Short comments by W. Qin

We thank W. Qin for the comments on our manuscript. Below are the comments in blue and our response in black. Any modification made to the text of the manuscript has been highlighted within a green box. The line numbers correspond to the version of the manuscript available for online discussion.

Comment 1

The paper misrepresents the GLER product (Vasilkov et al., 2017) as GLER climatology (line 15, page 3). GLER is not a climatology, but a bidirectional (sun-view geometry dependent) LER product at a scale of satellite pixel (OMI is used as an example). GLER is derived using real OMI pixel geometry and MODIS high-resolution BRDF product over land averaged over an OMI field of view (FOV) and the Cox-Munk slope distribution over ocean with a contribution of water-leaving radiance. This is the kind of product the authors recommended for TROPOMI in the conclusion section.

We apologize for the misrepresentation by the use of the term climatology. We have modified that.

"Vasilkov et al. (2017) created a geometry dependent surface LER (GLER) product"

Comment 2

The authors implemented MODIS BRDF model into the RT DAK and use it for UV/Vis wavelengths of OMI and GOME-2 (section 3.2, see line 30, page 11). It is not clear if DAK is a scalar or vector RT model in terms of atmospheric RT simulation. But the models that DAK is compared to for evaluation include a scalar model (LIDORT) and a model (SCIATRAN) that has both modes (scalar or vector), and which mode is used is not clear either. However, as indicated in Vasilkov et al, 2017, our experience with VLIDORT has shown that ignoring polarization for UV wavelengths would result up to 10% error in TOA radiance simulations.

DAK is capable of simulating radiative transfer in the atmosphere with and without accounting for polarization. The simulations shown in the comparison do not account for polarization. The only purpose of the comparison with LIDORT and SCIATRAN was to assure that surface BRDF was correctly implemented into DAK. Therefore we did not give many details on the settings of the radiative transfer simulations. We have now added a sentence that gives some information on the main settings (P11, L32):

These settings include no polarization, a plane parallel standard mid-latitude atmosphere and absorption by O3, O2-O2.

Comment 3

The operational MODIS product (MCD43A1) is used in this paper for surface BRDF characterization (line 15, page 11). However, as we know, operational MODIS BRDF product usually has up to 20% gaps globally due to cloudiness. That's why we use gap-filled MODIS product (MCD43GF) in our GLER product.

The surface BRDF parameters used in the simulations in Sect. 3 (Figs. 4, 5 and 6) from MCD43A1 MODIS product are the spatial average over Amazonia. We used it as an example of combination of f_{iso}, f_{vol} and f_{geo} for surface and TOA reflectance simulations in Sect. 3. Because it was spatially averaged we did not worry about the gaps that the product might have. In the following sections, we used a climatology created by the QA4ECV Land group (page 15, line 10). This climatology is a daily climatology based on 16 years of measurements (2000-2016).

Comment 4

This paper only covers BRDF effects on NO_2 and cloud products (FRESCO and OMCLDO2) over land, and ocean is not mentioned at all. But ocean reflection is nonLambertian either. A good example is the sunglint effect caused by Fresnel reflection, which creates strong forward reflection as significant as the so-called hot-spot effect in the backward scattering direction over land as discussed in this paper. To characterize the surface BRDF effect globally, one has to consider both land and ocean.

We fully agree with the importance of the ocean and the necessity of accounting for ocean reflection in a global retrieval that fully accounts for surface BRDF effects. However, for our study the main focus was over land, so we did not take ocean into account. Regarding the radiative transfer model DAK, the next step to take is to implement the Cox-Munk model for sea surface reflectance.

Comment 5

It is mentioned in couple of places (line 5, page 1; line 11, page 21) that rugged terrain causes strong backscattering reflection. However, not only rugged terrain, any rough surfaces like vegetation and soils produce strong backscattering, even the terrain is flat.

We have modified the term rugged terrain from the abstract (P1, L5). In this case we were referring to forested area (Amazon) where we found the highest cloud fraction bias. In page 21, line 11 we also meant forested terrain, so we have also changed the term “rough terrain”.

Comment 6

The discontinuity of the green curve at nadir in Fig.9b indicates something is not correct in the simulations, which needs more explanation.

The discontinuity in Fig. 9b is because in the forward scattering regime (positive ϑ) we assume an increase in the cloud fraction and in the backward scattering regime (negative ϑ) we assume a decrease. This means that cloud fractions in Eq. 12 are different for each scattering regime, causing the “discontinuity” in the cloud radiance fraction (Fig. 9b) and in the total AMF (Fig. 9c) when $\vartheta = 0°$.