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Conundrums in recent global data sets across the Mid-Pleistocene Transition

Peter Köhler and Peter U. Clark

The most recent time series of global surface mean temperature (GMST) across the Mid-Pleistocene Transition (MPT), based on global mean sea surface temperature (GMSST), contains a shift from warmer than present interglacials with small glacial-interglacial amplitudes of <4K with 41kyr periods toward colder than present interglacials and amplitudes of ~6K in 100kyr periodicities (Clark et al., 2024, doi:10.1126/science.adi1908). Although different in detail, long-term mean ocean temperature (MOT) based on these GMSST (Clark et al., 2025, doi:10.5194/cp-21-973-2025) agrees within uncertainties with an estimate from Antarctic ice for the period 3.1-1.2 Ma (Shackleton et al., 2026, doi:10.1038/s41586-026-10116-3) and with EPICA MOT estimates for the last 0.7Myr, supporting the need for a MOT:GMSST scaling change across the MPT. Global mean sea level (GMSL) based on these GMSST and MOT reconstructions varied only in frequency, but not in amplitude across the MPT (Clark et al., 2025, doi:10.1126/science.adv8389). This is the only GMSL reconstruction with such a feature, but it is also the only approach that agrees with well-dated evidence for large ice sheets in North America in the Early Pleistocene. The reconstructed change in atmospheric CO_2 is still unclear. Some proxies and simulations that already considered these changes in GMST and GMSL propose higher than preindustrial CO_2 before the MPT (Köhler & Clark, 2026, doi:10.1029/2025GL120608), but recent data from Antarctica suggest little long-term trend (Marks-Peterson et al., 2026, doi:10.1038/s41586-025-10032-y). Thus, long-term trend in atmospheric CO_2 seems to be in phase with either GMST or GMSL, but not with both.

We here highlight several conundrums these recent findings imply, e.g.:

- If CO_2 was low before the MPT, what other globally relevant processes were responsible for the warming?
- What process is responsible for the GMST-GMSL decoupling?
- Why are global variables more inline in the 100-kyr world, but partly decoupled in the 41-kyr regime before the MPT?