Cloud screening and quality control algorithms for the AERONET database

Automatic globally distributed networks for monitoring aerosol optical depth provide measurements of natural and anthropogenic aerosol loading important in many local and regional studies as well as global change research investigations. The strength of such networks relies on imposing a standardization of measurement and processing allowing multi year and large scale comparisons. The development of the Aerosol Robotic Network (AERONET) for systematic ground based sunphotometer measurements of aerosol optical depth is an essential and evolving step in this process. The growing database requires development of a consistent, reproducible and system-wide cloud screening procedure.

1. Data quality checks.

If the aerosol optical depth is lower than -0.01 at any wavelength we do not accept the corresponding τ_a . We eliminate only measurements in that particular channel where τ_a <-0.01, while preserving τ_a in all channels that yielded optical depths higher than -0.01

Because measurements made during low sun elevation angles have a higher chance of cloud contamination (due to a decreased probability gap for vertically developed clouds) and in order not to unduly weight daily averages with the higher frequency data acquired during the Langley sequence, $\tau_a(\lambda)$ for air mass m > 5 are not considered in the screened data base.

2. Triplet stability criterion.

A measurement triplet taken with the CIMEL sun/sky radiometer consists of 3 measurements, each made 30 seconds apart over a total of a 1 minute period. We presume that the aerosol optical depth in the total atmospheric column should vary by less than 0.02 within one triplet for all wavelengths if the atmosphere is to be considered stable and cloud free. In other words, $(\tau_{max} - \tau_{min}) < 0.02$ for triplets defines τ_i^{good} (eliminate high frequency temporal unstability). When optical depth is high (biomass burning, extremely hazy conditions etc.) we allow triplet variability to be a maximum of $0.03\tau_a$. Thus, we accept measurements with a triplet variability of either 0.02 or $0.03\tau_a$ (whichever is higher).

3. Diurnal stability check.

If the standard deviation of the averaged aerosol optical depth at 500 nm (or 440 nm, if 500 nm is not available) for an entire day is less than 0.015 (after triplet variability screening), then we stop the screening and accept all the remaining measurements.

4. Smoothness criteria.

The smoothness criterion (of a time series) is based on limiting the root mean square of the aerosol optical depth second derivative with time. The first derivative yields the rate of temporal change (both negative and positive). The second derivative defines the variability of that tendency and, consequently, it is very sensitive to the local oscillations of optical depth caused by clouds: the average second derivative increases substantially in the presence of such oscillations.

$$(D2)^2 = \int_{t_1}^{t_2} \left(\frac{\partial^2 \tau(t)}{\partial t^2} \right)^2 dt \leq D^2_{critic},$$

where D^2_{critic} is a priori defined and corresponds to the maximum expected variability of aerosol optical depth.

5. Three standard deviation criteria.

In this step we check if any measurements fall outside of the 3σ range about the mean of τ_a(500 nm) as well as for the Angstrom parameter α (estimated using least-square regression in the 440-870 nm range), taken over the entire day (i.e. τ_a(500 nm) $\pm 3\sigma$ and $\alpha \pm 3\sigma$).

