

Gomes et al. "Rising atmospheric CO₂ concentrations: the overlooked factor promoting SW Iberian Forest development across the LGM and the last deglaciation?"

General comments

This study examines pollen and alkenone-based SST records from Iberian Margin Site U1385 to study vegetation changes during the LGM and the deglaciation, linking them to climate and CO₂ variations. A biomarker proxy (the C₂₉/C₃₁ leaf wax ratio) proves effective in reconstructing paleo aridity across the Mediterranean.

Key findings show that low CO₂ concentrations (<225 ppm) during the LGM and Heinrich Stadial 1 intensified cold and arid conditions, suppressing forest development while favoring drought-tolerant Ericaceae. Forest expansion during the Bølling-Allerød interstadial was driven by rising CO₂ levels and a warmer, wetter climate. Interestingly, despite cooler temperatures during the Younger Dryas, woodland cover persisted—likely sustained by elevated CO₂ and increased moisture availability. These results suggest that CO₂ exerted its strongest influence on vegetation under cold, low-CO₂ conditions, with a critical threshold near 225 ppm. Below this level, forest expansion was severely limited, and climatic stressors were amplified. In contrast, during warmer periods, changes in temperature and precipitation played a more dominant role in shaping vegetation dynamics.

The study emphasizes the role of CO₂ in modulating plant–moisture relationships, offering insights into how future vegetation patterns may respond to anthropogenic CO₂ increases. Further research is also recommended to refine a biomarker that can more effectively distinguish between woody and herbaceous vegetation in Mediterranean ecosystems.

This is a high-quality study that enhances our understanding of vegetation dynamics during the last deglaciation by thoroughly integrating paleo-proxies and highlighting the role of pCO₂. The findings are relevant for paleoclimatology, paleoecology, and ecological modeling. However, I believe several revisions are still needed before this manuscript can be published:

- Modify the introduction because it is long and complex, covering multiple concepts (climate dynamics, CO₂ physiology, modeling uncertainties, regional paleoecology), which overwhelms readers and hides the main message.
- Strengthen the discussion on why approximately 225 ppmv is a critical threshold (link to plant physiology studies).
- Address biomarker uncertainties with more explicit caveats.
- Typographical and stylistic issues, including mixing British and American English, should be corrected for clarity and consistency (see **line-by-line comments**).

Specific comments

The introduction could be improved by addressing several key issues. The logical flow could be better by smoothing abrupt transitions between general and regional topics, using clearer topic sentences and linking phrases. Additionally, some points are repeated unnecessarily, such as discussions of pCO₂ effects on water-use efficiency and modeling limitations, which could be made more concise. The research aim, while stated, should be more explicitly and concisely positioned at the end of the introduction to sharpen focus.

The suggested improvements recommend restructuring the content into three or four thematic sections, such as deglaciation and climate background, the role of pCO₂ in global and plant physiological dynamics, the regional context of SW Iberia and its vegetation records, and the motivation and goals of the study. Additionally, it advises including a clear statement of objectives at the end, emphasizing the study's purpose to reconstruct high-resolution vegetation changes in SW Iberia using IODP Site U1385 and to evaluate the

influence of pCO₂ on forest dynamics during the Last Glacial Maximum and deglaciation. The feedback also highlights the need to explicitly clarify the study's novelty by identifying gaps not addressed in previous Iberian or global research. Lastly, it suggests reducing repetitive technical jargon, especially regarding the physiological effects of pCO₂, by summarizing key points concisely instead of reiterating them across multiple paragraphs.

In Methods (3.1. Chronological framework), the authors need to briefly describe why the combination of monospecific and mixed foraminiferal assemblages was used for dating. Are there implications for age reliability? You also clarify whether the chronological uncertainty from the Bacon model was incorporated into subsequent analyses.

In Methods (3.2. Pollen analysis), the reason for excluding aquatic plants and spores from the total could be briefly explained for non-specialist readers.

In Methods (3.3 Compilation of Iberian margin pollen records), the authors can indicate whether chronological alignment or any synchronization across sites was performed, or if all records rely solely on published age models. The GAM model parameters are well-described; however, a brief explanation of why $k = 30$ and $sp = 0.0001$ were chosen would strengthen the statistical justification.

In the Results and Discussion section, although the content is dense and scientifically rich, some parts, especially 4.1.1, 4.1.2, and 4.2, would benefit from clearer and more concise organization. The authors might consider dividing long paragraphs into thematic subsections (e.g., separating observational results from interpretive commentary). There is a slight imbalance between the narrative discussion and data presentation. It could be helpful to include more direct references to quantitative changes (such as percentage increases/decreases, ΔSST , pCO₂ rise rates) within the text to more explicitly connect interpretations to measured trends.

The identification of a potential pCO₂ threshold (~225 ppmv) for forest development is compelling and well-supported by cross-referenced records. However, some statements treat this threshold as fixed or universal. Consider emphasizing that thresholds may vary by taxa, edaphic conditions, or microclimate, and explicitly acknowledge uncertainties in this area.

The discussion on C₂₉/C₃₁ ratios is thoughtful and cautiously presented, but it could be clearer by organizing it to distinguish between established knowledge, such as the plant physiology of leaf waxes, site-specific observations like correlations in U1385, and interpretive hypotheses, including stress responses versus vegetation shifts. The latter should be explicitly marked as speculative or needing further validation.

