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Intercomparison of satellite retrieved aerosol optical depth over ocean during the period September 1997 to December 2000

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Abstract. Monthly mean aerosol optical depth (AOD) over ocean is compared from a total of 9 aerosol retrievals during a 40 months period. Comparisons of AOD have been made both for the entire period and sub periods. We identify regions where there is large disagreement and good agreement between the aerosol satellite retrievals. Significant differences in AOD have been identified in most of the oceanic regions. Several analyses are performed including spatial correlation between the retrievals as well as comparison with AERONET data. During the 40 months period studied there have been several major aerosol field campaigns as well as events of high aerosol content. It is studied how the aerosol retrievals compare during such circumstances. The differences found in this study are larger than found in a previous study where 5 aerosol retrievals over an 8 months period were compared. Part of the differences can be explained by limitations and deficiencies in some of the aerosol retrievals. In particular, results in coastal regions are promising especially for aerosol retrievals from satellite instruments particularly suited for aerosol research. In depth analyses explaining the differences between AOD obtained in different retrievals are clearly needed. We limit this study to identifying differences and similarities and indicating possible sources that affect the quality of the retrievals. This is a necessary first step towards understanding the differences and improving the retrievals.

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1 Introduction

Satellite retrievals of aerosols and clouds have given much insight into the problem of quantification of the direct and indirect aerosol effects (e.g. Husar et al., 1997; Kaufman and Fraser, 1997; Nakajima and Higurashi, 1998; Boucher and Tanre 2000; Nakajima et al., 2001; Tanre et al. 2001; Rosenfeld, 2000; Rosenfeld et al., 2002; Koren et al., 2004). However, significant uncertainties remain regarding the radiative and climate effect of aerosols of anthropogenic origin (Haywood and Boucher, 2000; IPCC, 2001; Ramanathan et al., 2001; Kaufman et al., 2002a). For the direct aerosol effect uncertainties exist both due to limited information on spatial and temporal variation in the aerosol optical properties and the composition of the aerosols. Of particular importance is the fact that the crucial parameter single scattering albedo is poorly quantified. Satellite data have greatly improved the knowledge about the distribution of aerosols in the atmosphere. Given the complicated task of retrieving aerosol information from satellite instruments (King et al., 1999), it was perhaps not surprising that Myhre et al. (2004) showed, by comparing 5 satellite aerosol retrievals over ocean for an eight month period (November 1996 to June 1997), that substantial differences in aerosol optical depth (AOD) are present. In general, they found differences in AOD of a factor of two between the different datasets, but in some regions it was even higher. The best agreement in AOD was found in coastal regions with high AOD, whereas the largest discrepancies were found over large areas of remote oceanic regions in the southern hemisphere. Cloud screening was implicated as probably one of the main reasons for the large disagreement.

In this study we investigate AOD over ocean from several satellite aerosol retrievals over a 40 months period from September 1997 until December 2000. This is a much longer period than studied in Myhre et al. (2004) and allows investigation of inter-annual variability in AOD. For this period, 4 different aerosol satellite retrievals are investigated that were producing data for the entire period. Out of these 4 retrievals, 3 were also used in the intercomparison study in Myhre et al. (2004). In addition we focus on two shorter time periods; (i) an 8 months period with one additional satellite aerosol retrieval and two supplementary versions of one of the four main retrievals, (ii) a 10 months period with two additional retrievals for dedicated aerosol research. A particularly interesting issue is to see how the long term monitoring satellite retrievals compare to retrievals from satellite instruments especially suited for monitoring of aerosols (e.g. such as POLDER, MODIS, MISR).

A significant advantage of our intercomparison of AOD in this 3 years period compared to the earlier intercomparison period is that much more ground based sunphotometer data from AERONET are available. This allows a broader comparison between the satellite aerosol retrievals and the AERONET measurements and furthermore an evaluation of under which conditions differences in the retrievals are largest. The aim of this study is to explore data for potential use by the global modelling community for comparing and improving global aerosol models. Hence validation of satellite data against AERONET in this study is done on spatial (1 degree) and temporal (1 month) scales consistent with this task. Refinement of those scales is subject of future research. Finally, we also compare AOD from the various satellite retrievals in some selected regions and time periods with particular focus on e.g. episodes of large AODs or measurement campaigns. Also, we discuss whether differences in AOD are particularly large for e.g. certain satellite retrievals, oceanic regions, aerosol sizes, and ranges of AOD.

5 Summary and discussion

In this study monthly mean aerosol optical depth (AOD) is compared from a total of nine aerosol retrievals during a 40 months period, from September 1997 to December 2000. We have identified that differences in various satellite retrievals are substantial and even larger than found in an earlier study based on five different aerosol retrievals during a period of eight months prior to the period analysed here. Aerosol remote sensing from space is a complicated task involving a wide range of physical processes that must be taken into account. Issues related to cloud screening are particularly important. It appears that one problem is that, in many retrievals, the cloud screening is not strict enough resulting in AOD being contaminated by clouds. On the other hand it also appears that some aerosol retrievals are too strict, i.e. high aerosol loadings are classified as clouds and thus no aerosol information is retrieved. In this study we have seen examples of aerosol retrievals adopting upper threshold values for AOD in an effort to avoid cloud influence. For small particles (e.g. from industrial pollution or biomass burning) this procedure could be improved by introducing an additional criterion for the Ångström exponent. However, this is more difficult for larger particles (e.g. mineral dust and sea salt) with smaller Ångström exponents more similar to those of clouds. For example, retrieval of aerosol information under major dust episodes, where AOD can be significantly above 1.0 is particularly difficult. To distinguish heavy dust loads from clouds is difficult and multi channel information is needed. Dedicated aerosol satellite instruments have this capacity and therefore this is a tractable problem for these retrievals. Additionally, in conditions of heavy dust loading, sunphotometers may screen out heavy dust loadings by miss-classification as cloud. During the SHADE campaign there was an indication that during the period of maximum AOD during a major dust storm, the procedure for processing level 1.5 to level 2 sunphotometer data led to rejection of much of the sun-photometer data (Haywood et al., 2003). Overall, it cannot be ruled out that both sunphotometers and satellite retrievals miss-classify some of the major dust storms as clouds and thus are biased towards lower dust conditions.

Despite the fact that the differences in AOD are substantial, there are also many promising results. The agreement with regard to spatial and temporal distribution in AOD between the two dedicated aerosol instruments in many of the subregions investigated in this study is impressing. This finding is both based on the averaged AOD and its variation in magnitude, as well as spatial and temporal correlation coefficient. Furthermore, in several regions the other aerosol retrievals compare well to MODIS and MISR. It seems that for comparisons in smaller regions the agreement between the aerosol retrievals is best where the influence of only few aerosol types is typical.