Quality Assurance Plan for China Collection 2.0 aerosol datasets

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ABSTRACT

The inversion of atmospheric aerosol optical depth (AOD) using satellite data has always been a challenge topic in atmospheric research. In order to solve the aerosol retrieval problem over bright land surface, the Synergetic Retrieval of Aerosol Properties (SRAP) algorithm has been developed based on the synergetic using of the MODIS data of TERRA and AQUA satellites [1, 2]. In this paper we describe, in details, the quality assessment or quality assurance (QA) plan for AOD products derived using the SRAP algorithm. The pixel-based QA plan is to give a QA flag to every step of the process in the AOD retrieval. The quality assessment procedures include three common aspects: 1) input data resource flags, 2) retrieval processing flags, 3) product quality flags [3]. Besides, all AOD products are assigned a QA 'confidence' flag (QAC) that represents the aggregation of all the individual QA flags. This QAC value ranges from 3 to 0, with QA = 3 indicating the retrievals of highest confidence and QA = 2/QA = 1 progressively lower confidence [4], and 0 means 'bad' quality. These QA (QAC) flags indicate how the particular retrieval process should be considered. It is also used as a filter for expected quantitative value of the retrieval, or to provide weighting for aggregating/averaging computations [5]. All of the QA flags are stored as a "bit flag" scientific dataset array in which QA flags of each step are stored in particular bit positions.

Index Terms— Aerosol retrieval, MODIS, Quality assessment, QA flag, Scientific dataset

1. INTRODUCTION

Aerosols play a significant role in Earth's energy balance and hydrological cycle. It also has direct effects on visibility, air quality, human health, clouds and precipitation [6]. Aerosol Optical Depth (AOD) is an important physical parameter used to describe the attenuation of electromagnetic radiative transfer in air by aerosols. In the recent years, the application of satellite data to characterize global aerosol distribution has advanced dramatically. The Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on board the Terra and Aqua platforms provide daily global measurements with 36 channels spanning the spectral range from 0.41μm to 15μm at three different spatial resolutions (250 m, 500 m, and 1 km). Retrievals of AODs from MODIS data are the most commonly used among satellite AOD products [7]. The traditional Dark Target algorithm for retrieving AOD is only appropriate for the dark pixels which have low reflectance. If the surface reflectance is very high, the algorithm is ineffective.

To address the aerosol retrieval over higher reflective surface over land, the Synergetic Retrieval of Aerosol Properties (SRAP) algorithm has been developed [2]. By exploiting the synergy of MODIS data from two successive orbit of lesser interval for the same area, the ground surface reflectance, Angstrom exponent, and aerosol optical depth of two overpasses can be simultaneously retrieved over various ground types including higher reflective surface such as urban areas. An aerosol datasets (China Collection 2.0) has been produced using the SRAP algorithm.

For better use of data and facilitating users to make rapid judgments on the retrieval quality of aerosol datasets with a detailed consideration of both input data and retrieval processing, we present a QA (quality assessment) plan for AOD products. The purpose of this study is to provide access to quality information along with traceable processing steps for each retrieval and act as a rough indication of the accuracy on AOD derived from the SRAP algorithm. Based on this analysis, a "bit flag" scientific datasets is presented as the outcome of this study. Section 2 describes our detailed quality assessment approach. Section 3 provides exemplified aerosol products including AOD datasets and QA datasets. Validations are shown in section 4. Section 5 gives a summary and discussion about the QA plan.

2. QUALITY ASSESSMENT APPROACH

The QA flags of each pixel are assigned based on the retrieval processing and the product quality. The QA plan is applied to AOD retrieval with 10km x 10km resolution. Considering every step of the algorithm, we give an individual QA flag about gas absorption correction, cloud mask and inversion convergence. In addition, when the inversion performed, specific QA flags would be given to indicate different retrieving conditions and AOD confidence. The QA approaches include two main aspects: (1) retrieval processing flags, (2) product quality flags. The detailed description about the approach for each QA flag is presented as following.

2.1. Retrieval Processing Flags

Retrieval processing flags are used to provide information on the processing path taken in the aerosol retrieval. At present, it contains the gas correction flag, cloud mask flag, inversion convergence flag and retrieval rationality flag.

The data we used to retrieve AOD include TERRA & AQUA MODIS data and National Center for Environmental Prediction (NCEP) data. In the preprocessing of data, we have a correction of gaseous absorption to correct for water vapor, ozone absorption before further proceeding. In this gas absorption correction, we used daily value of water vapor and ozone from NCEP to correct the atmosphere absorption. Although the correction normally needs the NCEP data, it can also be implemented without these supplements by using global average value of water vapor and ozone. We used a QA flag to represent the influence of different ancillary data, i.e. a flag of QA=3 indicates NCEP data was used in the correction, while 2 means the average value was used..

