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Atmospheric Measurement Techniques Discussions

Interactive comment on "Increased aerosols content in the atmosphere over Ukraine during summer 2010" *by* Evgenia Galytska et al.

Evgenia Galytska et al.

egalytska@iup.physik.uni-bremen.de

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We thank the Referee's helpful comments on our manuscript. Many sentences of the manuscript have been carefully rewritten and reorganized to make the statements clear. Authors' responses are highlighted in blue. The notation is as follows: P1 L12 means page 1, line 12.

The paper by Galytska et al. analyses in details the influence of the 2010 eastern Europe wildfires on the atmosphere of Ukraine. It combines both retro-trajectories modelling and different sets of remote-sensing observations.
This work is interesting and the analysis thorough but the manuscript in its present

form need improvements.

We thank the Referee for the positive comment and we agree that the manuscript needed improvements.

The paper is very long and should be shortened and better focused (see specific comments below).

We are following the Referee's suggestion and we have reworked and reorganized the manuscript to highlight its novelty; we have reduced its length by restructuring methodological paragraphs and better concentrating on main messages. We have optimized the titles of Section 2 and 3 to better address the sections subject.

For instance, the introduction written as it looks like a detailed summary of previous works on the subject rather than a presentation of scientific objectives. The authors should clearly state in the introduction the adding contribution of their study compared to previous works.

We agree to the Referee and we have reworked the Introduction entirely. The rewritten Introduction is structured as follows:

- We highlight that wildfires are an important global source of aerosol.
- We explain importance of wildfires events during summer 2010. We address to previous studies (in chronological order) devoted to aerosol dynamics over the European territory of Russia (ETR) and Eastern Europe. Also, we highlight the papers of aerosol research performed for the territory of Ukraine.

- We explain the contribution of our research in comparison with previously mentioned in the Introduction papers. We have made suggested changes on P2 L2-P4 L11.

Also, the analyse should include POLDER data that are well designed to track fine aerosols.

We thank the Referee for having drew our attention on this. This is a good point. Though, from our point of view, POLDER data are useful while estimating the content of fine aerosol, with particle size of approx. 0.3 μm. If the purpose of our manuscript would be estimating the physical and chemical properties of aerosol in the wildfires and its evolution during transport, or estimating the peculiarities of the formation of particle in the wildfires, then these data certainly would be involved. But the purpose of our research is to analyze where, when and how the aerosol component of the wildfires was transported to the investigated region. In addition, inclusion of POLDER data would increase the size of the manuscript. Therefore, it seems that for such a synergetic data analysis from various satellite and terrestrial measurements it is necessary to perform a separate research.

Throughout the paper, the contribution of biomass burnings on the aerosol load over Ukraine is often discussed in a qualitative way. A more quantitative analysis could improve the quality of the paper : what is the ratio between transported biomass burning aerosols and locally-emitted particles during polluted days ? Is this ratio constant or variable according to meteorological situations ?

Thank you for having raised this issue. The ratio between transported biomass burning aerosols and locally-emitted particles depends significantly on various factors, in particular weather conditions. AERONET and satellite measurements do not enable

to identify locally-emitted aerosol in the atmospheric column. In situ measurements of aerosol properties, sources etc. could be used to resolve this issue. Although, we did not apply in situ data in our research. Thus, in our study we only estimated the impact of wildfires over Kyiv by comparing the aerosol properties for the dates when aerosol from wildfires was observed to those dates when aerosol from wildfires was absent. We address to the latter issue on P15 L11-17 as follows:

'In our study we estimated the impact of wildfires over Kyiv by comparing the aerosol properties for the dates when aerosol from wildfires was observed to those dates when aerosol from wildfires was absent.We identified respective dates from the analysis of air masses transport to Kyiv, as described above. We compared aerosol properties as averaged values over different time periods: 1) when the number of fires and their brightness temperature were low, June 1-26 (40–65N and 10–60E, see Fig.2), 2) when the numbers of fires significantly increased, July 18-August 14, and 3) when the number of fires and their brightness temperature remained high and the highest AOD values were observed, August 15-17'.

Specific comments and technical corrections :

P2 : The largest numbers of these fires[. . .] and Kazakhstan : please add a reference

We have added the reference of Barnaba et al., 2011. Thank you.

P2 : The papers provided results ->the papers providing results

Thank you for the suggestion. Finally, we have withdrawn the entire sentence in the reworked version of Introduction.

P3 : in the UV band Holben et al. (1998) : add parenthesis to the citation

Added parenthesis (Holben et al., 1998). Thank you. P4 L24.

