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CO_2 as an emergent climate forcing over the course of the Pleistocene

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Records of atmospheric carbon dioxide (CO_2) from the Late Pleistocene are tightly correlated with many climate parameters making it difficult to deconvolve the root causes of CO_2 change. Here we present well-resolved (1 sample every ~3 kyr) CO_2 reconstructions based on boron-isotope records from the Early (2.3–2.7 million years ago, Ma) and Mid Pleistocene (1.1–1.5 Ma), intervals when northern hemisphere ice sheets were smaller than the late Pleistocene and paced by relatively short orbital cycles (obliquity). We observe a reduction in mean CO_2 over the course of the Pleistocene consistent with large scale cooling and glacial intensification. Importantly, we also observe a change in the phasing between CO_2 and global climate state, here observed through benthic $\delta^{18}O$, from CO_2 lagging climate by an average of 12±0.2 thousand years (kyrs) in the earliest Pleistocene, 3.5±0.2 kyrs in the middle Pleistocene, to being largely in phase in the late Pleistocene. The reduction in CO_2, combined with increased phase locking between CO_2 and climate changes reflects the increasingly important forcing of orbitally paced climate variability by CO_2 with increasing ice mass. While it is the mean-CO_2 decline that drives global cooling during this time, our results suggest that the gradual change in of the phasing of CO_2 and orbital parameters plays a vital, ayet previously unrecognised, role in the glacial intensification that increasingly characterises later parts of the Quaternary.