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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Scattering and absorption properties of near-surface aerosol over Gangetic–Himalayan region: the role of boundary layer dynamics and long-range transport" *by* U. C. Dumka et al.

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Responses to comments by Anonymous Referee #1

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We would like to express our sincere gratitude to the anonymous referee for his/her insightful and constructive comments on this study. All the comments and suggestions are highly valuable for us to improve the quality of the manuscript. A point by point response is included below. The comments are indicated in black and our responses are in blue.

Review of "Scattering and absorption properties of near-surface aerosol over Gangetic-Himalayan region: the role of boundary layer dynamics and long-range transport" by Dumka et al. Manuscript number: acp-2014-521.

The manuscript presents the results from approximately 1 year of aerosol measurements performed during the GVAX campaign at Nainital. Measurements include aerosol scattering and absorption for particles below 1 um and 10 um in diameter.

The paper needs major revisions before it can be published in ACP.

The main issue with this manuscript is that some of the results were already presented in a recent paper published by Dumka and Kaskaoutis (2014).

In the Abstract the authors write that "The present study examines the temporal (monthly, seasonal) evolution of scattering and absorption coefficients, their wavelength dependence. . ." This was already presented in Dumka and Kaskaoutis (2014) together with the analysis of the scattering Angstrom exponent.

Thus, given the length of the manuscript, I suggest resuming in the Introduction the previously published results (obtained using the same database), shortening the present manuscript and avoiding repetitions. For example, the important differences between D1 and D10 optical properties at Nainital, as well as the effect of meteorology (monsoon vs. post-monsoon seasons) on aerosol extensive optical properties, were already presented in Dumka and Kaskaoutis (2014). Once the main findings from published articles are presented, the authors can better organize the manuscript presenting new results (which include analysis of AAE, backscatter, submicron scattering and absorption fractions) and avoiding repetitions.

Authors: The previous published article (Dumka and Kaskaoutis, 2014) emphasized on the temporal evolution of single scattering albedo (SSA) and aerosol radiative forcing efficiency (ARFE), using the scattering and absorption coefficient measurements. In order to support that analysis, the monthly variation of both scattering and absorption was presented before the results of SSA and ARFE.The present work does not reiterate those results, but exhibits (for the first time) the diurnal variation of scattering and absorption along with their wavelength dependency. Some references to the monthly variation of scattering and absorption coefficients are logic to exist in the current paper, which are all accompanied by the reference Dumka and Kaskaoutis (2014). In the Introduction section, we summarize the already published results from GVAX campaign (Dumka and Kaskaoutis, 2014; Manoharan et al., 2014). The whole manuscript has been edited and modified according to the reviewer comments. The main findings and highlights of the present work, i.e. the role of the boundary-layer dynamics and long-range transport are underlined at the end of the Introduction section, as well as in the Abstract and Conclusions and are further supported by the inclusion of two new figures (Figures 8 and 10). This supports the innovation of the present work and prevents from any duplication with previous results.

The Introduction should resume the main findings from previous studies. For example (Page 21104, Lines 1-7) the main results from Panwar et al. (2013), Komppula et al. (2009) and Neitola et al. (2011) should be discussed in the Introduction.

Authors: The objectives and main findings from previous studies are briefly discussed in the revised manuscript.

The Abstract should be rewritten and it should present the novelty of this manuscript. As such, the Abstract only presents a list of measurements/analyses performed (some of these already presented in Dumka and Kaskaoutis (2014)).

Authors: We have improved the abstract, which now includes the main findings and

highlights of the present work, i.e. the influence of boundary-layer height and dynamics in the diurnal variation of the aerosol properties and the role of long-range transport.

The second issue, which has been not yet addressed by the authors, is related with the comparison of optical properties (both extensive and intensive) measured at Nainital with those measured at other mountain top sites worldwide. This will improve the scientific quality of the manuscript. To my opinion this is very important given the peculiar characteristics of aerosols in the Gangetic-Himalayan region in terms of scattering and absorption.

Authors: The Table 2 has been enriched with aerosol properties from more mountainous sites over the globe. The comparison shows that Nainital, although it is far from urban/industrialized sites, exhibits higher values of scattering and absorption corresponding to more turbid atmospheres due to the strong influence of transported aerosols from the Ganges Valley and southwest Asia. This is briefly discussed in the revised manuscript, and from the values summarized in Table 2, readers can easily exclude their conclusions.

Another issue is related with in-cloud data. I have understood that “handling such data is outside the scope of the present study”, but it would be useful to know how (and if) authors detected and removed the in-cloud data from the database.

Authors: The present analysis did not include or even being involved with in-cloud data. The methodology for performing the Nephelometer and PSAP measurements is fully described in the current manuscript, as well as in the previous publications by Manoharan et al. (2014) and Dumka and Kaskaoutis (2014). The in-cloud data were removed from the analyzed data series by the AMF technical staff.

