Response to Reviewer #1

Comments:
This paper evaluates the representation of the decoupling coefficient in an ESM model. This is an important observational based study with a lot of discussion on the model processes and it will contribute to the model development of evapotranspiration process. The study also uses a machine learning approach to rank the controlling factors, which is a new alternative of regression coefficients. The article structure is clear but there are quite a few grammar errors in the writing, please fix them for readability.

[Response] We thank the Reviewer for the positive comments and helpful suggestions. We have addressed all the suggestions and comments in our revision. Please find below the Reviewer’s comments (italics), followed by our responses (roman font), with red color indicating relevant changes in the manuscript. We hope that the revised manuscript addresses all the issues raised by the Reviewer.

Title: coupling strength is used in the title. However, coupling strength is the reverse of Omega, the main concept of the paper. It could be confusing to readers when both coupling strength and decoupling strength are used. I suggest use “decoupling strength” consistently. You can still say “coupling”.

[Response] Thanks for this suggestion, we had a discussion on the title and we thought that decoupling coefficient is a proxy to measure the coupling between vegetation and the atmosphere. It is named “decoupling” because of its large values corresponding to smaller coupling strength. We used “coupling strength” rather than “decoupling strength” in the title so that readers who are not familiar with this coefficient can better understand. To avoid confusion, we have revised the manuscript to use only “coupling strength” and “decoupling coefficient” in the manuscript.

Paragraph 1-2: Lack of literature support. Please add more references for each statement.

[Response] Thanks for this suggestion. We have added more references to support our statements.
L44: improve the simulation of transpiration
L59: total evapotranspiration (e.g., Peng et al. 2019)

[Response] They have been corrected accordingly

Equation 6: how is the $Ga$ estimated when calculating the empirical Omega? Not clear whether this study is following Thom et al. 1975, equation 3, or taking from the De Kauwe dataset? I am afraid the selection of this formula will greatly affect your results of $Gs$, Omega, and the following analysis.

[Response] Sorry for the confusion. In this study, the reference data (flux) is from the De Kauwe dataset, in which $Ga$ was estimated following Thom et al. (1975). In the model, $Ga$ is calculated using Eq 3. We agree that the different formulation for $Ga$ can result in biases, but we don’t have enough information to estimate Flux $Ga$ using the same equations as in ORCHIDEE. To investigate the impact of the $Ga$ estimation, we performed a sensitivity test by perturbing $Ga$ by 30% (see the response to the 2nd comment of Reviewer 2). We found that decreasing $Ga$ by 30% may result in smaller model bias in $Ga$, but the change of $Ga$ does not alter the overall pattern of omega and $Gs$ across PFTs and the dependence of omega to different factors, thus not affecting our conclusions. We added a discussion on the impact of empirical omega uncertainties.

Lines 625-634: “In the observation-based estimates, $Ga$ was estimated using an empirical method from Thom et al. (1975), which was derived from a bean crop. $Ga$ estimates from this method are found to be 81%-116% of the estimates of a more physically based method (Knauer et al., 2017) in 6 forest sites. To test how biased $Ga$ affects our evaluation, we increased/decreased $Ga$ by 30% and re-estimated $Gs$ and $\Omega$ (Fig S6). We found that perturbing $Ga$ does not result in large changes in $Gs$. However, when $Ga$ is 30% smaller than current observation-based estimates, we obtained smaller biases in $Ga$ and $\Omega$ in ORCHIDEE Ctrl simulation in forest PFTs. Whereas in short PFTs, decreasing the reference $Ga$ results in even larger biases in $\Omega$, indicating that the large biases in model vegetation coupling strength in short vegetation is not due to uncertainties in the observation-based estimates.”

Figure 3a shows a systematic large gap of $Ga$ between Flux and Ctrl. There are uncertainties in both data and the parameterization. When you compare it with
**ORCHIDEE**, have you validated if the modelled Ga is consistent the empirical Ga when you use the same ORCHIDEE formula?

**[Response]** We also noticed the big difference between modeled and observed Ga. The comparison proposed by the reviewer would be helpful to understand the bias, however, some variables used in ORCHIDEE formula are not available at flux sites (e.g. \( z_{0h}, z_{0m} \)).

To further investigate the reason of this large gap, reliable estimates of these variables are needed to evaluate the parameterization of \( z_{0h} \) and \( z_{0m} \) in the model.

*Also the equations (4)-(5) are highly dependent on vegetation structure. I am afraid this is not going to work very well across biomes. Can you do a sensitivity test of the formula across biomes?*

**[Response]** The calculation of \( z_{0h} \) and \( z_{0m} \) in all PFTs follow the same equation in ORCHIDEE model. The calculation depends on LAI and canopy height. Following the reviewer’s suggestion, we performed a sensitivity test of \( z_{0h} \) and \( z_{0m} \) across different LAI and canopy height (Fig R1) and have put the result in the supplementary. We also added a more detailed description of these formula to the manuscript: Lines 162-177: “

\[
\begin{align*}
    z_{0m} &= (z - d)e^{-\frac{\kappa}{\eta}} \\
    \eta &= 0.32 - 0.264e^{-3.02LAI} \\
    z_{0h} &= \frac{z_{0m}}{e^{kB^{-1}}} \\
    B &= \text{the Stanton number. } \kappa B^{-1} \text{ is estimated following} \ Su \ et \ al. \ (2001; 2002): \\
    \kappa B^{-1} &= \frac{\kappa Cd}{4Ct\eta(1-e^{-\frac{\pi\kappa}{\eta}})}fc^2 + 2fcs\frac{\kappa\eta z_{0m}}{C_t} + \kappa B_s^{-1}f s^2 \\
    Bs &= \text{the Stanton number for bare soil, with } \kappa B_s^{-1} \text{ estimated following Brutsaert } (1999): \\
    \kappa B_s^{-1} &= 2.46Re_s^{\frac{1}{4}} - \ln(7.4) \\
    \text{Where } Re_s \text{ is the Reynolds number.} 
\end{align*}
\]

**[Response]**
L140: The Gs in the equation has the “s” as subscript, but the text is different. Similar in other places.

[Response] Thanks for this remark, we have unified the symbols in the equations and the text.

Fig 6 – the scales of yaxis are different and difficult to compare.

[Response] The y axes are now unified.

L255: the response of Omega to temperature is nonlinear because VPD also depends on temperature. Does this RF reflect such nonlinear relationship?

[Response] Yes, the RF model is able to deal with nonlinear relationships, as it regresses data by grouping but not by fitting lines. However, RF is still a statistical method, it cannot fully decompose the impact of factors that have strong dependence relationships. If there are factors with very strong dependence, the RF algorithm may randomly select one of these factors to split the trees, resulting in non-robust results. In this study, we found robust contributions of VPD and temperature in the RF models built with different data (Fig 5), indicating that our result is not an artifact due to the dependence between factors.