Referee # 1

The authors are grateful to the distinguished referee #1 for reviewing the manuscript and also for him/her valuable comments. We have tried to apply all the comments and answer all the questions that had been asked by the referee #1.

General Comments:

This study retrieves some aerosol optical properties over Zanjan, northwestern Iran, giving extra emphasis on aerosol polarized phase functions and single scattering albedo (SSA) by examining their dependence on Angstrom exponent and refractive index in the atmosphere. The results of the study are clear and the figures of high quality, however, the discussion is rather poor and the objective of the paper is not well established. These are the main drawbacks, along with the absence of a conclusion section, that do not allow the publication of the manuscript in AMT without strong revisions in the text and results/discussion sections mainly. The authors must highlight the innovation of their research in a more clear way as well as the methodology approach, i.e. what analysis do they follow in order to justify their method for identification of different aerosol types. From the figures, I can see that the qa(max) from the author's new approach, in combination with AOD, SSA and α can be used for identifying different aerosol types over this arid environment.

We have tried to discuss the results and highlight our research innovation in a clear way, based on the referee's comments. Section 2 (Instrumentation and Data) has been added to gather all the information about the instrumentation and data recordings. In section 4 (Results and Discussion), Figure 1, 2, and 10, and Table 3 have been added to the manuscript; also Table 2 has been changed. Finally a conclusion section is added to the manuscript.

The General changes in this version of manuscript are listed in the following:

- **Abstract:** Some sentences have been added to the abstract as the referee #1 specific comment.

- **Introduction:** We re-wrote the introduction section as the referees' comments**.**

- **Instrumentation and Data:** This section has been added in P2L64 to P2L98 to gather all the information about the instrumentation and data recordings as the referee #1 specific comment #2.

- **Method:** This section has been changed as follows:
    1. First paragraph has been added for describing aerosol optical depth and Ångström exponent retrievals.
    2. Second paragraph has been changed (P3L27 to P3L41) and added some sentences (P3L41 to P3L48) to insert some descriptions about spheroid model.
    3. Table 1 has been changed (rows #8 and 9).

- **Results and discussions:** The results and discussions merged with together in section 4; Figure 1 has been added to the manuscript to check the aerosol shape sensitivity of the parameters. Also figure 2 has been added to compare AERONET and our retrievals for single scattering albedo. Table 2 has been changed to give more detail information from the measurements and categories what that have been emphasized in the text. The correlation coefficients and equations for the linear fits are added to Figs. 5 and 7. Also, Figure 9 has been changed. Furthermore root mean square distance (RMSD) of data points from the curves in Fig 9 have calculated and summarized in Table 3. Figure 10 has been added to show the sensitivity of the polarized phase function to the imaginary part of the refractive index.
- **Conclusions:** This section has been added to the manuscript in P9L8 to P9L60.

- Finally some references have been added to the manuscript as follows:

1. Basart, S., Pe´rez, C., Cuevas, E., Baldasano, J.M., and Gobbi, G. P.: Aerosol characterization in Northern Africa, Northeastern Atlantic, Mediterranean Basin and Middle East from direct-sun AERONET observations, Atmos. Chem. Phys., 9, 8265-8282, doi:10.5194/acp-9-8265, 2009.

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3. Boselli, A., Caggiano, R., Cornacchia, C., Madonna, F., Mona, L., Macchiato, M., Pappalardo, G., and Trippetta, S.: Multi year Sun photometer measurements for aerosol characterization in a Central Mediterranean site, Atmos. Res., 104105, 98110, doi:10.1016/j.atmosres.2011.08.002, 2012.

4. Bösenberg, J., and Matthias, V.: EARLINET: a European aerosol research lidar network to establish an aerosol climatology, MPIReport 348, Hamburg, Germany, 2003.

5. Burrows, J. P., Richter, A., Dehn, A., Deters, B., Himmelmann, S., Voigt, S., Orphal, J.: Atmospheric remote-sensing reference data from GOME-2. Temperature-dependent absorption cross sections of O3 in the 231794 nm range, J. Quant. Spectrosc. Radiat. Transf., 61, 509-517, 1999.