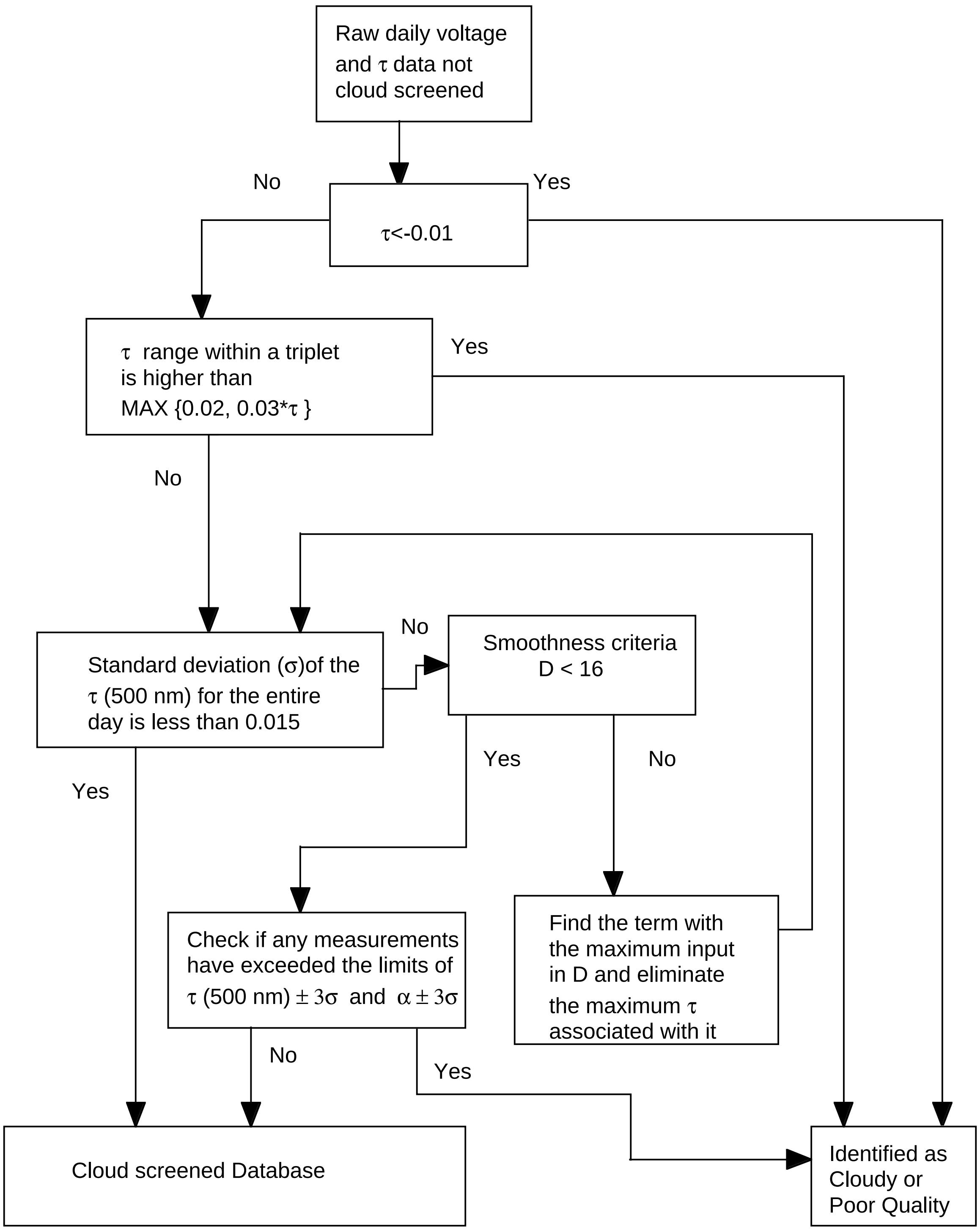
The principal conclusions drawn from this study can be summarized as follows:

1. A cloud-screening algorithm for the AERONET aerosol optical depth database was created, comprehensively tested and implemented. The corresponding flow diagram (Fig.1) describes the procedure. The two principal threshold criteria are both related to temporal variations of τ_a. One (the triplet stability criterion) is applied to short time period variability (one minute) and the other (smoothness criterion) to hourly and diurnal time period variations of τ_a.

2. The conditions imposed on aerosol optical depth diurnal variability are not excessive and do not strongly bias the computation of daily averages. The proposed algorithm can be applied to any site of the AERONET network inasmuch as the paradigm was developed across an ensemble of network sites and aerosol conditions.

3. Since temporal variations of τ_a are identified as cloud contamination, it is noted that this algorithm will screen some cases of variable aerosol plumes. Conversely, stable uniform cloud will pass the algorithm thresholds and be identified as cloud free. However, we emphasize that the original (non-screened) data base for AERONET sites is also available on the web page (http://aeronet.gsfc.nasa.gov:8080/). For more details, please, see a paper by A.Smirnov, B.N.Holben, T.F.Eck, O.Dubovik, and I.Slutsker, “Cloud screening and quality control algorithms for the AERONET database”.

Figure 1



Raw daily voltage and τ data not cloud screened
No
Yes
τ<-0.01
τ range within a triplet is higher than MAX {0.02, 0.03*τ }
Yes
No
No
Smoothness criteria D < 16
Standard deviation (σ)of the τ (500 nm) for the entire day is less than 0.015
Yes
No
Yes
Check if any measurements have exceeded the limits of τ (500 nm) ± 3σ and α ± 3σ
Find the term with the maximum input in D and eliminate the maximum τ associated with it
No
Yes
Cloud screened Database
Identified as Cloudy or Poor Quality