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Interactive comment on "In-Flight Calibration of SCIAMACHY's Polarization Sensitivity" *by* Patricia Liebing et al.

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AMT 2017-175: Author's Response

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We thank the referee very much for the positive and concise review. The referee's comment on intrinsic model errors will be discussed below and addressed in the revised version of the paper.

Comment: "The vector radiative transfer model is used to calculate maximum possible polarization values for the analysis with several assumed atmospheric state terms and boundary conditions. The approach uses the model to derive limiting values for the polarization of the nadir and limb radiances and is a good idea, in my opinion. The question that arises is about the accuracy of the model, both with regard to the assumed states and boundary conditions as well as the algorithm itself (for example, overestimation of multiple scattering in a plane parallel atmosphere as pointed out by the authors). The model reference paper, Rozanov et al., 2014, shows relatively large differences between SCIATRAN and other vector RT codes for limb radiances, especially in certain geometries. This should at least be mentioned in this paper and if possible the potential impact on the results quantified."

This is a very valid point, and the investigation of the effects of intrinsic model errors on the results, mainly on the polarization sensitivities, represents a large body of the work performed preceeding this publication. The reason why the discussion of these matters has been kept to a minimum is that with a more detailed discussion, the paper would have been even longer and more tedious. The *Extrapolation method* relies on the assertion that in most cases, a distribution of scenes with varying albedo and aerosol conditions can be extrapolated using their reflectance distribution to a converging point with minimum reflectance and maximum polarization. This has been confirmed with a limited sample of simulated scenarios in nadir, and extensively for limb. Errors of the extrapolation have been minimized through careful choice of the included geometries and locations, as described in section 3.1. They cannot be fully avoided though, and one reason for integrating data over the relatively long period of one year was to add data points from slightly different geometries or seasons into a cell of (q, u) so as to achieve perhaps less systematic errors at the expense of higher noise. However, especially for nadir there is indeed no robust quantitative estimate on the effect of systematic extrapolation errors. Instead, the study concentrated on specific variations of the zero-point in nadir, e.g., by varying the wind speed over ocean or completely neglecting the surface reflectance (pure Rayleigh scattering). Data over land for limited wavelengths and scan angles provided additional consistency checks. The study basically resulted in the specific choice of reliable wavelengths (< 500 nm) and wind speeds. The optimal wind speed and its variation were for instance chosen by comparing the resulting distributions of R/R_{RTM} and requiring that most of the data, especially at larger wavelengths, have $R/R_{RTM} \geq 1$. In limb, the results of the extrapolation method can be directly compared to those from the *LUT method* and give an estimate of errors related to extrapolation and assumptions in deriving the LUT. Further studies regarded the potential influence of absorption by trace gases such as O_3 and H_2O which was found to be negligble. Additional confidence in the results is given by Fig. 13, which shows that at least for the beginning of the mission a χ^2-distribution consistent with associated systematic errors.

Another issue is the theoretical accuracy of the RTM for a given scenario, both in the limiting cases as well as the distribution for the LUT method. For nadir, comparisons of several RTM for Rayleigh scattering and BRDF modelling showed sufficiently high ac-

curacy (Kokhanovsky et al., 2010; Rozanov et al., 2014). In limb, the approximation of the multiple scattering contribution by a plane parallel atmosphere leads to the aforementioned overestimation of reflectances, increasing with TH. Further comparisons between the MYSTIC Monte Carlo model and SCIATRAN showed an overestimation of the depolarization as well Rozanov et al. (2014). For the extrapolation method, and the normalization point of the LUT method, the error is larger at shorter wavelengths due to the contribution of multiple Rayleigh scattering. At the THs considered in this analysis, this error does not exceed 0.01 for both q and u, and depends on geometry. At larger wavelengths multiple scattering is introduced by surface reflectance or aerosols and clouds. It therefore does affect the predictions of the *LUT method* at higher values of the reflectance or R/R_{RTM}. This method, however, suffers from many more prevailing errors, such as the choice of the scenarios contributing to the averaged polarization vs. reflectance curve as shown in Fig. 5. The effect of the approximation of multiple Rayeigh scattering has in fact been taken into account in the calculation of the limb systematic errors. A set of polarization sensitivities has been obtained by correcting the limiting reflectance and polarization values with a rough parametrization of the observed differences between SCIATRAN and MYSTIC values. The resulting differences in polarization sensitivities lie typically within the error bands generated by the $\delta R/R = \pm 0.05$ variations. It has been added to that error, but does not contribute significantly to it.

We suggest the following changes to the paper to address ths concern:

In section 3.3.2., after the first paragraph, we add:
"For limb data, an estimate of a theoretical model uncertainty arising from the plane parallel approximation of the multiple scattering contribution on both reflectance and polarization is included in the total systematic error. The uncertainty has been estimated from a comparison between SCIATRAN and the MYSTIC (Emde and Mayer, 2007) Monte Carlo model (Rozanov et al., 2014). Its contribution to the systematic error of the polarization sensitivities is in general smaller than the error arising from the

normalization uncertainty and is therefore not depicted explicitly."

At the end of that same section, we propose the following statement:

"Generally, studies on the sensitivity of both methods with respect to model input parameters and data selection criteria indicate that at wavelengths above 500 nm the results become rather unstable. At lower wavelengths the measurements are less influenced by the unknown atmospheric and surface conditions, such that results are more reliable. In the following, the discussion is therefore restricted to the results obtained from PMDs 1 and 2 and Channel 2."

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