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Continental temperature seasonality from Eocene Warmhouse to Oligocene Coolhouse — A model-data comparison

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At the junction of warmhouse and coolhouse climate phases, the Eocene Oligocene Transition (EOT) is a key moment in the history of the Cenozoic climate. Yet, while it is accompanied by severe extinctions and biodiversity turnovers, terrestrial climate evolution remains poorly resolved. On lands, some fossil and geochemistry records suggest a particularly marked cooling in winter, which would have led to the development of more pronounced seasons (higher Mean Annual Range of Temperatures, MATR) in certain regions of the Northern Hemisphere. This type of climate change should have had consequences on biodiversity and an implication in some of the fauna and flora renewals described at the EOT. However, this season strengthening has been studied only superficially by model studies, and questions remain about the geographical extent of this phenomenon and the associated climatic processes. Although other components of the climate system vary seasonally (e.g., precipitation, wind), we therefore focus on the seasonality of temperatures only.

In order to better understand and describe temperature seasonality change patterns from the middle Eocene to the early Oligocene, we use the Earth System Model IPSL-CM5A2 and a set of simulations reconstructing the EOT through three major climate forcings: pCO2 decrease (1120/840 to 560 ppm), the Antarctic ice-sheet (AIS) formation, and the associated sea-level decrease (-70 m).

Our results suggest that seasonality changes across the EOT rely on the combined effects of the different tested mechanisms which result in zonal to regional climate responses. Sea-level changes associated with the earliest stage of the AIS formation may have also contributed to middle to late

Eocene MATR reinforcement. We reconstruct strong and heterogeneous patterns of seasonality changes across the EOT. Broad continental areas of increased MATR reflect a strengthening of seasonality (from 4°C to > 10°C increase of the MATR) in agreement with MATR and Coldest Month Mean Temperatures (CMMT) changes indicated by a review of existing proxies. pCO2 decrease induces a zonal pattern with alternating increasing and decreasing seasonality bands. In the northern high-latitudes, it results in sea-ice and surface albedo feedback, driving a strong increase in seasonality (up to 8°C MATR increase). Conversely, the onset of the AIS is responsible for a more constant surface albedo, which leads to a strong decrease in seasonality in the southern mid- to high-latitudes (> 40°S). Finally, continental areas emerged due to the sea level lowering cause the largest increase in seasonality and explain most of the global heterogeneity in MATR changes patterns. The seasonality change patterns we reconstruct are consistent with the variability of the EOT biotic crisis intensity across the Northern Hemisphere.