Section 2 : Please add a map highlighting the localization of Ukraine and the observational sites used in this study.

Thank you, we have inserted the map with the AERONET observational sites in Eastern Europe and Ukraine, which were used in our study. Please, see reworked manuscript Fig.1 on P5 or below.

P4 MODIS data : Why corrected MODIS AOD has much lower data than the collection 051 AOD for this specific region and period ?

Thank you for raising this issue. MODIS Scientific Data Set (SDS) Ðąorrected_Optical_Depth_Land contains AOD with the highest accuracy (Quality Assurance Confidence flag (QAC) = 3 over land). In our research we have used AOD with QAC = 2 and 1 to increase the amount of data. That is why we have further compared AOD between MODIS and AERONET.

Section 3.1 : This section should include meteorological data mentioned in section 2.4.

We have reworded the titles of Sect. 2 and 3.
Section 2 has been renamed from “Data sources“ to “Methods and data sources”. We aimed to collect all relevant information about methods used in our study in a respective section. Therein, Section 2.4 has also been renamed from “Meteorological data and the means of study of air masses transport in the investigated region” to “Weather conditions and transport of air masses” now even more precisely states the purpose of the information provided there.
We have renamed Section 3 from “Methodology and results” to “Results and Discussion”. After careful consideration of your suggestion, we retained Section 2.4 in the same position.

Table 2 : Milinevsky did not use AERONET data for the year 2014.

We thank the Referee for having drew our attention on this issue. We have updated Table 2 with AOD values at 500 nm to make our analysis of AERONET data consistent and avoid switching between 440 nm and 500nm. In the reworked version of the manuscript we address to this issue as follows: ’In Table 2 we show a prolongation of the data record of Milinevsky et al. (2014, 2008-2013) for the Kyiv AERONET site by three more years up to the end of 2016. Even in this extended record the most significant aerosol pollution was observed in August 2010. This event is related, in particular to wildfires in the ETR and Eastern Europe’. Please, see P12 L15-18.

P7 : The highest content of aerosols over Kyiv was observed every year in spring (April-May) and late summer (July-August) : Could you explain why maximum pollution occur during these periods ? Is this the result of specific meteorological regimes ? Local emissions ? Absence of washout ?

We thank the Referee for his/her comment. We have addressed this issue on P12 L10-14 as follows: 'Between 2003 and 2014 ground-based and satellite observations showed the highest aerosol content over Kyiv every year in spring (April–May) and late summer (July–August; Bovchaliuk et al., 2013; Milinevsky et al., 2014). According to both studies, the observed spring peak in aerosol content is associated with transport of the Saharan dust across Eastern Europe, transport of sea salt aerosol from the Black Sea and the Sea of Azov, and occasionally occurring agricultural fires. The summer peak results from wildfires, soil dust aerosol due to harvesting activity, and transport of Saharan dust'.

P8 : Coarse aerosol particles were mainly of local origin : which origin ? Please be more specific.

We have been more specific and added the information as follows: 'Coarse aerosol was mainly of local origin, such as city transport and heavy industry, while the fine mode particle likely was brought by air currents from Europe'. Also, we have moved this piece of text to the Supplement (P2) as suggested by other Referees.

Section 3.2 : This section could be shortened. The main conclusions should be highlighted to improve the clarity of this section.

We thank the Referee for highlighting this issue. We reworked this section, shortened it by moving entire analysis of air transport during June 1-August 31 to the Supplement.

P11 : Could you explain the influence of the multiple scattering effect on the retrieval of the SSA. This part is not clear.

We thank the Referee for this comment. We have reconsidered our statement regarding the effect of multiple scattering on higher SSA values over Kyiv in comparison with Moscow. Also, we believe that this issue requires further thorough analysis, which can be in focus of further studies. In the rewritten version of our manuscript we have explained increased SSA values during August 15-17, 2010 by increased size of particles, which caused an increase of atmospheric column reflectance. We have addressed this issue on P15 L35-P16 L1 as follows: 'According to Eck et al. (2009), larger SSA values can be explained by an increased particle size which increases the total reflectance of atmospheric column'.

P15 : AE is often larger than 1 for fine biomass burning aerosols so the AOD bias between MODIS and CALIOP is potentially larger than 2-4 %.

