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Discussions

Interactive comment on “Estimating a relationship between aerosol optical thickness and surface wind speed over the ocean” *by* P. Glantz et al.

P. Glantz et al.

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Estimating a relationship between aerosol optical thickness and surface wind speed

by Paul Glantz, Douglas Nilsson and Wolfgang von Hoyningen-Huene

Since a more reliable cloud screening approach has been included in the revised version of the manuscript (see major concern 1 by reviewer 2), which is illustrated with new figures presented and our answers below refer to the new numbering of the figures.

Major revision to Reviewer comments

1) The reviewer suggests that we should focus on the relationship between AOT and surface wind speed in areas of the ocean where direct measurements are available. The reviewer mean that direct measurements of sea salt mass, hygroscopic growth of sea salt and AOT could then be used to validate the results. In opposite to the

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AERONET ground based stations, which are located only at disturbed placed on earth, measurements obtained from ship over the remote ocean areas can be classified as undisturbed conditions. We agree that the latter measurements could then be used to validate the SeaWiFS retrievals of AOT. To use direct measurements of sea salt mass for the validation could be a stronger approach compared with the present box model derived AOT, but only if well represented data are available. The box model derived AOT is in any case based on a large data set over the North Pacific for September 2001 that is well represented according to the present wind speed range. This is a better statistical basis compared with limited available in-situ measurements. Furthermore, from empirically derived parameterizations, we know that the emissions of both sea salt and water vapor over the oceans are dependent on the surface wind speed (e.g., Gong et al., 1997; O'Dowd et al., 1997 Svensson et al., 2000; Glantz et al., 2004). We do not agree that we should move the present operation area to another region on earth just because of available in-situ measurements. Other aspects must be taken into consideration. For an example, the areas near Hawaii of the North Pacific are in summer less covered with clouds compared with other period of the year and also compared with all other ocean areas on earth. The question arise how much direct data measurements are available for this study? Furthermore, the ACE-1 campaign was actually performed before the SeaWiFS instrument began to operate. The SeaStar satellite was launched on the 1 August 1997. Despite that we use a simple box model we have found that the introduced sea salt parameterization and hygroscopic growth of the particles in combination with independent ECMWF parameters more or less reflect the change in SeaWiFS derived AOT for the present wind speed range. We think that this major comment expressed by the reviewer is outside the scope of the current study. In any case we suggest (end of Section 6) that the present relationship should be tested over other regions of the globe, which we also intend to do in subsequent studies.

2) The reviewer refer to previously reported results showing poor correlations between local wind speed and sea salt mass. Considering extinction effects sea salt can be

subdivided according to accumulation and coarse mode ranges, with a relatively long turn over time (2 days, Gong et al. 1997) for the former while expected strong local wind dependence for the latter. We expect also that a background ammonium sulfate aerosol influence the incoming short wave radiation over the North Pacific, while then also more efficient due to hygroscopic growth. It is also reasonable to assume that the sea salt and vapor emissions are the dominant wind driven factors behind the present AOT-wind relationship. We agree that the longer turn over time for the sea salt accumulation mode particles could reduce the local wind influence on AOT. We also discuss this in the last paragraph of Section 5.4 which could explain, at least partly, the large variability that occurs around the mean AOT when a single scene is analyzed (Fig.5). Even so, by analyzing the relatively large SeaWiFS and ECMWF scenes (Figures 4a and 4b) over the North Pacific it seems realistic that the averaged of retrieved AOT is also more or less sensitive to the more long-lived sea salt particles. This is because the wind speed fields, estimated by the ECMWF model, are homogenous over a relatively large area (Fig. 4a) and also varies relatively smoothly from day to day over the operation area for September 2001 (the latter not shown). Additionally, once again the two remaining effects, increase in the coarse mode sea salt particle surface and hygroscopic growth of both sea salt and ammonium sulfate particles, occur during time scales short enough to respond locally. The results obtained by the present box model (section 5.2 and Fig. 7) also support that the hygroscopic growth of the aerosols seems to be sensitive to the surface wind speeds, despite that a simplified validation approach is used and that we use both wind speed and relative humidity as well as boundary layer height from the ECMWF model. We have included several references, which all support relatively strong relationship between measured AOT and local surface wind speed at the end of Section 5.4. The referee is not the first one to wonder how local sea salt concentration can agree so well with the local wind (see for an example major comments 1 and 3 by reviewers 1 and 2, respectively), when the aerosol concentration is a product not only of the local wind but also of the accumulated wind driven sources and the sinks backward in time along the lagrangian air parcel history. Despite this, Gong et al. 1997

