Integrating Climate Model Output and Paleoclimate Proxies: An Example from the Latest Cretaceous (Maastrichtian)

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Past periods of warm climate are an important means of evaluating the models that predict future climate change. The study of past warm climates is also important for understanding the origin of hydrocarbon deposits. Discrepancies between climate models and paleoclimate proxies are most acute for times of warm climate, which limits our understanding of climatic process. Climate models have potential problems, including incorrect boundary conditions, coarse spatial resolution, insufficient complexity, and lack of critical feedbacks. Climate proxies also have potential problems, including misidentification of fossils, small sample size, diagenesis of carbonate, and error caused by the choice of statistical model used to describe proxy-climate relations.

The Maastrichtian is a good time for model-data comparisons because of multiple modeling studies and numerous proxy studies of the Cretaceous-Paleocene boundary. Models used to study the Maastrichtian include GENESIS, CCSM3, and the Hadley Center model. For terrestrial regions, model mean annual temperatures and seasonality are compared with data from angiosperm leaf physiognomy (CLAMP, Leaf Margin Analysis), plant life form distribution, nearest living relatives, and vertebrate δ18O. Model precipitation is compared with a database of climatically restricted sediments and angiosperm leaf physiognomy for specific sites. For oceanic regions, simulations are compared to marine proxies of surface temperature, especially the δ18O of exceptionally preserved carbonate and fish tooth enamel. For temperature, terrestrial and marine proxies are combined to show a global latitudinal pattern and a range of uncertainty. The newer climate models do a better job of reproducing the latitudinal gradient of surface temperature, including Mean Annual Temperature (MAT) and Cold Month Mean (CMM). Different models correctly predict tropical rainforest climate in small regions along the paleoequator; however, the relatively simple GENESIS model correctly predicts tropical rainforest in northern Mexico, while the more complex CCSM3 model does not. No model correctly simulates MAT and CMM for the Siberian Interior, though the degree of discrepancy is sensitive to the choice of paleogeography. These results imply that the study of past climates should include climate models of differing complexity and incorporate uncertainties in both paleogeography and proxy data.