Department of Meteorology

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

University of Reading

The impact canopy structure on global photosynthesis

T Quaife & RK Braghiere

email: t.l.quaife@reading.ac.uk twitter: @tquaife

Introduction

Clumping of leaves around branches or tree crowns results in greater light penetration through the canopy than if leaves were positioned purely at random. As a consequence clumping tends to reduce light interception. Intuitively it might seem that a consequence of this should be to always decrease photosynthesis because less energy has been absorbed. However, we show that clumping can lead to increased photosynthesis, especially in dense canopies. This result is strongly dependant on the way radiative transfer is represented inside models.

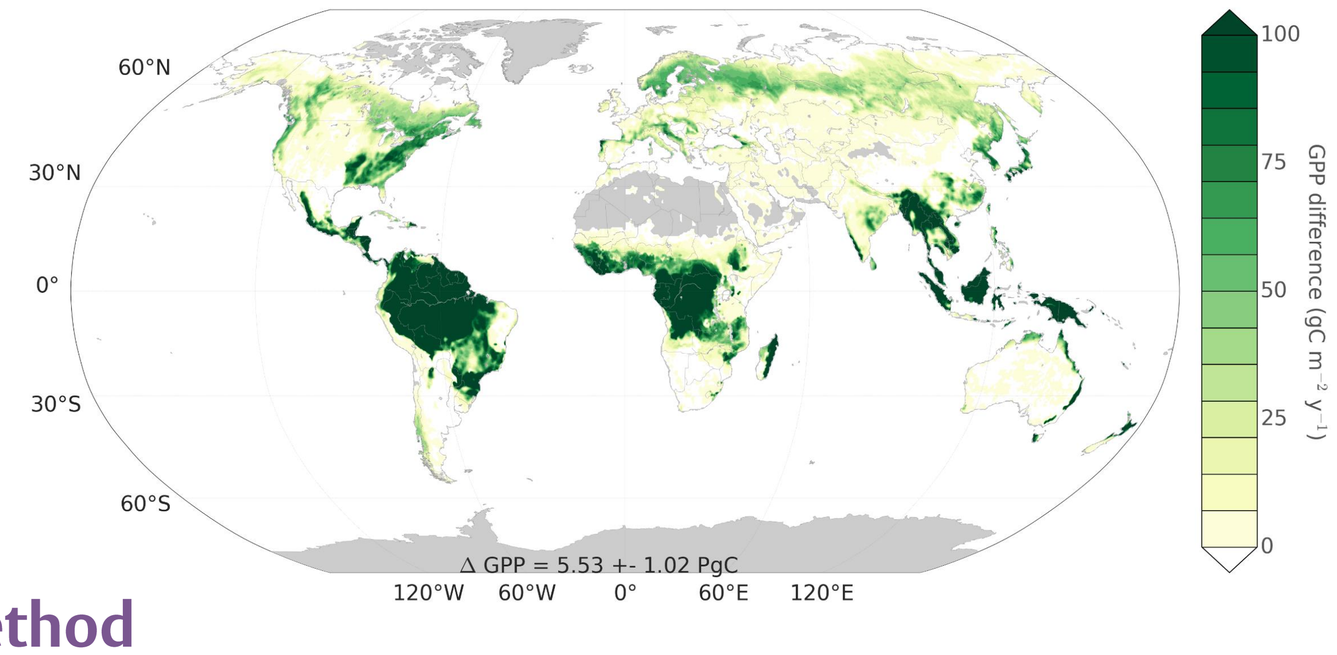
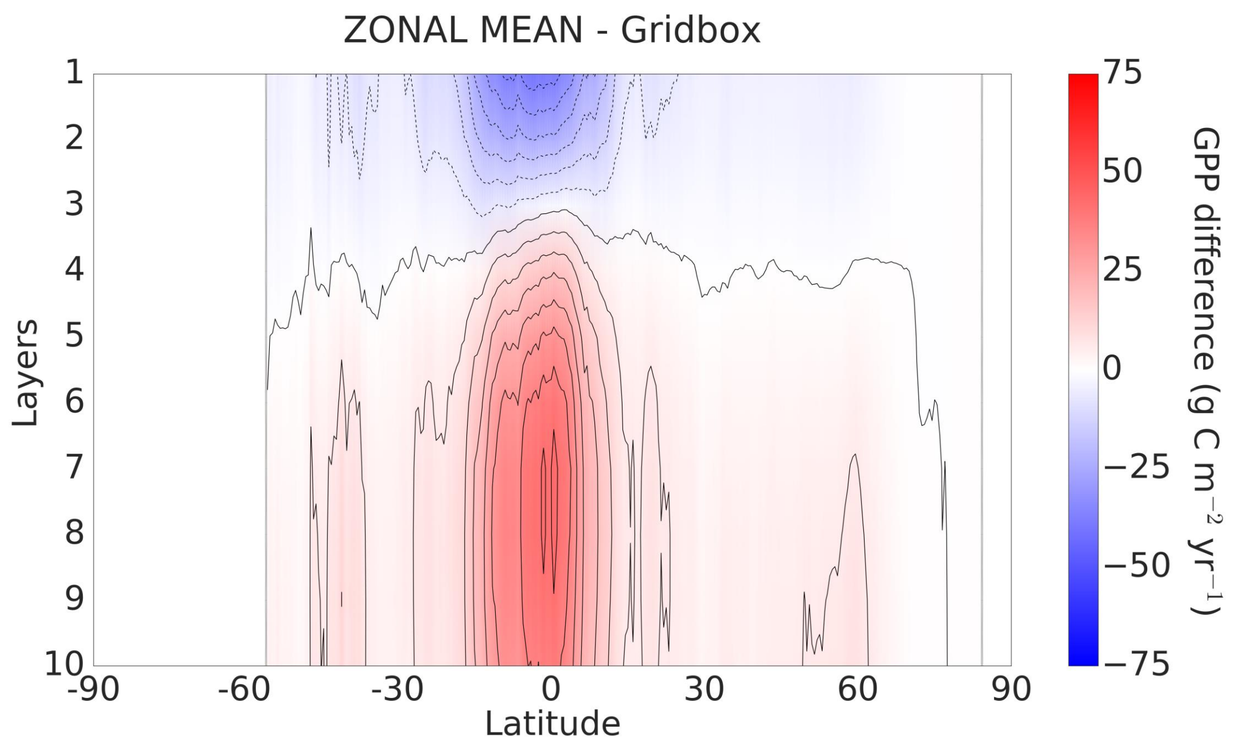


