The Scorching Inferno of the early Eocene: Lessons for the Current Climate Crisis

(Proposer: Prof. Claudia Agnini)

This interdisciplinary research focuses on the environmental changes leading to major carbon cycle aberrations that occurred 56-52 million years ago. The time interval, corresponding to the late Paleocene-early Eocene, saw long-term warming and a series of transient episodes of global warming and ocean acidification, known as hyperthermals, caused by natural carbon stocks crossing a threshold for carbon release. By studying the behavior of the climate system across hyperthermals, the research aims to test the long-term response of climate following large greenhouse gas emission events. The goal is to provide a quantification of the forcing processes and feedbacks involved in the release of carbon from natural stocks across individual hyperthermal events. This will be achieved by obtaining geochemical and biotic proxy records from various sites and integrating them with an Earth Model of Intermediate Complexity. The results of this research will contribute to evaluating the stability of present-day natural carbon reservoirs under increasing global temperature conditions.

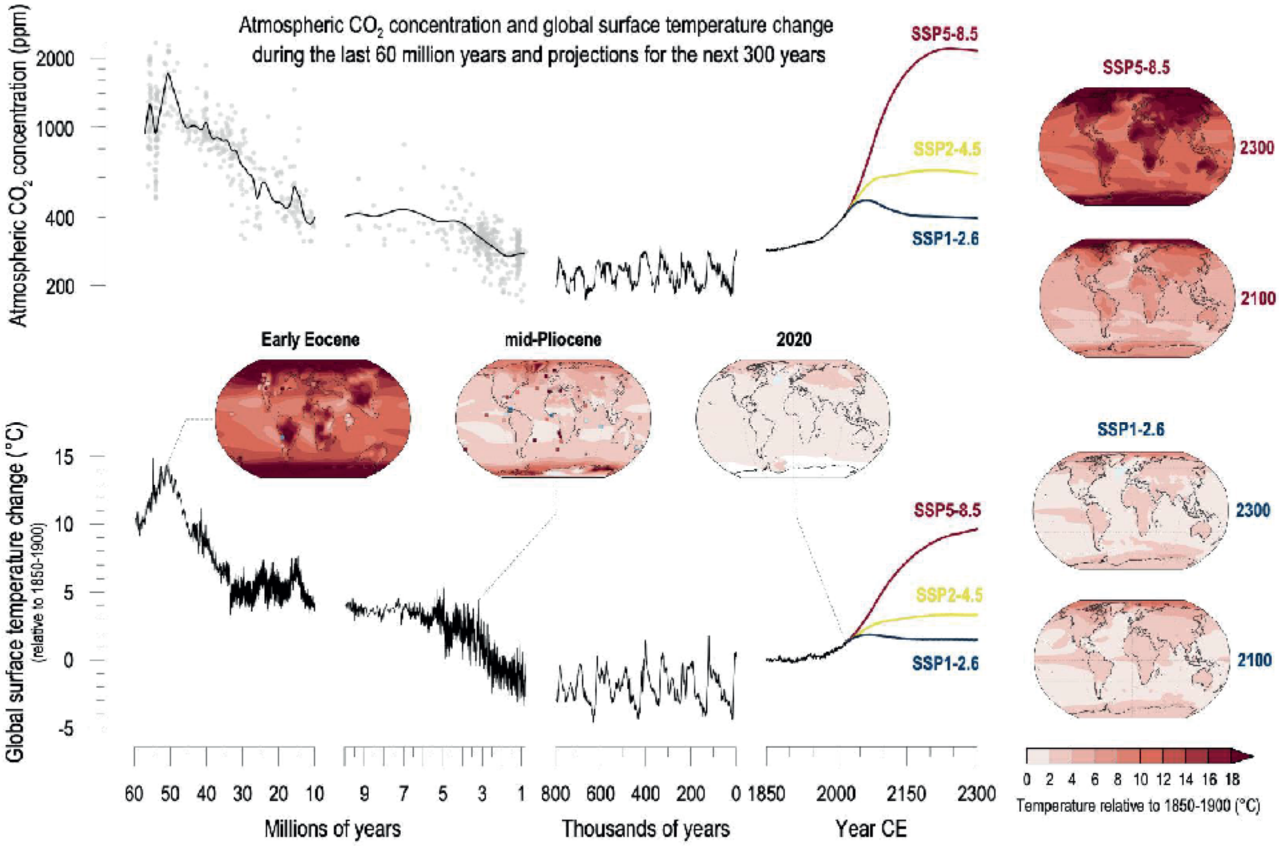

Figure 1. Changes in atmospheric CO_2 and global surface temperature (relative to 1850-1900) from the deep past to the next 300 years (from IPCC AR6 Climate Change 2021: The Physical Science Basis)

Hyperthermals are events of extreme global warming that have occurred relatively frequently in the geological record, particularly under conditions of enhanced greenhouse gases. Some of the larger hyperthermal episodes include those at the Permian/Triassic and late Triassic boundaries, the Toarcian Oceanic Anoxic Event, and the Paleocene Eocene Thermal Maximum (PETM). These events are characterized by a negative carbon isotope excursion (CIE) of up to 4‰ at the start of the event, indicating the addition of vast amounts of isotopically light carbon to the exogenic pool. The PETM is of particular interest, as it is the most recent and rapid hyperthermal episode, with a global warming of 5-7°C and ocean acidification. This occurred within a long-term trend of increasing temperature and declining carbon stable isotope values that started around 60 million years ago and culminated at the Early Eocene Climatic Optimum (EECO). Other hyperthermal events have also been identified and correlated globally, leading to the hypothesis that these events may represent threshold or tipping point processes rather than independent events.

