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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Extremely large anthropogenic aerosol component over the Bay of Bengal during winter season" *by* D. G. Kaskaoutis et al.

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Reviewer 1

The paper presents a unique dataset of aerosols optical thicknesses and total precipitable water content in the Bay of Bengal during the dry season taken during the W-ICARB cruise campaign. The dataset is obtained using two handheld Microtops II photometers. The authors highlight the occurrence of 'extremely' high (> 0.4 @ 500 nm) values of aerosols optical thickness that uniquely on the basis of the analyses of spectral dependence are defined as anthropogenic.

This large anthropogenic component over BoB during W-ICARB obtained from the

present analysis is also compared with the results of the chemical analysis during the cruise campaign (Kumar et al., 2010). The chemical analysis strongly verifies our results for large fine-mode or anthropogenic component especially over the eastern part of BoB, which was under the influence of air masses from southeast Asia. In the revised version the verification of our own results with those of chemical analysis is discussed in more detail.

The tools used for the analyses of the spectral dependence demonstrate the knowledge of the status of the art in this field that it is also evident by the rich bibliography cited, even if in some case the analyses appears as redundant.

In the revised version we have taken care of the suggestions of the Reviewer to avoid redundancy.

Apart for few details in the processing of the Microtops data, the weakness of this paper is to be limited to the analyses of a subset of Microtops II observations while other relevant observations were available to support or discuss the results. For this reason the paper is not suitable for publication in reviewed scientiïňĄc literature. Reviewed scientiïňĄc literature should contain contributions that exploit the best available information to support conclusions or that make use of intensive and not frequent observational efforts, as for example from oceanographic campaign, to discuss the limits of relatively inexpensive observations or such of more global ones as the satellite derived products. In fact, as evident by the cited literature, during the W-ICARB cruise there were other observations that could have been used to support some of the conclusions. The paper could be published if it would include in the discussion other observations or alternatively if the dataset would be used to validate satellite products and then discuss on this basis the spatial and low frequency temporal variability as deduced form satellite products.

This paper uses a unique analysis focusing mainly on investigation of the aerosol types highlighting the large fine-mode or anthropogenic component over BoB during winter season. We do agree with the Reviewer that that there may be datasets available by several other during the cruise campaign, which are not analyzed in the present work. We had approached several groups to share their datasets and work jointly but the Reviewer will appreciate that sharing of datasets is a “real” problem unless the funding agencies like NASA make a firm rule for sharing datasets. However, some of the data collected by other groups during the campaign are recently published (Moorthy et al., 2010; Kumar et al., 2010; Raghavendra Kumar et al., 2011; Sinha et al., 2011) and, therefore, in the present paper we have avoided duplication of studies carried out or published by other groups. For example, Moorthy et al. (2010) analyzed the spatial distributions of AOD, alpha, coarse and fine aerosols, accumulation mass fraction, CALIPSO profiles, etc, while Raghavendra Kumar et al. (2010) compared the MODIS observations with ship-borne measurements. So, the comparison of our results with satellite observations would probably be considered as duplication and for this reason such an analysis is avoided. However, in the revised version, following the suggestions of the Reviewer we have included discussion based on the recent publications during the same cruise campaign that also support our conclusions. Apart from these, the modeled OPAC results, which are analyzed and discussed in detail at the end of this manuscript, are in considerable agreement with the previous analysis and with concurrent surface measurements of various aerosol optical parameters as well as their chemical components presented elsewhere (Gogoi et al., Sarin et al., submitted manuscripts).

Even accepting the hypothesis of a paper based only on Microtopts II data there would be some issues to be better discussed before the spectral analyses. For example: - The screening of the data on the basis of the results of the 2nd order polynomial ïňĄt.

We are grateful to the comments/suggestions of the Reviewer. Before the campaign the MICROTOPS instruments were compared to each other and similar protocol was followed by everyone. Before analyzing the spectral AODs, we took special care of cloud screening and diurnal artifacts of the AODs by using the method of Cachorro

et al. (2004) and the relationship a2-a1=α. Furthermore, in all spectral data used for the analysis the second-order polynomial fit had excellent simulation on the measured data.

- All preprocessing steps that are likely to introduce a spectral dependence in the retrieved aerosols optical thicknesses. Corrections for molecular optical thickness (both in terms of error in the surface pressure value and used formula) and gas absorbtion introduce, as discussed in the literature, relatively low uncertainties in the value of optical thickness. Are these uncertainties acceptable also when computing the Angstrom coefficient?

We hope that the Reviewer agrees with us and several others who are using MICROTOPS for obtaining the aerosol properties. MICROTOPOS is a very reliable instrument; it was handled with care, although we cannot compare with the super quality of data observed from CIMEL AERONET. The spectral AOD retrievals from Microtops-II are based on the instrument's internal calibration. The corrections for molecular scattering (Rayleigh component) as pointed out by the Reviewer, which is based on surface pressure, corrections for ozone and/or water vapor absorption at specific wavelengths are done internally and these uncertainties have a relatively low contribution to the AOD. However, these uncertainties in AOD have a larger contribution to the uncertainties in Angstrom exponent, especially in case of Volz method as discussed by Kaskaoutis et al. (2006). The AOD uncertainties contribute less than 10% to the uncertainties in Angstrom coefficient and such uncertainties are not systematic, i.e. causing a systematic increase or decrease in alpha values. In averaging the results such low uncertainties in alpha are nearly vanished in the classification of the aerosol types or in the dalpha values used in the aerosol identification scheme. So, all these low uncertainties are acceptable when computing alpha and dalpha values. In the revised manuscript we discuss all the above in more detail.

