The Early Eocene Climate Optimum reconstructed with Bayesian multi-proxy integration

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# Abstract

Here goes the abstract

# Introduction

The early Eocene climate optimum (EECO, ~ 53 - 49 million years ago) is thought to have been the warmest episode ever since. The EECO has received much attention due to its use as an analogue for extreme warming scenarios, depicting a possible future high-CO2 world. To reconstruct the climate of EECO, a variety of proxy data and Earth System Models have been used. Early modelers have soon noticed that their models struggle to reproduce the climate indicated by proxy data: Without unrealistically high concentrations of atmospheric CO2, early climate models struggled to reproduce the equitable polar climates indicated by early Eocene proxy data, e.g. the occurrence of mangroves in polar latitudes, and d18O data from x indicates a temperature of ~ y at latitude z.

In order to properly compare model output to proxy data, latitudinal temperature patterns need to be reconstructed from noisy data (impossible to properly compare model gradients with scattered proxy points “by eye”)

Example reference (R Core Team 2019)

# Materials & Methods

## early Eocene SST proxies

Proxy-based reconstructions of Cenozoic shallow water temperatures chose a range of proxies for marine, shallow water temperatures proxies: d18O, D47, Mg/Ca, TEX86 mangroves, corals, sharks?

**d18O.**

**d47.**

**Mg/Ca.**

**TEX86.**

**Coral reefs.** Coral reefs built by zooxanthellate-bearing, shallow water corals are confined to the tropics - substropics. The coldest

**Mangroves.** Recent mangroves occur in the tropics - subtropics. Although many factors besides temperature determine the extent of mangrove distributions, empirical temperature limits have been established for the genera *Avicennia* and *Rhizophora*, with lower mean annual SST limits of 15.6 degC and 20.8 degC, respectively (**Quisthoudt2012?**). Both *Avicennia* and members of the Rhizophoraceae family were widespread in the early Eocene, but only *Avicennia* occurred in polar latitudes (**Suan2017?**; **Popescu2021?**). Assuming that Eocene members of these mangrove taxa had similar climatic requirements as their modern relatives, the presence and absence of *Avicennia* and Rhizophoraceae pollen can be used as a temperature proxy. To translate mangrove occurrences from the compilation by (**Popescu2021?**) to a quantitative temperature proxy, we allocate locations at which *Avicennia* pollen, but no Rhizophoraceae pollen were found, a mean temperature between the lower *Avicennia* and Rhizophoraceae limit (18.2 degC), with a standard deviation of 1.33 degC, thus placing 95 % of the probability density within that interval (see Fig. 1x). The range of temperatures in which both taxa occur in the modern is very wide (20.8 and 28 deC), hence occurrences of both *Avicennia* and Rhizophoraceae pollen were not used in the analysis.

[Fig 1: In this part we can show a figure with the proxy data and the distributions of temperature proxies we specify, like mangroves]

## A hierarchical model of latitudinal temperature gradients

[Fig 2: In this part we can show a figure with the model structure and the priors we put on the parameters. Also, try it on the modern data? Alternatively, this figure goes to the SI]

* alternative to current implementation: prior on (A+DKA) instead of on DKA? Then constrain DKA to be positive by proposing it in the log-space? This would allow for putting a direct prior on the upper temperature limit

# Results

## Fig 3 - Eocene gradient

## Fig 4 - compare Eocene gradient with previous reconstructions / ES models

* x1 Draw samples from the posterior gradient to get a latitudinal gradient of deg C / deg lat with uncertainty (intercept gradient at 0 and 90 deg lat)
* x2 generate global average temperature, and tropical, temperate, polar temperatures in a similar way, accounting for area

# Discussion

* x1 compare lat gradient to literature estimates, e.g. Zhang2019

# Conclusions

# Acknowledgements

# Author contributions

# Data accessibility

# References

R CORE TEAM. 2019. [*R: A language and environment for statistical computing*](https://www.R-project.org). R Foundation for Statistical Computing, Vienna, Austria.

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