Answer to RC C3989, 'Comments', Anonymous Referee #1

Dear Referee #1

We appreciate your useful comments and proposed corrections. We corrected the text and added a new text and figures according your suggestions. Our revisions and comments see below as answers on your comments and proposed corrections.

Referee #1. General comments.
1.R#1. However, presentation of this data is not sufficient.
G. Milinevsky. We rearranged and corrected the text to improve presentation of results in form of discussion of aerosol behavior illustrated by figures.

2.R#1. Authors describes data from Ukraine and Belarus, which is suggested by title. They are concentrated rather on Kyiv data and related other data to them. I can understand that because main authors come from Kyiv. Title suggests rather analysis of data form whole region instead of comparison to Kyiv.
GM. We changed the title to better correspond to the paper content and concentrated on analysis of aerosol season behavior over Kyiv and few urban/industrial areas of Ukraine. New title is: "Aerosol seasonal variations over urban/industrial regions in Ukraine according to AERONET and POLDER measurements"

3.R#1. I suggest revision of the paper in that way to obtain: introduction, description of instrumentation and measurements sites/region, results, discussion and conclusions.
GM. We revised and rearranged the paper in proposed way. To explain that we add the text in Introduction Section:

"A preliminary analysis of general aerosol parameters for the East European region has been done by the authors in (Bovchaliuk et al., 2013). In development of that previous study in this paper we concentrated on analysis of seasonal aerosol properties and dynamics over the urban industrial areas of Ukraine based on AERONET sites and POLDER/PARASOL satellite imaging spectroradiometer data. Unlike the previous paper (Bovchaliuk et al., 2013) we analyse the AOD variations for total AOD and separately for fine and coarse modes of AOD, SSA, and refractive index for AERONET sites in Ukraine and expand analysis of POLDER data to a larger number of urban/industrial areas. The purpose of our analysis is to evaluate what kind of aerosol dominates in specific season and to find indications of the possible aerosol sources. In Section 2 we describe the instrumentation and measurement sites/regions. The results of seasonal variations of aerosol parameters are given in Section 3. In Section 4 we discuss and compare the results for individual sites and regions with conclusion remarks in Section 5."

4.R#1. I suggest to group results rather by product then by sites. That means description of seasonal variability of AOT at selected sites/region, variability of aerosol volume concentration (like Figure 5), seasonal variability of SSA and seasonal variability of fine and coarse aerosol. Then discuss differences between sites and regions and conclude them.
GM. We group results and discuss them according your suggestion.

5.R#1. It seams that discussion of obtained results is weak part of the paper. Sentences like “parameter varies form year to year or month to month” are insufficient. Why it varies.
GM. We expanded the discussion part significantly and removed insufficient sentences.

6.R#1. Make some analysis, even case studies. In general presented pattern of seasonal variability of AOT in Central and eastern Europe is known, see cited data form Belsk and Minsk

as well as data presented by Zawadzka et al. (2013) in Atmos. Env. 69, figure 4 in cited work of Israelevich and data from Kasprowy Wierch (Uscka-Kowalkowska, 2013, Atmos. Res. 137, pp 175-185).
GM. We have analysed obtained results in order to have understanding of the specific aerosol behavior in studied region. Discussion includes consideration of the results of seasonal variability in the Eastern Europe published in papers mentioned above.

7.R#1. Authors should find aerosol types or aerosol sources responsible for such pattern. What kinds of aerosol dominate in each part of the year? Please analyze spectral dependence of presented parameter to find potential types of aerosol or make simple cluster analysis of AOT and Angstrom exponent to find aerosol types.
GM. In order to find aerosol types responsible for obtained pattern we made analysis of SSA and refractive index spectral dependence. We consider also scatter plots of Angstrom exponent versus AOD, Absorption Angstrom Exponent (AAE) versus Extinction Angstrom Exponent (EAE) (440-870 nm), SSA (440 nm) versus EAE (440-870 nm), and EAE (440-870 nm) versus extinction AOD Total (440 nm). These relationships are based on the results published by Dubovik et al. (2002); Omar et al. (2005); Russell et al. (2010); Boselli et al. (2012); Yoon et al. (2012); Giles at al. (2012); Pavese et al. (2012). We divide data by specific months when the AOD maximum values appeared and separate intermediate months with small amount of aerosol to make simple cluster analysis. See new Figs. 6N, 7N below.

