Biogeosciences Discuss., 9, C8042–C8049, 2013
www.biogeosciences-discuss.net/9/C8042/2013/

Biogeosciences Discussions

Interactive comment on "Causes of variation in soil carbon predictions from CMIP5 Earth system models and comparison with observations" *by* K. E. O. Todd-Brown et al.

K. E. O. Todd-Brown et al.

ktoddbro@uci.edu

Received and published: 7 February 2013

We would like to update our initial reply to this review

The paper by Todd-Brown et al. is an interesting study aiming to evaluate the C stock of the ESMs against data. The authors used simulations from CMIP5 using climate/carbon models and used two databases. The amazing stock of C stored in soils need to be better understood and represented in the models and in particular in the ESMs because few changes in the decomposition rate could lead to very important emissions. The paper is generally well written and the methods used are adapted. I think that this paper ïňĄts well with the BG scopes and is interesting for several

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

scientiïňĄc communities but some points must be discussed in more details before publication.

I was a bit disappointed by the discussion section. The paper shows clearly that the ESMs could be improved in particular in the spatial distribution of C. But the discussion does not really suggest ideas or theories that must be incorporated in the next ESMs generation. I suggest the authors to look in details the Schmidt et al. (2011) review in Nature and write another paragraph with a more mechanistic approach. For example, do we need more biology in the models? or a better representation of the soil C proïňĄles?

Response: Thank you for the reference. The final paragraphs of the discussion now read: "All ESMs may be missing key processes governing long term carbon storage that affect model-data agreement. Decomposition models currently used in all ESMs are built on the assumption that carbon substrates have intrinsic chemical decomposition rates (Parton et al., 1993). However there is an emerging consensus that key abiotic and biotic factors have a stronger governing role in decomposition than the carbon compounds themselves (Schmidt et al., 2011). These key governing components may include aggregate interactions (Six et al., 2000), microbial dynamics (Todd-Brown et al., 2012), cryoturbation (Koven et al., 2011), syngenetic soil formation (Fan et al., 2008; Shur et al., 2004), extracellular enzyme dynamics (German et al., 2011), and rare substrate formation (Allison, 2006). Representing these processes in the structure of soil carbon models remains a major challenge. However smaller scale decomposition models have begun to explore several of these mechanisms (Manzoni and Porporato, 2009)."

The authors also explained that all the ESMs are based on the same main scheme for soil C decomposition and the others existing schemes and how they could be used in this context are also not discussed (see Wutzler and Reichstein, 2008 or Manzoni Porporato 2009 for review). The huge diversity of the existing soil C dynamic models must be presented brieïňĆy and the interest (or the absence of interest) of these new schemes in ESMs must be also discussed.

Response: We have expounded on the potential effects of biomass kinetics on decomposition modeling in the conclusion: "Recent advances in the theory of microbial decomposition could provide a foundation for major changes in the structure of soil carbon models used in ESMs. Schimel and Weintraub (2003) proposed a model in which decomposition was mediated by soil enzymes and microbial biomass. Later models expanded this framework to include microbial functional groups that preferentially decompose specific substrate types (Moorhead and Sinsabaugh, 2006). In contrast to current substrate pool models used in ESMs, biomass-mediated decomposition models would likely include non-linear processes such as Monod uptake or Michaelis-Menten enzyme kinetics. These non-linear effects could produce very different behaviors at daily, annual, and centennial time scales. Compared to substrate pool models, models driven by microbial biomass predict smaller losses of soil carbon under warming due to declines in microbial growth efficiency with higher temperature (Allison et al., 2010)."

The authors considered that the soil C stocks calculated by the models represent the ïňĄrst meter but the model CENTURY where the main schemes of the ESMs soil modules came from was designed to simulate the SOC dynamics at a 20cm depth (Kelly et al., 1997). It is probably a problem if the data are re-analyze with only the ïňĄrst 20cm. The authors must justify better why they choose the ïňĄrst meter or reanalyze the data with the soil C stored in the 0-20cm layers.

Response: You are correct that the soil profile depth could have major implications for model evaluation. We have expanded final paragraph describing the ESM output to read as follows: "ESMs do not report the depth of carbon in the soil profile to CMIP5, making direct comparison with empirical estimates of soil carbon difficult. Although many soil models were originally constructed to represent C dynamics at an approximate depth range of 0 to 20 cm (e.g. Kelly et al., 1997), we assumed that all simulated soil carbon was contained within the top 1 meter to simplify comparison with data sets.

