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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Satellite monitoring of different vegetation types by differential optical absorption spectroscopy (DOAS) in the red spectral range" *by* T. Wagner et al.

T. Wagner et al.

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Reply to Ref. #1

First we want to thank this (and also a second) anonymous reviewer for the positive assessment of our study and the constructive and very helpful comments and suggestions. Following these suggestions it was possible to correct and improve our method in several important aspects. Especially the recommendation to include the formulation of a forward model and the analysis of synthetic spectra put our conclusions on a much more solid basis. Before we comment the reviewers suggestions on an individual basis we give an overview on the most important changes compared to our original version of the manuscript.

1) We included the formulation of a forward model for the satellite observations of spectral albedo structures (new section 3.2). This model not only helps to understand better, under which conditions the DOAS method can be applied to the retrieval of narrow band albedo structures. It also drew our attention to two important aspects which were not treated correctly in the original version. First, it turned out that not the original albedo spectra, but the logarithms of the albedo spectra have to be included in the DOAS analysis. The fitting coefficients of the logarithms of the albedo spectra then represent the vegetation coverage of the observed satellite ground pixel. Second, it turned out that atmospheric scattering processes decrease the sensitivity of the satellite observations to the spectral signatures of the albedo. This effect is moderate (˜30%) for high sun and an atmosphere without significant scattering by aerosols and clouds. However, for large solar zenith angles (about $>80^{\circ}$) and/or strong aerosol or cloud scattering the sensitivity rapidly decreases. Fortunately, even for cloudy scenes the sensitivity can in principle be easily calculated and corrected. In contrast to the correction of tropospheric trace gas observations, only the knowledge on the cloud fraction (but no information on the height of the cloud layer) is needed. We added this information (including the new figure 4) to our manuscript. According to the new findings we also modified the following statement in several parts in the text 'One additional advantage is that the influence of atmospheric scattering and absorption is automatically corrected.' to 'One additional advantage is that the influence of atmospheric absorption is automatically corrected.' According to the findings of the forward model, we also modified the (new) Figure 1 (old Figure 2). The high-pass filtering is now performed by dividing (instead of subtracting) the fitted polynomial.

2) According to the findings from the forward model, we reanalysed the whole data set using the logarithm of the vegetation spectra (instead using the vegetation spectra directly). We also excluded the spectrum of dry grass, because the respective fitting coefficients were always very close to zero. While the temporal and spatial variation of the retrieved results almost not changed, the absolute values became much more realistic. The maximum fitting coefficients found for individual spectra are about 0.5,

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which is very close to the expected maximum derived from the forward model (0.7). We changed Figures 2, 7 and 8 accordingly.

3)We included a new section (3.3) describing the modelling and analysis of synthetic spectra. This exercise allowed us not only to confirm the results of the analysis of the real spectra and of the forward model, but also allowed us to perform additional sensitivity studies. In particular we could confirm the strong influence of spectral vegetation structures on the retrieved results of the O4 absorption. Like for the measured spectra the O4 results are strongly altered (and can become even negative) if the vegetation spectra are not included in the DOAS analysis. In addition, it was possible to investigate the potential effects of too low spectral resolution and wrong spectral sampling of the vegetation spectra. These sensitivity studies confirmed the results of the analysis of the measured spectra and supported the suggestion to improve the quality of vegetation spectra. We describe the results of our sensitivity studies in detail in the new section 3.3. and added new figures (new Figures 4, 5 and 6).

4) We added an additional Figure (new Fig. 3) which compares the retrieved results for part of a satellite orbit with the vegetation spectra either included or excluded in the fitting process. Also shown in the new figure are the results of the O4 absorption in the UV spectral range, which are not affected by the spectral structures of the albedo. The results presented in this figure clearly indicate that over areas with a strong vegetation signal the retrieved O4 absorptions deviate systematically and strongly from the true values (as e.g. retrieved in the UV); they even can become negative. If the vegetation spectra are included in the fitting procedure, the O4 values become much more reasonable.

5) We included an additional co-author (Tim Deutschmann). Tim Deutschmann developed the radiative transfer model which was used for the calculation of the synthetic spectra.

