First of all, we want to thank this reviewer for the positive assessment of our manuscript and the constructive comments. We followed them as described in detail below.

In the following reviewer comments will be in italics, our response in normal typeface.

1. Response to general comments

Manuscript amt-2010-41 deals with the issue of surface reflectance as a key parameter in satellite trace gas retrievals in the UV/visible range and in particular for the retrieval of nitrogen dioxide vertical tropospheric columns. A new methodology which uses the MODIS bi-directional reflectance distribution function has been applied to two years of OMI NO_2 observations. The methodology is well-defined, explained and discussed with ample examples and statistical analysis. The authors have demonstrated the importance of using these detailed reflectance distributions for the calculation of the air mass factors, the basis of any DOAS analysis techniques. Overall, I recommend publication in Atmospheric Measurements and Techniques subject to one issue that I discuss in the attached supplement: the authors have not shown to my satisfaction the relative importance of using different a priori profiles compared to the use of the new reflectances in the algorithm. On this issue, I refer the authors to the annotated text C673 attached and note that I would like to see these amendments before the final article is accepted.

Author response: We followed the referee' suggestions to add further analysis and discussions about the importance of a priori profiles used in the algorithm. Please see our responses to Comments M11, M13 and M14 below and the amendments in the article, especially in Sect. 3.3. However, we would also like to stress that the referee appears to have misunderstood an important point concerning the application of a-priori profiles as stated in our response to Comment M11: The vertical a priori profile itself is not retrieved but is taken from an external data set, in our case (and in DOMINO) from the TM4 chemical transport model [P1982, L22]. The a-priori profiles are therefore independent from the albedo data set used in the retrieval.

2. Response to specific comments

Comment [M1]: The abstract is well-written, however I feel it would benefit with some actual numerical results from your work, from the results section.

Author response: The following numerical results referring to the comparison between GOME/TOMS LER-based NO_2 and BRDF-based NO_2 from Sect. 4 will be added in the abstract: "The relative differences are mostly below 15% in July but in November the NO_2 VTCs from TOMS/GOME are lower by 20-60%."

Comment [M2]: This point is, I feel, one of the most important findings from this work. I would hence like to see some numbers instead of the word "partly", especially since you say that these differences have nothing to do with the BRDF issue. Might it be that these two effects, i.e. high SZA & choice of a priori are more important than the use of more detailed albedo information? Some numbers here and a proper comment else where in the text would be appropriate.

Author response: We agree that the statement "the retrieval difference is not sensitive to the choice of a priori profile" which was based on a limited case study should be replaced by more quantitative results. Please see our responses to Comment M11, M13 and M14 below. However, it is difficult to give exact numbers for the relative importance of the two effects

since they will vary for different scenarios. The corresponding sentence in the abstract will be changed to "The much larger differences in November are mainly due to stronger BRDF effects at higher solar zenith angles. To a smaller extent, they are also caused by the typically more pronounced maximum of the NO_2 a priori profiles in the boundary layer during the cold season, which make the retrieval more sensitive to radiation changes near the surface.".

Comment [M3]: This first paragraph is rather weak, like a "copy&paste" from a report or webpage, please re-write.

Author response: This paragraph is re-written and shortened in the modified manuscript as follows:
"Since the first satellite observations of tropospheric NO_2 from the Global Ozone Monitoring Experiment (GOME) (Burrows et al., 1999) launched in 1995, the spatial resolution of space-borne UV/VIS instruments has been gradually improved. The pixel size of the OMI sensor (Levelt et al., 2006) on the Aura satellite launched in 2004 is up to 13×24 km^2 at nadir, which is much smaller than the pixel size of earlier instruments such as GOME (40×320 km^2) and SCIAMACHY (30x60 km^2) (Bovensmann et al., 1999). The improvement in spatial resolution increasingly allows the sensors to detect NO_2 pollution features on a regional scale, and retrieval algorithms should take full advantage of this capability. For satellite NO_2 retrievals, measurement precision and uncertainty depend on a number of factors. A detailed general error analysis was presented by Boersma et al. (2004). It showed that the retrieval errors are dominated by the uncertainty in the tropospheric air mass factor (AMF_{trop}), estimated to be of the order of 20–50% for polluted-scene pixels.

Comment [M4]: "Furthermore" does not follow here the logical sequence of the phrases above, maybe you mean something else?

Author response: "Furthermore" is used here to indicate another shortcoming of the LER climatologies apart from the coarse resolution. The sentence is modified as "Apart from their coarse resolution, these LER climatologies also do not account for interannual and short-term variability".

Comment [M5]: This phrase is a bit too informal for the written expression, please re-write.

Author response: This phrase is modified as "look-up table error corrected".

Comment [M6]: Put these references in proper order.

Author response: The order has been corrected.

Comment [M7]: What do you mean here?

Author response: "full inversion" is a term defined in the operational MODIS BRDF/albedo algorithm. A full retrieval of the RossThick-LiSparse-R model parameters is attempted only if there are seven or more high-quality observations well distributed over the viewing hemisphere necessary to constrain the shape of the BRDF function.