Figure (1) Difference in GPP estimated by JULES including clumping and the default JULES GL4.0 configuration. The global increase in GPP is 5.5 PgC for one year. Tropical forests account for the majority of this increase and for a small proportion of the land surface, mostly low LAI grasslands, GPP decreases (areas of the land surface that are white).

Method

The Joint UK Land Environment Simulator (JULES) has recently been modified to include clumping information on a per-plant functional type (PFT) basis (Williams *et al.*, 2017). Here we further modify JULES to read in clumping for each PFT in each grid cell independently. We used a global clumping map derived from MODIS data (He *et al.*, 2012) and ran JULES 4.6 for the year 2008 both with and without clumping using the GL4.0 configuration forced with the WFDEI data set.

Figure (2) Difference in longitudinally averaged GPP as a function of depth in the canopy. The y-axis is the vertical position in the canopy, with layer 1 at the top. Each layer has 0.1 of the total canopy LAI in it. Clumping allows greater light penetration to lower canopy layers in which photosynthesis is typically light limited. Upper canopy layers always do slightly less photosynthesis, where as lower layer tend to do more. On average this results in a net increase in the GPP.



Discussion

Fig. 1 shows an almost ubiquitous increase in GPP globally when clumping is included in JULES. Full results are given in Braghiere *et al.* (2019). The mechanism that produces this effect is that, although less light is absorbed in the canopy overall, absorption in lower layers increases due to the increased transmission of light from the layers above them. These layers tend to be light limited and hence photosynthesis increases. Upper layers, on the other hand, tend not to be light limited and hence the reduction in light absorption has little effect on carbon uptake. This is shown in Figure 2 – upper layers do less photosynthesis and lower layers tend to do more. This result can only arise from a layered canopy model and it highlights the need for better radiative transfer modelling of the vertical canopy profile. It also highlights the potentially important role that sub-canopy species play in the global carbon cycle. It is important to stress, however, that our representation of clumping is very simplistic. More detailed investigation into the impacts of vegetation on photosynthesis are likely to yield a wider variety of regional responses, including some stronger than the ones shown here.

References

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