Moreover, Table 1 shows the set of optical parameters derived during the GVAX campaign. Some of these (i.e.: up-scatter fraction, asymmetry parameter and hygroscopic growth factor) were presented in Table 1 but not discussed in the present manuscript. The backscatter Angstrom exponent is highlighted in Table 1 but not presented in the manuscript.

Authors: Actually, several parameters have been measured or calculated from the initial experiments during the GVAX campaign, which are impossible to be presented and discussed in a single paper. Thus, SSA and ARFE were well documented in Dumka and Kaskaoutis (2014), while CCN concentrations and growth factor are the topics of forthcoming research (on going analysis). For avoiding any misunderstanding, in the revised Table 1 we removed all the parameters that are not analyzed in the present work.

Among the intensive aerosol optical properties available from the GVAX campaign, the SSA and scattering Angstrom exponents were already presented in Dumka and Kaskaoutis (2014), the scattering Angstrom exponent (with a few more details), absorption Angstrom exponent and hemispheric backscatter fraction were presented in this manuscript. The asymmetry parameter and hygroscopic growth factor are two important parameters derived from the GVAX campaign but not presented here. What are the reasons for this exclusion? To my opinion, adding these results will considerably improve the scientific quality of the present work.

Authors: Only a very brief discussion for the Scattering Angstrom Exponent (SAE) was given in Dumka and Kaskaoutis (2014), just for comparison purposes with columnar Angstrom exponent via MFR measurements. This parameter, along with Absorption Angstrom Exponent, etc. is analyzed in the current work. Some preliminary results of the hygroscopic growth factor are already with us after comprehensive analysis of this dataset, but their inclusion in the current work will enhance strength of the manuscript but disorientate the main objectives. In order to improve the scientific quality of the present work and to emphasize more on the significant role of boundary-layer dynamics, long-range transport and source regions, two new figures (as stated above) have been included.

The authors could remove Figures 11 and 12 (which do not add relevant additional

information compared to what already discussed in the manuscript) leaving space for additional results.

Authors: We removed these figures (11 and 12), as well as the figures 3 and 6 of the original version, as suggested by the reviewer.

Moreover, it would be nice to know if the aerosol absorption at Nainital shows any trend given that absorption measurements are available since 2004 at this site (See Table 2 of this manuscript).

Authors: We cannot perform such analysis in scattering and/or absorption coefficients near the ground, since the measurements are not continuous. The previous measurements over the site (included in Table 2) correspond to results from previous campaigns performed at the specific time intervals. Overall, there is no continuous database of absorption coefficient measurements at Nainital that allows any trend analysis.

Another issue is related with Paragraph 3.2.2. The SAE measured at ground is higher during Monsoon and lower during post-Monsoon season. The former was related to the removal of aerosol accumulation mode by the rain, the latter was an indication of abundance of aged aerosols at the site. As stated by the authors these results deviate from those obtained using columnar data (Guleria et al., 2011; Dumka et al., 2008; Srivastava et al., 2012) showing lower columnar Angstrom exponent during premonsoon and monsoon, due to the influence of dust, and larger columnar SAE during post-Monsoon season, due to the dominance of anthropogenic aerosols and biomass burning.

However, this difference between ground and columnar SAE is not as evident looking at Figure 7a in Dumka and Kaskaoutis (2014) where the seasonal evolution of columnar SAE and ground PM1 SAE during GVAX seems to agree quite well. What's the reason for this? Is this due to different periods analyzed in these different papers?

Authors: It is true that previous studies have shown lower columnar Angstrom exponent values during monsoon compared to post-monsoon and winter. However, the columnar monsoon measurements were rather rare due to mostly cloudy skies. The present results show higher values of SAE during monsoon, which are in agreement with the measurements at Mukteshwar due to the reasons explained in the manuscript. The coincidence in the monthly variation between the near-ground and columnar SAE values shown in Dumka and Kaskaoutis (2014) may be the result of a specific year only (GVAX campaign). However, note that there is lack of columnar Angstrom exponent values in June and July, while the columnar values in December are the highest, which is not coincident with that observed in surface. In synopsis, for avoiding any misunderstanding and confusion between columnar and near-surface aerosol properties, this sentence has been removed in the revised manuscript.

How many dust episodes were detected during the study period reported in this manuscript?

Authors: We did not analyze any individual case, since this is beyond the scope of the present manuscript. So, we do not have a number of dust episodes (if any) over the site. The dust episodes should be defined by specific criteria, i.e. MODIS imagery, visibility records, peaks in aerosol loading and scattering data series, etc… However, since the main dust period over northern India (April-June) is only partly examined (June measurements), intense dust storms were not detected over the site.

