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 sl., 2017) in 6 forest sites. To test how biased Ga affects our evaluation, we increased/decreased Ga by 30% and re-estimated Gs and Ω (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 Ω in ORCHIDEE Ctrl simulation in forest PFTs. Whereas in short PFTs, decreasing the reference Ga results in even larger biases in Ω, 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 z0h and z0m 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: “

z_{0m} and z_{0h} are respectively the roughness heights (m) for momentum and heat transfer estimated following Su et al. (2001) and Ershadi et al. (2015) using canopy height (z) and LAI:

$$z_{0m} = (z - d)e^{-\frac{\kappa}{\eta}} \qquad (4)$$

Where

$$\eta = 0.32 - 0.264e^{-3.02LAI} \qquad (5)$$

z_{0h} is estimated using z_{0m} :

$$z_{0h} = \frac{z_{0m}}{e^{\kappa B^{-1}}} \qquad (6)$$

B is the Stanton number. κB^{-1} is estimated following Su et al. (2001; 2002):

$$\kappa B^{-1} = \frac{\kappa Cd}{4Ct\eta(1-e^{-\frac{nec}{2}})}\mathrm{fc}^2 + 2\mathrm{fcfs}\frac{\kappa\eta\frac{z_{0m}}{z}}{C_t^*} + \kappa B_s^{-1}fs^2 \qquad (7)$$

Where Cd, Ct are drag and heat transfer coefficient of leaves, nec is within canopy wind profile extinction coefficient, calculated as nec = CdLAI/($2\eta^2$). fc, fs are the fraction of canopy and bare soil, C_t^* is the heat transfer coefficient of soil. Bs is the Stanton number for bare soil, with κB_s^{-1} estimated following Brutsaert (1999):

$$\kappa B_s^{-1} = 2.46\mathrm{Re}_*^{\frac{1}{4}} - \ln(7.4) \qquad (8)$$

Where Re_* is the Reynolds number.”

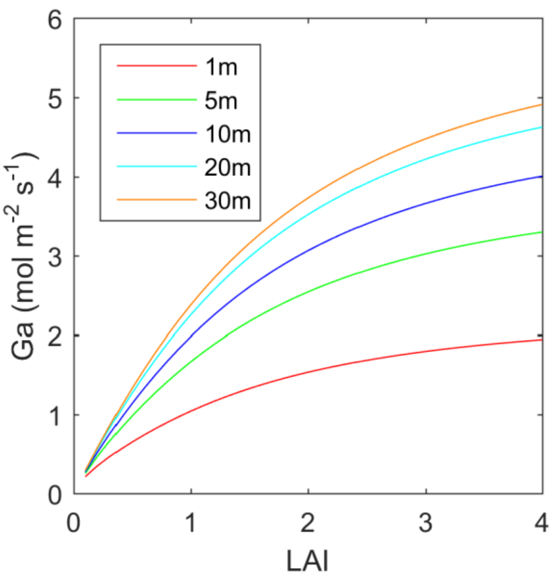

Figure R1. The dependence of Ga on LAI and different canopy heights in ORCHIDEE parameterization under 3 m s^{-1} wind speed, sea level pressure and 15 ℃ condition

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.