

Reply to Referee, Referee #3

We thank the Referee 3 for the thorough review of this manuscript and really appreciate the comments and suggestions. They have significantly contributed to improve the quality of the publication. Please find below a detailed response to the each of the general, specific and minor comments.

General Comments:

GC#1: Several aspects regarding the calibration are not convincing: the rapid changes in V0 suggest large uncertainty; the AOD diurnal cycle corrected by Cachorro et al method also suggests that the Langley procedure was not satisfactory in many cases/periods. Why only cases with AOD diurnal cycle >0.3 are subject to recalibration? This seems arbitrary and not consistent.

>> We agree with the Reviewer. The information explaining the high variability in V0 provided in the paper is clearly insufficient and also leads to unnecessary misleading interpretations. This point has been addressed by Reviewers #1 and #2 and we invite you to read the following responses:

GC#1 Reviewer1

GC#4 Reviewer2

GC#6 Reviewer2

We performed a first recalibration procedure, accounting for those events in which amplitude in AOD was >0.3 (see figure 1 as a case example). These events are characterized by extremely high AOD values that need to be corrected first. The second stage involves AOD < 0.3 (see fig. 1 referee 2 comment) and the last one is devoted to correct negative AOD values (when the AOD is very low; AOD<0.03). The threshold set in 0.3 is not arbitrary since it was selected according to the exhaustive data analysis performed in the validation procedure.

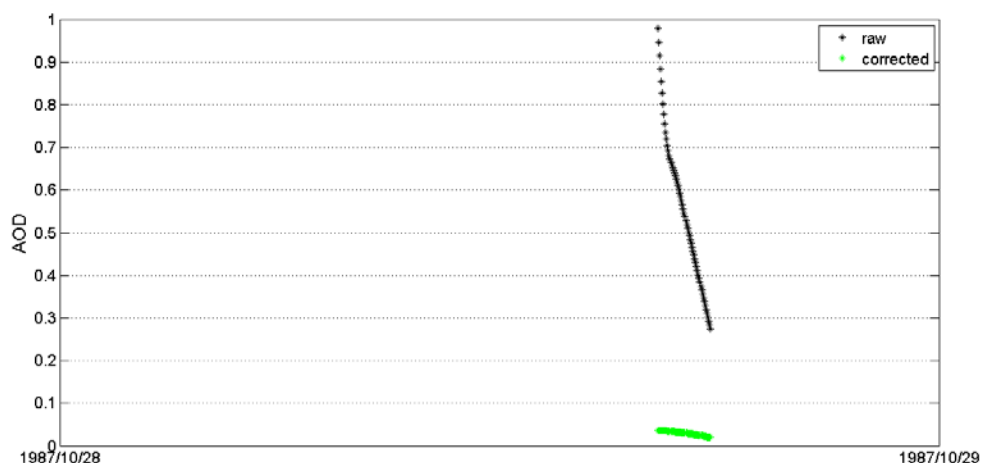


Figure 1: Case example of AOD correction after K-ciclo procedure (October 29th, 1987)

GC#2: Furthermore, it is well stated that the Langley plot method accuracy does not depend on AOD but on AOD stability. However the stability is much easier to guarantee under low AOD conditions (that is the reason why AERONET masters are sent to Izana and Mauna Loa). The condition of high correlation coefficient in the Langley plot does not completely exclude temporal AOD variations (see Marengo, 2007): “On the assumption of a constant atmospheric optical depth τ , the plot of $(\ln I)$ versus m is a straight line, and its y-intercept represents $(\ln I_0)$: $\ln I = \ln I_0 - m \cdot \tau$. However, the contrary is not necessarily true: obtaining a straight line in the plot of $(\ln I)$ versus m does not allow one to conclude that τ is constant, nor that the y-intercept is $(\ln I_0)$.” That is the reason behind the need of a number of Langley plots close in time to perform adequate calibration. However, the exhibited rapid changes in V_0 for the astronomical device do not seem to allow this approach.

>> We totally agree with this comment. We also consider that it is quite important to have the greatest number of Langleys close in time to correctly calibrate the instrument, mainly when the instruments is subject to frequent changes as occurs with Mark-I. That’s why we have performed a “quasi-continuous” Langley calibration procedure in which, Langley calibration is performed each day characterized by suitable AOD conditions, being the calibration in the rest of cases estimated by means of a smoothing process (corrected later for calibration problems). Thus, we have one calibration value for each day of the whole period, assuring the adequate number of V_0 ’s to guarantee the calibration performance.

GC#3: The claimed AOD accuracy of 0.03 must be better justified. The large diurnal cycles and negative AOD’s make it very suspect. Even if proved true, it would be in any case much larger than the accuracy of PFR and Cimel, which is below 0.005 for master instruments (Holben et al., 1998), especially for visible and near infrared channels. The

0.01-0.02 accuracy is for field instruments and would be insufficient for a high altitude location with mean AOD of 0.05 or less.