R#1. Minor comments
8.R#1. Change title or rearrange text so that title should match the text. (see general comments)
GM. We have changed the title to better match the text. See 2.R#1 above.

9.R#1. Abstract seams to be to long.
GM. Abstract has been shortened and corrected.

10.R#1. Please include general decryption of the region and potential sources in Introduction and remove from chapter 2 (lines 7 to 17 p. 10735).
GM. We have included the general decryption of the region and potential sources in Introduction and rearranged the text (mentioned text has been removed chapter 2) according this comment. Also we give information on AERONET sites and regions on POLDER investigation in new Table 1. The map with location of the AERONET sites and investigated areas covered by POLDER measurements provided in new Fig. 1N.

"In a previous analysis (e.g., see Chubarova, 2009; Giles et al., 2012; Pietruczuk and Chaikovsky, 2012; Zawadzka et al., 2013) the East European region is considered as a source of urban-industrial aerosols according to the general aerosol type classification by Dubovik et al. (2002). Indeed, there are many existing and potential aerosol pollution sources in this region including Ukraine territory: intensive transport and agriculture, heavy industry, open steppe fields, as well as exploitation of open mines. Besides, this region is characterized by numerous forest, grassland and peat wildfires, and also we can sometimes consider this region as a source of biomass burning aerosols (Barnaba et al., 2011; Witte et al., 2011; Bovchaliuk et al., 2013). The steppe regions of Southern Ukraine are also sources of periodical dust storms (e.g., Birmili et al., 2008).

The investigated region is mostly flat terrain with altitude difference between the Center and East of Ukraine of about 300 meters a.s.l.. The developed heavy industry is concentrated in Donetsk, Lugansk, Kharkov city areas, industry and open mines are in the East-Central Ukraine (Dnepropetrovsk, Kirovograd areas), and steppe is located in the South-East of Ukraine. In the West of Ukraine altitude of the terrestrial surface increased to about 400 meters a.s.l. with mountains up to 2000 meters high in the far west. This part of Ukraine has less developed industry (Rivne, Lviv city areas). Therefore the potential urban-industrial aerosol sources are concentrated in East, East-Central and South East regions. For big cities like Kyiv and Kharkov the large potential source of aerosol is car traffic. For example, the concentration of cars in the central part of Kyiv city sometimes reached 800 cars per one kilometer producing ~90% of all atmosphere pollution in the area."

11.R#1. AERONET products are quite known and should not be defined like Angstrom exponent (end of p. 10735).
GM. We shortened description of AERONET products.

12.R#1. Please distinguish parameters downloaded from AERONET site from that calculated by authors. Please list used parameters, they errors and level of used data. Do not repeat it in the text. Presented description is a little bit it to long.
GM. We present the level of used data, describe their errors, and explain which parameters were downloaded from AERONET site and which ones were calculated. Text added:

"For aerosol dynamics analysis in this paper, we extracted the aerosol Version 2 Direct Sun Algorithm Level 2.0 parameters from AERONET data base: daily and monthly weighted averages of AOD 440 and 870 nm, and Ångström exponent (440–675 nm) and (440–870 nm). The almucantar retrievals Inversion Products level 2.0 and level 1.5 were obtained from AERONET data base: Level 2.0 size distribution and volume concentration, Level 1.5 single scattering albedo and complex index of refraction, Level 1.5 absorption AOD and extinction AOD. To determine seasonal behavior we calculated monthly averaged parameters through 2008–2013 years for Kyiv site, 2002–2013 years for Minsk site, and Nov 2011–Aug 2013 for Lugansk site. Ångström exponent (675–870 nm) was calculated from Level 2 AOD data."

13.R#1. Description of relation of Angstrom exponent to size distribution it a little bit to long too and unclear. Please get some literature data to prove that small Angstrom is related to large particles and large Angstrom to fine mode particles. On the other hand author can deduce that from Junge size distribution.
GM. We describe the relation of Angstrom exponent to size distribution shortly with references. See text below:

"The Angstrom exponent is the parameter that is related to the aerosol particles size distribution and depends on the effective radius of particles that allows dividing aerosol by fraction: small Angstrom exponent is related to large particles and large Angstrom exponent corresponds to fine mode particles. But it is influenced also by the coefficient of variance of the size distribution (Tanre et al., 2001, Schuster et al., 2006, Kokhanovsky, 2008). For Angstrom exponent values analysis we used data calculated according AERONET procedures as $\alpha(\lambda_1, \lambda_2) = \ln[AOD(\lambda_1)/AOD(\lambda_2)] / \ln(\lambda_2/\lambda_1)$ from AOD data (Holben et al., 1998)."

