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How best to optimize a global process-based carbon land surface model ?

Philippe Peylin (1), Cedric Bacour (2), Natasha MacBean (1), Sebastien Leonard (1), Fabienne Maignan (1), Tea Thum (3), Frederic Chevallier (1), Philippe Ciais (1), Patricia Cadule (1), and Diego Santaren (1)

(1) LSCE, Gif sur yvette, France (peylin@lsce.ipsl.fr), (2) Noveltis, France, (3) FMI, Finland

Global process-based land surface models are used to predict the response of the Earth's ecosystems to environmental changes. However, the estimated water and carbon fluxes remain subject to large uncertainties, partly because of unknown or poorly calibrated parameters. Assimilation of in situ data, remote sensing products, and/or atmospheric trace gas concentrations, into these models is a promising approach to optimize key parameters, providing that all major processes are well represented.
So far, most of the studies have focused on using one single data stream, either remotely sensed estimates of the vegetation activity (fAPAR or NDVI) to constrain the modeled plant phenology, in situ measurements of net CO_2 and latent heat fluxes (NEE, LE at FluxNet sites) or atmospheric CO_2 concentrations (through the use of a transport model) to provide constraint on the net carbon fluxes at hourly to inter-annual time-scales. However, the combination of these data streams is expected to provide a much larger constraint on ecosystem carbon, water and energy dynamics.

At LSCE we have constructed a global Carbon Cycle Multi-Data Assimilation System (CCDAS) to assimilate i) MODIS-NDVI observations at around 15 points for each plant functional type (PFT) in the model, ii) in situ NEE and LE fluxes at around 70 FluxNet sites and iii) atmospheric CO_2 measurements at more than 80 sites. We used different methods of data assimilation (including a 4D-Var approach), depending on the number and type of data streams that are considered in order to optimize the main parameters of the global vegetation model ORCHIDEE (around 15 parameters per PFT).

Using such a CCDAS, we investigated several methodological to scientific questions: How does a variational scheme perform compared to a "Monte Carlo" approach (the genetic algorithm) to minimize an objective function (using FluxNet data)? What is the additional information brought by the measurements of above ground biomass data on the top of eddy covariance fluxes to constrain the C allocation within ORCHIDEE? What is the level of constraint brought by the global atmospheric CO_2 data compared to FluxNet NEE/LE and satellite-derived NDVI data? What is the impact of the multi-data stream assimilation on the projected global land carbon balance at the horizon 2100 using future climate scenarios?

In order to answer these questions we have conducted several studies over a 3-year period with the assimilation of i) each data stream separately and ii) several combinations of them in both a step-wise and simultaneous mode. The estimated parameters from each experiment will be compared together and the corresponding land carbon fluxes/stocks (and to a lesser extend the land water fluxes) will be analyzed in terms of seasonal and inter-annual variations at continental to global scales. These estimates will be compared against independent datasets (e.g., Forest biomass from FAO) and independent approaches (e.g. optimized carbon fluxes from atmospheric CO_2 inversions) in order to highlight the benefit of Carbon Cycle Data Assimilation Systems.