

Simultaneous assimilation of FAPAR and atmospheric CO₂ into a Terrestrial Vegetation Model

Marko Scholze[†]; Thomas Kaminski; Wolfgang Knorr; Nadine Gobron; Bernard Pinty; Ralf Giering; Pierre-Philippe Mathieu

[†] University of Bristol & CliSAP, University of Hamburg, Germany

Leading author: marko.scholze@bristol.ac.uk

Tackling the possible severe impacts of climate change on the carbon cycle and land water resources requires further development of simulation models and monitoring capabilities. Carbon cycle impacts can lead to further climate change through releases of CO₂, and impacts on water resources are critical for human survival. A rapidly increasing monitoring capability is Earth Observation (EO) by satellites. Usually, EO by its very nature focuses on diagnosing the current state of the planet. However, it is possible to use EO products in data assimilation systems to improve not only the diagnostics of the current state, but also the accuracy of future predictions. This study investigates the simultaneous assimilation of ground-based atmospheric CO₂ concentration measurements and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) derived from measurements made by the MERIS sensor on-board ENVISAT and to what extent these data can be used to improve models of terrestrial ecosystems, carbon cycling and hydrology. Further development of the Carbon Cycle Data Assimilation System (CCDAS, see <http://CCDAS.org>) for the purpose of simultaneous assimilation of FAPAR and atmospheric carbon dioxide measurements showed that the design of the ecosystem model is critical for successful implementation of highly efficient variational data assimilation schemes. This is important, because each newly added data stream will typically require a separate observational operator. In the case of this study, it was the leaf development (phenology) sub-model that needed to be developed. As a variational data assimilation scheme, CCDAS relies on first and second derivatives of the underlying model for estimating process parameters with uncertainty ranges. In a subsequent step these parameter uncertainties are mapped forward onto uncertainty ranges for predicted carbon and water fluxes. We present assimilation experiments of MERIS FAPAR at the global scale together with in situ observations of atmospheric CO₂ in a coarse-resolution setup of CCDAS and address the systematic application of CCDAS for the design of future monitoring missions. Assimilation experiments were developed from a base case, where both FAPAR and carbon dioxide data were assimilated, and several variants: assimilation of only FAPAR, of only CO₂ data and increase of sensor resolution approximated by smaller data uncertainty. The reduction of uncertainties from assimilating FAPAR is modest for carbon fluxes, but considerable for hydrological quantities (evapotranspiration). Regionally, the highest constraint for both carbon fluxes and hydrological quantities is found for Australia and Africa (in that order). This can be explained by the fact that most of the vegetation on these continents grows in tropical or sub-tropical semi-arid environments, where observation conditions are especially favourable. Here, vegetation is water limited, which underlines the usefulness of FAPAR assimilation for hydrological studies. Sensor resolution has only a moderate effect on uncertainty reduction for carbon fluxes. The study demonstrates that variational data assimilation can be used to assess the value of multiple data streams and multi-data synergies. A significant result is that FAPAR data are useful for constraining hydrological quantities.