Development of a prototype remote sensing data assimilation system for improving land products

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The NASA Earth Observing System (EOS) Program is routinely producing high-level land products from multiple sensors. However, there exist a series of generic issues: 1). multiple sensors have not been used effectively; 2). products are not continuous in both space and time; 3). most products are generated by one instrument algorithm regardless of many algorithms developed by the remote sensing community; and 4). most algorithms have not taken advantage of temporal signatures and incorporated a priori knowledge objectively. As a result, almost all products continue to have large uncertainties that have not been well characterized, and many products are not physically consistent.

To address these issues, we have been funded to reformulate the analysis of EOS data by developing a prototype remote sensing data assimilation system. After more than two years of work, significant progress has been made. Specifically, we have 1). developed methods for generating the spatially and temporally continuous land climatology as the first guesses; 2). conducted extensive validation for determining the accuracies of the existing products; 3). developed several new algorithms for producing different estimates of variables (e.g., aerosol optical depth, leaf area index, broadband albedo) that can be incorporated into the prototype system, and 4). evaluated and developed different assimilation algorithms (e.g., ensemble Kalman filter, variational optimization with the adjoint method, neural networks).

Land surface climatology

We have generated spatially and temporally continuous fields of the following products over North America for six years (2000-2005): spectral albedos of MODIS bands, three broadband albedos, LAI and FPAR. Fig. 2 shows the MODIS LAI product around August 12, 2000 and the "gap-filled" LAI map. If we "zoom-in" into the details, the "gaps" are seen everywhere in the MODIS standard product. Fig. 3 shows the MODIS shortwave albedo product around April 7, 2001 and the corresponding "gap-filled" product.

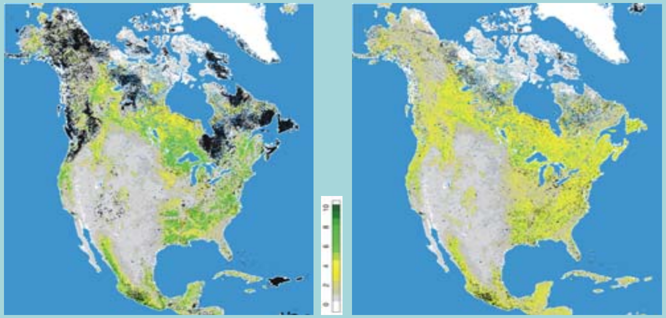

Fig. 2. Comparison of MODIS LAI maps before (L) and after (R) the gap-filling (Aug 12, 2000).

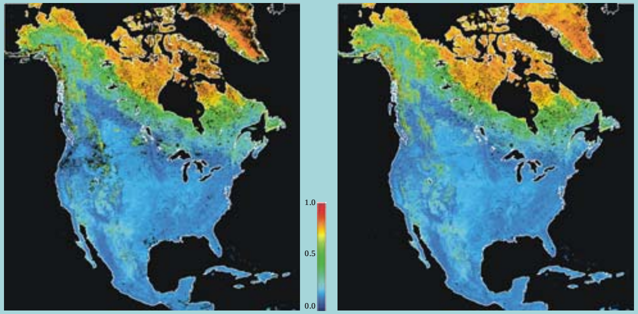

Fig. 3. North America total shortwave (TSW) black-sky albedo (Apr 7, 2001). (L) The original MODIS albedo; (R) Derived with the new filter.

Determining the errors of the land climatology

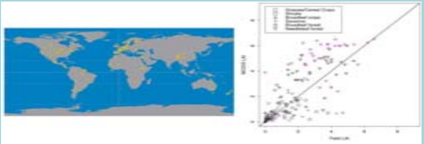

Fig. 4. Comparison of the MODIS LAI and field measurements for different cover types: site distribution (L) and scatterplot (R). Black/pink colors in the scatterplot indicate the MODIS retrieval from the main/backup algorithms, respectively.

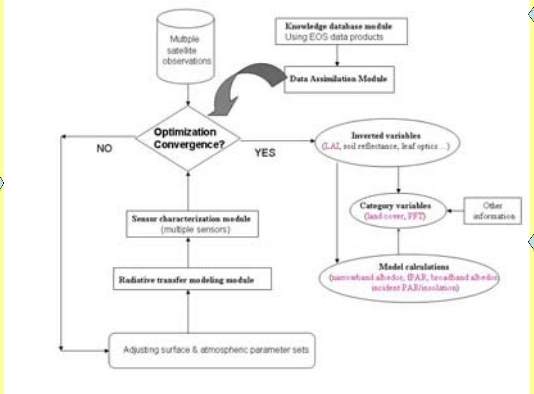

Fig. 1. Flowchart of the prototype remote sensing data assimilation system;

Remote sensing data assimilation system

The EOS land products will be improved by the remote sensing data assimilation system as illustrated in Fig. 1. It is being tested and evaluated at both points and regions. One example of the LAI improvements is shown in Fig. 5.

New inversion algorithms

1). A new algorithm was developed to estimate aerosol optical depth (AOD) over land surfaces from MODIS using the multitemporal signature. This new method performed very well, particularly over "bright" surfaces (non-vegetated) after comparison with AERONET measurements.
2). Two new algorithms for estimating LAI were developed using the neural network method and the variational optimization approach with adjoint method, respectively.
3). A new algorithm for estimating daily broadband albedo of bright surfaces (e.g., snow and ice) was developed. The new algorithm performs much better than the MODIS standard algorithm over non-vegetated surfaces, particularly with snow and ice in the winter.
4). Based on the knowledge database (mainly land climatology) and the improved estimates using the alternative methods, a new method to improve the mapping of plant functional types using the Dempster-Shafer Theory of Evidence was developed.

Assimilation algorithms

Multiple algorithms widely used in meteorological and oceanographic data assimilation systems have been explored and evaluated, such as variational algorithms, ensemble Kalman filters, and several machine learning techniques.

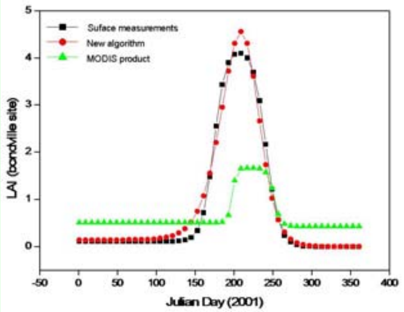

Fig. 5. Comparison of our retrieved LAI, MODIS standard product and ground measurements at Bondville, IL, 2001.

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