1st TERRABITES Symposium
Hamburg, Germany, 9-11 February 2010
TERRABITES-84

Vegetation variables retrievable from remote sensing data: from proxies to physical meaning

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Monitoring vegetation dynamical processes in the terrestrial biosphere requires consistent series of data at adequate spatial and temporal resolutions, with proper spectral and angular information. The study of land surface processes associated to vegetation dynamics has been a central objective of remote sensing since the very beginning, either by using satellite data sources defined for general mapping purposes or by making explicit use of dedicated missions explicitly oriented to monitoring vegetation.

While in many cases data exploitation has consisted on a rather simple way of extracting qualitative information by means of spectral indices or other simple indicators for change detection, there is a growing tendency to move to more quantitative data analysis, describing more in detail physical processes and linking individual processes with biochemical cycles by means of quantitative variables. Contrary to the approach of retrieving the information directly from the measured data by means of simple correlations or empirical approaches, the tendency is the simultaneous derivation from the data of a number of variables in a more consistent way, in most cases through model-inversion techniques. Instead of retrieving separately each biophysical variable, measured data –time series in most cases- are used together with models, in a data assimilation scenario where inputs from multiple data sources are integrated. Such approach is more and more necessary as models tend to be more complex and the number of variables tends to increase.

The derivation of quantitative information from remote sensing data beyond qualitative attributes is becoming possible with well radiometrically calibrated and stable time series of data, as well as more advanced data processing algorithms. Such data processing includes not only the retrieval component following a model-inversion / data assimilation approach, but also advanced pre-processing schemes to compensate for all geometric and atmospheric effects, topographic distortions, and better cloud screening procedures to produce more stable time series, with increasing spatial resolution and better account for scaling effects.

The vegetation variables retrieved from space have more precise meaning as they become more accurate, and new variables are incorporated to provide such more precise meaning to the derived information. While very simple vegetation reflectance models capture only the elementary aspects, the availability of sophisticate soil / leaf / canopy / atmosphere 3D radiative transfer models allow incorporation of more variables with clear and precise physical meaning, able to describe multiple scales of processes. The derivation of more and more precise variables runs in parallel to the developments of models able to interpret such information, and thus usable for model-inversion, and to accommodate such information in dynamical vegetation models describing temporal processes, then allowing data assimilation schemes beyond the retrieval of variables from a particular scene or limited dataset.

The synergistic exploitation of all the available spectral ranges (optical reflective, thermal, passive and active microwaves, etc.) for vegetation monitoring is still a challenge, but it has been identified a key element for the operational usage of the information in modelling approaches making use of vegetation maps and canopy structural and biochemical variables. Scaling issues play a key role in such data synergy, while the coupling of the different physical meaning of information (biochemical versus structural) still requires a better understanding.

Another aspect to be addressed is the emergence of new type of data structures where land use/land cover classes are identified by means of an object-oriented classification approach where the data format allows giving additional attributes to each polygon corresponding to structural and biochemical information about each class, thus producing rich datasets quite useful as input for modelling purposes replacing current fixed parameterizations schemes based only on land cover / use classes.

This paper will review with historical perspective the evolution of vegetation monitoring from space, starting with qualitative indicators taken as indices or proxies to the actual desired information up to model inversion techniques and advanced data assimilation concepts, emphasizing the trends to move from empirical approaches to physical modelling of processes, looking also at the improvements in models/retrievals versus improvements in technical characteristics of the sensors.