A Generic Aerosol-Surface Reflectance Retrieval Algorithm for MODIS

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Introduction

The contemporary remote sensing from whisk-broom (MODIS-like) sensors is pixel-based and uses a single-orbit data. In this case, the problem of retrieving atmospheric aerosol and surface reflectance parameters is under-defined (single measurement vs two unknowns) and cannot be solved without apriory assumptions (spectral regression from 2 μm channel for the "dark target" method [1-2]) or ancillary data (surface reflectance database for the "deep blue" method [3]). The approximate nature of these apriory constraints and use of common simplifications to the radiative transfer model (Lambertian model of surface reflectance) limit the applicability and accuracy of retrievals.

This work introduces a new generic aerosol-surface reflectance retrieval algorithm *applicable globally over the land* surface, with the current exception of snow-covered surfaces. It uses latest sensor data along with the previous measurements, taking advantage of existing invariants of the atmosphere-surface system, such as: 1) surface reflective properties (BRF) change little on relatively short time intervals, and 2) globally, the scale of aerosol variation ~50-60 km [4] (meso-scale). In other words, AOT can be assumed constant at short distances (~20km). Under these generic assumptions, the system of equations becomes over-defined and formally can be resolved. Indeed, the algorithm defines the elementary processing area as a block with the size of N (N~20 km) pixels. With K days in the simultaneous processing, the number of measurements (KN^2) exceeds the number of unknown $K+(3N)^2$ (K values of AOT, N^2 pixels, and 3 is the number of free parameters of the Li-Sparse Ross-Thick [5] BRF model). To simplify the inversion problem, the algorithm uses BRF, initially retrieved in B7, along with an assumption of the spectral invariance of BRF shape between the 2μm and the red and blue spectral channels. This physically well-based approach reduces the number of unknown surface parameters to N^2 values of the BRF scaling (or spectral regression) coefficient.

The two main assumptions are well controlled in the algorithm which is based on minimization of an objective function. The rapid surface change or proximity to the aerosol sources, causing high spatial variability of aerosols across the processing block, manifest themselves as high values of an objective function, which are easily filtered. The algorithm combines the block-level and the pixel-level processing, and produces AOT, Angstrom exponent, and surface BRF and albedo at 1 km grid resolution.

Theoretically, the algorithm is based on a high accuracy semi-analytical formula derived with the Green's function method [6-7]. This formula gives an analytical expression for the top-of-atmosphere radiance as a function of coefficients of the linear LSRT BRF model, which in turn translates into a very efficient inversion algorithm. The necessary RTM functions, including integrals of the BRF kernels with atmospheric path radiance and Green's function are pre-calculated and stored in the look-up table. The algorithm is fast, and the work is underway to prepare it for operational applications.

Initial tests show an excellent agreement of retrievals with AERONET [8] aerosol optical thickness (AOT) measurements, low noise in the surface BRF and albedo after initialization stage, and robust physically expected behavior of the time series of surface reflectance.

The Algorithm

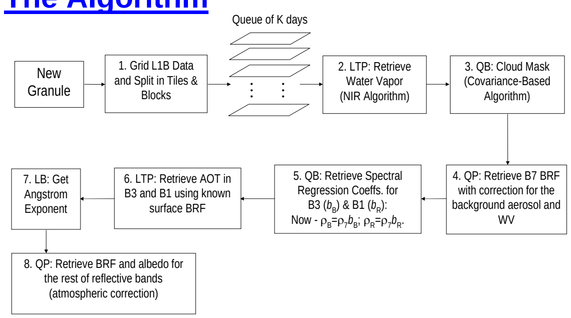


Figure 1. **Block-diagram of processing algorithm.**

The LTP, QB and QP abbreviations are used to discriminate between the different time- and scale-dimensions of processing (**LT** – last tile vs **Q** – K-day queue of blocks (**B**) or pixels (**P**)). 1) The received data are gridded, split in Tiles (~600-1000 km) and Blocks (~20km), and placed in a Queue with previous data. 2) Water vapor is retrieved from the last tile at grid resolution. 3) Cloud Mask is generated at a block and grid resolution. 4) B7 BRF and albedo are retrieved from queue at grid resolution. 5) The *main algorithm* simultaneously retrieves AOT for K-days and N^2 values of the spectral regression coefficient b_{ij} for the Blue (B3) and Red (B1) bands. This algorithm assumes that the BRF shape is similar among bands B7, and B1, B3. 6) The AOT is retrieved in the Blue and Red bands at grid resolution using known surface BRF, e.g. $\rho_{ij}^{Blue} = b_{ij}^{Blue}\rho_{ij}^{B7}$. 7) The ratio of volumetric concentrations of coarse-to-fine aerosol fractions ("Angstrom exponent") is calculated for the last tile at the block resolution. 8) Finally, surface BRF and albedo are retrieved at grid resolution from K-day queue for the rest of reflective MODIS bands.

