# Estimating leaf area index by coupling radiative transfer model and a dynamic model from multi-source remote sensing data

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**Abstract:**

Leaf area index (LAI) is an important parameter in canopy interception, evapotranspiration, and net photosynthesis. Satellite remote sensing enables derivation of LAI globally at desired spatial resolution and temporal frequency. And several LAI products have been produced from data acquired by Moderate Resolution Imaging Spectroradiometer (MODIS), Multi-angle Imaging Spectrometer (MISR), Advanced Very High Resolution Radiometer (AVHRR) and VEGETATION. However, there are some problems for the current global or regional LAI product, which restricts the application of these products. On the one hand, there are gaps between the large number of parameters of physical models and the small amount of data obtained by single sensor. Current methods of generating the LAI products above must work under certain hypothesis and these methods could not maximize the advantage of different information from multiple sensors. So it may cause the decrease in accuracy that LAI products should have. On the other hand, there are gaps between instantaneous observation of remote sensing and parameters which have change rules. Mature methods of satellite LAI product are just involving the transient of observation, discarding the information about process.

To resolve these problems, we develop a methodology to retrieve LAI by involving diverse data from multiple sensor and LAI change rule. The algorithm couples a canopy radiative transfer model with a LAI temporal profile model. LAI is an important input parameter of radiative transfer models, and it is also an output parameter of some plant growth models. The radiative transfer model is coupled with plant growth model through LAI to simulate the time series reflectance. And optimization methods are used to adjust the values of parameters of the coupled model to seek a

model trajectory that best fits a set of observations in a given time window.

A preliminary analysis using time series MODIS and MISR data was performed to validate this method. the cost function to be minimized is as follows:

$$J(\theta) = (\theta - \theta_b)^T \mathbf{B}^{-1} (\theta - \theta_b) + \omega_{\mathrm{mod}} \sum_{i=1}^{N} (\mathbf{y}_i - H_i[LAI_i(\theta)])^T \mathbf{R}_i^{-1} (\mathbf{y}_i - H_i[LAI_i(\theta)])$$
$$+ \omega_{misr} \sum_{j=1}^{M} (\mathbf{y}_j - H_j[LAI_j(\theta)])^T \mathbf{R}_j^{-1} (\mathbf{y}_j - H_j[LAI_j(\theta)])$$

where $N$ is the observation times of the MODIS sensor in crop growing season, $\mathbf{y}_i$ is the surface reflectance obtained by MODIS sensor, $M$ is the observation times of the MISR sensor in crop growing season, $\mathbf{y}_j$ is the surface reflectance obtained by MISR sensor, $\theta$ is the set of input parameters to be estimated, and $\theta_b$ is the a priori information on these parameters, $LAI_i(\theta)$ and $LAI_j(\theta)$ is logistic model, $H(\cdot)$ is the Markov chain reflectance model (MCRM), $\mathbf{B}$ and $\mathbf{R}$ are the background error covariance and the observation error covariance respectively, $\omega_{\mathrm{mod}}$ and $\omega_{misr}$ is the weight of MODIS data and MISR data. In consideration of some factors affecting the quality of some observation data, we give the higher weight for the data of higher quality or more information, in opposite condition, we give a lower weight. So the performance of more accurate observations is enhanced.

The time series MODIS surface reflectance data and MISR BRF data at some American flux stations were used to validate this method. And the results show that the algorithm can take full advantage of the different band and angle information of time series MODIS and MISR data to significantly improve the accuracy of the retrieved LAI over the MODIS LAI product compared to the field measured LAI data. And the retrieved LAI is also temporally continuous.