Use of an Ensemble Kalman Filter for Real-time Inversion of Leaf Area Index from MODIS Time Series Data

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Abstract:

Leaf area index (LAI) is an important vegetation biophysical variable, and has been widely applied to estimation of crop yield, evapotranspiration, and net photosynthesis. Currently, there are many methods to estimate LAI from remote sensing data through the statistical relationship between LAI and spectral vegetation indices, physical model inversion or other nonparametric methods. Among them, the model inversion methods are more and more used in the inverse mode to estimate LAI from remotely sensed data since these methods are physically based and can be adjusted for a wide range of situations.

It is well known that the inverse problem is by nature an ill-posed one mainly because of the multiple solutions and the measurement and model uncertainties. Therefore, as much information as possible will be used in the inversion process to improve the accuracy of surface variables estimates. One way is to use spatial contextual information and particularly multi-temporal information. However, these methods assumed that the number of observations is fixed and is known in advance, and is suitable for analyze the historical data.

In practice, it is an urgent need for natural disaster (such as forest fire, floods, hurricane) monitoring to generate biophysical variables data with high accuracy timely from remotely sensed data and to carry out real-time or near real-time monitor and alarm. This requires new algorithms to be developed that could exploit the temporal observations to real-time retrieve biophysical variables In this study, we develop a real-time inversion method to estimate LAI from MODIS data based on coupled dynamic model and radiative transfer model.

It is well known that the biophysical variables possess inherent temporal change rules and many dynamic models are developed to express and model the behaviour of these biophysical variables over time. Taking LAI as an example, many mechanical or semi-mechanical models were proposed to describe LAI dynamics. However, these models are generally too complex to be suitable for parameter inversion on the regional or global scale.

Since 2000, the MODIS LAI product (MOD15A2) is being routinely produced from data acquired by MODIS sensors onboard Terra and Aqua platforms. In this study, Seasonal Autoregressive Integrated Moving Average (SARIMA) are applied to model MODIS LAI time series, and forecast future LAI values because the time series LAI of vegetation exhibit strong seasonal variation. And a dynamic model is constructed based on the prediction from SARIMA model to evolve LAI in time and used it to provide the short-range forecast of LAI. Predictions from the model were used with the the ensemble Kalman filter (EnKF) techniques to estimate real-time LAI from time series MODIS reflectance data.

The EnKF has proven to efficiently handle strongly nonlinear dynamics and large state spaces and gained popularity because of its simple conceptual formulation and relative ease of implementation. The observations are not known in advance and arrive sequentially in time. The EnKF is used to update recursively biophysical variables as new observations arrive. And the biophysical variables can be propagated using the dynamic model in the absence of new observations.

The validation results using MODIS surface reflectance data and field measured LAI data at FLUXNET sites show that the near real-time inversion method is able to produce a relatively smooth LAI product efficiently, and the accuracy is significantly improved over the MODIS LAI product. And the most important is the production of biophysical variables in near real-time for applications of natural disaster monitoring and alarming.