Reply (in blue) to Referee #2

We thank the referee #2 for the constructive comments. Our reply is included after the referee comments.

This manuscript presents a new approach to derive effective scene albedo on a pixel per-pixel basis from TROPOMI observations and to build a viewing zenith angle dependent LER climatology with an improved spatial resolution compared to former data bases. Although the topic of the study fits well within AMT and there is no obvious issue with the approach, I would suggest to further discuss the results and to extend the comparisons to better demonstrate the added-value of the database. For example, results are discussed for only one spectral region and a limited amount of data (April 2018).
It would be beneficial to have more illustrations for different months. Reading the manuscript, I had many comments similar to those from reviewer 1. I won't list those again but encourage the authors to carefully reply to them. Below are a few additional comments. Once the comments have been addressed and the manuscript
consolidated, this work will be worth being published within AMT.

As general reply we would like to highlight that the G3_LER is not a climatology or database as commonly created by other methods but a dynamic map updated every day and in this way it represents the current surface conditions.

Furthermore, the main focus of this paper is to present the algorithms for obtaining G3_LER and G3_LER, the results for S5P UV (ozone) are shown as demonstration. Results for different seasons were already included in the submitted version, see for example Fig. 8.

Comments:
• The description of the smart sampling and machine learning approaches is quite technical. It would be beneficial to the readers to further describe the general ideas/concepts on which rely those methods.

The following text is included in Section 2.2. "Training data is traditionally created at fixed intervals uniformly distributed for each input variable; as a consequence the training samples are grouped around the node points and a very poor coverage of the multidimensional input space is reached. Deterministic sampling methods provide a more uniform distribution of the training data covering the entire space of each input variable" and "For this work we select a Halton sequence that uses prime numbers for creating sample points in each input dimension and a radiative transfer model computes the corresponding simulated radiances".

• Section 3: Could you provide more details here on how clear-sky pixels are selected? Such details are given later in the manuscript but it would good to already describe this in section 3. Could you also provide some statistics on the number of days required to have a global coverage? There must be some regions with persistent clouds for which the update frequency drastically decreases. Actually, it would be useful for traceability to provide this information

in the database along with the G3_LER values. For example, for one given cell, the LER value has been derived from day-1, -2, -3, or . . .

TROPOMI and VIIRS data are used for the clear-sky determination. The following sentence is included in the paper: “In the case of S5P, clear-sky is determined using both the operational cloud properties retrieved from TROPOMI (Loyola et al., 2018) and the VIIRS/SNPP (Visible Infrared Imaging Radiometer Suite sensor onboard Suomi National Polar-orbiting Partnership satellite) cloud mask regridded to the TROPOMI resolution (R. Siddans, 2016). Note that S5P and SNPP fly in loose formation, the S5P orbit trails 3.5 to 5 minutes behind SNPP”

One month of data is usually enough for obtaining a globe map. The following explanation is added in section 3: “The spatial resolution of the G3_LER maps for TROPOMI is 0.1° and global maps can be generally derived combining data from one month. Two to three months of data are only needed for regions covered with persistent clouds like the Intertropical Convergence Zone (ITCZ).”

The G3_LER is not a classical static database, as explained in section 4.3 the G3_LER maps are updated on a daily basis to represent the current surface conditions. To address the traceability question of the reviewer, we added the following in section 4.3: ”Time information (orbit number) of the LER used in each grid cell is included in the GE_LER maps.”

• G3_LER data seems to be available only for the ozone fitting window and for three surface types. Could you comment why only those three surface have been considered? In other regions than UV, BRDFs effects will differ much more significantly as a function of the surface type. Could you clarify if you intend to provide GLER data in other spectral ranges and how you intend to proceed with respect to this aspect.

The selected land, water and snow/ice cover well the BRDF effects in the UV. We include the following sentence in section 4.3 “Note that the selected surface types cover the BRDF effects in the UV ozone fitting window; other trace gases like NO_2 in the VIS will require different land cover types (e.g. water, snow/ice, urban, paddy, crop, deciduous forest, evergreen forest) to properly model the BRDF effects, see Noguchi et al., 2014.”.

Regarding the second question about the spectral ranges, in the Conclusions we already indicate our plans to apply the GE_LER/G3_LER to other S5P fitting windows.