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related successfully sea salt mass to the local wind, as numerous other investigators. Indeed, the co-authors of the current manuscript was been deeply worried about this problem when we first entered this field if research. It was not difficult to understand why the aerosol emission fluxes by eddy covariance measurements varied with the local wind when we published the first successful such measurements from the AOE-96 expedition (Nilsson et al., 2001). However, in the same study we showed a good sea-salt aerosol concentration to wind speed correlation from 0.161 to 10 micrometer diameter from impactor mass analysis, and 0.015 to 2.2 micrometer in terms of aerosol number concentration. The life time of the aerosol in these wide size ranges varies from $<$1 hour to days. How could they all have such a good correlation to the local wind? The explanation we found was that when we compared the local wind with the average wind over a longer and longer time interval of lagrangian wind speed, it remained on about the same level of correlation for 24 hours, and then only gradually decreased to a lower level after 96 hours (which was the peak synoptic time scale in the wind power spectra). At the 2 days life-time for the accumulation mode aerosol (according to Gong et al., 1997), the correlation was still better than 0.6. We concluded that the local wind over the ocean was a good substitute for the lagrangian wind over scales up to a considerably part of the scale of the synoptic weather systems, that is, if you are on for example the most windy side of a low pressure system, your local conditions are similar to the conditions over almost half that low pressure system. Not identical, but similar. We believe that this is the general explanation to why local wind is such a successful substitute for lagrangian wind when analyzing marine sea salt aerosol data. Since we never included any figure for our analysis on the lagrangian versus local wind speed in the 2001 paper we could send the figure if the reviewer ask for it.

Of course the current paper is a different data set, in a different region of the planet, but if anything, the weather patterns in the current study area are slower than those we studied in 1996, which would make the assumption even more valid. In fact, one of the key points in our current study is to show how surprisingly well correlated even the AOT is with the local wind speed.

Detailed remarks

p. 11624, line 25: “Durke” has been changed to “Durkee”

p.11627, line 6: Both sentences refer to Fig. 1 and not to Fig. 2, as it is wrongly written in the original text. Therefore the following text “Ě.black rectangle shown in Fig 2.” has been changed to “Ě.black rectangle shown in Fig. 1.” Therefore, the following sentence “Ěare also shown in the figure.” is unchanged.

p. 11628, last paragraph and Figure 4: We have now estimated a power fit for the day 11 September 2001 (see the first paragraph of Section 5.1 and Figures 5a and 5b) . We agree with the reviewer that over some areas in Fig.4 weak or no correlations occurs between AOT and surface wind speed. This we also mention in the last sentence of Section 4.2 The relatively large one standard deviations around the mean values shown in Fig. 5b are also discussed in the first paragraph of Section 5.1 as well as in the last paragraph of Section 5.4.

p. 11629, first lines: This refers to the area of North Pacific shown in Fig. 4. We agree the present relationship should be tested over other regions of the globe, which we also intend to do in subsequent studies. We also discuss this at the end of Section 6.

p. 11629, line 15: see our comments to the major concern 1 above

p. 11629, line 19: The calculation of the growth factor (GF) is based on a work by Seinfeld and Pandis, (1998) and is also dependent on particle size. However, the values are similar for sizes above about 0.02 micron dry diameter for both sea salt and ammonium sulfate aerosols.

p. 11630, equation 3: It is (NH4)2SO4 and to make it more clear for the readers we have also change it in equation 3. For ammonium sulfate particles we have not estimate an absolute change in AOT but just a relative change, for the present wind speed range, according to a work by Charlson et al. (1978). This is explained at the end of paragraph 2 of Section 4.3. The ammonium sulfate particles are indirectly

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dependent on surface wind speed due to hygroscopic growth. We assume that there is enough ammonium over this area to neutralize sulfate. The RHi and BLHi parameters refer to the wind speed range Ui , where I = 1.2ĚĚ..13. The GFi and GF1, from Seinfled and Pandis, are calculated for sea salt and ammonium sulfate particles separately, dependent on relative humidity and temperature. The latter parameters have been estimated according to the ECMWF data. Figure 4: The mean and corresponding one standard deviation shown in Fig. 5b (revised version) have been obtained based on binning the values shown in Fig. 5a (revised version) according to the wind speed range 0 to 12 m/s. The following sentence “The resultant data set was sorted into bins based on the wind speed. Each bin is 1 m s-1 wide and the mean AOT of each bin has then been calculated.” has been included in Section 5.1. Figure 6 (Fig. 7 in the revised version of the manuscript): The stars denote the total change in AOT, including increase in sea salt particles and hygroscopic growth of both sea salt and ammonium sulfate particles. The squares include only a change due to hygroscopic growth. We agree with the reviewer that this is not clear. Therefore, we have rewritten the second and the third sentences of Section 5.2 in an attempt to make it easier for the readers to understand Fig.6 and after this we have also included a new sentence; “The total change in mean AOT, according to increased sea salt particle mass concentrations and hygroscopic growth of the marine aerosol is denoted by the stars in the figure (Eq.1). The squares describe the changes that are associated only by hygroscopic growth of the sea salt and ammonium sulfate particles (Eq.1 - Eq.2 - Eq.3). Furthermore, the mean values shown in the figure have been averaged according to the box model derived mean AOT values, obtained for all SeaWiFS scenes retrieved over the North Pacific for September 2001. ”

