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Radiative Transfer Based Synergistic MODIS /MISR Algorithm for the Estimation of Global LAI & FPAR

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The objective of our effort is to develop a radiative transfer based synergistic algorithm for estimation of global leaf ares index (LAI) and fraction of photosynthetically active radiation absorbed by vegetation (FPAR). The algorithm consists of a main procedure that exploits the spectral information content, of MODIS measurements and the angular information content of MISR measurements to derive accurate estimation of LAI and FPAR. Should this main algorithm fail, a hack-up algorithm is triggered to estimate LAI and FPAR using vegetation indices Both algorithms are capable of executing in MODIS-only or MISR-only mode, should cloud contamination, data frequency and spatial or temporal resolution requirements hinder a joint MODIS/MISR mode of operation. A comprehensive three dimensional radiative transfer model for vegetated surfaces is utilized by both the algorithms to connect remote observation to surface variables of interest. The algorithm require a land cover classification that is compatible with the radiative transfer model used in their derivation, Such a classification based on vegetation structure was proposed and it is expected to be derived from the MODIS Land Cover Product. Therefore, our algorithm has interfaces with the MODIS/MISR surface reflectance product and the MODIS Land Cover Product. The following is a brief description of our activities during the first-half of 1997 (January through June).

(1) The backup algorithm has been fully derived and the biome-dependent vegetation index vs LAI and FPAR relationships have been established. This was done with the improved radiative transfer model, especially in the case of forest canopies. The derived relations have been coded into the algorithm by the University of Montana group (PI: Dr. Running)

(2) The main algorithm for the estimation of LAI and FPAR from MODIS/MISR is based on the fact that canopy reflectance can be explicity expressed in terms of the soil reflection coefficient, and solution of the following two (soil-independent) radiative transfer problems:

(a.) *Black-Soil Problem (BP):* Interaction of incoming radiation with vegetation when soil reflectance is equal to zero, The solution of this problem depends on sun-view geometry, canopy structure and leaf optical properties.

(b) *Adoint problem (CP):* The radiation regime in the vegetation canopy generated by isotropic sources located at the bottom of the canopy. The solution of this problem depends on view angles, canopy structure and optical properties of leaves.

Such a description allows us to reduce the size of the LUT significantly without loss of accuracy of solution. Our previous investigations of BP and CP with respect to variations in leaf spectral properties allowed us to derive simple and accurate equations which relate canopy structure (parametrized in terms of LAI), leaf optical properties (parametrized in terms of leaf albedo) and BiHemispherical Reflectance (BHR). This made possible the formulation of the problem of LAI and FPAR estimation in terms of BHR for the black-soil and adoint problems at a fixed wavelength, together with some structure-dependent coefficients and optical properties of phytoelements, which are now the elements of the LUT. Thus, the main algorithm uses BHR to estimate LAI and FPAR which is the same for MODIS and MISR instruments. However, these instruments measure canopy reflection in a different manner and so different techniques are needed to convert their measurements into BHR. Therefore, our activities during report period were devoted to the creation of a Version 0 for MODIS-only and MISR-only modes of algorithm operation.

(3) LUT containing solutions of the black soil and adojnt problems at a fixed wavelength were built. The problem of choosing the optimal wavelength was investigated.

(4) Given BHR (or Directional Hemispherical Reflectance, DHR), a method to find all values of LAI and soil reflectance with differences between measured and simulated results within a given accuracy was developed.

(5) The problem of estimating LAI allows for multiple solutions. An algorithm which estimates the most probable solution was developed and incorporated in our Version 0.

(6) MISR allows estimation of BHR directly from measurements, as well as DHR by using a three-parameter canopy-radiation model (which does not, depend on our main algorithm). Our equations for BHR depend on the ratio, fdir, of direct radiation to total (diffuse and direct) radiation incident, on the canopy. This parameter is available from MISR measurements and is independent of the canopy radiation model. Thus, we formulated an *extended set* of equations for finding all possible solutions of the inverse problem. The first set relates BHR at fdir with measured values of BHR. The second set, relates BHR at fdir=1 with derived values of DHR. Once a set of all solutions of the extended system is found, the algorithm estimates the most probable LAI value by minimizing a functional, which also provides us with information to quantitatively

formulate QA

(7) MODIS measures canopy reflectance in one direction at a time. In order to convert this information to BHR, we introduced weights, defined as the ratio of reflected radiance in a direction to BHR. Their weights were evaluated using our three-dimensional model for the black soil and adjoint problems, as a function of sun-view geometry; these weights are also elements of our LU'T.

(8) The above mentioned algorithm also allows for the estimation of radiation absorbed by vegetation at a fixed wavelength. We have developed methods to relate this quantity to absorption at other PAR wavelengths and integrate the resulting analytical expression. Such an algorithm for FPAR is currently implemented in our Version 0.

(9) The MISR-only mode of our algorithm was delivered to MISR, and MISR project is currently developing software to implement our Version O. The MODIS-only mode of our Version 0 is ready to be delivered; plans for implementation will be developed in early August during a visit, to the University of Montana.

(10) A paper describing the validation of our radiation model in forest canopies has been accepted for publication in Agricultural and Forest Meteorology. Articles devoted to the theoretical basis of our algorithm, implementation for MODIS-only and MISR-only modes are currently in preparation.

(11) During the next quarter, we will continue work on the implementation of our algorithm, with aim of creating the LUT containing the solution of the above-mentioned black-soil and adjoint problems in the case of three-dimensional vegetation canopies and testing of the main algorithm.