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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global and regional trends in aerosol optical depth based on remote sensing products and pollutant emission estimates between 2000 and 2009" *by* A. de Meij et al.

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Reviewer 3 This study investigates trends in Aerosol Optical Depth (AOD) from MODIS, MISR and AERONET and associated aerosol emissions over the period 2000 – 2009. The knowledge of trends in AOD on global and regional scales is critical for the discussion of decadal climate change, and may have greatly improved with the availability of recent products from MODIS, MISR and AERONET. The present study therefore touches upon an important issue. I think it is a worthwhile (and necessary) endeavour to evaluate and intercompare these different products with respect to their degree of

consistency in terms of global and regional trends, as done in this study, and should be encouraged. There are, however, a number of issues which have to be addressed before the manuscript can be considered for publication in ACP.

General comments: I have some concerns regarding the structure of the analysis, particularly Section 3.2. I do not see the point of comparing MISR and MODIS at 152 AERONET stations if they are not compared also to the AERONET values. A comparison at specific points only makes sense to me when there is also the observational reference added (as done in section 3.3), otherwise it is an unnecessary restriction to isolate these points in gridded datasets. As it is now, a discussion of MISR and MODIS only, at 152 points, without the AERONET references, and then in section 3.3 a discussion now at 60 points with the AERONET data in addition, leads to duplication and makes the paper unnecessary lengthy. I understand that it is because only 60 out of the 152 Aeronet sites have enough data for a proper comparison. But then I would replace the pointwise comparisons in Section 3.2 with a more representative comparison of continental scale trends in MODIS and MISR. On the other hand I would find it usefulful to have a discussion and a first order comparison of AOD trends on a global mean as well as ocean and land mean basis before going into the regional details. I would structure the analysis therefore as follows, first a global mean (+land/ocean mean) trend discussion, second a regional (continental scale) discussion without restriction to points where there are no observations anyway, and third a pointwise discussion at those sites where there are useful observations (as done in Section 3.3).

Reviewer 1 had a similar comment, and we removed section 3.2. We merged some relevant results into the section “Global AOD trends by MODIS, MISR and AERONET” (now 3.2). We removed Table 1a and transferred Figure 3 to the Electronic Supplement and we made the appropriate changes and references to the Tables and Figures in the text.

2. A main merit of this paper is from my point of view the evaluation of the satellite products with surface reference sites from Aeronet. So a couple of clear statements

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and recommendations on the usefulness and limitations of the two satellite products, which could serve as guidelines for readers who may apply these data, would be helpful and enhance the practical usefulness of the paper. As it reads now, it is not too clear to what extent we can trust these datasets and whether there are any distinct differences in the quality and usefulness of AOD trends in MISR and MODIS.

We added to the text after section 2.1.3 the following: "MODIS and MISR are aboard the Terra platform, which was launched in December 1999. MODIS has a swath width of ± 2330km and has therefore a daily global coverage. MISR has a swath width of ± 360km with a 9-day repeat cycle. The MODIS Terra retrieval algorithm is based on a dark surface approach (vegetated land surfaces). This is more accurate over densely vegetated regions as these areas have low reflectance in the blue and red compared to non-vegetated surfaces such as deserts, snow and ice. Therefore the Terra MODIS products are not provided over bright surfaces, whereas MISR retrieval is generally less sensitive to surface characteristics (Abdou et al., 2005), because it uses a multi-angle and multi-spectral viewing technique. MODIS retrieval over dark water bodies is affected by sun glint where the multi-angular cameras of MISR make aerosol retrieval possible. Algorithmic issues occur for MODIS and MISR (e.g., Levy et al., 2010, Kahn et al., 2010) which can also contribute to differences between the two instruments. For example, the current MISR algorithm does not account for mixtures of biomass burning and dust aerosols and tends to overestimate AOD in such situations, whereas MODIS tends to overestimate AOD over bright surfaces (Kahn et al. 2009). In this study we calculate the error of the slope for MODIS, MISR and AERONET to estimate the uncertainty of the trend for each location."

3. For the reader not familiar with satellite products, the extensive use of the terms level 2 and 3 is confusing and should therefore be clearly explained, before they are used for the first time (e.g. in the introduction, or maybe even briefly in the abstract, to understand this one properly).

Done. We added to the text in section 1: "MODIS and MISR data are available at

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different processing Levels. Level 1 data contain calibrated radiances. Level 2 products are produced at a spatial resolution of 10x10km for MODIS and 17.6x17.6km for MISR. Level 3 products contain parameters from the Level 2 products on a 1°x1° for MODIS and 0.5°x0.5° for MISR."

4. It is interesting to note that the AOD trends identified in this study qualitatively agree well with trends in surface radiation observations in time series after 2000. The surface radiation observations indicate increasing solar radiation over Europe and the US, and declines over south and East Asia. See Wild et al. 2009. Global dimming and brightening: An update beyond 2000, J. Geophys. Res., 114, D00D13, doi:10.1029/2008JD011382. This agreement could be mentioned in the paper.