In our research we have compared AODs from CALIOP at 532 nm and MODIS/Aqua at 550 nm without corrections for the spectral differences. This could cause AOD bias between MODIS and CALIOP, larger than 2-4 %. We have addressed this issue in P8 L9-12 as follows: 'We did not apply any correction for potential spectral 10 differences while comparing CALIOP AOD 532 nm and MODIS/Aqua AOD 550 nm. It yields to an estimated systematic bias in our AOD comparison of approximately 2–6 % in the AE range between 0.5 to 1.8 (see Fig. 5b) and can be neglected in our cases, following Kittaka et al. (2011)'.

Figure 9 : Why 3 types of aerosol vertical profiles can be distinguished ? Is the result of different transport pathways ? Emissions processes ? Specific local meteorology ? Orography ?

We have analyzed 58 aerosol profiles for the period August 7-18, 2010. The main

criterion for the definition of 3 types of profiles was the peculiarities of aerosol vertical distribution. We have addressed this issues on P19 L6-16 of reworked manuscript as follows:
'We also analyzed vertical distributions of aerosol extinction at 532 nm. We compiled analyzed profiles for the cases with high AOD 532 nm. This selection leads to 58 profiles for 11 tracks for the period August 7–18, 2010. The corresponding AOD 532 nm ranged from 0.44 (on August 13 11:00:06) to 2.93 (on August 18 00:08:26). Among selected profiles, 37 on 7 ground tracks were nocturnal, and 21 profiles on 4 tracks were measured during daytime. The profiles reveal that aerosol ranged from about 40 m to mostly 5 km altitude. The vertical distributions varied significantly during both day- and nighttime. According to the peculiarities of aerosol vertical distribution, we identified three types of profiles. 1) Type 1 consists of profiles showing at least a single aerosol layer of some hundred meters thickness, located at about 1 km altitude or higher. 2) Type 2 consists of profiles showing a decrease of extinction coefficients with altitude, with a maximum extinction coefficient located near the surface. 3) Type 3 is characterized by relatively high extinction values over comparably large altitude ranges, spanning several km without showing distinct maxima. Fig. 9 depicts corresponding profiles, selected for those cases when the above mentioned features are well pronounced. All other cases are shown in the Supplement Fig. S37-S94'.

P19 : authors stated that satellite data has always lower accuracy : please explain

The satellite AOD is determined by inverse problem solution. As a rule it is ill-posed problem. That is why AOD from satellite measurements needs validation by ground-based measurements, mainly AERONET. These problems are widely discussed in scientific publications on the remote sensing techniques. Concerning MODIS see e.g. (Remer et al., 2005; Remer et al. 2008; Levy et al., 2009, 2010, 2013), CALIOP see e.g. (Kittaka et al 2011) etc. More general discussion of the problem see e.g. in King

et al. (1999).

P21 : Results on SSA presented in this study are contradictory to Chubarova et al. (2012) results. Please explain.

Observed SSA values in Kyiv during the period of active wildfires were higher in comparison with results, shown in Chubarova et al. We have explained the increased SSA by an increased size of particles, which caused an increase of the atmospheric column reflectance. We have addressed this issue on P15 L35-P16 L1 as follows: 'According to Eck et al. (2009), larger SSA values can be explained by an increased particle size which increases the total reflectance of atmospheric column'.

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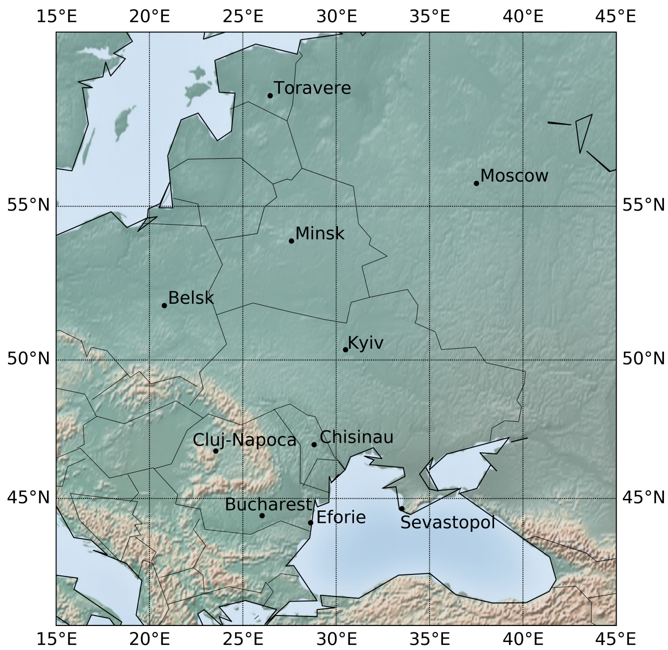

Fig. 1. AERONET observational sites in Eastern Europe and Ukraine used in this study.