Characterization of Surface Spatial Heterogeneity for Scaling Non Linear Processes

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S.GARRIGUES[1], D.ALLARD[2], F.BARET[1].

1. INRA, Site Agroparc , Domaine St Paul, 84914 Avignon Cedex 9, France

Phone : (33) 4 32 72 24 23, Fax : (33) 4 32 72 23 62, email : sgarrig@avignon.inra.fr (corresponding author)

2. INRA-Biométrie, Avignon, France,

The monitoring of earth surface dynamic processes at global scale, such as primary production, carbon and water fluxes, requires high temporal frequency remote sensing observations. Because of technological constraints, the sensors are characterized by coarse spatial resolution, *i.e.* a resolution from few hundred meters (MERIS/ENVISAT, MODIS/TERRA) up to few kilometres (VEGETATION/SPOT, SEVIRI/MSG). At these scales, the spatial heterogeneity of the observed scenes together with the non linearity of the relationship (or so called "transfer function") between the biophysical variable of interest and the radiometric data, generate a bias in the estimation of this variable. The aim of this study is to quantify the spatial heterogeneity so as to correct the biophysical variable estimation bias at coarse spatial resolution.

Four landscapes are studied. The data come from the VALERI database (http:\www.avignon.inra.fr\valeri). The NDVI vegetation index derived from high spatial resolution images (SPOT 20m) is used to characterize the spatial structure of each landscape. These NDVI images are then used to describe their heterogeneity as a function of the spatial resolution.

The apparent spatial heterogeneity as observed on satellite images depends on:

- the actual spatial structure which results from different processes that operate at specific length scales,
- the instrument characteristics determined mainly by its spatial resolution and sampling interval.

The spatial heterogeneity is defined as the spatial variance of the characteristics considered, within the coarse resolution pixel.

A geostatistical methodology based on the variogram concept is developed to analyze the image spatial structure. The sample variogram computed over the image describes the NDVI spatial distribution for the different landscapes. A variogram model can be adjusted, whose parameters characterize the specific spatial structure associated to each landscape:

- the sill *i.e.* the true variance of the data indicates the level of variability between landscapes
- the ranges indicate the spatial variation within the image. Homogeneous sites (like tropical forest) has spatial correlation at short range whereas heterogeneous sites (like cropland) show spatial structure at larger distances.

The dispersion variance computed from the variogram model quantifies the spatial heterogeneity as a function of the spatial resolution. The dispersion variance evolution with decreasing resolution shows faster data regularization for homogeneous site than heterogeneous site.

An analytical model of the estimation bias is built: it is a function both of the spatial heterogeneity (dispersion variance) parameter and of the degree of non linearity of the transfer function that relates canopy structural characteristics to their radiometric signature. In this case we used a simple empirical exponential transfer function between LAI and NDVI. The results show that the model is efficient to correct the bias for highly heterogeneous landscapes and for a range of coarse spatial resolution higher than 300m. However poor results of the model appear for some pixels that can be explained by local non stationarity of the variogram model. To account for the availability of multiple wavebands, a multivariate description of the spatial heterogeneity is proposed.

The problem of temporal stationarity of the variogram is discussed to determine the relevance of fusing high and coarse spatial resolution data to correct the biophysical variable estimates.

This study underlines that accounting for image spatial information for quantitative remote sensing is an important concern. The SPECTRA observations could be used to adjust variogram models and investigate their temporal stationnarity. Finally, the results of this study are discussed in order to define an optimal spatial resolution for future monitoring missions.