Reviewer 2

The accurate projections of future climate change impacts on land surface carbon cycles are key to understand the climate change carbon cycle feedback and to mitigate climate change. This paper provides a way by using the observational constraints of the optimal temperature and the emergent relationship between optimal temperature and atmospheric CO2 changes to narrow the uncertainty in the projected future CO2 changes. This method combined the short-term optimization with the long-term climate-carbon feedback and provided a new way of understanding the climate change.

I enjoyed reading the manuscript in its novel idea.

Thank you, we are glad the reviewer enjoyed reading our manuscript and thank them for providing insightful comments.

While before it can be accepted for publication, I have some questions on its suitability for application to broader model groups.

1. This study used the relationship between Topt and atmospheric CO2 changes, over the tropics for the broadleaf forests. I was wondering about the atmospheric CO2 used for the global mean or the tropical regions? Since the global CO2 can also be mediated by other vegetation types.
Atmospheric CO_2 changes are due to the prescribed fossil fuel emissions, and the global ocean and land carbon sinks. As the reviewer correctly suggests, the latter is due to the total response across the land-surface, rather than just in the tropics. However, in the carbon cycle ensemble results of Booth et al. (2012) the dominant cause of spread in future CO_2 was due to the tropical land, and specifically due to the assumed optimum temperature for tropical forests. We have added the following to the discussion (L160):

> **Although both the calibration of T_{opt} (Raoult et al., 2016) and the parameter perturbation experiment were conducted globally (Booth et al., 2012), the latter found that the dominant cause of the spread in future CO_2 was due to the tropical land, and specifically due to the assumed optimum temperature for photosynthesis tropical forests.**

2. This study used the adjoint of JULES, which happened to be of the land component of the Earth system model that is used for projections. I wonder how can this relationship be transferred to other models, such as the CMIP5/6 models?
Interesting point. We believe this is an artefact of the UK ESM CMIP5 model. However, is it possible that similar relationships exist in other and more recent models, although we would need to perform costly parameters perturbation experiments to unearth them. We have added the following to the conclusions to highlight this (L167):

> **These results are no doubt model and scenario dependent. Nevertheless, this study highlights a new methodology to use should future models show strong emergent relationships between model parameters and future climate change.**

3. Data assimilation is a good tool for optimizing parameters from different processes. The nonlinearity of the terrestrial ecosystem models can have few parameters that are interacted and this would result in the joint-distributions of parameters from different processes. While in the data assimilation we seldom considered that or put little focus on the parameter interactions. So how can we properly obtain the relationships between paramters and variables that can be projected to futures? As the authors mentioned soil moisture and other variables. Why do not we use the emergent relationships between optimized variables instead?

Our apologies, it seems that we may not have been clear enough about the nature of the Data Assimilation in this study, which is used to constrain internal model parameters rather than state variables. We will add the following text to clarify this:

> "**Unlike the more orthodox application of Data Assimilation (DA) in weather forecasting, the Raoult et al. (2016) study used DA to derive optimum JULES parameters to fit FluxNet observational data, rather than to nudge state variables. The paper shows that the resulting constraint on the optimum temperature for photosynthesis (T_{opt}) in turn provides an emergent constraint on the increase in atmospheric CO_2 by 2100 in a coupled climate-carbon cycle model (Booth e al., 2012). Although this clear link is very likely to be model dependent, we present it here as a first example of how local model calibration and the emergent constraint technique can be used to constrain global climate-carbon cycle projections.**"