How much the seasonal evolution of the PBL is affecting the intensive aerosol optical properties measured at ground compared to the columnar ones?

Authors: The new Figure 8 clearly reveals that the PBL strongly affects the extensive aerosol properties and only partly the intensive ones. For the respective columnar analysis, we need measurements from spectral absorption and scattering coefficients from satellite sensors (i.e. OMI) and/or Lidar observations for the vertical atmospheric structure. Satellite observations have more uncertainties and these issues cannot be examined in greater accuracy. Analysis of the diurnal evolution of the aerosol scattering

(on ground) and AOD (in vertical) as a function of the evolution of the mixing-layer height maybe an interesting topic for further research.

The last issue is related with the effect of LRT and PBL on the measurements presented in this manuscript. LRT and PBL effects are highlighted in the title and abstract. However, only a small section (Paragraph 3.4) is dedicated to these issues. This part should be improved for example adding some cluster analysis using backtrajectory analysis and not only using wind data.

Authors: We spent our main efforts on improving this part of the manuscript. In this respect, two more figures are included in the revised manuscript (Figs. 8 and 10), highlighting the role of boundary-layer height and dynamics as well as long-range transport and source regions (CWT analysis). We chose the CWT analysis instead of trajectory clusters in order to reveal hot-spot areas favoring the dominance of specific aerosol properties over Nainital.

We believe that the new inclusions, modifications and general edits in the manuscript help in its improvement and would be accepted by the reviewer. We are very much grateful to the reviewer's comments.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 21101, 2014.

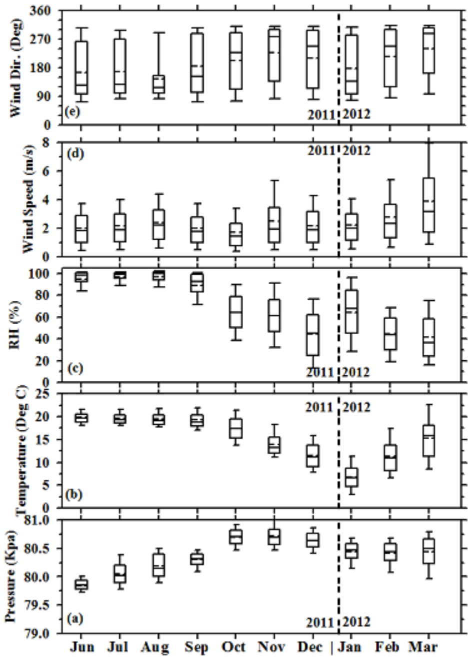

Figure 1: Monthly surface meteorological variables (ambient pressure, air Temperature, Relative Humidity, wind speed and direction) at Nainital during the period June 2011 to March 2012 in box and whisker charts. The dashed line represents the mean and the solid line the median. The box contains the range of values from 25% (bottom) to 75% (top).

Fig. 1.

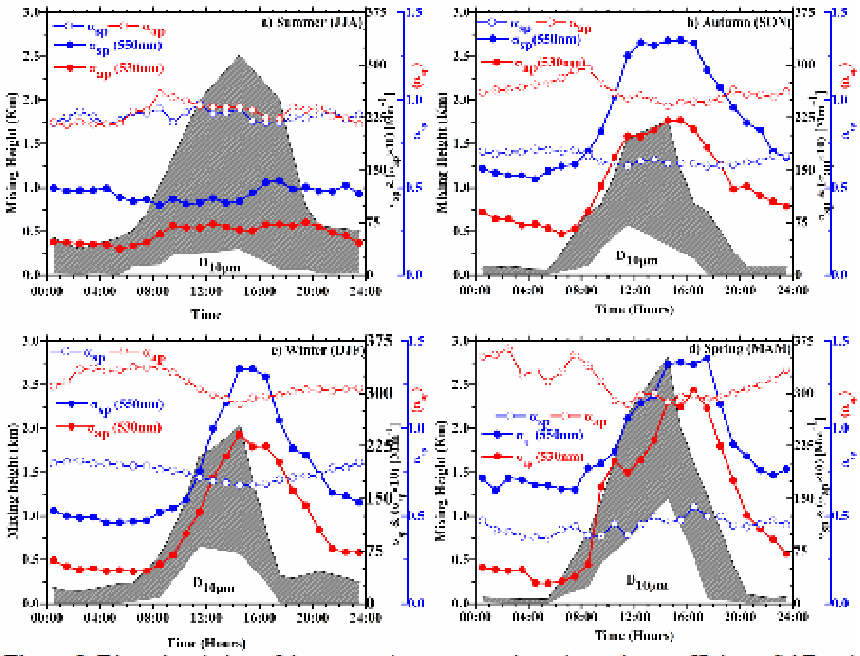

Figure 8: Diurnal variation of the seasonal mean scattering, absorption coefficients, SAE and AAE for $D_{10\mu m}$ particles along with respective variations in the maximum and minimum mixing-layer height over Nainital. The absorption coefficient was multiplied by 10.

