Response to Editor and Referee#1

We would like to thank the editor and Referee#1 for the constructive comments and suggestions. We are grateful to them, for this revision has benefited much from their reviews. We have made major revisions and present the item-by-item response to the editor and referee#1's comments.

Response to Editor

Comments

One of the referees still has some concerns, especially on the quality of Level 1.5 AERONET data you use. Please consider the comments from this referee seriously and make necessary revisions. Actually, this issue has been raised in the discussion status of the manuscript.

Response

Thank you very much for your comments. We changed to use only level 2.0 data which have been updated at three stations recently. All the results and figures have been modified in the revised manuscript. We also estimated the uncertainty in AE again using the method recommended by Referee #1. Then we re-plotted Figure 3 and Figure 4 with linear scales using only level 2.0 data. Please see the revised manuscript in detail.

Response to Anonymous Referee #1

General Comment

(1) The authors have used both level 1.5 and level 2 AERONET data even though level 1.5 data are of significantly poorer quality. Since the AERONET data are the primary data used in this study it is strongly recommended that only Level 2 data be analyzed to maintain consistent and high quality data throughout the paper. At the minimum you need to state very clearly on Page 7, after lines 11-13 that the L1.5 data is of poorer quality and that significant instrumental, calibration and cloud contamination issues may exist in the L1.5 data (note that additional cloud screening and quality control is done from L1.5 to L2). Additionally if you made any quality control screening of your own to this L1.5 data then you need to clearly specify what data checks were implemented in this study and give detailed steps of what was done.

Response

Thank you very much for your comments and suggestions. We followed your suggestions and used only level 2.0 data to maintain high quality data. We have been able to obtain the new level 2.0 data from http://aeronet.gsfc.nasa.gov/new_web/file_help.html. The level 2.0 data have been updated to December 2012 at QOMS_CAS and Pokhara, and May 2011 at EVK2-CNR. There are enough level 2 AERONET data to analyze the aerosol optical properties now. We recalculated all the results in this paper. No significant changes occurred in the results, although some of annual, monthly and diurnal values changed a little. Using only level 2.0 data, the annual mean changed from 0.06 to 0.05 at QOMS_CAS, but did not change at EVK2-CNR and Pokhara. Some of monthly mean and median values have changed a little, however, the seasonal variation pattern has not changed. Using only level 2.0 data, we had fewer available observations in the afternoon during summer due to heavy precipitation at EVK2-CNR and Pokhara. Meanwhile, the values of the absolute and relative diurnal variation ranges have also changed, but the diurnal patterns have not changed in each season at three stations. We have revised all the results marked in blue in the revised manuscript. Please see the revised manuscript in Section 3.2, 3.3 and 4 in detail.

(2) It should be noted in the paper that Angstrom Exponent (AE) has large uncertainty at low AOD. It is well known that errors in AE increase dramatically when AOD is low, especially as low as they often are at the QOMS_CAS and EVK2-CNR sites. The equation that the authors used to estimate the error in AE from Hamonou et al. (1999) does not account for the magnitude of the AOD in the uncertainty estimate and therefore gives a falsely low value of the actual AE uncertainty for the low AOD sites, and only gives a reasonable estimate for the Pokhara site (high AOD). A more accurate uncertainty estimate for AE using equation 6 in Kato et al. (2000; JGR) should be applied, as this accounts for the magnitude of the AOD. Note that Kato et al. call the Angstrom Exponent the Lundholm Exponent, however they are equivalent (see Equation 5 in the Kato et al. paper).

