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Interactive comment on "Intercomparison of Terrestrial Carbon Fluxes and Carbon Use Efficiency Simulated by CMIP5 Earth System Models" *by* Dongmin Kim et al.

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General Comments This paper is a model comparison of 10 ESMs with satellite data from MODIS. The novel contribution of this paper is that is breaks down the analysis of model differences and biases by PFT. Similar comparisons of NBP, GPP, and CUE have been done already, as described in the Introduction section (Anav et al. 2013, Shao et al. 2013, Zhang et al. 2014).

I thought an interesting and underemphasized point was that reduced C uptake due to N limitation decreased CUE in models that added a representation of the N cycle, bringing up questions about whether we need coupled C and N or if so, whether the implementation in these models (reducing C uptake) is correct.

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Discussion paper

The writing is clear and the methodologies are described well, though the Results section is indeed largely results, as well as large portions of the Summary section. In the Specific Comments, I asked some questions in places where I thought more discussion was needed. I think this paper could be improved with either a dedicated Discussion section or more development of the main findings and their implications. To me, the most interesting points in the paper are that: ESMs are biased in similar ways, CUE depends on climate (and therefore indirectly on PFT?), and the bias pattern of CUE differs in C-N coupled models.

Specific Comments L63-68 That MME-values of CUE are dependent on temperature but MODIS-derived CUE is not suggests to me that we don't know what controls CUE in the real world. This is perhaps the more intriguing call to action than better model validation (because these models are clearly deficient, the question is why?).

⇒ Actually, the sensitivity of CUE is not only function of temperature (Tucker et al., 2013) but also nitrogen availability (Zha et al., 2013). However, most existing ESMs don't consider the nitrogen cycle except CESM-BGC and NorESM. Moreover, ESMs adapted the nitrogen cycle are not perfect (e.g., nitrogen fluxes and amounts are too much dependent on carbon fluxes and amount in the models). This might lead to a non-linearity and complex relationship between CUE and temperature in the real case. In addition, the parameterization of terrestrial carbon cycle in ESMs is imperfect. For instance, most ESMs adjusted the vegetation growth by the minimum of carbon, water, light limitation based on Farquhar et al. (1980). We have included additional discussion in the revised manuscript (L591-599).

L238 Clarify that "the only exception" refers to NPP calculated by GPP-Ra, not to the previous sentence about nitrogen cycling.

⇒ This part might be the Line 268. Expect for MRI-ESM, NPP is calculated by GPP and Ra from dynamical parameterization method. In MRI-ESM, the terrestrial carbon cycle is calculated by empirical methods derived from precipitation and temperature.

This is major difference of simulated NPP from MRI-ESM with other ESMs. We clarify the sentence (L274)

L279-293 Just to clarify: Did you use the model runs with their native PFTs, but then make Figures 12, S4 by breaking down the output by the classifications in Figure 1?

⇒ We classified model PFTs using observed MODIS MCD12Q1 land cover classification data (L181-L189 and figure 1). We mentioned it with related issues in L285-286.

L326 I like Taylor diagrams, but I think you need a citation for the method.

⇒ We added the reference in Taylor diagram method (L336 and references page).

L354 What do you mean by this statement? I think you need to clarify what "higher model performance" would be in this case (e.g., greater precision or accuracy). I also think that you could have large biases in individual models but still get a good mean estimate as long as those biases are different and random in each model, but I think your point is that many of the models are biased in similar ways.

⇒ We clarify the meaning in the manuscript (L359-L367). "Unlike the cases in temperature and precipitation, the pattern correlation of the MME in terms of GPP and NPP is not necessarily higher than that of the individual models in this case. This suggests the presence of similar type of systematic model deficiencies in current CMIP5 ESMs, which is even larger than random individual model errors supposed to be cancelled out through the multi-model ensemble average."

L378-388 It is hard to identify whether biases are due to parameterization, or the climate forcings. Are there papers that use identical climate forcings to diagnose biases? I love to see some discussion here that tries to diagnose where biases come from using previous studies.

