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Improving carbon cycle models using inverse modelling techniques with in-situ measurements and satellite observations

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Improving our understanding of the carbon cycle is an important component of modelling climate and the Earth system, and a variety of inverse modelling techniques have been used to combine process models with different types of observational data. Model data fusion, or inverse modelling, is the process of best combining our understanding of the dynamics of a system, observations and our prior knowledge of the state of the system.

We consider a simple model for the carbon budget allocation for terrestrial ecosystems, the Data Assimilation-Linked Ecosystem model (DALEC). DALEC is a box model simulating a large range of processes occurring at different time scales from days to millennia. Eddy covariance measurements of net ecosystem exchange of CO_2 have been used intensively for over a decade to confront DALEC with real data to estimate model parameters and quantify uncertainty of the model predictions. The REgional FLux Estimation eXperiment (REFLEX), compared the strengths and weaknesses of various inverse modelling strategies (MCMC, ENKF) to estimate parameters and initial stocks for DALEC; most results agreed on the fact that parameters and initial stocks directly related to fast processes were best estimated with narrow confidence intervals, whereas those related to slow processes were poorly estimated with very large uncertainties. While other studies have tried to overcome this difficulty by adding complementary data streams or by considering longer observation windows no systematic analysis has been carried out so far to explain the large differences among results of REFLEX.

One of the merits of DALEC is its simplicity that facilitates close mathematical scrutiny. Using variational techniques we quantify the ill-posedness of the inverse problem and we discuss various regularisation techniques. Using the tangent linear model we study the information content of multiple data sources and show how these multiple data sources help constraining initial carbon stocks and parameters.