• It is mentioned that the Bodeker ozone database is combined with the McPeters/Labow climatology as input of the RT simulations. Could you be more specific on the needs for this combination and on what is provided by each of those databases. Also in Table 1, the ozone profiles appear to be classified only as a function of the total column. Is it sufficient or are the geographic variations of the profiles accounted for somehow? Is there any latitude/longitude dependence taken into account? If not, please be more specific on the profiles that have been used. Also could you provide typical sampling steps of the different dimensions?

The corresponding paragraph in section 4.1 was rephrased as follows: “We use the Bodeker et al., (2013) database for representing the stratospheric ozone combined with the McPeters/Labow (Labow et al., 2015) climatology for the lower tropospheric ozone.”

A classification as function of the total column is sufficient thanks to the strong correlation between the total ozone and the ozone profile shape.

The smart sampling does not use “sampling steps”. Please see our reply to your first comment.

• Figure 7: to better illustrate the possible impact of BRDF, could you show such clear-sky histograms for different range of viewing angles. If BRDF effect is important, we could expect systematic biases varying as a function of the VZA.
Also, biases are more important for cloud cases. Is it because cloud albedo are retrieved in a different spectral region?

We created histograms as function of VZA but they are not really informative. The BRDF dependency on the VZA can be better appreciated in the plots from Figure 8.

• Figure 8 : what are the implications of the numerical instability of the RT simulations around VZA=0 on the retrieved LER?

We removed the numerical instability and created extra simulations around nadir (VZA=0).

• Figure 9: There is a clear general bias between the G3_LER and OMI_LER data, even at low/mid-latitudes. Could you better quantify and discuss this? Is there any indication that one of the two data sets would be more realistic?

We found out that the small bias was due to imperfections on the current TROPOMI L1 products. The following sentence was added in section 4.2 “The version 1 of the TROPOMI Level 1 product has small deficiencies on the UV band; therefore a soft-correction based on comparisons with OMPS radiances is applied to S5P. It is expected that the version 2 of the TROPOMI Level 1 product will include a more accurate radiometric calibration”.

In chapter 4 we include a new section describing the comparison with GOME-2 and OMI LER. However, it is not obvious which of the three data basis is actually best / most realistic. For some cases two of them agree well for other cases other two agree better.

Minor/Technical comments:
• Quality of figures is generally low. Could you increase the quality as well as the size of labels?

Figure quality and font size improved

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• Page 2 – line 6: 35% on ozone column seems large. Is this value correct?

Figure 4 of Lerot et al. shows AMF changes in this magnitude when a surface albedo of snow/ice is used instead of surface albedo of water.

• Page 2 – line 12: Could you be more specific with that statement? Are there some references providing estimates of errors on TROPOMI products caused by the too coarse resolution of old databases?

Error estimates are not yet available, but this is a known data quality issue listed in the "Product Readme File" of the S5P L2 products, see http://www.tropomi.eu/documents/prf

• Page 3 – line 29: Add "solar and" before "viewing geometry"?

Done

• Page 6 – line 8: The LER data could still differ from the actual surface properties in case of sudden snow fall combined with significant cloudiness.

That is correct, at the end of the sentence we added "The only exceptions are cases of sudden snow fall combined with significant cloudiness".

• Page 6 – line 16: remove "viewing geometry"

Done

• Figure 4 shows negative optical densities, which is not physical. In the text, those quantities are referred to optical densities differences but it is not clear what is the reference. Could you homogenize the text and y-label and clarify what are those optical density differences?

Negative optical densities are indeed misleading. What is shown here is the optical density of the DOAS polynomial ($p(\lambda)$ in Equation 2). This information is added in Section 4.1 and in Figure 4.

• Page 7 – lines 5-6: This is very technical and the meaning is not clear at all for me. Could you rephrase this?

We use common nomenclature of machine learning; the text has been updated as follows: "The best results are obtained using a feedforward NN (the neurons are grouped in layers) with a topology …"

• Page 8 – line 2: "from the couple of days" is not clear. Please be more specific.

This sentence is reformulated as follows "The TROPOMI G3_LER map for a given day is created by regridding (using a 0.1° x 0.1° resolution) the clear-sky LER data from the same day with the G3_LER map based on the LER data from previous days"

• Page 8 – line 29: "smoother" instead of "smother"

Done

• Page 9 – line 31: Mention that those numbers are valid for April 2018.

Done