BGD

9, C8042–C8049, 2013

We recommend that future model inter-comparison projects request soil carbon output from model simulations with specific depth ranges (for example, soil carbon above 1 meter and below 1 meter) to allow for more accurate and direct comparison to survey data."

Another point that must be clearly presented is the use of ESMs with speciïňĄc climate for each model. It could be one of the main causes of differences between models. Indeed a 'warm model' is assumed to have less C in soils than a 'cool model'. The study would have more sense with simulations of only the land surface models forced by the same climate. This must be clearly presented and the differences between the soil moisture and the soil temperature between the models must be presented.

Response: We've added several biome level comparisons with data sets to show that temperature does not very as much as NPP across the models (Figures S6 and S7). In addition we included an inter-model comparison using our reduced complexity model to show that NPP differences are the primary driver of soil carbon, followed by a weak temperature effect and negligible soil moisture effect (Figure 5). This new analysis is explained in more detail below.

Finally, I do not really understand the interest of the reduced complexity models. This approach lead to reduce the differences between models to simple parameters that are almost impossible to evaluate against data and the results obtained are almost not discussed. I suggest removing this part.

Response: As discussed in the discussion (page 14454 lines 6-18) the reduced complexity models show two main things (1) most ESMs share an underlying structure which can be simplified to a one pool model and (2) that these models have unique parameterization for each ESM which when combined with their unique environmental variables describe most of the spatial variation within each model as well as the differing global totals between the models.

We also added an additional figure (Figure 5) and analysis to highlight controlling ef-

fects of model parameterization and NPP on soil carbon stocks which are drawn from the reduced complexity model. In this new analysis we take the reduced complexity model parameters fitted for each ESM (turnover time and Q10 factor) and apply them to either the ESM-specific global NPP and mean soil temperature or multi-model mean NPP and soil temperature. We were able to explain 98

Interactive comment on Biogeosciences Discuss., 9, 14437, 2012.

BGD

9, C8042–C8049, 2013

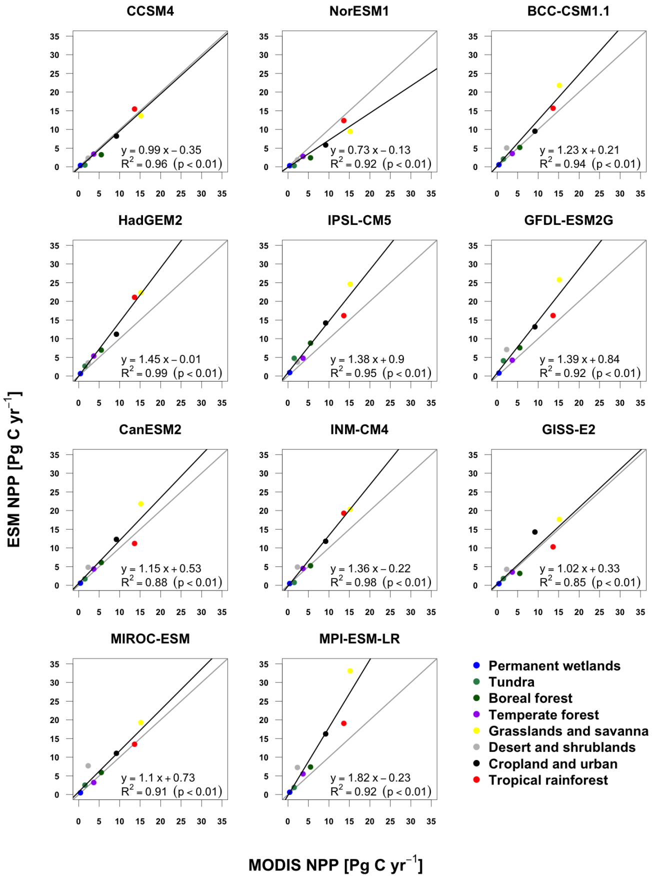

Fig. 1. (Figure S7 in manuscript) Biome comparison between Earth system model (ESM) net primary productivity (NPP) and MODIS NPP.

