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Aerosol and surface properties characterization from joint inversion of ground-based and satellite observations

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Abstract: A method for simultaneously retrieving aerosol and surface parameters from ground based and satellite observations collocated in space and time is presented. The improvements in aerosol and surface reflectance characterization are discussed.

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1. Introduction

The lack of detailed information on global distribution and optical properties of atmospheric aerosol presents the largest uncertainty in the assessment of the global climate change. Recently, the fusion of measurements from multiple instruments, both ground- and space- based, has been recognized as a promising approach to improve detailed aerosol characterization. Combining data from coincident ground-based and satellite observations into single retrieval gives an example of multi-instrument synergy with a potential of enhancing both aerosol and surface characterization. In particular, using the combination of up- and down-looking observations allows one to simultaneously retrieve the properties of both aerosol and surface with minimal assumptions. Here we present the algorithm retrieving aerosol and surface properties from joint time and space collocated AERONET and satellite observations. The results of algorithm application to the real AERONET/MISR/MODIS/POLDER-2 data are discussed.

2. Algorithm

The algorithm retrieves aerosol and surface information from a combination of spatially and temporally collocated AERONET and satellite observations. The aerosol information retrieved includes the aerosol volume

size distribution in the total atmospheric column, and aerosol complex refractive index at both AERONET and satellite spectral channels. Using this microphysical information, single scattering albedo is calculated as a function of wavelength. In addition to aerosol properties, the method also retrieves spectral bidirectional reflectance factors (BRF) and surface albedo. Bidirectional surface reflectance is described by the three-parameter semi-empirical Rahman-Pinty-Verstraete (RPV) model [1]. Once the model parameters are retrieved the BRF and surface albedo are calculated. The inversion is performed by a modified version of the AERONET retrieval algorithm, based on simultaneous fitting the entire data set of measurements and *a priori* constraints with a theoretical model [2]. The detailed description of the algorithm can be found in [3].

2. Surface retrievals

The method was applied to observations of smoke and desert dust over the Mongu (Zambia) and Solar Village (Saudi Arabia) AERONET sites respectively. The AERONET data were complemented by available observations from the MISR, MODIS, and POLDER-2 satellite sensors. For a joint AERONET/MODIS inversion, the Lambertian approximation was used since MODIS lacks the same day multi-angle capability to retrieve BRF from one day only. Figure 1 shows examples of surface retrievals. In all cases, the algorithm fit both ground-based and satellite observations by the theoretical model to the level of measurement accuracy (the values of residual were below 3-5%). The retrievals of BRF (left panel) and surface albedo (right panel) obtained by inverting AERONET/MISR and AERONET/POLDER-2 observations agree well although their measurements are fully independent. In particular, for all spectral channels the retrievals produce consistent BRF angular shapes, including a hot-spot maximum near the view angle of 40° (the solar zenith angle $\sim 40^\circ$). The results of joint inversion also agree well with retrievals by MISR operational algorithm.

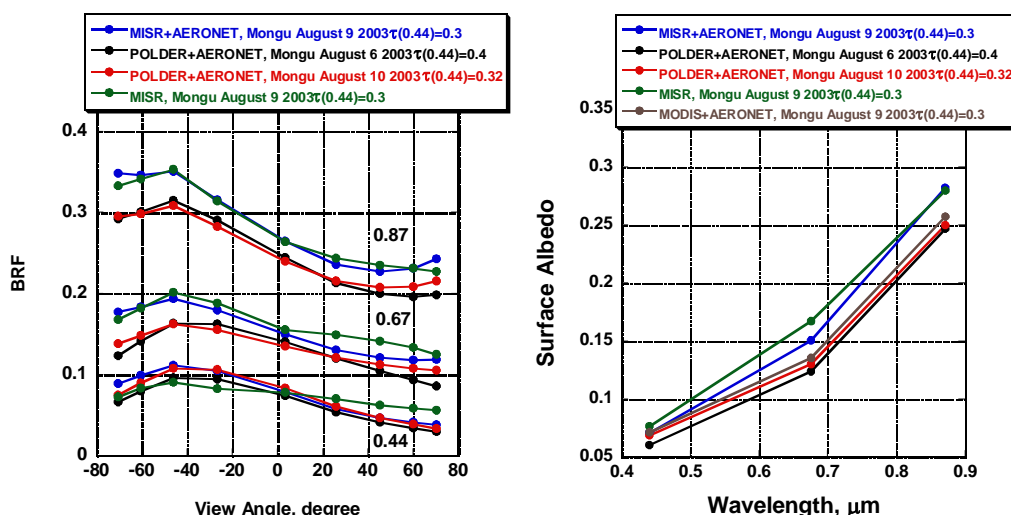


Figure 1. BRF and surface albedo retrievals at the Mongu AERONET site.