Comment [M8]: This is rather vague, what input parameters does this algorithm need, how were they chosen, and so on. In general, this whole point should become clearer.

Author response: The following sentences are added in the modified manuscript. “In the backup algorithm, a global land cover classification derived from the Olson classification [Olson, 1994] and a seasonal model is employed, and archetypal BRDFs compiled from various field measurements are assigned to each land cover. For each pixel, the corresponding archetypal BRDF is assumed as an a priori guess and its shape is then constrained by the available observations.”

Comment [M9]: “Quite well under most situations” is extremely vague to say the least. Please expand.

Author response: Agreed. The sentence will be modified as follows: “Jin et al. (2003) and Salomon et al. (2006) demonstrated that the albedo changed only slightly when the MODIS BRDF/albedo algorithm switched from the backup algorithm to the full inversion, indicating that data quality is only little reduced when the backup algorithm has to be used.” Unfortunately, a more quantitative statement was not given in the two publications.

Comment [M10]: You mean pixels, cells, degrees?

Author response: The sentence will be changed to “between the neighboring 5 x 5 pixels”.

Comment [M11]: The choice of apriori profile seems to be a very important issue that, in my opinion, has not be dealt with in the text in a sufficient manner. There is a heavy dependence of the AMFtrop on the apriori profile. Has the issue been looked into? Also, what happens if you use as apriori the retrieved profile but using the nominal OMI algorithm? Does the algorithm return the same apriori profile or not? Such a test would strengthen the case that the differences discussed further on in the text are indeed coming from the new surface albedo treatment. I would like to see some numerical discussion on this point.

Author response: We agree that the a priori NO_2 profile is an important input parameter for the AMF_{trop}. The uncertainty in the AMF_{trop} due to profile uncertainties is approximately 10% [Boersma et al., 2004. To better distinguish between the effects of changing solar zenith angles and changing vertical profiles between summer and winter we therefore added an additional scenario in Sect.3.3 and Fig. 8.
However, we believe there is an important misunderstanding: the vertical profile itself is not retrieved but is taken from an external data set, in our case (and in DOMINO) from the TM4 chemical transport model [P1982, L22]. Satellite observations in the UV/VIS do not provide enough independent information to retrieve a vertical profile of NO_2 but only provide total columns. Therefore we can not answer this question.

Comment [M12]: However, the “best case” scenario is shown here. By how much doe the AMFs differ when the SZAs are extremely low or high? Still 10%?

Author response: Yes, this is only an example, but it is not a “best case” scenario but rather a typical winter case with a representative solar zenith angle. The AMF_{trop} differences between the three surface treatments vary strongly for different geometries and BRDF coefficients. As can be seen in Fig. 6, for the few selected cases the relative differences between BRF and black-sky albedo vary between 0% and 80%. When the SZAs are extremely low or high the box AMF profiles will look differently. For instance, with the same VZA, AZA and BRDF coefficients as in Fig. 3, the box AMFs differ by up to 1% for SZA=10° and 25% for SZA=70°. The largest difference in the box AMF profiles still occurs close to the surface, just not necessarily differ by up to 10% as is shown here.

Comment [M13]: On geometries or on the apriori profile shape or on the SCD_{trop} amount?

Author response: First all, following the suggestion from referee two, the Fig. 8 has been modified in the revised manuscript including a discussion of the sensitivity of AMFs instead of VCD_{trop}. Air mass factors indeed do not only depend on geometries but also on a priori profile shape. To better distinguish between the effects of changing solar zenith angles and changing vertical profiles, we will add another winter situation with a summer a-priori profile as an additional case in the paper (new Fig. 8b), and move the original Fig. 8b down to Fig. 8c. The new Fig. 8b versus Fig. 8a shows the effect of different solar illumination and BRDF parameters in winter as compared to summer. Fig. 8c versus Fig. 8b shows the additional effect of the different a-priori profiles. The winter profile has more NO_2 at low altitudes which amplifies the sensitivity of the result to the properties of the radiative transfer close to the surface.

Comment [M14]: Without some statistics, I fail to see from the article how you can be so sure of this. For e.g. a table with statistics & differences, case A1-B1 etc.

Author response: Thanks for this good point. It is true that a strong statement should not be made here since we compared only two cases (case A2a and A2b) calculated from two a priori profiles in November (TM4 and EURAD-IM) which are quite similar in shape. We will therefore replace case A2b in Fig. 9 with results calculated using the same summer a priori profile as in case A1 and extend the discussion in the modified manuscript.

Comment [M15]: A sentence as to the physical meaning of such an asymmetry will be useful here.

Author response: The following sentence is added in the revised manuscript: “This is caused by the surface anisotropy which makes the surface appear brighter or darker depending on whether the observer is on the same or opposite side of the local vertical as the sun”.

Comment [M16]: Have there been validation works for example that also have this as finding? Would be good to reference here.

Author response: This study investigates, to our knowledge, for the first time in literature, the impact of surface reflectance anisotropy on tropspheric NO_2. Therefore we can not provide a reference to validation work here at this moment.