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Atmospheric COS measurements and satellite-derived vegetation fluorescence data to evaluate the terrestrial gross primary productivity of CMIP5 model

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Predicting the fate of the ecosystem carbon stocks and their sensitivity to climate change strongly relies on our ability to accurately model the gross carbon fluxes, i.e. photosynthesis and respiration. The Gross Primary Productivity (GPP) simulated by the different terrestrial models used in CMIP5 show large differences however, not only in terms of mean value but also in terms of phase and amplitude, thus hampering accurate investigations into carbon-climate feedbacks.

While the net C flux of an ecosystem (NEE) can be measured in situ with the eddy covariance technique, the GPP is not directly accessible at larger scales and usually estimates are based on indirect measurements combining different tracers. Recent measurements of a new atmospheric tracer, the Carbonyl sulphide (COS), as well as the global measurement of Solar Induced Fluorescence (SIF) from satellite instruments (GOSAT, GOME2) open a new window for evaluating the GPP of earth system models. The use of COS relies on the fact that it is absorbed by the leaves in a similar manner to CO_2, while there seems to be nothing equivalent to respiration for COS. Following recent work by Launois et al. (ACP, 2015), there is a potential to evaluate model GPP from atmospheric COS and CO_2 measurements, using a transport model and recent parameterizations for the non-photosynthetic sinks (oxic soils, atmospheric oxidation) and biogenic sources (oceans and anoxic soils) of COS. Vegetation uptake of COS is modeled as a linear function of GPP and the ratio of COS to CO_2 rate of uptake by plants. For the fluorescence, recent measurements of SIF from space appear to be highly correlated with monthly variations of data-driven GPP estimates (Guanter et al., 2012), following a strong dependence of vegetation SIF on photosynthetic activity. These global measurements thus provide new indications on the timing of canopy carbon uptake.

In this work, we propose a dual approach that combines the strength of both COS and SIF observations to evaluate the seasonal variations and the amplitude of the GPP simulated by the CMIP5 models. We will follow the approach of Launois et al. (2015) using the LMDz transport model to investigate the phase and amplitude of CMIP5-GPP. Forward transport simulations and inverse approaches where the monthly GPP and respiration fluxes are optimized to match the spatial and temporal gradient of COS and CO_2 concentrations will be used. A more simple correlation analysis between GPP and SIF from the GOME-2 product (Köhler et al., 2014) will provide an independent diagnostic of the phase of the simulated GPP. The combination of both tracers will be key to avoid the potential flaws of each method and to derive a more robust diagnostic of any model-GPP biases.

We will review the strength and weaknesses of both approaches and then present a synthesis of GPP biases at regional scale for each CMIP5 terrestrial model, in terms of phase and seasonal amplitude. We will further compare these results against more conventional diagnostics based on the comparison with NEE measurements at FluxNet sites and will discuss the potential impact of model GPP biases on the predicted terrestrial carbon budgets.