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- ▣ Special Issues
- ▣ Library Search
- ▣ Title and Author Search

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- ▣ Contents of Issue 3
- ▣ Special Issue

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Climate and CO₂ modulate the C₃/C₄ balance and δ¹³C signal in simulated vegetation

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Abstract. Climate and atmospheric CO₂ effects on the balance between C₃ and C₄ plants have received conflicting interpretations based on the analysis of carbon isotopic fractionation (δ¹³C) in sediments. But, climate and CO₂ effects on the C₃/C₄ balance and δ¹³C signal are rarely addressed together. Here, we use a process-based model (BIOME4) to disentangle these effects. We simulated the vegetation response to climate and CO₂ atmospheric concentration (pCO₂) in two sites in which vegetation changed oppositely, with respect to C₃ and C₄ plants abundance, during the Last Glacial Maximum to Holocene transition. The C₃/C₄ balance and δ¹³C signal were primarily sensitive to temperature and CO₂ atmospheric partial pressure. The simulated variations were in agreement with patterns observed in palaeorecords. Water limitation favoured C₄ plants in case of large negative deviation in rainfall. Although a global parameter, pCO₂ affected the δ¹³C signal differently from one site to the other because of its effects on the C₃/C₄ balance and on carbon isotopic fractionation in C₃ and C₄ plants. Simulated Plant functional types (PFT) also differed in their composition and response from one site to the other. The C₃/C₄ balance involved different competing C₃ and C₄ PFT, and not homogeneous C₃ and C₄ poles as often assumed. Process-based vegetation modelling emphasizes the need to account for multiple factors when a palaeo-δ¹³C signal is used to reconstruct the C₃/C₄ balance.

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