Referee comments:

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General comments The paper presents a method for satellite monitoring of vegetation types. The main idea of the paper is to fit the contribution of different vegetation spectra together with trace gas columns. This is a solid approach, and to my knowledge it has not been applied earlier to satellite measurements. However, I find the conclusions too speculative and the validity of the approach has not been demonstrated convincingly enough. Therefore, I propose revisions as given below. After these revisions I believe this will be a good paper and acceptable for publication in ACP.

Specific comments Ţ To give the reader more confidence in the proposed approach, it should be demonstrated using simulated measurements. The DOAS approach followed in the paper basically is a retrieval approach with an approximate forward model. The forward model equation, with its approximations, should be given explicitly in the paper. For many trace gas retrievals the DOAS approach has been demonstrated to be very useful, i.e. the assumptions made in the forward model are valid. However, for this new application the validity of DOAS is not obvious and should be demonstrated again. The validity of the approach could be demonstrated by performing retrievals from measurements simulated by a radiation transfer model including scattering by molecules and aerosols.

Author response: We thank the reviewer very much for this very helpful suggestion. We included a forward model with its approximations in the paper (new section 3.2), see also point 1) above. We also performed several sensitivity studies using synthetic spectra. This exercises are described in the new section 3.3, see also point 3) above.

Referee comment: Ţ The authors give several possible causes for the problems they encounter. These causes should be investigated in more detail. I suggest that the authors perform a sensitivity study based on (again) synthetic measurements. In this way it can be investigated how important spectral resolution issues are, and how sensitive the result is to imperfect vegetation spectra. In fact, the authors claim that the quality of the vegetation spectra is not sufficient. It would be helpful if the authors would indicate what requirements the vegetation spectra should fulfil (based on the sensitivity study).

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Author response: Using synthetic spectra we investigated the influence of poor spectral resolution and wavelength calibration. Both potential error sources have a strong influence on the retrieved results, both for the atmospheric trace gas absorptions and the vegetation spectra. The influence of an incorrect wavelength calibration is especially strong. We recommend an accuracy of the wavelength calibration of better than 0.2nm. We summarise the results of our sensitivity studies in the new section 3.3 (see also the new Fig. 6).

Referee comment: Ţ The retrieval results should be “validated”. Although I realize that it is not possible to validate the fitting coefficients, it could be investigated if the results are qualitatively consistent with vegetation products from other satellite sensors. Furthermore, a validation of the trace gas columns would also give an indication of the quality of the vegetation retrievals. Especially, it would be interesting to see the improvement in the trace gas columns due to the inclusion of the vegetation spectra in the fit.

Author response: We compared the spatial and temporal patterns of the results of the vegetation spectra with those of other data sets (e.g. the NOAA Global Vegetation Index Products, available via http://www.osdpd.noaa.gov/PSB/IMAGES/gvi.html) and we found good agreement. A comprehensive validation study should, however, be the subject of future studies. We added this information to the text. As an example for the results of part of one satellite orbit we added the new figure 2. It compares the results retrieved with the vegetation spectra included or excluded in the DOAS analysis. For O4, it also shows the results from the UV spectral region which are not affected by the interference with spectral albedo structures. While the absorptions of H2O and O2 are only weakly affected by the inclusion if the vegetation spectra, those of O4 change strongly. Only if the vegetation spectra are included they become similar to those retrieved in the UV.

Referee comment: Ţ I suggest that the authors include an albedo spectrum representative for oceanic chlorophyll and derivative products (see for example: Morel, A., S.

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Maritorena, Bio-optical properties of oceanic waters: A reappraisal, J. Geophys. Res., 106(C4), 7163-7180, 10.1029/2000JC000319, 2001, and references therein). This would make the retrievals over the ocean much more meaningful.

Author response: Many thanks for this hint. We found the paper very interesting and found therein also additional interesting references. However, unfortunately, the provided ocean spectra were sampled on a much too coarse spectral resolution to be useful for our study. We had no success in finding other well suited ocean spectra.

Technical Referee comment: In the title apparently the word vegetation is missing, please correct.

Author response: We corrected the title.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 7945, 2006.