14.R#1. Presented figures are unreadable. Fig. 1 has too many lines. Please add colors or change figure to present only mean with standard deviation. In general I suggest to present median value in case of log-normally distributed values (AOT) instead of mean one. In case of presentation of median percentiles should be also presented (10, 25, 75 and 90%). Presentation of median should also reduce influence of outliers on seasonal pattern.
GM. We redrew all figures to make them more readable. For Fig. 1 (new Fig.2N see below) we extended analysis of Kyiv site measurements including Level 2.0 data of 2013 (averaged period 2008–2013). The features of seasonal variations for Kyiv site from year to year are seen in new Fig. 2N (a), (b). In new Fig. 2N (c)–(e) mean values of seasonal changes of AOD (440 nm) and AOD (870 nm) by AERONET data and AOD (865 nm) by POLDER data for Kyiv and Minsk

are shown. In new Fig 2N (f) the set of Angstrom exponent (440–870 nm) values are given. For all data, STD is shown except POLDER data to avoid overloading.

15.R#1. Comparison of both Kyiv sites should be done at the end of the paper as a separate subchapter in discussion as well as comparison between other sites and regions.
GM. We have removed text related to Kyiv/Kyiv-AO analysis due to insufficient amount of measurements in the AERONET Kyiv-AO site to make strict conclusions. In the separate paper we will make this analysis including with Microtops II measurements after their processing.

16.R#1. Make Fig. 2 more readable, why there is presented linear fit? Make text more clear and easier to read.
GM. We have removed Fig. 2 and text related to Kyiv/Kyiv-AO analysis due to insufficient amount of measurements in the Kyiv-AO site to make strict conclusions. See also 15.R#1.

17.R#1. Seasonal variability of size distribution is in my opinion wrongly presented and unreadable. It seams that authors want to present variability of fine and coarse mode. So do that. Please present seasonal variability of volume concentration of fine and coarse mode separately as it was done in case of Minsk and Kyiv for all aerosol sizes. From such analysis authors can deduce when fine or coarse aerosol dominates in the atmosphere and deduce why.
GM. We present new figures of seasonal variability of volume concentration for fine and coarse mode separately for Minsk and Kyiv. See new Fig. 3N.

18.R#1. Regarding comparison between Minsk and Kyiv. What is conclusion regarding that in Kyiv is performed more measurements? I can see that in case of Kyiv volume concentration does not have two peaks whilst AOT has two peaks. In case of Minsk two peaks at AOT and volume concentrations are visible, why?
GM. This point was revised. We consider separately the aerosol volume concentration of fine and coarse modes and of total particles for both Kyiv and Minsk (see new Fig 3N) and have removed number of measurements comparison. We consider seasonal alteration of particles optical properties over Kyiv to explain the AOD peak in April.

19.R#1. Presentation of AERONET data form Lugansk makes no sense. In my opinion it is too short period of measurements for this paper. I suggest to use satellite data when groundbased data are unavailable.
GM. We used PORDER/PARASOL satellite data for analysis of aerosol behavior over Lugansk, as well as over few other urban/industrial cities. The AERONET data from the Lugansk site were used in comparison with satellite data. See new Figs. 4N, 5N.

20.R#1. Conclusions and discussion will be better when authors include some analysis of trajectories, model results or something like that. Even in some case studies.
GM. We expand the discussion relying on our results of aerosol transfer study in the East European region using the back-trajectory and cluster analysis methods (e.g. see our paper published in Russian in (Kabashnikov, V.P., Aculinin, A.A., Danylevsky, V.O., Kalinskaya, D.V., Korchemkina, E.M., Miatselskaya, N.S., Milinevsky, G.P., Bovchaliuk, A.P., Pietruczuk, A., Sobolewsky, P., Chaikovsky, A.P.: Atmosphere aerosol transfer in the East European region by AERONET network data using the cluster analysis method, Research Reports (Naukovi Pratsi) UHMI, 262, 40–59, 2012, http://uhmi.org.ua/pub/np/262/)).

