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Analysis of the diurnal cycles for a better understanding of the mean annual cycle of forests greenness in Central Africa

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ABSTRACT

Central Africa hosts the world's second largest tropical forest after the Amazonian basin. However, as compared to its Amazonian counterpart, the Central Africa forests receive much less rain (~1500 mm/year in mean spread over two rainy seasons in March-May and September-November, and two dry seasons). They also experience a slower deforestation rate, so that the main threat for the next decades might come from climate variations. Nonetheless, their response to the annual cycle of solar radiation and rainfall/clouds is still poorly known. Analysing high resolution remote sensing data of Enhanced Vegetation Index, rainfall, cloudiness, and solar radiation for a target region located between 0 and 5°N and 12–19°E, we explore the climatic drivers of the forests greenness mean annual cycle. Three main points emerge; first, the diurnal cycle is a key-scale for understanding the mean annual cycles of rainfall and incoming solar radiation at surface, then how climate shapes the greenness mean annual evolution; second, neither the two dry seasons nor the two rainy seasons resemble each other in terms of cloud cover, solar radiation and rainfall, and their links with greenness levels; third, whereas the first rainy season (March-May) appears optimal for greenness especially because of favorable light conditions, water availability is the main controlling factor during the main dry season and at the start of the first vegetative season (February). Regarding the little dry season (mid-June-mid-August) and the second rainy season (September-October), light availability might be the main limiting factor. These findings pave the way for further studies of the climate interannual variability and change impacts on the Central Africa forests, taking into account time-scale interactions.

1. Introduction

Tropical forests are a key component of the global climate system as they act as water vapor sources (Spracklen et al., 2012) and carbon dioxide sinks (Lewis et al., 2009) and also correspond to the main ascending sectors of the thermal direct circulations across the tropical zone. For these reasons their evolution in response to both human pressure and climate change is critical. Most of the previous studies devoted to tropical forests' sensitivity to climate focused on the Amazonian forests and suggested that light availability is the main driver of their photosynthetic activity and leaf area seasonal and interannual variations (Huete et al., 2006; Myneni et al., 2007).

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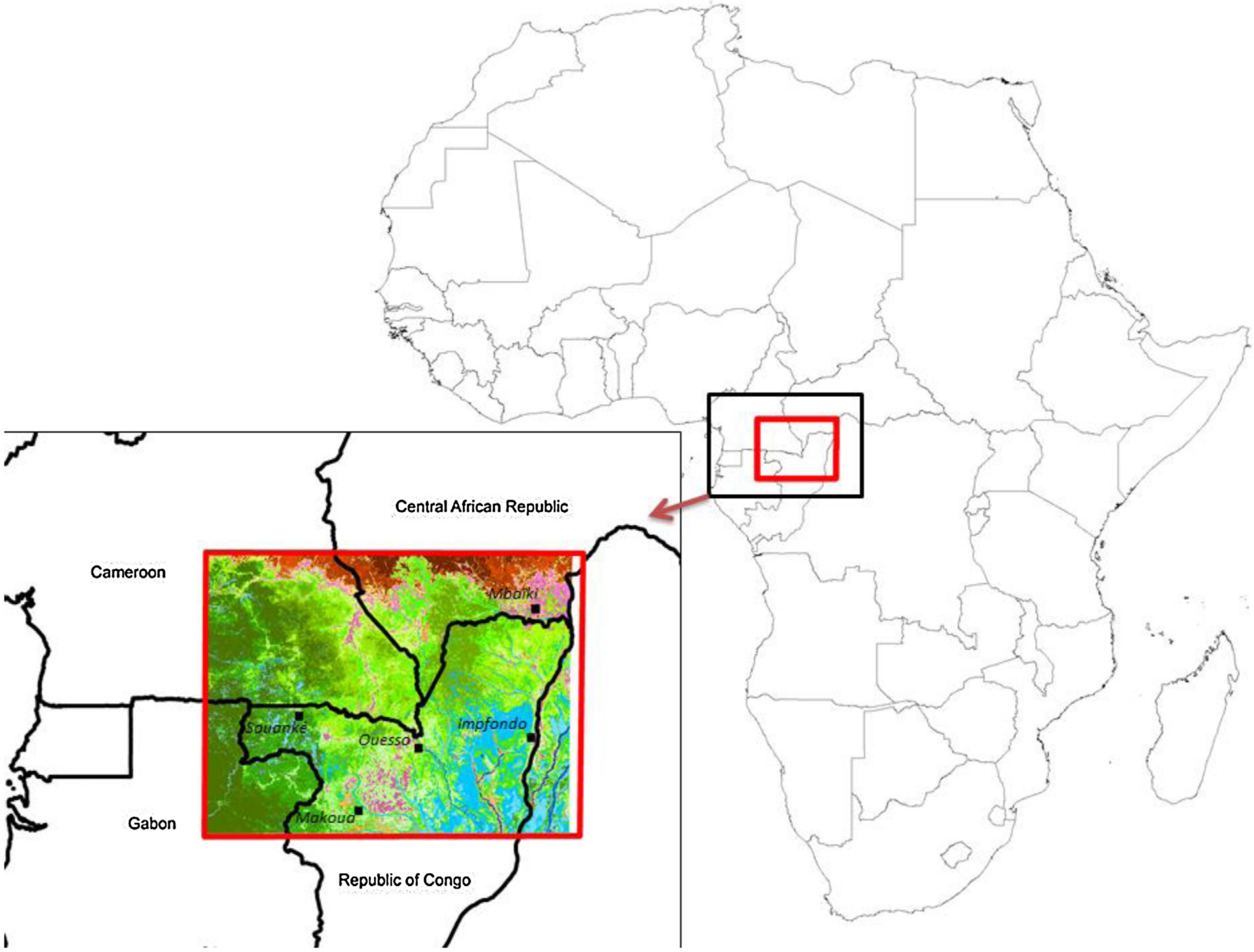