3. Aerosol retrievals

The joint inversion of AERONET/satellite observations improves accuracy of aerosol retrievals. The improvements are due to both complementary aerosol backscattering information from satellite observations and more accurate characterization of surface reflectance. In general, the retrieval of aerosol by joint inversion is similar to the retrieval from AERONET alone. However, it was found that in some situations the retrieval from a combination of data is superior. For example, comparisons of joint inversion retrievals with the results from the current version of the AERONET operational algorithm (version1) revealed large differences for the real part of a refractive index (~ 0.05 - 0.07 increase) and maximum of particle size distribution ($\sim 20\%$ decrease) retrievals for biomass burning aerosols as illustrated by Figure 2. In this case the error in surface assumptions used by the AERONET operational retrieval algorithm causes unrealistic spectral dependence in the real part of the refractive index. The joint retrieval does not need such assumptions and, therefore corrects the retrieval of the refractive index. The retrieval results from joint inversion also revealed much larger absorption by desert dust aerosols at short wavelengths than it is provided by the current version of the AERONET operational algorithm. In particular, Figure 3 shows that AERONET version 1 retrievals overestimate the $0.44 \mu\text{m}$ single scattering albedo by a factor of 0.08 and 0.06 for the low and high aerosol loadings respectively. The above examples

clearly demonstrate the potential of joint inversion in improving the accuracy of aerosol retrievals including climatically important information on aerosol absorption.

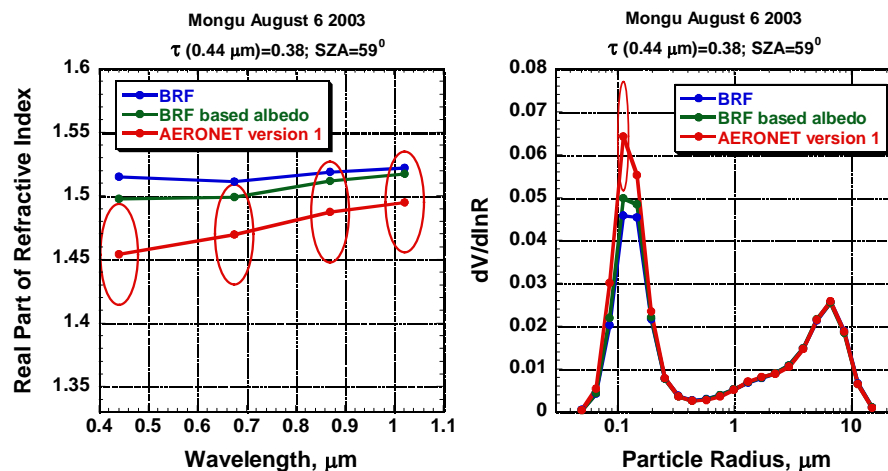


Figure 2. Comparison of the real part of a refractive index (left panel) and particle size distribution (right panel) retrieved from joint inversion (BRF) and by the current version of the AERONET operational algorithm (AERONET version 1) at the Mongu AERONET site. Error bars for the version 1 AERONET operational algorithm are from [4].

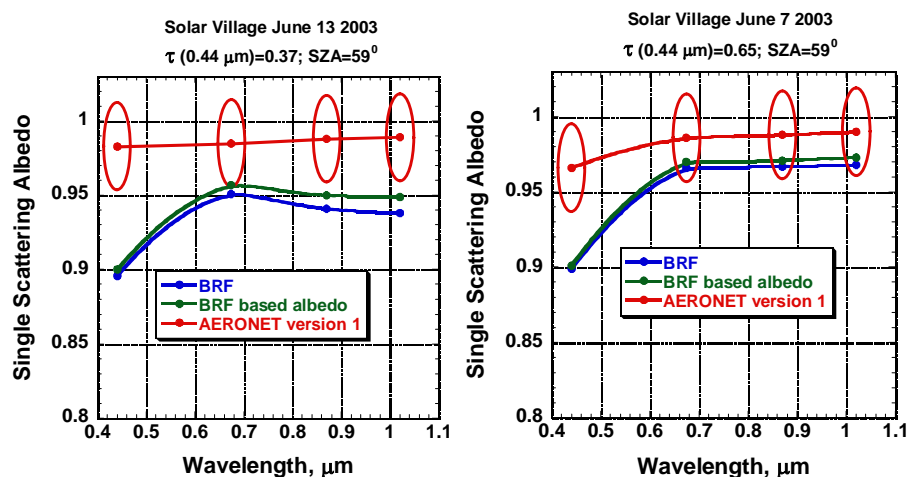


Figure 3. Comparison of the single scattering albedo retrieved from joint inversion (BRF) and by the current version of the AERONET operational algorithm (AERONET version 1) at the Solar Village AERONET site. Error bars for the version 1 AERONET operational algorithm are from [4].

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