References added:

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., 104–105, 98–110, 2012.

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Pavese, G., Calvello, M., Esposito, F., Leone, L., and Restieri, R.: Effects of Saharan Dust Advection on Atmospheric Aerosol Properties in the West-Mediterranean Area, Advances in Meteorology, 2012, Article ID 730579, doi:10.1155/2012/730579, 2012.

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Yoon, J., von Hoyningen-Huene, W., Kokhanovsky, A. A., Vountas, M., and Burrows, J. P.: Trend analysis of aerosol optical thickness and Ångström exponent derived from the global AERONET spectral observations, Atmos. Meas. Tech., 5, 1271-1299, doi:10.5194/amt-5-1271-2012, 2012.

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Table 1. AERONET sites and Ukraine urban/industrial areas selected for analysis.

Site/area	Coordinates, elevation a. s. l.	Comment
Kyiv, Ukraine	50.36°N, 30.50°E, 200 m	AERONET/POLDER
Lugansk, Ukraine	48.57°N, 39.36°E, 90 m	AERONET/POLDER
Donetsk	48.03°N, 37.81°E, 300 m	POLDER/AERONET
Kharkiv	50.00°N, 36.25°E, 135 m	POLDER
Dnipropetrovsk	48.45°N, 34.98°E, 68 m	POLDER
Rinve	50.62°N, 26.25°E, 230 m	POLDER
Lviv	49.83°N, 24.00°E, 270 m	POLDER
Martova, Ukraine	49.94°N, 36.95°E, 120 m	AERONET
Sevastopol*, Ukraine	44.62°N, 33.52°E, 80 m	AERONET/POLDER
Minsk, Belarus	53.92°N, 27.60°E, 200 m	AERONET/POLDER

* The data of Sevastopol site discussed on the base of our results in (Bovchaliuk et al., 2013)

Figures caption

Fig. 1N. Location of the AERONET sites (Kyiv, Minsk, Lugansk, Sevastopol) and areas covered by POLDER measurements (Kyiv, Lugansk, Donetsk, Kharkiv, Dnepropetrovsk, Lviv, Rivne and Minsk) discussed in the paper.

Fig. 2N. (a), (b) The features of AOD (440 nm) and Angstrom exponent (440–870 nm) season variations for Kyiv site from year to year, (c)–(e) mean values seasonal changes of AOD (440 nm) and AOD (870 nm) by AERONET data and AOD (865 nm) by POLDER data for Kyiv and Minsk, (f) the set of Angstrom exponent (440–870 nm) values. For all data STD is shown except POLDER data to avoid overloading. Months are shown by their first letters in the order January–December.

Fig. 3N. Seasonal behavior of aerosol volume concentration of total, fine and coarse mode particles in (a) Kyiv and (b) Minsk AERONET sites.

Fig. 4N. Seasonal variations of AOD (865 nm) values and Angstrom exponent (670–875 nm) values averaged over 2008–2011 in the atmosphere over the Kyiv, Minsk, Donetsk, Lugansk, Dnipropetrovsk, Kharkov, Lviv and Rivne urban/industrial areas based on POLDER data. Months are shown by their first letters in the order January–December.

Fig. 5N. AOD season variations over Lugansk by AOD (870 nm) total, fine and coarse mode from AERONET site data and POLDER AOD (865 nm) data.

Fig. 6N. (a) Single scattering albedo and (b), (c) refractive index spectral dependence by the Kyiv AERONET site data.

Fig. 7N. (a), Scatter plots SSA versus extinction Angstrom exponent (EAE), (b) SSA versus EAE for April and August months separately, (c) Angstrom exponent (AE) difference (AE (440–675 nm) – AE (675–870 nm)) versus AE (440–870 nm), and (d) absorption Angstrom exponent versus EAE (440–870 nm). The Kyiv AERONET site data.

Figures added, corrected:

To 10.R#1.

Fig. 1N. Location of the AERONET sites (Kyiv, Minsk, Lugansk, Sevastopol) and areas covered by POLDER measurements (Kyiv, Lugansk, Donetsk, Kharkiv, Dnepropetrovsk, Lviv, Rivne and Minsk) discussed in the paper.

To 14.R#1.

