Controlling vegetation growth models with satellite measurements

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Since the early 80's, satellite-borne sensors devoted to the observation of the Earth have collected considerable datasets. These measurements proved very interesting for the monitoring of terrestrial vegetation at different scales. Remotely sensed data typically give access to large domains and also to systematic and repeated observations of the surface. In that respect, they are most valuable *where and when* intensive ground studies are not possible. Moreover, this kind of data may reveal spatial patterns or changes with time, which are not discernable from the ground.

All the measurements taken from space share an essential characteristic: they measure electromagnetic fields, which interact with the surface. Remotely-sensed data depict how the surface reflects the solar irradiance in different wavelengths, or how much radiation is emitted or scattered by the vegetation or the soil. Data interpretation requires a good understanding of the surface spectral properties. Numerous studies are therefore focused on the relationships between surface spectral properties and biological or physical variables, which are really useful for ecological purposes. These studies have accumulated strong evidence that some biophysical variables like the amount of leaves in a plant canopy are related to the surface spectral properties, in that case to the reflectance in the red and near-infrared domain. As a result, remotely-sensed data have been widely used in vegetation mapping and monitoring. For example, vegetation seasonal and inter-annual variability (including trends over 10 years, Myneni et al. 1997), net primary productivity, and standing biomass have been assessed at local, regional and global scale with the help of remote sensing.

Over the same period, ecology has benefited from a significant development of numerical modeling. The focus here is not on the results that have been obtained from modeling approaches. In fact, this paper addresses model errors, and some methodologies to correct them. Errors in ecological modeling are caused by a number of reasons. In the example of vegetation growth modeling, individual or even species are often grouped as an 'average plant', on the basis of functional similarities. However, biological diversity and complexity ensure some departure from an average behavior. Moreover, ecological systems often are open systems, exposed to environmental forcings, for instance climate factors, which are not controlled. Duplicate experiments are therefore difficult or to carry out, and that is a problem for designing models. Even ground measurements may be challenging in some cases. Thus, a numerical model is at best an approximation of the ecological system. Due to the scarcity of input data, or uncertainties in model parameters, that can only be measured at the site level, the spatial extension of an ecosystem model is another source of errors. This is why intensive dataset, including remotely-sensed measurements, are of great value for ecological modeling. Remotely-sensed dataset may help *wherever and whenever* ground-based information is insufficient.

In that context, we present here a methodology to combine vegetation growth models and remotely-sensed data. The basic idea is to take advantage of both model knowledge and data, by fitting the model to the data, i.e. by *assimilating* the data in the model. Section 2 presents a general view of this approach in the specific case of satellite data. Section 3 then shows an example of assimilation of visible and near infrared measurements in a crop growth model. Section 4 describes an example of assimilation of both short-wave and thermal infrared data in a coupled vegetation/water budget model, simulating a Sahelian grassland. Lastly, section 5 summarizes some concluding remarks.

2000, Advances in environmental and ecological modelling, (Blasco F. and Weill A. ed.) Elsevier Publishers, pp 73-89.