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Comment on “Recent global decline of CO_2 fertilization effects on vegetation photosynthesis”

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Abstract

Wang *et al.* (Research Articles, 11 December, 2020, p.1295) reported a large decrease in CO_2 fertilization effect (CFE) across the globe during 1982-2015 and suggested that ecosystem models underestimated the rate of CFE decline. We find their claims are artifacts of incorrect processing

of satellite data and problematic methods to derive and compare CFE between satellite data and model simulations.

Using satellite data as proxies of gross primary production (GPP), Wang *et al.* presented a statistical analysis quantifying changes in CO_2 fertilization effect (CFE) on global vegetation photosynthesis (*1*). They concluded that "global CFE has declined across most terrestrial regions of the globe from 1982 to 2015" and attributed this decline in CFE partly to nutrient limitations. However, we notice in their analysis a relatively constant CFE decline across much of the global vegetated land, including both regions with decreasing (e.g., Europe) and increasing (e.g., China and India) nitrogen and phosphorus deposition (*2*) (see Fig. 2 and Fig. S31 of (*1*)), suggesting that nutrient limitations are unlikely to explain the reported CFE decline. Importantly, the relatively uniform rate of CFE decline over the highly heterogeneous global land, where the environmental control of photosynthesis varies enormously, raises the concern that their derived CFE could actually be an artifact of the data and/or model used in their study.

In Wang *et al*. (*1*), the main satellite proxy for pre-2000 vegetation photosynthesis was derived from the Advanced Very High Resolution Radiometers (AVHRR), which have large uncertainties in monitoring vegetation dynamics (see Table S1 in (*6*) for a detailed description). To correct this issue, Wang *et al.* merged the AVHRR (1982-2000) and the more advanced Moderate Resolution Imaging Spectroradiometer (MODIS) (2001-2015) data using a cumulative distribution frequency (CDF) matching approach (Text S1 in (*1*)). However, rather than adjusting the less accurate and unreliable AVHRR data according to the more accurate and reliable MODIS data, they corrected the MODIS data to match the AVHRR data. Thus, their analysis brings even more uncertainties into their fused dataset. To test how this data fusion may have impacted β, the regression-derived coefficient of CO_2 against GPP proxies that Wang *et al*. inferred as CFE (*1*), we calculated MODIS NIRv (2001-2015) from the MODIS reflectance product (MCD43C4 C6) following the methodology in (*4*) without adjustments. This original MODIS NIRv shows a larger increasing trend than the CDF-adjusted MODIS NIRv (Fig. 1A). Hence, $\beta^{2001-2015}_{MODIS\ NIRv\ (original)}$ (18.3 ± 32.3% 100 ppm^{-1}) is significantly larger than $\beta^{2001-2015}_{MODIS\ NIRv\ (CDF-adjusted)}$ (13.4 ± 29.1% 100 ppm^{-1}) (Fig.1 B and C).

Similar problems also exist in the way that Wang *et al.* use leaf area index (LAI) data. They used the GIMMS LAI3g and a CDF-fused GIMMS+MODIS LAI data (degrading the more accurate MODIS LAI data to match GIMMS LAI3g) to help substantiate the large decreasing trend in β during 1982-2015. However, these two LAI data sets inherit the same large uncertainties from AVHRR-derived LAI before 2000 (*3, 5*). To test the robustness of LAI-derived β changes, we performed the same analyses as in (*1*) using the latest version of GIMMS LAI3g, GLASS LAI, GLOBMAP LAI, MODIS LAI, and CGLS LAI. These widely-used long-term LAI data show large discrepancies (Fig. 1D). Furthermore, except for GIMMS LAI3g, analyses with other LAI data do not show a clear decreasing trend in β during 1982-2015 (Fig. 1E). Indeed, analyses with LAI data derived from the more advanced sensors, i.e., MODIS LAI and CGLS LAI, reveal much higher β values during 2001-2015 (19.3±33.6% 100 ppm^{-1} and 37.7±49.7% 100 ppm^{-1}, respectively) than that estimated from the AVHRR-based LAI data (Fig.1 F).