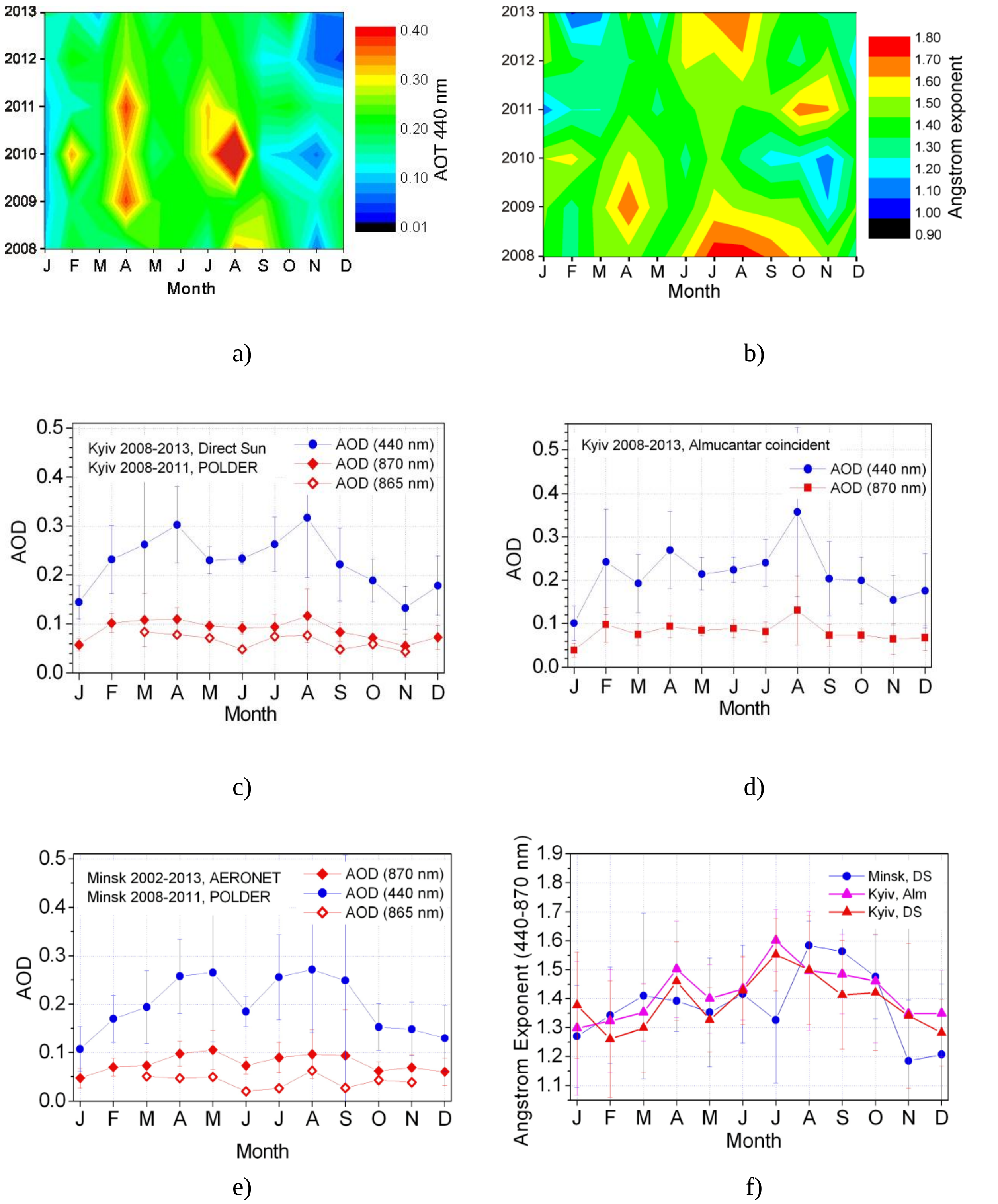
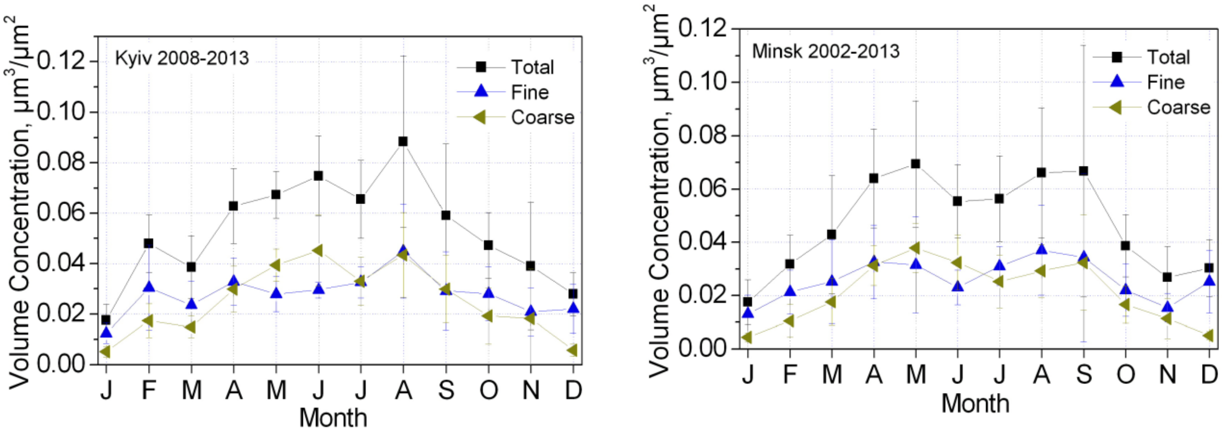