Fig. 1. Location of the studied region in Africa/Central Africa as a red square, and with the 11 types of terra-firme forests detected as shades of green (see Gond et al., 2013). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Although studies pointed to the artificial nature of these variations – dry season greening could result from an artificial increase of canopy reflectance at near-infrared wavelengths caused by variations in the sun-satellite sensor geometry (Morton et al., 2014; Samanta et al., 2012) – more recent studies confirm that the seasonality observed is not an artefact of changes in sun position in the sky or how sensors measure the reflected radiation field (Bi et al., 2015). This call for the use of better corrected vegetation products such as those issued from the MAIAC algorithm (Hilker et al., 2012, 2015).

The Central African forests which extend over Cameroon, Gabon, Guinea, and the Central African, Congo and Democratic Congo Republics, display a greenness mean annual cycle very different from the Amazonian forests: it is bimodal (vs unimodal), and seems controlled first by the rainfall mean annual cycle (Gond et al., 2013). At the interannual time-scale, the control of the Central African forests' greenness variability by rainfall has also been recently highlighted by Zhou et al. (2014) for the April-June season: a significant greenness decrease is synchronous to a rainfall decrease. However, looking both at greenness and rainfall mean annual cycles shapes (Gond et al., 2013) and at correlations between the interannual variations of greenness and rainfall (Zhou et al., 2014), there are indications that rainfall is not the sole determinant of forests' greenness in Central Africa.

As a first step towards a better understanding of the sensitivity of the Central African forests to present-day climate variability, and a better evaluation of its response to climate change, a detailed analysis of its greenness mean annual cycle is performed. We also examine those of several climate variables considered as potential drivers, i.e., rainfall, cloudiness and solar radiation. Indeed it is still unclear (1) what is the respective weight of these parameters on the forests' greenness mean annual cycle in Central Africa and (2) how these parameters relate to each other, notably because neither the cloudiness nor the solar radiation mean annual cycles are sufficiently known over the region.

We explore these questions focusing on the area of Central Africa located between 0 and 5°N and 12–19°E (Fig. 1, red square) which encompasses the Southeastern Cameroon, the Southwestern Central African Republic, the Northern Congo Republic and the Northwestern Congo Democratic Republic for which 11 types of forest, and their respective seasonal profiles of Enhanced Vegetation Index (EVI) have been precisely determined by Gond et al. (2013). In-situ data over Central Africa and our study area in particular are scarce. This is particularly true for rainfall, temperature, and solar radiation while in-situ measurements of evapotranspiration, photosynthetic activity, and leaf area do not exist here. Therefore, high resolution remote sensed products are exclusively used and presented in Section 2. Section 3 briefly depicts the methods used. Results are provided in Section 4: after presenting and comparing the mean annual cycles of EVI and the climate parameters considered, the focus is on the diurnal cycles of cloud cover and solar radiation. Then regressions and residual analyses are performed to disentangle the respective roles of rainfall and light on forests' greenness. Section 5 discusses the results and closes the paper.