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7. Giles, D. M., Holben, B. N., Eck, T. F., Sinyuk, A., Smirnov, A., Slutsker, I., Dickerson, R. R., Thompson, A. M., and Schafer, J. S.: An Analysis of AERONET Aerosol Absorption Properties and Classifications Representative of Aerosol Source Regions, J. Geophys. Res., 117, D17203, doi:10.1029/2012JD018127, 2012.

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9. Gobbi, G. P., Kaufman, Y. J., Koren, I., and Eck, T. F.: Classification of aerosol properties derived from AERONET direct sun data, Atmos. Chem. Phys., 7, 453-458, doi:10.5194/acp-7-453, 2007.

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11. Kaskaoutis, D. G., Kambezidis, H. D., Hatzianastassiou, N., Kosmopoulos, P. G., Badarinath, K. V. S.: Aerosol climatology: dependence of the °Angstr¨om exponent on wavelength over four 70 AERONET sites, Atmos. Chem. Phys. Discuss., 7, 7347–7397, 2007.

12. Lee, J., Kim, J., Song, C. H., Kim, S. B., Chun, Y., Sohn, B. J., and 75 Holben, B. N.: Characteristics of aerosol types from AERONET sunphotometer measurements, Atmos. Environ., 44, 31103117, doi:10.1016/j.atmosenv.2010.05.035, 2010.

13. Mielonen, T., Arola, A., Komppula, M., Kukkonen, J., Koskinen, J., de Leeuw, G., and Lehtinen, K. E. J.: Comparison of CALIOP level 2 aerosol subtypes to aerosol types derived from AERONET inversion data, Geophys. Res. Lett., 36, L18804, doi:10.1029/2009GL039609, 2009.

14. Omar, A. H., Won, J.-G.,Winker, D. M., Yoon, S.-C., Dubovik, O., and McCormick, M. P.: Development of global aerosol models using cluster analysis of Aerosol Robotic Network (AERONET) measurements, J. Geophys. 5 Res., 110, D10S14, doi:10.1029/2004JD004874, 2005.

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16. Winker, D. M., Hunt, W. H., and McGill, M. J.: Initial performance assessment of CALIOP, Geophysical Research Letters, vol. 34, no. 19, Article ID L19803, 2007.

Specific comments:

1. **The authors may be more informative in the abstract section about the instrumentation that they used and the significance and/or applicability of their method to aerosol scattering studies.**

   The abstract has been revised and more information concerning the instrumentation and obtained results have been added to it.

2. **In the introduction section a paragraph describing the phase function properties, the usefulness of its use for aerosol studies, as well as the other aerosol properties used in the current analysis would be useful. The instruments and the experimental procedure, briefly described in the introduction, must be discussed more analytically (also including references) in the next section (Instrument, analysis and method), or even separating them further. However, the data recording cannot be discussed together with the results. According to my opinion, this structure will benefit the manuscript.**

   - Polarized phase function properties and its usefulness for the aerosol studies are added in P2L26 to P2L40.

   - The other aerosol parameters have been discussed in P2L5 to P2L20.

   - The instruments and the experimental procedure are discussed in P2L41 to P2L57.

   - Furthermore, the manuscript structure has been changed as suggested in this comment.

3. **The differences between SPM and SPP instruments are not so clear. Are they used for different retrievals and which are these? This part of the manuscript needs better clarification especially for the readers who have not used these techniques.**

   SunPhotoMeter is abbreviated as SPM which is the instruments that measure the solar radiance in Sun mode (direct measurements on the sun radiance) and Sky mode. The sky mode consists of two main sub-modes 1) Solar principle Plane (SPP) and 2) Almucantar. AERONET network,

using Almucantar measurements to retrieve aerosol optical and physical properties, but we used SPP mode recordings in the manuscript. The abbreviation is addressed in P2L4 and P2L44 to P2L48 in the manuscript.

4. **There is no discussion about the method for the α retrievals (I suppose that the authors use the least squares method) as well as typical errors in the calculation of α occurred due to curvature of the ln AOD vs. ln α plot. Why the authors plot the AOD at 870 nm and not that at 500 nm, which is more commonly used? I suppose because AOD870 has a better response on dust changes, but this has to be mentioned.**

   The method for the α retrieval is discussed in P3L12 to P3L17.