⇒ This is a very interesting point suggested by the reviewer. The multi-model comparison could be possible by driving off-line LSM models with the same climate forcing. To our knowledge there has been no study related with this problem. Instead, we have included some relevant discussion from Mao et al. (2010) in the revised manuscript as below (L391-L395): “Mao et al. (2010) showed a quite similar bias pattern in GPP from their offline CLM4 experiment with observed climate forcing to the pattern of CESM1-BGC shown in this study (e.g., positive over tropics and negative over northern hemisphere high latitudes). This implies that the uncertainty in climate forcing is not a primary one for the GPP biases”

L395 This may be the motivation for why you used it here, but it not the only reason to care about CUE: it is also an important control on the C cycle and may change under future climate or with land use.

⇒ Following your comment, we emphasize this aspect in the manuscript (L412-413).

L402-403 Explanation for why CUE is higher in cold weather? Growth more limited by access to C and respiration more limited by temperature?

⇒ Ise et al. (2010) and Bradford and Crowther (2013) suggested that CUE could be limited substantially by overly-sensitive autotropic respiration by plants in warm climate based on their observational studies. We added this in the text (L416-419).

L444 How do you know that nitrogen limitation effects CUE more than temperature and precipitation?

⇒ This study suspect that the nitrogen limitation is affecting the simulated CUE more in the model rather than temperature or precipitation. Figure 13 shows the uniform increase of CUE in the Only C experiment. Moreover, Fig. S4 shows that this increase tends to occur in all PFTs. The temperature and precipitation change between the two runs are regional and they are not able to explain this globally-uniform signal, such as in southern hemisphere (See the supplementary figure 1 below).

L450-453 The explanation for high needleleaf CUE in this paragraph is just a definition of CUE, can you provide a biophysical explanation?

⇒ We added biophysical explanation of needleaf forest (L472), which is defined as gymnosperms.

L464-470 I think it's very interesting that models with C and N cycles simulate lowerCUE. Seems to agree with theory that N limitation lowers CUE (Sinsabaugh et al. 2013Ecology Letters).

⇒ Yes. I agree with your opinion. Pervasive nutrient (e.g., Nitrogen) may induce the lower CUE values in this study.

L495-496 By what mechanism do these plants increase CUE?

⇒ We clarify the sentence (L517-518). Vegetation in cold climate with less rainfall is more efficient in storing carbon for growing and maintenance, which tends to increase CUE. Vegetation in warmer climate is overly sensitive to temperature in respiration (Ise et al. 2010); Bradford and Crowther 2013), which tends to lower CUE.

L500 Seems from Figure 14 that the opposite is true: that ESMs don't respond enough to temperature, especially at >20C.

⇒ Red dots (MME) is more sensitive to temperature, particularly in EBF and GRA over 20 C, which encompass largest area.

L527-529 Here you say that the parameterization is more important than the climate, which seems to be in contradiction to the uncertainty in L378-388.

⇒ As we mentioned in the above, the systematic biases in the models may reflect the uncertainties in the parameterized carbon cycles, as well as in the simulated climates. However, this study emphasizes more important role of parameterization in explaining the CMIP5 model diversity in GPP. Indeed, Mao et al. (2010)'s GPP pattern driven from observed climate forcing does not make significant difference from fully interactive simulations that might drift the climate from the observation. This implies that the uncertainty in climate forcing is not a primary one for the GPP biases

Figures A lot of 9 panel maps are hard to look at and not all seem necessary. For example, Figure 10 does a much better job of summarizing the main points of CUE spatial distribution than does Figure 9 (which could probably go in the Supplement).

⇒ Although we agreed with the reviewers comment, the display of 9-panel maps is an inevitable choice to address the model differences in regional scale. This is basically driven by the spatial variation of PFTs, which is our major theme of this study.

Technical Comments

L451 Do you mean “deciduous forests” instead of “dense forests” L540 “In different with MODIS”, suggest edit to “In contrast with MODIS”.

⇒ We modified L546

Figures Can you label the multi-panel figures with letters (i.e., a,b,c..)

⇒ We added labels in figures.

Figure 5 Remove title.

⇒ We removed title.

Figure 6 Why is there a red MODIS symbol in the legend?

⇒ We removed MODIS symbol

Figure S4 Change 1. and 2. in legend to blue triange and green circle, respectively.

⇒ We changed these symbols.