Fig. 2N. (a), (b) The features of AOD (440 nm) and Angstrom exponent (440–870 nm) season variations for Kyiv site from year to year, (c)–(e) mean values seasonal changes of AOD (440 nm) and AOD (870 nm) by AERONET data and AOD (865 nm) by POLDER data for Kyiv and Minsk, (f) the set of Angstrom exponent (440–870 nm) values. For all data STD is shown except POLDER data to avoid overloading. Months are shown by their first letters in the order January–December.

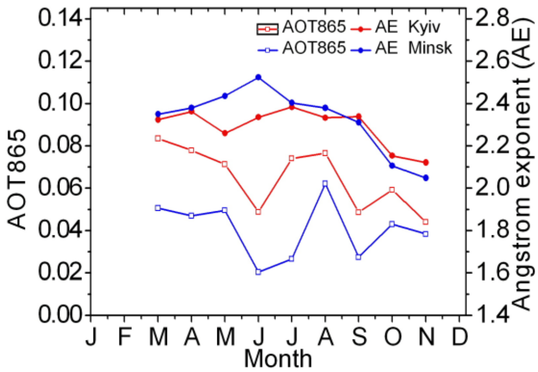
To 17.R#1.



a) b)

Fig. 3N. Seasonal behavior of aerosol volume concentration of total, fine and coarse mode particles in (a) Kyiv and (b) Minsk AERONET sites.

To 19.R#1.



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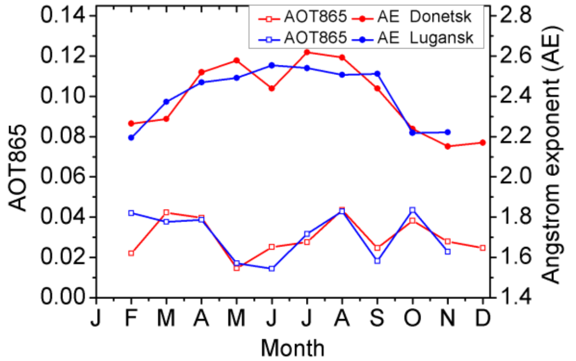

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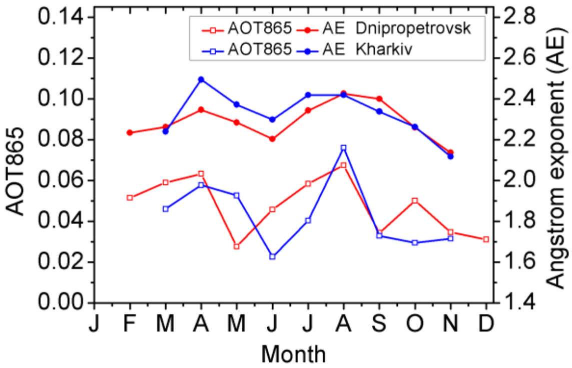

