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Potential yield simulated by Global Gridded Crop Models: what explains their difference

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Introduction

Yield gap analysis are based on the difference between potential and actual yields. Such analysis tend to be used at regional to global scales to investigate questions about global food security, management of resources with global perspective, etc. (van Ittersum et al., 2013). However, while crop models used at local scale to compute potential yield can be tuned to account for local specificities, it is much more complicated at the global scale as Global Gridded Crop Models (GGCMs) have difficulties to account for genotype x environment x management interactions. The GGCM Intercomparison (GGCMI, phase I) provides a framework relevant to understand the difference among GGCMs (Müller et al., 2019) and we aimed here to investigate the differences in simulated potential yield between GGCMs.

Methods

To do so, we built a very simple model (called SIM in the following) based on well-known formalisms such as the sum of growing degree days, canopy-integration of Beer-Lambert law, constant light-use efficiency (*LUE*) to simulate the final aboveground biomass (*biom* in the following). We then calibrated SIM independently against each GGCM. For each GGCM, we used the so-called "harmon" (harmonized growing season and no nutrient limitation) and "irrigated" simulations from GGCMI for maize. The calibration of SIM concerns the *LUE* and one parameter related to the heat requirements (called GGD_{1leaf} hereafter). A globally-constant *LUE* has been tuned for each GGCM while GGD_{1leaf} varies in space to mimic the procedure given to GGCM modellers in the GGCMI protocol (in which GGCM modellers tuned heat requirements to match the growing season provided by global datasets). Besides, the calibration of SIM concerns also two additional parameters related to the computation of the final yield: one parameter related to the start of the grain filling (*thresh*) and the fraction of the productivity filling the grains (*frac*, constant in time). SIM was forced by daily radiation, daily temperature, as well as by begin/end of the growing season simulated by each GGCM.

Results

$biom_{GGCM}$ strongly varies between GGCMs (1st column of Figure). We showed that once a global *LUE* and a spatially varying GGD_{1leaf} are calibrated in SIM, this latter is able to reproduce $biom_{GGCM}$ simulated by most GGCMs (2nd and 3rd columns of Figure). Some mismatch exists between SIM and EPIC models and we found that this mismatch is explained by the existence of a heat stress in EPIC models. Investigations to understand why SIM cannot reproduce *biom* simulated by CLM and PEGASUS are in progress. We found that the calibration of two other parameters (*thresh* and *frac*) allows SIM to mimic the relationship *biom* vs *grain* simulated by each GGCM. A spatial variability in *frac* is nevertheless required to reproduce EPIC models as these models consider a cultivar diversity.

Conclusions

Differences in few parameters explained most of the difference in simulated potential yield between GGCMs. In purpose to simulate potential yield at the global scale, our proposed set of equations (feed by daily temperature, daily radiation and begin/end of the growing season) is an interesting alternative to complex GGCMs as they are easier to manipulate and allow much faster uncertainty analysis.

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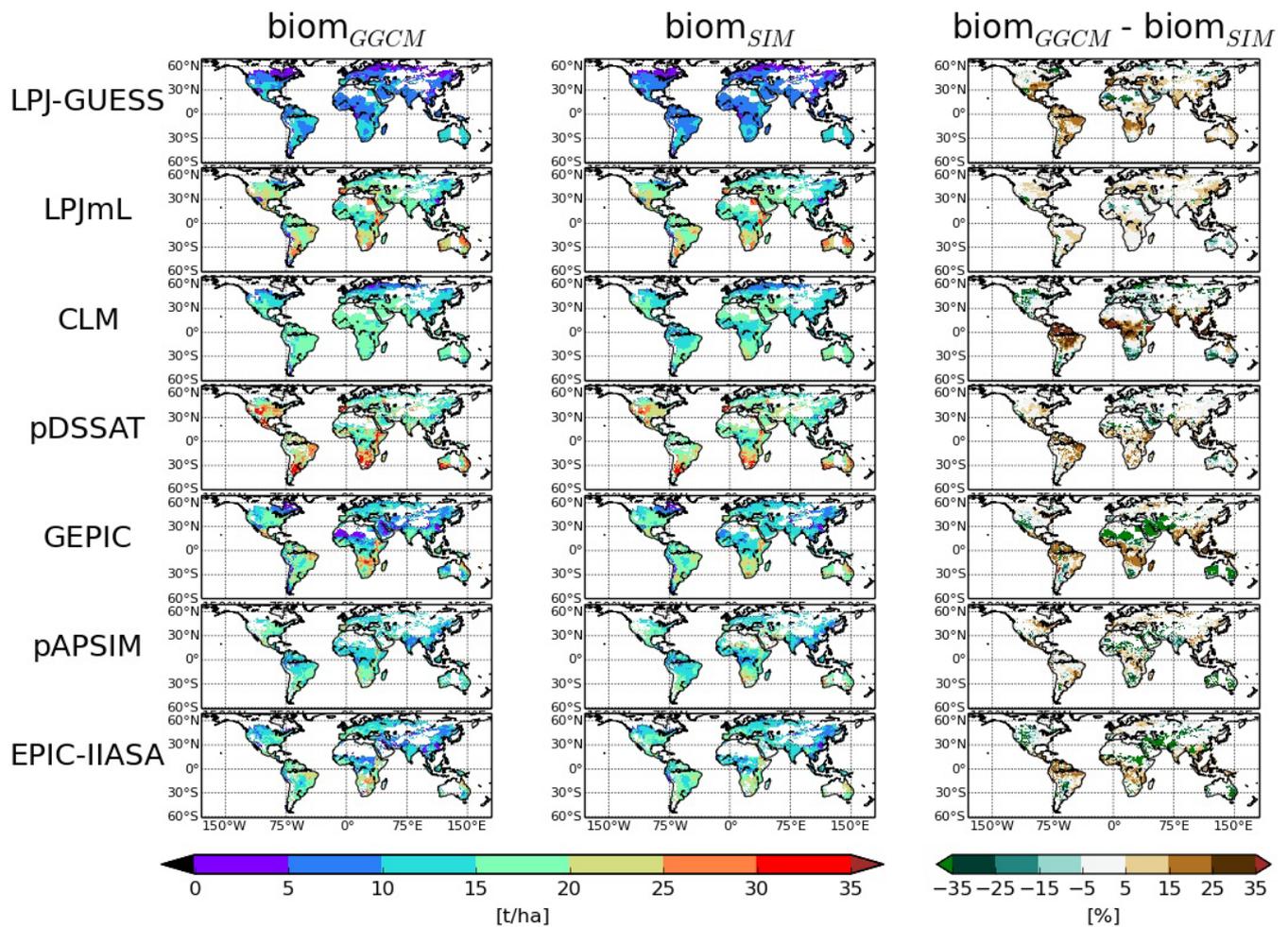


Figure: Comparison between biom_{GGCM} (1st column) and biom_{SIM} (2nd column) for few GGCMs involved in the GGCM intercomparison. Last column shows the difference ($\text{biom}_{GGCM} - \text{biom}_{SIM}$) (in % of biom_{SIM}). biom_{SIM} varies between lines as the SIM calibration is GGCM-dependent.

References:

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