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Increased diffuse radiation fraction does not significantly accelerate plant growth

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A recent modelling study (Mercado et al., 2009) claims that increased numbers of scattering aerosols are responsible for a substantial fraction of the terrestrial carbon sink in recent decades because higher diffuse light fraction enhances plant net primary production (NPP). Here we show that observations of atmospheric CO_2 seasonal cycle and tree ring data indicate that the relation between diffuse light and NPP is actually quite weak on annual timescales. The inconsistency of these data with the modelling results may arise because the relationships used to quantify the enhancement of NPP were calibrated with eddy covariance measurements of hourly carbon uptake. The effect of diffuse-light fraction on carbon uptake could depend on timescale, since this effect varies rapidly as sun angle and cloudiness change, and since plants can respond dynamically over various timescales to change in incoming radiation.

Volcanic eruptions, such as the eruption of Mount Pinatubo in 1991, provide the best available tests for the effect of an annual-scale increase in the diffuse light fraction. Following the Pinatubo Eruption, in 1992 and 1993, a sharp decrease in the atmospheric CO_2 growth rate was observed. This could have resulted from enhanced plant carbon uptake. Mercado et al. (2009) argue that largely as a result of the (volcanic aerosol driven) increase in diffuse light fraction, NPP was elevated in 1992, particularly between 25˚N-45˚N where annual NPP was modelled to be ∼0.8 PgC (∼10%) above average. In a previous study (Angert et al., 2004) a biogeochemical model (CASA) linked to an atmospheric tracer model (MATCH), was used to show that a diffuse-radiation driven increase in NPP in the extratropics will enhance carbon uptake mostly in summer, leading to a lower CO_2 seasonal minimum. Here we use a "toy model" to show that this conclusion is general and model-independent. The model shows that an enhanced sink of 0.8 PgC, similar to that modelled by Mercado et al. (2009), will result in a measurable decrease (∼0.6ppm) in the seasonal CO_2 minimum. This holds regardless of whether the sink is the result of 1) An increase in NPP, or 2) The combined effect of a temperature-driven decrease in heterotrophic respiration (Rh) and no change in NPP. This is since both NPP and Rh peak in summer. By contrast, observations from the NOAA global CO_2 monitoring network show the opposite change in the seasonal minimum in 1992 and 1993 (∼0.2ppm increase) both at Mauna Loa, and in the Marine Boundary Layer mean (>20˚N), which is hard to reconcile with increased NPP in northern summer. Another indicator of annual NPP is tree wood increment. Previous work (Krakauer et al., 2003) showed that the average response in tree ring series after past Pinatubo-size volcanic eruptions implied lower NPP north of 45˚N, presumably as a result of shorter growing season and lower total irradiance induced by scattering aerosols, and no significant change in NPP at lower latitudes. Here we show that In 1992, after the Pinatubo eruption, ring width in the 25˚N-45˚N band was 99.3±2.9% of average (n=351 sites), similar to the average of 100.4±2.2% over past eruptions (n=15 eruptions) (Uncertainty is given as 2 SE.). These results are also inconsistent with substantial NPP enhancement, although a limitation of the tree-ring approach is that available measurements do not uniformly sample the latitude band. The combined evidence of tree rings and the CO_2 seasonal cycle shows that the enhancement of NPP by scattering aerosols on annual timescales is weak. This result suggests that reducing aerosols through stricter pollution controls may strengthen the land carbon sink, while geo-engineering schemes which aim to mitigate global warming by spreading scattering aerosols in the stratosphere may weaken it.