Response to anonymous referee #2

We would like to acknowledge the referee for their helpful and thorough review. We believe that their comments improved the quality of this work.

Some of the measurements and statistics presented in the study have changed as a result of some of the reviewers' suggestions. Moreover, an updated OMI overpass data set has been used, generated by the Aura Validation Data Center (AVDC) (http://avdc.gsfc.nasa.gov) in November 28th 2016.

At first, we address the reviewer's general comments remaining from the first review phase and then we answer to the reviewer's comments submitted during the interactive discussion. Our responses follow the reviewer's comments (in bold).

General comments from first review phase:

Few satellite data and many different models are used but we can not find any map or plot from these data. Please try to visualize, what you use. I expect maps from all applied models and satellites (examples) in this study.

Maps of NOx emissions, CAMx simulations and satellite observations (OMI, GOME2A and GOME2B) used in this study have been added (figures 5 and 6 in the revised manuscript).

The three measurement areas (fig. 1) are more complex because of the sea, how is this problem (sea-land) in the model considered? This makes the selected albedo also complex.

The land-use spatial distribution is accounted for in CAMx which considers 11 land-use categories namely: 1) Urban, 2) Agricultural, 3) Rangeland, 4) Deciduous forest, 5) Coniferous forest, wetland, 6) Mixed forest, 7) Water, 8) Barren land, 9) Non-forested wetlands, 10) Mixed agricultural/range, 11) Rocky (with low shrubs). CAMx assigns a single dominant land-use to each grid cell while translating the gridded land-use fields from the meteorological model WRF applied with the use of a 20-category MODIS-based land use database of 30 arc-second (~ 1 km) resolution. Each CAMx land-use type is associated with a single UV albedo, which can take one of the values 0.04, 0.05 or 0.08. Under this view, CAMx can distinguish between sea- and land-dominated grid cells and assigns the most appropriate albedo value.

The selected areas overlap each other, how is this problem considered?

We think that this is not a problem for our study. We investigate each location separately by averaging the modeled NO_2 tropospheric columns over a typical pixel size area.

The campaigns have different time periods, to compare these data-sets, we need the same time period. Maybe an additional fit for the overlapping time!

Unfortunately, for technical reasons we were unable to achieve a longer common period of measurements for the three locations which would increase the confidence of the results. The common period is too short for comparing ground-based with satellite data and deriving meaningful statistics. However, this study is mainly focused on comparing the ground-based data sets with satellite retrievals over locations characterized by different atmospheric pollution loadings. We do not compare directly the NO_2 observations at the three campaign sites. However, the NOx emissions and NO_2 levels observed in the

urban site are different compared to the other two sites during the whole campaign period, due to enhanced anthropogenic activities (mostly road transport). Thus, the differences in NO_2 loading are mentioned and discussed.

Please clarify the wind directions for the period of the campaigns.

We have investigated the wind data for the period of the campaigns. Certainly there is no prevailing wind direction that can be used to explain robustly differences of NO_2 concentrations among the three locations. One can identify cases where NO_2 from the city could be potentially transported towards the direction of the suburban site, but such attribution would be rather speculative since there is no other supporting information to make a consistent case.

Comments during interactive discussion:

The map of satellite can show the variability of NOx and corresponding the emissions, this means, if the applied OMI data shows really the emitted from this area or not.

Maps of the mean tropospheric NO_2 columns over the campaign time period measured by OMI, GOME2A and GOME2B have been included in the manuscript (figure 5 in the revised manuscript). It seems that OMI does not detect the elevated NO_2 concentrations of the urban area for this period of time.

The comparison of the NO_2 tropospheric from different sites (UC, RC and SC) is less relevant because the data are from different time periods, for such comparison, you need the same time period.

We absolutely agree. Therefore this study is mainly focused on comparing the ground-based data sets with satellite retrievals. There is no direct comparison of NO_2 data from the different campaign sites. However, the higher NO_2 levels observed in the urban area due to enhanced anthropogenic activities, which can be seen also from the CAMx simulations, are discussed.

The adjustment factors are more depend on the model data than OMI data; this rescaling can be used but it is somehow banal. Without any adjustment factors, the results can be seen from fig. 4, what I expect for OMI reconstructed.

We are not sure why the reviewer mentions Fig.4. In the discussion paper this figure shows examples of the AMFs calculated by radiative transfer modeling. The use of the adjustment factors calculated by model simulations seems to improve the comparison between the MAX-DOAS and satellite measurements over the urban area (figure 10 in the revised manuscript).

Generally, you can compare every ground based with every satellite with different time periods but in this case, you can not compare the results together.

In general we agree. However, the NO_2 spatial distribution in the greater area of Thessaloniki follows the NOx emissions pattern, which does not change significantly during the campaign period. In this study, we investigate how the satellite and ground-based data sets compare over locations characterized by different NO_2 concentration levels.

P4, l16: direct sun light, we have only scattered sun light, but if we look directly in the sun (still scattered), the measured spectra have structures, which should be removed from the analysis.

We do not use direct sun spectra in this study. We only mention the capability of the systems to perform direct sun measurements in the systems' description section.

P5,l5: albedo: 0.1. The three different areas (UC, SC and RC) have definitely different albedos.

Since uvspec is not a 3D radiative transfer model, we cannot use spatially variable albedo. Instead we assumed an average albedo over each area. An albedo of 0.1 can be considered representative of the urban site (UC) for the wavelength region 400-450 nm that is used in the DOAS analysis. For the other two locations (SC and RC) we have run the AMF simulations again using the more realistic value of 0.07 and the manuscript has been revised accordingly. However, the differences in tropospheric NO_2 VCDs are quite small and the comparison results are not significantly affected.

Fig. 5 down: Some pixels are missing after averaging!

Only the pixels included in the typical OMI pixel size area over each campaign site were available. We have extracted the rest of the pixels from the model simulations and we present the mean NO_2 spatial distribution for the whole domain in the revised manuscript (Fig. 6).

Fig. 7: It is not clear to me, if you used all data from different campaigns with different time periods or not, if yes, they are not comparable in such form. You need a significant criteria, namely the same time period.

Unfortunately, due to technical issues, the three instruments were performing measurements at the different sites in different time periods. However, this study focuses on the comparison between ground-based and satellite observations over areas with different NO_2 loadings and different spatial patterns. We do not compare directly the MAX-DOAS measurements at the different stations.

Fig. 9: You can not compare the slopes from different time periods specially with seasonal difference!

We agree that we cannot resolve with the available data any seasonal differences in the comparison of ground-based with satellite data. As argued already in other comments above, in this study we focus mainly on how different NO_2 levels and their spatial patterns affect the comparisons.