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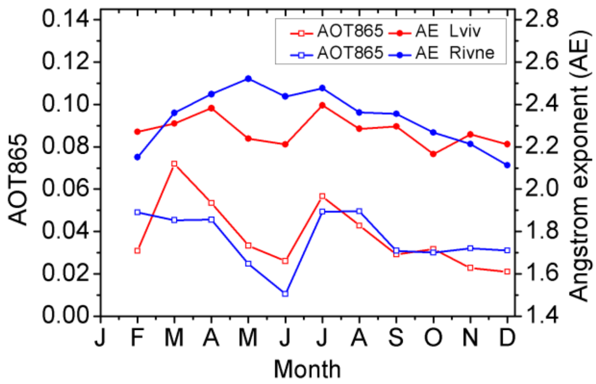


d)

Fig. 4N. Seasonal variations of AOD (865 nm) values and Angstrom exponent (670–875 nm) values averaged over 2008–2011 in the atmosphere over the Kyiv, Minsk, Donetsk, Lugansk, Dnipropetrovsk, Kharkov, Lviv and Rivne urban/industrial areas based on POLDER data. Months are shown by their first letters in the order January–December.

To 19.R#1.

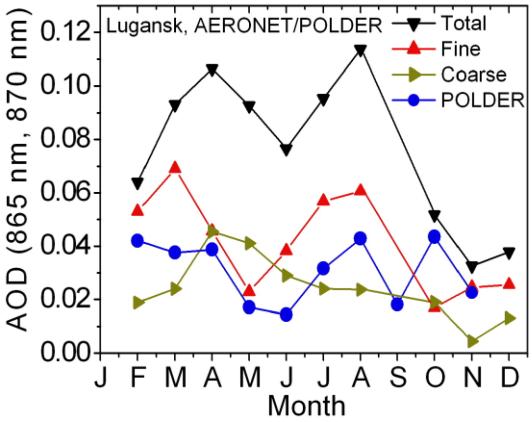
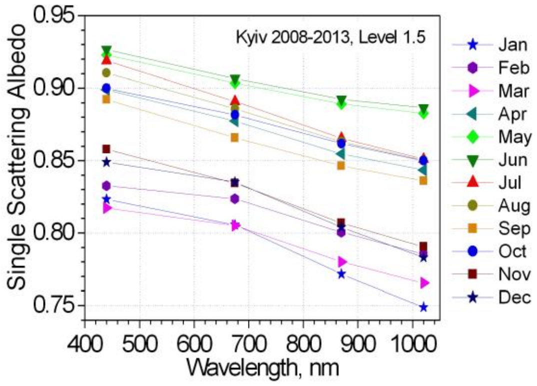


Fig. 5N. AOD season variations over Lugansk by AOD (870 nm) total, fine and coarse mode from AERONET site data and POLDER AOD (865 nm) data.

To 7.R#1.



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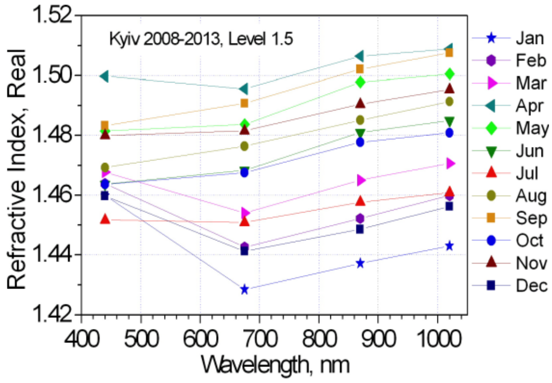

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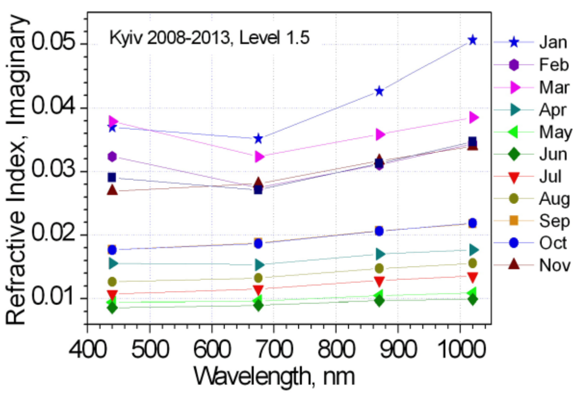

c)

Fig. 6N. (a) Single scattering albedo and (b), (c) refractive index spectral dependence by the Kyiv AERONET site data.