The treatment of C₃/C₄ dynamics is detailed and shows skepticism toward simple explanations. The authors correctly highlight the limitations of pollen resolution and suggest promising future directions, such as isotopic or compound-specific research. However, this section could benefit from a summary that outlines the current data limitations and reinforces why C₃ dominance remains the most supported interpretation for SW Iberia during this period.

The hypothesis that pCO₂ played a significant and previously underrecognized role in governing vegetation development during the last glacial cycle is compelling and well-supported. This discussion makes a valuable contribution to debates in paleoclimatology, paleoecology, and vegetation modeling, although future data-model comparisons and experimental validations will be crucial to test some of the more speculative physiological mechanisms proposed.

Line-by-line comments

L44. "often overlooked" to "often-overlooked"

L45. "during last deglaciation" to "during the last deglaciation"

L46. "forest" to "forests"

L47. "phase, when" to "phase when"

L53. "of" to "during"

L57. "suppress" to "suppresses"

L60. "BP contributed" to "BP, contributed"

L61. "persistance" to "persistence"

L99. "in shaping global climate" to "in shaping the global climate"

L104. "stomata which" to "stomata, which"

L118. "and typically observed" to "and are typically observed"

L125. "2023," to "2023;"

L128. "(e.g. Piao et al., 2020)" to "(e.g. Piao et al., 2020),"

L147 "resolution, and" to "resolution and"

L153. "precipitation than" to "precipitation rather than"

L154. "regional-based" to "region-based"

L159. "other factors than" to "factors other than"

L183. "the the" to "the"

L212. "were" to "was"

L213. "processed" to "was processed"

L214. "age-model" to "age model"

L215. "approach, through" to "approach through"

L226. "France using" to "France, using"

L226. "between 3.84 to 1.08" to "between 3.84 and 1.08" or "from 3.84 to 1.08"

L228. "coarse-sieving" to "coarse sieving"

L230. "50%) eliminated" to "50%), eliminated"

L230-231. There appear to be fragmented sentences.

L260. "plants type" to "plants"

L261. "Pollen analysis," to "Pollen analysis"

L293. "*k-index* obtained" to "*k-index* was"

L295. "TMF with" to "TMF, along with"

L308. "temperatures values" to "temperature values"

L316. "through the time" to "through time"

L316. "Eglinton and Hamiltom 1967" – no reference list

L317. "vs grasses plants" to "and grass plants"

L319. "plants, by increasing" to "plants by increasing"

L319-320. "increasing leaf wax long chain production" to "increasing the production of long-chain leaf wax"

L320. ", to reduce" to ", which reduces"

L325. "dependent" to "depend" or "be dependent"

L339. "Iberian Peninsula" to "the Iberian Peninsula"

L352. "Nevertheless" to "Nevertheless,"

L354. "conditions are" to "conditions, are"

L391. "in addition of" to "in addition to"

L408. "BIOMEOD" to "BIOME3"

L428. "Iberia; including" to "Iberia, including"

L429. "pCO₂ yields" to "pCO₂, yields"

L432. "simulations which" to "simulations, which"

L436. "warmer summer" to "warmer summers"

L438. "warmer winter temperature" to "warmer winter temperatures"

L469. "support" to "supports"

L479. "increase" to "an increase"

L490. "show" to "shows"

L500. "are" to "is"

L516. "was" to "were"

L531. "Fig 3c" to "Fig. 3c"

L534. "high latitude" to "high-latitude"

L545. "a lack of reliability in the speleothem proxies" to "the unreliability of speleothem proxies"

L553. "nearby" to "near"

L560. "the forest development" to "forest development"

L569. "promotor" to "promoter"

L570. "However" to "However,"

L591. "thus may" to "may thus"

L592. "the forest development" to "forest development"

L597. "using C₂₉/C₃₁ n-alkanes of Site U1385" to "by analysing C₂₉/C₃₁ n-alkanes from Site U1385"

L603-604. "chain-lengths" to "chain lengths"

L613. "C₂₉/C₃₁ ratio" to "the C₂₉/C₃₁ ratio"

L617. "requirments" to requirements

L618. "Consequently the" to "Consequently, the"

L630. "different forcing" to "different forcings"

L630. "the Mediterranean forest development" to "Mediterranean forest development"

L636-637. "majority C₄" to "majority of C₄"

L642. "TMF or STE or C₂₉/C₃₁" to "TMF, STE, or C₂₉/C₃₁"

L649. "Modeling" to "Modelling"

L650. "favored" to "favoured"

- L651. "humidty" to "humidity"
- L652. "most of the C4" to "most C4"
- L652. "the tropical" to "tropical"
- L662. "although" to ", although"
- L662. "single grain" to "single-grain"
- L675. "ratio) which" to "ratio), which"
- L677. "region)." to "region."
- L679. "palaeonvironment" to "palaeoenvironment"
- L686. "favoring" to "favouring"
- L687. "advantageDuring HS1" to "advantage. During HS1"
- L704. "paleo-data" to "palaeodata"
- L707. "C₃/C₄ plants ratio" to "the C₃/C₄ plant ratio"
- L708. "the dynamic" to "the dynamics"