In addition to problematic uses of satellite data, we also find the claim in (*1*) that TRENDY models underestimated the decreasing rate of CFE, incorrect. The authors drew this conclusion by comparing regression-based β trends from satellite proxies and factorial simulation-based β trends from TRENDY models (Fig. 2D in (*1*)). We used the same methods as in (*1*) to derive both regression-based and factorial simulation-based β trends from TRENDY models, and found the two quantities completely unrelated (Fig. 2). This suggests that β derived from regression models does not represent CFE. Furthermore, the comparison in (*1*) is also fundamentally flawed because the regression-based β was derived from observations/simulations with varying climate, while the simulation-based β was from simulations with preindustrial climatic conditions.

The magnitude of CO_2 fertilization effect on plants in a CO_2 richer world is still poorly understood. A careful examination of Wang *et al. (1)* reveals their main conclusion of a large decline in CFE during 1982-2015 to be an artifact of incorrect processing of satellite data and the regression methods used. Furthermore, their comparison between CFE changes estimated from a regression model with satellite data and from factorial simulations with TRENDY models is flawed and the claim of underestimated CFE changes by TRENDY models is unjustified. Thus, Wang *et al. (1)* have at best proven a declining trend of an unknown quantity based on dubious data and faulty methods. Therefore, we suggest use of all available remote sensing and *in situ* data and model simulations to carefully account for uncertainties in the quantification of CFE before drawing firm conclusions.

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Figure legends

Fig. 1. Changes in CO_2 fertilization effect (CFE) on global vegetation. (A) Interannual changes in anomalies of the growing season mean NIRv derived from AVHRR NIRv and MODIS NIRv obtained from (*1*) (AVHRR (W) and MODIS (W), respectively), and the original MODIS NIRv (*4*) (MODIS (O)). (B) Changes in CFE(β) estimated from the NIRv data sets with 15-year moving windows. (C) Histograms showing the distribution of β across all pixels during 1982-1996 (blue) and 2001-2015 (orange) based on the NIRv data sets. (D) Interannual changes in anomalies of the growing season mean leaf area index (LAI) derived from the GIMMS LAI3g (*8*), GLOBMAP LAI (*7*), GLASS LAI (*9*), MODIS LAI (*10*), and CGLS LAI(*11*). (E) Changes in β estimated from the LAI data sets with 15-year moving windows. (F) Histograms showing the distribution of β across all pixels during 1982-1996 (blue) and 2001-2015 (orange) based on the LAI data sets.

Fig. 2. Comparison between regression-based and factorial simulation-based β trends derived from 12 TRENDYv6 models using the methods as in (*1*). The dotted lines and shadings show the mean and standard deviation of the β trends.

Figures

Fig. 1

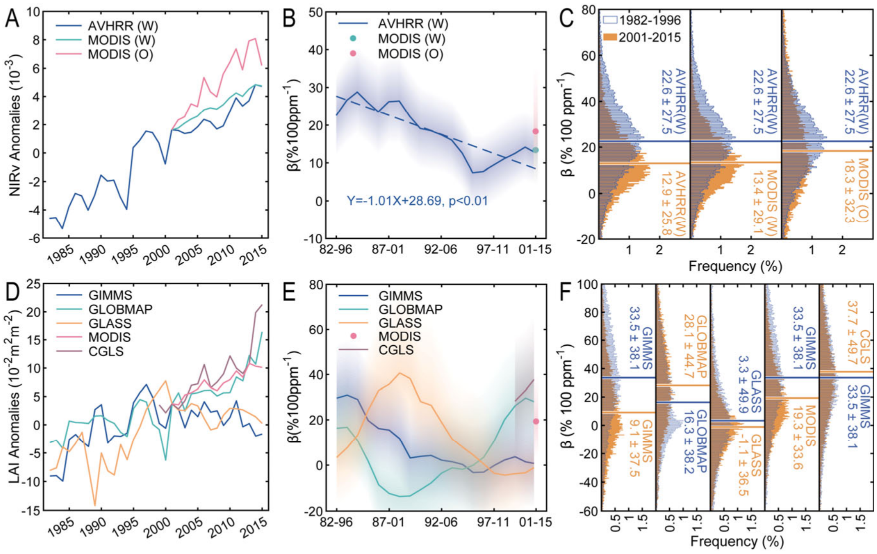

Fig. 2