

Biogeosciences Discuss., referee comment RC2
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Comment on bg-2021-37

Christian Frankenberg (Referee)

Referee comment on "Slowdown of the greening trend in natural vegetation with further rise in atmospheric CO₂" by Alexander J. Winkler et al., Biogeosciences Discuss., <https://doi.org/10.5194/bg-2021-37-RC2>, 2021

The manuscript by Winkler et al investigates drivers of global LAI trends using a mix of long-term observations from AVHRR combined with Earth System Model sensitivity runs to provide causal attribution. The manuscript is in general well written and the results interesting and of general scientific interest. Please find some comments/questions below:

Title: I am not convinced the title conveys the gist of the paper, in fact I find it somewhat misleading. It reads as if the slow down of greening is driven by a further rise in CO₂. The word "instead" instead of "with" would have made more sense but then again, the authors would have to make the topic of the title the key message of their paper, which it isn't (and it is hard to attribute to a weakening CO₂ fertilization effect anyhow). For this, the author would have to use their counter-factual theory on the change in LAI changes between the beginning and end of the time period.

That said, it would be necessary to also discuss the results of Wang et al (Recent global decline of CO₂ fertilization effects on vegetation photosynthesis) in the current manuscript as it is related to trends in CO₂ fertilization as well (especially a reported decline of it, which differs strongly from Trendy).

One main strong statement of the paper is that it challenges finding by Zhu et al in 2016 (with some shared co-authors!). It sounds like a strong statement early on but if I look at Figure 3, I would say that the CO₂ fertilization effect appears to be dominant at the global scale (despite some regional variations). It expands and adds nuance to Zhu et al, but challenges is too strong a word in my mind. There is enough material in this paper to warrant publication and no need to over-emphasize differences wrt to a previous publication.

Browning Trend in 2000-2017: When I look at Figure 3B, it appears a lot of the apparent browning trend in the later time-period is driven by a sudden decline in the relative change in years 2015-2017. What happens if you omit these years from the investigated

time-period? What might cause such a sudden decline that might be related to the effects of CO₂ fertilization or Radiative Effects? If this is related to detector issues or years with strong internal variability, I would remove these years (as long term drivers appear unlikely to suddenly appear). In fact, models and obs seem very consistent with each other between 2000-2014. As far as I can see, most discrepancies might be due to years 2015-2017 but I might be wrong. A critical discussion would be required here. Surprisingly, I couldn't find these strong effects of the last 3 years in the SOM plots, was it specific to some areas only? Can it be checked against MODIS data as well, which could be more reliable now? In fact, the first few years in Figure 3B are also VERY small, so you are fitting a linear trend through a time-period in which both ends are highly unusual. This can heavily bias derived trends, please evaluate and discuss the impact of chosen time-periods for trend analysis critically. <https://doi.org/10.31223/X5K89V> outlines some concerns I have with respect to AVHRR and the application to look at small changes (beyond pure trends). Please answer all questions in this paragraph.

A more general question regarding vegetation dynamics and CO₂ fertilization, as you mention "as thoroughly equilibrated global carbon cycle" on line 192: What are the time-scales in ESM for CO₂ fertilization? At the leaf scale, the gain in GPP is immediate but if you consider LAI, CO₂ fertilization might cause a new state, which won't be achieved within a year, especially if species compositions will be affected. I would be curious what time-scales the models predict. E.g. if you changed CO₂ suddenly but kept it at a higher level, how long would it take to run the carbon cycle into a new steady-state? I am mostly asking because the CC was certainly not in equilibrium in 1980 as CO₂ increase and human land impacts are constantly shifting the needle. How much of the greening effects would have occurred (persisted for a while) even if we had suddenly frozen the CO₂ levels at the 1983 mixing ratio and how would these "legacy" effects affect your overall conclusion? This is not a strong criticism but rather scientific curiosity.

Causal theory: One caveat that could/should be added is that this is only valid if the models, which are the basis for the sensitivity runs, are representing the truth. E.g. for the browning trend, you would actually find NO causal attribution from models alone, is that right?

Line 36: Stomata can even respond at short time-scales when CO₂ changes, stomatal density or max conductance takes time to adapt. (you mention "in time").

Line 88: "not dominant globally". Again, I am having difficulty to not see a similar effect in Figure 3c. In line 421, you even say so yourself. I am a bit lost here.

Line 449: weaken->weaker

Sections 3.10+: I was just a bit confused as the discussions now move from causal theories to more local descriptions, partially just citing other papers to explain specific events. It also shows the limits of your causal method as the lack of drought legacy

effects (e.g. in tropics) can potentially bias your mode sensitivity runs. For some effects that you mention are due to RF, it would actually be interesting to separate out effects of CO2 RF into VPD, temperature and PAR effects (due to cloud cover changes), CO2 RF has various impact factors, which can vary regionally in importance...

Overall, I would recommend revisiting the statements regarding Zhu et al, mention caveats in counter-factual theory using models as surrogate truth, investigate the impact of 2015-2017 on the greening/browning trend in the later time-period