casts doubt on the suitability of the Eemian as an analogue for future climate.

The complete melting of the present-day Greenland ice sheet would raise sea level by seven metres. Although it is not expected that the entire ice sheet could melt in less than a thousand years, it nevertheless represents an important contribution to present and future sea-level rise. Current model-based predictions of Greenland ice sheet mass loss are rather uncertain and, for this century, are typically only equivalent to several centimetres of sea-level rise[5]. However, observational data suggest that the ice sheet is currently out of balance. During the past decade, it has been losing mass at a rate corresponding to a sea-level rise of up to 0.5 mm yr^{-1}(ref. 6). Discrepancies between predicted and observed rates of global sea-level rise[7] naturally raise the question of how reliable existing models are and whether there are means to test them against observational data for climate conditions different from those at present.

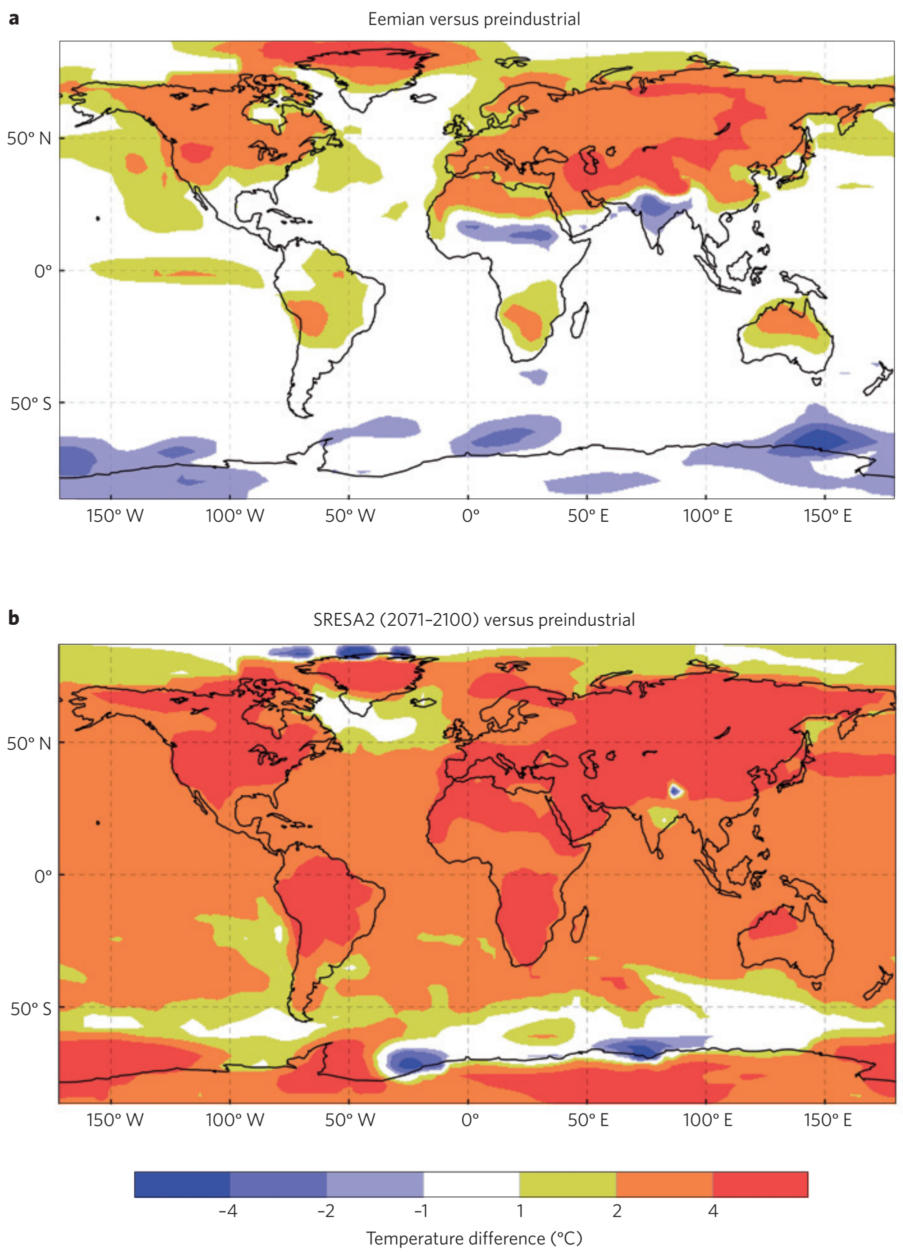

Figure 1 | Summer warming, past and future. The ECHO-G climate model used by van de Berg and colleagues[4] implies that over Greenland, patterns of summer warming during **a**, the Eemian and **b**, at the end of the twenty-first century (seen here relative to the preindustrial period) should be similar. However, van de Berg and colleagues show that the melting of the Greenland ice sheet during the Eemian was caused by both higher temperatures and stronger insolation that at present, suggesting that the future melting of the Greenland ice sheet may not follow a similar path.

