Retrieving LAI and FPAR from MERIS data with advanced algorithms

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The primary motivation of this research activity is to document the feasibility of deriving global fields of LAI (leaf area index) and FPAR (fraction of photosynthetically active radiation absorbed by vegetation) from atmosphere corrected ESA (European Space Agency) MERIS (Medium Resolution Imaging Spectrometer) data, validate and evaluate the MERIS LAI and FPAR products by intercomparison with MODIS (Moderate Resolution Imaging Spectrometer) LAI and FPAR products and with field data collected at the EOS Core sites distributed around the world.

Our activities during Year 1 (January through December, 2001) have focused on the modification of the MODIS LAI/FPAR algorithm to facilitate its ability to process MERIS data. We considered a related but wider problem, i.e., fusion of biophysical parameters derived from data acquired by spectroradiometers of different spectral bands and different resolutions. This problem can be formulated as follows.

Consider two hypothetical spectroradiometers of resolutions, say, 8 km and 1 km and which measure at different wavelength bands. Let $R(\lambda)$ be the surface reflectances of a 8 km by 8 km vegetated pixel at wavelength $\lambda = \lambda_1, \lambda_2, \ldots \lambda_n$ provided by the first instrument (instrument 1). Let the same pixel be sensed by the second instrument (instrument 2) and $r_i(\beta)$, $i = 1, 2, \ldots, 64$ be surface reflectances at wavelength $\beta = \beta_1, \beta_2 \ldots \beta_m$ at 1 km resolution covering the 8 km by 8 km pixel. Suppose that one uses instrument 1 and instrument 2 reflectance data independently to produce biophysical parameters at 8 km and 1 km resolution. The fusion (or scaling, if only the spatial dimension is considered) is said to be accomplished if the biophysical variable at 8 km resolution is equal to the mean value of the 1 km resolution retrievals.

Results

To investigate resolution effects on LAI retrievals, an understanding of the relation between changes in reflectance and spatial resolution is needed. A common approach to study this effect is to compare data from sensors with varying resolutions or to aggregate fine resolution data to larger cell sizes. The latter was utilized to assess the impact of surface heterogeneity on LAI/FPAR retrievals.

- The effect of pixel heterogeneity on spectral reflectances and LAI/FPAR retrievals has been investigated. It is shown that LAI retrieval errors are inversely related to the proportion of the dominant land cover in a pixel. Errors are particularly large when forests are minority biomes in non-forest pixels.
- If LAI is to be retrieved using data with a pixel size that almost guarantees substantial biome mixing, then it can be underestimated if the resolution of the data is not considered in the retrieval technique.

Most of the algorithms that estimate surface biophysical parameters from remote sensing data use vegetation maps as *a priori* information to constrain the parameter space. A common problem with land cover characterization is one of mixture. The designated biome type may be just the dominant biome type, and other biomes can exist within moderate and coarse resolution pixels. Pixel heterogeneity is an important factor causing variations in surface reflectance data. This information should therefore be taken into account in algorithms in order to correctly interpret data acquired by spectroradiometers of different spectral bands and different resolutions.

- A physically based technique for fusion with explicit scale dependent radiative transfer formulation was developed and successfully applied to adjust the MODIS LAI/FPAR retrieval technique to retrieve LAI and FPAR fields from data acquired by spectroradiometers of different spectral bands and different resolutions (Figure 1). A paper describing this technique is currently in preparation.

Conclusions

The problem of the modification of the MODIS LAI/FPAR algorithm to process data of any spectral band composition and varying spatial resolution is addressed here. This problem arises in two contexts. The first, as previously mentioned, is in the context of adjusting the MODIS LAI/FPAR retrieval technique to process MERIS surface reflectances. The second is in the validation of moderate resolution sensor products such as MODIS and MERIS LAI and FPAR. By validation we mean specification of the uncertainty in the products in relation to ground truth data. The latter are often collected at resolutions much finer that the products for practical reasons. Therefore, the retrieval algorithm must be scale dependent so that the products can be properly compared. Results reported here not only accomplish our task for the Year 1 but also constitute a strong basis for our activities during Year 2 Year 3 which are the intercomparison of LAI and FPAR fields derived from MODIS/MERIS data and ground based measurements. The ESA MERIS is expected to be in orbit in January 2002 (http://envisat.esa.int/, updated on Oct-27-2001).

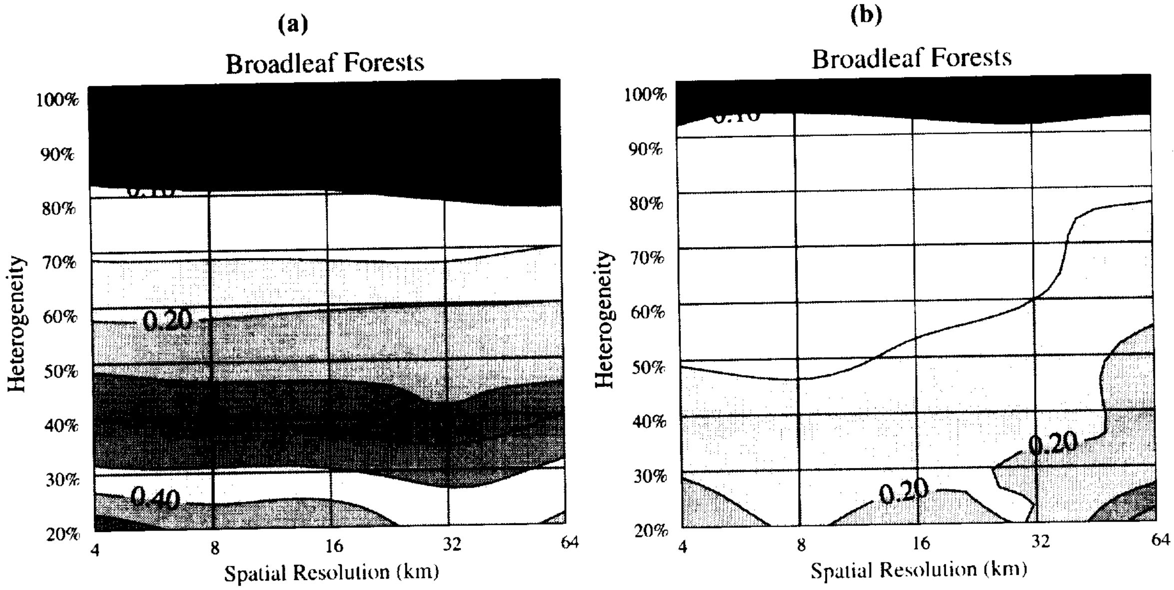

Figure 1. Countor plots of uncertainty in LAI derived from (a) unadjusted and (b) adjusted LAI retrieval algorithms as a function of spatial resolution and pixel heterogeneity. The heterogeneity is defined as the percent occupation of the dominant biome type within the pixel. Pixels with low heterogeneity value are more heterogeneous than those having high values. Note significant improvements in LAI retrievals in all cases, including the case of large pixels with significant heterogeneity. Tuning of the Look-up-Tables by adjusting the single scattering albedo to minimize uncertainties in LAI/FPAR retrievals constitutes the radiative transfer based approach to adjust the MODIS LAI/FPAR algorithm to retrieve biophysical parameters from data acquired by spectroradiometers of different spectral bands and different resolutions. Land surface reflectances at 1 km resolution from AVHRR over North America for July 1995 aggregated to different coarse scale resolutions were used in this example.