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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Temporal trends of anthropogenic SO_2 emitted by non-ferrous metal smelters in Peru and Russia estimated from Satellite observations" *by* M. F. Khokhar et al.

M. F. Khokhar et al.

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Dear Werner Thomas,

Thanks for showing your interest in our study and raising some important questions.

According to limitation from ACPD, we are unable to have additional Figures while submitting author’s comments in order to support/justify our point of view.

External link for all additional figures are added with the consent of editorial office of ACPD and you have to simply copy and paste given link in your web browser (Please accept our apologizes for any inconvenience).

Below you find detailed answers/justifications in accordance to your questions/comments.

1:- Why 315 nm wavelength is representative for the SO2 spectral ﬁtting window you chose?

Reply:

We selected a spectral window of 312.5 to 326.5 nm for SO2 DOAS fit analysis. Of course, by selecting a single wavelength for the AMF calculation, one has to make a compromise between AMF for the large wavelength edge where the AMF are largest and for the short wavelength edge, where the AMF are smallest. We believe that our choice close to the small wavelength edge is well suited because the SO2 absorption cross section increases towards smaller wavelengths and thus the retrieved SO2 SCD is weighted towards the low wavelength edge. Nevertheless, the AMF at 315nm might still differ from the exact (see e.g. Marquard et al., 2000). This difference, however, should be rather small. Most important, this difference will not affect the results of our trend analysis.

From a sensitive study by applying radiative transfer modeling (TRACY-II) for different wavelengths in the chosen wavelength range (see Fig. 1 under link http://www.flickr.com/photos/34386593@N03/3198308213/) it was found that that the errors caused by the exact selection of the wavelength are in the order of 10%. Which is comparable to 15% range stated by Thomas et al., [2005] due to spectral variation of AMF between 315 and 327 nm for 5% surface albedo and SZA$<60^\circ$.

PS: The reference “Thomas et el., 2004” has been corrected as “Thomas et el., 2005” and will be updated in the final version

2:- The impact of the aerosol profile on calculated AMFs may probably deserve further attention, especially over bright surfaces.

Reply:

The impact of aerosols on SO2 AMF calculations has been studied by select-

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ing different parameters in different scenarios. Results presented in Figure 2 (http://www.flickr.com/photos/34386593@N03/3198308213/) illustrate the results of TRACY-II simulations for different SSA and surface albedo. We agree that in principle aerosol effects can become rather large and should therefore deserve further attention. However, primary the aim of our study was to analyse temporal trends and thus we limited our efforts on the aerosol influence. Nevertheless, we tried to select scenarios for the radiative transfer modelling which on average cover the true measurement conditions.

3:- The surface albedo of 80% is assumed for Norilsk

Reply

We agree that 80% albedo is quite high. As it resulted in larger AMF as compared to 50% albedo and it might have resulted in an underestimation of SO2 emissions. But in our case we selected this albedo only for the time period – (March to April) with full snow covered surface in the Norilsk area (based on snow cover data base from Rutgers University Global Snow Lab).

Koelemeijer et al., [2003], study represents the wavelength range from 335 nm and above. Although this study did not deal with wavelengths exactly matching our requirements, however, according to Figure 3 in this study, the Lambert-equivalent reflectivity (LER) over snow/ice is even more than 80% at 335 nm for April. We think the selection of 80% albedo for March and April is best suitable. From the comparison of the results over Norilsk in summer and winter, we conclude that our choice was not that bad.

In our revised version, however, we will mention that the surface albedo at Norilsk might probably be smaller than 80%.

Finally, basic aim of this study is to identify the temporal trends in SO2 emissions from these point sources. Previous studies [Khokhar et al., 2004-2006] mentioned that for temporal trends analysis, AMF is not that important i.e. one can identify in slant

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4:- the statistical significance of the trends.

Reply:

In order to check the significance of our calculated trend we used statistical methods and performed regression analysis of our data sets. Our analysis showed that trends calculated from Ilo and La Oroya smelters from Peru are significant while the trend calculated over Norilsk smelters are insignificant. Therefore, linear trend mentioned in time series over Norilsk smelters will be corrected by mentioning the insignificance of calculated linear trend. Although, it is hard to interpret any trend from Norilsk data, however, polynomials (4°) fitted to time series showed almost consistent behaviour for both winter and summer periods. It illustrates multiple behaviour of increase during 1998-2000 and 2002 followed by a decrease in 1997 and 2001 respectively. Finally the paper draft will be updated according to new analysis and the Figure 7 will replace the Figure 3 in the article. Some details about statistical trend analysis are as under:

Tool used:

i) Analyse-it: Statistics add-in software to extend Excel available on-line free for 30 days trial version. See (http://www.analyse-it.com/)

ii) IDL built in function “TM_Test” it computes the student t-test

Statistical Tool applied: Regression analysis by using Analyse-it and T- Test by using IDL

Results: We applied linear fit to all data sets and performed regression analysis with 95% CI (confidence Interval) and 95% PI (prediction Interval) in order to check the significance of the calculated trends. In case of Peru smelters our calculated trends are highly significant (see Figure 3 and 4 - http://www.flickr.com/photos/34386593@N03/3198308285/) as p-value is (=0.001 and =0.002) for Ilo and La Oroya time series respectively. Trend is sig-

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nificant for p≤0.050 and else it is insignificant, as it happened in case of Norilsk smelter with p-value (= 0.6143) for winter and (= 0.5598) for summer time series respectively (see Figure 5 and 6 – see link http://www.flickr.com/photos/34386593@N03/3198308315/). For further details about p-value, see webpage (http://en.wikipedia.org/wiki/P-value#References) and references therein.

Finally, we decided to fit polynomials of 4° to Norilsk data sets (after testing polynomials of various degrees($<5^\circ$)) and results are given by the Figure 7 (http://www.flickr.com/photos/34386593@N03/3199155222/).

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Interactive Comment

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