Response

Thank you very much for your comment and suggestion. We are very grateful for your recommendation for a more suitable method. We followed your suggestions and used the equation 6 in Kato et al. (2000) to estimate the uncertainties in AE. There are large uncertainties in AE with quite low AOD observations at QOMS_CAS and EVK2-CNR. We added this estimation of AE uncertainty in Section 2.2 in the revised manuscript. The sentences are 'The equation $\Delta AE = \left[\frac{\sum_{i=1}^{n} e_i^2}{(n-2)\sum_{i=1}^{n}(ln\lambda_i - \overline{ln\lambda})^2}\right]^{\frac{1}{2}}$ can be used to estimate the uncertainty in AE, where e_i is the error of the Angström relation, n is the number of wavelengths λ_i used to fit the Angström relation, and $\overline{ln\lambda}$ is the average of logarithm of the wavelengths (Kato et al., 2000). The ratio $\frac{\epsilon_i}{AOD_i}$ can be used to represent e_i, and the uncertainty in AOD of 0.01 for ϵ_i recommended by Kato et al. (2000) is used. The equation, accounting for different kinds of errors in AOD, can help us obtain the usual maximum error for AE. In each measurement, the uncertainty in AE 440-870 nm can be estimated using 870, 675, 500 and 440 nm AOD data. Table 2 shows the monthly median uncertainties in AE. Uncertainties in AE at QOMS_CAS and EVK2-CNR are higher than those at Pokhara, because uncertainties in AE increase dramatically when AOD is as low as measurement uncertainty. Therefore, there are large uncertainties in AE with quite low AOD observations.'.

In the analysis of seasonal variations, using AE and FMF together, we deduced the possible aerosol type. Meanwhile, the effect of vegetation fires or dust from previous studies also showed similar results to our study. Although there are large uncertainties in AE with quite low AOD observations, we can deduce the possible aerosol type reasonably.

In the analysis of diurnal variations, we also improved the discussion in Section 3.3.3 (Page 19 line 28 and Page 20 line 1-13) of the revised manuscript: 'The diurnal variations of AE can just reflect the relative aerosol size qualitatively, and cannot show the range of particle size exactly. A possible explanation of the larger relative daytime variation ranges at QOMS_CAS and EVK2-CNR may be due to greater uncertainties in AE. The calibration error partly resulting from air mass factor in AOD measurement may influence the error for AE (Wagner and Silva, 2008), when AOD is quite low. Although the large uncertainty of AE in a region with such low AOD makes the detection of daytime variation difficult, the consistent daytime variation at QOMS_CAS and EVK2-CNR may indicate the presence of relatively larger size aerosol at noon or in the early afternoon. The direct measurement of aerosol size distribution observations at the Nepal Climate Observatory at Pyramid (collocated with the EVK2-CNR AERONET station) have found that aerosol size grows during late morning and early afternoon, while aerosols in the accumulation mode peak between noon and early afternoon in all seasons (Venzac et al., 2008). These direct observation results are in accord with our results.'

Kato, S., Bergin, M. H., Ackerman, T. P., Charlock, T. P., Clothiaux, E. E., Ferrare, R. A., Halthore, R. N., Laulainen, N., Mace, G. G., Michalsky, J., and Turner, D. D.: A comparison of the aerosol thickness derived from ground-based and airborne measurements, J. Geophys. Res.-Atmos., 105, 14701-14717, doi:10.1029/2000JD900013, 2000.

Wagner, F., and Silva, A. M.: Some considerations about Ångström exponent distributions, Atmos. Chem. Phys., 8, 481-489, doi:10.5194/acp-8-481-2008, 2008.

(3) Figures 3 and 4 are two of the most important in the paper yet the data on the linear scales (left side panels) compress the data into the bottom of the plots making them almost useless. I strongly suggest removing the 99% and 1% percentile values in the plots (these can be listed in a table if you feel they are valuable). I also suggest using a lower y-axis maximum value of AOD for the QOMS_CAS and EVK2-CNR sites linear-scale plots to allow the reader to see the monthly variations better.

Response

Thank you very much for your comment and suggestion. We followed your suggestions and plotted AOD figures with linear y-axis scales using a lower y-axis maximum value. There are no extreme high values using only level 2.0 data in the revised manuscript now, while the y-axis maximum value of AOD is also lower. Meanwhile, the data will not be compressed into the bottom. If we don't remove the 99% and 1% percentile values, the seasonal variations can be also seen clearly. Therefore, we don't remove the 99% and 1% percentile values in the plots. To show figures more clearly and concise, we removed the symbols which represent the 99% and 1% percentile values, maximum values and minimum values. Please see Figure 3 and Figure 4 in the revised manuscript.