References:

Amthor, J. S.: The McCree–de Wit–Penning de Vries–Thornley respiration paradigms: 30 years later, Annals of Botany, 86, 1–20, 2000. Bradford, M. A., Keiser, A. D., Davies, C. A., Mersman,n C. A., Strickland, M. S.: Empirical evidence that soil carbon formation from plant inputs is positively related to microbial growth, Biogeochem., 113, 271–281, 2013. Farquhar, G. D., von Caemmerer, S., and Berry, J. A.: A biochemical model of photosynthetic CO2 assimilation in leaves of C3 species, Planta, 149, 78–90, doi:10.1007/BF00386231, 1980. Ise, T., Litton, C. M., Giardina, C. P., Ito, A.: Comparison of modeling approaches for carbon partitioning: impact on estimates of global net primary production and equilibrium biomass of woody vegetation from MODIS GPP, J. Geophys, Res., 115: G040205, 2010. Mao, J. Thornton, P. E. and Shi, X.: Remote Sensing Evaluation of CLM4 GPP for the Period 2000–09, J. Clim., 25, 5327-5342, 2012. Tucker, C. L., Bell, J., Pendall, E., Ogle, K.: Does declining carbon-use efficiency explain thermal acclimation of soil respiration with warming?, Glob. Change Biol., 19, 252–263, 2013. Zha, T. S., Barr, A. G., Bernier, P. -Y., Lavigne, M. B., Trofymow. J. A., Amiro. B. D., Arain,M. A., Bhatti, J. S., Black, T. A., Margolis, H. A. McCaughey, J. H., Xing, Z. S., VanRees, K. C. J., Coursolle. C.: Gross and aboveground net primary production at Canadian forest carbon flux sites, Agricul. and Fore. Meteorol., 174–175: 54–64, 2013.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/bg-2016-536/bg-2016-536-AC1-supplement.pdf

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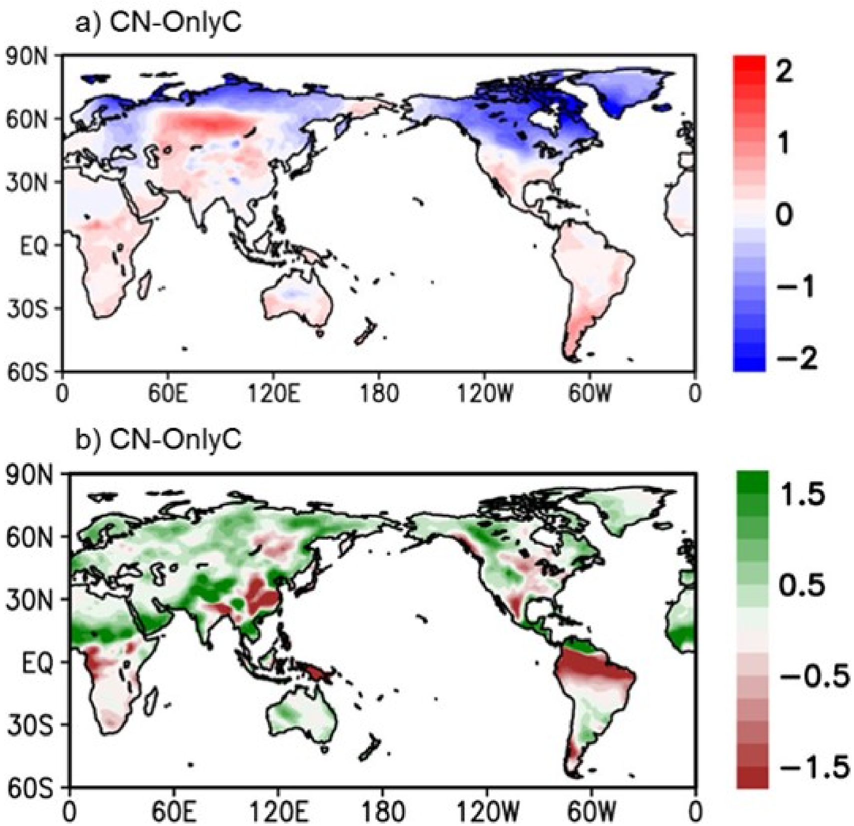

Fig. 1. The temperature (top) and precipitation (bottom) differences between CN and Only C experiments using NCAR CESM.