Response to Anonymous Reviewer

The authors would like to thank the anonymous reviewer for his/her comments that gave us the opportunity to change/clarify various things in the revised version of our manuscript. Below, please find our response to each one of the reviewer's comments.

Major comments

1. I agree with the other reviewer that having all the equations in the Appendices is not optimal, also one would indeed like to see the result of each step on the data.

We thank the reviewer for giving us the opportunity to improve substantially our manuscript by putting the equations in Section 2.2 (Methodology). This Section has been enhanced with details about the method we followed and we also include a new plot that shows how the NO_2 patterns changed from step to step (Fig. 1 in the revised manuscript).

2. I do not understand why CF1 has these specific systematic 'worm-like' patterns. Please explain.

As discussed in the revised manuscript CF1 exhibits characteristic spatial patterns with values greater than and lower than 1 over and adjacent to pollution hotspots, respectively. This leads to the worm-like patterns which are pretty persistent throughout the year. Now, the reader may get an idea about the seasonal variability of the CF patterns. The CF1 patterns are given in high resolution in the supplement along with similar figures for CF2 and CF3.

3. Why would CF2 (and CF3) be (so) different for each grid cell around the world. Please explain why that is. And can we then understand the observed patterns/behaviour ?

The purpose of using CF2 and CF3 is to correct possible over and under corrections inserted during step 1 (resolution correction) which depends on the tropospheric NO_2 levels. Within the revised manuscript (Section 2.2) we give several details about the methodology and discuss about the observed CF patterns. As discussed there, CF2 takes higher positive and negative values over several pollution hot spots (absolute values higher than 0.5) pointing towards an under or overcorrection, respectively, during step 1. The CF3 patterns are pretty patchy and cannot be connected to areas with low or high tropospheric NO_2 like in the case of CF1 and CF2. CF3 accounts for the amplitude and shape of the seasonal variability and takes values that generally vary significantly from month to month over each grid cell.

Minor comments

1. What is the expected effect of the max 1 hour difference in local overpass tie between the NO_2 measurements from various satellites ?

Studies around the world do not give large differences around the overpass time of the morning satellites we study here (e.g. Boersma et al., 2009; Kanaya et al., 2014; Hendrick et al., 2014; Drosoglou et al., 2018). The reported differences are expected to be lower than the differences stemming from the special characteristics of each instrument and this is why we did not mention it in the text. The difference between morning and noon is definitely much larger and explains part of e.g. SCIAMACHY-GOME difference.

- *Boersma, K. F., Jacob, D. J., Trainic, M., Rudich, Y., DeSmedt, I., Dirksen, R., and Eskes, H. J.: Validation of urban NO_2 concentrations and their diurnal and seasonal variations observed from the SCIAMACHY and OMI sensors using in situ surface measurements in Israeli cities, Atmos. Chem. Phys., 9, 3867-3879, https://doi.org/10.5194/acp-9-3867-2009, 2009.*

- *Hendrick, F., Müller, J.-F., Clémer, K., Wang, P., De Mazière, M., Fayt, C., Gielen, C., Hermans, C., Ma, J. Z., Pinardi, G., Stavrakou, T., Vlemmix, T., and Van Roozendael, M.: Four years of ground-based MAX-DOAS observations of HONO and NO_2 in the Beijing area, Atmos. Chem. Phys., 14, 765-781, https://doi.org/10.5194/acp-14-765-2014, 2014.*

- *Kanaya, Y., Irie, H., Takashima, H., Iwabuchi, H., Akimoto, H., Sudo, K., Gu, M., Chong, J., Kim, Y. J., Lee, H., Li, A., Si, F., Xu, J., Xie, P.-H., Liu, W.-Q., Dzhola, A., Postylyakov, O., Ivanov, V., Grechko, E., Terpugova, S., and Panchenko, M.: Long-term MAX-DOAS network observations of NO_2 in Russia and Asia (MADRAS) during the period 2007-2012: instrumentation, elucidation of climatology, and comparisons with OMI satellite observations and global model simulations, Atmos. Chem. Phys., 14, 7909-7927, https://doi.org/10.5194/acp-14-7909-2014, 2014.*
- *Drosoglou, T., Koukouli, M. E., Kouremeti, N., Bais, A. F., Zyrichidou, I., Balis, D., van der A, R. J., Xu, J., and Li, A.: MAX-DOAS NO_2 observations over Guangzhou, China; ground-based and satellite comparisons, Atmos. Meas. Tech., 11, 2239-2255, https://doi.org/10.5194/amt-11-2239-2018, 2018.*

2. What is the uncertainty on all these CF1s, for example stdv on the 12 CF1s for each month ? I have no idea how well you can determine these CF1s.

By applying error propagation we found that CF1 could be calculated with a relative error of around 20%. This is a very conservative calculation as the SCIAMACHY precision 0.1 x 10^{15} molecules cm^{-2} is taken into account in the standard deviations per se. Hence, the uncertainty is expected on a global scale to be well below this value.

3. Same question for CF2.

Similar as above.

4. P6, l8, ‘shown below’ should be ‘shown’

Corrected.

5. P6.l10 ‘to one’ should be ‘to the one’

Corrected.

6. Looking at Fig. 4 it looks like the yearly variation is much better fitted in the b) curves than in the a) curves. In fact it looks like the seasonal amplitudes are more or less fixed in the single linear trend analysis (a). Is that really a direct consequence of the reversal trend fit and not something prescribed in the linear trend fit ? I find the difference strikingly large.

The grey lines are just connecting the monthly values (grey points). The black lines in the first column panels depict the seasonal component which is fitted to the data. In the second column panels we did not plot the fitted seasonal component because there would be two seasonal components for the year of trend reversal with different amplitudes (as the trends are calculated for the years before and after the reversal but include the reversal year in both cases) and the figure

would be very noisy. Hence, we decided to plot only the trend lines (blue or red) and connect the grey points with a grey line in order to get a better idea of the seasonal variability.