Figure 8: We agree that measurements obtained from ship over the remote ocean areas can be classified as undisturbed conditions and could be used for validation of the SeaWiFS derived AOT. We also agree that the present comparisons between SeaWiFS and AERONET derived wind speeds is somewhat weak mainly because SeaWiFS land retrieval are associated with unrealistic values, probably due to uncertainties

in the surface characteristics of the island, described in the model. In any case, a more appropriate comparison between SeaWiFS derived AOT and AOD obtained at AERONET ground based stations are important in an attempt to validate the satellite retrievals. However, the comparisons should be performed over the land pixel corresponding to the land stations but then when land reflections are better described in the aerosol retrieval model for remote islands and coastal sites. To compare the present results with ship measurements we prefer data over the North Pacific obtained for the period of September 2001. In any case we have included several references, which all support relatively strong relationship between measured AOT and local surface wind speed at the end of Section 5.1. The reviewer suggests that scatter plots for the satellite and AERONET retrievals of AOT and corresponding correlation coefficients should be presented. However, the few values obtained here for a relatively narrow AOT range in combination with the relatively large standard deviations shown in Fig. 9 do not give any justice to such comparisons.

p. 11636, lines 14 - 22: In the original version of the manuscript we refer to a study by Ignatov et al. (1995) that have found that white foam presented on the sea surface has a small effect on the retrieval of AOT, which means that the AOT increased by less than 0.005 according a wind speed range of 5 to 8 m s-1. This value is obtained when the production is weak. For the present upper wind speed range (9 - 12 m s-1) you expect somewhat higher production while not a dramatic change. We have also included an additionally study (Moore et al., 2000) that support relatively small increase in AOT due to white foam according to this wind speed range (end of Section 5.4). They find that the augmented reflectance of whitecaps in the open ocean for the 410 - 670 nm spectral range is between 0.001 and 0.002 over the wind speed range 9 - 12 m s-1. Thus, these values are significant lower than the surface reflectance over sea water used in the retrieval approach for the wave length 555 nm (Hoyningen-Huene et al., 2003). The reviewer is right that sun glints influence satellite observed radiances not only at glint angles but also at non-glint angles as well, and which have already been shown to hamper for an example MODIS and MERIS. In that perspective SeaWiFS instrument is, however, operated with a scanner tilt mechanism oriented in the long-track direction to avoid sun glint effects from the sea surface. We do not claim that sun glint effects are completely avoided due to the tilt angle, but are probably of minor concern for the period of September and areas higher than 15N. This is because the present satellite/orbit zenith angles are above 20 degrees in combination with the present sun and satellite/orbit azimuth angles that were similar and both in the backward direction (retrievals on the side of the orbit facing away from the sun) over the present operation area. Thus, because of the present geometry we are in the backward direction and not in the region associated with pure glint angles (Zhang et al., 2005). In any case, higher wind speeds probably also influence AOT at areas associated with non-glint angles, because higher wind speeds cause broader glint regions. Even so, for the present study, due to the geometry described above, this effect is small for wind speeds in the range 0 - 9 m s-1 and probably also small for the range 9 - 12 m s-1 (Zhang et al., 2005). Zhang et al., 2005 found that for higher wind speeds the anisotropic factor (R, ratio between the assumed Lambertian and the actual fluxes) decrease in glint regions due to higher aerosol loading. This was found for AOT (550 nm) values in the range 0 - 0.1. The present validation of the present results also suggests that beside aerosol loading hygroscopic growth of the aerosol particles in the marine boundary layer also causes more efficient scattering of short wave radiation, despite that we use wind speed and relative humidity as well as boundary layer height from the ECMWF model. Zhang et al. 2005 conclude also that an overall uncertainty of 10% will be introduced in derived shortwave aerosol direct forcing over cloud-free oceans if aerosol angular distribution models are constructed without considering aerosol brightening over non-glints regions. In the perspective to the above discussion it appears that the present SeaWiFS satellite retrieval of AOT, associated with non-glint angles, over the North Pacific for September 2001is major caused by real physical processes, while artifacts at the sea surface may induce minor errors in the results.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 11621, 2006.