- Ozone retrieved columnar content can contain some useful and independent information? For example the disagreement between around 0.5-0.6 micron ïňĄt and observations in ïňĄg 14 couldn't be explained by residual absorption from ozone? Ozone absorption in the Chappuis band can cause some uncertainties in the derivation of AODs at these wavelengths. However, Microtops-II provides an accurate measure of ozone amount, which is used for the subtraction of the ozone optical depth from the total atmospheric optical depth. Kaskaoutis et al. (2006) showed that the uncertainties in AOD retrievals due to ozone subtraction are very low. However, the ozone can contribute to the AODs in the Chappuis band. On the other hand, the disagreement between measured spectral AODs and OPAC-derived AODs (Fig. 14) at 0.5-0.6 microns is relatively low and observed only in west and south BoB. Such a disagreement is mainly attributed to the incapability of OPAC to simulate accurately the spectral AODs and not to the ozone contribution, which is expected to be much lower. However, the OPAC simulations to the spectral AODs shown in Fig. 14 are very good and acceptable for the concept of the present work. We have briefly included few lines in the revised manuscript to take care of the points made by the Reviewer.

- The OPAC dataset is based, in terms of complex refractive indices, mostly on the Shettle and Fenn (1979) aerosol models. Status of the art modeling should include more recent results both in terms of size distribution as well as of complex refractive indices. As an example the HITRAN package contains a regularly updated and well documented datasets in terms of complex refractive indices.

In the present work, we choose to use OPAC results for the retrieval of aerosol optical properties over BoB, since OPAC is well known for its capability in retrieval of aerosol properties and it has extensively been used over Indian sub-continent for calculation of aerosol radiative forcing. Despite the numerous previous studies using OPAC over India, Raghavendra Kumar et al. (2011) used the same package for the retrieval of aerosol properties and aerosol radiative forcing over BoB during W-ICARB. Their results on SSA are in close agreement with ours as well as with SSA values obtained over BoB from previous cruises and are cited in Raghavendra Kumar et al. (2011). We strongly believe that the use of OPAC is valid and our results are reliable and compare

well with other studies. We strongly agree with the Reviewer that the HITRAN package contains a regularly updated (although not over BoB or India) and well documented datasets in terms of complex refractive indices, but its use on the present study will increase the length of the manuscript without providing something new in the analysis, since the OPAC is commonly being used by several authors over India.

- The residual effect of aerosol correction in the computation of total precipitable water vapour, particularly when discussing fig. 13.

As we previously mentioned we took special care for spectral AOD screening. In addition to that, some low uncertainties exist in the retrievals of water vapor content. In the revised manuscript, we discuss about the residual effect of aerosol correction in the computations of WVC. However, the results in Figs. 12 and 13 can be discussed ONLY qualitatively and NOT quantitatively. In the manuscript we refer that there are several parameters influencing the aerosol size distribution and the coefficient a2, while in Figs. 12 and 13 only the humidification process is discussed. Nevertheless, the results show a considerable influence of the WVC on AOD curvature effects, especially in southern parts of BoB, which partly supporting the humidification effect discussed in Fig. 10 for south-central BoB. Note also that such an analysis is unique over BoB at least for the W-ICARB campaign.

Minor comments:

- is the use of correlation to indicate scatterplots correct?

All correlations used in the manuscript are correct. However, in the revised manuscript some of them will be removed as Reviewer suggested (see our response below).

- table 2 contains the 4 columns from the extinction coefficient to the SSA that can be summarized by any combination of two columns among the 4. Also the number of digits used in this table could be reduced.

We have given these four values for helping the readers to see the results and not to have to make calculations for computing the scattering coefficient, or SSA by providing only two of the four parameters. Also, we use three digits for the derived parameters because some of them are very close to each other over the different regions of the Bay of Bengal and, therefore, the use of two digits will reduce the accuracy of the retrievals.

- the meaning of the comparison of spatial distribution shown in figure 12 is not clear.

This comparison constitutes an effort of relating the coefficient a2 of the second-order polynomial fit, which constitutes a measure of the coarse and fine mode aerosols, with the water vapor content in order to reveal the humidification processes over the marine environment, especially in the open oceanic areas. We make it more clear in the revised manuscript as pointed out by the Reviewer.

- figures 4, 11 and 13: what is the purpose of computing a linear fit?

The linear fits in Fig. 4 reveal good correlation between a2-a1 and alpha, which constitutes a measure of the reliability of our dataset as discussed in detail in the manuscript. The linear fits in Fig. 11 just show the disagreement between alpha values computed at shorter and longer wavelengths suggesting the spectral dependence of alpha. The same can be revealed from the scatter of the data points and, therefore, the linear fits are rather meaningless and are removed in the revised version.

The linear fits in Fig. 13 show the increasing of the coefficient a2 with WVC for AOD values below 0.6. They do not have any physical meaning and for this reason the respective linear equations are not given. We initially provided to highlight this increasing trend, which can be also revealed from the scatter of the data points. Since these trends are rather meaningless, we have removed them in the revised version.

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