BGD

9, C8042–C8049, 2013

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

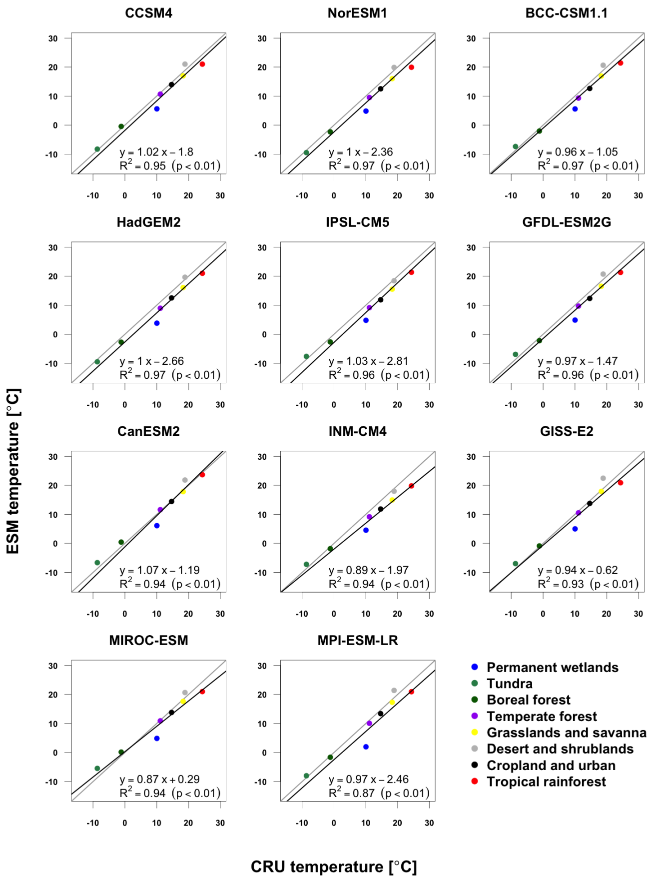

Fig. 2. (Figure S8) Mean surface air temperature (2 m, 1995-2005 mean), versus mean Climate Research Unit (CRU) temperature (2 m, observed 1995-2005) by biome for each Earth system model (ESM).

BGD

9, C8042–C8049, 2013

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

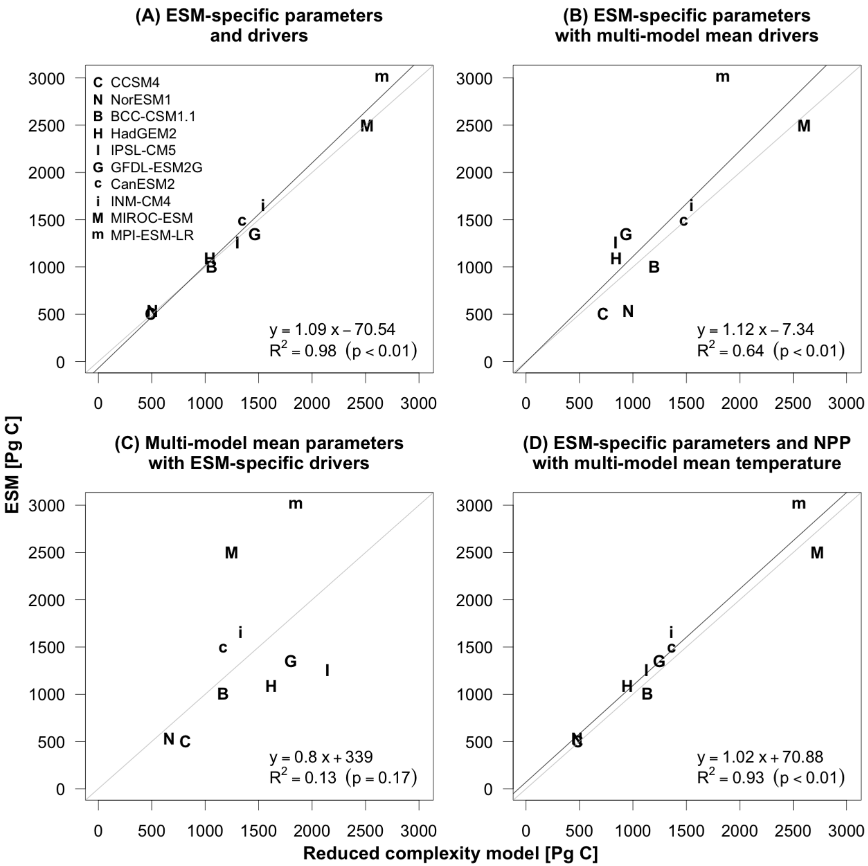

Fig. 3. (Figure 5) Relationship between global soil carbon totals from Earth system models (ESMs) and global soil carbon totals predicted by reduced complexity models.

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper