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Integrated multi-proxy reconstruction of atmospheric CO_2 evolution through the Miocene

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Miocene Earth systems have received attention as potential analogues for modern or near-future conditions influenced by anthropogenic forcing. The middle Miocene (17 – 14 Ma), while solidly within the coolhouse climate regime, was the most recent period during which global temperatures were substantially warmer than modern. Syntheses of proxy records have suggested that the middle Miocene may have been characterized by a transient increase in atmospheric CO_2 concentrations and may have been the most recent time that CO_2 exceeded the modern concentration of ~427 ppm.

Existing paleo-CO_2 assessments are based on post-hoc integration of independently interpreted proxy data. This approach may not accurately reflect shared biases or tradeoffs between various proxy systems. To address this issue, we report the results of a joint analysis of data from four major paleo-CO_2 proxy systems (foraminiferal boron isotopes, alkenone carbon isotopes, land plant gas exchange, and paleosol carbonate isotopes) conducted in the context of new forward proxy system models. These models explicitly represent environmental and geochemical factors, including but not limited to atmospheric CO_2 concentration, that affect proxy values individually or collectively. Sensitivity testing shows how the joint PSM inversion approach inherently weights reconstructions to reflect the information content of different proxy data and accounts for potential shared bias due to factors such as global temperature change. The integrated reconstruction offers refined, quantitative estimates of CO_2 trends throughout the Miocene and informs future work by (1) highlighting intervals characterized by substantial uncertainty or conflicting proxy evidence and (2) serving as a proof of concept for application of a similar approach to deeper time, longer term reconstructions.