EGUsphere, author comment AC1
https://doi.org/10.5194/egusphere-2022-34-AC1, 2022

Reply on RC1

Carlos A. Sierra et al.

Author comment on "Ideas and perspectives: Allocation of carbon from net primary production in models is inconsistent with observations of the age of respired carbon" by Carlos A. Sierra et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-34-AC1, 2022

Dear Reviewer,

Thanks for your comments to our manuscript. In the text below you can find a copy of your comment in italics and an answer immediately below.

This is a well written piece. The authored argued why carbon allocation should be based on GPP rather than NPP, as often done in most land surface or ecosystem models. These models assume zero residence time of respired carbon through autotrophic respiration, which contradicts the field measurements of the age of respired C from plants.

We thank the reviewer for recognizing the relevance of our manuscript.

However, there are several significant limitations with the proposed approach: (1) ecosystem GPP cannot be measured directly; where NPP can be easily measured in the field and with a large number of observations available globally;

Measuring GPP in the field is challenging, but so is measuring NPP. In a comprehensive review on the NPP concept and its quantification, Clark et al. (2001, Ecological Application 11:356) stated that 'Forest NPP cannot be measured directly; it must be approached by indirect methods'. These authors convincingly showed that there is a significant discrepancy between the concept of NPP and the way it is measured in the field. Most field studies provide only an approximation to the real value, very likely with an underestimation. Few studies quantify belowground NPP, and many only quantify one component of NPP, usually wood biomass production.
Although GPP is also difficult to quantify from field measurements, eddy-covariance estimates of GPP are providing now a wealth of data from a large number of ecosystems world wide. Synthesis efforts such as Fluxnet and Fluxcom provide well-curated data-products of global GPP. In particular, Fluxcom combines remote sensing information with eddy-flux data to produce global gridded products of GPP at high spatial and temporal resolution, which could be of immense value for modeling studies. MODIS GPP is an additional product that has been very useful in providing approximations to ecosystem level GPP for a number of empirical and modeling studies.
Therefore, we do not think that this concern from the reviewer is valid given that both NPP and GPP are difficult to obtain, and information from both can obtained from the literature for a large variety of sites.

(2) autotrophic respiration of individual biomass components are rarely measured, therefore allocation fractions of GPP to individual biomass components often are not available at ecosystem scale;

We agree with the reviewer in that there are currently few observations of biomass and respiration for individual pools, which are rarely measured in field studies. However, we do not see this point as a limitation, but rather as an opportunity for new scientific studies that would combine pool-specific measurements with model development of respiratory processes in these pools. We think it is important to highlight the limitations of current models in our manuscript so new improvements are developed. This is better than pessimistically conclude that there is currently not enough data so models cannot be improved.

(3) to model the age of respired C in an ecosystem or land surface model using the proposed approach by the authors here, we will need to represent the total carbon in each biomass component using multiple pools with different availability for respiration and their responses to stresses, which will introduce quite a few additional, poorly constrained model parameters, and additional uncertainties in the model. On the other hand, most of the respired carbon is less than one-year old in leaf, and much younger than the mean age of woody carbon in stem. In my view, the authors should provide a more balanced view of the pros and cons of GPP-based and NPP-based approaches for carbon allocations, and their potential limitations.

Yes, the proposed approach would likely introduce a set of poorly constrained parameters. But the current approach of allocating carbon from NPP has also a set of poorly constrained parameters that cannot be optimized with the new set of data on the age of respired CO2. Our aim here is not to show what cannot be done with the current models, but rather to show what can be done in the future with models that are consistent with new data on respiration from specific pools and their radiocarbon content. There are large opportunities to develop new data-assimilation studies testing different allocation approaches based on GPP, and incorporating new datasets on respiration.

Although we showed that a large proportion of carbon is respired in less than one year, we also showed that a small proportion is respired several years after fixation. To understand the transit time of carbon in ecosystems we need to better understand both, processes occurring at fast timescales and processes occurring on longer timescales. However, the current approach of allocating carbon from NPP does not allow us to study these ranges of timescales.

We understand the concern of the reviewer in that our statements may be too strong, and we tried to balance our text in the new revised version. Nevertheless, we think it is important to clearly identify the limitations of current models, and also the opportunities for future studies.

Some detailed comments
Figure 1. I disagree with the statement that majority of the models assume "a constant proportion of GPP". I know that ACCESS-ESM, GFDL, NorESM2, BCC are not. Not sure about other models. Because of the pool-size based approach, there is a negative feedback between respiration and pools, therefore the ratio of autotrophic respiration of GPP is rather constant when averaged over a year globally.

The reviewer is right on this point. The majority of models do not have a constant allocation scheme but rather show a relatively constant proportion when aggregating globally. We modified the text in this section to decrease emphasis on constant respiration ratios. We also eliminated Figure 1 for the same reason.
Nevertheless, we would like to emphasize that the issue is not that models have constant

allocation coefficients. The issue is the source of carbon for allocation, NPP rather than GPP.
We made changes in the manuscript to put less emphasis on the constancy of C allocation, and more emphasis on the source of carbon.

L121. CABLE does not assume a fixed fraction of GPP being respired by plants. See Wang et al. (2012), GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L19405, doi:10.1029/2012GL053461.

We apologize for this inaccuracy. In our original review, we used an earlier description of CABLE to determine the type of allocation scheme (Wang et al. 2010, Biogeosciences 7:221), and overlooked the more recent model description. We updated now the text based on this more recent reference.

P9, the last two lines below Figure 3. "the median transit time is 0 yr, because the autotrophic respiration flux, which corresponds to 50% of GPP..". That statement may be specific to the model of Emanuel et al. (1981) and that model is more than 40-year old! In most land surface models, Ra/GPP is not constant, particularly at daily or seasonal time scale. The median transit time would have to be weighted by the carbon flux, then the median transit time will not be zero!

The statement is indeed specific to this model, and the specific value may change for other models.
However, we noticed a potential misunderstanding in this comment. In the majority of models, allocation is done from NPP and Ra is subtracted immediately from GPP as we show in the manuscript. It does not matter if the median transit time is flux corrected because the age of the respired carbon is still zero (i.e., age_C_in_Pool * respired_flux_from_pool = 0 * respired_flux_from_pool = 0).
Also, we used here the model of Emanuel et al (1981) because it is a useful model to make our point clearly. It has a minimum of complexity to show the differences between allocation schemes without additional details that would be irrelevant and would obscure our point with extra complexity. The model may not be appropriate to make specific numerical predictions, but it is very useful as a reduced complexity model that helps to express ideas clearly.