To 7.R#1.

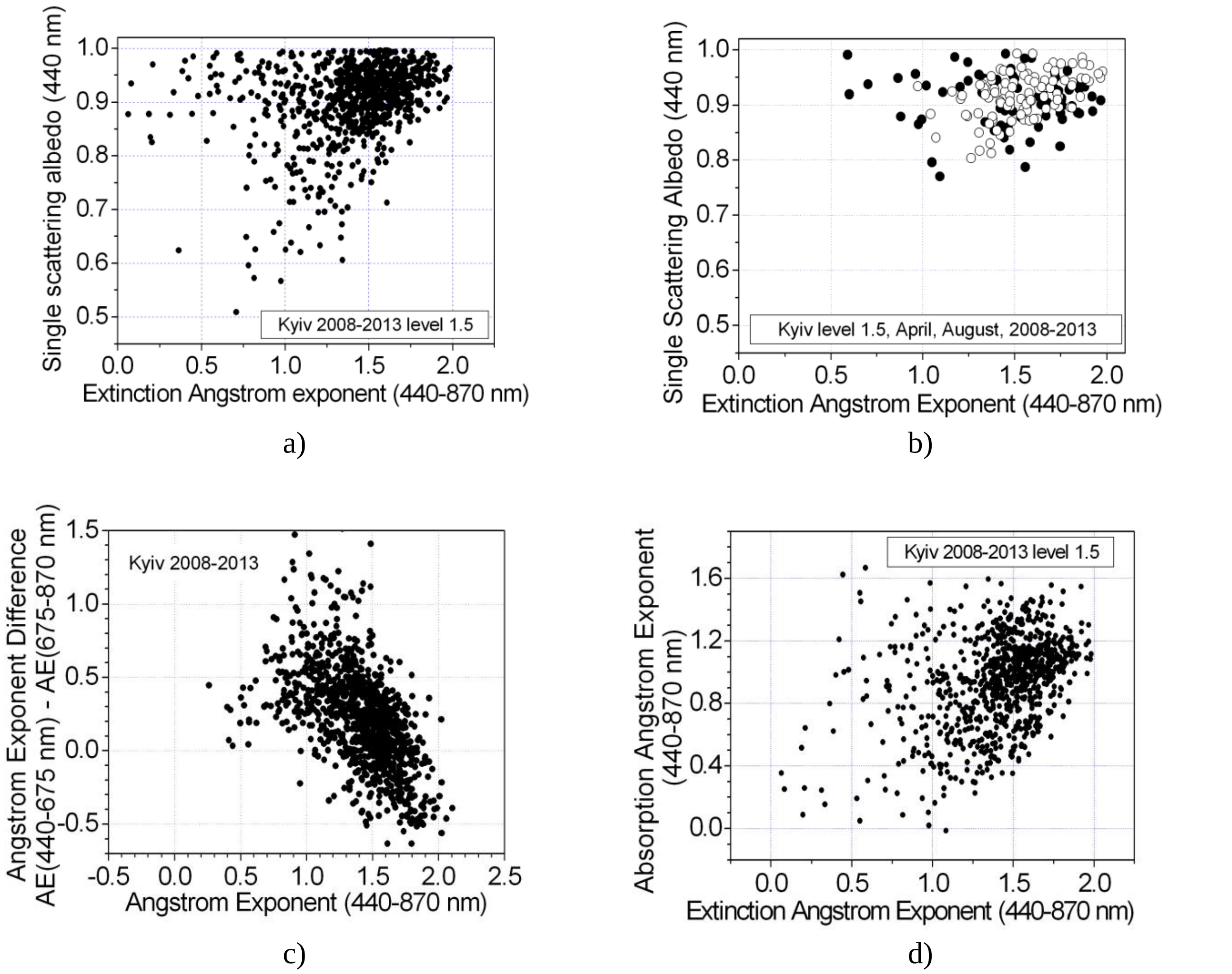

Fig. 7N. (a), Scatter plots SSA versus extinction Angstrom exponent (EAE), (b) SSA versus EAE for April and August months separately, (c) Angstrom exponent (AE) difference (AE (440–675 nm) – AE (675–870 nm)) versus AE (440–870 nm), and (d) absorption Angstrom exponent versus EAE (440–870 nm). The Kyiv AERONET site data.