Reply on Reviewer 2

This is a high-quality study that adds to the literature on projecting coral reef futures with climate models over the remainder of this century. Although the results are not highly novel, being quite similar to previous efforts, the different approach here makes it a valuable contribution to the literature. I have three main areas that could be improved:

Why this model? In the Introduction, the authors make the argument that previous works were limited by using only climate model output, which could be an issue because that approach does not allow interaction between corals and climate and is constrained to the temporal and spatial resolution of the provided output. That makes sense, however it doesn't seem like the present work really improves on the previous works. The iLOVECLIM model seems quite coarse (3° ocean grids, larger than the climate model output used in at least some previous works) and the authors consider the effects of carbonate processes negligible on climate on centennial timescales. I think it is fine to present the results from this single model and explain its features and any new insights, but I am not seeing the argument that this is clearly an improvement over previous efforts in this field.

We thank the reviewer for their comments and questions.

We agree that iLOVECLIM might not be the best model to study a few future simulations, however it is a very useful model to study a large amount of future simulations, which we do here. As it is a fast model (around 700 simulated years per day) it allows us to test various sources of uncertainties and evaluate the range of possibilities.

Because it is fast and allows numerous simulations, it was also the perfect model to develop and test this first coral module embedded with in climate model. But as it is limited by the resolution and inherent simplifications of the intermediate model, we plan to also implement this module in a higher resolution GCM and evaluate the changes of carbonate production in such a model.

It would help readers if there were more explanation of the carbonate model embedded in iLOVECLIM. The results do seem highly similar to the Cornwall works, especially in the sense that the future state of reef carbonate production depends primarily on emissions scenario and heat-induced changes in coral communities and cover. The authors here note that their method of calculating carbonate production differs from the Cornwall approach of synthesizing laboratory studies. However, we never really get a clear explanation of how the carbonate module in the present study works. How was it parameterized and validated? Perhaps more emphasis could be placed on the similarity with Cornwall et al works from different approaches, but at present it is difficult to judge just how different the methods are.

As also suggested by reviewer 1, we have added more details on the coral reef module that was described and tested in Bouttes et al., 2024 so that the reader does not have to read this other paper to know how carbonate production is computed.

It should be stated that the NOAA approach to estimating bleaching is indeed an estimate and it carries substantial uncertainty. It would be difficult to do, but ideally the current error of the NOAA method for estimating bleaching could be included in uncertainty assessment run into

the future. But since the current uncertainty may not be well known, the authors should at least clearly describe this assumption.

Following the reviewer's comment, we have added some discussion in the text:

"It is thus assumed that accumulated thermal stress is the primary driver of mass bleaching events. This is of course a simplification, and the method has substantial associated uncertainty – see Klein et al. (2024) for an extensive discussion of the strengths and weaknesses of this so-called 'excess heat' threshold model (as well as those of alternatives, such as population dynamic, species distribution or ecology-evolutionary models). It should be noticed that different taxa have different responses to thermal stress and local temperature variability also plays a role (McClanahan et al., 2020). The predictive power of the method can be improved if, e.g., region-specific threshold values are adopted (DeCarlo, 2020). Here we decided to closely follow the original Coral Reef Watch methodology as it is most suitable for the level of complexity of the climatic forcings iLOVECLIM can provide. We furthermore use the original global threshold values as iCORAL does not carry any information about the reef ecosystem structure and does therefore not allow for any regional differentiation. Other stress factors besides excess heat that may lead to bleaching, such as anomalously low temperatures, anomalous nutrient concentrations, salinities etc., are already considered in the habitability criteria."

New references:

DeCarlo, T. M.: Treating coral bleaching as weather: a framework to validate and optimize prediction skill, PeerJ 8:e9449, doi: 10.7717/peerj.9449, 2020.

Klein, S. G., Roch, C. and Duarte, C. M.: Systematic review of the uncertainty of coral reef futures under climate change. Nature Communications, 15:2224, doi: 10.1038/s41467-024-46255-2, 2024

McClanahan, T. R., Darling, E. S., Maina, J. M., Muthiga, N. A., D'agata, S., Leblond, J., Arthur, R., Jupiter, S. D., Wilson, S. K., Mangubhai, S., Ussi, A. M., Guillaume, M. M. M., Humphries, A. T., Patankar, V., Shedrawi, G., Pagu, J. and Grimsditch, G.: Highly variable taxa-specific coral bleaching responses to thermal stresses, Marine Ecology Progress Series 648:135-151, doi: 10.3354/meps13402, 2020.

Along these lines, it is not clear how degree heating weeks are calculated in the present works: Is one value calculated for an entire 3x3° area? That does seem really quite coarse relative to spatial scales of marine heatwaves. At least, this should be discussed to a greater extent.

Yes, there is one DHW value computed for each grid cell. This is a limitation that is discussed in the discussion section:

"iLOVECLIM has a relatively coarse ocean resolution of 3° by 3° on the horizontal grid. While we have been able to take into account the spatial heterogeneity of the seafloor topography by adopting a subgrid parametrization, this is not possible for other variables such as temperature, as they depend on local circulation dynamics. Hence the model cannot

account for small scale features such as local temperature and Ω_{ar} changes. A consequence of this is that while large-scale changes can be evaluated with the model, local changes dependent on small-scale dynamics cannot be simulated. Such limitations could be partially addressed by the use of a higher resolution model in which the same coral module could be implemented. In addition, higher resolution models also have a higher temporal resolution, resulting in better tropical variability, which would further improve the modelled coral reef response."