>> We recognize that the claimed value of 0.03 for the instrument's accuracy might be rather speculative. In AERONET, the AOD absolute errors can be derived from Beer's law by error propagation theory, considering that the uncertainty derived from the calibration is, in general, much larger than the other terms. For masters, the uncertainty in AOD is retrieved by means of V0 stability and, for field instruments, is also included the consequence of the calibration transference from the master, set in $\pm 0.01-0.02$. In our case, it is not possible to adequately perform a propagation errors technique to estimate the instrument accuracy because the complexity of the observation process and because our instrument is changing very frequently (V0 changing) and has suffered important changes in the past (replacement of mirrors, electronic components, gains in the photomultiplier ...) which have not been adequately documented. It is important to understand the inability to account for several effects, like the effect that the potassium cell has on the scattered and transmitted beams, to quantify the amount of parasite light in the transmitted component as a result of scattering inside the cell, the effect of the magnetic field or the presence of two external mirrors (frequently replaced) to collect the sunlight (manufacturing defects? Transmission? Cleaning frequency?).

As a result, we have assessed the instrument performance by means of exhaustive comparison study between Mark-I and two references as GAW-PFR and AERONET-Cimel, both with an uncertainty well defined. We consider that the 12 and 11 year comparison using PFR and AERONET data, respectively, can be used to assess the instrument performance, however we agree with the referee and we admit it is not enough to estimate Mark-I accuracy. For this reason we will remove in the text all the references to Mark-I precision and only references for the discrepancies with reference instruments will be mentioned.

GC#4: The dataset must be shown: a short time series of about 1 week from both Mark1 and PFR would allow a visualization of the data quality. Scatter plots of Mark1 and PFR/Cimel data are needed.

>> Scatterplots have been included for every year of the intercomparison with PFR and Cimel (see referee 1 CG#1 and referee 1 figure 8). The short time series is presented in Fig. 2. We can see a good agreement between Mark-I and PFR/AERONET in cases of low and high aerosol content but it is clearly visible the fictitious diurnal cycle affecting Mark-I data. However, it seems that PFR and AERONET level 2 data are also affected during Oct 29th and 30th. It is clear that the fictitious amplitude in AOD as a result of calibration problems is a common problem in sun-photometry and it is not only restricted to Mark-I.

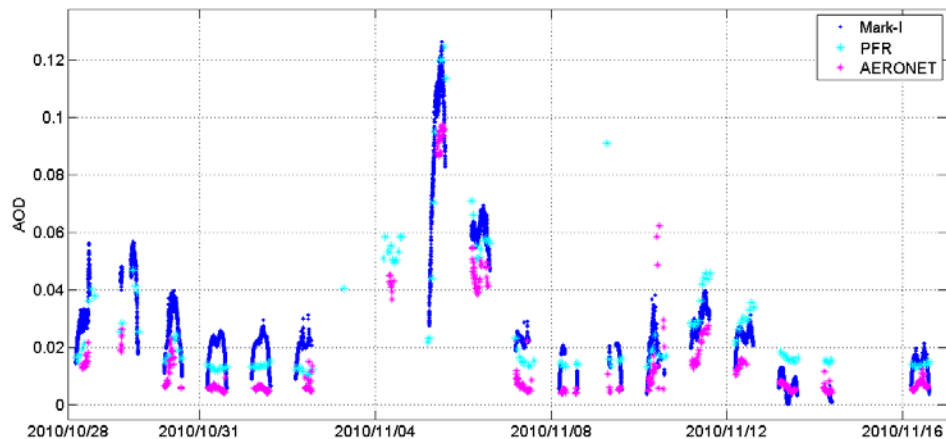


Figure 2: 20 days evolution of AOD extracted from Mark-I, Cimel-AERONET and GAW-PFR.

GC#5: The cloud-screening is a key issue in AOD determination and must be explained. Thin cirrus clouds for instance are difficult to detect with ordinary sun photometers. Nothing is said about this issue and it could introduce significant AOD error (Chew et al, 2010).

>> We fully agree. Please read the GC#4 Reviewer#1.

Specific comments

SC#1: The jump in the minimum AOD values after Pinatubo seems to be larger than 0.02. Such value is actually very small as compared to those reported by other authors. How was this estimation made?

>> Please, see Reviewer# 1 GC#3. This estimation was made as the difference between the mean value in 1992 and the decadal AOD mean. A new approach has been performed now using months not affected by dust intrusions (winter months), median values, instead of means, and a subsequent transference of AOD anomalies from ~770nm to 500 nm.

SC#2: Gaps in the dataset are not necessarily a problem in trend analysis if an adequate method is chosen.

>> We select only Winter (DEF) data, and wintertime data is only available from 1984 on.

SC#3: The AOD decadal trend of -0.047 seems huge compared to typical AOD of 0.05 at Izana.

>> Answered in Reviewer# 1 GC#3.

Minor comments

MC#1: P4094, L10: "mirror"

>> Done

MC#2: P4101, L22:"affect"

>> Done

MC#3: P4097: Holben 2001 is not adequate citation for GAW network.

>> Done

MC#4: P4098, L7: "have"»"has"

>> We can't find in this page and line "have". Maybe there is an error in the page number.

MC#5: Conclusions: remove "very" preliminary. "Preliminary" is enough.

>> Done

MC#6: P4108, L12: "mirror"

>> Done

MC#7: P4109, L2: "compared with". L25: "is required"

>> Done