AERONET Validation

At our request, initially the Goddard DAAC and presently MODAPS are producing the subsets of MODIS L1B data for small areas (50 km) for about 160 active AERONET sites globally. We prototype our algorithm on these subsets. Comparing retrievals of water vapor and AOT with available AERONET data provides the means of validating the accuracy and robustness of our retrievals. The examples of validation given below use the MODIS TERRA subsets for 2003 (courtesy of N. Saleous)

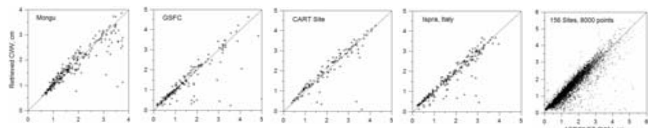


Figure 2. Comparison of retrieved column water vapor with AERONET water vapor data.

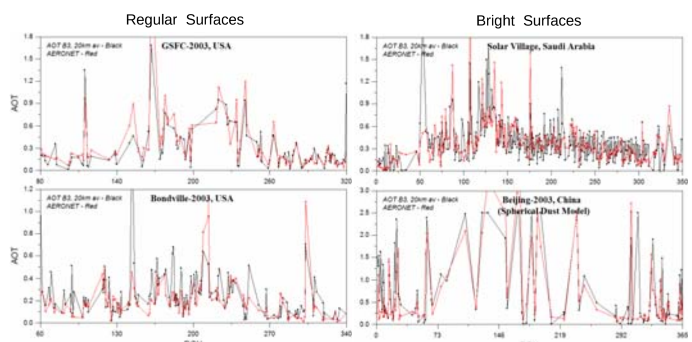
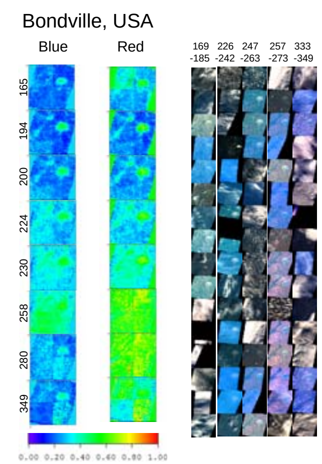


Figure 3. Comparison of retrieved AOT for the Blue band with AERONET data within ±30 min of TERRA overpass. The retrieved data are averaged over 20 km area.

Sp. Regr. Coefficient

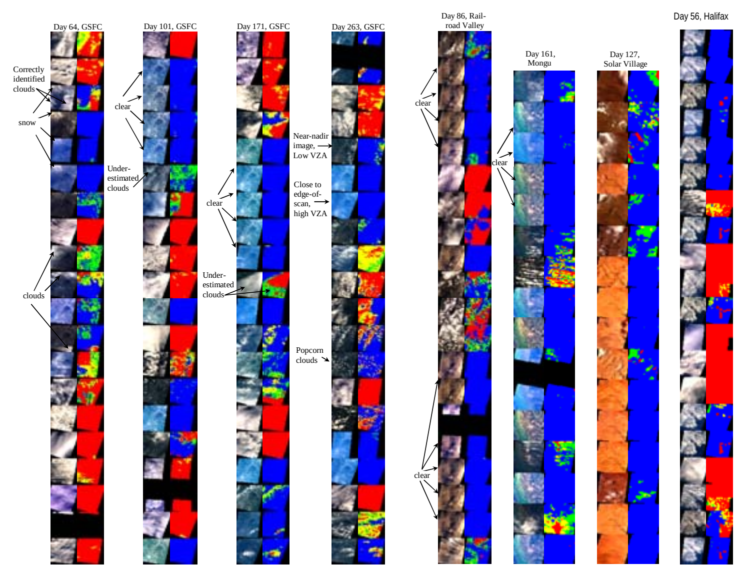
Our algorithm retrieves spectral regression coefficients independently. This parameter changes geographically and seasonally as a function of the landcover type. An example for Bondville (USA) presented below shows this variability. The spectral regression coefficients in the Blue (B3) and Red (B1) MODIS TERRA bands are shown on the left, and a sequence of RGB TOA images, which visibly show the seasonal LC change are shown on the right.



MODIS TERRA, DOY=177

An example of atmospheric correction for north-eastern USA. The top RGB image shows the TOA MODIS TERRA measurements, followed by the normalized BRF (SZA=45°, VZA=0°) and albedo).

New Covariance-Based Cloud Mask



Examples of the cloud mask performance over different world regions. The left RGB images show the 16-day queue of MODIS TERRA top-of-atmosphere measurements. The generated cloud mask is shown on the right. The new algorithm does not use absolute thresholds, and is equally successful over the bright deserts (e.g. Solar Village) and snow (Halifax).

CM Legend:

Blue – Clear
Green – Possibly Clear
Yellow – Possibly Cloudy
Red - Cloudy

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