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Exploiting sun-induced fluorescence and temperature anomalies to enhance biosphere flux estimates in an atmospheric CO_2 inversion

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One of the challenges in obtaining accurate estimates of CO_2 fluxes at the Earth's surface is the still high uncertainty related to biospheric carbon exchange. The net uptake of CO_2 by the biosphere (NEE) is the result of the imbalance between gross primary production (GPP) and terrestrial ecosystem respiration (TER), both of which respond individually to environmental drivers, and this response differs between ecosystems.

NEE estimates are typically obtained by assimilating measurements of atmospheric CO_2 mole fractions into a framework that includes biospheric surface fluxes. Due to the sparse coverage of observation locations and the poorly known error covariance structure, the resulting spatial NEE patterns remain to a large extent determined by the patterns of GPP and TER predicted by the original biosphere model. As these can be validated at only a limited set of surface eddy-covariance sites, multi-decadal and global high-resolution NEE fluxes remain only weakly constrained by observations.

In this research we try to alleviate these limitations by making use of sun-induced fluorescence (SIF) and temperature observations which are both available at high spatial and temporal coverage. As shown in Rödenbeck et al. 2018, the mean seasonal cycle and long-term trend of NEE can generally be represented by a simple statistical function. Interannual variability in NEE can be introduced through a linear regression of temperature anomalies onto NEE anomalies, based on their known high correlation across large parts of the globe. Additionally, remotely-sensed SIF recently emerged as a powerful proxy for GPP anomalies on regional to global scale. Like for temperature, we will show that SIF anomalies can be used in a similar way to capture NEE anomalies on interannual time scales.

Inspired by the work of Rödenbeck and the availability of multiple years of SIF observations from the GOME-2 sensor (Koren et al. 2018), a new state vector was implemented in the CarbonTracker data assimilation system (which is based on a sequential ensemble square root filter algorithm, Peters et al. 2005). It allows direct optimization of the statistical function parameters that describe long-term and seasonal NEE, as well as the monthly SIF and temperature sensitivities (i.e. the regression coefficients). A single set of parameters, valid for the full temporal window, is optimized per ecoregion subject to an atmospheric CO_2 constraint in a global inversion. We will present how this approach exploits the spatiotemporal patterns of SIF and temperature to improve NEE estimates, and how this new set-up is expected to be of value to separately estimate GPP and TER responses to large climate anomalies.

References:
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