As part of this project, the doctoral candidate will collaborate with other members of the research team, participate in sampling and data analysis activities, contribute to the writing of scientific articles, and present research findings at conferences and seminars. Specifically, the doctoral candidate will deepen their knowledge of micropaleontological and geochemical data analysis techniques. The evolution of environmental conditions preceding the carbon release for the PETM (as well as for the other hyperthermals) will be reconstructed using geochemical and biotic proxies. This will involve analyzing well-preserved, continuous, and expanded marine sedimentary archives that represent a wide range of depositional and paleogeographic settings.

The PhD student will be dedicated to establish a robust chronology by refining the biostratigraphy of calcareous plankton (nannofossils). Through analysis of assemblage composition, she/he can gain insights into the response of calcareous plankton to short-term climate change events at a higher resolution than orbital scales, allowing for comparisons between orbital forcings, climate change, and biosphere response. To achieve this, the PhD student will acquire new $\delta^{13}C$ and $\delta^{18}O$ data in specific intervals to increase the stratigraphic resolution of already available records, with a focus on the onset of events. We will also correlate these data with high-quality magnetostratigraphy.

Moreover, the PhD student will perform calcareous nannoplankton quantitative analyses, using standard procedures to obtain (semi)quantitative estimates of taxa abundances on the whole assemblage. Scanning Electron Microscope analysis on selected samples to evaluate the assemblage preservation, which can be used to estimate the reliability of the isotopic signal, will be also performed. In some cases, the PhD student will perform morphometric analysis of selected nannofossil taxa to investigate size variation and relative carbonate production, which can be linked to changes in paleoenvironmental conditions, such as the paleo-geochemistry of the oceans. The analyses will be carried out at a time resolution of approximately 4-5 kyr around the intervals of interest.

Finally, the PhD student will perform routine stable isotope analysis on bulk samples to obtain high-resolution $\delta^{13}C$ and $\delta^{18}O$ records, particularly in cases where such records are not already available or are at low resolution. This analysis will provide information on paleotemperatures and the degree of diagenetic alteration of biogenic carbonate near or below the seafloor. The carbon isotope signal will be used as a valuable tool for stratigraphic correlation and for refining the orbital tuning of the records.

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