Palaeoclimatic data, although imperfect and incomplete, do provide such an opportunity. The Eemian interglacial period (130,000–115,000 yr ago) is the most recent time when the climate was considerably warmer than now — at least regionally and seasonally. However, the warmth was not caused by high concentrations of greenhouse gases, the principal cause of anthropogenic climate change. Instead, the summertime warmth in the high northern latitudes was the result of the Eemian distribution of summer radiation between latitudes and seasons as determined by the Earth's orbit.

The mass balance of ice sheets is affected both by air temperature, which determines downward long-wave radiation and sensible heat flux, and by the absorption of solar radiation. However the relative role of these two factors for different climate conditions has not been analysed in detail until recently. Moreover, most previous attempts to model the Eemian Greenland ice sheet[8] did not explicitly account for changes in solar radiation. Instead, they imposed only temperature changes, by employing a 20-yr-old semi-empirical approach called the positive-degree-day method[9]. The method is based on an assumption that for each day with a temperature above freezing, the amount of ice-sheet melt that occurs is propositional to the number of degrees above freezing. Obvious advantages of this method are its simplicity and that it requires only temperature changes as input. For present-day conditions, it works reasonably well, but that does not necessarily guarantee that it can also be applied to different climate states.

van de Berg and colleagues[4] tested whether the method could also be applied to the Eemian. They analysed the response of the surface mass balance of the Greenland ice sheet to climate change during the last interglacial, using a state-of-the-art regional climate model[10] driven by output from a global climate model. This is arguably the most advanced approach to modelling the surface mass balance of the Greenland ice sheet that has been used so far. van de Berg and colleagues found that the combined effect of high temperatures and solar radiation changes leads to a dramatic increase in the surface melt of the ice sheet, in line with previous studies.

However, they also performed two sensitivity experiments in which they isolated the individual effects of temperature and solar radiation changes on surface mass balance. They found that the direct effect of warmer summer temperatures explains a little more than half of the enhanced melting, whereas the rest results from changes in solar radiation and the nonlinear interactions between these two mechanisms. Thereby, for the same temperature increase, the Greenland ice sheet would lose mass much faster in the Eemian climate state than under future anthropogenic climate change. In other words, although the Eemian still represents a very important test case for climate and ice-sheet models, the last interglacial period cannot be considered as a straightforward analogue for future Greenland melt.

van de Berg and colleagues[4] show that the convenient but simplistic positive-degree-day approach should not be used for modelling the past evolution of the ice sheets. Moreover, they demonstrate that this method may have serious problems in simulating even the present surface mass balance of the Greenland ice sheet. But even if the positive-degree-day method overestimates the amount of melting in some regions, it does not necessarily mean that the Greenland ice sheet is more stable than deduced from earlier studies that used this approach. ❐

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PALAEONTOLOGY

Microfossils from early Earth

Proof that purported fossils of early life are truly old and biological is often controversial. Detailed analyses confirm the early evolution of microbial sulphur cycling and reveal microfossils in 3.4-billion-year-old beach sandstones.

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Possible traces of life in Archaean rocks suggest that more than 3 billion years ago, a diverse community of microbes already flourished in environments ranging from shallow lakes and open marine settings to deep hydrothermal systems. The evidence of life includes chemicals produced only by biological activity, isotopic fractionation of carbon and sulphur indicative of biological cycling of these elements, sedimentary structures induced by microbial mats such as stromatolites, and microstructures interpreted as fossil microorganisms. However, these traces can in some cases also be produced by abiotic processes or later contamination, leaving a controversy surrounding the earliest record of life on Earth[1,2]. Writing in *Nature Geoscience*, Wacey *et al.*[3] report populations of spheroidal and tubular microfossils from the 3.4-billion-year-old Strelley Pool Formation of Western Australia, which they link to sulphur-metabolizing bacteria.

Any purported ancient microfossil must pass essential tests before it can be considered evidence of early life. Evidence for contamination must first be discarded. Microbes can enter existing rock through borings or fluids in veins and pores, or during sample preparation. Therefore the petrology of the rock must be carefully assessed to show that the microstructures are indeed endemic to the rock. The microstructures must also be shown to be contemporaneous to the enclosing