   The reasons for using aerosol optical depth at 870 nm are added in P2L48 to P2L50 and P2L83 to P2L86.

5. **The annual variability of the aerosol characteristics is rather poorly discussed. The authors are mainly based on citing the previous results obtained over Zanjan. In that case, which is the scope and the innovation of the current analysis? Furthermore, a clear seasonal pattern is observed, which has to be discussed thoroughly. The seasonality of the aerosol properties and types must be also taken into consideration when discussing the results of the next figures also.**

   In our previous works (Bayat et al., 2011; Masoumi et al., 2013) this issue has been discussed in detail. In this work, we mostly focused on the potential of polarized phase function, q_a, in categorization of the atmospheric aerosols as appeared in P5L29 to end of the section. The seasonal variations of aerosols types are appeared in P5L12 to P5L28 in this version.

   Also the seasonality of the aerosol properties and their types has been taken into consideration when discussing the results of the next figures.

6. **How significant is the nearly constant anthropogenic aerosol background? What's about its contribution to the total AOD? Can be estimated via the current methods? I think that the authors have not been involved with such an analysis and this statement seems to be fairly justified.**

We did not go to detail analysis of the background atmospheric pollution. Just based on over observations with the SPM we are reporting the results. In this version we mentioned that. The discussion about Fig 3 (Fig1 in previous version) now appears in P5L12 to P5L28. The sentence that mentioned by referee is not brought in the current version.

7. **The agreement in the SSA retrievals between the almucantar AERONET method and the current one cannot be seen via Fig. 1. A new graph correlating them, even for different values of AOD and α, seems to be necessary. Also, the bias and the significance of the correlation need to be examined and provided in the analysis.**

   Figure 2 is added into the manuscript and discussed in P4L35 to P5L6.

8. **Authors provide a combination of scatter plots between qa(max), AOD, SSA, α without a clear objective of what they are looking for, i.e. which is their objective in their current research. Although the figures are of high quality and informative, the discussion of the results is rather poor. Authors just discuss some positive or negative correlations between the examined parameters, which are obvious to anybody. However, they do not provide explanations about the physical meaning of these correlations and the type of aerosols that dominate the Zanjan atmosphere, but they only refer to previous works. The critical for the current analysis is to discuss the physical meaning of the correlations shown in the graphs with the aerosol field over Zanjan. In case that this is the main objective of the work, it must be underlined from the beginning. Furthermore, there is no connection between the current results and other studies dealing with identification of aerosol types. All the above are the main drawback of the work; otherwise it's an interesting study providing new methods for discrimination of aerosol types over an arid environment.**

   Classification of different types of aerosols in the atmosphere of Zanjan, using the polarized phase function and its correlations with α, τ_a, ω_0 are the main objectives of this paper that has been addressed in P5L62 to P5L75, P5L76 to P5L88, and P5L89 to P6L14, respectively. In current manuscript the purpose has been underline from the beginning of the paper. In this version, we have tried to explain the physical meaning of the correlations and the type of aerosols that dominate in the atmosphere of Zanjan in section "Results and Discussions". Table 3 and also Figure 10 are added to this section. The detail of reported parameters for the

atmospheric aerosols of the atmosphere has been discussed in table 2. Also a Conclusion section has been added in the current version of the manuscript.

9. **In Figure 7, the three curves for different values of refractive index are very close to each other for low values of α. So, the statement that for lower α the data points match more the m3 (dust) curve is not so valid. I can see several "dust points" above the m1 (anthropogenic) curve, the reason is clearly explained, and far away from the "dust" curve. These discussions must be more coincident to the results.**

   Many thanks for this comment, this discussion almost has been revised completely and appeared in P7L13 to P8L10. It is also mentioned that for $\alpha < 0.6$ the technique can not distinguish the type of the particles.

10. **A separate conclusion section is absolutely necessary, highlighting the scope and achievements of the current work. It is surprisingly that Conclusions are absent from a scientific article.**

    The conclusion section has been added to the manuscript in P9L8-P9L60.