The cloud mask flag is to tell the cloud fraction information. In aerosol retrieval, cloud detection and mask influence much to the quality of retrieved AOD [7] [8]. In our algorithm all 1 km pixels are evaluated pixel by pixel to identify whether the pixel is cloudy. For each retrieval, we give a specific QA value according to the fraction of cloudy 1 km x 1 km-pixels within each 10km x 10km retrieval. The computation of QA flag is performed using specific numerical thresholds of percentage of 1km cloud mask pixels that meet certain criteria within the aerosol retrieval area. So for each 10 km x 10 km pixel, up to 100 1 km cloud mask pixels are queried [3]. The value of cloud mask flag is set from 0 to 3, a retrieval with lesser cloudy pixels assigned a higher QA value. See detailed approach in the table 1 below.

Tab.1 SRAP Could Mask Flag

The proportion of Cloudy pixels	0% to 30%	30% to 60%	60% to 90%	>90%
QAC flag	3	2	1	0

Inversion convergence flag is used to describe the convergence of the iteration equations of the results. In our SRAP retrieval algorithm, Newton iteration algorithm was used in obtaining the solution of the model equations. When the retrieval is done, we put the iterative results into the equations and calculate the square (V) of the residual vector. The QA flag is assigned based on the value of V. A smaller V value means a better convergence, and the convergence of iteration equations indicate the accuracy and precision of AOD retrievals to some degree. The specific numerical thresholds and QA values are shown in table 2.

Tab.2 SRAP Inversion Convergence Flag

The value of V	v<0.05	0.05<v< 0.10	0.10<v< 0.15	0.15<v
QAC flag	3	2	1	0

2.2. Product Quality Flags

The product quality flags are used to indicate the quality of each retrieval including a homogeneity flag, a usefulness flag and a confidence flag.

The AOD Homogeneity flag is used to represent the homogeneity of the scene and the local variations which can used to identify the noisy data points. Noisy features introduced large local variations [8]. the standard deviation and the coefficient of variance in the square box of 50 km×50 km (25 pixels) are calculated. The first step is determining whether the retrieved value of the pixel is normal: if the retrieved AOD at 0.55μm is less than 0 or greater than 5 [5], it would be regarded as 'out of range' and are reported with QA flag = 0. For the second step, the 5 × 5 surrounding pixels around the valid retrieval were searched. We require at least 5 out of possible 25 retrievals [9], otherwise this homogeneity flag of the pixel would be set as 0. Only when the number is greater than 5, the standard deviation (σ) and coefficient of variance (CV) (coefficient of variance is calculated by dividing the standard deviation by the mean) of all valid AOD in the 5 × 5 box around that retrieval are calculated. Specific numerical thresholds of CV is set to determine the Homogeneity flag. See detailed approach in table 3.

Tab.3 SRAP AOD Homogeneity Flag

The value of CV	CV<10%	10%<CV < 15%	15%< CV < 25%	25%< CV
QAC flag	3	2	1	0

AOD Usefulness flag is given to indicate the usefulness of the AOD at 0.55μm. When a retrieval have more than one QA flags set 0 among the QA flags we described above, we could consider this retrieval of poor quality, and the AOD usefulness flag is assigned 0. Others will get a "1" flag meaning it's useful.

For those 'useful' pixels, the products are assigned a QA 'confidence' flag (QAC) that represents the aggregation of all the individual QA flags [5], the QAC flag is computed based on all the QA flags described above. The average of all QA values is calculated, the nearest integer of average is the final QAC value. There are 4 confidence levels, the QAC value ranges from 0(bad quality) to 3(good quality). Details of the QAC are given in table 4.

Tab.4 SRAP AOD QAC Flag

Value Definitions	Very Good	Good	Marginal	No Confidence
QAC flag	3	2	1	0

3. DATA AND ANALYSIS

In this paper, MODIS data aboard TERRA and AQUA overpassing Asia area from September 2011 to August 2012 was used to produce aerosol products which include AOD datasets and QA datasets.

Examples of the two main aerosol products over Asia are shown in Figure 1-2. Figure 1 shows the AOD of Asia area at 0.55μm, Figure 2 shows the QAC of the AOD product.

We can find that the AOD results in northeast and northwest China have higher quality, and the retrievals in southern Russian, west Asia also performed well. However, in east and Southeast Asia, the AOD shows poor quality, which may be caused by the complex aerosol and land surface environments in that area while the SRAP model does not fully account for these factors. In general, the AOD retrievals over homogeneous environment are of higher quality compared to those over heterogeneous environment such as cloudy regions and coastal regions.

4. VALIDATION

Our primary means of validation is comparison with equivalent measurements from AERONET ground-based sun/sky radiometers [7]. In the following validation, the current Level 2.0 (cloud-screened and quality-assured) direct-Sun dataset is used. More than 25 AERONET stations in Asia area were chosen to validate our results in September 2011 .

