Response to Editor

Dear Editor, we are sincerely grateful for your constructive comment, which have encouraged and helped us to improve the manuscript. We have revised the manuscript carefully based on your comment. In the responses below, your comment is provided in black text and our responses are provided in blue text.

To the authors,

You have done a good job of responding to the reviewers' recommendations. I have one further comment of my own, which I would like to see addressed before I can recommend publication here.

The scope of this journal states the following (see https://www.atmospheric-chemistry-and-physics.net/about/aims_and_scope.html):

"Articles should have important and clearly argued implications for our understanding of the state and behaviour of the atmosphere and climate or present substantial new insights into the atmosphere's role in other parts of the Earth system."

I would like to see it stated more explicitly in the conclusions section (and potentially in the abstract) how your research addresses these aims.

Many thanks.

Many thanks for your thoughtful comment. We add a few sentences to the Abstract and the Conclusion to address the implications of this study for understanding of the state and behavior of the atmosphere and climate.

The sentence *and provides insights into the regional-scale characteristics of atmospheric CO_2* has been added to the Abstract in line 29 of the revised manuscript.

The last paragraph of the Conclusion has been revised to:

This study systematically characterizes and evaluates the distribution of CO_2 concentrations across multiple observational sites, with a particular focus on regions surrounding Belgium, demonstrates the feasibility of using the WRF-GHG model to simulate CO_2 concentration variations in the core region of Western Europe, and provides a basis for applying this model to the study of other long-lived greenhouse gases like CH_4 and N_2O in this region. It further emphasizes the importance of optimizing initial and boundary conditions and refining the construction of source-specific vertical emission profiles to enhance simulation accuracy. Additionally, due to the relatively simplified parameterization of the current VPRM, its applicability across different climatic conditions remains limited. Nonlinear ecosystem responses under extreme temperature and moisture conditions may lead to biases in simulated respiration fluxes,

which indirectly reflect the complexity of the biosphere-atmosphere system under extreme environmental stress and indicate that a modified VPRM model is necessary (Gourdji et al., 2022). At the same time, this study highlights the critical role of observations in evaluating regional simulations and supporting the understanding of carbon emissions and the distribution of CO_2 concentrations in the atmosphere. Overall, this work not only advances the understanding of the spatiotemporal variations of CO_2 in the core region of Western Europe, but also provides an important reference for developing more reliable regional-scale carbon-climate feedback modelling tools, thereby contributing to a deeper understanding of the interactions between extreme climate and the carbon cycle. in lines 502-515 of the revised manuscript.