We thank the reviewer for their comments on the paper. Our response to the specific points is given below in *italics* and proposed changes to the text in blue.

Zhao et al. investigated the impacts of climate fluctuations and CO2-induced alterations on gross primary production (GPP) using an eco-evolutionary optimality (EEO) based modelling approach. Two contrasting periods are focused, including the Last Glacial Maximum (LGM) and the mid-Holocene (MH), and compared to pre-industrial conditions (PI). This study assessed the importance of CO2, climate change, and light on the GPP at the global scale and pixel level. I have a few concerns about the robustness and implications of this study.

There is a large model range of GPP at the LGM (61-109 PgC yr-1 or 40-110 PgC yr-1), which could be primarily attributed to uncertainties in the effects of tree cover, distribution of C4 plants, and/or effects of climate change and changing CO2. Thus, the uncertainties associated with climate change and CO2 may be much larger than or at least comparable to their effects on the GPP differences between LGM and PI estimated by this study (Figure 5). This substantial uncertainty could raise questions about the robustness and reliability of the results presented in this study.

The large range of GPP from the CMIP6/PMIP4 simulations was an issue raised by the first reviewer. As we said in our previous response, this range reflects differences in the input data between the simulations (e.g. the ice sheet configurations used) as well as model-dependent differences in simulated climate and vegetation. As we pointed out in the Discussion (lines 338 to 342), attempts to constrain simulated GPP using oxygen isotope data from ice cores show an equally large range, because of large uncertainties in estimates of ocean productivity as well as model-dependent differences. We are not claiming that our EEO-based estimate of 84 Pg is necessarily correct – only that the relative contribution of different factors to this reduction in GPP shown by the decomposition should be reasonable. We chose the MPI model because it has been shown to reproduce simulated climate better than most of the other models in CMIP6/PMIP4 (see lines 396-399). We did not use the simulated vegetation from this experiment because the EEO approach applies independently of vegetation types. In response to reviewer 1 we proposed expanding the discussion of the LGM reduction to clarify that, while the absolute magnitude is uncertain, the partitioning of the causes of the reduction are more likely to be robust:

Thus, although there is a consensus that GPP was considerably lower at the LGM than during pre-industrial times, and this is consistent with pollen evidence for a very large reduction in tree cover over much of the world (Prentice et al., 2000; Williams, 2003; Pickett et al., 2004; Marchant et al., 2009), the absolute magnitude of this change is uncertain. Nevertheless, since the climate simulated by the MPI ESM has been shown to reproduce pollen-based climate reconstructions better than most other CMIP6/PMIP4 models (Kageyama et al., 2021) and we use robust EEO-models to estimate the change in GPP, the partitioning of the impacts of different factors in the simulated reduction of GPP is likely to be robust.

This study emphasizes the impacts of CO2 on the GPP and vegetation dynamics during both LGM and MH. Different levels of CO2 during LGM, MH, and PI, cause various light-use efficiency and distribution of C4 plants, thereby inducing different GPP. Figure 5 shows the magnitudes of effects of CO2 on the GPP during LGM and MH, thus could be used to estimate the sensitivity of GPP to CO2 changes. Although it is CO2 sensitivity based on the long-term changes, it would be meaningful and interesting to compared it with that based on the recent observations and simulations.

This was an issue that was also raised by Reviewer 1. We have shown that the response of our model is consistent with both controlled-environment studies (Smith and Keenan, 2020), including plants grown at low CO_2 (Harrison et al., 2021), and FACE experiments (Wang et al., 2017). We have proposed to add text in the Methods (Section 2.1) to make this explicit:

The responses of photosynthetic properties to enhanced CO_2 as simulated by the P model have been validated against both Free Air Carbon dioxide Enrichment (FACE) experiments (Wang et al., 2017) and controlled-environment experiments (Smith and Keenan, 2020). Moreover, the model's implied response of photosynthetic capacity to CO_2 has been validated by measurements on plants experimentally grown at low (160 ppm) CO_2 (Harrison et al., 2021).

The description of units is confusing. For example, the unit of global GPP is PgC yr-1 rather than PgC. In Table 3, the unit of the contribution of C3/C4 to GPP is gC m2 yr. It should be checked because gC m-2 yr-1 is more commonly used.

We gave the unit as PgC since we were referring to the annual total, but we agree that this is confusing and so we will change this systematically in the text and the tables to PgC yr^{-1}. The unit for the contribution of C3 and C4 to GPP is a global average contribution and thus is indeed gC m^{-2} yr^{-1}. However, we will correct the typo in the units in this table.