We compare the results of all retrieved points, points of QAC=3 and points of QAC > 1 with the results of AERONET stations, respectively. At the time of this analysis, MODIS aerosol products of one month (September 2011) were co-located with AERONET retrievals. Figure 3-5 shows the plots of co-located points over land at wavelengths 0.55μm. Figures 3 shows that the AOD is well-correlated between SRAP and AERONET with linear slope~ o.637, intercept ~0.095, and the correlation coefficients (R^2) reached 0.659. The scatter plots in Figures 4 and Figures 5 depict overall a better precision of SRAP AOD of different QAC(QAC=3, QAC >1) with AERONET-derived τ (a) with S 1~ 0.696-0.780, I c~ 0.080-0.058, and high R^2 ~ 0.702-0.751.Overall, the points with higher QAC value are with higher correlation coefficients, and as the assigned QA decreases, the bias becomes larger and the data become less well-correlated, although the level of correspondence remains high.

The statistics presented here show a good agreement between the QA values with the actual quality of retrievals. Validation against AERONET suggests that retrievals assigned higher QA value are anticipated to have higher precision and less uncertainty, the QA plan is significant for understanding AOD quality and retrieval status.

5. CONCLUSIONS

The study presents a quality assurance approach for China Collection 2.0 AOD retrieval over-land used SRAP algorithm. To validate the rationality of the presented QA plan, we compared the retrieved AOD of different QA values with AERONET AOD, respectively. The result presented here indicates that the QAC do provides a reference for user to estimate the validity of retrieved AOD. The China Collection 2.0 aerosol product with the QA procedures laid out in this study can be applied to produce a dataset with desirable qualities for different applications.

However, the QA plan cannot identify the various sources of error exactly. In future research, we may try to encompass more information not only to estimate the data quality but also to report the detailed condition of each process, furthermore, filters and correction would be developed to improve data quality according to specific sources of error when possible.

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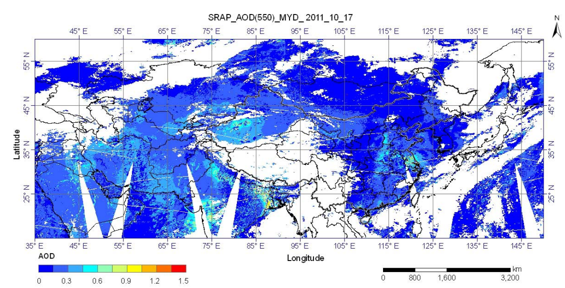

Fig. 1. 10 km AOD by SRAP algorithm on October. 22, 2011

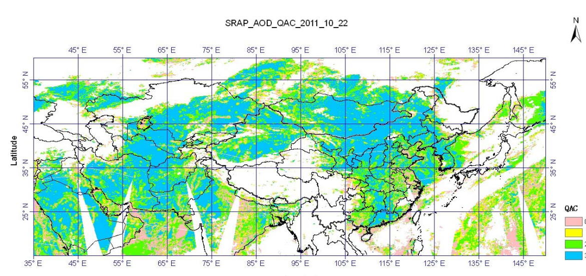

Fig. 2. QAC of 10 km AOD on October. 22, 2011

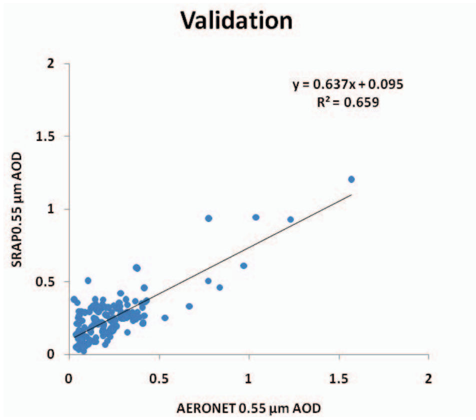

Fig. 3. Comparison between
all retrieved AOD and AERONET data

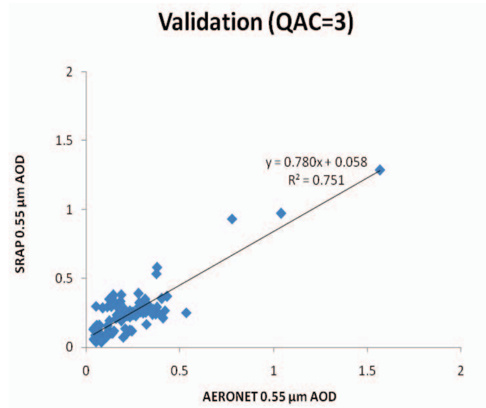

Fig. 4. Comparison between
AOD of QAC = 3 and AERONET data

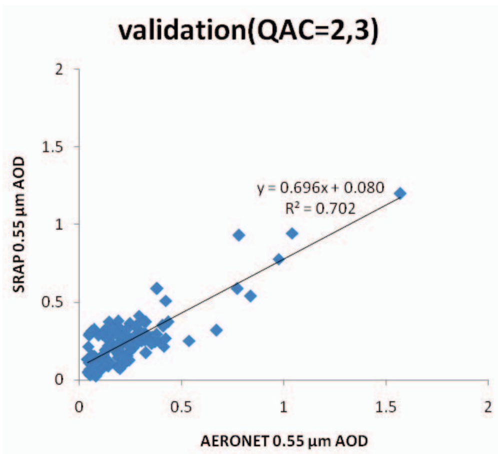

Fig. 5. Comparison between
AOD of QAC > 1 and AERONET data