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Sensitivity of Ball-Berry stomatal conductance model parameters to leaf age in the upper canopy of a central Amazon forest

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Eddy-flux tower measurements detect large (∼27%) seasonality of gross primary productivity (GPP) in central Amazon rainforest. Earth system models (ESMs) do not correctly predict this seasonality in GPP. ESMs consider environmental drivers and leaf area index (LAI), but not the seasonally changing intrinsic functionality of (for example) leaves or roots. Seasonal change in the leaf age composition of the upper canopy has been singled out as the most important driver of photosynthetic capacity (PC) seasonality. Studies point to stomatal conductance (gs) as the main factor limiting leaf-level photosynthesis during leaf aging, by reducing CO_2 uptake. ESMs usually use the Ball-Berry model to estimate or predict gs. Despite its simplicity, the model has been applied across a broad range of biomes and environmental conditions. Nevertheless, changes in gs due to leaf aging are not represented. Here we investigated the behavior of gs with leaf age. To this end, starting October 2016 at the Amazon Tall Tower Observatory (ATTO), tagged leaves were censused monthly on ten upper canopy branches per tree (n = 37 trees). The gs response curves to CO_2 and relative humidity were obtained for leaves of known ages. For each measured leaf the Ball index was calculated and regressed against gs to obtain the stomatal response sensitivity (m) and minimum stomatal conductance (g0) parameters. The behaviors of these parameters were then examined as a function of leaf age. The m parameter was high for young and for mature leaves and then declined with age, while g0 increased from young to mature, then decreased in older leaves. Reduction of m with age was conservative across plant species, but g0 values as a function of leaf age varied widely between plant species. These results suggest that as leaves age they lose the ability to fully open and fully close their stomates. Consequently, it is advantageous to have more young and mature leaves in place in the late dry season as an insurance policy against drought. Indeed, around 80% of the trees in our study flushed new leaves massively in the dry season, causing the fraction of mature leaves to peak in November and December. This sets up a chain of consequences. Mature and old leaves alternate as the dominant class at different times of the year, causing seasonality at the ecosystem scale for m and g0. These may then drive the seasonality of ecosystem-scale PC, which limits GPP. We hope to improve our understanding of stomatal function during leaf aging and how this influences PC and transpiration at the leaf level. Lastly, upgrading ESMs to include a representation of age-related stomatal function of leaves will lead to better estimations and predictions of CO_2 and water vapor fluxes between forest and atmosphere at local and regional scales as well as for ozone and carbonyl sulfide.