Fig. 2.

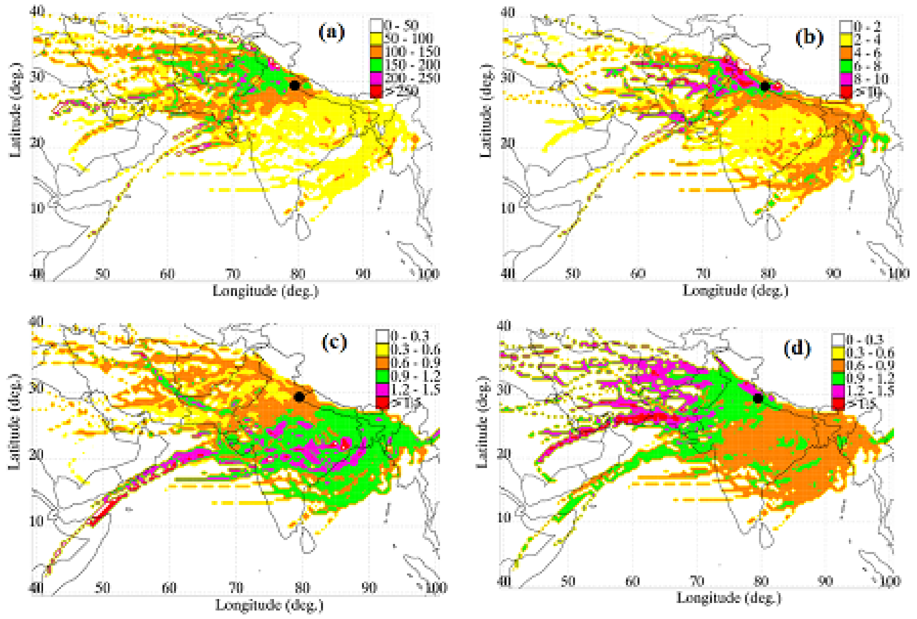

Figure 10: Concentrated Weighted Trajectory (CWT) maps using 5-days backward trajectories ending at Nainital at 500 m for scattering (a), absorption (b) coefficients, SAE (c) and AAE (d) for $D_{10\mu m}$ particles.

Fig. 3.

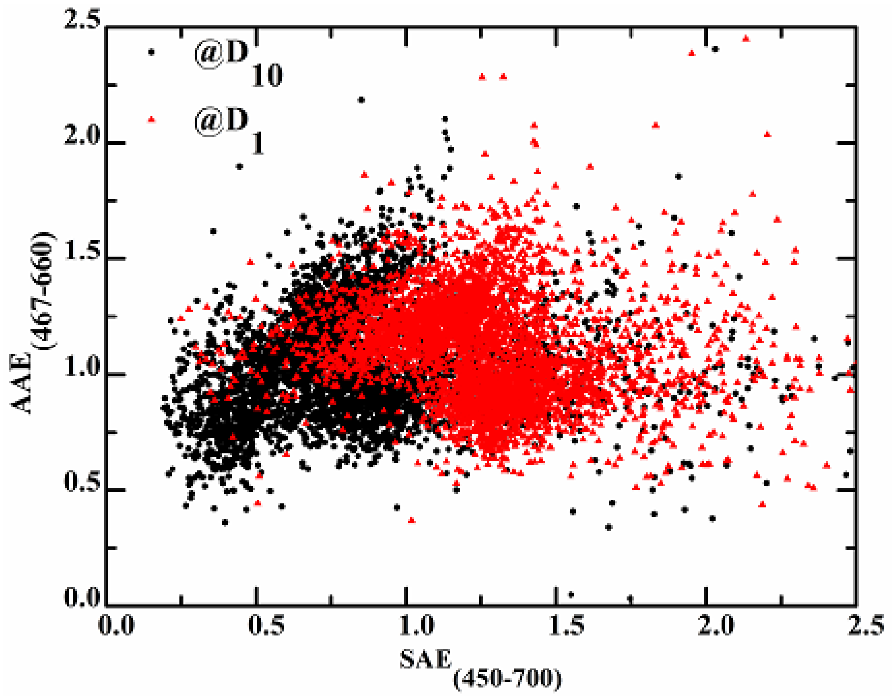

Figure 11: Correlation between scattering and absorption Ångström exponents (hourly-averaged values) at Nainital for $D_{1\mu m}$ and $D_{10\mu m}$ particle-size groups.

Fig. 4.