Thank you for the reference. We included the following in the text in section: "The general increase in the AOD over East Asia and the general decrease over Europe and North America found in our study corroborate the previous study of Wild et al. (2009). They use global solar surface observations from different observational networks between 2000 and 2005 in order to estimate the tendencies in the surface solar radiation for the different regions in the world and confirm that these tendencies are typical for these regions."

Specifics: Abstract L 21, "other criteria pollutants" sounds unfamiliar to me.

The term criteria pollutants has been introduced by the EPA, and contains six pollutants which are known to be harmful to human health. These pollutants are: ozone, carbon monoxide, total suspended particulates, sulfur dioxide, lead, and nitrogen oxide. For these six pollutants ambient air quality standards have been applied for which the concentration is set to limits. We removed "criteria".

P30736, L 24 why do you use the 550nm and 870 nm band and not other ones for the calculation?

MODIS and MISR AODs are given on 550nm and 558 nm respectively. We interpolate

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AERONET AOD to 550nm using AOD from 440nm and 870nm (S. Kinne, personal communication and Kinne 2003 JGR).

P 30739, L 16. What is the meaning of 3-PD? Peak and decline, corrected in the text.

Section 3.1. As noted above, it would be interesting to show and discuss here in a figure also global mean as well as land /ocean mean trends and the consistency therein between MODIS and MISR AODs.

In Figure 2 and section 3.1 we present the global trends by MODIS and MISR over land and ocean, together with the confidence of the trend greater than 95%.

P 30744 L 6. How about seasonal differences in the trends? Is there something noteworthy to say?

We did not look at the seasonal differences in trends, but we know that several studies, such as Mishchenko and Geogdzhayev (2007), Papadimas et al. (2008), Zhao et al. (2008) did so. We included in the text (section 3.2) the following: "We did not estimate seasonal patterns in the trends, but we briefly mention some other studies. Mishchenko and Geogdzhayev (2007) analyzed long AOD trends which have occurred between 1988 - 1991 and 2002 - 2005 using the AVHRR instrument. They found a strong increase along the western coast of Africa due to biomass burning events, which have a strong seasonal cycle, followed by a decrease in the AOD trend during autumn. They also found an increasing AOD trend along south-east Asia, especially in summer. Papadimas et al. (2008) studied the spatial and temporal variability in AOD over the Mediterranean basin for the period 2000 – 2006 using MODIS Level 3 products. They found a decrease of $\sim$0.04 during the summer and an increase in the AOD of $\sim$0.03 during the winter. Zhao et al. (2008) studied the long-term (nearly 25 years) AOD trends over the global oceans using the AVHRR Pathfinder Atmosphere extended (PATMOS-x) data set. They found a decreasing tendency in the AOD trend (with high confidence) during the winter, spring and summer for the two hemispheres, with a more evident decreasing trend in the northern hemisphere. They also found a

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positive trend over biomass burning regions, with a strong seasonal cycle. Over industrialized regions (e.g. Europe) a negative trends is observed for all seasons, also from the GACP data (Mishchenko and Geogdzhayev, 2007)."

P 30744 L 13, is there an explanation why MODIS AOD is in general higher than MISR AOD?

"One of the reasons why the MODIS AOD is generally higher than of MISR is that in polluted regimes over land the MISR retrieval algorithm sometimes overestimates the single scattering albedos when the AOD is higher than 0.6 (Kahn et al, 2009)." We included this in the text in section 3.2.1.

P 30745 L 22. What could be the reasons that the SSA trend in the US is so different from Europe?

We see that the anthropogenic BC emissions over the USA are somewhat increasing between 2000 and 2010, 0.028 Tg (6%). While over Europe first we see an increase in the BC emissions between 2000 and 2005, followed by a decrease between 2005 and 2010. These differences could contribute to the differences in SSA between the USA and Europe. However, it is not recommended to draw strong conclusions using MISR SSA products, because a limited selection of absorbing particles is included in the current algorithm, aerosol mixtures of BC and dust are not included, and the MISR SSA values are not fully validated (Kahn et al., 2010).

P 30752 L 3 "are generally positive", this doesn't seem to apply to MODIS with a trend of -1%.

Corrected.

P 30752 L 22ff, as pointed out above these AOD trends are in surprising agreement with the trends in surface radiation records after 2000.

We added the comparison with Wild et al. (2009) to the text, see comment earlier.

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I do not see an added value of Figures 2 c) and d) compared to Figures 2 a) and b). They provide the same information, if I understand the figure correctly. More useful could e.g. be difference plots between MISR and MODIS slopes to see more clearly where the 2 estimate agree and disagree the most.

We received a similar comment of reviewer 1, therefore we eliminated the figures 2a and 2b.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 30731, 2010.

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